Soil Science Society of Serbia

Soil Science Institute, Belgrade, Serbia

PROCEEDINGS

The 1st International Congress on Soil Science

XIII National Congress in Soil Science

SOIL – WATER – PLANT

September 23 – 26th, 2013

Belgrade, SERBIA

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Foreword

Contemporary soil related issues impose big challenges in terms of building healthy environment and soil-water-plant system. Maintaining soil fertility and healthy environment, while keeping satisfactory crop yield is a most urgent issues for soil scientists. Integrating the researches of soil scientists from different countries can help for better understanding the tasks in resolving much of the questions.

I am glad to report that in September 23-26, 2013 The Soil Science Institute in Belgrade, for the first time organized and successfully held a 1st International Congress on Soil Science, titled 'SOIL-WATER-PLANT'.

The Congress addresses to recent developments in emerging fields, and also a unique opportunity to meet scientists, to have stimulating discussions and to hear about the latest developments in soil science. This congress is of big importance at a time when soil degradation, environmental changes, crop growing difficulties etc., make soil scientists and environmentalists more concerned than ever about issues dealing with the scientific basis of optimizing soil use and conservation.

The Congress is co-organized by Serbian Soil Science Society, University of Belgrade, Faculty of Agriculture and The Chamber of Commerce of the Republic of Serbia.

This book comprises a total 65 full original papers, submitted by 252 authors from 13 countries from Europe and Asia. There are 7 invited papers in plenary section. The Book is organized in accordance with the Congress sections:

1. Plenary Section
2. Soil Use, Fertility and Management
3. Soil- Water- Environmental Protection
4. Soil In Space And Time

I hope that this first International Congress will become a tradition and will expand its geography continuing to gather the soil scientists from all the continents.

Finally, I would like to thank the Ministry of Education Science and Technological Development of the Republic of Serbia; Ministry of Agriculture, Forestry and Water management of the Republic of Serbia - Directorate for management of forests; Ministry of Agriculture, Forestry and Water management of the Republic of Serbia - Directorate for management of agricultural lands; Ministry of Natural Resources, Mining and Spatial Planning of the Republic of Serbia; Megra d.o.o. and DPS Chromatorgaphy for their valuable financial support in holding the Congress.

The Chairman of the organizing Committee of the Congress

Dr. Maksimović Srboljub

General Secretary

Dr. Saljnikov Elmira

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International Congress: SOIL-WATER-PLANT

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INTRODUCTION OF CONTINUOUS MONITORING OF AGRICULTURAL LAND OF REPUBLIC OF SRPSKA

PREDIĆ Tihomir, LUKIĆ Rade, NIKIĆ – NAUTH Petra, CVIJANOVIĆ Tatjana, DOCIĆ-KOJADINOVIĆ Tatjana, MALČIĆ Tanja, JOKIĆ Duška, RADANOVIĆ Bojana

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ABSTRACT

Strategy of sustainable agricultural development is impossible without monitoring the changes in the soil as an integral part of environmental monitoring. From 1992 to 1997, the monitoring of land is introduced respectively: Bulgaria, England, Finland, Czech Republic, Norway, Slovakia, France, Holland, Hungary, Austria, Spain and Germany. Slovenia introduced it in 2007 and Croatia in 2010. Because of specificity of lands in relation to water and air, this job is very complex and expensive. The importance of land protection was not well recognized by decision makers in the RS and FBiH. However, the importance of land monitoring is stressed by the EU. This paper presents the results of previous research and implemented projects that were aimed to finding the most appropriate model for establishing a permanent monitoring of agricultural land in the RS. Also, it presented a model for establishing a permanent monitoring of pollution of agricultural land of the RS, which will meet all EU requirements and is acceptable for the economic situation of the Republic of Srpska.

Keywords: monitoring, agricultural land, pollution

INTRODUCTION

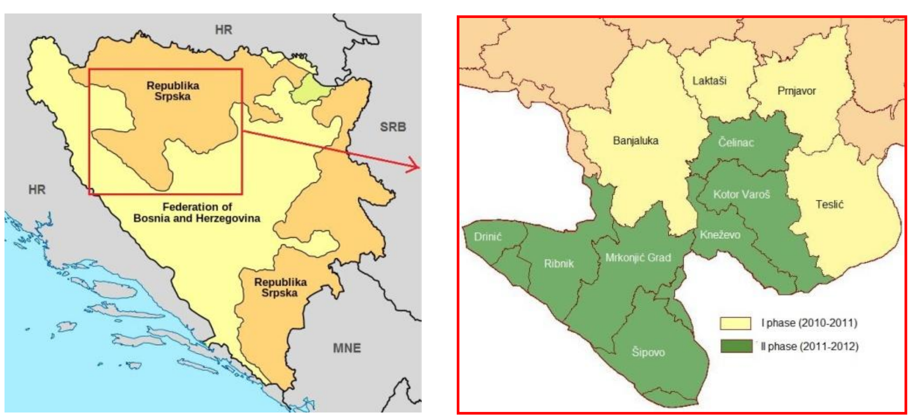
Bosnia and Herzegovina (BiH) is a complex country, which consists of two entities: Federation of Bosnia and Herzegovina (FBiH) that covers 51% of the territory, and Republic of Srpska (RS) with 49 % of the territory, including Brcko District which is partially located in both FBiH and RS. Complex territorial organization is accompanied with complex political and legislative organization in BiH. A smaller part of laws are at the state level, and most of the laws are under jurisdiction of entities. The Law on Environmental Protection is under the jurisdiction of the ministries at the entity level that contains guidelines related to environmental monitoring. To date in RS is only established water monitoring and partially air monitoring. Due to numerous soil specificities comparing water (and air), establishment of soil monitoring is very complex and expensive work, and importance of soil protection is not sufficiently recognized by decision makers. Being aware of the importance of this work Agricultural Institute of RS, namely Department of Agroecology, has been working for several years on establishment of soil monitoring using the results of the projects implemented at the territory of BiH. In a period 2000 – 2007 a FAO project "Inventory of Post War Situation of Land Resources in Bosnia and Herzegovina" was implemented, that created digital data bases on existing soil resources data in BiH and performed agroecological zoning of BiH (Predic *et al.*, 2011). Project „Development of National System for Environmental Monitoring in Bosnia and Herzegovina" was conducted in 2004/2005 (project supported BiH to adjust with the European Environment Information and Observation Network – EIONET). The project established an institutional scheme for functioning soil monitoring in BiH and RS, with the Agricultural Institute of RS appointed as National Reference Center (NRC) for soil monitoring in RS (Guidance on Environmental Monitoring in Bosnia and Herzegovina, 2005). Started activities related to establishment of soil monitoring were incorporated into strategic document of the Government of RS in 2009 „Groundwork for Agricultural Land Protection, Use and Restructuring for Republic of Srpska as the Component Land Use Planning Process"(Predic *et al.*, 2009). In the «Development of Proposal for Soil Monitoring» the state of equipment in institutions, obligations and role of institutions as well as necessary steps for the establishment of permanent soil monitoring in RS are described. Putting legislation on force by implementing specific activities started in 2009, when Agricultural Institute of RS together with Fund for Environmental Protection and Energy Efficiency of RS co-financed three projects (2009–2012) related to establishment of a permanent monitoring of agricultural soil pollution in RS. With these projects a methodology of determination of starting state of agricultural soil pollution was developed and conducted on pilot areas. In year 2012 City of Banja Luka financed the project „Establishment of Permanent Soil Monitoring Stations“. This project has developed a system of establishing of permanent soil monitoring stations in RS, based on experiences from former Yugoslav countries, Slovenia (Zupan *et al.*, 2008) and Croatia (Mesic *et al.*, 2006; Komesarovic, *et al.*, 2010) respecting the specifics of BiH. This paper will present methodology of determination of starting state of agricultural soil pollution, a method of area selection and a method of establishment of permanent soil monitoring stations based on model adapted to specific conditions of the Republic of Srpska.

MATERIALS AND METHODS

Elaboration of the model of permanent monitoring of pollution of agricultural land in terms of the Republic of Srpska was done in several phases:

- Review of existing models of established monitoring of land,
- Collection and update of existing data,
- Development of models to determine the current (initial) state of pollution of agricultural land,
- Testing of the model in the pilot area

Pilot area covers the area of fourteen municipalities in the central part of the Republic of Srpska (Pic.1).



Pic. 1. Position pilot project area

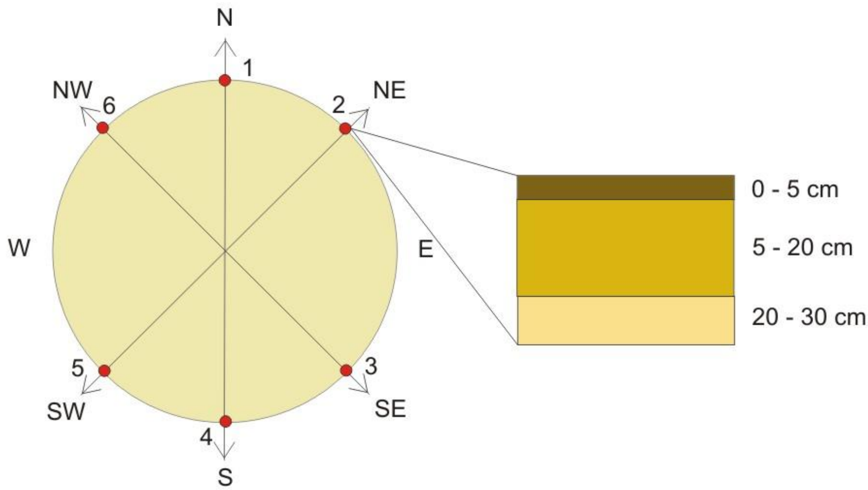
- Field work – sampling,
- Laboratory works:
  - Soil acidity pH in H_2O and KCl; electrometrically combined electrode in pH-metre (pHM240 pH/ion meter–Radiometer)
  - Humus – by Turin, the Simakov's modification (1957).
  - The total content of heavy metals: Lead (Pb), Cadmium (Cd), Nickel (Ni) and Chromium (Cr); destruction of the sample conc. HNO_3 (Krishnamurthy *et al.*, 1976) - reading–flame techniques - AAS – Solar S4 Thermo Electron
- The GIS modelling (ArcGIS 9.1)
- The development of models for the establishment of permanent monitoring stations

RESULTS AND DISCUSSION

Soil pollution assessment/monitoring methodology in Slovenia

To establish a monitoring of soil in Slovenia, the results of previous researches were used, as well as the results of new researches of soils. New researches are based on the determination of initial state of soil pollution in Slovenia, which are conducted through the project Research soil pollution in Slovenia (ROTS) under the National Programme for Environmental Protection (NPVO, 1999 -2003). The project ROTS fully developed research model of establishing methodologies (network selection, choosing the location, model sampling) field work, laboratory analysis, database creation, to the final results (Zupan *et al.*, 2008). For determining the initial state of pollution, it was necessary to analyse soils from 2689 locations of network of points 2 x 2 km and 4 x 4 km. According to adopted methodology, the samples were taken from 6 sites on the circle of 25 – 50 m diameter (rarely from ellipse). Places on circle were selected based on the sides of the world: N/1, NE/2, SE/3, S/4, SW/5, and NW/6. (Pic. 2).

At each of the six sampling sites profile has been opened (described) and soil samples were taken from two or three different depths, depending on the land use. On arable lands, it was taken from two depths: 0 - 20 cm and 20 - 30 cm. Pastures and meadows - 3 depths: 0-5 cm; 5-20 cm and 20-30 cm.

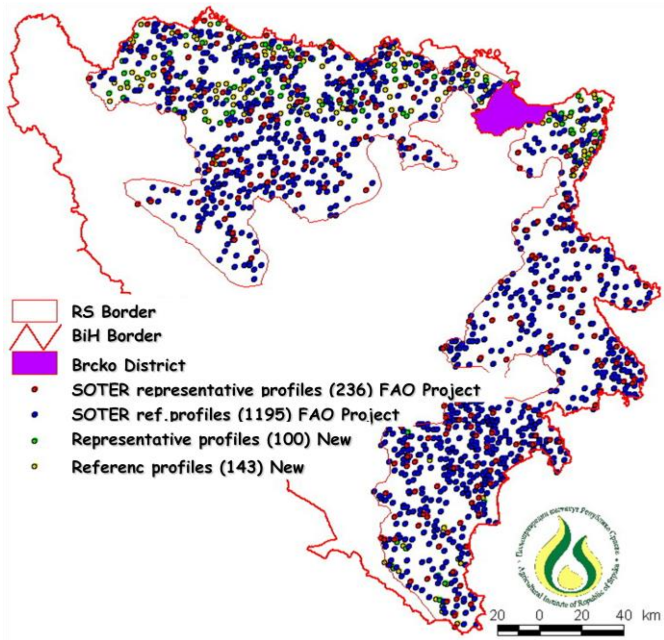


Pic. 2. Schedule of taking samples from selected location (Slovenian System)

Basic pedology parameters, and organic pollutants were analysed in each sample, (55 compounds including PAO, PCB and others), 14 metals and fluorides. Implementation of the plan was only 7,9 % i.e. 212 out of 2689 locations. Due to the high cost made, the audit was made by NPVO (ReNVPO, 2005 - 2007) and 530 spots was selected from the network of 4 x 4 and 8 x 8 km (network selection depends on the land use and altitude). The 44,2% of the plan was achieved, i.e. 234 locations out of 530 planned (Zupan *et al.*, 2008). Regardless of conducted comprehensive researches (synthesis of previous and new results), model of adopted monitoring and designing the database, Slovenia has not yet selected and established permanent stations of monitoring of soil pollution.

Experiences in Slovenian models were used to establish a model for monitoring contamination of agricultural land in the Republic of Srpska. The model is modified, revised and simplified so that it can be established and continuously conducted in the RS.

Our model is, the same as the Slovenian, is the outcome of analysing existing data and the results of new researches. The following GIS basis were used out of the existing data: DEM, geological map (1:200000), pedology map 1:50000, hydrography, climate parameters, potential erosion - USLE, protected areas, agroecology zoning of the RS, CORINE land cover, FAO LCCS land cover/land use; SOTER database of soil profiles (Pic. 3).



Pic. 3. Profiles and semi profiles within the RS with total 1674 points, SOTER data base (Soil and Terrain data base) Source of data from Pedology map of SFRJ (ex Yugoslavia)

Existing digital data of soil resources of the RS are good basis for establishment of thematic monitoring of soils with no additional researches. This model was used by EU countries (1992-97) and Croatia (2006-2010 (Mesic *et al.*, 2006). However, for the establishment of monitoring of agricultural land pollution in the RS, there are no sufficient relevant data. Data from pedology map, concerning physical and chemical characteristics of the soil profile do not contain on concentration of organic and non-organic pollutants (*analysis were not made at the time of making of pedology map)*. Therefore, additional researches are needed in order to determine current status of pollution of agricultural land. Afterwards, analysis of all data and GIS modelling would give us relevant results which will significantly facilitate making decisions on number and location of permanent monitoring stations of soil pollution in the RS.

Selection of base network of points

On the contrary from Slovenian model and model of most EU countries, which at the time of establishment of the monitoring system, used local base networks of points (0,5 x 0,5 or 1 x 1 km), the RS used ETRS89 reference European Network *(Lambert Azimuthal Equal Area)* 500 m x 500 m. The reference grid was created according to the INSPIRE directive (Infrastructure for Spatial Information in Europe). The grid is intended for statistical reporting purposes. The grid - proposed as the multipurpose Pan-European standard (Scott, 2010). ETRS89 grid has been redesigned for our needs in Gauss Krueger projection, in order to be used at local level in the RS and BiH. This network of points is used by the project LUCAS *(**L**and **U**se/**C**over **A**rea frame statistical **S**urvey)*, so in this way, the selected points for determination of the initial pollution determination, and afterwards permanent monitoring stations, will be a part of European multipurpose reference grid of points. In this way, research results of soil pollution in the RS will be used in other researches relating to the soil such as LC, LU, researches on yield.

Slovenian experiences with certain modifications were used for selection of reference network points for the purpose of determination of initial pollution. For the area of the RS, the points have been selected from four networks depending on the existence and visible potential source of contamination of agricultural land:

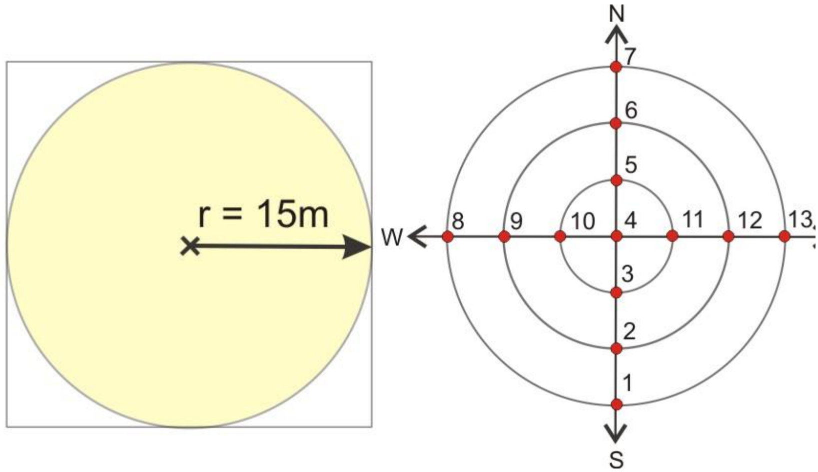
- Network of the 1st level danger: 1 x 1 km will be used areas close to the known sources of possible contamination (*with factories that emit pollution , power plants , refineries , floodplains)*
- Network of the 2nd level danger: 2 x 2 km will be used in zones of intensive agricultural production*(irrigated areas, vegetable regions, and fruit regions)*
- Network of the 3rd level danger: 4 x 4 km will be used in zones of dominant crop production
- Network of the 4th level danger: 8 x 8 km will be used in zones of pastures and meadows

As it is well known, land may be contaminated, even in those areas where there is no visible source of pollution, which is confirmed by the results of researches in BiH and the region. Researches of mercury (Hg) in mushrooms of the Boletus genus on natural sites (in the forest) in the area of the northern part of the Republic of Srpska showed that three out of ten of the analysed sites, the content of mercury in mushrooms was above the MRL (3 mg Hg kg^{-1}) and ranged in the range 5 - 11 mg Hg kg^{-1} (Predić *et al*., 2011). Similar results were given by Radanović, Antic-Mladenovic (2008), in the herb of S. Loannis strutio, which is grown in natural habitats in specific locations of Tara mountain (mountains along the border of Serbia/Bosnia and Herzegovina), content of cadmium (Cd) of 3.0 mg Cd kg^{-1} which is 6x higher content of cadmium than it is determined in the herb of Cantarion (S. Loannis strutio) plantation grown on land of Pancevo near Belgrade (0.5 mg Cd kg^{-1}).

In case when the increased content of certain elements and compounds in the soil are found at the state of determining the initial conditions of soil pollution in certain locations, additional research shall be conducted. Additional points that are on the next denser network than previously used will be selected. Example, increased Cd content was found on the site, which is located on the network 8 x 8 km. Around this point, there will be additional two or four locations selected, that are on the network 4 x 4 km. This will determine if there is a wider area of contamination.

Method of sampling from selected locations

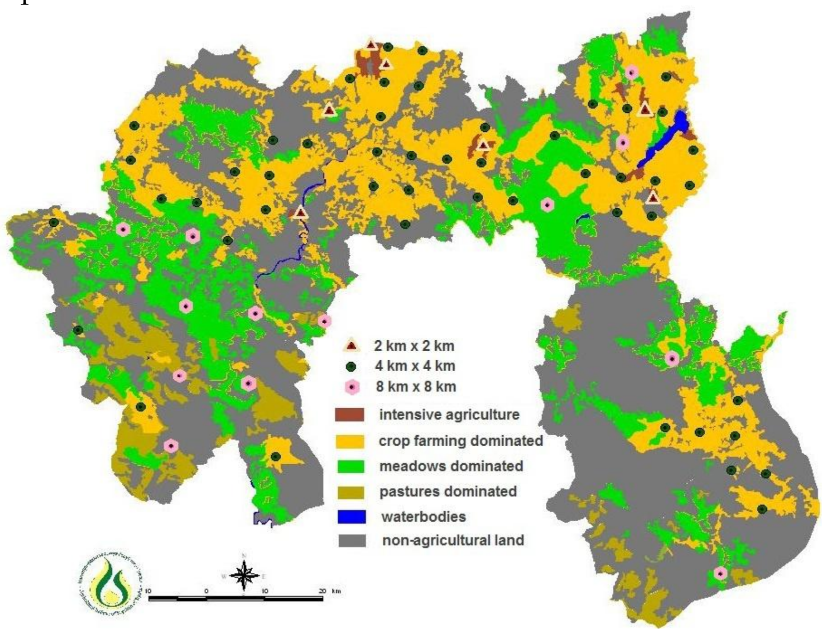
Since this is about determining the state of pollution, rather than establishing permanent monitoring stations, an average soil sample will be taken from one location to be tested and it will represent the status of that land surface. The location is determined by the circle radius of 15 m area of 706.5 m^2. Average sample consists of 12 individual samples that are on the sides of the world north/south and east/west. From the centre of the circle, there are three circles r = 5 m, r = 10 m and basic r = 15 m described. Centre and diameter circle with the directions of the world means taking of 12 individual soil samples which are used for preparation of average soil samples from the test surface (Pic. 4). Depending on the land use, an average sample is taken from two or three depths. On arable land, from two depths: 0-25 cm (topsoil) and 25-50 cm (sub arable horizon). In meadows and pastures - 3 depths: 0-10 cm, 10- 25 cm and 25-50 cm.



Pic. 4. Determination of selected soil location and scheme of taking an average soil sample

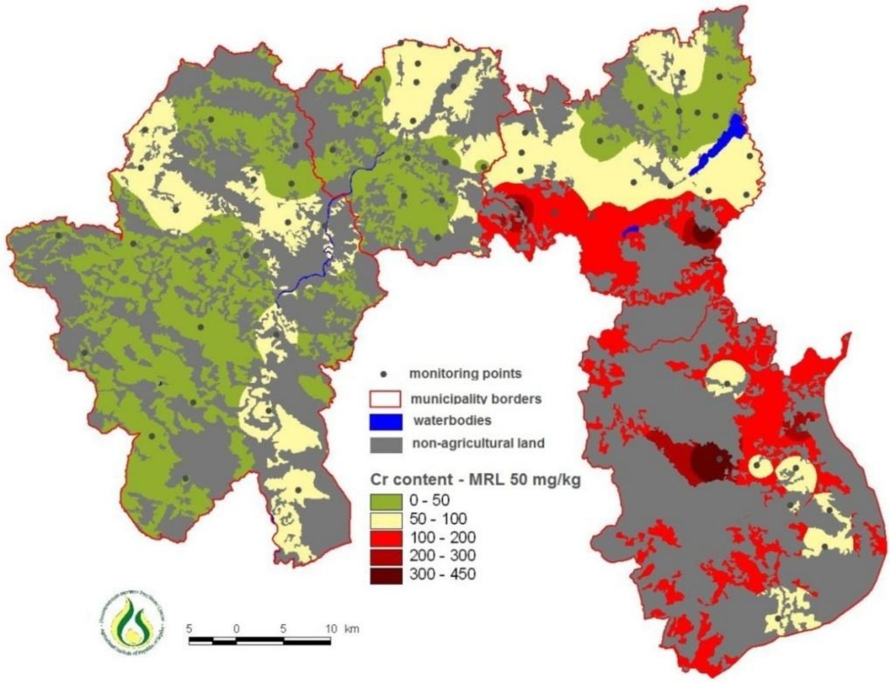
It is easy to find selected area in described way by GPS (centre of circle) and positions of taking an average sample are determined by the sides of the world. In the end of sampling, on location, characterized by two or three average soil samples, makes it much cheaper in comparison with Slovenian model (12 or 18 samples from one location). Described model above meet the set objectives - determining the condition of soil pollution. For continuous monitoring of soil pollution, permanent stations on the other principles will be established, which will enable fulfilment of set objective - monitoring changes in the soil for a period of time.

Testing the model in the pilot area was conducted in two phases. In the first phase (2010-2011) the whole process of selection of reference points for the network was tested, depending on the potential pollutants and agricultural land use, sampling, chemical analysis and further processing of the results and their presentation in GIS. To select points from reference networks LC/LU was used that is created in the projects making Groundwork RS (Predic *et al.*, 2009). For the selected pilot area, LC/LU is further enhanced by the use of satellite image LANDSAT7 *(RGB and panchromatic band, 15m resolution)* from the 2009 The IRS and satellite images (*Indian Remote Sensing, 15 m resolution*) in 2007. Existing LC/LU classes (*LCCS Classification - FAO Land Cover Classification System*, modified for specific requirements of Bosnia and Herzegovina; Predic *et al.*, 2004) were re-coded so that the pilot area was shown through 6 LC/LU classes: intensive agriculture, dominated by crop production, dominated by meadows, pastures dominated, water land and non-agricultural land. GIS modeling was performed - each class is overlapped with the appropriate network points (for example, LU class meadows and pastures with a network of 8 x 8 km) and obtained a network of points (Pic. 5) from which the average soil samples were collected.



Pic. 5. Distribution of points from which average soil samples were taken – total of 69 of which 7 with network 2x2 km, 49 network of 4x4 km, and 13 with network of 8x8 km

Chemical analysis of the pH, humus Pb, Cd, Ni, and Cr content was performed. The obtained results were spatially presented in GIS (Pic. 6)



Pic. 6. Distribution of chromium content in the analyzed area

Part of the sample was stored in permanent storage, so that other parameters (where keeping in prescribed circumstances has no adverse effects), can be subsequently analyzed (if necessary, and funding is provided).

The second phase (2011-2012) was carried out on the territory of 10 municipalities (Pic.1) where, in contrast to the previous area, agricultural land is predominantly used as meadows and pastures. Industry is underdeveloped, thus there are almost no visible sources of pollution, except populated places.

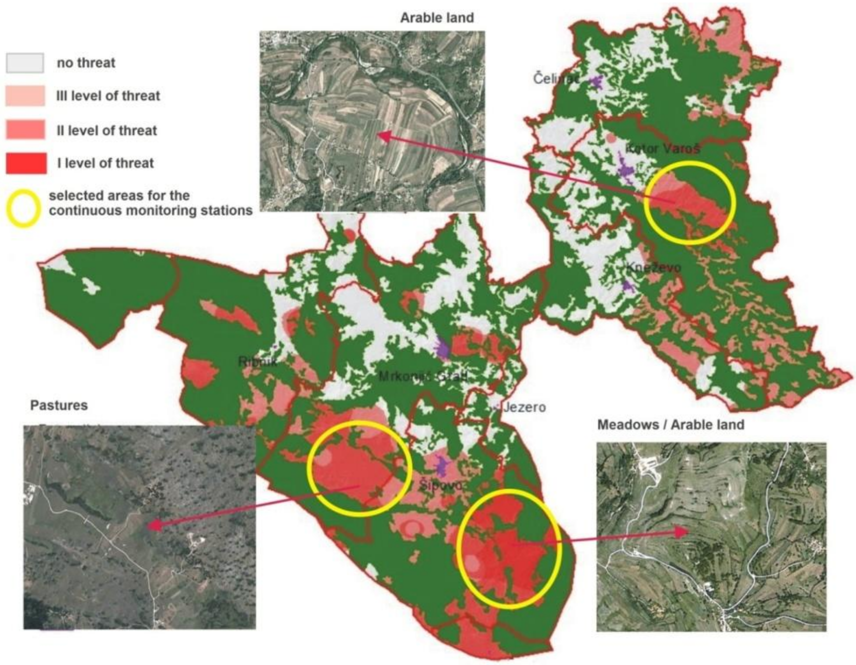
In this pilot area, 69 points were selected and 138 average soil samples taken by the adopted principle. Regardless of not having any visible source of soil pollution, chemical analyzes have shown that the land in some areas contain concentrations of heavy metals above the permissible concentration (MRL). In soils (0-10-20 cm), which are used as pastures in the southern part of the pilot areas, at 5 sites (7.2% of samples) the lead (Pb) content were above the MRL *(100 mg Pb kg^{-1} - The European Council Regulation EEC No 2092/91*) - in the interval 120 - 160 *mg Pb kg^{-1}*. Other elements above MRLs: Cd - 11 samples *(2.1 to 4.1 mg Cd kg^{-1})*, Cr - 13 samples (*102 - 160 mg Cr kg^{-1}*), Ni - 36 samples or 52% *(50 - 196 mg Ni kg^{-1})*. Although there was no additional research on these sites, it is presumed that the increased concentration of heavy metals is likely of natural origin, arising from the geological formation of the land in the process. These assumptions are confirmed by the results of the analysis from the same location but the deeper soil horizon (*25–50 cm*) where almost identical concentration as in the surface layer: Pb - 5 samples above the MRL *(115 - 237 mg Pb kg^{-1}*), Cd - 11 samples *(2.1 - 4.1 mg Cd kg^{-1})*, Cr - 14 samples *(102 - 150 mg Cr kg^{-1})* and Ni - 39 samples above the MRL *(50 - 218 mg Ni kg^{-1})*. Regardless of the origin of the increased content of heavy metals in the soil (above MRL), the number of samples (network 4 km x 4 km) in these locations should be increased and the content of heavy metals in plant material should be analyzed. Based on the obtained results certain measures should be taken.

Based on these results, GIS basis of spatial content of Pb, Cd, Ni and Cr were created. Their overlapping and GIS modeling performed. Potential areas with increased levels of heavy metals in the soil are obtained (Pic. 7) expressed through three levels of pollution hazard: III level-zones in which one of the elements is above MRL, II level-the zone in which two heavy metal concentrations are above the MRL; I level-zones where concentrations of three or four heavy metals are above the MRL (in our case, there were no locations where all 4 the examined heavy metals were above the MRL).

Using this digital display, soil maps, land cover and land use, three specific areas are selected (Pic. 7) where stations for permanent monitoring of soil pollution should be placed. Weather the permanent station form will be placed in one of these three separate areas will be known after conducting research at the entire territory of RS, when the optimal number of permanent stations for monitoring of pollution is established.

Model for establishing of permanent stations for monitoring pollution of agricultural land

The experiences from Croatia were used to determine the exact position of permanent monitoring stations within the selected areas and the process of establishing a permanent station for pollution monitoring of agricultural land. Croatia used the EU pre-accession funds to establish a system of permanent monitoring of land. From 2006 - 2010 three projects were implemented: I) Development of the Croatian Land Monitoring Program with a Pilot Project (2006 - 2008), II) Program of agricultural soil monitoring in Croatia (2009), III). The continuous monitoring of agricultural land (2010) in which a detailed description of the establishment of a permanent monitoring station was given. Monitoring station consists of the following: a specified area, soil profile and piezometer inserted into the ground in which the percolated water is collected (Komesarovic *et al.* 2010).



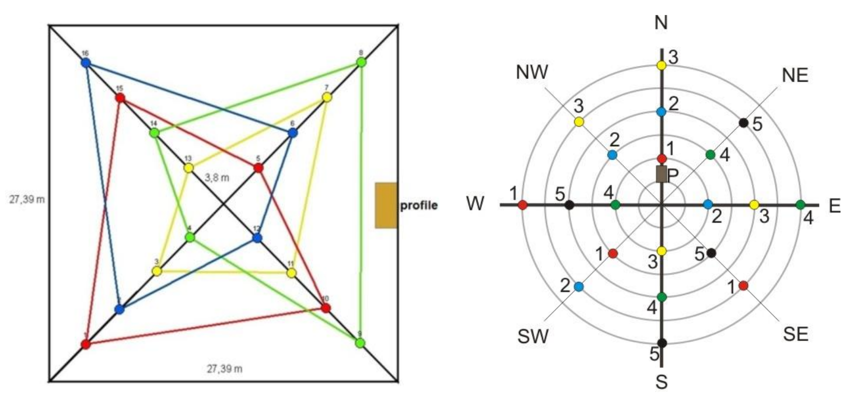
Pic. 7. GIS model of the areas in which the increased content of heavy metals in soil is possible (three levels) and the display of isolated areas where it is necessary to establish permanent stations for soil pollution monitoring

Model used in Croatia is modified to the conditions of RS. Station in Croatia is square (*sides 27,39 m, size 750m*^{2}). The square was determined with four points thus when establishing a permanent station and with every subsequent measurements there should be theodolite or high precision GPS. Average soil samples are taken from the squares diagonals (Pic. 8-left). The station in RS is circular, r

= 15 m, P = 706 m^2. To place it, it is necessary to determine the center, and soil samples are taken by the cardinal directions N/S, NE/SW, E/W, NW/SE (Pic. 8-right).

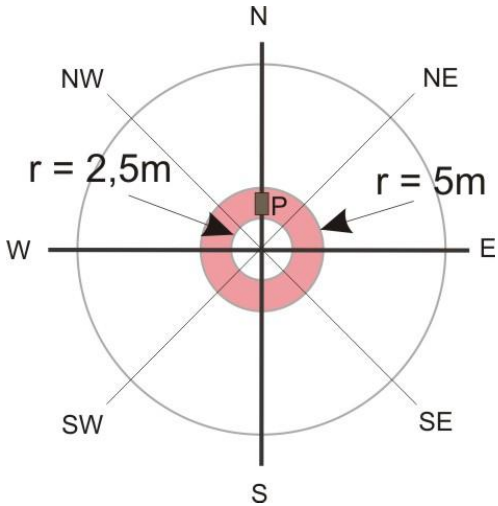
Five average samples are taken from the surface of the station (circle) according to the prescribed methodology from two or three depths. Average samples consist of four individual (*20 in total*) which are located at the intersections of cardinal directions and the circle diameter, 2.5; 5; 7.5; 10; 12.5; and 15 m (Pic. 8-right). By this method, samples more evenly cover the surface than square model (Croatia), which enables secure tracking of changes in the period of time.

Another difference in comparison to the Croatian model is a position of soil profile at the monitoring station. In our model, the profile is located inside the stations in the zone 2.5 - 5 m from the center of the circle to the north (Pic. 9). The subsequent profile opening will be done at the same distance from the center, but in the direction of northwest. In Croatian model, the profile is on the periphery of the station (Pic. 8-left). Both positions have their advantages and disadvantages.



Pic. 8. Models for establishing of permanent station for land monitoring: Left – used in Croatia; Right: model for Republic of Srpska.

Testing the detailed model of establishing permanent monitoring stations (*partially described above*) was performed in 2011 in the area of the municipality of Banja Luka (*one of the first municipalities in the pilot areas, which have all the necessary digital media*).



Pic. 9. Profile position inside the permanent monitoring station

Thus, Banja Luka became the first municipality in the Republic of Srpska and the entire Bosnia and Herzegovina in which he established a permanent station for soil pollution monitoring was established. In the future, it is necessary to design and establish a base for data placement and processing of which is one of the prerequisite for the successful functioning of the land monitoring.

CONCLUSIONS

- Establishment of permanent land monitoring is a complex and expensive.
- Establish a system that fits the current economic situation by using the experiences of other countries and our own specifics.
- Establish the system in phases.
- Use the EUpre-accession funds and propose joint (cross-border) projects, Bosnia and Herzegovina – Serbia, Croatia and Montenegro

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THE BEHAVIOR OF CA AND SR IN THE SOIL-PLANT SYSTEM FROM LIMING WITH A STRONTIUM-CONTAINING AMELIORANT

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ABSTRACT

The behavior of Ca and Sr in the soil-plant system from liming with a strontium-containing ameliorant was studied in two long-term liming pot experiences and in a series of simulation experiments. It was established the waste lime containing 1.5 % of stable strontium is possessed a high chemical activity, and the full dissolution of the ameliorant added in considerable quantities was reached 3–4 years after its application. The scope of strontium migration in the loamy sand soddy-podzolic soils was determined in columns in a series of simulation experiments. It was found that the amount of leached strontium to depend on its initial content in the soils, the humus content and the volume of percolated moisture. The artificial enrichment of soils with strontium increases the losses of the element due to its leaching. However, strontium is not completely removed even upon repeated water percolation. It was found what the HA1 fraction plays a leading role in the fixation of strontium in the non limed soil; it contains about 50 % of the total soil strontium. Differences in the accumulation of strontium by plants from different families were revealed. It was found that the transition of Sr to the generative and vegetative organs of plant was followed with different mechanisms.
Keywords: stable strontium, calcium, soil, contamination

INTRODUCTION

The stable strontium refers to the elements of the third class of danger (GOST 17.04.02–83). In the body of animals and humans, Sr replaces Ca in bone tissue, leading to a variety of bone diseases. Such diseases are local in nature and confined to biochemical provinces with excess Sr in soils. An example is the Chita and Amur regions (Urovskaya endemic) (Kowalski *et al.*, 1964). There is a risk of contamination by stable strontium the soils and plants as a result of extensive use of fertilizers and ameliorants in agriculture that contain strontium. Particularly dangerous strontium containing chemical ameliorants, application rates which, unlike mineral fertilizers, are a few tons per hectare. One of these ameliorants is Conversion Chalk (CC) containing 1.5% strontium. The Conversion chalk is a byproduct of the production of complex fertilizers. For 20 years, was used on the fields of the Novgorod region. From 1994-1995 it was used in the Leningrad region. The purpose of this research - to study the behavior of Ca and Sr in the soil - plant system by using the Conversion Chalk for liming of acid soddy-podzolic soils. Objectives of the study were:

- Study the dissolution rate of Conversion Chalk in the soil and identify patterns of distribution of mobile and soluble forms of calcium and strontium in the soil
- Comparison of the rate of migration of calcium and strontium in the soddy-podzolic soils;
- Define the role of humic acids in the binding of Sr in the soil;
- Determine the ability of individual plant species to accumulate strontium,
- Identify differences in the accumulation of calcium and strontium in grain and barley straw.

MATERIALS AND METHODS

The objects of study were two sour soddy-podzolic soils. Soil № 1 has been selected from the natural grassland and therefore contains more humus and has a higher absorption capacity. The soil № 2 was selected from the forest (Tab. 1).

Table 1 The physico-chemical characterization of soddy-podzolic soils

Humus, %	pH $_{KCl}$	Total acidity (TA)	Exch. acidity	CEC	Ca	Sr	Ca:Sr	Content of fractions <0.01 mm
		meq/100 g			mg kg^{-1}			
				Soil № 1				
3.02	4.1	5.4	2.5	22	7358	135	54,5	18.6
				Soil № 2				
1.76	4.2	5.6	0.75	14	5396	112	48,2	21.6

As the ameliorant, that Sr contains, the Conversion Chalk (CC) is used. It's byproduct of industrial production of nitrogen fertilizers by joint-stock company "Akron" (Veliky Novgorod). The Chalk contains 90% CaCO3 and 1,5% Sr. The study was performed in two long-term pot experiences.

The pot **experiment № 1** was conducted on both soils under the scheme: 1) NPK (background); 2) Background + CC (0,1TA); 3) Background + CC (0,2TA); 4) Background + CC (0,5TA); 5) Background + CC (1TA), where the dose 1TA (ton per hectare) = 1.5 * TA (total acidity). The pots contain 5 kg of soil. The experiment was performed in four replications for 3 years. Rape, vetch and wheat were grown successively. **Experiment № 2** (precision pot experiment) was performed, according to the scheme shown in Fig. 3. The Precision of experiments is allowed by the significant increase in the number of options by eliminating repetitions. In our case it is allowed to reach the largest possible number of situations that occur in a production environment and get an array of data that is sufficient to identify a clear dependence of accumulation of Sr selected crops and plant organs in a wide range of lime doses. The pots contain 5 kg of soil. The duration is 5 years. In the experiment were grown successively crops: rape, vetch, barley, rape, rape.

In laboratory experiment № 3 with columns the migration ability of Ca and Sr in the soil was studied. The soil for columns is limed by chalk and composted for 30 days in thermostat at 28°C. Humidity during composting was maintained at 60% of full field capacity. After composting the soil dried, milled, passed through a sieve with a mesh diameter of 1 mm and put into a column. Packing density was 1-1.1 g cm^{-3}. The height of the soil layer in the column 17 cm. Lavage was performed strictly calculated amount of distilled water, corresponding to an average annual amount of moisture to simulate the annual level of seepage through the soil layer moisture. For the one lavage used 400 ml of distilled water.

After 8 lavages the soil removed from the columns, limed again and composted for 30 days, as in the first case. The total duration of the experience, not counting the 2 periods composting - 9 months. The break between the individual lavages was no more than 1-2-days. A total number of lavages are 16. The experiment was performed in five replications. The total content of Ca and Sr in the soil was determined on an ORTEC X-ray fluorescence spectral analyzer. Mobile and water-soluble forms of metals in soils extracted by ammonium acetate buffer, pH 4.8, and distilled water, followed by determination by atomic absorption spectrophotometer. The content of un-reacted carbonates measured using a Portable Analyzer of Carbonates (PAC-1).

The total humus content was determined by the Tyurin method. The group and fractional composition of humus was determined by the Ponomareva method modified by Plotnikova and Orlova (1984). The concentrations of Ca and Sr in the individual fractions of humus acids (HAs) were determined using atomic absorption spectroscopy after the digestion of extracts in the HCl + HNO3 mixture by refluxing followed by the dissolution of the residue in the deionized water. Statistical analysis of the data was performed using Microsoft Excel, using correlation and regression analysis.

RESULTS AND DISCUSSION

The rate of chalk dissolution is judged by the content of unreacted carbonates (Tab. 2). Complete decomposition of chalk in the soil, limed at a dose of 0.2TA was achieved in the year of application KM, limed at a dose of 0.5TA - in the third year of experience. In treatment, the soil was limed at a dose of 1TA, residual carbonates was only 7.5%. Thus, there is almost complete dissolution ameliorant in the third year of experience.

Table 2 Dynamics of un-reacted carbonates content in the soils, %

Treatment	1st year	2nd year	3rd year
1. NPK (background)	0	0	0
2. Background + CC (0,1TA)	trace	0	0
3. Background + CC (0,2TA)	trace	0	0
4. Background + CC (0,5TA)	15,1±4,2	9,0±1,5	0
5. Background + CC (1,0TA)	26,0±8,2	20,0±5,4	7,5±1,9

The results of the study of the influence of liming with CC on the content of different solubility forms of Ca and Sr are shown in Table. 3. The data show that the use of CC at a dose 1TA increased the total content of Ca in both soils at 27-32% of the initial. There were significant differences in the accumulation of mobile Ca in the soils with different humus content. After the first year of experience content of mobile compounds of Ca in the soil 1 depending on the doses CC ranged from 1390 to 3356 mg kg^{-1} (20,4-36,4% of the total contents) and in the soil 2 ranged between 171-1118 mg kg^{-1} (3,2-15,8% of the total content).

Apparently, replenishment the content of mobile compounds of Ca in the soil number 1 is due to the mineralization of root residues of herbs. Also formed in this process, low molecular weight organic acids contribute to increased decomposition of carbonate of chalk. Due to the higher absorption capacity of the soil number 1, part of mobile Ca is fixed in the soil absorption complex. During the experiment continues to increase content of mobile Ca, due to the continuing dissolution of CC.

The content of water-soluble forms of Ca in the soil also depends on the dose of CC. After the first year the concentration of water-soluble Ca ranged from 9,4-26,6 mg kg^{-1} in the soil № 1 and from 50 to 205 mg kg^{-1} - in the soil № 2.

Differences in content of water-soluble forms of Ca is probably due to the fact that the dissolution of chalk in the soil № 1 accompanied saturation of absorption complex of soil , while in the soil № 2, where capacity of absorption complex is low large number of the available Ca for plants remained in the soil solution. During the experiment the content of water-soluble forms of Ca increases.

The use of chalk in a dose 1TA increased the total content of Sr in the soils in the 60-63% of the initial. The proportion of movable compounds of Sr dependently from the doses of CC ranged from 2.6 to 29.9% (12,0-66,2 mg kg^{-1}) of the total contents in the soil № 1 and 9,2-28,8% (9,2-51,8 mg kg^{-1}) in the soil № 2. During the experiment, the proportion of mobile compounds of Sr from its total content in the soil increased. Regularities identified in the study of the dynamics of water-soluble forms of Sr are very similar to the dynamics of the content of water-soluble Ca. To assess the level of soil contamination by mobile (available to plants) forms of Sr compounds we used the scale, proposed by Popov *et al.* (1991) According to this scale there are the following gradation levels of soil contamination by Sr: low < 10 mg kg^{-1}, medium - 10-15 mg kg^{-1}, moderately dangerous -15-25 mg kg^{-1}, high-dangerous -25-50 mg kg^{-1}, and the soil is not agricultural use - more than 50 mg kg^{-1}. Extraction Sr from soil carried ammonium acetate buffer (pH 4.5).

Advantages and disadvantages of the proposed scale are discussed in Litvinovich (2008). Comparison of the results with the scale indicates that as a result of liming not even high doses of chalk (0.1-0.2TA) after complete dissolution the soil moves into the category of moderately dangerous and high-dangerous.

The increase content of mobile forms of Ca and Sr in the soils will contribute not only to their entry into the plant, but also their migration into the lower layers of the soil profile. The results of the study of migratory ability of Ca and Sr in the experiment are shown in Table. 4.

The maximum content of Ca in lavages water in the control treatment was found in the filtrate of the first period of observation. The total metal loss from eight lavages were very significant and amounted to 70.2 mg. High migratory ability of Ca in the native soil due to the large stock of its water-soluble compounds formed after mineralization root residues of herbs, and the weak capacity of loamy sand soils to hold the bases.

From liming the Ca loss from the soil by washing intensified. The total volume of the eluted Ca from limed soil from 8 lavages was 266.3 mg. This is 3.8 times higher than in control treatment. The share lavage Ca from CC was 67.25%.

Complete removal of mobile compounds of Sr from the native soil was achieved by the third time of observation. Obviously, the content of mobile compounds of Sr in the native soil is low, accounting for only 0.12% of the total content. Artificial enrichment soil by Sr from liming with chalk leads to increased migration. Strontium is found in all portions of leachate, the maximum concentration is characteristic for eluates first lavage. Eluvial loss of Sr from Conversion Chalk in contrast to Ca per 8 lavages was only 29.95% of the added Sr.

Table 3 The content of the different forms of the compounds of Ca and Sr in the soil, mg kg^{-1}

Treatment	1st year						2nd year						3rd year					
	Total		Mobile		Water-soluble		Total		Mobile		Water-soluble		Total		Mobile		Water-soluble	
	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr	Ca	Sr
Soil № 1																		
1. NPK (background)	7245	119	1366	8,5	16,7	Нет	7003	121	1200	11,1	180	1,2	6767	110	555	16,1	220	2,9
2. Background + CC (0,1TA)	7351	125	1390	12,0	9,4	0,5	7185	149	1675	23,5	225	2,3	7475	134	1620	35,3	236	4,2
3. Background + CC (0,2TA)	8144	181	1665	17,9	10,6	0,4	6889	129	1725	20,5	220	1,9	7300	139	1644	34,4	267	4,9
4. Background + CC (0,5TA)	8386	198	2270	33,7	6,6	0,1	7891	178	2250	35,2	222	3,5	7891	160	1930	49,8	365	9,0
5. Background + CC (1,0TA)	9213	221	3356	66,2	26,6	0,6	8944	213	4025	67,2	585	16,3	8677	210	3730	86,1	660	19,5
Soil № 2																		
1. NPK (background)	5370	116	113	5,1	50	0,9	5122	82	98	5,2	-	-	No data					
2. Background + CC (0,1TA)	5411	120	171	9,2	50	1,2	5361	120	1313	13,8	216	7,8						
3. Background + CC (0,2TA)	5759	123	286	13,6	89	2,3	5691	107	815	18,8	274	10,0						
4. Background + CC (0,5TA)	6117	130	592	28,5	140	4,4	6008	114	528	31,5	421	17,						
5. Background + CC (1,0TA)	7066	180	1118	51,8	205	7,5	7000	137	267	63,8	687	32,0						

Table 4 Amount of leached calcium and strontium, mg

Treatment	Ca		Sr	
	Control	Laming	Control	Laming
1-st liming (Ca - 291,6 mg/column; Sr – 12,15 mg/column)				
1	40,00	79,80	0,12	1,2
2	2,20	39,00	0	0,4
3	1,40	38,00	0,04	0,5
4	8,00	28,50	0	0,4
5	4,00	26,40	0	0,4
6	7,60	21,00	0	0,4
7	4,80	19,80	0	0,3
8	2,20	13,80	0	0,2
Σ	70,2	266,3	0,16	3,8
% of the introduced		67,25 %		29,95
2-nd liming (Ca – 291,6 mg/column; Sr – 12,15 mg/column) For two liming Ca - 583,2 mg /column; Sr - 24,3 mg /column				
9	1,98	33,20	0	0,7
10	1,80	15,40	0	0,42
11	1,30	17,40	0	0,41
12	1,17	12,90	0	0,48
13	0,98	11,80	0	0,36
14	0,71	11,60	0	0,34
15	0,59	11,40	0	0,35
16	0,40	10,00	0	0,32
Σ	8,93	123,7	0	3,38
% of the introduced	-	39,35 %	-	27,8
For 16	79,13	390	0,16	7,18
% of the introduced for 16 lavages	-	53,3 %	-	28,9 %

Repeated composting of soil in the control treatment didn't lead to increased migration of Ca.

The Ca content in the filtrates of the second phase observation was lower than in the first experiment. Second liming contributed intensification the eluvial Ca losses.

The total amount of leached Ca of conversion chalk for 16 lavages was 390 mg (53.3% of the added with CC) and Sr 7.02 mg (28.9% of the added with CC). Thus, the rate of migration Ca almost two times higher than Sr.

Obviously, this is due to different bond strength alkali-earth metals with an absorbing complex of the soil.

Given the competitive nature translocation of Ca and Sr in plants be expected narrowing of Ca/Sr in the soil from dissolution of chalk and, as a consequence, the deterioration of the quality of crops .

Field studies (Litvinovich *et al.*, 2011) have shown that long-term use of fertilizers containing Sr (single and double superphosphate, azofoska) and ameliorants (limestone and dolomite powder) resulted in increased levels of stable Sr in the soil.

In 33 years of experiment the fertilizers and ameliorants were added depending on the treatment, from 53 to 70,9 kg Sr ha^{-1}. The content of mobile Sr compounds increased in comparison with the native soil to 5.1-6.1 times.

The question arises: what are the components of the soil that contribute to the retention of Sr, preventing it from washing away? In this aspect, the data of determining the concentration of alkaline earth metals in certain fractions of humic substances is promising.

The capacity of individual humic acid fractions for retaining Sr hasn't yet been elucidated. For revealing the contribution of each HA fraction to the accumulation of Sr in their extracts, we found the Sr content as well as the Ca concentration. The fractional composition of humus was determined using 0,1 N NaOH as extractant. The NaOH solution is not used for the extraction of metals from soils, but it extracts most humus substances without disturbing their chemical nature (Tyurin, 1937; Aleksandrova, 1970; Orlov, 1974). The mineral elements directly linked to humic acids pass into the solution on the case. The investigations of the ash composition of humic substances extracted by 0,1 N NaOH have gained wide acceptance in the practice of humus study. Hence, the direct determination of ashy elements in the extracts of humic acids after their digestion provides information about their confinement to the individual HA fractions and permits the calculation of the contribution of each fraction to their fixation.

The content of Ca in the HA1 fraction isolated from the control soil is low (Tab. 5). The calculations shows that this fraction contains only 0,6% of the total soil Ca content. Mathematical processing of data revealed no significant distinctions between the experimental treatments, although a tendency toward the increase in the Ca content in the studied fraction after liming should be noted. The obtained results agree sell with the published data about the low capacity of "brown" humic acids for Ca fixation (Ponomareva *et al.*, 1980; Bakina, 1987).

The analysis of Sr content in the HA1 fraction, on the contrary, attests to the significant role of this fraction in the accumulation of the pollutant. This fraction composes only 0,4 % of soil weight, but it contains about 50 % of the total Sr in the soil. It is important that the absolute content of Sr in the HA1 fraction exceeds the amount of adsorbed Ca by almost six times.

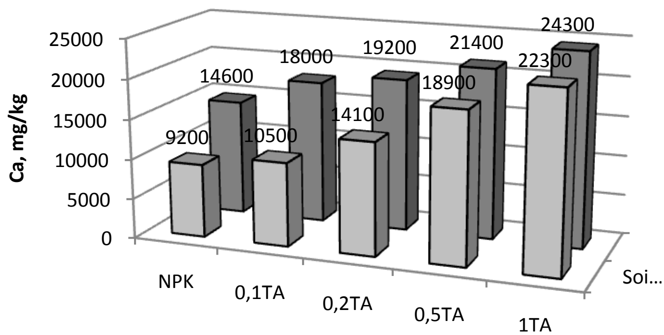
The difference between the contributions of humic acids from the HA1 fraction that is slightly soluble in water and predominant in the studied soil to the absorption of Ca and Sr explains, in part, the different susceptibility of these elements to leaching that we revealed previously.

Table 5 The content of alkaline-earth metals in different fractions of humic acids

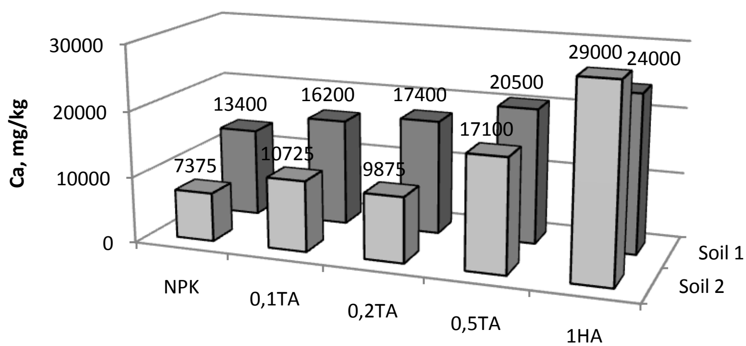
Treatment	Ca		Sr	
	% of the fraction weight	% of the total Ca content in the soil	% of the fraction weight	% of the total Sr content in the soil
		HA1		
Control	0,25	0,60	1,48	49,9
Liming	0,51	0,46	1,33	21,2
LSD_{05}	-	-	0,168	-
		HA2		
Control	0.061	0.008	0,073	0,60
Liming	0.119	0.015	0,073	0,39
		HA3		
Control	0.022	0,003	0,089	0,72
Liming	0.019	0,002	0,066	0,63
LSD_{05}	0.0116		0,0465	

The experiment on columns showed that 79,1 mg Ca and 0,16 mg Sr were leached from the analyzed (non-limed) soil. The migration of Sr was already terminated after the third leaching procedure, while appreciable amounts of Ca were found in the filtrate after the 16 leaching procedure, at the end of the experiment. Consequently, the confinement of Sr and Ca to definite humus fractions and the strength of their bond with the soil adsorbing complex are different, in spite of the similar geochemical properties of these metals. Comparing their contents extracted from soils with the ammonium acetate buffer solution confirms this conclusion. The obtained results indicate that the share of exchangeable Ca in the non-limed soil was 17 %, and that of Sr was two times lower, only 9 % of their total reserve.

It is suggested that the sorption of Sr by the HA1 fraction is a process that extends in time, and its realization requires definite soil conditions. It is evident that other components of soil humus also participate in the fixation of Sr added with lime. The actual contribution of the HA2 fraction to the fixation of alkaline-earth metals is quite difficult to evaluate, because decalcification (the removal of Ca by the repeated washing of soil with a 0.05N H_2SO_4 solution) is required before the isolation of this fraction. A major part of HA-bond Sr evidently passes into the solution in this case.



a) Doses of Conversive chalk by total acidity, Rape



b) Doses of Conversive chalk by total acidity

Fig. 1 The accumulation of Ca by plants: a) rape; b) vetch

Adding CC to the soil led to an intense accumulation of Ca in plant tissues (Fig.1). Calcium accumulated by plants from soil N 1 more than from soil N 2. This is due to the large number of mobile connections of Ca in the soil 1 than in the soil 2. This is particularly evident in the treatments with the introduction of low doses of chalk.

The experimental results showed a high degree of accumulation of Sr by plants. The higher dose of the chalk leads in the more Sr accumulating in plants. In this case, plants accumulate more intensively Sr from soils with low cation exchange capacity (CEC), where there is a shortage of mobile Ca (Fig. 2).

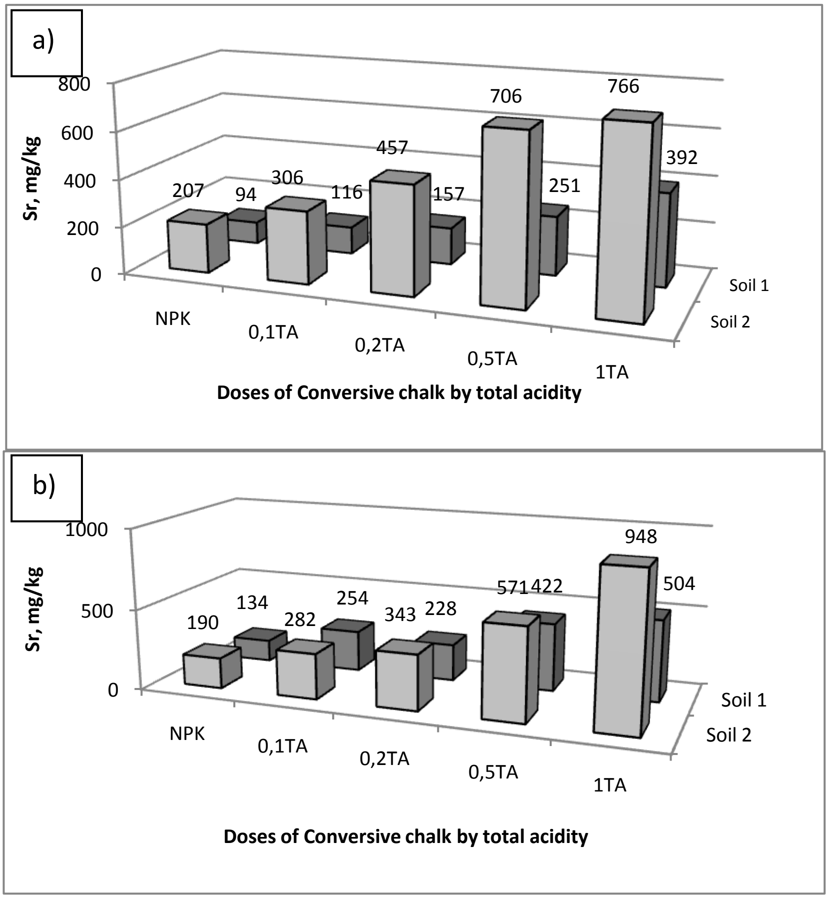


Fig. 2 The accumulation of Sr by plants: a) rape; b) vetch

We didn't reveal a clear pattern of accumulation by plants from different biological families. In vetch grown on soil with a high cation exchange capacity, Sr accumulated 1.4-1.8 times greater than in rape. In the soil with low CEC, this pattern confirmed only in the treatment using chalk in dose of 1TA. In all other treatments in soil N 2 the rape absorbed Sr intense than vetch.

The stage of chalk dissolution will affect also on the accumulation of Sr in plants. In precision pot experiment N 3, which was conducted during five years, was grown rape, vetch, barley, rape, rape.

The results show how differently Sr can accumulate in the same culture grown in different years after the application of the chalk (Fig. 3). In the year of application of ameliorant concentration of Sr in its tissues increased, depending on the treatment from 22 to 245 mg kg^{-1}. Accumulation ratio was varied from 1.8 to 8. Accumulating Sr in plants of rape 4-year studies ranged from 110 to 1650 mg kg^{-1}, and the accumulation ratio - from 7.5 to 23.3. On the 5th year of studying the accumulation of Sr in plants ranged from 487 to 1690 mg kg^{-1} air-dry weight of plants, and the coefficients of accumulation ranged from 10.4 to 34.1.

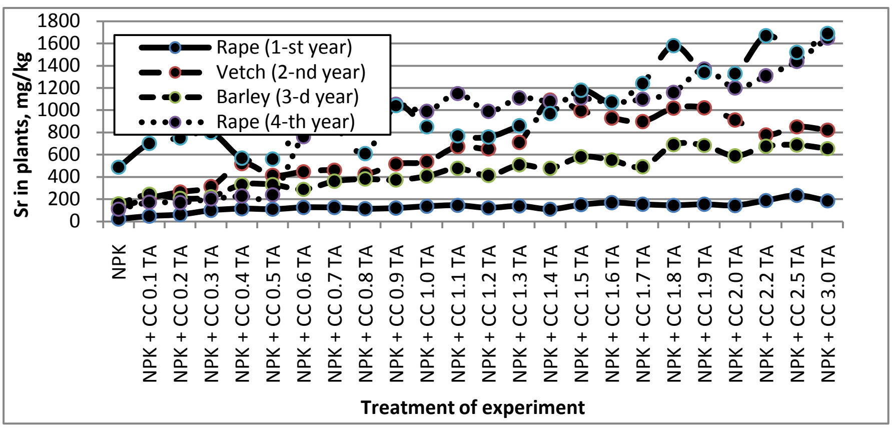
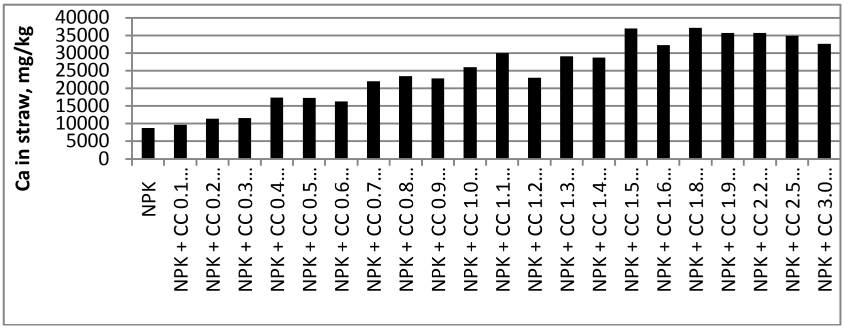
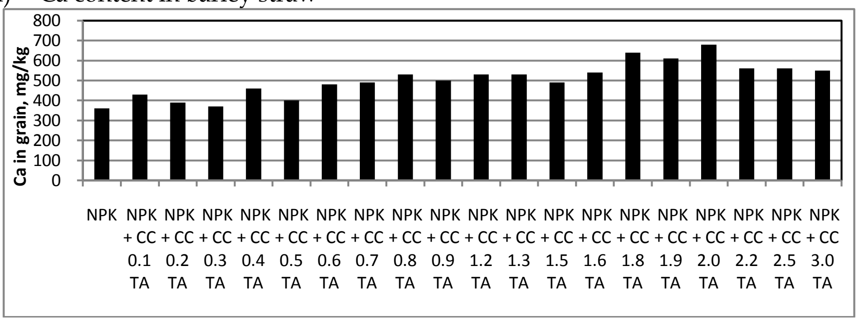


Fig.. 3. Strontium content in plants

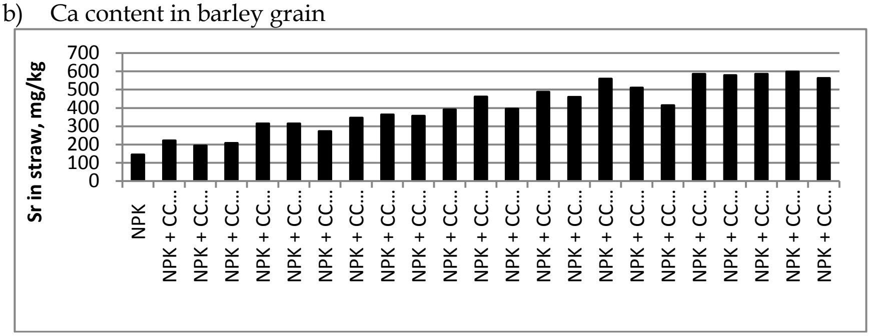
We also faced the task to reveal differences in the accumulation of alkaline earth metals in the vegetative and generative organs of plants (Fig. 4).



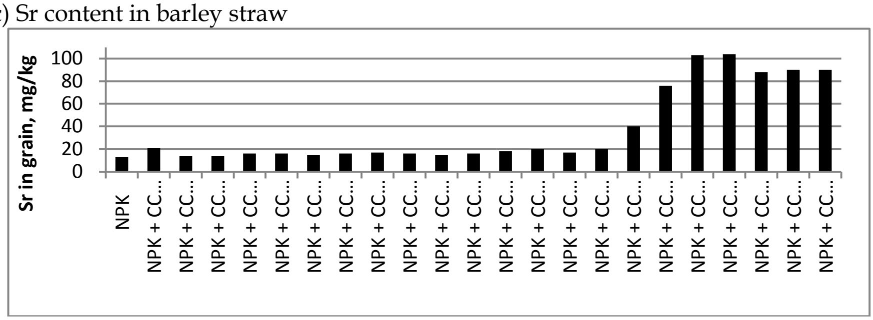
a) Ca content in barley straw



b) Ca content in barley grain



c) Sr content in barley straw



d) Sr content in barley grain

Fig.. 4. Calcium and Strontium in barley

Calcium uptake in barley straw came on barrier-free type. Despite some variability in the data increase the Ca content of barley straw using chalk before dose of 1.8 TA (5400 mg kg^{-1}), at higher doses did not observe it.

Accumulation of Ca in the barley grain is also dose-dependent introduction of chalk. The increase in Ca content continued until treatment of liming on 2 TA (6000 mg kg^{-1} soil). At higher doses the use of chalk, Ca content in the grain decreased. Thus, for this species (possibly grade) of barley was obtain limit accumulation of Ca in both the vegetative and generative organs.

Importantly, the Ca content in the treatment with the highest accumulation in the grain (2 TA) exceeds this figure without liming treatment only 1.8 times, i.e. Ca accumulation in the straw more intense than in the grain. In general, the generative organs of barley were characterized by a significantly lower accumulation of Ca than vegetative organs, which is consistent with the data (Shugarov, 1970).

Comparison of the histogram accumulation of Ca and Sr in the straw of barley revealed their essential similarity.

The supply of Sr, as well as Ca, into the barley straw took place on barrier-free type.

The coefficients of accumulation of Sr ranged from 3.0 to 11.7. Calcium-strontium ratio for the plants in all variants of the experiment was unfavorable (<80). The optimum ratio of Ca: Sr in plants is 160: 1 or more, relatively favorable-80: 1 and unfavorable - < 80:1 (Mineev, 1989). Describing the movement of these elements in the system soil - barley straw, it may be noted that Ca moves into the straw relatively more intensive than Sr. Discrimination coefficient (DC) in all cases was > 1. Consequently, the discrimination of Sr to Ca occurs. In general, the analysis of the histogram accumulation of Ca and Sr in the straw and Ca in barley grain testified about their essential similarity. The transition of elements in plants occurs on barrier-free type and depends of CC dose. Limit level of accumulation of these elements in the aerial parts of plants made in the dose range of chalk from 1.8 to 2.5 TA. In contrast, intake of Sr in the grain was going on barrier type. Until dose of chalk 1.5 TA (4500 mg kg^{-1} soil) strontium accumulation in grain varied slightly (from 13.6 to 16-20 mg kg^{-1}). The growth of the Sr content in the grain (40 mg kg^{-1}) was registered with liming at dose 1.6 TA (4800 mg kg^{-1} soil) and was maximum (115 mg kg^{-1}) in the treatment with the introduction of chalk at 1.9 TA (5700 mg kg^{-1} soil). In treatments with higher doses of chalk observed a slight decrease in the Sr content in the grain. The mechanism of transition Ca and Sr in the generative organs of barley varied. The uneven uptake of Ca and Sr in the plants was explained by different significance of these elements for the plants.

Physiological function of Ca in the plant associated with photosynthesis. Calcium is a part of the nucleus of the cell is linked to chromosomes with nucleoproteins. A certain amount of Ca is absorbed state in colloids plasma. Much of the Ca used by plants to neutralize the acids in the cells and in the form of salts of pectic acid, carbonate, sulfate, oxalate. Calcium is involved in the movement of carbohydrates, acts as a regulator of acid-base balance in plants (Nebolsin *et al*. 2005).

The physiological role of Sr in plants is not well studied. Mevius found that Sr can partially replace Ca in plants that have the need for it (Mevius, 1927). In research by Byhun *et al*. (1980) reported that the amylase, wherein the Ca was replaced by Sr, retained its activity, but differ in some physical properties.

Conversely, Walsh (1945) believes that Sr carbonate can replace Ca carbonate only for neutralizing the acid environment but cannot be replaced in its biochemical features. There are indications that toxic level of Sr to plants is 30 mg kg^{-1} of ash (Weinberg, 1977).

The content of Sr in the barley grain was less than in the straw in all treatments of experiment.

According to Austenfeld (1979), the content of pollutants in generative organs is minimal, because the reproductive phase is relatively late and generative organs less exposed to excessive influence by pollutants than vegetative organs. According to another point of view (Ilyin, 1991), plants are able to maintain the metabolic pools of the required content of chemical elements (within a certain range of their content in the soil), providing reproductive function. Describing the movement of Ca and Sr in system of soil-grain must be said that the use of chalk to a dose equal to 1.6 TA, Ca moving to the grain more intensely than Sr.

CONCLUSION

Complete dissolution of Conversion Chalk occurred on the third year of the experiment. In our studies were significant differences in the accumulation of mobile Ca in the soils with different cation exchange capacity and humus content. After the first year of experience content of mobile compounds of Ca in the soil 1 depending on the doses CC ranged 20,4-36,4% of the total contents and in the soil 2 ranged between 3,2-15,8% of the total content. Meanwhile, the differences in the content of exchangeable forms of Sr between soils number 1 and number 2 was not as contrasting.

Comparative study of migration ability of Ca and Sr showed that the rate of migration Ca almost two times higher than of Sr.

The total amount of leached Ca of conversion chalk for 16 lavages was 53.3% of the added with CC and Sr 28.9% of the added with CC.

The HA1 fraction plays a leading role in the fixation of Sr in the no limed soil; it contains about 50 % of the total soil Sr. In the limed soil, the HA1 fraction contains 21,2 % of the total Sr reserve.

The experiments showed a high degree of accumulation of Sr by plants. The plants accumulate more intensively Sr from soils with low CEC, where there is a shortage of mobile Ca.

There is different ability to accumulate Sr one and the same culture grown in different years after the application of the chalk

Studies have revealed that the alkaline earth metal delivery in vegetative and generative plant organs is different. The transport of Ca to the straw and to the barley grain and Sr to the straw occurred on barrier-free type. Opposite, the transport of Sr to the barley grain was going on barrier type. The increase in Sr content in the grain is observed only in the treatment of liming by 1.6 TA dose.

Apparently, this is due to the protective function of the plant against transport toxic elements in the bodies that provide reproductive function.

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DEVELOPMENT OF THE FUNDAMENTALS OF MINIMUM TILLAGE SYSTEMS OF CHERNOZEM SOIL OF NORTHERN KAZAKHSTAN

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ABSTRACT

Kazakh Research Institute for Soil Science and Agricultural Chemistry named after Uspanov in recent years is doing an experimental research in Kostanai Agricultural Research Institute, Kazakhstan, to develop a theoretical framework for minimizing tillage systems in order to study effective water accumulation, reducing the mineralization of soil humus and to improve farming technologies. The studies were conducted on the southern Chernozems in Kostanai region using the minimum and zero tillage. The research results showed that under conditions of frequent drought in May and June on Chernozem an application of the direct seeding into stubble technology makes it possible to save more productive moisture.

Keywords: minimum tillage, zero tillage, Chernozem, soil moisture, soil humus

INTRODUCTION

Climatic and soil conditions of Kazakhstan is very diverse. Existing farming systems applied to cereal crops are mainly include non-irrigated agriculture with a primary cultivation of spring crops in the northern and central parts of the country. The majority of the areas of cultivation of basic grains, especially wheat, have the unfavorable conditions of sharply continental climate in Kazakhstan, whose territory is exposed to wind and water erosion. Drought and salinity problems are becoming more acute. In all regions of the country has been recorded significant loss of soil fertility. There are significantly decreased the humus content in plow layer of soil and increased infestation of grain crops. Moisture deficit in the soil has been one of the most pressing problems of the country's agriculture. It becomes obvious that in these circumstances an improvement in crop sector is to be achieved primarily through the use of moisture-, soil-, energy-, resource and environment saving farming systems. The system of conservation agriculture, based on zero technology, today is a key lever for the survival of farmers engaged in crop production and, above all, the main export crop of Kazakhstan – wheat.

Conversion of natural ecosystems to agriculture as well as increasing intensity of tillage are known to decrease soil organic matter (SOM) levels and contribute significantly to the increase in atmospheric CO2 concentration (Lal *et al*., 1998). Continual soil inversion can in some situations lead to a degradation of soil structure, decreasing in available soil water, depletion of soil organic carbon, and increasing greenhouse gases emissions into the atmosphere (Castellini and Ventrella, 2012).

A number of technical innovations (zero tillage, appropriate crop rotations and residue management) could improve the productivity and biophysical sustainability of sub-tropical highland cropping systems Govaerts *et al.,* (2007).

The conservation farming includes minimum mechanical impact on soil up to its complete elimination; maintenance and availability of crop residues on the surface of soil and crop rotation systems. Under rainfed agriculture, these technologies significantly increase the fertility of soil, due to the higher control over wind and water erosion; improve soil's water holding capacity and increase organic matter content. Leave-in on field the high stubble retains and accumulates more snow, while pulverized and scattered straw through biological degradation improves the structure of soil quality.

All of these processes contribute to the accumulation of moisture in the soil, which is essential for sustainable wheat production in rainfed regions of Kazakhstan. In Kazakhstan the area of 1million 800 hectares is under zero till technology, which allowed increase in wheat production in 2012 up to 717.9 thousand tons.

Soil degradation is the single most important threat to global food production and security. Wind and water erosion are the main forms of this degradation, and conservation tillage represents an effective method for controlling this problem. The objective of this study was to quantify the effects of three tillage methods zero (ZT), minimum (MT) and conventional (CT).

MATERIALS AND METHODS

The experiments were conducted on the basis of Field Experimental Station of Kostanai Research Institute of Agriculture. The soils from studied treatments - minimum and zero tillage systems were analyzed for the depth of genetic horizons, depth and forms of carbonate layer, the pattern of effervescence, the structure, density, moisture reserves, moisture content and main agrochemical properties. The content of soil humus was determined by Tyurin method (Mineev, 2001), total nitrogen by Kjeldal (Mineev 2001), carbon dioxide was determined by gas-volumetric method, soil pH – potentiometrically in water solution. The mechanical composition was measured by Kachinski method (Mineev, 2001). The bulk density was determined picnometrically. Soil moisture was measured by drying the samples in thermostat.

RESULTS AND DISCUSSION:

Zero and minimum till in half-meter layer are similar with a slight advantage of zero tillage. Minimal, especially no-till - is an element of intensive technologies, possibly with sufficient provision of fertilizers, pesticides in the optimal crop rotations under the high culture of farming.

No-till system should be preceded by clearing fields from weeds and leveling the soil surface. At low culture farming with the lack of productive resources the propaganda of no-till system leads to a dead end. Best of all, the minimum and no-till is proved to be for cereals and industrial crops such as rapeseed - their root system has no strong central stem and not in need of a deep seedling. In addition, the no-till and mini-till technology can save on sawing process – which in Kazakhstan is often the main argument in their favor.

Govaerts *et al.*, (2007) also found that to improve moisture infiltration rates and soil moisture levels under zero till, it was critical to leave crop residues in the field. Crop rotation and appropriate residue management are key factors for controlling disease dynamics.

T**able 1** Water - physical properties of Chernozem southern

Soil depth, cm	Moisture, %	Compactness, g/cm^3	Total porosity, %	Water holding capacity, %	Moisture reserves, mm	Maximum hygroscopic moisture, %	specific weight, %	Wilt point, %
Zero till								
0 -10	14,05	1,07	58	54,21	15,03	7,99	42,97	10,71
10 -20	21,15	1,06	58	54,72	22,42	8,56	35,59	11,47
20 -30	21,22	1,05	58	55,24	22,28	8,52	35,72	11,42
30 - 40	17,75	1,09	57	52,29	19,35	8,50	37,65	11,39
40 - 50	14,57	1,16	54	46,55	16,90	8,30	37,10	11,12
Minimum till								
0 -10	10,92	1,23	51	41,46	13,43	6,51	37,57	8,72
10 -20	15,52	1,26	50	39,68	19,55	6,40	30,45	8,58
20 -30	13,92	1,30	48	36,92	18,09	6,45	29,91	8,64
30 - 40	10,25	1,55	38	24,52	15,88	3,93	22,11	5,27
40 - 50	9,15	1,60	36	22,50	14,64	8,09	21,36	10,84
Traditional till								
0 -10	6,25	1,09	57	52,29	6,81	5,87	50,19	7,86
10 -20	13,82	1,15	54	46,95	15,89	5,56	38,11	7,45
20 -30	11,70	1,29	49	37,98	15,09	4,98	33,91	6,67
30 - 40	10,02	1,30	48	36,92	13,03	5,31	34,98	7,11
40 - 50	9,05	1,40	44	31,43	12,67	3,84	31,33	5,14

High water infiltration rates and favorable moisture dynamics supported high yields. Our results provide a substantial basis to promote this technology with farmers in Chernozem soil of Northern Kazakhstan.

Table 2 Chemical properties of Chernozem southern at zero and minimum tillage

Depth	humus, %	CO_2	pH	Hydrolysable N, %	Total N, %	Total K_2O, %
				Zero till		
0-10	4,96	-	7,94	39,2	0,27	1,74
10-20	4,56	-	7,90	36,4	0,27	1,70
20-30	3,75	-	8,05	33,6	0,24	1,64
30-40	3,55	-	8,24	28,0	0,21	1,53
40-50	3,24	-	8,45	19,6	0,18	1,53
				Minimum till		
0-10	4,05	-		7,0	11,20	1,53
10-20	3,55	-		7,3	8,40	1,38
20-30	3,04	-		7,4	11,20	1,35
30-40	1,93	-		7,7	5,60	1,01
40-50	0,91	-		8,0	5,60	0,74

Removal of crop residues from the fields is known to hasten soil organic carbon (SOC) decline especially when coupled with conventional tillage (Yang and Wander, 1999; Mann *et al.*, 2002). Higher soil organic C contents under the treatment where mulch was applied, which is mostly a result of residue retention. Similar results were obtained by Chivenge *et al.*, (2007). Zero tillage has been shown to favor increases in soil water storage due to better infiltration and higher water retention capacity (Arshad *et al.*, 1999).

In our study zero-till system showed most positive effects on water use efficiency (Table 1). Similar results were reported by other researchers (e.g. Lafond *et al.*, 2006)

Apart from the economic benefits, the introduction of diversified crop rotations with zero technology reduces the field infestation; infection background (plant diseases); increases nutrient cycle, while the cultivation of legumes in the rotation increases the nitrogen content of the soil.

However, the problem of diversification should be addressed in parallel with the tasks of processing and marketing of crop production. Also, in-depth studies are needed on the use of fertilizers, dynamics and balance of core elements of mineral nutrition in soil for no-till technologies of cultivation of wheat and other crops. It is important to note that the use of fertilizers is important not only to obtain high yields of grain, but also for the formation of a large mass of plants remaining on the field, which is an important component of the zero technology.

CONCLUSIONS

Thus, the research results show that under conditions of frequent drought in May and June on Chernozem the application of the technology of direct seeding into stubble makes it possible to save more productive moisture.

To prevent a drop in wheat yields in the no-till cultivation, especially in the first years after the elimination of mechanical tillage can be achieved through the use of low doses of economically feasible nitrogen fertilizers and herbicides.

The success of no-till system in the South American countries is greatly due to the creation of powerful mulch from shredded pieces of corn, wheat, sorghum and other crops with high plant biomass. Reference to the overseas experience of minimum, especially no-till cultivation systems is not always justified due to various agro-ecological conditions.

There is growing awareness that the viability of agricultural performance -is certainly the conservation agriculture and no-till technology that will continue to grow throughout the world. But for the growth of the adoption of no-till technology it is necessary to overcome the following barriers: mentality (traditions, prejudices); knowledge, availability of appropriate machinery, availability of appropriate herbicides and appropriate policies to promote technology adoption.

Kazakhstan was 1st place on using zero-till among the Eastern Europe countries and Central Asia in 2008, and 8th place in the world on the areas under direct seeding. In 2012, Kazakhstan was on the 7th place in the world after China. In the last three years, Kazakhstan is out of competition, taking the 1st place on this aspect. The development and introduction of cost-effective crop rotations and diversification of production systems are also critical to the successful implementation zero soil conservation technologies in Kazakhstan.

These barriers must be overcome by politicians, community leaders, farmers, researchers, additional agencies, universities. With appropriate policies in promoting the conservation agriculture and no-till, many economic, social, and environmental issues can be solved, while improving soil fertility and increasing productivity.

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RHIZOBIA AS INOCULANTS AND THEIR USE IN AGRICULTURAL PRODUCTION

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ABSTRACT

Rhizobium-legume symbiosis provides about 50% of the total amount of nitrogen fixed (N_2) on the Earth which makes the symbiotic association the most efficient which reflected in increment of crop yield spatially legumes. Effectiveness of rhizobia is its ability to satisfy plant needs for nitrogen (N). Most indigenous legumes nodulated by native rhizobia do not require artificial inoculation however artificial inoculation of legumes with N_2 -fixing rhizobia is always applied on soils with no recent legume cultivation as well as on soils with low fertility. The process of adding these commercially prepared high effective rhizobial strains to seed or soil is called artificial inoculation with the aim to increase the number and effectivenes of rhizobia in a soil which increase quantity and quality of nodulation and N_2 fixation in legume crops. Desired characteristics of high quality inoculants are: sterile carrier media, long shelf-life, high number of highly effective rhizobia as active agent and low number of microbial contaminants as well as low cost. Good rhizobial inoculant increases the legume yield by 30-50%. Average values of N_2 fixed by various legumes are 60% depending of legume species, type of soil and evinromental factors as well as the measurement method.

Keywords: rhizobial bacteria, symbiotic nitrogen fixation, rhizobial inoculants, legumes, yield

INTRODUCTION

Nitrogen (N) is one of the most important plant nutrient. Its deficiency of soil N immediately influences quantity and quality of crop yield. Plant supply with accessible forms of soil nitrogen (NO_3^-, NH_4^+) is generally insufficient for intensive crop production due to changeable content of these forms (Zahran, 1999; Mengel and

Kirkby, 2001). Consequently the large-scale use of artificial N fertilizers since the middle of the 20th century has led to considerable yield increase in agricultural production. Global demand for N fertilizer is predicted to increase 1.4% annually (23.1 million tones increase by 2012) (FAO, 2008; Abi-Ghanem *et al.*, 2012). The increased crop productivity has been associated with a 20-fold increase in the global use of N fertilizer applications during the past five decades (Glass 2003) while this is expected to increase at least 3-fold by 2015. Generally, however, crop plants are able to take up and convert about 30–40% of applied mineral N to useful products while much of the surplus N is lost to the aqueous and atmospheric environment where it can become a serious pollutant and a conservation concern (Firbank, 2005; Jackson *et al.*, 2008; Dawson *et al.*, 2008; Kant *et al.*, 2011). In the 70th of last century the alarming reduction of fossil fuel in nature, necessary for the production of N mineral fertilizer, have focused the attention of the world on biological N_2 fixation-(BNF) -natural and healthy way of supplying plant and soil with molecular nitrogen from atmosphere (N_2) (Peoples *et al.*, 1995).

Earth's atmosphere consists of 78% of N making it the largest pool of N which would be unavailable for plants as well as animals and human world if there is no N_2 reduction i.e. N_2 fixation. Lightning probably accounts for about 10% of the world's supply of fixed N_2 and 25% in chemical industry -Haber-Bosch process while the most fixation is done by biological process i.e. BNF (60%) (Zahran, 1999). BNF is a major source of N for plant protein production (Herridge *et al.*, 2008). Since atmospheric N_2 is renewable resource, BNF in agricultural system is a sustainable source of N in cropping systems (Jensen and Hauggaard-Nielsen, 2003). This process is done by some prokaryote: *Archaea,* some bacteria and cyanobacteria. Through the process of BNF, particular prokaryote organisms possessing enzyme nitrogenase can reduce i.e. fix atmospheric N_2 gas into the ammonia (NH_3) form of N that will be converted into other organic form of nitrogenous compounds (Dixon and Wheeler, 1986; Rengel, 2002; Sytnikov, 2013). The best known N_2 fixing bacteria are: symbiotic (rhizobial) bacteria and nonsymbiotic free leaving (*Azotobacter, Clostridium*). It is complex relationship between prokaryotes and eukaryotes (Dixon and Wheeler, 1986; Garrity *et al.*, 2004). Soil bacteria collectively called "rhizobia" fix N_2

in symbiotic association with some genera of higher plants mainly legumes (fam. *Fabaceae*). They are known as legume root-nodule bacteria because they induce the formation of new organs (nodules) on the roots of their host plants to accommodate the rhizobia (Schumpp *et al.*, 2009). Therefore legumes (soybean, alfalfa, clovers, peas, beans, etc.) have the unique ability to form a symbiotic relationship with rhizobia (species of *Rhizobium, Mesorhizobium, Bradyrhizobium, Azorhizobium, Allorhizobium and Ensifer* i.e. *Sinorhizobium*) (Pawlowski and Bisseling, 1996; Zahran *et al.*, 1999).

Rhizobium-legume symbiosis provides about 50% of the total amount of nitrogen fixed on the Earth which makes the symbiotic association the most efficient (Villatoro, 2000). Worldwide, legumes are grown on approximately 250 million hectares and fix about 90 Tg (or 9×10^{13} g) of de-nitrogen per year (Xavier *et al.*, 2004). Effective rhizobia in legume root nodules inject approximately 40-48 million tonnes of nitrogen into agricultural systems each year (Jensen and Hauggaard-Nielsen, 2003). This amount has a particular significance for plant nutrition and soil fertility and productivity of low-N soils (Zahran, 1999) and in addition reduces the environmental pollution associated with the use of nitrogen fertilizer. Efficient supply of legumes as host plant is reflected in increment of crop yield (Tab.1), but also supply of non-leguminous crops with N in crop rotation (Provorov and Tikhonovich, 2003).

Table 1. Efficiency of symbiotic nitrogen fixation in the major leguminous crops (Kozhemyakov and Tikhonovich 1998; Smil, 1999)

Crops	Amount of nitrogen fixed kg/ha per 1 year		Ndfa*	Increase of yield %
	Potential	Usual		
pea (grain)	135	40–60	0.66	10
pea (herbage)	135	40–60	0.66	14
vetch	157	40–65	0.70	18
lupin (grain)	220	80–120	0.81	15
soybean	390	60–90	0.88	24
alfalfa	550	140–210	0.88	25
goat's rue	480	130–220	0.91	35
common bean		30-50	0.73	

*% of nitrogen derived from atmosphere in the total plant nitrogen (determined using the isotope N dilution methods)

Molecularly based rhizobium-legume symbiosis is highly specific process achieved due to the specific affinity of particular rhizobial species to a particular genus or species of legumes (Graham, 1999;

Ferguson *et al.*, 2010). In nodules transformed rhizobial bacteria into bacteroides reduce N_2 by enzyme nitrogenase and considerable energy. In exchange for reduced nitrogen from the bacteria (NH_3 followed by amino acids), the plant provides rhizobia with reduced carbon (carbohydrates) and all the essential nutrients required for bacterial metabolism (Rengel, 2002; Sytnikov, 2013). To achieve efficient exchange of metabolites between the symbionts (rhizobial bacteria and host plant) there has to be the appropriate compatibility between them because nodulation and nitrogen fixation efficiency is a complex activity, involving and interacting genes in both symbionts (Kondorosi, 1986; Ferguson *et al.*, 2010).

Effective symbiosis between rhizobia and legume host rests mainly with the strain of microsymbiont used (Thangaraju and Werner, 2004). Effectiveness of rhizobia is its ability to satisfy plant needs for N. Rhizobial strain activity, abundance and density influence soil N_2 fixing potential (Delić-Vukmir, 1994; Delić-Vukmir, 1995; Rengel, 2002). In natural symbiotic process in soil indigenous rhizobial populations fix N_2 with different efficiency depending on biotic factors (N_2 fixing potential of soil, rhizobial strain competitiveness, host plant and rhizobial strain genotypes, presence of antagonistic bacteria in rhizosphere, viruses and PGP bacteria) as well as abiotic i.e. environmental factors (type of soil, soil tillage, soil temperature, moisture, pH, availability of soil N) (Vojinović, 1964; Dixon and Wheeler, 1986; Montanez, 2000; Hefny *et al.*, 2001). Native rhizobial populations found in soil often are less effective in nitrogen fixation potential or presented in a less number causing needs for artificial inoculation of particular legumes.

Rhizobial inoculants and need for inoculation

One of the strategies to enhance BNF in agricultural systems is the use of rhizobial inoculants. They are N biofertilizers which contain living rhizobial strains as active agent selected for maximum N_2 fixation potential and competitive ability for nodulation (Rebah, 2007; Montanez, 2000). The process of adding these commercially prepared high effective rhizobial strains to seed or soil is called artificial inoculation with the aim to increase the number and effectivenes of rhizobia in a soil which increase quantity and quality of nodulation and N_2 fixation in legume crops. It is the kay element in sustainable agriculture because it decreases N mineral fertilizer use and increases legume yield, total N content of plant, seed protein content, supply non-legume crops with N, supply soil with N, supply plants with vitamins and growth substances (PGPR abilities) (Antoun and Prevost, 2000; Biswas *et al.*, 2000; Montanez, 2000; Thangaraju and Werner 2004; Delic *et al.*, 2011; Abi-Ghanem *et al.*, 2012). If the legume crop was grown in the field previously, there is possibility that the soil already contains indigenous strains of specific rhizobial species that can nodulate host plant. Most indigenous legumes nodulated by native rhizobia do not require artificial inoculation however artificial inoculation of legumes with N fixing rhizobia is always applied on soils with no recent cultivation of legumes as well as on soils with low fertility in the soil as well as in acid soils, also when soils has a high sand content or in anaerobic soil conditions (field has been flooded for more than a week). Inoculation of non-indigenous legumes crops is especially important because indigenous soils usually do not contain rhizobial species specific for non-indigenous legume crop. For example, this is the case with soybean production in Serbia; Serbian soils do not contain indigenous strains specific for soybean (Tešić and Todorović, 1963).

Rhizobial inoculants have been used successfully in world agriculture for almost 120 years (Herridge *et al.,* 2002; Phillips, 2004; Hirsch, 2004). They have been produced around the world, primarily by small companies. Beginning of rhizobial inoculant as agronomic practice was established by the end of the 19th century in the USA: naturally inoculated" soil was mixed with seeds of legumes. A decade later, the first patent named "Nitragin" was registered for plant inoculation with *Rhizobium* sp. (Nobbe and Hiltner, 1896) causing that legume inoculation with rhizobial inoculants became common practice in production of legume crops. Significant improvement in inoculants production was done to the end of 20th and the beginning of 21th century. It was estimated that about 20 million hectares of crops and pastures in legumes were inoculated in the world every year (Herridge, 2002). Approximately 2000 tonnes of inoculants was sufficient to inoculate this area. The largest single producers are in the USA with an annual production of 1000 tons (Ben Rebah, 2007). In Republic of Serbia artificial inoculation is essential mainly for soybean which is grown on 140-160 000 ha per year of which 56% of this area is inoculated with rhizobial inoculants produced in Institute of Field and Vegetables

Crops, Novi Sad while 24% with inoculants from Institute of Soil Science, Belgrade (Figure 1). It is interesting that soybean and some legumes in Brazil, are only inoculated, not fertilized with nitrogen. In the USA, Brazil, and Argentina soybean inoculation has made a major agricultural impact while significant contributions of inoculation to the production of other legumes were made in Australia, North America, Eastern Europe, Egypt, Israel, South Africa, New Zealand and, to a less extent, Southeast Asia. For the large majority of less developed countries in Asia, Africa, and Central and South America, inoculant technology has had no impact on productivity of the family farms, because inoculants are not used or are of poor quality (Bashan, 1998; Xavier *et al.*, 2004).

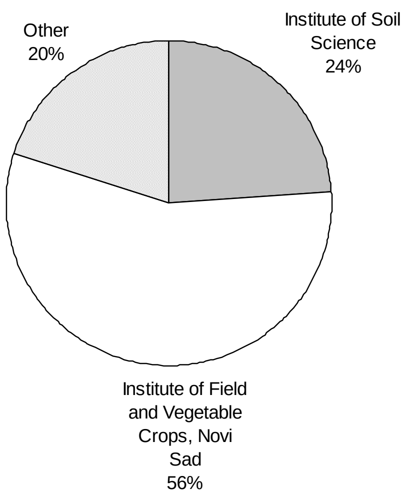

Fig. 1. Average values of inoculated soybean area in last 5 years in Serbia

Development of high quality inoculants

Development of high quality inoculants is one of the main aims in production of N microbiological fertilizer and consists of: strain selection, selection of a carrier, mass multiplication, formulation of the inoculants, and packaging and marketing.

1. Strain selection. Specificity, competition, mobility and virulence as well as N_2 fixing activity are important rhizobial characteristics (Rengel, 2002; Sytnikov, 2013). After isolation of rhizobial strains and their characterization (Stajković-Srbinović *et al.*, 2012) in order to obtain highly quality inoculum, great attention is paid to the selection of favourable rhizobial abilities: high N_2 fixing capacity, virulence and competitiveness ability, occupation of significant proportion of nodules, greater activity of nitrogenase and associate enzymes, to achieve high number of rhizobia in inoculums, strain mobility as well as strains tolerant to the following environmental factors: low soil pH, high temperature, drought, pesticides, antibiotics, heavy metals (Vojinović, 1963; Somesegaran *et al.*, 1994; Miličić *et al.*, 2006). Also, rhizobial ability to survive on seeds and to nodulate host root in the presence of mineral nitrogen is important properties of rhizobia as active agent of microbiological fertilizer (Rengel, 2002; Milicic *et al.*, 2006). The wide diversity of rhizobial strains is utilized for selection of highly effective strains and other favourable rhizobial abilities by two ways. One way is selection of specific highly effective strains in particular and local conditions for: host plant, particular soils, locations and crop (plant genotypes) for tolerant to some environmental factors (Rengel, 2002). However, in most cases, the best performing strain in one location did not differ significantly at other locations tested. The other way of selection is by genetic improvement of the selected strains (Montanez, 2000; Xavier *et al.*, 2004; Thangaraju and Werner 2004).

The monitoring of survival and spread of introducing rhizobia was greatly improved by the presence of novel marker genes indicating how genetic modification has been used in some cases to improve inoculants' efficacy. Tagging of rhizobia with marker genes provided more accurate information compared to the use of conventional strains, illustrating an important application of genetic modification, for tracking bacteria in the environment (Hirsch, 2004). Thus inoculation of alfalfa with genetically modified *S. meliloti* increased the intensity of nitrogen fixation by 31-128% (Phillips and Teuber, 1985; Montanez. 2000; Hirsch, 2004).

To the mid-70s research of BNF were directed to rhizobial role in this process, especially to the efficiency of the strains. The selection of rhizobia and host legumes for a high N_2 fixing potential were separated in the middle of the 20th century. But the results of these studies indicated that plant selection is a potential method to enhance BNF as well as the importance comparative selection of both symbionts (Viands *et al.*, 1981; Montanez, 2000; Rengel, 2002; Smith *et al.,* 2001; Delic *et al.*, 2009; Ferguson *et al.*, 2010). Legume-rhizobium association is a genetically complex, so that phenotypic differences can be brought about by genetic variation in both symbionts. Consequently, selection of highly compatible pairs of rhizobial strains-legume genotypes for high SNF is very important (Montanez, 2000; Provorov and Tichonovich, 2003; Abi-Ghanem *et al.*, 2012; Delic *et al.*, 2013; Sytnikov, 2013). Beside the selection of highly efficient and highly competitive strains, the program of leguminous selection for high effective N_2 fixation should be included in Serbian conventional crop breeding. Strain selection is done under controlled laboratory conditions as well as green-house and field conditions. Figure 2 showes the effect of *Bradyrhizobium japonicum* strains applied in the form of Azotofiksin on soybean grean yield. Yield increase in soybean cultivar varied between 19% and over 200% depended on strain compared to control (Fig. 2) (Miličić *et al.*, 2007). N fixing potential of particular strains was tested also in long term period in the field conditions (Gibson *et al.*, 1990; Delic *et al.*, 2010; Delic *et al.*, 2013).

Additional researches also indicate that rhizobia have the potential to be used as plant growth promoting rhizobacteria (PGPR) with non-legumes. Yield increase and plant growth improvement caused by inoculation of non-legumes with PGP rhizobia have been reported. Rhizobia promoted the growth of maize, spring wheat and spring barley, wild rice, grasses, cereals. This growth-promoting effect appears to involve the plant growth regulators indole-3-acetic acid and cytokine, siderophore production, effect on phosphorus availability, antagonistic activity of rhizobia against plant pathogenic micro-organisms, synergistic effect of rhizobia on vesicular-arbuscular mycorrhizal fungi (Domit *et al., 1990;* Mehboob *et al.*, 2009; Baset Mia and Shamsuddin, 2010; Delic *et al.*, 2011). Rhizobial co-inoculation with PGP microorganisms having different mechanisms of plant growth promotion is the new fashion in agriculture and has additive or synergistic effect on plant growth (Barea *et al.*, 2005).

The production of selected rhizobia in pure culture is a quite common practice making use of fermenters. The development of techniques for the production mixture culture of rhizobia with other species of microorganisms is the main issue to be tackled in order to allow a wide use of biofertilizers (Malusa *et al.*, 2012).

Finally, inoculants with high quality strains must have the following characteristics: nodulation and N_2 fixing ability with all commonly used cultivars of the legume(s) for which it is recommended; ability to compete with less effective indigenous soil rhizobia, and so form most of the nodules produced; ability to persist in the soil over time; tolerance to soil stresses, such as high temperature, desiccation, acidity and drought, pesticides, heavy metals; ability to grow well in simple and inexpensive laboratory media; strain must be genetically stable, must survive in the inoculant formulation and maintain their properties during storage.

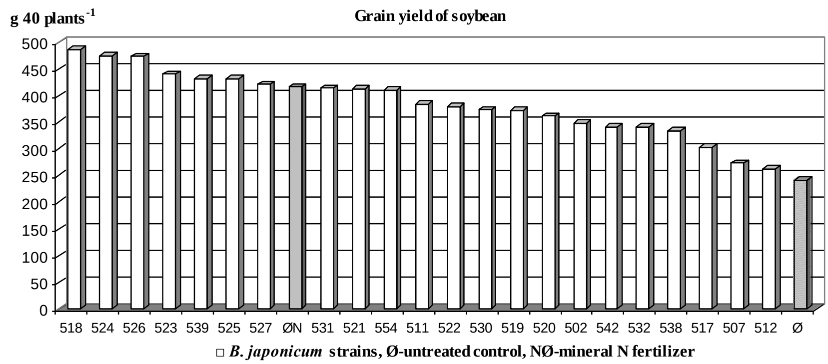

Fig. 2. Effect of different *Bradyrhizobium japonicum* strains on the yield in soybean grain* (Miličić *et al.*, 2007)

Good rhizobial inoculant increases the legume yield by 30-50%. Average values of N fixed by various legumes are about 60% depending on legume species, type of soil and evinromental factors as well as the measurement method (Papstylianou, 1987; Delic *et al.*, 2011). Acording species of legumes percentages of fixed N (%Ndfa) are: up to 70% in soybean, about 60 % in common bean, up to 66% - 80% in pea up to 60% in alfalfa about 70 % in read clover up to 45% in *Vigna radiata* (Delic *et al.*, 2011; Phillips, 2004).

2. Carriers are an integral part of microbiological fertilizers because carrier with its capacity should allow growth and protection of the bacterial cell during storage, and then deliver viable cells in good physiological condition at the right time to target site (Bashan, 1998; Xavier *et al.*, 2004). A good carrier have to have additional desirable characteristic: a high percentage of organic matter (>30%), the optimal pH, 6.8-7.0 (pH> 5.5), and N content, an easily adjustable pH, favourable water-air capacity (for wet carriers) (55-60% when the inoculum added in carrier dried 10-12%), and environmental characteristics as non-toxic, biodegradable and non-polluting, with minimize environmental risks such as the dispersal of cells to the atmosphere or to the ground water.

Also, it should allow addition of nutrients, and to allow the survival of rhizobia after seed inoculation. It is important to say that the raw materials of most commercial carriers should be cheap and naturally abundant (peat and soil fractions). Each new type of carriers has been tested in order to facilitate the maintenance of rhizobial inoculants characterised with permanent metabolic activity and growth and multiply. Rhizobial inoculants named “Azotofiksin” of Institute of Soil Science, Belgrade satisfies all the criteria for more than 50 years of production and peat is the subject of permanent scientific research in the Institute. However, peat is not available to most tropic and subtopic countries (Halliday and Graham, 1978; Tilak and Subba Rao, 1978; Corby, 1976) which had to find alternative carriers. Alternatively different materials were evaluated as carriers for rhizobia.

According to the origin, carriers can be divided into: soils (peat, coal, clay, and inorganic soil); plant waste materials (composts, farmyard manure, soybean meal, soybean and peanut oil, wheat bran, "press-mud" by-product from the sugar industry, agricultural waste material, spent mushroom compost, and plant debris); inert materials (vermiculite, perlite, ground rock, phosphate, calcium sulphate, polyacrylamide gels) and plain lyophilized microbial cultures and oil-dried bacteria (Daza *et al.*, 2000; Ben Rebah *et al.*, 2002). These preparations can be used as they are or they can later be incorporated into a solid carrier. Freeze dried rhizobial cultures or mixture of talc and freeze-dried culture were used as commercial inoculants in Australia for several years. Clay and vermiculite based rhizobial formulation has been successfully commercialized in North America (Bashan, 1998; Xavier *et al.*, 2004). For example, some results showed that mixture of peat and corn meal generally had the highest stimulating effect on the growth of all investigated *Bradyrhizobium japonicum* strains, but good effect was also achieved by a mixture of peat and perlite, which is far more cost-efficient (Milicic *et al.* 2006).

3. Formulation of the inoculants is a crucial aspect for producing inoculants containing an effective bacterial strain in suitable carrier. It can determine the success or failure of active agent (Bashan, 1998). Formulation typically consists of establishing the active agent in a suitable carrier together with additives that aid in the stabilization and protection of the microbial cells during storage and transport, and at the target site. The formulation should be cost effective, easy to handle and apply as well as stable during production, distribution, storage, and transportation, protects the microbial cells from harmful environmental factors (desiccation, high temperature and pesticide) and maintains or enhances activity of the organism in the field (Jones *et al.*, 1998).

Commercial formulations of inoculants are available as powder, granule, and liquid (Hungria *et al.*, 2005). Powder formulation is widespread used in developed and developing countries as a seed coating before planting (Smith, 1992; Tang and Yang, 1997). Guided by rule that the smaller the particle size, the better the inoculant will adhere to the seeds, standard sizes can vary from 0.075 to 0.25 mm. The amount of inoculants used is around 200 to 300 g ha^{-1}. Generally, peat has been the preferred carrier in powder form (Burton, 1967; Xavier *et al.*, 2004). Many factors (the type of peat, the origin and batch, as well as sterility of the peat) affect the titter of rhizobia and its long-term storage survival. Sterility of the peat carrier before addition of rhizobial broth culture has advantages: the high sustaining level of rhizobia, higher yield in the field and chance of extending culture production by diluting the broth without reduction of the final inoculant quality (Wadoux, 1991). The main peat drawbacks are: its variability of quality (bacterial titre and inoculants effectiveness) due to its complex organic matter; the way of sterilization have to be by gamma rays (often its heat sterilization realize compounds toxic to bacteria), some types of peat can reduce plant growth, its prone to contamination that can reduce shelf life of the inoculant (Montanez. 2000; Bashan 1998). It can be recommended addition of adhesive materials during seed inoculation due to insurance of enhanced seed coverage with powder.

Granules containing rhizobia are generally available as peat pills and as hard mineral-based. Increasing interest in the granular form of inoculants in the North American market (Xavier *et al.*, 2004) may be because granules are easy to apply and less dusty than powders. In addition they must be free-flowing when applied through seeding equipment, and free of "sticky" or "tacky" granule aggregates. Granules incorporate directly in soil furrows in field and near seeds. Size ranges are from 0.35 to 1.18 mm. Rhizobia inoculant is used at a rate of 5 to 30 kg ha^{-1}. These inoculants are popular and have been successfully commercialized since 1975 (Tang, 1994; Tang and Yang, 1997). Bead-like forms are synthetic variations of granular forms. These can be in macro sizes (1 to 3 mm in diameter) used as granules form, or in micro size (100 to 200 μm) used as a powder technology. These inoculants are a new, as yet unproven, possibility in inoculation. Granular form has the advantage when pesticide-treated seeds were applied and inoculant granules are not in direct contact with treated seeds and therefore rhizobial survival is enhanced. By placing the inoculant granule in close proximity with the seed is important when rhizobial bacteria have limited mobility like bradyrhizobia. Unavailable trait of the granular form of inoculants is their bulking and higher storage and transportation costs (Xavier *et al.,* 2004). Mixture of classical peat inoculants with mineral granules at sowing can be used (Wadoux, 1991).

Liquids inoculants use broth cultures or liquid formulations, mainly in water, but also in mineral or organic oils and or polymer-based products. Polysaccharides such as gums, carboxymethylcellulose and polyalcohol derivatives are frequently used to alter the fluid properties of liquid formulations (Xaviar, 2004; Sytnilov, 2013). The seeds are dipped into the inoculant before sowing and after drying the seeds are sown. Alternatively, the suspension can be sprayed directly into the furrow or on the seeds before sowing. This method ensures good coverage of the seeds. Due to ease of application of a liquid inoculant, use of these inoculants are popular in the USA, Canada, Argentina, and Brazil, mainly for soybeans, but also for lentils, peas, and peanuts (Smith, 1992). This formulation should be applied several days after sowing at seedling germination. Beside the microbial inoculant other materials might be involved in the final formulation of liquid inoculant (alginate with inert calcium carbonate) which allowed for the right bacterial concentration.

The use of each type of inoculants depends upon market availability, cost, and the needs of a particular crop under specific environmental conditions. The granular form is better than powder inoculants for rhizobia, under stressful planting conditions, but since more is required, it is costlier (Smith 1992). Characteristic of liquid rhizobial formulations is similar to that of peat-based products under field conditions. Several liquid formulations available today sustain high viable rhizobial numbers for extended periods of time. However, physiological changes in aspects such as on-seed stability and their ability to form nodules have been shown in *Rhizobium* that have been stored in commercial liquid formulations for several years (Xaviar, 2004).

Slurry inoculant is based on powder-type inoculants suspended in liquid (usually water). The suspension is directly applied to the furrow or alternatively, the seeds are dipped just prior to sowing. Often, the same active agent has to be formulated in diverse forms depends on climates, type of soil and preferences of user.

Technological process of inoculant production

Technological process of inoculant production includes the following phases: maintenance and storing cultures of *Rhizobium* spp., choice of the carrier and formulation; sterilization of carrier; defined bacterial culture and the effectiveness of strains; obtaining a liquid inoculum (fermenter grown broth), adding the inoculum to a powder carrier followed by a period of maturation to ensure multiplication or adaptation of rhizobial cell, storage inoculant products, permanently quality control but particularly of the finished inoculant (Herridge, 2002).

Most of legume inoculants are prepared by adding fermenter grown broth, containing a large amount of highly-efficient rhizobia, to suitable carrier usually peat as powder carrier. This is the important step in the production of powdered rhizobial inoculants. The most important factor for inoculant quality is a high number of alive rhizobia (more than $2x10^9$ CFU g^{-1}) and minimal contamination by microorganisms not detrimental to rhizobia or pathogen to plant or humans (Lupwayi *et al.*, 2000; Rebax *et al.*, 2007). Commonly known methods in microbiology are used to determinate the bacterial number; the traditional Plate Count method and Most Probable Number (Woomer *et al.*, 1990), ELISA, and Immunoblot (Bashan, 1998). The titter of rhizobia required in inoculants varies worldwide. There is no common international standard. In countries with establishing standards for rhizobial inoculant, such as Australia, carriers (mainly peat) must contain rhizobia more than 10^9 CFU g^{-1} of inoculant and contaminants less than 10^6 g^{-1} of inoculant (0.001%) which is achieved in Azotofiksin N. In some countries (Australia, Netherlands, Thailand, Rwanda) titre have to be 5x 10^7 – 4x 10^9 CFU g^1 of inoculant, but in Canada 10^6 - 10^9 CFU g^1 or ml of inoculant. In France the titter of rhizobial inoculant should provide 10^6 CFU of rhizobia soybean seed^{-1} while in Canada 10^3 – 10^5 CFU g^{-1} seed^{-1} (Bashan, 1998). Many developed countries as Canada and France have regulations for inoculant quality. In some countries (Australia, Rwanda, 10-10^3 CFU g^{-1} or ml of inoculants, respectively) low levels of contaminants are allowed (Olsen *et al.*, 1994a,b; Bashan, 1998; Xaviar *et al.*, 2004).

Inoculation of legumes with high population of specific and effective rhizobium strains ensuring optimal nodulation and efficient SNF has proven to be a valuable agronomic strategy to improve crop productivity and produce economic gain. According to research from many countries the most effective inoculants are made of sterile carriers and for a period of up to 6 months because rhizobial inoculants lose efficiency with the length of storage. This is applied in production of Azotofiksin of Institute of Soil Science. Shelf- life is important inoculant characteristic for manufacturers because they lose efficiency with length of storage. Consequently the aim of farmers is to maintain acceptable number of rhizobia for 1 season while manufacturers prefer 1,5 years in order to be able to sell them over two cropping seasons (Rebah 2004). In Serbia shelf-life of our inoculant is minimum 6-12 months. A good inoculant should allow for ease of handling (a major concern for the farmer), provides rapid and controlled release of bacteria into the soil, and can be applied with standard agro-technical machinery (Bashan, 1998).

Stringent assurance of quality at various steps of production ensures the production of consistently high quality inoculants. In the end of technological process of inoculant production, quality control of rhizobial inoculant as final product is done. For example it is presented results of alfalfa inoculation with appropriate rhizobial inoculant “Azotofiksin L” (Fig. 3). Results showed increased alfalfa shoot dry yield and total N content by more than 50% in comparison with unfertilized control (unpublished results) which indicate cost efficient symbiotic N fixation in alfalfa crop.

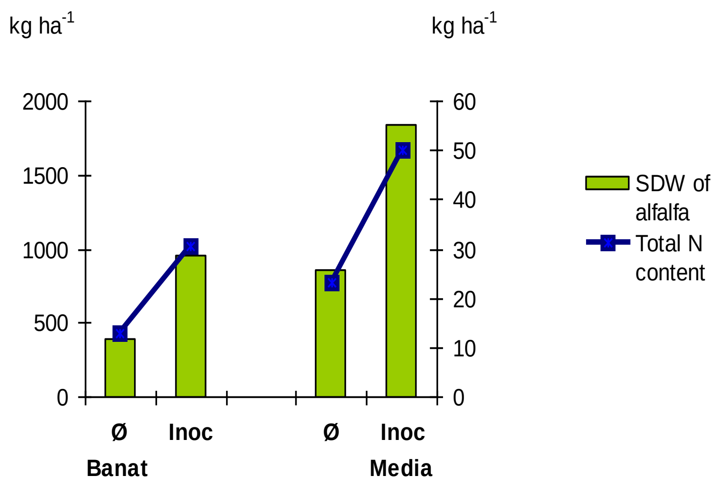

Fig. 3. Effect of rizobial inoculant “Azotofiksin” on properties alfalfa cultivars (kg ha^{-1})

Time and methods of inoculation

Seed and soil inoculation are two main methods of inoculation currently being used (Hegde, 1992). Inoculation of seeds can be applied by three different ways: as a seed coating, months before the actual sowing; "on site"- as a seed application just before sowing, or by inoculant delivery directly onto the seeds in the furrow; and after seedlings emerge (Gault, 1982; Bashan, 1986b). The most popular method to date is the "on site" method, primarily because of lower costs (Fages, 1992) .Major drawbacks of in situ method and when seeds are precoated by industry are additional work required during restricted time of sowing as well as possibility of reduction of the bacterial population due to exposure of alive bacteria to UV irradiation or to the chemically coated seeds.

Soil inoculation can be done either with peat-based granules or with microgranulated forms of inert materials: sand, calcium carbonate, powder. These materials have been previously mixed with the inoculum in the factory or can be mixed with the seeds by the farmer prior to sowing. The precoating of seeds and soil inoculation are more expensive technology of inoculation and sometimes not as effective but they are more convenient for the farmer. Soil inoculation is expensive because more inoculant is required.

Good quality commercial inoculant in the field

Inoculant quality control is left to market forces and the manufacturer's discretion (Bashan Smith, 1992) with exaction formal registration of inoculants. The paradox is that many of the inoculants in the world have the poor quality in spite of the hundred years of research and experience in manufacturing. Even good quality inoculants are often not given the greatest benefit in practice.

It can be concluded that desired characteristics of high quality inoculants are: high titer of highly effective and highly competitive strain as active agent causing yield increase (2.0-5.5x10^9 g^{-1} peat); sterile carrier media for multiplication active agent, defined bacterial culture and the effectiveness of strains; long shelf-life of inoculant (month to years); high number of competitive active agent remaining on the seed after inoculation (10^3-10^6 $seed^{-1}$); presence of microbial contaminants up to 10^6 g^{-1} of inoculant (Herridge, 2002). One more desire characteristic of inoculant is low cost.

The economic effect of rhizobial inoculants

Application of mineral N fertilizer per hectare is reduced by participation of N fixed (30-90% which depends on legume) causing decrease of financial investment in nutrition of legumes and indicating that rhizobial inoculants are cost effective (Phillips, 2010; Delic *et al.*, 2011).

Conclusions and future prospects

A benefit of inoculant production to the world’s agriculture depends on improving the quality of inoculants. Successful model for the production and use of high quality inoculants should be stricter quality control by certified public sectors. In addition, rhizobial inoculants with particular PGP microorganisms (binary composition of inoculant) become future in production of biofertilizers because polyvalent biofertilizers useful in legumes and non-legumes production. Rhizobial inoculants as supplement to mineral N fertilizers play an important role in sustainable agriculture.

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ROLE OF PLANT PRODUCTION IN VIRTUAL WATER TRADE

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ABSTRACT

Society development and increasing of population lead to increased demand for water. The concept of *Water Footprint* is developed with the main goal to provide a better assessment of water demand and water consumption in different countries. Water Footprint adjoined to an industrial product is the amount of water consumed in its production. In addition to the water that the product really contains there is water used (consumed) indirectly - the so-called virtual water. Therefore, trade in agricultural products (and other products and services) actually implies the virtual water trade. Water Footprint is made up of three components: blue, green, and gray water. Blue water is the amount of water that evaporates from the resources of surface and ground water in the production of goods and services (or built into the product during the manufacturing process). In agronomic terms, this water is used for irrigation. Green water is the quantity of water originating from precipitation that accumulates in the rhizosphere layer, which evapotranspirates or is incorporated into the product. In agronomic terms, this is the amount of water that plants use in the conditions of natural water supply. Grey water is the amount of contaminated water associated with the production of goods and services to the individual or the community. Developed countries export more virtual water than imported, and have high water productivity. Developing countries use their water reserves mostly groundwater for irrigation and by channeling those resources in more profitable agriculture production, it could lead to better management of water and its conservation. Serbia has a very good potential of green water, which can be very productively used with advanced agro-technical practices. The purpose of this paper is to present a general procedure for calculating the green and blue water.

Keywords: water footprint, virtual water, green and blue water

INTRODUCTION

The development of society and the growth of population lead to increased water requirements. Water is a natural resource of great importance, and agriculture is the largest consumer of water - more than 70% of water resources are spent in agriculture. The water requirement in agriculture is getting increased, not only due to the increase in production volume, but also due to climate changes, which are reflected in plants having increased water requirements.

In order to provide a better assessment of water requirements and water consumption in different countries, a concept of virtual water trade has been developed. The concept of virtual water (The Virtual Water, VW) was already defined in the 90s. (Allan, 1993; 1994). There are two main approaches to studying VW: the volumetric approach, developed by the Water Footprint Network (WFN) (Hoekstra *et al.*, 2011) and the life-cycle analysis approach (Life Cycle Analysis). In studies, WFN approach is primarily used (Seckler, 1998; Rockstrorӧm, 2001; Shiklomanov, 2003 Yang *et al.*, 2006).

The author of this concept, A. Hoekstra (2002), has described the relationship between water management, consumption and trade. The quantification of virtual water movement has been performed by Chapagain and Hoekstra (2003). The basic idea of this concept is that the Water Footprint has been defined as an indicator of the volume of consumption and pollution of water, which can be used to assess water resource consumption and water requirements, in the context of different directions of economic development.

The Water Footprint of one product is the amount of water used for its production. In addition to the water already contained in the product, the product also contains water used (consumed) indirectly - the so-called virtual water. The virtual-water content of the product (commodities, goods or services) is the volume of freshwater used to produce the product, measured at the place where the product has been produced. This refers to the sum of all water consumed in different steps of the production chain. This water is called virtual, because most of the water used in production is not physically contained in the product. It is used water, and its quantity is much higher than the actual water content. Therefore, the trade in agricultural products (and other products and services) actually implies the virtual-water trade, as well.

The Water Footprint can be viewed at different levels: for any defined group of consumers, individuals, families, cities, nations or manufacturers, factories, agricultural goods, etc. Although the Water Footprint concept has often been deprecated, the cooperation between global institutions in this area has led to the establishment of Water Footprint Network in 2008, with the goal to coordinate further development of this concept, along with the development of appropriate research and implementation methods.

MATERIAL AND METHODS

Virtual water in agriculture

Considering water consumption in agriculture, for which it has already been said to be the largest consumer of water of all areas of human activity, WF has a particularly important role in virtual-water assessment in the agricultural product trade. Although the term virtual is used, the water in question is actually real water, which is needed for agricultural production and which, in fact, represents water requirements of crops (Allann, 2003).

Although many people believe that Serbia has large water potential, in fact, it is not true, because the majority of surface water is water flowing through the country, and it can only be used in accordance with international protocols, so the potential of using that water for irrigation depends on those protocols.

Serbia is located in a specific area, where droughts and excess water occur periodically, and they have adverse effects on agricultural production. The problem of excess water is usually solved by building numerous infrastructural facilities, which are used to drain water away from the land. However, the problem of drought is more difficult to solve, because, on the one hand, the question of their effectiveness is raised, and on the other hand, there is the question of sustainable water management.

The Water Footprint concept aims to determine whether an area, region or country import or export virtual water, whether water productivity is higher or lower compared to other countries, and whether it might be better to, instead of investing in irrigation, invest water in some more profitable production. Considering the continuous debate on whether irrigation should be developed in larger areas or not, the Water Footprint concept can indicate the current situation and provide guidance for future water management and planning. This information can be of great importance in planning infrastructure, water resources, production facilities, etc.

The Water Footprint (WF) consists of three components: green, blue and gray water. Together, they make the WF of one product.

Green water is the quantity of water originating from precipitation that is accumulated in the rhizosphere region, that evaporates or that is incorporated into the product. In agronomic terms, it is the amount of water adopted by plants in natural water supply conditions. Green water represents evapotranspiration (ET), which includes a productive part - transpiration (T), and a non-productive part - evaporation (E), from the surface of lands, lakes, ponds, etc. Serbia has very good green water potential, which, with good agrotechnics, can be used productively.

Blue water is the amount of water that evaporates from surface and ground water resources during the production of goods and services (or that has been built into the product during the production process). In agronomic terms, it is water used for irrigation. (In assessment of virtual water in crops, one should bear in mind that significant errors may occur in estimating blue water. In calculating the amount of blue water, losses that occur during irrigation are usually not taken into account. In reality, irrigation delivers more water than it is necessary for evapotranspiration in agricultural crops. More than 50-80% of water is lost through evaporation from the soil surface, during transport, uncontrolled outflow or percolation. Therefore, real water productivity can be lower than in estimated models, and in cases where those losses are higher, such as in developing countries, water productivity in agricultural crops is even lower, Yang *et al*., 2006).

Gray water is the amount of contaminated water associated with the production of goods and services for individuals or communities. It can be estimated as the amount of water required to reduce pollution to such an extent that a satisfactory water quality is gained. From the agronomic point of view, this component is difficult to define, and it is usually neglected in the evaluation of virtual-water trade. The basis for assessment of the virtual-water content, which is included in the international food trade, is the virtual-water content in agricultural crops. The Crop Virtual Water

Content (CVWC) is the amount of water needed to produce a crop unit, and it is expressed in m^3/kg (Zimmer and Renault, 2003). This is, in fact, the reciprocal of a well-known measure - water productivity - crop water productivity (kg/m^3).

In estimating the crop virtual water content (CVWC), models such as CROPWAT, AQUACROP, and so on, are used. In this way, assessments of major crops in many countries can be encountered in literature. (Mekonnen and Hoekstra, 2010). It is clear that these assessments are rough, because of the lack of precise information from certain countries. Nevertheless, they can give approximate values regarding water consumption and they can assist in planning future agricultural production.

Water Saving

Some studies suggest that, in developed countries, more virtual water is exported than imported, and those countries have high water productivity, as opposed to developing countries, in which more virtual water is imported (in agricultural products) than exported. Given that developing countries use their own water reserves, mostly groundwater for irrigation, channeling water resources towards a more profitable production than agriculture could lead to better water management and water preservation. Certainly, it depends on numerous factors, mostly political, then economic, educational, and so on.

Water saving at the global level can be achieved if the countries that export food, i.e. virtual water, have higher water productivity than the importing countries. Taking into account the trade in certain agricultural crops, it is possible to achieve global water saving, depending on the agriculture. For example, in the case of wheat or corn, this saving is between 41% and 59%, so the trade in these products leads to a global decrease in water use, since virtual water content in these crops is lower in exporting countries than in importing countries. However, there are no strict rules, since there are exceptions, such as rice: the amount of virtual water included in export is much higher than in importing countries, because evapotranspiration of rice is much higher in countries which are the largest exporters (Thailand and Vietnam) than in importing countries (Yang *et al.*, 2006).

The price of blue water (for irrigation) is high. Blue water requires facilities for storage and water distribution prior to its delivery to users, and distribution itself implies investments and costs. In addition, the application of irrigation may have negative consequences on the environment, such as the phenomenon of salinization, soil structure degradation, etc.

On the other hand, the green water trade is much more efficient than the blue water trade, since it is a free natural resource that does not require additional costs. The countries that are the largest food exporters have the largest amounts of green water in their virtual-water export (the USA, Australia, France, Canada, Argentina, Thailand, Brazil), which indicates that their agricultural production (especially of grains) takes place primarily in the natural precipitation regime. This is primarily influenced by climate conditions and sufficient rainfall. In the countries that are the largest exporters of agricultural products, water productivity is significantly higher than in developing countries. In the USA and the countries in Western Europe, for example, water productivity of wheat is 1kg/m^3 and of corn 1.5 kg/m^3, while in North Africa and Central Asia, these values are 0.6 and 0.9 respectively. This situation is expected, not only due to climate conditions, but also due to higher financial investments, more efficient agronomic practices and better water management. (The data on water productivity should also be taken with caution, because the fact that, in agriculture of these countries, there is a high level of said cultural practices, fertilizers, plant protection products, etc. that have to be taken into account, making it difficult to distinguish whether the exporting countries truly use water more efficiently, or some other factors have contributed to this situation).

The most important virtual-water exporters in the world in the period between 1995 and 2005 were the USA (314 Gm^3/y), China (143 Gm^3/y), India (125 Gm^3/y), Brazil (112 Gm^3/y), Argentina (98 Gm^3/y) , Canada (91 Gm^3/y), Australia (89 Gm^3/y), Indonesia (72 Gm^3/y), France (65 Gm^3/y) and Germany (64 Gm^3/y) (Hoekstra and Mekonnen, 2011).

Although green water prevails in their export, it does not mean that these countries do not apply irrigation. On the contrary, it should be noted that the United States, Pakistan, India, Australia, Uzbekistan, China and Turkey are the largest exporters of blue virtual water, accounting for 49% of blue virtual water global export (Hoekstra, 2011). In all these countries, water stress is partly present, so it is questionable whether the use of limited national blue water resources for export is sustainable and most efficient in terms of water resource preservation.

In food-importing countries, the situation is diverse. Some of them have a high proportion of blue water for agricultural production, due to low rainfall and green water scarcity. In some countries, agricultural production is developed in irrigation conditions, and it has the government's support because, in that manner, the country provides its own food production, rural area development, employment, political stability, etc. In many poor countries, irrigation is not used enough, due to economic reasons.

A positive effect on the importing countries is a reduction of water stress, especially in case of crops that have a great CVCW and whose price has been decreased up to 50% in the past 30 years. However, this in no way means that they do not need to import food and develop their agriculture. Importing countries are often, in fact, poor countries, and the improvement of agricultural practices would contribute to the development of rural areas and living conditions (Hastings and Pegram, 2012).

Thus, it is not easy to estimate water resource saving, because it cannot be reduced to a simple comparison of required amounts of water in different locations; instead, numerous socio-economic, political and other aspects should be taken into account. For countries lacking in water, such as North Africa or the Middle East, it is very important to assess the dependency on external water resources and to continue developing foreign trade policy, which ensures safe and sustainable import of products that cannot be produced in the country (Hoekstra and Mekonnen, 2011).

Calculation of virtual water in the area

In order to calculate the amount of virtual water in agriculture in one area, first it is necessary to determine water requirements for crops by using some of the recognized models. In this study, FAO CROPWAT (Avakumovic *et al.*, 2005) has been used. The amount of water needed for irrigation, which represents the blue component, can also be determined by this model. Based on the known surface occupied by an agriculture crop, the amounts of blue and green water required for obtaining adequate crop yield can be determined.

Another way is first to determine how much blue and green water per hectare for each crop separately is needed and what the yield per hectare is, and then from their ratio, to determine how many m³ of water is necessary to obtain a yield unit (m^3/kg). Then, by multiplying the resulting value by the total yield of the studied area, the virtual water content is obtained.

If pure yield was the subject of trade, it would be easy to calculate the amount of imported/exported water.

The total amount of water, as well as the amount of green and blue water, can be calculated by:

$$Wz = 10 * (Pw - In) * A$$

$$Wp = 10 * In * A$$

$$Wtot = \frac{10 * Pw * A}{Y}$$

Wz - total volume of green water use (m^3)
Pw - crop water requirement ($m^3 \cdot ha^{-1}$)
In - irrigation water requirement ($m^3 \cdot ha^{-1}$)
Wp- total volume of blue water use (m^3)
Wtot - units of water per units of yield ($m^3\ kg^{-1}$)
Y - total yield (kg)

RESULTS AND DISCUSSION

A calculation of virtual water is shown in the example of Stara Pazova area. Table 1 shows the area of certain crops (2011), and Table 2 shows the production of major agricultural crops and required water content, according to the data obtained from the Statistical Office of the Republic of Serbia.

In case of dry farming, the volume of blue water is zero, and green water is obtained by summing the daily values of evapotranspiration ETc (mm/day) during the growing season. In the given area, crops grown in the natural precipitation regime were prevailing, so there was no blue water component. The exception is the apple, where irrigation was applied.

An example of calculating the amount of blue and green water is shown in Table 2. The table shows that direct trade subjects were wheat, corn and apples (no previous treatment or processing), so it is easy to determine the amount of water that was traded.

Table 1 Agricultural area in Stara Pazova

Agricultural land	Area (ha)
Total	29875
Fields and Gardens	28897
Grain production	20900
Industrial Crops	5542
Vegetables	1343
Roughage	1096
Orchards	166
Vineyards	70
Meadows	207

However, the virtual-water trade in animal products is much more complex. Yields of some crops, such as clover, alfalfa, meadows and pastures are used for feeding cattle (steers, dairy cows, pigs), and products derived from them are the subject of trade. Therefore, it is necessary to determine how much food and m^3 of water is needed for obtaining a product unit (kg, l) in order to determine the amount of exported water.

To obtain 4,500 liters of milk, 28 m^3 of water is required, that is, an average of 6.3 liters of water per year is needed to produce 1 liter of milk (Department of Agriculture and Agri-Food Canada). By raising a pig to the average weight of about 100 kg, about 1.8 m^3 of water is used, and for growing steers to the average weight of 600 kg, about 14.5 m^3 of water is used. However, the amount of water used to produce food that animals eat is not taken into account.

According to the Water Footprint Network data, the amount of virtual water needed for the production of one liter of milk is 1 m^3 of water, while 6 m^3 of water is required for the production of one kilogram of pork, and 15.5 m^3 of water is needed for the production of 1 kg of beef. In the examined area, the amount of water used for the production of food for cattle is already contained in the amount of water needed for the production of corn, clover, alfalfa, pastures and meadows, so this water is a subject of trade indirectly.

Comparing the amount of water required for the production of food for the cattle production according to the WF standards, with the amount of water required for the production of meat and milk, we conclude that all the food was produced in the area of Stara Pazova, suggesting that they mainly export water to other areas (Tab 3). In general, more than 50,000,000 m^3 of water from the area of Stara Pazova has gone to some other region.

Table 2 Yields of major agricultural products and water consumption

Crops or product	Yield (1000 kg or l)	Water Footprint (m^3/kg)	Green water (m^3)	Blue water (m^3)	Sale and purchase (1000 kg)	Total green water trade (m^3)	Total blue water trade (m^3)
Wheat	22345	0.65	14,524,250	-	9512	6,182,800	
Maize	88498	0.46	40,710,000	-	36997	17,018,000	
Sugar beet	121907	0.09	10,971,000	-			
Sunflower	1886	1.43	2,697,000	-			
Beans	118	0.4	47,200	-			
Potatoes	9785	0.4	3,960,000	-			
Clover	1806	0.5	903,000	-			
Alfalfa	4802	0.43	2,070,000	-			
Meadows	192	1.25	240,000	-			
Pastures	210	1.0	210,000	-			
Apples	931	0.73	340,000	340,000	121	44,000	44,000
Plums	435	0.30	130,500				
Vineyards	1290	0.08	107,500		16	1,280,000	
Pig meat	4062	0.018*	73,116			73,116	
Bovine meat	30	0.024*	720			720	
Milk	3,554	0.006*	22,390			22,390	

Table 3. The water footprint of some selected food products from animal origin (according to Water Footprint Network) and water consumption

Product	Kg or l	Water footprint, (m^3/kg)	Water consumption (m^3)
Pig meat	4,062,000	6	24,372,000
Bovine meat	30,000	15.5	46,500
Milk	3,554,000	1	3,554,000

CONCLUSION

One of the main goals of the WF concept is to enable the assessment of water use efficiency, which is reflected in the virtual water trade, taking water prices, water saving and environmental impacts into account. Therefore, food import enables water saving.

Although Water Footprint cannot clearly indicate whether water consumption has a positive or negative impact on water resources, it can still help us to use water in a more efficient and rational way, and protect and preserve water resources.

ACKNOWLEDGEMENTS

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BEHAVIOR OF PHOSPHORUS IN STAGNOSOL

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ABSTRACT

In soil the dynamic transformations of phosphorus between the forms occur continuously to maintain the equilibrium conditions. Low concentration and solubility of P in soils make it critical nutrient limiting plant growth. This paper was devoted to explanation of mechanisms and distribution of different forms of phosphorus, its transformations and dynamics in the soil based on 40-years field experiments in phosphate fertilization. The sequential extraction procedures were applied to identify the different forms of soil P (Chang & Jackson, and BCR methods). After extraction, P was determined by spectrophotometry. Trace elements were determined with an ICAP 6300 ICP optical emission spectrometer. Formation of the forms of soil P and binding largely depends on soil pH. The bounds Al-O-P forms much more labile forms than formations with double bounds of P. Al bound P is the most labile form that supplies the plants with P-nutrient, and is the most responsible form for the movement of P along the soil profile and replenishment of other soil P-fractions.

Keywords: phosphorus, sequential extraction, microelements

INTRODUCTION

In natural soil ecosystems the main source of inorganic phosphorus is rocks where the primary minerals are of the greatest importance, where in turn calcium phosphates are the most important (e.g. apatite) (Fig.1). In weathered soils, leaching of Ca ion results in formation of Al-phosphate (e.g. berilinite) and Fe-phosphate (e.g. stregnite); the complete list were given by Lindsay, (1979) and Lindsay, *et al.*, (1989). As far as phosphorus concentration in the soils is concerned, it can be very low from 50 mg kg^{-1} and high up to 3500 mg kg^{-1} (Foth & Ellis, 1997; Frossard *et al.*, 1995). Due to high fixation and immobilization of phosphorus in the soil, the agriculturists apply high amounts of p-fertilizer, what results in greater input of P into soil that plant uptake. Fertilization with mineral P in the inorganic pools explains 96 % of the variation in the level of available phosphorus (Beck&Sanchez, 1994). This paper is devoted to the explanation of mechanisms and distribution of different forms of phosphorus, its transformations and dynamics in the soil based upon the 40-years of experience in phosphate field application.

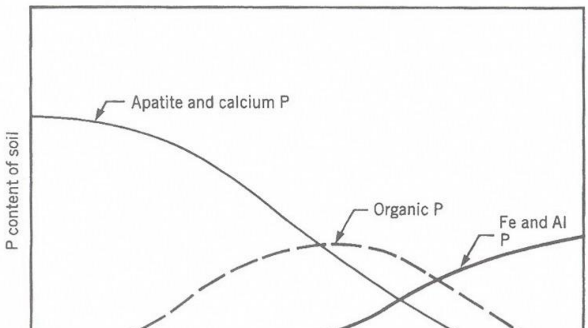

Fig. 1 Relative distribution of the major forms of soil P vs time of the soil development (Foth & Ellis, 1997)

MATERIALS AND METHODS

The investigation was conducted at the Varna experimental station, 44°41′38′′ and 19°39′10′′ (near Belgrade, Serbia), where a wide range of different fertilization treatments has been undertaken since 1968. The soil type is Stagnosol (WRB, 2006), a loam textured Pseudogley (Stagnosol). Average annual precipitation of the site is 705 mm, and the average temperature is 12°C. The mineralogical composition of the studied soil is: illite (50–70%), vermiculite (10–30%), and other clay minerals (kaolinite, chlorite, feldspar, quartz and amphibolites) (Aleksandrovic *et al.*, 1965). The cultivated crops are winter wheat (*Triticum aestivum* L.) and corn (*Zea maize* L.). Three rates (26, 39, and 52 kg P ha^{-1}) of P-fertilizer were applied in combination with a consistent rate of N and K. Composite samples of five soil subsamples were taken from each plot in the three field replications from two depths: surface (0–30 cm) and subsurface (30–60 cm) layers in spring 2008.

Available P and K were determined by the Al-method of Egner–Riehm (Enger & Riehm, 1958), where 0.1 M ammonium lactate (pH = 3.7) was used as an extract. After the extraction, P was determined by spectrophotometry after color development with ammonium molybdate and SnCl2 (Enger & Riehm, 1958). Determination of CEC was performed by the steam distillation method after the treatment with 1 M ammonium acetate (Sumner & Miller, 1996). Exchangeable Al was determined by the titration method by Sokolov: the extraction with 1 M KCl (1:2.5) followed shaking for 1 h and titration with 0.01 M NaOH (Jakovljević *et al.*, 1985).

Different fractions of phosphorus were determined in the sequential extraction analysis by Chang&Jackson procedure (Tab. 1):

Table 1. Sequential Extraction Procedure for different forms of P in studied soil (Chang and Jackson)

Procedure	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Manojlovic (2007) modificed from Chang & Jackson (1957)	1M NH_4Cl Water soluble P	0.5 M NH_4F Al bound P	0.25 M NaOH Fe bound P	0.3 M Na dithionite, Na citrate Reducible P	0.25 M Na OH Occluded P	0.25 M H_2SO_4 Ca bound P

Also, the sequential analysis was performed to establish the specific bounds between P fractions from Chang and Jackson procedure and other soil elements (Tab. 2):

Table 2 Sequential Extraction Procedure Applied to Fe, Mn, Al

Procedure	Step 1†	Step 2	Step 3	Step 4	Step 5
Petrovic *et al.* (2009)	1 M CH_3COONH_4 Exchangeable	0.1 M $NH_2OH{\cdot}HCl$ Bound to carbonates and easily reducible	0.2 M $(NH_4)_2C_2O_4$ and 0.2 M $H_2C_2O_4$ Moderately reducible	30 % H_2O_2 + 3.2 M CH_3COONH_4 Organic-sulphide	6M HCl Residual

RESULTS AND DISCUSSION

Fraction of soil P extracted by 1M solution of ammonium-chloride (water-soluble P)

This fraction of phosphorus is closely linked with the dynamics of P bounding in soil (Fig.2). Such bounding of phosphorous ions can be characterized as an initial reaction. And it represents a non-specific adsorption and ligand exchange on mineral edges or by amorphous oxides and carbonates. This fraction is bound to Mn isolated in step 2 from Table 1 (Mn II) (r=0.994**), which indicated its sorption on hydrated oxides of manganese. Due to specific further bounding of phosphorus, this fraction is very low in quantity (less than 1 % of the total mineral phosphorus) in acidic soils such as Stagnosol. However, due to application of mineral fertilizers and accumulation of phosphorus (Jaakola, *et al.* 1997) the processes of saturation of free spaces for adsorption of P in the soil (Vu *et al.*, 2010) result in its significant increase, by about 6 times compared to the control plots in the studied experiment. Considering the low movement of phosphate ions along a depth of the soil profile, which is slower than in the processes of bounding them into less soluble forms, such increase of P ions concentration is expressed distinct in the surface soil layer 0-30 cm.

Passage of this form of phosphorus into bounded-to-aluminum

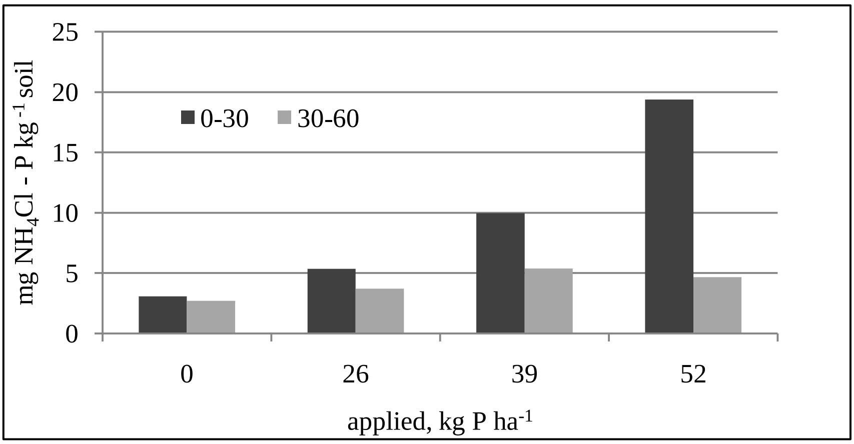

Fig. 2 Content of NH_4Cl extractable P upon 40-years of phosphate application (water-soluble P)

phosphorus is a process characteristic for acidic soils. The reverse process is also possible (correlation coefficients 0.974 and 0.780 for 0-30 and 30-60 cm, respectively) (Tab. 3). A very strong correlation between water-soluble P and available P (0.945 and 0.715 for 0-30 and 30-60 cm, respectively) proved that this form of phosphorus was available for plants.

Fraction of soil P extracted by 0.5M NH_4F solution (Al bound P)

Such an isolated fraction of phosphorus is a characteristic for monodent and bident bounds (Tisdale *et al.*, 1993). Consequently, these compounds are very labile and are described as pseudo sorption (Van der Zee *et al.*, 1987; Van der Zee *et al.*, 1988). In acid mineral soils, such as Podzols, P is mostly retained by Al and Fe oxides by the ligand exchange mechanism where the OH^- or H_2O groups of sesquioxides surfaces were are displaced by dihydrogenphosphate anions (Simard *et al.*, 1995).

In certain soils, this bound is not strictly confined to Al but can bound bind to Si, as well (Manojlovic, *et al.* 2007). However, in the studied Stagnosol, the strong correlation of Al-P with Al extracted in the step 2 (Al II) could be attributed to carbonates and alumosilicates (r=0.998**). Somewhat increased content of this fraction versus to the available phosphorus indicates that not only modettant bounds are involved (Fig. 3). It is obvious that this fraction of soil phosphorus is the most important for plants since there is a high correlation between the Al bound P and the available forms of phosphorus extracted by the Al-method (r=987**). Also, application of mineral phosphorus influences this fraction of soil P the most with the recorded increase of its content from 16.08% in the control to 34.51% in the treatment with 52 kg P ha^{-1}. This fraction of P is responsible for migration of phosphorus along the soil depth, which is confirmed by a significant correlation between the values at two depths (0.876**), as well as for the replenishment of the pool of other fractions of soil P (Tab. 3).

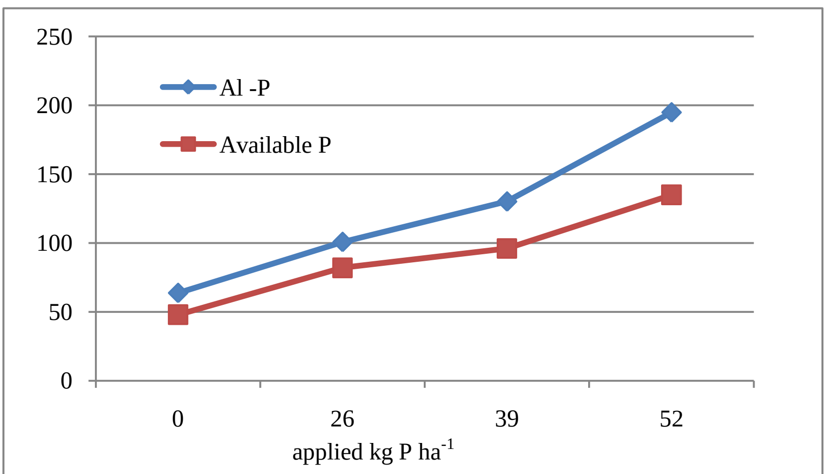

Fig. 3 Content of NH_4F extractable P (Al bound P) upon 40-years of phosphate application

Fraction of soil P extracted by M NaOH solution (Fe bound P)

Other researchers showed that fraction of soil P isolated by such a strong reagent may have a high content in soil and mainly is greater than that bound to Al (Manojlovic *et al.*, 2007, Mustapha *et al.*, 2007), ranging between few hundred mg per kilogram. From the chemistry viewpoint, such bounded P is characteristic for the slow-flowing processes involving formation of covalent Fe-P or Al-P bonds on Fe and Al oxide surfaces (Willett *et al.,* 1988) which can be an additional source of available P (Beck & Sanchez, 1994). However, the strength of this bound is quite high. Therefore, its availability is limited. That determines the absence of correlation between the mentioned fraction and the available P. However, in our study the Fe bound P showed the least amount comparing with other determined P-fractions (Tab. 3). In Stagnosol, due to constant wetting and alteration of oxidative – reductive conditions, the content of this form of P can be as low as less than 1 mg per kilogram due to passage into other forms (reducible and occluded). Its movement along the soil depth is also limited as indicated by the absence of correlation between the values at different depths. Sequential analysis didn't show marked correlation with the fraction of Fe, but the correlation with DTPA-extractable Fe was recorded (0.665*)

Fraction of soil P extracted by M Na dithionite, Na citrate solution (Reducible P)

In contrary to the previous types of bounding of P in soil, this fraction is characterized by the bounds within the particle. Such bounding results in the process of occlusion where the phosphate is adsorbed to the surface of Al hydroxide and is bound by poorly crystalline Fe oxides from that occluded in the crystalline Fe oxides (Delgado & Scalenghe, 2008). In this structure, the phosphate binds the Al- with Fe^{3+}hydroxide so the surface of Al phosphate particle is enveloped by a Fe^{3+}hydroxide skin. Such adsorbed phosphates are only indirectly available to plants. Thus, in the conditions determined by reduction processes the reduction of iron Fe^{2+} and the breakage of the earlier formed bounds take place, which makes this form of P available for plants. Although this fraction is small compared to other fractions of P in soils, under the oxidized conditions Fe-P represents the dominant fraction (Manojlovic et al, 2007, Mustapha *et al.*, 2007). But under the conditions of soil undergoing alterations of wet and dry regimes with high content of available Fe (Cakmak, *et al.*, 2010) the reducible-P can be of significant concentration up to 30% from the total mineral P. The high correlation found between the reducible and Al bound P (r=0.97**) (Tab.3) indicates the indirect availability of this form of P under the alteration reduced conditions in Stagnosol.

Fraction of soil P extracted by M NaOH solution (Occluded P)

Chang & Jackson (1957) noticed that during the sequential extraction some soils, rich in Fe oxides, contain significant amounts of Fe-phosphate occluded within the oxide, which cannot be extracted by sodium dithionite and sodium citrate. This occluded phosphate can be extracted by repeated alkali solution. The P tied in this manner might be increased in quantity by constant addition of mineral phosphate fertilizer where its total content ranges between few milligrams to tens of milligram per kg soil; i.e. in small amounts from 1% to about 10% from the total mineral P (Manojlovic *et al.*, 2007, Mustapha *et al.*, 2007).

Under the alteration of reduced and oxidized conditions that predominate in Stagnosol, this form is chemically tied to the reducible form of P, especially, in the upper soil layer (r=0.890**). Also, within such soil particle, Al-phosphate can be present, which can be available under certain conditions within Fe-oxide (Fig.4). Its migration along the soil depth is limited and is of very low mechanic intensity (Tab.3). Absence of correlation with DTPA-extractable Fe indicates the un-availability of Fe in such compounds. The correlation between the depths in content of O-P was not established. Considering that leaching of O-P is limited, its restoration in the second depth is associated to Al-P (Westin and Britio, 1969; Williams and Walker, 1969; Shelton and Coleman, 1968; Yost *et al.*, 1981).

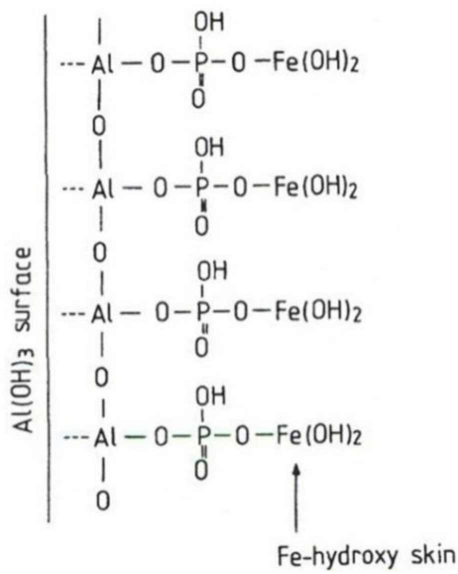

Fig. 4 Fe-hydroxy skin covering the phosphate adsorbed to Al oxide/hydroxide (Mengel & Kirkby, 2001)

Fraction of soil P extracted by M H_2SO_4 solution (Ca bound P)

In neutral to calcareous soil the concentration of phosphate in soil solution is governed mainly by the formation and dissolution of calcium phosphates. This in turn depends on soil pH and Ca^{2+} concentration in soil solution. The lower are Ca/P ratios in the Ca phosphates - the higher is their solubility in water. However, in acidic soils in spite of significant amount of this fraction (up to 40% from total mineral forms) the Ca-P was widely dispersed in soil minerals and it was weakly changeable. This is supported by the absence of significant correlation between exchangeable Ca and Ca-bound P. Therefore, in such soils fertilization does not result in significant changes in the content of Ca-bound P (Hartikainen, 1989). However, relative increase of this fraction is possible in the subsurface soil layer due to leaching and accumulation of Ca ions, under acidic conditions, in deeper layers where it is transformed into non-labile phosphate fractions (Tab.3). This process of phosphate ageing is especially rapid in acid soils with a high adsorption capacity. The start of this process can also be detected by the negative significant correlation between water-soluble P and DTPA-extractable Ca (-0.590*).

Soil chemical characteristics

Acidity (pH). Mineral fertilizers can change the soil pH depending on the dominance of alkali or acidic components. Because in MAP the acidic components predominates, since in soil the process of nitrification leads to formation of nitrate ions, the long-term fertilization unavoidably results in acidification (Magdof *et al.*, 1997; Belay *et al.*, 2002; Saleque *et al.*, 2004). Since the amounts of nitrogen components in the applied fertilizer were small and due to the negligible effect of phosphoric components, the decrease in soil pH after many years of application of MAP was slight but significant ($p < 0.05$ (Tab. 4). It should be mentioned that the other phosphoric fertilizers without nitrogen components did not have a negative impact on soil pH even after long application.

Available phosphorus (Al-method). Available phosphorus is a fraction of P that is considered available for plants. Chemical extraction is based on solvents, which more or less imitate adsorptive power of plant root. Phosphorus in the first four fractions obtained by the Chang&Jackson method by definition is more or less available to plants but this fact was not confirmed in the 40-year field experiment of application of MAP on Stagnosol.

Absence of correlation between the available P and Fe-P is probably due to the low amount of Fe-phosphate found in this experiment (< 1 mg kg^{-1}). Based on the results of coefficient of correlation, the direct correlation between the available forms of P is recorded for water-soluble P and the P bound to Al at both depths (for 0-30 cm is 945** and 987** respectively; for 30-60 cm 715** 888** respectively). On the other hand, reducible phosphate is indirectly correlated with the available P via water-soluble and Al bound P.

Table 3 Forms of phosphorous analyzed by sequential analysis in Stagnosol in long-term phosphate fertilization experiment

Treatment	NH4Cl -P	Al -P	Fe -P	R- P	Oc- P	Ca -P	Av. P
kg P ha^{-1}			mg kg^{-1}				
			0-30 cm				
0	3.08a	63.8a	0.30a	143.1a	46.94ab	139.3a	48a
26	5.35a	100.8b	0.54b	125.0a	32.57a	165.8a	82b
39	9.96b	130.2c	0.44ab	195.6b	67.37c	144.5a	96b
52	19.38c	194.9d	0.46b	176.1b	60.70bc	126.3a	135c
P	**	***	***	**	*	NS	***
			30-60 cm				
0	2.69a	48.5a	0.30a	120.3a	33.93a	132.2a	35a
26	3.71a	63.3ab	0.41a	130.4a	44.73a	157.0a	52ab
39	5.38a	79.0b	0.31a	172.1b	56.67b	137.9a	61b
52	4.67a	83.8b	0.28a	116.4a	47.47a	184.2a	70b
P	NS	**	NS	**	*	NS	***
Corr. depth	0.518*	0.876**	0.405	0.405	0.254	0.385	0.790**

*†† correlation coefficient between two depths; * Significant at P < 0.05; ** Significant at P < 0.01; *** Significant at P < 0.001; NH_4Cl-P, water soluble, free solution P; Al-P, phosphorous bound to Al; Fe-P, phosphorous bound to Fe; R-P, reducible P; Oc-P, occluded P; Ca-P, phosphorous bound to calcium; Av.P, available phosphorous*

The bounds of occluded P in the first depth with water-soluble (r=.585*) and in the second depth with water-soluble and Al-P indicates on its possible availability under the extreme conditions of wetting and drying, characteristic for Stagnosol. Except the Ca-bound phosphorus, all the fractions of soil P showed increasing trends accordingly to the applied phosphate fertilizers where the Al-bound phosphorus showed the clearest increasing tendency (Fig. 5).

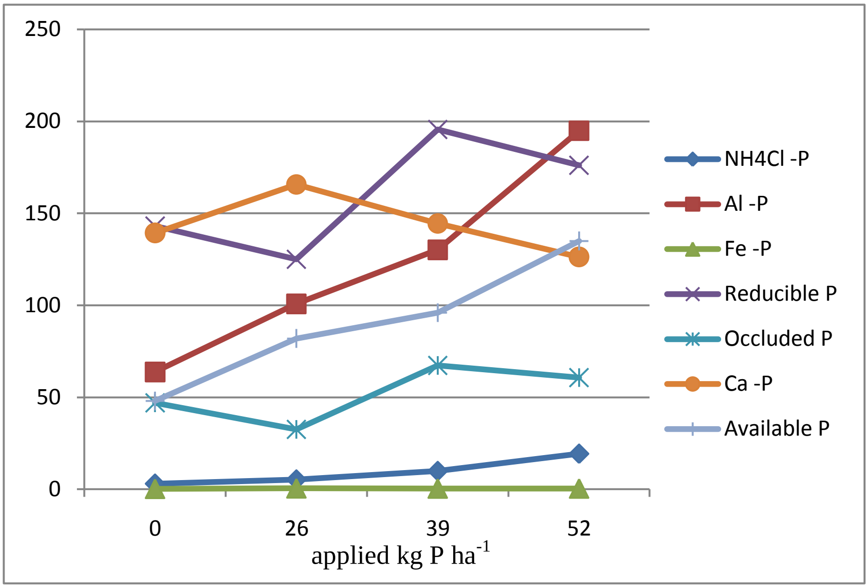

Fig. 5 Concentrations soil P extracted by different methods upon 40-years application of phosphate fertilizer in 0-30 cm

Mobile Al. One of the indirect consequences of phosphate fertilization that acidifies the soil is the increase in the amount of mobile Al. Soil acidity is caused by the formation of H^+ ions in the soil solution, which is neutralized by Al and Fe oxy/hydroxy complexes (Schwertmann *et al.*, 1987) where the end product of neutralization are species of Al cations such as Al^{3+}, $Al(OH)^{2+}$, $Al(OH)_2^+$. Connection of these two processes is confirmed by a high correlation between soluble Al and decreases in soil pH (r=.897**). It is known that the solubility of Al progressively increases below 5.5 soil pH (H_2O) (Abrahmsen, 1984; McKenzie & Nyborg, 1984; Mrvic *et al.*, 2007). In our experiments, in the 26 kgPha^{-1}, treatment in the subrface soil the amount of mobile Al is doubled versus to control (Tab. 4).

Exchangeable cataions and CEC. A recent research showed that the decrease of exchangeable Ca and Mg with P fertilization is caused by their replacement with H^+ ions and leaching to layers down the soil profile (Belay *et al.*, 2002), immobilization by phosphates, and by their assimilation by plants. However, destruction of clay minerals as affected by phosphorus and increase in CEC reduces the leaching.

In soils with pH above 5.0, increases in acidity results in destruction of minerals, i.e. exchangeable Ca^{2+} and in lesser degree Mg^{2+}, might be derived from structure of soil primary minerals thus increasing the Ca availability in soil solution (McLaughlin & Wimmer, 1999). This process of releasing Ca and Mg is much weaker than that of Al because the release of cations is proportional to charge, which results in higher amounts of cationic species in the soil solution. Under 40-years of phosphate application, the amount of exchangeable Ca is increased (Tab. 4), although the increase was not regular but significant in the surface soil due to the mentioned reverse processes.

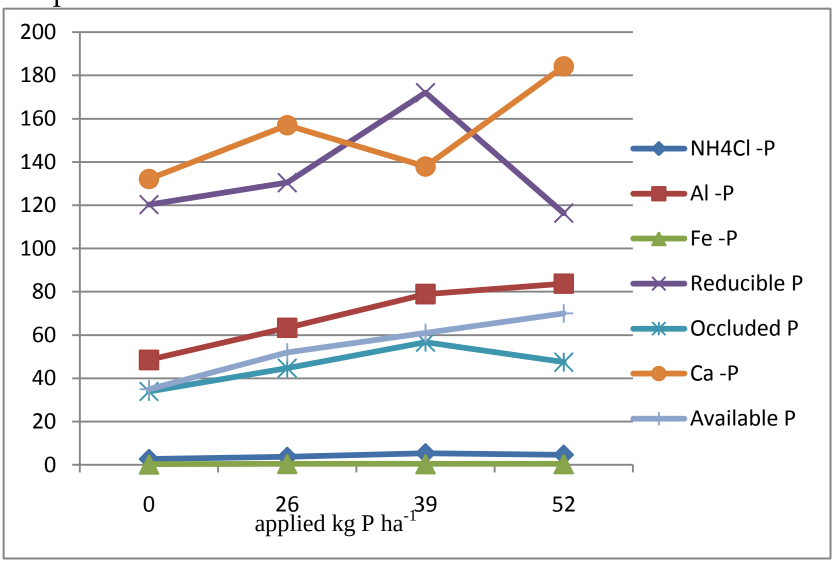

Fig. 6 Concentrations soil P extracted by different methods upon 40-years application of phosphate fertilizer in 30-60 cm

Soil physical characteristics

Long-term application of phosphate, besides the direct influence on the content and forms of P in soil, also influences the other soil properties. It can affect the structure of clay minerals where fractions of P can replace Al ions from the tetrahedral structure thus destructing the structure and pulverizing clay minerals (Rajan, 1975). Long-term fertilization with MAP distinguished that phenomenon since the changes in soil texture were due to the amount of added P, i.e. in the experiment a significant increase of clay fraction was detected correspondingly to the rates of fertilizer, which is the result of fragmentation of clay particles (Fig. 7). In spite the mineral fertilization causes decreases in soil CEC (Belay *et al.*, 2002) especially if the amount of organic matter did not change, in our case due to the increased content of clay the slight significant increase of CEC in the treatments with 39 and 52 kg P ha^{-1} ($p < 0,01$) was recorded. The consequence is increases of the value of sum of base in the second depth under the higher rates of fertilizer ($p < 0.05$).

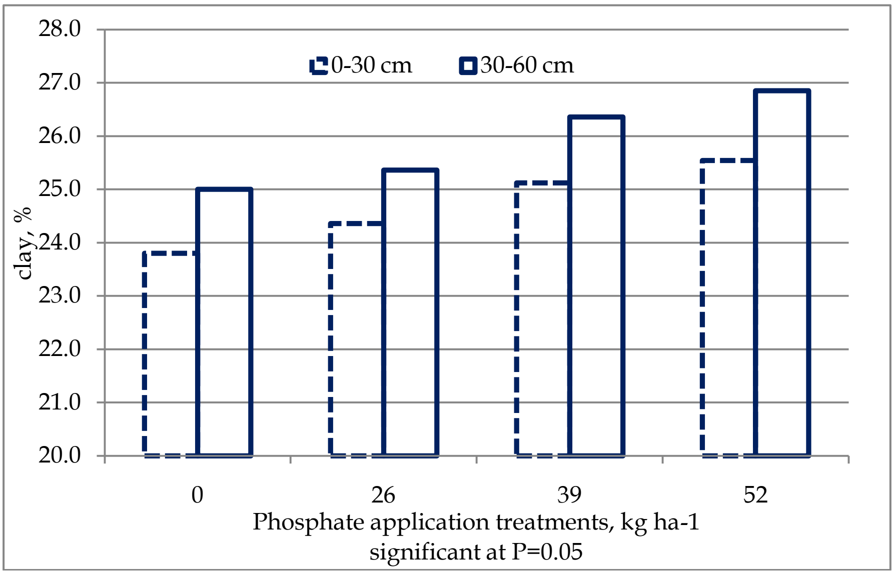

Fig. 7 Amount of clay fraction under long-term application of different rates of phosphate fertilizer in two depths on a Stagnosol soil.

Table 4 Soil chemical characteristics of Stagnosol in 40-years phosphate fertilization experiment

Treatment	Organic C	Total N	Avail. P†	Exch. Ca^{2+}†	Exch. Mg^{2+}	Mobile. Al	pH	CEC†	Sum of base
g P ha^{-1}	—— % ——		——— mg 100 g^{-1} ———					cmol kg^{-1}	
				0-30 cm					
0	0.99 ± 0.03	0.11 ± 0.001	4.8a‡ ± 0.6	237a ± 9	40.7 ± 4.2	3.7a ± 0.9	4.95a ± 0.0	16.4a ± 0.6	8.67a ± 0.2
26	1.06 ± 0.02	0.12 ± 0.003	8.2b ± 0.4	267b ± 2	43.8 ± 2.3	6.9b ± 1.5	4.80b ± 0.1	18ab ± 0.4	9.07b ± 0.2
39	1.03 ± 0.05	0.12 ± 0.004	9.6.c ± 0.3	251ba ± 7	45.9 ± 1.7	7.1b ± 1.0	4.84b ± 0.0	18.4b ± 0.2	9.34b ± 0.3
52	1.06 ± 0.04	0.12 ± 0.003	13.5d ± 2.8	241ba ± 6	43.8 ± 2.2	7.9c ± 0.9	4.76c ± 0.0	18.8b ± 0.4	8.94b ± 0.3
P	NS§	NS	***	*	NS	*	*	**	*
				30-60 cm					
0	0.81 ± 0.02	0.10 ± 0.000	3.5a ± 0.7	277 ± 3	48.1 ± 0.9	4.07 ± 0.6	5.03 ± 0.0	17.1 ± 0.5	9.87a ± 0.2
26	0.77 ± 0.05	0.09 ± 0.00	5.2b ± 1.6	262 ± 9	49.9 ± 4.4	5.51 ± 1.1	4.95 ± 0.1	16.9 ± 0.6	9.34a ± 0.5
39	0.83 ± 0.09	0.10 ± 0.01	6.1c ± 1.2	264 ± 16	48.2 ± 4.9	4.37 ± 0.1	5.02 ± 0.1	17.5 ± 0.4	10.44b ± 0.4
52	0.74 ± 0.03	0.09 ± 0.00	7.0d ± 1.5	272 ± 10	50.8 ± 1.8	4.68 ± 0.4	5.03 ± 0.0	17.9 ± 0.9	10.7b ± 0.6
P	NS	NS	***	NS	NS	NS	NS	NS	*

** Significant at P < 0.05; ** Significant at P < 0.01; *** Significant at P < 0.001; † Avail., available; Exch., exchangeable; CEC, cation exchange capacity; ‡ Within each depth increment, means with the same letter are not significantly different.; § NS, not significant.*

CONCLUSIONS

Long-term fertilization with MAP influenced content of all forms of P except P bound to Ca (by Chang and Jackson) in the first depth (0-30cm). Higher amounts of P-fertilizer resulted in dominance of Al-P fraction in studied soil. Leaching of water-soluble P, and especially Al-P was established. Available P was mostly influenced by P bound to Al because of similarity in their quantity, and then by the water-soluble P. In both depths, interrelation between the water-soluble P and Al-P indicates the quick binding and exchanging of P. There is a possibility of transformation of water-soluble P into reducible and occluded P in the first depth, while in the second depth it is associated with O-P. Small amounts of Fe-P and absence of correlation with the other forms indicates its quick transformation into stronger bound forms of P.

Formation of the fractions of soil phosphorus and their binding largely depends on soil pH. In neutral and acidic soil the adsorption and desorption of phosphate mainly occurs at Al and Fe oxide surfaces.

Al bound P is the most labile form that supplies the plants with P-nutrient, and is the most responsible form for the movement of P along the soil profile and replenishment of other soil P-fractions. Application of mineral phosphates results in the increase of Al bound P fraction thus increasing the amount of plant-available phosphorus in soil. The 40-years application of MAP destroys the structure of the clay minerals thus increasing the soil CEC.

Soil P can exist in a series of “pools”, which can be defined in terms of the extractability of P in different reagents. The P in these pools can be related to the availability of P to plants, recognizing that there is a continuum of both extractability and availability. The most important concept is the reversible transfer of P among the most of soil phosphorus pools, what opens a possibility of the effective use of the applied phosphorus. These complex transformations of soil phosphorus grant wide opportunities for further researches.

ACKNOWLEDGEMENT

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PEDOLOGICAL AND PEDOGEOCHEMICAL MAP OF SERBIA

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ABSTRACT

This paper shows the soil map of Serbia, which are consistent mapping units, both between provinces and within central Serbia. In central Serbia, mapping soil lasted for decades, using different classifications, and the southeastern part (700 000 ha) is mapped only two years ago. Based on maps of scale 1: 50 000, made by the Institute of Soil Science, Belgrade, Institute for Agricultural Research, Novi Sad, and Institute for Water Resources „Jaroslav Černi“, Belgrade, made a unique map of Serbia. The map shows 20 mapping units, referring to most soil types. In addition to soil map shows the results of years of research of heavy metals in central Serbia. It has been found to occur more frequently Ni, Cr, Pb and As as potential pollutants and areas of potential contamination are given on the maps. A review of heavy metals on soil types were differences in their content.

Keywords: soil type, pedology, map

INTRODUCTION

Soil research on **the pedological map** of Serbian in our country began between the two world wars, under the influence of Russian Genetic School of soil. The first soil map of Kingdom of Yugoslavia, was published by Stebut in 1926 (R = 1: 3 500 000) and 1931 (R = 1:1 200 000), as well as Serbian national first classification (1927). After the II World War Nejgebauer *et al.* published the map of Yugoslavia R 1:1 000 000, and later the map of Vojvodina 1:100 000 (1958) (Sekulić *et al*., 2005).

During this period, one of the most important works in the pedology was making Basic soil map of Yugoslavia R = 1:50 000.

This map was published in Vojvodina in 1971., and was implemented by the Institute for Agricultural Research, Novi Sad (authors: Nejgebauer, Živković, Tanasijević, Miljković). Soil Map of Kosovo and Metohija was completed in 1974, and the publisher was the Institute for Water Resources "Jaroslav Černi", Belgrade (Pavicević, Grujić, Milošević, Catalina, Vasić). In Central Serbia, the research was performed by the Soil Science Institute in Belgrade, in several stages, from 1958 to 1982 (the map of the basin of Velika Morava and Mlave was published in 1958, the Western and northwestern Serbia in 1963, Stari Vlah in 1967, Eastern Serbia from 1970 to 1976, part of southern Serbia in 1979 and 1982). The southeastern part of Serbia (about 700 000 ha) is mapped only in 2011, thanks to the financial support of the Ministry of Agriculture, Forestry and Water Management. Field and laboratory studies, mapping, digitizing and publishing of 19 maps were done by the Institute of Soil Science during 2009-2011, under the project "Development of a national soil map of part of central and southern Serbia " (project leader: Saljnikov, authors and contributors: Antonović, Nikoloski, Mrvić, Perović, Čakmak, Brebanović, Maksimović, Jaramaz, Kostić - Kravljanac).

In this long period of cartographic investigation of basic soil map of central Serbia, mapping was done by different details and different classifications. Object of this investigations was a presentation of the complete soil map of Serbia, which is for the first time created on the basis of all pedological maps on scale 1:50 000.

The second part of the paper shows the **pedogeochemical maps,** which are the results of the macro-project "Control of fertility and levels of harmful and hazardous substances in soils of Serbia", which for the first time shows the entire state of fertility and potential contamination of soils in Serbia. The project was funded by the Republic Fund for the protection, use, improvement and development of agricultural soil and by the Ministry of Agriculture, Forestry and Water Management of Serbia.

The project was implemented in Vojvodina in the period 1992-1997 by Institute of Field and Vegetable Crops, and Faculty of Agriculture, Novi Sad (the leader was professor Hadžić). In the central Serbia the project was implemented by the Institute of Soil Science, in cooperation with the Faculty of Agriculture in Belgrade. The part of the third phase involved the Institute of Field and

Vegetable Crops, Novi Sad. Research was taking place in the second cycle: I cycle 1993 -2007 (the leader were Nebojša Protić and Martinović), II cycle from 2008 (the leader – Mrvić Vesna).

Object of this paper is presentation the content of heavy metals by type of soils in central Serbia, and the map of remediation values.

MATERIAL AND METHODS

Pedological map of Serbia is created on the basis of existing digitalized pedological maps (scale 1:50 000), which are develop by the Institute of Soil Science in Belgrade, Institute for Agricultural Research in Novi Sad and Institute for Water Resources "Jaroslav Černi “in Belgrade. Spatial analysis and vectorization was performed using an ESRI ArcGIS software package.

Pedogeochemical map (map of remediation values) in central Serbia is created base on results that was obtained in the first cycle of research by the Institute of Soil Science, in period from 1993-2007. The surface (0-25cm) soil samples were taken by grid system 3.3 x 3.3 km, from agricultural and forest areas. Hot acid extractable forms ("pseudototals") of trace elements As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn were determined with an SensAA Dual atomic adsorption spectrophotometer, after the soils had been digested with concentrated HNO3 for extraction.

RESULTS AND DISCUSSION

Pedological map of Serbia. During a long period of preparation of basic soil map of central Serbia the mapping was performed using varying details and according to various classifications. In the early stages of mapping there was used a less detailed classification, in which many types of soil (luvisol, regosol, calcocambisol and calcomelanosol) weren’t included, while in the last phase (southern Serbia) the mapping was more detailed according to the current classification of Škorić, Filipovski and Ćirić (1985), to the lowest taxonomic unit.

This paper presents a map of Serbia for first time created on the basis of pedological maps of scale 1:50 000, but in smaller scale because of mentioned discrepancies (authors: Antonović, Mrvić, Perović). We made minor modifications to individual polygons in central Serbia. There are 20 mapping units, related to the most important types of soil, or grouping of more soil types, while the group: ranker, regosol and lithosol were classified by geological substrate.

The most common soils are Ranker (with Regosol and Lithosol), Eutric Cambisol and Chernosem (12-16%). Significant areas (6-10%), covered by the soil on hard limestone, Dystric Cambisol, Fluvisol and Vertisol, and 5% by Pseudogley, Luvisol, Humofluvisol and Semigley, Humogley and Eugley (Tab. 1). Other soil types occupy less than 2%

Table 1 Areas of soil types in Serbia

Soil type	Area (km^2)	Area %
Arenosol and regosol on sand	571,23	0,6
Colluvium	1279,35	1,4
Calcomelanosol, regosol, lithosol on limestone	5091,36	5,8
Rendzina, regosol, lithosol on carbonate supstrates	1621,97	1,8
Ranker, regosol, lithosol on granite, granodiorite, quarclatite	970,33	1,1
Ranker, regosol, lithosol on andesite, dacite, tuff	710,59	0,8
Ranker, regosol, lithosol on serpentine and basic rocks	3224,54	3,6
Ranker, regosol, lithosol on sandstones, flisch and cherks	3970,63	4,5
Ranker, regosol, lithosol on schist and gneiss	5665,60	6,4
Chernosem	10589,60	12,0
Vertisol	6836,65	7,7
Eutric cambisol	10958,30	12,4
Dystric cambisol and sporadically ranker	7289,61	8,2
Calcocambisol and calcomelanosol	3052,40	3,5
Luvisol and soils in the process leaching	4491,42	5,1
Pseudogley	4922,19	5,6
Fluvisol	7020,54	7,9
Humofluvisol and semigley	4485,52	5,1
Humogley i eugley	4468,90	5,1
Solonchak and solonetz	1140,29	1,3
Total	88361,00	100,0

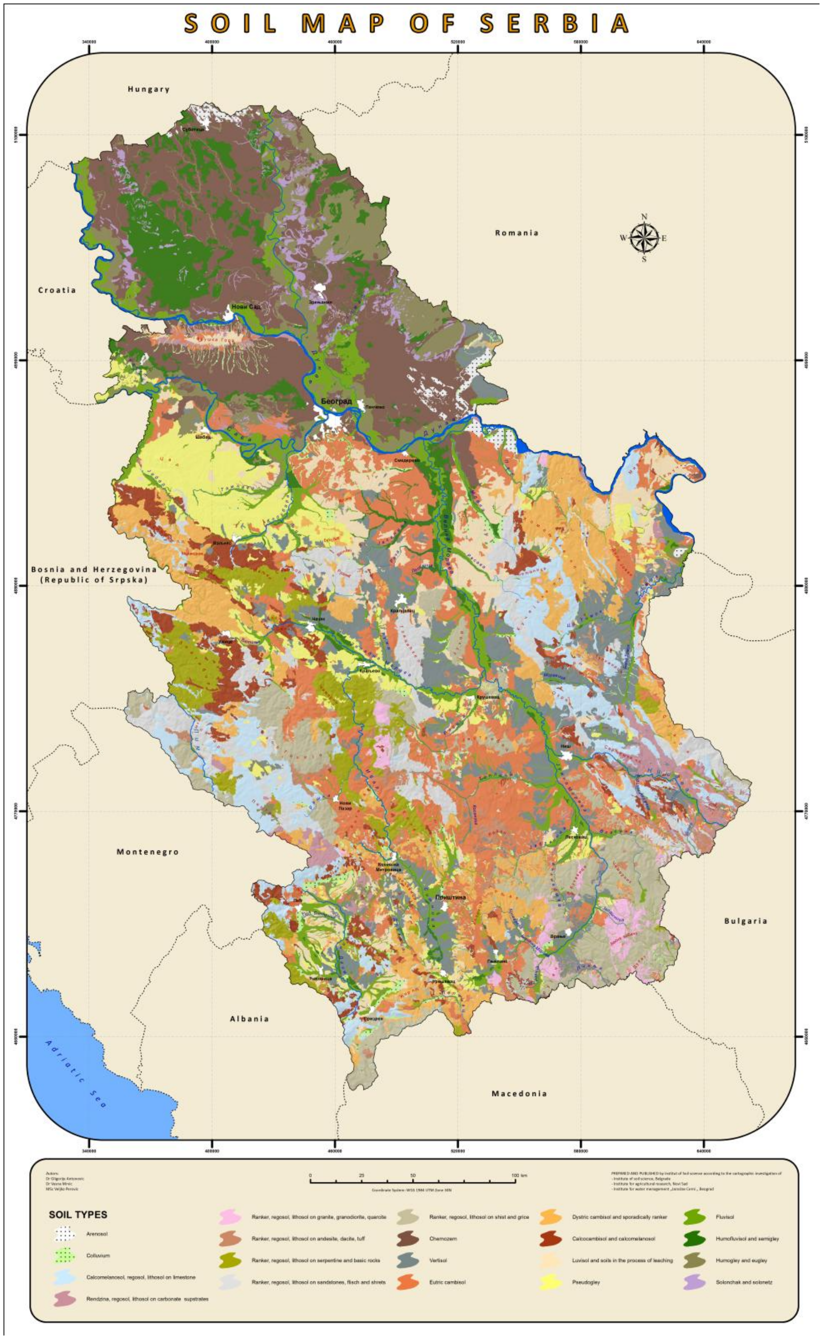

Fig. 1. Pedological Map of Serbia

Working on the soil map confirmed that one of the aim of future research should be corrected soil map of 1:50 000 and harmonization of all parts with current classification of Škorić, Filipovski, Ćirić (1985), based on the results of previous studies, satellite and aero photo images, and additional investigations of some areas.

In addition, the aims of future soil survey are:

- Making maps of larger scale using modern methodologies for the whole country. In these maps, homogeneous mapping units at the lowest taxonomic level should be allocated and more precise information about the soil present. According to Ćirić (1980) and Antonović (2010) there are should be created four types of maps - for agriculture, forestry, irrigation and urban areas, with different programs. For the forest soils the map should be in scale 1:25 000, and for the agricultural area 1:5 000 to 1:10 000. These soil maps are the basis for spatial planning (landuse: agricultural, forestry, industrial and urban spaces, roads and community facilities, recreation areas); reclamation plans and protective measures; capability map (use value of soil - soil suitability to different cultures and ways of management, rational organization of agricultural production; distribution of agricultural soil; development of differentiated crop management) and cadastral classification. The unique methodology enables the creation of compatible maps and gradually covers the entire country with maps of lager scale, which is necessary for adequate soil management.
- Development of the database of soil consistent with the database of the European Centre for soil (ESDAC).
- Harmonization of national soil classification with WRB classification (WRB, 2006).

Pedogeochemical map. This paper presents the results of the first cycle of investigation, which is related to the content of heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) in central Serbia.

The results showed that most of the soils are not contaminated with heavy metals (Mrvić *et al.*, 2009). Above maximum allowed concentration (MAC) there are often Ni and Cr (10% of samples above 100 mg kg^{-1}), and As (5% of samples above 25 mg kg^{-1}), relative to other elements – (Pb 3.5%, Cu 2%, Cd 1.3%, Zn 0.2%, Hg 0.06%). Origin of heavy metals is mainly geochemical.

Table 2 shows the concentration of heavy metals by soil types - the median values. The values are similar to the world values (Kabata-Pendias and Pendias, 2001).

Compared to other types the Rankers on serpentine stands out by significantly higher concentrations of Ni and Cr, above the MAC (Pravilnik, SG RS 23/1994), which is characteristic for a soil on this substrate (Adriano, 2001). Also on Humofluvisol concentrations of Ni and Cr is higher, because the alluvial deposits of some rivers (especially the Velika Morava), made up of materials originating from serpentine. This was also noted by Jakovljević *et al*. (1997) and Antić-Mladenović (2004). Values of other metals are below the allowed levels. Ranker on granite has a lower content of the most elements, which is typical for silica and quartz - rich rocks (Kabata - Pendias, 2001; Aubert and Pinta, 1977). Ranker on andesite and Calcomelanosol have higher As and Cu content, because these soils dominated in copper mines in Bor basin.

The heavy metal content varies depending on the distribution of soil type, parent material, on the distance from the pollutant and so on. Thus, the content of heavy metals greatly varied in the soil covering large areas: Dystric Cambisols, Eutric Cambisol, and Ranker on schist.

The map 2 shows the location where is the content of heavy metals are above the remediation values, by regulations of the Netherlands (Vegter, 1997) and by Serbia National Regulation (Uredba, SG 88/2010).

Increased concentrations of elements occur mainly in the hilly and mountainous areas. The largest number of samples is under forest and grass vegetation. Arable soils, orchards and gardens, compose about 1.5 % of the total samples.

In the western and central Serbia high concentrations of Ni and Cr in the soil on serpentine rocks is recorded (Zlatibor Mt., Maljen and Suvobor, mountains around river Ibar-Goč, Čemerno, Kopaonik, in Sandžak mountain Ozren; and also few samples in the river valleys of Jagodina and Čačak). South of Ivanjica, in foot of the Čemerno and Željin Mt., some samples with high contents of As found, most commonly at the contact of igneous rocks and shale, where there are contact- pneumatolytic and hydrothermally altered rocks, with occurrences of lead- zinc, tungsten and antimony (Brković *et al*., 1968)

Table 2 Areas of soil types in Serbia

Soil type	Area (km²)	Area %
Arenosol and regosol on sand	571,23	0,6
Colluvium	1279,35	1,4
Calcomelanosol, regosol, lithosol on limestone	5091,36	5,8
Rendzina, regosol, lithosol on carbonate supstrates	1621,97	1,8
Ranker, regosol, lithosol on granite, granodiorite, quarclatite	970,33	1,1
Ranker, regosol, lithosol on andesite, dacite, tuff	710,59	0,8
Ranker, regosol, lithosol on serpentine and basic rocks	3224,54	3,6
Ranker, regosol, lithosol on sandstones, flisch and cherks	3970,63	4,5
Ranker, regosol, lithosol on schist and gneiss	5665,60	6,4
Chernosem	10589,60	12,0
Vertisol	6836,65	7,7
Eutric cambisol	10958,30	12,4
Dystric cambisol and sporadically ranker	7289,61	8,2
Calcocambisol and calcomelanosol	3052,40	3,5
Luvisol and soils in the process leaching	4491,42	5,1
Pseudogley	4922,19	5,6
Fluvisol	7020,54	7,9
Humofluvisol and semigley	4485,52	5,1
Humogley i eugley	4468,90	5,1
Solonchak and solonetz	1140,29	1,3
Total	88361,00	100,0

In Eastern Serbia increased concentrations As and Cu around mining is found - smelting Company in Bor processing copper ore. O'Neill (1995) states that pollution from the mine and smelter accounts for 40% of total anthropogenic arsenic pollution in the world (higher when refining Cu, comparing to Pb and Zn).

There are a number of sites with elevated concentrations of As in southern Serbia; around Vranje the soil samples are taken the foot of the granitoids Bujanovac, on the Eocene sediments and pyroclastic rocks. Around Bosilegrad samples are on schist, where there is a deposit of phosphates, which can be a source of increased concentrations of As. According to Mehar *et al*. (1995) phosphorite and clay are the most important natural source of arsenic (containing 10-15 mg As kg^{-1}).

These results, along with data that will be obtained in the second cycle of research, will enable accurate identification of the sites that are potentially contaminated with heavy metals.

Table 3 Concentrations of heavy metals by soil type, median values.

Soil type	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Arenosol and regosol on sand	4,60	1,11	11,95	21,29	0,09	22,41	24,44	36,61
Colluvium	6,10	0,43	23,30	19,10	0,05	22,71	27,73	36,00
Calcomelanosol, regosol, lithosol	8,40	1,20	24,95	20,66	0,10	20,45	33,80	40,55
Rendzina, regosol, lithosol	7,50	1,10	24,40	17,00	0,09	18,00	25,20	35,00
Ranker on granite, granodiorite, quarclatite	5,30	0,30	12,00	13,00	0,08	11,00	23,00	35,80
Ranker on andesite, dacite, tuff	8,00	0,35	19,75	21,00	0,07	13,63	46,15	38,50
Ranker on serpentine and basic rocks	4,20	0,70	194,50	20,56	0,08	164,00	44,70	38,25
Ranker on sandstones, flisch and shrets	7,70	0,65	29,30	19,00	0,08	25,80	38,50	42,40
Ranker on schist and gneiss	7,70	0,35	21,00	19,00	0,08	18,00	32,50	41,00
Chernosem	4,70	0,20	29,95	20,35	0,04	32,00	23,00	43,02
Vertisol	6,80	0,70	32,05	21,90	0,06	22,21	29,53	37,00
Eutric cambisol	6,20	0,40	30,05	18,40	0,07	22,94	27,50	40,00
Dystric cambisol	6,40	0,65	15,10	19,48	0,08	14,64	26,66	42,58
Calcocambisol and calcomelanosol	7,80	0,78	29,05	19,65	0,12	29,18	37,58	47,88
Luvisol	5,50	0,71	25,00	17,50	0,05	26,77	26,10	42,63
Pseudogley	7,40	0,65	22,65	15,40	0,07	30,83	36,08	47,50
Fluvisol	8,00	0,50	30,05	20,90	0,08	32,00	30,00	44,55
Humofluvisol	7,15	0,30	47,50	21,86	0,05	58,22	33,72	44,84
Humogley i eugley	6,10	0,20	33,40	22,23	0,07	30,79	28,71	42,00

The aims of the future research:

- On the potentially contaminated sites to assess the environmental impact of high concentrations of elements on the flora and fauna, man, migration into waterways, to prevent the harmful effects of pollutants. To determined the forms of heavy metals in the soil (sequential analysis), basic chemical and physical soil properties relevant to the availability of heavy metal content in the water, and the most frequent crops.
- Based on an assessment to determine remediation techniques (physical, chemical and biological methods) or redevelopment of soil use, plant species and floristic composition of the grass.

- Reassess the MAC for some heavy metals in soil with natural origin, particularly Ni. It was noted that in areas that are potentially contaminated with heavy metals, people lives long-life, as well as in other parts of the country, so there is a discrepancy between the legislation and the real situation.

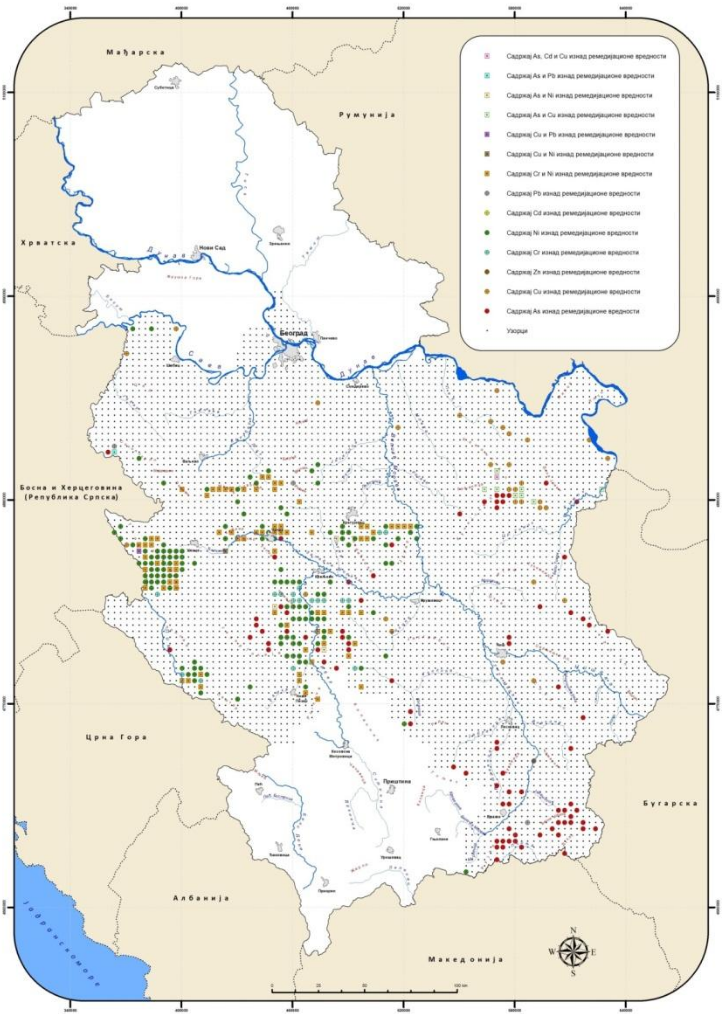

Fig. 2 Content of trace elements above remediation values (the regulations in the Netherlands, Vegter, 1997)

CONCLUSION

This paper shows the soil map of Serbia, which are consistent mapping units, both between provinces and within central Serbia. In central Serbia, mapping lasted for decades, and different classifications were applied. Based on maps of scale 1: 50 000, made by the Institute of Soil Science, Belgrade, Institute for Agricultural Research, Novi Sad, and Institute for Water Resources „Jaroslav Černi", Belgrade, a unique map of Serbia was created. The map shows 20 mapping units, referring to the most soil types.

In addition to soil map, the results of many years of research of heavy metals in central Serbia were presented. Content of heavy metals by soil type differs. Compared to other types Ranker on serpentine is standing out by significantly higher concentrations of Ni and Cr, as well as Humofluvisol with higher concentration of Ni, due the alluvial deposits of some rivers (especially Velika Morava), made up of the material originated from serpentine areas. Ranker on granite has the lowest content of the most studied elements.

Map of remediation values showed increased concentrations of elements occur mainly in the hilly and mountainous areas. The largest number of samples was under forest and grass vegetation, while arable soils were 1.5 % of the total samples. Found that Ni, Cr and As as potential pollutants occur more frequently. It is suggested that the aims of future research should relate to the pedological and pedogeochemical investigations.

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POTENTIALS AND REQUISITES OF NON-AGRICULTURAL LAND USE FOR THE ESTABLISHMENT OF FOREST PLANTATION

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ABSTRACT

This paper points to the need of rationally using land which is not otherwise used for agriculture, so it can be used for producing forest tree seedlings. The characteristics of soil are presented for the „Potok“ site, situated not far from the town of Crvenka in Vojvodina. The researched site is a part of an agricultural region. According to the criteria of the current pedological classification, the soil is chernozem, but is not used for agriculture due to unfavorable terrain configuration. The textural composition of soil is very beneficial. According to the established relation of granulometric fractions the soil can be classified as sandy loam and loam. The chemical properties are also very beneficial. The chemical reaction of the soil is relatively alkali; it is well supplied with humus, relatively supplied in nutrients and without the presence of salts. Considering that the researched land on the „Potok“ site stands out by its extremely high fertility and production capabilities, it is suitable for nursing forest seedlings of hard broadleaved trees. Optimal use of this land could be achieved by afforestation, considering it is not used for agricultural production.

Keywords: unused land, using soil, afforestation

INTRODUCTION

As it is the case in Vojvodina and other plain regions, most of the areas are used for intensive agriculture. A smaller section of areas of various irregular shapes and improper terrain configuration are not used for agriculture. Such sections offer possibilities for nursing forest seedlings, which would increase the wooded areas of Vojvodina that amount to 6.37% according to Vlatković (1981). According to Dožić (2006), Vojvodina has parts where there is not a single tree in the radius of 25 km, making these unused surfaces a potential for increasing the percentage of wooded areas, and on the other hand, to improve the spatial diversity of woodland areas, grouped at present mostly along rivers. In order for the afforestation of these areas to be as successful as possible, it is necessary to examine the soil for the correct choice of the species of trees that respond to the determined soil properties. The researched area discussed by this paper possesses chernozem, according to the classification of Škorić and assoc. (1985). Since the area is abundant in automorphic soil, the choice of trees for afforestation must be subject to these habitat conditions. While studying the selection of trees according to the habitat conditions in Vojvodina, Galić (2003) lists the black locust as the most represented alongside pedunculate oak, linden, cerris and nettle tree within the noted automorphic habitat type. The most common soils in Vojvodina are of the automorphic order with an amount of 50.77%, the most widespread is chernozem with 43.6% and according to Živanov and Ivanišević (1989) the greatest potential production value lies in chernozem. Considering its frequency and potential value, it is very important to study black earth as a soil type from the aspect of future land afforestation.

MATERIALS AND METHODS

The "Potok" site in the district of Crvenka is located 3km northeast of the town of Crvenka. The variation in altitude of this stroke of land is in a mild decline from west to east, with the altitude variation of 5 to 2 meters, from the highest to the lowest part of the site. A canal stretches next to the lower section of the locale in the north - south direction. The surface of the site is 27.42 ha.

Three morphological pedological profiles have been done, as well as photography of the pedological profiles and their surroundings, and 9 soil samples were taken for laboratory analysis. The laboratory of the Institute for lowland forestry and environment conducted standard pedological analysis of the soil samples. The type and characteristics of the soil were determined based on the conducted field and laboratory examinations and the species of trees for afforestation for this site were suggested.

Pic. 1 Research area

RESULTS AND DISCUSSION

The granulometric composition of the pedological profiles

After analyzing the pedological profile 1/10 from the depth of 120 cm, it can be concluded that the whole depth is prevalent with fine sand fraction (50.52%) and dust fraction (33.73%), while the occurrence of large sand and clay is significantly lower. The content of total sand and total clay varies in the entire profile with their average values 55.71% and 44.29% respectively. This soil is characterized by the following texture classes: sandy loam and loam.

The pedological profile 2/10 equally at the depth of 120cm is also prevalent with fraction of fine sand and dust on the profile depth. Their average value is 48.69% and 30.64%. Fraction of large sand is present to 7.20% while the content of clay fraction is 13.47%. The presence of total sand is 55.89% in average while total clay presence is 44.11%. With this pedological profile the texture class on the whole depth is sandy loam.

Table 1 Granulometric composition

Pedological profile	Horizon	Depth	Large sand 2-0.2 mm (%)	Fine sand 0.2-0.02 mm (%)	Dust 0.02-0.002 mm (%)	Clay 0.002-0.0002 mm (%)	Total sand (%)	Total clay (%)	Texture class
1/10	A	0-80	5,62	50,30	37,28	6,80	55,92	44,08	Sandy loam
	AC	80-100	6,56	40,28	38,16	15,00	46,84	53,16	Loam
	C	100-120	3,40	60,96	25,76	9,88	64,36	35,64	Sandy loam
	average	**0-120**	**5,19**	**50,52**	**33,73**	**10,56**	**55,71**	**44,29**	
2/10	A	0-80	4,60	52,32	30,84	12,24	56,92	43,08	Sandy loam
	AC	80-100	14,82	45,02	28,52	11,64	59,84	40,16	Sandy loam
	C	100-120	2,19	48,73	32,56	16,52	50,92	49,08	Sandy loam
	average	**0-120**	**7,20**	**48,69**	**30,64**	**13,47**	**55,89**	**44,11**	
3/10	A	0-115	1,94	40,98	35,36	21,72	42,92	57,08	Loam
	AC	115-125	7,73	57,75	22,16	12,36	65,48	34,52	Sandy loam
	CG	125-150	11,50	37,98	33,32	17,20	49,48	50,52	Loam
	average	**0-150**	**7,06**	**45,57**	**30,28**	**17,09**	**52,63**	**47,37**	

For the pedological profile 3/10 on the depth of 150cm apart from the prevailing fine sand fraction (45.57%) and dust (30.28%) there is an increased content of clay fraction in comparison to the other two profiles, amounting to an average of 17.09%. The content of total sand for this profile amounts to the average of 52.63% while the average total clay content is 47.37%. The texture classes of this profile are: loam and sandy loam.

With the pedological profile 1/10, the content of carbonates ranges from 5.48 to 18.78% and grows with depth due to drainage from the surface horizon. According to the average value, this soil belongs to the class of highly carbonated soils. Based on the pH value determined in H_20 with border values from 7.99 to 8.26, with its average value of 8.08 this soil belongs to medium alkali. The overview of the content of humus in this profile in the soil of the surface A horizon in the area of the rhizosphere up to the depth of 80 cm is highly abundant with humus (5.57%) and belongs to the class of humus-high soils, while the average value is 2.88. The nutrient supply for this profile is the following: content of total nitrogen is in the range from 0.075 to 1.116%, with the average of 0.10 which is a good supply of total nitrogen. The easily accessible phosphorus varies from 8.29 to 11.42 mg/100g, and in the average 9.84/100g which is on the threshold between low and medium supply of easily accessible phosphorus. The content of easily accessible potassium is in the ranges from 6.62 to 9.25 mg/100g, with the average of 7,92 mg/100g which is considered a low supply of easily accessible potassium. The total salts in this pedological profile are found below 0.03% which groups this soil in non-saline soils.

Chemical compound of the pedological profiles

In the profile 2/10, the content of carbonate increases with depth from 2.92 to 25.87%, with average of 17.66% grouping this soil into highly carbonated class of soil. According to the previously listed carbonate layout, the content pH values increase with depth from 7.95 to 8.41, with an average of 8.13, this places it in the medium alkali class. The humus content also decreases with depth and is the highest in the rhizosphere zone, or up to 80 cm and amounts to 5.61% placing this soil into humus-high soils.

Inner morphology of pedological profiles		
P1/10	**P2/10**	**P3/10**
Chernozem carbonate	Chernozem carbonate	Gleyic Chernozem carbonate
A-AC-C	A-AC-C	A-AC-CG
		
Outer morphology		
		

Pic. 2 Inner and outer morphology of pedological profiles

The amount of total nitrogen varies from 0.085 to 0.107% with the average value of 0.09% placing the studied soil into moderate supply of nitrogen class.

The content of easily accessible phosphorus is within the boundaries of 9.10 to 10.69 mg/100g, with the average value of 9.80 mg/100g, placing it on the threshold between low and medium soil supply of this element. The amount of easily accessible potassium ranges from 7.30 to 8.64 mg/100g and the average value is 7.89 mg/100g, or a low supply of easily accessible potassium. According to the content of total salts, this soil has a value below 0.03%, placing it into the classification of non-saline soils.

With the profile 3/10, the carbonate content ranges from 7.09 to 30.04 %, with the average value of 20.86 %, placing the soil of this profile into highly carbonated. The values of soil reaction range from 8.32 to 8.87 with the average of 8.67, making this soil highly alkali according to its pH value. The amount of organic matter decreases with depth from 2.42 to 4.75 %, and the average 3.44%. Considering the depth of the humus horizon, where the area of the development of the root system is also located, with the value of organic matter 4.75%, and this soil belongs to the class of humus-high soils while being close to passing over into the class of very high humus soils. When compared to the average values, the nutrients content points that this soil is well supplied with total nitrogen, with a medium supply of easily accessible phosphorus and a low supply of easily accessible potassium. The total salts in this pedological profile are below 0.03% as with the profile 1/10, grouping this soil into non-saline soils.

Considering that all of the analyzed profiles belong to the automorphic order of soil, to the class of humus accumulative soils of A-C structure and the same soil type or chernozem, to the subtype loess sediments, and to the variety: carbonate and gley-carbonate, it can be concluded that by the total production characteristics the black earth is considered a soil of high productivity. This soil has great development, consistence and a homogenous buildup of the active humus section, with its strength enabling basic processing on various depths, and with additional agrotechnical measures is considered a soil with the highest production capabilities.

Table 2 Chemical compound

Pedological profile	Horizon	Depth (cm)	$CaCO_3$ (%)	pH	Humus (%)	N (%)	P (mg/100g)	K (mg/100g)	Total salts (%)
1/10	A	0-80	5,48	7,99	5,57	0,116	11,42	9,25	<0,03
	AC	80-100	11,68	7,99	1,67	0,095	9,79	7,89	<0,03
	C	100-120	18,78	8,26	1,41	0,075	8,29	6,62	<0,03
	average	0-120	12,10	8,08	2,88	0,10	9,84	7,92	<0,03
2/10	A	0-80	2,92	7,95	5,61	0,107	10,69	8,64	<0,03
	AC	80-100	24,20	8,03	2,35	0,092	9,62	7,74	<0,03
	C	100-120	25,87	8,41	0,78	0,085	9,10	7,30	<0,03
	average	0-120	17,66	8,13	2,92	0,09	9,80	7,89	<0,03
3/10	A	0-115	7,09	8,32	4,75	0,126	12,13	9,83	<0,03
	AC	115-125	25,45	8,82	3,14	0,110	10,95	8,85	<0,03
	CG	125-150	30,04	8,87	2,42	0,072	8,08	6,46	<0,03
	average	0-150	20,86	8,67	3,44	0,10	10,39	8,38	<0,03

The abovementioned favorable mechanical composition of this soil forms an ideal granular structure even when in wet state significantly increases its production value. Due to this favorable mechanical structure, appropriate porosity is formed to create air, heat and moisture regimes of high production value.

From the standpoint of production value, the chemical properties are also agreeable which can be seen from the examples of analyzed pedological profiles. They are distinguished by increased carbonate content, are of medium to high alkali value, of medium, high and very high humus levels. They have a medium to high supply of total nitrogen, have a low to medium supply of easily accessible phosphorus and have a low supply of easily accessible potassium. The percentage of salt of analyzed soils is low and is not considered saline soil.

CONCLUSION

From all of the above stated, it can be inferred that chernozem stands out with extremely high fertility and production capabilities, with the great production potential lying in the favorable structure of the humus accumulative horizon and its appropriate mechanical and chemical properties. Based on the given properties of this soil, the "Potok" locale would be suitable for the following species of trees for afforestation: turkey oak (*Quercus cerris* L.), common walnut (*Juglans regia* L.), eastern black walnut (*Juglans nigra* L.), the black locust (*Robinia pseudoacacia* L.) and siberian elm (*Ulmus pummila* L.). The recommendations for the lower terrain are: pedunculate oak (*Quercus robur* L.) and narrow-leafed ash (*Fraxinus angustifolia* Vahl.). By afforestation of this locale which is not used for agricultural production, optimal use of the researched soil would be achieved.

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PODZOLS AND THEIR FLORA IN THE EASTERN PART OF REPUBLIC OF SRPSKA

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ABSTRACT

Forest soils and their flora in the Republic of Srpska are not explored enough. Podzols occupy less than 1% of the total area of forest soils of Bosnia and Herzegovina. Exact data about this percent in the Republic of Srpske doesn't exist. Due to the specific conditions of formation as well as specific acidophilic flora that are associated with podzols protection of this soil type in terms of habitat diversity is needed. Study was conducted in the eastern part of the Republic of Srpska, on following areas: Kalinovik (Dobre vode), Jahorina Mountain (Sarač polja) and Javor Mountain (Partizansko polje). Soil profiles were opened between 983 - 1395 meters above sea level. Podzols are found on the northern exposures and slopes with different inclinations. This type of soil is related with siliceous parent material such as quartz sandstone - quartz. Profiles are morphologically very different. Generally there is no many plant species. At all investigated sites *Vaccinium myrtillus* was dominant in the shrub layer, as a typical acidophilic species. However, this medical and edible plant is intensively exploited by man, which is why it is endangered. Therefore, it is very important to adopt the necessary measures for its protection and sustainable exploitation.

*Keywords***:** podzols, flora, Republic of Srpska, protection

INTRODUCTION

At a time when the forest ecosystems are endangered by negative impact of various factors, primarily anthropogenic, it is necessary to expand the existing knowledge about forest habitats, particularly forest soils that are naturally slow renewable resource. This is particularly expressed when we talk about rare soil types such as podzols which occupies less than 1% of the total fund of forest soil of Republic of Srpska (Inventory of forests and forest soil, 2009).

Due to the specific conditions of formation, flora of acidophilus character is related with this soil type. Podzols represent forest soils related with humid to perhumid climate, mountainous areas, extremely acid substrate and an unfavorable composition of mainly coniferous organic residues (Kapović, M. 2013). These soils cover about 485 million hectares of the Earth's surface and are typical soils of the boreal zone (IUSS Working Group WRB, 2006). Podzols are forest soils characterized by the appearance of faded E horizon from which organic matter, Al and Fe are leached which lies above illuvial B horizon where the leached matter is deposited (FAO - UNESCO, 1990). The significance of these researches is also reflected in the obtaining of knowledge about the variability of environmental conditions (especially climate, elevation, substrate and vegetation) where podzols can be formed. The aim of work is the identification of sites and properties of podzols in the eastern part of the Republic of Srpska and their seclusion and protection from regular forest management.

METHOD AND MATERIALS

Researches were conducted at three sites in the eastern part of the Republic of Srpska as following:

- Forest Management District „Hanpjesačko“ Han Pijesak, Economic Unit „Javor“, in forest units No. 3 and 106, location Javor planina.
- Forest Management District „Zelengora“ Kalinovik, Economic Unit „Ravna Gora - Mašća“, forest units No. 43/1 and 43/2, location Bijele Vode.
- Forest Management District „Jahorina“ Pale, Economic Unit „Jahorina“, forest units No. 61 and 62, location Saračeva polja.

Soil profiles were opened based on the geological maps where potential sites of podzols were highlighted starting from the assumption that they are related to the mountain regions and siliceous parent rocks and coniferous vegetation. Soil profiles were open between 983-1395 altitudes. Climate characteristics are analyzed based on data on average annual temperature and average annual precipitation from weather stations Han Pijesak (period 1961-1990), Pale (period 1961-1990) and Kalinovik (period 1961-1973). It was open 10 soil profiles, where is researched internal and external soil morphology, determination of basic genetic horizons and their properties. Floristic studies were conducted at the opening site of each profile. The color is determined using the Munsell's color scale.

RESULTS

Areas of research are mainly influenced by mountain climate. The average annual air temperature range from 5,6°C (Han Pijesak) to 7,4°C (Kalinovik). In the vegetation period the temperature value ranges 11,5-12,6°C. Average annual precipitation ranges from 1010 mm (Han Pijesak) to 1189 mm (Kalinovik). During the vegetation period it falls about 50% of the total annual amount of atmospheric depositions. Parent material of these sites is presented with quartz sandstones and quartzites. Podzols morphological characteristics are sometimes typical, and in some cases are not (e.g. in Kalinovik where they occur in combination with dystric cambisol). They occupy the northern exposures and slopes of different inclines.

Podzols characteristics in the area of Han Pijesak (Javor planina)

Five soil profiles were opened (profiles No. 1, 2, 3, 4 and 5) between 983-1137 altitudes, on the northern – northeastern exposure. Slope ranges from 2-28°, and relief along the contour line and the slope is not expressed as well as microrelief. Soil profiles are physiologically active mostly over 50 cm. They were developed on quartz sandstones - quartzite.

Soil profile No. 1: Profile is opened on the northern exposure and mild slope. The total depth is 83 cm, and profile is physiologically active to 64 cm in depth. Transitions between genetic horizons are completely clear, sharp and regular. Accumulation of leached iron begins at a depth of 42 cm, where B_1 horizon was formed with thickness of 12 cm, and below is developed very thick B_2 horizon - 29 cm. A large quantity of sand and larger particles affects the high water permeability and porosity of podzols. The following plant species were evidenced: *Picea abies, Vaccinium myrtillus, Pteridium aquilinum* and Hepaticae (mosses on acid supstrates).

Soil profile No. 2: Profile has typical characteristics for podzols. The total depth is 66 cm, and profile is physiologically active to a depth of 57 cm. Transitions between genetic horizons are clear and regular. Organogenic horizon (Ol and Oh) has thickness of only 5 cm, humus is mohr type. Elluvial horizon (32 cm) is very developed with a light ash gray color (according to Munsell Hue 10YR, 7/1), sandy texture and single-particle structure. Illuvial B_1 and B_2 horizons occupy almost half of the total depth of profile. Upper (B1) horizon has bright rusty color with a much smaller amount of accumulated humus and iron. It has thickness of 13 cm, color is Hue 10YR, 5/6. The texture is sandy-loamy. It is not well structured with sandy texture. The accumulation of humus and iron starting at a depth of 51 cm, where B_2 horizon was formed with thickness of 16 cm. It has sandy-loamy texture, structural units are tiny, spherical shape and very unstable. Color is Hue 10YR, 5/8. This is water permeable and very porous soil, especially in surface areas. The following plant species were evidenced: *Picea abies, Sorbus aucuparia, Vaccinium myrtillus, Pteridium aquilinum* and *Sphagnum sp*.

Soil profile No. 3: The total depth is 79 cm. Organic horizon reaches thickness of 10 cm, with the appearance of dark raw humus. The color of this horizon is Hue 7.5 YR, 3/3. It is consisted of half-decomposed and non-decomposed organic matter. Below organogenic horizon is elluvial horizon with thickness of 29 cm, and ash-gray color (Hue 7.5 YR, 7/1). According to soil texture it belongs to class of sandy soil, with single-particle structure. Illuvial B_1 horizon was developed between 39-55 cm, with sandy-loamy texture, and the single-particle structure. The color is 7.5 YR 4/6 and macroscopically it can be noticed the beginning of iron and humic substances accumulation in the upper part of this horizon. Illuvial B_2 horizon begins at a depth of 55 cm, with thickness of 23 cm, rusty color (7.5 YR 5/7), with sandy-loamy texture and appearance of finely granulated structural aggregates that are poorly expressed and unstable. Soil is mealy, loose, water permeable, and the whole profile is physiologically active to a depth of 72 cm.

Following plant species were evidenced: *Picea abies, Vaccinium myrtillus, Pteridium aquilinum* and *Sphagnum sp*. The site is poor in plant species diversity, there were identified blueberry and common bracken that indicates soil acidity.

<u>Podzols characteristics in the area of Kalinovik (Bijele Vode)</u>

Total of four soil profiles were opened (profiles No. 4, 5, 6 and 7) between 1213-1228 altitude, on the northern exposure and slope between 12-32°. Relief (by the contour line and the slope) is not expressed, slope is pretty uniform and microrelief is not expressed. Physiologically depth where root system is very developed ranges from 25-69 cm. Parent rocks are quartz sandstones.

Profile No. 4: Total depth is 75 cm. Organogenic horizon is poorly developed (4 cm), it is made of faintly decomposed organic residues. It sharply and properly transfers to eluvial horizon E whose thickness is 16 cm. It has single-particle structure and sandy texture. Its color is Hue 7.5YR, 5/1. Eluvial horizon has very high water permeability, and in the lower part is completely leached. Illuvial B_1 horizon is poorly developed, with thickness of 8 cm. It is characterized by sandy to sandy-loamy texture. The color is 7.5 YR, 6/1. Illuvial B_2 horizon is well developed (47 cm), rusty color (Hue 7.5 YR), with sandy-loamy texture. It is non-structural and skeletal especially in lower parts on the border with C_1 horizon. Profile is water permeable, porous in surface area, with a depth permeability decreases. It is physiologically active to the depth of 29 cm. Following plant species were evidenced: *Picea abies, Abies alba, Vaccinium myrtillus, Trifolium repens, Leontodon hispidus, Helianthemum nummulariium, Thymus serpyllum* and *Melampyrum silvaticum*.

Profile No. 5: It reaches a depth of 75 cm and has a composition Olf-O/E-E-B-C. Organogenic horizon is very poorly developed, only 1 cm. It is made mostly of litter that is poorly decomposed. Gradually and irregularly transfers to a mixed O/E horizon whose thickness is 6 cm. Color is Hue 7.5 YR, 5/1. Mechanical-granulate composition is loamy-sandy, with single-particle, unstable structure. Eluvial horizon has thickness of 26 cm. Color is 7.5 YR, 6/2, and texture is loamy sandy soil. Illuvial horizon is developed until 62 cm depth, and its thickness is 29 cm. Increase of sesquioxide and humus content is evident, the texture is sandy-loamy - loamy and structural aggregates have spherical shape, small and unstable. Color is 7.5 YR, 5/6. The content of fine and sharply-edged skeleton significantly increases in C_1 horizon. Soil is water permeable and with a high content of macropores due to the specific mechanical composition.

Following plant species were evidenced: *Picea abies, Abies alba, Fagus silvatica, Luzula albida* and *Hieracium murorum*.

Profile No. 6: The total depth is 54 cm. Organic horizon has thickness of 6 cm, sharply and irregularly transfers to eluvial horizon whose thickness is 23 cm. Color is Hue 7.5 YR, 5/3. The structure is single-particle, texture is loamy-sandy. Illuvial B horizon reaches thickness of 25 cm. Color is Hue 10YR, 5/6. It has spherical, grain sized structural aggregates, and texture is loamy to sandy-loamy. Water permeability is high. The whole profile is physiologically active. In this case the assumption is this is relatively young podzol or even spodo-dystric subtype of dystric cambisol, and therefore its morphological characteristics are not quite typical. After certain period, in both cases podzol will be developed thanks to specific constellation of pedogenetic factors in this area (climate, substrate and vegetation). Following plant species were evidenced: *Picea abies, Abies alba, Viola odorata, Hieracium murorum, Thymus serpyllum, Oxalis acetosa, Euphorbia amygdaloides, Glechoma hederacea* and *Lamium purpureum*.

Profile No. 7: The total depth is 57 cm. Organic horizon is very well developed and reaches thickness of 18 cm, with the appearance of raw humus. The color of this horizon is Hue 7.5 YR, 3/1. It sharply and irregularly transfers to O/E horizon with thickness 9 cm where decomposed organic matter is partially mixed with the mineral component. Color is Hue 7.5 YR 4/1. Typical eluvial horizon has thickness only of 9 cm. It is single-particle structured with sandy-loamy mechanical composition. Color is Hue 7.5 YR, 7/1. Below is developed illuvial horizon that extends to a depth 36-57 cm. It has rusty color (Hue 7.5 YR 4/6), loamy texture, with slight and unstable structural aggregates. On this site following plant species are found: *Picea abies, Abies alba, Vaccinium myrtillus, Rubus fruticosus, Hieracium murorum, Luzula sylvatica* and *Dryopteris filix-mas*.

<u>Podzols characteristics in the area of Jahorina (Saračeva polja)</u>

Total of three soil profiles were opened (profiles nr. 8, 9 and 10) in range 1378-1395 altitude, on the northern exposure. Slope does not exceed 10°. Relief is as in the previous cases uniform and poorly expressed. Physiologically active depth ranges 45-53 cm. They are developed on quartz sandstones.

Profile No. 8: Vegetation and relief characteristics are very specific. Microrelief is very pronounced, while tree floor consists only spruce and ground floor only moss and lichens. Total depth is 49 cm. Powerful organogenic horizon (16 cm) is comprised by hard decomposing litter of spruce and moss. Color is 7.5 YR, 3/3. Below is eluvial horizon with thickness of 14 cm, ash color (7.5 YR 4/1), sandy texture and single-particle structure. Gradually and irregularly transfers to illuvial B horizon where sesquioxide, washed from the upper horizons, precipitates under high acidity conditions. His color is 7.5YR, 5/8, and texture is sandy-loamy. Horizon of parent material C contains a higher amount of sharply-edged skeleton and extends to depths greater than 49 cm. There was identified a small number of acidophilic species: *Picea abies, Sorbus aucuparia, Vaccinium myrtillus, Melampyrum silvaticum* and *Luzula albida*.

Profile No. 9: The total depth is 59 cm. Organogenic horizon is poorly developed (2 cm) with color 7.5 YR, 3/3. Below it is thick eluvial horizon (28 cm), with ashy color (7.5 YR 4/1), sandy mechanical composition, and single-particle structure. Illuvial B horizon occupies 30 cm of profile until depth of 59 cm. Color of illuvial horizon is 7.5 YR 5/8 and it is not different from the color of C horizon. Sandy-loamy texture makes this part of the profile very water permeable. The structure aggregates are not stable. The site is characterized by indicator plants of acidic soil: *Picea abies, Sorbus aucuparia, Vaccinium myrtillus, Melampyrum silvaticum, Luzula sylvatica, Gentiana asclepiadea, Veronica officinalis* and *Sphagnum sp*.

Profile No. 10: The total depth is 56 cm. Organogenic horizon is well developed (with thickness of 13 cm), color is Hue 7.5 YR, 3/1. Eluvial horizon has a thickness of 19 cm, with light mechanical-granulate composition, unstructured. Color is 7.5 YR, 4/1. It is loose in dry state and porous. Illuvial B horizon has thickness of 24 cm, increased content of sesquioxides and humus that are deposited from the upper horizons, spheroid and weakly expressed structural aggregates, fine grain size. Horizon C is located at a depth of 56 cm. According to the color it is similar to the illuvial horizon, but it is characterized by a significantly higher content of fine stone fragments. A profile is a physiologically active to a depth of 49 cm. The site has a more opened canopy and it was noted a slightly higher number of plant species comparing with other researched sites at Jahorina: *Picea abies, Sorbus aucuparia, Vaccinium myrtillus, Melampyrum silvaticum, Luzula sylvatica, Gentiana asclepiadea, Veronica officinalis, Sphagnum sp., Juncus effusus, Marchantia polymorpha, Epilobium montanum, Potentilla erecta* and *Orchis maculata*.

DISCUSSION AND CONCLUSIONS

There are numerous factors that influence the genesis, characteristics and productivity of forest soils, and in this paper the most important are presented: climate, relief, parent material and vegetation. Climate with its elements affects many properties of soils and direction of the pedogenetic processes (Basic, 1981). Climate characteristics reflected through rainfall, temperature and saturation of air with water vapor, crucially affects on pedosphere (Martinovic, 1997).

Fig. 1. Podzols and their flora on the Javor planina profile No. 3 (photo Kapović, 2012)

Podzol belongs to the soils of cold and humid regions that are formed under mountain climate conditions**.** Ugolini, *et al.*, (1988), reveal that the beginning of active podzolization occurs with increasing of soil solution acidity, which increases the solubility of Fe, Al and the content of decomposed organic matter. With leaching occurs destruction and deposition of Fe, Al and organic matter.

Process of podzolization is explained by several theories.

Figure 2. Podzols and their flora on the site Bijele vode, profile No. 5 (photo Kapović & Šumatić, 2012)

Fig. 3. Podzols and their flora on the site Saračeva polja, profile No. 12 (photo Kapović & Hrkić Ilić, 2012)

Classic, fulvat theory (Peterson, 1976; De Conick, 1980) suggest that organic acids react with primary and secondary minerals in the eluvial horizon, destroying them, which resulted in free sesquioxide (Al and Fe) react with decomposed organic matter and produce organic - Al - Fe complex. Moving down in profile, more and more Al and Fe binds to this complex which leads to their deposition in the B horizon. Alternative theory indicating that decomposed organic matter has no active role (Anderson, *et al.*, 1982; Farmer&Lumsdon, 2001), but inorganic and readily soluble organic acids dissolve sesquioxide from readily soluble minerals in B horizon.

Along with these, there is deposition of Al and Fe in the lower part of the B horizon. Jansen, *et al.*, 2005, have investigated the mechanisms (i)mobilization of Al, Fe and organic matter in podzol in Netherlands that are in various stages of development. The results confirmed the importance of organic matter in the transport of Al and Fe in the profile and deposition in the illuvial horizon. However, according to these and other authors, and various theories about nature of podzolization arose due to research of podzols that are formed under different climatic and geological conditions usually „nordic countries“ (Norway, Sweden, Scotland, etc.) with a completely different climate compared to climate of the Republic of Srpska. Besides this the floristic composition affect the character of pedogenetic processes in the soil, and the differences in the character of organic matter between deciduous and coniferous tree species according to research of De Kimpe and Martel (1976), were directly related to the occurrence and development of podzols. Cold and moist climate with the interaction of acidic parent material is a condition for podzols formation. In the eastern part of the Republic of Srpska podzols are developed on quartz sandstones and quartzites, usually on northern exposures. In the studied sites the presence of various degrees of podzols formation was found. There were young podzols in the initial stages of formation (Kalinovik) but also developed podzols with typical morphology of soil profiles (Han Pijesak). These soils are deep, leached and poor. The presence of raw humus contributes additional acidification. Soil horizons are structureless with light mechanical composition, while the deeper parts, due to the deposition of iron and sesquioxide texture remains heavier and somewhat loamier. Acidophilus flora is related to them and they are mostly floristic poor, due to extreme acidophilus conditions, only acidophyte like spruce, blueberries and moss can survive. Podzols are the natural habitat for undemanding plant species, given that they have little capacity to hold water with a high drainage degree and large depots of groundwater. Because of that they are very important for maintaining water balance in the area where they are located. *Vaccinium myrtillus* L. (blueberry), as extremely acidophilus species, was found in almost all locations, indicating at the same time both soil acidity and humus type (slow decomposition of organic matter and raw humus type). On the studied sites blueberry is very abundant and it is characterized by an incidence of 50 to 100% in the shrub floor. However, blueberry is extensively exploited by people as edible and medicinal plant, why is pretty endangered. For this reason it is necessary to take the necessary measures for the protection and sustainable use of the plant. Podzols are the soils of small elementary areas and they are very significant in terms of habitat diversity. They are most appeared in the form of soil combination of dystric cambisols and brown podzols. As this are sandy soils, they are largely subject to erosion, to which must be addressed during cultivation of podzols.

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EFFECTS OF SOIL BONITATION ON YIELDS OF THE LATEST GENERATION OF ZP HYBRIDS IN LAND CONSOLIDATION AREA OF OBRENOVAC

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ABSTRACT

The effect of soil types and their bonitation class (soil quality index) (I-V) on the average yield of the latest, sixth generation of ZP hybrids of the FAO maturity group 600 (ZP 600, ZP 606 and ZP 666) was studied in the land consolidation area (8,801 ha) in the cadastral district Obrenovac during the two-year period (2010-2011). Different types of automorphic (17.61% or 1,550 ha) and hydromorphic soils (82.39% or 7,551 ha) were present. Of automorphic soils the following types were distributed: coarse textured sandy soil (300 ha), chernozem (350 ha), brown forest soil (eutric cambisol) (300 ha) and leached soil (luvisol) (600 ha). Hydromorphic soils are: alluvium (fluvisol) (351 ha), meadow soil (humofluvisol) (4,200 ha), pseudogley (500 ha), marshy black soil (humogley) (1,500 ha) and boggy soil (eugley) (700 ha). The average yields on automorphic soils ranged from 7.75 t ha^{-1} to 7.38 t ha^{-1} (2011) and from 7.75 t ha^{-1} to 8.11 t ha^{-1} (2010). On the other hand, the average yields on hydromorphic soils ranged from 8.33 t ha^{-1} to 8.13 t ha^{-1} (2011) and from 8.33 t ha^{-1} to 8.54 (2010). The difference is statistically significant. The average yields amounted to 9.42 t ha^{-1}, 8.95 t ha^{-1}, 8.57 t ha^{-1}, 7.10 t ha^{-1} and 6.95 t ha^{-1} on soils of the bonitation class I, II, III, IV and V, respectively. The average yield of ZP maize hybrids on nine types and 18 subtypes and varieties of soil was 8.04 t ha^{-1} (2010-2011), which is higher by 2.54 t ha^{-1} than the average yield obtained in the Sava basin in the vicinity of Obrenovac.

Keywords: Automorphic and hydromorphic soils, maize, yield, ZP hybrids, land consolidation area

INTRODUCTION

High-yielding hybrids, favourable agroecological (climatic and soil) conditions and a consistent application of cropping practices are necessary for a successful and stable maize production. Correctly selected and regionally distributed hybrids averagely participated in 50-60% in the yield formation, agroecological conditions in 20-30% and cropping practices in 20-30%.

The Sava basin (in the vicinity of Obrenovac) has excellent conditions for maize cultivation, especially in the land consolidation area (8,801 ha) with a wide alluvial plane where hydromorphic soils with the inadequately regulated water-air regime prevail, Antonović *et al.* (1978, 1979), Gligorić (1970), Pavićević *et al.* (1975). Physical and agrochemical soil properties are mainly favourable for getting high and stable yields of maize and other field and vegetable crops, Jovanović (1997, 1998). Nevertheless, the average maize yield in the high yield year of 2010 was only 5.50 t ha^{-1} on the area of 17,324 ha, which is slightly higher than the average yield in Serbia, Roljević *et al.* (2012).

Due to unregulated land territory, in 1984 it was planned to consolidate the whole land territory of the Sava basin in the vicinity of Obrenovac (cadastral district) in five stages. The first land consolidation stage was done in 1988 on the area of 8,801 ha (21.47 %) out of 40,995 ha encompassed by the cadastral district of Obrenovac. The aim of land consolidation was to improve unfavourable physical and mechanical properties of heavy marshy soils, increase plots by merging a greater number of small plots, to improve the road network, etc. The works were carried out in six cadastral municipalities - Krtinska, Urovci, Zvečka, Brgulice, Ratari and Skela.

Studies of different types of automorphic and hydromorphic soils in the Sava basin in the vicinity of Obrenovac were initiated in the second half of the 20th century, Tanasijević *et al.,* (1951), Moskovljević (1962), Gligorić (1970), Antonović *et al.,* (1978), Pavićević and Ćorović (1963), Antonović and Moskovljević (1989).

The objective of the present study carried out in 2010 and 2011 was to determine yields of the latest, sixth generation of the ZP maize hybrids (FAO 600) in dependence of a soil type and its bonitation class. Due to soil quality, a high level of ground waters, good roads and the vicinity of the market (Belgrade), cereals, forage crops and vegetables are mainly grown in the land consolidation area in the vicinity of Obrenovac.

MATERIAL AND METHODS

Evaluation studies on the yield of medium late maturity ZP hybrids (FAO maturity group 600 - the length of growing season of approximately 130 days: ZP 600, ZP 606 and ZP 666) were carried out on the basis of the soil map, bonitation map and the map of soil utilisation of a 1:20,000 scale (Pavićević *et al.*, 1975). Of 8,500 ha of maize-growing soil in the Sava basin in the vicinity of Obrenovac, ZP hybrids are distributed on over 50%.

The yield was evaluated per 10m² (14.30x1.40m) in four replicates. Basic parameters were the affiliation of the land consolidation area in the vicinity of Obrenovac with a certain soil type, subtype, variety and a form. Observed ZP hybrids are high yielding and well adapted to unfavourable environmental conditions. Due to inadequate cropping practices, yields significantly varied, especially in unfavourable seasons with dry years or too wet years.

Studies encompassed automorphic and hydromorphic soils (Dugalić and Gajić, 2012) including sandy soils (arenosol), chernozem, brown forest soil (eutric cambisol) and leached (illimerized) soil (luvisol).

Furthermore, studies on hydromorphic soils were carried out on alluvium (fluvisol), meadow (semi-gleyic) soil, pseudogley, marshy black soil (humogley) and boggy soil (eugley). All studies were performed on soils belonging to bonitation classes I-V. Moreover, studies were carried out on 18 different systematic soil categories (of the total of 26).

RESULTS AND DISCUSSION

The order of automorphic soils (17.61% - 1,550 ha) was much less distributed than the order of hydromorphic soils (82.39% - 7.551 ha) in the northern part of the Sava basin in the vicinity of Obrenovac where soils had been formed under effects of ground waters and floodwaters of the Sava river. The land consolidation area in the vicinity of Obrenovac belongs to the Velika Bara-Kupinac hydro-system.

The following soils within automorphic soils stand out by the texture of their profiles: underdeveloped soils - coarse textured sandy soils (arenosols) - 300 ha (19.35%), humus-accumulative soils -

chernozem with its subtypes, varieties and forms on the area of about 350 ha (22.58%), cambic soils - brown forest soil (eutric cambisol) on 300 ha (19.35%) and eluvial-illuvial soil (leached soil - luvisol) on 600 ha (38.72%). Due to altered climatic conditions and a somewhat wetter climate, conditions for chernozem formation are unfavourable and processes of browning, leaching and acidification of soil were present, Antonović and Moskovljević (1989), Dugalić and Gajić (2012).

The latest, sixth generation of ZP hybrids of the FAO maturity group 600 (ZP 600, ZP 606 and ZP 666 - the growing season of approximately 130 days) has excellent yields even on soils of poorer production properties such as coarse textured sandy soil (arenosol) in the village of Zvečka nearby Obrenovac. However, statistically very significant yields of maize were recorded on chernozem (on average 8.76 t ha^{-1}) or brown forest soil (eutric cambisol) (7.14 t ha^{-1}) (Tab. 1).

Table 1. Effects of a soil type and bonitation on grain yield of ZP hybrids (automorphic soils)

Type, subtype and variety of soil	Location	Bonitation class	Yield (t ha^{-1})		Average
			2010	2011	
Coarse textured sandy soil (arenosol)	Zvečka	IV	6.30	5.20	5.75
Meadow chernozem loamy soil	Skela	I	9.78	9.06	9.42
Chernozem loamy soil in the process of browning (brownized)	Brgulice	II	9.54	8.88	9.21
Chernozem loamy soil in the process of browning (brownized)	Ratari	III	9.03	8.06	8.54
Meadow chernozem soil in the process of leaching	Skela	IV	8.66	7.86	8.26
Brown forest soil on loess	Skela	III	7.49	6.98	7.24
Brown forest soil in the process of leaching	Skela	IV	7.32	6.78	7.05
Leached (illimerized) soil (luvisol)	Skela	IV	6.78	6.23	6.51
	Average		8.11	7.38	7.75
LSD	0.54			0.05	
	0.79			0.01	

Leached soils, due to their poorer production properties, are less suitable for maize cultivation and therefore measures of soil amendment for the improvement of physical and chemical properties are necessary on the old terrace in Skela where moderately acid soil prevail, Antonović *et al.* (1978), Dragićević *et al.* (2008).

Chernozem and brown forest soil should be regularly fertilised to preserve their positive properties, while measures of soil amendment should be applied to sandy soils (frequent application of smaller amounts (20-40 t ha^{-1}) of manure). On the other hand, a ploughing layer of leached soils (luvisol) should be deepened.

Unlike automorphic soils formed under effects of the climate, hydromorphic soils were formed by the river Sava in the wide alluvial plane where meadow (semigley), marshy (humogley) and boggy (eugley) soils prevail. These soils are of high potential and effective fertility especially in dry years unfavourable for plant production. Namely, the level of ground waters have a crucial effect on the formation of high yields of maize as well as whether soil, as in the case of marshy black soil (humogley), is rich in humus or not. Problems in plant production arise in wet years due to a high level of ground waters. Hydrotechnical amelioration by digging a canal network was done 65 year ago.

The greatest problems during wet years occur on boggy gleyic soils (eugley) in Velika bara (600 ha) and Nurča (45 ha), then on marshy black soils (humogley), while maize growing on pseudogley is directly related to precipitation during the growing season. Alluvium (fluvisol) and meadow (semigley) soils are favourable for growing maize and obtaining high yields.

The average maize yield of 8.63 t ha^{-1} (9.04 t ha^{-1} in 2010 and 8.23 t ha^{-1} in 2011) was recorded on alluvium (fluvisol) - Tab. 2 The two-year average maize yield obtained on meadow (semigley) soil amounted to 9.32 t ha^{-1}, which was a statistically very significant increase of the yield. Furthermore, marshy black soil (humogley) is suitable for growing maize. In comparison to the two-year average (8.07 t ha^{-1}), the average maize yield of 5.53 t ha^{-1} recorded on pseudogley was low and it classifies this soil type into the least productive soils that requires agro- and hydro-ameliorative measures of soil amendment (Antonović *et al.* 1978, Jovanović and Vesković, 1997, Jovanović, 1997).

Maize yields recorded on boggy gleyic clay soil (eugley) are high in favourable years such as 2010 and 2011 (8.38 t ha^{-1}), while yields obtained in excessively wet years significantly vary. Under conditions of good drainage of hydrogenic soils and dry to usually wet years the advantage of hydromorphic over automorphic soils for growing maize is obvious. Hence, the average yield on automorphic and hydromorphic soils in the land consolidation area in the vicinity of Obrenovac amounted to 7.75 t/ha and 8.33 t/ha, respectively, which is a statistically significant difference of 0.58 t/ha.

Table 2. Effects of a soil type and bonitation on grain yield of ZP hybrids (hydromorphic soils)

Type, subtype and variety of soil	Location	Bonitation class	Yield (t/ha)		Average
			2010	2011	
Calcareous loamy alluvium (fluvisol)	Krtinska	II	9.22	8.16	8.69
Calcareous clayey alluvium (fluvisol)	Skela	III	8.86	8.30	8.58
Meadow black clay soil	Ratari	III	9.76	8.94	9.35
Loamy meadow brown soil	Ratari	III	9.33	9.04	9.18
Clayey meadow brown soil	Krtinska	III	9.45	9.38	9.42
Calcareous marshy black loamy soil	Urovci	III	8.16	8.06	8.11
Calcareous marshy black clay soil	Urovci	III	8.34	8.00	8.17
Non-calcareous marshy black clay soil	Ratari	IV	7.96	7.90	7.93
Lowland pseudogley	Skela	V	6.06	5.00	5.53
Boggy gleyic clay soil (eugley)	Ratari	V	8.23	8.52	8.38
	Average		8.54	8.13	8.33
	0.05		0.66		
		LSD			
	0.01		0.90		

Table 3. Effects of bonitation class on average yields of the latest generation of ZP medium late hybrids (FAO 600)

Bonitation class	Soil type	Yield (t/ha)	Index
I	Chernozem	9.42	1.00
II	Chernozem, alluvium	8.95	0.95
III	Chernozem, brown forest soil, alluvium, meadow soil and marshy black soil	8.57	0.91
IV	Chernozem, brown forest soil, leached soil, marshy black soil, sandy soil	7.10	0.75
V	Pseudogley, boggy gleyic soil	6.95	0.73

A special attention has to be paid to soil bonitation that has to be occasionally renewed, updated and upgraded, Karišik (1988), Milićević (1982, 1982a, 1983), Ristić *et al.* (1975). The estimation of the soil productivity in the process of land consolidation is a very delicate task, especially under conditions of so-called "bonitation inversion", Karišik (1988), Milićević (1982), when yields of agricultural plants are higher on soils with poorer productivities.

Table 3 shows that the highest maize yield (9.42 t ha^{-1}) was obtained on the soil of the bonitation class I (meadow chernozem loamy soil) and then on the soils of the bonitation classes II, III, IV and V (8.95, 8.57, 7.10 and 6.95 t ha^{-1}, respectively), which means that "bonitation inversion" did not occur as in our previous studies (Jovanović and Vesković, 1997) carried out in the land consolidation area in the Sava basin in the vicinity of Obrenovac.

CONCLUSIONS

Based on the two-year studies (2010-2011) on effects of a soil type and bonitation on yields of the latest ZP medium late hybrids of the FAO 600 recorded in the land consolidation area in the vicinity of Obrenovac the following can be concluded:

Studies were carried out on automorphic and hydromorphic soils in the lower course of the Sava River in the land consolidation area in the vicinity of Obrenovac. The following six cadastral municipalities - Krtinska, Urovci, Zvečka, Brgulice, Ratari and Skela were included into studies.

The following soil types are present in automorphic soils: chernozem (bonitation class I-IV), coarse textured sandy soil (bonitation class IV), and brown forest soil (eutric cambisol -bonitation class III-IV) and leached soil (luvisol - bonitation class IV). The average ZP maize hybrid yield was 7.75 t ha^{-1} - 7.38 t ha^{-1} in 2011 and 8.11 t ha^{-1} in 2010, which is statistically significantly different. The most fertile soil type is chernozem (average yield - 8.86 t ha^{-1}), then brown forest soil (eutric cambisol - 7.14 t ha^{-1}), leached soil (luvisol - 6,51 t ha^{-1}) and coarse textured sandy soil (5.75 t ha^{-1}).

Hydromorphic soils, dominant in the land consolidation area (7,551 ha or 82.39%), encompass the following soil types: alluvium (fluvisol - bonitation class II and III), meadow soils (semigley - 4,200 ha, bonitation class III), marshy black soil (humogley - bonitation class III-IV), pseudogley (bonitation class V) and boggy soil (eugley - bonitation class V). The average maize yield was 8.33 t ha^{-1} as follows: 8.63 t ha^{-1} on alluvium, 9.32 t ha^{-1} on meadow soils, 8.07 t ha^{-1} on brown forest soil, 5.53 t ha^{-1} on pseudogley and 8.38 t ha^{-1} on boggy soils. Statistically significant difference in yields was obtained in favour of hydromorphic over automorphic soils.

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THE IMPACT OF VEGETATION ON ARENOSOL PROPERTIES AT DELIBLATO SANDS

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ABSTRACT

The area of Deliblato Sands is characterized by extreme and specific ecological habitat conditions, with dominant steppe vegetation and forest ecosystems at different stages of development of Arenosols. The impact of vegetation, particularly forests, has a positive role in the process of pedogenesis. Forest trees with their root systems and a crown mitigate the extremes of habitat conditions creating a specific microclimate. Steppe vegetation also has a positive impact on the soil, but its impact on microclimate is significantly lower. This paper presents an analysis of the impact of vegetation type on soil properties. The soil was sampled from soil profiles at depths of 0-5, 5-10, 10 -20 and 20 - 40 cm. Physical and chemical properties of the soils were analyzed using the JDPZ method (1966, 1997). The Analysis of Variance (one way ANOVA) was used to show differences in soil properties between the soils covered by different vegetation types.

Keywords: Arenosol, soil properties, pasture, forests, Deliblato Sands

INTRODUCTION

The area of Deliblato Sands has been studied for almost two centuries, and hundreds of papers have been published presenting the results of experiments and lessons learned in the efforts to calm down the power of eolian activity. Arenosol is a type of soil characteristic of arid and semi-arid regions, and the degree of development of these soils in the area of Deliblato Sands is under the impact of the type of vegetation. Vegetation affects the properties and genesis of soils (Košanin, Tomic, 2002). Along with soil development soil properties, including erodibility, texture, structure and the content of nutrients and moisture get significantly altered (Zhenghu *et al.,* 2004).

At the initial stage of evolution the soil of Deliblato Sands was much more influenced by forest vegetation than by grass communities, and at later stages of development the influence of mesorelief, microclimates and differences in the amount of soil moisture was more distinguished (Košanin, 2001, Košanin and Tomic, 2002). Different vegetation covers and their development during the growing season, as well as the development of aboveground biomass significantly affect the changes in abiotic site parameters (Brandt *et al.,* 2006). Vegetation is a very important factor in the reduction of soil erosion, and its importance has been highlighted in many studies (Kadović, 1999).

The aim of this study was to determine the importance of the impact of different vegetation covers (forest, pasture) on the change of the basic properties of soils at the initial stage of development on sand. In addition, another goal was to assess the impact of different types of vegetation on soil erodibility.

MATERIALS AND METHODS

Study area

The area of Deliblato Sands is located in southern Banat (Republic of Serbia). It extends along the northwest-southeast direction and is characterized by eolian relief forms. This area is characterized by a specific microclimate, which is a result of frequent changes in the shape of relief, a variety of plant communities and the properties of sand as a substrate (Košanin, 2001). The characteristics of the vegetation of Deliblato Sands are influenced by long-term amelioration works, so that besides steppe vegetation both natural forests and plantations of black pine and black locust can be found in this area. The soil study was conducted in seven soil profiles covered by steppe vegetation and 12 soil profiles covered by forest ecosystems. An overview of profiles is shown in Figure 1 and Tab.1.

Soil Analyses

The study involved soils covered by different vegetation covers (forest, pasture). The soil samples for the analysis of properties were taken at depths of 0-10; 10-20 and 20-40 cm. The laboratory studies of the soil were conducted using the JDPZ methods (1997, 1966). Soil granulometric fractions were separated using the combined method of sieving by 0.2 mm mesh sieves and the pyrophosphate pipette B-method. Bulk density samples were obtained for each layer using a standard container with a volume of 100 cm^3 (55.50 mm in diameter and 41.40 mm in height) and weighed to the nearest 0.1 g.

Table 1. Soil sampling locations

Profile	Vegetation	Soil type
1/013	Steppe grass vegetation	Haplic Arenosol
4/013	Steppe grass vegetation	Protic Arenosol
9/013	Steppe grass vegetation	Haplic Arenosol
10/013	Steppe grass vegetation with hawthorn	Protic Arenosol
11/013	Steppe grass vegetation with hawthorn	Protic Arenosol
12/013	Steppe grass vegetation with hawthorn	Protic Arenosol
13/013	Steppe grass vegetation	Haplic Arenosol
14/013	Virgilian oak	Protic Arenosol
15/013	Virgilian oak	Haplic Arenosol
16/013	Virgilian oak	Haplic Arenosol
17/013	Linden and Virgilian oak	Protic Arenosol
7/013	Black locust	Protic Arenosol
19/013	Black locust	Protic Arenosol
20/013	Black locust	Protic Arenosol
22/013	Black locust	Protic Arenosol
8/013	Black pine	Protic Arenosol
18/013	Black pine	Protic Arenosol
21/013	Black pine	Protic Arenosol

The retention capacity of the soil was determined using a container with a volume of 100 cm^3. The soil samples for analysis were air dried, and sieved (2 mm mesh), handpicked to remove fine roots, and then milled. The measurement of pH was conducted both in water and $CaCl_2$ using a 1:3 soil:solution ratio. SOC was determined using the Tyurin method. Total Nitrogen was determined by the Kjeldahl method, available P and K after extraction by the Egner-Riehm method, potassium was measured on a flame emission photometer, and phosphorus on a colorimeter. All analyses were performed in three replicates.

The wind-erodible fraction (EF) of soils was calculated using the Fryrear *et al*. (1994) equation.

$$EF=(29.09+0.31\ sand+0.17\ silt + 0.33\ sand/clay - 2.59\ organic\ matter - 0.95\ CaCO_3)/ 100$$

(R^2=0.67)

All variables are expressed in %, and they are used for soil samples with a content of $CaCO_3$ of below 25% and sand: clay ratio higher than 1.2%. Lopez *et al.* (2007) suggested a modified equation for soils with a higher $CaCO_3$ content.

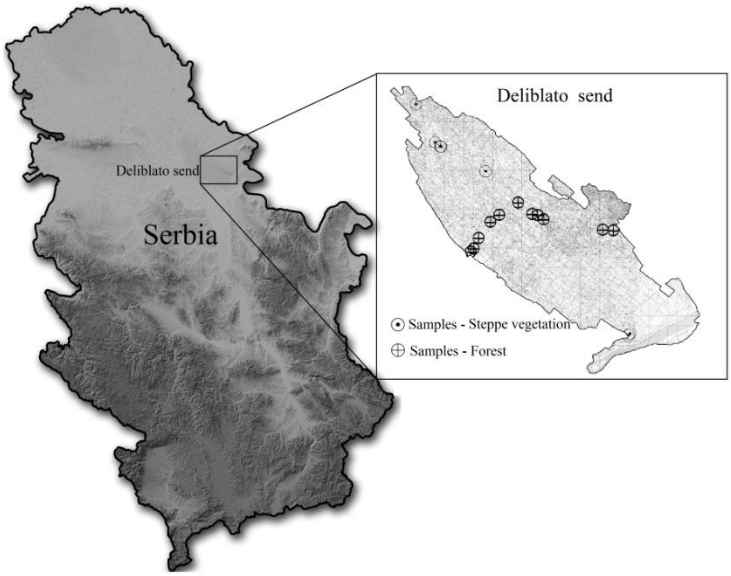

Fig.1. Study area - Deliblato Sands with sample plots

Statistical data

Ordinary least squares (OLS) regression analyses were conducted to evaluate the relationships between the wind erodible fraction of the soil and the water retention capacity of the soil and evaluate the relationships between the water retention capacity and humus content. The One-way ANOVA test was used to compare the properties of soils covered by different vegetation types. The statistical analyses were performed in the statistical program Statgraphics Plus.

RESULTS AND DISCUSSION

Vegetation played a decisive role at the initial stage of evolution of the soil in Deliblato Sands, and the influence of forest vegetation was much stronger than the influence of grassland communities (Košanin, Tomic, 2002). The study soils belong to the type of underdeveloped soils on sand or Arenosols (Haplic and Protic) according to the WRB classification. The average values of the chemical and physical properties of the study soils are presented in Table 2 by the type of land use. Also, the wind erodible fraction of the soils (EF) was calculated using the Fryrear *et al.* (1994) equation and the moisture content of the water retention capacity and these are shown in Table 3.

Table 2. Average values of chemical and physical properties of the study soils

Vegetation	Steppe			Forest		
Layer (cm)	0-10	10-20	20-40	0-10	10-20	20-40
pH(H_2O)	7,89±0,48	8,02±0,53	8,06±0,46	7,92±0,21	8,21±0,16	8,30±0,16
pH ($CaCl_2$)	7,26±0,47	7,37±0,39	7,40±0,34	7,39±0,14	7,52±0,06	7,58±0,08
$CaCO_3$ %	6,55±3,91	6,80±4,25	7,27±4,47	4,64±2,03	6,87±2,18	7,70±2,64
Humus %	1,75±0,9	1,24±0,74	1,12±0,46	4,25±1,60	1,59±0,73	1,28±0,55
Total N %	0,16±0,09	0,12 ±0,08	0,00±0,00	0,27±0,12	0,19±0,09	0,09±0,06
P_2O_5	2,88±1,02	1,96±0,26	1,39±0,39	4,43±2,91	3,37±2,23	2,87±1,77
K_2O	10,14±4,89	5,89±1,65	4,42±0,78	13,79±3,86	8,19±4,01	6,67±2,50
Sand %	93,04±2,62	92,31±3,20	91,74±3,36	91,09±2,74	92,48±3,55	93,16±3,05
Silt %	4,66±2,25	4,49±2,37	4,36±1,83	6,14±2,14	4,62±2,75	4,21±2,02
Clay %	2,30±0,74	3,39±0,92	3,90±1,72	2,77±0,84	2,90±0,97	2,53±1,05

The study soils represent the initial stages of the development of soils on the sand of siliceous calcareous origin. The soil reaction is moderately alkaline and calcareous. In terms of humus content, the soils covered by grass vegetation are poor and well supplied with N, while the soils covered by forest ecosystems are moderately rich in humus and rich in nitrogen. These soils are characterized by an imbalance in the level of soil development and vegetation, which was also observed by Košanin (2001). Soil properties and especially soil moisture are in addition to vegetation influenced by the morphology of the terrain.

Table 3. Average values of retention capacity and wind erodible fraction in the surface layer of the study soils

Vegetation	Steppe	Forest
Layer (cm)	0-10	0-10
Water retent.cap. %	39,03±3,13	43,88±4,22
EF	0,64±0,05	0,56±0,06

In terms of the values of water retention capacity the studied soils are in the medium class according to Gračanin. Water retention capacity was greater in the soils covered by forest vegetation, whereas wind erodible fraction was smaller.

Zhenghu *et al.* (2004) reported that in the case of 35 - year cultivated vegetation water is retained in the surface layer of 10 cm, while in the case of shifting sand the moisture is distributed uniformly with depth. The depth of root system distribution is of particular importance (Zhenghu *et al.*, 2004), and although the evaporation of vegetated soil is lower than that of quicksand, the transpiration of plants is high accounting for 20 - 40% of the annual precipitation, which causes a deeper infiltration of moisture into the soil.

There are statistically significant differences between the properties of the soil in the surface soil layer (0-10cm) covered by grass and forest vegetations. A statistically significant difference was found at 95% confidential level (method 95% LSD) in the contents of organic matter, total N, $CaCO_3$ content, moisture content and wind erodible fraction (Tab. 4).

Table 4. Results of the analysis of variance between the properties of the soils covered by grass and forest vegetation

	Humus	Total N	$CaCO_3$	Water ret.cap.	EF
F - value	12,74	10,65	5,45	6,25	8,13
p-value	0,002	0,005	0,03	0,02	0,01
Vegetation					
Steppe	a	a	a	a	a
Forest	b	b	b	b	b

Increases in the biomass on the soil surface and water retention capacity significantly accelerate the accumulation and mineralization of organic matter. The content of humus and total nitrogen contents are higher in the soil covered by forest vegetation compared to these contents in the soils covered by steppe vegetation. Statistically significant difference in the content of humus in the soils covered by different vegetation types is among other things caused by biological activity in the rhizosphere zone. Li *et al*. (2009) reported that the accumulation of C, N and P in the surface layer of 20 cm in sandy soils depends on the level of degradation caused by wind erosion.

Soil erodibility is largely caused by the texture of the soil. The selection of a particular textural fraction for erodibility assumption is often confusing due to different soil fractions that are used for the erodibility index (Nezshabouri *et.al.,* 2011). A proper erodibility index should follow the principles of uniqueness and applicability. Literature sources report that particles larger than 0.8 mm are stable and can be considered non-erodible (Woodroff, Siddoway, 1978; Fryrae *et al*., 1994, Kadović, 1999; Kostadinov 2008). Soil moisture and organic matter content increase the resistance of the soil to wind blows, primarily because the moisture produces a water film that creates a force of cohesion and organic matter binds particles to form aggregates (Jia *et al.,* 2011).

A regression correlation was found between the wind erodible fraction and water retention capacity of the soil (Table 5). It was also found that there is a correlation between the water retention capacity and humus content of both the soils covered by grass and the soils covered by forest vegetation.

Table 5. Regression analysis

Vegetation	Regression equation	R	R^2 (%)	t_a p- value	t_b p-value
Steppe	EF = 1.04594 - 0.0104336*WCR	-0,68	46,41	0,003	0,09
	WCR = 36.3153 + 1.54628*Humus	0,44	19,67	0,000	0,3
Forest	EF = 1/(2.06011 - 11.0356/WCR)	-0,12	1.68	0,007	0,68
	WCR = 41.697 + 1.59981*ln(Humus)	0,16	2.77	0,000	0,6

EF - The wind erodibile fraction
wrc - %water retention capacity

There is a strong negative correlation between the wind erodible fraction and moisture content at the water retention capacity in the case of soils covered by grass, while in the case of soils covered by forest this correlation is also negative but very weak. In the soils covered by grass the increasing amounts of humus lead to a strong increase in water retention capacity. The presence of a weak correlation was observed between the amount of humus and moisture content at water retention capacity in the soils covered by forest vegetation. Additional research is needed to investigate the relationships between certain soil properties and soil erodibility.

CONCLUSION

The area of Deliblato Sands is characterized by extreme and specific ecological site conditions, with dominant pasture and forest ecosystems at different stages of development of Arenosols. The aim of this study was to determine the magnitude of the impact of different vegetation covers (forest, pasture) on the changes in basic soil properties at the initial stage of development on sand. In addition, another goal was to assess the impact of different types of vegetation on soil erodibility.

The analysis showed that there was a statistically significant difference between the surface soil layers (0-10cm) covered by grass and those covered by forest vegetation in terms of the contents of organic matter, total N, $CaCO_3$, moisture content and wind erodible fraction. Water retention capacity is higher in soils covered by forest vegetation, and wind erodible fraction is smaller. The wind erodible fraction and moisture content of the water retention capacity are also marked by a strong negative correlation in the case of soils covered by grass, whereas in the case of soils covered by forest this correlation is also negative but very weak. In the soil covered by grass the increasing amount of humus causes a considerable increase in water retention capacity. A weak correlative relationship between the amount of humus and moisture content of the water retention capacity was observed in soils covered by forest vegetation. Additional research is needed to investigate the relationships between certain soil properties and soil erodibility.

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THE RESPONSE OF AGRICULTURAL CROPS TO INOCULATION WITH *Glomus intraradices*

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ABSTRACT

The arbuscular mycorrhiza is a symbiotic association formed between the roots of members of over 80% of terrestrial plants and a small group of common soil-borne fungi (*Glomales*). In general, this association is beneficial for both partners. Therefore, arbuscular mycorrhizal fungi (AMF) are potentially important tools in agricultural production. The response of wheat *(Triticum vulgare* L.*)*, maize *(Zea mays* L.*)*, lettuce *(Lactuca sativa* L.*)* and English ryegrass *(Lolium perenne* L.) to inoculation with AMF were tested in controlled conditions. Inoculation treatments included two commercially available inoculums containing *Glomus intraradices.* Plant material was taken 30 days after inoculation. Mycorrhizal root colonization and plant growth (stem length, root length, plant dry mass) were analyzed. Internal hyphae of the fungi were observed in the roots of all four investigated plants. The AMF did affect significantly the growth of maize plants. The results of this investigation showed the potential of using inocula containing AMF in sustainable plant production. Further research needs to be carried out in order to increase the benefits of mycorrhizal inoculation (MI) in semi controlled and field conditions.

Key words: mycorrhiza, wheat, maize, plant growth, root colonization.

INTRODUCTION

Arbuscular mycorrhizal fungi occur on a wide spectrum of temperate and tropical plant species. They are absent in less than 30 plant families (Tester *et al.*, 1987). This fungi-plant association is beneficial for both partners. AMF absorb macro and micro nutrients from the soil and then translocate these nutrients to the plant roots (Ortas, 2010). Their most consistent and important nutritional effect is to improve uptake of immobile nutrients such as P, Cu, and Zn (Pacovsky, 1986; Manjunath and Habte 1988). Furthermore, a growing number of researches suggest that AMF could contribute to plant health and productivity independently of their role in enhancing nutrient uptake. For example, the fungi have been found to be involved in the suppression of plant diseases (Trotta *et al.*, 1996; Hooker *et al.*, 1994), including nematode infection (Cooper and Grandison 1986). AMF stimulate hormone production in plants (Frankenberger and Arshad 1995), aid in improving soil structure (Bethlenfalvay *et al.*, 1998; Wright and Upadhyaya 1998), enhance leaf chlorophyll content and improve plant tolerance to water stress, salinity, soil acidity, and heavy metal toxicity (Tsang and Maun 1999; Bethlenfalvay, 1992). Therefore, AMF are potentially important tools in increasing productivity in agricultural plant production. The aim of this research was to test the response of wheat *(Triticum vulgare* L.*),* maize *(Zea mays* L.*),* lettuce *(Lactuca sativa* L.*)* and English ryegrass *(Lolium perenne* L.) to inoculation with AMF (*Glomus intraradices*) in controlled conditions.

MATERIAL AND METHOD

Planting and experimental design

The experiment was set up in the Laboratory of Microbiology, Faculty of Agriculture. Inoculation treatments included two commercially available inoculums containing *Glomus intraradices* (Rhizo-Vam Basic and Aegis Sym Microgranulo 50sp). Before sowing, soil was mixed with 2g of AMF and placed in pots, respectively. Wheat *(Triticum vulgare* L.*)*- NSR-5 variety, maize *(Zea mays* L.*)* - NS6010 hybrid, lettuce *(Lactuca sativa* L.*)*-Majska kraljica variety and English ryegrass *(Lolium perenne* L.) - Calibra variety were used as plant material. The seeds of each plant species were sowed in pots containing soil and AMF inoculum in three replication. The control treatment was without AMF inoculum. The pots were arranged in a randomized complete block design with 3 replicates per treatment. They were placed under natural light (daylight approximately 12 h, mean temperature 25 ^{0}C day). After 30 days, 10 plants were randomly chosen from each treatment. They were uprooted and the root systems gently washed. Mycorrhizal root colonization and plant growth (stem length, root length, plant dry mass) were analyzed.

Internal hyphae determination

A combined methods of Phillips and Hayman (1970) and Vierheilig *et al.* (1998) were used for the observation of internal hyphae of the AMF. Infection intensity of internal hyphae on plant roots was determined by staining with Pelican blue ink. The plants were harvested 30 days after planting, and the root system was taken, washed thoroughly with tap water. Roots were cleared by boiling in 10% (wt/vol) KOH (boiling times differed according to the type of plant and then rinsed several times with tap water). Cleared roots were boiled for 3 min in a 5% ink-vinegar solution with pure white household vinegar (5% acetic acid). Roots were distained by rinsing in tap water (acidified with a few drops of vinegar). The root colonization was assessed by cutting the distained roots into 1 cm sections in Petridish. Ten cuttings were mounted in glycerol into a glass slide and covered with cover glass. The root segments were examined for the presence or absence of AMF arbuscules, vesicles and/or internal hyphae under a compound microscope at 40´ magnification. The STATISTICA 12 software was used for data analysis. Data were treated with one-way analysis of variance. Means were compared using Fisher test ($p < 0.05$).

RESULTS

Inoculation with mycorrhizal fungus *Glomus intraradices* had different effect on the growth parameters of the investigated plants. The stem length of maize plants was significantly affected by MI (Rhizo-Vam Basic) as well as lettuce plants inoculated with Aegis Sym Microgranulo 50sp (Table 1.). The tested treatments on wheat and English ryegrass did not have strong enough effect to obtain statistically significant influence.

Table 1. Effect of Glomus intraradices on stem length (cm)

	Wheat	Maize	Lettuce	English Ryegrass
Rhizo-Vam Basic	30,05^{a}	34,37^{b}	6,90^{b}	19,15^{a}
Aegis Sym Microgranulo 50sp	29,11^{a}	30,70^{b}	8,23^{a}	17,30^{a}
Control	31,50^{a}	13,20^{a}	6,39^{b}	16,96^{a}
$LSD_{0,05}$	5,30	12,97	1,05	6,48

Note: The table shows mean values (arithmetic mean of ten repetitions). Mean values with the same superscript(s) are not significantly different according to Fisher's LSD test ($p < 0.05$)

Root length of maize was significantly increased in treatment with Rhizo-Vam Basic (Tab. 2). With other plants inoculation did not affect root growth in order to achieve statistically significant result.

Table 2. Effect of Glomus intraradices on root length (cm)

	Wheat	Maize	Lettuce	English Ryegrass
Rhizo-Vam Basic	$14{,}97^{a}$	$40{,}20^{a}$	$4{,}15^{a}$	$13{,}97^{a}$
Aegis Sym Microgranulo 50sp	$15{,}25^{a}$	$33{,}63^{ab}$	$4{,}36^{a}$	$11{,}70^{a}$
Control	$16{,}15^{a}$	$9{,}90^{b}$	$4{,}86^{a}$	$10{,}57^{a}$
$LSD_{0,05}$	3,22	26,13	1,69	3,50

Note: The table shows mean values (arithmetic mean of ten repetitions). Mean values with the same superscript(s) are not significantly different according to Fisher's LSD test ($p< 0.05$)

Dry mass of maize was significantly increased in both treatments containing *Glomus intraradices* (Tab. 3). Dry mass of other plants was not affected by MI.

The plant roots were examined for the presence or absence of AMF arbuscules, vesicles and/or internal hyphae under a light microscope at 40´ magnification. Internal hyphae of the fungi were observed in the roots of all four investigated plants (Picture 1-4).

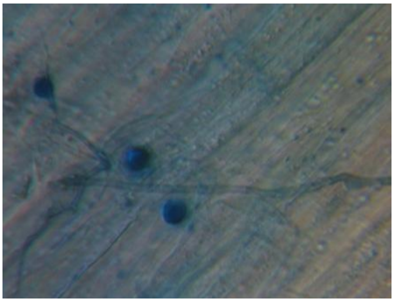
Table 3. Effect of Glomus intraradices on plant dry mass (g)

	Wheat	Maize	Lettuce	English Ryegrass
Rhizo-Vam Basic	$0{,}046^{a}$	$0{,}53^{b}$	$0{,}0039^{a}$	$0{,}0077^{a}$
Aegis Sym Microgranulo 50sp	$0{,}036^{a}$	$0{,}54^{b}$	$0{,}0058^{a}$	$0{,}0067^{a}$
Control	$0{,}046^{a}$	$0{,}19^{a}$	$0{,}0050^{a}$	$0{,}0052^{a}$
$LSD_{0,05}$	0,01	0,28	0,003	0,0029

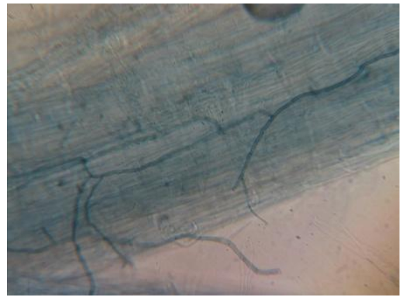
Note: The table shows mean values (arithmetic mean of ten repetitions). Mean values with the same superscript(s) are not significantly different according to Fisher's LSD test ($p< 0.05$)

DISCUSSION

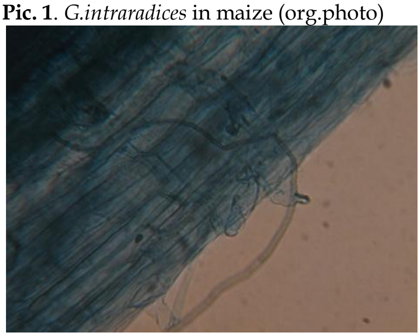
Maize stem length, root length and dry mass were increased after MI with two commercial AMF inocula, both containing *Glomus intraradices*. That increase was in the range of statistically significant changes. Corkidi *et al.* (2004) also indicated the existence of a significant effect of commercial mycorrhizal inoculant as well as potting medium for shoot height and dry mass of maize.



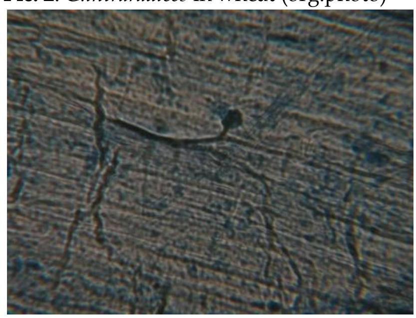
Pic. 1. *G.intraradices* in maize (org.photo)



Pic. 2. *G.intraradices* in wheat (org.photo)



Pic. 3. *G.intraradices* in lettuce (org.photo)



Pic. 4. *G.intraradices* in Eng. Ryegrass (org.photo)

The authors also stated that the percentage of mycorrhizal colonization obtained with the different mycorrhizal inoculants ranged from 0 to 50 %. Ortas *et al*., (2011) investigated the impact of several mycorrhizal inoculums on plant growth of six maize genotypes and concluded that for shoot and root dry weight production, *Glomus intraradices* is one of the most efficient mycorrhiza species, on average all maize genotypes. Miranda *et al*., (2011) demonstrated that MI significantly increased dry weigth accumulation in vegetative and generative plant organs of cape gooseberry plants. The mycorrhizal plants shows increased root and shoot dry weight according to Yassen *et al.* (2012). MI increases the plant total biomass which commonly leads to more plant dry weight. Maize is a warm-season plant reaching vegetative and generative maturity by early fall and, unlike wheat and ryegrass, it benefits significantly from mycorrhizal symbiosis. Even if field conditions maize respond better and have a much higher mycorrhizal dependency than wheat (Dape and Monreal, 2004). The positive effect of AMF on dry matter growth may be attributed to the increased nutrient acquisition of plants. Due to the uptake of carbohydrates from the plant, the AMF enhance the sink capacity of the root system and, in turn, increase the photosynthetic performance of the plant leading to improved plant growth (Bresinski *et al*., 2008).

No statistically significant changes in plant growth were obtained with wheat and English ryegrass. These two crops are so called cold-season grasses which are less affected and dependent by mycorrhizal colonization (Wilson *et al*., 1998). The authors tested numerous warm and cold-season grasses and their response to MI. They observed that all cold-season grasses were able to grow normally in the absence of mycorrhiza. This is in accordance with our results since no significant changes were gained as a result of MI. It implies that AM fungal communities are influenced by the structure of their associated plant communities. Recently, host specificity and the influence of plant species composition have also been demonstrated in natural ecosystems, using both spore production (Eom *et al*., 2000) and AM fungal DNA (Husband, 2002; Vandenkoornhuyse *et al*., 2002).

In conclusion, plant stem length, root length and dry mass were affected by MI. The AMF did affect significantly the growth of maize plants. Internal hyphae of *Glomus intraradices* were observed in the roots of all four investigated plants. The results of this investigation showed the potential of using inocula containing AMF in sustainable plant production, especially maize production. Further research needs to be carried out in order to increase the benefits of MI in semi controlled and field conditions.

ACKNOWLEDGMENT

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DIRECT AND RESIDUAL EFFECTS OF APPLIED FERTILIZERS ON NO_3–N DYNAMICS IN THE SOIL AND TOMATO YIELD IN GREENHOUSE EXPERIMENTS

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ABSTRACT

NO_3-N dynamics in the soil as dependent on applied fertilizers and their effect on tomato yield was observed in greenhouse experiments set up on experimental fields of the agricultural advisory service station in Sombor in 2011 and 2012. In order to determine the impact of the application of different fertilizers, mineral fertilizers and organic and mineral fertilizers combined (mature cattle manure 20 t ha^{-1}; composted pig manure 20 t ha^{-1}; mature cattle manure 20 t ha^{-1} + mineral fertilizer 11:11:21; composted pig manure 20t ha^{-1} + mineral fertilizer 11:11:21; and unfertilized- control), in two greenhouse experiments were conducted to monitor the direct and residual effects of the applied fertilizers on NO_3-N dynamics and on tomato yield. Organic fertilizers have a residual effect in plant nutrient supply and they enhance chemical, physical and microbiological properties of the soil. The combined application of organic and mineral fertilizers is instrumental in securing better nutrient supply in early stages of plants' development. In the experiment where fertilization was performed under tomato, the measured amounts of NO_3-N with all treatments are statistically significantly higher than in the experiment were fertilization was performed under the previous crop. The residual effects of fertilization (of the previous crop) were monitored at all sampling times. In the experiment with the residual effects of fertilization, no correlation was found between the measured amounts of NO_3-N in the soil at planting time and tomato yield. At later sampling times, especially at the first harvest, we found a high correlation (r= 0,69) between soil NO_3-N and the yield. In tomato fertilization treatment, a high correlation between soil NO_3-N and the yield was observed at all sampling times.

Keywords: fertilization systems, mineral nitrogen, tomato yield, organic fertilization

INTRODUCTION

In short growing season vegetable cultures form extremely high yield and therefore have higher demands for nutrients, above all for nitrogen that is carrier of the yield. Also, in comparison to the above ground mass – fruit, vegetable plants have weaker developed root system, and therefore, presence of adequate quantity of nutrients all over vegetation period is necessary. Assurance of the soil by available forms of nutritive elements at the beginning of growing season is very important, because in this period yield and quality of product are defined.

Vegetable production indoor provides high yields and for such yields in addition to varieties and hybrids the presence of nutrients and irrigation are essential prerequisites. Use of different organic, mineral and combined organic and mineral fertilization systems, in greenhouse vegetable production can result in high yield of good quality (Bogdanović *et al*. 2011; Bogdanović 2012).

Organic fertilizers provide grown plants with nutrients and have a significant role in increasing of soil fertility by improving its structure, water-physical and microbiological properties (Clark *et al*., 1998; Grandy *et al*., 2002). Unlike mineral fertilizers, a few years after application of manure a prolonged effect on the soil chemical properties and hence to the crop yield is observed (Eghball *et al*. 2004; Ferguson *et al*., 2005; Guster *et al*., 2005; Čabilovski 2009). Mineralization rate of organic fertilizers depends on the types of fertilizers, level of organic matter decomposition, temperature and microbiological activity, and that is why their value as a plant nutrient source is very differerent (Pang and Letely 2000; Leita *et al*., 1999). Considering conditions for growing vegetables indoor, i.e. high temperatures and humidity, uncontrolled use of organic fertilizers can lead to negative effects: nitrate leaching into ground water, toxic effects of heavy metals and organic substances, weed infestation. On the other hand use of mineral fertilizer in greenhouse vegetable production can cause negative consequences, primarily due to the increased accumulation of NO_3, especially in green vegetables which is very harmful (Burnns, 1996; Kastori and Petrović 2003; Bogdanović and Čuvardić 2002). Moreover, due to permanent irrigation of vegetables, soil structure is disturbed, NO_3 is leached, and antagonism of ions in the diet occurs. Combined fertilization system with organic and mineral fertilizers is common practice in indoor vegetable production and provides a satisfactory solution. The aim of the study was to determine direct and residual effects of different systems and fertilizer treatments on tomato yield in greenhouse production in 2011 and 2012.

MATERIALS AND METHODS

NO_3 –N dynamics in soil depend from fertilizer system and treatments that were observed in two greenhouse experiments of the agricultural advisory station in Sombor in 2011 and 2012. In Experiment A a direct impact of the applied systems and fertilizer treatments to the dynamic of NO_3 –N in the soil and tomato yield was determined. In Experiment B the residual effects of the applied systems and fertilizer (fertilized under previous crop-cabbages) on NO_3 –N dynamics and on tomato yield were monitored.

Table 1 Fertilization systems and tomato treatments in greenhouse experiments (direct and residual effects of fertilization)

	Experiment A	Experiment B
No.	Fertilization in a year of tomato production	Tomato in the experiment on residual effect of the applied fertilizers (fertilization under previous crop)
1.	Control – no fertilizer	control
2.	CPM 20 t ha^{-1}	CPM 20 t ha^{-1}
3.	MCM 20 t ha^{-1}	MCM 20 t ha^{-1}
4.	CPM 20 t ha^{-1} + MF 11:11:21 (500 kg ha^{-1})	CPM 20 t ha^{-1} + MF 11:11:21 (500 kg ha^{-1})
5.	MCM 20 t ha^{-1} + MF 11:11:21(500 kg ha^{-1})	MCM 20 t ha^{-1} + MF 11:11:21(500 kg ha^{-1})

Note: CPM – composted pig manure; MCM – mature cattle manure; MF – mineral fertilizer

Before setting up of the experiments A and B in a greenhouse, soil samples for agrochemical analysis were taken from the layers of 0-30 and 30-60 cm.

In Table 2 are presented results of agrochemical analysis of the soil in experiments before tomato planting. In both of the experiments, soil was alkaline, moderate to highly calcareous, moderate to poor supplied with humus for vegetable production, in the class of moderate supplied in total nitrogen, and well in mineral nitrogen, moderate to poor in easy available phosphorous and moderate to poor in easy available potassium.

Table 2 Chemical properties of the soil before tomato planting

Experiment	Depth cm	pH		% $CaCO_3$	% humus	% N	mg $100g^{-1}$ soil		mg NO_3-N kg^{-1} before planting
		H_2O	KCl				P_2O_5	K_2O	
B	0-30	7.96	7.45	7.16	3.19	0.16	21.3	16.8	32.5
	30-60	8.26	7.47	15.59	2.35	0.11	3.3	13.7	64.5
A	0-30	8.22	7.21	5.79	3.26	0.16	16.6	18.5	35.9
	30-60	8.30	7.41	20.23	2.43	0.12	4.5	10.9	56.8

A – direct effect of fertilization
B – residual effect of fertilization

For analysis of the soil fertility standard methods were applied. Determination of NO_3–N in the soil layers of 0-30 cm and 30-60 cm was performed before planting of the nursery plants, in intensive tomato growth, before the first and second harvest according to the N min. (Sharpf and Wehrmann, 1979).

Chemical composition of the applied organic and mineral fertilizers is shown in Table 3. Based upon nitrogen content in organic fertilizers, quantity of composted pig manure and mature cattle manure needed for incorporation of 250 kg N ha^{-1} was calculated either under direct tomato planting or under previous crop – cabbages.

For determination of plant-available fraction of Fe, Mn, Cu and Zn in organic fertilizer samples were extracted with DTPA – TEA buffer and analyzed by Atomic Absorption Spectrometer (Shimadzu 6300) with flame technique (Lindsay *et al*. 1978). „Pseudo (partially)“ total content of heavy metals Cd, Pb, Ni and Cr in organic fertilizers was determined by effecting the sample of HNO_3 in H_2O_2 and analyzed by Atomic Absorption Spectrometry with flame technique (Lindsay *et al*. 1978). Results of the study were processed by regression analysis, and significant differences of medium treatments were performed by LSD test.

RESULTS AND DISCUSSION

NO_3-N dynamics in the soil in experiments under tomatoes with direct and residual effects of the applied fertilization systems and treatments in experiments under tomatoes with direct and residual effect of the applied fertilization systems is shown on Graph 1.

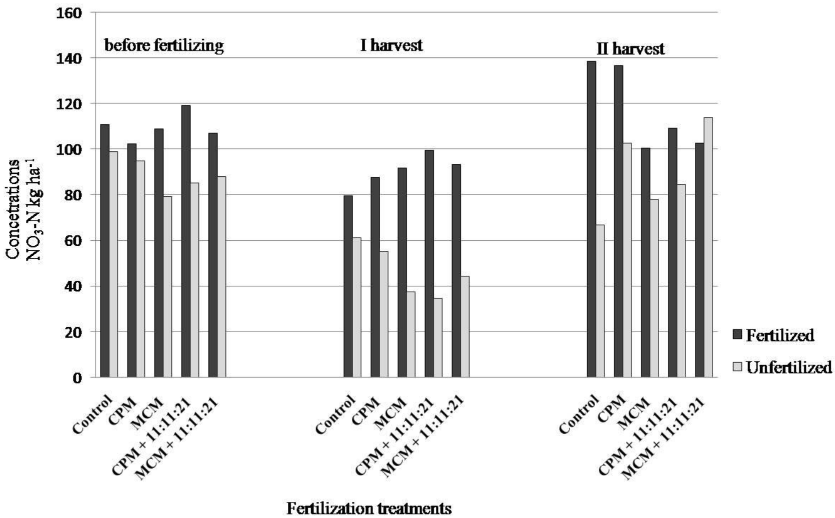
Table 3 Chemical composition of the applied organic fertilizers at the experiments

Fertilizer	%	%	%	mg kg^{-1}						
	N	$P_2O_{\%}$	K_2O	Mn	Fe	Zn	Cu	Cd	Ni	Pb
Composted pig manure (CPM)	1.25	3.58	1.68	123.0	792.0	170.1	32.1	1.52	88.6	3.6
Mature catle manure (MCM)	1.21	2.59	1.33	177.0	1087.1	36.1	6.0	1.6	78.9	7.1
Mineral fertilizer (MF)	11	11	21	-	-	-	-	Trace	Trace	Trace

According to the Graph 1 the measured quantities of NO_3-N in the same fertilization systems and treatments and at measurement times were statistically higher in the experiment where fertilization was performed directly under tomato in comparison to the experiment with the residual effects of fertilization. The smallest difference in the amount of NO_3-N between direct and residual effect of fertilization was measured during tomato planting and the highest during the second tomato harvest. In direct fertilization of tomato plants, during growing period plants adopted mineral nitrogen from the applied fertilizers and soil reserves, while in the experiment with the residual effect of fertilization they adopted only residual nitrogen from the soil. As the needs of tomato for NO_3-N from intensive growth to the end of growing season increased, so the difference between mineral nitrogen in the soil from direct fertilization and the residual effect was even greater.

In the experiment with direct fertilization under potatoes, measured amounts of NO_3-N per sampling times represented an equilibrium between mineralization of the applied fertilizers and soil organic matters on the one hand and immobilization of the mineral nitrogen by tomato crops and microorganisms on the other (Bogdanović and Čabilovski, 2007; Čabilovski, 2010; Bogdanović *et.al.*, 2012).

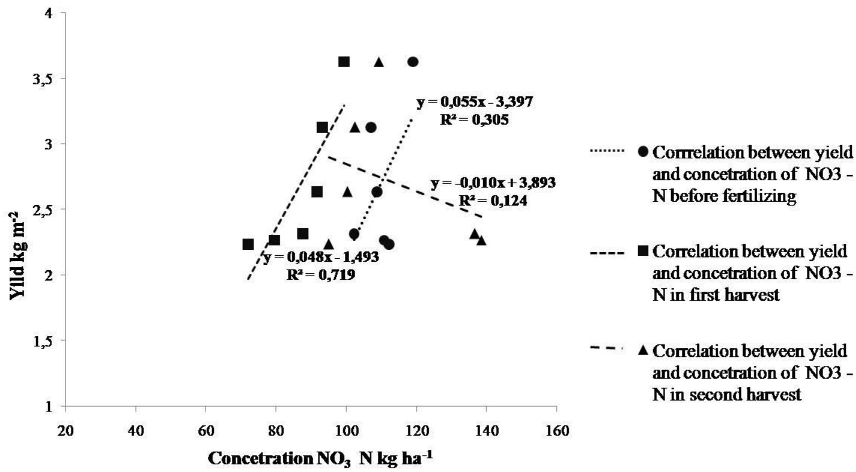
In the experiment with the residual effect of fertilization were measured small amounts of NO_3-N per sampling times and it represented a state of equilibrium only between the soil organic matter mineralization and immobilization of tomato plants and microorganisms, and consequently were significantly lower. Correlation between measured amounts of soil NO_3-N per sampling times and achieved tomato yields in experiments with direct fertilization and fertilization under previous crop is shown in Graph 2 and Graph 3.



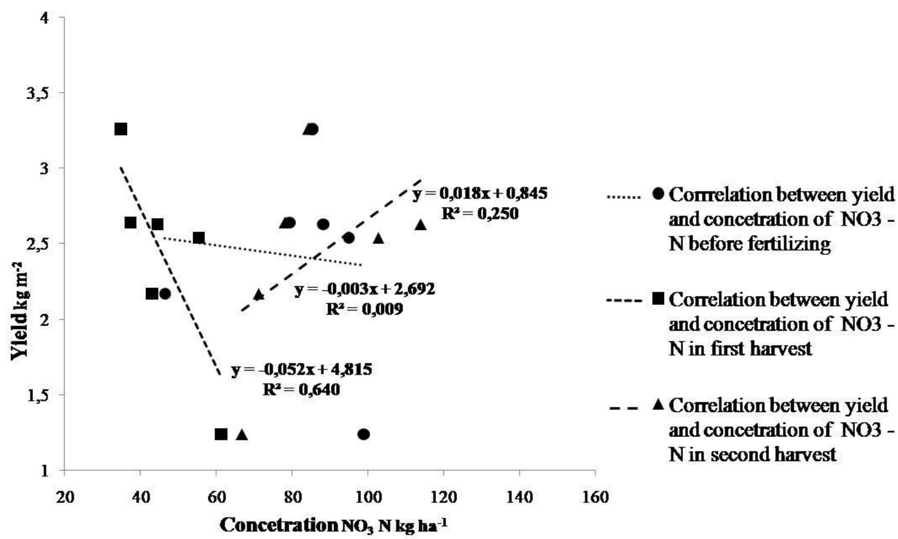
Graph 1. Dynamics NO_3-N in soil in experiments with direct and residual effect of applied fertilizer in tomato production

In the experiment with direct fertilization under tomatoes (Graph 2) per sampling times, high correlation was established between soil NO_3-N at the beginning of growing season, the first harvest and the achieved yield, while in the second harvest the established correlation between NO_3–N and the yield was low. In the experiment under tomatoes in which the residual effects of fertilization were monitored (Graph 3), no correlation was found between the measured amounts of soil NO_3-N before planting and tomato yield.

However, high correlation was found between soil NO_3-N and tomato yield at the first harvest, and somewhat lower at the second harvest. Better conditions for mineralization of the soil organic matter, high temperatures and irrigation of the crops during growing period contributed to strong correlation between residual nitrogen in the soil and tomato yield. Studies of some authors show that spring application of organic fertilizers has greater impact on the yield of cultivated crops in the year of application in comparison to autumn one (Hansen *et. al.*; Randall *et al.* 1999).

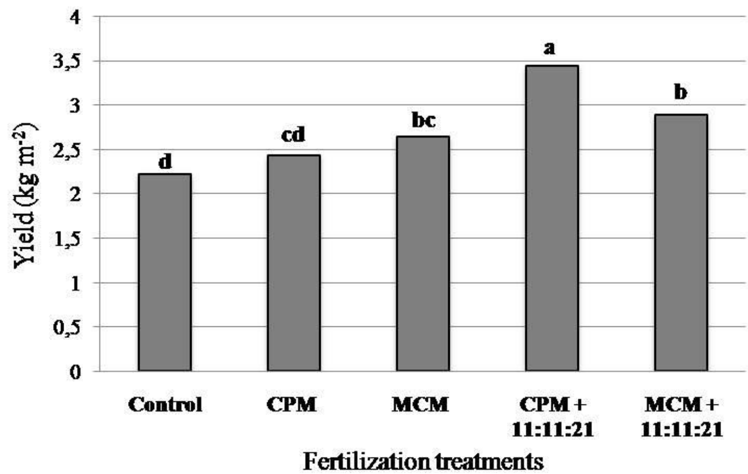


Graf 2. Correlation between concetration of NO3-N in the soil and tomato yield in experiment with direct fertilizing



Graf 3. Correlation between concentration of NO3-N in the soil and tomato yield in experiment with residual effect of fertilizing

After the applied LSD test it was established that there were no statistically significant interactions between fertilization systems and treatments, i.e. statistically significant increase of the yield occurred due to treatments (Graph 4). Statistically significantly higher tomato yield was achieved with CPM fertilization+mineral fertilizer in relation to the other fertilization treatments and the control. On the other hand, in the experiment with direct fertilization under tomatoes in the fertilizer treatment MCM+mineral fertilizer recorded statistically significantly higher tomato yield in relation to the other fertilizer treatments and control, except for the treatment CPM+mineral fertilizer and treatment MCM. Higher yield of tomato in the fertilizer treatment CPM + fertilizer can be explained by much higher solubility of biogenous elements, especially nitrogen from CPM in comparison to other fertilization treatments and hence their greater accessibility for plants (Denić 2010; Bogdanović *et al.* 1995).



***Values followed by different upper- and lowercase letters are statistically significantly different at $p < 0.05$**

Graph 4. Average tomato yield as dependent on applied fertilizer

CONCLUSION

Based on the monitoring of direct and residual effects of the applied fertilizers to the dynamic of soil NO_3-N and tomato yield in greenhouse experiments, the following conclusions can be carried out:

- Measured amounts of NO_3-N in the identical systems and fertilizer treatments and sampling times were significantly higher in the experiment in which fertilizers were applied directly under tomatoes in comparison to the experiment with the residual effect of fertilization.

- In the experiment with residual effects of fertilization, no correlation was found between the measured amounts of soil NO_3-N before planting time and tomato yield. In the same experiment at later sampling times during growing season, high correlation was found between soil NO_3-N and tomato yield.
- In the experiment with direct fertilization under tomato a high correlation was found between soil NO_3-N and the yield at all sampling times.
- Use of LSD test showed that there were no statistically significant interactions between fertilizer systems and treatments, while statistically significant increase of tomato yield was influenced by fertilization treatments.
- Significantly higher tomato yield in direct fertilization and fertilization under previous crop were achieved in treatment by composted pig manure and mineral fertilizer in relation to other fertilization treatments and control.

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NH_4^+-ZEOLITE/RAW PHOSPHATE COMPOSITE AS A NATURAL FERTILIZER AND SOIL REMEDIATION AMENDMENT

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ABSTRACT

The application of raw phosphates for soil fertilization is economically cost-effective and environmentally eligible than industrial P fertilizers, but it is limited on acid soils. Our investigations is focused on design of novel multifunctional material based on the synergistic conjunction of ammonium modified zeolites and raw phosphate, contributing to increase phosphor-mobilization in various soil conditions and in a wide pH range, through the Ca^{2+} cation exchange. The results indicates that an addition of zeolites to the rock phosphate contributes to releasing phosphorus in the first 24^h for about 60%, while modified NH_4^+ -zeolite increases the release of phosphorus for additional 150%. Released phosphate ions could have a dual role as a natural fertilizer, as nutrient donor, and soil remediation amendment through phosphate-induced stabilization of heavy metals, as acceptor. The efficiency of alumosilicate composites, as a nature fertilizer, was investigated through the vegetation experiments setup with maize on soil type distric cambisol. On the other side we investigate the acceptor properties of composite through phosphate precipitation of heavy metals and reducing their bioavailability. The obtained results indicate that NH_4^+-zeolite/raw phosphate composite has multifunctional properties applicable in sustainable agricultures and environmental.

Keywords: modified zeolite, phosphate rock, nature mineral fertilizers, soil remediation amendment

INTRODUCTION

Phosphorus, from rock phosphate (RP) has a significant impact on increasing crop yields and the content of physiologically active form of phosphorus, as well as plant nutrient, but with limited use on acid soils (Hinsinger and Gilkes, 1997; Pickering *et al.*,2002). In case of very acidic soils (pH below 4.5), effects of raw phosphate are identical with the used water-soluble industrial phosphorus fertilizers (Stojanović *et al.*, 2009). The dissolution of the RP in soils depend on the availability of H^+, humidity, Ca^{2+} and P removal from the solution. Cation exchange capacity of acidic soils are low, the concentration of Ca^{2+} in the soil solution around the particles increases rapidly, delaying RP dissolution (Lai and Eberl, 1986). Zeolites, as aluminosilicate porous minerals, with high cation-exchange capacity, that can help control the release of plant nutrients in agricultural systems and can contribute to increase the solubility of rock phosphate (Vaughan, 1978). When saturated with monovalent nutrient cations, such as NH_4^+ , zeolites additionally enhance increase dissolution of RP (Allen *et al.*, 1993). The mechanism proposed for solubilisation of RP is exchange-induced dissolution in wich plant uptake of NH4+ liberates exchange sites which are occupied by Ca^{2+}, lowering the soil solution Ca^{2+} concentration and inducing further dissolution of RP, respectively the zeolite takes up Ca^{2+} from the phosphate rock, thereby releasing both, phosphate and ammonium ions, according to equation No. 1.

$$RP + NH_4^+\text{-zeolite} \leftrightarrow \text{Ca-zeolite} + NH_4^+ + H_2PO_4^- \qquad (1)$$

Unlike the leaching of very soluble phosphate fertilizers (for example, superphosphate), the controlled release phosphate is released as a result of a specific chemical reaction in the soil. As phosphate is taken up by plants or by soil fixation, the chemical reaction releases more phosphate and ammonium in the attempt to reestablish equilibrium.

The tribochemical activation of natural phosphate-NH_4-exchanged clinoptilolite mixtures facilitates the transitions of hardly assimilated by plants P_2O_5 forms into readily accessible ones. Procedure leads to deformation and rupture of Si-O-Si and Si-O-Al bonds and decreasing of ionexchange capacity in the clinoptilolite sample and defectiveness and isomorphism in the apatite structure which caused to increased reactivity, especially in the case of apatite domination (Petrova and Petkova, 2011).

It is proved that zeolite modified with ammonium ions has a higher capacity than natural zeolite to protect *Hieracium aurantium* and *Rumex acetosella* growing on tailing ponds, by reducing the quantity of heavy metal ions (Pb, Zn, Cu, Fe) these plants would accumulate in their roots and leaves. *Hieracium aurantium* and *Rumex acetosella* accumulate a smaller quantity of metal ions in roots and leaves in the presence of zeolite modified with ammonium ions than in the presence of natural zeolite. In terms of reducing the uptake of ions of heavy metals, only the zeolite modified with ammonium has a significant protective effect on *Hieracium aurantium*, while both natural zeolite and zeolite modified demonstrate a significant role for *Rumex acetosella*, as revealed by statistical tests (Peter *et al.*, 2011).

On the other hand, research indicates that natural apatite from Lisina can be used for in situ phosphate-induced immobilization of heavy metals, Pb and Cd, in polluted soils, as inexpensive remediation amendments(Raičević *et al.*, 2005, Kaludjerović *et al.*, 2008). Phosphate amendment is less effective for Cu and Zn immobilization (Caoa *et al.*, 2003). This is explained by the fact that. Pb was immobilized by P via formation of an insoluble pyromorphite mineral in the surface and subsurface of the soil, which is not the case with Zn or Cu.

Researches in this study were led in three directions: (i) The basic parameters of zeolite modification with ammonium ions, to be most economically in the respective raw materials needed to produce an effective supplement for ecological fertilizer and soils remediation amendments, (ii) The efficiency of natural fertilizer was further investigated through the vegetation experiments with maize in semi-controlled conditions and correlations of P and Ca^{+2} accumulated in maize shoots, with the concentrations of the same elements in the experimental solutions of used fertilizer systems were presented (iii) The efficiency of natural fertilizer as soil remediation amendment through phosphate-induced stabilization of heavy metals, as acceptor.

New cost-effective natural mineral fertilizers based on phosphate and zeolite with competitive characteristics compare with chemical fertilizers. Their implementation will improve soil fertility and safe food production. Utilisation of phosphorus mineral resource in

Bosilegrad-“Lisina”creates economic revitalization and development of the chemical industry with competitive products at an international level.

MATERIAL AND METHODS

(i) Zeolites originating from deposit Baia Mare, Romania (K-zeolite) and Igros, Kopaonik, Serbia (Ca- zeolite), were used for this study. Chemical composition of starting zeolitic tuff was determined by atomic absorption spectrophotometry (AAS) using the Perkin Elmer AAS "703”. The natural K -zeolite tuff contained: 63.60% SiO_2, 11.81% Al_2O_3, 1.74% Fe_2O_3, 7.35% CaO, 0.69% MgO, 0.17% TiO_2, 0.4% Na_2O, 4.40% K_2O and loss of ignition was 9.81%. The natural Ca -zeolite tuff contained: 65.89% SiO_2, 12.86% Al_2O_3, 2.06% Fe_2O_3, 4.90% CaO, 0.95% MgO, 0.17% TiO_2, 0.97% Na_2O, 1.14% K_2O and loss of ignition was 11.26%. Modification of zeolites with different initial concentrations of ammonium sulfate (AS) (1 M $(NH4)_2SO_4$) was performed at four ratios of natural zeolite and modifier (1:1, 1:2, 1: 5 and 1:10). 20 g of each zeolite was modified with 75 ml of 0.2 M AS (1:1 ratio), 0.4 M AS (1:2 ratio) and 1M AS (1:5 ratio) and 150 ml 1M AS for 1:10 ratio. The above ratios are the stoichiometric ratios between the cation exchange capacity of natural zeolite and ammonium ions from AS required for complete ion exchange. Samples were shaken on rotary shaker for 24 hours at 220 rounds per min. After draining, the resulting solutions were examined on the contents of Ca, K, Na, and Mg. The concentration of the exchanged cations has been measured using the “Perkin Elmer AAS "703”.

(ii) The fertilizer, concentrate of RP, used in these experiments was made by flotation method of apatite, from ore deposit „Lisina“ Bosilegrad, containing 32-35% P_2O_5. RP was grounded to about 80μm size particles. The used zeolites was of Romanian origin from deposit Baia Mare. With a wet milling and wet classification process was excluded fraction of < 37 μm, which were used in the experiments. Modification of zeolite with NH_4^+ was performed by treating the natural zeolite with 1M NH_4Cl. Vegetation experiment in semi-controlled conditions was set up with a hybrid ZP 434 on soil type distric cambisol (pH_{KCl} 5.5).Three different growing media placed in the 3 different pots: (RP)/soil, (RP+zeolite)/soil and (RP+NH_4-zeolite)/soil, were tested. In each experimental variants were entered 20g of fertilizer per 100 kg of soil. Based on the literature data it was decided that the fertilizer contains initial ratio the zeolite and the RP of 5:1 [2]. Plants were collected with three to five leaves and dried. Maize yield was determined via total increase of dry matter content (m) and its heights (h). The amounts of P after sample preparation were mesaured by analysis of the supernantant by colorimetry.

(iii) The effectiveness of natural mineral fertilizers on physiological and morphological and nutritional properties of corn were conducted at the experimental field "Radmilovac", the type of soil leached chernozem, owned by the Faculty of Agriculture – Zemun. Zemun. Hybrid FAO560 planted on leached chernozem soil type.

The field experiment was set up and carried out during the 2012th on a plot size of 15m x 60m, which included ten basic plot size 12m x 7.5m., or unit of 90 m^2, with nine rows of corn. Each plot, except the control and treated with different variant model of manure. Each variant is composed of different combinations of modified zeolite grain size <100 µm, natural and concentrated apatite grain size <63 um and ash pit cherries grain size <0.9 mm, as donors of potassium (12.08% K_2O), compared 5:1, in two doses. Dose 1 is the input of 25 kg fertilize, dose 2 is the input of 40 kg fertilizer unit area of 90 m^2 (Table 1). Fertilizer efficiency was evaluated by measuring the content of nutritive elements and heavy metal (Pb, Zn, Cd and Cu) in soils and plants.

Table 1. Nutrition treatments on vegetation experiments

Nutrition treatments	Nutrition variant
control	without treatment
AZA 1	20 kg of modified zeolite, 4 kg of natural apatite, (Dose 1)
AZA 2	20 kg of modified zeolite, 4 kg of natural apatite, (Dose 2)
AZAK 1	20 kg of modified zeolite, 4 kg of apatite concentrate, (Dose 1)
AZAK 2	20 kg of modified zeolite, 4 kg of apatite concentrate, (Dose 2)
PEP	20 kg modif. Zeolite, a natural apatite 4 kg, 4 kg ash pit cherries, (Dose 1)
PEPK	20 kg modif. Zeolite, a natural apatite 4 kg, 4 kg ash pit cherries, (Dose 2)

In order to enable more comprehensive comparison between examined samples, particularly the effects of different fertilization treatments, standard score (SS), assigning equal weight to all assays applied, has been introduced. Analyses of variance (ANOVA) have been applied to show relations between applied assays. Descriptive statistical analyses for all the obtained results were expressed as the mean ± standard deviation (SD). Furthermore, the evaluations of one-way analysis of variance (ANOVA) of the obtained results were performed using StatSoft Statistica 10.0® software. Collected data were subjected to one-way ANOVA for the comparison of means and significant differences are calculated according to Turkey's HSD test at $P < 0.05$ level. Data were reported as means ± standard deviations. To get a more complex observation of the ranking of contents of the elements in the soil and maize roots, standard scores (SS) were evaluated using statistical approach by integrating the measured values generated from various fertilization treatments. In order to compare various characteristics of complex soil and root samples after different fertilization treatments using multiple measurements, samples were ranked based on the ratio of mean value and standard deviation of the measurement used. As the scale of the data from various samples were different, the data in each data set should be transformed into standard scores (SS), dimensionless quantity derived by subtracting the mean from the raw data divided by the standard deviation. The standard scores of a sample for different measurements when averaged give a single unit less value termed as SS, which was a specific combination of data from different measuring methods with no unit limitation and no variance among methods.

RESULTS AND DISCUSSION

(i) After modification of both zeolite types, with different initial concentrations of AS, ion-exchangeable cation concentration in the residual solution was investigated and results show a gradual increase in concentrations of Ca, Mg and Na with increasing of initial concentrations of modifier, in both cases. In the K-zeolite, content of K in the solution increases rapidly at 1:5 ratio, after which it decreases. In the Ca-zeolite an increase of K was significant at 1:10 ratio modification. At the same ratio in Ca-zeolite, gradual decrease of Mg displacement was observed (Fig.1).

(ii) The results of the experiment setup with maize, as test culture, indicate that the addition of natural zeolite to RP favors the growth of the culture and its yield (Table 1). The yield in the mass of maize was increased for an additional 85%, in the treatment with (RP+Z) fertilizer and for 95% in the treatment with (RP+ NH_4^+-Z), in comparison with the RP treatment.

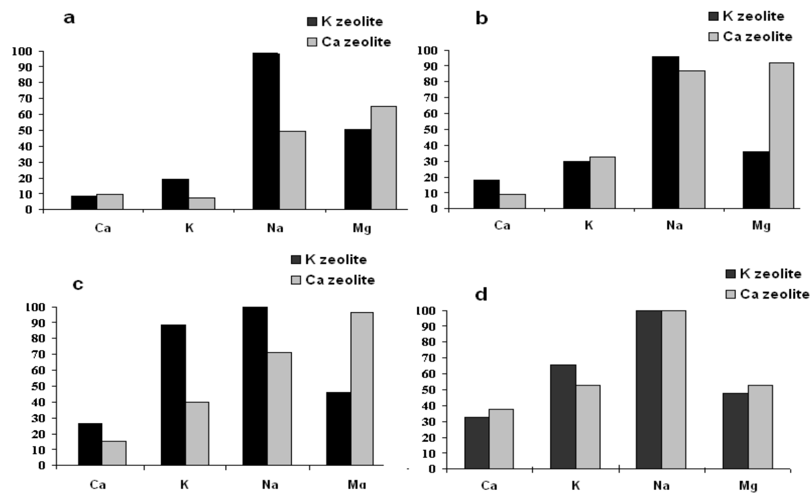

Fig. 1. The percentage of exchanged cations after modification of natural zeolite with different ratios of AS (a) 1: 1 (b) 1 : 2 (c) 1 : 5 (d) 1 : 10 (Mihajlović *et al.*,2013)

The obtained values of K^+ content in all three samples of maize showed higher amounts of this nutrient in plants treated with zeolite enriched fertilizer. The highest Ca^{+2} content of 1.66 % was found in sample with (RP + Z) treatment. The expected decrease in content of Ca^{+2} was observed in the sample treated with fertilizer which has the least of this element (0.73%). Surely the most significant parameter of the applied fertilizer treatments was P content in the prepared plant samples. At the treatment with the addition zeolite to the RP, content of P was increased from 0,181% to 0.198%. As what was expected, the highest P content of 0.263%, was detected in the sample of maize treated with the (RP + NH_4^+-Z) fertilizer. This increase in P content is in correlation with the increase in maize yield when using NH_4-zeolites as a supplement to the RP. To examine the effects of zeolite addition to natural fertilizer on the crops yield and the level of nutrient adoption, we compared the content of Ca^{2+} and P which was previously determined in the solutions, with those found in maize, Figure 1.

Table 2. The results of vegetation experiment with maize.

Treatment	h (%) [a]	m (%)[b]	K (%)	Ca (%)	P (%)
RP	100	100	1,62	0,77	0,181
RP+Z	143	185	2,08	1,66	0,198
RP+ NH_4^+- Z	153	195	2,37	0,73	0,263

[a] *The percentage of increase in heigh of the maize, compared to the RP treatment*
[b] *The percentage of increase of maize yield, compared to the RP treatment*

Pearson's correlations coefficients obtained for Ca^{2+} and P were r = 0.99 and r = 0.96, respectively. High values of correlation coefficients indicate that the additions of zeolites to the RP facilitate the release of phosphorus, and therefore it's better adoption from the fertilized soil by maize.

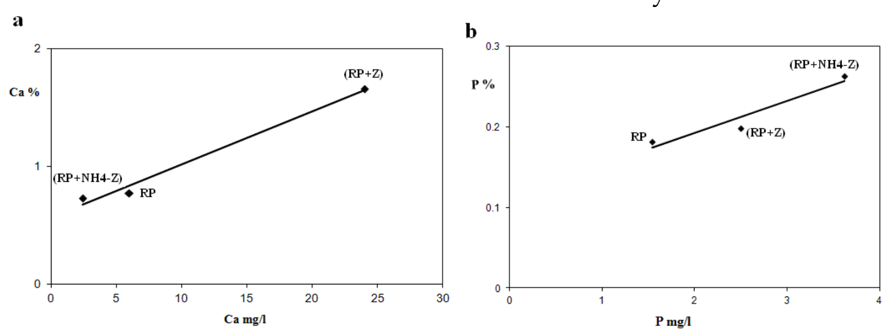

Fig. 2. The relationship between the $Ca^{2+}$and P released from the different fertilizer systems in the solution and the same elements adopted by maize. Pearson's correlations coefficient for $Ca^{2+}$is r = 0.99 (1a) and for is r = 0.96 (1b).

(iii) Analyzing of the soil samples and maize roots, ANOVA and the subsequent post-hoc Tukey's HSD test were evaluated for comparison of element concentration under different fertilization treatments (Table 1, 2). Statistically significant differences for quantity of elements were found in almost all samples. Standard scores (SS) for the evaluations of the content of different elements under different methods of fertilization have been calculated for the soil (Table 2.) and maize roots (Table 3.) samples. It can be seen from the results that different fertilization treatments strongly influence the final score result. Final score of control soil samples demonstrated generally better SS results. Best scores of maize roots have been obtained for samples of AZA2 (0.380) and AZAK1 (0.341) fertilization treatments.

With regard the mobility of metal, AZA2 and AZAK1 fertilizer , compared 5:1 (NH_4^+-zeolite:raw phosphate/concentrate) contributed to the increased adoption of nutritional elements Zn and Cu by plant, while contributes to the reduction of adoption Pb forming stable insoluble phosphate forms, also contributed to increased content of phosphorus in corn roots. Peter *et al.*, (2011) concluded that zeolite modified with ammonium can be used to reduce the uptake of heavy metal ions in the roots and leaves of Hieracium aurantium and Rumex acetosella. The increase of the pH, at the end of the experiments, in all the substrates investigated was explained by two reasons: the presence of humic acids generated during the degradation of the organic and of the pyrite materials, on one hand, and the rhizosphere effect, on the other hand. The rhizosphere effect consists in the local acidification of the environment due to the adsorption of the heavy metal ions on the cell walls by replacing the protons from -COOH, -OH, -SH, and -NH2 groups with heavy metal ions. The protons increase the acidity and, subsequently, lead to the decrease of the pH.

This paper presents the results of preliminary investigations contribution of pit cherries ash on the solubility of phosphate ore, thanks to H^+ present in the ash structure. Ashes pit cherries contributed less soluble phosphates and natural concentrates compared to AZA and AZAK as naturally fertilizer but higher than the control.

Table 3. The mean concentration of elements ±SD found in soil following different fertilization treatments

	Ca	Mg	Fe	Na	K	Cu	Pb	Cd	Zn	P	SS
Kontrola	3,4867±0,0153^{b}	0,8333±0,0153^{ab}	4,0867±0,0153^{d}	1,1067±0,0115^{b}	2,1133±0,0153^{d}	0,0039±0,0001^{e}	0,0031±0,0001^{a}	0,0003±0,0000^{a}	0,0082±0,0001^{c}	0,0096±0,0002^{e}	**0,986**
AZA1	3,5000±0,0600^{b}	0,8000±0,0100^{a}	3,8033±0,0153^{a}	1,0300±0,0100^{a}	1,8100±0,0100^{ab}	0,0032±0,0002^{bcd}	0,0030±0,0002^{a}	0,0003±0,0000^{a}	0,0076±0,0002^{a}	0,0041±0,0001^{a}	-0,251
AZA2	3,7500±0,0500^{c}	0,7967±0,0153^{a}	3,3833±0,0153^{f}	0,9900±0,0100^{a}	1,7800±0,0100^{ac}	0,0031±0,0001^{abc}	0,0029±0,0001^{a}	0,0005±0,0000^{a}	0,0073±0,0001^{ab}	0,0032±0,0003^{b}	-0,575
AZAK1	3,2667±0,0351^{a}	0,8033±0,0153^{a}	4,0000±0,0200^{c}	1,0267±0,0252^{a}	1,8400±0,0100^{b}	0,0030±0,0002^{ab}	0,0025±0,0001^{b}	0,0015±0,0020^{a}	0,0076±0,0001^{a}	0,0039±0,0002^{a}	-0,116
AZAK2	4,3333±0,1528^{e}	0,8800±0,0100^{c}	4,0300±0,0608^{cd}	1,0000±0,0173^{a}	1,7433±0,0375^{c}	0,0028±0,0001^{a}	0,0045±0,0001^{d}	0,0003±0,0000^{a}	0,0071±0,0001^{b}	0,0039±0,0001^{a}	0,150
PEP	3,2533±0,0153^{a}	0,8000±0,0200^{a}	3,8967±0,0153^{b}	0,9900±0,0100^{a}	1,8300±0,0100^{ab}	0,0035±0,0001^{de}	0,0030±0,0001^{a}	0,0002±0,0002^{a}	0,0074±0,0002^{ab}	0,0054±0,0001^{c}	-0,329
PEPK	3,2400±0,0200^{a}	0,8533±0,0153^{bc}	3,1867±0,0153^{e}	1,0367±0,0153^{a}	1,8167±0,0153^{ab}	0,0028±0,0003^{a}	0,0035±0,0002^{c}	0,0011±0,0014^{a}	0,0073±0,0002^{ab}	0,0081±0,0002^{d}	-0,128

$^{a\text{-}f}$ Different letter within the same row indicate significant differences $p<0.05$ level (according to post-hoc Tukey's HSD test)

Table 4. The mean concentration of elements ±SD found in maize roots following different fertilization treatments

	Ca	Mg	Fe	Na	K	Cu	Pb	Cd	Zn	P	SS
Kontrola	4,6600±0,0200^{bc}	0,8667±0,0208^{ab}	3,0367±0,0208^{ab}	0,0447±0,0029^{a}	0,8800±0,0100^{a}	0,0034±0,0002^{a}	0,0078±0,0002^{d}	0,0004±0,0000^{a}	0,0098±0,0001^{a}	0,2933±0,0153^{b}	-0,309
AZA1	4,4667±0,0289^{a}	0,8667±0,0115^{ab}	3,0600±0,0520^{a}	0,0447±0,0006^{a}	0,7600±0,0173^{a}	0,0063±0,0000^{d}	0,0049±0,0001^{ab}	0,0011±0,0014^{a}	0,0083±0,0003^{a}	0,5233±0,0321a	-0,121
AZA2	6,0100±0,0100^{e}	0,8633±0,0058^{ab}	3,0333±0,0577^{ab}	0,1593±0,2352^{a}	0,8300±0,0000^{a}	0,0049±0,0000^{bc}	0,0048±0,0000^{ab}	0,0014±0,0019^{a}	0,0110±0,0000^{a}	0,5560±0,0000^{ac}	**0,380**
AZAK1	5,6733±0,0231^{d}	0,8733±0,0231^{ab}	2,7933±0,0058^{bc}	0,0580±0,0035^{a}	0,9267±0,0058^{a}	0,0054±0,0001^{c}	0,0051±0,0002^{b}	0,0007±0,0000^{a}	0,1027±0,0023^{b}	0,6667±0,1155^{c}	**0,341**
AZAK2	4,5267±0,0643^{ab}	0,8700±0,0265^{ab}	3,0200±0,0265^{ab}	0,0500±0,0020^{a}	0,8267±0,0306^{a}	0,0065±0,0001^{d}	0,0045±0,0001^{a}	0,0006±0,0000^{a}	0,0095±0,0001^{a}	0,5933±0,0058^{ac}	-0,128
PEP	6,8067±0,1007^{f}	0,8233±0,0208^{a}	2,5967±0,1704^{c}	0,0560±0,0026^{a}	0,6767±0,5000^{a}	0,0045±0,0002^{b}	0,0075±0,0003^{d}	0,0007±0,0001^{a}	0,0087±0,0067^{a}	0,3200±0,0361^{b}	-0,416
PEPK	5,7400±0,0557^{d}	0,9167±0,0153^{bc}	3,2133±0,0808^{a}	0,0560±0,0040^{a}	0,7067±0,0306^{a}	0,0036±0,0004^{a}	0,0067±0,0002^{c}	0,0005±0,0000^{a}	0,0083±0,0064^{a}	0,3467±0,0153^{b}	-0,137

$^{a\text{-}f}$ Different letter within the same row indicate significant differences $p<0.05$ level (according to post-hoc Tukey's HSD test)

CONCLUSION

Our preliminary results of the optimization and verification process process parameters to obtain natural fertilizer based on natural phosphate and modified zeolite with ammonium ions, through the vegetation test in real and controlled conditions with maize plants indicate that it contributes to the increase of corn yield. Presence of NH^{4+-}zeolite in RP additionally facilitates release of P in soil which affects the increase in maize yield. Decrease in content of Ca^{2+} observed in the sample treated with fertilizer with at least of this element, was also expected. The contents of Ca^{2+} and P expressed through Pearson's coefficients in the solution and in maize indicate a direct connection between their content in the soil and the level of adoption by the plant.

Results indicate chemical immobilization heavy metals, so that $NH4^{+-}$zeolite/RP composite material has a multifunctional effect as an “eco friendly” natural fertilizer and as a soil amendment for in situ remediation of heavy metals.

ew cost-effective natural mineral fertilizers based on phosphate and zeolite with competitive characteristics compare with chemical fertilizers. Their implementation will improve soil fertility and safe food production. Utilisation of phosphorus mineral resource in Bosilegrad -“Lisina” creates economic revitalization and development of the chemical industry with competitive products at an international level.

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THE OPTIMISATION OF SUBSTRATA COMPOSITION FOR THE PRODUCTION OF MARIGOLD SEEDLINGS

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ABSTRACT

Since Serbia has significant resources of peat and mineral raw materials (zeolite and perlite), the application of which ensures not only economically but also ecologically justifiable production, this paper investigates the possibility of using domestic raw materials for the preparation of substrata suitable for growing one of the most common flower species in the country, Tagetes patula L. – marigold. We tested the influence of 14 variants of substrata, which were prepared using Tutin peat, perlite and zeoplant, on the development of marigold seedlings. The tests were conducted in the glasshouse of the Faculty of Agriculture in Belgrade during 2010. Marigold seedlings were produced by applying modern technologies of growing and using the seedling system and the pot system containers. It was determined that examined substrata, with their physical and agrochemical characteristics, exerted a favorable influence on the growing of marigold seedlings. The results of the research showed that the best development of marigold seedlings, examined using the root to shoot ratios, was recorded on substrata in which Tutin peat accounted for 60-80%, perlite 10-20% and zeoplant 10-20%. Using substrata of such a composition, the substitution of the imported substratum is made possible. Since domestic raw materials are used, the price of substrata and therefore the price of the final product would be lower.

Keywords: substratum, seedling, annual flowers, marigold, Tutin peat, perlite, zeoplant

INTRODUCTION

Rapid technological change in glasshouse production of flower seedlings calls for the standardization of the entire production process which includes not only all factors which affect the growth and development of flowers but also substrata used for their production. In contemporary production of flower seedlings, which entails the use of containers (the seedling system of growth), choosing the right substratum plays a very important role. The container size directly affects the characteristics of the chosen substratum and consequently the development of the root system of plant seedlings. Therefore, in order to produce high-quality seedlings it is imperative to familiarize oneself with physical and chemical properties of chosen substrata before initiating the production process. In today's market, it is easy to find substrata which are prepared on the basis of various components of organic and mineral origin. According to Tunis and McDonald (1979) and Landis *et al.* modern substrata which are mostly suitable for the container production of flower seedlings consist of peat, sand, perlite and vermiculite. As the price of peat rises worldwide (Frolking *et al.*, 2001; Schilstra, 2001), the need for new alternative materials which will be used in the production becomes essential (Abad et.al, 2001; Guerin et.al, 2001; Garcia-Gomez *et al.,* 2002; Adalberto, *et al.*, 2006). The results obtained by several independent researchers (Boyer *et al.,* 2007; Samadi, 2011) underline the importance of finding alternative substrata for the production of flowers in glasshouse production. For countries such as Serbia one of the ways, according to Stevanović *et al.*, (1994), Stevanović and Pavlović (1995), and Vujošević (2012) may be the use of domestic resources. The research encompasses domestic resources of peat (organic component in substrata) and mineral raw materials of zeolite and perlite (mineral component in substrata) which Serbia has in abundance. Their application may ensure not only a more economical production but also an ecologically justified use. Peat, due to specific weight, favorable water and air properties as well as slower mineralization after use, according to Đžamić and Stevanović (2000) has a priority in the preparation of substrata in the production of seedlings over other organic fertilizers (e.g. manure).

Zeolites as "the purest materials on Earth" belong to rock minerals which are composite alumosilicate minerals. Their structure is crystal, three-dimensional, hard and more such much more stable than the structure of clay minerals. In their natural geochemical composition, zeolites have some biogenic elements which plants may use directly as nutrients. Therefore, zeolites perform the function of a nutritious substratum and conditioner. In the report on the use of natural mineral raw materials in agriculture Dumić *et al.* (1995) state that it is necessary to familiarize oneself in detail with the possibilities of their processing, refining and the influence they exert on the environment of their application. The results obtained from several independent researchers (Minato, 1985; Mueller, 1985; Cicišvili *et al.*, (1984) on the use of zeolites have shown that they favorably influence germination, formation of strong root systems, intensify growth and shorten vegetation period. Similarly, it is proven that zeolite minerals reduce the content of heavy metals and radionuclide in final products (Stevanović *et al.*, 1994; Tomasević-Canović *et al.*, 1995; Dmitrov and Chakalov, 1995; Rybicka *et al.*, 1995) which makes their use not only economically but also ecologically justified. In the glasshouse production of seedlings, a particular kind of fertilizer – *Zeoplant* has a widespread use today; it is produced on the basis of natural zeolite and it is enriched with nutrients (nitrogen, phosphorus, potassium, calcium, and magnesium). The results of research have shown that the use of zeoplant in substrata for the production of tomatoes, in the amount of 15-25%, enhances the plant development (Glintić and Pavlović, 1994) and improves the quality of fruits (Damjanović *et al.*, 1994). The quality of substrata, as pointed out by Compton and Nelson (1996) is determined by their physical and chemical properties. As regards physical properties, porosity which affects water, air, and thermal properties of substrata is emphasized. On the other hand, as regards chemical properties, the same authors suggest that the emphasis is placed on pH value, the content of soluble salts (EC) and the quantity of accessible elements. For mending the water and air capacity of substrata, the materials of mineral origin including perlite are used most frequently according to Gunterher (1987). Perlite is a generic term for the alumosilicate material of volcanic origin; it is produced in Serbia and as an indispensible component in substrata it is easily accessible and cheap. This is a completely ecologically pure material, chemically inactive and pH neutral. On its surface it retains water which does not penetrate inside the particle thus increasing the air capacity of a substratum to which it is added.

Considering the resources of organo-mineral raw materials which Serbia has in abundance and which can be used for the preparation of substrata, the aim of this research was to test the justifiability of their use for the preparation of substrata suitable for growing one of the most commonly grown kinds of annual flowers, marigold.

MATERIALS AND METODS

The research on the optimization of the composition of substrata for the production of marigold seedlings by using domestic raw materials was done during 2010 in the glasshouse of the Faculty of Agriculture, University of Belgrade. We investigated substrata of different composition, prepared on the basis of domestic raw materials: Tutin peat (T), Perlite (P) and Zeoplant (Z). We tested the physical and agrochemical properties of substrata and monitored their impact on the development of seedlings of annual flowers *Tagetes patula L.- marigold,* series `*Bonanza*` yellow PanAmerican seed as the most frequently grown kind of annual flowers. The production of the initial seedling was done according to the *seedling system* in plastic containers of the HP QP 144/4,5P type in the ready-made seeding substratum *Floragard B-fine*. After the transplantation to plastic TEKU pots (pot system) of the VVC 9cm series, with a volume of 0.32l, the plants were grown on substrata of different compositions according to the following variants: 1.Control-imported substratum (Floragard Medium Coarse); 2. Control-Tutin peat 100%; 3. Tutin peat 90% with 10% zeoplant; 4. Tutin peat 80% with 20% zeoplant; 5. Tutin peat 70% with 30% zeoplant; 6. Tutin peat 90% with 10% perlite and without zeoplant; 7. Tutin peat 80% with 10% perlite and with 10% zeoplant; 8. Tutin peat 70% with 10% perlite and with 20% zeoplant; 9. Tutin peat 60% with 10% perlite and 30% zeoplant, 10. Tutin peat 50% with 10% perlite and 40% zeoplant; 11. Tutin peat 80% with 20% perlite and without zeoplant; 12. Tutin peat 70% with 20% perlite and with 10% zeoplant; 13. Tutin peat 60% with 20% perlite and 20% zeoplant; 14. Tutin peat 50% with 20% perlite and with 30% zeoplant. Substrata were made based on the volume ratio of components. For each variant we tested, we took 50 plants of the initial seedling for transplantation, while the selection was made randomly. The development of plant seedlings was tested at the end of the production cycle using the calculated dry root masses (g) to dry above-ground masses (g) ratio.

The laboratory tests of physical and agrochemical characteristics of substrata were performed before as well as after transplantation into pots. The tests were carried out in the Laboratories for Physics and Soil Agrochemistry at the Faculty of Agriculture, University of Belgrade. To determine the physical properties of tested substrata, we used internationally recognized methods which are also adopted by the ex-YU societies (Bošnjak, 1997): *density (volume) weight* – by Kopecky's cylinders of 100 cm^3, *specific weight* with xylol, Albert-Rogs method, maximum water capacity (%)–by Kopecky's cylinders, *water retention capacity* at 0.33 Mpa, at 15-bar pressure plate extractor–by computation and *prompt moisture*–by computation.

As regards the agrochemical properties, we analyzed: *pH reaction of substratum* – using potentiometric method; *salt content (EC)* – by measuring electrical conductivity of water extract of substratum – conductometric method (Jakovljević *et al.*1985); *organic carbon and humus* – the Tyurin dichromate method, Simakov's modification (Mineen, 2001); *total nitrogen* – semi-micro Kjeldahl method, Bremner's modification (1996); *accessible nitrogen* – the direct distillation method according to Bremner (1965); *accessible phosphorus and potassium* – Al method of Egner Riehm (1960); *the content of accessible Ca and Mg* – the extraction with 1M of ammonium acetate, AAS-Atomic Absorption Spectrophotometry (Pantović *et al.*, 1989); *the content of accessible microelements Fe, Mn, Cu and Zn*, using the AAS method from the DTPA solution (Jakovljević, 1985).

Considering the aim of the paper, we statistically tested the claim that the computed average values of the root to shoot ratios obtained by using substrata of different composition are mutually indistinguishable. Transforming the data we managed to achieve the homogeneity of values in all samples but not the homogeneity of sample variances according to the Levene's test. Even so, since the samples are of the same size, the importance of difference in average values of the ratio in the development of root and above-ground mass was tested using the parameter model of the analysis of variance (ANOVA) and the least significant difference test.

RESULTS AND DISSCUSION

All substrata we tested had good physical properties (Tab. 1). Specific mass of substrata changed as the share of organic matter in them changed. As the share of organic matter (peat) was higher, the values of specific mass were lower. Thus, the smallest value of specific mass of 1.39 g/cm^3 was determined in the substratum based on 100% of peat while the highest value of 2.11 g/cm^3 was found in the substratum in which the percentage of organic matter was the smallest, 50 % ($T_{50}+P_{20}+Z_{30}$). The volume weight of substrata indicates the suitability of using substrata for growing plants. It is always smaller than the specific mass value because of porosity. Certain values for volume weight in examined substrata ranged from 0.19 g/cm^3 (ready-made – commercial substratum) to 0.532 g/cm^3 in substratum 14 $T_{50}+P_{20}+Z_{30}$ (Tab. 1). As regards certain values for the overall porosity which was high in all examined substrata and ranged from 74.78 % to 87.01 % (Table 1) examined substrata can be considered as loose. Substrata in which organic matter (peat) was a dominant component compared to the share of mineral components had the highest values for porosity. Substratum 11, $T_{80}+P_{20}+Z_{0}$, had the highest porosity while substratum 14, $T_{50}+P_{20}+Z_{30}$ had the smallest porosity. Since the values of maximum water capacity directly depends on porosity, those substrata which had the highest and smallest values for porosity (substrata 11 and 14) could take in the highest (4.52 %) and the smallest (1.43%) amount of water. The values of retention capacity of substrata were high and ranged between 64.02 % and 235.29 % (Tab. 1). The highest values were found in substrata in which the percentage of organic matter, peat, ranged between 80-100 % (variants 2, 3, 4, 6 and 7) and in substrata in which perlite accounted for 20 % (variants 11, 12, and 13). All examined substrata in which perlite accounted for 20 % (variants 11, 12, 13, and 14) had higher values of retention capacity compared to other substrata in which perlite accounted for 10 % irrespective of the percentage of organic matter in them. This is understandable considering the perlite's ability to absorb and retain water through its surface, hence the more perlite the more water in substrata.

As to examined substrata, the difference in terms of agrochemical characteristics was set, it reflected the development of seedlings Tagetes patule L.-*Bonanza yellow* (Tab. 2). Many researchers (Bailey *et al.*, 1995; Harbaugh, 1994; Compton and Nelson, 1996) indicate the importance of continuous monitoring and maintenance of the most relevant agrochemical properties of substrata in contemporary (container) production of seedlings: pH, the content of soluble salts (EC), and the quantity of accessible elements.

At the beginning of the experiment, pH values of examined substrata were in the category from acidic to weakly acidic (Tab. 2). Due to the young plants' ability to affect the change in pH of substratum by increasing or decreasing it, certain pH value of substratum after the research showed that plant seedlings of *Tagetes* have the ability to increase pH value, therefore setting the optimal value for growing it 5.01-7.19 (Tab. 2), which is in accordance with the research of Bailey *et al.* (1995).

Table 1. Physical properties of tested substrata

Substrata	Maximum Water capacity (%)	Retention capacity (%)	Volume weight (g/cm)	Specific mass (g/cm^3)	Porosity (%)	Prompt moisture
1. Ready-made substratum	4.26	153.4	0.199	1.52	86.90	1.615
2. Peat 100%	3.67	221.24	0.219	1.39	84.89	2.70
3. $T_{90}+Z_{10}$	2.29	117.42	0.375	1.82	79.39	1.18
4. $T_{80}+Z_{20}$	1.93	105.9	0.431	1.89	77.19	1.06
5. $T_{70}+Z_{30}$	1.71	85.00	0.467	1.9	75.42	0.83
6. $T_{90}+P_{10}+Z_0$	3.41	177.14	0.252	1.46	82.73	1.73
7. $T_{80}+P_{10}+Z_{10}$	2.37	115.43	0.361	1.72	79.01	1.12
8. $T_{70}+P_{10}+Z_{20}$	1.96	93.66	0.416	1.86	77.63	0.89
9. $T_{60}+P_{10}+Z_{30}$	1.91	91.15	0.433	2.11	79.47	0.91
10.$T_{50}+P_{10}+Z_{40}$	1.53	67.28	0.487	2.0	75.65	0.67
11.$T_{80}+P_{20}+Z_0$	4.52	235.29	0.200	1.54	87.01	2.49
12.$T_{70}+P_{20}+Z_{10}$	2.43	120.55	0.356	1.84	80.65	1.14
13.$T_{60}+P_{20}+Z_{20}$	2.56	125.87	0.33	1.91	82.72	1.21
14.$T_{50}+P_{20}+Z_{30}$	1.43	64.02	0.532	2.11	74.78	0.59

Even though the initial content of the total nitrogen in all examined substrata was high and ranged between 0.769 % and 2.28 % (Table 2), its content increased at the end of vegetation which is in accordance with the results of Pavlovic and Stevanovic (1995) indicating low fertilizing ability of peat in the first part of vegetation due to small mineralization capacity and wider C/N ratio.

Table 2 The main agrochemical properties of tested substrata at the start and at the end of research

Ordinal No of variant	Substrata	pH (H_2O)		Humus (%)		Total N (%)		C/N		EC_{25} (mS/cm)	
		before	after	before	after	before	after	before	after	before	after
1.	Ready-made substratum	5.13	6.35	68.47	68.96	0.798	9.366	49.7:1	4.3	1.479	0.132
2.	Peat 100%	6.02	7.19	48.06	52.20	1.628	16.688	17.1:1	1.8	0.192	0.331
3.	$T_{90}+Z_{10}$	4.74	6.87	34.72	34.89	1.19	11.172	16.9:1	1.8	0.923	0.275
4.	$T_{80}+Z_{20}$	4.85	5.88	24.67	21.60	0.935	7.161	15.3:1	1.7	0.948	0.591
5.	$T_{70}+Z_{30}$	4.81	5.35	27.53	7.91	1.022	6.545	15.6:1	0.7	0.968	0.529
6.	$T_{90}+P_{10}+Z_0$	5.35	7.10	63.77	47.96	2.289	15.323	16.1:1	1.8	0.175	0.174
7.	$T_{80}+P_{10}+Z_{10}$	4.88	6.17	36.13	21.13	1.202	6.86	17.2:1	1.8	0.830	0.241
8.	$T_{70}+P_{10}+Z_{20}$	4.99	5.28	26.75	15.67	1.019	5.929	15.2:1	1.5	0.918	0.311
9.	$T_{60}+P_{10}+Z_{30}$	4.96	5.01	20.98	17.02	0.864	5.859	14.1:1	1.7	0.953	0.562
10.	$T_{50}+P_{10}+Z_{40}$	4.97	5.03	16.18	16.09	0.804	4.795	11.6:1	1.9	0.900	0.612
11.	$T_{80}+P_{20}+Z_0$	5.38	6.79	59.80	45.13	1.648	14.763	21.0:1	1.8	0.182	0.181
12.	$T_{70}+P_{20}+Z_{10}$	4.78	6.16	37.548	24.05	1.170	7.917	18.6:1	1.8	0.815	0.263
13.	$T_{60}+P_{20}+Z_{20}$	5.13	6.08	21.33	19.88	0.842	6.923	14.7:1	1.7	0.993	0.178
14.	$T_{50}+P_{20}+Z_{30}$	5.07	5.10	14.40	12.19	0.762	4.536	10.9:1	1.6	0.940	0.341

The content of humus in examined substrata decreased as the percentage of peat (Tab. 2) declined. The highest percentage of humus was found in the ready-made commercial substratum (68.47%) and then in the examined substratum with 90% peat (63.77%). The lowest percentage of humus was determined in the examined substratum with the smallest share of peat, variant 14 and it was 14.4 %. Based on the C/N ratio in the examined substrata with Tutin peat, perlite, and zeoplant (from 10.9:1 to 21:1), examined substrata had a favorable C/N ratio with respect to mineralization compared to the ready-made commercial substratum (49.7:1)

The content of soluble salts (EC) in all examined substrata from variant 2 to variant 14 both before and after the research was within optimal limits, smaller than 1mS/cm (Tab. 2) which is in accordance with the recommendation of Harbaugh, (1994); Elfeky *et al.*, (2007). The initial content of soluble salts in the ready-made commercial substratum was the highest (1.479 mS/cm).

The differences in the content of easily accessible, macro and micro elements (Tab. 3 and 4) in examined substrata were determined. The most deficient substratum in terms of the content of easily accessible macro nutrients was pure peat followed by substrata which had mostly peat without the mineral component – zeoplant (Tab. 3). The naturally small content of easily accessible nutrients in peat and small fertilization capacity, especially in the first part of vegetation, are indicated by Hanić (1984), and Stevanović and Pavlović (1995) in their research. The content of easily accessible forms of nitrogen, phosphorus, and potassium in examined substrata increased with the application of zeoplant which is in accordance with the research results of Minato (1985); Pavlović (1997) who found that zeolite-zeoplant have a positive effect in substrata as regards nutrients. The initial content of easily accessible forms of nitrogen in examined substrata was smaller in those substrata in which there was no zeoplant (2, 6, and 11) and higher in substrata with additional 30 volume percent of zeoplant (5, 9. and14) and it ranged between 3445.6 mg/kg and 3606.4 mg/kg (Table 3). Upon the completion of vegetation, significantly smaller content of nitrogen was determined (Table 3), especially NH_4-N which shows that optimal conditions were created during the production process of seedlings, especially the temperature of substratum which agreed with its transformation to NO_3-N. Similarly, the initial C/N ratio in examined substrata (Tab. 2) favored the mineralization of nitrogen. The content of easily accessible phosphorus and potassium was also the smallest in substrata without the prepared zeoplant (Table 3).

The small content of these necessary macroelements was compensated for by the use of zeoplant. The highest content (885mg/kg P_2O_5 and 300mg/kg K_2O) was reached by using 30 % zeoplant for phosphorus and 40 % zeoplant for potassium (Table 3). Reaching the maximum content of easily accessible potassium by using the highest dose of zeoplant is in accordance with the data presented by Hanić (1990) and Pavlović (1997) in which they underline the fact that peat is very scarce in this macronutrient and that the application of zeoplant leads to the increase of its content.

As regards the balanced nutrition, it is necessary to establish a good potassium (Ca^{2+}) to magnesium (Mg^{2+}) ratio in substrata. A well balanced ratio of these elements affects the acceptance of necessary microelements. Therefore, in examined substrata in which zeoplant accounted for 20 volume percent, an optimal ratio of these two tested indispensible macronutrients was established, 2:1 (Tab.3).

In the beginning, the smaller content of easily accessible microelements (manganese-Mn, zinc-Zn, and copper-Cu) in examined substrata was increased by applying zeoplant (Table 4). The content of accessible iron, which was dependent on the amount of organic matter as indicated by Stevanović (2000), decreased in examined substrata in which the share of organic component (peat) was smaller and mineral component (zeoplant) higher. As the percentage of mineral component was higher the content of accessible iron in examined substrata was smaller. Iron was mostly taken in from substrata in which Tutin peat accounted for 80-100 %. This speaks of not only greater demands of marigold for iron but also of favorable conditions for taking it in: favorable water and air properties of substrata, optimal pH, and low content of phosphorus in substrata with predominantly organic matter.

Table 3 The content of accessible macroelements in tested substrata at the start and at the end of research

No.	Substrata	Accessible N (mg/kg)						Easily accessible (mg/100g)				Ratio cmol/kg	
		NH_4^+		NO_3^-		NH_4+NO_3		P_2O_5		K_2O		Ca/Mg	
		bef.	after	Bef.	after	bef.	after	bef.	after	bef.	after	bef.	after
1.	Ready-made substratum	74.9	8.4	1554	2.8	1628.9	11.2	280	4.8	183	2.9	9. 2:1	4.8
2.	Peat 100%	140	1.4	164.5	40.6	304.5	42	3.5	1.4	10	3.2	4.2:1	4.6
3.	T_{90}+Z_{10}	2692.9	9.8	143.5	64.4	2836.4	74.2	585	20.2	300	90	1.7:1	4.0
4.	T_{80}+Z_{20}	2661.4	32.2	427	205.8	3088.4	238	765	268	282	288	2.0:1	4.2
5.	T_{70}+Z_{30}	3238.9	39.2	206.5	249.2	3445.4	288.4	785	236	366	152	2.5:1	4.2
6.	T_{90}+P_{10}+Z_0	41.3	11.2	206.5	36.4	247.8	47.6	9.1	2.3	10.4	3.2	1.1:1	5.0
7.	T_{80}+P_{10}+Z_{10}	1177.4	28	165.9	70	1343.3	98	475	97	200	72	1.5:1	3.4
8.	T_{70}+P_{10}+Z_{20}	3095.4	60.2	101.5	149.8	3196.9	210	720	136	282	67	1.8:1	4.1
9.	T_{60}+P_{10}+Z_{30}	3392.9	130.2	213.5	211.4	3606.4	341.6	695	197	234	152	2.3:1	3.9
10.	T_{50}+P_{10}+Z_{40}	3336.9	737.8	76.3	225.4	3413.2	963.2	825	288	300	276	2.6:1	4.0
11.	T_{80}+P_{20}+Z_0	46.9	11.2	196	22.4	242.9	33.6	9.5	2.6	13.3	2.5	0.8:1	3.4
12.	T_{70}+P_{20}+Z_{10}	1947.4	46.2	413	82.6	2306.4	128.8	540	278	200	158	1.4:1	3.1
13.	T_{60}+P_{20}+Z_{20}	3112.9	32.2	315	56	3427.9	88.2	765	166	274	74	2.1:1	4.2
14.	T_{50}+P_{20}+Z_{30}	3476.9	161	98	113.4	3574.9	274.4	885	194	282	186	2.6:1	4.0

The use of zeoplant in the amount of 20 to 30 volume percent resulted in an increase in the accessible manganese and copper in examined substrata compared to the small content in the beginning but even though it was increased, its content remained at the level of low supply. The content of accessible zinc in examined substrata from the initial small values reached the values of mean supply (Tab. 4).

The results on the development of produced seedlings of marigold, seen through the calculated dry root mass to dry above-ground mass ratio (Tab. 5) indicate that it is justifiable to introduce domestic raw materials (T, P and Z) into the preparation of substrata for growing it.

It can be noted that in all examined substrata without the added zeoplant (variants 2, 6, and 11) the seedlings of marigold had the most unfavorable ratio in the development of root and above-ground mass. As physical characteristics of substrata were improved by using the smallest tested dose of perlite (10 %), there was a better ratio in the development of root and above-ground mass of marigold seedlings compared to substrata in which perlite was not used (variants 2, 3, 4, and 5). In all examined substrata with improved nutritious composition by using zeoplant in the amount of 10 and 20 % (variants 7, 8, 13, and 14) the achieved ratio ranged from 1:5.6 to 1:6.2 which is in accordance with the results of Harris (1992) who emphasizes that a more optimal ratio in the development of root and above-ground mass can range from 1:5 to 1:6 in favor of the above-ground mass. Similarly, the results indicate that the use of zeoplant in substrata of 10 or 20 % exerted influence on the ratio in the development of root and above-ground mass which almost became equal to the ratio which was achieved when plants were grown on the standardized, ready-made commercial substratum, 1:5.5 (variant 1). The widest ratio examined 1:10 was achieved in variant 5 (T_{70}+Z_{30}), and the narrowest in variant 2 (T_{100}) 1:3.6.

Table 4 The content of accessible microelements in tested substrata (mg/kg) at the start and at the end of research

Ordinal No of variant	Substrata	Fe		Mn		Cu		Zn	
		Before	After	Before	After	Before	After	Before	After
1.	Ready-made substratum	15.69	7.04	7.96	3.92	1.20	0.90	3.30	12.75
2.	Peat 100%	267.12	146.98	1.37	0.87	0.48	0.89	0.10	1.44
3.	$T_{90}+Z_{10}$	200.75	163.34	2.40	1.46	0.56	0.98	0.59	2.68
4.	$T_{80}+Z_{20}$	183.59	181.44	1.99	4.20	0.46	1.10	0.63	2.51
5.	$T_{70}+Z_{30}$	189.19	173.20	1.89	9.04	0.43	1.26	0.08	2.71
6.	$T_{90}+P_{10}+Z_{0}$	294.38	125.28	1.53	0.70	0.44	0.83	0.49	1.20
7.	$T_{80}+P_{10}+Z_{10}$	198.97	219.80	1.90	2.44	0.47	1.18	0.63	2.57
8.	$T_{70}+P_{10}+Z_{20}$	172.09	189.24	2.14	6.90	0.48	1.27	0.69	2.46
9.	$T_{60}+P_{10}+Z_{30}$	140.33	210.96	2.20	11.25	0.37	1.53	0.69	3.21
10.	$T_{50}+P_{10}+Z_{40}$	135.92	162.43	2.02	13.77	0.35	1.51	0.10	2.58
11.	$T_{80}+P_{20}+Z_{0}$	262.48	136.47	1.54	0.99	0.46	0.83	0.50	1.55
12.	$T_{70}+P_{20}+Z_{10}$	193.88	172.91	2.09	1.90	0.48	1.11	0.70	8.92
13.	$T_{60}+P_{20}+Z_{20}$	144.98	155.71	2.14	2.28	0.40	1.45	0.64	28.27
14.	$T_{50}+P_{20}+Z_{30}$	134.66	169.38	1.95	8.68	0.36	1.06	0.58	1.81

Table 5 The root to shoot ratios

Ordinal No of variant	Variants	Root-shoot ratios	Ordinal No of variant	Variants	Root-shoot ratios
1.	Ready-made sub.	1:5.5	8.	$Т_{70}$+$П_{10}$+$З_{20}$	1:5.6
2.	Т $_{100}$	1:3.6	9.	$Т_{60}$+$П_{10}$+$З_{30}$	1:7.0
3.	$Т_{90}$+$З_{10}$	1:7.5	10.	$Т_{50}$+$П_{10}$+$З_{40}$	1:5.8
4.	$Т_{80}$+$З_{20}$	1:7.6	11.	$Т_{80}$+$П_{20}$+$З_{0}$	1:3.9
5.	$Т_{70}$+$З_{30}$	1:10	12.	$Т_{70}$+$П_{20}$+$З_{10}$	1:6.6
6.	$Т_{90}$+$П_{10}$+$З_{0}$	1:3.9	13.	$Т_{60}$+$П_{20}$+$З_{20}$	1:6.1
7.	$Т_{80}$+$П_{10}$+$З_{10}$	1:6.2	14.	$Т_{50}$+$П_{20}$+$З_{30}$	1:5.8

Transforming the data by using the relation $\sqrt{\log\frac{1}{x}}$ the homogeneity of values in all samples was achieved but not the homogeneity of their variances (the result of the Leven's test: (F=4.742; p<0.001)). Since samples are of the same size, the significant difference of their average values was tested using the parameter model of the analysis of variance. According to the result of this test (F= 25.942; p<0.001) by using the tested variants of substrata, the plant groups which were obtained are considerably different with respect to the obtained dry root to above-ground mass ratio. The least significant difference test was used to investigate the significant differences of the obtained mean dry root to above-ground mass ratio between two groups of plants (Tab. 6).

The results of the LSD test (Tab. 6) confirm that by growing the seedlings of *Tegetes* on substrata lacking in nutrients (variants 2, 6 and 11) the dry root to above-ground mass ratio which is not statistically that different was achieved but it becomes narrow with respect to the dry root to above-ground ratio which was achieved on all other tested substrata.

Improving the nutritional regime by adding zeoplant of 10 to 30 volume percent (variants 3, 4 and 5) the dry root to dry above-ground mass ratio increased in favor of the above-ground mass. When there is 30 % of zeoplant in substratum, the observed ratio is statistically so much higher than the ratio when smaller doses were used (10 %). This is understandable since more nutrition accounts for feebler root development and better development of the above-ground mass.

With respect to the ready-made substratum, the dry root to above-ground ratio in tested variants 3, 4, and 5 is statistically significantly higher. Therefore, the use of zeoplant can be said to have improved the nutritional regime of substrata which primarily resulted in the growth of the above-ground mass leading to the widening of the observed ratio.

Improving the physical properties of examined substrata by adding perlite in the amount of 10 % (variants 6, 7, 8, 9, and 10) with the use of zeoplant, a more favorable root development to above-ground mass ratio was found (Table 5). This ratio ranged from 1:3.8 to 1:7. The results of the LSD test (Tab. 6) show that the most favorable ratio was achieved in the variants with 20 % of zeoplant (T_{70}+P_{10}+Z_{20}). The ratio (1:5.6) was statistically significantly narrower than the 1:7.6 ratio in variant 4, T_{80}+Z_{20}, with also 20 % of zeoplant but without perlite. This not only confirms the importance of nutritional regime of substrata for the development of seedlings but also the importance of its physical properties. A further increase in the use of zeoplant, of 40 % (variant 10) resulted in a decrease of the examined ratio but it was not statistically significantly different from the ratio found on substrata with a smaller share of zeoplant (variants 7 and 8).

Increasing the share of perlite in substrata to 20 % led to a more favorable ratio than the one in examined variants with no perlite (variants 3, 4 and 5). This decrease in the ratio was not statistically significant between variants 13 and 14 (T_{60}+P_{20}+Z_{20}; T_{50}+P_{20}+Z_{30}) and variants 4 and 5 (T_{80}+Z_{20}; T_{70}+Z_{30}) while it was statistically significant with respect to variant 3, T_{90}+Z_{10}. This further confirms the importance of physical properties of substrata in the development, especially as regards the root of marigold seedlings.

Table 6 The level and significant differences of the root to shoot ratio of *Tagetes patula`bonanza`* seedlings based on the LSD test

Variants	2. T_{100}	3. T_{90}+Z_{10}	4. T_{80}+Z_{20}	5. T_{70}+Z_{30}	6. T_{90}+ P_{10}+Z_0	7. T_{80}+ P_{10}+Z_{10}	8. T_{70}+ P_{10}+Z_{20}	9. T_{60}+ P_{10}+Z_{30}	10. T_{50}+ P_{10}+Z_{40}	11. T_{80}+ P_{20}+Z_0	12. T_{70}+ P_{20}+Z_{10}	13. T_{60}+ P_{20}+Z_{20}	14. T_{50}+ P_{20}+Z_{30}
1. Ready-made substratum	<0.001	<0.001	<0.001	<0.001	<0.001	0.026	0.669	<0.001	0.109	<0.001	0.001	0.116	0.252
2. T_{100}		<0.001	<0.001	<0.001	0.845	<0.001	<0.001	<0.001	<0.001	0.212	<0.001	<0.001	<0.001
3. T_{90}+Z_{10}			0.228	0.001	<0.001	0.175	0.002	0.566	0.048	<0.001	0.703	0.045	0.015
4. T_{80}+Z_{20}				0.031	<0.001	0.011	<0.001	0.528	0.002	<0.001	0.113	0.001	<0.001
5. T_{70}+Z_{30}					<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001	<0.001
6. T_{90}+P_{10}+Z_0						<0.001	<0.001	<0.001	<0.001	0.293	<0.001	<0.001	<0.001
7. T_{80}+P_{10}+Z_{10}							0.072	0.054	0.535	<0.001	0.329	0.515	0.280
8. T_{70}+P_{10}+Z_{20}								<0.001	0.239	<0.001	0.006	0.251	0.473
9. T_{60}+P_{10}+Z_{30}									0.011	<0.001	0.339	0.0101	0.003
10. T_{50}+P_{10}+Z_{40}										<0.001	0.111	0.975	0.645
11. T_{80}+P_{20}+Z_0											<0.001	<0.001	<0.001
12. T_{70}+P_{20}+Z_{10}												0.104	0.040
13. T_{60}+P_{20}+Z_{20}													0.667

CONCLUSION

Based on the results of research into the possibilities of using domestic raw materials in the optimization of substratum composition for the production of marigold seedlings (*Tagetes patula* L.) the following conclusions can be made:

Examined substrata prepared on the basis of domestic raw materials (Tutin peat, zeoplant and perlite) with their physical and agrochemical properties were suitable for growing marigold seedlings, *Tagetes patula-„Bonanza“-yellow.*

The overall porosity of tested substrata as the most important physical property of substrata ranged from 74.75 % to 87.01 % and it indicated that we are dealing with loose substrata. Substrata in which Tutin peat dominated and in which the share of perlite was 20 % had the highest values for porosity.

A certain pH value of examined substrata, from 5.01-7.19 was suitable for growing marigold seedlings.

The content of water-soluble salts in all examined substrata variants on the basis of domestic raw materials was optimal, smaller than 1mS/cm.

The most favorable calcium to magnesium ratio was achieved in all examined substrata in which the share of zeoplant was 20 %.

The content of accessible nutrients in examined substrata was increased with the use of zeoplant. The highest content of accessible nitrogen, phosphorus and potassium was determined in substrata in which the share of zeoplant was 30 %.

As regards accessible microelements, initially small content of manganese, zinc and copper was increased with the use of zeoplant in the amount of 20-30 %. The amount of accessible iron in substrata decreased as the share of zeoplant increased to 20-40 % at the expense of reducing the organic component (Tutin peat).

The best development of marigold seedlings on the basis of the calculated dry root mass to dry above-ground mass ratio was recorded on substrata in which the organic component (Tutin peat) varied from 60-80 %, the share of perlite ranged from 10-20 %, and the share of zeoplant from 10-20 %.

Using substrata of these compositions for growing marigold makes the substitution of the imported substratum possible. The use of these substrata produces the seedlings of good quality. The price of substratum and therefore the price of the final product are lower.

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INFLUENCE OF LONG-TERM APPLICATION OF FERTILIZERS AND AMELIORATIVE MEASURES ON SOIL PROPERTIES AND GRAIN YIELD

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ABSTRACT

The influence of long-term fertilization and liming, on the changes of agro-chemical properties of acid soils and yields of grain of three winter wheat cultivars has been studied. The trials have been conduced on acid Pseudogley soil, during multy-year period, including control and two fertilization variants (N_{120}, P_{100}, K_{80}; N_{120}, P_{100}, K_{80} + 4000 kg ha^{-1} $CaCO_3$ + 30000 kg ha^{-1} stable manure). Long-term treatment by fertilizers and pedo-ameliorative measures, shows a significant effect on the changes of agro-chemical properties, especially in very acidic pseudogley, which is poor in buffering, with unfavorable and unstable chemical properties. The most significant changes in agrochemical soil properties considered: soil pH, soil adsorption complex composition and content of biogenous elements (P, K, Ca, Fe and Mn), as well as the content of toxic amounts of Al. Long-term periodical usage of chemical ameliorative substances (limestone and manure) thogether with the regular fertilizers has significantly reduced soil acidity (pH from 0.83 to 1.38); the amount of adsorbed base cations has increased for 3.7 $cmol^{+}$ kg^{-1}; V% for 22.89% and enhanced composition of adsorption complex. It has also given an average increased content of most nutrients (available phosphorus up to 9.4 mg 100 g^{-1}, 6.3 mg 100 g^{-1}, calcium from 85 to 105 mg 100 g^{-1}), and the mobility of iron has been reduced for about 24%, manganese for over 100%, zinc for 41 % and particularly aluminum which content has been reduced from 13.61 to 0.14 mg 100 g^{-1}). As a result of improving of soil fertility the average yield of winter wheat has been tripled.

Keywords: Ameliorative, fertilizer, pseudogley, soil, yield, winter wheat

INTRODUCTION

Pseudogley covers significant areas of Serbia, and considered about 285,000 ha, or 78.73% of the total land area in Western Serbia (Tanasijević *et al.*, 1966). These soils are formed in moderately humid, to humid climates, and they have disturbed water and air relationships characterised by an occasional decrease in very moist i.e. wet and dry phases. Therefore, this soil type is unfavourable for the cultivation of most plants. The unfavourable soil moisture regime is due to the compact underlying Btg horizon, which is poorly permeable or impermeable. Under dry conditions, the soil surface horizon undergoes intense desiccation, whereas the deeper impermeable horizon hardens. During the wet phase, reduction conditions occur in the soil, resulting in the reduction of different elements, primarily iron (Fe^{3+} to Fe^{2+}), manganese, etc. Since the wet phase is short, only more susceptible substances undergo reduction. During the dry phase, oxygen enters the soil, and oxidises the substances that were reduced during the wet phase (Fe^{2+} to Fe^{3+}).

Pseudogleys are rather poor in alkalis, having medium to strongly acid in reaction. They have a highly unfavourable soil-structure, and a low content of organic matter. The acid reaction of the pseudogley, its low humus content, and a low supply with available phosphorus and potassium are limiting factors for higher crop yields (Dugalic *et al.*, 2005).

According to citations of Babovic (1964) pseudogley soil of Kosovo and Metohia has very high substitution acidity, caused not only by hydrogen ions, but also by aluminium ions. According to this author, over then 90% of substitution acidity is caused by Al ions. Also, according to other authors as well, the major problem with soil pH in H_2O (<5.0), is an Al ion toxicity (Foy, 1984; Sumner, 2004; Welcker *et al.*, 2005). The high content of mobile aluminium in pseudogley soils cited in their papers: Jakovljevic *et al.* (1990), Carver and Ownby (1995), Jelic *et al.* (2004). It has been determined that the easily mobile Al ions content in the soil from 6 to 10 mg 100 g^{-1}, have unfavourable impact on the majority of field plants as a consequence of not only the immobilization of phosphate ions in the soil and their poor availability to the plants, but and "deterioration of the root system development", then deterioration of metabolism of "carbohydrates, nitrogen and phosphorus in plants" (Arsenijevic-Maksimovic *et al.*, 2001).

The effect of long-term fertilization and liming on crop yield and quality has been observed in many studies and trials; however, which show differences in the intensity of the effect. Crop yield and quality are also significantly affected by soil conditions, climatic factors and weather conditions in a given year (Fageria and Balligar, 2008; Rastija *et al.*, 2010; Jelic *et al.*, 2012).

The objective of our research was to study the most important chemical properties of the cultivated pseudogley soil, in the determined genetic horizons, as well as the impact of application of lime, manure and mineral NPK fertilizers, on the increase of productive capacity of this soil, by testing different varieties of winter wheat.

MATERIALS AND METHODS

The experiment was established in 1995 at the Agricultural Chemical- high school "Dr. Djordje Radic" in Kraljevo. The studied soil is extremely acid pseudogley. For the experiment, two-field crop rotation of wheat-corn was applied.

The experiment was established as randomized block system in three replications on the plots of 100 m^2. The amounts of pure nutrients that have been applied in the wheat were: 120 kg N ha^{-1} and 100 kg ha^{-1} P_2O_5 and 80 kg K_2O ha^{-1}, which have been used in the form of complex NPK fertilizer (8:24:16) , superphosphate (17% P_2O_5) and ammonium nitrate (AN = 17% N).

For maize the same concentrations of P and K were applied, while N was applied in higher dosage of 150 kg N ha^{-1}.

In the experiment a lime fertilizer "Njival Ca" (product of Paracin glass factory) was applied at a rate of 4.0 t ha^{-1}.

In wheat total quantity of lime, phosphorus and potassium fertilizers along with 1/3 of nitrogen were used in the preparation of soil, while the remaining quantity of nitrogen applied in one plant feeding in early spring. In maize entire quantity of nutrients has been applied after soil preparation. Lime fertilizer has been used periodically every five years (1995, 2000, 2005 and 2010). Quantity of the applied well matured manure was 30 t ha^{-1}. Other measures of care that have been carried out during the growing season of winter wheat and maize have been standard.

Three winter wheat cultivars (Pobeda, Planeta and Nora) have been evaluated. The crop has been harvested at full maturity. Grain yield (kg ha^{-1}) has been harvested and reported at 14% moisture.

At the site of stationary field trial, soil profiles have been opened and soil samples have been taken for analysis; of the: unfertilized control-area (1), NPK (2) and NPK + CaCO3 + manure (3) variants of fertilizing. Samples have been taken after wheat harvest in late July 2012, from humic horizon (Ah = 0-15 cm), subhumic eluvial-pseudogley horizon (Eg=15-40 cm) and of a transitional B1tg horizon (60-80 cm).

Soil analyzes have been performed by standard chemical methods, as follows: pH in H2O and KCl, electrometrically with a glass electrode in a 1:2.5 suspension; content humus by Kotzmann's method-in; sum of adsorbed base cations by Kappen's method; hydrolytic acidity, Ca-acetate Kappen's method; degree of saturation of soil-adsorbed exchangeable cations has been calculated by Hissink; total nitrogen has been determined by the Kjeldahl's method, available phosphorus and potassium by Egner-Riehm's Al method, mobile Al by colorimeter with aluminum acetate buffer, while the content of available forms of heavy metals have been determined by AAS in 0.1 HCl soil extract.

The results of the analysis are given in average values and statistically analyzed using analysis of variance (Mead *et al.*, 1996).

RESULTS AND DISCUSSION

Agrochemical properties of the treated pseudogley are very unfavorable (Tab. 1). The treated soil is highly acid, which in the surface topsoil horizon (0-20 cm) has a relatively low active acidity (pH in H_2O 5,24), while the deepest layers of the soil there was a significant decrease in acidity (pH in H_2O 6,04). Exchangeable acidity (pH in KCl) of this type of soil throughout the profile ranges from 4,48 to 4,80. The value of hydrolytic acidity (Y1) in the topsoil horizon (0-20 cm) was relatively high (15,47 ccm), while in the deeper layers of the hydrolytic acidity significantly reduced (7,35). The examined soil is characterized by very unfavorable composition of the adsorptive complex (Tab. 1). The values of adsorption capacity, sum of adsorbed base cations, as well as the degree of saturation adsorptive complex with bases, are very low.

Table 1. Agrochemical properties of Pseudogley

Depth (cm)	Humus (%)	Y^1 (ccm)	N (%)	T	S	-S	pH		P_2O_5	K_2O
				(cmol$^+$ kg^{-1})			H_2O	KCl	(mg 100 g^{-1})	
0-20	2.18	15.47	0.14	16.71	8.08	8.63	5.24	4.48	8.0	13.8
20-40	1.84	13.98	0.13	16.69	9.79	6.90	5.55	4.58	7.0	13.6
40-60	0.66	12.45	0.09	26.24	20.02	6.22	5.46	4.42	1.3	8.5
60-80	0.71	9.97	0.07	26.29	21.31	4.98	5.64	4.52	1.0	7.6
80-100	0.63	7.35	0.02	25.62	22.02	3.60	6.04	4.80	0.8	4.3

Also it is low (2.18%) humus content in the surface layer (0-20 cm) and significantly decreases with increasing of depth. Reduced humus content in cultivated pseudogley soil profiles, points out the need for a projection of fertilizing system and application of pedomeliorative measures, in order to preserve and enrich the adsorptive complex, it is a must to apply ameliorative measure of humification. Analyzed pseudogley profile shows median coverage with total nitrogen in the humus-accumulative horizon. Total nitrogen in the topsoil is represented with an average value of 0.14% and significantly decreases with increasing depth (0.02%). Supply with available phosphorus in this soil type is poor 7.0-8.0 mg 100 g-1 of soil, in the soil layer from 0 to 40 cm. When it comes to the content of easily available potassium the treated soil is well supplied, and it belongs to an average supplied soil class (13.8 mg 100 g-1).

The control variant had a very low pH (KCl) value of the soil, which ranged between 3.94 (Ah) up to 4,58 (B1tg) (Tab. 2). Perennial application of mineral fertilizers has only partially increased the soil pH for maximum 0,34 pH units. However, the combined application of lime, manure and mineral NPK fertilizers resulted in a significant decrease of soil acidity. Compared to the control ($pH_{(H2O)}$) in the Ah horizon soil pH increased by 0.86 pH, and by 0.83 pH in B1tg horizon. Also, liming reduced the acidity of the soil pH units for 1,38 $pH_{(KCl)}$ units in (Ah) and 1,26 pH units (Eg) compared to the control.

The content of humus in the control, in Ah horizon was low (2.19%) and with the increase of profiles depth decreased up to 0.66% in B1tg horizon (Tab. 2). In the variant with mineral fertilizer compared with the control it has been recorded slightly lower values of humus in all tested soil horizons. By application of lime, manure and mineral NPK fertilizer there was a further reduction in the amount of humus in all depths of the investigated profiles. Similar results have got earlier other authors as well (Brocic, 1994, Dugalic, 1998).

Table 2. Changes of pH, humus content, nitrogen and base cations in the treated soil

Variants of fert.	Horizons	pH		Humus	N	T-S	S	T	V
		H_2O	KCl	(%)	(%)	cmol$^+$ kg^{-1}			(%)
Control	Ah	5.17	3.94	2.19	0.124	9.8	9.6	19.4	47.7
	Eg	5.46	4.42	1.84	0.113	9.3	20.3	29.6	50.5
	B_1tg	5.55	4.58	0.66	0.079	12.2	20.9	33.1	62.8
NPK	Ah	5.32	4.02	2.12	0.120	11.5	9.9	21.4	46.8
	Eg	5.66	4.52	1.67	0.112	11.0	20.6	31.6	49.8
	B_1tg	6.12	4.92	0.64	0.076	11.7	21.7	33.4	60.7
NPK+ $CaCO_3$+ manure	Ah	6.03	5.32	1.79	0.125	14.5	13.7	27.9	58.0
	Eg	6.46	5.68	1.66	0.111	14.5	23.8	38.4	58.6
	B_1tg	6.38	5.52	0.63	0.070	9.9	24.7	34.6	60.0
LSD	5%	0.09	0.55	0.05	0.006	0.74	10.0	6.91	3.02
	1%	0.13	0.76	0.07	0.009	1.02	13.8	9.52	4.16

Total N content in the studied soil profile has been decreased with increasing of profiles depth (Ah-0.124%, 0.079% B_1tg-) and was proportional to the decrease of humus content in the topsoil (Tab. 2). Long-term application of mineral fertilizers and liming did not significantly affect the changes of total nitrogen content in the horizons of the soil.

The sum of the adsorbed bases (S) and cation adsorption capacity (T) in Ah horizon soil were very low in the control (9.6 and 19.4 cmol + kg^{-1}) (Tab. 2). With increase of depth, increases the sum of adsorbed base cations and their adsorption capacity too. Long-term application of fertilizers and liming led to the enrichment in soil base cations (Ca^{2+}), which is accompanied by increased amounts of adsorbed bases (S). Thus, with the largest increase of S compared to the control variant has been recorded in the combined application of NPK, manure and CaCO3 in the Ah soil horizon and Eg (4.1 and 3.5 cmol $^+$ kg^{-1}).

The degree of saturation of the adsorptive complex with bases (V-value) of soil in the control of Ah horizon was 47.7% and is classified as moderately unsaturated soil. Compared to the control, application of lime, manure and NPK fertilizer significantly increased the degree of soil saturation in bases in Eg and Ah soil horizons. Deeper in B1tg horizon (60-80 cm) soil base saturation with soil bases was influenced by the combined application of NPK, manure and $CaCO_3$

Remained steady, considering determined values of the same depth of the control have been very similar. The degree of base saturation (V) and pH values show a linear dependence. Similar results have been noted previously by other authors (Radanovic 1995 Dugalic, 1998 Dugalic *et al*., 2006).

Content of the easily available phosphorus in the examined soil has been low (Tab. 3). Thus, in the surface Ah horizon it was 7.0 mg 100 g^{-1} and in the deepest horizon (B_1tg) it has been only 1.3 mg 100 g^{-1}. By long-term use of NPK fertilizers availability of nutrients compared to the control increased to 2.3 mg 100 g^{-1} in Ah and 0.8 mg 100 g^{-1} in the Eg horizon.

Table 3. Changes in the content of some available forms of macro and micro nutrients and aluminium in the studied soil profile

Variants of fert.	Horizons	P_2O_5	K_2O	Ca	Al	Fe	Mn	Zn
		mg 100 g^{-1} soil				mg kg^{-1} soil		
Control	Ah	7.0	8.5	165	6.4	227	70	1.7
	Eg	5.3	12.0	175	11.2	255	66	1.5
	B_1tg	1.3	22.6	204	5.3	248	45	1.2
NPK	Ah	9.3	8.5	164	8.7	237	24	1.5
	Eg	6.1	10.2	168	11.2	262	26	1.6
	B_1tg	1.1	23.8	225	3.6	258	23	1.1
NPK+	Ah	16.4	14.8	240	0.1	183	18	1.2
$CaCO_3$+	Eg	16.3	16.6	280	0.2	193	26	1.0
manure	B_1tg	2.7	24.0	255	0.1	256	15	0.8
LSD	5%	0.37	13.6	19.8	0.26	5.68	1.15	0.13
	1%	0.51	18.8	27.3	0.36	7.83	1.58	0.18

Liming with NPK and manure is very important to increase the content easily available phosphorus as follows: for 9.4 mg 100 g^{-1} in the Ah horizon, and 11.0 mg 100 g^{-1} in the Eg horizon compared to the control.

Significantly increased the content of available phosphorus after the lime application is being explained by the "mobilization" of phosphorus from the harder-soluble compounds of Al, Mn and Fe-phosphates due to increased of soil pH and the presence of higher concentrations of Ca^{2+} ions in the soil solution and the adsorptive soil complex (Jelic, 1991, Dugalic, 1998 ; Jelic *et al*., 2006).

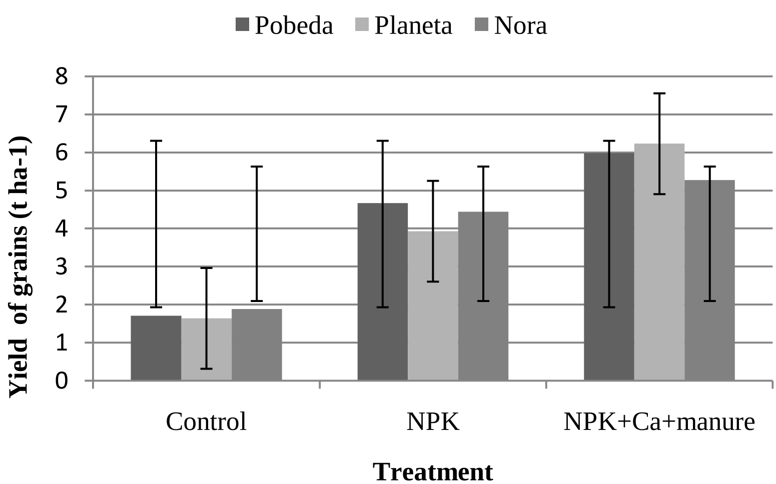
The content of easily available potassium of control in the Ah horizon was 8.5 mg 100 g^{-1} soil, while with increasing of depth the content of easily available potassium increases (Eg horizon - 12.0 mg 100 g^{-1} and B1tg horizon - 22.6 mg 100 g^{-1}) . By long-term application of NPK fertilizers easily available potassium content increased only in B1tg horizon (23.8 mg 100 g^{-1}). Periodic application of liming compared to the control has increased the easily available potassium content to 6.3 mg 100 g^{-1} in Ah; to 4.6 mg 100 g^{-1} in Eg and 1.4 mg 100 g^{-1} in B1tg horizon. Other authors, such Jelic (1991, 1996), Dugalic (1998) and Jelic *et al.* (2006) reported that the use of lime and mineral NPK fertilizers has led to a significant increase in the easily available potassium in acid soils.

At the control the content of available Ca in the Ah horizon was 165 mg 100 g^{-1} and it has increased with soil profile depth (B1tg-204 mg 100 g^{-1}) (Tab. 3). The long-term use of NPK fertilizers has led to some reduction of the available Ca in the Ah and Eg horizons, while in the deeper horizon B1tg accumulation of this element increased up to 21 mg 100 g^{-1} soil compared to the control. Increasing the availability of this element in the deeper layers of the obviously came as the result of intensification of rinsing into the deeper soil layers (Jelic, 1991). Derived calcification by application of limestone with application of manure and NPK fertilizer increased the content of available calcium in relation to control of 85 mg 100 g^{-1} soil (Ah horizon), 105 mg 100 g^{-1} soil (Eg horizon) and 51 mg 100 g^{-1} soil (B1tg horizon).

The highest content of mobile Al has been found in the control, especially in sub-arable Eg horizon (11.2 mg 100 g^{-1}) (Tab. 3). Long-term use of NPK fertilizer did not significantly change the mobility of Al in the soil, and even led to an increase in its content in relation to the control of surface Ah horizon (8.7 mg Al 100 g^{-1}). The combined use of lime, manure and NPK in relation to the control and NPK fertilization treatments significantly decreased mobile aluminium content in all studied depths of the soil profile. So, by using the above mentioned pedo-meliorative measures, mobile aluminium content has drastically decreased; from the toxic values of the control and NPK variants, which has created an optimal conditions for the growth and development of winter wheat and it has resulted in significantly higher yields of all cultivars (Jelic *et al.*, 2006; Jelic *et al.*, 2010; Jelic *et al.*, 2012).

The content of the most available forms of micronutrient elements (Fe, Mn and Zn) in the studied soil was much different and changeable under the influence of the application of liming and fertilization (Tab. 3). In the control the content of mobile Fe ranged between 227 and 248 mg kg^{-1}, which had an increasing trend in accordance with depth increasing. However, the content of mobile forms of Mn decreased with increasing of soil depth. According to the research in the control content of available Mn in the Ah horizon was 70 mg kg^{-1}, while in B1tg horizon Mn content decreased to 45 mg kg^{-1}. With multiannual application of NPK, content of available iron has been increased in all horizons of the soil, while the manganese content is continuously decreased. However, the combined application of lime, manure and mineral NPK fertilizer significantly reduced the content of available forms of both elements (Fe and Mn) in all studied horizons in relation to the control and NPK fertilization treatments. The content of available zinc in the studied soil horizons, has generally showed low levels, and did not significantly change under the influence of fertilization.

The grain yield of particular winter wheat varieties in the observed multiyear period has varied significantly depending on the applied N fertilization (Fig. 1). Comparing the actual average yields of different wheat varieties and statistical analysis showed significant differences between the studied variants of fertilization and cultivated varieties of wheat.



Graph 1. Grain yields of different varieties of winter wheat depending on fertilization and liming

Continuous application of mineral NPK fertilizers has contributed to a very significant increase of wheat yields (over 2 times) compared to the control. The highest average yield in variant with NPK fertilizing had variety Pobeda, which had a significant increase of yield compared to the cultivated varieties on an unfertilized variants. Derived liming by entering a limestone with application of manure and NPK fertilizer significantly increased the yields compared to the control, but with variant of application of NPK fertilizers too. The positive effect of liming and fertilization on wheat grain yields on acid soils has been also previously observed (Kulhanek *et al.*, 2007; Jelic *et al.*, 2009; Rusty *et al.*, 2010).

CONCLUSIONS

Based on the research on the influence of long-term amelioration measure of lime application, manure and mineral NPK fertilizing on changes of the most important agrochemical soil properties of pseudogley, and usage of different varieties of winter wheat as a test culture, it can be concluded as follows:

The most significant changes in agrochemical soil properties have been reached in the soil pH, soil adsorptive complex, composition and content of biogenous nutrients (phosphorus, potassium, calcium, iron, manganese and zinc), as well as the content of toxic amounts of aluminium. Perennial of periodical using chemical ameliorative substances (limestone and manure) together with the regular use of fertilizers has significantly reduced soil acidity (0.83 to 1:38 pH units), increased amount of adsorbed base cations for 3.7 cmol^{+} kg^{-1}, V% for 22.89% and enhanced adsorptive complex composition. It also gave an average increase the content of most nutrients (available phosphorus to 9.4 mg 100 g^{-1}, 6.3 mg 100 g^{-1}, calcium from 85 to 105 mg 100 g^{-1}), and the mobility of iron reduced for about 24 %, manganese for over 100%, 41%, and zinc and aluminium particularly in which the content is reduced from 13.61 to 0.14 mg 100 g^{-1}). As a result of improving soil fertility the grain yield of winter wheat has been increased in average for about three times.

Low productive capacity of these soils due to unfavourable physical and chemical properties, especially the very poor supply with available forms of phosphorus, potassium and nitrogen, the presence of high concentrations of mobile aluminium, mainly in the humic horizon and Eg. Therefore for successful production of wheat recommends mandatory applying of adequate chemical ameliorative measures.

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ESTIMATION OF POTENTIALLY MINERALIZABLE N FROM FERTILIZERS IN ORGANIC AGRICULTURE

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ABSTRACT

Due to great diversity of materials that can be used as N fertilizers, a simple, cheap and efficient procedure is required for their characterization. An incubation experiment was set up in order to determine the mineralization potential of different organic N fertilizers (seabird guano, forage pea meal, soybean meal, sunflower meal, vermicompost, mushroom compost, sheep manure and farmyard manure), and kinetics of mineral nitrogen release. The highest value for net N mineralization at the end of the incubation was obtained for guano (77.56%) and it was followed by sunflower (46.6% of total N) and soybean meal (41.23%). The lowest value for net N mineralization obtained for mushroom compost (19.5%) and vermicompost (21.8%). Net N mineralization linearly correlated with total N content, and square correlated with C/N ratio. The mineralization rate constant, k, had a square correlation with total N content and a linear correlation with C/N ratio of the tested fertilizers. The results show that total N content and C/N ratio of organic N fertilizers are good indicators of their N release. These interactions could be a starting point, besides other factors, in determining an appropriate rate of fertilization for an efficient use of N inputs, especially in organic production where environment protection and product quality are some of the fundamental principles.

Keywords: organic fertilizers, mineralization, potentially mineralizable N

INTRODUCTION

The most efficient production of organic products is on integrated organic farms, i.e. farms where plant and livestock production are integrated in one unit and where part of plant products is used for feeding animals, which in turn provide organic fertilizers. However, if there is no livestock production, plant nutrition can be a problem (Steinshamn *et al.*, 2006). In the past, most organic growers provided nitrogen (N) through external inputs – organic fertilizers of animal origin, which predominantly contained residues such as horn, blood, meat meal, or other protein-rich materials (Stadler *et al.*, 2006). Today, the usage of most of these substances is questionable or even forbidden in organic farming because of *Bovine Spongiform Encephalopathy* (BSE), commonly known as mad-cow disease (Schmitz and Fischer, 2003; Plakolm, 2006). As a consequence, supplying the plants with nitrogen in organic production relies on organic sources of N such as: soil organic matter, farmyard manures, milled seeds of grain legumes, crop residues, different organic fertilizers and industrially processed plant residues. The content of N and rate of mineralization (N release) of these materials are very different (Pansu and Thuries, 2003), and so is their value as N fertilizers in organic production.

Excessive or inopportune use of organic fertilizers (OFs) can cause intensive mineralization and drastically increase mineral N in the soil and harmful accumulation of nitrates in the plants (Burns, 1996; Andersen and Nielsen, 1992). Nitrogen dynamics after the application of any organic material is vital for achieving a correct and effective use of the material, minimizing the losses of nitrate through leaching and avoiding the negative environmental effects that may be produced in groundwater (Burgos *et al.*, 2006).

In many studies, a relation between N mineralization and biochemical characteristics of organic materials has been described. Most often, total N content and C/N ratio of organic materials were strongly correlated to their mineralization (Pansu and Thuries, 2003; Burgos *et al.*, 2006; Trinsoutrot *et al.*, 2000; Chaves *et al.*, 2004; Cordovil *et al.*, 2005). However, other factors such as polyphenol and lignin content or their ratio with total N content are also very important for the mineralization process and mineral N release (Palm and Sanchez, 1991; Fox *et al.*, 1990; Lupwayi and Haque, 1999; De Neve *et al.*, 2004). In generally, through application of OFs containing relatively high contents of N (>1.5%) and narrow C/N ratio (<20), and their mineralization in the soil, significant amounts of mineral N could be released and so satisfy the needs of crops for N (Amilinger *et al.*, 2003; Bavec *et al.*, 2006). However, nitrogen availability from applied N sources must be known in order to achieve an efficient management of N inputs (Pang and Letey, 2000). Our previous research showed that based on the incubation experiment, the mineralization of OFs can be predicted in a relatively short period after application in the field (Manojlovic *et al.*, 2010). Due to great diversity of materials that can be used as N fertilizers in organic farming, a simple, cheap and efficient procedure is required for their characterization (Stadler *et al.*, 2006). Despite a continuing research effort (Jalil *et al.*, 2002; Picone *et al.*, 2002), chemical tests that are selective for the mineralizable portion of N are not available and incubation assays remain the preferred way of estimating mineralizable N (Curtin and Campbell, 2004). The goals of the present study were:

To determine the mineralization potential of different OFs, the kinetics of mineral N release, and the correlation between content of total N and C in OFs and the quantity of mineralized N by means of an incubation experiment. To establish whether the mineralization of differently derived organic materials with C/N ratio narrower than 20 can be characterized with the same quality parameters (C/N ratio and total N content).

MATERIALS AND METHODS

Eight different plant- and animal-derived organic fertilizers (OFs) were analyzed in two incubation experiments. In first experiment we analyzed four OFs: seabird guano, forage pea meal (*Pisum sativum*), soybean meal *(Glycine hispida)* and farmyard manure. The results from this experiment were used as a baseline for field experiment were different rate of these OFs were applied in organic lettuce production (Manojlovic *et al.*, 2010). In the second experiment four other plant- and animal-derived OFs were analyzed: sunflower meal (*Helianthus annuus*), vermicompost, spent compost from mushroom production, and sheep manure. These fertilizers were selected in order to obtain a wide range of N contents and C/N ratios, but at the same time for all these fertilizers it was assumed that they would release mineral N during the decomposition process because they all had a C/N ratio narrower than 20 (Table 2). Both experiments were conducted under the same conditions and by the same procedures.

The soil used in the incubation experiments was a non-calcareous chernozem. A soil sample was taken from the topsoil layer (0-30 cm) of a farm in Kisac, northern Serbia (lat 45°35′N, long 19°72′E; 85 m altitude a.s.l.), which is certified for organic production. The soil was sampled at a moisture content well above the field water capacity (FWC) and was allowed to dry to a moisture content of 70% of FWC. The soil was not air-dried in order to minimize the disturbance of microbial activity. Visible plant material and stones were removed by hand and large soil aggregates were crumbled. The basic chemical properties of the soil are listed in Table 2.

In order to minimize particle-size effects in the experiment, the analized fertilizers were milled to pass through a 1.5 mm sieve. Dry matter content was determined gravimetrically (70 °C for 24h). Total C and N contents were determined using a CHNS analyzer (ELEMENTAR VARIO EL, GmbH, Hanau, Germany). Mineral N (NH_4-N and NO_3-N) content in the OMs was determined after extraction in water, using the steam distillation method (Keeny and Nelson, 1982).

Bulk density was determined by Kopecki cylinders; particle size distribution by the pipette method (Thun *et al.*, 1955); pH value of the soil was determined in a suspension of soil and H_2O (1:2.5) using a METREL MA 3657 pH meter. $CaCO_3$ content was determined volumetrically using a Scheibler calcimeter. Total N and C content was determined using a CHNS analyzer (ELEMENTAR Vario EL, GmbH, Hanau, Germany).

Table 1 Chemical properties of OFs used in the incubation experiment

Treatments	DM[1] (%)	Total N (%)	Total C (%)	C/N ratio	WSN[2] (mg kg^{-1})
Guano	93.65	15.52	44.40	2.89	3352
Forage pea meal	96.86	4.08	41.55	10.17	61
Soybean meal	97.35	6.65	49.93	7.50	86
Sunflower meal	95.42	5.96	42.24	7.08	59
Vermicompost	75.46	1.99	27.24	13.83	240
Mushroom compost	80.26	1.65	18.37	11.11	236
Sheep manure	74.25	2.56	36.22	14.14	483
Farmyard manure	76.36	2.71	36.95	16.64	346

[1]DM: dry matter; [2]WSN: water-soluble N

Table 2 Basic physical and chemical properties of soil used in the incubation experiment

Physical properties					Chemical properties				
Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Bulk density (g cm^{-3})	pH (H_2O)	$CaCO_3$ (%)	Organic C (%)	C/N ratio	N total (%)
0.27	40.0	35.9	23.8	1.26	7.92	0.17	2.50	11.02	0.227

PVC containers (100 cm^3) were filled with soil (with 70% of holding water capacity, which corresponds to the mass of 50 g of absolutely dry soil) mixed with miled OF, which was added in the amount that incorporated 5 mg of total N. Then the containers were covered with semi-permeable wax parafilm in order to reduce water loss during the incubation. Moisture in the soil was maintained at the same level by weighing the mass of the containers every 7 days and adding distilled water when the mass dropped by more than 0.05 g. The incubation in the dark lasted for 62 days and at the constant temperature of 28°C. A sample of soil without added OF was incubated as a control so that we could assess the soil's mineralization potential and calculate the portion of mineralized N in total N contained in the OF.

Sampling was destructive, by removing containers in quadruplicate for each treatment on each sampling date (28 containers per treatment/fertilizer). Samples were taken on day 0, 7, 14, 21, 35, 51 and 62 after the onset of incubation. The soil was removed from the containers and mineral N (NO_3^--N+ NH_4^+-N) was extracted by adding 40 ml of 2 N KCl to 10 g of fresh soil (KCl: soil - ratio, 4:1), and determined by a distillation method (Bremner *et al.*, 1965).

Net mineralization (NM) of OF was calculated as the difference between mineral N content in the containers with OF and mineral N content in the containers without OF (soil only), by using the following equation:

$$\mathrm{NM}\,(\%) = \frac{\mathrm{T}-\mathrm{K}-\mathrm{P}}{\mathrm{V}} \times 100\% \qquad [1]$$

where: NM, net mineralization of OF; T, mineral N content in the container with OF (mg NH_4-N + NO_3-N); K, mineral N content in the container without OM (mg NH_4-N + NO_3-N); P, initial mineral N content and V, total N content in OF (5 mg N per container).

Statistical analysis

At the end of the incubation, the content of mineral N was subjected to a variance analysis (One-way ANOVA), and treatments' means results were compared using Tukey's test ($P<0.05$). Single first-order kinetics model was fitted to the net N mineralization data (Stanford and Smith, 1972). A correlation analysis was done using STATISTICA v.8.0 (StatSoft Inc., OK, USA).

RESULTS AND DISCUSSION

Mineral nitrogen released from OFs during incubation

At the end of incubation, mineral N content in the control treatment (soil without OFs) was 28.63 mg N kg^{-1}, which calculated for the 0-30 cm soil layer amounts to 108.22 kg N ha^{-1}. In the treatments with OFs, mineral N content was significantly higher than in the control and ranged from 48.05 mg N kg^{-1} (mushroom compost) to 95.0 mg N kg^{-1} (seabird guano), which is equivalent to 181.6 kg N ha^{-1} and 359.1 kg N ha^{-1}, for the 0-30 cm layer. Except treatment with seabird guano, where was recorded the highest content of mineral N, plant-derived OFs produced significantly higher amounts of mineral nitrogen compared to animal-derived OFs (Fig. 1).

Net N mineralization patterns of OFs

The net mineralization patterns of the OF are fitted to a single first-order kinetics model:

$$A_N(t) = A_N\,(1 - exp(- kt)) \qquad [2]$$

where $A_N(t)$ is the amount (%) of total N mineralized at time t; A_N is the amount of potentially mineralizable total N (percentage of total N) and k is the first-order N mineralization rate constant (per day). The net N mineralization curves of added OFs in a function of time are presented in Figure 2. During the first half of the incubation period, plant-derived OFs (soybean, forage pea and sunflower meal) showed intensive net N mineralization, and they reached the maximum value of net N mineralization during this period. Our results are consistent with previous findings. Stadler *et al.* (2006) reported that for similar organic materials (milled seeds of yellow lupine, fababean and pea) net N mineralization occurred primarily within the first 15 days, and the maximum amount of net N mineralization was attained during the first 4 weeks of incubation.

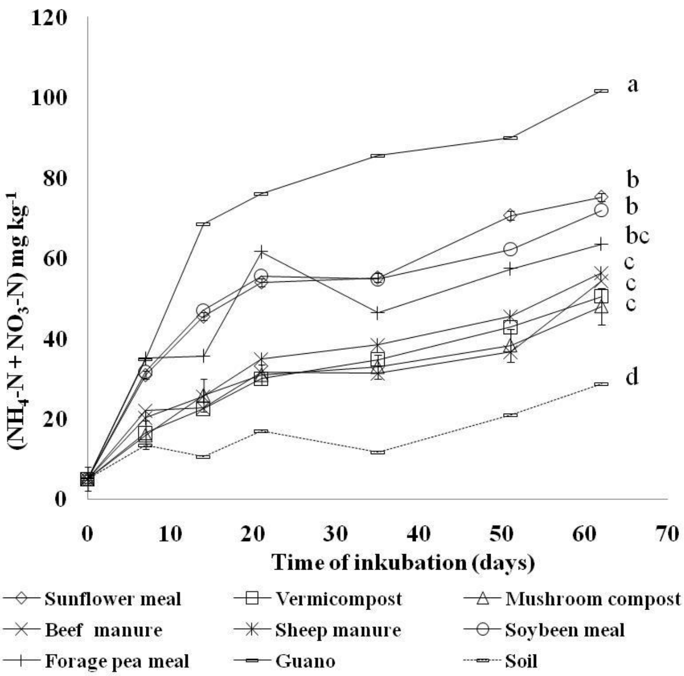

Fig. 1 Mineral N (NH_4-N+NO_3-N) produced during incubation (mg N kg^{-1})

The treatment with guano had a very similar mineralization pattern as plant-derived OF, while treatments with composts and manures had lower values for net N mineralization in the same period of incubation (Fig. 2). The differences in mineralization patterns can be explained by different origin of OFs, and proportion of readily available carbon and nitrogen for microbial transformation processes (Chaves *et al.*, 2005; Stadler *et al.*, 2006). Some authors maintain that, regardless of N content in the OFs, during the first 2 weeks of incubation mineralization is slow (lag phase in N mineralization) and then mineral N is released later, but this was not the case in our research. A lag phase may be exhibited by soils containing C-rich substrates (e.g., forest soils) where net N mineralization may initially be low because N immobilization predominates (Paustian and Bond, 1987). Although the soil we used in our research had a high content of organic matter, it had a narrow C/N ration, which is why the lag phase did not occur.

The first-order model was fitted to all eight OFs and the results of curve fitting are given in Table 3. The highest value for net N mineralization (as percentage of total N) at the end of the incubation was obtained for guano (77.56 %) and it was followed by sunflower (46.6 %) and soybean meal (41.23 %).

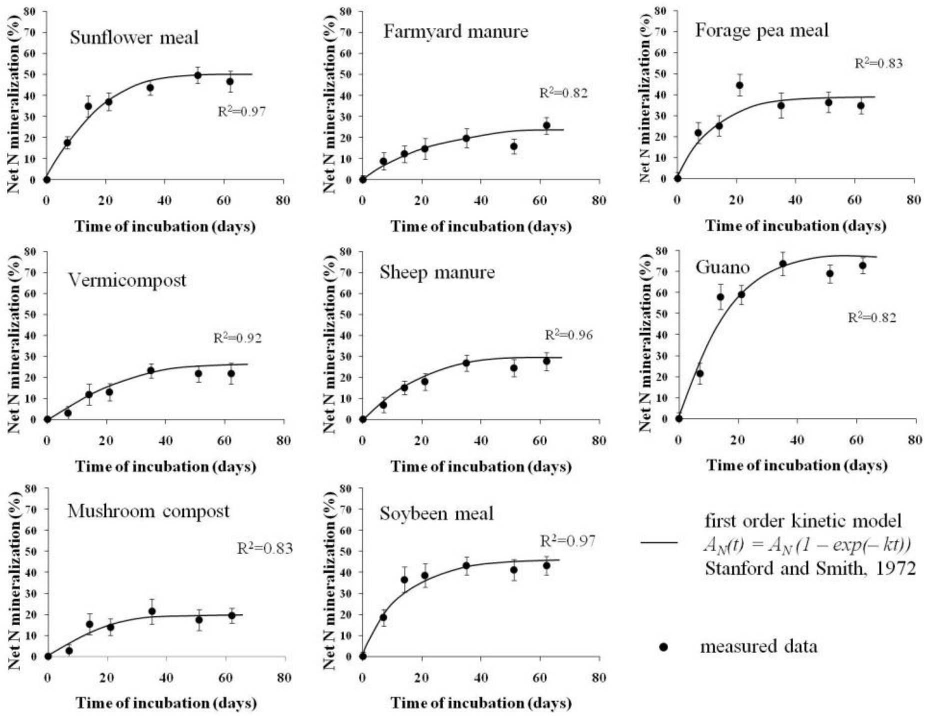

Fig. 2 Net N mineralization patterns of organic fertilizers (% of total N added)

The lowest value for net N mineralization was obtained for mushroom compost (19.5%) and vermicompost (21.8%). At the same time, the analyzed OFs showed different mineralization kinetics, which were not correlated with net mineralization at the end of the incubation. The mineralization rate constant *k* ranged from 0.045 d^{-1} (mushroom compost) to 0.128 d^{-1} (Forage pea meal) (Tab. 3). Guano and forage pea meal had approximately equal values for *k,* but at the end of the incubation, net N mineralization for guano was twice as high as net N mineralization recorded for forage pea meal. This inverse relationship between net N mineralization and *k*, where values of net N mineralization tend to increase and *k* to decrease as incubation time is extended was previously reported by Paustian and Bonde (1987) and Wang *et al.* (2003).

Correlation between net N mineralization and the chemical parameters of OFs

At the end of the incubation, net N mineralization and mineralization rate constant *k* of the investigated OFs were significantly related to their C/N ratio and total N content (Fig. 3). Net N mineralization was linearly correlated with total N content (Fig. 3 D), and square correlated with C/N ratio (Fig. 3 C). The mineralization rate constant *k* had a square correlation with total N content and a linear correlation with C/N ratio of the tested OFs (Fig. 3 A and B).

Table 3 Observed net N mineralization of the organic fertilizers at the end of the incubation and the parameters of the first-order model fitted to the N mineralization data

Organic fertilizers	Nmin (%)[1]	k (per day)[2]	A_N[3]	R^2
Guano	77.56 a	0.127 a	74.07	0.82
Forage pea meal	36.10 c	0.128 a	37.06	0.83
Soybean meal	41.23 bc	0.104 b	43.39	0.97
Sunflower meal	46.6 b	0.070 c	48.28	0.97
Vermicompost	21.8 de	0.045 d	24.88	0.92
Mushroom compost	19.5 e	0.069 c	20.06	0.83
Sheep manure	27.6 d	0.053 dc	28.46	0.96
Farmyard manure	25.7de	0.052 dc	22.35	0.82

[1]Nmin, observed net N mineralization in percentage of total N; [2]*k*, rate constant for mineralization of total N; [3]AN, potentially mineralizable N as percentage of total N; *Values followed by different letters was significantly different at P<0.01.

In our research, the origin of the fertilizers did not affect the relation between the chemical composition (total N content and C/N ratio) and the mineralization process of OFs, which is in accordance with the results a number of authors who also found a close relationship between N release and N content or C/N ratio for crop residues with C/N ratio lower than 20 (Trinsoutrot *et al.*, 2000; Chaves *et al.*, 2004; Frankenberger and Abdelmagid, 1985; De neve *et al.*, 1994). However, Stedler *et al.* (2006) found that some fertilizers (industrially processed residues from plants and microorganisms), although similar in their chemical composition to other studied materials (C/N<15 and total N content>5), had a significantly different mineralized N content at the end of the incubation. This may indicate a need for more detailed analyses in order to understand the effect which chemical composition has on the dynamics of the mineralization of organic materials expected to lead to N release.

The results of our study show that the 8 organic fertilizers, depending on total N content and C/N ratio, had different levels of potentially mineralizable N and different mineralization kinetics. As a result of this, they are not equally valuable as N fertilizers in organic production. Nevertheless, to create a comprehensive model of fertilization in organic production, it is necessary not only to assess the amount of potentially mineralizable N in every OF, but also to determine the sensitivity to temperature and soil moisture change during mineralization, as well as the effect of soil on the process of mineralization.

CONCLUSIONS

The eight organic N fertilizers used in this study had different characteristics of chemical composition and varied in their N release patterns and mineralization kinetics. As assumed, at the end of the incubation all analyzed materials showed a net N release, where the amounts of mineralized N among individual fertilizers differed significantly. Some of the fertilizers (soybean, sunflower and guano) had 2-3.5 times as high net N mineralization values at the end of the incubation as the other fertilizers (manures and composts), which indicates that generalizations cannot be made. It is also evident that among high N content organic materials, which are characterized as organic N fertilizers, it is necessary to classify these materials according to N availability. The interactions between the chemical composition of OFs and their mineralization must be considered in determining an appropriate rate of fertilization for an efficient use of N inputs, especially in organic production where the environment protection and products quality are some of the fundamental principles.

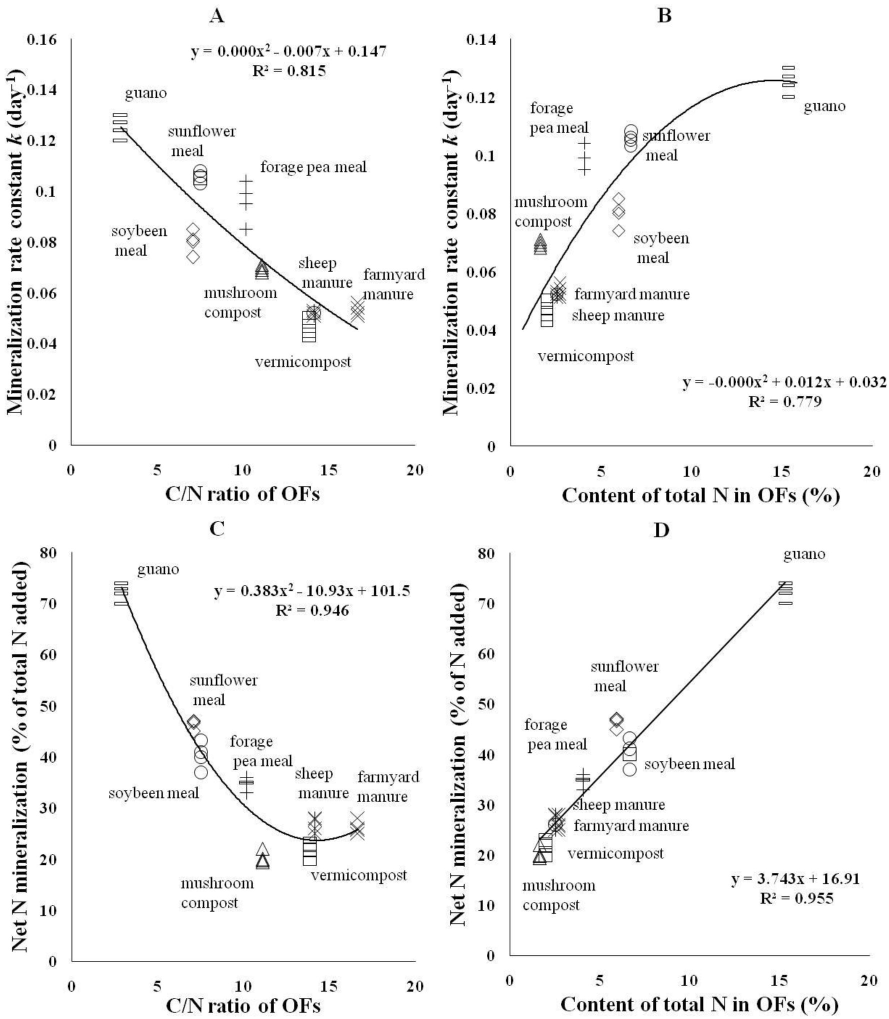

Fig. 3 Correlation coefficients and the linear or curvilinear regression equations between net N mineralization parameters and the chemical parameters of OFs

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THE EFFECT OF PLANTING IN BENCH TERRACES ON CARBON SEQUESTRATION IN SOIL

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ABSTRACT

Deforestation leads to degradation of former forest soil mostly due to inappropriate usage in agriculture. Degraded soils are unsuitable for agricultural production and require the application of ameliorative measures to control degradation. One of the effects of ameliorative afforestation is the carbon sequestration in biomass and soil, which contributes to the reduction of CO_2 concentration in the atmosphere and climate change mitigation. This paper describes the effects of ameliorative afforestation methods on carbon sequestration in soil and litter. This research was conducted on soils of Grdelička gorge and Vranjska valley afforested in mid-1950's with black pine (*Pinus nigra* Arnold) applying the pit planting method and planting in bench terraces method. Estimation of sequestrated C in soil and litter is based on equations recommended by Good Practice Guidance for LULUCF. The results showed that sequestrated C is considerable higher in the soil profiles in bench terraces both in relation to soil profiles between the bench terraces and the soil profiles planted by pit planting method. It was found that the thickness of A-horizon and sequestrated carbon are directly correlated and the influence of thickness of A-horizon exhibits differently on soils planted by different afforestation methods. It was also found that the slope angle influences the carbon sequestration in litter on soils afforested by pit planting method pit, and the influence of slope angle on the carbon sequestration in litter is not confirmed in soils planted in bench terraces afforestation method.

Keywords: ameliorative afforestation, bench terraces, carbon sequestration, soil properties

INTRODUCTION

The main reason of deforestation is making a space for food production. Turning forest soil into arable land and applying inappropriate agricultural measures leads to soil degradation, loosing ability of soil for crop production and finally bare land. As vegetation cover brings the most efficient soil protection, afforestation is efficient method of establishing vegetation on degraded soil and provides many ameliorative benefits.

Control of erosion process on degraded soil is the primary function of afforestation (Đorović *et al.*, 2003; Chirino *et al.*, 2006; Blanco-Canqui and Lal, 2008). Ameliorative effects of afforestation can be estimated through the density of vegetation cover and the amount of soil loss on afforested soil. Although, ameliorative effects of afforestation should be observed in context of improvement of the environment in terms of microclimate conditions, biodiversity richness (Wenhua, 2004; El-Keblewy and Ksiksi, 2005) and spread existing carbon depots and make new carbon sinks (Richter *et al.*, 1999; Lal *et al.*, 2003; Wang and Medley, 2004; Niu and Duiker, 2006).

Sequestration of atmospheric carbon is mighty tool to climate change mitigation on global level (Moffat, 1997; Ingham, 2000), and forests represent the most important vegetation type in terms of net emission, sequestration and retention of carbon in terrestrial ecosystems (Kadović and Medarević, 2007). According to Niu and Duiker (2006), afforestation of degraded lands is environmentally beneficial strategy for carbon sequestration. Forest soil is the most important terrestrial carbon pool (Jobbágy and Jackson, 2000). According to Henderson (1995) about 75% of carbon is sequestrated in world soils and forest soils hold about 40% of all below ground C (Dixon *et al.*, 1994), till the highest C density is in surface level of soil to depth of 30 cm (Lal, 2005).

The aim of this paper is to assess whether the afforestation method have any influence on the amount of sequestrated C in soil and litter and which parameters best define C sequestration in soil and litter.

MATERIALS AND METHODS

The research was conducted in the area of Grdelička gorge and Vranjska valley which is situated between 42°22′ and 42°55′N and between 19º21′ and 20º00′E. According to Köppen's climatic classification, this area is placed in the Dfb's climate subtype where average annual temperature is 10.4 ºC and average annual precipitation is 729 mm. This research deals with the soils of the Grdelička gorge and Vranska valley, which was afforested in the mid-1950s in the frame of numerous afforestation programmes conducted to control erosion processes. The object of research is afforestation by black pine (*Pinus nigra* Arnold) applying two afforestation methods: pit planting and planting in bench terraces. Pit planting method is the most frequently used and very simple planting method, while the bench terrace planting method was applied because concerned the most efficient in erosion control (Soljanik 1952, 1955, Andrejević, 1959; Đorović, 1969).

The sample plots for this research were established on warm sides: south (S), southwest (SW) and southeast (SE) and on slope angle higher the 20%, in order to minimize the differences caused by different exposure and slope angles. (Soljanik, 1955; Lujić, 1960; Økland *et al.*, 2003; Wang and Medley, 2004).

There are 3 sample plots on soils afforested by the pit planting method (sp 5–in the Lještarska dolina, sp 11 and sp 12 on the Momin kamen location), and 4 sample plots on soils afforested by the bench terrace method (sp 2 – in the Predejanska river basin, sp 3 and sp 9 – in the Kalimanska river basin, sp 6 – in the Zla dolina 2 basin). On sample plots afforested by pit planting, 2 soil profiles were opened and 4 samples of the litter (30 × 30 cm) were taken per plot. On sample plots afforested by planting in bench terraces one profile was opened in the bench terrace and 2 samples of litter per plot, and the other profile was opened between adjacent bench terraces and 2 samples of litter per plot.

The soils were sampled at the depth of: 0-5, 5-10, 10-20 and 20-40 cm. The main physical and chemical properties of soil and litter were determined using JDPZ methods (Bošnjak, 1966; Cencelj, 1997): particle fractions-pipette B method, pH-using pH-electrode, organic C (Org. C)- by method according Tyurin, N (total nitrogen)- Kjeldahl method, P (available P_2O_5) and K (available K_2O)– by extraction after Enger- Riehm method (1958).

The estimation of sequestrated carbon in soil and litter is based on equations recommended by Good Practice Guidance for LULUCF (IPCC, 2003; Ouimet *et al.*, 2007):

$$\mathrm{ResC_{Soil}} = \sum_{layer=1}^{layer=j} \left(SOC_{content} \cdot BulkDensity \cdot Depth \cdot (1 - frag) \right)_{layer}$$

where: $\mathrm{ResC_{Soil}}$ – soil carbon density for *j* layers of sampling site, (C m[2]); $\mathrm{SOC}_{content}$ – soil organic carbon content for the single sampled depth, (% of mass or $\mathrm{gC{\cdot}kg^{-1}}$); *BulkDensity*– soil mass of the undisturbed volume of the single sampled depth, ($\mathrm{t{\cdot}cm^{-3}}$); *Depth* – thickness of the sampled layer, (cm); *frag*– volume of coarse fragments in the single sampled depth, (%).

The analysis of variance (ANOVA) was used to test whether there are significant variations in the reserve of sequestrated C in soil depending on the method of afforestation applied. Levels of significance were tested using the *F*-test ($p < 0.05$) and multiple rang test to compare the results. The impact of thickness of A-horizon and slope angle on the reserve of sequestrated carbon in soil and litter performed by regresion analysis. The coefficient of correlation and coefficient of determination and Reomer-Orphal distribution were determined using Portable Statgraphics Centurion 15.2.11.0.

RESULTS AND DISCUSION

The largest amount of sequestrated C in soil is in soil profiles in bench terraces (in BT) comparing to soil profiles between bench terraces (btw BT) and profiles afforested by pit planting (Tab. 1). This result implicates on better soil conditions in bench terraces for carbon sequestration. Therefore, the construction of bench terraces involves contour line terracing, and while planting in bench terraces forms the counter-slope. With that, the erosion is controled by reducing the energy of splashing water in bench terrace (Đorović, 1969; Sheng, 2000). On surfaces afforested by pit planting method there are no special soil preparation.

Table 1 Carbon sequestration in soils afforested by different plating methods

Method	Count	Mean	Standard deviation	Homog. Groups	Contrast	Sig.	Difference	+/- Limits
btw BT	4	21.825	8.37471	X	btw BT - in BT	*	-41.725	40.9464
pit	6	24.6333	12.307	X	btw BT - pit		-2.80833	37.3787
in BT	4	63.55	47.0686	X	in BT - pit	*	38.9167	37.3787

* denotes a statistically significant difference.

Spain *et al.* (1983) and Burke *et al.* (1989) state the highest carbon accumulation in soil occure in A-horizont of soil, accordingly, it was analysed the effect of tickness of A-horizon on the reserve of sequestrated C in soils afforested by planting in bench terraces and pit planting. In A-horizon of soils afforested by pit planting, the reserve of sequestrated C ($ResC_A$) depends on thickness of A-horizon (Ah), which is best illustrated by function of S-curve (Fig. 1):

$$ResC_A = \exp(3.96441 - \frac{12.7354}{Ah})$$

where: $ResC_A$ – reserve of sequestrated C in A-horizon ($t{\cdot}ha^{-1}$), Ah – thickness of A-horizon (cm). The model explains 97.30% of variability. The relationship between variables is strong (coefficient of correlation is -0.986). The thickness of A-horizon significantly effects on sequestrated C in A-horizon on the level of significance of 99% (p<0.01).

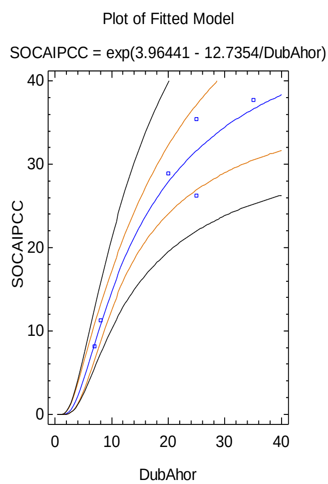

Fig. 1. S-curve function model of reserve of sequestrated C in A-horizon ($ResC_A$) and thickness of A-horizon (Ah) in afforestation by pit planting

This function shows that the reserve of sequestrated C has sudden growth by depth of 20 cm. Increasing the depth, the growth of C reserve is lower and tends to be constant. In afforestation by planting in bench terraces, the reserve of sequestrated C depends on thickness of A-horizon which is best shown by linear function (Fig. 2):

$$ResC_A = -1.91196 + 2.10663{\cdot}Ah,$$

where:

$ResC_A$ – reserve of sequestrated C in A-horizon ($t{\cdot}ha^{-1}$),
Ah – thickness of A-horizon (cm).
The model explains 90.22% variability of reserve of sequestrated C in A-horizon, and the relationship between variables is strong (coefficient of correlation is 0.950). The effect of thickness of A-horizon The thickness of A-horizon significantly effects on sequestrated C in A-horizon on the level of significance of 99% ($p<0.01$).

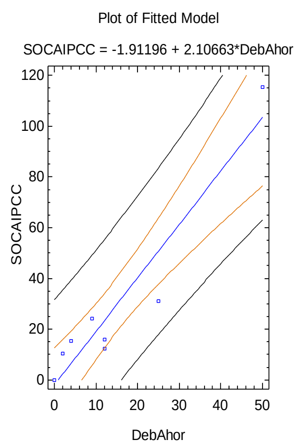

Fig. 2. Linear function model of reserve of sequestrated C in A-horizon ($ResC_A$) and thickness of A-horizon (*Ah*) in afforestation by planting in bench terraces

This function shows the linear increase in the reserve of sequestrated C in A-horizon increasing the thickness of A-horizon. On the sample plots afforested by pit planting, the reserve of sequestrated C in litter depends on the slope angle class which is best shown by logarithmic-X function (Fig. 3):

$$ResC_{Ol} = 48.65 - 46.9561 \cdot \ln(SlopeClass),$$

where: $ResC_{Ol}$ – reserve of sequestrated C in litter ($t{\cdot}ha^{-1}$), SlopeClass - slope angle class (according to Kostadinov *et al.*, 2008).
This model explains 92.47% of variability. Coefficient of correlation is -0.962 and implicates strong relationship between variables. The influence of the slope angle class on the reserve of sequestrated C in litter is 99% ($p<0.01$) level of significance.

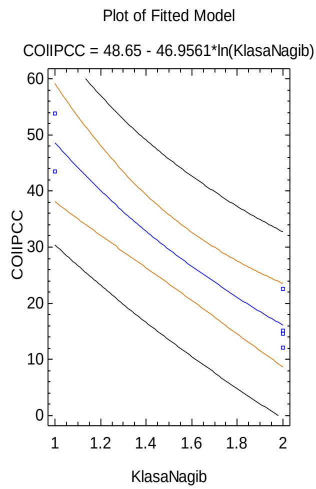

Fig. 3. Logarithmic-X function model of reserve of sequestrated C in litter ($ResC_{Ol}$) and slope angle class (SlopeClass) in afforestation by pit planting

According to obtained function, with the increase of slope angle the reserve of sequestrated C in litter decreasing. In this research, on afforestation by planting in bench terraces, the impact of slope angle on the reserve of sequestrated C in litter is not confirmed.

CONCLUSIONS

The results of research show higher C sequestration in soil profiles in bench terraces then in soil profiles between adjacent bench terraces and soil afforested by pit planting.

The thickness of A-horizon affects soil C sequestration. That effect is different in soils afforested by pit planting method and plating in bench terraces method. In soils afforested by planting in bench terraces the reserve of sequestrated C linearly increasing, and in pit planted soils exponentially increasing and have sudden growth by depth of 20 cm.

The slope angle affects C sequestration in litter of soils afforested by pit planting and with the increase of slope angle the reserve of sequestrated C in litter decreasing. In soil afforested by planting in bench terraces the impact of slope angle is not confirmed.

Obtained data shows planting in bench terraces method is efficient in carbon accumulation in soil and litter on higher slope angles. Furthermore, pit planting method, which is cost-effective, could be used on lower slope angles.

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EFFECT OF INOCULATES ON ABUNDANCE OF FUNGI AND ACTINOMYCETES IN ALFALFA RHISOSPHERE

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ABSTRACT

Alfalfa (*Medicago sativa* L.) is the most important legume that, in addition to high yield potential and quality of biomass, is characterized by an intense process of biological nitrogen fixation. Various microorganisms that can have a positive or negative effect on plant development are present in the rhizosphere of alfalfa. Certain rhizosphere microorganisms such as *Rhizobium meliloti* and *Azotobacter chroococcum* have nitrogen-fixing role and the role of bio-stimulators. But in addition to beneficial microorganisms, phytopathogen fungi can also occur. The aim of the research was to investigate the effect of inoculating alfalfa with two nitrogen-fixing bacteria (*Azotobacter chroococcum* and *Rhizobium meliloti*) and two species of the phytopathogen fungus *Colletotrichum* (*Colletotrichum trifolii* and *Colletotrichum destructivum*) on the number fungi and actinomycetes in the alfalfa rhizosphere. The highest number of fungi was determined in the treatment of inoculation with *C. destructivum* (isolate CC 657) and *A. chroococcum*, while the lowest number was recorded in treatment where *C. trifolii* (isolate Coll-4) was applied. In the control treatment (without inoculation) there was the highest number of actinomycetes, and the lowest abundance of these microorganisms was determined in the treatment with *C. destructivum (*isolate CC 657) and *R. meliloti* inoculation.

Keywords: rhizosphere, fungi, actinomycetes, nitrogen-fixing bacteria, phytopathogen fungi

INTRODUCTION

The root of alfalfa deeply penetrates the soil, improving aeration, structure and microbiological activity of it. In the rhizosphere of alfalfa, there are numerous microorganisms which can have different effects on the plant development. Rhizosphere microorganisms are directly influenced by root secretions (Macek *et al.*, 2000), so that microorganisms and plant make one cohesive unit (Raaijmakers *et al.*, 2009). Rhizosphere microorganisms have the multiple roles, such as the mineralization of organic compounds, maintaining the soil structure, suppressing pathogens (Janvier *et al.*, 2007), stimulating plant growth (Jarak *et al.*, 2007). Some of these microorganisms thrive on the root or by the root (azotobacter, actinomycetes, etc.), while rhizobia enters the tissue of plant roots. *Sinorhizobium meliloti* besides that it provides nitrogen to its macro-symbionts, also synthesizes polysaccharides, vitamins B_{12}, B_1, B_2 (Denison and Kiers 2004) and bio-control substances (Avis *et al.*, 2008). Besides binding elemental nitrogen, azotobacter produces biologically active substances: auxin, gibberellins, pyridoxine, biotin and nicotinic acid (Dobbelaere *et al.*, 2003). Due to their favorable impact, these microorganisms are used in the production of alfalfa.

In addition to beneficial microorganisms found in the soil, several phytopathogenic microorganisms are also present. These microorganisms cause weaker growth or death of plants and lower microbial activity in the rhizosphere of infested plants. One of the most important alfalfa diseases is anthracnose (Vasić *et al.*, 2009). It is most commonly caused by *Colletotrichum trifolii* Bain et Essary but also by *Colletotrichum destructivum* O'Gara (Boland and Brochu, 1989).

The aim of the research was to investigate the effect of inoculating alfalfa with two nitrogen-fixing bacteria (*Sinorhizobium meliloti and Azotobacter chroococcum*) and two species of the phytopathogenic fungus *Colletotrichum* (*C. trifolii* and *C. destructivum*) on number of fungi and actinomycetes in the alfalfa rhizosphere.

MATERIAL AND METHODS

The experiment was carried out in 10 l volume vegetation pots in semi-controlled conditions at the Institute for Forage Crops in

Kruševac. The soil chemical characteristics were the following: pH/KCl 5.90; pH/H_2O 6.44; total nitrogen 0.138%; humus 2.62%; P_2O_5 6.6 mg 100 g^{-1}; K_2O 24.05 mg 100 g^{-1}. For this study, alfalfa cultivar "K-28" was used, bred in the Institute for forage crops in Kruševac. Before sowing, the seeds were inoculated with *Sinorhizobium meliloti* and *Azotobacter chroococcum* (10 ml of inoculum per pot with 10^8 cells in 1 ml). The plants were mown after six-seven weeks and thereafter treated with *Colletotrichum destructivum* (Coll-11 isolate and CC 657 isolate) and *Colletotrichum trifolii* (Coll-4 isolate) conidia. The number of conidia was 4-6x10^4/ml. The number of conidia was determined by means of hemocytometer according to Tom.

The variants of the experiment were the following:

1. *C. destructivum* (Coll-11) + *R. meliloti*;
2. *C. destructivum* (Coll-11) + *A. chroococcum*;
3. *C. destructivum* (Coll-11);
4. *C. destructivum* (CC 657) + *R. meliloti*;
5. *C. destructivum* (CC 657) + *A. chroococcum*;
6. *C. destructivum* (CC 657);
7. *C. trifolii* (Coll-4) + *R. meliloti*;
8. *C. trifolii* (Coll-4) + *A. chroococcum*;
9. *C. trifolii* (Coll-4);
10. Control.

The effect of inoculation was determined at the end of the vegetation period. The number of microorganisms was determined by the method of agar plates, by introducing a diluted soil suspension into proper media and counted per one gram of absolutely dry soil. The number of fungi was determined on Capek's agar medium (dilution 10^{-4}) and the number of actinomycetes on synthetic agar according to Krasiljnikov (dilution 10^{-4}) (Jarak and Djurić, 2006). The results were processed by means of STATISTICS 8.0 programme. The significance of the difference between the investigated treatments was determined upon the analysis of variance, i.e. LSD test.

RESULTS

The results obtained in this research showed that applied inoculation had different effects on the abundance of observed microorganisms.

The highest number of fungi was recorded in the treatment with inoculation with *C. destructivum* (CC 657) and *A. chroococum*. In addition, compared to control, statistically significant increase was achieved in the inoculation with *C. destructivum* (Coll -11), as well as treatment with the combination *C. destructivum* (CC 657) and *S. meliloti.* In the treatment where only *C. destructivum* (CC 657) was applied, there was no change in number, while in other variants of inoculation the number of fungi was significantly reduced compared to the control. The highest number of actinomycetes was recorded in the control treatment. All of the inoculation variants achieved statistically significant reduction in number compared to the control. The minimum number of actinomycetes was recorded in the treatment with inoculation with *S. meliloti* and *C. destructivum* (CC 657).

Table 1 The effect of inoculants on the number (log) of fungi and actinomycetes (log of number) in the rhizosphere of alfalfa

Variant		The number of fungi	The number of actinomycetes
1.	Coll-11+ R. meliloti	4,602 ^{f}	5,185 ^{c}
2.	Coll-11+ A. chroococcum	4,674 ^{e}	5,114 ^{d}
3.	Coll-11	4,820 ^{b}	5,079 ^{f}
4.	CC 657+ Rhizobium meliloti	4,820 ^{b}	4,892 ^{h}
5.	CC 657+ A. chroococcum	4,857 ^{a}	5,182 ^{c}
6.	CC 657	4,690 ^{d}	5,000 ^{g}
7.	Coll-4+ R. meliloti	4,602 ^{f}	5,076 ^{f}
8.	Coll-4+ A. chroococcum	4,806 ^{c}	5,201 ^{b}
9.	Coll-4	4,524 ^{g}	5,086 ^{e}
10.	Control	4,690 ^{d}	5,212 ^{a}

Note: Mean values with the same superscript(s) are not significantly different according to Fisher's LSD test ($p< 0.05$)

DISCUSSION

A large number of microorganisms is introduced into the soil by application of microbial inoculation that brings changes in the abundance and composition of the indigenous population. The effect of inoculation depends on the abundance of indigenous population, activity of the host plant, soil properties, etc. (Brockwell *et al.*, 1995).

Fungi are very widespread in the rhizosphere of plants. For agricultural production most important are saprophytic fungi that act as decomposers (Jarak *et al.*, 2008). Our results indicate that the use of different species and different isolates of a phytopathogenic fungus *Colletotrichum* has different effects on the number of fungi in alfalfa rhizosphere soil.

There are also differences in the treatments and depending on whether only inoculation with *Colletotrichum* was applied or *Colletotrichum* isolates in combination with *S. meliloti* and *A. chroococcum* were applied. Generally, in all variants of inoculation, there were statistically significant differences comparing to the control, except for the variation where the isolate CC 657 of *C. destructivum* was applied. According to Schwieger and Tebbe (2000), introduced organisms may or may not have to have the influence on the existing structure of the microbial population.

Actinomycetes represent a group of organisms which encompass the significant share of the soil micro-flora (Takisawa *et al.*, 1993). They provide substances that act favorably on physiological processes in plants (Kumar *et al.*, 2010), and those that suppress plant pathogens (Getha *et al.*, 2005) and they actively decompose organic matter (Williams *et al.*, 1984). In our research, the application of inoculation with certain microorganisms negatively affected the number of actinomycetes. In concordance to our results, Mrkovački *et al.* (2008) recorded a decrease in the number of actinomycetes (1.6 to 5.4%) in the rhizosphere of sugar beet using inoculation with *Azotobacter chroococcum*. However, Gharib *et al.* (2009) point out that the inoculation of *Phaseolus vulgaris* L. with *Rhizobium leguminoarum bv. phaseoli* and *Azotobacter chroococcum* showed increase in the number of actinomycetes.

The effect of the applied inoculation showed a clear negative effect on the abundance of actinomycetes in the rhizosphere of alfalfa. Unlike actinomycetes, fungi abundance varied depending on the variant of inoculation. These are preliminary studies and to obtain complete information about presence of fungi or whether they are saprophytes or pathogens, it is necessary to continue research in this direction.

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NEMATODE COMMUNITY STRUCTURE AND THEIR FUNCTIONAL CHARACTERISTICS IN CHERNOZEMS

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ABSTRACT

The Nematode community structure and their functional characteristics were investigated in virgin and arable Chernozem of Northern Kazakhstan. Fourteen nematode families were found in the survey. In the ordinary chernozem, the most abundant feeding group was the group of plant parasitic nematodes (herbivores), bacterivores were less abundant and fungivores were the least abundant trophic group. In the southern chernozem, herbivores were dominant as well; bacterivores were less represented and followed by omnivores. The fungivores were the least abundant. The maturity index in ordinary chernozem showed that the most favorable conditions were in virgin soil in depth of 10-20 cm and 20-30 cm in arable soils. In the southern chernozem the most favorable conditions were in the upper soil layer. There were no significant differences in the sense of faunal composition, environmental conditions, ratio of families and trophic groups of nematodes in ordinary and southern Chernozem.

Key words: Nematode, community, structure, maturity index

INTRODUCTION

Nematode communities were used as bioindicators of changes in agroecosystems caused by anthropogenic factors (Bongers, 1990). The maturity index (MI), based on the nematode fauna is reflected by the condition of soil ecosystem. The use of this index in environmental studies is discussed.

Soil nematodes can be classified according to their food habits. A simplified Yeates trophic classification is being used (Yeates *et al*, 1993), which is based on the definition of nematodes community composition. This classification includes nematodes bacterial feeders

- bacterivores, hyphal feeders- fungivores, plant feeders- herbivores (plant parasites), omnivores, and predators. Bacterivores are the most abundant group in the agricultural lands. Nematodes that feed on fungi are abundant in old-growth (no-till) and natural ecosystems with suitable conditions for the growth of fungi (Ettema, 1998). Bacterivores contribute to the accumulation of nitrogen.

The study of soil nematodes as bioindicators of soil ecosystems is one of the important direct. There are changes in nematode complex that reflect the pollution and other disturbance of the soil (Ettema *et al*., 1998; Ferris *et al.,* 2001; Wasilewska 1997; Nahar *et al*., 2006). Indexes which characterize the nematode fauna reflect changes in communities with variations in environmental conditions. Ecological and trophic grouping of nematodes is used. Analysis of nematodes associated with plants contributes to a better understanding of the relationship between the plants and the processes occurring in the soil. More diverse plants composition contributes to the qualitative and quantitative enrichment of nematode fauna.

METHODS

The research was conducted 2011 in Northern Kazakhstan. The nematode communities were investigated in the southern and ordinary Chernozem, both virgin and arable soils, under the wheat in spring and summer. Each sampling was done in four replications, in 3 soil depths: 0-10, 10-20 and 20-30 cm. Soil was plowed for 25 cm and harrowed. Nematodes were extracted from 50 cm^3 of soil by the Seinhorst method (Seinhorst, 1956). Nematodes were identified to the family taxonomic level. Trophic structure was determined according to Yeates *et al.,* 1993. Maturity index was determined as described by Bongers (1990). The data were analyzed statistically, using ANOVA and LSD test.

RESULTS AND DISCUSSION

In total 14 nematode families were observed in ordinary Chernozem: 14 nematode families were founded in the virgin lands and 13 were founded at the arable lands. In the spring the greatest density of nematodes was on virgin soil at 0-10cm depth, which decreased by 1.8 - 4 times in 30 cm. The quantitative and qualitative nematode composition was richer in virgin, than in arable lands. The nematode density was 1.5 times less in the summer than in the spring. Nematode density on arable land was 2.4 - 7.6 times lower than in the virgin lands (Tab. 1).

Taxonomic structure based on composition of families. The average composition included 17.2 - 34.6% Cephalobidae in virgin soil and 14.3 - 30.0% in the plow soil. *Dorylaimidae* or *Oadsianematidae* amounted to 20% in virgin and arable Chernozem. Sometimes the plant parasitic nematode families, as *Hoplolaimidae*, *Longidoridae* and *Tylenchidae* were the first or second at density in virgin and the plow soils - to 20%. In most of the samples was founded *Pratylenchidae*, which was the dangerous for wheat and other crops. Rarely encountered and few were *Plectidae* and *Oxistominidae* families.

Soil nematodes can classified according to their feeding habits. The nematode feeding groups are called as bacteriovores, fungivores, predators, omnivores, herbivores by some authors. Bacteriovores are free-living nematodes feed on bacteria. They were included the families of *Cephalobidae*.

Fungivores feeds on fungi. Many members of the *Aphelenchidae* and *Aphelenchoididae* families are in this group. Bacteriovores and fungivores are very important in decomposition. Omnivores may feed more than one type of food. Some members of the families of *Dorylaimidae* and *Oadsianematidae* feed on fungi, algae, and other food. Herbivores are the plant parasites, which include many members of the order *Tylenchidae* and a few genera in the orders *Aphelenchida* and *Dorylaimida*.

According to the trophic classification by Yeates (1993) fining nematodes in soil samples belong to four feeding groups: bacteriovores, fungivores, omnivores, herbivores. Omnivores were represented by five families: *Dorylaimidae*, *Oadsianematidae*, *Oxistominidae*, *Panogrolaimidae*, *and Discolaimidae*. Bacteriovores were represented by family of *Cephalobidae*. Fungivores were represented by two families: *Aphelenchidae* and *Aphelenchoididae*. Herbivores had six families: *Tylenchidae, Nothotylenchidae, Paratylenchidae, Hoplolaimidae, Longidoridae, and Pratylenchidae*.

Table 1 Density of nematode families in ordinary Chernozem

Nematodes families	May						July					
	0-10		10-20		20-30		0-10		10-20		20-30	
	V	A	V	A	V	A	V	A	V	A	V	A
Plectidae	6.2		7.6				7.0		4.4			
Cephalobidae	84.2	9.6	41.8	5.9	10.3	5.6	31.6	6.7	26.1	6.2	6.4	5.0
Aphelenchidae	12.5	2.6	11.4		2.1	2.8	7.0	3.3	8.7	3.1	3.2	2.0
Aphelenchoididae	6.2	1.9		1.5			10.5	1.7	8.7	3.1		
Tylenchidae	18.7		7.6	2.9	10.3		10.5		4.4		3.2	2.0
Nothotylenchidae	9.4		7.6	1.5	4.1		7.0		8.7	3.1		
Paratylenchidae	9.4	2.6		2.9		2.8	7.0	8.3	8.7	4.6	3.2	3.0
Hoplolaimidae	9.4	2.6	15.2	1.5	14.5	1.4	10.5		4.4	4.6		4.0
Pratylenchidae	12.5	1.9	11.4	2.9		2.8	10.5		13.0	3.1	3.2	
Dorylaimidae	31.2	3.2	11.4	5.8	10.3	4.2	28.1	6.7	18.5	6.2	4.8	3.0
Oadsianematidae	28.3	2.6	19.0	4.4	8.3	2.8	21.0	3.3	4.4	6.2	4.8	2.0
Oxistominidae	6.2	1.9		1.5								
Discolaimidae			3.8				10.5	3.3	18.5		4.8	
Longidoridae		2.6	7.6	2.2	4.1	2.8	7.0		13.0	3.1		4.0
Total	243.3	32.0	136.7	30.0	60.0	25.0	168.3	33.3	148.3	43.3	34.0	25.0
Maturity index MI	1.18	1.72	1.89	1.72	1.65	2.08	1.64	1.8	1.76	1.35	2.2	1.57

Note: 0-10; 10-20; 20-30 – deepness of samples in cm. V-virgin soil, A-arable soil

In our study herbivores were found to be the most abundant feeding group of nematodes in ordinary Chernozem in virgin and tillage soils. Their relative abundance of bacteriovores averaged to 30.7 - 52%. Fungivores were the least abundant trophic group in this study. The average of relative abundance of fungivores was 3.4 - 15%.

Thirteen families of nematodes were founded in southern Chernozem on virgin soil and 12 were founded in arable. Faunal composition of nematodes in the ordinary and southern Chernozem was similar. The density of nematodes decreased to 30cm in virgin and arable soil (Tab. 2). The absolute abundance in 0-10cm depth was lower than in 10-20 and 20-30cm in the virgin and arable soil (Tab. 2). The absolute abundance in the virgin soil was lower than in arable soil to 1.3-2.6.

The average composition included 20.0 - 30.0% *Cephalobidae* in virgin soil and in the plow soil. *Dorylaimidae* were to 15.8%, or *Oadsianematidae* amounted to 13.6%-in southern Chernozem. Sometimes the plant parasitic nematode families, as *Hoplolaimidae*, *Longidoridae* and *Tylenchidae* were the first or second at density in virgin and the plow soils - to 20%. In the spring parasites *Longidoridae*, *Pratylenchidae*, *Hoplolaimidae*, and *Paratylenchidae* included 13,6-15,8%. Rarely encountered and few were *Plectidae* and *Oxistominidae* families.

Three families of omnivores - *Dorylaimidae, Oadsianematidae, Oxistominidae*, two fungivores - *Aphelenchidae, Aphelenchoididae*; two bacteriovores: *Panogrolaimidae, Cephalobidae*; six herbivores - *Tylenchidae, Nothotylenchidae, Hoplolaimidae, Paratylenchidae, Pratylenchidae* and *Longidoridae* were presented in southern Chernozem. Herbivores were dominated in the virgin and arable southern Chernozem (23.3 - 50.0%). Bacteriovores were 21.1 - 32.2%. Omnivores were represented by 17.9-36.4%. Mycotrophs were smallest trophic group (7.7-17.2%). The percentage of phytotrophs in the arable soil was higher than on virgin in the summer because the development of the root system of the host plant was developed.

Table 2 Density of nematodes families of southern Chernozem

Nematodes families	May						July					
	0-10		10-20		20-30		0-10		10-20		20-30	
	V	A	V	A	V	A	V	A	V	A	V	A
Cephalobidae	18.3	14.6	11.0	8.0	6.0	5.0	19.9	10.3	14.2	6.9	6.9	5.9
Panogrolaimidae	5.2						8.3					
Aphelenchidae	7.9	3.2	4.0	2.0	2.0	1.0	8.3	4.1	4.7	2.8	3.0	2.9
Aphelenchoididae	7.9	3.2	3.0	2.0		1.0	5.5	2.1		1.4	3.0	
Tylenchidae	7.9	3.2	3.0	2.0	3.0		8.3	4.1	7.1	1.4	3.0	
Nothotylenchidae	7.9		3.0		2.0	2.0		4.1		2.8		
Paratylenchidae	5.2	3.2	4.0	4.0	2.0	2.0	5.5	6.2	4.7	4.2	3.0	2.9
Hoplolaimidae	5.2	4.9	2.0	4.0	2.0	3.0	8.3		4.7		3.0	
Pratylenchidae			2.0	4.0					4.7	4.2	2.0	4.4
Dorylaimidae	10.5	4.9	4.0	4.0		3.0		6.2	7.1	4.2	3.0	4.4
Oadsianematidae	10.5	6.5	5.0	3.0	3.0	3.0	5.5	4.1	7.1	1.4	2.0	2.9
Oxistominidae	10.5	4.9	2.0	2.0	2.0	2.0	5.5					
Longidoridae				4.0					4.5			4.4
Total amount of Nematode:	91.7	48.7	43.0	39.0	26.09	22.0	85.3	41.3	59.0	33.3	28.0	28.0
Maturity index MI	2.1	2.2	1.86	1.63	2.9	2.08	1.9	1.8	2.26	1.34	1.56	1.68

Note: 0-10; 10-20; 20-30 – deepness of samples in cm. V-virgin soil, A-arable soil.

The maturity index (MI) of nematode populations in ordinary Chernozem showed that the most favorable conditions were formed on virgin soil at a depth of 10-20 cm, and in arable soils in a depth of 20-30cm. Determination of maturity index nematode populations (MI) in southern Chernozems showed that the most favorable conditions in the spring were formed on virgin and arable land in the upper soil layer. Thus, the faunal composition, the ratio of families and trophic groups of nematodes and environmental conditions of ordinary and southern Chernozem were similar.

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MICROBIOLOGICAL PROPERTIES OF CALCOCAMBISOLS IN WESTERN SERBIA DEPENDING ON EXPLOITATION WAY

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ABSTRACT

One of the most characteristic soil types in the hilly-mountainous region of western Serbia is calcocambisol or brown soil on limestone. In order to establish biogenity of this soil type, the representation of total microflora, fungi, actinomycetes, ammonifiers, azotobacter and oligonitrofiles was tested as well as dehydrogenase activity of this soil type. Samples were taken from the soil used in four different ways: plough-field, orchards, meadows and forests. Standard microbiological methods were used to introduce a specific decimal dilution on corresponding nutritive medium. The results showed the major variation in the presence of total microflora in plough-field, whereas the other ways of calcocambisol use resulted in a rather uniform presence of total microflora. No correlation was established between the number of other groups of microorganisms and the way of soil use and no correlation between dehydrogenase activity of analyzed samples and the total number of microorganisms.

Key words: biogenity, calcocambisols, microflora

INTRODUCTION

Microorganisms are the most significant biological soil component since with their enzymatic systems, they actively take part in the processes of decomposition of organic matter, synthesis of humus and creation of readily available plant assimilations (Milošević *et al.*, 2003). Tolerance of microorganisms to pesticides and heavy metals allows that particular species and types are used for soil bioremediation. Also, some bacteria live in the rhizosphere and they colonize the roots of plants and enhance plant growth

(PGPR - Plant Growth Promoting Bacteria) by synthesizing specific substances useful for plants (Glick, 1995), facilitating an adoption of specific feed from soil (Zahir *et al.*, 2004, Cakmakci *et al.*, 2006) and protecting plants from diseases. The number of some groups of microorganisms and dehydrogenase activity are used as one of the indicators of the general microbiological activity and potential soil fertility. A small number of some groups of microorganisms (i. e. nitrogen fixators) and a small value of dehydrogenase activity lead to smaller biogenity, or soil fertility (Milošević, 2008). Any type of soil has its own characteristic micro-biocenosis and the way of soil use may have positive or negative effects on microbiological activities and what is directly reflected on soil fertility (Tintor *et al.*, 2009).

Calcocambisols are relatively largely spread in Serbia and they are found on all solid limestone and dolomite. They exist in the hilly-mountainous region of western Serbia, where they occupy middle altitudinal belts and slopes that are more moderate. Mainly, they have a heavier granulometric composition but are well drained even when they contain clay.

It has been established that the physical and chemical characteristic of soil are the most important property affecting the number and activities of microorganisms (Milošević *et al.*, 1997; Marinković *et al.*, 2007). Chemical properties of calcocambisols are characteristic for their moderate acid reaction and the degree of saturation with bases is higher than 50%. In respect of the content of easily available phosphorus, those soils are deficient. As regards the easily available potassium, it ranges in those soils from poor to medium. In order to evaluate biogenity of those soils, their biological activity has been tested with regard to their use (plough-field, orchards, meadows and forests) The presence of different groups of microorganisms has been determined for this purpose as well as their dehydrogenase activity.

MATERIAL AND METHOD

The number and enzymatic activities of microorganisms are the largest in the surface soil layer. This is why the samples of soil from 20 locations for microbiological analyses were aseptically taken from the depth of 0-25cm. The following agrochemical analyses were performed in the prepared samples: pH in 1MKCl by electrometrical method (Jakovljević *et al.*, 1985), humus content and easily available forms of phosphorus and potassium by the Al-method according to Egner-Rhiem (Rhiem, 1958).

Basic parameters to evaluate soil biogenity were the following: total microflora, total number of fungi, actinomycetes, ammonifiers, azotobacter, oligonitrofiles as well as dehydrogenase activity. The number of microorganisms was determined with standard microbiological methods of introducing specific quantities of soil suspension on appropriate nutritive medium by using decimal dilutions (10^1-10^8), (Pochon and Tardieux, 1962). The number of total microflora was specified on the agaric soil extract, fungi on the Chapek medium, actynomicetes on the synthetic agar with sucrose according to Krasiljnikov, ammonifiers on the liquid medium with asparagine as a source of nitrogen, azotobacter on the liquid non-nitrogen medium with manitol and oligonitrofiles on the medium according to Fyodorov. Dehydrogenase activity was determined according to the Lenhard method (1956), modified by Thalman (1968), which is based on measuring extinction of triphenylformazan (TPF) that came into being by reduction of 2,3,5-triphenyltetrazoliumchloride (Thalman, 1968).

RESULTS AND DISCUSSION

Table 1 shows basic chemical properties of tested soils. Based on the specific pH value, one could say that tested soils are characteristic for strong acid to weak acid reaction. This matches literary data (Antić *et al.*, 1990) and it could be reflected on the number and enzymatic activities of soil microorganisms. Namely, the value of soil pH directly affects mobility of nutritive elements and conditions their availability for plants, but it also conditions the contents of the soil microbe population (Tintor *et al.*, 2009). As far as the composition of organic matter is concerned, one could say that soil tests have shown high humus content, whereas plough-field and orchards were poorer in humus and this is probably due to constant elimination of organic matter through harvests. This is not the case with forests and meadows. Supply of tested soil with easily available phosphorus was unsatisfactory, while supply of easily available potassium was medium to very high.

The number of microorganisms and dehydrogenase activity that point to the degree of biogenity of tested soil (Milošević *et al*, 1992) are shown in Table 2. The total number of microorganisms mostly varied in tested plough-field and ranged from 1.33-36.00 $\cdot 10^6 g^{-1}$, whereas in orchards it ranged from 5.33-9.00 $\cdot 10^6 g^{-1}$, in meadows from 6.33-8.50 $\cdot 10^6 g^{-1}$ and in samples of forest soil from 1.67-11.50 $\cdot 10^6 g^{-1}$. The largest number of microorganisms was found in plough-field and the smallest in soil under forest vegetation. This could be attributed to the beneficial effects of the applied agrotechnical measures on soil biogenity.

Fungi were unevenly present in tested soil that means that their number didnćt depend on landuse. In the samples of plough field their number ranged from 6.33 to 36.00 $\cdot 10^4 g^{-1}$, in meadows from 6.00 to 75.50 $\cdot 10^4 g^{-1}$ which is the largest number of those important mineralizers of organic matter in soil. But in the forest soil they ranged from 4.00 to 16.00 $\cdot 10^4 g^{-1}$.

The number of actinomycetes was rather uneven. In tested plough-field it varied from 3.00 to 16.00 $\cdot 10^4 g^{-1}$, in orchards 1.33 - 25.50 $\cdot 10^4 g^{-1}$, in meadows 0.33-17.00 $\cdot 10^4 g^{-1}$, while in forest soil it was 0.33-18.67 $\cdot 10^4 g^{-1}$. So, the presence of actinomycetes didn't depend on landuse.

Ammonifiers, as consumers of organic nitrogen and decomposers of protein, are one of the most spread groups of microorganisms in soil (Bogdanović, 1990). Their number in chernozem soil may reach the values from 10^7 to $10^9 g^{-1}$ (Govedarica *et al.*, 2000). In the plough lands, their number greatly varied and ranged from 0.40 to 110.00 $\cdot 10^5 g^{-1}$, while in forest soil there was great variation from 0.9 to 110.00 $\cdot 10^5 g^{-1}$.

Azotobacter, as an indicator of soil fertility and the strongest associative fixer of atmospheric N, showed poor quantity in plough-field, orchards, meadows and forests. According to literature data, azotobacter in plough-field may reach the number of $10^3 \cdot g^{-1}$ (Govedarica *et al.*, 1996; Jarak *et al.*, 2003), and this leads to the conclusion that Calcocambisols don't supply optimum conditions for activity of this nitrogen fixer probably due to its unfavorable chemical properties and mainly because of acidity and small phosphorus supply (Milošević *et al.*, 2007). The research showed that these parameters of soil chemical property resulted in the absence of azotobacters.

Table 1 Basic chemical properties of tested soil

LAND USE	Location	pH (1MKCl)	Humus (%)	P_20_5 (mg·100g^{-1})	K_20 (mg·100g^{-1})
PLOUGH-FIELD	1	4.55	3.67	0.9	30.6
	2	5.15	2.98	9.64	19.4
	3	5.5	4.45	7.95	25.0
	4	4.75	3.1	5.68	27.2
	5	4.4	4.72	0.9	20.8
	6	6.1	5.2	16.18	31.4
ORCHARDS	1	5.55	2.08	10.13	34.6
	2	5.3	3.98	12.22	22.7
	3	4.1	4.16	0.9	42.00
	4	3.9	4.36	0.9	29.6
MEADOW	1	3.5	5.03	0.5	27.4
	2	5.75	6.55	1.02	23.6
	3	5.3	7.96	0.9	21.2
	4	5.95	8.95	6.78	41.0
	5	5.3	6.89	0.9	41.0
	6	6.15	9.42	5.8	42.0
FOREST	1	4.1	5.31	0.45	17.8
	2	5.35	4.21	0.9	17.7
	3	4.4	5.81	13.78	41.0
	4	4.15	12.4	8.8	32.4

Table 2 Number of microorganisms per „g" of absolute dry soil and dehydrogenase activity

Method of using soil	Sample N°	*Total microflora (x10^6)	*Fungi (x10^4)	*Actinomycetes (x10^4)	*Oligonitrophiles (x10^5)	*Ammonifiers (x10^5)	Azotobacter spp **(MPN)	Dehydrogenase activity (µg·TPF)
PLOUGH-FIELD	1	5.33	9.67	9.33	17.33	15	45	40.31
	2	8.67	11.33	12.50	18.11	10	95	81.72
	3	1.33	18.00	16.00	8.00	0.4	95	126.4
	4	91.00	36.00	12.67	223.00	110	95	21.47
	5	2.33	6.33	3.00	3.00	0.4	25	14.81
	6	3.33	12.00	14.67	96.00	2	25	84.69
ORCHARDS	1	9	3.50	17.67	108.00	45	95	67.51
	2	5.5	7.00	8.00	79.50	150	25	63.86
	3	5.00	9.00	25.50	49.67	45	25	62.19
	4	5.33	20.5	1.33	7.33	0.4	0	3.88
MEADOW	1	6.67	18.00	3.00	70.00	4.5	25	1.62
	2	6.33	8.00	9.33	85.33	7.5	95	45.85
	3	7.67	75.50	14.50	25.67	25	4	25.29
	4	8.33	9.00	17.00	57.00	25	45	109.51
	5	12.33	12.50	3.33	90.00	2	25	20.85
	6	8.50	6.00	0.33	60.33	2	95	53.44
FOREST	1	11.50	4.00	18.67	18.50	45	25	33.85
	2	6.33	5.00	9.33	70.33	110	25	25.66
	3	9.00	13.00	16.33	33.33	9.50	25	16.69
	4	2.67	16.00	0.33	12.00	0.9	0	2.66

* Number of microorganisms per "g" of absolute dry soil
**MPN – Most probable number of microorganisms

Oligonitrofiles, as fixers of atmospheric N for the supply of own needs and supplying plants with available N (Bogdanović, 1990), were dominant physiological group of microorganisms in tested samples. Their presence in tested plough-fields varied from 3.00 to $233.00 \cdot 10^5 g^{-1}$, in orchards $7.33\text{-}108.00 \cdot 10^5 g^{-1}$, in meadows 25.67-$90.00 \cdot 10^5 g^{-1}$ and in the forest soil $12.00\text{-}70.33 \cdot 10^5 g^{-1}$. Plough-field locations contained their largest number (sample 4).

Determination of enzyme activity taking part in mineralization of organic matter in soil is an indicator of soil biological activity (Najdenovska *et al.*, 2004). One of those enzymes is the oxydoreduction enzyme dehydrogenase. Dehydrogenase activity of tested plough-field ranged from14.81 to 126.4; in orchards 3.88-67.51; in meadows 1.62-109.51 and in forest 2.66-33.85 and it was not in correlation with the number of tested groups of microorganisms. The increased dehydrogenase activity of plough field and orchards in relations to meadows and forests could be attributed to beneficial effects of the application of agrotechnical measures to the activity of this enzyme.

CONCLUSION

Calcocambisols in the western Serbia showed uneven biogenity that didn't depend on landuse. Plough field samples showed major unevenness in the number of total microflora, whereas the presence of fungi, actinomycetes, ammonifiers, azotobacter and oligonitrofiles didn't depend on landuse. Azotobacter was poorly presented in all locations and this could be a result of unfavorable chemical properties of tested soil, or acidity and poor supply of easily available phosphorus. Dehydrogenase activity didn't correlate with the number of microorganisms and this was somewhat greater in locations under plough field and orchard than in meadows and forest soil.

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STATUS OF AVAILABLE P AND Fe IN VERTISOL UNDER LONG TERM APPLICATION OF PHOSPHORIC FERTILIZERS

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ABSTRACT

The trials have been done on a part of two-fields long-term experiment in the vicinity of Kragujevac. The experiment has been formed in the year 1978, at the soil type Vertisol, characterized with highly acid reaction, low content of of available P_2O_5 and very high concentration of available Fe. The crops in the experiment have been wheat and maize. The objective was to determine influence of continuous 33 years application of two doses of phosphoric fertilizers (60 kg and 100 kg P_2O_5), on a basic soil properties, as well as an influence on the content of available P_2O_5 and Fe. Variants of the experiment have been set up that phosphoric fertilizers have been applied individualy (P_{60} and P_{100}), then in combination with nitrogen ($P_{60}N_{80}$ and $P_{60}N_{120}$) and in combination with Nitrogen and Potassium ($P_{60}N_{80}K_{60}$ and $P_{100}N_{80}K_{60}$). The treatments were set in 7 combinations, with 4 repetitions each. Chemical analyses have been done in 2010. Results showed that long term application of phosphoric fertilizers has multıply increased innitial level of available phosphorus. At the same time, content of available Fe, instead of expected level, it has been slightly increased. The other parameters of fertility (pH, humus, available K_2O i.e.) have been mainly remained on a same level compared to initial status.

Key words: available phosphorus, available iron, Vertisol, long-term fertilizing

INTRODUCTION

Rational fertilization and soil fertility management are among the most important measures for improving the yields and for efficient use of water, which makes crop production sustainable, and it is important to meet the demand for food for growing world population (Fan *et al.*, 2005). However, the use of inorganic fertilizers, especially N, P and K is not only being used to maintain and improve crop yields, but directly and indirectly causes changes in chemical, physical and biological properties of soil. It is being believed that this change in the long-term use of fertilizers, have a significant impact on the quality and productive capacity of the soil (Belay *et al.*, 2002).

Awareness about the possible changes caused by long-term usage of fertilizers is of particular importance in acid soils. Namely, these soils more or less are the unfavorable environment for the successful cultivation of crops, and any inappropriate usage of fertilizers leads to a long-term further degradation. One of the numerous reasons of poor growth and development of plants in acid soils is difficult phosphorus fertilizing, which is related to the low solubility of its compounds. The appropriate concentration of phosphorus in the soil solution and its continuous filling in the solid phase of soil, are necessary to maintain a high level of agricultural production (Matula, 2011). Acidic soils, as a rule cannot meet these requirements, because the content of the available forms of phosphorus are often below the minimum amount required for normal growth and development of plants. In such conditions, the most common reason for the deficit of phosphorus in the plant nutrition is its low content in the parent substrate. However, it can be found the opinions that in acid soils factors of difficult nutrition with phosphorus and high concentrations of some metals that react with are forming an insoluble compounds. Specifically, in very acid soil phosphate ion deposition occurs due to high concentrations of Al, Fe and Mn. Then, mostly are being formed aluminum phosphate - Variscit Al (OH) $_2H_2PO_4$ and iron phosphate - Strengit $Fe(OH)_2H_2PO_4$ (Jomo *et al.*, 2007). Consequence of the formation of these compounds is insufficient content of plant available phosphorus.

On the other hand, high concentrations of Fe and increase oh its mobility over the allowed limits, influent harmful to the plant, then the plants are getting found in the so-called "Stressful conditions". Higher mobilities of Fe and Mn, are being expected in the soils having pH <6.5 (Kabata-Pendias, 2004), especially at values less than 5.5 (Jakovljević *et al.*, 1997; Milovac *et al.*, 1997).

The problems that occur as a result of limited availability of phosphorus in acid soils can be solved by regular use of fertilizers that contain this element. However, the long-term and continuous use of fertilizers, and phosphoric too, inevitably takes to the changes in soils. The occurred changes are the result of the structure of fertilizer and soil reaction to its constant application. Direction of the reaction can be positive (improve some properties) and/or negative (further degradation of existing bad qualities or appearance of new) which must be considered in choosing the type of fertilizer and its quantity. Therefore, the aim of the study has been that the perennial field experiment in acid conditions, determine the effect of phosphorus fertilizers on the accumulation of available phosphorus and iron, but also other characteristics of degraded Vertisol.

MATERIAL AND METHODS

The research has been carried out on two stationary field trials of the Center for Grain Crops in Kragujevac. Since 1978 it has begun examination of the influence of perrenial application of N, P and K fertilizers on the soil type Vertisol, related to the soil properties and yields of wheat and corn, which have been grown in two-field crop rotation. The main characteristic of Vertisol, which has been performed for the study, has been acidic reaction and very low phosphorus content. Applied technology of tillage, planting and care of crops has been done by the standards for the cultivation of wheat and maize.

Phosphoric fertilizers have been applied in two quantities, at the levels of 60 and 100 kg P_2O_5 ha^{-1} individualy (variants P_{60} - V2 and P_{100} - V3), than in combination with 80 kg ha^{-1} nitrogen (variants $N_{80}P_{60}$ - V4 and $N_{80}P_{100}$ - V5) and in combination with 80 kg ha^{-1} of nitrogen and 60 kg ha^{-1} potassium (variants $N_{80}P_{60}K_{60}$ - V6 and $N_{80}P_{100}K_{60}$ - V7). Treatments in wheach fertilizers which have been applied have been compared with the control, or with a variant which has not been fertilized (V1). During the research, for implementing of phosphorus it has being used super phosphate, urea for nitrogen and KAN, and for potassium 40% potassium salt.

The experiment has been conducted as a randomized block system with four repetitions. Average soil samples for analysis have been taken from the surface depth of 20 cm in the autumn of 2010. Formation of average samples was at the plot basic and the samples have exemplified a combination of the given plots.

Soil pH has been measured at pH-meter with a glass electrode in 1:2.5 suspensions with distilled water (active acidity) and 1N KCl (substitutional acidity). Available P and K were determined by the AL method of Egner-Riehm. The examined elements have been first extracted in aceto-lactate solution, followed by readings of the potassium content in the filtrate by flame photometer, and phosphorus content in a spectrophotometer after coloring the filtrate with ammonium molybdate and $SnCl_2$. Humus has been determined by the method of Kotzmann, and total N using the Kjeldahl. Available iron has been determined by atomic absorption spectrophotometry (AAS) after extraction in 1M CH_3COONH^4 (pH = 4.8).

Data were analyzed using standard statistical methods of analysis of variance (ANOVA) using Microsoft Excel 2007 and Statistical Program 5.0. Data analysis has been used to interpret the results and draw conclusions.

RESULTS

Perennial application of phosphoric fertilizers in a higher or lower extent have influenced on the changes of physiological parameters of the Vertisol's fertility (Table 1). Acidity in all variants of fertilization compared to the control was increased. An exception was noted only in the substitution acidity on the variant V6 ($N_{80}P_{60}K_{60}$), in which the acidity was 0.06 pH units lower compared to the control. It should be pointed out that the average pH of the active acidity when entering fertilizer reduced compared to the control, and set differences were generally statistically very significant. Namely, only between the control (V1) and variants of V3 (P_{100}) it was a significant difference in the level of statistical significance. Very significant differences were between variants of fertilization. It has been changes with substitutional acidity and its smallest average value, as well as at the active acidity, has been noted in the variant V5.

This direction in change and intensity of acidity justifies the idea that the perennial application of NP fertilizers, particularly where the applied combination was 80 kg N ha^{-1} P_2O_5 and 100 kg ha^{-1}, had the highest influence on the reduction of Vertisol's pH.

Table 1 Characteristics of Vertisol in the system perennial application of fertilizers after 33 years

Varijant	pH		Humus	Total N	K_2O
	H_2O	KCl	(%)	(%)	(mg 100^{-1}g)
V – 1	5.56	4.28	2.46	0.163	22.13
V – 2	5.36	4.13	3.02	0.173	25.18
V – 3	5.42	4.20	3.09	0.175	26.55
V – 4	5.20	4.18	3.43	0.168	23.80
V – 5	5.18	4.11	3.45	0.175	21.80
V – 6	5.30	4.34	3.28	0.183	31.63
V – 7	5.23	4.27	3.12	0.180	28.38
Lsd 0.05	0.11	0.071	0.33	0.015	3.47
Lsd 0.01	0.16	0.096	0.45	0.021	4.72

The major changes were detected in the amount of humus. In fact, at all the variants of fertilization it has been observed very significant increase of humus compared to unfertilized treatments. The highest average content has been found in variants of V4 ($N_{80}P_{60}$) and V5 ($N_{80}P_{100}$), or where they are used only phosphorus and nitrogen for fertilizing, and the lowest in the variant which where have been used the lowest amount of phosphorus fertilizer (60 kg ha^{-1}) or the variant V2. However, the differences between these variants were only at the level of statistical significance.

The lowest changes were noted in the content of total N and available K_2O and direction of change was similar. In fact, all variants of fertilization affected the increase of its content in the soil, and the highest concentrations were detected in variant were have been applied all three elements (V6 and V7).

Perennial application of phosphorus fertilizers significantly influenced the content of available phosphorus in the studied soil (Fig. 1). In all the treatments, regardless of the amount of phosphorus and combination with other elements, there is an increase in its concentration in the soil and differences compared to control are very significant. Precisely, after 33 years of continuous application of phosphorus in the smallest amount of 60 kg ha^{-1} (V2, V4 and V6) it came to its accumulation at the combination of these, and its content is at least tripled compared to baseline. The most likely reason for the accumulation of available P is its incomplete utilization by the wheat and maize.

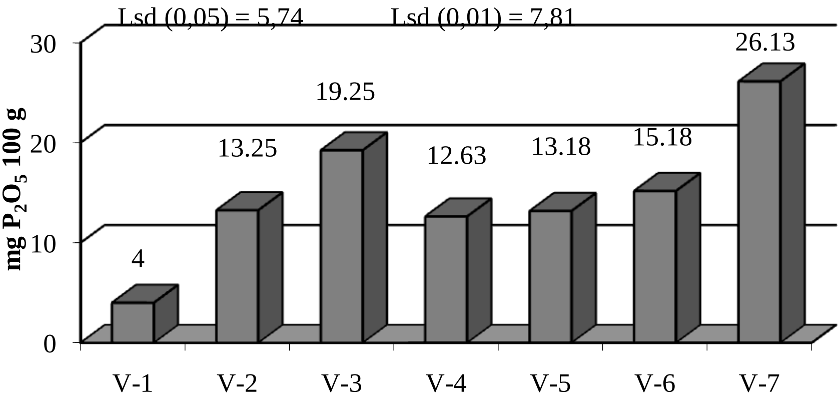

Fig. 1. Influence of perennial fertilizing on a content of available phosphorus

Presumption that applied phosphorus planted grains have not fully used and that this surplus very significant impacts on its balance, its corroboration finds in the fact that a further concentration increase occurred in variant with applied 100 kg P_2O_5 ha^{-1}. In fact, it is the largest recorded its content, which is the V7 variants was 26.13 mg 100 g-1, and the variant V3 19.25 mg 100 g^{-1}.

The content of an available iron in all variants in which fertilizers have been applied, have expressed a tendency of increase compared to the control. A review of the results shown in Graph 2, it can be noted that after 33 years, the combination in which were applied nitrogen and phosphorus have mostly affected the change in the content of available forms of Fe. Namely, among them an increase of Fe concentrations in the variant V4 ($N_{80}P_{60}$) occurred. The average content was 122.5 ppm, and in variant V5 ($N_{80}P_{100}$) 122.25 ppm.

Thus, the content of available Fe in both NP variants has been significantly higher than in the other variants, regardless of whether they were fertilized or not. The exception is the V3 variation in respect which of the NP variants had a higher content at the level of 5%. For other combinations of fertilization Fe content was generally equilized. Among them, there were no statistically significant differences, but they all had significantly higher concentrations of this element in relation to the variation that was not fertilized.

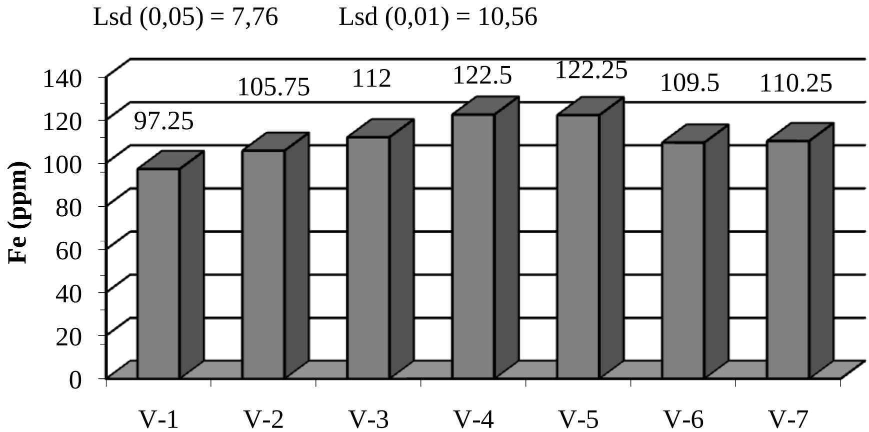

Fig. 2. Influence of perennial fertilizing on a content of an available iron

DISCUSSION

Perennial experiments with the application of fertilizers are an important source of information for understanding the factors that affect soils fertility and their sustainable production (Zhao *et al.*, 2010). It is known that inorganic fertilizers, especially NPK, besides of improving the crop yields, directly or indirectly cause changes in chemical, physical and biological properties of soil. Some studies suggest that perennial use of mineral fertilizers, results in deterioration of soil quality. One of the problems of phosphorus fertilizer usage may be the accumulation of heavy metals for instance: cadmium - Cd (Mulla *et al.*, 1980) or radioactive elements such as uranium - U (Stojanovic *et al.*, 2006) and Thorium - Th (Wetterlind *et al.*, 2012), and the long use of nitrogen fertilizers often leads to a reduction in soil pH (Bolan *et al.*, 1991; Khonje *et al.*, 1989). Particularily in Vertisol, which is characterized by primary acidity, the use of NP fertilizers led to a obvious increase of acidity, which can be considered as its further degradation.

As expected, the long-term application of phosphorus fertilizers had the highest impact on the phosphorus content, contributing to the accumulation of its available forms in the area of application (Cakmak *et al.*, 2010; Maroko *et al.*, 1999; Otto and Kilian, 2001; Richards *et al.*; 1998; Selles *et al.*, 2011). On such balance of available phosphorus certainly has influenced his incomplete adoption by the wheat and maize. However, it should not be excluded the possibility that the fertilized crops by stronger root systems used phosphorus from deeper layers as well. More precize, after the harvest through crop residues and their mineralization, crops have contributed to its further increase content in the surface layer.

The link between phosphorus in the soil reserves and entered by fertilizers and micronutrients in the soil is not always clear. However, numerous authors express oppinion that application of phosphorus fertilizers do not significantly affect the concentration of Fe and other trace elements (Richards *et al.*, 2011; Rutkowska *et al.*, 2009). The results of these studies indicate a stronger relationship between acidity and content of available Fe. In fact, it is observed that the highest concentration of available Fe is at the variants in which pH is time decreased (V4 and V5).

CONCLUSION

Continuous phosphorus fertilizers application of 33 years, without or in combination with nitrogen and potassium, has led to some changes in the basic properties of Vertisol. The change in pH was mainly influenced by a combination of NP, which contributed most to the increase in acidity. With this combination, we determined a significant impact on increasing the amount of humus and available iron. There was a connection between a simultaneously decrease of pH and increase of the content of available iron. The applied fertilizers did not significantly affect the content of total nitrogen and available K_2O. The highest changes have been observed at the content of available P_2O_5 which had the biggest influence on maximum dosage of phosphorus applied together with nitrogen and potassium (NPK), or independently. A significant increase of physiologically active forms of phosphorus have been observed at the usage of lower doses of phosphorus. This trend justifies the use of phosphoric fertilizers on acid soils with low and very low content of available phosphorus. However, the achieved level of available P_2O_5, after 33 years of fertilization, initiates awareness, because during a time it may increase concentrations which could be unacceptable from the economic and environmental aspects.

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ASSESSMENT OF SOIL PRODUCTION POTENTIAL OF SOME FOREST TYPES IN NATIONAL PARK "KOPAONIK"

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ABSTRACT

The soil production potential was researched in two forest types in the area of the National Park "Kopaonik" - MU "Samokovska Reka". The soil production potential was evaluated based on the study of the soil physical and chemical characteristics. As stand productivity indicators are in direct correlation with the soil fertility, this paper also evaluates the production potential based on mean heights. The correlation analysis shows to which extent some characteristics of the study soils affect the mean heights of spruce.

Keywords: soil, production potential, mean heights, Kopaonik

INTRODUCTION

In agriculture and forestry, soil represents the basic means of production. Consequently, the assessment of its productivity and finding the ways of its increase are the main problems of the soil science. The most reliable measure of forest soil productivity is the volume of produced timber.

Forest trees differ very much regarding their soil demands, and different species on the same soil can have different yields. Generally, there is not a universal measure for the assessment of forest soil productivity; it should be evaluated separately for each individual tree species.

The criteria for the assessment of forest and agricultural soil productivity are very much different. On many forest soils, woody species reach high increment (e.g.: spruce on brown podzolised soil), and simultaneously, from the aspect of agricultural production, the same soil is entirely unfavourable. This is not only the consequence of forest tree species lower demands for nutrients, but also it is the result of the ability to develop a sturdy and strong root system which occupies a large portion of soil mass. Forest tree species have higher ability of nutrient extraction by uptaking the less soluble compounds (Ćirić, 1984).

In modern conditions of sustainable forest management, one of the main tasks of forestry profession is, by all means, to reach high forest productivity. Forest productivity is the realised degree of soil fertility, i.e. soil potential, expressed through productivity, production, and yield.

Soil fertility is the result of a special constellation of pedogenetic factors (climate, vegetation, parent rock, relief, organisms and soil genesis), and also an unavoidable human impact in modern conditions. Soil fertility is a dynamic state of different physical, chemical and biological properties and processes in the soil. Džamić and Stevanović (2007) claim that general soil fertility is determined by the depth of the physiologically active soil horizon (layer), nutritive regime, air characteristics, temperature regime, soil pH, water and nutrient accumulation in the active soil layer, soil ability to eliminate the inhibitors of normal root development. The authors emphasise the equal significance of all the above factors, as well as the impossibility to replace one factor by another.

It is impossible to determine how much soil fertility affects the total wood volume production, because the effect of soil cannot be separated from other site factors. Still, it can be defined to which extent the productivity of the same tree species differs on two different soil types, and also how much two or more tree species differ in productivity on the same soil.

Soil study is a very significant foundation for the evaluation of productivity of forest types (Jović *et al.*, 1996). There are different methods of evaluation of soil fertility and plant yield. In forestry, the term which describes the potential for forest trees to grow at a particular location or site is called site index (Hamilton, 1995; Nyland, 2002; Avery and Burkhart, 2002) and it is most often determined using tree height.

MATERIAL AND METHOD

The base for this paper are the results of soil research performed in the area of MU "Samokovska Reka" for the definition of forest types. The ecological phase of the typological definition was researched by Knežević and Cvjetićanin (2002/2003), and the development-production phase was researched by Banković, Medarević and Pantić (2003).

The forest production potential is assessed based on the analysis of morphological, physical and chemical soil characteristics and based on some elements of stand productivity (mean heights). The impact of soil characteristics on productivity was evaluated using the correlation analysis of individual characteristics of the study soil types and mean heights.

The applied statistical analyses include the analysis of variance and regression analysis, i.e. correlation analysis. To determine the difference between mean heights in the forest type 745 - spruce, fir and beech (*Piceo-Abieti-Fagetum typicum*) on brown podzolised soil on granodiorite (Banković and Medarević, 2009), on the one hand, and mean heights in the forest type 755 - spruce, fir and beech with fescue grass (*Piceo-Abieti-Fagetum drymetosum*) on eutric humus-siliceous soil and eutric brown soil on serpentinite (Banković and Medarević, 2009), on the other hand, we applied the analysis of variance and LSD-test, at the significance level of 95%.

The effect of soil characteristics on the production in the above ecological units was determined using regression and correlation analysis. The comparison was based on analytical data on soil characteristics in the form of weighted arithmetic mean for the entire profile, in which the soil horizon depth was used as ponder. The production indicators of the study soil types were spruce mean heights.

The assessment of correlation strength was performed using Roemer-Orphal's distribution, by which the correlation is non-existent between characteristics from 0.00 to 0.10, correlation is very weak from 0.10 to 0.25, correlation is weak from 0.25 to 0.40, moderate from 0.40 to 0.50, strong from 0.50 to 0.75, very strong from 0.75 to 0.90 and perfect from 0.90 to 1.0.

RESULTS

Soil is a complex system resulting from the inter-relationship of a great number of factors biotic and abiotic nature, primarily geographic position, orographic factors, parent rock, climate, vegetation, etc.

Kopaonik is a mountain located in the centre of the southern part of Serbia. It is sited between the rivers Ibar and Sitnica in the west and Lab in the southeast. Its eastern border is the border between the Dinarids and the Rhodopes. The study area is the area of MU "Samokovska Reka" which covers 2,985.08 ha.

Kopaonik is a region with an intensive tectonic activity during the geological history, especially during the Upper Cretaceous period and during the Tertiary, when its main geological and morphological structures were formed. It was especially characterised by magmatic-volcanic activity which is evidenced by the presence of deep complexes of magmatic, eruptive and metamorphic rocks and volcanic tuffs: granodiorites, andesites and dacites, serpentinites, diabases, hornfels, etc.

The highest, relatively flattened part, the so-called Ravni Kopaonik is a remnant of the fossil fluvial area, at the altitude of about 1,700 m, mostly composed of granodiorite. The granodiorite core is in the form of a ring surrounded by sericite-chlorite schist, and around them, to the south and west, there is a serpentinite ring, as far as Jošanička Banja, and to the east as far as Brzeće and more to the north. Very large areas in the western part, sited between granodiorite and serpentinite, consist of limestone and dolomites, marbles and calcschists. To the west of Suvo Rudište, and along the right side of the river Gobeljska Reka, there are crystalline and layered limestone. Eastern parts consist mostly of basalt breccias and conglomerates, and in the south and southeast there are quartz-latites and latites. Significant areas along the left bank of the Brzećka Reka consist of argillites, marls, sandstones, hornstones and diabases, as well as ***diabase-hornstone formations***.

Kopaonik is characterised by alpine humid to perhumid climate. Mean annual air temperature is 3.7°C, with the average annual precipitation above 1,000 mm, with snow from November to May.

The assessment of soil production potential and some elements of stand productivity is presented for two forest types:

1. Forest type spruce, fir and beech (*Piceo-Abieti-Fagetum typicum*) on brown podzolised soil-forest type 745;

2. Forest type spruce, fir and beech with fescue grass (*Piceo-Abieti-Fagetum drymetosum*) on eutric humus-siliceous soil and eutric brown soil on serpentinite-forest type 755;

The soil in forest type 745 (brown podzolised soil on granodiorite) was studied in the communities of spruce, fir and beech (*Piceo-Abieti-Fagetum typicum*), at the altitudes of about 1300 to 1500 m, with different aspects, but with the dominance of cooler aspects, on the slope of about 10-25°. Bedrock is composed of granites and granite-monconites of compact texture - unweathered, belonging to the group of magmatic rocks. They are characterised by a low content of minerals which are transformed into clay. The soils formed on these substrates contain a high percentage primarily of fine sand, then of coarse sand, and a low quantity of total clay, the content of which is uniformly distributed over the profile. There is no erosion hazard– it is a stable terrain in natural conditions. Humification processes are unfavourable leading to the formation of a horizon of semi-raw to raw humus on the soil surface. The layer of ground flora is dense and the shrub layer is moderately dense.

The soil in forest type 755 (eutric humus-siliceous soil and eutric brown soil on serpentinite), was researched in the community of spruce, fir and beech with fescue grass (*Piceo-Abieti-Fagetum drymetosum*), at the altitudes of about 1100-1450 m, on steep to very steep terrains (25-35°), mainly on the warmer, north-eastern and north-western aspects. Bedrock is composed of serpentinites of compact texture - unweathered. There is a risk of water erosion. The percentage of soil litter is average, and humification processes are unfavourable. The layer of ground vegetation is moderately dense, and the percentage of shrubs is low.

The aim of the paper was to assess the soil production potential in the study forest types in the area of MU "Samokovska Reka". The assessment of the production potential was based on:

- morphological, physical and chemical properties of the study soils - assessment based on soil characteristics;
- some elements of stand productivity (mean heights) - assessment based on mean heights of spruce;

- correlation analysis, which shows to which extent the particular characteristics of the study soils affect the spruce mean heights.

Assessment based on soil characteristics

The soil in forest type 745 (brown podzolised soil) is deep (depth 63-99 cm, average 80.20 cm), and the surface horizon - A/E is poorly developed (depth 9-18 cm, average 12.60 cm). As for the particle size distribution (Tab. 2), the study soil is sandy loam with a low percentage of colloid particles (5.90-15.40%, average 10.64%). Soil reaction (Tab. 1) is mainly very acid (pH in H_2O = 4.25-5.75, average 4.95). Hydrolytic acidity is high and ranges from 14.50-85.70 ccm n/10 NaOH, average 43.50 ccm n/10 NaOH. Total adsorption capacity varies from 14.12 to 58.82 cmol/kg, average 32.76 cmol/kg. Base saturation degree is low (ranges from 0.00-37.01%, average 15.52%). The layer of raw humus is 5-6 cm deep. Humus percentage varies from 1.28-18.15%, average 7.74%, and the percentage of total nitrogen is from 0.00-0.68%, average 0.30%). The amounts of readily available potassium are low and range within 1.30-18.00 mg/100 soil, average 6.66 mg/100g soil). The study soils are poorly supplied with readily available phosphorus (0.30-10.00 mg/100g soil, average 3.31 mg/100g soil). Slow transformation of organic residues has an adverse effect on the regime of mineral nutrition and soil fertility. The soil productivity in forest type 745 is medium. The unfavourable effect of the slow mineralisation on soil fertility is to some extent compensated by favourable physical, i.e. water and air properties.

Eutric humus-siliceous soil and eutric brown soil on serpentinite occur in different forms, both from the aspect of development, and from the aspect of solum depth and content of skeleton. Soil depth, in forest type 755, varies from 30 to 75 cm, average 48.17 cm. The depth of surface A-horizon depends on the degree of soil development and varies from 10-40 cm, average 28.17 cm. The main characteristic of this soil type is the presence of skeleton and its content ranges between medium and high (Škorić *et al.*, 1985). The study soils vary from sandy loams to loams (Table 2). The sizes of dominant particles in all analysed soils vary from 0.06-0.002 mm (silt). The percentage of colloid particles is low (1.10-15.40%, average 7.39%). Because of slow decomposition processes of organic residues, the acidification of the surface soil layer is high. The intensity of acidification decreases with depth and, in deeper forms, in the lower solum layers, the reaction is close to neutral (Tab. 1). Soil pH is mainly within the limits of moderately acid to weakly acid (pH in H_2O =5.95-6.84, average 6.40).

Hydrolytic acidity is low and varies from 5.33-22.77 ccm n/10 NaOH, average 12.10 ccm n/10 NaOH. Total adsorption capacity varies from 22.82-57.69 cmol/kg, average 41.85cmol/kg. The study soils are saturated with base cations. Base saturation degree varies from 71.46-88.75% (average 81.85%).

Slow transformation of organic residues leads to the formation of a deep layer of semi-raw humus on the soil surface. Humus percentage in the profile is high (2.22-12.65%, average 7.41%). The high percentage of total nitrogen (0.20-0.65%, average 0.41%) is consistent with the humus percentage. The content of readily available potassium is low and varies from 3.80-13.40 mg/100 g soil, average 7.2 mg/100g soil). The content of readily available phosphorus is practically in all profiles below the detection limit. The main causes of low production potential of the soil on serpentinite in forest type 755 are its limited depth, often a high content of skeleton, and a low content of colloid fraction.

Assessment based on mean heights - hs

Mean heights (in addition to mean maximal heights) are the least variable elements, and as such, they are the best indicator of site potential and site conditions. The significance of mean heights in the determination of site productivity is reported by Miletić (1962), Vučković (1989), Jović (1979), etc.

The differences between spruce mean heights (hs) in forest type 745 and forest type 755 were determined using the analysis of variance and LSD-test, at the 95% significance level.

The analysis of variance and LSD-test show that there are statistically significant differences between spruce mean heights in forest type 745 and forest type 755 (Tab. 3).

Table 1. Chemical properties of the soil

Prof No	Depth (cm)	Horizon	pH		Y1 ccm n/10 NaOH	Adsorptive complex				Humus	C	N	C/N	Available	
			H_2O	$CaCl_2$		(T-S)	S	T	V					P_2O_5	K_2O
						cmol/kg				(%)				mg/100g	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
rankers and eutheric cambisol on serpentine - forest type 755															
1/02	0 - 35	A	6,6	6,0	10,7	6,9	50,8	57,7	88,0	9,2	5,3	0,6	9,7	-	9,4
2/02	0 - 40	A	6,6	6,0	10,2	6,6	35,4	42,1	84,3	8,0	4,7	0,5	10,1	-	6,5
3/02	0 - 30	A	6,0	5,3	22,8	14,8	37,1	51,9	71,5	12,7	7,3	0,7	11,3	0,4	13,4
4/02	0 - 10	A	6,0	5,3	20,8	13,5	38,2	51,7	73,8	12,1	7,0	0,6	11,6	-	9,4
	10 - 55	(B)	6,8	6,1	5,8	3,8	29,8	33,6	88,8	1,3	0,8	0,0	-	-	5,0
5/02	6 - 35	A	6,3	5,8	14,9	9,7	32,0	41,6	76,8	10,2	5,9	0,5	11,0	-	9,4
	35 - 60	(B)	6,0	6,2	5,3	3,5	19,4	22,8	84,8	2,2	1,3	0,2	8,6	-	4,1
6/02	0 - 25	A	6,5	5,8	11,6	7,6	33,5	41,1	81,6	8,3	4,8	0,5	9,6	-	9,4
	25 - 75	(B)	6,8	6,2	6,8	4,4	29,8	34,2	87,1	2,7	1,5	0,2	7,7	-	3,8
brown podzolised soil on granodiorite - forest type 745															
7/02	6 - 24	A/E	4,6	3,8	52,4	34,0	9,2	43,2	21,2	11,0	6,4	0,5	12,0	0,9	10,0
	24 - 55	B	5,6	4,8	19,2	12,5	7,3	19,8	37,0	3,9	2,2	0,3	7,7	0,3	3,5
	55 - 105	B	5,8	4,9	14,5	9,4	4,7	14,1	33,3	2,4	1,4	0,0	-	0,3	2,8
8/02	6 - 15	A/E	4,3	3,7	85,7	55,6	3,2	58,8	5,5	18,2	-	0,6	16,6	4,5	18,0
	15-27	B	4,4	3,9	72,6	47,2	3,2	50,4	6,4	12,8	-	0,8	9,1	5,1	10,0
	27-45	B	4,6	4,0	55,5	35,9	1,2	37,0	3,2	8,1	-	0,0	-	3,9	3,5
	45-70	B	4,9	4,2	37,3	24,2	0,4	24,6	1,5	4,4	-	0,0	-	3,3	2,1
9/02	14-24	A/E	4,6	3,9	59,0	38,4	3,3	41,7	8,0	12,7	-	0,7	10,8	7,5	7,3
	24-33	B	4,9	4,3	52,4	34,1	1,8	35,9	5,0	8,5	-	0,0	-	10,0	2,9
	33-47	B	5,1	4,4	40,3	26,2	1,4	27,6	5,1	6,8	-	0,0	-	9,5	1,7
	47-75	B	5,2	4,5	35,3	22,9	0,0	22,9	0,0	4,4	-	0,0	-	8,8	1,3
10/02	0 - 12	A/E	4,7	4,0	58,4	37,9	8,9	46,8	19,0	11,5	6,7	0,6	11,9	-	17,0
	12 - 40	B	4,9	4,1	43,6	28,4	4,2	32,6	13,0	5,8	3,4	0,4	8,8	-	8,0
	40 - 85	B	5,4	4,5	19,9	12,9	3,1	16,0	19,3	1,3	0,7	0,0	-	-	3,0
11/02	0 - 14	A/E	5,0	4,2	46,0	29,9	12,2	42,2	28,9	12,3	7,1	0,6	12,3	0,4	12,6
	14 - 45	B	5,1	4,3	27,6	18,0	6,9	24,9	27,9	4,5	2,6	0,4	7,5	0,3	5,0
	45 - 90	B	5,3	4,4	19,9	12,9	5,4	18,3	29,5	3,2	1,9	0,3	7,1	1,7	4,5

Table 2. Texture of the soil

Profile No	Depth (cm)	Horizon	Hyg. moisture (%)	Particle size composition (%) 2.0 -0.2 mm	0.2 - 0.06 mm	0.06 -0.02 mm	0.02-0.006 mm	0.006-0.002 mm	manje od 0.002 mm	Total Sand	Total Clay
1	2	3	4	5	6	7	8	9	10	11	12
rankers and eutheric cambisol on serpentine - forest type 755											
1/02	0 - 35	A	6,35	8,98	32,02	17,60	24,10	7,40	9,90	58,60	41,40
2/02	0 - 40	A	4,51	6,40	34,80	22,20	21,10	13,80	1,70	63,40	36,60
3/02	0 - 30	A	6,82	6,56	45,74	24,10	14,30	3,90	5,40	76,40	23,60
4/02	0 - 10	A	5,69	8,04	30,66	24,30	21,50	14,40	1,10	63,00	37,00
	10 - 55	(B)	3,88	17,63	32,07	13,30	19,80	6,50	10,70	63,00	37,00
5/02	6 - 35	A	4,50	17,96	17,24	15,00	27,70	14,00	8,10	50,20	49,80
	35 - 60	(B)	2,67	15,21	20,99	8,00	26,70	13,70	15,40	44,20	55,80
6/02	0 - 25	A	4,41	8,65	25,05	21,40	31,00	11,70	2,20	55,10	44,90
	25 - 75	(B)	3,69	10,72	20,48	14,20	35,80	6,80	12,00	45,40	54,60
brown podzolised soil on granodiorite - forest type 745											
7/02	6 - 24	A/E	3,30	35,57	34,13	7,10	10,10	4,50	8,60	76,80	23,20
	24 - 55	B	2,04	26,09	45,21	3,30	10,40	1,90	13,10	74,60	25,40
	55 - 105	B	1,58	48,47	27,33	7,30	4,10	2,90	9,90	83,10	16,90
8/02	6 - 15	A/E	4,59	7,78	35,72	20,50	21,70	5,50	8,80	64,00	36,00
	15 - 27	B	3,44	13,41	27,69	18,50	22,30	4,60	13,50	59,60	40,40
	27 - 45	B	3,06	23,35	23,95	11,90	20,30	10,00	10,50	59,20	40,80
	45 - 70	B	2,65	18,45	25,75	15,50	18,10	6,80	15,40	59,70	40,30
9/02	14 - 24	A/E	3,66	34,06	29,54	11,40	10,80	3,90	10,30	75,00	25,00
	24 - 33	B	3,15	38,00	25,10	7,20	14,30	4,30	12,10	69,30	30,70
	33 - 47	B	2,78	38,77	29,03	3,70	7,50	7,30	13,70	69,50	30,50
	47 - 75	B	2,25	40,55	25,85	7,90	7,90	4,70	13,10	74,30	25,70
10/02	0 - 12	A/E	4,61	13,16	51,04	11,60	13,60	4,70	5,90	75,80	24,20
	12 - 40	B	3,72	18,02	38,38	13,40	13,50	6,10	10,60	69,80	30,20
	40 - 85	B	2,46	18,14	39,46	9,50	13,50	6,00	13,40	67,10	32,90
11/02	0 - 14	A/E	3,97	29,38	34,42	10,90	14,60	4,60	6,10	74,70	25,30
	14 - 45	B	2,74	31,09	32,71	9,40	13,50	4,90	8,40	73,20	26,80
	45 - 90	B	2,11	30,83	36,17	7,40	12,90	5,20	7,50	74,40	25,60

Table 3. Analysis of variance of spruce mean heights (hs) in forest types 745 and 755

Type	F-ratio	P-value	Mean value	Group homogeneity	
Brown podzolised soil on granodiorite	31.61	0.0005	22.56	x	
Eutric humus-siliceous soil and eutric brown soil			17.88		x

Effects of soil characteristics on productivity

To determine the effects of the particular soil characteristics in forest type 745 and forest type 755 on spruce mean heights in the study ecological units, the analytical data are compared based on correlation analysis. The results are presented in Tables 4 and 5.

Based on the results of regression analysis using Roemer-Orphal's distribution, we can make the following conclusions:

- Characteristics of brown podzolised soil are in stronger correlation with mean heights compared to characteristics of eutric humus-siliceous soil and eutric brown soil on serpentinites;
- Very strong correlation between mean heights and solum depth, A horizon depth and pH values in H_2O;
- Strong correlation between mean heights and total soil adsorption capacity, humus percentage, base saturation degree, hydrolytic acidity, total adsorption capacity and the content of colloid particles;
- The characteristics of the soil on serpentinites (eutric humus-siliceous soil and eutric brown soil) have a somewhat lower effect on mean heights in the study forest type;
- Strong correlation between mean heights and the percentage of colloid clay particles;
- Moderate correlation between mean heights and hydrolytic acidity;
- Very weak correlation between mean heights and solum depth, A horizon depth and pH values in H_2O, and base saturation degree;

Weak correlation between mean heights and humus percentage and base saturation degree.

Table 4. Regression analysis between the characteristics of brown podzolised soil on granodiorite and spruce mean heights in forest type 745 - spruce, fir and beech (*Piceo-Abieti-Fagetum typicum*)

Characteristic	Correlation coefficient	Correlation strength	R^2	Equation of the selected model
depth	0.76	very strong	57.78	hs=(4.29091+0.00570573*depth)^2
depth of A horizon	0.77	very strong		hgmax=exp(2.97811+0.0108761*depth A)
content of clay particles (<0.002 mm)	-0.53	strong	28.31	hgmax=24.9296-0.228903*clay %
pH value in H_2O	0.77	very strong	59.10	hs=14.8215+36.5782/pH
humus percentage	0.58	strong	34.10	hs=20.1432+13.4429/humus %
base saturation degree (%)	0.64	strong	41.32	hs=1/(0.0429175+0.0100052/V%)
hydrolytic acidity (ccm n/10 NaOH)	0.61	strong	37.34	hs=20.332+74.3981/*Y_1
total adsorptive capacity (cmol/kg)	0.70	strong	48.66	hs= 18.8943+96.323/T

Table 5. Regression analysis between the characteristics of eutric humus-siliceous soil and eutric brown soil on serpentinite and spruce mean heights in forest type 755 - spruce, fir and beech with fescue grass (*Piceo-Abieti-Fagetum drymetosum*)

Characteristic	Correlation coefficient	Correlation strength	R^2	Equation of the selected model
depth	-0.16	very weak	2.60	hs=1/(0.059106-0.137158/depth)
depth of A horizon	0.17	very weak	2.98	hs=17.5076+8.16557/depth A
content of clay particles (<0.002 mm)	0.64	strong	40.81	hs=1/(0.0450499+0.0013261/clay%)
pH value in H_2O	0.13	very weak	1.72	hs=16.3667+9.30767/pH
humus %	0.29	weak	8.56	hs= 16.9954+4.47962/humus %
base saturation degree (%)	0.15	very weak	2.16	hs=16.3377+122.585/V%
hydrolytic acidity (ccm n/10 NaOH)	-0.44	modest	19.33	hs=21.1106-0.350083*Y1
total adsorptive capacity (cmol/kg)	0.30	weak	9.04	hs=exp(2.79222+0.00224899*T)

DISCUSSION

Many authors have tried to assess the potential fertility of forest soils using different methods. After Antić *et al.* (2007), soil fertility potential of forest soils can be assessed based on the crop yield, as a measure of site productivity potential, ground vegetation as the indicator of soil fertility and soil productivity, and soil fertility assessment based on the land evaluation. Antonović and Vidaček (1979) claim that the soil quality can be assessed based on mean annual increment of wood volume, assortment structure, wood volume, etc., in other words based on "the productivity of natural forests and forest plantations".

Numerous authors agree (Vasu, 1994, 1997; Peng *et al*., 2002) that the assessment of site production potential and plant productivity requires the knowledge of soil characteristics. The opinion that all site factors affect both the soil characteristics and soil genesis, and the plant community yield and increment is completely acceptable. However, not all site factors (especially in forest ecosystems) have equal effects. Knežević *et al.* (2011) and Košanin *et al.* (2012) found that other site factors have stronger impacts on beech forest yield and increment on the soils of lower production potential.

This paper presents the assessment of the study soil production potential based on physical-chemical characteristics of the soils and spruce mean heights which is followed by the correlation between individual soil characteristics and spruce mean heights. In Serbia, the biological-ecological optimum of spruce is achieved at higher altitudes in the conditions of cool and moist alpine perhumid climate, on acid parent rocks.

Ecological-productivity value of the soil in forest type 745, is rather heterogeneous and depends on the solum depth, the content of skeleton and soil pH. The unfavourable effect of slow mineralisation on soil fertility is to some degree compensated by favourable physical, i.e. water and air properties. The assessed production potential of brown podzolised soil on granodiorite is in agreement with the attained values of spruce mean heights (hs=22.56m). In general, brown podzolised soil offers good conditions for spruce, satisfactory for fir, and poor for beech. The correlation analysis shows that spruce mean heights are affected by all analysed characteristics of brown podzolised soil.

The soil in forest type 755 is characterised by a lower ecological-productivity potential and it is mostly determined by the degree of evolution-genetic development, solum depth, and the content of skeleton. Correlation analysis shows that the content of colloid clay fraction has the highest effect on mean height in the above forest type. The effect of other soil properties on mean height in forest type 755 is low. Spruce mean height is hs=17.88m. Taking into account the spruce biological demands and the actual ecological conditions of the soils on serpentinites, it can be concluded that low mean heights are the result of this relationship. In other words, eutric humus-siliceous soil and eutric brown soil on serpentinite do not offer optimal conditions for acidophilous and frigoriphilous spruce growth and development

CONCLUSIONS

Based on the study results, it can be concluded that there are great differences in the soil production potentials in forest type 745 and forest type 755, in the area of NP "Kopaonik"- MU "Samokovska Reka". More exactly, it was found there are differences in the production potential between the brown podzolised soil on granodiorite, on the one hand, and eutric humus-siliceous soil and eutric brown soil on serpentinite, on the other hand. The differences in soil characteristics caused the differences in the production potential between two forest types: forest type spruce, fir and beech (*Piceo-Abieti-Fagetum typicum*), and forest type spruce, fir and beech with fescue grass (*Piceo-Abieti-Fagetum drymetosum*).

Brown podzolised soil on granodiorite is deep, with a high content of fine sand fraction, low content of colloid clay, high acidity, and slow humus mineralisation. All the above properties characterise the soil of medium ecological-productivity potential.

Eutric humus-siliceous soil and eutric brown soil on serpentinite occur in different forms, both from the aspect of development, and from the aspect of solum depth and content of skeleton. The more developed forms, with deeper solum, less skeleton, and a higher percentage of the colloid fraction, offer more favourable conditions for plant growth.

The production potential of the study forest types was assessed based on the values of spruce mean heights (hs) in both forest types. Statistical analysis confirms that there are statistically significant differences between spruce mean heights in forest type 755 (on eutric humus-siliceous and eutric brown soil on serpentinite) and spruce mean heights in forest type 745 (on brown podzolised soil on granodiorite). Namely, the attained values of spruce mean heights (hs =17.88 m) in forest type 755, indicate the stands of lower production potential. Mean heights in forest type 745, (hs =22.56 m) show a higher increment.

The correlation analysis confirms that the characteristics of eutric humus-siliceous soil and eutric brown soil on serpentinite (in forest type 755) have a very weak effect on spruce mean heights. On the other hand, the analysed properties of brown podzolised soil on granodiorite (in forest type 745) have a strong effect spruce on mean heights.

Taking into account the characteristics of the study soils and the prevailing conditions, it can be concluded that spruce in forest type 755 is sited outside its ecological-biological optimum, and that in forest type 745 it finds good conditions for growth and development. The achieved values of mean heights are consistent with the above facts.

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COMPARISON OF THREE METHODS FOR DETERMINATION OF ORGANIC CARBON IN SOIL

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ABSTRACT

For the analysis of parameters obtained from long-term experiments and monitoring of the quality of the soil in an area or a region, it is essential to have comparability and traceability of the results. The amount of organic matter is one of the most important parameters of soil fertility. Years of testing the content of humus in soil samples from the Republic of Serbia, with the Kotzman and Tyurin methods provided information for high-quality databases. However, newer methods (CHNS analyzer, TOC analyzer) allow faster analysis of samples. The transition to modern techniques for determination the organic matter in the soil caused the need for the comparison of practicing methods. The result obtained by using a CHNS analyzer represents the amount of total carbon in the sample. Therefore, the coefficient which is the ratio of the results obtained by old and new methods must be determined. Two soil types from Serbia were analyzed for the content of soil organic matter: by Kotzman method and with the CNS analyzer, with and without prior removal of carbonate from the sample. Correlation coefficient was determined to compare the results of two different methods.

Keywords: soil organic carbon, Kotzman, CNS analzyer, Rendzina, Fluvisol

INTRODUCTION

Soil carbon storage, as the third largest carbon pool in the earth system, plays an important role in the global carbon cycle and climate change (Lal&Kimble, 2000). The majority of carbon, in most soils, is held as soil organic carbon (SOC), whereas in soils of the arid and semiarid regions, the most common form is inorganic carbon, primarily carbonate (Eswaran *et al.*, 2000). Even in small amounts SOC is very important for soil fertility which is determined by chemical, physical and biological properties. Higher levels of SOC reduce bulk density and nutrient leaching, increase aggregate stability, cation exchange capacity, pH buffering, water-holding capacity, infiltration, resistance to soil compaction and to soil erosion and enhance soil fertility (Manojlović *et al*., 2010).

Longtime research of SOC content in soil samples from Republic of Serbia, according to methods of Kotzman and Tyurin, has produced data for formation of quality databases. Introduction of new methods (CHNS analyzer and TOC analyzer) has contributed to faster sample analysis. The results of CHNS analysis represent the total amount of carbon in the soil. Because of the introduction of new methods the need for method comparison has arisen. The coefficient obtained from this comparison can serve to correlate the results from old and new methods. It was previously shown that the correlation coefficient for the SOC content depends on the type of soil, reaction, temperature and the type of vegetation present on the soil (Pansu *et al.*, 2006; Sleutel *et al.*, 2007; Sparks *et al.*, 1996; Wang *et al.*, 2012).

The aim of our study was to determine the correlation between the amount of organic carbon using Kotzman method and CHNS method with and without prior carbonate removal, in two type of soil.

MATERIALS AND METHOD

The analyzed soil samples were taken from Central and Western Serbia (Fig 1.) and the sample was collected at depth from 0 - 25 cm. The two types of the soils were analyzed: Fluvisol, widespread in the river valleys of Western and Central Serbia, and Rendzina, mostly spread at the hilly-mountainous areas. To each soil type were taken 10 average soil samples (Tab 1).

Fluvisol belongs to the group of hydrogenic soils, formed during floods in river valleys, by transport and accumulation of materials. Different forming conditions of the alluvial sediments result in different mechanical composition, which is accompanied by differences in mineral composition. With certain agrotechnical methods high and stable agricultural production can be achieved on it. Rendzina belongs to the humus accumulative soils, and it can also be found in loess and loess-like substrates, marl, soft marly limestones and flysch in Šumadija. Depending on the parent rock on which it is formed rendzinas have different granulometric composition, and different physical and chemical properties (Hadžić, *et al.*, 2002; Glamočlija *et al.*, 2012).

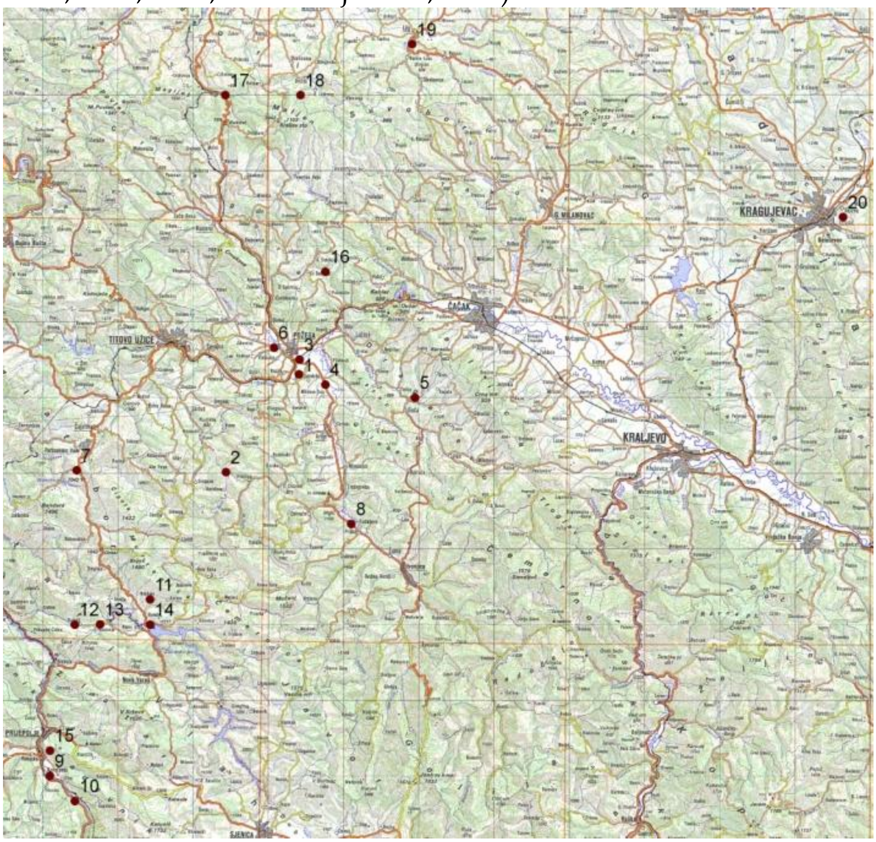

Fig. 1. Sampling area with locations of 20 soil profiles

It was selected samples of these soil types (based on previous reasearcs) that make it possible to well detect differences between various methods of SOC: Rendzinas, more and less calcareous soils and Fluvisol with varieties of non-carbonate and carbonate, whereas the other soil properties vary (Tab. 1). The three methods for determination of SOC were compared: Kotzman (by oxidation with solution $KMnO_4$ in acidic solution), CHNS analyzer-dry combustion with prior removal of carbonate (SOC1) and CHNS analyzer-dry combustion without the removal of carbonate (SOC2).

For SOC1 (with prior removal of carbonate from the sample), 20 mg of soil was measured and was pretreated with 10 drips of H_3PO_4 for 12 hours to remove carbonate. The sample was combusted at 1150°C with constant helium flow carrying pure oxygen to ensure complete oxidation of organic materials. CO_2 production was determined by a thermal conductivity detector. It was used CNS analyzer Elementar Vario EL III.

For SOC2 (without prior removal of carbonate), TC (total carbon) was measured, using the same procedure without pretreatment with H_3PO_4, and SOC was calculated as the difference between TC and inorganic C (Wang, X. *et al.*, 2012).

Analyses were done in four replicates and average values are shown in table 3. To determine the main chemical and physical parameters the following methods were used: pH in KCl and pH in H_2O – electrometrically, SRPS ISO 10390:2007, available P and K - AL method by Egner- Riehm, the content of carbonates - volumetric method, SRPS ISO 10693:2005, granulometric analyses - modified International "B" method, textural classes –by Fere.

Data was statistically analyzed using regression analysis and descriptive statistics (SPSS 21 statistical package).

RESULTS AND DISCUSSION

On the basis of the data on pH values, it may be concluded that Fluvisol has very different reaction, from acid to slightly alkaline, while the reaction in Rendzina is neutral to weakly alkaline (Tab. 1). Soil samples of Fluvisol are mainly noncalcareus and slightly calcareus, and samples of Renzina are middle and highly calcareus.

In terms of the content of P and K, investigated soils are poor to rich supplied, wich is the result of different fertilization and clay content (Tab. 1).

Granulometric composition of Fluvisol manifested great diversity, the texture is sandy loam, loam, sandy clayey loam and clayey loam. Rendzina is somewhat heavier soil, with the content of clay above 26%, and silt+clay above 50%, in texture it is mainly sandy clayey loam and clayey loam (Tab. 2). The content of organic carbon (Kotzman) in Fluvisol is rather variable, since it is a sedimented soil, and it ranges from 1,2 to 4,8% (average 2,2%). Rendzina contains more OC (average 3,36 %) (Tab. 3).

Table 1 Locations and main chemical parameters of soil

Samples	Locations	Soil type	pH KCl	pH H_2O	CaCO3 %	P_2O_5 (mg/100g)	K_2O (mg/100g)
1	Požega, riv. Đetinje	Fluvisol	7.55	7.95	4.47	29.20	16.65
2	Arilje, riv. Veliki Rzav	Fluvisol	7.60	8.05	7.19	22.42	19.40
3	Požega, riv. Đetinja	Fluvisol	7.45	8.10	2.22	4.75	14.68
4	Požega, riv.Moravica	Fluvisol	7.80	8.05	1.08	6.58	4.84
5	Guča, riv.Bjelica	Fluvisol	6.85	7.40	0.10	37.60	71.42
6	Požega, riv.Skrapež	Fluvisol	6.15	7.30	0.00	90.00	16.25
7	Zlatibor, riv.Crni Rzav	Fluvisol	5.50	6.45	0.00	0.36	3.26
8	Arilje, riv.Moravica	Fluvisol	5.00	5.85	0.00	6.60	13.89
9	Prijepolje, riv.Lim	Fluvisol	6.55	6.75	0.00	0.10	2.08
10	Prijepolje, riv.Lim	Fluvisol	4.70	5.85	0.00	2.20	12.71
average			6.51	7.17	1.51	19.98	17.52
11	Priboj na Limu	Rendzina	7.10	7.60	7.35	0.43	34.76
12	Kokin Brod	Rendzina	6.70	7.40	0.87	48.83	65.51
13	Kokin Brod	Rendzina	7.55	8.00	58.24	22.70	17.43
14	Kokin Brod	Rendzina	7.55	8.05	5.61	0.20	27.67
15	Prijepolje, Jadovnik Mt.	Rendzina	7.70	8.00	26.88	27.00	51.74
16	Kosjerić, G.Gora Mt.	Rendzina	7.50	7.80	34.88	4.12	36.53
17	Valjevo, Podgorina Mt.	Rendzina	7.50	8.00	7.73	1.38	11.13
18	Valjevo, Maljen Mt.	Rendzina	7.30	7.90	7.51	1.87	19.40
19	Ljig, Suvobor Mt.	Rendzina	7.10	7.50	2.62	13.18	77.33
20	Kragujevac, Gledić Mt.	Rendzina	7.55	7.95	37.88	29.20	16.65
average			7.35	7.82	18.95	14.89	35.81

There is significant correlation between the SOCKotzman and SOC2 (R^2=0.94), and between SOC2 and SOC1 (R^2=0,94), and strong correlation between the SOCKotzman and SOC1 (R^2= 0,89) (Fig. 2). If we compare the results obtained for both soil types separately, there is also a very significant, strong correlation between methods (R^2= 0,92). Sleutel *et al.* (2007) and Wang *et al.* (2012) also found very close relationships between the SOC content measured with modern dry-combustion methods and traditional wet-oxidation methods.

The smallest average value of the organic carbon was obtained by method of Kotzman (average 2,776%), while the average value of SOC1 is higher (1,065 times) and value of SOC2 the highest (1,129 times). Relatioship between SOC2 and SOC1 is 1,06 (Tab. 3). If we consider these relations by type of soil, can be seen, that are same relations in Rendzina, while in Fluvisol the lowest average values has SOC1.

Table 2 Content of organic, inorganic and total carbon and granulometric analyses

Samples	Coarse sand >0.2mm (%)	Fine sand 0.2-0.02mm (%)	Silt 0.02-0.002 mm (%)	Clay <0.002 mm (%)	Total sand >0.02mm (%)	Silt + clay <0.02mm (%)	Texture class
1	2.2	54.9	24.7	18.2	57.1	42.9	sandy loam
2	38.1	40.9	11.7	9.3	79.0	21.0	sandy loam
3	1.6	22.8	44.3	31.3	24.4	75.6	clayey loam
4	6.1	61.9	21.2	10.8	68.0	32.0	sandy loam
5	10.2	45.0	22.0	22.8	55.2	44.8	sandy clayey loam
6	3.9	30.0	31.5	34.6	33.9	66.1	clayey loam
7	11.5	40.6	28.1	19.8	52.1	47.9	loam
8	11.1	30.0	34.9	24.0	41.1	58.9	loam
9	7.1	47.4	32.1	13.4	54.5	45.5	sandy loam
10	29.9	28.7	18.9	22.5	58.6	41.4	sandy clayey loam
11	5.4	21.3	30.1	43.2	26.7	73.3	clay
12	14.7	33.1	24.0	28.2	47.8	52.2	sandy clayey loam
13	1.6	12.0	47.2	39.2	13.6	86.4	silty clayey loam
14	25.3	22.5	17.6	34.6	47.8	52.2	sandy clayey loam
15	21.1	25.1	27.5	26.3	46.2	53.8	loam
16	9.5	22.3	28.9	39.3	31.8	68.2	clayey loam
17	6.2	25.0	39.0	29.8	31.2	68.8	clayey loam
18	20.9	27.9	22.5	28.7	48.8	51.2	sandy clayey loam
19	4.7	36.0	30.7	28.6	40.7	59.3	clayey loam
20	1.7	18.4	40.8	39.1	20.1	79.9	clayey loam

Table 3 Content of total, inorganic and organic carbon with three methods

Samples	TC	Inorganic C	SOC2	SOC1	SOC Kotzman
			%		
1	1.767	0.537	1.230	1.154	1.608
2	2.214	0.863	1.351	1.418	1.850
3	1.842	0.267	1.575	1.482	1.758
4	1.102	0.130	0.971	1.626	1.216
5	2.145	0.012	2.133	2.431	2.420
6	1.707	0.000	1.707	1.650	1.972
7	6.866	0.000	6.866	4.975	4.784
8	1.951	0.000	1.951	2.178	2.233
9	2.417	0.000	2.417	2.257	2.146
10	1.840	0.000	1.840	1.657	1.973
Average Fluvisol	2.385	0.181	2.204	2,083	2,196
11	5.176	0.882	4.294	4.115	3.906
12	4.244	0.104	4.140	4.337	3.712
13	9.049	6.991	2.058	2.316	2.154
14	2.614	0.673	1.941	1.787	2.114
15	6.182	3.227	2.955	2.687	3.057
16	11.321	4.187	7.134	7.568	4.876
17	3.454	0.928	2.526	2.410	2.485
18	4.466	0.901	3.564	2.637	3.218
19	10.022	0.315	9.707	8.296	5.402
20	6.858	4.547	2.312	2.145	2.638
Average Rendzina	6.339	2.275	4.063	3.830	3.356
All	4.362	1.228	3.134	2.956	2.776

Differences in the content of the SOC determined with three methods are most expreseed in soils samples rich in humus, primarily in Rendzina (graph 2; Tab. 3). In these samples was extracted less carbon by using $KMnO_4$, compared to other methods. Results De Vos *et al.* (2007) indicate that by using Walkley-Black method (in related to CNS analysis) can be oxidized less than 82% SOC in forest soils across Flanders region. Wang *et al.* (1996, 2012), however, state that with this method almost 100% SOC can be oxidized in the brown desert soil and in most Tasmanian soils.

In this study, the influence of other soil properties on the differences in the content of SOC determined different methods has not been established.

Our study demonstrates that is necessary to analyze a larger number of samples and confirms conclusion of Sleutel *et al.* (2007) that region-specific factors should be determined and used

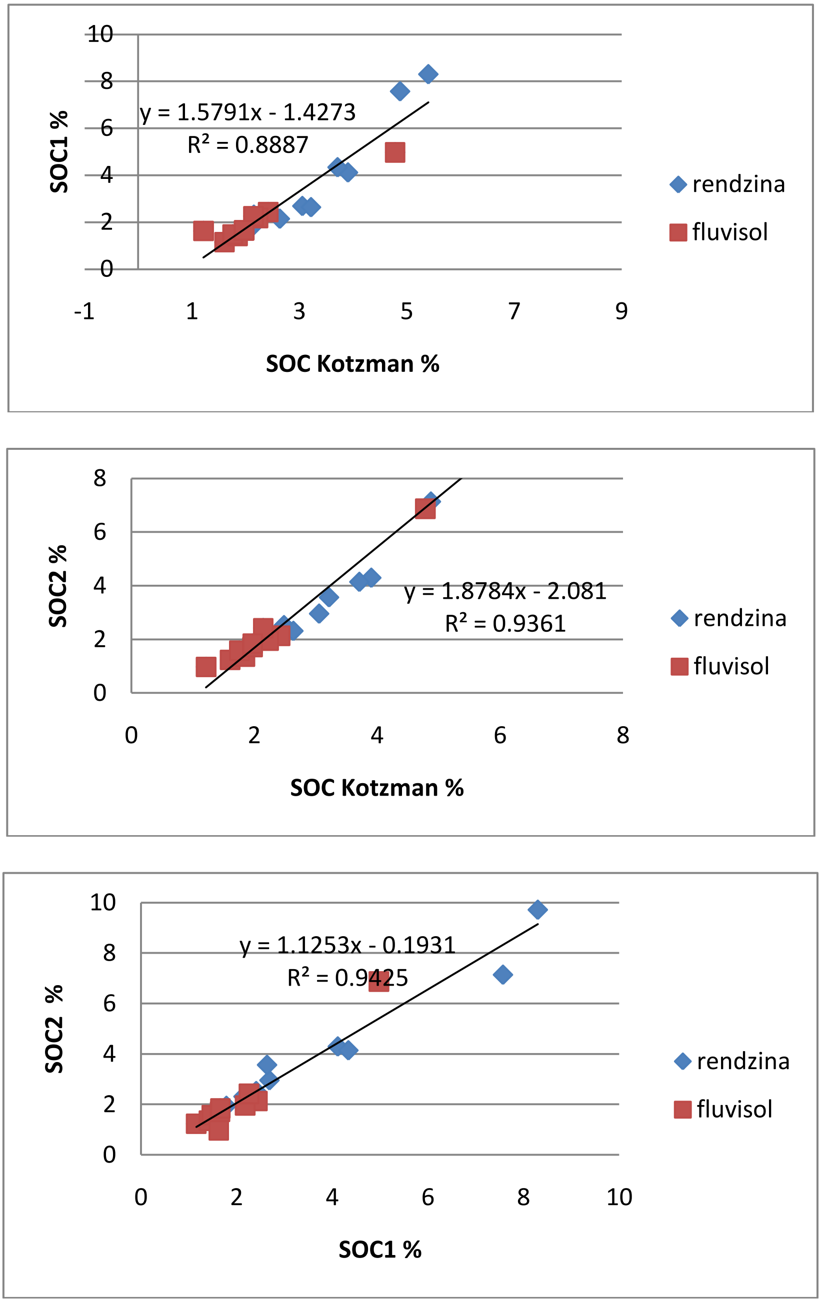

Fig. 2 The relationship between SOCKotzman and SOC1 and SOC2 by soil types

CONCLUSION

The research results show that soil type Fluvisol has very different soil acidity, from acid to slightly alkaline, and it is mainly noncalcareus and slightly calcareous soil. Renzina is middle and highly calcareous, with neutral to weakly alkaline reaction, and somewhat heavier texture, mainly sandy clayey loam and clayey loam.

Based on the analysis of the results obtained using the three methods for the determination of organic carbon, we concluded that the smallest average value of the organic carbon was obtained using method of Kotzman (average 2,776 %), while the average value of SOC1 is higher (1,065 times) and value of SOC2 the highest (1,129 times). In soils samples rich in humus, primarily in Rendzina, there was extracted less carbon by using $KMnO_4$ extraction method, compared to other methods. Comparing the content of organic carbon with different methods in all the samples, as well as individualy by soil types, we obtained a strong and significant correlations.

Analyzing the results and relationships it can be concluded that it is necessary to analyze a larger number of samples, of one soil type, to determine the degree of correlation with respect to carbonate content, texture class and other properties of soil.

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FERTILITY CONTROL IN THE MUNICIPALITY OF PANČEVO

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ABSTRACT

For the purpose of the determination of the fertility of the soil in the course of the year 2002, an analysis was carried out of four types of soil from several locations at a distance of 10,000m from the industrial complex (the Petrochemical Industry "Petrohemija", the Fertilizer Factory "Azotara" and the Oil Refinery) in Pančevo. In the study, the results were displayed of the fertility analysis of the following soil types: alluvium, non-carbonated black soil, carbonated chernozem on loess terrace and chernozem with signs of gley in loess. In those soil samples, laboratory analyses were performed of chemical soil properties. Apart from that, on the mentioned samples, bulk density, particle density and total porosity were established. In total, 36 samples were analyzed at the depth of 0-30cm. On average, the highest percentage of humus (4.33%), nitrogen (0.233%) and organic carbon (2.51%) was discovered in chernozem on loess terrace.

Keywords: soil, industrial zone, fertility analysis.

INTRODUCTION

Alluvium is characterized by light mechanical composition, which is most commonly a sandy type, more rarely a sandy loam one, determines water and air properties. The water capacity is low, and the air one is relatively large. Plants are supplied with water mainly through groundwater. This is the reason why hot waters, following groundwater, lower their vessel system up to 2 meters and even deeper than 2 meters underground.

The chemical properties result from the chemical composition of mineral components and groundwater. Our alluvia are usually more or less carbonated. Due to the coarse mechanical texture, the mobilization of nutritive substances is very slow, and the supply of food to vegetation mostly comes through groundwater. Ecological value of undeveloped alluvial soils depends primarily on their mechanical composition as well as of the duration of the detention of groundwater in the profile. It is the smallest with coarse sands and gravels, and the most favorable with sandy-loamy and loamy variants (Antić *et al*., 1982)

Non-carbonated black soil is a deep and fertile soil. Its chemical properties are favorable on the whole. The reaction is neutral or slightly alkaline, and the content of $CaCO_3$ under decarbonated chernozem soils begins right from the surface and, in the lower part, it reaches 20% and more than 20%. Difficulties arise when working the soil, because it takes deep working due to the low filtration capacity (Antić *et al*., 1982).

Carbonated chernozem on loess terrace is characterized by crumbly structure and favorable porosity. Its favorable mechanical texture results in good physical properties. In combination, all these results in good filtering ability and balanced water-air capacity. The chemical properties of chernozem are largely determined by the character of humus, which is multi type with the narrow C:N ratio. Chernozem clay minerals have a prevailing character of illite and montmorillonite. The humus content ranges from 3 to 5%. Clay minerals hold high absorption capacity, which ranges up to 50mg-eq per 100g of soil. Right from the surface, Chernozem soils contain calcium carbonate, which is finely dispersed throughout the soil mass, and which causes a neutral or even slightly alkaline reaction. Chernozem soils belong to high productive capacity soils, which is why they are used for agricultural production in this country most of all soils. Extremely small areas of most commonly degraded chernozem soils are under forest vegetation (Antić *et al*., 1982). Chernozem with signs of loess gleyzation is present in depressions where groundwater is near the surface (Antić *et al*., 1982).

MATERIAL AND METHODS

The soil sampling for these tests was conducted in the period of July-August 2002. Altogether, 36 samples were sampled at the depth of 0-30cm.

In the prepared samples, the following analyses of physical properties were carried out: particle density, bulk density, total porosity. The laboratory analyses of soil chemical properties were performed by the following methods: humus – by Turin method; total nitrogen – by Kjeldahl; organic carbon – by the modified Mebius method (Manojlović *et al.*, 1969).

RESULTS

The variations in physical and chemical properties of agricultural soils in all the locations are rather pronounced. The physical properties of soil are shown in the Table 1. Particle densities are used to study the amount of humus and nutritive substances (N, P, K) in the soil. Particle density is closely related to and depending on the total porosity in a given soil. If their relationship is known, it is possible that the porosity is not measured. Leenheer, L. (1958) provides the following relationships between the particle density and the porosity of clay (Tab. 2).

Table 1 The physical properties of the soil (at the depth of 0-30cm)

soil type	profile No	particle density ($g\ cm^{-3}$)	bulk density ($g\ cm^{-3}$)	total porosity (%)
alluvium	1	2.65	1.57	40.87
	14	2.62	1.53	41.76
average		2.635	1.55	41.32
non-carbonated black soil	2	2.62	1.82	30.48
	4	2.60	1.67	35.79
	5	2.57	1.59	37.99
	8	2.57	1.43	44.54
average		2.59	1.63	37.2
carbonated chernozem on loess terrace	10	2.56	1.40	45.51
	11	2.57	1.27	50.72
	12	2.53	1.24	51.13
average		2.55	1.30	49.12
chernozem with signs of gley in loess	3	2.55	1.54	39.78
	6	2.55	1.54	39.50
	7	2.61	1.41	45.79
	9	2.54	1.38	45.56
	13	2.54	1.47	42.26
average		2.56	1.47	42.58

Table 2 The relationship between the particle density and clay porosity

particle density, (g cm^{-3})	Porosity, (%)
1.0-1.2	55-62
1.2-1.4	46-54
1.4-1.6	40-46
1.6-1.8	<40

According to the extent of total porosity, soils can be divided into several groups:

1. fairly porous >60% of voids
2. porous 45-60% of voids
3. poorly porous 30-45% pore
4. very poorly porous <30% pore (Antić *et al.*, 1982)

The chemical properties of the soil are shown in the Table 3.

The humus content is an important indicator of soil fertility. Humic substances in soil have an affinity for the forming of organic complexes with metals. If it comes to the formation of the complex between metals and soluble organic forms, metals remain mobile, and therefore, more accessible to plants (Milivojević *et al.*, 2012). Based on the results obtained, low humic soils (humus percentage 1.01-3.00%) include alluvium and non-carbonated black soil. The class of humic soils, according to the results obtained, includes carbonated chernozem on loess terrace and chernozem with signs of gley in loess. The maintenance and increase of the amount of humus in the soil can be achieved in several ways. Due to the reduced livestock resources, the amounts of available manure are less and less every year. Therefore, the ploughing of crop residues such as straw, corn stalks, sunflower stalks, roots and leaves of sugar beet, has a growing importance. (Vasin *et al.*, 2004). The majority of the samples belong to the group of medium humic soils.

DISCUSSION

According to the classification (Antić *et al.*, 1982), the alluvial soil which we examined belongs to the group of poorly porous soil (41.32%). Non-carbonated black soil belongs to the group of poorly porous soil (37.2%). Carbonated chernozem on loess terrace with 49.12% of porosity belongs to the group of porous soils. Chernozem with signs of gley in loess has the porosity of 42.58% on average, which means that it belongs to the group of poorly porous soils.

Table 3 The chemical properties of the soil (at the depth of 0-30cm)

soil type	profile N^0	N (%)	humus (%)	organic C (%)
alluvium	1	0.095	1.74	1.01
	14	0.077	1.36	0.79
average		0.086	1.55	0.9
non-carbonated	2	0.122	2.30	1.33
black soil	4	0.147	2.47	1.47
	5	0.080	3.15	1.83
	8	0.193	3.95	2.29
average		0.1355	2.97	1.73
carbonated	10	0.188	3.70	2.15
chernozem on	11	0.277	4.50	2.61
loess terrace	12	0.235	4.80	2.78
average		0.233	4.33	2.51
chernozem with	3	0.227	4.17	2.42
signs of gley in	6	0.181	3.84	2.23
loess	7	0.207	4.22	2.45
	9	0.220	4.63	2.69
	13	0.220	4.42	2.56
	1	0.139	2.54	1.47
	2	0.224	4.55	2.64
	3	0.147	2.24	1.30
	4	0.126	3.31	1.92
	5	0.213	3.97	2.30
	6	0.235	4.20	2.44
	7	0.230	4.73	2.74
	8	0.260	5.45	3.16
	9	0.233	4.10	2.38
	10	0.070	1.18	0.68
	11	0.212	4.25	2.47
	12	0.219	4.05	2.35
	13	0.220	4.30	2.49
	14	0.226	4.76	2.76
	15	0.106	2.12	1.23
	16	0.174	3.38	1.96
	17	0.212	4.61	2.67
	18	0.235	4.51	2.62
	19	0.297	5.75	3.34
	20	0.221	4.28	2.48
	21	0.173	4.40	2.55
	22	0.215	4.50	2.61
average		0.202	4.017	2.33

The content analysis shows that most of the examined soil belongs to the class of very humic soils, where 8.33% of the soil has 4.33% of humus and 75% of the soil is 4.017% humic.

The average nitrogen content ranges from 0.086 to 0.233%. The majority of samples of chernozem with signs of gley in loess are at the level of good supply with N (0.202%). Among the soils with low nitrogen supply, there is alluvium (0.086%) and non-carbonated black soil (0.1355%).

The Industrial Complex ("Petrohemija", "Azotara", "Rafinerija"), which is located at a distance of 10,000m from the agricultural land has no negative impact on soil fertility.

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THE MONITORING OF POTATO AND SUGAR BEET CYST NEMATODES IN THE SOIL IN SERBIA

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ABSTRACT

Soil is the habitat of many parasites which have harmful influence on cultivated plants, significantly causing yield loss. The cyst nematodes are among the most dangerous pests worldwide, especially those of potato (*Globodera rostochiensis* and *Globodera pallida*) and sugar beet (*Heterodera schachtii*). These microscopic worms, feeding on roots, are adapted by cysts for long-term survival in the soil in the absence of a suitable host. Quarantine nematodes *G. rostochiensis* and *G. pallida* have been present in Serbia since 1999 and 2005, respectively. In order to prevent their spread, an official surveillance of the presence of these species in soil, originated from the potato growing areas of Serbia, has been carried out. Many beet producers have been reporting the wilting and early death of beet in the last few years in Vojvodina. The monitoring of *H. schachtii* and their population densities (counts of viable cysts) in soil were necessary in order to offer the farmers a proper recommendation on how to control sugar beet cyst nematode. This paper presents the results of the inventory of potato and sugar beet cyst nematodes in soil in the period between 2009 and 2012. In total, 4196 soil samples were taken from the potato and sugar beet fields of Serbia. *Globodera rostochiensis* was detected in 0.94 % soil samples. The highest percentage of infested samples was found in the district of Mačva. *Heterodera schachtii* occurred in 2.11% of soil samples with the most infested fields in the district of Bačka.

Keywords: soil, monitoring, *Globodera rostochiensis*, *Heterodera schachtii*, Serbia

INTRODUCTION

Soil is the habitat of many parasites which attack the roots of cultivated plants causing yield reduction. The cyst nematodes are among the most dangerous pests, especially those of potato – *Globodera rostochiensis* (Wollenweber, 1923) Behrens, 1975 and *Globodera pallida* (Stone, 1973) and sugar beet *Heterodera schachtii* Schmidt, 1871. Potato (*Solanum tuberosum* L.) is one of the most important cultivated plants in Serbia, the third by its area of presence, right after maize and wheat (Milošević *et al.*, 1996). According to the official statistical data of Serbia, in 2011, potato was sown on 78,377 ha, of which 60,596 was grown in Central Serbia. Sugar beet (*Beta vulgaris* L.) is cultivated in the northern part of Serbia, in the Autonomous Province of Vojvodina, covering about 61,000 hectares (the last three years average, Statistical Office of the Republic of Serbia, 2012).

The potato and sugar beet cyst nematodes are adapted through cysts to long-term survival in soil. Cysts represent dead females containing eggs and juveniles which can maintain the viability for several years in the absence of suitable hosts. These species differ in the shape of cyst. Potato cyst nematodes (PCN) are round, whereas sugar beet nematode is characterized lemon-shape cysts. *Globodera rostochiensis* and *G. pallida* have a quarantine status and have been present in Serbia since 1999 (Krnjaić *et al.*, 2002; Radivojević *et al.*, 2001) and 2005 (Radivojević *et al.*, 2006), respectively. Both species were found in the official monitoring of soil samples originating from the fields for the production of seed potato in Western Serbia. In order to prevent their spread, an official monitoring of the presence of these species in the ware potato growing areas has been carried out in Serbia since 2009. Only *G. rostochiensis* was found in the already infected areas of Western Serbia (Bačić, 2012).

According to the data from the 1970s, *Heterodera schachtii* was the most frequent in the sugar beet growing areas of Vojvodina (Krnjaić *et al.*, 1981). Many sugar beet producers from this region have been reporting wilting and yield loss in the last few years. In order to get more stable yields on farms, the monitoring of *H. schachtii* in sugar beet fields before planting is necessary in order to get information on the population density in the soil. The survey of the occcurrence of *H. schachtii* has been perfomed since 2006 as a result of long-term cooperation between Agcicultural Extension Service Institute

"Tamiš" and the farmers reporting yield reduction (Bačić, 2013). This review paper presents the compilation of the results of the monitoring of potato and sugar beet cyst nematodes in the soil in Serbia in the period between 2009 and 2012.

MATERIAL AND METHODS

In total, 4196 soil samples were taken from the potato (3582) and sugar beet fields (614) of Serbia. The samples were processed in order to determine the presence of cysts and their population density in the soil. The cysts were extracted by the flotation method using the Fenwick Can. The organic soil particles including cysts from the soil samples were extracted on 250 μm sieve and transferred on filter paper for a binocular inspection, as described by Turner, 1998. The morphological identification of PCN and *H. schachtii* was based on combination cyst and second-stage juvenile (J2) characters (Franklin, 1972; Fleming and Powers, 1998).

For the determination of the content of cysts, the method of KWS SAAT AG Company was performed (Stephani, 2006 personal communication). An electric device was used to crush cysts extracted from 100 cm^3 of soil. An estimation of the number of eggs and J2 in homogenized solution was determined using counting chamber glass with a microscope. The population density in 100 cm^3 of soil was calculated by multiplying the number of viable eggs and J2 in 1 ml of solution with the number of ml in the cylinder.

RESULTS AND DISCUSSION

In the period of the offical monitoring of potato cyst nematodes between 2009 and 2012, only the species *Globodera rostochiensis* was detected in the Western Serbia in 3 districts (Mačva, Moravica and Zlatibor). The occurrence of *G. rostochiensis* in the soil originated from seed and ware potato fields is presented in Tab. 1. *Globodera rostochiensis* was detected in 34 soil samples (0.94%) collected from 31 fields, in 6 locations: the district of Mačva (Jagodnja Mountain), the district of Moravica (Milatovići—Kaona, Gojna Gora, Teočin) and the district of Zlatibor (Tabanovići—Loret, Tara Mountain—Ponikve, Bioska). The majority of infested samples originated from ware potato fields (29), while the rest of samples were from the fields planted with seed potato (2). The highest number of infested fields were detected on Jagodnja Mountain, in the district Mačva

(17), where only one seed potato field was infested, as well as in Zlatibor district. The same number of infested fields (7) were registered in the districts of Moravica and Zlatibor. The minimum population density was found in the district of Mačva (80 eggs and J2 in 100 cm^3 of soil—the location of Čardaci). The maximum population density was registered in the soil from a ware potato field in the district of Zlatibor district—the location on Tara mountain—Bioska (8040 eggs and J2 in 100 cm^3 of soil). According to the results presented above, the soil contamination with *G. rostochiensis* in Serbia in the period of 2009-2012 was consequently directly related to the infestation of seed potato fields in the last decade in the quarantine areas of Western Serbia. The highest population density and the the largest number of infested fields were registred in Zlatibor and Mačva district, where *G. rostochiensis* was found for the first time. In 2009, *G. rostochiensis* was registered in the soil originating from the ware potato fields on Javor Mountain (the location of Kušići—Ograđenik) in the district of Zlatibor, where only the species *G. pallida* was detected in the soil from fields planted with seed potato in 2005 (Radivojević and Labudović, 2010). In the district of Moravica, in the location of Gojna Gora and Milatovići—Kaona, *G. rostochiensis* was found in the soil from seed and ware potato fields a few years later than in the districts of Zlatibor and Mačva (Krnjaić *et al.*, 2006; Bačić, 2010). The latest published findings of *G. rostochiensis* in the soil from seed and ware potato fields were originated from Moravica district— the location of Teočin (Oro, 2011; Bačić, 2012).

Table 1 The monitoring of PCN in the soil in Serbia in the period 2009-2012

Year of monitoring	Number of analyzed soil samples	Number of infested soil samples	Number of infested potato fields (district)	Min-max eggs and J2/100 cm^3 of soil (district)
2009	828	25	15 (Mačva) 6 (Moravica) 2 (Zlatibor)	80-6462 (Mačva)
2010	644	4	1 (Mačva) 2 (Zlatibor)	400-6500 (Zlatibor)
2011	1188	3	1 (Mačva) 2 (Zlatibor)	340-6800 (Mačva-Zlatibor)
2012	922	2	1 (Zlatibor) 1 (Moravica)	760-8040 (Zlatibor)
Total	3582	34	31	80-8040 (Mačva-Zlatibor)

The occurrence of *G. rostochiensis* with high cyst vitality in the districts of Mačva, Zlatibor and Moravica indicates that susceptible potato varieties were grown in a narrow crop rotation in the last decade. The increasing number of infected ware potato fields suggest that ware potato is the main focus of this pest in recent years. The continual monitoring of KCN in the soil originated from ware and potato fields is the best way of the implementation of phytosanitary measures of their control and eradication.

The monitoring of *H. schachtii* in the soil in Serbia is presented in Tab. 2. In the period of 2009-2012, this species was detected in Vojvodina, in all 3 districts: Srem, Bačka and Banat. *Heterodera schachtii* was found in 133 soil samples (2.11%), originating from 20 sugar beet fields in 9 locations: the district of Srem (Vojka, Stara Pazova), the district of Bačka (Crvenka, Kula, Sivac, Vrbas, Novi Bečej, Bačka Moravica) and Banat district (Orlovat). Only in 2010, infested fields were not found. The most of infested sugar beet fields (15) originated from the district of Bačka. Four infested fields were registered in Srem while only one field was infested in the district of Banat. The minimum population density was discovered in the district of Bačka (20 eggs and J2 in 100 cm^3 of soil—the location of Bačka Moravica). The maximum population density was ascertained in Srem district (2180 eggs and J2 in 100 cm^3 of soil—the location of Vojka).

Table 2 The monitoring of *H. schachtii* in the soil in Serbia in the period 2009-2012

Year of monitoring	Number of analyzed soil samples	Number of infested soil samples	Number of infested potato fields (district)	Min-max eggs and J2/100 cm^3 of soil (district)
2009	190	63	4 (Bačka)	20-660 (Bačka)
2010	102	0	0	0
2011	82	22	3 (Bačka) 4 (Srem)	20-2180 (Bačka-Srem)
2012	240	48	8 (Bačka) 1 (Banat)	80-1820 (Banat-Bačka)
Total	614	133	20	20-2180 (Bačka-Srem)

The current occurrence of vital cysts in the soil from 20 fields in Vojvodina indicates the use of narrow crop rotation as a consequence of the lack of available fields. The latest findings suggest that *H. schachtii* is the most frequent near old sugar-beet factories in Vojvodina. This has become a problem in the sugar beet growing areas of the districts of Bačka and Srem as a result of intensive cultivation (Bačić, 2013).

The most useful ways to combat the sugar beet cyst nematode are crop rotation (Greco, 1983) and the use of tolerant beet varieties (Wauters *et al.*, 2010). The crop rotation period is usually more than once in 5 years (OEPP/EPPO, 1994). Nematode tolerant varieties have been tested and available in Serbia recent years (Bačić *et al.*, 2007). The basic strategy of control is to keep the nematode population below the economic threshold. The population densities between 2 and 4 juveniles in 1 cm^3 of soil may result in yield loss (Gray *et al.*, 1992). Damaging level depends on calendar year, different weather conditions and the age of plant. The weather conditions in Vojvodina during 2007 and 2012, with a rainy spring and a dry summer were very favorable for nematodes (Bačić, 2013). In order to offer the right advice to farmers to choose crop rotation or tolerant varieties, regular monitoring of this pest in the soil is necessary to obtain the information about the number of eggs and juveniles in the soil before planting.

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IMPORTANCE OF TILLAGE SYSTEMS ON SOME PHYSICAL PROPERTIES OF SOIL UNDER CLIMATE CHANGE IN SERBIA

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ABSTRACT

Future of agriculture depends on flexible cultural practice, biotechnology and appreciation of basic ecological principles in soil usage. Crop production systems are influenced by a complex array of factors combining various crops, soil water, and climate and management. Detail analysis of climatic factors in the multi-year period for the Belgrade region, showed some changes in terms of temperature and precipitation. Agronomic aspect of looking into the problem requires a good knowledge of our crop needs for primary vegetative factors as well as temperature and moisture. It is necessary to consider the adaptation of many cropping practices that indirectly can reduce damages from drought starting from the adequate tillage systems, dates, depths, methods and densities of sowing, fertilizing, and cultivation methods during the growing season and selection of hybrids resistant to drought stress or *vice versa* in wet conditions. Crop production based upon high mechanical and chemical inputs (deep tillage, high fertilizer and pesticide rates etc.) are becoming less rational because of economic and environmental problems. The limiting factor for the successful agricultural production on this plot is over-wetting the soil. This fact does not allow the respect optimum time for application cultural measures like tillage, seeding, and normal conditions for growth and development of plants or crop-harvesting. Poor infiltration or permeability of soil is the reason of water logging, which leads to suppression of crops, lack of normal operation of machinery (jamming and deterioration of the tractor up to the height of the wheels on some depressions).

Keywords: climate change, tillage systems, physical properties of soil, Serbia

INTRODUCTION

During the recent three decades, the issues of climate variability and climate change have been at the center of many scientific studies (Olesen and Bindi, 2002; Olesen, *et al.*, 2011; Kovacevic *et al.*, 2012c). Global climate variability and change caused by natural processes as well as anthropogenic factors are major and important environmental issues that will affect the world at the beginning of the 21st century. High and quality yields of different field crops largely depend on climatic conditions. Since climate in Serbia provides good light conditions and sufficient heat energy in a greater part of Serbian territory, the success of spring crops (maize, soybean, sunflower, etc) mainly depends on precipitation sums and their distribution. Weather conditions during each production year significantly affect plants directly or indirectly through the soil. In recent decades, abiotic extremes caused by climate factors have had stress effects on field crops (Kovacevic *et al.*, 1999; Kovacevic *et al.*, 2005).

The application of cropping practices can provide the undisturbed growth and development of grain crops and can neutralise extreme abiotic climate factors (precipitation, temperature) and their stress effects on crops (Kovacevic *et al.*, 2009; Kovacevic *et al.*, 2010; Dolijanovic *et al.*, 2008).

Under climate conditions of our country, crops primarily develop when there is a sufficient or even surplus amount of precipitation. If there is a precipitation deficit the following indirect measures, which resulted in reduced water requirements by grain crops are employed: tillage systems, balanced NPK nutrition, optimum nitrogen rates, optimum density in accordance with cultivar properties and climate conditions, well developed crop free of disease and pests. The selection of a proper cultivar for certain agroecological conditions is increasingly important, because not only dry but also extremely wet years last in a longer period of time. Extremely wet years also cause problems that need to be solved with different agromelioration measures (Kovacevic *et al.*, 2010). All cultivars have a high potential for yield, but resistance to stress conditions, especially to high temperatures or drought, will be a very important criterion, particularly for more arid regions.

It is necessary to reconsider the following each year: the applied agricultural management systems in all crops, each cropping practice, the period of its application that is meeting deadlines, types of tools, proper selection of cultivars and hybrids for certain regions, level intensities of wheat growing practices (high and low-inputs), optimum sowing density, amounts of applied agrochemicals (fertilisers, pesticides), good agricultural practice.

This review examines the research priorities for crop and soil management practices first of all current tillage systems to mitigate global climate changes that are needed to achieve high stable yield under drought or wet conditions. Research must combine the latest knowledge including agroecology, general farming practices, soil physics, genetics and ecophysiological understanding of the interactions between crop plant genotypes and the growing environment to better inform crop improvement.

Meteorological conditions (1990-2012) in relations to main crops in Serbia

Based on many-decade analysis of the data obtained from the Republic Hydrometeorological Service of Serbia in the Belgrade area (Tab. 1 and 2), it can be noticed that droughts have been increasingly frequent in these regions for the last twenty years. Even six years of the last twelve years were dry. It is very important for agriculture when drought occurs. If the drought occurs during the critical periods for moisture in a given crop, or when the fruit is being formed and grain filled, then the damages are the greatest. For example, in the analyzed period of 20 years: 1992, 2000, 2007, 2003, 2001 were very dry. In these years, drought was observed in the spring, and it was especially noticeable in the summer period so that the adverse consequences for most of the spring crops were great. In Serbia, 2007 even higher temperatures than those were recorded. The subject under discussion is the highest temperature ever recorded in the area and up to 45 ^{0}C, when some previous maximums were exceeded. Damages that are registered via reducing yields were severe. Obtained maize yields were lower in comparison with the previous year by 32 per cent, and yields of sunflower as the most resistant to drought were decreased by 23 per cent. The spring drought also occurred in 2009, but it was overcomed and was severe drought. During the vegetation period of maize an increasingly frequent heat waves are observed. In the beginning, these were the waves in the month of September, which contributed to more rapid maturation of spring crops first of all maize and soybean. However, in recent years, tropical heat waves in which the nighttime temperatures do not drop below 20 occur earlier in August, and this year they occurred in the second half of July. These waves contributed to the accelerated maturation and disturbed the grain filling. This is becoming a real problem these days.

In Serbia, the precipitation distribution in the crop cultivation under rainfed conditions has very often a decisive effect on the occurrence of longer or shorter dry spells. The favourable precipitation distribution during the year is the distribution that provides a proportionally large numbers rainy days and equal intervals between rainy and rainless periods, particularly during the growing season. The occurrence of longer rainless periods in spring and autumn, especially in years with dry summers, when drought continues from summer into autumn, regularly affects grain crops due to uneven and long emergence. Under conditions of our climate, the greatest precipitation sums are recorded in June. If sum of precipitation is well distributed over the decades and if there are rainfalls during July, then maize is the most important crop in Serbia that rarely suffers from drought. Insufficiency of precipitation in July, and the following long rainless period accompanied with high temperatures and heat waves cause the greatest problems (Spasov and Spasova, 2001). Causes of droughts are different. Insufficient annual precipitations and their distribution during the growing season of crops as well as the evaporation intensity of the falling rain are the most important causes of droughts (Kovacevic and Milic 2010; Kovacevic *et al.*, 2012d). Under climate conditions of our region drought is an occasional phenomenon, which can be moderate or extremely severe. The evaporation intensity depends on temperature, effects of wind and geographic location of a certain region and increases from west to east or from north to south of our country.

According Kovacevic *et al.*, (2012e) analysis of the past 20 years shows that 1992/93, 1995/96, 2002/03 and 2006/07 (Tab. 1) were extremely dry years for winter wheat and other small grains cereals. However, observations of the whole growing season of winter small grains show that there were extremely wet years, such as 2003/04, 2008/09 and 2009/10, which also caused damages such as complete smothering of crops in heavy soil with waterlogging and outbreak of diseases, which significantly reduced the yield, aggravated harvest and decreased grain quality. The greatest problems related to moisture is insufficient precipitation sums during October and November, as they aggravate emergence, inhibit the growth and accelerate later winter small grains getting around through in the other qualitative stages of organogenesis.

Table 1 Mean temperature and precipitation in different periods growing season of winter small grain cereals in Central Serbia (1991-2011)

Year	Temperature (^{o}C)				Precipitation in mm			
	Autumn	Win.	Spring	Grow. season	Autumn	Wint.	Spring	Grow. season
	X-XII	I-III	IV-VI	X-VI	X-XII	I-III	IV-VI	X-VI
1991/92	6.0	3.7	17.2	9.0	178.6	48.0	258.2	484.8
1992/93	6.5	5.9	18.1	8.9	187.0	130.8	91.9	409.7
1993/94	7.4	6.0	17.4	10.3	185.5	91.1	318.2	594.8
1994/95	7.4	5.2	16.6	9.7	108.2	172.0	209.3	489.5
1995/96	6.6	1.8	16.3	7.8	124.4	146.0	217.4	487.8
1996/97	8.1	3.6	15.6	9.1	215.6	93.6	169.0	478.2
1997/98	7.8	4.9	17.1	9.9	217.0	102.8	142.6	462.4
1998/99	4.9	3.8	16.8	8.5	175.4	145.3	273.2	593.9
1999/00	6.4	4.1	19.6	10.0	273.6	85.9	95.5	455.0
2000/01	10.6	7.1	16.4	11.4	78.5	128.1	390.9	597.5
Average	7.2	4.6	17.1	9.5	174.4	114.4	216.7	505.4
2001/02	5.9	7.1	18.4	10.5	114.0	43.0	156.0	313.0
2002/03	9.0	2.1	19.6	10.2	167.0	88.0	95.0	350.0
2003/04	8.3	3.9	16.8	9.7	195.0	145.7	238.9	579.6
2004/05	9.5	2.4	17.0	9.6	210.7	172.0	195.0	577.7
2005/06	8.2	3.0	17.3	9.5	133.0	206.0	274.0	613.0
2006/07	10.1	8.8	19.6	12.9	94.0	189.0	191.0	474.0
2007/08	6.4	6.6	18.8	10.6	269.0	131.0	141.0	541.0
2008/09	10.2	4.0	19.0	11.1	147.0	201.0	193.0	541.0
2009/10	9.8	4.5	17.9	10.7	285.0	246.0	306.0	837.0
2010/11	8.4	3.9	18.1	10.1	155.0	119.0	114.0	388.0
Average	8.6	4.6	18.2	10.5	177.0	154.1	190.3	521.4
Differ.	1.4	0	1.1	1.0	2.6	39.7	-26.4	16.0

These analyses in which the growing season of small grains was divided into three subperiods (Tab. 1) show the increase in the average temperature of 1.4 ^{o}C and 1.1 ^{o}C in the autumnal and spring period in the second decade (2001/02-2010/11) in relation to the first decade (1991/92-2000/01), respectively, while the winter average temperatures were equal.

At the same time, the average winter temperatures were equal in both decades. The three-month cumulative precipitations were insignificantly higher in autumn (2.6 mm), significantly higher in winter (39.7 mm) and lower in spring (26.4 mm), which is especially important as early and later spring when is a critical period for moisture for grain filling.

The precipitation amount has a crucial effect on occurrence of shorter or longer dry spells in crop cultivation under rainfed conditions. The favourable precipitation distribution during the year is the distribution that provides a proportionally large numbers rainy days and equal intervals between rainy and rainless periods, particularly during the growing season. The occurrence of longer rainless periods in spring and autumn, especially in years with dry summers, when drought continues from summer into autumn regularly affects grain crops due to uneven and long emergence.

Table 2 Mean temperatures and precipitation sums during the growing season main spring crops in the region of Central Serbia (1991-2010)

Year	Mean temperature (^oC)			Total precipitation sum (mm)		
	VI-VIII	IV-IX	Year	VI-VIII	IV-IX	Year
1991	18.5	16.1	10.7	163.0	334.8	628.5
1992	23.4	19.4	12.3	247.8	351.2	586.2
1993	22.5	19.7	12.2	131.8	224.8	541.1
1994	23.1	20.4	13.6	348.8	484.3	683.6
1995	22.3	18.8	12.4	167.6	404.8	701.2
1996	22.0	17.8	11.1	159.2	427.2	788.8
1997	21.5	17.9	11.8	275.0	444.0	754.6
1998	21.8	18.5	11.7	159.2	348.9	627.1
1999	20.7	18.5	11.8	418.4	611.5	1030.4
2000	24.1	21.0	14.2	56.2	203.3	367.7
Average	22.0	18.8	12.2	212.7	383.5	670.9
2001	22.0	18.7	12.6	262.4	651.0	893.1
2002	23.3	20.1	14.1	249.0	375.0	585.0
2003	24.7	21.1	13.1	154.0	273.0	556.0
2004	22.0	18.9	12.8	288.9	466.5	822.9
2005	21.5	19.0	12.2	329.0	486.0	791.0
2006	22.2	19.6	13.1	282.0	445.0	745.0
2007	25.5	21.1	14.4	198.0	316.0	774.0
2008	23.6	20.3	14.4	155.0	319.0	597.0
2009	23.2	21.1	14.0	277.0	321.0	807.0
2010	23.4	20.1	13.3	275.0	452.0	853.0
Average	23.1	20.0	13.4	247.0	410.4	742.4
Difference	1.1	1.2	1.2	34.3	26.9	71.5

Drought during summer months (June, July and August) mostly affects broadcast crops germinating in spring.

The analysis of weather conditions in the 1991-2000 periods related to spring crops: maize, sunflower, soybean etc (Kovacevic *et* *al*., 2012f). shows that 1992, 1993, 1998 and especially 2000 were extremely dry years (Tab 2). Out of 12 years of 21st century four were favourable and high yield years (2004, 2005, 2009 and 2010); while the following three years were very dry: 2003, 2007 and 2012. The driest year was 2012, when very low amounts of rainfall were recorded, while maximum daily temperatures in the May-August period were over 35^{o}C. Frequent heat waves have been observed during summer months of the growing season. In the beginning, heat waves were characteristic for September and they contributed to faster maize maturing, but during the last few years, heat waves have been occurring in August, while in 2012 they occurred in the second half of July. Heat waves contributed to accelerated maturation and they disturbed grain filling. Today, this is becoming a problem.

Possibilities for adaptation tillage systems to mitigate climate changes

Scientists and agronomists should respond on many challenges and on several question marks regarding soil tillage strategies for different regional circumstances. It is crucial to define how and until which level we could reduce tillage intensity and to adopt system issues according predominant soil types, climate conditions, and cultural practice.

Soil tillage which depends of many factors: climate and soil characteristics, landscape, crop responses, previous crops, fertilizing systems, cultivars, have different consequences upon a time and more or less success trough years. Correctly defined tillage system is very important issue regarding yield potential, which all together with crop rotation and fertilizing system could afford most rationale and accurate usage of soil fertility. Soil tillage has been developed into a two ways, both higher depth and increased number of passes. Precisely, numerous passes of heavy machines have conducted to a deteriorating of soil physical properties because of high compaction and worsening yielding capacity and soil fertility. On the other hand, multiple passes and increasing tillage depth have influenced higher energy inputs, which was very dangerous in the last decades of XX century. Consequently, the demands for inputs are less, which is lowering production costs and increasing farmers competitively in foreign and domestic markets. Considering fact that only plowing could takes 50 to 55% from the total inputs dedicated for tillage operations or 38 to 42% of overall inputs during production, it sounds logical that this segment offering the certain ways for more rationale solution. Appearance of wide range of herbicides and its massive acceptance had influenced a new strategies based on their economical efficiency and simplicity (Momirovic *et al.*, 1995; Momirovic *et al.*,1998; Kovacevic *et al.*, 1998; Kovacevic and Lazic, 2012b).

Still in Serbia dominating common sense that any successful tillage system practically is not possible without deep ploughing, because of clear benefits of it. Of course several possibilities could exist including combined tools and multitillers, with integrated tillage operations both on the base and at the secondary level.

The effect of different tillage systems on soil physical properties

Essential change of soil tillage systems, along different levels of tillage reduction until no tillage, has a great impact on soil physical and agrochemical characteristics. Reduction of soil tillage intensity or its total avoidance could affect significantly porosity, especially on heavier soils, increasing shares of micro pores in spite of macro porosity and lowering air capacity and air permeability. The most important issue under these conditions is higher bulk density of non tilled soils on direct drilling plots, compared to conventionally ploughed soils. Contents of certain nutrients have been changed along the depth of top soil layer. Potassium and phosphorous are present rather shallow, near to the soil subsurface, while calcium and magnesium become more disposed to a leaching. Much slower mineralization of nitrogen during the cold winter months corresponding to an incidental denitrification processes. Due to a certain changes in soil properties, the new tillage systems could affect micro climate conditions, and then soil micro topography, influencing more or less homogenised size of soil structure aggregates.

Kovacevic *et al.,* (1999) have showed significant influence on soil bulk density and porosity, weediness and yielding capacity in different crops. With no tillage practice bulk density increasing significantly in winter wheat, soyabean, whereas in maize crop mulch tillage becoming very acceptable regarding favorable bulk density. This tendency are more visible in double cropping of maize, where is, due to a short season bulk density and available soil water on the no tillage and especially mulch tillage variants are almost optimal for such soil types (Tab. 3).

Conventional soil tillage systems based on moldboard plowing with additional pre sowing preparation showed better performance in weed control comparing to conservation ones. Under Serbian conditions among examined conservation soil tillage systems, no tillage being characterized with severe weed infestation, which could have serious implication, having necessity to include mechanical control measures in addition to the common chemical treatments.

Table 3 Long term effects of tillage systems on soil bulk density in different crops

Tillage systems	Soil depth	Bulk density (g cm^{-3})		
	cm	Winter wheat	Maize	Soybean
Conventional tillage	0-10	1.34	1.47	1.43
	10-20	1.43	1.49	1.53
	20-30	1.45	1.49	1.52
	Average	1.41	1.48	1.49
Mulch tillage	0-10	1.37	1.46	1.51
	10-20	1.39	1.50	1.55
	20-30	1.38	1.36	1.44
	Average	1.38	1.44	1.50
No tillage	0-10	1.56	1.47	1.52
	10-20	1.58	1.45	1.53
	20-30	1.51	1.35	1.57
	Average	1.55	1.43	1.54

Fighting against drought is mainly focused on the implementation of certain measures through soil and through the plants.

Basic tillage with seedbed preparation. The creation of favorable conditions in the soil through tillage and fertilization (agromeliorative tillage, creation of tilth, autumn deep tillage) makes a layer of soil that is able to receive and carry or accumulate sufficient reserves of moisture from the period when it is abundant as well as to put them at the disposal of the plants in their critical periods for moisture. Hence the autumn deep tillage is of enormous significance for all, especially for the spring crops. All practices of pre-sowing tillage methods as well as care treatment aimed at capillarity cutting and moisture conservation are also welcome for this purpose (drilling, inter-row cultivation and hoe and ridge cultivation). According Kovacevic *et al*., (2009a) for the purpose of eliminating various unfavorable abiotic influences which are directly manifested in the soil and creating favorable conditions for crops, different care treatments are used, first of all, those of mechanical nature: drilling, rolling and inter[row cultivation with hoe and ridge cultivation (Tab. 4).

Table 4 The effect of different tillage methods on physical properties of soil in maize (calcareous Chernozem)

Pressowing tillage methods	Bulk density g cm^{-3}	Total porosity vol.%	Air capacity vol.%	Soil moisture w %	Penetration resistance MPa
Harrowing	1,32	49,57	14,08	15,54	3,32
Tillage by rotary tool	1,27	51,58	17,49	14,37	2,85
Tillage by combine tool	1,29	50,82	16,18	14,96	3,09
Tillage by combine tool 2x	1,26	51,75	17,75	14,55	2,90
Discing+ Harrowing	1,28	51,48	17,28	14,73	2,87

Inter-row cultivation and hoeing. The soil sown with wide-row crops is unprotected for a long period of time. Applying inter-row cultivation, with cultivators intended only for such purposes, the soil is cut and the loosed between the rows. In this way, the following objectives are achieved: the existing crust is destroyed and the emergence of a new one is prevented, capillarity cutting creates a loose layer on the soil surface, which also prevents unnecessary loss of the existing moisture in the soil, as well as the ability of soil to absorb new moisture from rainfall; bulk density is reduced while the porosity and air capacity are increased, which increases aeration and improves the soil thermal regime, weeds from the inter-row space, which can be strong competitors to cultivated crops for moisture, are destroyed.

Ameliorative measures. Vice versa, in wet years ameliorative tillage have important role. In the researched areas, an important and limiting factor for the successful production is over-wetting of the soil. Bearing in mind that in Serbia we have more than 400.000 ha of soil heavy mechanical texture and approximately 1 million hectares of degraded soil in different ways, this kind of researches are important and useful from the standpoint of science, and even more from the point of using this research into practice (Hadas, 1997; Kovacevic *et al*., 2009; Ercegovic *et al*., 2010). This fact does not allow the respect optimum time for application cultural measures like tillage, seeding, and normal conditions for growth and development of plants or crop-harvesting. Compaction in some layer this soils reduces pore size that can occur when soils are cultivated under wet conditions which can damage pores by soil smearing creating an impenetrable layer for plant roots. This means that roots are dependent for soil penetration on the existence of pores in the soil which are both wide enough to accept them and continuous enough for lengthy root systems to develop. Poor infiltration or permeability of soil is the reason of water logging, which leads to suppression of crops, lack of normal operation of machinery (jamming and deterioration of the tractor up to the height of the wheels on some depressions).

According Kovacevic *et al.*, (2012c) ameliorative tillage with new types of machines was obtained a significantly lower bulk density in compared with control (Tab. 5). In the first period of research there is a significant difference between the two examined variations and the examined soil depth, except the third (20-30cm). Greater soil loosening in the experimental area can be seen from the higher porosity. Higher porosity allows better air flow and rapid infiltration of water. This can be seen from the moisture content. Higher moisture content on the control variants is a result of higher density of individual layers. The total amount of water has significantly contributed to this. It can be seen that the control variation at all depths has higher amount of water. In loam soils it does not mean and higher availability of water. This circumstance at higher rainfall could be the limit for fast water flow. Tillage system that was used, was consisted of leveling of the field, of undermining with the drainage plough and of tillage with vibrating subsoiler, has resulted in an increased soil loosening as we can see from significantly lower values of bulk density, higher total porosity and a better connection between the solid, liquid and gaseous phases.

The soil properties were repaired in the first year and it became more favorable habitat for growing crops, also, it should be noted and the prolonged effect on the other crops (winter wheat in third year of investigations 2010). High precipitation in autumn, winter and early spring in previous year (2010) were a reason to water logging on the control variant.

Ameliorative tillage with new types of machines was obtained a significantly lower bulk density in compared with control. In the first period of research there is a significant difference between the two examined variations and the examined depth, except the third (20-30 cm).

Table 5 Effects of tillage system on physical properties of soil after first interrow cultivation in maize and sunflower

Variants	Depth in cm	Bulk density g cm^3	Total porosity %	Max. water content % vol.	% moisture vol.	% moisture weight	Amounth of water m ^{3} ha^{-1}
Ameliorative tillage system	0-10	1.08	57.8	40.6	27.1	21.9	714
	10-20	1.34	48.5	41.2	27.8	20.9	837
	20-30	1.35	48.7	36.6	29.7	21.9	892
Average	0-30	1.26	51.6	39.5	28.2	21.6	814
Control	0-10	1.44	43.9	34.4	29.6	20.6	888
	10-20	1.42	45.6	37.1	34.9	24.5	1042
	20-30	1.42	45.6	36.1	28.4	20.0	851
Average	0-30	1.43	45.0	35.8	31.3	21.9	927

Greater soil loosening in the experimental area can be seen from the higher porosity. Higher porosity allows better air flow and rapid infiltration of water. This can be seen from the moisture content. Higher moisture content on the control variants is a result of higher density of individual layers. The total amount of water has significantly contributed to this. It can be seen that the control variation at all depths has higher amount of water. In loam soils it does not mean and higher availability of water. This circumstance at higher rainfall could be the limit for fast water flow. Tillage system that was used, was consisted of leveling of the field, of undermining with the drainage plough and of tillage with vibrating subsoiler, has resulted in an increased soil loosening as we can see from significantly lower values of bulk density, higher total porosity and a better connection between the solid, liquid and gaseous phases.

CONCLUSION

According to the detailed analysis of temperature and precipitation regimes on the territory of Belgrade in the 1991-2011 and their importance to plant, the following can be concluded:

Drought is one of the major hazards affecting Serbia and drought is a normal part of the climate. Most global climate models project increased summer continental interior drying and, as a result, a greater risk of droughts is projected for the twenty-first century.

Two most important climate parameters in agronomy, temperatures and precipitations, have been changing faster during the past two decades.

The primary source of water for agricultural production for most of the world is rainfall. Amount of rainfall, frequency and intensity are three values of which vary from place to place, day to day, month to month and also year to year.The extremely dry years were 1992, 1993, 1998 and particularly 2000, 2003 and 2007.

Heat wave with extremely hot summer days and tropical nights contribute to the yield reduction. The temperature increase did not resulted in the precipitation reduction. Rainfalls were shifted more towards the first decade of June and the last decade of August and in such a way they simply masked the actual moisture insufficiency in the critical period for maize that lasts from the mid June to mid July under our climate conditions.

Based on these analyses it is necessary to consider the adaptation of many cultural practices that indirectly can reduce damages from drought or too wet problems starting from the adequate tillage systems. Extremely wet years also cause problems that need to be solved with different amelioration measures. Long term wise, conservation tillage systems as scientifically based concept and integral part of sustainable agriculture, should be transformed into a widely accepted package of cultural measures for successful management of all resources.

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BIOLOGICAL ACTIVITY OF SOIL IN ORGANIC FARMING IN THE REPUBLIC OF KAZAKHSTAN

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ABSTRACT

The use of biologically balanced farming systems must be accompanied by ecological and economic assessment of environmental change. Among the indicators of environmental changes leading place belongs to soil micro-organisms: the structure of the microbial community and its biological activity. Microbiological monitoring of the soil of biological farming is an important and necessary element in the management and preservation of fertility of agricultural land. In general, organic and mineral fertilizers in organic farming system increases the biological activity of the soil in average per rotation for 164% compared with the control. By the end of green manure phase in crop rotations the mineralization processes in the soil are enhanced, the ratio of the number of amylolytic bacteria to ammonificators rises to the threshold limit (2.3-2.7 times).

Keywords: soil fertility, microorganisms, biological activity, rotation, bacteria

INTRODUCTION

Agricultural production on the current stage of development needs a systematic and widespread increase in the fertility of irrigated lands in Kazakhstan. The severity of the current situation in modern agriculture is partly due to the shortage and high cost of energy (Saljnikov *et al.*, 2013). The expansion of modern, resource-intensive agriculture has multiplied yields of the world's major crops – wheat, rice, and maize – by a factor of 2.6–3.6 over the last fifty years (Leifeld, 2013). In most cases, agricultural intensification and landscape simplification lead to a loss of biodiversity (Stoate *et al.*, 2001; Benton *et al.*, 2003;

Foley *et al.*, 2005). Organic farming often counteracts these detrimental effects (Bengtsson *et al.*, 2005; Hole *et al.*, 2005).
Therefore, the issues of improving the environmental situation in modern agricultural landscapes, maintenance, and reproduction in soil fertility and increase crop productivity is being acquired special urgency. There is a need to create not only a sustainable and environmentally sound technologies and techniques, but also to conduct a biological farming system as a whole. One of the most promising measures in improving soil fertility is organic farming: crop rotation, the introduction of legumes in crop rotation, perennial legumes and legume-grass mixtures, the intensification and maximum use of associative and symbiotic nitrogen fixation, the use of green manure and non-market part of the harvest for fertilizer , the use of organic fertilizers, crop adaptive highly productive varieties and hybrids that are resistant to pests and diseases, a moderate use of mineral fertilizers and pesticides, coupled with differentiated minimum tillage.

The use of biologically balanced farming systems must be accompanied by ecological and economic assessment of environmental change. Among the indicators of environmental changes the leading place belongs to soil micro-organisms: the structure of the microbial community and its biological activity. Microbiological monitoring of the soil in biological farming is an important and necessary element in the management and preservation of fertility of agricultural land. Function and response of soil biocenosis on human intervention has both general laws for all types of soils and their zonal characteristics that are unique to a particular type of soil, which determines the need for research, particularly in view of the zonal aspect.

The intensity and pattern of mineralization processes, humus formation and transformation of humic substances driven by microorganisms, which are responsible for the plant nutrients, can be applied to control soil processes, which are defined in many ways by the quantity and quality of crop residues. The study of these factors is of paramount importance for the further development of biological farming. Formation of the soil microbial community under the influence of different agro-ecological conditions can change the flow of the elements in the direction of mineralization or immobilization. The purpose of this study is to reveal the dynamics of the microorganisms of the major taxonomic and physiological groups in the soil of organic farming crop rotations.

MATERIALS AND METHODS

Microbiological analyses: For microbiological analyses soil samples were taken from 0-10 cm three times in a vegetation period: at soil temperature +10^0 C (May), at most warm period (July) and before harvest (September).

Ammonifiers assimilating the organic forms of nitrogen were determined on meat-peptone agar (MPA). Bacteria assimilating the mineral forms of nitrogen were determined on the starch-ammonia agar (SAA). The total number of actinomycetes was determined on starch-ammonia agar *ISP-4* (SAA) (Bondartsev, 1954; Prauser, 1964). The total number of fungi was determined on malt agar dilution of 1:1000.

Crop rotation design:

I. 8-year grass-cereal-row crop: winter wheat + alfalfa; alfalfa 2nd year; alfalfa 3rd year; winter wheat; sugar beet; soybean; sugar beet; corn. In this rotation the fertilization treatments were studied: control without fertilization; $N_{80}P_{50}K_{140}$; siderate 8.9 t ha^{-1}; manure 20 t ha^{-1}. The organic and mineral fertilizers were applied for sugar beet sown after winter wheat (after 4th year). The experiment studied effects and aftereffects of the different amendments in the culture that most productively use the growing season for the maximum accumulation of organic matter. In this experiment two controls were introduced. The first control is without fertilizer and the second is application of mineral fertilizer for sugar beet.

II. 3-year cereal-row crop: winter wheat + (siderates (10.0 t ha^{-1}); sugar beet; soybean. In this rotation experiment after winter wheat the vetch and oats mixture (green manure) was planted and then the green plant mass of 10 t ha^{-1}, was plowed into the soil

RESULTS AND DISCUSSION

The microbial population of soil are extremely numerous and varied (bacteria, actinomycetes, fungi, algae, protozoa, and close to them living beings).

In the processes of transformation of plant residues, formation of nitrates and other plant nutrients, as well as components necessary for the synthesis of humus, mainly bacteria, actinomycetes and fungi are involved (Mishustin, 1956; Ilyaletdinov, 1988; Paul, 2000). The experimental data suggest that the field crops are not equally affect the growth and reproduction of the soil ammonifiers in green farming rotations. The results of the ammonifier's number showed that in the soil of control treatment the number of ammonifiers ranges from 3.4 to 8.0 million per 1 g of air-dried soil. The use of fertilizers increases their number to 13.8 million and thus increases soil biogenity. The higher content of mobile soil phosphorus and potassium in soil leads to the less content of available nitrogen in the rhizosphere. The most active propagation of ammonifying bacteria was observed when using green manure. Through the research years their number increased by 217% relative to the control. The quantity of ammonifiers was high in the year after plowed in peas, both as direct effect in the soil (under sugar beet) and as aftereffect - under soya and sugar beet.

In the 3-year rotation, also the largest number of bacteria metabolizing organic forms of nitrogen (5,6-6,6 million) was found in the soil where the sugar beet was sown after green manure (siderate). However, their number is 2 times less than in the 8-year rotation, which is probably due to the large stocks of plant residues in the soil after plowing of alfalfa. The maximum amount of ammonifiers often occurs in the spring and autumn, when the soil has fresh vegetable residues and sufficient moisture.

Light chestnut soils are common in the area of increased activity of mineralization processes, which increases sharply during irrigation of soils. The numbers of bacteria assimilating mineral forms of nitrogen in the soil depends on the supply of mineral forms of nitrogen. Favorable conditions for amylolytic bacteria are introduced into the soil with nitrogen fertilizers. The most active growth and development of amylolytic bacteria in the soil of organic farming was observed in the spring. In summer the number of soil bacteria that allocated on the SAA, is reduced, and in the fall is increasing again, due to the decline of high temperatures. Their number ranges in the soil of 8-year rotation from 8.2 to 29.6 million; and in 3-year rotation from 8.3 to 17.4 million, depending from the growing crop and fertilization.

The most favorable conditions for the growth of bacteria utilizing mineral forms of nitrogen in the 8-year crop rotation were registered in the soil, where organic fertilizers was applied, especially under soybeans (average for growing season 21,0-22,1 million). In the soil of the control treatment the number of amylolytic bacteria does not exceed 5,8-18,8 million. In the 3-year crop rotation the highest number of these bacteria was found under sugar beet grown after vetch and oats mixture – 14.2 million (from 10.0 to 17.4 million for vegetation). Under soybean their number is 11.8 million (10,2 - 14,5 million); under winter wheat is only 11.8 (8,3-14,5 million). It should be noted that a significant increase in the number of amylolytic bacteria in the summer (to 14.5 million) in the soil is due to the pre-sowing treatments (basic processing, irrigation) and sowing of siderates (green manure).

An important part of the soil microflora, both in quantitative and qualitative terms belongs to actinomycetes. Ray fungi, having a potent enzymatic apparatus, are actively involved in the decomposition of soil organic matter, complex carbon compounds, which are inaccessible to other taxonomic groups of microorganisms.

In our experiments, the most active growth and propagation of actinomycetes in the soil of studied treatments observed in summer period from 3.0 to 7.0 million. In the soil of organic farming of 3- and 8-year crop rotations were created optimal conditions for habitat of actinomycetes. Their number amounts to 2.9-3.0 million in average per organic crop rotation. Studies showed that the best growth of actinomycetes was under application of organic fertilizer (manure, green manure).

In 3-year crop rotation the highest number of actinomycetes was detected in the soil under winter wheat. On average, during the growing season they number 4.3 million, due to a high content of substances inaccessible to microorganisms with a wide C: N ratio, in the litter and in the crop and root residues of wheat. Flohrea *et al.*, also found that microbial biomass were efficiently enhanced by organic farming.

Green mass of vetch-oat mixture applied before sowing of sugar beet, also contributed to the active propagation of the soil actinomycetes. Compared to the control their number increased to

144%. The aftereffect of green manure lasts also for soybean not less than 3.0 million.

Correlation analysis of microflora - yield indicates a close positive correlation between the number of actinomycetes and other taxonomic groups of organisms common in the soil under sugar beet, in the treatments with mineral and organic fertilizers ($r = 0,78$; 1,0).

In addition to bacteria and actinomycetes, fungi are also the very common soil microorganisms. Until recently, the main focus in the study of soil microflora has been focused on the study of bacteria, but this approach is not correct, because the fungi play a very big role in the soil processes. The sequential replacement of one species of fungi by other species in the decomposition of plant residues in the soil is an example of the metabolic relationships between organisms.

In this study, the minimum propagation of fungi in the studied soil observed in summer due to a reduction in the soil organic matter, high temperatures and intense evaporation of moisture, and the soil compaction.

In the 8-year rotation the number of fungi in the spring varies by treatments of experience from 9,7-21,1 thousand; in summer from 5.1 to 14.1 thousand; in fall from 8.4 to 17.1 thousand per 1 g air-dry soil. Most of their increase observed in the cultivation of peas for green manure - 170%; with 20 t/ha of manure - 141%; with mineral fertilizer - 132% compared to the control (not fertilized) treatment.

Fungal population is better represented under maize (24.1 thousand per 1 g of air-dry soil), which seems to be due to the biological features of this culture and its crop residues as corn stalks contain the highest percentage of moisture, and the roots – air.

In the 3-year crop rotation, using the roots, stems and leaves of vetch as fertilizer, that contains 2.4-3.4% N, contribute to a sharp enrichment of the soil in mobile forms of nitrogen.

When plowing green manure the following genera of fungi are developed: *Penicillium*, *Mucor*, *Fusarium*, *Trichoderma*, which transform the complex carbon compounds of plant residues, thus releasing organic nitrogen. The maximum number of microscopic fungi -20.1 thousand per 1 g of soil was observed after the winter wheat when the vetch-oat mixture plowed in as green manure.

Thus, the development of saprophytic fungi in the fields of crop rotation depends on many complex factors, primarily from its saturation with legumes, including green manure.

Based on the above, it was established that the most favorable conditions for the growth and propagation of microorganisms in the 8-year crop rotation are in cultivation of soybean (22.7 million), and in 3-year crop rotation with winter wheat + vetch-oat mixture (19.8 million) (Table 1).

Table 1. Overall biological activity light chestnut irrigated soils, million per 1 g air-dry soil

Crop rotation		Treatments			
		control	$N_{80}P_{50}K_{140}$	peas (green manure)	manure 20 t/ha
8-year crop rotation					
Sugar beet	million	19,6	28,2	36,1	27,0
	% to control	100	144	184	138
Soybean	million	22,7	36,0	36,1	34,4
	% to control	100	158	159	152
Sugar beet	million	22,9	36,1	37,2	28,9
	% to control	100	158	218	169
Average	million	19,8	28,4	36,5	28,1
	% to control	100	143	184	142
3-year crop rotation					
Crop rotation		Control without green manure		Green manure with vetch-oat mix	
Winter wheat + vetch-oat mix	million	24,8		19,8	
	%	100		80	
Sugar beet	million	15,2		25,6	
	%	100		168	
Soybean	million	19,4		20,4	
	%	100		105	
Average per rotation	million	20,0		22,3	
	%	100		112	

CONCLUSIONS

Summarizing, we can say that organic and mineral fertilizers in organic farming system increases the biological activity of the soil in average per rotation for 164% compared to the control. To the end of siderate link in the rotation, the mineralization processes in soil increase, the ratio of the number of amylolytic bacteria to ammonifiers rises to the threshold limit (2.3-2.7 times).

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SOIL FERTILITY OF WEST KAZAKHSTAN REGION

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ABSTRACT

In the dry steppe zone of Western Kazakhstan zonal soils are Chestnut soils, which are cultivated for main agricultural crops. This soil is formed under lack of moisture in non-percolative water regime, under the dwarf fescue-feather-incana association. Chestnut soils have low natural fertility about 2-4%. Cation exchange capacity is 25-35 meq 100 g^{-1} soil. Exchangeable cations consist of calcium, magnesium and sodium. In the upper horizons of the largest share belongs to calcium and magnesium; in the deeper layers the amount of exchangeable sodium increases. Cationic-anionic composition is represented by soluble form of calcium, magnesium, sodium carbonates, bicarbonates, chlorides and sulfates. During the use of dark chestnut soils as arable land its fertility is deteriorated. With the transformation of arable soils into the fallow condition the humus and nutrient regime is gradually improved.

Keywords: fertility, humus, soluble salts, the amount of absorbed bases, alkalinity, pH, total nitrogen.

INTRODUCTION

Soils of Western Kazakhstan are not completely studied. Chestnut soils are zonal soils of dry steppe zone, which are divided into three types: light chestnut, chestnut and dark chestnut. In the West Kazakhstan region, they are the main soil type of agricultural and arable land. The region has 2.08 million hectares of zonal soils suitable for agriculture without irrigation and indigenous improvements. These soils are used in agriculture as a pasture and hay land. The zonal soils in Kazakhstan are used for cultivation of the most valuable varieties of hard wheat, corn and other crops.

Globally, there are three sub-boreal steppe regions with Chestnut soils. The biggest is Eurasian, located on the territory of the CIS (south Moldova and Ukraine, along the Black and Azov Sea, East Caucasus, the Middle and Lower Volga region, Kazakhstan, the southern part of Western Siberia, the individual arrays of Chestnut soils are found in Central Siberia and the Trans-Baikal) extending latitudinal and outlying on the one side into Western Europe, on the other side into Mongolia and China.

Second biggest Chestnut soil zone is North American sub-boreal prairie region with meridian extended soil zones, covering the states of the Midwest and southern provinces of Canada. The American chestnut soils in the structure and properties of the profile close to the corresponding soils in CIS. Among the American chestnut soils there are two subzones: the dark-chestnut (Dark Brown) and light - chestnut (Brown).

The third South American sub-boreal steppe region is small and located in southern Argentina and captures the southernmost foothills of Chile.

Dokuchaev (1949) and Sibircev (1900) and other researchers have associated the origin of chestnut soils with arid climate and xerophytes vegetation, as part of which a wormwood plays a significant role. Over the past 15-20years agriculture in Western Kazakhstan has undergone changes. With the development of the oil and gas industry, the agricultural enterprises went to the second plan. In a program of studies on the Russian Chernozem, Dokuchaev indicates that he "tried, whenever possible, to explore the Russian Chernozem from the natural scientific and historical point of view" and that "only on this basis, and only after a thorough scientific investigations of these basics the various kinds of practical measures can be constructed to raise agriculture on the Chernozem zone of Russia" (1949). Therefore, we believe that the development of agriculture in our region must begin with a deep study of fallow soils. The aim of the present work was to study the agro-chemical, physic-chemical properties and humus regime, in order to identify the level of soil fertility study in Western Kazakhstan. The goals were:

1. To study changes in morphology, physic-chemical, agro-chemical properties of virgin and fallow dark-chestnut soil;
2. To study nature of changes in composition, property and fertility of fallow dark-chestnut soil

MATERIALS AND METHODS

There were applied field, laboratory and cameral analyses. Analytical works were carried out in accordance with state standards and generally accepted methods. Soil profiles are laid on a dark chestnut virgin soil and dark chestnut fallow soil. The studied soils are heavy loam. Sampled coordinates were:

1. Virgin plot: elevation 91m; 51º07ˈ480˝ N; 53º42ˈ844˝ E. Vegetation cover – 60-65%.
2. Fallow plot, abundant for 19 years: elevation 95m; 51º07ˈ356˝ N; 53º42ˈ771˝ E.

Dark-chestnut soils are formed on flat elevated watershed areas in the upper parts of the gentle slopes. Vegetation cover in virgin state is represented by fescue-feather grass associations with a mixture of herbs and shrubs. Due to the almost completely tilled territory it survived only on a very small area. Ground water table is deep (usually deeper than 10 meters), so they have no effect on soil formation processes. Parent material is eluvial deposits of the Upper Cretaceous and Paleocene age and Neocene and Quaternary.

Soil humus was determined by Tyurin method. Organic C was measured by acidification of organic C of the soil by excess amount of potassium dichromate. Acidification was accompanied by reduction of Cr^{4+} into Cr^{3+}. Excess dichromate in the solution after acidification of organic C was titrated by Mohr's Salt (Mineev, 2001). Soil Hydrolysable nitrogen, mobile phosphorus and potassium were determined as described by Mineev (2001).

RESULTS AND DISCUSSION

Humus content of studied soils was low and does not exceed 2.01% (Tab. 1). The maximum amount of humus is characteristic for the humus-accumulative horizon; its amount is gradually reduced to 0.30% downward the profile. In the dry steppe zone the projective cover of the soil does not exceed 70%; the vegetation is stunted, respectively, the humus content is not high. Virgin steppes in our region are not preserved. As a control treatment the virgin soil were sampled. Virgin soils are used for pasture. Therefore, the humus content is low. Profile distribution of humus is gradually decreasing. Both the size and shape of the accumulation of humus in nature depend on a number of conditions, where the accumulation of humus is critical factor affecting the intensity of microbial processes of decomposition and mineralization of organic residues and formation of soil humus. With a favorable combination of these conditions there is a relatively small accumulation of humus, which has a distinctly dynamic character due to on-going processes of decay and replenishment. Such a condition is typical for most studied soils. Under less favorable conditions for microbial decomposition processes, the reversibility of the cycle of biogenic elements is far from complete, and in these cases, under the sufficiently large influx of organic residues there is a significant accumulation of organic matter, which in the present geological era leads to the formation of peat and sapropel, while in bygone eras such accumulation led to deposits of humic coals and sapropelites in the thickness of sedimentary rocks (Ulianova *et al.*, 1992).

One of the central issues in the soil fertility is the issue of changing the composition of organic matter since it depends on the nutrient status and important physical properties of the soil. The increasing importance of soil organic matter requires careful control over the dynamics of humus, depending on the set of technical measures (Egorov *et al.*, 1977; Lykov, 1981).

As known, the distribution of humus along profile and its pool in the soil are determined primarily by bio-climatic conditions. The processes of accumulation and mineralization of organic matter are dependent on humidity and temperature of the soil, on the crop residues entering soil and on the penetration depth of the roots.

In this regard, it should be expected that the agricultural practices that provide additional revenue of precipitation into the soil, and more powerful development of the root systems of plants will be favorable for the accumulation of humus. Humus content is difficult to judge about the changes that occur as a result of the use of soil in agriculture. Therefore, we calculated the pool of humus in the root zone. Amount of rainfall in this area is less than 200-250mm a year, so the root system is distributed in the upper 0-50 cm layer.

In the A_1 horizon of virgin dark chestnut soil pool of humus amounted to 47.63 t ha^{-1}, down the profile its amount decreases to

13.22 t ha^{-1}. In contrast to virgin soil, on the horizon A_1 of fallow soil the pool of humus amounted to 62.89 t ha^{-1}, and in the lower layers is reduced to 9.46 t ha^{-1}.

According to the unequal humus content of the studied soils there is different absolute accumulation of organic matter in them. In the 0-20 cm layer of virgin dark chestnut soil humus pool amounted to 48.83 t ha^{-1}; in the 0-100cm layer - 84.83 t ha^{-1}. According to the gradation of Orlova and Grishina, the humus stock in 0-20cm and 0-50cm is low (Aleksandrova, 1953). Unlike virgin soil in fallow dark chestnut soil the humus reserves in the layer 0-20cm were 54.67 t ha^{-1}; in 0-50cm - 77.62 t ha^{-1}. In 0-20cm in fallow soil humus content increased by 5.84 t ha^{-1}or 5.84%, while in the 0-50cm humus reserves decreased to 6.91 t ha^{-1} or 8.17%.

These changes are results of de-humification of soil due to cultivation of virgin soils. While fallow soils were for a long time (around 28-30 years) used as a plow lands. With the transformation of arable soils in the fallow state the soil humus is gradually build-ups. Therefore humus content in the 0-20 cm layer increases.

Nitrogen is an essential element of plant nutrition, so the total stock of it in the soil is considered an indicator of its potential fertility. The presence of N in the soil is linked to the activity of living organisms. It is bound to the biological fixation of free N from atmosphere. Soil N is represented mainly by organic compounds that make up humus. Only a small part of N is in the form of mineral compounds. Dokuchaev (1949) pointed out the biological accumulation of N and other elements during the formation of soils. Williams (1914) considered that biologically accumulated elements in the soils as an essential and common feature of all soil formations. Tyurin (1965) concludes that the essential feature of the soil-forming processes is the processes of assimilation and nitrogen cycling. A characteristic feature of soil formations is nitrogen accumulation mainly in organic form of humic substances and partially plant and animal residues and microorganisms.

Table 1 Agrochemical characteristics of studied Dark chestnut soil

Horizon, cm	humus, %	Hydrolys. N	P_2O_5	K_2O	Humus		Hydrolysable N		Mobile P		Mobile K	
		mg/100g soil			0-20	0-50	0-20	0-50	0-20	0-50	0-20	0-50
					t/ha		kg/ha					
Dark-chestnut soil (virgin)												
A_1(0,5-18)	2,01	20,93	1,42	27,7	48,83	84,53	558,9	1327	38,03	59,29	710	1301
B_1(18-40)	0,75	18,01	0,63	14,0								
B_2(40-61)	0,40	15,91	0,34	11,1								
BC(61-100)	trace	-	-	10,3								
Dark-chestnut soil (fallow)												
A_1(0-23)	1,86	19,67	1,63	27,4	54,67	77,62	578,3	1316	47,92	83,19	778	1961
B_1(23-37)	0,66	15,68	0,90	12,5								
B_2(37-57)	0,30	15,03	0,41	10,5								
BC(57-100)	trace	-	-	10,8								

On this basis, the content and reserves of N in soils can be considered as a quantitative indicator of the soil fertility. And the amount of N that plants uptake annually represents a measure of actual or effective soil fertility. The essence of the soil-forming process is the accumulation of nitrogen and mineral nutrients in soil and other changes determined by influence of vegetation on the parent rock.

Content of hydrolysable nitrogen in our study is quite high: in the upper soil layer is 19,67-20,93 mg per 100 g of soil. Down the profile this amount gradually decreases to 15.03 mg per 100 g of soil. Throughout the profile the content of hydrolysable nitrogen is quite high. Stocks of hydrolysable nitrogen in dark chestnut virgin soil were 558.85 and 1326.67 kg ha^{-1} in the 0-20 cm and 0-50 cm layers, respectively. That is a 20 cm layer the stocks of hydrolysable nitrogen on fallow dark chestnut soil for 20 kg ha^{-1} higher than in the virgin dark chestnut soil. This is due to the fact that in recent years, as a result of fallow state, readily mineralizable nitrogen gradually began to accumulate in the upper horizon. But during the cultivation of these soils, there was a decline in stocks of hydrolysable nitrogen. Therefore, the 0-50 cm layer the amount of hydrolysable nitrogen is less in fallow soil than a virgin for 10 kg ha^{-1}. That is, in the lower layers during the 19 years the readily mineralizable nitrogen is still has been recovering.

Thompson and Troug (1982) reported that phosphorus follows nitrogen on the frequency of the use as a biological element. Mineral phosphorus is retained by compounds of Ca, Fe, Al and soil colloids in soil. Chestnut soils contain calcium carbonates on the surface that bound mobile P and transfer mono-substituted forms of phosphorus into the two-and three - substituted forms. Therefore chestnut soils contain low and very low amount of available phosphorus. In the upper horizons of the studied soils, the content of available phosphorus is 1.42-1.63 mg per 100 g of soil. Down the profile it is reduced to 0.34 mg/100 g of soil. In accordance with different content of mobile phosphorus in the studied the pool of phosphorus in these soils also varies in them. In the dark chestnut soils in the upper (0-20 cm) horizon 38-47 kg P_2O_5 per ha is accumulated. Low level of accumulation of these compounds is also characteristic for the root zone (0-50 cm) layer - 59-83 kg per ha.

According to the degree of mobility and accessibility to plant the potassium compounds are classified into three groups: 1) potassium of mineral soil (silicate), 2) exchangeable or absorbed cation, and 3) water-soluble potassium compounds. The bulk of the potassium is concentrated in the primary silicates and clay minerals, where this element is in the inactive forms. The most available form of potassium is water-soluble K that represented by nitrates, sulfates, chlorides and phosphates. Absorbed potassium cation relates to mobile and easily accessible form, as this form of potassium easily passes into the soil solution. Absorbed potassium cation is the main source of potassium nutrition of plants, and its content in the soil is an indicator of the degree of supply of the soil by K. In a calcareous soil for determination of mobile compounds of K the alkaline salt extraction 0,2н $(NH_4)_2CO_3$ или 0,2н Na_2CO_3 is used.

In the process of soil formation in chestnut soils a large amount of kaolinite and vermiculite is accumulated. These secondary minerals are the sources of potassium. Therefore originally the chestnut soils have a high content of available potassium. In this case, the content of available potassium in the soil profiles was high - 10-27 mg per 100g soil. Maximum amount of K is typical for upper horizon. Down the profile its amount gradually decreases. In 20 cm layer, mobile potassium amounted 710,0-778,2 kg ha^{-1}; in 0-50 cm layer – 1300,5-1960,6 kg ha^{-1}.

Chestnut soil on the genesis has a high content of available potassium and during its agricultural use nitrogen -phosphorus fertilizer was applied. Dark chestnut soils used mainly for the cultivation of crops. Removal of potassium by crops is not high. Therefore, during the fallow state of these soil the amount of potassium increased not only in the 0-20cm (for 68 kg/ha) but also in the 0-50 cm (for 660 kg ha^{-1}). The soil cation exchange capacity of virgin dark chestnut soil in A_1 horizon was 33.98 mg-ekv per 100g soil. At a depth 61-100 cm its amount decreased to 12.48 mg-ekv per 100g soil. On fallow dark chestnut soil in the A_1 horizon CEC was 29.90 mg-ekv per 100g soil; down the profile its amount gradually decreases to 10.48 mg-ekv per 100g soil. Thus, it should be noted that the during the use of dark chestnut soils as arable land its fertility is deteriorated. With the transformation of arable soils into the fallow condition the humus and nutrient regime is gradually improved.

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GREENING AGRICULTURE IN THE REPUBLIC OF KAZAKHSTAN

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ABSTRACT

Reconnaissance soil survey was conducted at foothill plains near Almaty and Zhambyl region. There are allocated 5 typical for soil and geomorphological conditions lands in agricultural landscapes of the region. Accordingly a large-scale (1:10000, 1:5000) soil maps and maps grouping of elementary soil structures were developed. For Karasai, Jambul and Talgar district of Almaty region have also been compiled the geomorphic and soil-landscape maps in the scale 1:200 000. On a typical areas the agro-ecological assessment were held by the main indicators of soil fertility (humus, mobile and gross forms of N, P, K, absorbed bases, pH, dry residue, CO_2, particle size distribution, specific and volumetric weight, the maximum water absorption, wilting point, field capacity, morphology), the risk of erosion and erosion. On the elementary areoles of agricultural landscapes (EAA) of agroenvironmental group of eroded lands also was held an evaluation of adaptability of various methods of primary tillage and grain crops - winter wheat and spring barley. This allowed for the differentiation of their application depending on the geomorphological conditions of the area, which provided the increase of soil fertility, and the grain yield - for 15-20% from the adaptation of the basic processing and for 15-40% - from of the adaptation of crops. The developed maps and the results of the adaptation of the basic processing of soil and crops by EAA are the basis for the further development of adaptive landscape agriculture at typical environmental conditions of the land plots and identify the need for similar studies on other EAA and typing lands.

Keywords: greening, adaptation, agriculture, areole, landscape.

INTRODUCTION

Over the last 22 years the agribusiness sector of Kazakhstan passed a long way to go. Privatization of state and collective farms and transfer of agricultural production to the market economy has allowed the country's agricultural enterprises first in the former Soviet Union to begin the entrepreneurial initiative and apply new technologies in all areas of agriculture. A significant achievement of the agricultural sector over the years of independence, our country is to become world's top ten exporters of wheat.

However, the yield of the cereals are still is for 3-4 times lower than world average. This is due to the lack of agricultural infrastructure that is not appropriately fit the regional ecology.

Zonal farming systems differ mostly at the level of the agricultural provinces that have similar farming systems, a narrow range of crops, and uniform set of fertilizer and lack of soil fertility indicators. All these result in low profitability of applied technologies, in decline of soil fertility, development of erosion and other negative processes on plough lands.

The content of humus in plough land of east-south, east and south of the republic declined in average for 20-25% from the initial level. The compactness of plough and sub-plough horizons increased in average for 0.02-0.04 g cm^{-3}. The content of water-stable aggregates decreased for 3-8%. The water-permeability and water erosion resistance decreased for 1.1-1.2 times. Similar processes are observed in other regions of the republic. The problem of the effective conservation of soil resources, reproduction of its fertility, improvement of the environment and enhancement of the productivity of agricultural landscapes as a whole requires a speedy resolution. The world experience showed that in this situation first of all it is necessary the greening (ecologization) –maximum approach to the natural analogues on the most important properties and resistance, and high productivity. Since, in natural ecosystem the soil resources are qualitatively and quantitatively are better than in agro-systems.

Greening agriculture at the same time means the maximum adaptation of crops and agricultural technologies to specific landscape and environmental conditions, which is the determinative for high productivity.

At the Kazakh Research Institute there are numerous researches studying the techniques and systems of soil cultivation, crop-rotations, agro-technical measures, resource-saving technologies, development of optimal and effective fertilization systems with predictable production, crop yield forecast, the economic benefits and environmental safety; the development of more adaptive varieties of crops to various landscape and environmental conditions of a particular territory, etc.

All above mentioned measures are effective under the so called adaptive-landscape systems of agriculture (ALSA). This system is being developed in Russia and other countries. In 2005 the academician Kiryushin developed and organized the ALSA program in Kazakhstan toward greening and improvement of agricultural productivity. Under the ALSA the use of landscapes is the more adaptive and environmentally friendly than in the regional systems, because it is achieved the necessary genetic provincially and locally landscape and geomorphological differentiation technologies in soil use.

MATERIALS AND METHODS

In the compiling the soil maps a combination of geographical, pedology, cartography, hydrology research methods, the analysis and use of various archive materials related to the investigated objects using GIS technology, and field large-scale reconnaissance soil survey of agricultural landscapes to match the stock of cartographic materials with their natural analogues were done. The use of GIS technology for mapping was associated with the digitization of cartographic material by mean of selected software for processing of remote sensing and GIS analysis-ENVI and ArcGIS. The following research methods were used: humus content was determined by Tyurin method (1986), nitrate nitrogen by Grandval-Lyazhu (1986), exchangeable potassium by Protasov (1986), mobile phosphorus by Machigin (1986). The experimental data were processed by analysis of variance for Dospehov (1985).

RESULTS AND DISCUSSION

For the development and implementation of ALSA it is necessary to conduct soil-landscape mapping, that is, generate various maps showing the landscape differentiation conditions; as well as adequate agro-ecological estimation of lands, which is used in development of the agricultural systems. The basic component of such a mapping is a showing of the soil cover, i.e. the spatial distribution of soils associated with lithologic - geomorphic conditions. This makes it necessary to make the transition from soil mapping to land mapping with drawing new maps with better and more complete information about the structure of the soil, the geomorphological, lithological, hydrological, micro-climatic conditions.

The primary structural unit of land evaluation is considered an elementary area of agricultural landscape (EAA), i.e. plot of land occupied by a soil - elementary soil habitat (ESH), or the unit of soil structure (USS) - soil micro-combinations (kind of land).

Rotations in ALSA are formed within the land of homogeneous in terms of cultivation culture or group of cultures with similar agro-ecological requirements (land types), and elements (processing methods, planting, etc.) are differentiated according to the EAA, i.e. types of land. This provides the necessary landscape-geomorphological locally and provincially genetic differentiation in the agricultural technologies of soil use and more adaptive and ecological use of agricultural landscapes in accordance with their natural environment, resource potential and resistance. The Kazakh Research institute of Agriculture already started such studies and compiled new soil maps and the maps of soil structure on the typical landscape-ecological conditions in the scale of 1:25000 и 1:10000, in Kordai, Zhualin regions of Zhambyl province. Similar maps as well as soil-geo-morphological and landscape maps in 1:200000 scales were developed for Zhambyl and Karasai regions of Almaty province (Fig. 1, 2 and 3).

On the maps of typical plots the territories occupied by one ESH or USS are components of EAA, from the point of view of economic use is a whole. These maps are the basis for further evaluation of agro-land, adaptability of crops and varieties used and new farming techniques for each EAA, as well as the formation of agro-ecological types and groups of lands, agro-ecological zoning of arable land and development of ALSA as a whole for a specific agricultural enterprise, administrative areas, regions and the Republics with the specific environmental target, which is not possible in the zonal farming systems.

Thus, the essence of the mechanism of formation ALSA and effective greening of agriculture as a whole is that, on the basis of agro-ecological requirements of crops, to find appropriate agro-ecological conditions and the most adaptive techniques for their cultivation, consistently optimizing limiting factors for improving the environment and increasing the productivity of agricultural landscapes in general, subject to the limitations technogenesis.

From the above it follows that the system solution for greening and improving the productivity of agriculture is associated with a very large and multi-stage research. However, even in the early stages of this work it is possible to improve the technologies and increase the productivity and sustainability of agriculture with positive results of the study, in the first place by adaptability of various methods of farming, crops and varieties in the EAA when used under similar conditions of production.

Thus, the assessment of erosion in agricultural landscapes adaptability of the basic cultivation in rain-fed light-chestnut soil at the meso-and micro-landscape conditions showed that the plowing is more efficient in watersheds, and in the northern and eastern slopes of the exposures. The compactness of topsoil average for the growing season was for 0.02-0.04 g cm^{-3} less than at sub-soil cutting treatment. While, on the slopes of the southern and western exposures on contrary the sub-soil cutting treatment helped to reduce compaction of the arable layer for 0.03-0.05 g per cm^3 and improve the resistance for soil erosion by 1.2-1.5 times.

On the slopes of the northern and eastern exposure and watershed the plowing provides a more effective weed control, and sub-soil cutting on the south and west - a higher and more uniform accumulation of snow and moisture management. On the gravelly soils of the region the sub-soil cutting treatment for 10-12 cm is more effective.

Evaluation of the content of mobile nutrients in light-chestnut soils in rainfed of the different elementary habitats agro-landscapes, suggests a substantial influence of the type of primary treatment. On more fertile and more northern and eastern slopes almost the same amount of nutrient in soils for plowing and sub-soil cutting treatments is observed.

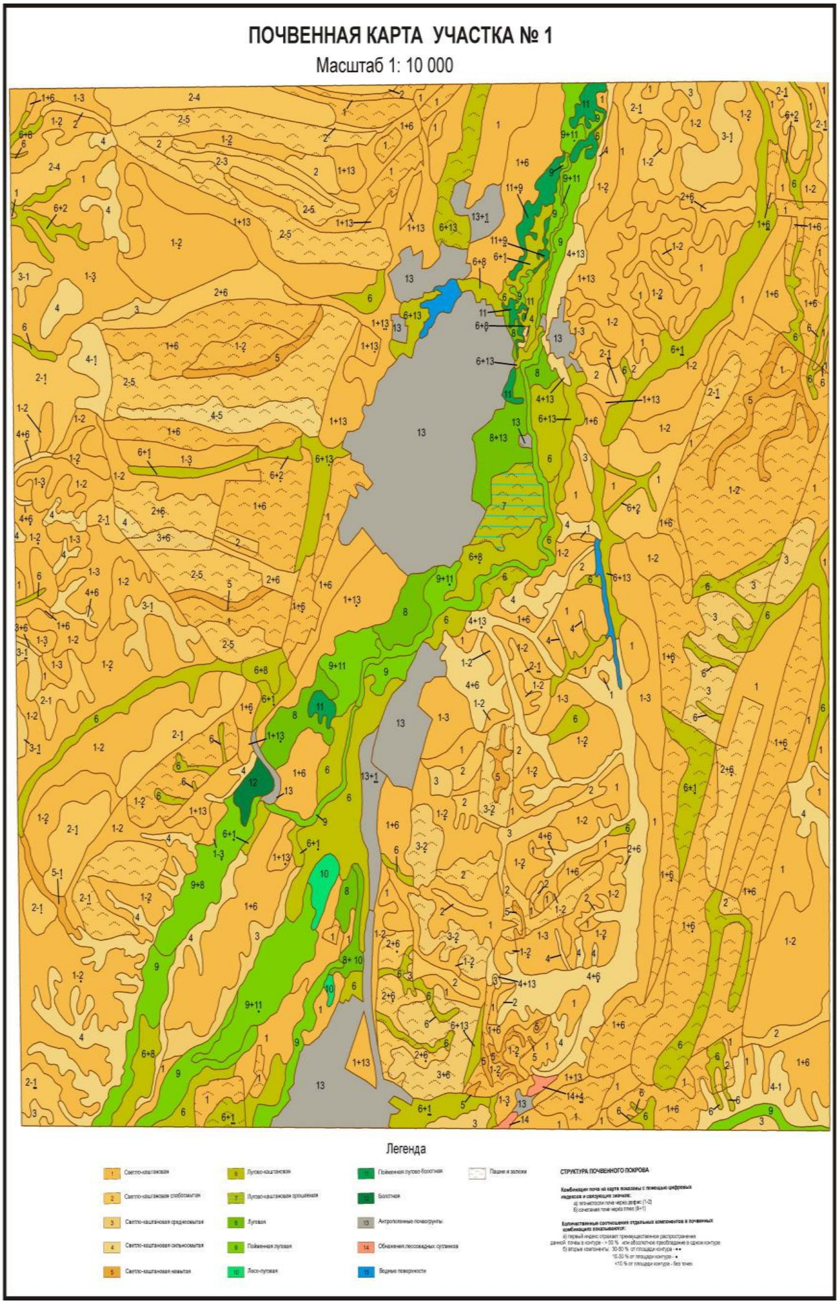

Fig. 1 Soil map of the Plot No. 1. Scale 1:10 000

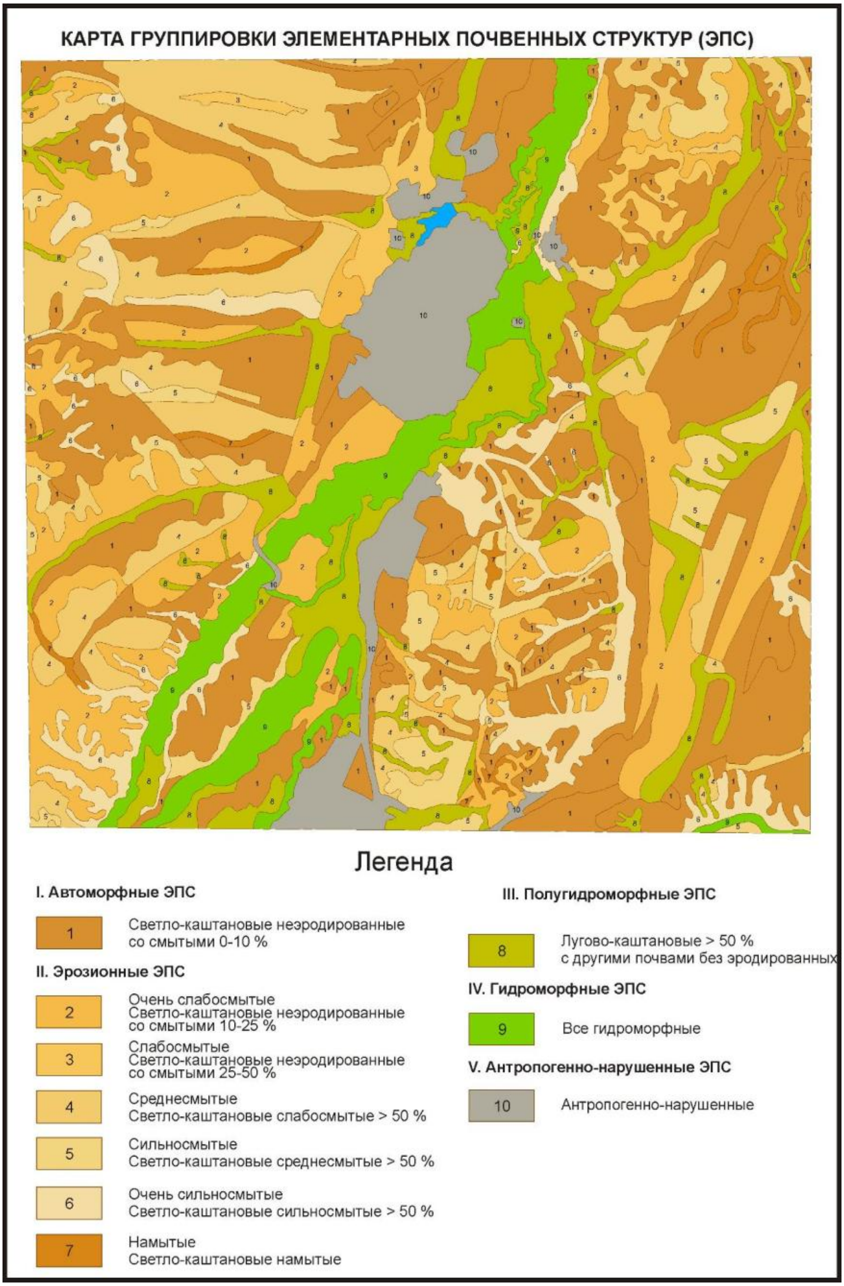

Fig. 2. Map of grouping of elementary soil structures

On the slopes of the southern and western exposures sub-soil cutting treatment for 20-22 cm and 10-12 cm especially, contribute to the content of available phosphorus in the soil for 8-12, potassium for 40-50, nitrate N for 2,3-4,1 mg kg^{-1} and humus for 0.05-0.09% compared with plowing, indicating a more favorable nutrient and humus soil regimes in these conditions.

Comparative evaluation of adaptation of different varieties of winter wheat in the agricultural landscapes of alpine erosive zone of Almaty region on mountain chernozem and dark chestnut soils in the northern slopes of the EAA has shown that the adaptive crops here are varieties of Naz, Steklovidnaya 24, and triticale, which produce the yields in the range 2,1-2,3 t ha^{-1}, while others, mostly used so far varieties of Kazakhstan 10 and Kazakhstan 4 showed yields in the range of 1,0-1,2 t ha^{-1}, or for 0,9-1,3 t ha^{-1} less. On the southern slopes such difference was not observed.

In the middle and low mountain areas of Zhambyl on chernozem and dark chestnut soils in upland landscapes and northern slopes the greater adaptability showed the winter wheat Bogarnaya 56 and Naz. Their productivity averaged 2,85 and 2,70 t ha^{-1}, respectively, and was higher than the yield of cultivated varieties Zhetisu and Steklovidnaya 24 for 0,8-1,0 t ha^{-1}. Of spring crops the most adaptive varieties of barley was Arna – 1,45 t ha^{-1}, whereas others have shown yield at around 1,0 t ha^{-1}. Very important is the fact that in the above-mentioned crops and varieties in these EAA a more favorable nutrient status of soil and humus state are provided.

In arid agricultural landscapes of particular importance in maintaining soil fertility is the cultivation of non-traditional less water-consuming and soil improving, more adaptive cultures. The expansion of areas under rye, safflower, chickpea and other legumes can improve the sustainability of agriculture and maintain soil fertility. Sowing of winter wheat and rye fit well with the rice crop rotations of different saline irrigated agricultural landscapes as intercropping, which helps to improve soil fertility, reduce salinity and contamination of the soil and reduce weeds infestation; increase the content of root and crop residues.

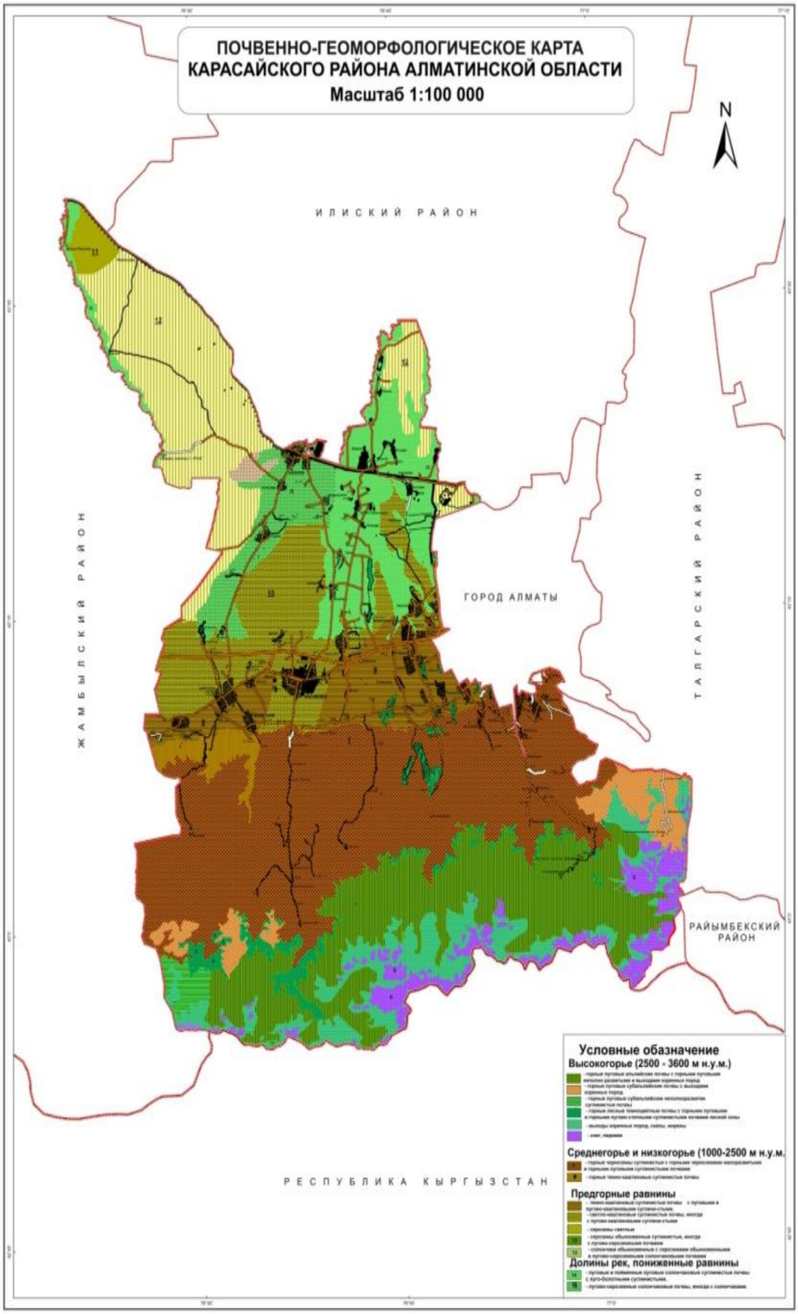

Fig. 3. Soil geomorphologic map of Karasi, Almaty region, 1:100 000

It is clear that the development of ALSA undergo changes in the structure of sown areas and crop rotations, which are the basis. Therefore, it is necessary to focus on the one hand to a certain group or agro-ecological land type, and on the other on the state of the market. This will determine the variety of cultivated area, both in space and in time. The sown area also depends on the profitability of the production of certain crops, as the results indicate that when designing an agro-environmental groups and types of land the difference can increase for 2 or more times. Important environmental significance has a growing influence of various cultures in relation to agro-ecological groups of land, which in this case is always more environmentally friendly than conventional farming systems. With landscape systems will be much more efficient and environmentally friendly the use of fertilizers, as it systematically reinforced by other elements of agricultural technologies, while having a specific agroecological address that is already part of the landscape agrochemistry.

Thus, the landscape agriculture would not only increase the productivity of the industry, resource conservation, but also its environmental friendliness, which generally have a beneficial effect on the environment. Now is the time when the assessment of agriculture should be based not on the absolute yield of crops but based on the effective use and conservation of the existing agro-ecological potential. The solution to this problem involves the solution of many other problems: the rational use of land resources, social programs, the development of animal husbandry, etc. And it should be developed at different territorial levels - from the country as a whole to agricultural enterprises. In this target due to the changing of socio-economic environment the role of land use planning is further enhanced in terms of greening economic activity, its differentiation to the natural environment, to adapt to the market and potential production.

CONCLUSIONS

State of fertility of arable lands in Kazakhstan indicates the need to improve it in the first place on the principles of maximum greening agriculture, which can be successfully achieved, as the experience of Russia and other countries of the world, based on the development and design of adaptive-landscape systems of agriculture. They should reflect the ecological diversity of the land, with consideration of agronomic, environmental, landscape and lithological conditions. This calls for a new soil-landscape mapping, compilation of new soil and landscape maps, with reflection in them of the soil cover, and the allocation of land types (EAA), their typing and agro-ecological assessment, evaluation and adaptation of crops in relation to the EAA agricultural technologies. This will provide a basis for the development ALSA and their zoning in the future. It will need also to clarify the existing natural and agricultural zoning of lands of the Republic and the development of landscape - environmental classification. In general, taking into account all the above factors, it is possible to achieve the sustainable greening agriculture.

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THE EFFECTIVENESS OF BARE FALLOW WITHOUT IRRIGATION IN KAZAKHSTAN

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ABSTRACT

The greatest effect of bare fallow as a precursor of winter wheat is shown on the non-irrigated gray soils. The yield of winter wheat after fallow in comparison with non-fallow predecessors in average- humid years was twofold, and in dry years, more than three fold. Cultivation of winter wheat in this area without bare fallow is almost impossible due to the absence in most of the years of productive moisture in the seed layer during the sowing of winter wheat. On light chestnut soils in semi-rain-fed area the efficiency is of bare fallow is significantly lower. A best practice of the basic cultivation of bare fallow on non-irrigated area in south-east Kazakhstan is the minimum till without turning the layer, to a depth of 10-12 cm. The increase in yield of winter wheat in this treatment compared to the standard at deep plowing (25-27 cm) was from 0.05 to 0.11 t ha^{-1}. Adding to the fallow field of 30 t ha^{-1} of manure increases the yield of winter wheat: on an non-irrigated area in medium humid years for 0.50-0.53 t ha^{-1}, and in the favorable rainfall years for 1.27 -1.29 t ha^{-1}, on the semi-rainfed area respectively 0.43-0.49 and 0.65-0.66 t ha^{-1}. The manure on non-irrigated dry land should be applied only in the fallow field of the crop rotation as the most secured with moisture. Manure application for permanent sowing of winter wheat is inefficient; since the yield increase is not always justify the costs associated with its transportation and application. For the first time the effectiveness of a surface manure application was established. Compared with the traditional method (plowing it into subsoil) the yield increase was 0.06-0.08 t ha^{-1}. This improves the water regime and soil main agrophysical properties.

Keywords: bare fallow, manure, non-irrigated dry land

INTRODUCTION

Rain-fed agriculture in Kazakhstan is concentrated in its southern and south-eastern region. Main cereal crops in the region are winter wheat and spring barley. Environmental conditions of this area are characterized by increased aridity. According to the annual precipitation, altitude and the amount of total solar radiation the rain-fed lands are divided into insufficient with annual precipitation from 200 to 280 mm, semi-sufficient (from 280 to 400 mm) and sufficient (over 400 mm) precipitation. In Kazakhstan, of the total area of non-irrigated arable land the greatest weight belongs to insufficient rain-fed (64%). The semi-sufficient and sufficient rainfed occupy, respectively 26 and 10%. Maximum precipitation in this region falls in early spring and therefore cropping system, built on the effective use of early-spring precipitation, called rain-fed farming. Rain-fed agriculture is a system using non-irrigated land, historically rooted in the Central Asian republics of the former Soviet Union, in the south and south-east of Kazakhstan, as well as in countries such as Iraq, Iran, Afghanistan and others.

Fallow field is of great agronomical importance in the rotation. It solves the following problems: the accumulation and retention of moisture in the soil, mobilizing available for plants nutrients, weed, and pest and crop diseases control. The fallow field is the best precursor for the winter and spring wheat, especially in arid areas.

In the rain-fed agriculture the winter cereals placed on a bare fallow are the most productive and drought-resistant crops that are far superior in this regard of spring cereals. The reason is, first of all, an effective use of two-year rainfall by winter crops: fallow and vegetation period. Transpiration coefficient of winter crops on bare fallow is two times less than that of spring wheat on plowed fields. In practice, this means that at the same amount of moisture, winter crops has twice higher yield than spring wheat (Shulmeyster, 1975). In rain-fed agriculture in Western Siberia sowing of spring wheat on bare fertilized fallow is a very reliable, efficient agricultural measure against drought. According to its water regime bare fallow acquire the value of small irrigation, which allows obtaining high and stable grain yields (Moshchenko, 1975).

Generally in a crop rotation, the bare fallow always had a great importance as its leading link. Also, bare fallow was important as a field that is convenient for the use of organic fertilizers and weed control, indicating the absolute necessity of the inclusion of the fallow in the structure of crop rotations (Tulaikov, 1962; Williams, 1951).

With regard to the conditions of the steppe regions of Northern Kazakhstan in 1986-ies the introduction of 3-4-year cereal-fallow rotations with fallow weight of 25-30% in the crop rotation was recommended. Where, with decreasing the amount of precipitation it was proposed to increase the area of fallow (Baraev, 1988). In the Omsk region of the Russian Federation, the climatic conditions are similar to the Northern Kazakhstan, both with and without fallow was recommended, considering the debris weed-infestation of the fields (Milaschenko, 1988)

One of the factors that negate the need for bare-fallow is the loss of organic matter in the fallow field. Recently, in northern Kazakhstan at the high culture of farming the replacement of bare fallow with borrowed cereals, legumes and fodder crops is suitable. The arguments in favor of such a change are a number of shortcomings of bare fallow, in particular, the absence of yield in the fallowing year, erosion vulnerability of fallow field and reduced soil fertility. Thus, in assessing the role of fallow in steppe agriculture the negative side of it cannot be ignored: the increased risk of erosion, wastage of water, reduction of inputs of plant residues in the soil, excessive mineralization of organic matter, nitrogen loss due to migration of nitrate beyond the root zone (Sulejmenov, 1994).

On the rain-fed lands of Kazakhstan main precursor of winter wheat is bare fallow. Cultivation of winter wheat after non-fallow predecessor has great difficulty, especially in the insufficient rain-fed area, since in the absence of precipitation in late summer and early fall is very difficult to get full germination of winter wheat.

The reason for conducting the research to establish the effectiveness of bare fallow was that at the end of the last century, there were statements that in the conditions of Northern Kazakhstan the bare fallows that lead to the soil degradation could be excluded (Suleimenov, 2006). Suleimenov (2006) notes that the inconsistency of statements that non-fallow agriculture in arid areas is not possible is proved today. In a real situation this statement should be interpreted as: with an increase of farming culture the share of bare fallow in arable land should be reduced. There is no need from time to time to give the earth "rest". Such statements about fallow refer to the regions, cultivating spring wheat. Nevertheless, we decided to explore the possibility of fallow-free farming in the winter-wheat area, which is the area of rain-fed agriculture of south and south-east of Kazakhstan.

MATERIALS AND METHODS

Research objects were gray desert and light-chestnut soils with humus content in the plow layer, respectively 0.9-1.1 and 2.1-2.2%. Gray soils are mainly concentrated in the area of insufficient rain-fed with an average annual rainfall 243 mm, and light chestnut soil in the area of semi-sufficient rain-fed with annual rainfall 414 mm. Manure at 30 t ha^{-1} was applied on an insufficient rain-fed on the two predecessors of winter wheat: the bare-fallow and a permanent sowing; and on semi-sufficient rain-fed on a fallow field.

RESULTS AND DISCUSSION

On rain-fed land of south-east Kazakhstan that is characterized by a lack and unstable moisture, the primary goal of agriculture is the accumulation of soil moisture, reducing unproductive losses and managing water spending. In this regard, among the all predecessors in crop rotations on rain-fed land the most effective was the fallow field. Long-term studies at the Kazakh Institute of Agriculture found that in the conditions of insufficient rain-fed the cereal-fallow crop rotation is effective with a specific weight of bare fallow of 20-25% (Zenkova, 1988). In this zone, the harvest of winter wheat on the bare-fallow for 1.5-2.0 times higher than in the non-fallow predecessors and in drought years the yield of winter wheat on the bare-fallow increased almost four-fold compared to the permanent seeding (Fig. 1).

Under the semi-sufficient rain-fed on light chestnut soils, where the average precipitation is 414 mm, the efficiency of bare fallow is somewhat smaller compared to the insufficient rain-fed, but still remains high (Fig. 2). So, the yield of winter wheat on non-fallow predecessor (oats) on average for all tillage treatments was 2,05 t ha^{-1}, and on the bare fallow was 2,96 t ha^{-1}, or more than 1.4 times.

The results show that the effectiveness of bare fallow as the best precursor of winter wheat, can be significantly improved by the application of organic fertilizers, in particular manure. It was established, that to achieve a positive balance of humus in cereal-fallow crop rotations it is necessary to apply 30 t ha^{-1} of manure per crop rotation on ordinary gray soil in south-east of Kazakhstan (Zenkova, 1984).

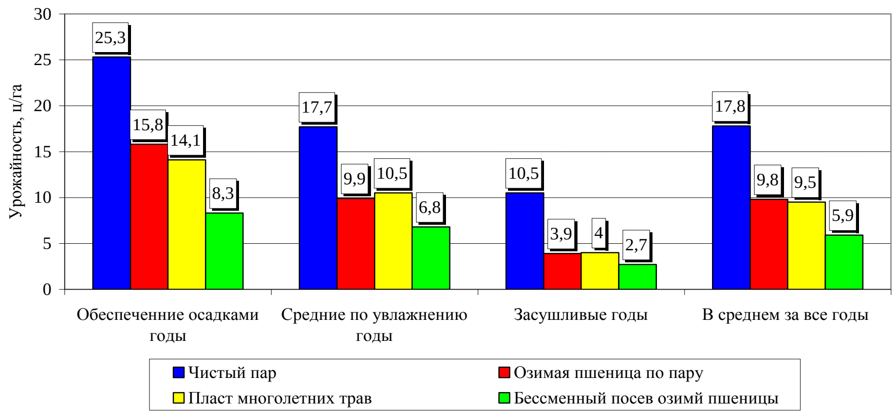

Fig. 1. Influence of precursors on the yield of winter wheat in the insufficient rain-fed in the different moisture years (average for 1961-1991), C ha^{-1}

The widespread use of chemical fertilizers, herbicides, pesticides and other chemicals in agriculture allowed in recent years in many countries around the world dramatically improve crop yields. Use of chemicals in agriculture in a number of countries in Western Europe has now reached the point where further expansion of the use of chemicals does not bring noticeable yield increase. In addition, it was revealed significant negative sides of the broad application of chemicals in agriculture, which related to imbalance in the ecological system of "plant-soil-man" (Vorobyov and Chetvernja, 1984). Prianishnikov (1965) wrote: "It would be a grave error to assume that an increase in the production of mineral fertilizers the role of manure as one of the most important fertilizer is reduced. On the contrary, the intensive use of chemicals the importance of manure increases more”.

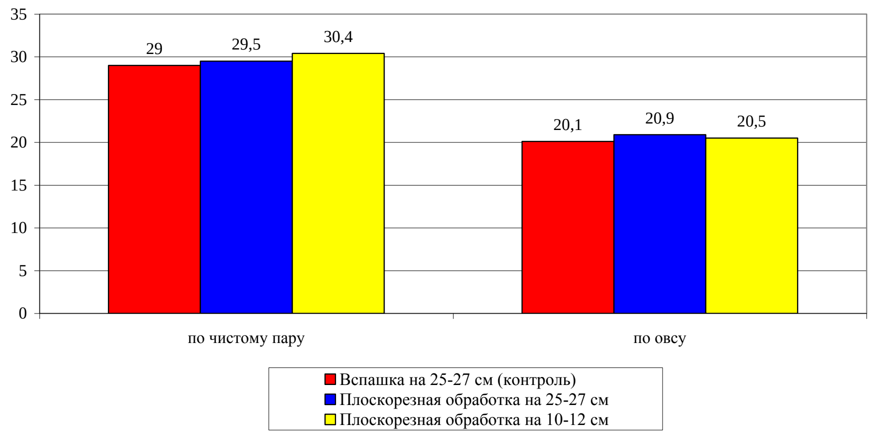

Fig. 2. Influence of precursors and methods of tillage on yield of winter wheat in the semi-sufficient rain-fed area in south-east Kazakhstan (average 2003-2009) 0.1t ha^{-1}

Application of manure leads in progressive increase in the number generated nutrients needed by plants. The coordinated use of all three sources of these substances: fertilizers, legumes and manure to increase their circulation, allow the best way to ensure the steady growth of yield and the progressive improvement of soil fertility. Organic fertilizers in organic farming practically serve as the primary source of soil fertility reproduction. They contain a large amount of biogenic elements, above all nitrogen, phosphorus, potassium, calcium, magnesium and micronutrients. Therefore, the use of organic fertilizers is a way of improving the balance of nutrients in the soil. Organic fertilizers improve the physical properties of the soil: an increasing absorption capacity, buffering, and other indicators. Unlike mineral fertilizers, organic possess prolonged aftereffect that enables them to apply periodically in crop rotations.

In experiments on an insufficient rain-fed application of 30 t ha^{-1} of manure had a positive influence on the content of humus in the soil. In a cereal-fallow rotation on the treatment without manure the decrease of humus content was clearly observed in 0-30 cm soil layer.

Table 1 Influence of precursors and methods of manure application on bare-fallow on winter wheat yield (t/ha) on an insufficient rain-fed fields

Treatments	Medium moist years									Dry years		
	1992	1993	1994	1995	1996	1997	1998	1999	aver.	2000	2001	Aver.
Plowing of fallow for 25-27 cm												
Control (no manure)	12,8	15,3	17,1	17,7	13,3	12,9	15,0	19,1	15,4	4,6	4,1	4,4
manure 30 t ha^{-1}	15,1	28,2	20,4	18,3	22,0	15,8	18,6	25,3	0,5	6,9	5,9	6,4
Sub-soil cutting of fallow for 25-27 cm												
Control (no manure)	13,2	16,6	17,4	17,7	15,4	13,5	15,8	18,9	16,1	6,7	4,4	5,6
manure 30 t ha^{-1}	15,2	29,5	22,0	17,4	32,2	16,6	18,9	25,8	21,1	8,6	6,8	7,7
Sub-soil cutting of fallow for 10-12 cm												
Control (no manure)	12,7	16,7	17,5	17,7	14,7	12,0	16,8	19,6	16,0	7,4	4,4	5,9
manure 30 t ha^{-1}	14,8	29,4	21,1	18,7	23,5	16,6	20,6	25,8	21,3	9,1	6,8	8,0
Permanent cropping												
Control (no manure)	-	8,6	7,7	7,4	7,2	7,7	11,1	7,0	8,1	0	1,2	0,6
manure 30 t ha^{-1}	-	13,4	9,8	9,1	11,0	10,3	13,5	8,5	10,8	0	1,5	0,8

At the same time, there was a positive balance of humus, in the treatment where 30 t ha^{-1} manure was applied in bare-fallow once per rotation. On the gray soils the manure at 30 t ha^{-1} was applied to the bare-fallow and under permanent cropping of winter wheat. The fallow on the rain-fed field is the most secured with moisture. Therefore, the best effect of manure was observed in fallow field (Tab. 1). The yield increase of winter wheat in the moderately moist years (1992-1999) was 0.5-0.5 t ha^{-1} depending on the processing methods of fallow. In very droughty years, such as 2000-2001, the effectiveness of manure is decreased and the yield increase was 0.2-0.21 t ha^{-1}. In a favorable year (1993) yield increase of winter wheat from manure application was 1,27-1,29 t ha^{-1} (76,0-84,3%).

The results showed that manure on an insufficient rain-fed should be applied only in the fallow field. When applying manure under permanent cropping of wheat, the yield increases in average for 1993-1999 was 0.27 t ha^{-1}, which is far short of the costs associated with the application of manure.

Table 2 Influence of treatment of bare fallow and manure application on the yield of winter wheat in the semi-sufficient rain-fed fields, t ha^{-1}

Treatment	Years						Average
	2003	2004	2005	2006	2007	2008	
Plow on 25-27 cm							
Control (no fertilizer)	22,4	43,8	30,5	29,0	31,8	15,4	28,8
Manure 30 t ha^{-1}	27,7	47,9	36,2	35,6	35,7	19,2	33,7
Sub-soil cutting on 25-27 cm							
Control (no fertilizer)	21,5	43,6	31,3	29,3	32,6	16,5	29,1
Manure 30 t ha^{-1}	27,0	48,0	34,6	35,8	36,4	19,7	33,6
Sub-soil cutting on 10-12 cm							
Control (no fertilizer)	22,3	45,0	29,0	31,6	33,5	17,9	29,9
Manure 30 t ha^{-1}	26,6	47,8	33,6	38,1	38,2	20,8	34,2

Two ways of manure application were tested in the fallow field: plowing into plow layer and surface application (mulching), followed sub-soil cutting. In the first case, the yield of winter wheat on average for the 1992-1999 was 2,05 t ha^{-1}, while the mulching increased the yield for 0.06-0.08 t ha^{-1}. The effect of surface mulch method with manure increased in highly droughty 2000-2001 years. With the average yield of winter wheat (0.64 kg ha^{-1}) the yield increase in the treatment of manure mulching method, followed by sub-soil cutting for 10-12 cm was 0.16 t ha^{-1}, or 25%.

On light chestnut soils of semi-sufficient rain-fed the yield increase of winter wheat from manure application were slightly lower than in the gray soils and averaged in 2003-2008 from 0,43 to 0,49 t ha^{-1} (Tab. 2). However, in a favorable 2006 the yield increase compared to the control reach 0,65-0,66 t ha^{-1}, or 20,6-22,8%.

CONCLUSIONS

Thus, the manure on dry lands is recommended to apply only in fallow field rotation. Technique of application is surface, followed by sub-soil cutting on 10-12 cm. For a more even distribution and mixing with the upper (0-5 cm) layer of the soil and creation of a mulch layer it is recommended to process the needle harrow BIG 3A with active working bodies (teeth) after primary treatment.

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THE EFFECT OF COMPLEX AND MIXED FERTILIZERS ON MAIZE YIELD AND SOIL FERTILITY STATUS OF LAND

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ABSTRACT

This paper devoted to determination of the fertilization value of different mixed fertilizers compared to complex fertilizers. Field experiments showed how the distribution of mixed and complex fertilizers affected their total effect on soil and plant. There were not statistically significant differences in the total effect on the yield between complex and mixed fertilizers, as well as between different mixed fertilizers, applied manually. The effect of compound fertilizer distribution method on total fertilization effect was significant. Manual handling of mixed fertilizers, due to homogeneous spreading of nutrients showed a better fertilization effect. Also, mechanized application of complex fertilizers showed a statistically significantly better effect on the yield compared to the application of granular mixed fertilizers. Machine spreading didn't uniformly applied the mixed granular fertilizers over the area. After three-year application of complex and mixed fertilizers in the experimental soils (pseudogley and eutric cambisol), there were no statistically significant differences in the contents of the applied NPK nutrients in the soil, and in the homogeneity of their distribution.

Keywords: fertilization value, compound fertilizers, mixed fertilizers, formulation of nutrients

INTRODUCTION

Technology of production of complex fertilizers varies, and is classified into: complex and mixed. Mixed fertilizers are produced in the chemical fertilizer factories, as well as in a special booth for mixing fertilizers, which are built on the fields by farmers. By chemical properties the mixed fertilizers were produced accordingly the standards and are indistinguishable from complex fertilizers. The advantages of these fertilizers are easiness of their manufacturing in a very wide range, with different ratios of nutrients, which suit different plants needs (Stanojlović and Milovanovic, 1983). The following defects may occur when handling and applying fertilizer in bulk: possible greater wastage of fertilizers; heavy dosage of precise fertilization when transporting from the warehouse to the plot and to the small-scale producers and individual farmers. The problems when loading, transporting and storing of bulk fertilizers and their application might occur. All these defects can be overcomed by organization and working techniques(Stanojlović and Milovanovic, 1983). The individual farmers can come to the warehouse to pick up fertilizer at the time of application to the plot. This would avoid unfavorable trait of mixed fertilizers (hygroscopicity and possible formation of insoluble compounds).

In the United States, the bulk fertilizers stored within the plant for mixing and making the appropriate combination of simple fertilizers (Yong, 1971; Beaton,1988). In Germany the bulk fertilizers for 5-20% cheaper than bagged ones (Oehring, 1976). Cost of bagging is 6-7% of the selling price of fertilizers (Radosavljevic, 1977).

In addition to blended mixed fertilizers (mixed granules of individual fertilizers) there are the mixed fertilizers that after grinding and mixing of the individual fertilizers undergoes the process of subsequent fertilizer granulation. The granulation process can be done in various ways, one of which has recently is the most popular that is the process of compaction (pressure) of previously ground and mixed basic fertilizers. After compaction the obtained product is crushed and sieved for removal of granules that haven't required diameter. In this way, each granule has a similar composition as complex fertilizers, without above mentioned drawbacks, like the simple mixture of single fertilizers.

To increase the efficiency of fertilizers is necessary to ensure uniformity of spreading. This can only be achieved if the fertilizer is of suitable physical state, of uniform size and specific gravity; as well as the granules must be of adequate hardness for easy spreading on the soil. Uniformity of granules has a great influence because it affects the uniformity of its distribution (Hofstee, 1992). Because most mechanized fertilizer application throws granules giving them certain acceleration by centrifugal force of spinning drives, the unequal masses of granules leads to uneven distribution. This is especially pronounced for mixed blended fertilizers, because they are composed of different individual granule fertilizers, which haven't the same specific weight. Considering the different effect of air resistance to the movement of different particles, then it becomes clearer how important to have uniform fertilizer composition.

Unevenly applied fertilizers lead to uneven development of plants, resulting in uneven development of plants that might result in large economic losses in the production (Đevic *et al.*, 2009). The effect of uneven fertilization can be more significant than the increase in yield. This may reach 19% of the yield increase that can be achieved in an even fertilization (Popovic, 1985).

This study aimed to determine whether the method of distribution of mixed and complex fertilizers affect their overall fertilization effect. And whether the soil where mixed fertilizers were applied can evenly get the required amount of nutrients.

MATERIAL AND METHODS

In order to determine the distribution of complex fertilizers the experiment was performed under the field conditions. Pseudogley and Brown Forest soil represent study area and are very significant for agricultural production in Serbia. The experiment was conducted on three treatments with four replications each:

1. 600 kg blended mixed fertilizers 15:15:15, by cyclone distributor
2. 600 kg blended mixed fertilizers 15:15:15, manually
3. 600 kg of 15:15:15 complex fertilizer, by cyclone distributor

Size of the plots was 4 acres. Grown crop was maize (hybrid ZP 341). In 2006 on Pseudogley and in 2005 and 2007 on the Brown Forest soil the wheat was introduced in a crop rotation. In the 1 and 2 treatments, the mixed domestic fertilizer was applied: a mixture of single fertilizers: potassium chloride, monoammonium phosphate, and lime ammonium nitrate. In the treatment 3 the Russian complex fertilizer was used.

The grain yield was measured as an indicator of the effect of fertilizer. To determine the impact of three years of application of fertilizers on soil fertility and the homogeneity of nutrient in soil the average of four samples were taken from all the plots. They are equally taken along three different distances (0.5, 2 and 3.5 m) from edges of the parcels, where each of them represents an average of 20 individual samples.

In order to provide a more detailed examination of the uniformity of nutrient distribution using blended mixed and complex fertilizers an experiment with mechanical cyclone spreader was undertaken. At a certain distance from the passage of the spreader the nylon frames of $1m^2$ were placed, where fertilizer was collected and measured for mass and NPK content. In this experiment the following compound fertilizers were used: complex fertilizer, blended, and compacted mixed fertilizer. All three formulations of fertilizers were 15:15:15, which is confirmed by previous chemical analysis.

Average air temperature was approximately equal to the long-term average values. Compared to the long-term average total precipitation at the site of Sabac they were higher, with outstanding of 2005, when at this site there was grown wheat. At the Mladenovac site the precipitation was very close to the annual average. Both sites are characterized by insufficient rainfall in the growing season of maize. Especially low amounts were in July, in Sabac 38.7 and 38.9 mm, and in Mladenovac 20.6 and 15.3 mm, which is significantly lower than the long-term average for the month. Therefore, the occurrence of drought particularly adversely affected the yield of corn.

RESULTS AND DISCUSSION

Both soils are very acidic (tab. 2); medium supplied with humus, phosphorus and potassium. In spite of leaching of cations the content of Mg and Ca is within the required limits. Supply with microelements is generally good (high content of Fe, Mn, Cu and medium of B), except for slightly lower Zn content.

The results of grain yield (Tab.2) show that in both soil types the highest yield was achieved at use of the complex fertilizer (treat. 3), while the lowest (except for 2005 in Varna) using mixed fertilizers with spreader (treat. 2).

Applying complex fertilizer by spreader machine (treat. 3) gave the highest yield of maize compared to the mixed fertilizer applied in the same way (treat. 2) on both soil types. The differences in all the cases are highly significant.

Table 1 The main agrochemical properties of soils assumptions on field

Soil type	pH u KCl	Humus	P_2O_5	K_2O	Ca	Mg	Ca/Mg
		%	mg/100g				
Pseudogley	3.85	2.81	8.11	12.15	271	42.2	6.4
Eutric Cambisols in leaching	4.01	3.01	7.92	19.01	305	24.5	12.5

Complex fertilizers had a favorable effect compared to a treatment with mixed fertilizer spread manually (treat. 1). The yield differences were significant in all cases except in 2005 at Mladenovac. In contrast to the application of mixed fertilizer by spreader machine (treat. 2), on the treatment with manual spreading (treat. 1) there were obtained a slightly higher corn yield, but the differences were not statistically significant. This indicates that the manual application of mixed fertilizers leads to more uniform distribution of nutrients versus to mechanical spreading.

Table 2 The influence of the distribution of fertilizers on maize yield

	Combination	**Pseudogley** 2005		2007		**Eutric cambisol** 2006		2008	
		t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%
1	Mixed fertilizers NPK 15:15:15 (cyclone spreader)	5,40	100	4,78	100	5,02	100	6,73	100
2	Mixed fertilizers NPK 15:15:15 (manually)	5,48	101	4,65	97	4,87	97	6,69	99,4
3	Complex fertilizer 15:15:15 (cyclone)	5,75	106	4,96	104	5,21	103,7	7,05	104,7
	LSD 0,05	0,15		0,11		0,16		0,17	
	0,01	0,25		0,17		0,25		0,24	

Similar to our findings, Reuter *et al.* (1974) found that applied complex fertilizer of diameter < 2.1 compared to commercial size particle < 4.8 mm, increases all the studied indicators, due to better distribution of fertilizer within the plots. Brković *et al.* (2002) established positional availability of nutrients due to uneven incorporation of mineral fertilizers as the basic reason of low fertility of some grape in Metohija.

Table 3 The content of available phosphorus and potassium in Pseudogley, after three years of application of complex fertilizers (field trials)

Treatment	Combination	Sampling distance from the edge, average (m))	P_2O_5 (mg/100g)	K_2O (mg/100g)
1.	Mixed fertilizers NPK 15:15:15 (manually) 600 kg ha^{-1}	0,5	8,10	14,50
		2,0	8,52	15,02
		3,5	9,03	14,23
Average			8,55	14,58
2.	Mixed fertilizers NPK 15:15:15 (cyclone) 600 kg ha^{-1}	0,5	8,89	14,01
		2,0	9,20	14,73
		3,5	8.41	15,03
Average			8,83	14,59
3.	Complex fertilizer NPK 15:15:15 (cyclone) 600 kg ha^{-1}	0,5	8,29	15,07
		2,0	9,19	14,53
		3,5	8,92	14,58
Average			8,80	14,73
		LSD 0,05	0,67	0,64
		0,01	1,05	0,99

Examination the effect of P and Mn on plant dry mass, uptake of P and Mn, and grain yield in lime soil, Reuter *et al.* (1973) found that all the three factors increased when applying these two elements with complex fertilizers. Also the symptoms of Mn deficit more successfully were resolve with complex fertilizer application.

Table 4 The content of available of phosphorus and potassium in Eutric cambisols, after three years of application of complex fertilizers

Treatment	Combination	Sampling distance from the edge, average (m)	P_2O_5 (mg/100g)	K_2O (mg/100g)
1.	Mixed fertilizers NPK 15:15:15 (manually) 600 kg ha^{-1}	0,5	8,50	20,11
		2,0	8,30	22,30
		3,5	9,08	21,90
Average			8,63	21,44
2.	Mixed fertilizers NPK 15:15:15 (cyclone) 600 kg ha^{-1}	0,5	8,89	23,20
		2,0	8,36	21,80
		3,5	7,96	22,40
Average			8,40	22,47
3.	Complex fertilizer NPK 15:15:15 (cyclone) 600 kg ha^{-1}	0,5	8,87	21,02
		2,0	9,19	19,80
		3,5	9,15	20,90
Average			9,07	20,57
		LSD 0,05	0,56	1,33
		0,01	0,88	2,17

To determine whether different types of complex fertilizers and method of application influence the uniformity of distribution of nutrients in the soil across the field the available forms of P and K at different distances (0.5, 2 and 3.5 m) from the edge of the plot variants were analyzed (Tab. 3 and 4). There weren't significant differences in homogeneity of distribution of basic nutrients on the surface of the different treatments.

The influence of cyclonic distribution of fertilizers on the homogeneity of distribution of nutrients

In order to provide a more detailed examination of the uniformity of distribution of nutrients, an experiment with the machine spreader, where at a certain distance (3 m) from the cyclone were placed a plastic film of 1m² frame, from which fertilizer was collected and analyzed. The experiment was conducted in five random replicates.

Table 5 The masses of various complex fertilizers and NPK ratio, after dismantling the cyclone spreader

Treatment	Combination	Mass of fertilizer (g)	NPK ratio
1	Mixed compact complex fertilizer NPK - 15:15:15 (600 kg ha^{-1})	58.2	15:15:15
		57.9	15:15:15
		60.5	15:15:15
		59.9	15:15:15
		60.8	15:15:15
	Average	**59.46**	**15:15:15**
2	Mixed blended compound fertilizer NPK -15:15:15 (600 kg ha^{-1})	59.8	12:16.5:16.6
		62	11.8:16.5:16
		58.7	13.5:16.1:14.3
		60.3	12.1:15.8:16.6
		60.1	14.2:14.8:17.1
	Average	**60.18**	**12.7:15.9:16.1**
3	Complex compound fertilizer NPK-15:15:15 (600 kg ha^{-1})	59.4	15:15:15
		59.8	15:15:15
		59.7	15:15:15
		58.2	15:15:15
		60.7	15:15:15
	Average	**59.56**	**15:15:15**

Based on the results of the experiment (Tab. 5), we can say that blended mixed fertilizers cannot be evenly distributed throughout the required arable area.

Chemical analysis of fertilizers showed that before processing they had declared formulation of 15:15:15 in all the treatments.

Mechanical breakup of fertilizer in the second treatment with blended mixed fertilizer (simple mechanical mixture of simple fertilizers) showed different formulations that don't correspond to the initial 15:15:15. This means that this type of mixed fertilizers, cann't evenly distribute applied formulation over the entire surface. This is due to non-homogeneity of these fertilizers, as well as different specific weight of individual granules of fertilizer.

The results obtained with complex and compact mixed fertilizers indicate a significant advantage of these fertilizers, due to the homogeneity of their distribution. In all replicates there were obtained correct formulations, as well as approximately the same mass of nutrients per unit area.

CONCLUSION

The distribution method of complex fertilizers obviously influenced the overall fertilization effect.

Manual application of mixed fertilizers due to the homogeneous distribution of nutrients comparing to mechanical cyclonic distribution had a better effect. Also the application of mineral fertilizers by machine showed significantly better effect comparing to the application of blended mixed fertilizers.

Using mixed blended fertilizer by machine didn't evenly distribute the declared nutrients over the entire surface. This adverse effect of blended mixed fertilizers weren't manifested in the application of mechanical spreading of complex and compact mixed fertilizers, because the declared active NPK substances in them were equal in each granule, and because the bulk density of granules was equal, and therefore the problem of segregation didn't exist.

After three years of implementation of complex and mixed fertilizers on the studied soils, statistically significant differences in the content of applied NPK nutrients in the soil, and the homogeneity of their distribution were not recorded.

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EVAPOTRANSPIRATION AND WATER USE EFFICIENCY OF WINTER WHEAT IN SOUTHERN SERBIA

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ABSTRACT

Water deficiency during winter wheat vegetation is an important limiting factor in achieving high and stable grain yield. Irrigation is the only efficient measure against drought, but limited water resources can be rationally used only if water use efficiency is improved. For that reason, the experimental investigation through field trials has been carried out in the river valley of Southern Morava, municipality of Merošina, on the alluvium soil type, during the period 2009-2011. The trials included three irrigation variants with pre-irrigation soil water content 60%, 70% and 80% of FWC, as well as unirrigated control. The highest winter wheat grain yield of 7110-7480 kg ha^{-1} was observed at the variant with pre-irrigation soil humidity 70% of FWC. Evapotranspiration value of 346.0-410.7 mm was observed in the conditions of irrigation, while such value at the unirrigated control was from 289.5 mm to 372.2 mm. The highest values (18.65-19.03 kg ha^{-1} mm^{-1}) of water use efficiency (WUE) were found at the variant where pre-irrigation soil humidity was kept at 70% of FWC. At the other two irrigated variants we observed WUE values in the range of 15.46-18.32 kg ha^{-1} mm^{-1}. The established values of WUE have a potential use in planning irrigation practice with the aim of rational winter wheat production.

Keywords: evapotranspiration, water use efficiency, winter wheat, irrigation, grain yield.

INTRODUCTION

The average winter wheat grain yield in Serbia during the 2009-2011 was 3.7 t ha^{-1} (Statistic Yearbook of Serbia, 2012), while genetic potential of wheat cultivars grown in Serbia was over 11 t ha^{-1}. Limiting factors for winter wheat production include climatic conditions and incomplete production technology. Global climate change caused in our country appearance of extremely high air temperatures with prolonged droughty periods. Irrigation is the only efficient measure against drought. However, quality water is a limited resource, so for the rational irrigation it is important to establish plant water demand (potential evapotranspiration) and water use efficiency of wheat. Water consumption of winter wheat for evapotranspiration, in the conditions of optimal soil humidity during whole vegetation period, is called potential evapotranspiration (ETP). Considering wheat water demand, Vučić (1976) stated this demand was between 320-360 mm in the conditions of our country. Dragović and Maksimović (2000), in the conditions of irrigation, observed wheat ETP of 293-346 mm. Luchiari *et al.* (1997) established wheat water consumption for ET of 345-385 mm. Xiying *et al.* (2011) stated values of wheat ETP from 401 to 458 mm. In a three-year investigation, Haijun *et al.* (2011) found wheat ETP within range of 266-499 mm. Numerous researchers (Taylor *et al.*, 1983; Musick *et al.*, 1994; Li and Shu, 1991; Li *et al.*, 2000; Shao *et al.*, 2002; Zhu *et al.*, 1994; Kang *et al.*, 2002; etc.) pointed to importance of water use efficiency (WUE) for reaching high wheat grain yield. Significance of relation between grain yield and evapotranspiration for wheat production in the conditions of irrigation is beyond doubt. So this study was aimed to establish potential evapotranspiration and water use efficiency of wheat in the conditions of southern Serbia.

MATERIAL AND METHODS

The experimental investigation through field trials has been carried out in the river valley of Južna Morava, municipality of Merošina, on the alluvium soil type, during the period 2009-2011. The trials were set at 198 m of altitude, 43°19' N of latitude and 21°54' E of longitude, in random complete block design (RCBD) with five replications. Areas of elementary plots were 35 m^2, and during vegetation were carried out usual agrotechnical measures for wheat.

The winter wheat cultivar NS Rana 5 was sown at October 12th in 2009, and at October 17th in 2010. Seeding rate was 500 germinative seeds per m^2. Harvest was carried out during second decade of July in both years of investigation.

Irrigation was carried out by spray irrigation method, and its term was determined by observing dynamics of soil humidity down to 60 cm of depth. Soil moisture content was measured by thermogravimetric analysis in the oven at 105-110°C. Trials included three irrigation variants with pre-irrigation soil humidity 60%, 70% and 80% of FWC, as well as unirrigated control.

Calculation of water consumption for evapotranspiration in the conditions of irrigation was done for each month and for vegetation period in whole (1), by balancing water from precipitation during vegetation period, soil supplies (2), irrigation, and potentially percolated and runoff water after heavy rains (3).

$ET_{vp} = (W_1 - W_2) + P + I - D$ (mm) (1) where ET_{vp} is evapotranspiration for the vegetation period; W_1 is amount of water in soil to the depth of 2 m at the beginning of vegetation; W_2 is amount of water in soil to the depth of 2 m at the end of vegetation; P is water amount from precipitation; I is water amount from irrigation; D is water loss by deep percolation and runoff.

$W = 100 \cdot h \cdot d \cdot s$ (mm) (2) where W is amount of water in soil to the depth of 2 m; h is depth of soil; d is bulk density; s is soil moisture.

Following heavy precipitation, water percolation into deeper soil layers and runoof was calculated:

$D = (W_1 + P) - FWC$ (mm) (3) where D is deep percolation and runoff; W_1 is soil water amount to the depth of 2 m at the beginning of vegetation; P is precipitation amount (mm); FWC is field water capacity. The obtained values of texture analysis (tab. 1) were expected, because fractional relations confirmed that this is a loamy alluvial soil.

Table 1. Mechanical properties of soil

Depth (cm)	Total sand (%)	Powder (%)	Clay (%)
	> 0.02 mm	0.02-0.002 mm	< 0.002 mm
0-20	42.1	40.5	17.4
20-40	40.3	337.8	21.9
40-60	38.7	36.3	25.0
60-80	36.7	35.9	27.4
80-100	35.1	32.3	32.6

Immediately before the study began, water-physical properties of soil in the experimental field were determined (tab. 2).

Rainfall was measured at the experimental field by rain gauge. The average monthly air temperatures for the studied period and many-year average for the city of Niš (tab.3) were downloaded from the website of Serbian Hydrometeorological Institute (2013).

Table 2. Water-physical properties of soil

Depth (cm)	FWC (weight %)	Specific weight (g cm^{-3})	Bulk density (g cm^{-3})	Total porosity (vol. %)	Capacity for water (vol. %)	Capacity for air (vol. %)
0-20	27.32	2.65	1.35	49.05	36.88	12.17
20-40	25.94	2.58	1.34	48.06	34.76	13.30
40-60	24.44	2.56	1.34	47.65	32.75	14.90

Table 3. Mean monthly temperatures (°C) and monthly amount of precipitation (mm)

Year	**Month**												
	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X-IX
	Mean monthly temperatures												
2009/10	12.1	8.3	4.5	1.2	3.5	7.6	12.9	17.2	21	23	23.6	17.9	12.7
2010/11	10.1	12.1	2.8	0.6	0.3	6.9	12.5	16.4	21.2	23.5	24.2	21.6	12.7
1981-2010	12.3	6.4	2.1	0.6	2.4	7	12.2	17.1	20.4	22.5	22.3	17.4	11.9
	Amount of precipitation												
2009/10	84	101	73	54	88	52	79	65	53	35	29	14	727
2010/11	73	44	72	24	43	30	12	58	42	47	4	38	487
1981-2010	38.8	36.8	42.5	56.6	58	57.3	44	46.7	48	45.5	54.8	51.5	580.3

Around middle of October 2009 abundant precipitation was observed. Beginning of November was also characterized by daily rainfall and slightly lower air temperature regarding long-term average. Until middle of December weather was fairly warm for this part of year with excess precipitation. Amount of precipitation in March was almost the same as long-term average for this month, but because of excess rain and snow in previous months (October and February) soil was oversaturated by water. Rain in April was regular daily phenomenon, so precipitation in this month was also higher than the many-year average. June was characterized by extreme temperatures. Second decade was very hot, with maximal temperature reaching 30-35°C. High air temperature at days and especially at nights, as well as high percent of air moisture, shortened and disturbed fulfilling of wheat grain. Maturation process was accelerated which influenced grain yield and quality of wheat.

Beginning of production year in October 2010 was characterized by cooler weather than usual with heavy precipitation. Favorable thermal conditions and good rainfall distribution during November and early December allowed good development of wheat crop and its preparing for winter. During second half of April, especially third decade, small amount of rainfall, relatively high air temperature and frequent wind caused drying soil surface layer. Rainfall in May usually had local character, but the most intensive showers were observed in the last decade of May. In the last decade of June maximal air temperature exceeded 33°C which caused shortening of grain fulfilling and accelerated wheat maturation.

Water utilization efficiency of winter wheat (WUE) has been calculated as the observed wheat grain yield divided by water consumption for evapotranspiration according to Hussain *et al.* (1995).

$$WUE = GY / ET \qquad (4)$$

where WUE is water utilization efficiency (kg ha^{-1} mm^{-1}); GY is wheat grain yield (kg ha^{-1}); ET is evapotranspiration (mm).

The collected data were processed by standard statistic methods usually used in biological studies (Hadživuković, 1991), i.e. analysis of variance, and LSD for probability of error under 0.01 and 0.05 were presented. Correlation of ET and grain yield, as well as of ET and water use efficiency of winter wheat (WUE), was analyzed by square regression.

RESULTS

Wheat grain yield was higher in the vegetation season 2009/10 in regard to the season 2010/11 at the level of significance $P<0.01$ (tab. 4). The highest difference between the investigated years was when control variants were compared, which was a consequence of different weather conditions and water supplies in soil. The highest average grain yield of 7295 kg ha^{-1} was achieved at the variant with pre-irrigation soil humidity 70% of FWC, and the difference was highly significant comparing with the other two irrigation variants and unirrigated control. Furthermore, grain yield was higher at the level of significance $P<0.01$ at the variant with pre-irrigation humidity 60% of FWC in regard to the variant where soil humidity was kept at 80% of FWC. Water consumption for evapotranspiration of winter wheat (289.5-410.7 mm) was measured by water balance method.

Table 4. Grain yield of winter wheat (kg ha^{-1})

Year (B)	Pre-irrigation soil humidity (A) FWC 80%	FWC 70%	FWC 60%	Control	**Average (B)**
2009/10	6350	7480	6870	6070	6692.5
2010/11	6520	7110	6340	4780	6187.5
Average (A)	6435	7295	6605	5425	6440.0

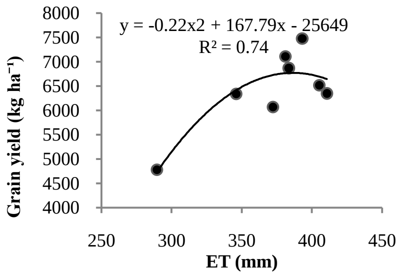
LSD	A	B	AB
0.05	91.30	64.56	129.08
0.01	122.94	86.93	173.81

The highest values of winter wheat ET (Tab. 5) for the studied period were observed at the variant with pre-irrigation soil humidity 80% of FWC (405.2-410.7 mm), while the lowest ET values were measured at the control (289.5 mm) and the variant with pre-irrigation soil humidity 60% of FWC (346 mm). Considering average for both investigated years, the highest grain yield of winter wheat was observed at the variant with pre-irrigation soil humidity 70% of FWC (7110 kg ha^{-1} and 7480 kg ha^{-1}). At this irrigation variant also were measured the highest values of wheat WUE (18.65 and 19.03 kg ha^{-1} mm^{-1}), so measured values of ET at this variant from 381.1 to 393.1 mm represent potential evapotranspiration (ETP) of winter wheat in southern Serbia. Increased soil humidity (80% of FWC) caused lower average grain yield in regard to the other two irrigation variants. Higher values of measured evapotranspiration and lower grain yield at the variant with pre-irrigation soil humidity 80% of FWC comparing with the irrigation variant 70% of FWC, point to an unreasonable consumption of water for irrigation at the variant 80% of FWC.

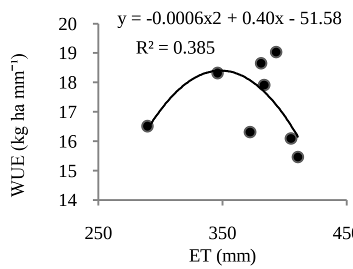
Table 5. ET, ETP_o, grain yield and WUE of winter wheat

Year	Pre-irrigation soil humidity	Soil water supplies (mm)	Precipitation (mm)	Irrigation (mm)	Grain Yield kg ha^{-1}	ET (mm)	WUE kg ha^{-1} mm^{-1}
2009/10	80% FWC	51.2	279.5	80	6350	410.7	15.46
	70% FWC	63.6	279.5	40	7480	393.1	19.03
	60% FWC	84.0	279.5	20	6870	383.5	17.91
	Control	92.7	279.5	-	6070	372.2	16.31
2010/11	80% FWC	43,5	211.7	150	6520	405.2	16.09
	70% FWC	49.4	211.7	120	7110	381.1	18.65
	60% FWC	54.3	211.7	80	6340	346.0	18.32
	Control	77.8	211.7	-	4780	289.5	16.51

Square regression analysis of the effect of ET on grain yield (graph 1) pointed out to a high level of correlation between wheat grain yield and water consumption for evapotranspiration (correlation coefficient R^2=0.74). Regression analysis of the effect of ET on wheat WUE showed parabolic curve (graph 2), which pointed to a fact that increased water consumption for ET of wheat was not efficiently used for increasing grain yield.



Graph 1. The effect of ET on wheat grain yield



Graph 2. The effect of ET on WUE of wheat

DISCUSSION

Values of wheat potential evapotranspiration established in our study (381.1-393.1 mm) were higher than the values reported by Vučić (1976) and Bošnjak (1999). Measured ETP in our investigation were close to the values (345-385 mm) observed by Luchiari *et al.* (1997) and Balwinder *et al.* (2011), who found plants demand for water in the conditions of irrigation within range from 345 to 404 mm. Higher values of winter wheat evapotranspiration (401-458 mm) comparing with our study were reported by Xiying *et al.* (2011). Haijun *et al.* (2011) also found high value of wheat ET of 499 mm. Different values of wheat potential evapotranspiration reported by various researchers were caused by different soil and climatic conditions of areas where studies were carried out.

Values of wheat WUE observed in our study were within range from 15.46 to 19.03 kg ha^{-1} mm^{-1}. French and Schultz (1984) found similar value of wheat WUE of 20 kg ha^{-1} mm^{-1}, while other researchers observed lower values 16 kg ha^{-1} mm^{-1} (Steiner *et al.* 1985) and 15 kg ha^{-1} mm^{-1} (Cornish and Murray, 1989). In the conditions of North China Plain, Sun *et al.* (2006) established value of wheat WUE of 9.7-18.3 ha^{-1} mm^{-1}.

The highest values of wheat WUE observed in our experimental field were at the variant with pre-irrigation soil humidity 70% of FWC. That means in order to reach high and stabile grain yield soil ought to be kept at this level of humidity. This statement is in accordance with the one of Kijne *et al.* (2003) that most efficient way to reach optimal WUE is application of proper irrigation regime.

CONCLUSION

On the basis of the investigation results obtained in the conditions of wheat irrigation the following conclusion can be drawn out:

- Irrigation regime based on monitoring dynamics of soil humidity is efficient, and the best term for wheat irrigation in the conditions of southern Serbia is when soil humidity is 70% of FWC.
- Potential evapotranspiration of wheat is established (381.1–393.1 mm) as well as its significant effect on grain yield.
- Regression analysis of the effect of ET on wheat WUE showed unreasonable water consumption when irrigation was applied at soil humidity 80% of FWC.
- The established values of ETP, WUE and grain yield allow, together with further investigations of modern agrotechniques and proper choice of cultivars, adequate exploitation of high and stable grain yield.

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CONSTRUCTION OF COMPOSTER ON PRODUCTION AND PROCESSING UNIT

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ABSTRACT

This paper presents the procedures and goals of construction of composter in the Production and Processing Unit (PPU) of the Institute for Medicinal Plant Research "Dr Josif Pančić". Annually, during production and processing of medicinal and aromatic plants (MAPs), 25 t of various plant residues remains unused as by-products. According to the law on the waste management, such a generated waste must be stored, treated and disposed not to endanger human health and environment. Detailed analysis of the current state provided the information on the number of MAP species and physico-mechanical state following their processing, as well as the approximate quantities of the wastes created during their processing. Determination of proper location, construction of composter, and development of procedures and methods of the waste disposal are specified in the document entitled *"Biological Waste Management Plan"*. For the waste treatment procedure, biological treatment that makes biodegradable organic waste decomposition useful material for soil conditioning (compost) was selected. Composting belongs to treatments of organic wastes under the action of microorganisms aimed to create compost, which is carried out in the presence of oxygen and under controlled conditions. The construction of composting, apart from the proper disposal of the waste, will provide us with compost-a potentially highly valuable organic fertilizer, which in addition could also be used as a soil structure improver as well as raw materials for production of various substrates and mulches. Development of clean technologies, such as composting, by-products or wastes resulting from MAP production and processing, will be once again recovered and recycled.

Keywords: compost, plant residues, medicinal and aromatic plants (MAPs), biological treatment of waste, composter.

INTRODUCTION

During the process of production and processing of medicinal plants, in the Production and Processing Unit (PPU) of the Institute for Medicinal Plant Research “Dr Josif Pančić” in Pančevo, approximately 25 t of various crop residues annually remains as a by-product. According to the Law on Waste Management (″Sl. glasnik RS″ no. 36/2009 and 88/2010), this type of waste must be properly disposed of, which implies a way that doesn’t endanger human health and the environment. Development of clean technologies, such as composting, waste resulting from production and processing of aromatic and medicinal plants (MAPs) will be recovered and recycled. As the end product following composting procedure, compost is created, which, in addition to its primary use as an organic fertilizer, is also used as an improver of the soil structure, as a raw material for production of substrates or as mulch (Filipovic, 2012).

For instance, the European Economic Commission was asked to elaborate guide lines for EU member states and competent regional authorities to revise the EU directive on sludge and elaborate a new directive on composting (Ondo *et al.*, 2012).

By the National Waste Management Strategy 2010-2019, several methods of waste management practices have been proposed, such as decrease of waste at sources, re-use, recycling, composting, anaerobic digestion, incineration and other waste treatment procedures. This framework seems to be flexible enough to include some other innovative approaches to the problem of organic solid waste, such as considering it as a suitable and inexpensive source of various raw materials for pharmaceutical and chemical industry (Government of the Republic of Serbia, 2010).

The aim of this paper is to present the procedures and necessity of composting construction on PPU of the Institute for Medicinal Plant Research “Dr Josif Pančić″, in order to adequately store, treat and dispose the waste that remains following production and processing of MAPs.

MATERIALS AND METHODS

Application of relevant legislation and determination of appropriate location of composting construction

In order to achieve objective of this research, the actual Laws and by-Laws of the Republic of Serbia, as well as various internal documents of the Institute for Medicinal Plant Research, related to the biological treatment of organic waste, were implemented. Also, a special attention was paid to determination of the most appropriate location of composting construction, in accordance to proposed regulations.

Development of composting construction procedure and supporting documentation

Development of appropriate procedure for composting construction and all activities with regard to it are to be presented in details in following supporting documents: *˝Conceptual design for the construction of composting"; ˝Biological waste management plan˝* ; and *˝Instructions for collection and disposal of herbal waste generated from production and processing of MAPs˝*

Classification and quantification of the herbal waste

The total herbal waste collected during 2012th originated from the PPU of the Institute for Medicinal Plant Research "Dr Josif Pančić" in Pančevo. It was classified in following waste types according to place of origin and their agrochemical and physical properties:

UP-P –waste in the form of pulverized herbal material of several MAPs;

UP-S–waste in the form of chopped herbal material of several MAPs;

UP-K –herbal waste of several MAPs in the form of large particles;

UP-M– represents waste in the form of mixed UP-P, UP-S and UP-K;

UE –herbal waste of several MAPs following extraction process;

UP-G–herbal waste of the several so-called "bitter drugs" in the form of pulvis;

UP-E–waste from a single plant (*Equiseti*) in the form of pulvis.

Following the herbal waste classification, quantification of each waste type has been performed and recorded through the 2012, on month basis.

Herbal waste analysis

Agrochemical analysis of the herbal waste types has been carried out at the Faculty of Agriculture, University of Belgrade, in the Laboratory for Agrochemistry and Plant Physiology.

In all herbal waste samples, ash content, pH value and total content of C, N, P, and K, were determined. Total ash content was determined by measuring the rest of the sample following its burning at 450° C. Active acidity, pH in water, was determined in suspension (10g: 25cm^3) of the ground sample in water, potentiometrically, by the use of pH meter. Total nitrogen was determined according to the method of Kjehldal after destroying the sample in concentrated H_2SO_4 + H_2O_2. Total concentrations of other macroelements determined in the same solution, obtained by the destruction of the samples with a mixture of acids HNO_3, H_2SO_4, $HClO_4$. Content of phosphorus was measured spectrophotometrically and potassium by the use of the flame-photometrical method.

RESULTS AND DISCUSSION

Implementation of relevant legislation

According to Article 61, Item 1, of the "Law on Waste Management" (***, 2009), the license for the management of waste is not required from authorities for the movement of the waste within the site of the waste production. Therefore, there were no legal obstacles for all the pre-set goals which were realized thru several phases a number of planned activities.

Herbal waste quantities

According to the internal inventory for the 2012th, in the Institute for Medicinal Plant Research "Dr Josif Pančić", it has been identified a total of 25225,7 kg of the waste resulted from production and processing of MAPs (including 4.300 kg of additional waste that was generated following the process of MAPs distillation, which is not presented the Tab. 1). In the total waste amount, prevailed the waste marked as "Other herbal drugs" which, with its annual amount of 18681.4 kg, contributes with 89.3% to the total herbal waste (Tab. 1). Significant quantity (978.3 kg) of the waste was gained following the processing of a single herb species, i.e. the aboveground part of the horsetail (*Eguisetum*), which contributed to the total waste amount with 4.7%. Another type of herbal waste, composed of several representatives of the root herbs ("bitter drugs") created 1,266.0 kg of the waste, contributing to the total herbal waste in the 2012th, with 6.0%.

Table 1. Approximate amounts of the herbal waste generated during production and processing of MAPs, in the 2012th *

Herbal waste classes	Herbal waste quantities generated in the 2012.*												Annual amount (kg)
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Eguiseti herba	82,3	35,9	154.,3	86,6	78,6	32,7	165,5	128,8	140,3	60,4	83,6	83,6	978,3
Valerianae radix, Primulae radix, Gentianae radix	108,3	126,8	186,1	38,9	-	135,2	132,6	112	-	86,1	170	170	1.266,0
Other herbal drugs	1.849,0	1.921,7	1.798,0	1.798,0	1.735,0	1.080	1.636	1.123,7	1.438,1	1.401,9	1.450,0	1.450,0	18.681,4
Total amount (kg)	2.039,6	2.084,4	1.984,1	1.923,5	1.813,6	1.247,9	1.934,1	1.364,5	1.578,4	1.548,4	1.703,6	1.703,6	20.925,7

* Note: In addition to presented herbal waste amounts, 4.300 kg of additional waste was generated following the process of MAPs distillation.

Agrochemical analysis of the herbal waste

According to agrochemical analysis of the herbal waste generated in the production and processing of MAPs, the highest content of ash (65.9%) was recorded in the sample from processing unit (UP-G) and the lowest (7.9%) in the chopped sample from processing unit (UP-S). The pH value ranged from 5.47, in the sample from processing unit – large, (UP-K) to 6.72, in the sample from extraction (UE). The lowest phosphorus content (0.16%) was generated in the sample from processing of the horsetail (*Equiseti pulvis*) and the highest P content was identified in the chopped and large sample from the processing (0.33%). Content of total Potassium varied in the range of 0.50%, in the sample (UP-G), to 2.00%, in the sample (UP-K). The highest total Nitrogen (1.64%) was recorded in the chopped sample (UP-S), while the lowest content was recorded in the so-called "bitter substances" sample (0.98%). Content of total Carbon was the same (ca. 45.9%) in the number of the waste samples (UP-S, UP-K and UE). Significantly lower content (17.06%) was recorded in the "bitter drugs" waste sample.

In order to be considered as a good raw material for production of good quality compost, regardless its origin, the organic herbal waste must have an optimal Carbon: Nitrogen ratio, which influences the rate of composting. Bacteria and fungi use the carbon and nitrogen from the waste to produce proteins for their growth and reproduction. They use about 30 parts of carbon to 1 part of nitrogen from the waste. When the C:N ratio exceeds 30:1, the composting process slows. Inorganic nitrogen, such as urea or ammonium nitrate, can be mixed with carbon-containing material, such as sawdust, to provide the desired 30:1 ratio. If the C:N ratio decreases to 25: 1 or less, the bacteria and fungi cannot use all of the available nitrogen. Excess ammonia accumulates, resulting in an unpleasant odour when the compost pile is turned (Joeseph *et al.*, 2011). Compost with high carbon content is a yellow or brown in color, dry and stodgy, while one with high nitrogen content is greenish, moist and sometimes silty. Carbon and nitrogen ratio (C:N) in samples of organic herbal waste, deriving from the processing of MAPs is presented in the Table 2.

Table 2. Agrochemical analysis of the waste generated in the production and processing of MAPs in the PPU of the Institute for Medicinal Plant Research "Dr Josif Pančić"

Types of the herbal waste	Ash (%)	pH	Total P (%)	Total K (%)	Total N (%)	Total C (%)	C:N ratio
UP-P	33,0	6,19	0,27	1,32	1,12	33,50	29,91:1
UP-S	7,9	5,63	0,33	1,67	1,64	46,02	28,06:1
UP-K	8,3	5,47	0,33	2,00	1,56	45,85	29,39:1
UP-M	21,5	5,97	0,25	1,79	1,39	39,26	28,24:1
UE	8,3	6,72	0,27	1,07	1,47	45,84	31,19:1
UP-G	65,9	5,73	0,20	0,50	0,98	17,06	17,41:1
UP-E	42,7	6,08	0,16	1,67	1,40	28,63	20,45:1

According to data presented in Tables 1 and 2, the most appropriate waste sample intended for biological treatment proved to be a sample from the processing - *Equiseti pulvis* (UP-E). This sample had the optimal values of almost the all examined parameters (except for total P). Except for the quantity of the sample from the "bitter drugs" (1,266 kg), for the remaining 23,960 kg of herbal waste, according to its agrochemical properties, it can be said that represents a suitable raw material for the production of the high quality compost.

Determination of location for composting construction

Based on the *"Conceptual design for construction of composting"*, along German field 2, at the part of the cadastral parcel 13149/1 KO

Pančevo, and based on the internal projects[2], among other issues, a proper place is selected for realization of the task (***, 2013), within the PPU of the Institute for Medicinal Plant Research, in Pančevo. The composting is located 50 m from the nearest PPU facility (44 ° 52'20 .96 "N, 20 ° 42'5 .02" E, 75 m a.s.l.), so that the availability and proximity of storage of this kind of waste is solved in a best possible manner. On the other hand, the final product (compost) will be carried out and applied to nearby 53 ha of the land on which the Institute produces herbal raw material (Photo 1).

Composting construction procedure and developed supporting documentation

Composting construction procedure is supported by specific documentation: *"Conceptual design for construction of composting"*

The conceptual design is composed of the textual part and the drawing of the future composting (***, 2013b). In the textual part, the information about the approximate amount of the bio-waste generated in the production and processing of MAPs is given together with data on the capacity and required area for the construction of composting.

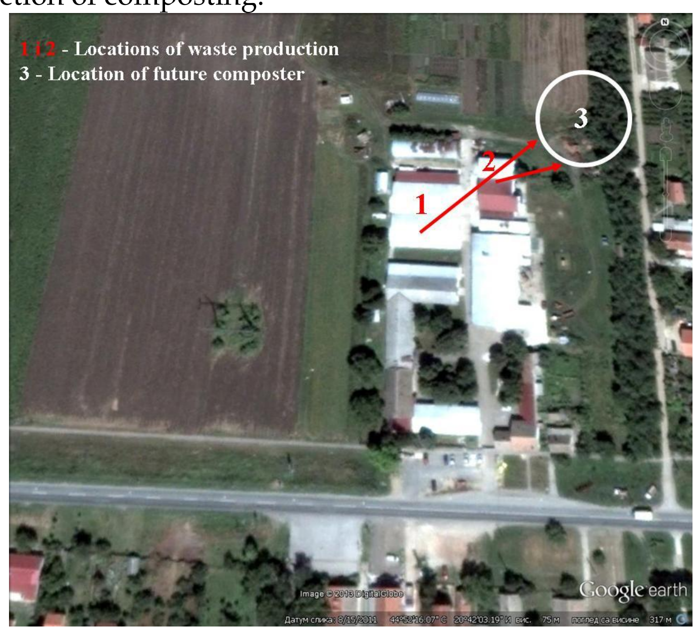

Photo 1. Location of PPU of the Institute for Medicinal Plant Research ˝Dr Josif Pančić˝ in Pančevo *(Source: Google Earth, 26.06.2013)*

Planned future composting dimensions are presented both in the text and in the graphic presentation, thru the drawings of the composting (Fig. 1). Type of procedure development and methods of the herbal waste disposal, were defined in the document entitled *˝Biological waste management plan˝* that follow the document entitled *˝Instructions for collection and disposal of waste generated from production*

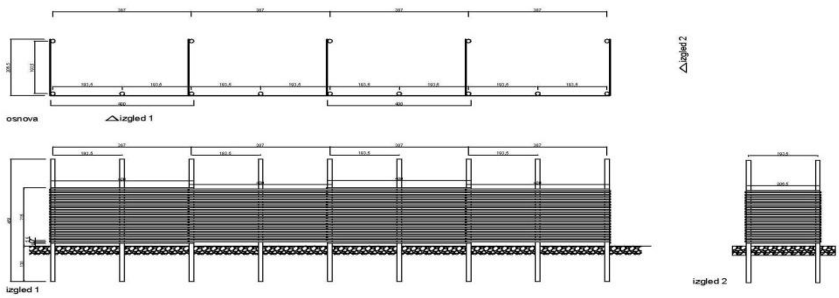

Fig. 1. Shematic presentation of the “Conceptual design for construction of composting”

and processing of MAPs˝, both being integrated into “The Quality Manual” of the Institute for Medicinal Plant Research ˝Dr Josif Pančić ˝ (***, 2011).

“Biological waste management plan”

The Waste Management Plan (in our case *“Biological waste management plan”*), is defined by in the local Waste Management Low ("Sl glasnik RS " no. 36/09 and 88/2010) and it is required for all companies that annually generate more than 200 kg of hazardous waste or 100 tons of non-hazardous waste (our plan is related to non-hazardous waste).

The aims of development of *“Biological waste management plan”* for each company (***, 2013d) are comprised in following issues that are to integrated in this plan: waste identification, establishment of biological waste stream (Fig. 2), establishment of a systemic solution for the management of biological waste, establishing accountability in the management of biological waste, defining of responsibilities for the safe removal/non removal of biological waste, re-use and recycling (composting), raising the awareness of employees, as well as actions to protect the environment and human health.

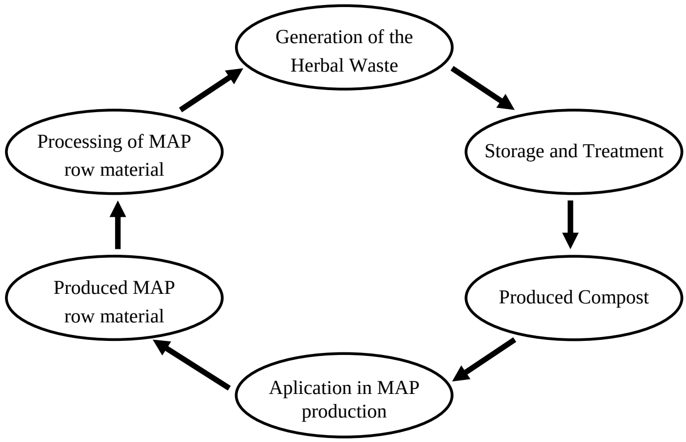

Fig. 2. Schematic flow of biological (non-hazardous) waste.

˝Instructions for collection and disposal of waste generated from production and processing of MAPs˝

According to "The Quality Manual" of the Institute for Medicinal Plant Research ˝Dr Josif Pančić˝ (***, 2011), document entitled *˝Instructions for collection and disposal of waste generated from production and processing of MAPs˝* belongs to the group of so-call "RU documents" (Working Instruction documents). These are instructions that in details describe, particularly, some of the key activities in particular processes, as well as activities of technological, administrative and logistics sub-processes, as a control points requested by HCCP. In its content the plan includes: subject, scope, responsibilities, definitions and abbreviations, a link to other documents, a description of the activities and documentation.

CONCLUSIONS

According to the current legislation on the waste management and environmental protection, in the 2013, at location of the manufacturing facility of the Institute for Medicinal Plant Research "Dr Josif Pančić˝ in Pančevo, it has been started with activities on storage, treatment and disposal of biological waste generated in the production and processing of MAPs. Preparation and completing of a number of specific documents, the status of the herbal waste was resolved and conditions for its systemic resolution and the environmental protection were created. Given the favorable agro-chemical properties of the herbal waste, construction of the composting provides pre-conditions for good biological waste treatment procedure (composting), thus production of high-value organic fertilizer (compost) is expected.

ACKNOWLEDGEMENTS

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CONTENT OF HEAVY METALS IN SOILS FORMED ON LIMESTONE AND DOLOMITES ON JABLANICA MOUNTAIN

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ABSTRACT

The scope of the investigations was to determine the quantity of total (Cu, Zn and Pb) and available forms of heavy metals (Cu, Fe, Mn and Zn) in soils formed on limestone and dolomite on the Jablanica Mountain in Macedonia. Dissolution of soil samples was performed by concentrated HCl and HNO_3 in a ratio 3:1. The available forms of heavy metals are extracted with the DTPA method. Determination of the content is perfumed with AA spectrophotometer Agilent 55 and Agilent graphite furnace 240 Z. The results of investigation showed that the total zinc content in all soil samples are slightly higher than the reference, but lower than the intervention value, while the total lead content is lower than the reference value. Total copper content is lower than the reference values, except for two soil samples with a higher content of the reference values, but much lower than intervention value. The quantities of available copper are in the ranges of high to very high, of iron are between low to very high, while the quantities of available zinc are very low to very high. The quantities of available manganese in all soil samples are very high.

Keywords: heavy metals, lead, zinc, copper, iron, manganese

INTRODUCTION

On different locations of the Jablanica mountain 4 basic pedological profiles were excavated of calcomelanosols with the following subtypes: organogenic (prof. 38), organomineral (prof.3 and 7) and brownized (prof.8) and 1 profile of calcocambisol with typical subtype (prof.1). The investigated soils are classified according classification of the Former Yougoslavia (Škorić *et al.*, 1985).

In addition, data were collected for the soil forming factor (parent material, relief, climate, vegetation and human impact). Surveyed soils are formed only on pure limestones (prof.3 and 8) and dolomitized limestone (prof.38, 7 and 1), on mountainous terrain at altitude of 1000-1500 m. Investigated soils were formed under variety of oak and beech communities.

The only available data for the content of total forms Cu and Zn and available forms of Cu, Mn and Zn from a profile of calcomelanosol of mountain Galichica can be found in the paper of Jekić & Savić (1970). Petkovski & Melovski (2006) reported data for the content of total forms of Pb, Cu and Zn in arable horizon of riperated calcocambisols in the area of Skopje.

The main goal of this paper is to examine the content of total (Pb, Cu and Zn) and available forms of Cu, Fe, Mn and Zn in different subtypes of calcomelanosols and calcocambisols, which will contribute to getting a better idea for the contents of heavy metals in this widespread soli type in Republic of Macedonia.

MATERIALS AND METHODS

Field examinations have been performed according to accepted methods in Former Yugoslavia (Filipovski, 1967). The laboratory analyses were according to the standard adopted methods in Former Yugoslavia and Republic of Macedonia. Mechanical composition was determined by the standard method (Resulovič, *et al.*, 1971); the dispersion of particles was done with 0,4N Na-pyrophosphate. Soil pH was determined with glass electrode in water suspension and in NKCI suspension (Bogdanovič *et al.*, 1966). Available forms of P_2O_5 and K_2O were determinate by Al method (Džamić *et al.* 1996). The content of humus was determinate by Tjurin method modified by Simakov (Orlov & Grišina 1981). Dissolution of soil samples was performed by concentrated HCl and HNO_3 acids in a ratio 3:1 (Džamić *et al.* 1996). The available forms of heavy metals were extracted with the DTPA (Page *et al.*, 1982), and their content was read with AA spectrophotometer Agilent 55 and Agilent graphite furnace 240 Z.

RESULTS AND DISCUSSION

1. *Mechanical composition and chemical properties (tab.1 and 2)*

The mechanical composition of the soil affects the availability of heavy metals. At the same level of total content of heavy metals their availability will be less in the soils with heavier texture. There will be considered only the chemical properties, which have influence on heavy metal availability.

Table 1 Mechanical composition of calcomelanosols and calcocambisol (in % of fine earth)

Profile No	Horizon and depth cm	Coarse sand 0.2 - 2mm	Fine sand 0.02 - 0.2mm	Coarse + fine sand 0.02 - 2mm	Silt 0.002 - 0.02mm	Clay <0.002mm	Silt + clay <0.02mm
			Calcomelanosol-organogenic				
38	A 4-24	3.1	47.4	50.5	15.8	33.7	49.5
	R						
			Calcomelanosol-organomineral				
3	A 3-28	19.2	28.0	47.2	18.4	34.4	52.8
	R						
7	A 0-21	7.0	28.8	35.8	25.8	38.4	64.2
	R						
			Calcomelanosol-brownized				
8	A 0-8	1.0	36.5	37.5	18.2	44.3	62.5
8	A 8-36	2.3	21.9	24.2	18.5	57.3	75.8
8	(B)rz 36-52	3.3	20.3	23.6	17.8	58.6	76.4
	R						
			Calcocambisol-typical				
1	A 2-21	6.4	23.6	30.0	13.0	57.0	70.0
1	(B)rz 21-55	2.1	13.6	15.7	19.1	65.2	84.3
	R						

Table 2. Chemical properties of calcomelanosols and calcocambisol from Jablanica mountain

Profile No.	Horizon and Depth, cm	$CaCO_3$ %	Humus %	pH H_2O	pH nKCl	Easyavailable mg/100g soil P_2O_5	Easyavailable mg/100g soil K_2O
			Calcomelanosol-organogenic				
38	A 4-24	0	27.36	6.75	6.25	7.0	26.7
	R						
			Calcomelanosol-organomineral				
3	A 3-28	0	7.11	5.55	4.60	2.5	16.1
	R						
7	A 0-21	0	10.5	6.30	5.65	4.20	34.2
			Calcomelanosol-brownized				
8	A 0-8	0	20.41	5.95	5.2	7.2	39.2
8	A 8-36	0	7.69	6.3	5.3	1.2	13.9
8	(B)rz 36-52	0	3.36	6.95	6.2	1.0	17.0
			Calcocambisol-typical				
1	A 2-21	0	9.51	6.75	6.05	2.0	31.7
1	(B)rz 21-55	0	2.91	6.90	6.10	1.3	20.8

2. Content of total forms heavy metals Cu, Pb and Zn (tab. 3)

For comparison of the results the Dutch reference standards were used (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer 2010).

Table 3 Content of total forms heavy metals in soils formed on limestone and dolomite rock on Jablanica Mt.

Profile No.	Horizon and Depth, cm	Total content in $mg.kg^{-1}$ Zn	Pb	Cu
		Calcomelanosol-organogenic		
38	A 4-24	223.67	57.34	18.00
	R			
		Calcomelanosol-organomineral		
3	A 3-28	167.06	39.35	38.68
	R			
7	A 0-21	182.65	51.99	26.00
	R			
		Calcomelanosol-brownized		
8	A 0-8	228.32	60.66	34.66
8	A 8-36	186.99	51.00	33.00
8	(B)rz 36-52	166.03	46.01	28.34
	R			
		Calcocambisol-typical		
1	A 2-21	170.70	57.34	34.34
1	(B)rz 21-55	184.02	49.67	47.01
	R			
Referent value		140	85	36
Intervene value		720	530	190

The content of total Zn in all tested soil samples is higher than the reference values, but significantly below intervention values. According to Lindsay (1982) and Kastori (1997) the total content of Zn in soil is between 10 and 300 mg kg-1, with average 50 mg kg^{-1}.

High content of total Zn in calcomelanosol of Galichica Mountain ranging from 122 to 132 mg kg^{-1} is reported by Jekić&Savić (1970). It is interesting to note that these researchers have examined the content of total Zn in different soil types, but the highest content was determined in soils on limestone (calcomelanosol). Contents of total zinc ranging between 31.65-45,7 mg kg-1 was determined in calcocambisol in the area of Skopje by Petkovski&Melovski (2006).

The total Pb content ranges from 39.35 to 60,66 mg kg^{-1}, and is lower than the reference values in all soil samples, which means that there is no danger of contamination of soil and plants with this heavy metal. Lower values for the two surface soil samples of calcocambisol from Skopje area, are ranging from 6 to 13 mg kg^{-1} are determined by Petkovski&Melovski (2006).

Results show that the total copper content is lower than the reference values, except in two soil samples that are somewhat higher than the reference values, but with much lower values than the intervene values, which means that there is no danger of contamination of soil and plant with this metal (Tab. 3). Jekić&Savić (1970) reported data on the total copper content in calcomelanosol of Galichica mountain in range from 38.4 to 40,8 mg kg^{-1} which are similar to our results. Lower values for the two surface soil samples from calcocambisol from Skopje ranging from 8,3 to 10,2 mg kg^{-1} concluded Petkovski&Melovski (2006).

3. Content of the available forms of Cu, Fe, Mn and Zn

Content of available forms of heavy metals Cu, Fe, Mn and Zn in the studied soils (Tab. 4). These heavy metals are essential trace elements in plant nutrition and their deficiency can cause growth failure while the greater scarcity can cause death of plants. On the other hand, their high concentrations can lead to phytotocsicity.

The results indicate that 7 soil samples contains very high quantities of available Cu, while one sample have high quantities of available Cu. Tested soils have high content of soil organic matter which is probably one of the reasons for high content of available Cu (Tab. 2). Although very little is known about the soluble organic Cu forms; about 80% of the soluble Cu have been estimated to be organic chelates (Pendias-Kabata&Pendias 2001). Jekić&Savić (1970) report data for high content with the available Cu in calcomelanosol of the Galicica Mt.

The content of available Fe in tested soil samples is from low to very high. Out of the 8 tested soil samples, 5 have high content of Fe, 2 have medium quantity while only one have low quantity of available Fe. Good quantities of easy available Fe is related to absence of $CaCO_3$, weakly acid to neutral soil reaction; in this interval of soil reaction the availability of Fe is increased.

The quantities of available Mn in examined soil samples are several times higher than the limit values. Džamić & Stevanović (2000) presents data according to which the MAC for easy soluble Mn is 300 mg kg^{-1}. From the table it can be seen that despite high levels of available Mn, they are still within the ranges of MAC. The content of available Mn decreases with depth of soil profile (Prof. 8 and 1). According Kastori (1990) the quantities of available Mn decreases in the depth of soil profile. Jekić & Savić (1970) report data for very high contents of easy available Mn in one soil profile of the Galicica Mt.

The content of available Zn in the examined soil samples is as follows: three soil samples have very low quantities, one sample has a low content, two soil samples have medium content, and one sample have high and another one a very high content of Zn. From the data presented in Tables 2 and 4 it can be concluded that soil samples with highest quantity of soil organic matter (prof.38, first depth of hor.A of prof.8) have the highest quantities of available Zn.

Soil organic matter is known to be capable of bonding Zn in stable forms; therefore, the accumulation of Zn in organic soil horizons and in some peat soils is already reported (Pendias-Kabata &Pendias 2001). Jekić&Savić (1970) noted poor quantity of available Zn in calcomelanosol of the Galicica Mt. On the base of our research and the previous data from Jekić&Savić (1970) it can be concluded that despite the high quantities of total Zn, the quantities of available Zn are not satisfactory.

Tab. 4 Content of available forms heavy metals in soils formed on limestone and dolomitic rock on Jablanica Mt.

Profile	Horizon and	Available form in mg/kg^{-1}			
No	Depth, cm	Cu	Fe	Mn	Zn
		Calcomelanosol-organogenic			
38	A 4-24	2.95	46.56	168.0	9.52
	R				
		Calcomelanosol-organomineral			
3	A 3-28	2.58	47.56	128.2	0.54
	R				
7	A 0-21	2.50	40.44	164.6	1.91
	R				
		Calcomelanosol-brownized			
8	A 0-8	3.00	45.76	209.4	3.98
8	A 8-36	2.60	31.12	160.5	0.45
8	(B)rz 36-52	1.85	11.28	90.2	0.25
	R				
		Calcocambisol-typical			
1	A 2-21	2.68	14.44	198.8	1.46
1	(B)rz 21-55	2.57	7.84	143.0	0.48
	R				
very low		<0,3	0-5	0-4	<0.5
low		0.3-0.8	5-10	4-8	0.5-1.0
medium		0.9-0.1,2	11-16	9-12	1.1-3.0
high		1.3-2,5	17-25	13-30	3.1-6.0
very high		>2,5	>25	>30	>6.0

Out of the data for total and available forms of copper and zinc it can be concluded that despite the high content of total zinc its availability is lower. On the other side, despite lower values of total copper its availability is higher.

CONCLUSIONS

Based on the conducted research the following conclusions can be drawn:

- The content of total zinc in all soil samples is higher than the reference value, while the total lead is lower than the reference values. Total copper content is lower than the reference values, except for two soil samples with a higher content of the reference values, but much lower than intervention value.
- The quantities of available copper are in the ranges of high to very high, of iron are between low to very high, while the quantities of available zinc are very low to very high. The quantities of easy available manganese in all soil samples are very high.
- The examined soils are characterized with weak acidic to neutral reaction, non-carbonate, with high content of soil organic matter, which have influence on the availability of the examined trace elements.
- Out of the data for total (Cu, Zn and Pb) and the available forms of heavy metals (Cu, Fe, Mn and Zn) it can be concluded that there is no threat of toxic amounts of heavy metals to the soils. Quantities of available forms of Cu, Fe and Mn are good while the quantities of available Zn is unsatisfactory.

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IRRIGATION OF MAIZE IN RELATION TO REFERENCE POTENTIAL EVAPOTRANSPIRATION (ETo)

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ABSTRACT

The objective of the present study was to observe maize grain yield under various water regimes of the soil. The aim was to determine the most favourable ration between actual, i.e. maximally real evapotranspiration (ETRm) and reference potential evapotranspiration (ETo) for achieving record grain yields of maize. The experiments were carried out on slightly calcareous chernozem under conditions of eastern Srem in Zemun Polje in the period from 2003 to 2005. The medium late maize hybrid ZP 677 (FAO 600) was grown in three sowing densities: G_1-54,900 plants ha^{-1}; G_2-64,900 plants ha^{-1} and G_3-75,200 plants ha^{-1} under various water regimes obtained by the maximum actual to reference potential evapotranspiration ratio of ETo:ETRm=1:1; ETo:ETRm=1:0.8 and ETo:ETRm=1:0.6 as well as under rainfed conditions (control). Reference potential evapotranspiration (ETo) was estimated by the Penman-Monteith method. Gained results show that various irrigation regimes very significantly affected the formation of maize yields. The highest average yield (14.03 t ha^{-1}) was achieved in the variant with ETo:ETRm=1:0.8 and water consumption, depending on a year, varying from 401 to 442 mm. A maize sowing density also significantly affected the level of achieved maize yields, hence the highest average yield (13.16 t ha^{-1}) was recorded at the highest observed sowing density (G_3-75,200 plants ha^{-1}). The analysis of the soil water regime and the sowing density indicates that the highest yield (15.22 t ha^{-1}) was obtained at the highest sowing density and the water regime acquired by the ratio of ETo:ETRm=1:0.8.

Keywords: maize, evapotranspiration, irrigation regime, density, yield

INTRODUCTION

Maize is one of the most important field crops and is cultivated either as a main or a stubble crop for either grain or silage. Maize grain has multiple purposes, primarily as feed, while it is also a significant raw material for food.

Due to its multiple purpose, maize ranks third in the world in sown areas, just behind wheat and rice. In contrast to the world, in Serbia maize is sown on 1/3 of field plots. Considering the long-term average maize is sown on approximately 1,200,000 hectares in Serbia. Maize is also a major row crop on irrigated areas.

However, dry grain yields of 3.0 to 6.0 t ha^{-1}, achieved in commercial production, do not even remotely correspond to maize importance and ranking. The low level of the utilization of maize genetic potential is a consequence of the inappropriate application of cropping practices and insufficient sums and uneven distribution of precipitation during the growing season. Hence, the average maize yield amounted to 5.08 t·ha^{-1} in Vojvodina in the 1965-2003 period. It also greatly varied from 2.26 to 7.11 t ha^{-1}. Stated variations correlate with the sums and distribution of precipitation (Bošnjak, 2004).

Irrigation of maize under such conditions, as an additional practice, should correct imbalance of precipitation, regulate water regime of the soil and should provide a favourable nutritional regime for a crop. Therefore, the water regime of soil, which includes quantitative and qualitative changes in soil moisture throughout the profile and time, caused by water inflow, movements, retention and losses, loses its natural status and becomes anthropogenic water regime of the irrigation type (Milivojević, 1984.) and as such it has been an objective of many national and international studies related to maize irrigation.

Since irrigation can be applied without any restriction only in the chernozem zone, in which the maize growing is the most common, it is logical that this kind of studies have been carried out on this type of soil. For instance, Vasić (1983), concluded that furrow and sprinkler irrigations were more favourable water regimes than drop irrigation or subirrigation. On the other hand, Kresović *et al.* (1997), stated that maize grown on the soil with a permanently high moisture level in the shallower rhizosphere zone yielded more than maize grown in sparsely infiltrated deeper horizons. Similar results were obtained in studies on irrigation regimes carried out in southern Bačka on the chernozem cultivated with maize (Pejić, 1999). Furthermore, a great attention in these studies was also paid to pre-irrigation soil moisture, which amounted in chernozem to 60-65% FWC (Bošnjak, 1993), i.e. 75% FWC (Milivojević, 1984), while certain studies show that irrigation should start when 50% of accessible water in the 0-50-cm horizon is consumed (Kresović *et al.*, 1993).

Another very important factor in maize irrigation is the total amount of water consumed by maize and required for the maximum actual evapotranspiration during the growing season, so called "water requirement of maize". There are different data on this topic in literature depending on pedoclimatic conditions under which maize is grown. Hence, ETRm of maize in Minnesota, Central Asian part of Russia, Texas and moderate semi-arid and semi-humid conditions amounts to 375 mm (Morey *et al.*, 1980), 890 mm (Zaporožčenko, 1978), 964 mm (Eck, 1986) and 480-650 mm (Zaporožčenko, 1978), respectively.

Under agroecological conditions of the Zemun Polje region, ETRm of maize amounts to 545-642 mm (Milivojević, 1984), that is to 425 mm (Vasić, 1979), while it amounts to 460-520 mm under conditions of Vojvodina (Bošnjak, 1993).

Thus, there is still a dilemma in answering the question: what is the optimum irrigation regime of soil cultivated with maize? Therefore, the objective of the present study was to analyze the irrigation regime from the aspect that has never been included into previous studies. Due to the fact that maize irrationally consumes water if it is plentiful, the objective of this study was to observe a reduced irrigation regime based on three different levels of reference potential evapotranspiration (ETo), including all remaining relevant factors of high and stable yields of maize.

MATERIALS AND METHOD

Long-term (2003-2005) studies on irrigation regimes of maize were carried out on slightly calcareous chernozem in the irrigation experimental plots of the Maize Research Institute, Zemun Polje under agroecological conditions of eastern Srem. The four-replicate trial was set up according to the randomised complete-block design. The experimental plot size amounted to 11.2 m^2.

The medium late maize hybrid ZP 677 belonging to the FAO maturity group 600 was used in the trial. The hybrid was sown in three different densities (G_1=54,900 plants ha^{-1}; G_2=64,900 plants ha^{-1} and G_3=75,200 plants ha^{-1}). Winter wheat was used as a preceding crop in all years of investigation. Sowing was done manually in mid-April, and all other cropping practices were applied as in commercial production of this crop. The only difference was in the irrigation regime, which was applied in the following variants:

W_o– natural water irrigation regime of the soil (without irrigation) and

W_i – irrigation water regime of the soil with three subtypes conditioned by different irrigation rates based on the interrelation of the maximum actual (ETRm) to reference potential evapotranspiration (ETo) ratio:

Wi_1 – variant, ETRm / ETo = 1:1
Wi_2 – variant, ETRm / ETo = 0.8:1
Wi_3 – variant, ETRm / ETo = 0.6:1

When the soil was irrigated, water was added superficially by sprinkler irrigation. The amounts of added water were precisely measured for each investigation variant by a water gauge. Water was added until the physiological maturity of maize that is until the formation of the black layer on maize kernels.

Meteorological observations were made at the meteorological station located in the vicinity of the experimental field. Reference potential evapotranspiration (ETo) was calculated by the Penman-Monteith method (Allen and Pruitt, 1992).

Maize grain yield ($t \cdot ha^{-1}$) was estimated at 14% moisture. Obtained results were processed by the analysis of variance and tested by the LSD test.

RESULTS AND DISCUSSION

The analysis of meteorological parameters recorded during the investigation period (2003-2005) show that the mean monthly air temperatures for the growing season of maize in 2003 were higher by 2.1 ^oC than the long-term mean, while the corresponding temperatures in remaining two years were at the level of the long-term mean (Tab. 1).

These parameters are important because the air temperature does not only affect the length of the growing season of the crop, but also directly affects the level of potential evapotranspiration (ETo). Therefore, many evapotranspiration estimation methods based on air temperature dynamics have been developed. It can be observed that values of evapotranspiration in the warmest year were higher than the values in the remaining two years.

Table 1. Mean monthly air temperature (°C), monthly precipitation sum (mm) and monthly reference evapotranspiration (mm) (GMS Zemun Polje)

Month	Year									Long term average (1952-2005)	
	2003			2004			2005				
	T °C	P mm	ETo mm	T °C	P mm	ETo mm	T °C	P mm	ETo mm	T °C	P mm
April	11.5	14.6	70	12.9	27.2	66	11.8	28.2	69	11.8	50.2
May	20.9	36.4	129	16	53.6	97	17.1	39.6	101	17.4	60.0
June	24.6	19.0	159	20.3	27.2	114	18.9	65.0	116	20.4	77.9
July	22.6	105.4	132	21.9	66.4	132	22.1	44.0	126	22.1	65.2
August	24.7	26.4	143	21.0	39.4	114	20.1	64.0	91	21.9	50.9
September	19.2	41.2	81	18.1	44.8	68	18.9	21.4	70	17.3	46.6
Growing season	20.6	243.0	714	18.4	258.6	592	18.2	262.2	574	18.5	350.8

On the other hand, precipitation, as an element of soil water regime, by its sums and distribution, essentially affected the achieved water regime during the experimental period (Tab. 2). All three years of investigation can be considered dry, since precipitation sums during the growing season were significantly below the long-year average.

As the objective of the present study was the irrigation regime of maize related to reference evapotranspiration thus achieved irrigation regimes also depended on its estimates. In the warmest year of 2003, the greatest amount of water was applied, while the irrigation rate in the remaining two years was significantly lower. Similar results were obtained in studies performed on chernozem in central Bačka (Stričević *et al.*, 2001).

Table 2. Irrigation schedule, irrigation rate (mm) and irrigation requirement (mm)

Year	Date of irrigation	Irrigation rate (mm)			Irrigation requirement (mm)		
		W_1	W_2	W_3	W_1	W_2	W_3
2003	May 5	12	15	19	143	251	354
	May 12	19	27	33			
	May 19	14	20	26			
	June 2	-	10	20			
	June 9	12	20	27			
	June 16	22	30	38			
	June 23	13	21	28			
	June 30	22	29	36			
	July 21	-	-	12			
	July 28	-	5	17			
	August 4	-	10	16			
	August 11	-	17	23			
	August 18	14	25	31			
	August 25	15	22	28			
2004	May 10	-	6	11	78	173	264
	May 24	-	-	8			
	May 31	-	15	21			
	June 7	4	13	17			
	June 14	6	11	16			
	June 21	13	19	25			
	June 28	9	15	21			
	July 5	7	13	20			
	July 12	19	26	33			
	July 19	11	17	23			
	July 26	9	14	20			
	August 9	-	-	6			
	August 16	-	15	24			
	August 23	-	4	9			
	August 30	-	5	10			
2005	May 9	11	15	19	64	141	224
	May 23	-	-	7			
	May 30	7	22	29			
	June 6	6	11	16			
	June 27	-	9	26			
	July 4	4	17	23			
	July 11	4	8	13			
	July 18	-	-	3			
	July25	3	14	23			
	August 1	21	28	35			
	August 8	5	10	15			
	August 15	3	7	11			
	August 22	-	-	4			

In addition to reference evapotranspiration, the achieved irrigation regime depended on the precipitation sum and distribution during the growing season, which also conditioned water consumption, i.e. maximum actual evapotranspiration of maize (Tab.3). Thus, the greatest maximum actual evapotranspiration of maize was recorded in 2003. Values of reference evapotranspiration in remaining two years were similar, but a more favourable precipitation regime in 2005 resulted in a smaller number of watering in comparison with 2004.

Table 3. Maximum actual evapotranspiration (mm)

Year	Variant	Irrigation requirement Nn (mm)	Precipitation P (mm)	Nn+P (mm)
2003	W_1	143	191	334
	W_2	251		442
	W_3	354		545
	Control	-		191
2004	W_1	78	228	306
	W_2	173		401
	W_3	264		492
	Control	-		228
2005	W_1	64	261	325
	W_2	141		402
	W_3	224		485
	Control	-		261

The analysis of the three-year results shows that irrigation significantly affected the level of obtained yields of maize, which is confirmed by significantly higher yields in all investigated variants of irrigation (W_1-13.510 t ha^{-1}; W_2-14.033 t ha^{-1}; W_3-13.339 t ha^{-1};) in relation to control without irrigation (9.986 tha^{-1}). Moreover, differences in obtained yields were significant over observed irrigation regimes (Tab. 4).

From this point of view, the most favourable irrigation regime was achieved in the W_2 variant at reduced watering in relation to the values of reference evapotranspiration of 0.8 and achieved average maximum actual evapotranspiration of 415 mm. Similar results, that is values of actual in relation to potential evapotranspiration of maize were obtained at maize sowing densities of 57,000-69,000 plants ha^{-1} (Al-Kaisi *et al.*, 2003). In contrast to obtained results, the highest maize yields under agroecological conditions of western Turkey were achieve when maximum actual evapotranspiration equalled reference evapotranspiration (Dagdelen *et al.*, 2006). Furthermore, the irrigation regimes x years interaction very significantly affected the level of obtained yields, hence from this aspect it can be stated that the year with the greatest precipitation sum and its best distribution was the most favourable for maize growing. In contrast to 2003, when the highest irrigation rate was applied, maize yields obtained in 2005 were significantly higher, although the irrigation rate was lower by 80-130 mm in relation to the rate in 2003. Such results can, first of all, be attributed to the fact that the mean air temperatures were significantly above the long-term mean, which resulted in shortening of the growing season of maize, which despite the achieved favourable irrigation regime of the soil could not express its full genetic potential of yield.

Another observed factor, sowing density, also very significantly affected the level of obtained yields. Hence, the highest average yields (13.160 t·ha^{-1}) were recorded at the highest sowing density (G_3=75,200 plants ha^{-1}). Results gained in previous studies carried out under agroecological conditions of eastern Srem show that the most favourable sowing densities for growing medium late maize hybrids under irrigation conditions ranged from 70,000 to 90,000 plants ha^{-1} (Videnović *et al.*, 2003; Kresović *et al.*, 2004)

Table 4. Yields of maize hybrid (t ha^{-1}) with and without irrigation

Variant (B)	Density (C)	Year (A)			Average	
		2003	2004	2005	(B)	(C)
W_1	D_1	10.865	14.370	14.745	13.510	12.392
	D_2	10.973	14.295	14.747	14.033	12.599
	D_3	10.610	15.445	15.540	13.339	13.160
W_2	D_1	9.515	13.900	14.628	9.986	
	D_2	12.013	14.810	15.780		
	D_3	12.580	15.573	17.503		
W_3	D_1	10.568	13.487	15.497		
	D_2	11.622	13.848	14.675		
	D_3	10.848	14.620	14.885		
Control	D_1	7.420	11.418	9.795		
	D_2	10.903	10.662	9.358		
	D_3	9.382	10.352	10.582		
Average (A)		10.608	13.565	13.978		

LSD	%	A	B	C	AB	AC	BC	ABC
	5	0.208	0.242	0.210	0.419	0.363	0.419	0.726
	1	0.277	0.320	0.277	0.555	0.481	0.555	0.961

The highest individual yield of 17.503 t·ha^{-1} was recorded in the moderately warm year (2005) with the best pluviometric regime.

CONCLUSION

According to the three-year studies on irrigation regimes of maize grown on chernozem in eastern Srem the following conclusions can be drawn:

The highest average yield (14.033 t ha^{-1}) was achieved in the variant with ETo:ETRm=1:0.8. Maintenance of a permanently high level of soil moisture resulted in more reasonable water consumption by the crop. The average maximum actual evapotranspiration amounted to 415 mm in the most favourable irrigation regime. The increase of the sowing density positively affected achieved yields, hence the highest yield of 13.160 t ha^{-1} was recorded at the greatest sowing density. Yields obtained under conditions without irrigation were directly correlated with achieved pluviometric regimes during the investigation years.

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POSSIBILITY OF RECULTIVATION OF THE MARLY SUBSTRATE IN THE "BOGUTOVO SELO" OPEN PIT IN UGLJEVIK

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ABSTRACT

The paper focuses on a one-year research of the possibility of recultivation of the marly substrate (deposol) at the Great Western Depot of the «Bogutovo Selo» Ugljevik open pit, by sowing grasses and clovers, for the purpose of conducting a comparative study of the two methods of biological recultivation (direct and indirect). The results show that the reclamation of marly deposols with grass and clover is possible. Of all tested variants, the sorghum and Sudan grass (sweet Sioux) hybrid was the best in terms of total biomass yield in both direct and indirect recultivation, while alfalfa was proven to have the highest possibility of success and is the most financially viable variant.

Keywords: marly substrates, possibility of reclamation, biological cultivation, grass and clover.

INTRODUCTION

The development of the industrial civilisation was entirely founded on exploiting mineral ores, fore-fronting energy resources (Dražić, 2002). The exploiting of mineral ores, particularly the process of open-pit coal mining, inevitably changes the environment. The nature and scope of these influences are different for each particular case and determines on the basis of natural, productive and technological characteristics of the exploitation of the deposits (Pavlović, 2000).

Open pit or deep-shaft mining have a negative effect on the environment, including the area where the mining is conducted and the areas where barren soil resulted from open-pit mining is deposited (Pehlić, *et al*., 2008). Barren soil at inner or outer deposits somewhat is a challenge for experts and institutions which deal with this complex issue. Therefore, soil recultivation must be approached expertly, not haphazardly, considering many factors such as the defined goals of recultivation, the real situation and means for their use (Đorđević-Miloradović, *et al*., 2012). For this reason, the biological recultivation of the barren land at the «Drmno» open-pit, in addition to reforestation, included sowing a grass-legume mix of alfalfa and rapeseed.

The «Bogutovo Selo» open pit is part of the Ugljevičko-Pribojski basin. The exploitation of this open pit has degraded a significant area and the barren soil is deposited at several depots: Sjeverno odlagalište (Nothern Depot), Veliko zapadno odlagalište (Great Western Depot), and Unutrašnje odlagalište (Inner Depot). The area of the Ugljevičko-Pribojski basin consists of Eocene deposits, mostly sandstone, part of the conglomerate being limestone, with the addition of lower Triassic and upper Cretaceous deposits. Oligocene deposits consist of Leitha limestone, partly sandy marlstone or clay, and partly Sarmatian limestone (The main mining project PK "Bogutovo Selo" - the technical project of reclamation of the southern slopes of the final).

The surface of the depot consists of intercalations of the main coal layer, marls and calcareous marls, while other types of rocks are at the base and inside the depot. A laboratory analysis of the chemical properties of the soil was used to determine the pedological characteristics of the surface layer (Resulović, 1980) and they are as follows: pH in H_2O from 7,7 to 8,4, content of $CaCO_3$ from 56,78 to 84,80%, content of physiologically active lime 28-32%, humus content from 0,0 to 1,62%, and 3,2-3,6 mg of easily available phosphorus (P_2O_5) in 100 g of soil and 5,0-9,75 mg of easily available potassium (K_2O).

The average annual temperature for Ugljevik in the period 1961-1990 was 11,2^{o}C. Minimum monthly average temperatures are reached in January (-0,5 ^{o}C) and the warmest months was July (21,2 ^{o}C) and August (20,7 ^{o}C). The annual amplitude of minimum and maximum temperature fluctuations for the observed period is large – around 70,4^{o}C.

The reasons behind the lack of clover and grass based recultivation in this area is the opinion that the initial risks for these biological cultures (small seed and low-quality substrate may cause sprouting to fail) are higher than in the recultivation of forests and orchards. In order to obtain relevant data on possible forms of biological recultivation of the degraded soil of the «Bogutovo Selo» Ugljevik, a field experiment was conducted which comprised sowing grass and clover species at the Great Western Depot.

Definition of Recultivation

Newly-formed substrates created through the depositon of coal overburden layers during surface mining are called deposols or technogenic soils. There are different subtypes of deposols (Lat. *deponere*–to deposit) depending on the type of overlaid material (soil, ore, slag, etc.).

Recultivation is «a combination of mining, technical, engineering, ameliorative, agricultural and forestry activities, conducted within a certain time frame, aiming to improve the condition of soil previously degraded by industry, to the point of being able to use it in agriculture, forestry purposes, recreation, water accumulations, capital and construction» (Ćirjaković, 1981).

Biologoial recultivation is «the entirety of works conducted and capital invested in creating humus, improving soil quality and bringing it to a stage where it can be used in agricultural or forestrypurposes, or otherwise managed (Drlik, 1964).

Direct biological recultivation entails direct planting-sowing on the deposited geological series, without having overlaid it with hummus. Indirect recultivation entails a hummus layerover the deposited geological series. From the financial viewpoint, the indirect recultivation is much more costly.

MATERIALS AND METHODS

Direct experiments in the field are the safest and most reliable method for obtaining data on the recultibility of the land which is considered for recultivation. This method demands a longer time frame for research, from one to several years. The topic of this paper is a one-year research study on the recultibility of the marly substrate at the Great Western Depot, «Bogutovo Selo» open pit in Ugljevik, by sowing grasses and clovers, in order to conduct a comparative study of the two types of recultivation (direct and indirect). The research focused on biomass yields of every particular variant, and every repetition within a variant.

The field experiment was started in March 1989 (ended in September 1989; the green phytomass was mowed 3 times –end of May, in June and September); on the flat section of the Great Western Depot, at 169 m a.s.l., on the area of 3200 m^2. One half of the surface (40x40m=1.600 m^2) was overlaid with 20 cm humus (indirect recultivation), while on the other half the original geological substrate was kept (direct recultivation). The Latin square design was used in the experiment, with 4 identical variants and 4 repetitions in the experimental plots with both direct and indirect recultivation.

A - Sainfoin (*Onobrychis sativa* L.),sown: 1,6 kg 100 m^{-2},

B - Gramineae and legumes mix: *Medicago sativa* L., *Onobrychis sativa* L., *Trifolium repens* L., *Dactylis glomerata* L., *Avena elatior* L., *Festuca pratensis* L., *Bromus inermis Lesus*, sown 0,5kg/100 m^2,

C - Common alfalfa (*Medicago sativa* L.), sown 0,3 kg/100 m^2,

D - Sorghum and Sudan grass (*Sweet sioux*), sown 0,5kg 100 m^{-2}.

A_1	B_1	C_1	D_1
A_2	B_1	C_2	D_2
A_3	B_1	C_3	D_3
A_4	B_1	C_4	D_4
4 x 10 m = 40 m			

Direct recultivation

A_1	B_1	C_1	D_1	4 x 10 m = 40 m
A_2	B_1	C_2	D_2	
A_3	B_1	C_3	D_3	
A_4	B_1	C_4	D_4	
4 x 10 m = 40 m				

Indirect recultivation

Legend: A, B, C and D – variants; 1, 2, 3 and 4 – repetitions

Image 1 Scheme of experimental plots at the Great Western Depot

The data obtained in this research must be taken with caution (necessary for this type of research where three-year research period was planned) because these are one-year research results. Considering that the experiment was significantly compromised by anthropogenic damage, cattle and weeds in 1990 and 1991, the results from these years were not taken into consideration.

RESULTS AND DISCUSSION

A large number of grass and clover species could thrive in the climatic conditions of Ugljevik. Orographic factors don't significantly reduce the number of species that thrive in the Great western landfill. The substrate (deposol), however, does significantly reduce the number of species and their yields.

The most significant indicators in the research of the biomass yield of grasses and clovers is the phytomass yield of the above-ground plant parts. In our research the yield mass was determined by mowing and weighing for every experimental plot and every variant. Based on these measurements, biomass yields were calculated for direct and indirect recultivation by variants and repetitions, per area unit, as shown in Tables 1 and 2.

Table 1 Biomass yields (direct recultivation)

Variant: „A“ - Sainfoin				
Repetitions	A_1	A_2	A_3	A_4
Amount (t/ha)	4,64	7,12	6,40	3,16
Variant: „B“ – Gramineae and legumes mix				
Repetitions	B_1	B_2	B_3	B_4
Amount (t/ha)	4,08	7,64	7,20	4,60
Variant: „C“ – Alfalfa				
Repetitions	C_1	C_2	C_3	C_4
Amount (t/ha)	5,52	10,20	5,08	12,64
Variant: „D“ – Sorghum and Sudan grass hybrid				
Repetitions	D_1	D_2	D_3	D_4
Amount (t/ha)	12,20	17,52	14,20	14,08

Table 2 Biomass yields (indirect recultivation)

Variant: „A“ - Sainfoin				
Repetitions	A_1	A_2	A_3	A_4
Amount (t/ha)	10,72	5,60	8,40	14,08
Variant: „B“ – Gramineae and legumes mix				
Repetitions	B_1	B_2	B_3	B_4
Amount (t/ha)	11,00	4,64	9,64	14,24
Variant: „C“ – Alfalfa				
Repetitions	C_1	C_2	C_3	C_4
Amount (t/ha)	4,40	5,00	8,20	10,40
Variant: „D“ – Sorghum and Sudan grass hybrid				
Repetitions	D_1	D_2	D_3	D_4
Amount (t/ha)	12,80	14,00	15,80	17,40

The results of the research show that recultivation of marly deposols with grass and clover is possible. Chart 1 provides a clearer picture of the biomass yields, or phytomass of the above-ground plant parts (sainfoin, mix, alfalfa, sorghum and Sudan grass hybrid).

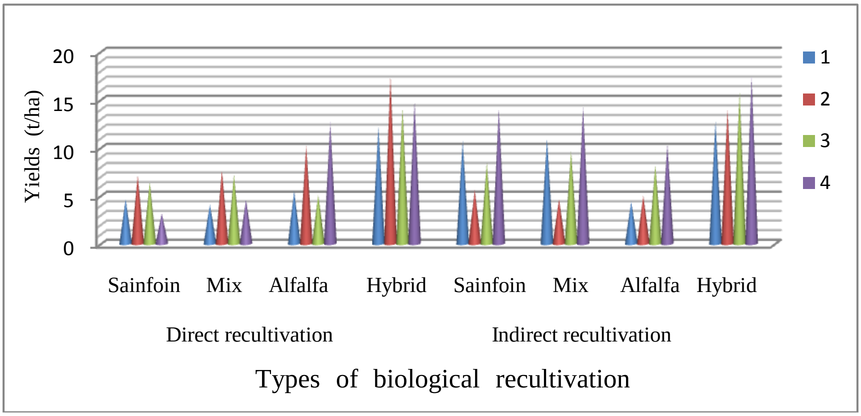

Chart 1 Biomass yields by type of recultivation, treatments and repetitions at the Great Western Depot deposol

A statistical analysis was performed based on the determined biomass yields for specific treatments in the experiment, and the differences were determined through the use of statistical parameters (mean values, variation measurements or the dispersion of quantitative features). This was done through a t-test which is used often in biometric analyses) and p-values to confirm of reject the null hypothesis (the smaller the p-value is, evidence against the null-hypothesis is stronger and vice versa), as shown in Tab. 3, 4, 5.

Table 3 Testing differences in the experiment – direct recultivation («NP»)

No.	Compared species	Variant	d	Sd	t	p (%)
1.	Sainfoin - Mix	A - B	-0,50	1,259	0,40	70,6
2.	Sainfoin - Alfalfa	A - C	-2,98	2,040	1,46	18,4
3.	Sainfoin - Sweet sioux	A - D	-9,12	1,420	6,42	0,1
4.	Mix - Alfalfa	B - C	-2,48	2,050	1,21	27,6
5.	Mix - Sweet sioux	B -D	-8,62	1,430	6,03	0,1
6.	Alfalfa - Sweet sioux	C - D	-6,14	2,150	2,86	2,7

Table 4 Testing differences in the experiment – indirect recultivation („P“)

No.	Compared species	Variant	d	Sd	t	p (%)
1.	Sainfoin - Mix	A - B	-0,18	2,68	0,07	92,0
2.	Sainfoin - Alfalfa	A - C	-2,70	2,28	1,18	27,6
3.	Sainfoin - Sweet sioux	A - D	-5,30	2,06	2,57	3,5
4.	Mix - Alfalfa	B - C	2,88	2,44	1,18	27,6
5.	Mix - Sweet sioux	B - D	-5,12	2,23	2,30	4,6
6.	Alfalfa - Sweet sioux	C - D	-8,00	1,73	4,62	0,57

Table 5 Testing differences in the experiment- direct/indirect recultivation relation

No.	Compared species	Variant	d	Sd	t	p (%)
1.	Sainfoin - Sainfoin	„NP“ - „P“	-4,33	1,99	2,17	5,3
2.	Mix - Mix	„NP“ - „P“	-4,00	2,18	1,83	21,1
3.	Alfalfa - Alfalfa	„NP“ - „P“	1,36	2,32	0,59	70,6
4.	Sweet sioux - Sweet sioux	„NP“ - „P“	-0,50	1,50	0,33	77,3

The following conclusions can be drawn from the analysis of the data in Tables 3, 4 and 5:

a) biomass yields in most variants are better in experimental plots with indirect recultivation (calculated indicators have negative values: -4,33 i -4,0) except on the alfalfa experimental plots where the biomass yield is higher in direct recultivation (-0,5),

b) the slight difference in alfalfa yields, favouring the field with the direct recultivation, is unexpected, considering the less favourable chemical and physical properties of the substrate with respect to indirect recultivation (with a hummus overlay), so alfalfa proved to have the highest possibility of success in recultivating marly deposols,

c) of all the variants included in the experiment, the variant „D“ a hybrid of sorghum and Sudan grass (sweet sioux) is the best variant with regard to total biomass production, both in direct and indirect recultivation,

d) sainfoin had the lowest biomass yield in direct recultivation.

CONCLUSION

The results of the one-year research experiment on grass, clover and grass-clover mix biomass yields (although not entirely reliable) may serve as a relevant indicator of marly deposol recultibility of the Veliko zapadno odlagalište, and show that recultivation with these biological cultures is possible.

Biomass yields in most variants are higher on experimental plots with direct recultivation, except the plot sown with alfalfa. Among clover-grass mixes, alfalfa was proven to have the highest possibility of success in the recultivation of marly deposols. Nevertheless, in terms of total biomass production, the sorghum and Sudan grass hybrid is the best variant, both in direct and indirect recultivation.

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THE EFFECT OF IRRIGATION AND FERTILIZATION TECHNIQUES ON SPECIFIC WATER CONSUMPTION OF GREEN PEPPER

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ABSTRACT

The effect of different irrigation and fertilization techniques on specific water consumption of green pepper (*Capsicum annum* L. var. Bela dolga), were investigated in experimental plastic house in Northern part of the Republic of Macedonia. The field trials were conducted near the Faculty of Agricultural Sciences and Food in Skopje, during the period of May to October in 2005, 2006 and 2007. The aim of this investigation was to determine specific water consumption in two-stem pruned (“V” system) green pepper under different irrigation and fertilization techniques and regimes. Also, the evapotranspiration (ETP) and green pepper yield were determined during this investigation. Four experimental treatments were applied in this investigation. Three treatments were irrigated by drip irrigation and drip fertigation (KK1, KK2, KK3), while the last one was irrigated by furrow irrigation with conventional application of fertilizer (control treatment $Ø_B$). From the average results for specific water consumption obtained in the investigation, it can be concluded that there are not statistically significant differences between the treatments KK1 and KK2 (drip fertigation every 2 and 4 days), what is result of closer irrigation interval of these two treatments. As a result of longer frequencies between the irrigations, the treatment KK3 (drip fertigation scheduled by tensiometers) showed 15,2-18,7% higher specific water consumption in comparison with KK2 and KK1. The results showed statistically significant differences. The effect of the irrigation and fertilization techniques on specific water consumption is presented by the comparison of the results from the treatment KK3 and $Ø_B$. Namely, the control treatment showed

107,44 liter of used water per kilogram tomato yield or 31,7% higher value in comparison with KK3. The results are statistically significant at 0,01 level of probability.

Keywords: specific water consumption, potential evapotranspiration, drip fertigation, furrow irrigation, green pepper

INTRODUCTION

Specific water consumption is defined as a water quantity consumed for producing of unit yield by crop. This parameter can be estimated as a ratio between the evapotranspiration (ET) and obtained yield (fruit) during the vegetation. Generally, specific water consumption has great importance in agricultural practice. Namely, this parameter practically show the economical use of water in irrigation practice, or irrigation technique with highest yield and the lowest water use (Cukaliev, 1996; Tanaskovik, 2005). Untill today, specific water consumption was estimated in several crops in our country, as: sugar beet (Cukaliev, 1996; Jankuloski, 2000), alfalfa (Iljovski *et al.,* 2001), tomato (Petrevska, 1999; Iljovski *et al.,* 2001; Tanaskovik, 2005) etc. Also, some authors practice water use efficiency (WUE) as a parameter for determination of efficiency of applied irrigation and fertilization techniques (Phene *et al.,* 1989; Papadopoulos 1996; Halitligil *et al.,* 2002; Sagheb *et al.,* 2002; Iljovski *et al.,* 2003; Tanaskovik 2005) on water consumption by crop, but the main differences between WUE and specific water consumption is in the parameters used for estimation. Namely, WUE is defined as a ratio between the total fresh or dry biomass (fruit, leaves, stem) and water used by the crop (ET) (Phene *et al.,* 1993; Prihar *et al.,* 2000).

Geographic location and climatic conditions in the Republic of Macedonia enable quality agricultural production, but the limiting factor for high and more profitable yield is water deficiency and inefficient water use. The dry periods with a different duration and intensity are common appearance, even in years with floods. For example, in average of 20 years, 10 years are with more expressed dry period, 9 years are average, and 1 year is with appearance of floods. With global warming, risk for intensification of dry period is increasing, while water demand for any purpose became even more important (Tanaskovik *et al.,* 2011)

Irrigation always had great importance for climatic conditions of the Republic of Macedonia. Some crops regard as identical with irrigation period (vegetable crops, rise), but another group of crops (cereals, orchard, vineyard) can survive more or less without irrigation depending on climatic conditions, but yields decreased proportionally with deficit of water or draught intensity. Especially negative effects appeared at perennial plants (Iljovski *et al.,* 2003).

Combination of micro irrigation techniques with application of fertilizer through the system is a common practice in modern agriculture. Farmers in the Republic of Macedonia have wide use of micro irrigation techniques to increase crop yield in the recent years. Still there are problems especially related to irrigation scheduling, water use efficiency, as well as with proper use of fertiliser when drip fertigation practice is used (Tanaskovik *et al.,* 2011)

Therefore, the main objective of this study was to determine specific water consumption in green pepper crop production under different techniques and regimes of irrigation and fertilization, as well as to evaluate evapotranspiration and yield affected by methods of application of water and fertilizers.

MATERIAL AND METHODS

The field experiment was conducted with two-stem pruned (“V” system) green pepper (*Capsicum annum* L. var. Bela dolga) grown in experimental plastic house near by the Faculty of Agricultural Sciences and Food in Skopje (42° 00'N, 21° 27'E), during the period May to October in 2005, 2006 and 2007. The soil type is colluvial (delluvial) soil (FAO Classification) disturbed with urban activities. The soil chemical characteristics of the experimental field are presented in Table 1.

Table 1. Soil chemical characteristics of the experimental field

Layer cm	$CaCO_3$ %	Organic matter %	pH		ECe dS/m	Available N	Available forms mg/100 g soil	
			H_2O	KCl		mg/100 g soil	P_2O_5	K_2O
0-20	3,24	0,90	8,02	7,30	2,40	3,10	17,79	32,15
20-40	3,80	0,84	8,08	7,26	2,28	2,47	13,36	19,38
40-60	3,59	0,56	8,03	7,35	2,25	2,80	8,40	16,10

According to the recommendations and literature data for the region (Maksimović, 2002; Lazić *et al.*, 2001; Jankulovski, 1997), green pepper planted in our condition and yields up to 60 t ha^{-1}, needs the following amount of nutrients: N 485 kg ha^{-1}, P_2O_5 243 kg ha^{-1} and K_2O 585 kg ha^{-1}. The application of fertilizer in the treatments was done in two portions (before planting and during the growing season). For all treatments, the first portions of the fertilizers was done before planting of green pepper, while the rest of the fertilizers needed for achieving the targeted yield was applied through the fertigation system in drip fertigation treatments (Tab. 2) and conventional fertilization on soil for control treatments (spread in two portions, flowering stage and fruit formation). All investigated treatments have received the same amount of fertilizers, but with the different methods and frequencies of application of water and fertilizers. The idea was to investigate the effect of irrigation and fertilization method on specific water consumption in green pepper production.

Table 2. Type and amount of fertilizers in drip fertigation

N 485	P_2O_5 243	K_2O 585	kg/ha	N:P:K	
48	48	48	8 kg/ha	15:15:15	before replanting
/	195	128	5 kg/ha	0:52:34	drip fertigation
/	/	411	2 kg/ha	0:0:51+18S	drip fertigation
437	/	/	2 kg/ha	46:0:0	drip fertigation
485	243	585			

Remark: same amounts and quantity of fertilizers were used in the furrow irrigation treatment spread in 2 portions

The irrigation of the experiment (treatment KK1, KK2 and $Ø_B$) was scheduled according to long-term average daily evapotranspiration for green pepper crop for Skopje region (Tab. 3). Long term average evapotranspiration was calculated by FAO software CROPWAT for Windows 4.3 using crop coefficient (kc) and stage length adjusted for local condition by Faculty of Agricultural Sciences and Food. The daily evapotranspiration rate of drip irrigation treatments (KK1 and KK2) was decreased for 20% (coefficient of the coverage-application of water only on part of the total surface). In each experimental year, the irrigation and fertigation occurred from 20-25 May to 10-15 October.

Table 3. Daily and monthly crop water requirements for green pepper crop for the Skopje region

Months	V	VI	VII	VIII	IX	X
mm/day	1.9	3.6	5.5	5.0	3.7	1.8
mm/monthly	59	108	171	155	111	54

The irrigation scheme was designed as randomized block for experimental purposes with four treatments in three replications. The experimental treatments were set up according to the daily evapotranspiration rate. The idea was to investigate not only effect of irrigation and fertilization techniques, but also irrigation and fertilization frequency and their effect on specific water consumption.

Treatment 1 (KK1): Drip fertigation according to daily evapotranspiration with application of water and fertilizer every two days;

Treatment 2 (KK2): Drip fertigation according to daily evapotranspiration with application of water and fertilizer every four days;

Treatment 3 (KK3): Drip fertigation according to tensiometers measurements;

Treatment 4 ($Ø_B$): Furrow irrigation according to daily evapotranspiration with application of water every seven days and classic fertilization (spreading of fertilizer on soil).

The size of each plot (replication) was 6.6 m^2 (25 plants in 0.75 m of row spacing and 0.35 m plant spacing in the row). Each plot (replication) was designed with five rows of crop and five plants in each row.

The crop evapotranspiration was determined by direct measurement with soil water balance method at soil layer 0-100 cm depth (Tanaskovic *et al.*, 2006; Dragović, 2000; Bošnjak, 1999; Allen *et al.*, 1998; Cukaliev, 1996). The method consists of assessing the incoming and outgoing water flux at 100 cm soil depth during the vegetation. In our investigation, the main parameters for estimation of ETP were irrigation water (I) and initial or active soil moisture at the beginning of vegetation (Wi) as incoming water flux and active soil moisture on the end of vegetation (We) as potential outgoing water flux. The investigation was realized in experimental plastic house, where precipitations (P) were ignored. Also, as a result of controlled irrigation practice, the surface runoff (RO) and deep percolation (DP) were excluded from this estimation. The subsurface water and water transported upward by capillary rise (CR) didn't have influence on water income in the root zone, and they were ignored. Therefore, crop evapotranspiration (ETP) was determinate under equation ETP=(I+Wi)-We. The specific water consumption was estimated as ratio between ETP and obtained yield (fruit) during the vegetation. Collected data were subjected to statistical analysis of variance and means were compared using the least significant difference (LSD) at the 1 and 5% level of probability ($P<0.01$ and $P<0.05$) test.

RESULTS AND DISCUSSIONS

The meteorological conditions during the research

The pepper has exceptional requirements according to the climatic conditions. If climatic conditions are unfavorable or if they vary, the productivity and yield of the pepper crop can be significantly decreased.

The optimal temperature for growing of pepper in controlled environment is 20-25°C during the day time and 18-20°C during the night (Đurovka *et al.*, 2006). Bosland and Votava (2000) reported that the best pepper yields can be obtained when the air temperature during the day time is between 18-32°C, especially in the stage of fruit formation.

The average seasonal temperature in the experimental plastic house (average in the growing period) during 2005, 2006 and 2007 was 22.83°C, 22.95°C and 24.1°C respectively (Tab. 4). During the period of the biggest fructification (June-August) the average temperature in all three years was in the frame of the optimum values recommended by Bosland and Votava (2000).

Table 4. Monthly average air temperature (°C) in Skopje (National Hydro-meteorological Service) and in the experimental plastic house (our measurements), during the green pepper vegetation

Year/Months	Average temperature (°C) in Skopje region			Average temperature (°C) in the experimental plastic house		
	2005	2006	2007	2005	2006	2007
V	18,0	17,8	18,6	20,9	20,5	21,6
VI	20,9	20,6	23,9	24,1	23,6	27,1
VII	24,1	23,4	27,1	28,2	27,2	31,0
VIII	22,1	23,3	25,1	26,1	26,9	28,9
IX	19,1	19,5	17,7	22,2	22,7	20,6
X	12,7	14,0	12,7	15,5	16,8	15,4
Average	19,48	19,77	20,85	22,83	22,95	24,10

Generally, pepper has great water requirements during the vegetation period, what is a result of the poorly developed root system and huge biomass exposure to strong transpiration (Lazić *et* *al.*, 2001; Jankulovski, 1997; Iljovski and Cukaliev, 1994). It is well known that pepper is most sensitive to water shortage (drought) during the flowering and fruit formation. The Skopje that period is characterized with highest temperatures and insulation, so the evapotranspiration was in its highest rate. Usually rainfalls is minimal in that period. Data presented in Table 5 shows that all three years of investigation were characterized as very wet with a lot of rainfall in the growing season.

As was mentioned above, our investigation was conducted in a controlled environment (plastic house), where water income does not have any influence on the crop evapotranspiration, which means that the total water income was presented by irrigation water requirements (almost 75%) and initial or active soil moisture at the beginning of vegetation (almost 25%).

For normal growing of pepper and for high and quality yields, the optimal relative humidity should range from 60 to 70%. Gvozdenović (2004) reported that lower relative air humidity followed by high temperature can affect flower and fruit falling.

Jankulovski (1997) reported that relative air humidity in plastic houses should be around the 70%. With the exception of October, the average relative humidity during all three years of our investigation was close to recommended values for the plastic houses. Data for relative air humidity during the investigation are shown in Table 6.

Table 5. Monthly precipitation (mm) in Skopje region

Year	2005	2006	2007
Months	Precipitation (mm)	Precipitation (mm)	Precipitation (mm)
V	72,4	19,2	96,2
VI	38,4	94,7	34,8
VII	36,9	39,0	1,2
VIII	73,3	29,2	52,7
IX	34,2	43,3	27,2
X	50,1	56,9	140,0
Average	305,3	282,3	352,1

The crop evapotranspiration (ETP) was determined by direct measurement with soil water balance method at soil layer 0-100 cm depth, under permanent content of soil moisture and nutrients, as well as permanent agro-technical measures. The water balance method in our investigation was realized by assessment of the soil water income during the vegetation and active soil moisture at the end of vegetation.

Table 6. Monthly average relative humidity (%) in Skopje region (National Hydro-meteorological Service) and in the experimental plastic house (our measurements), during the green pepper vegetation

Year/ Months	Average relative humidity (%) in Skopje region			Average relative humidity (%) in the experimental plastic house		
	2005	2006	2007	2005	2006	2007
V	63	59	65	72	74	73
VI	56	64	56	63	71	61
VII	55	59	38	60	63	53
VIII	65	57	51	71	60	60
IX	68	60	58	74	66	68
X	71	70	75	81	80	83
Average	63	61,5	57,2	70,2	69	66,3

Effect of irrigation and fertilization techniques on ETP, pepper yield and specific water consumption

The soil water income was estimated through the irrigation water requirements and initial or active soil moisture at the beginning of vegetation. Irrigation water requirement (I) for the treatments KK1, KK2 and $Ø_B$ is presented as water quantity applied during the vegetation (read on the volumetric meter); with periodic soil samplings for controlling of momentary soil moisture and realized irrigation regime. The irrigation water requirement (I) for the treatment KK3 was obtained by tensiometers readings installed in the soil. The initial or active soil moisture at the beginning of vegetation is presented as a difference between field capacity (FC) and permanent wilting point (PWP). Cukaliev (1996) has calculated initial or active soil moisture at the beginning as a difference between momentary soil moisture and permanent wilting point, but in our investigation we refilled the soil moisture up to field capacity before starting with the irrigation regime. The active soil moisture at the end of vegetation is calculated as a difference between momentary soil moisture at the end of vegetation and permanent wilting point. The difference between soil water income (irrigation water requirements and active soil moisture at the beginning) and active soil moisture at the end of vegetation is the potential evapotranspiration (ETP). The average results for water balance and ETP for period 2005-2007 are presented in Tab. 7.

From the results shown in Table 7, it can be concluded that the content of active soil moisture at the end of vegetation in the treatments KK1 and KK2 is from 47,7 to 61,5% higher in comparison with KK3.

Table 7. Water balance and ETP (m^3 ha^{-1}) for the period 2005-2007

Treatment	Wi	I	Total income	We	ETP	Comparison with KK1 (%)	Comparison with KK2 (%)
KK1	1824	4650	6474	1586	4888	100,0	100,9
KK2	1824	4753	6577	1735	4841	/	100
KK3	1824	4392	6182	1074	5108	104,5	105,5
$Ø_B$	1824	5555	7375	1494	5881	120,3	121,5

The main reason for higher content of active soil moisture at the end of vegetation in the treatments KK1 and KK2 is irrigation regime scheduled according to the average daily evapotranspiration with continuous keeping of soil moisture in the frame of field capacity (short irrigation frequencies 2 or 4 days). In order to decrease the participation of irrigation water requirement (I) in total water income in the treatments KK1 and KK2, the final irrigation application rates (2-3 rates at the end of vegetation) couldn't be applied, without negative effects on the yields. Tanaskovik *et al.*, (2006) reported similar results in drip fertigation treatments at two and four days in tomato crop production in Skopje region. The treatment with tensiometers (KK3) and drip irrigation frequency at every 8 or 10 days, showed the lowest active soil moisture at the end of vegetation, while the control treatment showed the highest.

The results for ETP presented in Table 8, showed negligible differences between the treatments KK1 and KK2 (drip fertigation every 2 and 4 days), that is connected with closer irrigation interval of these two treatments. Statistically, there is no significant difference in ETP. On the other hand, as a result of longer application intervals, the treatment KK3 (drip fertigation scheduled by tensiometers) showed 4,5-5,5% higher ETP in comparison with KK2 and KK1. The results are statistically significant at 0,01 level of probability. The effect of drip fertigation on ETP is presented by the achieved results in treatments KK3 in comparison with $Ø_B$ (control treatment). Namely, in almost the same irrigation intervals, the treatment KK3 obtained about 15% lower ETP compared with $Ø_B$. The results are statistically significant at 0,01 level of probability.

The results for ETP in our investigation are lower than those recommended by Iljovski and Cukaliev (1994), from 7000 to 8000 m^3 ha^{-1} and Doorenbos *et al.*, (1986), from 600 to 900 mm, that is connected with proper and controlled irrigation and fertilization regime during all three years of investigation.

From the results of the average green pepper crop yields presented in Table 8, it is clear that the drip fertigation frequency at 2 and 4 days create better environment for increasing of yields in comparison with low drip fertigation treatment (KK3) controlled by tensiometers.

Table 8. Average results for ETP, green pepper yield and specific water consumption for Skopje region, during the period 2005-2007

Treatment	ETP m^3/ha	Yield (t/ha)	Specific water consumption (l/kg)	Comparison with KK1 (%)	Comparison with KK2 (%)
KK1	4888	71,11	68,74	100	/
KK2	4842	68,40	70,79	102,9	100,0
KK3	5108	62,61	81,58	118,7	115,2
$Ø_B$	5881	54,74	107,44	156,3	151,8
LSD: 0,05	56,45	3,77	6,21		
LSD: 0,01	76,16	5,09	8,38		

So, our results show that if farmers go with time difference between two applications of drip fertigation higher than four days, they will significantly decrease the yield and increase ETP, as result of increased water stress in pepper crop. Various researches reported better yields in pepper and other crops by using of high-frequency surface drip fertigation in comparison with low frequency drip fertigation (Tanaskovik *et al.*, 2011; Iljovski *et al.*, 2003; Tekinel and Kanber, 2002; Oğuzer *et al.*, 1991; Topçu 1988). Metin Sezen *et al.*, (2006) in their investigations with different irrigation regime in pepper crop, reported the highest yield in the treatment with drip irrigation frequency of 3 to 6 days with average ET from 519,5 mm, while in the drip irrigation treatment with irrigation frequency from 6 to 11 days and 9-15 days yield and water use efficiency decrease.

The effect of irrigation and fertigation technique on green pepper yield can be compared through the results obtained in treatments KK3 and $Ø_B$ (control treatment). Namely, drip fertigation treatment scheduled by tensiometers (KK3) showed 14,4% higher yield than treatment with furrow irrigation and spreading of fertilizers. The results are statistically significant at 0,01 level of probability. The effect of the drip fertigation on better yield of green pepper crop can be explained by the fact that with drip fertigation the root zone is simultaneously supplied with water and readily available nutrients. Haynes (1985) reported that if nutrients are applied outside the wetted soil volume they are generally not available for crop use. A number of other investigators emphasize results with higher yields, efficient use of water and fertilizers and lower ETP in different crops when fertilizers were injected through the drip system in comparison with conventional application of fertilizers (Tanaskovik *et al.*, 2011; Cukaliev *et al.*, 2008; Tanaskovik *et al.*, 2006; Halitligil *et al.*, 2002; Al-Wabel *et al.*, 2002; Castellanos *et al.*, 1999; Petrevska 1999; Papadopoulos, 1996).

According to the average results for specific water consumption of green pepper crop presented in Table 8, once again it is clear that treatments with drip fertigation at 2 and 4 days frequency have better results in comparison with treatment with drip fertigation scheduled by tensiometers. Namely, the treatment KK1 show the most economical water use, or 68,74 litre of water per kilogram produced green pepper fruits. The treatment KK2 shows almost 3% higher consumption than treatment KK1 or 70,79 l kg^{-1}, and results are not statistically significant. For producing of one kilogram green pepper fruits the treatment KK3 has almost 16 and 19% higher water consumption in comparison with KK2 and KK1. The results are statistically significant at 0,01 level of probability.

Even that the treatment KK3 had very similar irrigation interval with control treatment ($Ø_B$), sometimes longer for 2 to 3 days than $Ø_B$, as a result of simultaneously application of water and fertilizer KK3 show 31,9% lesser water consumption in comparison with $Ø_B$. The results are statistically significant at 0,01 level of probability. Cukaliev et al., (2003) reported 54,56 litre water consumption per kilogram green pepper in drip fertigation treatment in comparison with 66,16 in treatment with drip irrigation and classical fertilization. Similar results as ours with tomato crop are presented by various authors. So, Petrevska (1999) in three years of investigation with tomato crop noted that the lowest and the most economical specific water consumption showed the treatments with drip fertigation, while the treatment with furrow irrigation and classical fertilization showed the highest value. Also, Tanaskovik

(2005) presented high positive effect of drip fertigation on specific water consumption, while the most economical treatments are those with 2 and 4 days drip fertigation.

CONCLUSIONS

The least average potential evapotranspiration (ETP) is achieved in the treatments with drip fertigation at 2 (4888 m^3 ha^{-1}) and 4 days (4842 m^3 ha^{-1}). Statistically, there is no significant difference. On the other hand, as a result of longer application intervals, the treatment KK3 (5108 m^3 ha^{-1}) showed 4,5-5,5% higher ETP in comparison with KK2 and KK1. The results are statistically significant at 0,01 level of probability. The effect of drip fertigation on ETP is presented by the achieved results in treatments KK3 in comparison with $Ø_B$ (control treatment). Namely, in almost the same irrigation intervals, the treatment KK3 obtained about 15% lower ETP compared with $Ø_B$. The results are statistically significant at 0,01 level of probability.

The highest average yields are achieved in treatments KK1 and KK2 with 71,11 t $ha^{-1}$and 68,40 t ha^{-1}, while in treatment KK3 the average yield was almost 6-9 t ha^{-1}lower (62,61 t ha^{-1}). The results are statistically significant at 0,01 level of probability. The least average yield is achieved in treatment $Ø_B$ (54,74 t ha^{-1}). The treatments with drip fertigation showed statistically significantly higher yield compared with furrow irrigation and spreading of fertilizer.

The treatment KK1 show the most economical water use, or 68,74 litre of water per kilogram produced green pepper fruits, while the treatment KK2 shows almost 3% higher consumption or 70,79 l/kg. The results are not statistically significant. The treatment KK3 has almost 16 and 19% higher water consumption in comparison with KK2 and KK1. The results are statistically significant at 0,01 level of probability. The control treatment ($Ø_B$) shows almost 32 % higher specific water consumption in comparison with KK3. The results are statistically significant at 0,01 level of probability.

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A POSSIBILITY FOR ORGANIC BUCKWHEAT PRODUCTION UNDER IRRIGATION

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ABSTRACT

Buckwheat (*Fagopyrum esculentum* Moench) is an alternative crop in our country. Due to the low yields in comparison with those of the major cereal crops, buckwheat is grown on a relatively small area. Buckwheat growing is profitable due to low inputs in its production. Therefore, and because of high nutritional value and favorable chemical composition of grain, buckwheat is increasingly used in human nutrition. Organic buckwheat production begins to attract attention, especially because literature data claim that yields of organic buckwheat are significantly higher compared with those obtained in conventional production. Besides the choice of cultivar and proper cultural practices, buckwheat production is considerably affected by soil and climatic conditions. In dry conditions, lack of water affects the nutrient supply of plants. Transport of nutrients to actively growing branches and flower buds is reduced, which in turn lowers grain yield and quality. A local buckwheat cultivar was grown at the experiment field of the Institute's Department for Alternative Crops in Backi Petrovac, on a soil with favorable water-physical and chemical properties. Irrigation was performed when needed. The production itself and irrigation water quality were controlled by accredited laboratories. In 2012, which was dry and extremely warm, buckwheat plots were irrigated two times with the irrigation rate of 60 mm. The yield of irrigated buckwheat was 1235 kg ha^{-1}, i.e., 7.35% higher than without irrigation, which was not statistically significant.

Keywords: buckwheat, organic production, chernozem, irrigation

INTRODUCTION

Buckwheat (*Fagopyrum esculentum* Moench) is considered an alternative crop in our country - due to its relatively low grain yield, it is grown on a relatively small acreage when compared with the major cereal crops such as wheat and corn (Berenji *et al*., 2008). However, its production can be economically profitable because it requires low inputs (Joshi and Rana, 1995). This makes it interesting for organic production where low-input cultivars are recommended (Kovačević *et al*., 1997).

In addition to the choice of cultivar and proper crop management, buckwheat growing is significantly affected by environmental conditions (Gorski, 1986; Popović *et al*., 2013). Although the buckwheat production technology has been described in detail (Glamočlija *et al*., 2011), literature data on the impact of irrigation practice on the main agronomic characteristics of buckwheat are relatively scarce. Kreft (1983) claimed that insufficient plant supply with water and assimilates and their low transport into actively growing branches and flower buds are reasons for low buckwheat yields under drought conditions. Identical results were reported by Ruszkowski (1990) and Adhikari (1997). According to Ghouzhdi *et al*. (2009), irrigation with low doses of water causes a reduction in dry matter production and an increase in rutin content in the vegetative parts of plants. These results are in contrast to an earlier report of Lakhanov (1995) who claimed that water stress causes a successive reduction of photosynthetic activity, which in its turn results in the reduction of rutin content.

Due to its high nutritional value and chemical composition of grain, buckwheat is increasingly used in human nutrition. In this situation, its growing in organic production systems keeps arising interest (Oljača and Bavec, 2011). Varietal experiments performed in North Dakota have indicated that buckwheat may be successfully cultivated in organic production systems (www.ag.ndsu.edu/carrington/buckwheat). In these experiments, agronomic characteristics of four commercial buckwheat cultivars grown in two production systems were compared. The results showed that the yields obtained in organic farming were significantly higher than those obtained in conventional production.

The objective of this study was to determine possibilities for growing the buckwheat cultivar Novosadska as an alternative crop in the organic production system using reduced irrigation for disease prevention and yield increase.

MATERIAL AND METHOD

The experimental part of this study was conducted in the course of 2012 at Bački Petrovac experiment field of Organic Production and Biodiversity Department of Institute of Field and Vegetable Crops in Novi Sad. The geographic position of the field is N 45^{o} 20', E 19^{o} 40', 82 m above sea level.

Primary tillage was performed on 12 November 2011, seedbed preparation on 24 March and 30 April 2012, and planting on 5 May 2012. A planter for small-plot experiments was used, applying the seeding norm of 60 kg ha^{-1} and the plant arrangement 50x4 cm. Crop tending consisted of between-row cultivation and weeding. Harvest was performed by hand, at the stage of technological maturity. Grain yield was measured in each experimental plot separately and adjusted to 13% moisture. The analysis of the experimental data was performed by the statistical package STATISTICA 10 for Windows. Data significance was estimated by the LSD test for significance level 5% and 1%.

The soil in the experimental plot had a low alkaline reaction (pH in 1M KCl = 7.48). It was high in humus (2.42%), medium provided with nitrogen (0.184%), high in available phosphorus (33.7 mg 100 g^{-1} soil) and well provided with potassium (20.5 mg·100 g^{-1} soil). Soil quality in the experimental plot was monitored by standard methods, in accredited Laboratory for Soil and Agroecology of Institute of Field and Vegetable Crops in Novi Sad. Irrigation water quality was monitored by the same laboratory, according to standard methods. Soil moisture was monitored by the gravimetric method, twice a month, to a depth of 60 cm. Sprinkler irrigation was performed with a Typhoon sprinkler, at the critical soil moisture of 60% of the field capacity (FWC). Data for precipitation, air temperature, maximum air temperature and relative air humidity were obtained from Bački Petrovac meteorological station, which is located next to the experiment field.

RESULTS AND DISCUSSION

In addition to the choice of cultivar and proper crop management, buckwheat production was significantly affected by the local soil and climatic conditions. The soil parameters were systematically monitored at the experiment field, in the plowing layer to the depth of 30 cm. The climatic parameters were monitored by the meteorological station located in the vicinity of the experiment field.

Soil conditions

According to the pilot study (Antonović *et al.*,1996), the soil at Backi Petrovac experiment field is a chernozem on loess and loess-like sediments, calcareous, gleyed, medium deep. Its basic chemical characteristics are shown in Table 1.

Table 1. Chemical properties of the soil at the experiment site

Year	Depth (cm)	pH		$CaCO_3$	N	P_2O_5	K_2O	Organic matter
		1MKCl	H_2O	(%)	(%)	(mg/100g)	(mg/100g)	(%)
1996	0-30	7.19	8.11	2.55	0.18	58.10	35.20	2.73
2012	0-30	7.48	8.21	9.05	0.18	33.70	20.50	2.42

It was observed that the land cultivation during long period, first in conventional production and then in organic production since 2007, did not deteriorate soil quality. The objective of organic production, i.e., maintaining soil fertility levels at optimum level, was successfully met (Vasin *et al.*, 2013).

Quality of irrigation water

Surface water from the MCN HsDTD canal Novi Sad - Savino Selo was used for irrigation. According to previous analyses, presented in The basis for protection, use and management of agricultural land in Backi Petrovac municipality (1996), quality of this water was in the category C_2S_1 (U.S. Salinity Laboratory, 1954). According to the total salt concentration, i.e., the values of electric conductivity (ECw = 0.5 dS m) the water belonged to the second class, which met the quality requirements for irrigation water. Ca cations were dominant compared with Na cations. Regarding anions, highest contents were registered for bicarbonate and chloride. According to the SAR value (0.8), an indicator of alkalization risk, the water belonged to the first class. When compared with literature data, the concentrations of trace elements and toxic ions were below the maximum allowed concentration (Dragović and Kojčić, 1993). By the time of conversion to organic production, factories that had been polluting the canal with their waste waters have either ceased to operate or have installed the filters for primary water treatment. For these reasons, in the period from 2007 to 2012 (six years of organic production), quality of irrigation water was significantly improved (Tab. 2). Hazardous and harmful substances stipulated in Official Gazette of Republic of Serbia (No. 23/1994) were not detected, except for As whose concentration was much below the MAC.

The use of irrigation water of appropriate quality and reduced irrigation, only in critical periods for plant development, successfully maintained the quality of soil and crops grown in organic production.

Weather conditions. Shashkin (1989) reported that buckwheat yield is affected 38% by weather and 11% by agricultural practices, Accordingly, we paid special attention in this study to monitoring and analyzing the weather conditions. Also, since buckwheat cultivars may react differently to cultural practices under steady environmental conditions, the zoning of cultivars obviously plays an important role (Nikolić *et al.*, 2010).

The meteorological data gathered by Bački Petrovac meteorological station indicated that the drought in the 2012 growing season was severe and that it had a very unfavorable impact on the growth and development of the cultivated crops (Tab. 3).

During the summer months of 2012 (June, July and August), in the critical period for crop growth, high temperatures, low rainfall, low relative air humidity and frequent hot winds brought about a drought of variable intensity. The rainfall in these months was insufficient to meet the water requirements of plants. The total rainfall was significantly below the long-term average, amounting to 62.3 l m^{-2}, 44.3 l m^{-2}, 3.5 l m^{-2} and 13.0 l m^{-2} in June, July, August and September, respectively (Tab. 3). These amounts were far from sufficient to meet the water requirements of plants which are 100-120 l m^{-2} per month during summer period.

Table 2. Quality of irrigation water from MCN HsDTD* Novi Sad - Savino Selo canal

Type of analysis	Analyzed in 1994	2007	2012	Typical level in irrigation water (Ayers & Westcot, 1985)
pH value	8.20	8.01	7.63	6.0-8.5
Electric conductivity (dS/m)	0.5	1.843	0.386	0-3
Dry residue mg/l		239	205	0-2.000
CO_3 meq/l	72.0	0	0.38	0-0.1
HCO_3 meq/l	91.5	3.65	2.70	0-10
Cl meq/l	70.9	1.62	0.60	0-30
SO_4 meq/l	0.0	0.56	1.01	0-20
Ca meq/l	49.9	2.16	2.11	0-5
Mg meq/l	6.0	1.67	1.12	
K meq/l	39.1	0.11	0.06	0-40
Na meq/l	22.3	1.10	0.62	0-15
SAR	0.80	0.80	0.68	
Stebler's irrigation coefficient		93.3	236.1	> 18 – good water
Water class according to Nejgebauer		Ia	Ia	I and II class – excellent and good waters
Water class according to US Salinity Laboratory	C_2S_1	C_3S_1	C_2S_1	C_2 – Medium saline water C_3 – Saline water S_1 – Low Na content

* Main Canal Network of Danube-Tisza-Danube Hydrosystem

Table 3. Air temperatures and precipitation sum at Bački Petrovac meteorological station

Month	Long-term average (1984-2012)		2012	
	Temperature (^{0}C)	Rainfall (mm)	Temperature (^{0}C)	Rainfall (mm)
Winter precipitation	–	258.9	–	164.3
April	12.2	46.2	13.4	67.8
May	17.8	61.4	17.9	30.6
June	20.5	82.6	23.4	62.3
July	22.2	63.4	25.2	44.3
August	22.0	51.8	24.5	3.5
September	16.8	48.0	17.0	13.0
Growing season		360.9		219.2

Air temperatures too were unfavorable for crop production. The mean daily air temperatures were higher by 2.9°C (June) to 3.0°C (July) than the long-term average (Tab. 3). The number of tropical days, i.e., those with the maximum daily temperature above 30ºC, was 17 in June, 20 in July, and 23 in August (Fig. 1). The relative air humidity was extremely low, dropping below 30% in 9 days in June; 13 days in July and as many as 25 days in August.

Numerous studies have indicated an important impact of temperature and rainfall on seed yield and quality of various crops (Nikolić *et al*., 2010, Popović *et al*., 2013).

Yield performance of organic buckwheat. Due to simple cultivation requirements that involve crop growing without the use of chemicals, buckwheat is quite suitable for growing in organic production systems, where it may be grown as the main or a second crop (Marshall and Pomeranz, 1983).

In our study, buckwheat was irrigated only when it was absolutely necessary. Two irrigations were performed (with 30 mm each time), on 26th June and 10th July. In light of a small number of chemicals available and approved for use in organic production, irrigation was avoided in order to prevent disease outbreaks which might occur due to wetting of plants. Later on, irrigations were not performed because buckwheat flowering lasts until the end of growing season (June to September) and it is necessary to allow time for plant maturation. This explains why the effect of irrigation was low.

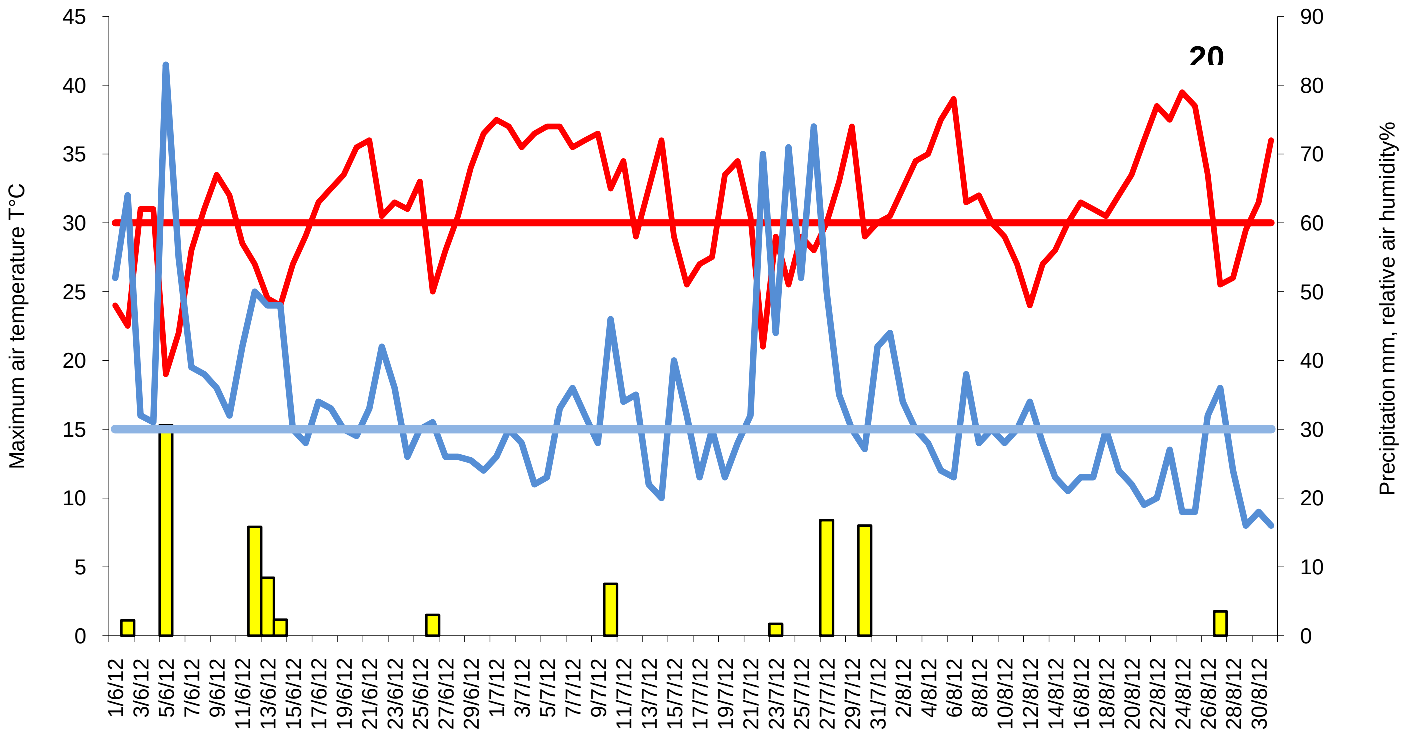

Fig. 1. Maximum air temperatures (°C) (—), relative air humidity (%) (—) and total rainfall (mm) in the course of June, July and August 2012

The yield of irrigated buckwheat was 1,235 kg·ha^{-1}, i.e., 7.35% higher than that of the dryland crop (1150 kg·ha^{-1}). The difference was not significant. The obtained yields indicated that buckwheat was resistant to drought. It confirmed the results of Glamočlija *et al*. (2011), but not those of Malešević *et al*. (2008) who claimed that buckwheat has high water requirements, especially during the stages of flowering and grain filling.

If the principles of organic farming are respected, soil productivity remains undisturbed and satisfactory production results may be achieved even under poor weather conditions. In our case, the soil capacity to supply water and essential minerals to plants via their root system, called "the productive capacity of soil" by Džamić and Stevanović (2000), has been fully preserved by good maintenance over the years.

Plant requirements for environmental conditions are extremely important when selecting cultivar and cultivation technology. It is important to be familiar with the critical stages for grain yield and quality formation, as well as with the time of application of certain cultivation practices (Malešević *et al*., 2008). Four buckwheat cultivars (Novi Sad, Darja, Prekmurska and Francuska) had a significantly higher average grain yield (3,235 kg·ha^{-1}) in 2010 than in 2011 and 2012 (1,770 kg·ha^{-1} and 1,225 kg·ha^{-1}, respectively) (Popović *et al*., 2013). The three years varied in the amount of rainfall during growing season - 635 mm in 2010, 246 mm in 2011, and 222 mm in 2012.

According to FAO data (www.ag.ndsu.edu/carrington/buckwheat), the average yields of buckwheat in the world are less than one ton of grain per hectare. Highest yields are achieved in North and South America (1.06 t·ha^{-1} and 1.24 t·ha^{-1}, respectively), lowest in Europe (0.77 t·ha^{-1}). The results of our experiment, with 1,235 kg·ha^{-1} obtained in an unfavorable year, is a good result. In favorable years in the Vojvodina Province, significantly higher yields are achieved both in conventional and organic production.

CONCLUSION

Following conclusions were drawn on the basis on the results of the experiment with organic production of buckwheat. Organic buckwheat can be successfully grown under the climatic and soil conditions of the Vojvodina Province. The average yield was 1,150 kg·ha^{-1}. In 2012, which was a dry and extremely warm year, reduced irrigation, i.e., two irrigations with 30 mm of water, brought the yield of 1,235 kg·ha^{-1}. This was an increase of 7.35%. This suggests that buckwheat tolerates drought well, without drastic yield reduction, while responding quite well to irrigation. In favorable years, or with high irrigation rates, buckwheat yields are much higher. Soil fertility and productivity can be successfully maintained by adhering to the basic principles of organic production.

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WATER SUPPLY AND BIOMASS PRODUCTION
***Miscanthus × giganteus*Greef et Deu.**

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ABSTRACT

Miscanthus is identified as one of the best options for low input bioenergy production in Europe.It is a perennial grassy crop for biomass production, the whole aboveground biomass of which can be utilized as energy raw material for combustion. Miscanthus is very adaptive to various agro-ecological conditions, which makes it promising for cultivation even on less fertile land areas. In this paper we have analyzed the impact of water supply from precipitation on the formation of the miscanthus aboveground biomass yield in an experiment lasting several years, established on carbonate chernozem.In the fourth season of cultivation a full establishing of the stands (maximum yield) of miscanthus was achieved. Sufficient water supply is necessary for ensuring good establishing rates and satisfactory biomass production. Insufficient water supply(drought) can cause considerable retardation of the crop growth and development in some fertilization treatments. Seasonal yield differences, that have been noticed, are mainly the result of aquatic stress.

Keywords: biomass, fuel, Miscanthus, moisture

INTRODUCTION

Biomass as a fuel represents an easily available, renewable energy source that is acceptable in technical and ecological sense. Miscanthus (*Miscanthus* × *giganteus* Greef et Deu., Fig. 1)is identified as one of the best options for low input bioenergy production in Europe and the USA (Khanna *et al*., 2008). It is a perennial grassy crop for biomass production, which is primarily of very good quality for combustion and the entire aboveground biomass of which can be utilized as energy raw material for combustion (Dželetović and Glamočlija, 2011; Dželetović *et al.*, 2012; Dželetović, 2012). *M.×giganteus*is a very tall C_4grass, with long-life span (15-20 years). It is harvested every year and has a very high potential yield (Zub and Brancourt-Hulmel, 2010), which is actually the basic pre-requisite for economic bioenergy production. Due to an efficient biomass production, this grass can have an important role in sustainable agricultural production of the fuel biomass in the near future (Ericsson *et al.*, 2009).

Fig. 1. Miscanthus (*Miscanthus*× *giganteus* Greef et Deu.) on the trial field of the INEP, during the harvest, end of February 2012.

Sufficient water supply is necessary for ensuring good establishing rates and satisfactory biomass production (Zuband Brancourt-Hulmel, 2010). Miscanthus is highly productive in moist environment, but it is very susceptible to insufficient water supply (Lewandowski *et al.*, 2003; Mantineo *et al.*, 2009). According to Lewandowski *et al.* (2003), the most important soil property is the water-holding capacity, because the highest yields are obtained on the soils with good water-holding capacity. Water-logged plots (plots that retain water) are not convenient for miscanthus cultivation (Lewandowski *et al.*, 2003).Monitoring of soil moisture up to 90 cm depth indicates that perennial grasses drain the soil earlier in the vegetation season in comparison with conventional crop cultivation systems. Namely, water budget calculations, carried out by McIsaac *et al.*, (2010), indicate that the evapotranspiration under miscanthus crop is by approx. 104 mm annually higher than under the corn-soybean crop, which can reduce the annual flow of drainage water, ensure the area water flow and aquatic ecosystems.

According to Cosentino *et al*. (2012) in the South and East Europe, which includes Serbia, climate changes will have an adverse effect on the yields of bioenergy crops, primarily due to potential water deficiency and extreme weather events (e.g. prolonged heat waves, hail, storms), which will increase the variability of annual production and lead to the contraction of areas convenient for cultivation of traditional crops. Besides, time distribution of precipitation can be very important for cultivated crops with high water requirements. Schwarz (1993) considers the precipitation quantity of 800 mm sufficient for obtaining high miscanthus yields in moderate climate conditions. This can be a potentially limiting factor and has been demonstrated for miscanthus (Clifton-Brownet *et al.,* 2001), for which the minimum annual precipitation quantity of 600 mm, according to Tucketal (2006), is eventually insufficient for growth.

The aim of our paper is to analyze the impact of water supply level from the precipitation on the formation of yield of the miscanthus aboveground biomass in agro-ecological conditions of Belgrade region, in Serbia.

MATERIAL AND METHODS

The data on the yield of the miscanthus biomass were used, and obtained from the field trial of the INEP, in Zemun (44°51´N, 20°22´E). The trial was established in 2008 on carbonate chernozem (light clay soil; pH_{H2O} 7.3; medium humus soil; total nitrogen content of 0.141%). The trial consists of 3 fertilization treatments and 3 plant density treatments. Trial plots, 5×4 м², have been randomly placed on an area. Each trial treatment has been performed in three repetitions. The entire aboveground part of the crop, after maturing and drying in the field during autumn and winter, has been harvested during February (Fig. 1), when the highest quality miscanthus biomass for combustion is obtained in agro-ecological conditions in Serbia (Dželetović *et al.,* 2009a, 2009b; Dželetović, 2012).

The data on the precipitation quantities was taken from the Annual Reports of the Republic Hydrometeorological Service of Serbia (RHSS) for the location near the trial field. Assuming that the precipitations in the areas with moderate climate are relatively well distributed, for the calculation of the effective precipitation, according to Stričević (2007), it is assumed that the precipitation effectiveness is about 80%, whereby the precipitations, the height (level) of which does not exceed 5mm, is not considered relevant, because the leaf surface of crops is such that it is hardly wetted by the precipitation, so the soil remains dry.

RESULTS AND DISCUSSION

In the first year the shooting up (sprouting) and initial growth are uneven, regardless of uniformity and planting density of rhizomes, and the biomass yield that has been formed, does not exceed 0,5 t of dry matter ha^{-1} (Tab.1). Low biomass yields obtained on chernozem in the first year are identical to the yields in the first season of miscanthus cultivation, stated by Riche *et al.* (2008) and Schwarz *et al.* (1994). We assume that the main reason for low yields in the first year is undeveloped miscanthus root system. A long drought during 2008, with regular occurrence of heat waves during the summer, when air temperatures were >35°C for several days in succession, very likely induced drying and decay of still very shallow root system in the first season of cultivation. In the first season of cultivation, frequent irrigation during the summer enabled only the maintenance of the crop, namely, the growth during the drought was slower, and with the occurrence of heat waves it was completely arrested.

In the second year a higher yield of the aboveground biomass was formed, up to 4,67 t ha^{-1}, in the treatment with 333 kg NPK 15:15:15 ha^{-1}and planting density of 2 rhizomes m^{-2}. A rather wide range of yields obtained in the second season of growing, from 0,32 to 4,67 t ha^{-1}, does not indicate a clear impact of fertilization with NPK or planting density of rhizomes on the yield amount (Tab. 1). In the second year Richeetal (2008) also obtained the yield that was identical to ours, but in a slightly limited range, i.e. from 1,78 to 3,53 t ha^{-1}. In the first two years of cultivation the obtained yields of the dry aboveground biomass for the harvest in February were low, and they are probably the consequence of unfavourable agro-meteorological conditions, first of all, a long drought during the summer months and difficulties concerning the eradication (control) of weeds in the crop.

In the third year of cultivation (2010/11) the rule is that with the increase of rhizome planting density the yield of the aboveground biomass also increases. Thus, with the increase of planting density, the deviation (±SD) from obtained yields on average has been reduced, namely, with higher rhizome planting density a more uniform yield is obtained (Dželetović, 2012).

Full establishment of the miscanthus stands is usually achieved from second to fifth year of cultivation, depending on climate conditions. Maximum yield is generally reached in the second year in the southern countries of the EU, and in the northern to the fifth year (Clifton-Brown *et al*., 2001). In the countries situated at lower latitudes (Greece and Italy) higher yields obtained due to longer vegetation season and higher temperatures, while in the countries at higher latitudes (Denmark, England, Germany, Ireland and the Netherlands) lower yields are due to a shorter vegetation season (Miguez *et al.,* 2008). Based on the data in Table 1, in the fourth year of cultivation a full establishment of the miscanthus stands (maximum yield) was achieved on the plot of the INEP plot. Thus, the treatment with planting density of 2 rhizomes m^{-2} is clearly outstnaded, with the highest yields in all three treatments. The planting density of 2 rhizomes m^{-2} Lewandowski *et al*., (2000) and Miguezetal (2008) consider optimal planting density for miscanthus. In the fifth year of cultivation (2012/13) lower yields were obtained on a majority of experimental plots compared to the previous year (Tab. 1). At the beginning of the summer of 2012, long-lasting high air temperatures and small precipitation quantities brought about a strong to an extreme drought on the entire territory of Serbia.

A cold spell with the precipitation at the middle of July interrupted for a short time the drought period that continued until the end of summer. According to Leto and Bilandžija (2013), even in Croatia, during 2012, the drought caused a considerable growth retardation and development of miscanthus on all locations. In the season of 2012/13 the yield decrease has not been recorded only in the treatment without introducing fertilizer (Tab. 1).

It appears that those plants, with insufficient nutrients, developed a more powerful root system that enabled them during the drought period to draw moisture from the deeper soil layers. Namely, in Serbia, the annual precipitation pattern shows two peaks: the primary maximum in the late spring and the secondary maximum in the late autumn, while winters and summers are mostly the drought periods.

Table 1. Impact of mineral fertilizer application and planting density on the yield of miscanthus aboveground biomass on carbonate chernozem (Zemun) during the plantation establishment (harvest performed in February, tons of dry matter per ha ± SD)

Treatment	Planting density	I year 2008/09.	II year 2009/10.	III year 2010/11.	IV year 2011/12.	V year 2012/13.
0 (without fertilization)	1 rhizomes m^{-2}	0.06± 0.01	0.32 ± 0.14	3.83 ± 1.27	8.50± 2.25	9.99 ± 2.34
	2rhizomes m^{-2}	0.20 ± 0.09	2.17 ± 0.83	14.85 ± 3.37	23.70 ± 4.97	19.46 ± 2.56
	3rhizomes m^{-2}	0.12 ± 0.05	0.43 ± 0.17	5.84 ± 0.41	13.65 ± 1.52	13.82± 1.42
333 kgNPK 15:15:15ha^{-1} annually	1 rhizomes m^{-2}	0.18 ± 0.08	1.07 ± 0.71	9.09 ± 3.53	14.71 ± 4.77	12.14 ± 3.38
	2rhizomes m^{-2}	0.29 ± 0.10	4.67 ± 1.42	18.60 ± 7.03	26.08 ± 12.57	19.64 ± 6.92
	3rhizomes m^{-2}	0.20 ± 0.09	1.23 ± 0.23	7.66 ± 0.58	14.19 ± 0.39	13.96± 1.36
667 kgNPK 15:15:15ha^{-1} annually	1 rhizomes m^{-2}	0.24 ± 0.16	2.33 ± 0.61	10.55 ± 6.33	15.94 ± 6.81	10.37 ± 2.93
	2rhizomes m^{-2}	0.34 ± 0.09	4.48 ± 1.00	20.22 ± 1.26	28.29 ± 0.44	21.86 ± 1.35
	3rhizomes m^{-2}	0.23 ± 0.13	2.49 ± 0.09	15.26 ± 0.02	19.56 ± 0.18	12.35 ± 1.01

Thereby, certain regions in Serbia belong to steppe areas, with the precipitation quantity below 600 mm: in the north-east Serbia, in Kikinda, Vojvodina, the annual quantity is only 589 mm, and in the south-east part, in Niš, only 555 mm (RHSS). This obviously leads to the conclusion that the mentioned parts of Serbia, due to small precipitation quantities, have only limited potential for miscanthus cultivation.

In Belgrade, in the period 1981-2010, there are the average annual precipitation of 690,9 mm, whereby 56,7% of precipitations are in the period April-September (Tab. 2). June is the month with the highest quantities of rainfall with average precipitation amount of 101,2 mm, which is almost 15% of the annual amount of precipitation. The percentage of precipitations during the vegetation period (April-September), in the annual amount of precipitation, varies from 40% in 2009 to 56% in 2011 (Tab. 2). Thereby, the percentage of effective precipitations (Tab. 3) during the vegetation period (April-September) is relatively identical to the percentage of the overall quantities of precipitation for the same period and year.

Table 2. Quantities of precipitations in Belgrade for the observed period and average quantity of precipitations for the period 1981-2010

Years	Total per year (mm)	From this value in the period April-September	
		mm	% of totalannual precipitations
2009	804.4	320.2	39.8
2010	865.5	458.5	53.0
2011	499.1	278.7	55.8
2012	563.7	283.7	50.3
Average for the period 1981-2010	690.9	391.9	56.7

Table 3. Quantities of effective precipitations in the period 2009-2012

Years	Total per year (mm)	From this value in the period April-September	
		mm	% of totalannual precipitations
2009	500.3	190.3	38.0
2010	530.6	288.2	54.3
2011	299.7	169.3	56.5
2012	334.1	178.2	53.3

We can notice in Tables 2 and 3 that there were more precipitations in 2009 and 2010 relative to several years on average (by 16% and by 25%). On the contrary, there was less precipitation in 2011 and 2012 (drought) and at that time the annual amount of precipitations was by 28% and by 18% lower relative to the average annual amount of precipitation. Cumulative distributions of the precipitations in the observed time period also differ by years (Fig. 2). It is evident that there were smaller quantities of precipitations from usual ones during April, May and June of 2011 and 2012 (at the time of primary maximum of the annual precipitation pattern) which brought about even considerably lower annual cumulative quantity of precipitations.

According to Maughanetal (2012), local soil conditions, precipitations and temperaturesduring the vegetation season have the greatest impact on the yield of dry biomass. The precipitations during the vegetation season (April-September) and availability of soil moisture turned out to be very important for achieving the potential of biomass yield of*M.×giganteus* (Richter *et al*., 2008), while Clifton-Brownetal (2002) state that minor quantity of precipitations or longer periods of drought are not favourable for cultivation of *M.×giganteus*.

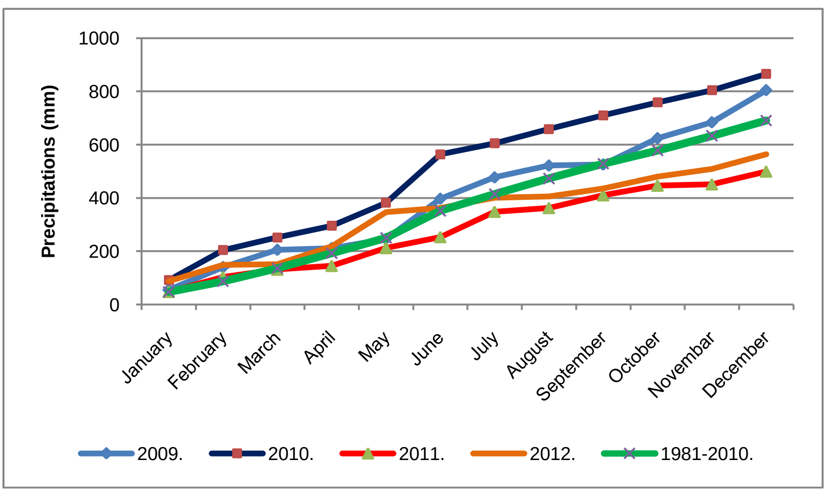

Fig. 2. Cumulative annual precipitations for the period 2009-2012 and average values in the period 1981-2010.

According to Naiduetal (2003), the optimal temperatures for cultivation of *M.×giganteus*are between 30 and 35°C. The combination of high temperatures and adequate quantities of precipitation extend the vegetation season creating ideal conditions for growth.

Namely, according to Davies *et al*. (2011), soil conditions are critical factor for plantation establishment when the precipitations are poor during the summer period. Drought may cause significant retardation of the crop growth and development. Water deficiency causes leaf senescence in *M.×giganteus* (Clifton-Brown and Lewandowski, 2000). The water use efficiency, calculated on the basis of harvested dry matter, amounts to 2.2 g d.m. kg^{-1} H_2O for*M.×giganteus* (Clifton-Brown and Lewandowski, 2000). Miscanthus shows a high yield potential in the conditions of good water supply (Cosentinoetal, 2007). Irrigation during the first cultivation season generally improves the establishing rates of the crop (Lewandowski *et al.,* 2000). Seasonal yield differences we noticed in the majority of plots may be the consequence of water stress (Price *et al*., 2004). With appropriate nitrogen supply, when water is not a limiting factor, the highest yield increase is obtained. Water supply (irrigation) and nitrogen level strongly affect the miscanthus biomass yield. If nitrogen nutrition is missing, irrigation cannot compensate for the biomass yield decrease, because the impact of irrigation increases with the increase of nitrogen level (Ercoli *et al*., 1999).

Crops with deeper roots are more tolerant during the period of drought, due to access to soil layers with higher moisture content (Chaves *et al*., 2002). Thereby, the highest values of water use efficiency were obtained in soils with limited quantity of available water (from 4,51 to 4,83 gl^{-1}), while in the conditions of unlimited availability of water in the soil they dropped to 2,56 gl^{-1} in the second and 3,49 gl^{-1} in the third year (Cosentino *et al*., 2007).However, Beale *et al*. (1999) have established that in the irrigated crops the water use efficiency is 9,1 g kg^{-1}, and in the crops without irrigation (which were supplied with water only from the precipitations) the water use efficiency is 9,5 g kg^{-1}. In the Mediterranean conditions miscanthus shows a high yield potential, even in the conditions of very limited water availability: more than 14 t ha^{-1} at 25% from the maximal evapotranspiration (Cosentino *et al*., 2007).

Measurings performed by Finch and Riche (2008) confirmed that the water content in the soil under miscanthus crop is reduced to the depth being considerably bigger than the depth of rooting of a majority of field crops. This depth is lower than the maximal depth of rooting, which was for miscanthus reported by Neukirchen *et al*. (1999) and Riche and Christian (2001). As a result, when one considers the use of water by miscanthus, according to Finch and Riche (2008), it would be convenient to use the effective maximum depth of rooting for miscanthus of 1,7 meters. They showed that the soil under the miscanthus crop had insufficient water and suggested that transpiration losses were lower than the losses under other crops. Miscanthus remains on the field even during the autumn-winter period, which can cause a reduction of infiltration of precipitations in the soil (Trianaetal, 2011). One should bear in mind that perennial grasses, like miscanthus, have a large biomass in the autumn, on the surface of which remain the precipitations. Non-productive evaporation of the precipitations that remain on leaf surface can influence a decrease of their effectiveness (Finch and Riche, 2010).

The survey of Donnelly *et al*. (2011) of the impact on the environmental receptors shows that the replacement of agricultural grass areas with miscanthus can improve the biodiversity, quality of water, air and soil, as well as the quality of climate factors as in the period of crop establishing so also in the period of full maturity. Furthermore, the perennial C_4grasses, such as miscanthus and switchgrass, turned out to be more productive (Dohleman *et al*., 2009) and more efficient in reducing the greenhouse gas emissions (Davis *et al*., 2010, 2012), relative to annual cultivated crops, which are also characterized by a high annual evapotranspiration (Van Loocke *et al,* 2010; Le *et al*., 2011;.Van Loocke *et al*., 2012), by comparing the water use efficiency of ecosystem, established that the miscanthus efficiency was higher than the efficiency of bioenergy crops like corn and switchgrass. It is considered that the miscanthus crop can affect the hydrological cycle in the existing climate conditions (Van Loocke *et al*., 2010), as well as in the future, unfavourable climate conditions (Le *et al*., 2011).

A potential deficiency of required quantities of water in the soil can be compensated through utilization of different mobile irrigation systems. The energy consumed for irrigation varies depending on the type of irrigation system. By analyzing energy consumption of mobile irrigation systems on conventional cultivated crops (corn, potato, peas) Miodragović *et al*. (2013) have established that the optimal relation of the energy output (yield energy) and energy input through the irrigation process in the case of mobile irrigation wing is the lowest (12.29), and that with mobile linear device the highest (288.19). With the mobile linear system energy consumption was 814.35 MJ/ha, with mobile rain (irrigation) wing 1338.54 MJ/ha and with the self-propelled rain gun 8041.17 MJ/ha (Miodragović *et al*., 2013).

Besides energy, technical parameters will also affect the choice of appropriate irrigation system for miscanthus. Namely, in the first two years the crop is relatively thinned out, while from the third year, practically immediately upon sprouting it forms a dense structure (Dzeletovic, 2010, 2012). Due to an intensive high growth of miscanthus, at the beginning of the vegetation season, already from the second season of growing, the crop reaches 2-meter height at the end of June and at the end of July even over 3 meters (Dzeletovic, 2010, 2012). The crop height, in the period of water supply deficiency, can limit a uniform irrigation of the crops and reduce the efficient utilization of some irrigation systems. For plantation cultivating on larger land areas all this requires corresponding calculations, that should suggest the choice of the most optimal technological process of miscanthus cultivation (rhizome planting density, application of mineral fertilizers, selection and utilization of irrigation system, etc.). Due to high water use efficiency and tolerance to high temperatures and long drought as from the second season of growing, it is certain that the use of the current mobile irrigation systems that already exist on the agricultural farm would be the most economical.

CONCLUSION

Miscanthus is a perennial bioenergy crop, which is very adaptive to different agro-ecological conditions. In the agro-ecological conditions of Lower Srem (Zemun) in the first two years of growing low yields of the aboveground biomass are obtained. Full establishing of the stands (maximal yield) of miscanthus is achieved in the fourth year of growing. Thereby, with the increase of rhizome planting density a deviation from obtained yields on average is reduced, namely, with higher planting density a more uniform yield is obtained. In the fifth year of cultivation, with drought, the plants in the treatment without the application of NPK fertilizer achieved the same or higher yield, in contrast to the plants subjected to NPK fertilization and the yield of which was considerably lower.

We think that the problem of water supply in the miscanthus biomass production in the steppe areas of Serbia (with annual amount of precipitations below 600 mm); will probably represent the main limiting factor for its successful and economical cultivation. This problem will, naturally, require a more detailed research, for establishing the most optimal technological processes of miscanthus cultivation for some agro-ecological regions and more precise insight into the potential of biomass production of this promising bioenergy crop for the territory of Serbia and in the neighbouring countries.

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WATER EROSION AND TORRENTIAL FLOODS - SIGNIFICANT FACTOR IN LAND DEGRADATION

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ABSTRACT

Water erosion and torrential floods, as its consequence, are considerably widespread degradation processes in Serbia. Practically, the whole territory of Serbia is under the attack of water erosion of different intensity which causes great damages such as: the loss of soil, the loss of soil fertility, the loss of water, the damage inflicted to the environment, etc. Extremely ramified network of torrential streams which exists on the territory of Serbia is the consequence of intensive erosive processes creating over 12,000 torrential streams registered so far. Damages caused by torrential streams are many: catastrophic torrential floods creating damages in settlements, industry, road infrastructure, agriculture and complete economy, and society as a whole, siltation of accumulations and other water management facilities by sediment, traffic interruptions, etc. For the purposes of preparing spatial plans and other development plans, it is necessary to have an updated erosion map and torrential stream cadastre. Erosion map which exists in Serbia was prepared in 1975 applying the Method of Erosion Potential by Prof. Gavrilovic and the map's partial alteration and amendment made in 1996. Having in mind that field properties change over time, it would be necessary to prepare the new erosion map applying some of the methods generally accepted in Europe and in the world. As for torrential streams, there are cadastres compiled in 1960s applying outdated methods. Also, field conditions changed and it is necessary to prepare new torrential stream cadastres applying contemporary methods and tools at our disposal.

Keywords: water erosion, torrential floods, land degradation

INTRODUCTION

Soil, as the integral part of the biosphere, plays an important part in survival of life on our planet for both flora and fauna, as well as for humans. As limited and perishable good, it is being slowly formed throughout the long-term process of pedogenesis on one hand but in the process of production it is often being degraded fast and irreversibly destroyed. In a situation where the population on Earth drastically increases, the need to increase the food production arises which could be achieved by:

- increasing arable land,
- increasing agricultural output,
- using new products in nutrition.

Many analyses show that currently main real sources for the nutrition of population on Earth remain to be agricultural areas, i.e. the increase of arable land. Therefore the preservation of arable land from various types of degradation i.e. prevention of its reduction imposes itself as an imperative. Because of its highland character arable land (crops) in Serbia cover 45.04% of total area which is small percentage compared to other countries (Czech Republic 53%, Romania 50%, Poland 63%, Hungary 70% and other).

Main reasons of the reduction of arable areas in Serbia are:

a) Intensive development of erosive processes on arable land in mountainous region;

b) The use of arable land for the purposes of the construction of settlements and industry, for mines, surface mines, quarries, roads, water reservoirs, canals, and other;

c) Pollution of valuable arable land by flooding them with industrial waste waters;

d) Soil pollution by hard materials, gasses, heavy metals, inappropriate use of mineral composts, excessive use of pesticides and other;

e) Leaving agricultural land because they are located on steep slopes and due to a migration from villages into cities.

This paper shows the distribution and intensity of water erosion, distribution of torrential floods in Serbia, as well as damages caused by these processes. This work resulted in the first inventory of torrential floods in Serbia and its analysis. Inventory of torrential floods is designed for the purpose of spatial and temporal distribution of this phenomenon in Serbia.

MATERIAL AND METHODS

Methodological approach in this work comprises of the following:

- The use of existing erosion map of Serbia,
- Detailed investigation of previous torrential flood research in Serbia,
- Compilation of data on torrential floods and its analysis,
- Analysis of current state of erosion and torrential floods and the possibility of prevention.

Erosion map of Serbia taken from Serbian Water Master Plan ("Jaroslav Černi" Institute, 2001) prepared applying the method of prof. Gavrilović (1972) was used for the purposes of this paper.

Initially, the inventory of torrential floods in Serbia was derived from the book "Torrential Rivers of SR Serbia" by Gavrilovic (1975) and archival documentation of the newspaper "Politics" for the period from 1970 to 2012. Moreover, all expert reports and particular explanations of torrential flood events, which are not numerous, are reviewed. Finally, the data on discharge, rain depth and duration quantify previous information. Since the torrential floods appear in ungauged watersheds interpolation method is needed.

To complete historical data series of torrential flood events, we sent the questionnaires to the authorities of local municipalities located in the watersheds affected by torrential floods. Beyond, all institutions in the state (such as Ministry of Agriculture, Forestry and Water Management, Water Directorate, Public Water Management Company "Serbia Water", Republic Hydrometeorological Service, Institute for Water Management "Jaroslav Cerni", municipalities) competent to participate in generating the inventory on torrential floods were invited to give a contribution with reports. However, the response from both national and local levels was unfortunately slight due to the fact there was no records and reports on torrential floods with continuity. Since the problem with lack and limited or incomplete information was envisaged, the inventory structure was based on the principle of collection of minimum data needed for further analysis: name of watershed; affected municipalities; date; damage; casualties; additional information; source of information.

Some torrential flood events are recorded with incomplete information, for instance, only year of torrential flood event and name of the torrent are given. However, there are some of them recorded with rainfall duration and depth, discharge, name of gauges, watershed area. Additional data (such as water level, trigger of the torrential flood occurrence, etc.) when available are used to make inventory more detailed. Here, flash floods as a consequence of breaching a dam are not included.

Study area

Since torrential floods are related to the hilly-mountainous part of Serbian territory, the research focus is on the area south of the Danube and the Sava (Fig.1). However, floods of torrents of Fruska Gora mountain and Vršačka Brda hills in Vojvodina were recorded as well. The most important torrential events in Serbia occur in the Southern and Western Morava river basins, where the proportion of high, medium and small water shows a greater disbalance indicating the intense erosion processes in their watersheds. The area of torrential watersheds in Serbia is in the scope from 0.2 km^2 to over 1000 km^2.

RESULTS

Water erosion in Serbia

Development, intensity and distribution of water erosion processes depend on natural properties of the research area. Various types of relief are found on the territory of Serbia which covers 88,361 km^2, starting with wide plains on the north, across upland areas and valleys towards the south up to mountainous areas in western, southern and eastern parts of the Republic. The relief of Serbia offers favourable conditions for the development of water erosion.

The largest part of Serbian territory is under the influence of moderate climate (typical for this type of climate are double maximum rainfall with frequent heavy rains during summer /June/, secondary maximum in autumn /November/ and quite dry winter season).

The north part of the Republic (Vojvodina) is under the influence of temperate continental climate. The characteristics of such climate are worm summer and cold winter with the annual fluctuations in temperature over 22°C (January – July). Here the autumn is warmer than the spring for about 0.7°C and the transition of winter into summer is harsher then of summer into winter. Central lowland areas of the Republic are characterized by similar climate. Mountainous climate is typical for medium and high mountains.

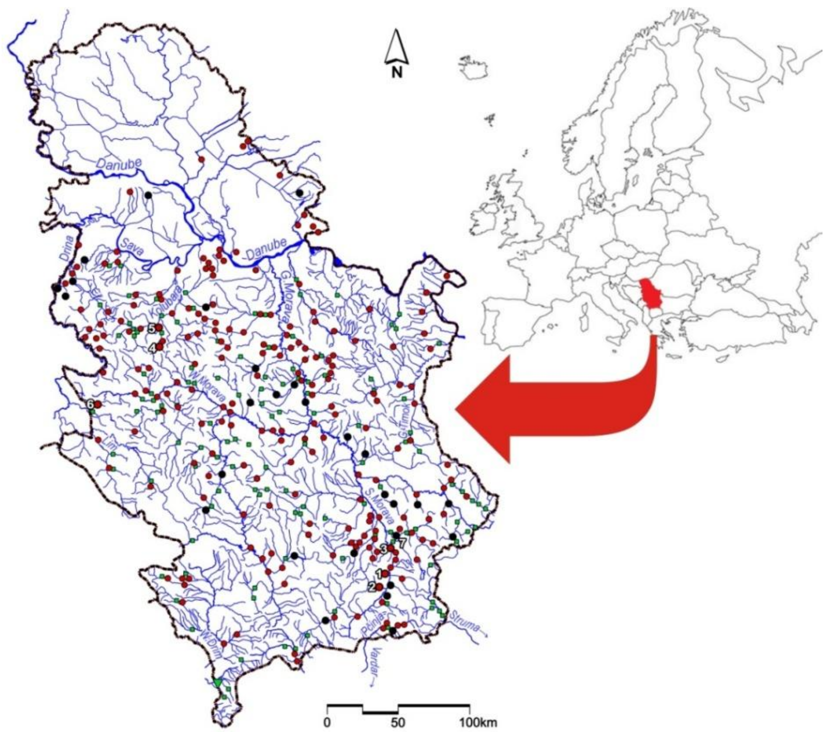

Fig. 1 Map of Serbia and areas jeopardized by torrential floods

Precipitation is one of the most important climate elements. Average precipitation in the Republic of Serbia is 734 mm/year. Precipitation is highly heterogeneous over the area since the annual precipitation ranges widely. Precipitation in the central area of the Republic varies from 1.000 mm year^{-1} (in mountainous regions) to 600 mm year^{-1}. General tendency of reductions in precipitation is recorded in the lowland going west to east. All lower areas in Serbia, including the lower watershed of the Drina river, have the precipitation below 800 mm year^{-1}.

Due to very complex geomorphic structure and frequent local modifications of continental and temperate continental climate, heterogeneity of land cover is highly prominent in the territory of

Serbia both concerning the distribution of certain soil-systematic units and its properties. The Republic of Serbia is dominated by automorphic soils, the class of humus-accumulative and cambic soils, while there is a smaller percentage of a land formation from the class of eluvial illuvial and undeveloped soil. Land formations of hydromorphic soil type are mainly found in the valleys of large rivers, and they are mainly distributed in Vojvodina.

Soil types in lowland and hilly terrains of Serbia are the following: chernozem, clay soil, eutric brown soil (forest soil), red soil, loessivized soil (luvisol), pseudogleys and humogleys. Pedological cover in mountainous area consists of: brown soil on limestone, rendzinas, dystric and eutric brown soils, podzols, brown podzolic soil, humus-siliceous soil and other. The territory of Serbia is divided into five pedogeographic regions (Resulović, 1991) (Fig. 2, Tab. 1).

Fig. 2 Pedogeographic regions in Serbia

Main soil types (in %) in the Republic of Serbia according to the data of Popović (1985) are shown in the Table 2.

The soil resistance to erosive processes is different, more precisely, it is determined by the critical properties of soil to erosion. The critical soil properties to erosion are: texture, soil structure stability, organic matter content, water permeability of soil, and other. (Košanin, 2001). Due to their properties, soils in mountainous region of Serbia are prone to water erosion. The development and intensity of erosive processes significantly depends upon slope inclinations and land use itself. Land use is a social category and it has an essential significance in the occurrence, development and intensity of water and wind erosion. Table 3 shows that land use in Serbia and Monte Negro enables the development of intensive processes of water and wind erosion.

Table 1 Natural conditions in Serbia

PARAMETER	PEDOGEOGRAPHIC REGION				
	1	2	3	5	6
Average annual temperature (^oC)	10.8	11.2	10.0-11.9	4.7	11.3
Average annual rainfall (mm)	556	678	600-924	779	592
Soil type	Chernozem, Fluvisol, arenosol, halomorphic soils, district and eutheric cambisol	Chernozem, eutheric brown soil, fluvisol, district brown soil	Euthric brown soil, Vertisol, chernozem on limited area; fluvisol in the river valleys	Black soil, brown eutheric calcocambisol and luvisol, rankers, brown district soil	Eutheric calcocambisol, terra rosa, district brown soils and luvisol, alluvial soils
Relief	Loess plateaus and alluvial terraces	Mostly flat	Hilly-mountainous region	Mountainous relief	Mountainous relief
Type of soil erosion	Wind erosion dominamt	Sheet, rill	Water erosion Sheet, rill, gully, landslides, wind erosion (near town Ram)	Sheet, rill, gully, landslides, karst erosion	Sheet, rill, gully, landslides

Serbia is not so rich in agricultural land to allow its degradation and destruction. Different forms of aggression upon the soil are present, from partial damage and different forms of pollution to total destruction and permanent disappearing. By his activity in the intensive vegetation production, through land utilization the man directly or indirectly seeks to maintain and preserve, or improve its properties, but frequently the opposite effects and deterioration of the productive properties occurs. All the analyzed factors present the favorable conditions for water erosion processes. As the consequence of such natural conditions practically all of territory of Serbia is under erosion processes of different intensities (from the low to the excessive erosion).

Table 2 Main soil types in the Republic of Serbia (*Source: Popović, 1995)*

Soil Type	(%)
Chernozem	15,00
Vertisol	8,50
Eutric cambisol	5,46
Pseudogley	6,25
Fluvisol	8,44
Arenosol	1,08
Halomorphic soils (Solonetz, Solonchak, Soloth)	2,93
Calcomelanosol and Calcocambisol	11,38
Rankers and eutheric cambisol on serpentine	3,35
Distric cambisol	32,60
Rankers	4,05
Lithosol	0,97
	100

Table 3 Land Use in Serbia and Montenegro

N^0	Republic	Total area	Plaughed land and vineyard		Meadows, pastures and orchards		Forests		Other	
			km^2	%	km^2	%	km^2	%	km^2	%
1	Serbia	88.361,0	34.381,0	38,91	19.255,0	21,79	26.508,0	30,0	8.217,0	9,3

The share of certain categories of erosion intensity, i.e. erosion intensity in stream channel and in watershed, according to Gavrilović's classification, has been analyzed based on erosion map prepared by Gavrilović's method (Gavrilovic, 1972) (Tab. 4). Sediment transport related to gross erosion (total erosion production), is also considerable. Total average annual gross erosion in Serbia amounts 37,249,975.0 m^3, i.e. specific annual gross erosion amounts to 421.57 m^3·km^{-2} while annual sediment transport is 9,350,765.0 m^3 and specific annual sediment transport is 105.80 m^3·km^{-2}. If annual gross erosion is turned into equivalent hectares of soil 20 cm thick, it can be concluded that every year 20,525 ha is endangered.(Đorđević, Jovanovski, 1987).

Table 4 Distribution of Water Erosion Processes in Serbia

Category	Erosion Processes Intensity	Area	
		km^2	%
I	Excessive Erosion	2,888.0	3.27
II	Intensive Erosion	9,138.0	10.34
III	Medium Erosion	19,386.0	21.94
IV	Weak Erosion	43,914.0	49.78
V	Very weak Erosion	13,035.0	14.75
	Total	88,361.0	100

Source: Water Resources Management Basic Plan of Serbia, 2001

Torrents and torrential floods

Torrents are the consequence of the intensive erosion processes in the watershed. The fundamental property of torrent streams is a direct link among phenomena in the watershed and in the stream.(Kostadinov, 2010). The processes taking place within the watershed are directly and nearly simultaneously manifested in the hydrographic network. The torrential character of hydrological regime is manifested in two ways: by a large range of yearly discharge and by a short duration of flood waves. The discharge ratio of flow and flood waters is of the order of magnitude 1:1000. As to the duration of flood waters, it is only few days a year, i.e. 1-5% of the total yearly duration (Kostadinov, 2003).

Torrential floods are the sort of natural disasters in Serbia with the most frequent occurrence and often with severe social, economic and environmental consequences. Local population faced many catastrophic flash floods in the past and will be a victim of more serious and frequent ones in the future. Specific characteristics of climate and relief, soil type and vegetation cover. This kind of floods occurs in the hilly-mountainous regions very endangered by erosion processes of different intensities. They are related to the torrential streams with a specific hydrologic and sediment transport regime. In the domestic subject literature, when occurs 30 kg of erosion sediment in 1 m^3 of water and flood wave duration shorter than 7 hours it is considered as torrential flood. In the watersheds of almost all Serbian rivers (and especially in the watersheds of the rivers Južna, Zapadna and Velika Morava), spreads the network of more than 12,000 torrents (Kostadinov, 2007).

The research on frequency of high intensity rains is of great significance for making the estimate of torrential flood frequency. Serbia had numerous torrential events, in the last 15 years, on the watersheds of main tributaries of: Kolubara, June 1996; Velika Morava, July 1999; Kolubara and Drina, June 2001; Južna Morava, November 2007; Zapadna Morava, Drina and Lim, November 2009; Timok, February 2010; Pčinja, May 2010; Drina, December, 2010 (Ristić *et al*., 2012).

DISCUSSION

According to the data from former Department of Torrent Control at the Ministry of Forestry and Mining in Former Yugoslavia, strong torrential floods in Južna and Zapadna Morava, Mlava, Timok and Drina rivers occurred approximately every tree years in: 1921, 1924, 1929, 1932, 1937, and 1940. After the World War II, great and harmful torrential floods occurred in almost all our regions in 1947, 1948, 1951, 1953, 1957, 1961, 1963, 1965, 1967, 1969, 1970, and 1972.

Fig. 3 Torrential flood in Trgoviste, May 2010

Based on the available data obtained from various resources (newspapers, reports from local and government services, data from literature, and similar) there are 427 major torrential floods occurred in Serbia in the last 100 years and registered in our data base. It must be noted that most of them occurred in mountainous area of Serbia, south from the Sava and Danube rivers. The floods that occurred in Autonomous Province of Vojvodina were caused by large alluvial rivers Danube, Sava, Tisa, Tamiš, whereas the number of torrential floods was very small.

Beside certain property damages, we would like to draw attention to mortality from torrential floods in Serbia. Table 5 shows the monthly distribution of registered torrential floods as well as the data on casualties that occurred during those floods. The majority of floods occurred in May (116) and June (106), followed by March (50) and February (43).

Table 5 Torrential flood events per month and casualties

Month	Number of torrential flood events	Casualties
I	3	-
II	43	1
III	50	2
IV	25	-
V	116	40
VI	106	27+several
VII	17	19+several
VIII	16	several
IX	8	several
X	6	17
XI	21	6
XII	16	-
Total	427	-

Table 6 shows the distribution of registered torrential floods which occurred in different periods as follows:

1. up to 1931,
2. 1931 – 1960,
3. 1961 – 1990,
4. 1991 - 2012.

Fig. 4 Torrential flood in Novi Pazar, 2011

Table 6 shows that the mean annual number of torrential floods in certain periods is different. It is noticed that from 1915 to 2012 the number chronologically increases. The average number of torrential floods per year was 2.187 for the period 1915 – 1930 increasing in each period reaching the highest value of 6.5 torrential floods per year in the last period 1991 – 2012. That means that the average number of torrential floods in Serbia increased three times in the last period 1991 – 2012 compared to period 1915 – 1930.

Table 6 Distribution of registered torrential floods in the periods

No.	Time period	Number of torrential flood events	Average per year
1.	1915-1930	35	2.187
2.	1931-1960	93	3.100
3.	1961-1990	156	5.200
4.	1991-2012	143	6.500
	Total (98 yrs)	427	4.357

Damages caused by soil erosion and torrents are multiple:

- Soil loss (primarily refers to surface layer, the bearer of fertility and production capacity of the soil);
- The loss of water (due to soil transport after the rain the water flows rapidly in the form of flood waves followed by draught);
- Torrential floods causing damages to agriculture, water management, traffic, forestry, energy, spatial planning, i.e. economy and society in general;
- Accretion of water reservoirs by sediment erosion. Namely, immediately after the construction of dams and water reservoirs (for water supply, energy, irrigation, flood defense, and other) the process of aggradation starts, carried by water streams as a consequence of erosion and sediment yield in the basin. That way the reservoirs become the reservoirs for the sediment instead of being water reservoirs. All reservoirs in Serbia are intensively silted by sediment but water reservoirs on Zapadna Morava, Drina and Južna Morava basin must be distinguished as an extreme example.

Particular types of damages are the ones erosion inflicts on the environment:

- Landscape degradation,
- Mechanical pollution of water by sediment erosion,
- Chemical pollution of water by sediment erosion.

The scope of the problem can be perceived by noting the following facts:

a) For further development of our economy it is necessary to consolidate and improve the agricultural production (husbandry, animal husbandry, and pomiculture). In cases when in mountainous area of Serbia (75% of the total territory) moderate to very strong erosion prevail, that is not possible to perform.

b) Spatial planning and Serbian Water Master Plan clearly state the problem of erosion and torrents. Namely, it is obvious that the problem of water supply in Serbia can only be solved by the construction of numerous water reservoirs because Serbia is poor in water resources. Because of that, these two significant documents, key to the further development of Serbia, clearly state that the existing reservoirs for water supply as well as 33 reservoirs planned to be constructed must be protected from siltation and pollution by sediment erosion. In the years to come, water becomes the key element in human survival, and water and soil (together with air) remain the resources upon which further human development depends.

CONCLUSION

1 Soil erosion and torrents (followed by catastrophic torrential floods) are the great problem and limiting factor in economic and social development of Serbia.

2 Having in mind on-going climate changes, the increase of extreme precipitation, intensifying of erosive and torrential processes can be expected.

3 Therefore urgent need arises for comprehensive erosion and torrent control, protection of settlements, roads, energy and industrial plants and other structures significant to economy and society as a whole.

4 According to the Law on Waters of the Republic of Serbia, each municipality is under an obligation to adopt two very important documents concerning torrential flood control:
   - tyn The Plan of Identifying Erosion Regions, and
   - The Plan of Torrential Flood Control

5 Apart from these direct measures and works it is also necessary to undertake the following activities which are applied in the flood control as prevention measures, and are included in Phase 1 of flood defense:
   - Draw an erosion map of Serbia,

Having in mind that field properties change over time, it would be necessary to prepare the new erosion map applying some of the methods generally accepted in Europe and in the world.

- Prepare the Plan for determining erosion areas for each municipality in Serbia,
- Prepare the Serbian cadastre of torrents, based upon watersheds,
- Prepare the cadastre of performed erosion control works and torrential flood control works

6 To effectively solve the problem of erosion and torrent control, basic prerequisites must be provided: finances and legislation, whereas we do not lack in expertise and operative staff. All relevant entities must work on improving the legislative (Water Law and other laws) which is dealing with these problems and the financial conditions will follow. The new Water Law, the chapter "Erosion and Torrents" must emphasize the significance of designing and executing anti-erosion works prior to the construction of any structures on waters (reservoirs, regulations, water streams and other).

7 Apart from the existing companies and institutions, it is necessary to form a Directorate (Agency) for erosion and torrent control for the purposes of better coordination of the works on erosion and torrent control.

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THE AVAILABLE CONTENTS OF HEAVY METALS COMPARED TO A SOIL PROPERTIES IN KRAGUJEVAC

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ABSTRACT

Since recent, it is increased concentration of heavy metals in some agricultural areas due to anthropogenic influences. The aim of this paper was to determine the level of DTPA-extracted heavy metals (Fe, Mn, Zn, Cu, Ni and Pb) in acidic soil (Vertisol) in order to obtain information on health safely food production. Available contents (extract of DTPA chelating agent) in the soil have been determined by AAS. It has been concluded that the contents of available elements in the investigated soil are lower, or within a limits for multifunctional soil use. By correlation analysis, it has been determined correlation between available content of heavy metals (Fe, Mn and Zn) and some of the soil properties investigated in the study. These soil properties did not influent on available contents of Cu, Ni and Pb indicating their geochemical origin.

Keywords: available, micronutrients, soil properties, Vertisol, arable land

INTRODUCTION

Heavy metals in soil are of natural or anthropogenic origin (Adriano, 2001). Normal concentration of one or more elements is influenced by anthropogenic factors and distanced transport of pollutants can be significantly increased (Kadović and Knežević, 2002). Heavy metals are natural compounds of the Earth's crust and, as such; generally do not create a risk to the agricultural production.

However, recent research shows that soils in different parts of the world, especially in the urban and industrial areas, contain extremely high concentrations of heavy metals (Cui *et al*., 2004; Duong and Lee, 2011; Mbila *et al.,* 2001; Wei and Yang, 2010). The main sources of heavy metals as contaminants of soil are: mineral and organic fertilizers, pesticides, transportation means, mining, metal smelting, municipal solid and liquid waste, etc. Fertilizers and pesticides especially, are containing different combinations of heavy metals. Soils distinguish within themselves by limited capacity to adhere heavy metals. Heavy metals in soil may pass into insoluble compounds that are difficult for plant up taking and thus are excluded from the biological cycle. The rest of the metals can form soluble compounds that can be folded by irrigation into the deeper layers.

In the urban areas, concentration of heavy metals in the soil is usually high, and they can accumulate in the human body directly through breathing and feeding (Flues *et al.*, 2004; Miguel *et al*., 2007; Poggio *et al*., 2008). In most agricultural soils the level of heavy metals is still not so high as to cause acute toxicity problems. However, increased concentrations of heavy metals in food can have a negative impact on human health, because the dominant mode of heavy metals entering is through the system soil-plant (Liu *et al.,* 2007).

Behavior of heavy metals in soil depends on many factors which influence on their dynamics, and therefore the solubility and availability to the plant, such as are: pH, Cation Exchange Capacity, content and type of clay, organic matter content (Golia *et al.*, 2008; Al-Khashman, 2004; Nezhad *et al*., 2011).

Determination of the chemical forms of the trace elements related to soil indicates their potential mobility and availability to the plants. The total content of trace elements in the soil does not show a good correlation with their biological availability, but these data are useful for legislation which evaluates soil contamination. Single or sequential methods are being used to assess the potential of affordable and available fraction of trace elements in the soil. Besides to various extraction solutions, one of the good indicators of available micronutrients (Fe, Mn, Zn, Cu, Ni and Pb) in the soil can be complexed by chelate agents are based on strong extraction reagents based on strong chelates (DTPA, EDTA). Determination of available metals in plants from DTPA extract (Lindsay and Norvll, 1978), it is widely accepted (Maiz *et al*., 2000; Duong and Lee, 2011). The aim of this study was to determine the level of DTPA-extracted contents of the trace elements (Fe, Mn, Zn, Cu, Ni and Pb), as well as the correlation of the content with the properties of the studied arable land. These studies should provide information on the accessibility of certain trace elements in order to obtain information on food safety as well as guidelines for its appropriate use.

MATERIALS AND METHODS

Tests were conducted on production plots in the vicinity of Kragujevac, on the acidic type of soil in areas of Gornje Komarice, Donje Komarice and Cumic. Soil samples have been sampled until the depth of 30 cm by a stainless steel shovels. A total of 299 soil samples have been sampled of the Vertisol soil type with different varieties. The collected samples were air-dried, milled and sifted through a sieve of 2 mm diameter.

In laboratory tests were determined available contents of heavy metals and basic chemical properties. To determine the content of available trace elements, soil sample has been extracted with DTPA solution containing 0.005 MDTPA-diethylene-triaminepentaaceticacid, 0.1 MTEA-triethanolamine p.a., and 0,01M $CaCl_2$ and 0.01 at pH 7.3 (Lindsay and Norvll, 1978). The content of Fe, Mn, Zn, Cu, Ni and Pb were measured by atomic absorption spectrophotometer on a Perkin Elmer instrument, 3300/96 with the MHS-10. Basic chemical properties were analyzed by the following methods: the pH of the soil suspension in water and 1N potassium chloride, humus by Kotzmann's method, the available phosphorus and potassium by-Al method. All laboratory analyzes were performed in the Agrochemical laboratory of Center for Small Grains in Kragujevac. The obtained results have been analyzed by usual variational statistics: the average value, finding interval, the arithmetic median error, and standard deviation. It has been used Analyst program SAS/STAT (SAS Institute, 2000).

RESULTS AND DISCUSSION

Depending on soil characteristics and origin, microelements are being adhered by soil components in different chemical forms (Čakmak *et al*., 2010). If the pollutants reached the land by human activities, they are mainly related to exchangeable chemical forms and probably available to the plants (Wei and Yang, 2010). Soluble, exchangeable and complexed elements in chelate compounds are labile in soil fractions and available to the plants (Maiz *et al*., 2000; Takač *et al*., 2009; Galfati *et al*., 2011). Mobility of microelements in some studies is being explained by multiple regression analysis between the content of easily exchangeable micronutrients and soil properties such as pH, organic matter content, CEC, and the presence of Fe and Al oxides (Carlon *et al*., 2004).

The results show that the chemical properties of the soil is characterized by strong to moderately acidity with a small portion of neutral soils (pH KCl 3.89-7.25). Based on previous studies (Milivojević *et al*., 2012) it was noted that most of the soil samples in Kragujevac area is acidic (about 86.56%). It was found that in the structure of acid soils with extremely acidic reaction (pH<4.5) are equal to 24.37%, medium acidic (4.51 to 5.50) with about 42.30% and with slightly acid reaction (pH 5.51 to 6.50) with 19.89%. Neutral soil reaction, which is the most favorable for crop production, is being present in a much smaller percentage of 15.63%.

The presented results in Table 1 show that the content of available phosphorus is 16.40 mg 100g^{-1} dry soil sample with a wide interval of variation of individual samples (0.00-290.0 mg per 100 g of soil). It is worrisome that a huge number of samples of Kragujevac area belong to the very poor (57.12%) and poor class (19.28%), and about 10.27% belong to classes with harmful toxic content of this macronutrient (Milivojević *et al*., 2012). Based on these average values of humus content in the soil of 3.11% it can be concluded that the investigated soils belong to the class humic soils. However, if the distribution of humus is being observed from the standpoint of production sites, it can be noted that the investigated sites (Gornje Komarice, Donje Komarice and Cumic) in a minority of cases belong to the humic class with a share of 28.89 to 45.45%. The percentage share of samples of very humic soils by production sites is low and it ranges from 2.27% to 9.09% (Milivojević *et al*., 2012).

The mean value of Fe extracted from the soils by DTPA extracting is 79.8 mg kg^{-1}, and it ranges from 6.60 to 378.0 mg kg^{-1}. According to the authors (Lindsay and Norvll, 1978) adequate Fe nutrition of plants is being ensured if its value in the DTPA extracting exceeds 4.5 mg kg^{-1}.

Table 1. Show the average values of some chemical properties of the studied area in the vicinity of Kragujevac

Location	Parameter	pH H_2O	pH KCl	Al P_2O_5 (mg $100g^{-1}$)	Al K_2O (mg $100g^{-1}$)	Humus (%)
Gornje	Min-max	5.06-7.32	4.30-6.96	0.00-290.0	9.60-94.00	1.52-8.55
Komarice	x±d	6.06±0.62	5.50±0.82	20.68±46.933	25.38±18.395	2.90±1.094
Donje	Min-max	5.20-7.80	4.43-7.25	0.00-176.00	10.00-146.00	0.87-4.90
Komarice	x±sd	6.23±0.728	5.62±0.853	49.76±69.511	44.65±46.429	3.12±0.980
Cumic	Min-max	4.60-8.06	3.89-7.10	0.00-264	11.00-208.00	0.78-5.91
	x±sd	6.12±0.824	5.29±0.866	12.40±28.263	33.98±30.291	3.14±0.953
Average	Min-max	4.60-8.06	3.89-7.25	0.00-290.00	9.60-208.00	0.780-8.55
	x±sd	6.12±0.790	5.35±0.861	16.40±37.179	33.47±30.536	3.11±0.978

Table 2. Minimum, maximum, average values, and standard deviation of the available heavy metals content

Location	Parameter	Fe_{DTPA}	Mn_{DTPA}	Zn_{DTPA}	Cu_{DTPA}	Ni_{DTPA}	Pb_{DTPA}
Gornje	Min-max	18.4-124.0	5.2-64.0	0.56-8.40	0.40-14.40	0.28-3.00	0.90-6.00
Komarice	x±sd	72.9±28.2	24.4±14.2	1.74±1.40	1.73±2.00	1.15±0.65	2.60±0.91
Donje	Min-max	36.6-144.0	5.10-48.0	0.56-5.60	1.20-2.40	0.70-3.76	1.30-2.90
Komarice	x±sd	84.8±25.5	27.0±13.30	2.34±1.80	1.73±0.29	1.68±0.82	2.19±0.45
Cumic	Min-max	6.6-378.0	4.1-163.0	0.40-11.60	0.70-32.00	0.20-16.80	0.00-7.50
	x±sd	80.7±57.0	23.9±16.58	1.36±1.20	3.63±4.90	3.17±3.07	2.19±0.87
Average	Min-max	6.60-378.0	4.10-163.0	0.40-11.6	0.40-32.0	0.20-16.8	0.00-7.50
	x±sd	79.8±51.9	24.2±16.0	1.49±1.31	3.21±4.45	2.76±2.83	2.25±0.87

The high contents of DTPA extractable Fe in individual samples are due to low pH. The analysis of the correlation coefficients (Table 3) showed that the DTPA accessible Fe expressed the highest effect is active (r=-0.63*) and potential acidity (r=-0.60*). Since the obtained coefficients are negative, it can be concluded that by increasing soil acidity increases the solubility of micronutrients too (except Mo) and therefore increases the availability of Fe.

The average value of the of Mn extraction, using 0.005 M DTPA is 24.2 mg kg^{-1}, with an interval varying from 4.10 to 163.0 mg kg^{-1}. On the basis of limit manganese values (Lindsay and Norvll, 1978; Lãcãtuşu and Lãcãtuşu, 2008) adequate nutrition is provided if its value in the DTPA extracting exceeds 1.0 mg kg^{-1}.

Increased DTPA extractable Mn content in some locations (Cumic) can be explained by the parent material out which the soil is formed, the reaction area (very acidic) and oxidation-reduction conditions that are, in fact, the main reason for its increased content (Vasin *et al.*, 2004). Correlation analysis showed that DTPA available Mn form is negatively correlated with soil pH (r=-0.63*) of the active acidity, and (r=-0.62*) for potential acidity. So, at low pH values in the acid soils a red-ox potential is reduced, which resulted in increased solubility of divalent Mn compounds.

Table 3. Correlation coefficients of available heavy metal content and soil properties

	pH H_2O	pH KCl	Al P_2O_5	Al K_2O	Hum	Fe_{DTPA}	Mn_{DTPA}	Zn_{DTPA}	Cu_{DTPA}	Ni_{DTPA}	Pb_{DTPA}
pH H_2O	1.00										
pH KCl	0.94***	1.00									
Al P_2O_5	0.38	0.49	1.00								
Al K_2O	0.35	0.43	0.69*	1.00							
Hum.	0.23	0.30	0.32	0.50*	1.00						
Fe_{DTPA}	-0.63*	-0.60*	-0.12	-0.06	0.12	1.00					
Mn_{DTPA}	-0.63*	-0.62*	-0.29	-0.24	-0.11	0.38	1.00				
Zn_{DTPA}	0.26	0.37	0.80**	0.74*	0.47	-0.02	-0.17	1.00			
Cu_{DTPA}	0.00	-0.02	0.03	0.14	0.12	0.05	-0.03	0.31	1.00		
Ni_{DTPA}	-0.40	-0.41	-0.20	-0.10	0.24	0.57*	0.25	-0.14	-0.04	1.00	
Pb_{DTPA}	-0.30	-0.24	-0.06	0.03	0.13	0.35	0.27	0.02	-0.05	0.25	1.00

In addition, the tillage of soils with a deficit of phosphorus, large amounts of macronutrients are being applied. In that case of Mn^{2+} with orto-phosphoric acid creates a one-two and trivalent salts to very acid soils, in presence of high concentrations of H_3O^+ ions, creating easily soluble primary Mn phosphates. On the other hand, it was proved that, at higher pH values, microorganisms have a particular impact on the availability of Mn, because many of them are oxidized manganese from the divalent to quadrivalent shape (Mn^{2+} to Mn^{4+}), which is unavailable to plants.

The mean value of DTPA-available Zn content is 1.49 mg kg^{-1} with an interval of finding 0.40 to 11.6 mg kg^{-1}. Based on the average Zn content it may be concluded that the analyzed soils are well supplied with available Zn (Ankerman and Large, 1977). If we consider the variation of individual samples, we can conclude that there are two groups of soils: with deficit content whose values < than 1.0 mg/kg, and the content which indicates adequate content of the Zn. Given the fact that most of the samples were acid reaction could be expected more available quantities of this metal. However, as the reserves of the total Zn content in some tested Vertisols are quite small and due to increased acidification and leaching to deeper soil layers, and exporting by plant yields, that means the content of available Zn in these conditions decreases. In our case the reduction goes below 1.0 mg/kg and reaches a minimum value of 0.40 mg/kg. Our results are consistent with the results of other studies (Milivojević, 2003).

Statistically significant coefficients between Zn DTPA available and their basic properties are obtained from the available phosphorus (r=0.80**), available potassium (r=0.74*) and to a lesser extent with humus (r=0.47). In previous studies it has been concluded that the deficient soils readily available Zn content depends on the content of organic matter and available phosphorus content (Milivojević, 2003). It is known that organic matter has a major impact on Zn because it can act as an important regulator of its mobility and availability in the soil if the content exceeds 2% (Kabata-Pendias, 2011).

Mean values of Cu extraction from the soils using DTPA is 3.21 mg/kg, with an interval finding of 0.40 to 32 mg kg^{-1}, the contents of which can range from low to very high values. According to the author (Ankerman and Large, 1977) if the value of 0.005 M DTPA-extractable Cu>2.5 mg kg^{-1}, it is on it's very high content of availability.

A state of Cu in the studied Vertisols can be found out more through mutual correlation between the amount of available content of Cu, the basic chemical and physical properties of soils (Jakovljević *et al.*, 2002). The correlation coefficients between the results for the amount of DTPA-accessible contents of Cu in soil and basic chemical and physical soil properties (Tab. 3) indicate that none of the traits significantly affected the DTPA-extractable contents of Cu. Although this is the acid soil in which it could expect higher mobility of Cu, it is because of its natural origin, because it is tightly bound in the crystal lattice of minerals and is therefore much less movable and available. Similar results have been made by other authors too (Kabata-Pendias, 2011).

The average contents of Ni in this study amounted to 2.76 mg kg^{-1} with an interval finding from 0.20 to 16.8 mg kg^{-1}. Based on the correlation analysis (Tab. 3) showed that almost none of the traits significantly affected the DTPA-extractable content which is suggesting its geochemical origin.

The mean value of available content of Pb in these soils is 2.25 mg/kg. Since Pb is not an element essential to the plants, there are no limits for its available content. However, the obtained values are close to those of other authors (Soon and Abboud, 1990). DTPA-extractable contents of lead showed no dependence of one set of soil characteristics indicating low mobility of this element and its natural content. Soil contamination by lead is mostly of anthropogenic origin, nut the examined sites are not near to the roads and other pollutants lead contamination has not been expected.

CONCLUSIONS

Based on a survey of basic chemical properties and available content of heavy metals (Fe, Mn, Zn, Cu, Ni and Pb) in the production plots of the Kragujevac area, the following can be concluded:

- Most of the soils studied at the locations have acid reaction with a very low content of available phosphorus. Therefore, it is necessary to apply to the soil reclamation measures, in the first line introduction of lime, phosphorus and organic fertilizers

- Average contents of micro-elements (Fe, Mn, Zn and Cu) in the agricultural soils indicate that there is no shortage of these microelements.
- Significant negative correlation between the active and potential acidity and DTPA extracted heavy metal contents have been found for Fe and Mn.
- Statistically significant and positive correlations were found between DTPA-extractable of Zn content and available forms of phosphorus and potassium.
- Examined the physical and chemical properties have not significantly affected DTPA-accessible contents of Cu, Pb and Ni indicating their geochemical origin.

Based on these optimal content of Fe, Mn, Zn and Cu and geochemical origin of Cu, Pb and Ni it can be concluded that the investigated soil is suitable for the health safely food production.

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THE PRESENCE OF HEAVY METALS IN THE NON-AGRICULTURAL SOIL IN THE FERTILIZER FACTORY AREAS IN PANCEVO

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ABSTRACT

This paper presents the results of the measurement of the quality of non-agricultural soil in the industrial areas of the Petrochemical Industry "Petrohemija" and the Fertilizer Factory "Azotara". The samplings were carried out from two depths: 0-30cm and 30-60cm. The sample preparation was performed by the Krishnamurty Method, and the determination of heavy metal content was performed by the atomic absorption spectrophotometry in the flame of acetylene/air. The determined content of heavy metals (zinc, lead, chrome, copper, cadmium) in the soil samples in both locations and from both depths was significantly lower than the maximum allowed value. The location of "Petrohemija" is more polluted compared to the location of "Azotara", because there was established a higher average content of heavy metals. It was established that, in the location of "Petrohemija", there was the highest content of zinc of 36.9 mg kg^{-1} and the lowest content of cadmium of 0.3 mg kg^{-1}.

Keywords: heavy metals, soil, industrial zone, atomic absorption spectrophotometry.

INTRODUCTION

The group of heavy metals consists of those elements whose particle density is greater than $5g/cm^3$ and mostly belongs to the group of transitional "elements of the periodic system (Conti *et al.*, 2000). Some of them are called trace elements or micronutritive elements, given their relatively low content in soils, and the fact that plants need them in small quantities. Other elements that are present in trace amounts, and are non-metallic in nature, are generally seen as soil pollutants. This group of elements most commonly includes: As, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Se, V and Zn. Many industrial facilities emit the mixture of two or more of the foregoing elements. In this way, the air is polluted first, followed by the water and the soil. People living in the areas contaminated by lead and cadmium, take in 30% more of these elements through food (Jakovljević *et al*., 1990) than those from non-polluted areas.

Burning of fossil fuels (coal, oil, oil shale) in industry, transport and households is a significant source of environmental pollution with heavy metals (Jakovljević *et al*., 1990). The air may be polluted by depositional dust (air-sediment), aerosols (soot and smoke), gases and vapors. The degree of air pollution in a region depends on the development of industry, transport and the level of urbanization. By the movement of air masses, pollutants can be transferred far from the source of pollution, because of which their damaging effects are often not limited to a single narrow area (Kiković, 1995).

MATERIAL AND METHODS

The sampling was carried out in the factory areas of "Petrohemija" and "Azotara" on the carbonated chernozem at two depths, 0-30cm and 30-60cm, in April 2009. The samples were air dried and sieved through 2mm, and subjected to the destruction with concentrated nitric acid and hydrogen peroxide. The content of heavy metals was analized on atomic absorption spectrophotometry (Varian Spectra AA220FS) in the flame of acetylene/air (Mickovski Stefanović, 2012). For the assessment of soil contamination with lead, chromium, copper, zinc and cadmium, the "Book of regulations on permitted amounts of hazardous and noxious substances in the soil" (Republic of Serbia, 1994) was used (Tab. 1).

Table 1 Maximum allowed values of heavy metals in soil

Chemical element	*MAV in soil (mg kg^{-1})
lead (Pb)	100
chromium (Cr)	100
copper (Cu)	100
zinc (Zn)	300
nickel (Ni)	50
cadmium (Cd)	2

*MAV – maximum allowed value

RESULTS

The variations in the contents of heavy metals in the non-agricultural soil of the factory areas of “Petrohemija” and “Azotara” are quite pronounced (Table 2). In both locations, the copper content in both depths was significantly less than the maximum allowed value (Jakovljević *et al*., 1987), and they indicate that the copper content in the soils of Vojvodina ranges from 1.85 mg kg^{-1} to 39.85 mg kg^{-1}. In these limits, the values in our study ranged as well.

Table 2 The content of heavy metals in the soil in the factory areas of “Petrohemija” and “Azotara” (mg kg^{-1})

chemical element	Petrohemija			Azotara		
	*D1	*D2	average	D1*	D2*	average
lead (Pb)	7,3	13,0	10,2	5,8	10,4	8,1
chromium (Cr)	20,5	22,3	21,4	14,5	19,3	16,9
copper (Cu)	22,2	48,7	35,5	3,2	22,0	12,6
zinc (Zn)	29,0	44,7	36,9	28,0	36,5	32,3
cadmium (Cd)	0,3	0,2	0,3	0,1	0,1	0,1

*D1 – depth 0-30cm; D2 *– depth 30-60cm.

In the location of “Petrohemija”, the average copper content was significantly higher (35.5 mg kg^{-1}) in relation to the location of “Azotara” (12.6 mg kg^{-1}). Also, on both sites, the content of this element measured at the greater depth was significantly higher compared to the smaller one: “Perohemija”: D1-22.2 mg kg^{-1}, D2-48.7 mg kg^{-1}; “Azotara”: D1-3.2 mg kg^{-1}, D2-22.0 mg kg^{-1}.

The lead content in both locations, on both depths, was significantly less than the maximum allowed value. In the location of “Petrohemija”, the average lead content was significantly higher (10.2 mg kg^{-1}) in relation to the location of “Azotara” (8.1 mg kg^{-1}). Also, a higher content of this element was measured at the greater depth than the smaller one in both locations: “Perohemija”: D1-7.3 mg kg^{-1}, D2-13.0 mg kg^{-1}; “Azotara”: D1-5.8 mg kg^{-1}, D2-10.4 mg kg^{-1}.

The prescribed upper allowed concentration of chromium in the countries of the European Union is 30-75 mg kg^{-1} (Williams, 1988). Ubavić *et al*. (1993) report that the average content of chromium in the soils of Vojvodina is 29.9 mg kg^{-1}. The concentration of chromium in both locations at both depths is considerably less than the maximum allowed value. The average chromium content was significantly higher at the location of “Petrohemija” (21.4 mg kg^{-1}) in relation to the location of “Azotara” (16.9 mg kg^{-1}). The results obtained show that the higher chromium content had been measured at the greater depth in both locations: "Petrohemija": D1-20.5 mg kg^{-1}, D2-22, 3 mg kg^{-1}; "Azotara": D1-14.5 mg kg^{-1}, D2-19.3 mg kg^{-1}.

The average zinc content was higher in the location of "Petrohemija" (36.9 mg kg^{-1}), in relation to the location of "Azotara" (32.5 mg kg^{-1}), and the values are significantly less than the maximum allowed value. The results obtained show that the higher content of this element had been measured at the greater depth in both locations: "Petrohemija": D1-29.0 mg kg^{-1}, D2-44.7 mg kg^{-1}; "Azotara": D1-28.0 mg kg^{-1}, D2-36.5 mg kg^{-1}. Kabata-Pendias *et al*. (1989) report that the average content of total zinc in the surface layers of different soil types in the world is from 17 mg kg^{-1} to 125 mg kg^{-1}.

The cadmium content in both locations, at both depths, was significantly lower than maximum allowed value. According to research (Ubavić *et al*., 1993), the average content of total cadmium in the soils of Vojvodina is 0.48 mg kg^{-1}. In the location of "Petrohemija", the content of this element was significantly higher (0.3 mg kg^{-1}) in relation to the location of "Azotara" (0.1 mg kg^{-1}). Also, on the location of "Petrohemija", a higher content was measured at the lower depth than the higher (D1-0.3 mg kg^{-1}, D2-0.2 mg kg^{-1}), whereas, in the location of "Azotara", the content was identical at both depths (D1-0.1 mg kg^{-1}, D2-0.1 mg kg^{-1}).

DISCUSSION

Based on the results of the research of the impact of the industrial zone on the level of the content of heavy metals in the soil, it can be said:

The total content of copper, lead, chromium, cadmium and zinc in the soil is greater in the location of the factory "Petrohemija" in relation to the location of the factory "Azotara". The soil samples from the depth of 0-30cm from the area of the factory "Azotara" had the least amount of cadmium, copper and lead, and a higher content of chromium and zinc. The soil samples from the depth of 30-60cm from the area of the factory "Azotara"had the least amount of cadmium and lead, a slightly higher chromium and copper content, and the highest zinc content. The soils from the depth of 0-30cm from the area of the factory "Petrohemija" had the least amount of cadmium and lead and a significantly greater amount of chromium, copper and zinc. The soil samples from the depth of 30-60cm from the area of the factory "Petrohemija" had the lowest quantity of cadmium and lead, a somewhat larger amount of chromium, and the highest content of zinc and copper.

The determined content of all the examined heavy metals is below the maximum allowed concentrations prescribed by the "Book of regulations on permitted amounts of hazardous and noxious substances in the soil".

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MONITORING OF SOIL AND VEGETABLE GROWTH IN PANCEVO

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ABSTRACT

The paper analyzes the characteristics of soil for growing vegetables on the territory of Pancevo. Since there is high level of emission of acid oxides, heavy metals and other toxics in nearby industrial zone, possible accumulation in environmental resources and plant material has been studied. Following indicators of quality have been studied: soil fertility, presence of heavy metals and metalloids in soil and vegetables. According to the analyses of all relevant parameters, the overall state of fertility shows that ¾ of the area have values that indicate highly fertile soil. Established values of heavy metals and metalloids in each sample of soil analyzed were lower compared to the regulations of maximum levels (in average Cd 0,77, Pb 19,93, Hg 0,24, As 2,33, Cr 26,42, Ni 33,21, Cu 22,92, Zn 73,86 mg kg^{-1}). Current regulations on maximum levels specify reference values for 4 elements (Pb, Cd, Hg and As) and samples of vegetables from various locations in Pancevo had lower values than specified (in average Pb <0.05, Cd<0.03, Hg<0.02, As<0.01 mg kg^{-1}). Values of elements that were subject to the analysis but not specified by the Republic of Serbia regulations are lower than specified in documents. Results obtained indicate that conditions for growing vegetables on the territory of Pancevo are favourable regardless possible sources of environmental pollution.

Keywords: soil, vegetables, soil fertility, heavy metals

INTRODUCTION

For long time, the territory of Pancevo has been exposed to numerous effects that may negatively influence the quality of agriculture soil; furthermore the quality of agricultural products of vegetable origin grown on such soil. The town of Pancevo in its periphery i.e. industrial zone has increased emission of acid oxides, heavy metals and other hazardous and toxic materials as well as their possible accumulation in natural resources. On the other hand, besides existing developed industry people in greater area of the town (around 85%) are engaged in basic agriculture which must be done in a way to provide products safe for health. Hence, in order to develop agricultural production of high quality there must be determined the quality of agricultural soil and water resources of the territory of Pancevo.

Total area of the soil in Pancevo is 75 627ha. Diversity of soil in its features (physical, chemical and biological) is primarily conditioned by expressed relief and altitude 67-150m. This powerful pedogenetic factor affected making numerous types of soil. The most frequent is chernozem soil with 70.45% (it has the most productive soil capacity), then marsh black soil 15.49%, alluvium 9.70%, meadow black soil 4.29% and marsh soil 1.23%.

Permanent sources of contamination by *Chromium (Cr)* and *Cadmium (Cd)* are related to its implementation in industry (Bogdanović *et al*., 2007; Pavlović *et al*., 2007). As a significant contaminator of agricultural soil in Cd and Cr , mineral fertilizers are indicated phosphorous fertilizers (Bogdanović at al., 2007; Ubavic *et al*. 1995). *Lead (Pb)* as a pollutant substantially comes from various industry plants, Accumulation of lead in superficial layer of soil reduces enzyme activity of microorganisms the consequence of which may be incomplete decomposition of organic materials (Pavlović *et al*., 2007). Accumulation, as well as toxicity of *Arsenic (As)* is higher in acid soil. In heavier soils arsenic toxic effect occurs more rarely than in sandy soil, since in former arsenic is more easily absorbed. Polluting the environment with *Mercury (Hg)* are industries that use it in the technical process of production and waste the mercury residue into waste waters. (Kastori, 1997). *Nickel (Ni)* reaches soil by anthropogenic ways (mines, metal smeltery, traffic, waste mud, pesticides, fertilizers and liquid manure etc.). Mobility of Ni in soil is increased as pH is reduced as well as by reducing capacity for ion exchange (Nikolić *et al*., 2011., Bogdanović *et al*., 2007). Ratio of *Zinc (Zn)* in nonagricultural soil is above MRL (Vasin *et al*., 2004). Nourishment reduces N-NO3 and N-NH4 increases iron consumption. Surplus of iron in soil rarely occurs with the exception of very acid and poorly perspicuous soil where toxic effect of iron surplus is possible (Bogdanović *et al*., 2002). In neutral and alkaline soil there may occur lack of *Manganese (Mn)* in conditions of which fertilizing the soil using this element may contribute to good yield. The manganese content is higher in plowed layers of soil, heavier and carbonated soil. In light, sandy soil deficit of bio approachable manganese more often occurs (Ubavić *et al*., 2002). This fact point to the need to check the status of agricultural soil the town of Pancevo since it is near industrial complex.

Plants absorb heavy metals primarily via roots from soil dilution; while they are absorbed via landline parts to less extent. Heavy metals may residue from the air via dry and wet ways as well as diffusion. A minor part of residues remains on plants, leaves in particular while greater part remains on the surface of soil. Due to its consistency, heavy metals are accumulated in soil where plants absorb them from via their roots. A part of heavy metals that retain residues on leaves is absorbed, while other parts may be washed by rain. Elution depends on the level of solubility. Absorption of elements by plants depends on physiological characteristics of plant itself, growing conditions, characteristics of soil, meteorology conditions and particularly on the ratio of fertilizers used. Mobility of contaminants depends on their type and pH value of soil.

MATERIAL AND METHOD

Monitoring conditions of soil and effects on vegetable plants on the territory of the town of Pancevo has encompassed the most significant spots for growing vegetables on the territory of Pancevo: Pancevo (9 samples), Banatski Brestovac (3 samples) and Glogonj (1 sample).

- Monitoring soil and keeping record about locations the samples shall be gathered from
- Sampling soil (13 samples) at the depth from 0 to 30 cm for the purpose of chemical testing the soil, examining content of heavy metals and metalloid
- Sampling agricultural plants (49 samples) once a year in accordance with the calendar of full physiological ripe of the product to be tested. Percentage of vegetable plants presence in vegetable samples is as follows: cucumber 49%, lettuce 2%, cabbage 4%, broccoli 2%, zucchini 4%, parsley 2%, pepper 41%, potato 11%, tomato 10%, garlic 6%, melon 2%, cauliflower 2%,

kohlrabi 2%, leek 2%, onion 4% of heavy metals and metalloid content.

RESULTS

Parameter testing results of soil fertility in sampled areas – locations of growing vegetables

Chernozem on meadow soil/loess

This type of soil covers the area of 29.333 ha i.e. 38.78% of the area on the total cultivated area of Pancevo,. It covers the largest area and the lowest parts of the relief in all chernozem subtypes which led to appearance of meadow soil/loess under the influence of subsurface water. In extremely arid years it gives the greatest yield. Textural composition is clay loam – loam. On this subtype of chernozem 6 samples have been sampled and analyzed; samples no. 6,7,8,9,10,11.

Agrochemical features of chernozem on meadow soil / loess

Response of the pH of soil (KCl) is 6.88 in average which matches neutral reaction. Out of all soil types, only chernozem on loess is in optimal interval of pH value (6.60–7.20). Content of CaCO3 is 1.99% in average which indicates low carbonate status of the soil. The soil is non-carbonated (<1.00%) in profiles 7,8 and 9 while the highest content of CaCO3 which amounts 5.01% can be found in profile 9. Higher concentration of CaCO# in profile no.9 is the result of notably higher altitude. Content of humus is high; it is 3.99% in average. Compared to meadow black soil, this is the highest content value of humus. Easily absorbed P_2O_5 is in the limit of low and average absorption with the average value of 14.48 mg 100 g^{-1}. The lowest value is 1.6 mg 100 g^{-1} only in profile no.8 (cadastre area Pancevo) which corresponds ameliorative level of phosphorous while the highest value of 52.0 mg 100 g^{-1} can be found in profile no. 9 (cadastre area Pancevo). Easily absorbed K_2O is 36.7 mg 100 g^{-1} in average which matches the value of high content of potassium in soil. Out of all soil types, chernozem on loess has the highest average value of potassium; the lowest value of 21.7 mg 100 g^{-1} can be found in profile no. 13 (cadastre area Glogonj).

Chernozem on loess terrace

It covers the area of 10,871 ha i.e. 22.38% of the total cultivated area of the town of Pancevo. It covers the parts of the relief from 90 to 100m and it has the greatest productive value compared with all other types of soil. Deep humus-accumulative horizon overreaches 120m regularly. The texture is mostly clay and the structure is stabile blobby-crumbly (dominant fractions of sand and dust) which conditions solid water, air, temperature and microbiological regime of the soil. 2 samples represent this subtype of chernozem and they are samples no. 11 and 12.

Agrochemical features of chernozem on loess terrace

Response of the soil pH (KCl) amounts 7.06 in average which matches low alkaline response. The lowest value of 6.89 can be found in profile no. 11 (cadastre area Pancevo) while the highest value is present in profile no. 12 (cadastre area Pancevo) and it amounts 7.23. The content of CaCO3 of 8.56% indicates that the soil is low carbonated. The content of humus is 3.43% in average which classifies this type of soil the third position on the rank list. The content of total nitrogen is 0.212% in average so the average value of total nitrogen of chernozem on loess terrace ranks this type of soil as the second on the ranking list. Easily absorbed P2O5 with the average value of 20.4 mg 100 g^{-1} matches the optimal level of sufficiency. The content of easily absorbed K2O is 19.74 mg 100 g^{-1} in average which also matches the optimal sufficiency of this nutrition.

Meadow black soil

It covers the area of 3248ha (4.29% of the total area). Besides chernozem, it is the only type of soil which does not require applying pedomeliorative measures. It covers parts of the relief from 80 to 90m altitude hence it is at the crossing line between chernozem on meadow soil/loess and chernozem loess terrace. Regarding mechanical composition, texture of clay loam predominates. As for this type of soil, fractions of dust dominate comparing to sand and clay. As about texture composition, it is predominantly loam. Out of this soil subtype, 2 samples have been sampled and analyzed (samples no. 2 and 3).

Agrochemical features of meadow black soil

Response of soil pH (KCl) is 7.25 which match low alkaline response and it is very close to optimal level (6.50-7.20). the content of Ca CO3 is 2.51 in average which matches average carbonated soil. Out of all soil types, meadow black soil has the lowest average values of Ca CO3. The content of humus is average-high and it amounts 4.05% which means that meadow black soil has the average values of humus content. The content of total nitrogen is 0.1902% in average. The content of easily absorbed P2O5 is 8.95 mg 100 g^{-1} in average which is the lowest value compared to any type of soil. In profile no.3 (cadastre area Brestovac), there is only 2.7 mg 100 g^{-1} which corresponds to ameliorative level. The content of K2O is 20.45 mg 100 g^{-1} in average.

Marsh black soil: Varieties, both carbonated and non-carbonated, cover the area of 10 781 ha (14.2% of the total area). It covers the lowest parts of the relief. Humus-accumulative horizon can be soaked to 50cm only while the terrain is sandy. Loam texture predominates while sandy loam and clay loam are partly present. As for this type of soil, there dominate fractions of dust and clay. Texture composition is sandy, dusty and clay loam. Sample no. 4 represents marsh black soil.

Agrochemical features of marsh black soil

Response of soil pH (KCl) is 7.32 which are around the limit of alkaline and neutral response. The content of CaCO3 is 7.52% in average. The content of humus is 3.41% in average which matches types of soil with humus. The content of total nitrogen is 0.130%. Easily absorbed P2O5 is at lower limit of optimal sufficiency – 17.0 mg 100 g^{-1}. The content of easily absorbed K2O is 15.2 mg 100 g^{-1} in average

Alluvium: It covers 7 336 ha (9.70% of the total area). Those are areas by the Danube and the Tamis rivers. They are characteristic for the lightest mechanical composition. It appears in sample no.5. As for this type of soil, fractions of fine sand and grit predominate. Texture composition is sandy loam. In this sample, there has been noted rather high values of phosphorus, so this area is not recommended for growing vegetables especially bearing in mind that this is the area of industrial zone of the town of Pancevo.

Agrochemical features of alluvium

Response of pH is 7.50 in average which matches weak alkaline repsonse. The content of CaCO3 is 10.23% in average which classifies this type of alluvium into carbonated soil. Out of all soil types, alluvium has the lowest content of humus; the tested sample shows 2.47 which indicates light mechanical structure of the soil. The content of total nitroge is 0.098% only. Concentration of easily absorbed P2O5: profile no.5 shows high concentration which amounts 150 mg 100 g^{-1}; the value of K2O is 14.7 mg 100 g^{-1}.

Marsh soil: Marsh soil covers the lowest parts of the relief (67 – 70 m altitude) and it stretches in the cadastre area of Banatski Brestovac only. It is characteristic for the heaviest mechanical composition which considerably lessens productivity capacity. Marsh soil is presented in one sample only (sample no.1).

Agrochemical features of marsh soil

Response of pH amounts 7.62 which matches weak alkaline response; note that this is the highest value of response comparing any type of soil. The content of CaCO3 is 13.41% which classifies this type of soil into poorly carbonated. With the concentration of 3.37%, marsh soil belongs to the humic type of soil. The content of total nitrogen is 0.139% while the content of vegetable assimilative phosphorous and potassium is 15.2 mg i.e. 12.1mg which is at the level of average and optimal sufficiency.

Hazardous and toxic materials in soil in tested samples in the area of the town of Pancevo

Table 1: Total concentration of heavy metals in tested samples of the territory of Pancevo

Sample	Cu	Cd	Cr	Pb	Zn	Ni	As	Hg	Mn	Fe
					mg kg^{-1}					%
1	25.70	1.08	53.87	24.98	93.94	35.62	1.85	0.18	596	2.76
2	24.73	0.84	35.81	23.93	77.06	40.81	1.64	0.14	758	3.50
3	16.56	0.92	24.57	14.68	53.93	31.55	1.80	0.13	519	2.28
4	23.77	0.71	26.61	23.41	81.12	39.56	2.01	0.54	731	3.58
5	20.61	0.77	21.00	16.44	62.73	32.94	3.03	0.43	851	2.95
6	20.29	0.75	19.33	16.48	62.44	32.62	1.82	0.45	673	2.89
7	20.32	0.76	16.39	16.98	59.80	29.91	2.77	0.21	700	3.15
8	22.12	0.78	42.61	17.34	68.25	30.56	1.68	0.19	699	3.01
9	28.48	0.72	20.90	21.65	82.50	37.33	2.87	0.18	824	3.79
10	20.96	0.70	19.24	18.98	68.24	30.36	2.83	0.18	745	3.08
11	22.81	0.69	18.74	17.67	80.27	29.07	1.77	0.18	603	3.54
12	25.06	0.62	19.36	23.96	89.79	31.64	1.29	0.20	562	3.91
13	26.60	0.64	25.06	22.62	80.17	29.84	5.03	0.17	768	3.64
Max	28.48	1.08	53.87	24.98	93.94	40.81	5.03	0.54	851	3.79
Min	16.56	0.62	16.39	14.68	53.93	29.07	1.29	0.13	519	2.28
Aver	22.92	0.77	26.42	19.93	73.86	33.21	2.33	0.24	694.5	3.23
MAC	Up to 100	Up to 3	Up to 100	Up to 100	Up to 300	Up to 50	Up to 25	Up to 2	-	-

World Health Organization has developed range studies that consider and indicate hazardous effects of heavy metals on humans' health . Maximum residue level (MRL) of heavy metals in limited layer of soil is the one expressed in mg kg^{-1} which does not affect (directly or indirectly) negative influence on environment having contact with soil, humans' health as well as the ability of self-purification of soil. Maximum residue level of heavy metals in soil along with its division into hazardous and toxic materials has been published in Rules and Regulations of maximum allowable concentration of hazardous and toxic materials in soil and water used for irrigation and testing methods "Sl.Glasnik RS" no. 23/94 and they are shown in Table 18. Set quantity in each tested sample is considerably lower than current MRL. Furthermore, in all tested samples, although the set content of Ni is below maximum allowable concentration indicated in the Rules and Regulations, it has been spotted that all values are above one half of MRL values which should be subjected to further research. According to the data listed in the literature and related to the concentration of Manganese (Mn) in soil anywhere in the world it is 200-1000 mg kg^{-1} in average, as about iron (Fe) between 0.5 and 4.0% which indicates that sampled soil from the territory of the town of Pancevo is in the range of standard limits (Bogdanović *et al*., 2002).

Content of heavy metals in vegetable samples in the territory of the town of Pancevo

Results indicate that values of heavy metals (As, Pb, Cd, Hg) in samples of vegetables are below MRL stated by the Rules and Regulations of the maximum allowable concentration of residue of chemicals used for protection of plants for nutrition and food for animals as well as for food and food for animals that the maximum allowable concentration of residue of chemicals used for protection of plants is set for "Sl.Glasnik RS" no. 25/10 and 28/1. Values of the elements (Cu, Fe, Mn in vegetables) subjected to the analysis but not set by the law and regulations of the Republic of Serbia are lower than data stated in literature. According to the literature data, concentration of copper in plant products which is above 15mg kg^{-1} indicates high concentration of this element; toxicity limit for Fe is 400-1000ppm (500ppm in average) and average concentration of manganese in plants is 50-25-ppm (Bogdanović *et al.,* 2002). Any analyzed samples contained lower values of heavy metals compared to the stated values

Table 2. Concentration of heavy metals in vegetable samples

No.	Vegetable	As	Cu	Zn	Fe	Cd	Mn	Pb	Hg
					mg kg^{-1}				
1.	Zucchini	< 0.10	< 1.00	2.81	5.43	< 0.05	1.11	< 0.047	< 0.02
2.	Parsley	< 0.10	1.96	5.33	9.25	< 0.05	5.26	< 0.060	< 0.10
3.	Cucumber	< 0.10	< 1.00	0.94	3.16	< 0.05	< 0.5	< 0.05	< 0.10
4.	Pepper	< 0.10	< 1.00	0.77	5.30	< 0.05	< 0.5	< 0.05	< 0.10
5.	Pepper	< 0.10	< 1.00	0.86	3.40	< 0.05	< 0.5	< 0.05	< 0.10
6.	Pepper	< 0.10	< 1.00	0.81	6.75	< 0.05	< 0.5	< 0.05	< 0.10
7.	Pepper	< 0.10	< 1.00	0.60	4.82	< 0.05	< 0.5	< 0.05	< 0.10
8.	Pepper	< 0.10	< 1.00	0.70	5.16	< 0.05	< 0.5	< 0.05	< 0.10
9.	Cucumber	< 0.10	< 1.00	0.90	3.16	< 0.05	< 0.5	< 0.05	< 0.10
10.	Pepper	< 0.10	< 1.00	< 0.5	7.14	< 0.05	< 0.5	< 0.05	< 0.10
11.	Tomato	< 0.10	< 1.00	1.18	5.55	< 0.05	< 0.5	< 0.05	< 0.10
12.	Garlic	< 0.10	< 1.00	1.05	1.31	< 0.05	< 0.5	< 0.05	< 0.10
13.	Tomato	< 0.10	< 1.00	0.82	4.92	< 0.05	< 0.5	< 0.05	< 0.10
14.	Pepper	< 0.10	< 1.00	1.06	5.89	< 0.05	< 0.5	< 0.05	< 0.10
15.	Tomato	< 0.10	< 1.00	0.96	5.70	< 0.05	< 0.5	< 0.05	< 0.10
16.	Potato	< 0.10	< 1.00	1.72	13.43	0.060	1.93	< 0.05	< 0.10
17.	Onion	< 0.10	< 1.00	2.10	1.71	< 0.05	1.63	< 0.05	< 0.10
18.	Garlic	< 0.10	< 1.00	1.21	1.50	< 0.05	< 0.5	< 0.05	< 0.10
19.	Melon	< 0.10	< 1.00	1.25	4.75	< 0.05	< 0.5	< 0.05	< 0.10
20.	Pepper	< 0.10	< 1.00	1.11	6.09	< 0.05	< 0.5	< 0.05	< 0.10
21.	Pepper	< 0.10	< 0.4	0.78	4.55	< 0.01	1.03	< 0.05	< 0.03
22.	Pepper	< 0.10	< 0.4	0.42	4.08	< 0.01	0.341	< 0.05	< 0.03
23.	Pepper	< 0.10	< 0.4	0.71	4.75	< 0.01	1.40	< 0.05	< 0.03
24.	Pepper	< 0.10	< 0.4	0.70	3.30	< 0.01	1.35	< 0.05	< 0.03
25.	Potato	< 0.10	< 0.4	1.84	8.97	< 0.028	2.11	< 0.05	< 0.03
26.	Pepper	< 0.10	< 0.4	0.90	3.57	< 0.003	1.79	< 0.05	< 0.03
27.	Pepper	< 0.10	< 0.4	0.53	4.29	< 0.01	1.20	< 0.05	< 0.03
28.	Pepper	< 0.10	< 0.4	0.60	3.65	< 0.01	1.73	< 0.05	< 0.03
29.	Cauliflower	< 0.10	< 0.4	0.99	2.77	< 0.01	1.85	< 0.05	< 0.03
30.	Zucchini	< 0.10	0.38	2.13	3.11	< 0.01	2.08	< 0.05	< 0.03
31.	Hot pepper	< 0.10	< 0.4	0.75	3.02	< 0.01	2.85	< 0.05	< 0.03
32.	Potato	< 0.10	< 0.4	2.15	18.63	0.023	2.13	< 0.05	< 0.03
33.	Pepper	< 0.10	< 0.4	1.03	4.29	< 0.01	2.07	< 0.05	< 0.03
34.	Potato	< 0.10	< 1.00	2.10	12.88	< 0.01	1.35	< 0.05	< 0.03
35.	Onion	< 0.10	< 0.4	2.17	5.16	< 0.01	3.40	< 0.05	< 0.03
36.	Kohlrabi	< 0.10	< 0.4	1.18	3.37	< 0.01	1.09	< 0.05	< 0.03
37.	Garlic	< 0.10	< 0.4	2.40	3.17	< 0.01	2.48	< 0.05	< 0.03
38.	Cabbage	< 0.10	1.65	2.48	2.45	< 0.01	2.09	< 0.05	< 0.03
39.	Tomato	< 0.10	< 0.4	1.17	3.42	< 0.01	1.80	< 0.05	< 0.03
40.	Lettuce	< 0.10	1.96	4.51	21.23	< 0.01	1.35	< 0.05	< 0.03

DISCUSSION

By analyzing all six parameters of soil fertility at sufficiency levels we may conclude that the territory of the town of Pancevo has rather high fertility. Out of total number of observation, 10 locations have high fertility, 2 of them have average fertility while only one location has low fertility. High soil fertility is present in chernozem and meadow black soil types; average and low fertility in soil types of marsh soil, alluvium and marsh clay soil which means that high soil fertility on the territory of the town of Pancevo is present at more than ¾ of the area and hence good yield of agriculture plants may be achieved. The content of heavy metals in soil is such that it enables production of food safe for health. Testing results have been interpreted referring to the Regulations on allowable presence of hazardous and toxic materials in soil and water and methods used for testing it "Sl Glasnik RS" no.23/94 according to which it has been concluded that all obtained results are notably lower than MRL stated in the Regulations.

Determined content of heavy metals in samples of vegetables taken from different locations in Pancevo are considerably lower MRL stated in the Regulations of maximum residue level of chemicals used for protecting plants grown for food and food for animals that the maximum allowable content of such residues is set "Sl.Glasnik RS"25/10 and 28/11.

Although the obtained results are encouraging, it is of an utter importance to systematically monitor pollution of soil as well as vegetable products grown on it with the aim of forming and filling database with the information about the level and characteristics of such pollution and the types of present pollutants, too.

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PRAVILNIK o dozvoljenim količinama opasnih i štetnih materija u zemljištu i vodi za navodnjavanje i metodama njihovog ispitivanja "Službeni Glasnik RS" broj 23/94

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"AGRO KAPILARIS"– A REVOLUTION IN IRRIGATION

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ABSTRACT

After twenty years of research on hydro-physical properties of the soil, the author of the proposed innovation has explored and developed an original concept of delivering the optimum amount of water to the plans. This method is classified as sub-surface irrigation. This method was named "Agro kapilaris" as the water is delivered to plants in the form of rising damp. The main characteristics of the concept of "Agro kapilaris", which distinguishes it from all other existing irrigation methods, are: High energy efficiency (very low working pressure - low energy consumption); Long life of the system (predicted life span over 50 years); Low water consumption (evaporation losses are minimized); High ecological safety while performing fertirrigation; Applicability to small plots, as well as on the large complexes; Applicability for irrigation as well as for drainage. In conditions of extreme drought in 2012 year, the system installed on an experimental plot showed excellent results for various agricultural plants, indicating possibilities of use of Agro kapilaris in semi arid, arid and desert conditions.

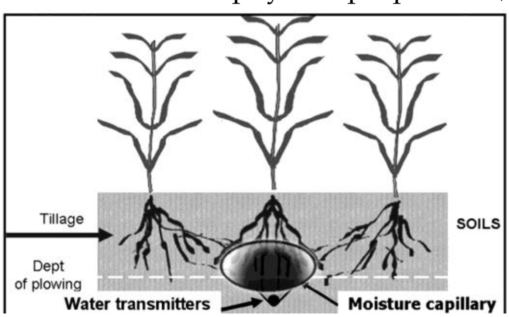
Keywords: "Agro kapilaris", subsurface irrigation, energy efficiency, drainage

INTRODUCTION

As a way to provide water for the plant, subsurface irrigation has advantages in comparison with surface irrigation. But due to some unresolved problems, the subsoil irrigation nowadays is not widely used (Huang P.N., *et al*.).

After twenty years of research and experimental work on water-physical properties of soil, the author designed a concept for subsurface capillary irrigation named “Agro kapilaris”. This new concept helps to overcome nearly all potential problems of underground irrigation systems.

By form, this concept may be classified as subsurface irrigation where the emitters are placed in a parallel manner at specific distance, bellow the land treatment depth. The huge difference with the application of the “Agro kapilaris” concept, is that water is distributed under very low pressure, using specifically constructed water transmitters. There is no other existing irrigation system functions under the working pressure of 0.2 bars and in the energy efficiency sense, it is considered as the most economical. The “Agro kapilaris” concept is a new approach in thinking when it comes to irrigation and plant – soil – water and air interactions**.** The plant is permanently provided with optimal amounts of water in the form of capillary moisture where the soil radially, ascendantly and laterally distributes moisture using capillary energy. The potential of the humid front is constant all along the transmitter and during the whole growing season. The humid front is elliptical with its core in the humidity transmitter. The size of a humid front depends on the type of soil, namely, mechanical content, structure, humus content and other water – physical properties. *(Scheme 1).*



Scheme 1. The humidity transmission in the root zone

The most distinguishable about the “Agro kapilaris” concept and what makes it unique is the improbability of obstruction, which is a condition for a long time of exploitation. According to current findings, a lifespan of this system is 70 years. According to our current test results and experiments, it is certain that this concept will take first place in providing plants with necessary moisture, which is a vitally important factor for sustainable agricultural production.

MATERIALS AND METHODS

Location of the experimental plot and soil typology

The location of the experiment is in Srem – Boljevci near Belgrade. The type of soil is chernozem in the process of leaching on the first loessial terrace *(Photo 1)*

Research experimental phase

After all the preliminary laboratory and field tests, in 2001 the experiment in field conditions was initiated. In the experiment the two moisture transmitters, 20m long, were placed at a distance of 2m. Different solutions were applied to these transmitters: one with medium pressure, the other with extremely low pressure, where the latter showed better perspectives and became the concept of “Agro kapilaris”.

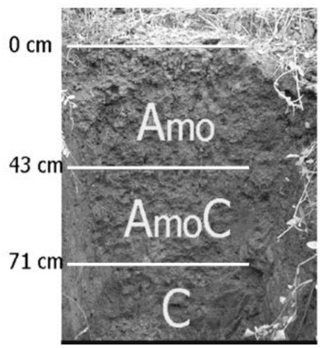


Photo 1. Chernozem in the process of leaching on the first loessial terrace

Experimental work was conducted until 2008 with under corn for two years, soy bean for two years, and alfalfa for four years.

The 8 year experiment confirmed the basic idea of the “Agro kapilaris” concept which says that the moisture transmitters cannot be obstructed: neither by the root system, soil particles, nor by the chemistry of irrigation water. This was the basis for the continuation of research and further elaboration of the concept. *(Photo 2,3 and 4)*

Photo 2. Herbal biomass of alfalfa in the “Agro kapilaris” experiment

Photo 3. Herbal biomass of soya in the “Agro kapilaris” experiment

The experimental part and experiments

The officially recognized methodology of parallel monitoring of differences with input and output parameters have been used, applying various irrigation types: dripping, sprinkling and the Agro kapilaris concept. Various hydro-physical soil analysis, agrochemical and microbiological analysis have been performed. The experiments monitored the irrigation effects in classic and organic production conditions. During the experiments with the Agro kapilaris irrigation concept, 1000 liter tanks were used. They were elevated above the ground with the water level creating an operating pressure ranging from 0,25 to 0,15 bars..

Standard equipment was used with the classic irrigation systems such as dripping and sprinkling. With the Agro kapilaris irrigation concept, moisture transmitter models were made using semi-mechanic methods. The system was buried into the ground mechanically and manually. With the mass use of the Agro kapilaris concept, factory lines will be used to manufacture moisture transmitters and machines for direct installation into the ground.

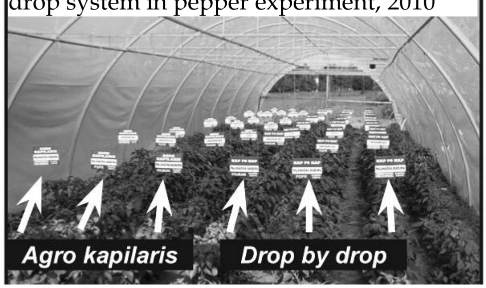
RESULTS AND DISCUTTIONS

Experiments in a protected environment

During the continuation of the research from 2009 until 2011, the experiment in a protected environment was initiated. It took place in a 20x5.5m tunnel-like greenhouse. Due to the water consumption requirements, pepper was selected as an experimental culture. After parallel monitoring of the effects of the “Agro kapilaris” concept and the “Drop by drop” system, in regards with the development of pepper the following significant findings were obtained (*Photo 5*).

Photo 4. Herbal biomass of maize in the “Agro kapilaris” experiment, 2001

Photo 5. “Agro kapilaris” and “Drop by drop system in pepper experiment, 2010



- The "Agro kapilaris" concept helps to develop a strong root system under all conditions. Due to the availability of water on the land surface, using the "Drop by drop" system the plant doesn't need to develop a strong root system.
- Unlike the "Drop by drop" irrigation, which presses the soil and degrades the structure after an extended period, "Agro kapilaris" maintains the structure of the soil and leaves it unaltered. Therefore, it preserves the soil as an invaluable natural resource. (*Photo 6 and 7*)

Photo 6. The pepper root system in the "Agro kapilaris" system and degraded soil structure

Photo 7. The pepper root system in the "Agro kapilaris" system and

Photo 8. Setting up the "Agro kapilaris" system, 2010.

- The dripping system is considered to be the most rational with a controlled dosage of the irrigation water. Usually, the watering norms are determined by man, based on his own assessments or various calculation methods. The "Agro kapilaris" concept is one step further. The capillary moisture front is formed in the soil without the loss of water, and the plants absorb the easily available water. The soil absorbs such an amount of water form the transmitter that is needed for plant. Thus, this is a self-regulating mechanism. This is a brand new quality in the norms for watering, because the plants itself define it very precisely with their water consumption–evapotranspiration requirements.

Experiments in the open

On the experimental plot conducted, in 2010, the 500m long “Agro kapilaris” model was set. There were 5 parallel moisture transmitters, 100 m in length with a distance of 105cm. The burial depth was between 20 and 40 cm. Around 80% of moisture transmitters were buried at 30 cm depth *(Photo 8).*

The experiments were conducted from 2010 until 2012 simultaneously observing the irrigation effects of “sprinkling” and the “Agro kapilaris” concept on vegetable and crop production, simulating commertial scale conditions. In farming conditions, tests were run on: pepper, tomato, cucumber, zucchini, melon and green beans. In crop conditions, the following were included: maze, soya, sunflower, sugar beet.

In this experiment, the plot was divided to approximately 1.2 acre partitions. Within these partitions, 0.5 acre surfaces were watered by sprinklingč 0.5 acres under “Agro kapilaris” and 0.2 acres without irrigation.

After three years of research in the open field, very useful experience has been gained regarding the use of a new irrigation concept called “Agro kapilaris”:

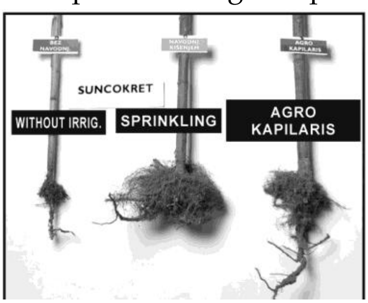


Photo 9. The sunflower root system, under different irrigation techniques, 2012

- The plant root system develops in deeper layer with the use of the “Agro kapilaris” system, while with the surface irrigation, it develops in the shallow surface. In severe and extreme drought years, such as 2012, due to very high evaporation and substantial moisture loss in the soil, the shallow root system remains without necessary moisture until the next watering. This not only affects the development of the plant mass, but the final yields as well. With the “Agro kapilaris”, during precipitation the strong root system uses moisture also from the soil surface *(Photo 9)*
- Farm crops consume the capillary moisture from the “Agro kapilaris” system very well. This primarily refers to soybean and sugar beet. According to the experimental results, the yields for

these two crops approaching their genetic potentials. Sunflower also responses well to capillary moisture, but because of the bird attack, we don't have numeric results. Studies of these two crops showed that in high temperature conditions, irrigation by sprinkling is not preferred. The plants experience temperature shocks and are susceptible to diseases *(Photo 10 and 11)*. Corn also uses capillary moisture well, but in contrast to soybean, sugar beet and sunflower, its growth is less affected by the sprinkling system.

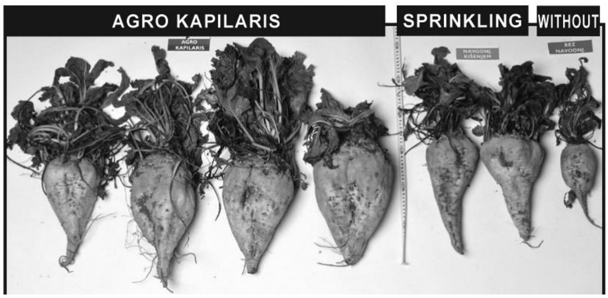


Photo 10. Surag beet roots under different irrigation techniques, 2012

- Vegetables with shallow root systems, such as peppers, require specific agro-technical measures during planting. In order to achieve good crop yield, deep planting is necessary for the root system to be as close as possible to the capillary moisture.

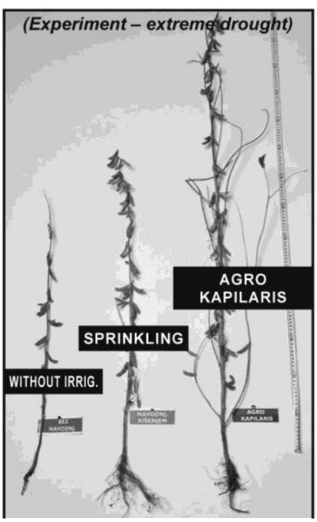


Photo 11. Soya bean root systems under different irrigation echniques, 2012

- Vegetables with "aggressive" root systems, such as tomato, don't require such deep planting. During the experiment in 2012, the "Agro kapilaris" system proved that density of planting, which exceeds one linear meter, may be doubled up to 6 plants per linear meter in contrast to the commercial growing with sprinkling irrigation system with 3 plants per linear meter. Thanks to the planting density and good yields per plant using the "Agro kapilaris" system, the total tomato yields substantially exceeded the yields of tomato under sprinkling (Zloh *et al*., 2013).

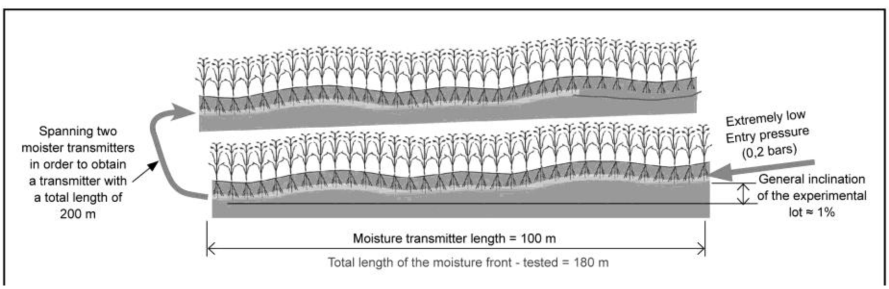
The mechanisms of the “Agro kapilaris” concept:

The basic idea of the “Agro kapilaris” concept is to supply plants with sufficient amounts of capillary moisture during the whole vegetation period. This idea was verified in practice through preliminary experiments in a protected area and in the open field.
The “Agro kapilaris” concept is special versus similar sub-surface irrigation systems, because it meets two main preconditions:

1. Long exploitation life: according to current findings, it exceeds 70 years, but due to practical reasons, (the duration of the man’s working period in agriculture is about 50 year), the 50 year life time of the system will be adopted (Huang W., *et al*., 2012). Such an extended life time of the system operation is primarily provided by the constructive moisture transmitter solution:

- The whole system is made of non-degradable plastic placed into the soil
- There is no possibility of clogging, which is experimentally confirmed.

2. High energy efficiency during exploitation was demonstrated in the experimental lot with an overall inclination of around 1%. With an operating work pressure of 0,2 bars, the capillary moisture front are evenly distributed at a length of 180 m. There is no any other existing system, which can accomplish this *(Scheme 2.)*



Scheme 2. Diagramm of the testing the energy efficiency of the “Agro kapilaris” concept

The possibility that the “Agro kapilaris” concept functions under extremely low pressure subjects to the two physical laws, *(Photo 12)*:

-The capillary Law in permeable environment (capillary forces of the soil)

-The Law of communicating vessels

There is also a third precondition which makes the "Agro kapilaris" concept unique and this is self-regulation with providing plants with moisture. This concept is not known in any other existing irrigation system (Frangi , *et al.*).

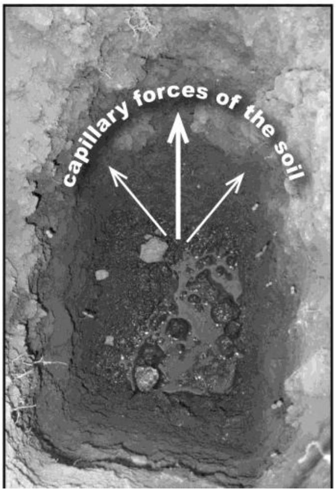


Photo 12. Self-regulation in providing plants with easily accessible water in the form of capillary moisture

3. Self-regulation in providing plants with easily available water in the form of capillary moisture *(Scheme 3)*

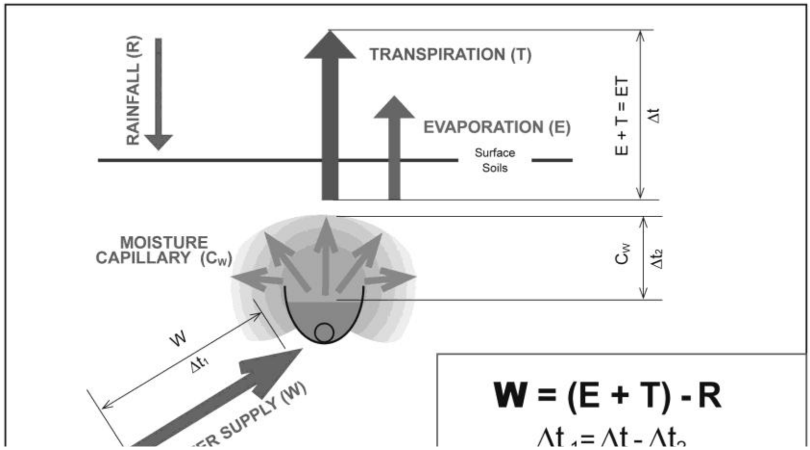
The self-regulation system in providing plants with easily available moisture is provided by a specific technical solution using a moisture transmitter. The moisture deficit is occurred due to negative balance of the precipitation (R) and evapotranspiration (ET) in the summer months. The "Agro kapilaris" concept compensates this effect with the permanent water supply (W) using a moisture transmitter.

Direct dependence of water supply (W) from evapotranspiration (ET) and precipitation (R) provide a value, which is variable and depends on the current conditions, air temperature, relative humidity, time of the day, sun exposure, wind, plant physiological needs and all other parameters which have effect on evapotranspiration.

In order to function, the self-regulation principles in supplying plants with easily available water it is necessary to fulfill the following condition:

$$\Delta t = \Delta t^1 + \Delta t^2 \quad \text{or:} \quad \Delta t^1 = \Delta t - \Delta t^2,$$

Where, the time period for the water deficit (Δt) to develop, must be compensated by water supply (W) during the influx and time of capillary moisture increase ($\Delta t1 + \Delta t2$). It should be emphasized that $\Delta t2$ depends on the soil characteristics (texture, structure, chemical composition etc.) *(Scheme 4)*.



Scheme 4. Diagram and formula of the self-regulation in providing plants with easily accessible water in the form of capillary moisture

As a result of all the stated facts, there is a need to define the flow rate (Q) and hydro module (q), as basic parameters in designing every irrigation system. With the “Agro kapilaris” concept, where the watering norm is a self-regulated there is other factors, which are necessary to research on different types of soil to obtain the coefficient of all other parameters as a designing basis.

Load test:

In order to prevent problems in the practical application of the “Agro kapilaris” concept due to heavy equipment treading over the buried transmitters, a preliminary test was performed where an IMT 577 tractor with a mass of 3.940 kg was driven over the buried transmitters. After this, sugar beet was planted from a container in the treaded soil. During the vegetation season, the plant development was monitored simultaneously with the “Agro kapilaris” and sprinkling systems. At the end of the vegetation season, it was concluded that the Agro kapilaris was safe regardless of the equipment used. Further research with heavy equipment is necessary *(Photo 13)*.

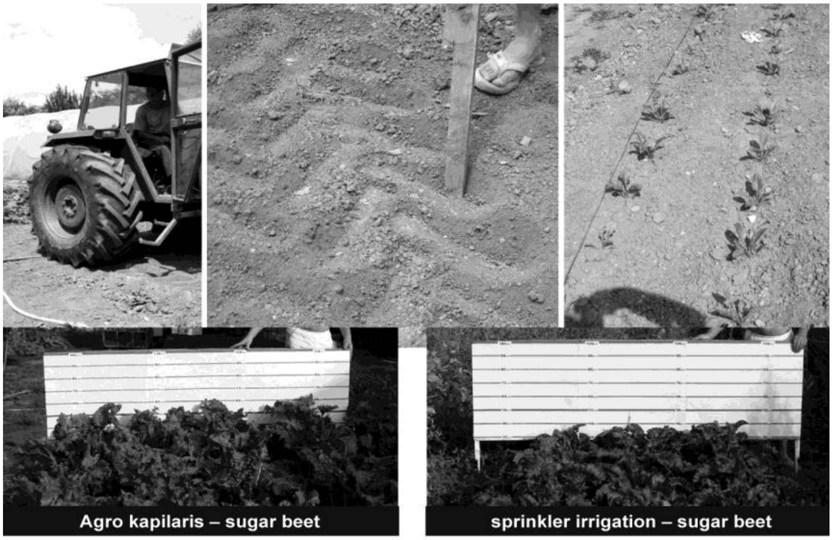


Photo 13. Load test on sugar beet in Agro kapilaris system

The health-beneficial and environmental aspect:

From the environmental point of view, underground irrigation is more acceptable, primarily from the health-beneficial aspect of plants.

With surface drip irrigation in summer conditions, when the temperatures are high, the lower part of the plant is exposed to high risks of disease. With the "Agro kapilaris" concept, the lower part is exposed to overwatering, so the risk of disease infestation is minimum *(Photo 14)* (Shukla., *et al.*, 2013).

During the hot summer days when the moisture deficiency is extremely high, with surface sprinkler irrigation, the plants are primarily exposed to a temperature stress. A temperature stress has a very negative impact on plants and is often unavoidable when the temperature of the irrigation water is much lower than the

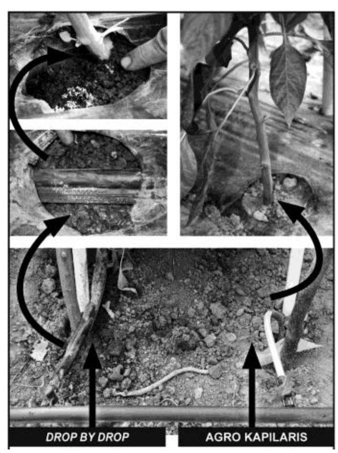


Photo 14. Environmenta; health benefit aspect on pepper from the two irrigation techniques

air temperature. With underground irrigation, the temperature stress problem is substantially relieved even if the same water were used at the same time from the same source with the same water temperature.

The working conditions for men in protected areas greatly depend not only on the temperature, but on the relative air humidity at this temperature. With high temperatures and high relative humidity the long exposures are not possible, while in the conditions with high temperatures and low relative air humidity, longer exposure and comfortable working is possible.

The repeated experiments in closed areas, in 2010, of the correlations between the temperatures and relative humidity, showed very favorable working environment in the "Agro kapilaris" system. With the drip irrigation the correlation between the temperature and relative air humidity are unfavorable for humans health and plants are more susceptible to diseases.

The perspectives of further researches:

Since the experiments performed so far are only demonstrative, the performed researches may be considered preliminary. The quality scientific expertise team of multi-disciplinary disciplines is being expanded. The next necessary step would be the inclusion of foreign scientific-research institutions in order to provide conditions for thorough research and speed the process of implementation the "Agro kapilaris" concept into general practice.

CONCLUSIONS

So far the research has pointed out the obvious advantages of the "Agro kapilaris" system in comparison to the conventional irrigation methods. Additionally, it was proved that the "Agro kapilaris" can beat the extreme droughts.

The main advantages of the "Agro kapilaris" concept are:

- Extremely low operating pressure (low electric energy consumption)
- Long life-time of the system (the system is made of plastic and according to current knowledge, over 70 years).
- It is applicable both in small lots (even irregularly shaped ones) and with large complexes.
- Easy to use and simple system maintenance

- The system provides fertigation with water-soluble mineral fertilizers
- Reduced risk of plant diseases (evaporation is reduced to the smallest possible level).

The "Agro kapilaris" irrigation concept has all the preconditions to occupy an important position in crop and vegetable growing both in open fields and protected environments.

ACKNOWLEDGEMENT:

Introduction of new, unknown concept of subsoil irrigation, which functions under extremely low pressure however provides exceptional positive effects, caused suspicion and disbelief in scientific circles. In this regard I am very gratefull to the following people for their various support: Mr. Rudić; (Institute of Melioration at the Faculty of Agriculture, Zemun); Mr. Miladinović and Mrs. Zdravković (Institute of Soil Sciences in Belgrade); Mr. Ugrinović (Vegetable Growing Institute in Smederevska Palanka; Mr. Cvijanović (Institute for Agricultural Economics in Belgrade); Mr. Radanović (Institute of Medicinal Plants Research Josif Pančić, Belgrade).

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SUCCESSFUL APPLICATION OF "AGRO KAPILARIS" CONCEPT IN AGRICULTURAL PRODUCTION

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ABSTRACT

On the experimental plot in Boljevci, Belgrade, the preliminary experiments were carried out in the open fields and in greenhouses in 2009. The aim was to investigate the effects of new ways of subsurface irrigation system "Agro kapilaris" related to the vegetable and field crops production. The application of "Agro kapilaris" in a protected area indicated the need to change the agro technique for planting when compared to the traditional way to get maximum effect: powerful and increased root system of plants and significant increase in yield. A two-year study in the open field was a novel application of this subsurface irrigation system has shown numerous advantages of subsurface over traditional surface irrigation. In conditions of extreme drought, in 2012 year, the results of comparative monitoring "Agro kapilaris" versus surface irrigation confirmed multiple positive effects in favor of "Agro kapilaris".

Keywords: irrigation, "Agro kapilaris", greenhouse

INTRODUCTION

The growing population worldwide requires the food production in a sustainable way to provide safe and nutritious products, while protecting natural resources such as water and soil and reducing the negative effects of land use on the climate (Yang, 2006; Swain *et al*. 2013). Unpredicted weather changes and occurrences of draughts can lead to devastating effects on food production and socioeconomic quality of life of general population. The subsurface irrigation could provide an answer to limitations of "drop by drop" and "sprinkle" irrigation (Rouphael *et al.* 2006, Wang *et al*. 2007), which are costly for equipment and management and generally require high levels of energy and water and most importantly, short service life, up to 15-20 years (Jin Qiu *et al*. 2012). In previous paper the author Zloh have reported a new concept for subsurface irrigation *Agro kapilaris*[1] that firstly has a long service life over 70 years, then low energy costs and thirdly it is environment and soil friendly. Here, we demonstrate the successful application and great potential of this novel "Agro kapilaris" subsurface irrigation system in the greenhouse cultivation and open field farming.

MATERIALS AND METHODS

Standard methods were used to monitor the effects of "Agro kapilaris" system, "drip" and "sprinkle" irrigation techniques. The main methodology is given in the papers of this book by author Zloh. More detailed presentation and interpretations of the results of this study will be available in the next papers.

RESULTS AND DISCUSSIONS

Experiments in a protected environment (2009-2011)

Result of the research in 2009: The "Drop by drop" irrigation, degrades the structure of the soils, after an extended period (Đurović *et al*. 2010). "Agro kapilaris" maintains the structure of the soil and leaves it unaltered. Therefore, it preserves the soil as an invaluable natural resource. *(Photo 1).*

The health-beneficial and environmental aspect: After a few repetitions of experiments in enclosed areas, in 2010 after parallel monitoring the relations between the temperatures and relative humidity, a conclusion was reached where the work environment conditions with the Agro kapilaris system are very favorable for work. In the greenhouses that are irrigated using the drip system the observed temperatures and relative air humidity indicate unfavorable working conditions as well as the conditions where the plants could be more susceptible to diseases. *(Photo 2).*

Photo 1. Experiments in a protected environment, pepper was selected as an experimental culture (2009)

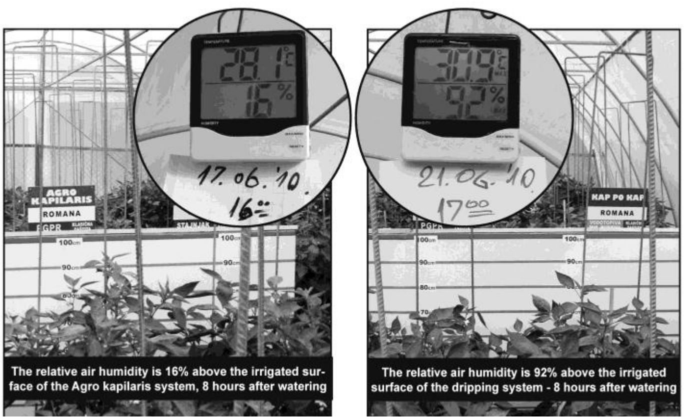

Photo 2. Environmental-helt benefit aspect - peppers (2010)

Result of experiment in 2011: Agro kapilaris has higher yields peppers than drip system averages for 20-30%. Agro kapilaris showed much more advantages than the dripping system for growing plants in greenhouses, however there is a need to validate this method for other conditions and vegetables.

Experiments in the open (2010-2012)

Sub-surface irrigation is not commonly used for massive open field farming due to various limitations (Bošnjak, 1999). We have previously shown that AgroKapilaris no such limitations and can meet the water needs of plants through a variety of topological settings and up to 180 meters of water reservoirs with extremely low pressure of 0.2 bar, these were achieved with minimal requirements for electricity. Similarly, the quality of the soil is not perturbed by using this system. Here we demonstrate result of micro experiment and projection yield per hectare and the superior performance of AgroKapilaris irrigation system in comparison to generally used sprinkling systems.

Tab. 1. Shugar beet yield under "Agro kapilaris" and "Sprinkling", 2012

Planting distance cm	Row spacing m	Rroots row^{-1}	Roots ha^{-1}	Net mass 10 roots kg	Digestion %	Yield t ha^{-1}	Sugar content t ha^{-1}
			Agro kapilaris				
20	0.5	500	99500	20.7	13.66	134	18.3
			Sprinkling				
20	0.5	500	99500	13.5	15.4	87	13.4

As seen in the Table 1, the total sugar content per hectare was higher for 26.5% under the "Agro kapilaris" comparing to the sprinkling irrigation system.

In the extreme droughty 2011 and 2012 years the yield of soybean under the "Aghro kapilaris" system was 6.5 - 6.9 t ha^{-1}, while under the spinkling irrigation the soybean yield was 4.8 - 5.4 t ha^{-1}.

Based on the obtained two-year results, it is estimated that the yields of sugar beet and soybean are approaching their genetic potential when the of subsoil irrigation by "Agro kapilaris" system is applied.

Similarily to sugar beet and soybean the yield of tomato was also significantely increased under the "Agro kapilaris" irrigation system in comparison to sprinkling irrigation: the yield of tomato average for 2011-2012 under "Agro kapilaris" was 96.9 t ha^{-1}, while under spinkling was 64.3 t ha^{-1}.

CONCLUSIONS

The two-year preliminary experiments proved that the "Agro kapilaris" can satisfy the needs for water of various farm vegetables in the open field even during the extreme droughts without affecting the soil quality.

The "Agro kapilaris" irrigation concept has all the necessary attributes of an irrigation system that can answer future demands for efficient farming, which is doesn't depend on weather conditions. The demonstrated advantages should be implemented in crop and vegetable production both in open fields and protected environments. The flexibility of the system will allow further developments and incorporation with other agro technique that could lead to even better effects.

The next necessary step would be the investment into validation of use of the system in farming of different crops and conditions for thorough research, which will speed the process of introducing the "Agro kapilaris" concept into general use.

- The system is proved to be economically profitable and cost effetive,
- "Agro kapilaris" preserves the water resources because water is delivered only when is needed by vegetation and
- Application of subsoil "Agro kapilaris" system significantely improves the vegetable yields.

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INFLUENCE OF CLIMATE FACTORS ON RICE YIELD IN THE SOUTH OF UKRAINE

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ABSTRACT

The influence of climatic factors during ontogeny of rice to form its productivity in Southern Ukraine was investigated. Objectives of the research: to develop a classification of years supply of atmospheric precipitation in the dry steppe zone of Ukraine; to determine the effect of climatic factors on the ontogeny of rice; to develop recommendations to improve the yield of rice. The classification of years by water content based on the amount of rainfall per year and growing season was designed. Feedback observed between rice harvest and amount of precipitation during the growing season: wet years are directly connected with a decrease in temperature and increase in its relative humidity, which adversely affect on the yield of rice. Also in wetter years due to heavy torrential rains during the growing season there is a danger infection rice plant fungal diseases and lodging. A model of the influence of temperature on the yield of rice, depending on the phase of culture was made.

Keywords: climate changes, irrigation, rice yield.

INTRODUCTION

Rice - the culture of tropical origin, which has increased demands on the temperature regime of air and water, humidity and lighting conditions. Period of rice ontogenesis involves the development of culture from its beginnings (sowing) to the end of growing cycle (harvest). Varieties of rice grown in the South of Ukraine, which belong to the northern region of the world rice cultivation, adapted to the temperate climate, the culture is lightweight of temperature conditions along the growing season. In different phases of growth and development plants require different levels of heat. In the development of rice distinguish the following vegetation phenological phases: germination, sprouts, tillering, exit in tube throwing bunches, maturation (Ushkaernko, 1994; Dudchenko *et al.*, 2008).

Purposes of the research- determine the influence of climatic factors on yield formation of rice in the south of Ukraine. Objectives of the research:

- To develop a classification of years supply of atmospheric precipitation in the dry steppe zone of Ukraine;
- To determine the effect of climatic factors on the ontogeny of rice;
- To develop recommendations to improve the yield of rice.

METHODS OF THE RESEARCH

The main method of research is field long-term studies in production at stations in typical southern Ukraine, the area under rice cultivation: soil, climate, agricultural, landscape and water management, used a systematic approach to the investigated processes. In determining the impact of irrigation on soil load of rice irrigation systems used methods: reconnaissance, laboratory, complex experimental reclamation, soil and environmental research, the historical method, analysis and synthesis of data of long-term field studies. The data processed by standard statistical methods.

RESULTS AND DISCUSSION

Minimum average daily temperature in which is possible progress of the growing season phases of rice: germination, sprouts - 12-14°C, tillering - 16-18°C, throwing panicle, flowering - 18-21°C, lactic ripeness - 15-19°C, wax ripeness - 15-20°C. Reducing the temperature in the individual phases of vegetation after forming sprouts below physiologically active levels leads to delays in the development phase, the extension of the growing season, reduced plant productivity, deterioration of seed and grain quality product of rice. The required amount of active temperatures during the growing season for early ripening varieties of rice is 2200-2400°C, and middle 2400-2600°C medium late - 2600-2800°C (Ushkarenko, 1994; Dudchenko *et al.*, 2008; Vantsovskyy, 2004).

Big importance in the development of rice plants has interfacial thermal conditions in the period from exit in tube to the ejection of panicle. During this period, the optimal conditions prevailing in the average daily air temperature of 25-28°C. When conducting research during interphase exit in tube - throwing rice panicle, of course, been reported in the third week of June - the third week of July, depending on the ripeness of sorts. The average daily temperature in this period was observed within 19-24,6°C, minimum - 14.5°C, and the maximum was raised to 35.6°C. In the phase of flowering unfavorable conditions for the growth and development of rice plants consist when the air temperature 22°C and below, while a phase dairy and wax ripeness - when the air temperature 18°C and less. The optimum temperature during flowering rice 25-32°C and below 15°C is critical for this period. When conducting of research flowering is usually held at the optimum temperature for this period.

Dairy and wax ripeness certainly observed in the first decade of August - the third decade of September, depending on the ripeness of sorts. Temperature during this period was 10,0-26,7°C, the minimum temperature was lowered to 4.5°C, the maximum end of August increased to 34,6-38,0°C, and in September it was 17,3-24,5°C. Full ripeness of different rice varieties marked in the second decade of August and the second decade of October. The growing season lasts is 100-140 days, depending on the ripeness of sorts. The required amount of active temperatures during the growing season is for:

- early ripening varieties 2200-2400°C;
- Middle varieties 2400-2600°C;
- Medium late varieties 2600-2800°C.

The optimal ratio in structure of sowing areas of different rice varieties groups’ ripeness enables maximum use of existing weather conditions of the year.

Important natural resources for growing rice are indicators of climate - precipitation, air temperature, relative humidity and so on. According to many scientists and experts of the World and Europe in the last 45-50 years (the period of rice cultivation area in Ukraine) there are significant changes in climate that affect the efficiency of agricultural production, environmental and reclamation treatment of irrigated soils, mode of irrigation of crops and their yield, the structure of crop rotation, soil fertility.

It is important to note that different researchers in the study of climatic factors, sometimes differently assess the water content of the same years. This is connected with the fact on which the meteorological posts climatic data are summarized for the territory for which time period they analyzed.

For use in the industry of rice cultivation (the design and exploitation rice irrigated systems in the dry steppe region of Ukraine as an example of generalized meteorological data (for example, Kherson region) for the period 1966-2011 years we offered (according to the Kherson Regional Center for Hydrometeorology) classification of years provision precipitation (Tab. 1).

Table 1. Characteristics of years precipitation supply in the dry steppe zone of Ukraine (for example, Kherson region)

№	Characteristics of years for moisture	Precipitation, mm	
		per year (average multiyear rate 450mm)	per vegetation (average multiyear rate 280mm)
1	2	3	4
	Dry	to 400	to 250
	Average	401-499	251-309
	Wet	Over 500	over 310

Table 2 The distribution of years by water content in the period 1966 to 2011.

Characteristics of years for water content	Analysis data of precipitation					
	per year			per vegetation		
	interval data	amount	%	interval data	amount	%
very dry	to 300	2	4,4	to 150	2	4,4
medium dry	301-350	6	13,04	151-200	6	13,04
moderately dry	351-400	10	21,74	201-250	11	23,9
moderately medium humid	401-450	6	13,04	251-280	5	10,8
excessive medium humid	451-500	9	19,6	281-310	6	13,04
insufficiently wet	501-550	4	8,69	311-350	9	19,6
moderately wet	551-600	4	8,69	351- 400	2	4,4
overly wet	601-650	3	6,5	401-450	3	6,5
very wet	over651	2	4,4	over 451	2	4,4
Total		46	100		46	100

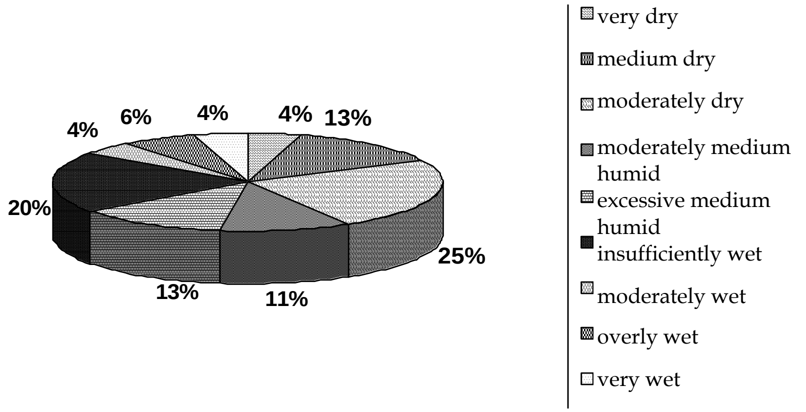

Fig. 1. The distribution of years by precipitation supply in the period 1966 - 2011 years (average years data).

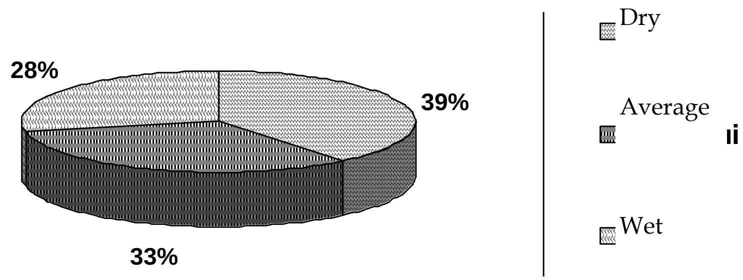

Fig. 2. The structure of years precipitation supply during the 1966 - 2011 biennium (average years data).

According to map of agro climatic zones of Ukraine, prepared by the hydro meteorological data up to 1970, Kherson region is located in the very arid, hot temperate, with mild winters, HTC = 0.7 - 0.5, the average annual active air temperatures 3300-3400°C. Average year rate of precipitation- 450mm, average vegetation (growing season: from April 1 - September 30) rate - 280 mm. Detailed analysis of water content years are shown in Table 2 and Fig. 1. Analysis of the structure of water content years is given in Table 3 (Fig. 2).

The results of the analysis of climatic data, which are typical for Dry steppe zone of Ukraine can quickly determine the year's supply of precipitation, in the respective year, and with the growing season.

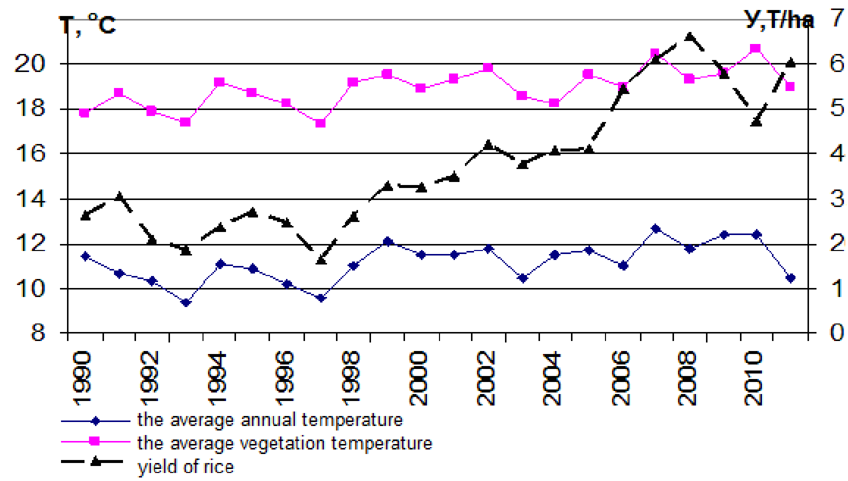

Fig. 3. The dynamics of average year and average vegetation air temperature

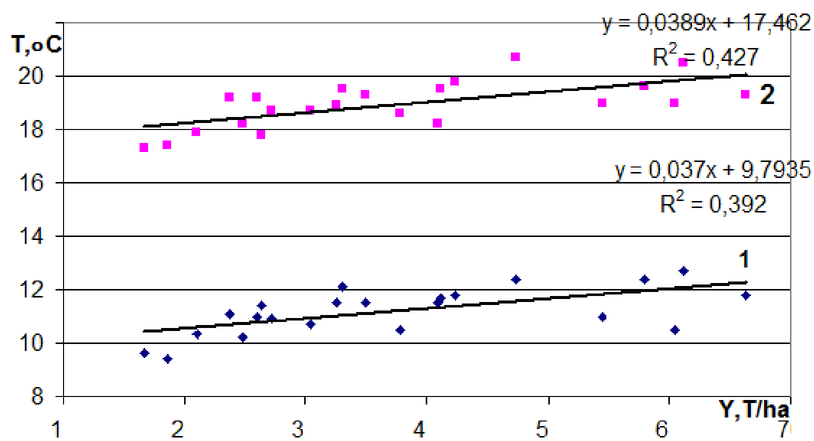

Fig.. 4. The dependence of the yield of rice by temperature:

1 - the average annual temperature;
2- the average vegetation temperature

Table 3. The structure of years precipitation supply during the period 1966 to 2011

Characteristics of years for water content	Analysis data of precipitation			
	per year		per vegetation	
	amount	%	amount	%
Dry	18	39,1	19	41,3
Average	15	32,6	11	23,91
Wet	13	28,3	16	34,8
Total	46	100	46	100

Since the yield of rice in years (the period analyzed of research 1990-2010, Fig. 3) varies greatly, there is a need for modeling the formation of rice yield based on agro-climatic conditions, especially temperature.

To generate models of yield of rice agro-climatic monitoring system in the current economic conditions in the Southern Steppe of Ukraine was used regression analysis by which an association resulting features Y (yield) and average growing season temperature (n). To generate a linear regression model of rice yield based on air temperature during the growing season was used indicator - average temperature of rice growing season months: May, June, July, August, September (equation 1):

$$Y=1,04*X_1+2,91*X_2+2,8*X_3+0,57*X_4+0,54*X_5-126,64 \quad (1)$$

where: X1-average temperature in May, °C; X2-average temperature for June,°C; X3-average temperature for July,°C; X4-average temperature for August, °C, X5-average temperature for September, °C. The structure of the impact of the investigated factors in shaping the rice yield in the steppe rice zone of Ukraine is shown in Fig. 5.

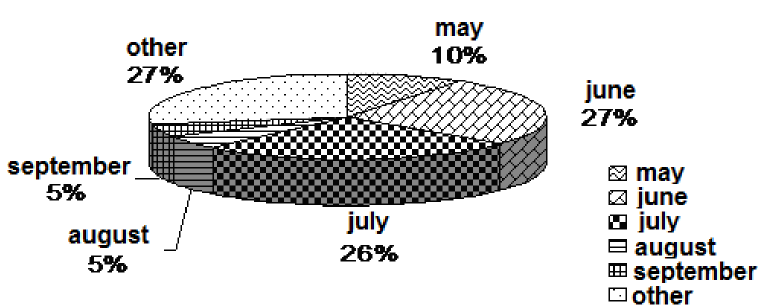

Fig.. 5. Influence of average temperature during the growing period on rice yield

Multiple correlation coefficient of regression model (R=0,84) indicates a close relationship between the yield of rice and agro-climatic factors studied. Multiple coefficient of determination (R^2=0,72) indicates that 72% rice yield in southern steppe formed by the average air temperature, confirming the importance of this factor in shaping the model. Calculated level of significance AR=0.00052 <0.05 confirms the significance of R^2. Absolute deviation is 7.8%.

Dispersion analysis of agro-climatic monitoring system found that the formation of yields of rice in the Southern Steppe of Ukraine is most affected by average temperature in June (shared participation factor-27%). Tillering vegetation phase happens in June, when average air temperature is 23-26°C. The average daily temperature in July is the degree of influence on the formation of rice yield 26%. July - phenological phases - exit in tube flowering. It was determined that the average daily temperature during this period of 25-30°C is formed rice yield at 47-61 kg ha^{-1} (2007-medium dry, 2010-insufficiently wet). Air temperature in remained months of the growing season has less impact on yield formation of rice (Tab. 4).

The average daily temperature in April - May have a degree of influence on the formation yield of rice 10%. April - May - Phase ontogeny of rice - germination sprouts. Summarizing the experience of rice cultivation indicates significant effect of planting rice in the third decade of April in the year, characterized as very dry and medium dry; for example 2011, 2012.

Table 4 The optimum temperature for growing agricultural crop rice

Phase of development	month	The optimum temperature, °C	The correlation coefficient
Germination, stairs	may	16-20	0.58 - noticeable relationship
tillering	June	23-26	0.61 - noticeable relationship
Out in the tube	July	25-30	0.72 - strong relationship
Throwing panicle, flowering	august	25-30	0.32 - moderate relationship
maturation	September	25-30	0.45 - moderate relationship

Other factors that affect the yield of rice in south steppe include - irrigation, crop rotation, tillage, plant protection, varietal composition, ecological-agromeliorative condition of lands and others. These factors are interrelated and interact with each other (the law of interaction factors).

CONCLUSION

According to the results there is a direct relationship between the average air temperature during the year (R^2=0.39), during the growing season (R^2=0.42), and yield of rice. The result model is based on the yield of rice average air temperature during the growing season.

During ontogenesis of rice the role of temperature on yield of rice distributed as follows: the main meteorological factors influencing the productivity of rice are as follows: average temperature in June (r=0,61), and July (r=0,72).

Feedback observed between rice harvest and the amount of precipitation during the growing season: wet years are directly connected with a decrease in temperature and increase in its relative humidity, which adversely affect on the yield of rice. Also in wetter years due to heavy torrential rains during the growing season there is a danger of infection of rice by fungal diseases and lodging. To predict the level of productivity and the value of gross fees it must be considered the agrometeorological factors as a major factor in significant changes in rice yield.

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THE CONCENTRATION OF SOME METALS IN SOIL ON TWO SERPENTINE LOCATIONS (SERBIA)

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ABSTRACT

Ultramafic (serpentine) soils, developed upon ultramafic rocks, are widely distributed in different parts of the world and also cover quite large areas in the Balkans, more than in other parts of Europe. The aim of presented research was to assess the content of eleven metals (Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co, Cr) in serpentine soils near Kamenica village in Central part of Serbia. Metal concentrations in soil on location Kamenica had following order Mg>Fe>Ca>Ni>Cr>Mn>Co>Zn>Pb>Cu>Cd and on location Kamenjar Mg>Fe>Ni>Ca>Cr>Mn>Co> Pb >Zn>Cu>Cd. Soil collected on location Kamenjar contained higher concentration of Fe, Mn, Zn, Pb, Cd and Co, and lower concentration of Ca than soil on location Kamenica. The content of Mg, Cu, Ni and Cr in soil was approximately the same on the both locations. Our study exhibited different metal concentration in serpentine soils, depending on kinds of metal, and confirm that serpentine soils content high concentration of some heavy metals (Fe, Ni, Cr, Co). The extreme chemical nature of serpentine soils, with abnormally high concentrations of Ni, Cr and Co (in addition to Mg and Fe) and low concentrations of the important nutrients Ca and K, often leads to creation of specific type of soil (serpentine soils) and characteristic serpentine flora.

Keywords: serpentine soil, metal concentrations.

INTRODUCTION

Ultrabasic magmatic stones of different chemical composed changed under atmospheric influence are understood under the term serpentinite. Also, serpentine is a metamorphic rock, composed partly of the phyllosilicate serpentine ($(Mg,Fe)_3Si_2O_5(OH)_4$, magnesium iron silicate hydroxide). Ultramafic (serpentine) soils, developed upon ultramafic rocks, are widely distributed in different parts of the world. Serpentine substrates cover quite large areas in the Balkans, more than in other parts of Europe (Brooks, 1987; Tatić and Veljović, 1992). They exist as large blocks or as small outcrops separated from other geological formations, in Central Bosnia and Western and Central Serbia, and extend towards North, Central and South-Eastern parts of Albania and further to the serpentine formations in the regions of Epirus and Thessaly in Greece (Bani *et al.*, 2010). Some fairly isolated serpentine "islands" occur in the North-Eastern Serbia and Greece and in the Northern part of Macedonia. Small quantities of serpentine bedrock are distributed in South-Western, South and Central parts of Bulgaria, mainly in the Eastern and Central Rhodopean mountains (Pavlova *et al.*, 1998). Serpentine soils in Serbia occur in the hilly and mountain regions, covering a large area of about 250 000 ha (Stevanović *et al.*, 2003).

Serpentine ecosystems can generally be distinguished by their grey-green or reddish rocky soils (soils are very thin), and shrubby or stunted vegetation with plants having small leathery leaves. Serpentine outcrops have been referred to as barrens because they are often sparsely vegetated and extremely poor in essential nutrients, and thus of not much agricultural value. Serpentine environments are typically inhospitable for many plants due to several factors of their soil chemistry, collectively called the "serpentine syndrome" (Kruckeberg, 1984; Kazakou *et al.*, 2008; Kazakou *et al.*, 2010): a) low availability of calcium relative to magnesium; b) deficiency of other essential macronutrients (P, N, K) and c) high levels of potentially phytotoxic elements (Ni, Cr, Co, and sometimes Mn and/or Cu). Among the limiting factors that make ultramafic soils unfavourable substrates for plant growth, the most attention has been given to low Ca:Mg quotients (due to low Ca and high Mg) and high heavy metal concentrations, especially Ni (Brady *et al.*, 2005). Since the serpentine soil properties are disadvantageous for most plants, distinctive vegetation communities have evolved on serpentine soils (Brooks, 1987). The influence of geological substrate on the flora comes to the full force in the initial stage of development of vegetation. This influence becomes smaller during the gradual formation of the soil that leads to the convergence of vegetation, which causes a change of soil properties.

In spite of the fact that ultramafic soils cover substantial areas at many locations in Serbia, there is little information about their biogeochemistry in small outcrops or in small serpentine locations. The aims of this study were to determine the content of eleven metals in serpentine soils of two locations near the village Kamenica on mountain Goč, and to assess the difference in metal concentration between soils.

MATERIAL AND METHODS

Study location: The two researched locations are situated near the village Kamenica (Central Serbia) (Fig.1). This area presents a part of a much larger part of serpentine substrate, as it was noted before, is located in Western and Central Serbia, and extends towards North, Central and South-Eastern parts of Albania.

The location Kamenica is at 359 m above sea level, and on 74° 76′ 284″N, 48° 29′ 864″E and location Kamenjar at 425-457 m a.s.l., and on 74° 75′ 817″N, 48° 27′ 174″E (GPS Garmin-etrex, vista HCx).

Fig. 1 Study location

On location Kamenjar there is very thinly skeletal rendzinas and on location Kamenica is deeply skeletal rendzinas (Figure 2). Mentioned locations are on the serpentine parent rock and belong to different association of plant: *Potentillo-Stipetum pennatae* (Markovic, 1986) (Kamenjar) and *Helleboro-Danthonietum calycinae* (Kamenica) (Obratov *et al.*, 1997).

Soil and plant sampling and analysis: The field work was conducted during March-August 2011, when six soil replications were collected from 1 to 10 cm depth. Soil samples were initially air-dried and stone pieces were removed, sieved to 2 mm, and stored at 4 °C until analysis. Sub-samples of 10 g were ground to pass a 70-mesh sieve (< 215 µm) and then oven-dried at 105 °C for 24h. After drying on l05°C to constant mass, 3 g of soil sample with accuracy of ± 0.01g were measured on analytic scale. The measured samples were transferred in Kjeldahl's balloon and perfused with 10 ml of concentrated HNO_3. Reaction mixture was heated carefully by flame, until the solution became dry. The treatment was repeated until clearing up of the solution, and stopping of releasing of nitric vapours.

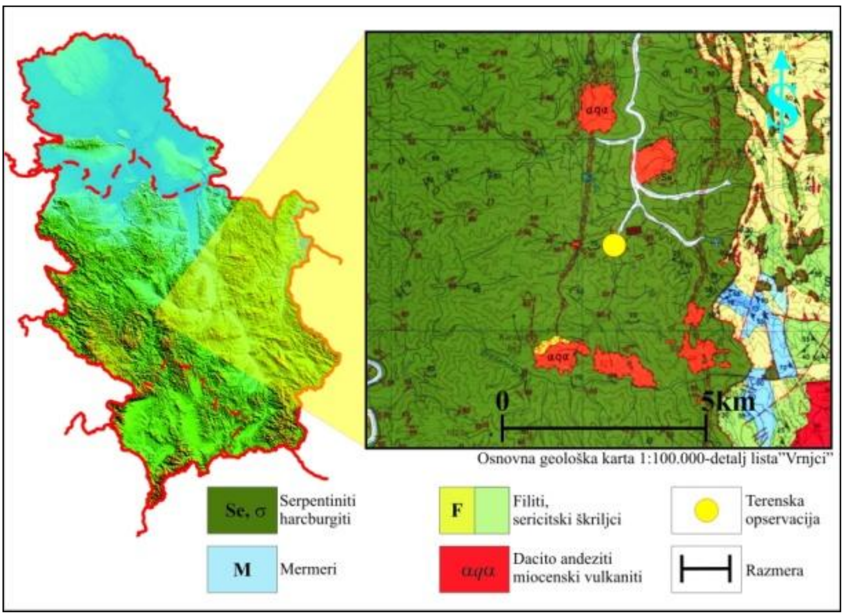

Fig. 2 Geological substrate

After that, samples were cooled, and content in the Kjeldahl's dish was perfused with 6 ml of concentrated $HClO_4$ and than heated. The heating was stopped at solution volume of approximately 3 ml in Kjeldahl's balloon, when solution has become clear and achromatic. Also, the solution was cooled and distilled water was added. The content from Kjeldahl's dish was filtered through a moistened Whatman No. 40 filter paper into a 50 ml volumetric flask. These solutions were used for determination of metals in soil.

Eleven metals (Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co and Cr) were analyzed in soil. Chemical analysis of soil samples were done by SRPS EN 12506:2007; SRPS EN 13656:2008 methods (www.jus.org.rs), at the Institute of Public Health Division of Hygiene and Medical Ecology in Kragujevac. The metal concentrations in soil samples were determined by inductively coupled plasma-mass atomic emission spectrometry (ICP-OES iCAP 6500, ICP-20100908), directly from the solution. The detection limits for Ca, Mg, Fe, Mn, Cu, Zn, Ni, Pb, Cd, Co and Cr in soil were: 0.009, 0.007, 0.0056, 0.0065, 0.0076, 0.0051, 0.0059, 0.0089, 0.003, 0.0079 and 0.0092 mg kg^{-1}, respectively. The six soil replications of one sample were prepared. The mean values of metal concentrations were calculated. The contents of metals in soil materials were expressed in mg kg^{-1} of dry matter (mg kg^{-1} d.m.).

Data analysis

Differences of metal concentrations between soil samples were examined using one-way ANOVA. The differences at $p \leq 0.05$, $p \leq 0.005$ and $p \leq 0.001$ were considered to be significant. Also, the Pearson correlation coefficient analysis was done to check if differences existed between soil samples (Norusis, 1993). The product of Pearson correlation coefficient analysis, the correlation coefficient (r) was evaluated as follows: 0-0.3: no correlation; 0.3-0.5: low correlation; 0.5-0.7: medium correlation; 0.7-0.9: high correlation; 0.9-1.0: very high correlation. In this study, the statistical analysis of data was performed using the computing package called Statistical Package for Social Science (SPSS 10 for Windows).

RESULTS AND DISCUSSION

Metal content of soil is dependent on natural and anthropogenic sources in the local ecosystems. The concentration of metals in uncontaminated soil is primarily related to the geology of the parent material from which the soil was formed. The determination of metals in soils is very important in monitoring of environmental pollution.

In this study, the mean concentrations of 11 metals in soil samples collected on two locations near village Kamenica are shown in Tab.1.

Metals in according to their concentrations in soil samples on location Kamenica had following order: Mg>Fe>Ca>Ni>Cr>Mn>Co>Zn>Pb>Cu>Cd and on location Kamenjar Mg>Fe>Ni>Ca>Cr>Mn>Co>Pb>Zn>Cu>Cd. The results of this study showed that the content of investigated metals in soil depended on kind of metals.

Table 1 The mean* concentrations of studied metals in soil

Elements	Kamenica	Kamenjar
	mg kg^{-1}	
Ca	1109±6.1	706.1±10.4
Mg	59604±312.0	56402.9±178.2
Fe	35710±320.9	56233.5±188.5
Mn	289±6.4	507.1±9.7
Cu	6±0.3	5±0.7
Zn	23±0.1	36.3±0.2
Ni	931±23.7	921.9±30.6
Pb	13±0.1	39.4±0.2
Cd	1.4±0	2.5±0
Co	34±0.1	89.4±0.2
Cr	485±10.7	516.4±23.0

*The mean value (n=6) ± standard deviation

The results obtained from the ANOVA test (Tab. 2) showed that very high statistically significant differences (p≤0.001) in the content of metals exist between soil samples from the two locations Kamenica and Kamenjar (except for Ni and Cr). However, high statistically significant differences (p≤0.005) in the content of Cr and no statistically significant differences of Ni were also established.

Table 2 The difference in metal concentration using ANOVA

	soil	
metal	F-value	p-level
Ca	6648.2	***
Mg	476.1	***
Fe	18246.4	***
Mn	2105.2	***
Cu	75.6	***
Zn	14134.1	***
Ni	0.4	0.56
Pb	90421.7	***
Cd	69897.7	***
Co	284122.4	***
Cr	9.0	0.01

Correlation analysis has been used to establish difference between soils collected on two serpentine locations. The results obtained from the Pearson correlation coefficient analysis indicated that very high positive or negative correlation exists between soils in relation to kind of metal (except for Ni and Cr). The results showed that very high positive correlation exists between investigated soils for Fe, Mn, Zn, Pb, Cd and Co. As well as, medium positive correlation exists between soils for Cr. Obtained data indicated that very high negative correlation exists between soils for Ca, Mg and Cu, and that have no correlation in content of Ni between investigated soils.

Table 3 The Pearson correlation coefficient (r) analysis of metal concentrations between soils

	Ca	Mg	Fe	Mn	Cu	Zn	Ni	Pb	Cd	Co	Cr
soil	-1.00	-0.99	1.00	1.00	-0.94	1.00	0.19	1.00	1.00	1.00	0.69

r - correlation coefficient (0-0.3: no correlation; 0.3-0.5: low correlation; 0.5-0.7: medium correlation; 0.7-0.9: high correlation; 0.9-1.0: very high correlation)

The investigated soils contained 706.1 to 1109 mg Ca kg^{-1}. The results of this study are in accordance with previous findings of some researches (Robinson *et al.*, 1997; Shallari *et al.*, 1998; Reeves *et al.*, 2007). The Figure 3 shows that the ratio of Ca to Mg in soil samples varied from 0.013 on Kamenjar to 0.019 on Kamenica.

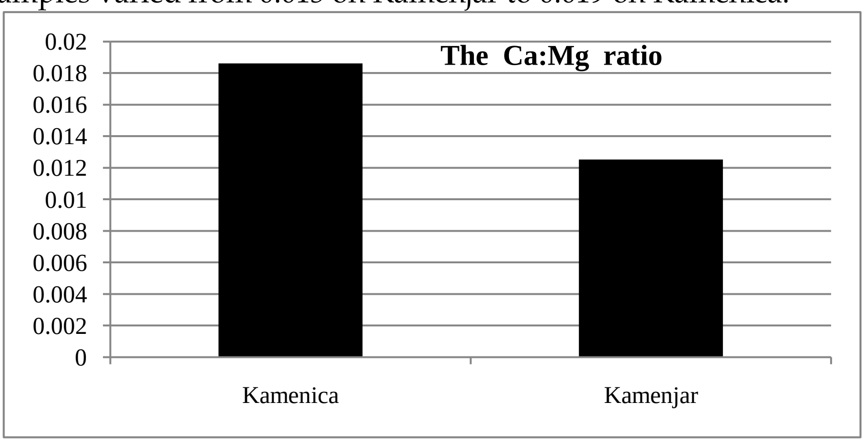

Fig. 3. The Ca:Mg ratio

Generally, the serpentine soils are rich in Mg, but deficient in Ca. Mg content in the analyzed soils was higher and ranged from 56402.9 to 59604 mg kg^{-1}. The findings of some researchers showed that among the limiting, stress factors that make ultramafic soils unfavourable substrates for plant growth, the low Ca:Mg quotients (commonly about 0.1) was very important (Brady *et al.*, 2005). Our results showed low Ca:Mg ratio in soil was similar with results were described by many authors (Robinson *et al.*, 1997; Shallari *et al.*, 1998).

As a principal element in the Earth's crust, iron is found in association with coarse atmospheric dust particles (Kabata-Pendias, 2011). In this study, Fe concentration in the soils varied from 35710 to 56233.5 mg kg^{-1}, which is in agreement with earlier findings that serpentine soils contain high amounts of iron (Reeves *et al.*, 2007; Bech *et al.*, 2008).

According Adriano (2001), regular Mn content for most of soil ranges from 500-1000 mg kg^{-1}. The results of this study showed lower concentration of Mn (289 - 507.1 mg kg^{-1}) for our soil samples.

Kabata-Pendias (2011) reported that Cu levels of various soils ranged 1-200 mg kg^{-1}. In this study, the mean concentration of Cu in soil samples varied from 5 to 6 mg kg^{-1} .

Zinc is distributed evenly in the Earth's crust and Kabata-Pendias (2011) reported that regular Zn content for most of soil types ranges from 1 to 800 mg kg^{-1}. Therefore, comparing our data with the findings of some researches (Shallari *et al.*, 1998; Obratov-Petković *et al.*, 2006; Bech *et al.* 2008) it can be concluded that Zn content in the analyzed soils is higher than in our soil samples (23-36.3 mg kg^{-1}).

High Ni and Cr concentrations were observed only at the serpentine sites where soils were derived from gabbros and ultrabasic rocks rich in Fe, Ni and Cr (Kabata-Pendias, 2011). The total Ni concentrations reported for serpentine soils are generally in the range 500-8000 mg kg^{-1} (Ghaderian *et al.*, 2007). Nickel content in our soils varied from 921.9 to 931 mg kg^{-1} what is in accordance with the previous findings (Shallari *et al.*, 1998; Reeves *et al.*, 2007). Most Ni in soil is expected to be either NiO (from emission sources), Ni chelated by organic matter, Ni in spinal and other Mg silicate minerals, Ni adsorbed or occluded in Fe and Mn oxides, Ni-Al layered double hydroxide and soluble chelated and ionic Ni^{2+}. Serpentine contains high levels of potentially toxic elements such as Ni^{2+} and Cr^{3+} but Ni^{2+} is more bio available than Cr^{3+} and appears to be the most toxic element in ultramafic soils (Kabata-Pendias, 2011).

On average, the Earth's crust is estimated to contain about 15 ppm of Pb, with parent rocks contributing the natural content (Bech *et al.*, 2008). However, most soil, especially topsoil, is enriched in Pb content due to anthropogenic pollution. Kabata-Pendias (2011) reported that Pb levels of various soils ranged 2-200 mg kg^{-1}. Our results (13-39.4 mg Pb kg^{-1}) are in accordance with this and other previous cited data (Robinson *et al.*, 1997; Shallari *et al.*, 1998; Reeves *et al.*, 2007).

Kabata-Pendias (2011) reported that Cd levels of various soils ranged 0.001-2.5 mg kg^{-1}. The Cd contents in investigated soils were low and ranged 1.4-2.5 mg Cd kg^{-1} d.m.

The results obtained in this study showed 34-89.4 mg Co kg^{-1} d.m. in soil samples. Similar results were described by some authors (Robinson *et al.*, 1997; Bech *et al.*, 2008).

The investigated soils samples contained 485 to 516.4 mg Cr kg^{-1} d.m. According to Brunetti *et al.* (2009), the Cr concentrations ranged from 36.18 to 115.15 mg kg^{-1}. The chromium is the pollutant with highest total contents in soils, but it showed only average extractability of 0.008% because of the fact that all the soil Cr is in a more resistant fraction (less soluble forms) (Zayed *et al.*, 2003). Not all metals provide the same bioavailability and it depends on the mineralogy of the soil. For example, the high-Cr contents in the serpentine soils often are in the form of chromites, an unalterable mineral, and so Cr remains not bio available.

Soils are preferred monitoring tools, and they show less variation in time and space, allowing more consistent assessment of spatial and temporal contamination (Keshav *et al.*, 2011). The contents of metals in the soil depend on numerous factors, such as: specific ability of some plants to over-accumulate various toxic metals, chemical and physical characteristics of soil and metal interactions (Sústriková and Hecl, 2004). It is generally regarded that the bioavailability of metals is closely related to their chemical speciation, rather than total concentration in soils. Also, metals in soils occur in different geochemical forms, which have distinct mobility, biological toxicity and chemical behaviours.

Results of this study presented different metal concentration in investigated soils, depending on kind of metals. Soil collected on Kamenjar contained higher concentration of Fe, Mn, Zn, Pb, Cd and Co, and lower concentration of Ca than soil on village Kamenica. The content of Mg, Cu, Ni and Cr in soil was approximately the same on the both locations. Obtained value is in accordance with results of ANOVA and Pearson test. Also, obtained results are confirmed that soils which are formed on serpentine contain high concentration of

Fe, Mg, Ni, Cr and Co. One of reasons of higher content of Ca, as well as different concentration of Fe, Mn, Zn, Pb, Cd and Co in investigated soils we can find in highly developed flora (association *Helleboro-Danthonietum calycinae*) and the appearance of deeply and significant developed soil on Kamenica.

Serpentine is composed partly of the phyllosilicate serpentine and due to its origin from earth mantle material, the chemistry of serpentine is unlike that of other minerals in the earth's crust. The extreme chemical nature of such as soils, with abnormally high concentrations of Ni, Cr and Co (in addition to Mg and Fe) and low concentrations of the important nutrients Ca and K, often leads to creation of specific type of soil and characteristic serpentine flora.

CONCLUSIONS

The concentration of metals in soil is primarily related to the geology of the parent material from which the soil was formed. The aims of this study were to determine the contents of eleven metals, in serpentine soils of two locations near the village Kamenica on mountain Goč, and to assess the difference in metal concentration between their soils. Metal concentrations in soil on Kamenica had following order: Mg>Fe>Ca>Ni>Cr>Mn>Co>Zn>Pb>Cu>Cd and on Kamenjar: Mg>Fe>Ni>Ca>Cr>Mn>Co>Pb>Zn>Cu>Cd. Soil collected on Kamenjar is contained higher concentration of Fe, Mn, Zn, Pb, Cd and Co, and lower concentration of Ca than soil on Kamenica. The content of Mg, Cu, Ni and Cr was the very same on the both locations.

The results of this study showed that the content of investigated metals in soil depended on their kind of metals. Also, obtained results are confirmed that soils which were formed on serpentine contained high concentration of Fe, Mg, Ni, Cr and Co. One of the reasons of higher contain of Ca, as well as different concentration of Fe, Mn, Zn, Pb, Cd and Co in investigated soils can be find found in presence of highly developed flora and the appearance of deeply and significant developed soil on Kamenica.

The extreme chemical nature of serpentine soils, with abnormally high concentrations of Ni, Cr and Co (in addition to Mg and Fe) and low concentrations of the important nutrients Ca and K, often leads to creation of specific type of soil (serpentine soils) and characteristic serpentine flora.

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ESTIMATION OF SOIL EROSION INTENSITY AND RUNOFF IN THE RIVER BASIN OF BIJELI POTOK, MONTENEGRO

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ABSTRACT

The area of Polimlje in Montenegro covers an area of around 2,200 km^2 and consists of 57 river basins. For one of the tributaries of the river Lim, the river basin of Bijeli potok, the authors of this paper studied soil erosion processes. It was concluded that many factors have influenced the development of erosion processes in the territory of the subject river basin. The most significant factors are the area's climate, relief, geological substrate and pedological composition, as well as the land use. The intensity of soil erosion and runoff for the river basin of Bijeli potok was calculated using the IntErO model, with the Erosion Potential Method embedded in the algorithm of this computer-graphic method. The research foresees that the maximal outflow from the river basin, Qmax, is 62 m^{3}s^{-1} (incidence for the next 100 years). The river basin belongs in „Destruction Category IV", according to the classification system of Professor Gavrilovic. The strength of the erosion process is weak, and the type is mixed erosion. The real soil losses were 612 m^3 per year (211 m^3 km^{-2} year^{-1}).

Keywords: Soil erosion, runoff, river basin, land use, modelling, IntErO model

INTRODUCTION

Soil erosion is as one of the major environmental problems the world faces. According to Spalevic (2011), Kostadinov *et al.* (2006), Lazarevic (1996) water erosion has affected 13,135 km^2 or 95% of the total territory of Montenegro (13,812 km^2). Erosion caused by water is dominant in the terrains with high slopes due to complex physical and geographical conditions paired with reckless logging (Spalevic *et al.* 2012). The exploitation of forests and the irrational use of land caused a change in land use structure (Nyssen *et al.*), and the quality of vegetation cover in the river basin of Bijeli potok. The soil and geological substrate are exposed to the impact of various agents, particularly water, temperature, and gravity. A field survey shows that in some places, some ridges, gullies and ravines have appeared; around the highest mountain peaks sandbanks are present. All these facts obtained in the process of the field survey led the authors to analyze the impact of land use on runoff and soil erosion intensity in this area using a computer-graphic method.

MATERIAL AND METHODS

The study was conducted in the area of the river basin of Bijeli potok, a left-hand tributary of the river Lim, which lies on the slopes of the mountain massive of Visitor (Fig. 1). The river basin of Bijeli potok encompasses an area of 2.9 km^2. In terms of geomorphology and climate, it is part of the natural entity of the Polimlje region (North-East of Montenegro). The natural length of the main watercourse, Lv, is 2.7 km. The shortest distance between the fountainhead and the mouth, Lm, is 2.3 km. The total length of the main watercourse, with tributaries of I and II class, ΣL, is 7.9 km.

Fieldwork was undertaken to collect detailed information on the intensity and the forms of soil erosion, the status of plant cover, the type of land use, and the measures in place to reduce or alleviate the erosion processes. Morphometric methods were used to determine the slope, the specific lengths, the exposition and form of the slopes, the depth of the erosion base and the density of erosion rills.

We drew on the earlier pedological work of the Agricultural Institute in Podgorica (today, the Biotechnical Faculty) led by Djuretic and Fustic, who analyzed the physical and chemical properties of all the Montenegrin soils, including those in the study area of Bijeli potok. Furthermore, some pedological profiles had been reopened, and soil samples were taken for physical and chemical analysis. The granulometric composition of the soil was determined by the pipette method; the soil samples were air-dried at

105°C and dispersed using sodium pyrophosphate. The soil reaction (pH in H_2O and nKCl) was determined with a potentiometer.

Fig. 1. Study area

Polimlje: 43.245703 N, 19.580383 E (North); 42.508046 N, 19.905853 E (South); 43.148092 N, 19.485626 E (West); 42.963960 N, 20.120087 E (East).

The total carbonates were determined by the volumetric Scheibler method; the content of the total organic matter was determined by the Kotzman method; available phosphorous and potassium were determined by the Al-method, and the adsorptive complex (y1, S, T, V) was determined by the Kappen method.

An increasing awareness by scientists, governments and the general public that soil erosion is an important problem in Europe (Morgan and Rickson, 1990) has drawn attention to the lack of a satisfactory system for assessing the risk of erosion, predicting erosion rates and designing and evaluating different soil protection strategies (Morgan *et al.* 1998).

Reduction of soil erosion to preserve soil quality and to maintain land productivity constitutes a major challenge for mountainous soils. Soil erosion can be reduced by appropriate land management. It requires both the collection of field data and the predictive model for the evaluation of different management scenarios for the protection of soils. Field measurements of erosion and sedimentation using classical techniques is time-consuming and expensive (Bujan *et al.* 2000). The modelling of the erosion process has progressed rapidly, and a variety of models have been developed to predict both the runoff and soil loss (Zhang *et al.* 1996).

Most of the methodologies remained at the qualitative (descriptive) level, relying on empirical evidence and expert subjective evaluation of the conditions. In the South-Eastern European Region two methodologies have achieved the required level of standardization of research procedures to minimize subjective errors of the researchers, which allows obtaining uniform results, tracking the state of changes in erosion intensity over a period of time.

The first method is the "*Soil Loss Equation*" of the U.S. Soil Conservation Services, further improved, now known as USLE (*Universal Soil Loss Equation*). This method determines the intensity of erosion on agricultural land, but is also successful in very small catchments which are located on the surfaces with moderate slopes and on the nearly flat terrains.

Another method is the "*Erosion Potential Method - EPM*" and is in use in watershed management, studies and projects. It was created, developed, and calibrated in Yugoslavia (Gavrilovic, 1972).

Both of these methods are standard for use in agriculture and water management, according to its primary purpose, but it should be noted that the accuracy of the USLE method ends for the surfaces with the slope of less than 7^0 as it is developed for determining of erosion processes for agricultural production. "*Erosion Potential Method – EPM*" covers a wide range of soil erosion intensities.

According to previous experience, and verifications (Spalevic, 2011) the most reliable method for determining the sediment yields and the intensity of the erosion processes for the studied area is the *Erosion Potential Method (EPM)*.

Blinkov and Kostadinov (2010) evaluated applicability of various erosion risk assessment methods for engineering purposes. Factors taken into consideration depended on scale, various erosion tasks as well as various sector needs. The EPM was the most suitable on catchment level for the watershed management needs in this Region.

The use of computer-graphics in research on runoff and the intensity of soil erosion have been demonstrated in Montenegro, specifically in the Region of Polimlje (Spalevic *et al*. 2013, 2012, 2011, 2007, 2004, 2003, 2001, 2000, 2000a, 1999, 1999a), Fustic and Spalevic (2000). That approach was used in the research on the river basin of Bijeli potok. We used the **Int**ensity of **Er**osion and **O**utflow (IntErO) program package (Spalevic, 2011) to obtain data on forecasts of maximum runoff from the basin and soil erosion intensity. EPM is embedded in the algorithm of this computer-graphic method.

RESULTS AND DISCUSSION

Physical-geographical characteristics and erosion factors

Many authors have studied the physical-geographical characteristics of this area. Cvijic (1921) called attention to the geographical individuality of the region, with special emphasis on the Prokletije mountain group, where the river basin of Bijeli potok is located. Knezevic and Kicovic (2004) and Kicovic and Dragovic (2000) described the natural characteristics; Pavicevic (1956), Pavicevic and Antonovic (1976) erosion proceses of the upper part of the Polimlje Region.

The river basin of Bijeli potok stretches from its inflow to Lim (H_{min}, is 890 m) to the tops of the Visitor mountain, where the H_{max} is 2211 m. The basin is hilly and mountainous.

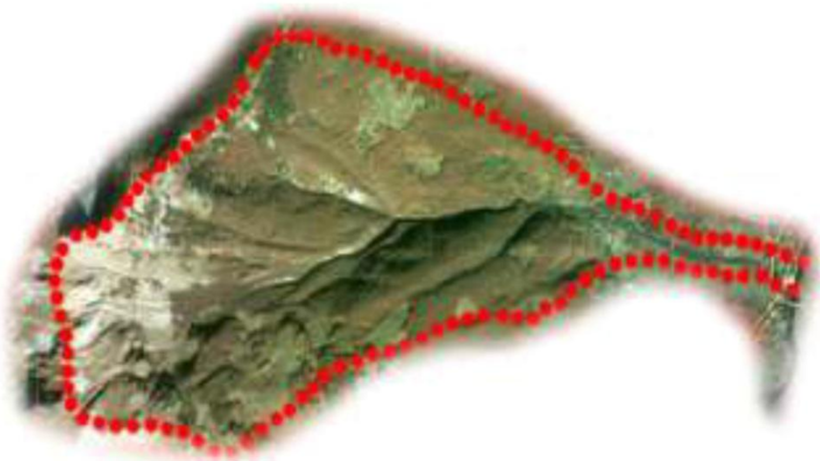

Figure 2. Satellite image of the studied area

Figure 3. Panoramic the Mt. Visitor and the River basin Bijeli potok

There are mild slopes around the village Brezojevice and steep slopes in the upper part of the Visitor massive. The average river basin decline, Isr, is 46.08%; the average river basin altitude, Hsr, is 1591 m; the average elevation difference of the river basin, D, is 701 m.

Climatic characteristics

The climate is determined by the proximity of one large water area (the Lake of Plav) as well as the Prokletije and Visitor Mountain. It is characterized by short, fresh, dry summers; rainy autumns and springs, and cold winters. The absolute maximum air temperature is 35^{O}C. Winters are severe, so much so that negative temperatures can fall to a minimum of -29.8 ^{O}C.

In terms of rainfall, there are two characteristically rainy periods of the year: the first-cold period (October-March) and the second-warm period (April-September).

Basic data on the area needed for the calculation of soil erosion, intensity, and runoff are presented in Tables l - 6.

The amount of torrential rain, h_b, is 89.4 mm. The average annual air temperature, t_0, is 8.1°C. The average annual precipitation, H_{year}, is 1345.4 mm.

The geological structure of the area

In the structural-tectonic sense, the area belongs to the Durmitor geotectonic unit of the inner Dinarides of Northern and North-eastern Montenegro (Zivaljevic, 1989). The geological structure of the area consists mainly of Paleozoic clastic, carbonate and silicate volcanic rocks and sediments of the Triassic, Jurassic, Cretaceous-Paleogene and Neogene sediments and Quaternary. The coefficient of the region's permeability, S_1, is calculated on 0.84.

Soil characteristics of the area

The fact that soil properties always have an effect on the intensity of erosion has been generally accepted and confirmed by Baver (1959) and Pavicevic (1968). Those studies paid particular attention to the types of soil and their properties, with particular focus on their propensity towards erosion. Pavicevic (1956, 1957), Pavicevic and Tancic (1970), Fustic and Djuretic (2000), Antonovic (2001) and Spalevic (2011) studied the soils of the high mountains in Upper Polimlje.

Table 1. Monthly precipitation sums in lit/m² – Gusinje, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	303.7	270.4	235.3	258.9	231.4	162.1	164.5	165.0	328.9	552.7	393.2	398.1
Av	137.9	119.3	104.5	127.6	89.1	73.9	58.6	66.5	90.8	138.5	174.9	163.8
St.d.	104.0	80.0	54.6	56.7	46.8	37.4	39.2	42.7	67.6	117.3	91.5	112.3

Year = 1345.4

Table 2. Monthly precipitation sums in lit/m²- Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
max	404.0	246.0	166.7	240.0	240.0	246.0	190.0	147.0	214.0	405.0	435.4	310.6
Av	124.1	101.2	89.1	106.4	81.8	69.3	53.9	61.6	85.1	118.7	156.4	134.6
St.d.	100.9	67.6	45.7	55.0	45.7	51.7	39.6	35.5	56.2	93.9	96.7	82.0

Year =1182.3

Table 3. Daily Maximum in lit/m² - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
max	89.4	88.7	76.5	58.8	51.0	48.5	45.7	40.5	40.8	70.0	71.8	65.7
Av	27.7	30.8	29.9	32.1	25.4	18.5	16.7	17.9	25.2	29.7	36.3	34.2
St.d.	25.7	20.7	16.8	12.6	14.8	12.5	10.9	10.0	11.4	18.3	21.7	19.7

Table 4. Monthly average air temperature in ^{O}C - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
max	1.9	2.9	5.8	9.8	13.6	16.4	20.4	20.0	16.1	11.3	6.3	3.4
min	-5.2	-4.9	-1.9	6.1	10.4	13.2	16.0	15.5	10.4	7.5	-1.3	-3.2
Av	-1.4	-0.4	3.2	7.6	12.4	15.2	17.4	17.1	13.4	9.3	3.2	0.0
St.d.	2.2	2.2	2.3	1.1	1.1	1.0	1.2	1.3	1.5	1.2	2.2	2.0

Table 5. Absolute maximum of air temperature in ^{O}C - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
max	14.0	18.0	24.0	24.0	28.4	33.0	35.0	35.0	32.0	27.2	22.0	18.8
Av	11.9	12.1	18.1	20.5	25.5	28.6	31.8	31.3	28.0	24.4	17.7	12.7
St.d.	2.1	2.8	3.4	2.4	2.3	2.7	2.0	1.9	2.7	1.8	3.2	2.4

Table 6. Absolute minimum of air temperature in ^{O}C - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
min	-29.8	-22.2	-18.0	-11.2	-1.6	0.0	0.0	1.0	-1.1	-6.4	-17.0	-21.0
Av	-16.1	-14.1	-9.2	-3.1	0.5	2.3	4.0	3.7	2.3	-3.1	-9.5	-13.6
St.d.	5.2	3.8	4.8	2.9	1.4	1.6	2.0	1.7	2.1	2.0	3.5	4.6

Going from the inflow of the Bijeli potok past Lim to the surrounding mountainous terrain, the most common soil types are: Alluvial and alluvial-delluvial soils, Brown eutric soils, Brown district (acid) soils (on sandstones, granite and gneiss), Brown soils on limestone and Limestone and dolomite soils.

The structure of the river basin of Bijeli potok, according to the soil types is presented in figure 4 and one of the soil profiles on figure 5.

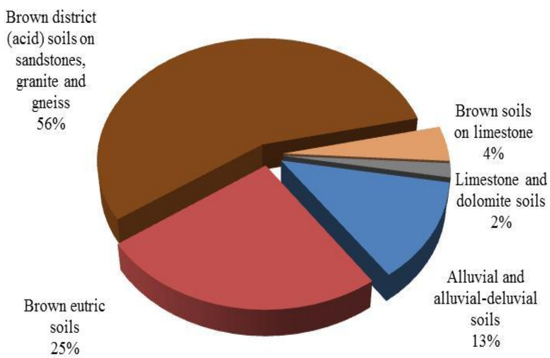

Fig. 4: The structure of Soil types

Fig. 5: Soil profiles (Brown eutric soils) basin of Bijeli potok

Vegetation

For the purposes of calculating the maximum outflow from the river basin of Bijeli potok (Q_{max}) we analyzed a vegetative cover (ratio S2: part of the basin covered by forest, the grasses, orchards, as well as the barren land).

The composition of the geological substrate and the soil formed on this substrate are, for the most part, resistant to erosion as the area is well protected by adequate vegetation cover. However, in places where the terrain is free from vegetation, runoff is intensive. This terrain is characterized by rill erosion, gully erosion.

The studied area is located in Dinarid Province of the Middle-Southern-East European mountainous biogeographical region. The dominant type of vegetation is forests accounting for more than half of the total vegetation cover. The most important plant communities of the area are in the following classes of vegetation: *Erico-pinetea,* *Vaccinio-picetea, Arhenanteretea, Festuco brometea, Bromion erecti, Scorzonerion villosa* and *Ulicionae*.

On the vertical profile, the river basin of Bijeli potok is differentiated from the following forest communities:

1. *Fagetum montanum.* Differentiated into several associations of which the most characteristic is Luzulo - *Fagion moesiacae*.
2. *Abieti - Fagetum moesiacae* Blec and Lak.
3. *Picetum excelsae montanum*
4. *Picetum excelsae subalpinum,* above 1600m.
5. *Fagetum subalpinum* between 1500-1800m at all exposures and different geological substrates.
6. *Pinetum heldreichii* between 1500-2000m.
7. *Pinetum peuces:*
   a. *Pinetum peuces montenegrinum* Blec. between 1800-2000 m;
   b. *Pinetum heldreichii-peuces* Lak. between 1700-2000 m;
   c. *Pinetum mughi* above 2000 m.

According to our analysis, the coefficient f_s, (part of the river basin under forests) is 0.50, f_t (grass, meadows, pastures and orchards) is 0.42 and f_g (bare land, plough-land and ground without grass vegetation) is 0.08.

The coefficient of the vegetation cover, S_2, is 0.71. The coefficient of the river basin planning, X_a, is 0.4. Of the total river basin area, related to the river basin structure, well-constituted forests are the most widespread form (35%). Further proportion is as follows: meadows (28%), degraded forests (15%), grassland (9%), bare land (6%), orchards (5%) and arable land - plough-lands (2%). The structure of the river basin of Bijeli potok, according to the land use is presented in Figure 6.

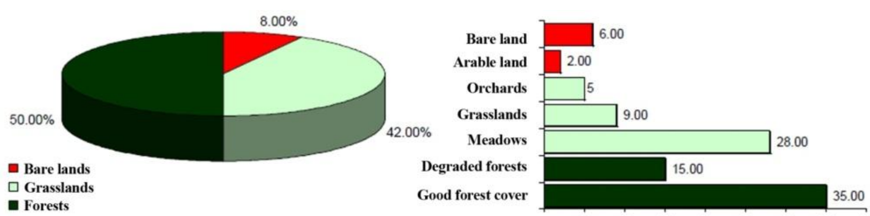

Fig. 6: Land use in the river basin of Bijeli potok

Characteristics of the basin regarding issues of soil erosion and runoff

The relief of the hilly-mountainous terrain is characterized by steep slopes from which the water runs off and flows quickly, which is favourable for triggering the soil erosion process. The dominant erosion form in this area is surface runoff, but more severe forms of erosion, such as rills, gullies and ravines, occur also.

The erosion causes some places to lose fertile land, and results in sterile alluvial deposits on the fertile soils of the small alluvial terraces close to the main watercourse. Surface erosion has taken place in all the soils on the slopes, with the effect that this erosion is most pronounced on the steep slopes with scarce or denuded vegetation cover.

We used the software IntErO to process the input data required for calculation of the soil erosion intensity and the maximum outflow.

A part of the report for the river basin of Bijeli potok is presented in Table 7. (A) symmetry coefficient (0.21) indicates that there is a possibility of a large flood waves in the river basin. Maximal outflow (appearance of 100 years) from the river basin, Q_{max}, is calculated on 62 m^3/s. The value of the Z coefficient was 0.286. According to the result of the value of Z the river basin belongs in the destruction category IV. The strength of the erosion process is weak, and according to the erosion type, it is mixed erosion.

According to Poesen *et al.* (2003) in this part of Europe, erosion has led to the formation of extensive degraded areas called badlands, in which high rates of soil loss is observed (Mathys *et al.* 2003). These eroded lands, which are subjected to rigorous management, often need ecological restoration (Rey, 2009). In recent years, ecological engineering solutions have developed and promote the use of vegetation to protect soils and prevent water erosion (Norris *et al.* 2008). This approach is recommended for the studied area.

Although the erosion process in the river basin of Bijeli potok is categorized as weak, the studied area deserved special attention of the soil conservation specialists. The inflow of the Bijeli potok to the river Lim is close to the outflow of the river Lim from the Plavsko Lake. Torrents that are appearing in the Bijeli potok in the periods of April-June and September-October are violating the riverbanks of the river Lim.

Table 7. Part of the IntErO report for river basin of Bijeli potok

River basin area	F	2.9	km²
The area of the bigger river basin part	Fv	1.6	km²
The area of the smaller river basin part	Fm	1.3	km²
Natural length of the main watercourse	Lv	2.7	km
The shortest distance between the fountainhead and mouth	Lm	2.3	km
The total length of the main watercourse with tributaries	ΣL	7.9	km
The lowest river basin elevation	Hmin	890	m
The highest river basin elevation	Hmax	2211	m
A part of the river basin consisted of a very permeable rocks	fp	0.05	
A part of the river basin consisted of medium permeable rocks	fpp	0.43	
A part of the river basin with poor water permeability rocks	fo	0.52	
A part of the river basin under forests	fs	0.50	
A part of the river basin under grass, and orchards	ft	0.42	
A part of the river basin under bare land and without grass	fg	0.08	
The volume of the torrent rain	hb	62.3	mm
Average annual air temperature	t0	8	°C
Average annual precipitation	Hyear	1182	mm
Types of soil products and related types	Y	0.8	
River basin planning, coefficient of the river basin planning	Xa	0.4	
Numeral equivalents of visible exposed erosion process	φ	0.27	
Coefficient of the river basin form	A	0.64	
Coefficient of the watershed development	m	0.45	
Average river basin width	B	0.78	km
(A)symmetry of the river basin	a	0.21	
Density of the river network of the basin	G	2.72	
Coefficient of the river basin tortuousness	K	1.17	
Average river basin altitude	Hsr	1591	m
Average elevation difference of the river basin	D	701	m
Average river basin decline	Isr	46.08	%
The height of the local erosion base of the river basin	Hleb	1321	m
Coefficient of the erosion energy of the river basin's relief	Er	322.22	
Coefficient of the region's permeability	S1	0.84	
Coefficient of the vegetation cover	S2	0.71	
Analytical presentation of the water retention in inflow	W	0.82	m
Energetic potential of water flow during torrent rains	2gDF^½	199.71	m km s
Maximal outflow from the river basin	Q_{max}	62	m³/s
Temperature coefficient of the region	T	0.95	
Coefficient of the river basin erosion	Z	0.290	
Production of erosion material in the river basin	Wyear	1565.22	m³/year
Coefficient of the deposit retention	Ru	0.39	
Real soil losses	G year	612.21	m³/year
Real soil losses per km2	G year/km²	211.11	m³/km² year

Additionally, eroded material produced in the river basin of Bijeli potok is lifting up to some extent the bottom of the river Lim riverbed. That has reflections on the Plavsko Lake, a hydrological pearl of this part of Montenegro.

CONCLUSION

Many factors influenced the erosion processes in the territory of the river basin of Bijeli potok. The most significant factors are the area's climate, relief, geological substrate and pedological composition, as well as the condition of the vegetation cover and the land use.

Maximal outflow (appearance of 100 years) from the river basin, Q_{max}, is 62 m^3/s and is suggesting the possibility of a large flood.

The strength of the erosion process is medium, and the erosion type is mixed erosion. The predicted soil losses were 612.21 m^3/year (211 m^3/km^2/year).

With the establishment of the new National Park "Prokletije", which is bordering with the studied river basin, this zone will experience intensive tourism in the future. That will cause further development of Agriculture and change of land use structure with the increase of arable lands. There is a need to take preventive measures against the possibility of increasing the soil erosion processes. As a balance, to support the faster renewal of the vegetation and slow down the erosion processes, biological protection measures need to be applied, together with technical ones, notably by using shoulders and ditches to partition water fluxes at the land surface. These would reduce runoff velocity and further support reforestation and the renewal of grass, shrubs and trees on the surfaces of non-agriculture land.

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RECLAMATION OF SALINE PADDY SOIL IN KAZAKHSTAN

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ABSTRACT

Problems of saline land with varying degrees of salinity require a differentiated science-based approach. Different method for reclamation of saline soils was used all over the world. However, the problem with salinization remains open in Kazakhstan soils. the use of traditional methods of reclamation does not allow to completely solving the problem of increasing soil fertility of saline paddy fields in Kazakhstan and, in particular, struggle with toxicity of boron, - a "bane" of paddy soil of the Republic. This issue is very important for the development of rice growing, not only in Kazakhstan but also in other countries. Improvements to existing and new methods of reclamation of saline soils TMS and LMS (without washing) to provide the designed and planned harvest in the first year of, and which have no analogues in the near and far abroad, from both an environmental and an economic feasibility is presented in this work. Under the proposed technology the water-physical properties of soil sharply improved and, so the reclamation indicators of saline heavy and light soil in terms of economic and environmental viability are also improved. This technology is a resource-saving which doesn't have analogues in the country and abroad.

Keywords: reclamation; multifunctional meliorant PFM; high valence chemical - HVC; bentonitic clay – BC.

INTRODUCTION

Problems of saline land with varying degrees of salinity require a differentiated science-based approach. This is especially crucial in soils with boric type of salinity, which are very difficult to reclamation, despite trying of different methods of reclamation.

Physical, chemical, biological and hydro-technical reclamation of saline soils (including the specific conditions of the Central Asian region) were widely studied in Russia. Studies of Avakian (1977), Aleshin, (1986), and others are devoted to physical methods of reclamation. These methods are mainly used to improve the Chernozem and Chestnut soils with thick humus horizons, where their solonetzic properties are pronounced, which is absolutely unacceptable for the conditions of Kazakhstan.

The use of chemical methods of reclamation with gypsum, phosphor-gypsum, various acids, polymers, etc., in. saline soils of rice fields are considered in publications of Bugaevskiy (1998), and others. However, these methods require a long period of disposal of toxic salts and are costly and environmentally risky that is likely to cause pollution of the environment.

Hydro-technical methods of reclamation studied by Aliyev (1973, 1983), Koshkarava (2000), were widely used for desalination of saline areas. However, this type of reclamation of saline soils are based on a long process of washing the salt from soil with the use of horizontal, vertical, and other drainage systems that also are costly, and the waste waters pollute rivers, lakes, and lower landscapes.

For the conditions of Kazakhstan the biological reclamation of saline soils, based on a phytomelioration with the inclusion of salt-tolerant crops in a rotation is also ineffective.

Thus from the above review it is clear that the use of traditional methods of reclamation does not allow to completely solve the problem of increasing soil fertility of saline paddy fields in Kazakhstan and, in particular, struggle with toxicity of boron, - a "bane" of paddy soil of the Republic. This issue is very important for the development of rice growing, not only in Kazakhstan but also in other countries.

Low-productive saline-alkaline soils of arid zones have extremely unfavorable conditions for growth, development and yield formation of rice, which is a serious obstacle to their intensive use in agricultural production. Because, all the current paddy arrays of Kazakhstan geographically located in the floodplains of major rivers, and in the province of boric biochemical salt accumulation (Borovsky, 1978), where about 80 thousand hectares of cultivated area is under rice, the high salinity is necessarily accompanied by high boron content, the exceptionally highly toxic trace element for plants. Under washing of saline soils, the boron is removed with great difficulty because of the exceptional specificity of its reversible transition from fixed to mobile forms. In this regard, it was found that one of the main factors of mass fatalities of rice seedlings is in an excess content of boron in the soil (Mamutov, 1993). Washing the soils from salts, doesn’t completely remove boron. Therefore, on the on previously re-cultivated strongly alkaline soils after the washing, there is no crop production for 3-4 years, but only mass death of rice seedlings in the phase of 3-4 leaves. For such kind of rice fields a "New technology of saline-alkaline soils" (NTOZ-1) aimed to obtain the yield in the first year was proposed (Egorichev *et al.,* 1982). This technology has been pilot tested and passed the refinement in saline medium-textured soils (Mamutov, 1993), and was brought up to the level of completion by the technologies NTOZ-1 and 2. Meanwhile, heavy and light textured saline soils remained without positive results. This phenomenon has been observed throughout the trial production, including rice fields in Kazakhstan, Uzbekistan (Fergana), Russia (Krasnodar), Ukraine (Kherson) and Korea.

One of the most important factors limiting the normal growing of rice in saline soils is the alkalinity of the soil solution and irrigation water. Up-to-date, Vorobeva (2006), Baymenova (1983) and Mamutov (1993) established that the alkalinity of the soil and irrigation water is a multifunctional phenomenon. Therefore, the evaluation of chemistry and the degree of soil salinity by the methods of Bazilevich and Pankov (1968) for specific geochemical provinces do not always give adequate results. Therefore, there is the need for new methods and technologies for the development of salt-affected soils of heavy and light texture.

In the last 30-40 years, for the effective methods of improving the reclamation of saline soils in the agronomic practices along with the traditional investigation, an active influence on physiological processes in plants by physical and chemical agents are being increasingly implemented

The Kazakh Research Institute for Soil Science and Agricultural Chemistry and the Kazakh Research Institute of Agriculture and Plant have been found previously unknown theoretical concepts that became the scientific-experimental basis for cultivation saline soils for rice growing in Kazakhstan with predicted production of rice without pre-washing of heavy textured (HTS) and light texture (LTS) soils.

The core of this technology is the use of PFM (polifunctional ameliorant) low-volume multifunctional cheap ameliorant - zinc sulphate (ZnSO4) and HVC - high valence chemical iron sulfate $Fe_2(SO_4)_2$, and the DA - a drug-adaptogen, as well as BG - bentonitic clay highly represented in Kazakhstan.

On saline heavy soils (HTS) with no filtering, the use of PFM, HVC and the DA, creates the favorable conditions for rapid reclamation without washing. The experimental results showed that they profoundly suppress boron toxicosis, with a reduction in the total alkalinity of soil solutions of paddy fields and with creating optimal filtering regime.

On light saline soils (LTS) application of BG, the PFM and the DA also showed favorable conditions for rapid reclamation without the washing with reduction of boron toxicity, and maximum reduction of filtration rate to improve plant nutrient regime.

MATERIALS AND METHODS

The objects of study were the soil of paddy fields, located in the lower reaches of the Syr-Daria (45°76′71″N and 62°10′29″E), Ili (45°43′10″N and 74°14′15″E) and Karatal (46°27′39″N and 77°28′31″E) rivers. The stationary studies from 1982 to 2009 were carried out mainly by Akdalinsky and Karatal irrigation arrays, and in Kazaly and Akdalinsky arrays the key experiments and production testing were also conducted.

The locations of the irrigated arrays located in desert and semi-desert areas characterized by sharply continental climate with large temperature difference between day and night, summer and winter, and with cold and snowy winters and hot dry summers. The average annual temperature is positive and the sum of temperatures is 3400-5000°C, that determines the capabilities of rice production. These rice irrigation arrays, where the stationary long-term research was held, belong to the province of soda-sulphate and boron biogeochemical soil salinity. In accordance with the existing modern classifications for Akdalinsky irrigation block allocated 44 soil types. The main soils are represented by Takyr soils, that in WRB classification corresponds to Calcisols in varying degrees salinity. Only in the western part of the massif there is limited distribution of alluvial-meadow soils under desertification processes (Kornienko *et al.*, 1977).

There is no doubt that regional conditions of rice growing in different regions of Kazakhstan have their own characteristics, due to a variety of soil and irrigation water. Despite this, they have a number of certain common patterns:

- all rice plantations of the Republic are confined to the deltaic areas of the rivers and areas with obstructed natural drainage;
- alkaline soils are developed mainly on desertification territories and are mainly represented by takyr soils in varying degrees of salinity;
- mostly of the rice fields belong to the boric biogeochemical salt accumulation provinces;
- all soils of rice fields are typically have high alkalinity of the soil solution and irrigation water;
- in flooded soils (for 3-4 months) a very special, specific ecological environment is formed that differ from the environment typical for growing other crops in arid areas.

In the development of techniques for cultivation of saline soils of heavy and light texture, the above described common features of paddy fields in Kazakhstan have been considered. In addition, the final-experimental validation of the results of long-term research by the method of reclamation of saline soils of HTS, LTS was introduced to Karatal and Kazaly irrigation massifs.

Methodological approach to the study adhered to the principle of consistency in time and space, consisting in determining the best and most promising options of laboratory, botanical, field, and then the commercial experiments to select for implementation in production.

Model-laboratory, vegetation, field and commercial tests were carried out in the experimental station "Pilot" Karatal district and state farms "Akdalinsky" "50 Years of October" and "Bahbaktinsky" in Balkhash, Almaty region, as well as the farm “Engels” Kazalinsky, Kyzyl-Orda region. The laboratory, vegetation and commercial experiments were laid on saline soils of heavy and light texture.

Bentonite clay is applied once in 4 years, while chemical ameliorants once in 5 years.

Chemical fertilizers have been applied at the rate of nitrogen 100 kg ha^{-1}, phosphorus 60 kg ha^{-1}. Rice seeding rate is 280 kg ha^{-1}. The irrigation regime is the shortened flooding type.

RESULTS AND DISCUSSIONS

It is known that saline soils are soils containing in any horizon of the soil profile the soluble salts in quantities toxic to medium-salt resistance crops. Therefore, to improve these soils it is needed to remove or reduce the toxic salts from cultivated area.

The theoretical basis and implementation of these activities are given by Bazilevich and Pankova (1968), which is the fundamental methodological guidance not only for the land reclamation in the CIS, but it is used by specialists around the world. An example of this is the design of reclamation of saline soils in the Republic of Kazakhstan. In Kzylorda, Akdalinsky, Karatal and South Kazahstan, the authors first of all expected that the rice crop will behave as ameliorant. To speed up this process the chemical reclamation the application of gypsum and the local use of vertical drainage was provided. As a result of these extensive measures the expected process of soil desalination was proved and salt content was below the threshold of toxicity for growth and development of rice. However, there was observed a paradox phenomenon as massive loss of rice seedlings in the phase of 3-4 leaves, particularly in the rice-fields of Ili river and Kyzyl-Orda region and Karatal irrigation massif. In the search for the cause of mass death of rice on the initially saline, but washed out "to the end" soils, attended a number of research institutes. The detailed investigations revealed that the main reason for this paradox is the presence of boron, which with increasing alkalinity transforms into highly toxic form and as a result of boron toxicity rice is killed in an early phase of development (Egoricheva, *et al.*, 1982).

Detailed studies were conducted to find out the mechanism of formation of the borate alkalinity; the threshold of toxicity for rice and effectiveness of Zn compounds against B toxicity (Baymenova, 1983); the influence of B and Zn on soil microflora of paddy fields (Pevzner and Kostovetsky, 1990); the impact of zinc in combination with rice straw in soils of rice fields (Nelidov *et al.*, 1991; Sadanov *et al.*, 1984); the impact of zinc on the ability of algae to form alkaline medium. All of these surveys were conducted in saline medium-textured soils.

At the same time we studied saline soils of heavy and light texture for: the state of B compounds in soils of rice fields and the threshold of toxicity for rice on Karatal irrigation massif; the behavior of zinc applied to the soil using a labeled ^{65}Zn; the relationship of zinc and boron in soils of rice fields; the behavior of phosphate fertilizer using NTOZ; the role of plant residues in the optimization of the zinc status of soils; the impact of the use of zinc to the environment; the development of technology of saline soils HTS (NTOZ-3) and LTS (NTOZ-4).

The difficulty of washing off the borates in land reclamation, especially in alkaline soils is associated with adsorption capacity of tetraborate ion. Studies in the United States (Menzel, 1927) demonstrated that the removal of boron from the soil to a level below the toxic requires 3 times more washing water than for other water-soluble salts, with all the economic and agrophysical consequences. The studies for B washing from saline alluvial soils of the Euphrates valley, which has high content of boron, established that boron salts are leached slowly than others (Esimbekov, 2010). To reduce the B up to about 20% of its initial content, the water layer per unit capacity of the soil profile was 5-8 times more than what is required for a comparable reduction in the total salt content. In the case when the washed soil, for some time, remained in a saturated state, the B content in this extract of soil rises again. There are results showing that this process can continue until the restoration of the original content of B. This situation is observed in the saline soils of rice fields in Kazakhstan (Baymenova, 1983).

For unambiguous confirmation of the suitability of any methods of reclamation of saline soils, including borate soil salinity should be set the threshold toxicity of these compounds, which have their own characteristics in certain regions and soil types. The results of laboratory experiments allowed defining the limits of B toxicity in the early stages of rice growth (Fig 1). The figure shows that, the concentration of B above 6 mg kg^{-1} in the soil can be considered as the threshold of toxicity for the young rice plants. At application of boron in 8 mg kg^{-1} the plant height was 2.4 cm, and at 10 mg kg^{-1} was 1.6 cm. At the same time there was revealed the un-saturation of takyr soil relative to B, whose adsorption capacity for this element is very high.

It is known that the main determinants of the high B adsorption by soils are the surface area, content of organic matter, oxides, and soil pH. Toward to keep the B content low, below toxic levels, it is often recommended, from time to time, even washed soil to expose to excessive amounts of water. However, due to the high adsorption capacity of soils to B ions it is necessary to know the concentration of borate in the irrigation water (Tab. 1).

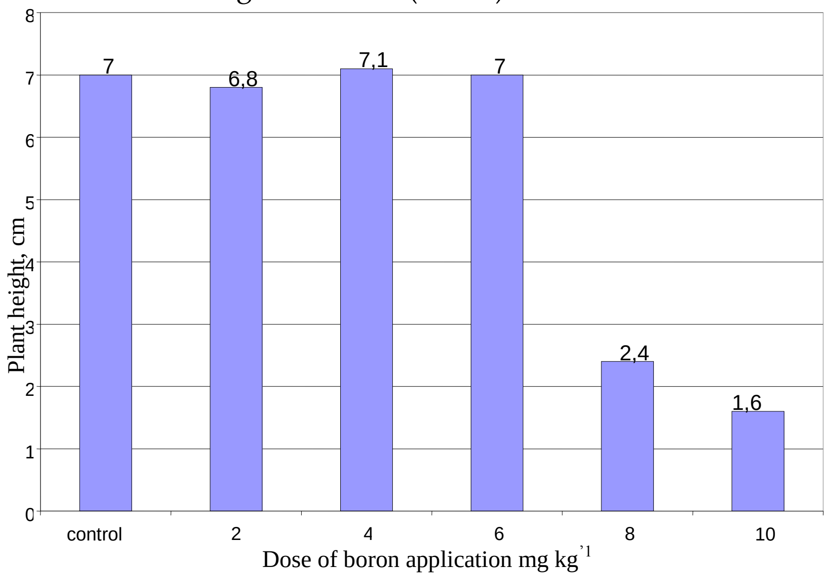

Fig. 1 Establishing threshold toxicity of boron in the light textured soil

Table 1 The boron content in a range of solutions, meq/l

Type of solution	Boron concentration	Type of solution	Boron concentration
Water from Ili river	0,060	Waste water	0,150
Water of irrigation channel	0,070	Ground water	1,75
Rice-field water	0,120	Soil solution:	
		0-5 cm	1,86
		5-10 cm	2,79

The results indicate that boron content in rice-field water two-times higher than in Ili River. This is due the dissolution of mobile compounds of B from the salt crust by watering, while in waste water is close to the rice-field. In the rice-field and the irrigation water the B concentration does not exceed the threshold of toxicity. According to Skofeld the B toxicity threshold for rice is above

0,000067-0,000025% in water, while in soil solutions is higher (Schofield and Wroth, 1968). So at constant watering of rice paddies with Ili water that has the relatively low content of B, due to the high alkalinity of the soil (even washed) there is possibility of accumulation of boron in the soil. The saturation of the soil with borates can also occur due to evaporation of ground water.

The results of this experiment were confirmed by pot-experiments of vegetation. The experiments were carried out in closed vessels without filtering on two backgrounds. Sandy- loamy is non-saline soil contained: salt-0, 117%, pH - 7.4, total alkalinity - 0.045%, mobile boron - 0.56 mg kg^{-1}; and clay- loamy saline soil, respectively 0.292%, 7.8%, 0.038%, 2,38 mg kg^{-1} (Tab. 2).

Table 2 Effect of boron application into non-saline HTS and LTS soil and its soluble form of the degree of boron toxicity

Treatment mg B/kg soil	Water-soluble B, mg kg^{-1}	Dry weigh of 10 plants, g above mass /roots	Signs of toxicity	Water-soluble B, mg kg^{-1}	Dry weigh of 10 plants, g above mass per root	Signs of toxicity
		Clay-loam soil			Sandy-loam soil	
Background	2,38	2,36 / 0,45	slight	0,56	2,6 / 2,1	no
Background +B-2	-	-	-	2,35	2,26 / 0,74	slight
Background +B-4	5,96	1,36 / 0,23	very noticeable	3,46	2,10 / 0,5	noticeable
Background +B-6	6,40	1,20 / 0,23	«	5,38	1,80 / 0,40	«
Background +B-8	7,55	1,09 / 0,25	«	6,25	1,38 / 0,40	«
Background +B-10	13,25	0,84 / 0,21	«	7,90	1,27 / 0,26	very noticeable

On clay-loamy soil the drying tops and chlorosis of leaves, plant stunting at a dose of 6, 8, 10 mg kg^{-1} were observed later than on sandy-loamy soil. Minor symptoms of toxicity were observed in the treatment without B addition, where water-soluble B in soil was 2.38 mg kg^{-1}. So, in rice cultivation on clay-loamy soils the boron toxicosis occurs at lower levels of the soluble form of boron than in sandy- loamy soil. In the early tillering stage the state of plants grown in B treatments deteriorated, resulting in reduced plant dry weight (10 plants at this phase weighed for 2-2,5 times less compared to control).

Thus, it was possible to trace that the content of B in the soil above 6 mg kg^{-1} in flooded conditions causes boron toxicity and reduced productivity of rice. Investigations of chemicals for the cultivation of saline HTS and LTS soils were started with the laboratory, pot, field and commercial experiments with the introduction into production process.

Thus, we established that the reclamation of saline soils of heavy and light textures the physical and chemical processes must be considered simultaneously.

An experiment in the implementation into production in 2009 for saline soil of heavy texture was founded on the area of 63 hectares, with treatments for use of PFM-40 kg ha^{-1} and HCS-5 t ha^{-1}. The control treatment was founded on an area of 37 hectares in LLP "Reza-Agro" Kazalinsky, Kyzylorda region with Russian varieties of rice "Leader". Rice variety was treated before sowing with adaptogen-drug (Tab. 3).

Table 3 Economic calculations of saline clay-loam soils

Total area, ha	Considered area, ha								Gain of yield, t ha^{-1}
	Commercial planting (control)				Amelioration mean				
	Sown area, ha	Yield t ha^{-1}	Net product t	Cost, t kg^{-1}	Sown area, ha	Yield t ha^{-1}	Net product t	Cost, t kg^{-1}	
100	37	3,523	1304	4,30	63	3,91	2463	3,711	0.387

The implementation into production the same 2009 year on saline sandy-loam soil was founded in SPC "Opytnoe" Karatal, Almaty region. The area of 27 hectares, with the use of bentonite clay (10t ha^{-1}) and CPM-40 kg ha^{-1} of active substance, while the control variant without the use of the above mentioned substances on the area of 24 hectares were laid out. The rice seeds of “Pak-Li” variety were treated with adaptogen-drug (Tab. 4).

Table 4 Economic calculations of saline sandy-loam soils

Total area, ha	Considered area, ha								Gain of yield, t ha^{-1}
	Commercial planting (control)				Amelioration mean				
	Sown area, ha	Yield, t ha^{-1}	Net product., t	Cost, t kg^{-1}	Sown area, ha	Yield, t ha^{-1}	Net product., t	Cost, t kg^{-1}	
51	24	1,98	475,2	5,34	27,0	3,16	799,2	4,20	1,18

The results show that the use of PFM and HCS on saline of clay-loam soils and of BG, PFM on saline sandy-loam soils, are economically and environmentally benefitial and are cost-effective:

- rice yield increased in, respectively, 0,387 and 1,18 t ha^{-1}, against the control; the net gross also increased respectively by 1159 and 324 tons, while cost decreased for 4.89 and 11.4 tenge;
- saving irrigation water, increased soil fertility, improved the quality of rice and the environment is not polluted;

The data of the studies indicate the possibility of obtaining the designed and planned of rice yield in saline solonetzic solonchakous heavy and light textured soils. These treatments are the only of many of its peers, which have passed the test in many years of laboratory, pot and field experiments. Consequently, they are recommended for implementation in the production of rice.

CONCLUSIONS

In the reclamation of saline heavy and light textured soils both physical and chemical processes must be considered, because they entirely depend on the method of reclamation.

The high efficiency of Zn compound to neutralize the toxicity of B (without washing) and incorporation into soil of Fe sulfate improves physicochemical properties and optimizes filtering regime of clay-loam saline soils.

Theoretical basis for reducing the rate of filtration of saline sandy-loam soils is the chemical process of the mudding between BG and chlorine-containing salts, and at the same time the physical process of improving the soil structure due to swelling of the BG, where against the toxicity of boron compounds zinc sulfate at a dose of 40 kg ha^{-1} was used.

Under this technology the water-physical properties of soil sharply improved and, so the reclamation indicators of saline heavy and light soil in terms of economic and environmental viability (Esimbekov, 2010) are also improved.

This technology is a resource-saving which doesn’t have analogues in the country and abroad.

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THE CONTENT OF HARMFUL TRACE ELEMENTS IN SOIL AND GROUND WATER IN POWER PLANT AREA

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ABSTRACT

Soil surrounding power-plants, such as coal power-plants, is often contaminated by some harmful substances, which migrated from the ash and slash after the combustion of coal and hydraulic transportation by water of ash in the special constructed boxes for ash. Among the contaminants we pointed out some harmful microelements as are Cr, Ni, Pb, Cd, Hg, S, As i B. The results obtained exhibit the higher content of harmful substances such as Pb, B and SO_4 in the nearby ground waters above the MAC (Decree for the classification of waters and water bodies - values for the fifth class of waters. At the other side the content of harmful microelements in the nearby soils is not above MAC (Regulation of maximum allowed content of harmful materials in soils and irrigation waters.

Keywords: harmful, trace elements, contamination, power plant

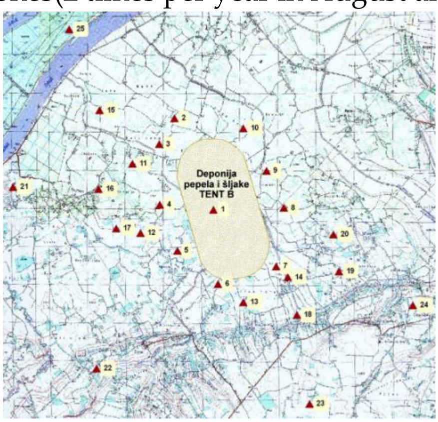
INTRODUCTION

Power-plant “Nikola Tesla”-TENT B in Obrenovac near Belgrade has installed power1650MW in 6 blocks. Lignite coals, from nearby coal mine Kolubara, is used as a fuel in the plant. Coal contains about 0.5% of S and 14-20% of ash. After combustion the smoke gasses contains some harmful and hazardous substances like SO_x,NOx ,CO and CO_2 and other dusty materials. Byproducts of combustion, ash and slash, are taken out by hydraulic transportation with water in the ratio 1:10. Since 2009 the ratio was decreased on 1:

1 that helped to prevent wind erosion of ash. Ash is disposed in specially constructed concrete blocks on the Disposal which spreads on the area of 600km². Disposal is surrounded by municipalities and arable soils, and represents permanent source of contamination of soils and waters by flying ash and drainage waters from the process of hydraulic transportation of ash. Ash contains some trace elements that might be very dangerous like As, Ni, Cd, B, Hg, Cr, Mo etc. The goal of our research was the estimation of the impact of coal power-plant on the main soil chemical properties and accumulation of trace elements Cr, Ni, Pb, Cd, Hg, S, As and B from ash and smoked gases in the nearby soils and ground waters (Adriano, 2001; Pacyana *et al.*, 1986).

MATERIALS AND METHODS

Soil samples were collected from 25 (Pic. 1) points divided in 5 zones(2 times per year in August and November).



Pic. 1. Scheme of location of soil samples

-First zone was up to 1km away of Disposal,
-second zone 1-3km away
-third zone 3-5km away
- fourth zone beyond river Sava and
- fifth zone more than 5 km away.

We performed soil analyses of trace elements by ICP after the digestion of soil samples by aqua-regia.(methods SRPS-ISO 11466 and SRPS-ISO11047). Boron was extracted from soil by hot water and determined by ICO. Main soil physical and chemical characteristics were also done; particle size-analyses(International B pipette method), pH value(SRPS-ISO 10390), organic matter in the form of humus(method by Kotzman), available P_2O_5 and K_2O (by Egner-Rhim), content of mineral forms of N (by Bremner), total C and total (CNS analyzer).

-Samples of water were collected from canals around Disposal (picture 2) and trace element were analyses on ICP analyzer.

Table 1.Main soil chemical parameters

Point No.Col.time	pH in nKCl		N %		org. C %		humus %		NO_3 (mg kg^{-1})		NO_2 (mg kg^{-1})		P_2O_5 (mg $100g^{-1}$)		K_2O (mg $100g^{-1}$)	
	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**
I zone of impact																
2	4,40	4,49	0,16	0,19	1,52	1,99	2,62	3,43	8,75	13,75	0,05	0,09	5,16	6,70	19,47	17,01
3	4,80	4,49	0,15	0,22	1,42	2,51	2,45	4,33	12,25	31,50	0,03	0,10	4,57	3,32	18,65	14,62
4	4,50	4,29	0,18	0,18	1,87	1,73	3,22	2,98	26,25	36,75	0,06	0,08	10,43	9,50	23,12	17,41
5	5,50	5,39	0,19	0,34	2,02	3,41	3,48	5,88	40,25	61,25	0,07	0,15	55,39	59,55	39,38	38,90
6	5,60	5,45	0,19	0,16	2,11	1,59	3,64	2,74	31,50	26,25	0,06	0,19	32,32	9,31	25,56	17,01
7	6,95	6,25	0,13	0,14	2,21	2,04	3,81	3,52	31,50	8,75	0,16	0,25	3,63	2,06	16,21	20,59
8	5,10	5,21	0,15	0,15	1,46	1,50	2,52	2,59	26,25	10,50	0,04	0,12	2,63	1,17	16,03	18,60
9	5,55	3,81	0,21	0,13	2,40	1,32	4,14	2,28	31,50	28,00	0,09	0,11	2,87	2,76	18,65	15,02
10	4,25	4,96	0,14	0,20	1,37	2,10	2,36	3,62	33,25	15,75	0,07	0,15	2,32	0,87	14,17	17,01
II zone of impact																
11	4,60	4,67	0,14	0,17	1,39	1,42	2,77	2,45	15,75	3,50	0,09	0,10	5,26	4,31	15,39	16,21
12	5,00	4,92	0,19	0,19	2,02	2,00	3,48	3,45	22,75	12,25	0,11	0,12	5,47	2,31	19,46	22,58
13	5,00	4,62	0,24	0,24	2,46	2,15	4,24	3,71	19,25	103,95	0,14	0,12	15,22	11,79	32,87	35,31
14	6,75	6,08	0,29	0,36	2,92	4,03	5,03	6,95	21,00	7,00	0,16	0,56	6,30	6,27	19,46	20,59
20	5,90	6,15	0,28	0,38	3,53	3,62	6,08	6,24	19,25	40,25	0,13	0,18	16,80	49,72	35,72	38,90
III zone of impact																
15	4,60	5,38	0,19	0,18	1,90	1,72	3,28	2,96	26,25	17,50	0,10	0,14	1,38	0,60	15,80	21,39
16	5,90	5,41	0,23	0,23	2,40	2,45	4,14	4,22	31,50	22,75	0,09	0,15	56,92	43,06	39,38	38,90
17	6,60	5,98	0,18	0,16	1,81	1,65	3,12	2,84	52,50	47,25	0,22	0,27	5,54	4,05	20,27	15,82
18	5,95	6,06	0,16	0,16	1,64	1,61	2,83	2,77	17,50	21,00	0,13	0,23	13,60	8,80	18,65	23,38
19	5,40	5,65	0,25	0,28	2,32	2,86	4,00	4,93	43,75	26,25	0,16	0,16	32,47	38,60	34,09	38,90
23	4,10	4,43	0,12	0,14	1,17	1,40	2,02	2,42	24,50	10,50	0,05	0,11	10,78	10,59	18,24	19,40
zone beyond river Sava																
25	6,95	6,31	0,21	0,20	3,65	3,57	4,30	6,15	33,25	42,00	0,18	0,36	21,06	5,89	18,65	22,58
control zone																
21	5,50	5,35	0,21	0,20	2,16	1,96	3,72	3,38	31,50	36,75	0,04	0,14	32,31	27,91	36,94	36,11
22	4,30	4,45	0,15	0,19	1,55	1,89	2,67	3,26	22,75	12,25	0,04	0,10	1,86	11,12	16,21	19,40
24	4,55	4,21	0,16	0,15	1,90	1,33	3,27	2,29	12,25	19,25	0,05	0,08	1,10	0,77	11,33	15,82

* - august 2009. / ** - November 2009

Tab. 2 Content of total trace elements and water soluble B in soils TENT -B

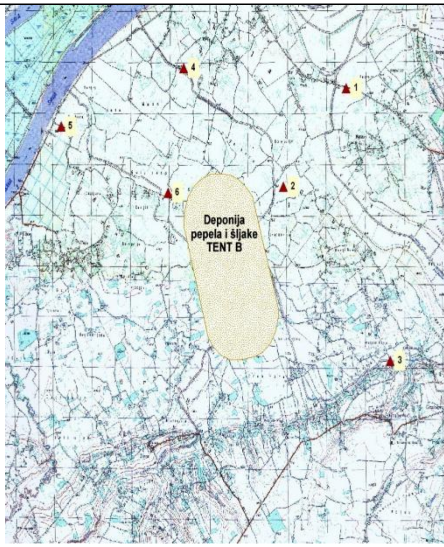
No.	Cr		Ni		Pb		Cu		Zn		Cd		Hg		B		As		Fe		water.sol. B	
									(mg/kg)										(%)		(mg kg-1)	
	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**
I zone of impact																						
2	42	41	31	31	24	28	21	22	52	64	0,20	0,27	0,06	0,03	45	37	7	8	2,08	1,72	0,80	1,02
3	43	39	31	25	35	33	16	15	73	54	0,30	0,22	0,12	0,03	52	42	10	11	2,30	1,83	1,28	0,75
4	36	45	35	36	26	30	17	19	53	58	0,27	0,27	0,06	0,04	40	32	7	7	1,90	1,46	0,94	0,76
5	46	46	39	41	27	25	19	19	69	64	0,31	0,29	0,08	0,05	42	36	7	7	1,96	1,40	1,87	1,78
6	30	43	21	26	26	27	15	17	56	63	0,23	0,25	0,04	0,03	39	34	4	5	1,89	1,63	1,37	0,94
7	46	50	43	43	21	23	22	24	61	66	0,23	0,23	0,06	0,05	50	33	9	9	2,22	1,76	0,90	0,77
8	48	45	38	37	30	29	19	19	59	60	0,31	0,31	0,06	0,04	55	36	9	8	2,35	1,83	1,10	0,98
9	44	51	39	39	33	33	17	19	58	62	0,35	0,22	0,04	0,03	65	43	12	10	2,55	1,99	1,35	0,51
10	53	49	43	39	32	33	19	19	65	67	0,30	0,32	0,06	0,03	73	42	12	12	2,68	2,16	0,80	1,30
II zone of impact																						
11	43	44	32	31	30	30	15	16	54	52	0,22	0,21	0,09	0,03	46	33	8	8	2,08	1,62	0,72	0,75
12	55	48	46	39	30	25	19	19	57	57	0,28	0,22	0,05	0,04	56	33	9	8	2,31	1,70	1,15	1,08
13	31	37	23	23	26	28	16	16	55	58	0,29	0,25	0,03	0,02	41	34	5	5	1,91	1,49	1,27	1,27
14	38	44	35	36	25	28	20	24	63	70	0,26	0,31	0,04	0,04	43	33	4	4	2,00	1,57	1,93	2,18
20	47	42	38	43	27	29	19	25	65	86	0,29	0,40	0,05	0,05	52	45	8	8	2,26	1,89	1,55	2,32
III zone of impact																						
15	54	58	51	50	42	31	21	22	88	68	0,30	0,30	0,02	0,04	58	45	8	8	2,41	1,95	0,95	0,95
16	56	58	49	48	37	32	26	26	91	44	0,42	0,34	0,08	0,04	54	40	9	10	2,28	1,79	1,20	1,29
17	55	59	58	55	29	24	21	22	60	58	0,18	0,19	0,07	0,07	57	33	9	8	2,42	1,86	0,77	0,61
18	42	46	29	37	33	28	19	21	69	61	0,27	0,25	0,05	0,05	56	39	8	9	2,31	1,90	0,89	0,77
19	47	55	42	42	26	29	22	25	71	82	0,28	0,34	0,05	0,05	52	42	7	7	2,23	1,79	1,58	1,60
23	33	33	25	23	28	29	16	17	50	54	0,20	0,19	0,05	0,04	55	34	8	7	2,27	1,81	0,43	0,61
zone beyond river Sava																						
25	78	64	110	91	50	39	31	29	189	108	0,89	0,53	0,436	0,20	60	44	16	13	2,44	1,83	0,87	0,86
control zone																						
21	47	46	38	37	30	31	21	22	65	66	0,33	0,32	0,05	0,05	54	38	11	11	2,31	1,82	0,98	1,06
22	32	39	27	28	27	29	16	17	48	60	0,24	0,27	0,05	0,04	51	41	8	9	2,21	1,82	0,61	0,80
24	33	37	29	28	27	30	16	17	48	54	0,24	0,26	0,05	0,04	48	36	8	9	2,21	1,76	0,70	0,72
MAC	100		50		100		100		300		3		2		50		25		-		-	

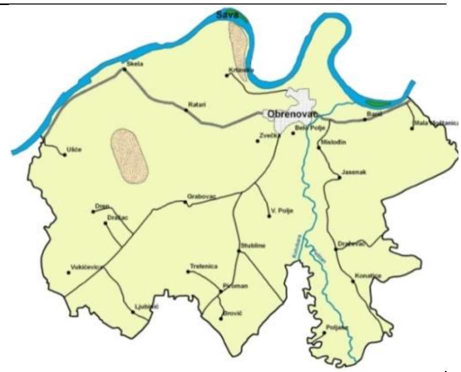
* - august 2009. / ** - november 2009; MAC – Regulation of allowed concentracins of harmful and hazardous substances in soil (Sl. Glasnik RS 23/94)

Table 3. Chemical analyses of water in drainage canals, TENT – B

No.	B		As		Hg		Pb		Fe		Cr		Ni		Zn		Cu		Cd		SO_4	
	mg l^{-1}																					
	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**
1	0,03	0,04	0,008	0,004	0,0011	0,0002	0,06	0,06	0,03	0,03	0,000	0,002	0,002	0,001	0,007	0,015	0,005	0,003	0,0006	0,000	36	52
2	2,77	3,09	0,052	0,027	0,0008	0,0003	0,02	0,04	0,01	0,08	0,003	0,001	0,002	0,002	0,009	0,012	0,006	0,003	0,0004	0,000	468	283
3	0,04	0,06	0,003	0,003	0,0007	0,0003	0,05	0,11	0,03	0,03	0,001	0,000	0,014	0,001	0,003	0,006	0,014	0,002	0,0005	0,000	36	22
4	2,78	3,15	0,052	0,029	0,0007	0,0003	0,01	0,04	0,01	0,09	0,002	0,000	0,001	0,001	0,005	0,012	0,001	0,004	0,0002	0,000	474	285
5	2,39	2,60	0,054	0,064	0,0007	0,0002	0,02	0,08	0,04	0,04	0,001	0,051	0,001	0,003	0,006	0,005	0,010	0,003	0,0000	0,000	411	247
6	2,40	2,64	0,055	0,063	0,0007	0,0002	0,02	0,03	0,04	0,04	0,000	0,053	0,001	0,002	0,008	0,007	0,010	0,003	0,0006	0,000	414	247
MAC	1		0,05		0,001		0,1		1		0,5		0,1		1		0,1		0,01		-	

*   - august 2009.
** - november 2009.
MAC –according to Regulation of classification of water and water bodies-values for V class of water (Sl. Glasnik Republike Srpske 3/97,3/99,29/00)





Point No.	Locations of collected wat. (TENT B)
1	At Nikolic
2	Near rail road
3	Grabovac Big canal
4	Skela
5	Vukicevica near power-plant
6	Vukicevica near Disposal

Pic. 2. Scheme of locations of collected water

RESULTANTS AND DISCUSSION

The impact of power-plant on the main soil chemical properties was not observed. There was not increasing of soil acidity in the zones nearby Disposal (Tab. 1).

Content of mineral forms of N(NO_3 and NO_2) was not increasing in the zones of higher impact comparing to control zones (Tab. 1).

Content of organic matter wasn't decreased in the zones of higher impact (Tab. 1).

Content of total B was above MAC (60% of soil samples) but there was not some main difference between zones of impact. Water soluble B was below MAC in all zones (Tab. 2). Content of Ni was above MAC on one sample of zone 3.There was not contamination of soils by Ni in the area of power-plant (Tab. 2). In the zone beyond river Sava (point 25) the soil sample contains Ni and Cr above MAC. But we did not assume it as a contamination by power plant. As soil near river Sava is flooded frequently it might be the contamination by water of river Sava (Tab. 2). We found high concentrations of B (above MAC) in water of drainage canals on the points 2,4,5 and 6.As was above MAC on the points2,5 and 6. SO_4-S was above MAC on the points 2,4,5 and 6 (tab. 3) (Kisic *et al.*, 2009).

CONCLUSIONS

The impact of power-plant on the degradation of main soil chemical properties either contamination by trace elements was not observed. Soils nearby power-plant exhibit high buffer capacity for now. It is necessary to keep on soil monitoring in the years ahead.

Water contamination by trace elements (B,As and SO_4-S) in the drainage canals around Disposal was high. That indicates to be very careful and avoid usage of water from canals for the irrigation purposes that might cause contamination of soils .

New way of hydraulic transport of ash with less content of water could be convenient for avoiding of contamination of ground waters.

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CHEMICAL PROPERTIES OF CALCAREOUS VERTISOLS OF PCINJA DISTRICT

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ABSTRACT

This paper presents the results of the chemical properties analyses of calcareous Vertisols. The samples were taken in Pcinja district, on four locations between 345 and 489 m.a.s.l. Chemical properties analyzed were: $CaCO_3$ content, active acidity, exchangeable acidity, humus and nitrogen content, available phosphorus and potassium, and available micronutrients: Fe, Mn, Cu, Zn and B. Formation of calcareous Vertisols is related to calcareous clay parent rock, and average $CaCO_3$ content is 9.1%. Depending on climate conditions and the process of decarbonization, $CaCO_3$ content increases with depth. These Vertisols, due to $CaCO_3$ present, have higher values of pH in water suspension, around 7.84 at the depth to 20 cm. According to the humus content, these soils are classified as poor to medium supplied. The value of available K is high, and the content of the available P is low. Content of available Fe, Mn and B is directly correlated to the $CaCO_3$ content. These soils have medium to high amount of available micronutrients.

Keywords: calcareous Vertisols, chemical properties, macro and micro nutrients.

INTRODUCTION

Vertisols are automorphic soils with A-AC-C soil profile, class of humus-accumulative soils (Ciric, 1991). Vertisols cover 335 million ha worldwide (WRB, 2006). In Serbia they cover 780 000 ha, mostly in the central region – Sumadija, but they are also found in almost all others parts: eastern (Negotinska Krajina), southern (Vranjska kotlina, Kosovo and Metohija) and northern parts (Vojvodina, around Vrsac and Bela Crkva) (Skoric, 1986). Common properties of Vertisols are described in many works of our researchers (Stebut, 1923; Filipovski and Ciric, 1963; Zivkovic *et al.*, 1964; Zivkovic, 1968; Filipovic, 1999). They all state that Vertisols are formed on clay sediments (mostly calcareous) with more than 30% of smectite clays or on mafic and ultramafic rocks that weather to smectite clays. Surface A horizon has vertic properties (Avt) and humus of specific character: it is formed under terrestrial conditions, but due to poor drainage it has some hydromorphic characteristics, especially colour. Vertic properties are a combination of deep cracks when dry, intersecting slickenside in the subsoil, wedge-shaped structural aggregates in the subsurface soil (25 to 100 cm deep) and strong nutty structure at the soil surface. Often these soils show a so-called gilgai microrelief. Humus-accumulative horizon of Vertisols is more than 30cm deep, and beneath it there is AC horizon (20-30cm). These horizons have clay texture, high porosity and high water capacity, low air capacity, high amount of unavailable water, low bulk and high particle density. Reaction of soil varies from slight acid to slightly alkaline. Carbonate content at calcareous Vertisols increases with depth. Base saturation is high and CEC has value ≥ 40 $cmol_c\ kg^{-1}$. Vertisols in Serbia have 2-6% of humus, and it gradually decreases with depth. When wet, Vertisols are dark-grey to black. This study was aimed to explore chemical characteristics of calcareous Vertisols from Pcinja district.

MATERIALS AND METHODS

Four soil profiles were positioned on locations corresponding to the formation of the Vertisols (Tab. 1).

Content of calcium-carbonate was determined using Scheibler's calcimeter (Rowell, 1994). Active acidity of the soil, pH in H_2O (1:2.5) and exchangeable acidity, pH in 1M KCl (1:2.5) was analyzed potentiometrically with a pH meter (YDPZ, 1966). Humus content was determined by Tyurin method and nitrogen content by Kjeldahl method. Available K and P were determined by A-L method of Egner-Riehm. Content of available Ca, Mg and available micronutrients was determined using AAS. Statistical analysis was performed using StatSoft Statistics 5.0

Table 1. Labels and locations of the sampled soil profiles

label	location			
	municipality	village	latitude and longitude	altitude
Profile 1	Vranje	Neradovac	N 42º 31.259' E 21º 53.207'	409 m
Profile 2	Vranje	Bustranje	N 42º 26.104' E 21º 54.232'	489 m
Profile 3	Vranje	Cukovac	N 42º 31.620' E 21º 56.410'	345 m
Profile 4	Vladicin Han	Rid	N 42º 42.320' E 022º 4.230'	405 m

RESULTS AND DISCUSSION

Chemical properties of investigated calcareous Vertisol depend upon numerous soil forming factors. Content of Ca-carbonates in Vertisols depends upon the content of carbonates in parent rock and upon evolution phase and degree of decarbonization which correlates to climatic conditions.

Vertisols soil reaction usually varies from slightly acid to slightly alkaline (pH ranges from 6 to 8). Filipovski (1996) showed that calcareous Vertisols in Macedonia have pH 6.47, and studied calcareous Vertisols, due to high carbonate content and arid climate, have pH around 7.8.

Results in table 1 show that Vertisols with higher content of carbonates have higher active acidity. As content of carbonates increase, soil pH in H_2O also increases (from 7.72 to 8.01 at 40-60 cm depth).

Results of the analysis in table 2 and graph 1 show that carbonates are present in all soil profiles. Carbonate content varies from 1.8% to 23.7%, and it increases with depth.

Table 2. Basic chemical properties of calcareous Vertisol from Pcinja District

profile	Depth (cm)	$CaCo_3$ (%)	pH	
			H_2O	1M KCl
1	0-20	4.2	7.81	6.63
	20-40	5.1	7.89	6.66
	40-65	8.2	8.18	6.74
	65-100	23.7	8.52	7.03
2	0-25	6.4	7.88	6.99
	25-50	3.9	7.87	6.95
	50-75	4.4	7.92	6.89
	75-100	0.5	7.98	6.83
	100-120	1.8	7.97	6.87
3	0-20	4.6	7.72	6.75
	20-40	3.9	7.83	6.84
	40-60	-	7.51	6.62
	60-80	-	7.60	6.54
	80-106	0.8	7.73	6.68
4	0-20	7.8	7.96	6.82
	20-40	8.9	8.01	6.95
	40-60	19.4	8.43	7.06
	60-80	18.8	8.16	7.08

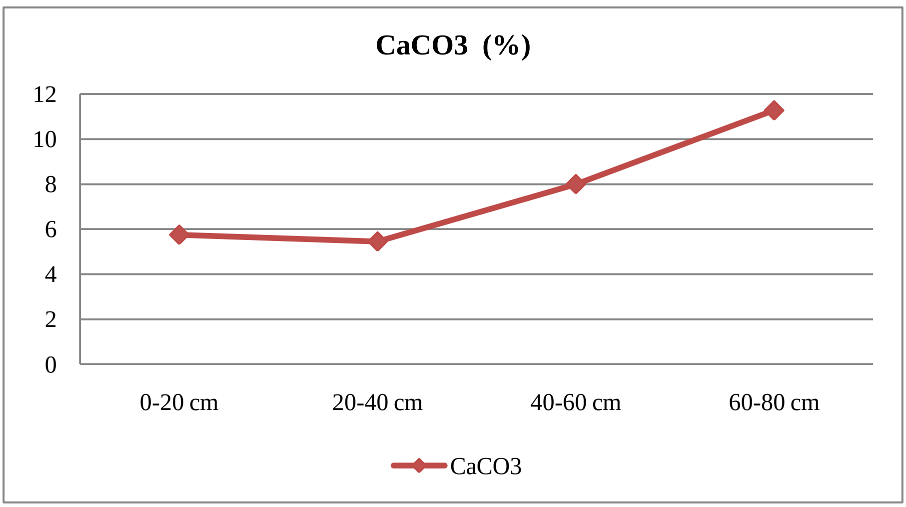

Fig. 1. Content of $CaCO_3$ (%) in calcareous Vertisols (average values)

The content of humus is the highest in humus-accumulative horizon, where average value is 2.63%, and it ranges from 2.41 to 2.94%, which (according to Gracanin, 1951) - low in humus. Humus content decreases with depth and in subsurface horizon it ranges from 0.82 to 1.15%. According to Gajic *et al.* (2001) humus content in Vertisols from Aleksinac Valley ranges from 3.9 to 4.8% (to 20 cm depth) - in cultivated soils, and in forest soils it ranges from 6.0 to

7.6%. Mitkova *et al.* (2003) pointed out that humus content in Vertisols in Macedonia is around 3.5%, and that humic acid is dominant in humus. Bogunovic (1988) showed that the content of humus in Croatian soils is fairly even by the whole profile depth, although it slightly decreases, but on 100 cm it ranges from 0.5 to 2% due to the process called vertigenesis.

Average content of total nitrogen in humus-accumulative horizon of calcareous Vertisols is 0.134% (ranges from 0.094 to 0.147%) and, according to Wohltmann's classification, is between low and moderate content. Total nitrogen decreases with depth, and in subsurface horizon the content is low, and ranges from 0.056 to 0.076%. Our analysis (Tab. 3) shows that the average continent of available phosphorus is 9.2 mg 100 g^{-1} on 0-20cm depth, which makes low content (Egner-Riehm). Content of available phosphorus abruptly decreases with depth, and on 20-40 cm it is 5.93 mg 100 g^{-1}, and on 80 cm depth it is 1.68mg 100 g^{-1} of soil.

Table 3. Content of humus, available P, K, Ca and Mg

profile	Depth, cm	Humus, %	N, %	Available			
				P_2O_5 mg $100g^{-1}$	K_2O mg $100g^{-1}$	Ca g kg^{-1}	Mg g kg^{-1}
1	0-20	2.68	0.134	6.82	28.32	20.20	2.20
	20-40	1.89	0.095	4.63	25.16	18.20	3.30
	40-65	1.24	0.062	2.32	34.84	21.90	3.80
	65-100	0.75	0.038	1.88	19.13	32.00	4.80
2	0-25	2.94	0.147	17.42	37.15	24.20	0.96
	25-50	1.88	0.094	10.38	37.04	22.20	0.93
	50-75	1.58	0.076	7.42	36.66	17.90	0.62
	75-100	0.82	0.041	2.32	30.15	15.50	0.98
	100-120	0.51	0.026	1.41	28.17	15.00	0.37
3	0-20	2.50	0.125	7.53	19.68	17.30	0.83
	20-40	2.23	0.112	5.82	17.31	25.00	1.20
	40-60	1.12	0.056	5.02	10.21	13.70	0.93
	60-80	1.05	0.053	2.48	7.02	19.00	1.00
	80-106	0.95	0.048	1.75	7.15	17.80	1.10
4	0-20	2.41	0.121	4.81	18.31	22.90	2.90
	20-40	1.73	0.087	3.01	14.17	28.50	3.20
	40-60	1.41	0.071	1.63	9.28	32.10	4.50
	60-80	1.15	0.058	1.43	7.77	31.40	2.80

Low availability of phosphorus in Vertisols is closely related to the presence of iron oxides and hydrous oxides and the amounts of calcium carbonate. In calcareous soils phosphate sorption to CaCo3 may be equal or greater importance than sorption to iron oxides (Porter and Sanches, 1992). Filipovski (1996) showed that Vertisols in Macedonia have low content of available phosphorus, but fair content of available potassium. Calcareous Vertisols from Pcinja district are well supplied with potassium - the highest content is in the surface horizon with an average of 22.02 mg 100 g^{-1} of soil. The content of available potassium decreases with depth.

Calcium is the main exchangeable base of clay minerals and, as such, is a major component of soils. One of the most important natural sources of calcium is parent rock. The results of analysis presented in table 3 show that the available calcium content is lowest in humus-accumulative horizon (21.15g kg^{-1}) and it increases with depth (24.35g kg^{-1} on 60-80cm depth). Correlation analysis, showed very strong correlation between the pH value and the content of available Ca (r = 0.80), the chart no. 2

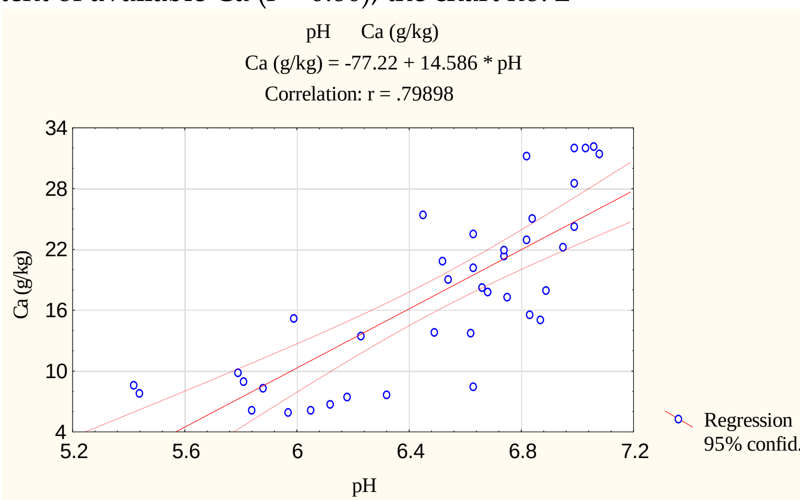

Fig. 2. Regression model between pH value and available Ca content

Magnesium concentrations usually range from 0.03 to 0.84%, with sandy soils typically having the lowest magnesium concentrations (0.05%), and clay soils containing the highest magnesium concentrations (0.50%). (Nilsson, 1987; Kirkby and Mengel, 1976). Sources of magnesium in the soil are primary (biotite, pyroxenes and amphiboles) and secondary minerals (hydrobiotite, vermiculite and montmorillonite). The average content of available magnesium in the humus-accumulative horizon of calcareous Vertisol from Pčinja district is 2.18 g kg^{-1} and it ranges from 0.83 to 2.90 g kg^{-1}. The content of available Mg increases with depth in most of the studied profiles.

Clay minerals absorb magnesium almost five times less than calcium. Due to competition with calcium ion in calcareous soils and H^+ ion in acid soil, adsorbed magnesium makes 2-20% of CEC (Aubert, *et al.*, 1997). Zivkovic *et al.* (1964) pointed out important role of absorbed magnesium on the genesis of Vertisols. The ratio Ca/Mg is within the favourable for growth and development of plants. Jakovljevic *et al.* (2001) investigated the total and available content of alkali elements (Ca, Mg, K and Na) in various soil types in Serbia. Total element content was as follows: Ca 2.22%; K 1.77%; Na 0.85% and Mg 0.61%. According to the average availabilities the most abundant was calcium with 947 mg $100g^{-1}$, and the averages of the other elements (Mg, K and Na) were quite similar (around 40 mg100 g^{-1} of soil). Studied Vertisols had 27 mg 100 g^{-1} of available Mg, 340 mg 100 g^{-1} of available Ca, 31 mg $100g^{-1}$ of available K, and 33 mg 100 g^{-1} of available N.

Table 4. Available micronutrients in calcareous Vertisol

profile	Depth, cm	Fe, mg kg^{-1}	Mn, mg kg^{-1}	Cu, mg kg^{-1}	Zn, mg kg^{-1}	B, mg kg^{-1}
1	0-20	18.2	29.2	2.8	1.2	0.36
	20-40	17.8	25.2	3.4	1.0	0.16
	40-65	18.4	24.2	3.0	0.4	0.46
	65-100	29.5	26.2	14.4	5.0	0.37
2	0-25	12.2	11.8	2.6	0.3	0.24
	25-50	12.0	15.8	7.4	0.2	0.12
	50-75	18.4	23.6	7.8	4.0	0.06
	75-100	15.8	27.2	3.0	1.0	<0.05
	100-120	14.4	25.2	3.4	1.3	0.4
3	0-20	69.8	78.6	7.4	2.8	0.12
	20-40	52.8	60.0	11.6	5.3	<0.05
	40-60	78.0	73.6	5.6	2.7	<0.05
	60-80	65.8	79.6	4.6	2.2	0.44
	80-106	49.0	55.4	5.0	2.2	0.41
4	0-20	15.4	28.2	2.6	0.5	0.32
	20-40	17.0	23.2	2.8	0.3	1.70
	40-60	14.1	14.5	2.6	0.3	0.32
	60-80	7.8	9.6	0.8	0.2	0.44

The major factors affecting availability of iron is soil pH (with high pH making iron less available and giving rise to chlorosis). In lime-induced chlorosis, it is the soil bicarbonate that is the key cause, largely due to the high pH in the rhizosphere and at the root uptake site, thereby affecting iron solubility and Fe(III)-chelate reductase activity (Romheld and Nikolic, 2007). The results of our study, presented in table 4, show that the average content of available iron in the humus-accumulative horizon of calcareous Vertisol is 28.90

mg kg^{-1}, and it ranges from 12.20 to 69.8 mg kg^{-1}. The regression model shows a negative correlation (r = -0.59) between the pH value and the content of available Fe.

Manganese is most abundant in soils developed from rocks rich in iron owing to its association with this element. It exists in soil solution as either the exchangeable ion Mn^{2+} or Mn^{3+}. Availability of manganese for plant uptake is affected by soil pH; it decreases as the pH increases. As soil pH decreases, the proportion of exchangeable Mn^{2+} increases dramatically and the proportions of manganese oxides and manganese bound to iron and manganese oxides decrease (Sims, 1986). The results of the analysis in table 3, show a large dispersion of available Mn, which directly depends on the presence of $CaCO_3$ in the soil profile. The average content of available Mn in the humus-accumulative horizon of calcareous Vertisol is 36.95 mg kg^{-1}, and it varies from 11.8 to 73.60 mg kg^{-1}. Based on data of Ubavic *et al.* (1995), the amount of available manganese in the soils in Serbia ranges from 25 to 100 mg kg^{-1} (0-20cm depth). The average Mn content is 59 mg kg^{-1}, and it decreases with depth. Correlation analysis showed a negative correlation between pH value and content of Mn (r = - 0.53).

Copper status in soil depends on parent material and formation processes. Atmospheric input of copper has been shown to partly replace or even exceed biomass removal from soils. Chelation and complexing govern copper behavior in most soils. Adsorption of $Cu2^{+}$ in variable charged soils is pH-dependent. Copper availability is affected substantially by soil pH, decreasing 99% for each unit increase in pH (Kopsell and Kopsell, 2007). The results of the analysis in table 3, show that the average available copper content in the calcareous Vertisol ranges between 3.03 and 4.97 mg kg^{-1}, which, according to Rinkis, makes high supply. Based on the research of Savic and Jekic (1977), available copper content in Vertisols ranges between 5.4 and 9.9 mg kg^{-1} , while Vertisols in Kratovo-zletovski region (Djordjiev *et al.*, 1992) have from 1.4 to 13.25 mg kg^{-1} of available copper.

The total zinc content in soils varies from 3 to 770 mg kg^{-1} with the world average being 64 mg kg^{-1} (Kabata-Pendias&Pendias, 1992). There are five major pools of zinc in the soil: (a) zinc in soil solution; (b) surface adsorbed and exchangeable zinc; (c) zinc associated with organic matter; (d) zinc associated with oxides and carbonates; and

(e) zinc in primary minerals and secondary alumo-silicate materials (Shuman, 1991). The analyses showed that average content of available zinc in calcareous Vertisol is around 1.58 mg kg^{-1}. According to Ubavić *et al.* (1995), the amount of available zinc ranges from 0.25 to 5.9 mg kg^{-1} (at 0 to 20 cm depth), and in calcareous Vertisol it ranges from 0.32 to 1.17 mg kg^{-1}.

The total boron content of most agricultural soils ranges from 1 to 467 mg kg^{-1}, with an average content of 9 to 85 mg kg^{-1}. Such wide variations among soils in the total boron content are mainly ascribed to the parent rock types and soil types falling under divergent geographical and climatic zones. Available boron, measured by various extraction methods in agricultural soils varies from 0.5 to 5 mg kg^{-1}. Most of the available boron in soil is believed to be derived from sediments and plant material. The average content of available boron in the humus-accumulative horizon of calcareous Vertisol is 0.61 mg kg^{-1}, and it varies between 0.05 and 1.7 mg kg^{-1} C.

CONCLUSIONS

Research on calcareous Vertisols in Pcinja districts showed that the average value of the active acidity (pH in H_2O) in surface horizon is 7.84. Values of exchangeable acidity (pH in 1M KCl) are correlated to the carbonates content in the soil. Content of humus is various, from low to medium. In all soil profiles the humus content decreases with depth. Average content of total nitrogen in the humus-accumulative horizon of calcareous Vertisol is 0.134%, and it rapidly decreases with depth. The average content of available phosphorus is 9.20 mg $100g^{-1}$ (0-20 cm depth), which is consistent with the pH values of the soil solution and makes low supply of available phosphorus. Calcareous Vertisols from Pcinja district have fair supply of available potassium, due to mineral composition of the parent rock. The content of available Ca and Mg in these soils depends upon their content in the parent rock. Ratio Ca/Mg is favourable for plant growth. The content of available Fe, Mn, and B is directly dependent on the presence of $CaCO_3$ in soil profile. These Vertisols showed approximately uniform values of available Cu and Zn.

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CATION EXCHANGE CAPACITY OF HYDROMORPHIC BLACK SOILS IN PELAGONIJA

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ABSTRACT

During the field examinations of hydromorphyc black soils in Pelagonia valley 25 soil profiles were sampled and examined. The main scope of these investigations was to examine the cation exchange capacity and the content of exchangeable cations of hydromorphic black soils. Cation exchange capacity is high ranging from 46,618 cmol (+) kg^{-1} soil in the horizon A of vertic subtypes, to 15,97 cmol (+) kg^{-1} of typical subtype of hydromorphic black soils. This difference is the result of: clay content, character of clay minerals and organic matter content. Base saturation is the highest 37,19 cmol (+) kg^{-1} in the halomorphic and alkaline subtypes. The base saturation is high in all the subtypes (>70 %). Exchangeable Ca dominate between the other cations in CEC, while the content of exchangeable Mg^{+2}, K^{+}, Na^{+} follows in the same order as indicated. The average content of exchangeable Ca^{+2} has the highest values in the vertic non-carbonate hydrogenic black soils, 31.34 cmol (+) kg^{-1} of soil and the lowest in the typical non-carbonate subtype with 8,03 cmol (+) kg^{-1} of soil. In almost all the horizons the content of exchangeable Ca^{+2} is over 50 %. Its content increases with the depth of the profile. The content of the other exchangeable cations vary in a very broad ranges: exchangeable Mg^{++} in the ranges of 2-25 %, K^{+} from 0,62-6,34 %, exchangeable Na^{+} in the ranges of 0,08-23,7 %, while the content of the acid cations H^{+}+Al^{+3} vary from 1,38-29,8 % of CEC.

Keywords: hydromorphic black soils, CEC, base saturation, exchangeable cations.

INTRODUCTION

Main goal of the investigations presented in this paper were to examine the CEC of the hydromorphic black soils in Pelagonia valley. Hydromorphyc black soils according Vukashinović, 1954 covers around 8660 ha of arable land in Pelagonia valley. In a complex with other hydromorphic soils; humogleys covers a total area of around 40.000 ha in the country. This soil types have a high potential fertility but very often seeks an immense agrotechnical and agromeliorative interventions in order to be transformed into high fertile agricultural soils. It should be emphasized that the investigated hydromorphyc black soils falls within the already meliorated valleys (Filipovski 1999) which additionally emphasizes its importance for the agricultural production of the country.

For the purpose, of this study a dense net of soil profiles of hydromorphyc black soil were excavated in the Prilep part of Pelagonia valley. Out of the whole number of more than 45 soil profiles, only 8 most representative soil profiles will be presented. The investigated soil profiles according the actual soil classification (Skorić *et al*., 1985) belongs to the following soil subtypes: vertic carbonate and non-carbonate, typical carbonate and non-carbonate, halomorphic and alkaline and alkaline. There are very limited data for the characteristics of the hydromorphic black soils. In the Republic of Macedonia there are no particular investigations on this soil type.

MATERIALS AND METHODS

The planned investigations have been performed in the part of the Pelagonia valley nearby the city of Prilep. Field examinations have been organized in a line with the referent methods for field surveying (Filipovski *et al*., 1967). During the laboratory investigations, the following methods have been used:

- Mechanical composition of soil was determined by the international method (Resulovič *et al*., 1971). The separation of the mechanical elements in fractions has been done by the international classification of Scheffer and Schachtschabel
- pH (acidity) of the soil solution was determined with glass electrode in water suspension and in NKCI suspension (Bogdanovič *et al*., 1966)

- available forms of P_2O_5 and K_2O were determinate by Al method (Džamić *et al.* 1996)
- The content of soil organic carbon was determinate at the base of total carbon by the method of Turin modified by Simakov (Orlov *et al.* 1981)
- Total N by Kjeldahl (Bogdanovic *et al.* 1966); classification of soils for the content of total nitrogen was done according to Wolthmann (Bogdanovic *et al.* 1966)
- Exchangeable acid cations (H^{+}+Al^{+3}) (cmol (+) kg^{-1} soil) was determined according to Melich (Bogdanovic *et al.* 1966)
- Exchangeable basic cations (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}) (cmol (+) kg^{-1} soil) in non-carbonate soils were extracted with $BaCl_2$ by the method of Hendershot and Duquette (1986), and analyzed on AAS. In carbonate soils the exchangeable Ca^{+2} was examined according the method of Chapman (1961).

RESULTS AND DISCUSSION

The mechanical composition of the hydromorphyc black soil is closely related to the parent material and significantly changes on small distances which are result to the micro relief (Pavicevic, 1963).

Specific characteristic of the hydromorphyc black soils is it`s vertical heterogeneity. The average content of skeleton is much lower in the topsoil in comparison with the other horizons of the soil profiles. The average content of skeleton over the whole depth of horizon A vary in the ranges of 0.2 (prof. 2) up to 5,54 (prof. 35). The data of fine earth fractions (Tab. 1) shows that the main characteristics of these soils is high clay content. In horizon A the content of clay vary in the ranges of 22,0% in (prof. 39) up to 62.6 (prof. 14), in average 46.29%.

The content of soil organic matter varies in broad ranges. The highest content in horizon A ranges from 1.71 to 4.02% or in average 2.86%. This variation of soil organic matter content and it`s declining in the depth of soil profile was noted in the works of other researchers (Pavicevic, 1963). Vukasinovic (1954 and 1956) have determined the content of soil organic matter in big number of hydromorphyc black soils.

According these investigations the content of SOM in horizon A ranges from 2.74 to 2.85% and drastically declines withe depth, where it ranges from 0.42 to 0.64% in soil substrate.

Among all the hydromorphyc soils, the hydromorphyc black soils have the highest content of carbonate. According the classification of Penkov (1996) the major part of the 40 investigated samples, or 37.5% are non-carbonate, 5,0% are poor with carbonates(<1%), 27,5% are carbonate (5-10%), 15.0 are rich with carbonates (10-20%), 12,5% are very rich (20-40%) and the rest of 2,5% are highly rich (>40%).

Soil acidity of hydromorphyc black soils vary in broad ranges and is highly dependent of the carbonate contents as well to the processes, which can change soil acidity such as: decarbonisation, salinization, alkalisation etc. In all investigated soil, it was noted that the increasing of soil acidity followed with increasing the content of Ca^{++} and Na^{+}.

Cation exchange capacity

Data for the cation exchange capacity (CEC) of the hydromorphic black soils are presented in Table 3. The high values of CEC in some subtypes of hydromorphic black soils are notable. In horizon A of the vertic subtype (prof. 21) the CEC is more than 50,21 cmol (+) kg^{-1} while in typical subtype is only 11,57 cmol (+) kg^{-1} which is much lower than in the previous subtype.

These variations of CEC between subtypes are due to several reasons: differences of the clay content, character of the clay minerals, differences of SOM content etc. Base saturation (S) of horizon A is in the ranges of 11,57-51,21 cmol (+) kg^{-1} soil, in average 30.81. The values in the intermediate horizon AC vary in the range of 16.7-44.41 cmol (+) kg^{-1} soil, or in average 32.62 cmol (+) kg^{-1} soil, while in the substrate it ranges from 13.69 to 38.78, or in average 27.91 cmol (+) kg^{-1} soil. Data about S can be found in the previous works of Vukasinovic (1954), who determined values which vary in broad ranges from 5,44 to 49,08 cmol (+) kg^{-1}; Spirovski (1965) who in seven profiles of hydromorphic black soils found 10,8-37,1 cmol (+) kg^{-1} of S; while Manuseva (1960) reports S content from 17,6 to 36,1 cmol (+) kg^{-1}.

The content of exchangeable cations in big extent is inherited from the parent material and it`s mineralogical content, and mostly consists of $CaCO_3$ and $MgCO_3$ (Filipovski 1999). Out of the data presented in Tab. 3 an absolute domination of Ca^{++} can be noted.

Table 1. Mechanical composition and texture class of hydromorphic black soils

Location	Prof. N°	horizon	Depth, cm	Hygroscopic moisture , %	Skeleton > 2 mm	Coarse sand 0.2-2 mm	Fine sand 0.02-0.2 mm	Total sand 0.02-2 mm	Silt 0.002-0.02 mm	Clay <0.002 mm	Clay+silt <0.002 mm	Texture Scheffer& Schachtschabel
1	2	3	4	5	6	7	8	9	10	11	12	13
						vertic carbonate hydromorphic black soil						
Golemo	1	Ap	0-30	3,07	0,28	3,37	21,03	24,40	23,60	52,00	75,60	heavy clay
Konjare		A	30-65	2,85	1,01	7,83	18,37	26,20	18,70	55,10	73,80	heavy clay
		AC	65-85	2,39	0,31	3,73	17,77	21,50	16,50	62,00	78,50	heavy clay
		Gso	85-124	2,21	0,14	2,73	26,97	29,70	14,80	55,50	70,30	heavy clay
Ropotovo	36	Ap	0-24	3,41	3,52	1,21	33,79	35,00	18,50	46,50	65,00	heavy clay
		A	24-71	3,96	11,83	1,50	27,30	28,80	13,70	57,50	71,20	heavy clay
		AC	71-101	2,68	59,60	9,80	38,00	47,80	13,40	38,80	52,20	loamy clay
		Gso	101-132	2,26	91,73	19,70	50,60	70,30	14,00	15,70	29,70	sandy clayey loam
						vertic non-carbonate hydromorphic black soil						
Star Kaish	2	A	0-30	2,32	0,20	10,68	28,02	38,70	19,90	41,40	61,30	loamy clay
(Slavej)		A	30-70	2,34	1,20	16,35	29,95	46,30	14,10	39,60	53,70	loamy clay
		AC	70-110	2,61	1,49	12,08	24,42	36,50	14,60	48,90	63,50	heavy clay
		Gso	110-135	1,76	0,66	7,64	32,06	39,70	19,80	40,50	60,30	loamy clay
Zabjani	19	A	0-32	2,61	0,28	2,89	37,01	39,90	16,20	43,90	60,10	loamy clay
		A/Ac	32-62	2,88	0,55	3,12	25,08	28,20	17,20	54,60	71,80	heavy clay
		AC	62-89	2,86	1,40	2,29	25,11	27,40	18,10	54,50	72,60	heavy clay
		Gso	89-115	2,50	5,40	10,96	27,04	38,00	19,70	42,30	62,00	loamy clay
						typical carbonate hydromorphic black soil						
Cetiri Krusi	27	A	0-35	2,58	0,40	12,35	35,85	48,20	22,40	29,40	51,80	loamy clay
		A/Ac	35-68	2,65	0,80	10,36	36,84	47,20	19,80	29,00	52,80	loamy clay
		AC	68-99	2,14	2,62	24,41	34,89	59,30	16,90	23,80	40,70	sandy clayey loam
		Gso	99-150	2,04	2,40	22,38	37,32	59,70	18,10	22,20	40,30	sandy clayey loam
						typical non-carbonate hydromorphic black soil						
Vrbjani	39	Ap	0-19	2,54	3,70	15,41	50,29	65,70	12,30	22,00	34,30	sandy clayey loam
		A	19-51	2,75	1,63	12,83	44,37	57,20	12,20	30,60	42,80	sandy clay
		AC	51-69	1,74	2,41	16,90	35,20	52,10	16,70	29,20	47,90	loamy clay
		Gso	69-103	2,25	15,75	9,05	49,95	59,00	13,80	27,20	41,00	sandy clay
						halomoprhyc and alkaline hydromorphic black soil						
Magjarica	35	Ap	0-24	3,48	5,54	0,45	16,25	16,70	22,10	61,20	83,30	heavy clay
		A	24-59	3,60	2,75	0,60	14,10	14,70	16,80	68,50	85,30	heavy clay
		AC	59-88	2,82	9,87	1,65	30,85	32,50	14,30	53,20	67,50	heavy clay
		Gso	88-115	1,87	41,70	2,31	22,89	25,20	40,70	34,10	74,80	silty clay
						alkaline hydromorphic black soil						
Slavej	4	A	0-30	2,64	0,26	4,30	29,91	34,20	15,90	49,90	65,80	heavy clay
		A	30-68	3,03	0,20	3,39	24,51	27,90	14,20	57,90	72,10	heavy clay
		AC	68-100	2,83	0,20	4,50	21,70	26,20	17,20	56,60	73,80	heavy clay
		Gso	100-130	2,02	0,56	5,22	21,59	26,80	25,80	47,40	73,20	heavy clay

Table 2. Chemical properties of hydromorphyc black soils

Location	Prof N°	Hor.	Depth cm.	OM %	N %	C/N	$CaCO_3$ %	pH in		mg/100 g soil		Total dissolved salts %
								H_2O	nKCl	P_2O_5	K_2O	
vertic carbonate hydromorphic black soil												
Golemo Konjare	1	Ap	0-30	3,08	0,149	11,97	-	7,40	6,50	31,20	38,60	0,067
		A	30-65	1,71	0,088	11,31	7,06	8,20	7,20	2,00	36,40	0,088
		AC	65-85	1,08	0,056	11,20	30,84	8,45	7,50	2,40	26,00	0,096
		Gso	85-124	0,70	0,040	10,11	42,04	8,50	7,55	4,60	21,40	0,109
Ropotovo	36	Ap	0-24	4,06	0,239	9,87	7,68	7,30	6,50	6,70	29,70	0,093
		A	24-71	3,96	0,205	11,23	6,44	8,10	7,00	6,20	22,80	0,093
		AC	71-101	1,79	0,079	13,20	16,46	8,20	7,10	5,80	17,40	0,093
		Gso	101-132	0,98	0,045	12,46	21,85	8,30	7,10	4,10	12,80	0,070
vertic non-carbonate hydromorphic black soil												
Star Kaish (Slavej)	2	A	0-30	3,52	0,196	10,40	-	6,77	6,01	15,80	33,80	0,061
		A	30-70	1,42	0,088	9,40	-	8,21	7,36	2,00	25,20	0,094
		AC	70-110	0,85	0,056	8,71	19,40	8,45	7,40	1,20	23,60	0,098
		Gso	110-135	0,46	0,040	6,55	-	8,30	7,40	4,60	14,40	0,115
Zabjani	19	A	0-32	1,76	0,078	13,11	-	7,20	6,20	5,80	27,40	0,038
		A/Ac	32-62	1,29	0,053	13,98	-	8,20	7,00	0,60	27,40	0,074
		AC	62-89	1,12	0,054	11,90	5,91	8,20	7,30	0,40	25,80	0,138
		Gso	89-115	0,78	0,042	10,77	18,79	8,50	7,40	0,60	18,20	0,157
typical carbonate hydromorphic black soil												
Cetiri Krusi	27	A	0-35	4,02	0,204	11,40	0,64	7,50	6,60	4,80	27,60	0,077
		A/Ac	35-68	1,43	0,073	11,35	0,51	7,70	6,80	4,60	27,60	0,077
		AC	68-99	1,10	0,055	11,63	5,32	7,80	6,90	2,15	21,00	0,090
		Gso	99-150	0,91	0,045	11,76	12,86	8,00	7,00	2,10	23,00	0,086
typical non-carbonate hydromorphic black soil												
Vrbjani	39	Ap	0-19	2,58	0,174	8,59	-	6,50	5,60	5,00	27,20	0,032
		A	19-51	1,64	0,101	9,40	-	7,55	6,50	8,60	34,30	0,064
		AC	51-69	0,76	0,051	8,68	32,01	8,30	7,50	7,80	18,20	0,064
		Gso	69-103	0,38	0,027	8,28	19,05	8,30	7,50	6,00	18,20	0,064
halomoprhyc and alkaline hydromorphic black soil												
Magjarica	35	Ap	0-24	2,43	0,139	10,12	-	7,35	6,20	0,85	45,00	0,512
		A	24-59	1,69	0,086	11,35	7,57	7,90	6,85	1,00	40,00	0,864
		AC	59-88	1,16	0,067	9,99	8,45	7,90	6,90	2,80	40,00	1,152
		Gso	88-115	0,36	0,017	12,47	9,44	8,10	7,30	7,20	35,00	1,152
alkaline hydromorphic black soil												
Slavej	4	A	0-30	3,18	0,177	10,40	-	7,20	6,10	3,60	40,00	0,064
		A	30-68	1,40	0,086	9,42	-	7,90	6,80	2,00	33,00	0,112
		AC	68-100	0,84	0,052	9,31	13,87	8,40	7,30	1,20	27,80	0,182
		Gso	100-130	0,53	0,038	8,10	33,42	8,50	7,50	3,20	16,40	0,134

It`s content in top soil significantly vary from 8.03 (prof. 39) to 46.36 lower layer of horizon A (prof. 36), or in average 24.51 cmol (+) kg^{-1} soil. In depth, the content of exchangeable Ca^{++} is increasing due to the increasing content of carbonates. Exchangeable Mg^{++} in terms of its content is on a second place among the exchangeable cations. Its content in horizon A vary from 1.31 to 8.11 cmol (+) kg^{-1} soil, in average 4.47.

Table 3. Cation exchange capacity content of the hydromorphyc black soils

Location	Profile N°	Depth cm	in cmol (+) kg^{-1}							V %
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	$H^{+}+Al^{3+}$	S	CEC	
vertic carbonate hydromorphic black soil										
Golemo Konjare	1	Ap 0-30	26,518	6,368	1,24	0,20	4,2	34,32	38,523	89,1
		A 30-65	31,862	4,167	2,36	0,22	-	38,61	38,606	100,0
		AC 65-85	32,043	3,841	0,60	1,71	-	38,20	38,196	100,0
		Gso 85-124	26,749	3,050	0,49	1,47	-	31,76	31,765	100,0
Ropotovo	36	Ap 0-24	38,573	1,312	0,63	0,98	-	41,50	41,500	100,0
		A 24-71	46,362	1,566	0,64	1,64	-	50,21	50,210	100,0
		AC 71-101	33,249	3,219	0,18	1,50	-	38,16	38,156	100,0
		Gso 101-132	27,561	0,867	0,21	0,75	-	29,40	29,395	100,0
		Gso 81-101	27,300	1,175	0,55	2,88	-	31,90	31,900	100,0
vertic non-carbonate hydromorphic black soil										
Star Kaish (Slavej)	2	A 0-30	18,401	5,829	0,53	0,13	5,4	24,88	30,284	82,2
		A 30-70	16,830	7,631	0,63	0,85	2,0	25,95	27,946	92,8
		AC 70-110	26,337	4,157	1,20	1,69	-	33,38	33,382	100,0
		Gso 110-135	20,693	3,551	0,57	0,76	-	25,57	25,573	100,0
Zabjani	19	A 0-32	24,644	5,710	0,40	0,28	6,2	31,03	37,234	83,3
		A/Ac32-62	30,619	5,415	0,39	1,85	5,05	38,28	43,328	88,3
		AC 62-89	36,695	4,015	0,55	3,15	-	44,41	44,408	100,0
		Gso 89-115	31,813	3,765	0,26	2,94	-	38,78	38,778	100,0
typical carbonate hydromorphic black soil										
Cetiri Krusi	27	A 0-35	23,879	1,600	0,52	0,27	-	26,28	26,277	100,0
		A/Ac 35-68	23,670	1,682	1,11	0,45	-	26,91	26,906	100,0
		AC 68-99	22,559	1,282	0,53	0,66	-	25,03	25,029	100,0
		Gso 99-150	22,589	1,102	0,36	0,35	-	24,40	24,400	100,0
typical non-carbonate hydromorphic black soil										
Vrbjani	39	A 0-19	8,032	2,331	1,00	0,20	4,4	11,57	15,967	72,4
		A 19-51	11,322	3,462	0,72	0,44	3,0	15,95	18,947	84,2
		AC 51-69	13,733	1,900	0,46	0,60	-	16,70	16,697	100,0
		Gso 69-103	11,024	1,078	0,52	1,07	-	13,69	13,686	100,0
halomorphic and alkaline hydromorphic black soil										
Magjarica	35	Ap 0-24	19,098	6,842	0,95	2,81	2,7	29,70	32,40	91,7
		A 24-59	24,185	2,685	1,18	2,04	-	30,09	30,09	100,0
		AC 59-88	19,315	2,195	1,25	3,92	-	26,68	26,68	100,0
		Gso 75-109	14,775	1,876	1,19	3,69	-	21,53	21,53	100,0
alkaline hydromorphic black soil										
Slavej	4	A 0-30	20,830	6,837	2,32	0,65	6.0	30,64	36,636	83,6
		A 30-68	27,279	8,110	0,48	1,22	3,2	37,09	40,294	92,1
		AC 68-100	28,667	5,473	0,52	3,76	-	38,42	38,421	100,0
		Gso 100-130	27,315	4,052	0,32	2,44	-	34,12	34,122	100,0

In the intermediate AC horizon content of Mg is lower ranging from 1.28 to 5.47, or in average 3.26 cmol(+) kg^{-1} soil. In the substrate the content of exchangeable Mg ranges between 0.87-4.05 or in average 2.46 cmol (+) kg^{-1} soil. The content of K in comparison with the other exchangeable cations is very low. In average it`s content in horizon A is 0.94 cmol(+) kg^{-1} soil, in the intermediate horizon AC its average content is 0.66, while in parent material the content of exchangeable K is only 0.41 cmol (+) kg^{-1} soil. Low content of K^{+} is due to its low content in the parent material and fixation in the crystal structure of the clay minerals. The higher content of K^{+} in the surface layer is due to the biological accumulation and fertilization.

Content of exchangeable Na^{+} in horizon A is in average 0.69 cmol(+) kg^{-1} soil in the lower part of horizon A is significantly higher and yields 1.09 cmol(+) kg^{-1} soil, while in the horizon AC has the highest values of 2.12 cmol(+) kg^{-1} soil.

In horizon Gso is slightly lower and is 1.82 cmol (+) kg^{-1} soil. The highest values of exchangeable Na^{+} are in the deep horizons of halomorphic and alkaline and alkaline hydromorphyc black soil. Munteanu *et al*., (1964) refers that in soil profiles with increased salinization the content of exchangeable Na^{+} might rich up to 8-15 % of CEC. Acid cations (H^{+} and Al^{+3}) were determined in the top soil of the non-carbonate subtypes of hydromorphyc black soils. Its content is varying in a broad ranges from 2,0 to 6,2 cmol(+) kg^{-1} soil.

CONCLUSIONS

- The mechanical composition of the hydromorphyc black soil is closely related to the parent material and significantly changes on small distances
- Specific characteristic of the hydromorphyc black soils is vertical heterogeneity
- Main characteristic of the fine earth fraction of the hydromorphyc black soils is richness in clay
- The content of SOM varies in broad ranges from 1.71 to 4.02%
- Among the all hydromorphyc soils, the hydromorphyc black soils have the highest content of carbonate
- There are differences in CEC between subtypes of hydromorphyc black soils, which is due to differences of the clay content, character of the clay minerals, differences of SOM content etc. The content of exchangeable cations in big extent is inherited from the parent material and it`s mineralogical content, and the most of the content consists of $CaCO_3$ and $MgCO_3$
- An absolute domination of Ca^{+2} can be noted. It`s content in top soil significantly varies from 8.03 to 46.36 in lower layer of horizon A, or in average 24.51 cmol (+) kg^{-1} soil. Content of exchangeable Mg^{+2} is on a second place among the exchangeable cations. The

content of K^+ in comparison with the other exchangeable cations is very low. The higher content of K^+ in the surface layer is due to the biological accumulation and fertilization. The highest values of exchangeable Na^+ are in the deep horizons of halomorphic and alkaline and alkaline hydromorphyc black soil

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INFLUENCE OF MECHANICAL COMPOSITION AND ORGANIC MATTER ON SOIL MOISTURE RETENTION CURVES

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ABSTRACT

The mechanical and organic matter content of the soil affects the water-physical relations. Soil water retention in different tension is in tight correlation with humus, clay, and silt content and mineralogical composition of the clay. The paper presents the results of the research on the influence of the mechanical composition and organic matter on the soil in retention curves on moisture soils in diver's pressures. Therefore different physical and chemical soil characteristics are in a constant interaction, while a good insight into these characteristics and their mutual influence is being applied in the modern agricultural production.

Keywords: mechanical composition, chemical properties, retention curves, humic calcaric regosol

INTRODUCTION

Rendzinas, which are formed by the weathering of the carbonate rocks of various geological formations, are inter- zonal soils developed in the subboreal, boreal, as well as in some regions of the subtropical zones. Their characteristic features are the occurrence of the fragments of the parent material in the surface level and neutral or abasic reactionof the soil in a solution with a high content of calcium (Dobrzański *et al.*, 1987; FAO/UNESCO, 1997; Pranagal *et al.*, 2005).

The hydrous and physical relations, in addition to the mineralogical composition of the soil, are also influenced by the mechanical content, the content of organic matter etc., (Hillel 1980). Maclean and Yager (1972), Jamison and Kroth (1958), Shaykewich and Zwarich (1968) as well as Heinonen (1971) studied the influence of organic matter and the mechanical composition over the retention of moisture in several different soils in the USA, Europe and Asia. In the research of Hollist *et al.* (1977), it is confirmed that the soil moisture retention in Western Midland (Great Britain) depends mainly on the organic matter and mineralogical composition of soil. According to Filipovski, (1996), the retention of moisture at different tensions is strongly correlated with the content of humus, clay, silt and the mineralogical composition of the clay.

The hydrophysical properties of soils is the water retention and the water permeability in the saturated and unsaturated zone, not only affect the water balance but also have a dominant influence on the conditions of growth and development of plants. They determine the availability of water to plants and leaching of nutrients dissolved to the deeper layers of the soil (Coquet *et al.*, 2005; Hillel, 1998, Kutilek and Nielsen, 1994; Witkowska-Walczak *et al.*, 2000). The knowledge of the hydrophysical properties of the soil is therefore essential in the interpretation and prediction of changes of the vegetation cover, which occur as a result of a natural succession.

The intensity of the impact of the mechanical composition and organic matter on the retention of soil moisture depends on the share of certain fractions of soil separates and the percentage of organic matter. Particles of clay, due to the large inner and outer active surface, high cation exchange capacity (CEC) and mineralogical composition, represent the most active fraction of the mechanical composition of the soil (Škorić, 1991).

In our research, the main emphasis is on the dependence and impact of organic matter and mechanical composition on the retention of water in the surveyed rendzinas. Due to the mentioned importance of the mechanical composition and organic matter of the other properties of soil, this paper investigates the impact on retention of soil moisture at different points of tension, ranging from 0.33 up to 15 bars, which correspond to the water constant, which is called permanent wilting point (PWP). The remaining moisture above 15 bars is unavailable to plants (Bogdanović 1973).

MATERIAL AND METHODS

The influence of the mechanical composition and organic matter on soil moisture retention curves has been investigated in the rendzinas around the village Barovo (Demir Kapija region), in the Veshka place. In this region three (3) basic pedological profiles were made and 9 soil samples were taken. During the laboratory phase, the following methods were used: the mechanical composition was determined by dispersing the soil in a 1 M solution of $Na_4P_2O_7$ x 10 H_2O. The fractionation of mechanical elements was carried out under the International Classification, while classification of soils in textured classes was made according to USDA triangle, described by Mitrikeski and Mitkova (2006). Determination of mechanical composition and chemical properties were done by standard methods described by Bogdanović *et al*, (1966), Mitrikeski&Mitkova, (2006); Resulović *et al*, (1971), Džamić *et al*. (1996).

The determination of moisture retention at a pressure of 0.33 bar (pF-2.54) and 1 bar (pF-3), was performed by a method of applying pressure with a Bar extractor. To determine the retention of soil moisture at higher pressures, the method of (Richards 1982), (Porous plate extractor), 2.0 bar (pF-3.3); 6.25 bar (pF-3.90); 11 bar (pF-4.04) and 15 bar (pF-4.2) was applied, described by Resulović *et al.*, (1971). The descriptive statistics and correlation coefficients were performed in Microsoft Excel.

RESULTS AND DISCUSSION

The mechanical composition and organic matter of the soil are of great importance to physical, physical-mechanical and chemical properties of the rendzinas. Rendzinas prevalent in Barovo were formed on Pliocene sediments, carbonate gravel and sand (geological map of the Republic Macedonia).

The mechanical composition and physical properties of rendzinas mostly depend on the nature of the substrate and the content of humus.

In our study among the fractions of the soil separates, the dominant fraction is fine sand, followed by silt and clay (Tab. 1). The fraction of physical clay (silt+clay) occurs with a higher percentage in terms of the physical sand fraction (coarse+fine) sand. In the humus accumulative horizon Amo, there is an average of 56.77%, in the transitional AC horizon it is reduced and amounts to 51.60%, while in the substrate (parent material) C it is 55.83% in average. In the fraction of physical sand, fine sand is dominant (in horizon Amo the average value is 32.89%, in the horizon AC–36.95%, while in horizon C-36.09%). Coarse sand is least present. According to Filipovski (1996) the small content of skeleton and coarse sand indicates that sediments are finely sorted and deposited in calm water (lake and sea).

According the American texture classification, the Amo horizon of examined soils is clay loam; the transitional AC horizon is sandy clay loam, and the substrate C is clay loam. The presented data on the mechanical composition of rendzinas are similar to the data for this soil type as presented by Filipovski (1996), Kalicka *et al.* (2008).

Besides the mechanical properties, the retention of soil moisture in the rendzinas is strongly influenced by the chemical properties. The average values of the chemical properties are shown in Tab. 2.
These properties in the surveyed rendzinas depend on the properties of the substrate (parent material) (its mechanical and mineralogical composition and content of carbonates in it) and of the intensity of pedogenetic processes (accumulation of humus and translocation of $CaCO_3$).

For the content of organic matter, it is of great importance whether rendzinas are under natural (grassland or forest) vegetation. Examined rendzinas are under natural forest vegetation of oak forests - *Quercus borealis*. The average content of humus in the humus accumulative horizon Amo is 2.39%, in the transitional horizon AC - 1.11% and it is the lowest in the substrate C, average 0.90%. According to (Filipovski, 1996) the average content of humus in the horizon Amo analyzed for 481 profiles of rendzinas in Macedonia is 2.63%.

Table 1. Mechanical composition

Hor.	N	> 2 mm		0.2 – 2 mm		0.02 – 0.2 mm		0.02 – 2 Mm		0.002 – 0.02 mm		< 0.002 Mm		< 0.02 Mm		**H.V%**	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
A	3	3.69	1.93	1.34	4.71	32.89	6.08	43.23	8.99	25.23	11.28	31.53	3.82	56.77	8.99	2.04	0.08
AC		2.93	0.76	11.45	5.91	36.95	3.70	48.40	2.26	23.83	2.42	27.77	1.29	51.60	2.26	1.61	0.42
C		3.21	0.74	8.08	2.93	36.09	1.56	44.17	1.48	27.38	6.00	28.45	5.50	55.83	1.48	1.20	0.15

Table 2. Chemical properties

Hor.	N	pH KCl		pH H_2O		Humus %		N%		P_2O_5		K_2O		$CaCO_3$	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
A		6.93	0.21	7.97	0.25	2.39	0.01	0.13	0.01	4.44	3.56	19.36	4.78	10.62	2.26
AC	3	7.00	0.26	8.00	0.20	1.11	0.01	0.12	0.01	3.91	3.24	9.61	5.21	11.10	1.81
C		7.03	0.29	8.13	0.25	0.90	0.10	0.07	0.01	3.00	1.68	4.81	1.75	14.03	2.50

Table 3. Soil moisture retentions

Hor	N	0,33		1		2		6.25		11		15	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
A		32.88	3.29	29.03	1.50	25.40	1.83	17.63	2.03	15.34	1.91	13.44	2.11
AC	3	32.19	2.17	27.58	1.00	23.20	0.89	15.60	0.62	13.55	0.82	11.67	0.83
C		30.72	2.15	28.82	2.61	24.67	2.53	16.12	2.65	14.11	2.59	12.33	2.63

The retention of water in the soil is the result of two forces: adhesion (attraction of water molecules by soil particles) and cohesion (water molecules attract each other). Adhesion is much stronger than cohesion. The force with which water is retained in the soil is called capillary potential and is closely related to water content. Free water in the soil has capillary potential equal to zero, a condition when all the soil pores, capillary and non-capillary, are filled with water. Soil water potential can be determined indirectly by recourse to measurements of soil water content and soil water release or soil moisture characteristic curves that relate volumetric or gravimetric content to soil water potential. The measurement of water potential is widely accepted as fundamental to quantifying both the water status in various media and the energetics of water movement in the soil- plant-atmospheric continuum (Livingston, 1993). Mukaetov (2004) points out that by reducing the moisture content in soil, the value of the capillary potential is increasing.

For assessment of soil moisture by means of capillary potential, quantified by Schofield, quoted by Vucić (1987), he suggested pF values, where the force of water in the soil was expressed by the height of the water column in cm (1 bar = 1063 cm water cm^{-2}). The pF values are affected by the change of the mechanical composition and, according to the same author, the greater the share of the smaller fractions, the greater the pF values, especially at a pressure of 0.33 bars. In our research, the water retention capacity (WRC) was established in laboratory conditions using pressure of 0.33 bars, and was expressed in mass percentage (Tab. 3).

From the data presented above, it can be seen that water retention capacity has the highest percentage in the Amo horizon of 32.88% due to the higher content of clay, colloid and organic matter, followed by the transitional AC horizon with a similar value of 32.19% and in the substrate C of 30.72%.

In all horizons of the examined rendzinas, high values were obtained for moisture of wilting point. In the Amo horizon where the highest retention of moisture was observed at a pressure of 15 bars, high average value of physical clay fraction 56.77% is shown.

The influence of mechanical and organic matter composition on the retention of moisture in the surveyed rendzinas best expresses the high correlation between moisture retention at 0.33 ($r = 0.62$) and 15.00 bars ($r = 0.98$) in relation with the content of clay and retention of 0.33 and 15 bars at the silt fraction (r = 0.75 and r = 0.25) presented in Table 4. Similar values were obtained by (Žic, 1976), (Rajkai, *et al.* 1996) and (Markoski, *et al.* 2009), who found that soils with heavier mechanical composition have greater moisture retention, where the correlation coefficient ranges from r= 0.75 to r=0.77. High correlation exists between the content of humus and retention moisture from 0.33 to 15 bars(r = 0.83 and r = 0.87). In contrast, a high negative correlation is established between moisture retention and the composition of coarse and fine sand. (Abrol *et al.*, quoted by Markoski, 2008), found a positive correlation between physical clay content and moisture retention at tensions of 0.33 and 15 bars (r = 0.948; r = 0.828), and the highest negative correlation (r = -0971 i.e. r = -0.912) between total sand content and moisture retention at same tensions.

If tension of soil moisture is measured, and for each tension, content of moisture is measured, expressed in volume percentage and the data obtained are applied to the coordinate system for each horizon, retention curves will be obtained. They reflect the ratio between attracting forces (tension) and the amount of moisture in the soil.

The knowledge of the essence of the retention and retention curves of rendzinas is of great importance to the availability of water for the plant and the movement of water in the soil.

Table 4. Correlation between soil texture and humus and soil moisture retention

Fraction	Soil moisture retention					
	0.33	1	2	6.25	11	15
Clay	0.62	0.74	0.86	0.99	0.99	0.98
Silt	0.75	0.71	0.56	0.13	0.19	0.25
Coarse sand	-0.49	-0.84	-0.93	-0.99	-0.99	-0.99
Fine sand	-0.60	-0.76	-0.87	-0.99	-0.99	-0.98
Humus	0.83	0.50	0.66	0.93	0.90	0.87

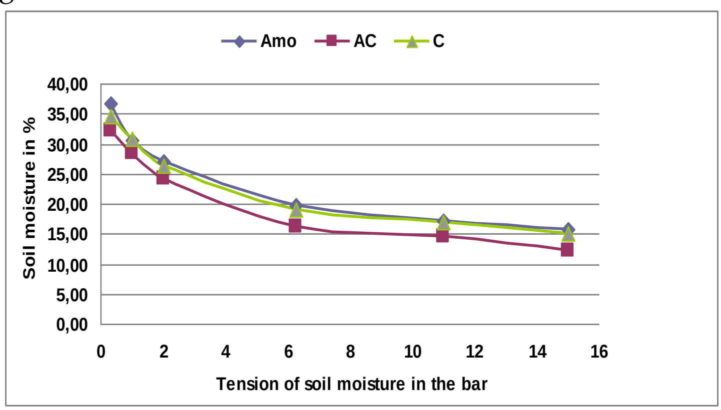
Matula *et al.*, (2007), emphasize that soil hydraulic characteristics, especially the soil water retention curve, are essential for many agricultural, environmental, and engineering applications. Their measurement is time-consuming and thus costly.

The data in the following graphs (1, 2 and 3) show lowering of the retention curves, which is most significant at lower pressures.

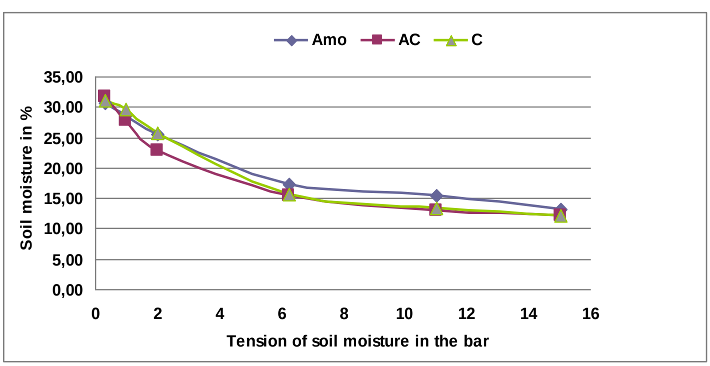
The influence of mechanical composition on the retention of soil moisture can be seen from all graphs, where there is a large retention in humus accumulative horizon due to the amount of clay and humus compared to other horizons.

The highest curve is the retention curve of the Amo horizon due to the high content of humus and physical clay. From Figures 1 and 2, it can be seen that the retention curves in the C horizon are above the retention curves in the transitional AC horizon as a result of the higher content of physical clay in this horizon C (55.83%).

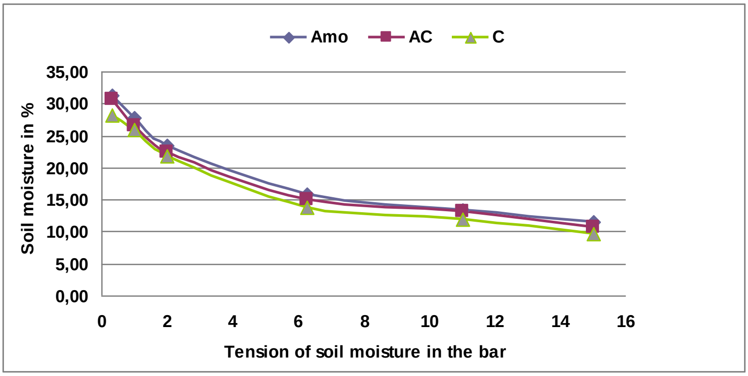
The retention curves in all the horizons, ranged from 2 to 15 tension bars, in almost all cases are nearly horizontal and show a small decline because content of clay and silt is not large. According to Filipovski (1996), the higher retention in rendzinas can be explained by the higher content of montmorillonite and allophanes and higher content of $CaCO_3$ in the silt fraction.



Graph 1. Soil moisture retention curves (profile 1)



Graph 2. Soil moisture retention curves (profile 2)



Graph 3. Soil moisture retention curves (profile 3)

Filipovski *et al.*, (1980) give data on the retention curves of a profile of a rendzina in the region of Kocani, where lower values of moisture at all applied pressures have been noted. The soil is characterized with lighter mechanical composition. The highest retention is present in the Amo horizon, as a result of the presence of organic matter and the influence of the mechanical composition (clay and silt). Similar values of retention curves for two horizons A and AC in rendzinas are presented by Wolińska *et al.*, (2010).

The results showgradual changes in retention forces with the change of moisture without oscillations (Graph 1, 2 and 3). It indicates that the distribution of soil moisture in various forms fails to find justification in the retention curve, as the reduction of the amount of water has no large oscillations at different tensions.

CONCLUSION

Based on the obtained results, the following conclusions can be drawn on the impact of mechanical composition of soil and humus content on the retention curves:

- The mechanical composition of the studied soils is characterized by domination of fractions of physical clay (clay + silt) and clay in soil separates, which strongly affect retention curves of soil moisture;
- In the humus accumulative Amo horizon, the average content of humus is the largest (2.39%) where we have the highest retention of soil moisture;
- Moisture content that is retained at pressure of 0.33 bars is high in all horizons. The highest retention of 32.88% (presence of clay,

physical clay and organic matter) is present in the Amo horizon, followed by the transitional AC and the substrate C;
- Values obtained for the wilting point (pressure of 15 bars) are high in all horizons of rendzinas. This is due to the high content of physical clay and content of $CaCO_3$.
- Positive correlation has been established between the retention of moisture at 0.33 and 15 bars and the content of clay, silt, humus, and high negative correlation between retention of moisture at 0.33 and 15 bars.

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THE PROPERTIES OF PLANOSOLS ON SERPENTINE ROCKS ON MALJEN MT.

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ABSTRACT

Results of morphology, and physical and chemical properties research of Planosols on serpentine parent material, investigated on Maljen Mt. in various plant communities (beech forests with admixed fir, scotch pine forests and wet meadow communities) were presented in this paper. Planosols forming process occurs as a consequence of heavy textural composition and weak water-permeability of soils on serpentine. Planosol stadium on serpentinites of Maljen Mt. develops after the illimerized or humus-accumulation soil stadia. Planosols in researched area are characterized by short wet phase during soil forming process. They occur on flat terrains and on milder inclinations in foothills.

Keywords: Planosol, Soil properties, Serpentine rock, Mountain Maljen

INTRODUCTION

Complete saturation of superficial layer of soil with water in certain time of year leads to creation of hydromorphism and Planosol forming process in superficial layer of solum. Presence of poorly permeable or impermeable layer of soil (horizon) at certain depth leads to water accumulation and stagnation. Literature describes Planosol under different names. According to official pedological classification used in Serbia (Škorić *et al.*, 1985), superficial Planosol is called pseudogley. Term "pseudogley" was originally used in pedological literature by Kubiena (1953). In

United States of America term "Planosol" is used. In WRB system this type of soil is classified in group of Planosols or albeluvisols. Planosol is characteristic for plain terrains. It is also present on mild inclinations of hilly terrains, where stagnated water drainages quickly. Planosol commonly occurs in lower elevation zones of old river and lake terraces, in a complex with illimerized soil, mostly in western and north-western areas of Serbia (Tanasijević, *et. al.*, 1966). In mountain areas of Serbia, Živković researched Planosol on Zlatibor (1952), and Antić *et al.* studied it at serpentinites of Goč (1985). This study shows Planosol characteristics at serpentinites of Maljen, in Divčibare area, under forest vegetation and wet mountain meadows.

MATERIAL AND METHODS

The soil profiles opened in the field were researched, i.e. their external and internal morphology. Three soil profiles were opened in forest communities; one was opened in mountain meadow community. In the Scotch pine forest (*Erico-Pinetum sylvestris* Stefanović 1963) two profiles were opened (profiles 18/12 and 21/12), one profile (17/12) was opened in the forest of beech and fir with blueberry (*Abieti- Fagetum moesiacae* B. Jovanović 1953 *s.l. myrtilletosum*). In wet meadow community profile 10/12 was opened. The definition of pedosystematic soil units was performed in compliance with the principles and criteria of the Pedological Classification after Škorić *et al*. (1985). The representative soil samples for laboratory analyses were taken by genetic horizons. The laboratory analyses were performed in the Pedological Laboratory of the Faculty of Forestry in Belgrade according to following methods:

- content of hygroscopic water was determined by desiccation in drying oven at the temperature of 105 °C during 6-8 hours;
- particle size distribution was determined by treating the samples with sodium-pyrophosphate. The soil was fractioned by combined pipette method and elutriation method by straining after Atterber, with fraction percentage determination: 2-0.2 *mm*, 0.2-0.06 *mm*, 0.06-0.02 *mm*, 0.02-0.006 *mm*, 0.006-0.002 *mm* and below 0.002 *mm*;
- soil active acidity, pH in H_2O and in soil suspension with 1 *N* KCl was determined electrometrically;

- hydrolytic acidity - by Kappen ;
- sum of adsorbed base cations - by Kappen (S in, *cmol ·kg*$^{-1}$);
- total adsorption capacity for cations (T in, cmol ·kg^{-1});
- sum of acid cations (T-S in, cmol ·kg^{-1}) was determined by calculation;
- base saturation level in the soil – by Hissink ;
- humus and carbon percentages – by Tyurin's method (1960) in Simakov's modification;
- total content of nitrogen in the soil - by Kjeldahl;
- carbon nitrogen ratio (C:N) was determined by calculation;
- readily available P_2O_5 and K_2O - by Al method.

The results of the laboratory analyses of physical and chemical soil properties are presented in Tables 1 and Tables 2.

RESULTS AND DISCUSSION

Planosol on serpentinites of Divčibare has secondary origin. Planosol forming stadium in forest communities develops after eutric brown soil and illimerized eutric brown soil stadia. Planosol under wet meadow community develops directly from humus-siliceous soil, eutric and vertic, as a consequence of heavy textural composition and weak water-permeability of these soils, which leads to total saturation of superficial layer of soil with water in certain time of year, creating hydromorphism. Planosol that occurs in forest communities on terrains with 5 – 15 ^{o} inclination belongs to slope subtype of Planosol, while Planosol in meadow community belongs to lowland subtype. Profile structure of Planosol in community of beech and fir with blueberry is Olfh – Ag – gBt –BC (profile 17/12); in Scotch pine community it is Olf – Ag – g – Bt – C (profile 18/12); Olfh – g – gBt – C (profile 21/12) and Ag – g – Bt – C1 under wet meadow community. On the soil surface in forest communities there is organogenic horizon, 3-5 cm thick. Superficial humus horizon is brownish-gray colored, with more or less prominent pseudogleyzation process. Typical Planosol horizon is 10-20 cm thick, ashy-whitish colored, speckled with rust stains of ferric compounds, powdery, with tongue-like transition to horizon below. Illuvial horizon under forest communities is brown with tongue-like gray zones, while it is dark brown under meadow community. Illuvial horizon is argillaceous, plastic in wet state, compact in dry state, poorly water-permeable, containing particles of decomposing serpentinites in lower layers. C-horizon represents argillaceous cortex of decomposed serpentinite rocks. According to depth on which weakly permeable or impermeable layer of soil (horizon) that leads to water stagnation is present, both types of Planosol, slope and lowland, belong to shallow Planosol variety.

The results of the laboratory analyses of physical soil properties are presented in Table 1 and chemical soil properties are presented in Table 2. Analysis of granulometric fractions percentage ratio indicate that participation of coarse sand fraction is rather high and variable in g-horizons, as well as in illuvial Bt-horizons. Participation of coarse sand fraction varies from 1.30% (Ag horizon in profile 17/12) do 19 % (Bt- horizon in profile 10/12). Profiles significantly differ from each other according to participation and distribution of fine sand fraction in individual horizons. Ag–horizon of profile 18/12 contains the biggest amount of fine sand (42.80%), while the Bt-horizon of profile 10/12 contains the smallest amount (4.90 %). Powder fraction, as a rule, has the highest percentage participation. The highest percentage participation of powder is in superficial horizons, from which colloid clay part has been washed out by illimerization process. Planosol on Divčibare serpentinites is non-calcareous soil. Superficial horizons show weakly acidic reaction, and illuvial horizons have neutral to weakly alkaline reaction. According to level of alkali saturation, it belongs to eutric Planosol form. Level of alkali saturation is in 73.10-90.37% span. The lowest level of alkali saturation is in superficial horizons, with values from 73.10–76.82%. Level of alkali saturation increases with depth, illuvial horizons mark the highest values, 83.87–90.37 %. Superficial horizons are rich with humus. Content of humus in superficial AG-horizon amounts 9.06–14.72 %. In forest community of beech and fir with blueberry, transformation of organic residues that accumulate on the soil surface is slow and forms Oh-stratum, so the content of humus in superficial soil layer is lower. Total nitrogen content and distribution by depth of profile correlates with humus content and distribution. Percentage of total nitrogen in Ag is 0.50–0.59%. It significantly decreases in sub-superficial g-horizon. Easily available phosphorus resources are very poor. Easily available potassium resources are better than phosphorus resources, but still insufficient.

Table 1. Chemical properties

Profile No	Horizon	Depth (cm)	pH H_2O	pH $CaCl_2$	Y1 mL NaOH/ 50g	(T-S)	Adsorptive complex S	T	V	$CaCO_3$	Humus	C	N	C/N	Available P_2O_5	Available K_2O
							cmol/kg				(%)				mg/100g	
	A	0-6	6.38	5.60	18.12	11.78	32.00	43.78	73.10	0.00	9.41	5.46	0.59	9.25	1.00	11.50
10/12	g	6-15	6.89	5.94	10.00	6.50	30.90	37.40	82.62	0.00	3.73	2.16	0.24	9.01	0.64	11.50
	Bt	15-27	7.40	6.04	5.31	3.45	32.40	35.85	90.37	0.00	0.94	0.55	0.00	-	0.21	21.90
	Ag	0-10	6,34	5,76	20,22	13.14	43,30	56.44	76.71	0,00	14,72	8.54	0,71	12.02	1,28	12,30
17/12	gBt	10-30	6,86	5,54	9,00	5.85	19,8	25.65	77.19	0,00	2,86	1.66	0,15	11.06	0,00	4,90
	BC	30-50	7,04	6,09	7,25	4.71	24,5	29.21	83.87	0,00	1,19	0.69	0.00	-	0,05	3,60
	A	0-4	6.49	5.80	13.97	9.08	30.10	39.18	76.82	0.00	9.06	5.25	0.50	10.51	1.14	10.40
18/12	g	4-24	6.71	5.81	8.50	5.53	17.00	22.53	75.47	0.00	2.38	1.38	0.10	13.80	0.68	3.10
	Bt	24-45	7.21	6.23	7.81	5.08	33.80	38.88	86.94	0.00	1.41	0.82	0.00	-	0.07	10.00
	g	3-20	7.09	5.88	8.25	5.36	17.80	23.16	76.85	0.00	1.97	1.14	0.14	8.16	0.00	4.60
21/12	Bt	20-40	7.42	6.20	7.50	4.88	32.30	37.18	86.89	0.00	1.22	0.71	0.00	-	0.06	9.60
	C1	40-65	7.19	6.23	8.75	5.69	37.90	43.59	86.95	0.00	1.62	0.94	0.00	-	0.19	6.40

Table2. Texture of the soil

Profile No	Horizon	Depth (cm)	Hyg. moisture (%)	Particle size composition (%) 2,0-0,2	0,2-0,06	0,06-0,02	0,002-0,006	0,006-0,002	< 0,002	Total sand >0,02	Total silt+clay <0,02
								mm			
	A	0-6	5,94	7.70	11.20	9.30	38.10	16.50	17.20	28.20	71.80
10/12	g	6-15	5.70	10.70	5.60	8.70	28.00	14.20	32.80	25.00	75.00
	Bt	15-27	7,62	19.00	0.90	4.00	17.70	7.50	50.90	23.90	76.10
	Ag	0-10	5.83	1.30	15.80	22.50	33.80	12.10	14.50	39.60	60.40
17/12	gBt	10-30	2.75	4.20	11.10	14.70	38.40	15.50	16.10	30.00	70.00
	BC	30-50	3.68	10.70	18.00	17.40	24.00	9.70	20.20	46.10	53.90
	A	0-4	3.74	4.80	19.80	23.00	31.80	11.30	9.30	47.60	52.40
18/12	g	4-24	2.46	10.30	15.70	15.30	30.00	13.40	15.30	41.30	58.70
	Bt	24-45	6.02	10.70	17.60	9.30	14.80	9.50	38.10	37.60	62.40
	g	3-20	2.33	6.30	10.40	11.90	40.30	14.10	17.00	28.60	71.40
21/12	Bt	20-40	5.27	5.80	17.70	17.60	21.90	10.30	26.70	41.10	58.90
	C1	40-65	6.89	5.00	28.00	20.60	16.10	7.20	23.10	53.60	46.40

Easily available potassium resources in meadow community are bigger than in forest communities. When it comes to distribution of potassium by depth, in meadow community and in communities of beech and fir with blueberry, the highest content of potassium is in illuvial horizons, and the lowest in g-horizon. In Scotch pine community, easily available potassium content is highest in superficial Ag-horizon.

In western and north-western areas of Serbia, Planosol is very frequent type of soil. It is mostly formed on plain terrains, in microdepressions and on mild inclinations with slow sidelong water drainage. Tanasijević *et al*. (1966) submitted that Planosol covers 285 000 hectares, i.e. 15.70 % of area. It is mostly present on argillaceous substrate of old river terraces. On higher elevation terrains Planosol also occurs on other geological substrates, where there is near the surface a water-impermeable layer which retains infiltrated water. Antić *et al*. (1965) studied Planosol on serpentinite of Goč. Antonović (1965) studied Planosol on red sandstone in eastern Serbia. Planosol on serpentinites of Divčibare has secondary origin, where impermeable layer represents argillaceous illuvial horizon. Elementary distribution of Planosol on Divčibare is small areas, as well as elementary distribution of Planosol on serpentinites of Goč.

CONCLUSIONS

Presence of Planosol on serpentinite is determined on smaller areas on Divčibare. Planosol on this area is of secondary origin. Heavy textural composition soils with high content of montmorillonite clay are formed on argillaceous cortex of decomposing serpentinite. Water impermeability of decomposing serpentinite cortex and weak permeability of soil lead to the formation of hydromorphism. Planosol stadia in forest communities develop after eutric brown soil and illimerized eutric brown soil stadia. In wet meadow community, Planosol develops directly from vertic humus-siliceous soil stadium. Planosol that occurs in forest communities on terrains with 5 – 15 ^{o} inclination belongs to slope subtype of Planosol, while Planosol in meadow community belongs to lowland subtype. Both subtypes have impermeable layer that retains water at a depth of less than 25 cm, and they belong to shallow Planosol variety. Level of alkali saturation is high. According to determined values of alkali saturation level, they belong to eutric Planosol form. Elementary distribution of Planosol on Divčibare is small areas. Lowland subtype of Planosol is present on flat parts of terrain, while slope subtype occurs on mildly inclined parts of hillside, where water that's drained from more inclined parts of hillside flows sideways.

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PROPERTIES OF THE SOILS FOR OLIVE PLANTATION IN THE SELEMLI, GEVGELIJA

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ABSTRACT

The soils researched in the Selemli location, Gevgelija belong to the soil type known as primary pseudogley. The conditions for formation of soils and their properties are described in detail in the complete material. These soils are noncarbonate and have slightly acid to neutral reaction. They contain very little amount of humus, nitrogen and are poorly supplied with available phosphates and medium to well supplied with available potassium. We have emphasized some negative processes as well as soil properties such as unfavorable water, air and thermic regimes well as water presence in all profiles (deepness 80-100cm). Special accentuate is given on the reclamation measurement for better fertility of the soils as an essential part of successful olive planting.

*Keywords***:** pseudogley (primary), mechanical composition, chemical properties, measures for reclamation

INTRODUCTION

For the agricultural producer, the soil, along with the atmosphere, represents an environment in which the plant grows and gives yields. It should provide the root system with all conditions necessary for living. The quantity and quality of the yields from the crops grown, highly depends on whether the soil performs its role. High quantities and stable yields may be obtained only if the crops are provided with all factors simultaneously, without interruption throughout the entire vegetation and in the optimum necessary quantities, in accordance with the phases of the plants' development.

In the agro-production, the soil represents a product of labor. People apply various agro-technical and ameliorative measures in order to create optimum conditions for the cultivated plants. Without good knowledge of the soils, none of the agro-technical and ameliorative measures can be applied, neither the right choice can be made as to which crops shall grown successfully according to the conditions on the terrain. The mistakes made in the application of these measures, due to lack of knowledge for the soils, can be disastrous, since the same require more investments whose effect shall be recognizable within a longer period.

The cultivation of the perennial plants (olives) is connected with high investments and any wrong choice of rootstock and varieties shall cause negative financial results. This should be especially emphasized if known the fact that no financial results are expected in the first two to three years, and that chlorosis might appear in the full development of plants.

Due to this, the pedological researches have a particular importance in the growth of expensive perennial plants, mainly because of the right selection of rootstock, varieties and application of the right agro-technical measures.

After conducted field survey, on the area of 5,7 ha, in the surrounding of the village of Selemli, Gevgelija, and depth of 130 cm, six basic pedological profiles, morphologically known, were excavated, and 24 soil samples in disturbed condition were taken for laboratory analyses. At the same time, during the field survey, data was collected on the relief, vegetation, the substrate (parent material), the climate, the hydrography etc. The field research of soils is carried out according to the methodology for field researches in our country (Mitrikeski and Mitkova, 2006).

MATERIAL AND METHODS

The following analyses were carried out during the laboratory phase: mechanical composition of soil – determined according to the International pipette method, while the dispersion of mechanical elements is carried out with 0,4 N solution of sodium pyrophosphate. The classification of the mechanical elements in texture classes is carried out according to Scheffer and

Schachtschabel; pH of the soil solution in H_2O and N KCl is determined electrometrically by means of glass electrode; the content of $CaCO_3$ is determined volumetrically by means of Scheibler's calcimeter; the determination of the content of active lime CaO in the soil is carried out according to the Drouineau-Galet method; the content of humus is determined according to the Kotzmann's method; and the total content of nitrogen (N) is determined according to Kjeldahl; the available potassium (K_2O) and available phosphorus (P_2O_5) are determined according to the Al's method.

The determination of the mechanical composition and the chemical properties of the soil is carried out according to the standard methods described by (Bogdanović *et al.*, 1966), (Mitrikeski and Mitkova 2006), (Resulović *et al.*, 1971), (Džamić et.al.1996).

Descriptive statistics has been prepared (the average value, the standard deviation and the coefficient of variation have been determined) for the mechanical composition and the chemical properties in Microsoft Excel.

RESULTS AND DISCUSSION

The formation, the spreading and the properties of soil are in close correlation with the environmental conditions, i.e. the pedogenetic factors: the substrate (parent material), the relief, the climate, the vegetation, the time and the human influence.

The examined soils are spread throughout the Sub-Mediterranean (modified Mediterranean) region. This region is mostly exposed to the influence of the Mediterranean climate, it is open to the Aegean sea, it is closest to it (60-95km) and it is protected against the stronger continental influences. The soils are spread on the altitude of 170 m. The data on the climate elements in the examined region are used in the paper of (Filipovski *et al.*1996) as well as the climate diagrams according to Walter, prepared by Rizovski, and presented in the same paper.

This area is characterized with highest insulation (2379 hours per annum). According to the Gracanin's heat designation, the climate is warm, and the rainfall regime has Mediterranean character: maximum in November, minimum in July and August, with not very emphasized secondary maximum in May and secondary minimum in January. The annual quantity of rainfalls is ranging from 611 to 695 mm. The degree of aridity is of particular significance. The draught index is low (24.2 to 28,7), and especially low during the months VII, VIII and IX, when it is amounting to 10-15. According to the Lang's annual rainfall factor (45,4 to 48,9), the climate is semiarid, and arid during four months (from VI to IX). During the colder half of the year, beginning from the month XI to III, the climate is humid, and during the months XII and I, the climate is even perhumid. The climate in this region, according to Köppen W quoted after Ristevski P (1982), has a designation C_3sa_1 (moderately warm climate). All data indicate on the change of the humid period with dry period, i.e. for mild, humid, cloudy winter, with high relative humidity, and hot, dry, cloudless summer with low relative humidity and high evapotranspiration.

The examined terrain is characterized with certain macro- and micro-relief, i.e. it represents a micro-depression which provides for gathering of water from the rainfalls and water flows, which has an effect on the formation of soils. The main characteristic of the soil is the water logging (saturation of all pores with water in the upper part of the profile, i.e. in the horizons g_1 and g_2. The formation of upper ground waters and the duration of the wet phase depend on multiple conditions. In this particular case, having known the fact that the terrain is inclined, the wet phase lasts longer in the lower part of the inclination and lasts shorter in the upper part due to the lateral movement of the water. This phase appears in the middle of autumn and lasts until the middle of the spring. All soil pores in the entire, or only in one part of the permeable upper part of the profile, are filled with water, and this results with appearance of anaerobic conditions and anaerobic microbiological processes. With the beginning of the warmer days and with the intensification of the evapotranspiration, the wet phase, through the moist phase, turns into dry phase. Air penetrates in the pores and the anaerobic processes are replaced with aerobic processes.

On the basis of the field researches, we established the formation of one soil type: primary pseudogley (profiles 1, 2, 3, 4, 5 and 6).

Pseudogley (primary)-Planosols-Stagnosol (*WRB, 2006 Classification*) are soils with a light-coloured, surface horizon that shows signs of periodic water stagnation and abruptly overlies a dense, slowly permeable subsoil with significantly more clay than the surface horizon. (Hraško, 1991, FAO/UNESCO, 1997, Raz, 1999, WRB, 2006). The primarily formed pseudogleys from two-layer sediments are designated as soils of profile type Ap-g_1-IIg_2-C. The profiles from this location have common characteristics, and differences too (depth of the impermeable layer, depth of the appearance of the oxide-reduction conditions). The arable Ap horizon is characterized with strength (depth) which is amounting to 30 cm in average. The passage towards the horizon g_1 is sudden. The main characteristic of the genesis of the pseudogley is the surface gleying (pseudogleying), i.e. the appearance of the oxide-reduction process. It appears as a result of the impact of the upper water laying over the impermeable horizon $g_{2,}$ appearing in various depths in the profiles (65, 70 and 80 cm) and it represents strongly cemented sandstone. The color of the basis is brown, green, olive green, but covered with grey spots (marmoreal). The signs of oxide reduction (horizon g_1) appear on various depths in the profiles (31, 45, 60 cm). After the drying of the soil, the wet phase turns into dry, and the reduction processes are replaced by oxidation processes. As a result, it has mosaic look (marmoreal), covered with plod sports and many concretions. It has no structure and noncarbonate.

On the basis of the analyzed mechanical composition (Tab. 1) it can be noted that among the fractions of soil separate, the physical sand fraction dominates (coarse sand + fine sand), over the physical clay fraction (clay+silt).

In the humus accumulative horizon Amo on average it amounts to 70.38%, in the g_1 horizon it increases and amounts to 72.47%, and IIg_2 decreases and amounts to 66.02%, in the substrate on average it amounts to 64.70%.

Table 1. Mechanical composition

Hor.	N	> 2 mm		0.2 – 2 mm		0.02 – 0.2mm		0.02 – 2 mm		0.002 – 0.02 mm		< 0.002 mm		< 0.02 mm	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
A		0.54	0.45	31.42	4.34	35.97	6.52	70.38	8.31	7.63	3.31	21.98	7.89	29.62	8.31
g1	6	1.27	0.73	39.04	5.06	33.42	4.48	72.47	0.97	13.83	4.67	13.70	3.90	27.53	0.97
IIg2		0.80	0.26	38.74	10.94	27.28	7.71	66.02	7.04	10.63	6.67	23.33	10.53	33.97	7.02
C		1.00	0.14	34.07	7.99	30.63	6.15	64.70	14.14	16.60	19.52	18.70	5.37	35.30	14.14

In the physical clay fraction, clay has higher value (there is the highest value in horizon IIg_2 average 23.33%, then there is the humus accumulative horizon A 21.98%, there is less in the substrate C 18.70%, and there is the lowest value in horizon g_1 (average 13.70%).

The upper horizon is sandy clay loam (prof. 1, 2, 3), sandy clay (prof. 4 and 5) and fine sandy loam (prof. 6), (Tab. 3).

Table 2. Textural classes

Profile	Horizon and depth, cm	Textural classes (by Schefer and Scachtcshabel)
1	0-30	sandy clay loam
	30-65	sandy clay loam
	65-90	sandy clay loam
	90-120	loamy coarse sand
2	0-31	sandy clay loam
	31-64	sandy clay loam
	64 -76	fine sandy loam
	76-87	sandy clay loam
	87 - 116	fine sandy loam
3	0-33	sandy clay loam
	33-50	sandy clay loam
	50-81	sandy clay loam
	81-110	loamy fine sand
4	0-27	sandy clay
	27-45	sandy clay loam
	45 – 100	sandy clay loam
5	0-30	sandy clay
	30-50	coarse sandy loam
	50-90	sandy clay
	90-130	coarse sandy loam
6	0 – 30	fine sandy loam
	30 – 75	sandy clay loam
	75 – 100	sandy clay
	100-130	sandy clay

These soils have unfavorable water, air and thermal regime. This is due to the saturation with water of the upper horizon due to impermeability (presence of strongly condensed sandstone) or the weak water permeability of the lower layer. In relation with the same, the three phases of moistening were described previously. The tillage, sowing and planting are possible only in the moist phase. It must be stressed that each improvement of the development conditions for plants must start with elimination of the wet phase and continuation of the duration of the moist phase on account of the other two phases.

The data (Tab. 3) provide possibility to accent the most significant characteristics of the chemical properties of researched soils. The soils have low humus in the upper horizons and very low humus in the lower part of the profile. Generally, arable soils have very little humus and that is why humification can be an efficient measure for increase of the productive capacity of soils. Simultaneously, together with the humus contents in soils, the total nitrogen contents also vary. During the field research, and later it was also confirmed with laboratory analyses, presence of carbonates in soils was not found. Only in the 2 and 5 profiles their presence was determined deep in the substrate (weak carbonate).

Table 3. Chemical properties

Horizon	N	pH KCl		pH H_2O		Humus %		N%		P_2O_5		K_2O	
		X	S.D	X	S.D	X	S.D	X	S.D	X	S.D	X	S.D
A	6	5.50	0.79	6.38	0.75	2.36	0.52	0.14	0.03	4.51	1.06	21.01	7.59
g1		6.10	0.49	7.04	0.29	1.72	0.10	0.10	0.01	3.34	1.16	15.62	8.24
IIg2		6.45	0.13	7.30	0.18	0.98	0.31	0.06	0.02	2.00	0.00	7.34	1.51
C		7.02	1.12	7.23	0.22	0.91	0.27	0.06	0.01	2.67	0.94	9.41	0.28

In tested soils (Tab. 4), the reaction of the soil solution varies from moderate to weakly acidic and neutral in the upper part of the profiles to neutral in the lower part of the profiles and weakly alkaline in the substrate of the 2 and 5 profiles. The received values for the reaction of the soil solution indicate that the degree of acidification in soils is lower.

Field and laboratory research show the need to undertake specific activities that will enable elimination of some negative aspects that have been determined with these soils. Non-meliorated Pseudogley soils provide low and very variable yields from year to year, which depends on the metrological conditions of the year.

There are several reasons for their low production value if appropriate measures are not undertaken. The main reason is violated water, air and heat regime when there is lack of oxygen in the wet phase and in the dry phase when there is lack of water as consequence of the presence of the less permeable lower water horizon and root system horizon. This is complemented by the low contents of organic matter and some nutritive elements (especially P_2O_5 and K_2O – especially for profile 3).

The unfavorable properties described can, not only negatively influence yields, but they can also have negative effects over tillage. The moisture favorable for high quality tillage has a short duration. If the soil is wetter, the machines get stuck in it.

Judging according to some of its properties (weak texture differentiation, lower contents of clay, not such strongly expressed water permeability, presence of sandstone, shorter duration of the wet phase due to climate conditions, lower degree of acidity) melioration would be easier.

The basic task of the entire complex of measures is to remove the stated unfavorable properties, but primarily to shorten the wet and dry phase and to continue the moist phase. For this to be achieved, the impermeable horizon must be broken with tillage that can be made with plantation ploughs very deep and by overturning the soil or with deep digging with application of special tools, deferent types of diggers, which can be stable and dynamic (vibrating), which are more efficient. In this manner of tillage, the soil does not overturn, it only granulates. Digging will enable removal of the forming of upper underground water and wet phase, whereby it continues the duration of the moist phase, it improves the infiltrations (absorption) and the moisture accumulation in a thicker layer of soil, it destroys the compactness and provides deep penetration of the root system (upon physiologically active layer) it improves the aeration in the deeper part of the profile, as well as the microbiological activity, provides fertilization deeper in the soil. In one word, there is homogenization of soil properties and it is enabled for plants to root deeper and to use greater quantity of water, air and nutrition from a larger volume of soil. This contributes to greater yields.

CONCLUSIONS

Taking into account the fact the growing olives is planned for the areas, care must be taken regarding olives requirements for soil conditions. Namely, olives are successfully grown in deep, fertile and properly aired soils whereby they produce high and quality yields. It must be stated that they do not tolerate moist soils where the soils have maximal water capacity during most of the year.

During the field research that was made at the beginning of April, water presence was determined in all profiles at depth of 80-100cm. This problem can be solved with the construction of side drainage channels around the lot and digging up to 1m depth.

Addition of organic matter to these soils, which are not rich in humus improves the structure and stability of aggregates, microbiological activity and provides nutrition elements. This can be achieved by adding manure, plowing of plant wastes, green fertilization and growing perennial grasses in between rows which require irrigation. Melioration fertilization with mineral fertilizers is necessary before growing the plantation in order to achieve at least medium provision of nutritive elements, Phosphorus P_2O_5 up to 12-18, and Potassium K_2O up to 20-30 mg 100 g^{-1} soil. This especially refers to Phosphorus (P_2O_5) since laboratory analyses have shown poor provision of soils with this nutritive element. Whereby, in addition to the calculated necessary quantity of P_2O_5 and K_2O for the planned yields, another 90 kg ha^{-1} P_2O_5 and 100 kg ha^{-1} K_2O is adder each year until good provision is achieved.

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SOIL MINERAL COMPOSITION OF VERTISOL IN PIROT VALLEY

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ABSTRACT

Calcareous Vertisol, non-calcareous Vertisol and brownised Vertisol were analyzed for chemical, mineralogical and physical properties in the Pirot Valley, Serbia. The results showed that the parent material and relief played a dominant role in the formation of given subtypes of Vertisol, as well as other factors such as climate, slope, relief, vegetation, and human activity. Physico- chemical processes in the soil are significantly intensified due to the increased of water flow from the slopes, carrying particles of colloidal clay fraction into the lower parts. Increased amounts of colloidal clay led to the intensification of argillogeneze, acidification and leaching $CaCO_3$. The content of colloidal clay is very high, and in some sections is over 60.0%. Sum of silt and clay fractions is about 80.0%. There are presence of mineral calcite, quartz, muscovite, alkali feldspar, plagioclases and small amounts of amphibole. The difference in mineral composition between these two subtypes of Vertisol is reflected in the content of calcite , which is absent in brownised Vertisol, as well as quantitative and qualitative presence of certain clay minerals from smectite (montmorillonite) groups. By content of colloidal clay in both Vertisols, the minerals with the three-layer lattice, type of group smectite (montmorillonite) dominated. Mineral illite is the second in representation of given Vertisol subtypes.

Key words: Vertisol, mineral composition, clay, Pirot

INTRODUCTION

About the genesis of Vertisol has been discussed, both here and abroad. Stebut *et al*., (1947), the first described Vertisol as represent of relict hydrogenic soil, formed in depressions of former lakes and swam. His view was accepted by the majority of Yugoslav soil scientist and some neighboring countries.

However, recent research has questioned the point of view of relict origin. Also, the Negebauer and Zakosek (1962) have determined through C14 , the age of the humus in Vertisol, on depth of 45 cm, from the area of Trnava in Šumadia is about 2770 years old. Pavićević *el al.,* (1969), Filipović and Nikodijević (1963), Filipović *et al.,* (1965), Filipovski and Ćirić (1963) and Živković *et al.*, (1968) concluded that Vertisol is not relict, but is younger terrestrial soil formed under conditions of increased moisture.

Conea *et al.,* (1964), believe that the genesis of Vertisol, closely related with the existence of clay sediments and flat terrain, and Crisan *et al*., (1964) think, that the Vertisol not formed only on the flat relief, but on hilly terrains and form part of a series with endopercolation of autohydromorphic soil, with slow movement of water, in the descending direction.

Vertisol in Bulgaria was formed on different Pliocene and Quaternary sediments, which originate from different parts of the basin and different petrographic structure. The origin of Vertisol should not be sought in a particular rock (Koinov *et al.,* 1964). Vertisol in Albania is classified in special meadow soil in the river valleys, emphasizing the special role of magnesium in the manifestation of physical properties (Bogatirev, 1958). Similar findings were recorded by Nikodijević (1972) who studied the clay soil on amphibolites from eastern Serbia.

Latest research of Vertisol in the basin of Timok river (Antonović *et al.*, 1974) has shown that they are formed on andesite on significantly large areas. According to the USA classification (7 Approximation) Vertisols are formed on a clay in different parts of the world with different names (Regur, Tirso, Black, Cotto, Tropical Black Claw).

MATERIALS AND METHODS

Field studies. Field investigations were conducted in August 2009. Soil samples were analyzed for mechanical and agrochemicals characteristics. The cylinders (Kopecky) were analyzed for water-physical analysis in laboratory conditions.

Water-physical analysis. Mechanical analysis was done by pipette method with Na-pyrophosphate; texture class was determined by Ferre triangle; Hygroscopic moisture was determined by calculation, after drying at 105^0 C. Maximum water holding capacity by saturation after drying at 105^0C. Water constants on (0.1; 6.25; 15 kPa) was measured on pressure meter. Coefficient of filtration (Kf) was measured on apparatus for filtration by the modified Stojićević method.

Agrochemical analyzes. Content of $CaCO_3$ was determined volumetrically on Schaiblers calcimeter. Soil pH in H_2O and in 1M KCl–electrometrically. Adsorbtive complex (Y_1, S, T, V) by Kappen method. Available P_2O_5 by Al- method by Egner-Riehm. Available K_2O by Al- method of Egner-Riehm. Total N and C were determined on CNS Analyzer.

Mineralogical research. These calcareous and brownised subtypes of Vertisol were analyzed for mineral composition by X-ray method (XRD), the Phillips Unit. Examination of soil profiles was performed on the powder diffraction-meter (Phillips PW 1710). Diffraction patterns (diagrams) were obtained from CuK_α radiation with copper anticathode wavelength $\lambda = 1.54184$ Å, occurring in the X-ray tube current is I = 30 mA and operating voltage of the tube U = 40 kV. Silt fraction (0,002 - 0,02 mm) analysis was carried out in the range of $2\text{-}60^0$, and clay fraction (< 0,002 mm) was recorded in the range of 2 - 15 ^{0} and an air dry sample (VS), saturated with ethylene glycol (EG) and annealed at 550°C (Z) for all depth profiles.

RESULTS AND DISCUSSION

In the area of Pirot basin three subtypes of Vertisol were studied: Calcareous and non calcareous Vertisol, and Brownised Vertisol.

1. ***Calcareous Vertisol.*** This subtype of Vertisol in the valley and surroundings was formed on the carbonate clay substrates of Pliocene lacustrine sediments and on carbonate alluvial clay sediments of the river Nišava. Place where it occurs are Sopot, V.Suvodol, Držina, Pirot - Berilovica, Pirot - Mamošnica - Rogoz.

This Vertisol is characterized by distinct black color (7,5yr 3/1), and heavy clay texture in humus-accumulative Avt horizon, that is usually 50-80 cm deep. Below there is mixed Avt C horizon, 30–50 cm, dark- brown color (7,5yr 3/2), and of heavy clay texture; then substrate C horizon of yellow-brown color (7,5yr 5/6).

Vertisol calcareous in all horizons contain carbonates, whose amount increases with depth, so the substrate has a maximum carbonates. By textural this Vertisol is clayey soils and less powdery loam-clay soils. The structure on the surface is prismatic horny, and at depth usually is columnar. Drying leads to the formation of deep vertical cracks, which is typical for this subtype of Vertisol. Morphological description of this subtype Vertisol is shown in figure 1.

Mechanical composition of subtype Vertisol calcareous is presented in Table 1. Clay fraction in Ap and Avt horizons is 41.2-55.5%, respectively. This affects its hydro-physical properties: plasticity, swelling and stickiness, which are in most cases very high. Clay and carbonates together make very stable structural aggregates. With depth, clay content is significantly reduced, while the amount of fine and coarse sand increases. Silt is the second in the percentage in Ap and Avt horizons ranging from 20.4 - 30.9 %, decreasing with depth. Silt and clay (total clay) are 65.3 - 79.90% in Ap and Avt horizons, and represents a large amount of total clay, as a direct indicator of adverse water- physical properties of Vertisol.

Horizon Ap, 0-20cm, black 7,5YR 3/1, prismatic structure, heavy clay. In the wet state, it's plastic and sticky, calcareous. Transition very gradually to
Horizon Avt, 20-58 cm, black color 7.5YR 3/1, clay, very dense, in the wet state plastic, prismatic to columnar structure, carbonate. Transition gradually to
Horizon Avt C, 58-78 cm, dark brown color, 7.5YR 3 /2, clay, prismatic structure, a lot of carbonate, poorly permeable. Transition is clear
Horizon C, below 78-100 cm, yellow-brown color, 7.5YR 5/6, silty clay loam, weak structural, strongly calcareous.

Fig. 1. Morphological description of the calcareous Vertisol, on the Pliocene sediments (prof.10) in Držina

Unfavorable **hydro-physical characteristics** (Tab.1) of Vertisol caused by the dominance of hydrophilic group of three-layer minerals of smectite (montmorillonite, vermiculite, badelite, nontronite), which causes swelling of clay colloids, resulting in poor permeability (Darsy coeff. is 10^{-5}-10^{-7} cm sec^{-1}). Increased percentage of hygroscopic moisture in Avt (4.0-6.6%) is a direct consequence of the presence of hydrophilic clay minerals of montmorillonite type, which caused the high water constant FWC (Field water capacity) and WP (Wilting point). So, FWC in Avt horizon is from 29.9-38.8%, and WP from 17.7-24.1%, while the physiological available water for plants (WAP) ranges between 11.7-16.0%.

Chemical properties (Table 2) indicate that pH is favorable for development of flora and fauna in this soil, resulting in an increase in soil fertility. Amount of $CaCO_3$ ranges from 0.84 to 15.00%, depending on the type of substrate on which the soil was formed. In most of the cases, the minimum amount of $CaCO_3$ is on the surface Ap horizon, increasing with depth with the largest amount in C horizon (substrate). The soil is neutral and slightly alkaline in the surface cultivated Ap horizon, pH ranging from 7.58 to 8.0 in H_2O, and 6.70-7.00 in nKCl. With the depth the soil pH increases.

Humus is present in medium amounts, in surface Ap and Avt horizons is 2.34-4.01%, in the transitional Avt C horizon is 1.35-3.04%. The amount of total N is the highest in surface horizons-0.12 to 0.26%, decreasing with depth.

Available phosphorus in Ap horizon is 4.1-14.6 mg 100 g^{-1} soil, which is a poor to good supply. Available potassium, also has the highest amount in Ap horizons, ranging between 26.5-40.0 mg 100 g^{-1} soil, which represents a good supply.

Mineralogy of calcareous Vertisol, profile 10, Držina.

Silt fractions (0.02- 0.002 mm): mineralogical composition (Fig. 2) showed presence of quartz with the main reflection of 4,25; 3.33; 2.45; 2.28… Å. In addition to quartz there are calcite (3.85, 2.85, 2.09, 1.91.. Å); muscovite/illite (10,05; 4:48; 3.87; 2.95… Å); K-feldspar (orthoclase) (6,46, 3.61, 3.20, 2,03… Å); plagioclase with fewer reflections of albite (3.19, 2.93, 2.86 Å) and with certain reflections of orthoclase/albite. In addition to these minerals traces of amphibole and secondary phyllosilicates such as MLS, smectite, illite and kaolinite were found.

Table1. The mechanical composition and water properties of calcareous Vertisol

Place	Horizon	Depth cm	Coarse sand (>0,2 mm) %	Fine sand (0,02-0,2 mm) %	Silt (0,002-0,02 mm) %	Clay (<0,002 mm) %	Total sand (>0,02 mm) %	Total clay (<0,02 mm) %	Hygro. Moist. %	FWC - Field wat. Cap. %	WP– Wilt.point %	WA – Wat.available %
Vertisol on alluvium (arable land)												
Pirot pr.3	Ap	0-10	2.7	22.0	28.2	47.1	24.7	75.3	4.7	29.9	18.2	11.7
	Avt	10--35	1.7	20.3	30.9	47.9	22.0	78.0	4.8	32.5	19.1	13.4
	Avt	40-67	2.5	32.2	24.1	41.2	34.7	65.3	4.0	30.3	17.7	12.6
	Avt C	60-84	4.3	39.4	21.3	35.0	43.7	56.3	3.1	24.6	14.2	10.4
Pirot pr.4	Ap	0-16	1.9	19.8	24.6	53.7	21.7	78.3	4.8			
	Avt	16-40	1.5	18.6	26.3	53.6	20.1	79.9	5.2			
	Avt	50-70	1.6	31.4	21.8	45.2	33.0	67.0	4.1			
	Avt C	85-104	0.9	39.1	23.0	37.0	40.0	60.0	3.7			
	C	104-130	3.3	50.1	21.9	24.7	53.4	46.6	2.8			
Vertisol on lacustrine Pliocene sediment (arable land)												
Držina pr.10	Ap	0-20	3,0	19,1	20,4	55,5	22,1	77,9	4,8			
	Avt	20-68	3,2	16,9	25,0	54,9	20,1	79,9	5,5			
	Avt C	68-78	3,6	19,4	24,4	52,6	23,0	77,0	4,7			
	C	78-110	4,1	17,0	28,7	50,2	21,1	78,9	5,0			
Sopot pr.5	Ap	0-19	2.6	22.6	22.4	52.4	25.2	74.8	6.5	38.7	22.7	16.0
	Avt	19-39	1.4	22.9	23.2	52.5	24.3	75.7	6.6	38.4	24.1	14.3
	Avt	39-59	2.1	23.1	23.2	51.6	25.2	74.8	6.3	38.8	23.0	15.8
V.Suvodol pr. 6	Ap	0-27	1.0	21.7	26.8	50.5	22.7	77.3	5.4	31.6	19.1	12.5
	Avt	27-47	0.8	20.3	25.2	53.7	21.1	78.9	5.7	32.9	20.3	12.6
	Avt C	47-67	1.2	21.4	27.5	49.9	22.6	77.4	5.5	32.4	19.9	12.5

T**able2** Chemical properties of calcareous Vertisol

Place	Horizont	Depth cm	$CaCO_3$ %	pH H_2O	pH KCl	Humus %	Total N %	Available P_2O_5 mg 100 g^{-1}	Available K_2O mg 100 g^{-1}	Y1 ccm	Adsorptive complex T-S meq 100 g^{-1}	S	T	V %
Vertisol on alluvium														
Pirot 3	Ap	0-10	6.34	7.80	6.90	4.01	0.26	13.0	26.5					
	Avt	10—35	2.54	8.00	6.90	3.40	0.20	4.4	21.1					
	Avt	40-67	5.92	8.00	6.92	3.21								
	Avt C	60-84	15.00	8.00	7.10	1.46								
Pirot 4	Ap	0-16	2.96	7.80	7.00	3.34	0.19	8.6	28.4					
	Avt	16-40	3.80	7.80	7.00	2.82	0.16	5.6	27.1					
	Avt	50-70	1.26	7.60	6.60	2.57				1.60	1.04	39.56	40.60	97.44
	Avt C	85-104	0.84	7.55	6.35	1.35				1.65	1.07	38.00	39.07	97.26
	C	104-130	9.30	7.90	6.90	1.04								
Vertisol on lacustrine Pliocene sediment														
Držina 10	Ap	0-20	1,2	7,58	6,70	3,62	0,18	4,89	33,72	5,00	3,25	40,40	43,65	92,55
	Avt	20-68	1,5	7,60	6,72	3,50	0,17	1,14	36,92	3,50	2,28	92,80	95,08	95,33
	Avt C	68-78	2,0	7,70	6,85	2,40	0,11	0,00	21,77	1,90	1,24	25,20	26,44	97,61
	C	78-110	3,85	7,85	7,02	0,76	0,08	0,00	18,54					
Sopot 5	Ap	0-19	2.51	7.80	6.80	3.20	0.17	4.1	26.4					
	Avt	19-39	1.25	7.80	6.60	2.34	0.12	<1	21.3					
	Avt	39-59	2.07	7.90	6.75	2.98	0.15	3.3	24.3					
V. Suvide l 6	Ap	0-27	2.50	8.00	6.85	3.34	0.18	14.6	>40.0					
	Avt	27-47	1.45	8.00	6.70	2.81	0.14	1.2	30.3					
	Avt C	47-67	2.49	8.05	6.85	3.04	0.17	5.2	37.5					

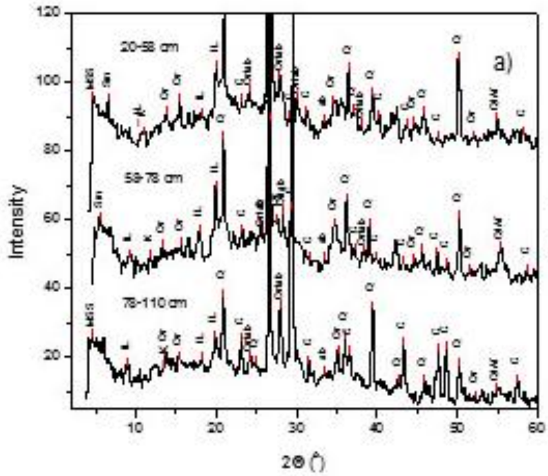

Fig. 2. X-ray diagram of the mineral composition of silt fractions, in the calcareous Vertisol in the Village – Držina (prof. 10)

The quartz content increases with depth. The content of calcite is also increased as evidenced by the intensity of reflections on the position 2.85 Å (Fig.2), which leads to an increase in $CaCO_3$content, base saturation (V%), and pH. With depth the content of feldspar (3.20 Å) is increased.

Mineralogical composition of clay fractions (<0.002 mm): in the clay fraction (<0.002mm) of profile 10 (Fig. 3), on Avt horizon (20-58 cm), the reflections were 14.49 - 27.61Å. After saturation with ethylene glycol (EG) the reflections were shifted to 17.67 - 29.46 Å, and after annealing at 550°C were 10,05-21,04Å. This change of position of the reflection corresponds to the content of smectite and MLS.

The second intensive reflection 10,53 Å after saturation and annealing remained at the same position of 10,05Å. Constant position of reflections, about 10Å, after all the treatments corresponds to illite. Reflection 7,14Å after saturation with EG doesn't change the position and after annealing showed a collapse corresponding to the content of kaolinite. Lower intensity was a reflection of 12,23Å expands and moves after saturation at 14,49 Å and after annealing restores of the 11.63 Å point to content of type smectite/clorite. With increasing the depth (58-78 cm) in AvtC horizon, the same minerals as in Avt horizon (MLS , smectite, illite, kaolinite) occurs, but there is a more mixed layered minerals, of smectite/illite and smectite/chlorite as pure chlorite.

At greater depths (78-110 cm) in C horizon, the MSL small amounts of smectite with a significant share of pure chlorite and MLS with chlorite, illite and kaolinite are dominated. This mineral composition is affected by the total absorption capacity (T), which would have been the biggest in the Avt horizon because of the highest content of smectite and (MLS) type of smectite/chlorite; and in the C horizont, due to the high (MLS) type of smectite/chlorite and smectite; and the lowest in Avt C horizont due to the presence of pure chloride and high contents of (MLS) with chlorite and also due to small amounts of smectite than in Avt horizont.

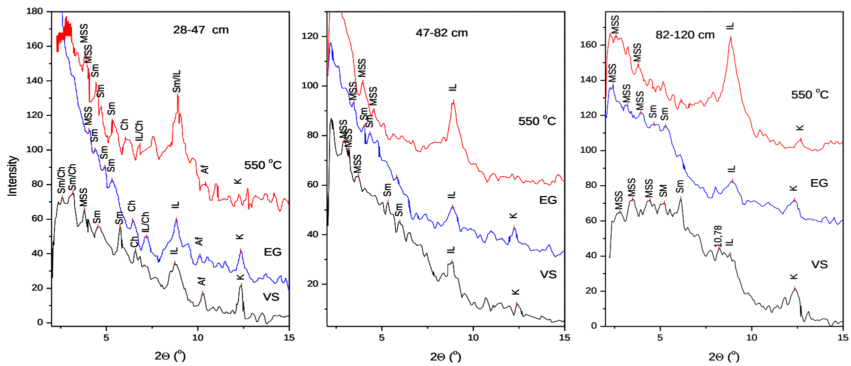

Fig. 3. The X-ray diagram of mechanical oriented samples of clay fractions, calcareous Vertisol, prof. 10, Držina

2. *Noncalcareous Vertisol*

This subtype of noncalcareous Vertisol, usually follows calcareous subtype and alternately rotate in the same area, south of the villages Petrovac in Pirot, Poljska Ržana and D. Držina.

Noncalcareous Vertisol was formed by transformation under increased hydration and leaching, so carbonates of Vertisol retained only in the substrate.

Morphological properties on noncalcareous subtype of Vertisol, is similar to the calcareous subtype. Black color (5YR 2,5/1), and heavy clay composition of humus accumulative Avt horizon.This subtype does not contain carbonates, because they are washed out. Stability of structural aggregates is disrupted resulting in deteriorating physical properties (soil permeability (K_F-Darssy), the density and plasticity). Mixed AvtC horizon is brown color (5YR 3/3) contain carbonates, but in much fewer than in C horizon (Fig. 4).

Hor.Ap (0-20cm). Black color (5YR 2,5/1). Textural composition is the clay, polyedric structure. The reaction of the lime is negative. Transition is gradually to,

hor.Avt (20-94cm). Black color (5YR 2,5/1), clay textural. In dry state very hard and compact. The structure is coarse prismatic to columnar with large cracks. The reaction of the carbonates is negative. In wet state is very sticky and plastic. Transition to,

hor.Avt C (94-113cm). Brown color (5YR 3/3) Vertic horizont mixed with the calcerous substrate C, clay composition. Reaction on the carboneit is the positive. Clear transition to,

hor.C (113-120cm). Light brown-yellow color (5 YR 4/6), texture is clay-loam, very calcareous.

Fig. 4. Morphological description of noncalcareous Vertisol, prof.1 in Poljska Ržana

Mechanical composition of the noncalcareous Vertisol (tab. 3) is very heavy, and the most common is clay fractions (from 42.1% in C to 61.1% in Avt horizons).

The next spread fraction is fine sand: in Avt horizon is 19.5-25, 8%. Exceptions is profile 1 in Poljska Ržana, where silt is the second and fine sand is the third fraction. Fraction of coarse sand has a negligible share in the mechanical composition of this soil, ranging between 2.6-7.7% in Avt horizon; while the highest amount, 12.3% was observed in the C horizon in Poljska Ržana (Prof. 1).

Unfavorable hydro-physical properties *(*tab. *3)* of this soil caused by the dominance of hydrophilic group in clay minerals, with very mobile lattice, and the possibility of swelling, which leads to the formation of the slickensides and gilgaj micro relief.

Hygroscopic moisture (4.4-7.4%) indicates the presence of hydrophilic montmorillonite. Total porosity is too high (44.0-55.0%), while the FWC ranges from 29.9 to 37.4%. The WP is 17.9-27.7%;

WAP is very little-9.7-13.6%. These soils are poorly permeable, Kf $=10^{-4}$-10^{-7} cm sec^{-1}. After heavy rain an waterlogging is occurs.

Chemical properties of noncalcareous Vertisol (table 4). Noncalcareous Vertisol during the acidification process lost free carbonate, so CaCO3 found in substrate C, from 1.5 to 6.3%. Soil acidity is the lowest in arable Ap horizon, from which the carbonates was leached to the lower horizonts, so pH in H_2O is 6.15 - 7.3, and in nKCI-in is 5.41- 6.2. Hydrolytic acidity (Y) has low values in the Ap and Avt horizons, of 3.27 – 13.6. Adsorbtive complex is highly saturated with bases, and the percentage of saturation (V%) ranges from 81.9 to 93.0%.

Humus content in humus-accumulative Avt and Ap horizons is from 2.08 to 4.40%. Total nitrogen (N) follows the distribution of humus and is highest in surface Ap horizon (0- 20 cm) - 0,14 - 0.21 %. Available phosphorus (P_2O_5) in Ap horizon is from < 1.0 to 17.5 mg 100 g^{-1} of soil. Available potassium (K_2O) is from medium to the high values-18.6-40.0mg 100 g^{-1} of soil.

3. Brownised Vertisol

This subtype of Vertisol formed on Pliocen lacustrine clay substrate. The locations where it found are Barje, M. Jovanovac and Sukovo. Brownised Vertisol usually was formed on gentle slopes and drainage fields, on warmer south or south-west expositions. The rapid acidification processes lead to the formation of a new clay minerals (argilogenesis), particularly notable in Bvt horizon. Mineralization of organic matter at the Avt horizon changed the typical blak color (5yr 2,5/1) to dark-brown color (5 yr 3/2). And iron oxide in the lower part at the Avt horizon resulted in the beginning of differentiation of profile, and formation of (B)vt horizon of reddish-brown (5yr 3/4), heavy clay composition, prismatic structure and slikensides.

Mechanical analysis of brownised Vertisol differs from the previous subtypes, because the clay fraction of Bvt horizon reach up to 68.1 %, leading to a deterioration of water- physical properties, reducing soil permeability, enhancing plasticity, specific gravity and weight, as well as the density of Bvt horizon (Tab. 5).

Table 3. Water - physical properties of noncalcareous Vertisol

Place	Horizon	Depth cm	Coarse sand (>0,2mm) %	Fine sand (0,02-0,2mm) %	Silt (0,002-0,02 mm) %	Clay (<0,002 mm) %	Total sand % (>0,02 mm)	Total clay (<0,02 mm) %	Hygroscopic moist.%	FWC Field water capac.%	WP– Wilt.point %	WA - Water av. %
Vertisol on lacustrine Pliocene sediment												
Petrovac pr.7	Ap	0-20	5.0	24.1	22.4	48.5	29.1	70.9	5.4			
	Avt,	20-40	3.8	19.5	15.6	61.1	23.3	76.7	6.7			
	Avt	40-60	3.4	19.9	16.8	59.9	23.3	76.7	7.4			
	Avt	60-80	2.6	20.3	18.2	58.9	22.9	77.1	6.9			
	Avt C	80-105	3.7	20.5	20.0	55.8	24.2	75.8	6.4			
	C	105-120	5.8	19.8	21.8	52.6	25.6	74.4	6.1			
Vertisol on alluvium												
Polj. Ržana pr.1	Ap	0-20	7,30	23,3	26,0	43,4	30,6	69,4	5,3			
	Avt,a	20-94	5,40	20,3	23,4	50,9	25,7	74,3	6,1			
	Avt C	94-113	5,80	21,5	21,6	51,1	27,3	72,7	5,5			
	C	113-120	12,3	20,8	24,8	42,1	33,1	66,9	4,8			
Polj. Ržana pr.2	Ap	0-27	4.4	25.0	25.1	45.5	29.4	70.6	4.4	29.9	17.9	12.0
	Avt	27-47	7.7	25.8	20.6	45.9	33.5	66.5	4.7	30.9	19.5	11.4
	Avt	47-77	4.4	25.0	16.3	54.3	29.4	70.6	6.6	37.4	27.7	9.7
	Avt C	77-98	4.4	25.0	16.3	54.3	29.4	70.6	6.6	37.4	27.7	9.7
	C	98-120	4.5	24.7	20.3	50.5	29.2	70.8	5.1	35.2	21.6	13.6

Table 4. Chemical properties of noncalcareous Vertisol

Place	Horizon	Depth cm	$CaCO_3$ %	pH H_2O	pH KCl	Humus %	Total N %	Available P_2O_5 mg/100g	Available K_2O mg/100g	Adsorptive complex Y1 ccm	T-S meq/100g	S meq/100g	T meq/100g	V %
						Vertisol on alluvium								
Petrovac pr.7	Ap	0-20	0,00	7,30	6,20	3,23	0,14	<1,0	24,6	4,10	2,66	35,24	37,90	93.0
	Avt	20-40	0,00	6,70	5,40	2,64	0,10	<1,0	27,1	9,09	5,91	35,60	41,51	85,8
	Avt	40-60	0,00	6,40	5,15	2,57				9,75	6,34	34,84	41,18	84,6
	Avt	60-80	0,00	7,05	5,90	2,37				13,6	8,86	39,96	48,82	81,9
	Avt C	80-105	2,10	7,85	6,75	1,85								
	C	105-120	6,31	8,35	7,15	0,89								
Polj. Ržana pr.2	Ap	0-27	0,00	6,50	5,50	2,92	0,15	1,7	21,1	7,80	5,07	29,68	34,75	85,4
	Avt	27-47	0,00	6,80	5,70	2,26	0,09	<1,0	24,3	5,26	3,42	31,08	34,50	90,1
	Avt	47-77	0,00	7,40	6,00	2,08				4,28	2,78	37,00	39,78	93,0
	Avt C	77-98	0,00	7,50	6,10	1,76				3,46	2,25	37,80	40,05	94,4
	C	98-120	0,00	7,55	6,10	1,38				3,47	2,25	38,47	40,65	94,5
						Vertisol on lacustrine Pliocene sediment								
Polj. Ržana pr. 1	Ap	0-20	0,00	6,15	5,41	4,40	0,21	17,5	29,7	5,50	3,58	31,2	34,78	89,7
	Avt	20-94	0,00	6,60	5,62	2,90	0,12	0,0	19,3	3,27	2,13	36,4	38,53	94,5
	Avt C	94-113	0,00	6,65	5,70	1,30	0,08	0,0	18,7	2,60	1,69	37,6	39,29	95,7
	C	113-120	1,50	7,70	6,89			0,0	14,1					

Hor. Ap (0-28cm). Dark-brown color (5 YR 3/2), lumps structure. In wet condition is very sticky and very hard, non-carbonat. Transition to,

hor.Avt (28-47cm). Humus-accumulative, vertic horizon, dark-brown color (5YR 3/2), clay, prismatic structure, non-calcareous . Transition to,

hor.(B)vt (47-82cm). Cambic and very chear, vertic horizon, reddish-brown color (5YR 3 / 4) prizmatic structure, with clear sliken sides , noncalcareous, gradually giving way to,

hor.(B)vt C (82-120cm). Reddish-yellow color (5 YR 4/6) cambic horizon mixed with subhorizon (Pliocene clay), heavy clay, noncancerous.

Fig. 5 Morphology of brownised Vertisol – profile 3, the village Sukovo

Hydro-physical properties of brownised Vertisol. Hydro-physical properties of the brownised Vertisol is in accordance with their extremely heavy texture. Destruction of structure, acidification, leaching of $CaCO_3$ and organic matter, directly led to a deterioration of almost all the hydro-physical characters (permeability, a bulk desitiy , total porosity, hardnes, hygroscopic moisture values, and other water constants) (Tab. 5).

Hygroscopic moisture depends on the amount of clay in the soil and increases with depth. Hygroscopic moisture of the surface Avt, horizon is 4.1- 5.8 %, and in (B)vt horizon, 5.5-7.6 %. Field water capacity (FWC) and wilting point (WP) are high. It has heavy texture and small amounts of physiologically available water.

Chemical properties of brownised Vertisol (table 6) are similar to noncalcareous Vertisol. Process of acidification is more pronounced and soil pH is lower; the hydrolytic acidity (Y) is higher, while base saturation is lower.

Table 5. Water - physical properties of brownised Vertisol

Place	Land use	Horizon	Depth cm	Coarse sand >0,2mm	Fine sand (0,02-0,2mm) %	Silt(0,002-0,02 mm) %	Clay (<0,002 mm) %	Total sand (>0,02 mm) %	Total clay (<0,02 mm) %	Hygros. moisture %	FWC - Field water cap.%	WP– Wilt. Point, %	WA- Water avail. %
						Brownised Vertisol on Pliocene sediment							
M.Jovanovac pr.8	orchard	Avt	0-22	3.9	25.4	25.2	45.5	29.3	70.7	4.1	25.2	15.8	9.4
		(B)vt	22-48	2.1	17.4	12.6	67.9	19.5	80.5	7.4	40.8	26.6	14.2
		(B)vt	48-60	1.9	17.7	12.3	68.1	19.6	80.4	7.6	44.1	27.8	16.3
		C	60-85	3.7	17.3	21.9	57.1	21.0	79.0	5.9	36.7	22.8	13.9
Sukovo pr. .3	arable land	Ap	0-28	11,1	26,5	27,9	45,8	33,3	66,7	4,3			
		Avt	28-47	10,5	22,8	20,9	56,2	25,9	74,1	5,8			
		(B)vt	47-82	6,0	19,9	17,9	50,9	29,3	70,7	5,5			
		(B)vt C	82-120	6,8	22,5	19,8	47,2	33,7	66,3	5,0			

Table 6. Chemical properties of brownised Vertisol

Place	Horizon	Depth cm	$CaCO_3$ %	pH		Hums %	Tot. N %	Available			Adsorptive complex			
				H_2O	KCl			P_2O_5 mg/100g	K_2O mg/100g	Y1 ccm	T-S meq/100g	S meq/100g	T meq/100g	V %
						Brownised Vertisol on Pliocene sediment								
M.Jovanovac pr.8	Avt	0-22	0.00	5.50	4.62	3.22	0.13	<1.0	23.1	14.5	9.4	23.8	33.18	71.61
	(B)vt	22-42	0.00	5.30	4.10	1.64	0.06	<1.0	26.7	18.8	12.2	32.4	44.63	72.69
	(B)vt	42-60	0.00	5.85	4.40	1.67				13.9	9.0	32.4	41.46	78.24
	C	60-85	10.14	8.00	7.10	1.15								
Sukovo pr. 3	Ap	0-28	0,0	6,30	5,35	3,35	0,14	<1,0	15,7	6,5	4,2	21,6	25,83	83,64
	Avt,	28-47	0,0	6,52	5,51	3,15	0,12	<1,0	16,9	5,2	3,4	26,8	30,21	88,71
	(B)vt	47-82	0,0	6,54	5,80	2,50	0,09	<1,0	22,9	4,5	2,9	34,0	36,95	92,01
	(B)vt C	82-120	0,0	6,80	5,88	2,00	0,07		16,7	3,0	1,9	33,6	35,55	94,51

Acidity in nKCI in Ap horizon is from acid to slightly acid, 4.62 - 5.35; in water 5.5 - 6.30. With depth, soil pH increases being highest in the substrate. Base saturation in Ap horizon is slightly lower, 71.61 – 83.64%, increasing with depth: in Bvt horizon 72.69 – 92.01%.

Humus content in Ap horizon is 3.22 to 3.35 %. Compared to other two subtypes of Vertisol, this is a smallest amount of humus. Available nitrogen in Ap horizon is small to medium 0.13 % - 0.17%, which is in direct proportion with the amount of humus. Available P_2O_5 is low, < 1.0 mg 100 g^{-1}. Available K_2O is 15.7 to 23.1 mg 100 g^{-1}.

Mineralogical composition of brownised Vertisol, profile 3, Sukovo

Mineralogical composition of silt (0.02-0.002 mm). Mineralogical composition of the soil (profile 3) differs both qualitatively and quantitatively for certain minerals. XRPD analysis showed similar content of quartz (4.26, 3.35, 2.46, 2.28Å) and potassium feldspar, feldspar (5.64, 3.87, 3.47... Å), albite (4.03, 3.19, 2.93, 2.86, 2.08Å). However, the brownised Vertisol contains significant amounts of amphibole and hornblende (8.40, 4.51, 2.71, 2.54 ... Å), while calcite content was not determined. The secondary phyllosilicates in the brownised Vertisol are similar as in profile 10: MLS, smectite, illite/muscovite with minor amounts of kaolinite, etc.(Fig. 6). Quartz content is slightly higher than in the calcareous Vertisol decreasing with depth whereas the MLS is increasing. It is significant that the content of amphibole increases with depth. In Avt horizon (47-82 cm) there is a significant transformation of feldspar and albite into phyllosilicates, which can lead to less increasing of CEC in comparison to other depths.

Mineralogical composition of clay fraction (<0.002 mm). In Avt horizon (28-47 cm) the content of reflection is 15,50 - 33,96Å. After saturation with EG the reflections were shifted to 16.67-35.34 Å , after annealing at 550°C it returned to 9.94-25.99Å. This change of position of the reflection corresponds to the content of smectite and montmorillonite and MLS (Fig. 7).

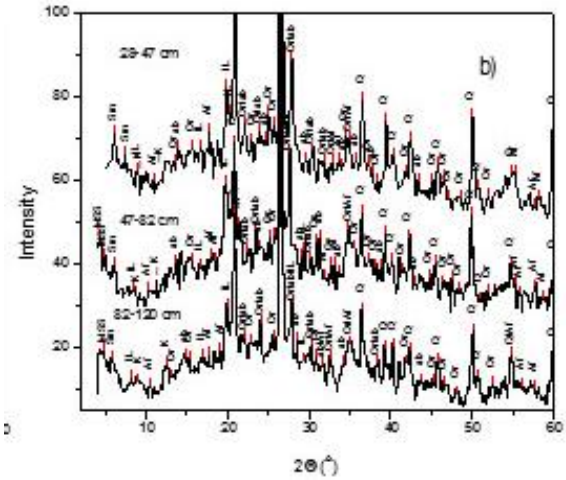

Fig. 6. X-ray diagram of the mineral composition of the brownised Vertisol, profile 3 in Sukovo

Width and intensity of other reflections on 10.16Å after saturation and after annealing remains in the same position, 9.94 Å. Constant positions of reflections about 10Å after all the treatments correspond to illite. Reflection on 7.14Å after saturation with EG didn't change the position and after the annealing showed collapse related to the content of kaolinite. Less reflection at about 14.20Å, which remains unchanged after the treatment indicates on the chlorite. Lower intensity is a reflection of 12,28Å is moved after saturation to 14,49Å, and after the annealing it was restored to 11.63Å, which points out to the presence of MLS of smectite/chlorite type.

In the (B)vt horizon (47-82 cm), the same minerals as in Avt horizon (MLS), montmorillonite, illite, kaolinite) were found, but there is more mixed layered minerals, of smectite/illite types and smectite/chlorite illite/chlorite as a pure chlorite. The content of montmorillonite and MLS smectite/illite type and smectite/ chlorite, certainly increases the CEC with depth, compared to the profile 10 in Držina. At greater depths of 82-120 cm, in (B)vt C horizon, the MLS, small amounts of montmorillonite, with significant participation of chlorite and MLS with chlorite, illite and kaolinite dominate.

The above composition of minerals is affected by the total absorption capacity (T), which would have been the biggest in (B)vt horizon, the highest content of montmorillonite and MLS smectite/chlorite, and smectite/chlorite type. In mixed (B)vtC horizon, due to the high content of smectite/illite, smectite/chlorite and montmorillonite, and the smallest content in Avt horizon, due to a higher content of kaolinite and chlorite and low content of montmorillonite and higher content of MLS with chlorite.

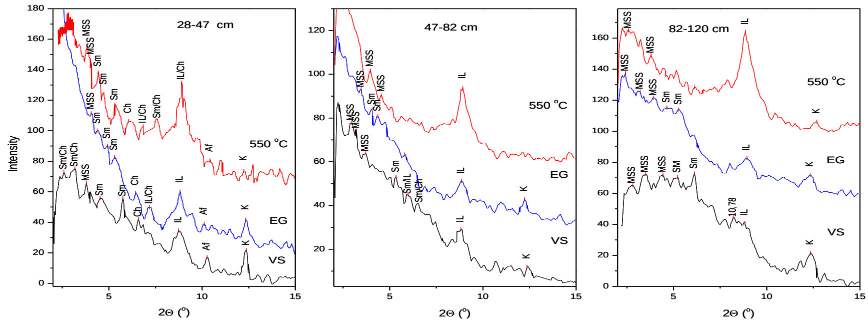

Fig. 7. The X-ray diagram of oriented samples of clay fractions , brownised Vertisol, profile 3 in Sukovo

CONCLUSION

In the valley of Pirot, Serbia three subtypes of Vertisol were found: calcareous, non-calcareous and brownised. They were analyzed for chemical, mineralogical and water- physical properties.

The parent material and relief played a dominant role in creating a given subtypes of Vertisol, as well as other factors such as climate, slope, relief, vegetation, and human activity.

Physicochemical processes in the soil are significantly intensified due to the increase in flow of water from the slopes that carries particles of colloidal clay into the lower parts of the valley. Increased amount of colloidal clay led to the intensification of argillogeneze, acidification and leaching of $CaCO_3$. The texture of studied Vertisols were heavy clay.

Comparison of morphology, physical and chemical properties and mineralogical composition, showed that calcareous Vertisol has the best features and structure, and thus has best soil fertility.

In non-calcareous Vertisol, acidification and the loss of $CaCO_3$ from soil profile causes destruction of soil structure and deterioration of physical and chemical properties, and thus loss of soil fertility.

Brownised Vertisol has much poorer properties due to the acidification of soil and the total loss of carbonate, which led to the destruction of soil structural and a significant reduction in fertility. Mineralogical analysis of calcareous and brownised Vertisol showed the direction of changes for certain minerals, which greatly corresponds with the morphological, physical and chemical changes in given subtypes. There was detected mineral calcite, quartz, muscovite, alkali feldspar, plagioclases and small amounts of amphibole.

The difference in mineral composition between these two subtypes of Vertisol is reflected in the content of calcite, which is absent in brownised Vertisol, as well as quantitative and qualitative presence of certain clay minerals from smectite (montmorillonite) groups.

In the colloidal clay composition of both Vertisol subtypes, minerals with the three-layer lattice, of smectite (montmorillonite) type was dominated. Illite was the second in representation of given Vertisol subtypes.

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PHOSPHORUS REGIME OF DARK CHESTNUT SOILS IN WEST KAZAKHSTAN

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ABSTRACT

Chestnut soils are formed in dry-steppe zone of West-Kazakhstan in the conditions of water deficiency. The calcium carbonate present in this soils sometimes from the surface, immobilizes the plant-available phosphorus. In Chestnut soils of dry-steppe there are not significant amount of total phosphorus and very low amount of available phosphorus. Application of phosphor mineral fertilizer the calcium carbonates results in transformation of mono-substituted forms of phosphorus into double- and triple-substituted forms of phosphates.

Keywords: soluble phosphorus, total phosphorus, fractional composition of phosphorus, phosphorus pool, phosphorus supply.

INTRODUCTION

Chestnut soils are zonal soils dry steppe zone. In the West Kazakhstan region they are the main soil type of agricultural and arable land. On these zonal soils in Kazakhstan there are cultivated the most valuable varieties of hard wheat, corn and other crops. In the last 20-25 years, large areas of arable soils transformed into fallow land. More than 50% of arable soils are in long-fallow state, so the study of this problem in the region remains one of the most pressing.

In recent years, much attention was paid to changes in the composition, properties and fertility of chestnut soil under long-term agricultural use. However, fallow soil that previously for a long time had been in the rotation was not studied well.

We carry out the research within the research project funded by the Ministry of Education and Science of the Republic of Kazakhstan "Fertility of fallow soil in dry steppe zones of the Ural and the way his recovery". The study was conducted on the territory of "Aschesay" district of West Kazakhstan region.

Phosphorus is an essential macronutrient element which has been observed to limit crop productivity. It is no coincidence it was called the "key of life" as it most directly involved in life processes, and is a component of plant cell (Amaizah, *et al.*, 2012). More than 90% of total phosphorus is present as insoluble forms (Mengel and Kirkby, 2001; Busman *et al.*, 2002).

Digestibility of P compounds depends on the availability of soil water and air, on the contents of other elements, on the properties of plants, phase of development, and many other factors. In plant nutrition is the most important factor in the plant itself, i.e. its biological features. Therefore, plants in relation to the supply of soil nutrients are divided into three groups: the crop of low nutrient removal - cereals, legumes, flax, perennial grasses; crops of increased removal - root vegetables and potatoes; crops of high removal - vegetables, fruit and technical crops. The aim of this work is to study the fertility of fallow soil, determination of nutrition elements and their stocks.

MATERIALS AND METHODS

Analytical work was carried out in accordance with GOST 26107-84 and 26205-91. Total phosphorus was determined in accordance with GOST 26107-84. This standard specifies a method for determination of total phosphorus in soils of natural and disturbed state. Soil sample is air-dried, milled, passed through a sieve with round holes of diameter 1-2mm, well mixed and distributed on a flat surface with a layer thickness of not more than 1 cm. Soil digestion is conducted by treatment with sulfuric acid and according to Ginzburg method: the soil was wetted with a few drops of distilled water and 8 ml of concentrated sulfuric acid and 0.5 - 0.8 ml of a solution with a mass fraction of 50% perchloric acid. Then after 1 hour the sample is heated till boiling. The digestion continued until the solution above soil sediment becomes colorless. After complete digestion the sample is cooled in 20-30 ml distilled water added and diluted to 200 or 250 ml, followed by filtration. The filtrate is analyzed for phosphorus by photometric method.

Determination of phosphorus by phosphorus-molybdenum blue method: The method is based on the formation of phosphor-molybdenum-vanadium hetero-poly-acid after extraction of phosphorus with ammonium with iron hydroxide. From hydrochloric filtrate obtained after decomposition an aliquot of the solution is diluted with distilled water and mixed with coloring molybdenum antimony staining reagent. The absorbance of the colored solution is measured relative to the zero of the solution at a wavelength of 650 nm and above.

Determination of available phosphorus by Machigin method (GOST 26205-91): The method is based on the extraction of mobile phosphorus and potassium compounds from the soil with a solution of ammonium carbonate at a concentration of 10 g/dm3 with soil to solution ratio 1:20, and the subsequent determination of phosphorus as phosphorus molybdenum blue complex by photoelectrocolorimeter.

RESULTS AND DISCUSSION

Soil profiles were laid on the virgin and fallow (ex-plow land) plots.

Profile No. 1. Land-use- virgin (control)

Projective cover – 60-65%
The surface is smooth, with slight slope to the north-east.
Macrorelief: Caspian Depression
Mesorelief: undulating plain
Microrelief: Micro-depressions
Effervescence is weak - from 27cm.

A_1(0,5-18)	Dark gray, heavy loam, lots of roots, dry, fragile-lumpy structure, compacted, no effervescence, the transition marked by the structure
B_1(18-40)	Gray, heavy loam, single plant roots, dry, prismatic-nutty structure, dense, with a slight effervescence from 27 cm, a transition marked by color
B_2(40-61)	Pale yellow, heavy loam, few roots, dry, prismatic-nutty structure, very dense, vigorous effervescence, distinct transition in color
$B\kappa$(61-100)	Pale yellow, heavy loam, carbonates in the form of lime nodules, vigorous effervescence, large-prismatic structure, dense.
Soil type:	Dark chestnut moderately deep heavy-loam soil.

Profile No. 2. Land-use: fallow (for 19 years)

The fallow in good condition, the surface is smooth, with a weak bias in the north-east.
Macrorelief: Caspian Depression
Mesorelief: undulating plain
Microrelief: Micro-depressions

A_1(0-23)	Dark gray, heavy loam, lots of roots, dry, fragile-lumpy structure, compacted, slight effervescence from surface, transition is gradual by color, noticeable by density.
B_1(23-37)	Gray, heavy loam, many roots, dry, prismatic-nutty structure, dense, vigorous effervescence, distinct transition in color and density.
B_2(37-57)	Brown, heavy-loam, few roots, dry, prismatic-nutty structure, very dense, vigorous effervescence, distinct transition in color.
Bк(57-100)	Pale yellow, heavy loam, few roots, dry, carbonates in the form of lime nodules, nutty-coarse-prismatic structure, dense, vigorous effervescence.
Soil type:	Dark chestnut moderately deep heavy-loam soil.

Assimilation of P compound depends on the availability of soil water and air, the contents of other elements, on the properties of plants, the phases of their development and many other factors (Steven C. Hodges 1996). In plant nutrition the biological features of plant is the most important factor. Therefore, by nutrition requirements plants are divided into three groups: the crops of low nutrient removal - cereals, legumes, flax, perennial grasses, and crops of increased removal - root vegetables and potatoes; culture of high removal - vegetables, fruit, and industrial crops. Availability of plant available phosphorus (Machigin method) compounds is shown in Table 1.

Table 1. Supply of plant available phosphorus (mg of P_2O_5) by Machigin method

Availability	Cereals	Root-vegetables	Vegetables
Very low	<1.0	<1.5	<3.0
Low	<1.5	3<.0	<4.5
Medium	1.5-3.0	3.0-4.5	4.5-6.0
High	>3.0	>4.5	>6.0

Basic data on the content of mobile phosphorus in soils under study are presented in Table 2. The table shows that the content of total forms of phosphorus in humus-accumulative horizon of virgin dark chestnut soil is 0.1200%. At a depth of 18-40cm it is slightly decreasing with depth and then again increased to 0.1285%.

The content of total phosphorus in the soil is low. We calculated the total phosphorus reserves by genetic horizons. Since the total phosphorus content is low. the amount of total phosphorus is also low. Pool of phosphorus do not exceed 4.29 t ha^{-1}. ranging in the profile of the studied soils between 2.84 and 4. 29 t ha^{-1}.

To comparative characterization of phosphorus regime we calculated the stocks of total phosphorus in the layer 0-20 and 0-50cm. Stock of total phosphorus in the layer 0-20cm was 6.02 t ha^{-1}. and in the 0-50cm layer was 8.45 t ha^{-1}.

In the dry steppe zone with a lack of moisture the calcium carbonates lie quite high. This calcium carbonate contributes in the transition of mobile phosphorus from mono-substituted forms into two and tri-substituted forms of phosphorus.

As can be seen from Table 2 the contents of mobile phosphorus compounds derived by the method Machigin is very low. In the A_1 horizon the content of available phosphorus is 14.2 mg kg^{-1} soil. while dramatically decreasing with depth. In accordance with various content of P in the study dark chestnut soils there are generated dissimilar stocks of P in the total layers. Stock of available phosphorus was 335.5-107.0 kg ha^{-1}. Stocks of mobile phosphorus in the 0-20 cm and 0-50cm layer were 432.7 and 499.2 kg ha^{-1}. respectively.

The share of available phosphorus of the gross phosphorus in the virgin dark chestnut soil was 11.8% in the upper horizon; in the subsurface horizon the share of total phosphorus was reduced to 2.6-3.0%. Unlike virgin dark chestnut soil on the long-fallow plot the amount of total phosphorus was higher both in the upper and the lower horizons. In the profile of fallow dark chestnut soil the content of total phosphorus ranged from 0.1345 to 0.1600%. with the maximum at depth 23-37 cm.

This is most likely due to the fact that arable soil have been earlier fertilized with phosphate. The soil was plowed to a depth of 22-25 cm so the soil well moistened to this depth. And the part of fertilizer was used by plants. and the rest was associated with the mineral part of the soil. Calcium carbonates occur at a depth of 30-35cm with the line of effervescence from 10% HCl at a depth of 25-30cm. Therefore. we observed binding of the mobile forms of phosphorus. This is confirmed by the amount of available phosphorus in the soil profile of fallow land. In the A_1 horizon amount of available phosphorus was 16.3 mg kg^{-1} soil, sharply reducing with depth to 9.4 mg kg^{-1} of soil.

Table 2. Content of available phosphorus and its stock in the dark chestnut soils

Horizon	Depth, cm	P_2O_5., %	Stock of total P, t ha^{-1}	The content of mobile P, mg kg^{-1}	Stock of mobile P, kg ha^{-1}	The degree of mobile P compounds, % of total
Dark chestnut soil (virgin)						
A_1	0.5-18	0.1200	2.84	14.2	335. 5	11.8
B_1	18-40	0.1115	3.51	6.3	107.0	3. 0
B_2	40-61	0.1285	4.29	3.4	113.5	2.6
	0–20		6.02		432.7	7. 2
	0–50		8.45		499.2	5.9
Dark chestnut soil (fallow)						
A_1	0-23	0.1345	4.55	16.3	551.1	12.1
B_1	23-37	0.1600	3.49	9.0	196.6	5.6
B_2	37-57	0.1400	4.42	4.1	129.6	2.9
	0–20		4.99		280.8	5.6
	0–50		10.92		831.9	7.6

Unlike virgin dark chestnut soil on the long-fallow variant the stocks of mobile P was higher - 129.6-551.1 kg ha^{-1}. Maximum stocks are characteristic of the uppermost horizon. In 0-20 cm layer the mobile phosphorus reserves were 280.8 and in the 0-50 cm 831.9 kg ha^{-1}. The share of gross mobile phosphorus in the fallow soil ranged from 2.9 to 12.1%.

The maximum proportion of available phosphorus is characteristic of the upper humus-accumulative horizon. Speaking of stocks of total phosphorus it should be noted that 20 cm layer the stocks decreased by 1.03 t ha^{-1} or 17.11%. In the 50 cm layer there were detected an increase in stock of P by 2.47 t ha^{-1} or 29.23%.

Stocks of available phosphorus also showed changes. In the 0-20cm layer the reserves of available phosphorus decreased by 151.9 kg ha^{-1} or 35.11%; and in the 0-50 cm layer its amount increased by 332.7 kg ha^{-1} or 66.64%.

Thus, we have detected that during transformation of arable lands into fallow state the phosphorus regime of soils undergoes changes. The amount and stock of phosphorus in upper 20 cm soil layer decrease for 17-35%. On the deeper layers the stock of mobile phosphorus increased for 66-99%.

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APPLICATION OF GIS IN CREATING INFORMATION SYSTEM FOR FOREST ECOSYSTEM MANAGEMENT IN BELGRADE

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Forest management integrates various activities of planning and management of forest resources and the related ecosystems. At its current level of development and complexity, it is hard to imagine forest management without the application of GIS. The need of forestry profession for quicker, more reliable and more economic method of collection and processing of spatial data for the purpose of more quality and easier management of forest resources imposes a need for developing a uniform methodology for the use of Geographic Information System (GIS). Intense industrialization, urbanisation, transportation development and the resulting changes to the lifestyle of modern people which, *inter alia*, imply higher and increasingly complex requests imposed on forests, confront traditional forestry with a need for changes, particularly in urban areas. According to the UN estimations of 1977, it is expected that more than 60% of the world's population will live in towns by 2030. Therefore, this paper presents the procedures and methods for GIS application in the development of information basis for management of forest ecosystems in the territory of the city of Belgrade. Out of the total territory of Belgrade, 15.7% is covered by forests. The preparation of plans and management is very complex due to the complexity of the requirements imposed on these forests and due to the need for their adjustment, avoidance of conflicts and functional durability. The preparation of planning documents is performed in three phases: preparatory works (control and updating of cadastral data, preparation of working maps, etc.), field work (spatial division of areas under forests, collection of qualitative and quantitative information about the site and forests within units resulting from such division) and office

work (computer data processing, analysis, preparation of management plans and preparation of thematic maps). In current conditions, it is impossible to imagine a successful implementation of these phases without an adequate and proven application of the GIS technology.

*Keywords***:** forest ecosystems, Belgrade, planning, management, GIS

INTRODUCTION

Forests are dynamic resources which change intensively under the influence of numerous environmental factors and management interventions. Along with these changes, the requirements imposed on forests and benefits they provide become qualitatively and quantitatively complex, which poses a complex challenge before planning, management and administration of forest ecosystems, in terms of permanent provision for these needs of the modern society. In the process of addressing extremely complex tasks, forest management planning nowadays relies increasingly on information and GIS technologies. Most of the work related to preparation of planning documents in forestry is based on spatial data. Until the end of the 20th century, almost all spatial data in forestry of Serbia had been presented on analogue maps (topographic maps, thematic maps, stands maps). However, given the increasing requirements for various types of information and the need for their appropriate processing, storing and use, it is hard to imagine successful management of forests and forest resources nowadays without an adequate use of information and GIS technologies. GIS can be considered as a set of functions which offers advance opportunities for storing, searching, handling and presenting spatially located data. This created an opportunity for a huge amount of information and spatial data, which are characteristic of forestry, to be integrated into a single unit. Handling of updated and quality information about growing stock is easier, inquiries are more efficient, and drawing conclusions is more reliable. The development and introduction of GIS technologies has given spatial meaning to, so to speak, non-spatial data. Consequently, spatial information, in more specific terms, has been given new meaning and treatment.

Due to prominent multifunctionality, forest administration and management in the territory of the city of Belgrade is very complex, complicated and, when it comes to state forests, it is entrusted to PE Srbijasume, PUC Zelenilo, PE Ada Ciganlija and PE Srbijavode.

High coverage of areas and indentation of forests of the city of Belgrade require the establishment and implementation of geographic-information system, which would, *inter alia*, create conditions for more quality, more complex and sustainable use of the city's natural potentials. This would facilitate the establishment of a uniform database on sites, potential forest communities, represented forest types, tree species (particularly rare and endangered species), biotopes, habitats, information relevant for forest protection, information about natural and cultural monuments, tourist facilities, roads, hiking trails and other important facilities in forest ecosystems. One of the main preconditions for the establishment of such a uniform information system is to define and collect relevant qualitative and quantitative information (including spatial data) about forest ecosystem of Belgrade in accordance with the uniform methodology. In addition, other components, such as hardware and software (forestry applications) are also important parts of the information system. Exact general and special methods – geodesy, dendrometry, statistical and mathematical methods, and systematic sensing (Medarevic, 2006) are used for collecting and analyzing the necessary information.

Quality and reliable information and documentary base creates a starting point for the preparation of planning documents. The types of information, permitted level of errors, planning documents, their appearance, contents and method of preparation are defined in detail by the Rulebook on the Contents of Forest Management Plans and Programmes, Annual Operational plan and Interim Annual Management Plan for Private Forests (*Official Gazette of the Republic of Serbia 122/03 of 12.12.2003)*. The preparation of planning documents takes place in several phases: *a) preparatory works*, including preparation of work maps based on the cadastral plan, list of parcels, ownership and appropriate orthophoto images, and measurement design; *b) field works* include field survey, geodetic surveys, securing of external borders of the forest complex and inner distribution of space, tree measurements (diameter, height, etc.) and *c) office work* including processing, analysis and presentation of results in the form of tabular and textual sections of planning documents. Forestry has clearly prominent spatial and time components, whose proper overview is only possible by using GIS, which allows us to establish links and search for relations between spatial and numerical data from the abovementioned phases. Having in mind the need of forestry profession for efficient use of spatial data on one hand, and a large volume of information it holds on the other hand, there are solid grounds for the development of a modern geographic-information system for the city of Belgrade. The subject and aim of the research are defined in line with the above considerations. The subject of the paper are procedures and methods of application of GIS in creating information base about forest ecosystems of the city of Belgrade aimed at reviewing possibilities for its practical application in forest management planning.

MATERIAL AND METHODS

Subject of research. The territory of the city of Belgrade is divided into 17 urban municipalities. Belgrade covers more than 3.6% of the territory of the Republic of Serbia. The city is located at the mouth of large rivers Dunav and Sava and consists of two geographically different units. Plains are located north from Sava and Danube, while hilly areas and highlands are located south from these rivers. The altitude of Belgrade ranges between 71 m (in Grocka) and 628 m (on Kosmaj). Average altitude of the city centre is 132 m. The size of the territory of the city of Belgrade is 322,800 ha. Given its geographic position, a rich floristic composition has been identified in this area. The structure of the territory of Belgrade is diverse (Tab. 1) due to its diverse orographic and edaphic conditions.

Table 1. Structure of areas of the city of Belgrade

Land category	Area	
	ha	%
Forest	50,800	15.7
Other forest land	10,800	3.3
Infertile land	5,600	1.7
Agricultural land	183,200	56.8
Meadows and pastures	20,000	6.2
Urban land	45,200	14.0
Water areas	7,200	2.3
Total	322,800	100,0

Forests cover 50,800 ha or 15.7% of the total territory and are distributed in fragments and enclaves, often as green lines along water courses of larger rivers (Bankovic *et al.*, 2008). Forests of the city of Belgrade are protection forests (Zivadinovic *et al*., 2006) and can be classified into two categories: urban and suburban. Urban forests are: Banjicka Forest, Topcider, Zvezdara, Kosutnjak, Milica Hill, Miljakovac, Makis, Ada Ciganlija and forests along the highway. All other forests are suburban: Kosmaj, Lipovica and Avala. Ownership structure of forests is shown in Tab. 2.

Table 2. Ownership structure of forests of the city of Belgrade

Ownership	Area	
	ha	%
State	18,400	36.2
Private	32,400	63.8
Total	50,800	100.0

Source: Database of the National Forest Inventory of the Republic of Serbia

State forests are managed by four public enterprises, which apply the same methodology for collecting, processing and analyzing data, and preparation of forest management plans. Forest management plans are prepared at the level of management units and include a comprehensive overview and analysis of the condition of forests, defined objectives, measures and guidelines for their implementation. So, the scope of forest management is very complex and intensive useage of GIS-related technologies is necessary. Based on the data contained in valid forest management plans, this paper researches the condition of a part of state forests, with analytical and critical overview of GIS in administration and management of this natural resource of Belgrade. It includes and presents state forests and forest complexes of 23 Management Units managed by PE Srbijasume, PUC Gradsko Zelenilo and PUC Ada Ciganlija (Fig. 1). Of the total area under state forests, the paper analyzes forests covering 14,816.46 ha or 80.5%. The share of state forests covering 3,583.4 ha or 19.5% is not covered by this analysis (Fig. 1). All collected data were previously coded as per the Coding Manual for Forest Information System of the Republic of Serbia and processed in OSNOVA software package. Spatial data are generated based on a review of cadastral status, and by digitalization of existing forest maps with spatial distribution.

Colleting and processing of data

Collecting data, their processing and establishing of the condition of forests based on various indicators, and preparation of forest management plans, took time form 2003 to 2013 under the process of preparation of special forest management plans. Field works implied marking of external borders of the management unit based on the Cadastre's data, inner spatial distribution into compartments and stands and marking their borders (Fig. 2). The elements used on this occasion to identify stands were: tree species, age, mixture, structural form, development phase, crown, etc.

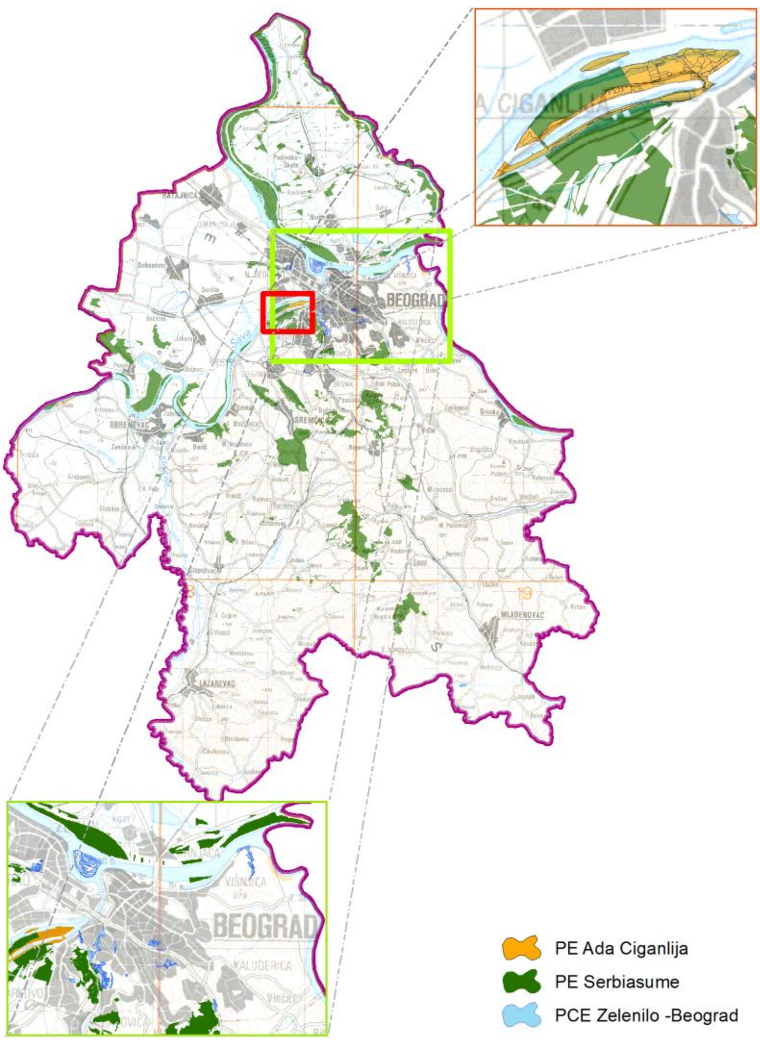
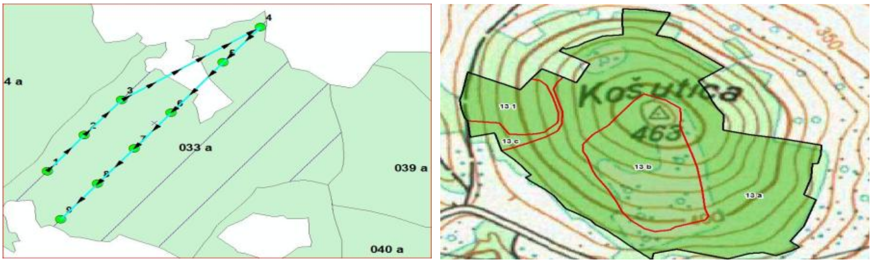


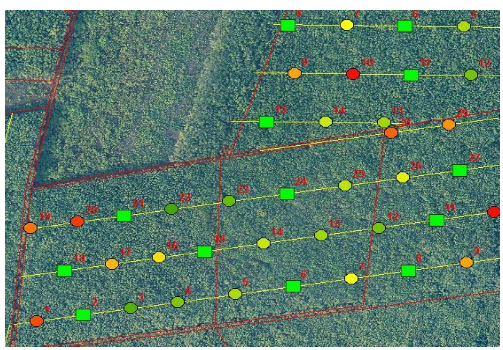
Fig. 1. Spatial distribution of forests managed by PE in the territory of the city of Belgrade



Compartment borders Stand border

Fig. 2. A segment of inner division of space into compartments and stands

The marking of borders of outer and inner division of space was followed by the implementation of forest inventory based on sampling technique, with systematically distributed sample plots (Fig. 3). Circles with constant radius of 1, 2, 5 or 10 acres were used, depending on approximate number of trees per ha, while squares and rectangles were used in poplar and willow plantations, depending on planting distance. Tree diameter, height, diameter increment, information on the quality and health status of trees, etc. were measured on sample plots.



Detailed circles Regular circles

Fig. 3. A segment of systematic distribution of sample plots on which data were collected

In addition to above information about trees on sample plots, a whole spectrum of information related to description of sites and stands of stands as units was collected as well. This information can be grouped as the information relating to geological surface and soil, orography and hydrographic characteristics, phytocenology characteristics, structural development of forests, their health status, etc.

All of this information is coded in accordance with the Coding Manual for the Forest Information System of Serbia, entered into OSNOVA software, subjected to logical control and processed following the procedure defined by this software package. Inquiries sent to the database, which is established like this, result in various tabular and graphical reports on the condition of forests by management units. Software has a special role in ensuring integral principle of planning in its individual phases, plan–implementation-evidence-control, as a necessary precondition for successful management planning of forest resources.

GIS preparation and analysis

Existing data for these surveys were obtained based on existing stand maps 1:5000 or 1:10000, which have been transformed from analogue format into digital vector format by scanning, geo-referencing and digitalization. Scanning of maps is most frequently performed in the resolution of 300 dpi. Geo-referencing implied placement of scanned stand maps in space based on previously identified and recognizable characteristic plots or objects of nature. Maps have been digitalized by a number of GIS software packages, such as ArcGIS, AutCad, and WinGIS. Old maps digitalized like this and transformed into vector format were used as the basis for checking of existing borders in the field against new collected data and the changes that took place in the last 10 years. In cases when changes occurred in terms of tree species, age, mixture, structural forms, development phases, crown, etc. under the influence of abiotic or biotic factors, corrections were made in the field, along with determination of real borders of stands.

The procedure of digitalization and coding was followed by integrating numerical and spatial data into a uniform database, i.e. a link was established between spatial data and numerical data from the OSNOVA database. Once all changes were registered and new borders determined, and after a link with numerical data from the OSNOVA database was established, GIS technology was used to prepare new thematic maps, which presented, in different scales, purpose of forests, management classes, tree species, planned works, etc.

RESULTS

The forests of the city of Belgrade change under strong anthropogenic influence (industrialization, increase in the number of population, pressure for meeting various needs, etc.) and under a combined influence of biotic and abiotic factors. These changes happen very quickly and are negative in most cases. Consequently, there is a growing need for multifunctional, quality forest management in the surrounding or directly in urban areas, based on sustainability principles. The review and analysis of factors influencing the development of forest ecosystems, proper making of decisions related to recovering of the found condition of forests and bringing it to a functionally optimum condition without GIS tools is difficult and less quality. GIS tool offers opportunities to forestry experts for better monitoring, analysis and understanding of dynamic changes in the forests and more efficient use of their potentials. GIS tool was used to review spatial distribution and analysis of the condition of forests of the city of Belgrade by purpose, origin, preservation stage and mixture, as parts of overall indicators required for planning and implementation of management of these forests.

Condition of forests by purpose

The establishment of purpose, priority and other functions of forests is performed based on the Law, general and special needs of the society, analysis of results of priority functions, conditions, needs and opportunities identified so far (Medarević, 1991). These criteria were used for functional zoning of forests in the territory of Belgrade, and it is presented in Table 3 together with main quantitative indicators of individual parts of the complex, while spatial distribution of defined purposes is presented in Figure 4.

The presented data show that the most represented forests in the analyzed area (80.5% of state forests) are intended for production of stacked wood - 3,404.74 ha or 23.0%, followed by forests with water protection function - 2,696.08 ha or 18.2% of the analyzed area. Forests with recreational purpose cover 1,826.22 ha or 12.3%. Forests covering 1,516.27 or 10.2% have an important role in protecting soil from erosion. Based on these data, Figure 4 shows that forests which are described as urban forests are mostly protection forests (protection of water, protection of water-supply systems, climate protection forests), while forests away from the city centre (suburban forests) have production purpose – production of stacked wood. It is realistic to expect that most forests in the future will have recreational and protection functions in the territory of the central area of the city of Belgrade.

Condition of forests by origin

High forests (natural and artificial) in the analyzed area cover 53.8%, coppice forests cover 44.9%, while the remaining 1.3% of the territory is under forests of mixed origin, shrubs and brushes (Table 4). Figure 5 shows that high forests are mostly found in the suburban zone, further away from the city centre of Belgrade. Forests in urban zone are mostly of coppice origin. A significant share of forests of vegetative origin implies weaker biological stability, often poorer health status, modest dimensions of trees, lower diversity of species and dimensions, shorter rotation and thus substantially reduced functional value of these forests.

Table 3. Condition of forests by purpose

Forest purpose (priority function)	Area		Volume			Volume increment		
	ha	%	m^3	%	$m^3 \cdot ha^{-1}$	m^3	%	$m^3 \cdot ha^{-1}$
	1.23	0.0						
Production of stacked wood	3,404.74	23.0	361,234.8	14.3	106.1	10,112.3	11.5	3.0
Hunting-silvicultural centre for big game	1,925.53	13.0	518,351.6	20.5	269.2	11,983.6	13.6	6.2
Seed stand	24.59	0.2	9,041.5	0.4	367.7	132.6	0.2	5.4
Protection of waters (water supply) under protection level I	184.68	1.2	25,364.5	1.0	137.3	505.4	0.6	2.7
Protection of waters (water supply) under protection level III	655.52	4.4	154,646.1	6.1	235.9	7,455.3	8.5	11.4
Protection from waters (water protection)	2,696.08	18.2	350,239.0	13.8	129.9	27,969.4	31.7	10.4
Protection of land from erosion	1,516.27	10.2	229,070.4	9.0	151.1	6,618.2	7.5	4.4
Climate – protection forest	207.11	1.4						
Strictly natural reserve under protection level I	3.48	0.0	1,161.2	0.0	333.7	23.3	0.0	6.7
Recreation-tourist centre	1,826.22	12.3	348,033.5	13.7	190.6	9,613.4	10.9	5.3
Park forest	361.93	2.4	64,515.4	2.5	178.3	1,596.9	1.8	4.4
Area of extraordinary characteristics under protection level I	83.29	0.6	28,757.6	1.1	345.3	497.1	0.6	6.0
Area of extraordinary characteristics under protection level II	150.14	1.0	42,257.2	1.7	281.5	879.5	1.0	5.9
Area of extraordinary characteristics under protection level III	247.14	1.7	54,673.1	2.2	221.2	1,311.0	1.5	5.3
Memorial park	60.18	0.4	11,283.6	0.4	187.5	276.3	0.3	4.6
Forests around historical and memorial complexes	2.53	0.0	727.0	0.0	287.4	11.4	0.0	4.5
Forests in urbanized zones	1,465.80	9.9	332,311.3	13.1	226.7	9,171.7	10.4	6.3
Total	**14,816.46**	**100.0**	**2,531,667.9**	**100.0**	**170.9**	**88,157.4**	**100.0**	**5.9**

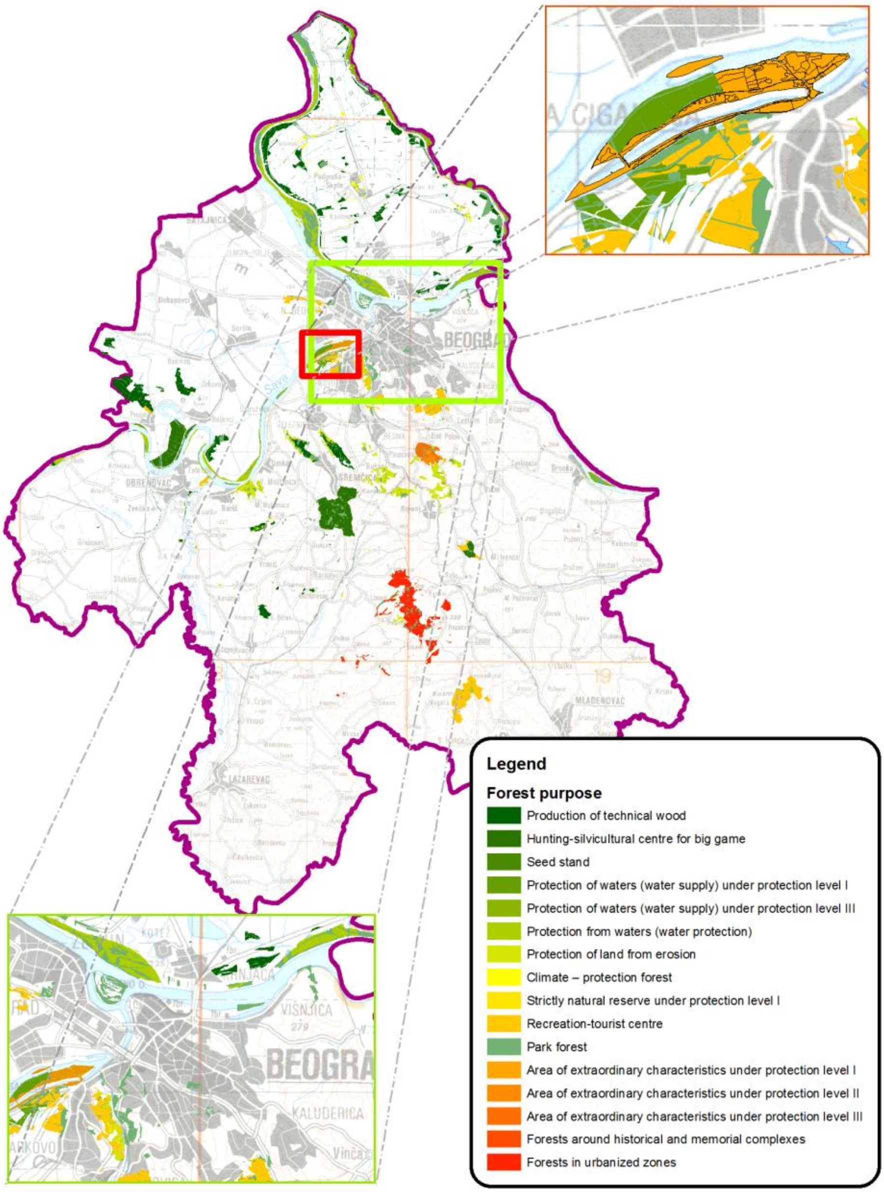


Fig. 4. Functional zoning of a part of state forests in the territory of the city of Belgrade

Table 4. Condition of forests by origin

Origin	Area		Volume			Volume increment		
	ha	%	m^3	%	$m^3 \cdot ha^{-1}$	m^3	%	$m^3 \cdot ha^{-1}$
	40.39	0.3						
High natural hardwood stand	1,260.47	8.5	379,671.2	15.0	301.2	6,885.2	7.8	5.5
High natural softwood stands	147.91	1.0	52,306.5	2.1	353.6	959.9	1.1	6.5
Coppice natural hardwood stand	5,974.32	40.3	1,146,775.0	45.3	192.0	31,745.0	36.0	5.3
Coppice natural softwood stand	645.81	4.4	53,285.0	2.1	82.5	1,826.1	2.1	2.8
Coppice natural hardwood and softwood stand	27.83	0.2	1,183.8	0.0	42.5	51.1	0.1	1.8
Mixed by origin – stand of both seed and vegetative origin in the same storey	94.21	0.6	14,474.6	0.6	153.6	317.0	0.4	3.4
Mixed by origin – stand of seed origin in the first storey, and of vegetative origin in the second storey	1.84	0.0	441.6	0.0	240.0	10.2	0.0	5.5
High natural hardwood stand with introduced conifers	3.18	0.0	296.5	0.0	93.2	10.4	0.0	3.3
Artificially established hardwood stand	2,174.98	14.7	375,276.7	14.8	172.5	11,651.7	13.2	5.4
Artificially established softwood stand	3,929.20	26.5	416,760.7	16.5	106.1	31,190.3	35.4	7.9
Artificially established conifer stand	461.28	3.1	91,196.4	3.6	197.7	3,510.7	4.0	7.6
Bushes	54.46	0.4						
Brushes	0.58	0.0						
Total	**14,816.46**	**100.0**	**2,531,667.9**	**100.0**	**170.9**	**88,157.4**	**100.0**	**5.9**

Table 5. Condition of forests by preservation stage

Preservation stage	Area		Volume			Volume increment		
	ha	%	m^3	%	$m^3 \cdot ha^{-1}$	m^3	%	$m^3 \cdot ha^{-1}$
Unspecified	524.74	3.5	623.8	0.0	1.2	19.1	0.0	0.0
Preserved	10,355.9	69.9	1,864,824.85	73.7	180.1	71,485.4	81.1	6.9
Thinned	3,351.16	22.6	628,150.2	24.8	187.4	15,332.0	17.4	4.6
Devastated	584.66	3.9	38,069.0	1.5	65.1	1,320.9	1.5	2.3
Total	**14,816.46**	**100.0**	**2,531,667.9**	**100.0**	**170.9**	**88,157.4**	**100.0**	**5.9**

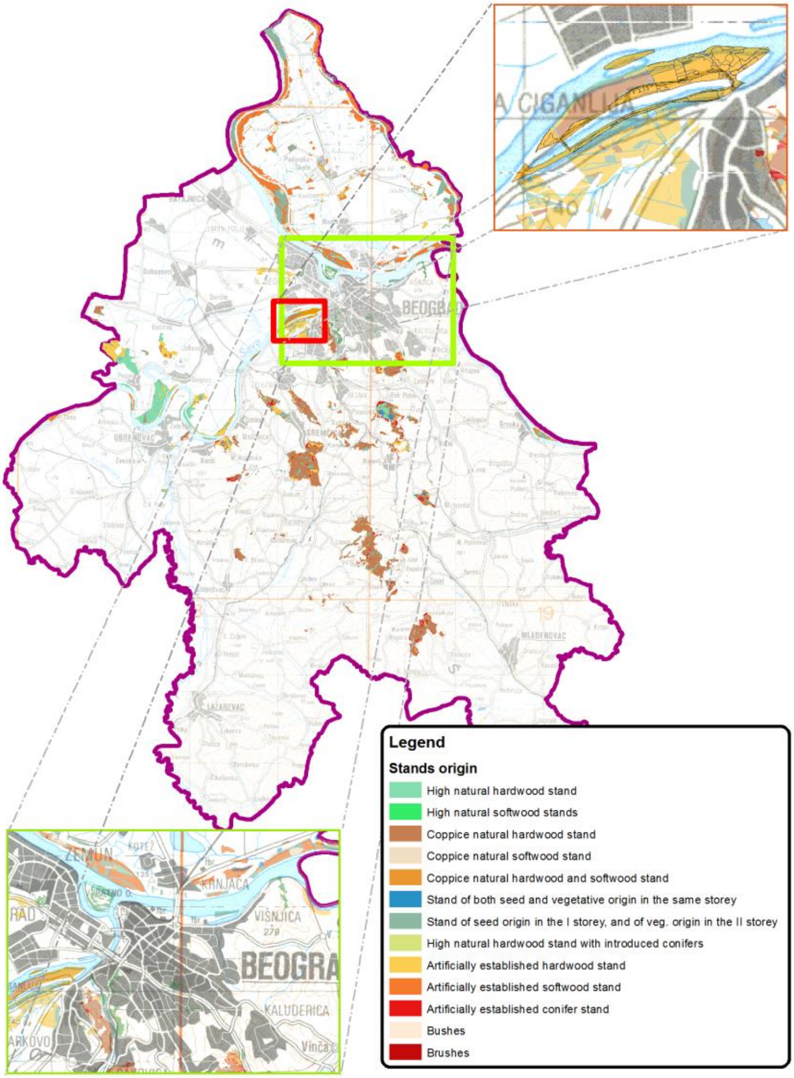


Fig. 5. Spatial division of a part of state forests by origin in the territory of the city of Belgrade

Condition of forests by preservation stage

The condition of forests by preservation stage is moderately favourable because preserved forests account for 69.9%, while thinned forests of reduced functionality account for 22.6% of the analyzed area (Tab. 5). There is a significant negative anthropogenic alternation to forest ecosystems compared to their natural composition. The overview of spatial distribution of these forests (Fig. 6) leads to a conclusion that preserved forests mostly belong to the category of suburban forests, while thinned and devastated forests are mostly found closer to the city centre.

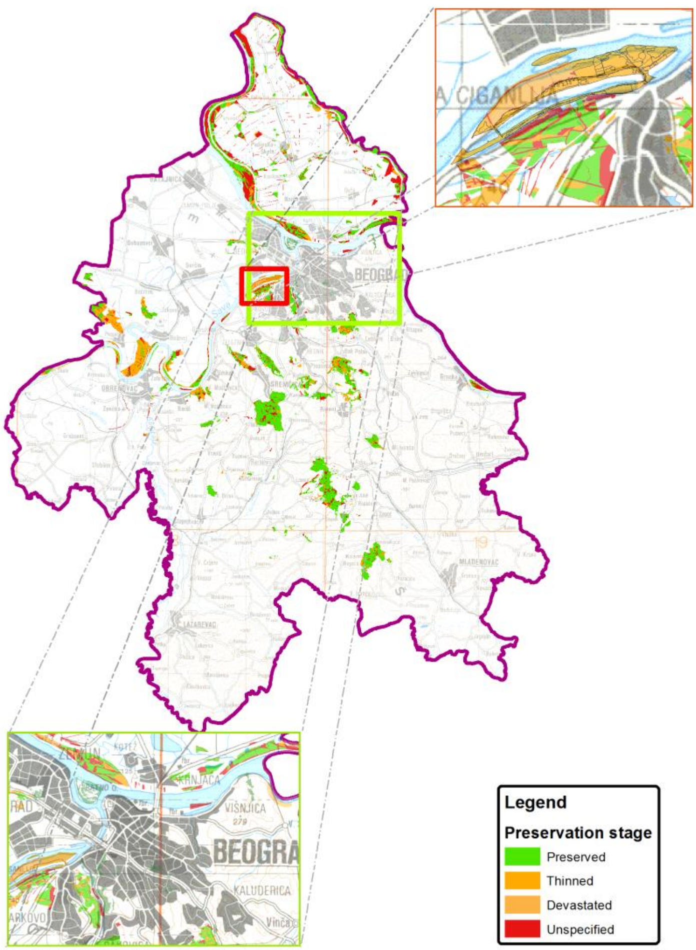


Fig. 6: Spatial distribution of a part of state forests by preservation stage in the territory of the city of Belgrade

Condition of forests by mixture

The territory of Belgrade is characterized by equal shares of clear and mixed forests (Table 6). If the fact that mixed forests are biologically more stable, with higher diversity and often higher productivity is taken into consideration, such condition can be considered unfavourable from the point of view of defined functions of forests of Belgrade. Most of mixed forests are located in the city centre. Clear stands are distributed across the suburban zone, mostly along courses of large rivers of Sava and Danube (Figure 7).

DISCUSSION

Forest Inventory includes collection, processing, analysis and presentation of data about growing stock for the purpose of preparing spatially specific forest management plans. The aim of these plans is to improve the condition of existing forests, expand areas under forests, fulfil permanently ecological, economic and social needs of the society in relation to forests, etc. A large volume of information held by the forestry sector imposes a need for introducing new, modern technologies and tools in the standard work practice in order to ensure successful handling of such information. The forests of the city of Belgrade are managed and administered by four public enterprises which are directed at each other for the purpose of exchange of information. In addition, institutions active in ecology, spatial planning, tourism, public health, etc. also have requests for information about forest resources of Belgrade. In order to avoid unnecessary overlapping of information, bottle necks in their exchange between different institutions, facilitate monitoring of dynamic changes to forest ecosystems and, in relation to this, ensure making of specific decisions, it is necessary to use GIS technology in planning and administration of forests of Belgrade.

Table 6. Condition of forests by mixture

Mixture	Area		Volume			Volume increment		
	ha	%	m^3	%	$m^3 \cdot ha^{-1}$	m^3	%	$m^3 \cdot ha^{-1}$
Unspecified	135.87	0.9	14.1	0.0	0.1	0.4	0.0	0.0
Clear stand	6,919.03	46.7	944,677.5	37.3	136.5	47,167.8	53.5	6.8
Mixed stand	7,761.56	52.4	1,586,976.3	62.7	204.5	40,989.2	46.5	5.3
Total	**14,816.46**	**100.0**	**2,531,667.9**	**100.0**	**170.9**	**88,157.3**	**100.0**	**5.9**

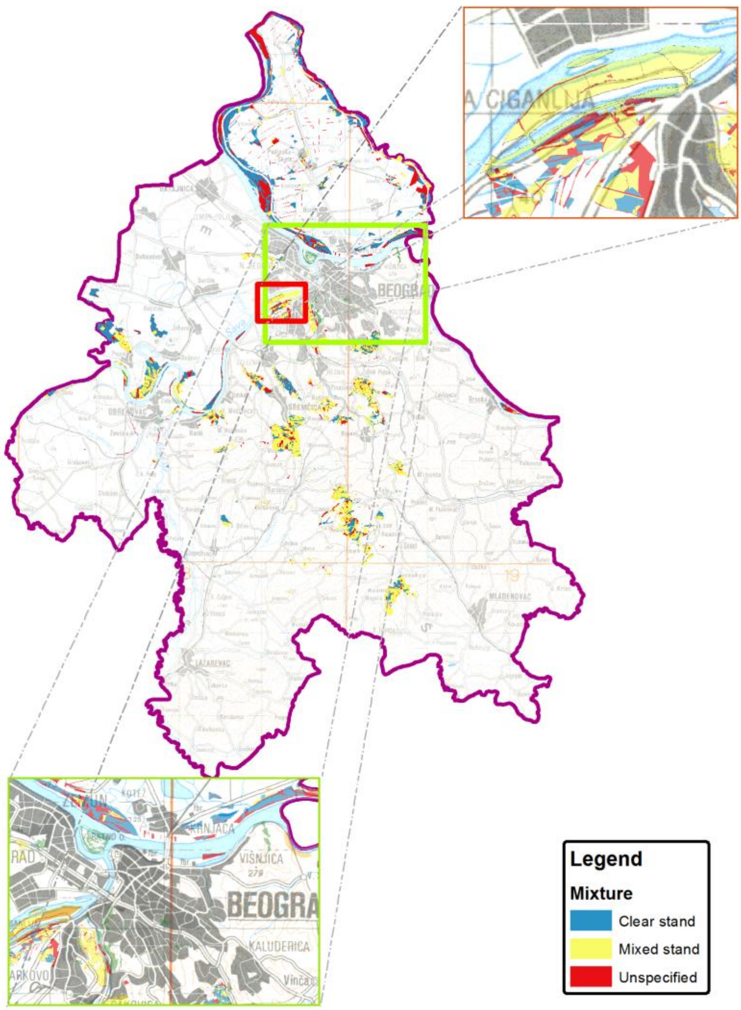


Fig. 7: Spatial distribution of a part of state forests by mixture in the territory of the city of Belgrade

Technologies for collecting spatial data about forest resources has been developing rapidly in recent years, and this trend will continue in the future. The researchers conducted in 1973 stated that only 3% of 172 cities in the United States had used computer and GIS technology in managing forest resources. The use of these technologies in managing city resources in the United States became standard practice in the nineties of the last century (Wood, 1999), and it is nowadays implemented in almost 90% of towns. The purpose of application of modern GIS systems and information systems is to facilitate modern forest planning and management. The purpose of the system's development is to have the lower level data serve the purpose and all users, to have them sufficiently accurate for a particular level of planning, and to have the costs of collecting and keeping the data proportionate to the planning needs.

Analysis of only some parameters, which are numerically and cartographically presented in this paper, indicates that the overall condition of forests in the territory of Belgrade is unsatisfactory and far from the functionally optimum condition. Only 15.7% of the city's territory is covered by forests of irregular spatial distribution, relatively low production capacity, with substantial share of coppice, clear and thinned categories. It should be noted here that the condition of suburban forests is better compared to the forests closer to the city centre. Experiences in application of GIS technology in managing and administering forest potentials show that it is possible to produce thematic maps easily and very quickly, and at the same time to meet efficiently permanent requests for aggregation of new data.

CONCLUSIONS

Modern requirements for administration and management of "urban forests" impose a need for quick, accurate and economic collection, processing, numeric and cartographic presentation of data on the condition of forest ecosystems, their spatial distribution, changes that have occured, etc. In those terms, application of information and GIS technologies is imposed as an optimum solution for management of this resource in the teritory of the city of Belgrade. Application of GIS and information system, when it comes to forests of Belgrade and generally, would create opportunities for the following:

- more efficient forest administration and management,
- more efficient protection of biodiversity,
- easier and more precise valorisation of natural potentials of forests,
- higher quality protection of other natural resources offered by forests,

- easier spatial and statistical data analysis,
- interactive approach and management of forest resources (simpler updating of information, deleting, adding, linking with other databases, etc.),
- preparation and presentation of various thematic digital maps,
- easier updating of changes and administration of forest cadastre,
- quick analysis and modification of existing data,
- easy handling of other sources of cartographic data (cadastre, old forest maps, topographic maps, air images, GPS coordinates from the field),
- clearer drawing of borders and more precise determination of areas, which implies higher accuracy of quantitative data presented by spatial unit (number of trees, volume, increment, etc.),
- more efficient exchange of information between different institutions,
- more precise field navigation.

Therefore, application of GIS and information systems offers multiple benefits, which are generally reflected in easier and more quality handling of spatial and other data about forest ecosystems in territories of large cities, and that creates more reliable grounds for more realistic and more reliable multifunctional administration and management of this natural resource.

ACKNOWLEDGEMENT

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PEDOGENESIS OF SOLONCHAK SOILS IN NORTHERN VOJVODINA

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ABSTRACT

Soil testing in Northern Vojvodina, as part of the project conducted by the Ministry of Education and Science of the Republic of Serbia, resulted in lower values of soil salinity indicators, in soils classified as Solonchak type in previous research. Desalinization trend was also observed in recent research. Desalinization is the resulti of hidromeliorative work on the territory of Vojvodina during the 20th century. After the removal of salinization agents, the process of pedogenesis focuses on the development of alkaline and hydromorphic soil types. Field and laboratory testings on these locations need to be expanded due to the methodological limitations.

Keywords: *solonchak, soil classification, pedogenesis*

INTRODUCTION

Naturally saline soils are created by pedogenetic factors activity, which predetermine the direction and intensity of pedogenetic processes, resulting in the formation of soils with different characteristics.

Halomorphic (saline) soils cover large surfaces worldwide, and can be found on all continents. Solonchak surfaces reach the estimated size of 260 million hectares (Milković, 1996), while the accumulation of salt as the dominant process globally endangers about 340 million hectares (Tóth *et al.*, 2002).

Halomorphic soils are represented by two types of soils: Solonchak – acute saline soil, and Solonetz – alkali soil (Škorić *et al.*, 1985; FAO, 2007). Criteria for the determination of solonchaks or saline horizons differ according to the classification system.

Halomorphic soils or salt marshes (solonchak or solonetz soil types) are not utilised in agriculture, due to the presence of harmful salts, adsorbed sodium and unfavourable water and physical properties.

Problems connected to research, improvements and utilisation of saline soils are the current local and global concern. Research on solonchak soils is important due to soil degradation, i.e. desertification of soils caused by the salinization process, found in solonchak soils.

MATERIALS AND METHODS

Since 1992, same locations have been used for soil sampling, in order to determine the quality of agricultural soils in Vojvodina in terms of soil fertility and the content of dangerous and harmful substances, with the purpose of determining the production abilities of nutritionally safe, high-quality food, and changes in soil properties. The selection of locations was based on the results achieved during project research "Control of fertility and determination of the content of dangerous and harmful substances in the soils of Vojvodina" ("Kontrola plodnosti zemljišta i utvrđivanje sadržaja opasnih i štetnih materija u zemljištima Vojvodine"), undertaken in 1992 (Hadžić *et al.*, 1993; 2004).

The soil map of Vojvodina was mapped using a grid divided into squares of size 4km by 4 km. Every sample represented the surface of 1600 ha, with the set GPS coordinates (Picture 1).

Soil samples were taken in disturbed condition, according to regulations of Soil Fertility and Fertilizer Use Control System (with the agrochemical probe up to the depth of 30 cm according to the circular plots system). Several individual sampling results were joined together and considered as the average value.

On the locations where reaching the setpoint was impossible (water surface setpoint or physical inaccessibility of the spot, such as a building structure), soil samples were taken at the closest point determined by the GPS coordinates.

Sampling was conducted in the period from July to October 2011, resulting in a total of 435 average soil samples, 282 of which were taken in Northern Bačka, and 153 in Northern Banat.

Soil sample coordinates were set on the Digital pedological map of Vojvodina R=1:50.000 (Nejgebauer *et al.*, 1971; Benka and Bulatović, 2009). Afterwards, soil samples belonging to solonchak type were selected according to the pedological map.

Pic. 1. Soil sampling setpoints in Northern Vojvodina

Table 1. Research results of solonchak soil samples

Sample no.	Latitude	Longitude	District	Elevation m	Utilization
965	45° 40' 219"	20° 08' 096"	Northern Banat	72	arable
1018	45° 43' 49,737"	19° 12' 28,292"	Western Bačka	92	arable
1088	45° 48' 07,083"	19° 09' 18,802"	Western Bačka	92	arable
1123	45° 50' 17,765"	19° 09' 13,123"	Western Bačka	91	arable
1188	45° 54' 08,694"	19° 05' 44,502"	Western Bačka	98	meadow
1189	45° 54' 36,62"	19° 09' 13,345"	Western Bačka	90	arable
1218	45° 56' 46,36"	19° 09' 175"	Western Bačka	134	pasture
1238	45° 57' 28,10"	20° 10' 54,90"	Northern Banat	84	arable
1244	45° 58' 52,37"	19° 05' 50,358"	Western Bačka	90	arable
1261	45° 59' 33,20"	19° 58' 28,90"	Northern Banat	88	pasture
1282	46° 01' 40,90"	19° 55' 23,00"	Northern Banat	92	arable
1283	46° 01' 42,40"	19° 58' 23,40"	Northern Banat	88	pasture

The main chemical analyses on the soil samples (reaction, CaCO3 content and humus content) and the analyses of salinity indicators (water soluble salts content, EC of saturated soil water extract, saturated soil paste pH, and saturated soil water extract pH), were conducted according to the methods approved by the Yugoslav Society of Soil Science JDPZ (1966).

RESULTS AND DISCUSSION

Results of analyses are provided in Table 2. Based on the results of the soluble salts content analyses, it can be concluded that the tested soil samples are below the satisfactory criteria for their classification as solonchak soil type – 1% (i.e. 0.7% of soda salinization) of salts (according to the national soil classification, Škorić *et al.*, 1985). Some soil samples belong to saline soils according to this classification (limiting value 0.15% of water soluble salts).

Table 2. Results of analyses of the basic chemical traits and soil salinity indicators

Sample no.	pH in KCl	pH in H_2O	$CaCO_3$ %	Humus %	Water soluble salts %	ECe 25°C dS/m	pH of soil paste	pH of extract
965	7,33	7,89	3,40	2,76	0,08	1,090	7,91	7,74
1018	7,65	8,16	22,45	2,57	0,09	1,691	7,90	7,35
1088	7,44	8,22	15,68	3,13	<0,03	0,668	8,09	7,87
1123	7,56	8,35	10,32	3,96	0,12	2,361	8,15	7,54
1188	7,85	9,80	7,43	2,56	0,15	1,765	8,66	7,67
1189	7,75	8,34	24,35	3,26	0,04	1,062	8,29	8,11
1218	8,67	10,11	26,61	1,72	0,16	5,300	9,11	9,08
1238	7,55	8,03	20,85	2,27	0,08	1,918	7,80	7,66
1244	7,64	8,23	11,64	2,15	<0,03	0,563	7,84	7,89
1261	8,12	9,50	22,55	2,53	0,04	1,498	7,01	7,89
1282	7,72	8,25	11,96	2,54	0,09	2,157	8,68	8,23
1283	7,91	9,59	30,77	2,17	0,06	1,537	8,36	8,40

It should be emphasized that the given criteria are applicable to the salt content in samples taken up to the depth of 125 cm; this research was conducted on soil samples taken up to the depth of 30 cm. On the other hand, research on solonchak soils conducted in this region, from the 1950s (authors, year) until today (Vasin, 2010, Vasin *et al.*, 2013), indicate that salinity occurs only on the soil surface, with lower salt content in deeper soils.

WRB classification (IUSS Working Group, 2006) determined the following criteria for salic horizon (the key for identifying the reference soil group of solonchaks):

- Averaged over the depth and electrical conductivity of the saturation extract (ECe) of 15 dS m^{-1} or more at 25 °C in certain periods of the year, or an ECe of 8 dS m^{-1} at 25 °C, provided that pH (H2O) of the saturated extract is 8.5 dS m^{-1}or more; and
- The product of thickness (in centimeters) and ECe - electrical conductivity of the saturated extract (in dS m^{-1}) of 450 or more; and
- Thickness of 15 cm or more.

Salic horizon (upper border) must be near the surface, up to 50 cm.

According to WRB, saline soils have electrical conductivity value of the saturated water extract ECe over 4 dS/m.

Similar to the local classification, WRB states that only some samples belong to the group of saline soils, and are far below the set criteria of salic horizons for solonchak soils.

Results of this research are equal to the results achieved by Vasin 2010, and Vasin *et al.* 2013. They determined the desalinization process in soils previously classified as solonchaks.

Typical pedogenetic process found in Northern Vojvodina solonchaks is aquifer salinization, i.e. groundwater salinization of the first aquifer. In the mid 20th century, extensive hydromeliorative work was done in the region, and salinization source was removed. Pedogenetic process classifies these soils, placing them into soil types depending on salinization levels, such as solonetz (alkali soil), humogley - hydromorphic black soil, eugley - hydromorpic mineral gleyed soil etc.

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Slovak Land Parcel Identification System

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ABSTRACT

Rural development Programme -RDP represents the second pillar of Common agricultural Policy -CAP of European Union. The SAPS – Single area payment scheme, direct payments represents the first pillar of CAP in Slovakia. Both pillars are based on Land Parcel Identification System –LPIS, which was created and is regularly updated in Slovakia on Soil Science and Conservation Research Institute. This system is compulsory for each EU member's state and its purpose is to enable assign to each LPIS reference parcel exact agriculture area, exact geographical location, unique code and several attributes concerning Cross Compliance (CC/XC) and Rural development programme. The LPIS was created and is regularly updated on the background of actual digital orthophotomaps which have to meet EC technical requirements. In Slovakia is LPIS based on reference parcel – physical blocks which represent agriculture land with stable boundaries. One of the most significant problems of agricultural land degradation in Slovakia is accelerated water erosion. The system of agri-environmental subsidies to farmers of the Rural Development Programme -RDP aspires to contribute to reducing the negative impacts of agricultural production on land and other basic environmental components, as well as strengthening greening of agriculture in Slovakia. A group of Soil protection measures, whose main purpose is reducing the extent of accelerated water erosion, is aimed at protecting agricultural land use in the frame of RDP. This contribution evaluates the application of Soil protection measures on agricultural land in Slovakia during the second programming period of the Rural Development Programme 2007–2013 by the Slovak regions. The analysis of ten agri-environment measures as well as their geographic location and cartographic interpretation were performed using geographic information system instruments. Its results form the basis for an important input for the development and evaluation of the effectiveness of state environmental measures with regard to the formulation of proposals and recommendations for action to the next programming period 2014 – 2020.

Keywords: Soil protection measures, Agri-environmental measures, Protection against erosion, LPIS, GIS, agricultural soil, Rural Development Programme

INTRODUCTION

Rural development Programme -RDP represents the second pillar of Common agricultural Policy -CAP of European Union. The SAPS – Single area payment scheme, direct payments represents the first pillar of CAP in Slovakia.

Both pillars are based on Land Parcel Identification System – LPIS, which was created and is regularly updated in Slovakia on Soil Science and Conservation research institute. This system is compulsory for each EU member's state and its purpose is to enable assign to each LPIS reference parcel exact agriculture area, exact geographical location, unique code and several attributes concerning Cross Compliance (CC/XC) and Rural development programme.

The LPIS was created and is regularly updated on the background of actual digital orthophotomaps which have to meet EC technical requirements. In Slovakia is LPIS based on reference parcel – physical blocks which represent agriculture land with stable boundaries, used by one or several users.

Rural Development Programme 2007-2013 (RDP) significantly influences the current trend in the development and formation of the rural, predominantly agricultural used landscape.

RDP helps to reduce the negative impacts of agricultural production on the environment and enhance the greening of agriculture in the Slovak Republic; this year (2013) ends its second programming period.

In the framework of the RDP there is a Soil protection measures group, which are focused on agricultural land degradation by quick-water erosion.

These measures exist in the frame of the Agri-environment payments: measures focused on sustainable use of agricultural land (part of Axis 2: Improving the environment and countryside).

RDP follow up on earlier programming period of the Rural Development Plan 2004-2006, which included also agri – environment measures. The first plan was created after accession to the EU in 2004, when was opened the possibility to obtain direct funding from the EU Structural Funds.

Rural Development Plan represents a programming tool of the Common agricultural policy on the basis of Council Regulation (EC) no. 1257/1999 - support for rural development from the EAGGF (European Agricultural Guidance and Guarantee Fund), which together with contributions from the state budget supported the environment respectful practices and acceptable actions to protect, preserve and improve the quality of soil, water and rural landscapes.

With the State and development effectiveness of agri-environmental measures of the Rural Development 2007-2013, as well as realisation of concrete measures through less favoured areas (LFA), vulnerable areas in terms of Nitrate directive, Natura 2000 sites and of high nature value (HNV), deals with the study of Zverková *et al.* (2012). Environmental effects resulting from the implementation of selected measures were evaluated in scientific research of Bujnovský (2010). Protection against erosion on arable soil through three agro-environmental measures (stabilizing crop rotation, acceptable size of the parcel and the greening of arable land) analyzed in his paper Styk and Palka (2012). On the specific issue of slope values, which constitutes one of the main criteria for the approval of subsidy payments for the Conservation of agri-environment sub-measures, is focused contribution Matečná, Jenčo and Matečný (2010).

The aim of this paper is to evaluate the implementation of agri-environmental measures (soil protection) on Slovakian agricultural land during the second programming period 2007-2013 of Rural development programme.

The analysis was made for the period 2008-2012 for different regions of Slovakia, at the regional level. Evaluations of soil protection measures, as well as the identification of its geographic location and final cartographic interpretation were performed using the tools of Geographic Information System (GIS).

Analysis of the period 2008-2012 is considered sufficiently for the purpose of evaluating the status and development effectiveness of agri-environmental measures with regard to the formulation of proposals and recommendations for measures in the frame of the next programming period 2014-2020.

MATERIALS AND METHODS

Creating of digital GIS layers and derived graphic cartographic outputs relevant to the Soil Conservation measures included: data collection, analysis and generation of new spatial data.

Preparation of table's data and selection of attributes was carried out in an MS Access database programme.

All data analysis, creation of GIS layers, subsequent export of graphical cartographic outputs was realized in an Arc GIS 9.

Input database for GIS data analysis consisted of farmers and agricultural subjects that implement specific soil protection measures. This information is stored in the Integrated Administration and Control System IACS database which is maintained on APA. SSRI obtained these data in the of spreadsheet exports form.

This export was supplemented by an explanation of the data structure for the years 2008 to 2012. Next inputs data were represent by digital LPIS unit of blocks vector layer and information about the agricultural land use registered in the LPIS for the years 2008 to 2012.

This information is maintained on the Soil Science and Conservation Research Institute. The basic unit used in spatial data analysis were the unit of LPIS blocks, the smallest size KD is 0.3 ha, that is the minimum surface area required for RDP agri-environmental financial support.

The identifying of the sub-measures surface extent was based on values of area "SAPS set" (approved area for the Single Area Payment Scheme - under APA, 2011) mentioned in applicants declarations Tables for years 2008-2012 stored in IACS.

To this data was added the declared area in HA obtained from previous Rural Development Plan 2004-2006 (of the Ministry of Agriculture 2007) applications. Output cartographic information has surface character.

Within us analyzed soil protection measures RDP were implemented also several obligations transferred from the previous planning period 2004-2006.

Implementation of these measures have significant environmental effects and importance in the protection of agricultural land, but it was not possible to include them in our spatial analysis, because their evidence on the APA has not yet been carried out on individual LPIS unit of blocks and therefore does not exist exact geographical location inside LPIS unit of blocks.

Available is only information, that given agroenviromental measures is realised on LPIS units of blocks, together with declared area of agroenviromental measures inside LIS unit of block, but no information is available about exact geographical location inside LPIS unit of block.

Characteristics of soil protection measures (Rural Development Programme 2007-2013)

The objective of RDP agri-environment support payments is the implementation of agricultural production methods compatible with the protection and improvement of the environment, land and natural resources that are beyond the relevant mandatory standards of CAP direct payments.

Especially on soil conservation the Soil protection measures are targeted.

Soil protection practice group consists of four measures: protection against erosion on arable land, protection against erosion in vineyards, protection against erosion in orchards, greening of arable land.

The main objectives of soil protection measures are reducing the extent of water erosion, and thus prevent soil erosion and prevent water contamination.

At the same time also contribute to preserving and enhancing biodiversity through the expansion of green areas (grassing, stabilizing bio-belts) and participate in the mitigating climate change by reducing greenhouse gas emissions and increase removals by sinks of greenhouse gases.

The main criterion for assessing the area in terms of approval and the amount of agri-environmental support for the implementation of anti-erosion measures laid down in accordance with the terms of arable land in vineyards and orchards is a morphometric parameter - the slope, respectively average slope of LPIS units of blocks.

Erosion protection of arable land through the Stabilisation crop rotation and / or Acceptable size of the parcel, erosion protection in vineyards and orchards is supported on soils vulnerable to erosion in LPIS units of blocks with an average sloping over 3 ^{o}, while be prioritized areas with higher erodibility in vulnerable areas (defined in accordance with Directive 91/676/EEC) and less-favoured areas (LFA).

Within protection against erosion measure in vineyards is the amount of support for the implementation of anti-erosion measures scaled to the average limits sloping vineyard 3 °, 10 °, 18 ° and for erosion protection in orchards is the average sloping 3 ° and 10 °.

For protection against erosion on arable land through the realizing appropriate size of the parcel measures can farmer get a subsidy and/or parts of the soil block larger than 30 ha.

Greening of arable land is supported on the LPIS unit of blocks with an average of 7 °; the preferred areas are vulnerable and disadvantaged areas. In addition, the applicant for support on the protection against erosion on arable land measure should also enter one other measure of agri-environmental payments: Basic support, protection of habitats of selected species of birds or Organic Agriculture (Ministry of Agriculture, 2007).

RESULTS AND DISSCUSION

Soil protection measures realisation in Slovakia during the 2008 – 2012 years

The largest land area supported under the protection against erosion on arable land measure was reached in 2010. For the whole country, this represents 85,581 ha (of which 22 293 ha was the current RDP and 63 288 ha were transfers from the previous programming period 2004-2006). Protection against erosion on arable land was implemented through whole area of the Slovak Republic, but has been recorded significant regional disparities.

Protection against erosion on arable land realized by acceptable size of the parcel was used to a minor extent, only 0.3% from all measures (only 12 LPIS units of blocks).

The largest land area supported under the measure protection against erosion in vineyards was reached in 2009. For the whole country on 707 ha (of which 61 ha was the current RDP and 646 ha were from the previous programming period 2004-2006). The largest land area supported by the measures against erosion protection in orchards was reached in 2010. For the whole country it was 919 ha (353 ha was from the current RDP and 566 ha were from the previous programming period 2004-2006). Greening of arable land and protection against erosion on arable land through reasonable sized plots belong to environmental measures with the highest environmental effects.

Among the arable land, vineyards and orchards farmed in Slovakia meets the criteria for obtaining support for anti-erosion protection within the soil protection measures RDP up to 64% of them. Conservation measures RDP were made however only on 7.5% of their area.

The overall effectiveness of soil protection measures RDP was reduced due to the economic "inefficiencies" of certain compensatory payments (Zverková *et al.*, 2012).

Table 1. Geographical distribution of Soil protection measures RDP 2007 – 2012

Region	Share in the region of the Slovak Republic (%)				
	protection against erosion on arable land		Greening of arable land	protection against erosion in vineyards	protection against erosion in orchards
	protection of arable land through the Stabilisation crop rotation	protection against erosion on arable land through reasonable sized plots			
Banskobystrický	10,63	0,00*	1,84	0,00*	22,83
Bratislavský	0,60*	0,00*	14,22	0,00*	1,50
Košický	16,23	37,23**	6,77	35,03	6,20
Nitriansky	25,44**	0,00*	1,49*	64,97**	7,97
Prešovský	8,58	34,72	9,72	0,00*	0,00*
Trenčiansky	22,63	0,00*	25,84	0,00*	61,51**
Trnavský	14,92	28,05	10,03	0,00*	0,00*
Žilinský	0,96	0,00*	30,10**	0,00*	0,00*

* region with the lowest share of measure ** region with the highest share of measure
Zdroj: Vlastný výskum podľa Deklarácie 2008-2012(APA); LPIS 2008-2012(VÚPOP).

Evaluation of the effectiveness of soil protection measures under the RDP in the frame of LPIS

Environmental effects of the soil-protection measures consist in reducing the risk of water erosion, to stabilize or increase soil organic matter content of the soil, reducing the risk of transport of nitrogen to water resources and improve biodiversity (Bujnovský, 2010).

Greening of arable land and protection against erosion on arable land through a reasonable sized plot measures are environmental measures with the highest environmental effects.

Partial view of the measures effectiveness implemented under the RDP SR, can be obtained through the comparison of the agricultural land area proportion where the soil conservation measures were carried out with proportion of whole agricultural land area registered in the LPIS (area which complies with the criteria for the implementation of anti-erosion measures, Tab. 2, 3). We analyzed the area of measures from year, when the maximum area was reached.

Among the arable land, vineyards and orchards managed in Slovakia meets the criteria for obtaining support for anti-erosion protection within the soil protection measures RDP 64% managed area of them. RDP Conservation measures were made but only on 7.5% of their area. More than half of the arable land registered in the LPIS is LPIS units of blocks with average slopping over 3 °, while protection measures have been implemented on only 6%.

Table 2. LPIS units of blocks meeting the criteria for the implementation of soil protection measures on arable land in vineyards and orchards

LPIS units of blocks	Area (ha)	Number	Share from whole area of certain land use in LPIS (%)
Arable land above 3º and to 30 ha	467 712	4 451	33,55
Arable land above 3º and above 30 ha	312 364	22 798	22,41
Arable land above 7º and to 30 ha	80 227	6 527	5,75
Arable land above 7º and above 30 ha	36 545	662	2,62
Vineyards from 3º to 9º	8 316	893	47,19
Vineyards from 10º to 17º	513	92	2,91
Orchards from 3º to 9º	3 816	424	41,69
Orchards above 10º	503	98	5,50

Zdroj: Vlastný výskum podľa LPIS 2008-2012 (VÚPOP).

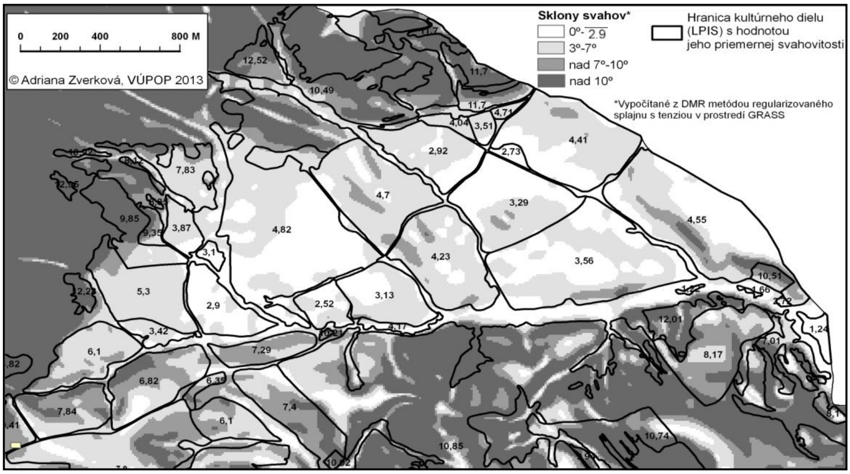
Table 3. Share of agricultural land where the soil protection measures were carried out from the agricultural land area of LPIS, which meets the criteria for their implementation

Soil protection measure (SPM)	Realization (ha)	LPIS (ha)*	Share of SPM from LPIS** (%)
Protection against erosion on arable land	85 581	780 076	10,97
Protection against erosion in vineyards	707	8 829	8,01
Protection against erosion in orchards	919	4 319	21,28
Greening of arable land	18 659	116 772	15,98
Soil protection measures together	*105 866*	*909 996*	*11,63*

* the agricultural land area of LPIS, which meets the criteria for their implementation

** : Share of agricultural land where the soil protection measures were carried out *from the* agricultural land area of LPIS, which meets the criteria for their implementation

Zdroj: Vlastný výskum podľa Deklarácie 2008-2012(APA); LPIS 2008-2012 (VÚPOP).



Pic. 1: Slopping variability in the frame of LPIS units of blocks

Almost half of the vineyard LPIS units of blocks registered in LPIS, has an average slope of 3 º to 9 º, only less than 3% have a slope of 10 º to 17 º and cultural parts of vineyards with an average sloping above 18 º do not occur at all (Tab. 2).

However, within these LPIS units of blocks also occurs a vineyards area with sloping over 18 º.

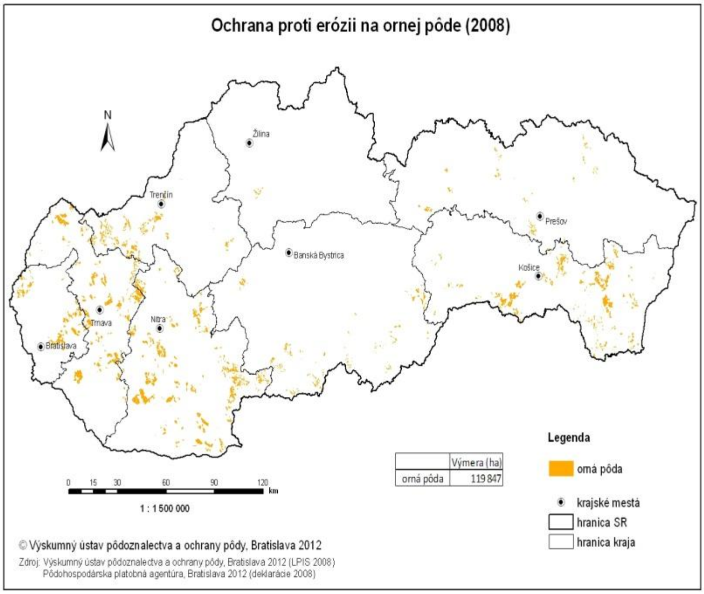
For these areas farmers cannot get more support as it is fixed, because support is tied to the value of the LPIS units of blocks average sloping.

This problem has been met, eg. 114 LPIS units of blocks with an area of 678 ha, which belong to the category with an average slopping from 3 º to 9 º and 50 KD LPIS units of blocks with an area of 158 ha, with an average sloping from 10 º to 17 º.

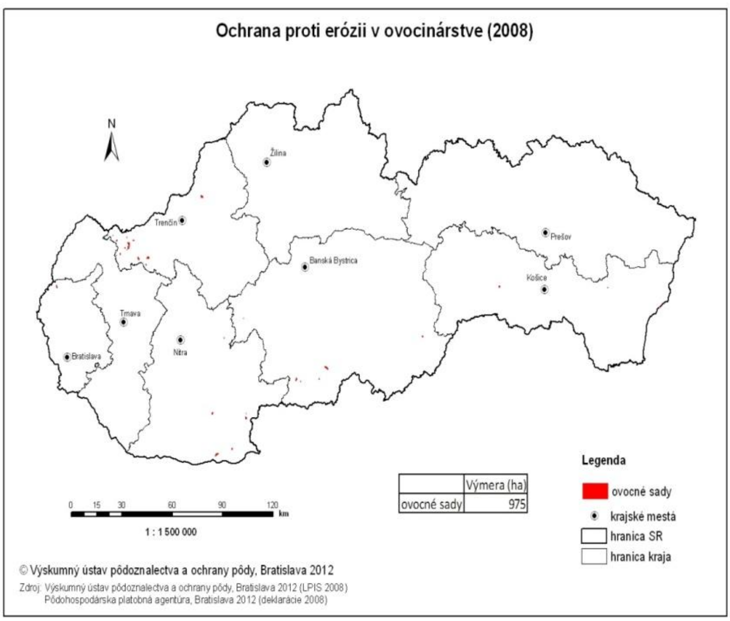
A similar problem occurs also by other limits of the average sloping vineyards (3 º, 10 º).

Orchard LPIS units of blocks KD with an average sloping from 3 º to 9 º constitute just over 40% of registered orchards in LPIS and above 10 º they are less than 6% (Tab. 2).

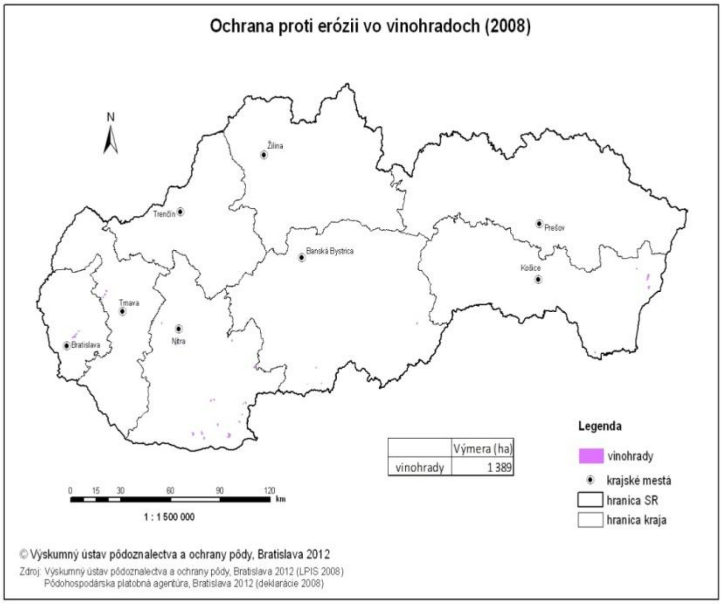
However, the LPIS units of blocks with an average sloping from 3 º to 9 º represents 252 LPIS units of blocks (1 975 ha), but within these units of blocks also exists orchards areas with an average slopping above 10 º. The geographical distribution of all four soil protection measures are presented on Picture 2, 3, 4, 5.



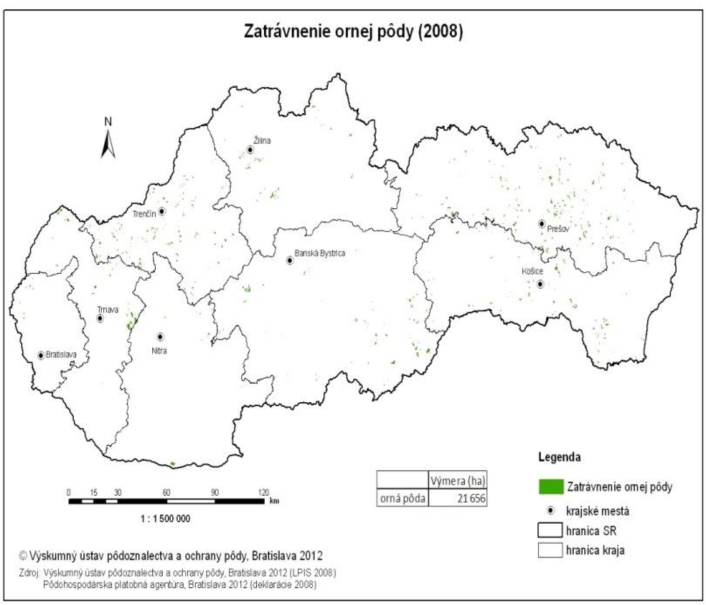
Pic. 2: Geographical distribution of Soil protection measure on arable land



Pic. 3: Geographical distribution of Soil protection measure in orchards



Pic. 4: Geographical distribution of Soil protection measure in vineyards



Pic. 5: Geographical distribution of Soil protection measure, greening of arable land

Large LPIS unit of block is divided by grass strips into smaller parcels after realisation of Soil protection on arable land -Acceptable size of the parcel - Picture 6.

Pic. 6. LPIS unit of block after realisation of Soil protection on arable land -Acceptable size of the parcel situation left and before realisation soil protection measure, situation on right side**.**

CONCLUSION

The largest land area supported under the measure protection against erosion on arable land was reached in 2010.

For the whole country, this represents 85,581 ha (of which 22 293 ha was the current RDP and 63 288 ha were transfer from the previous programming period 2004-2006).

Protection against erosion on arable land was implemented through whole area of the Slovak Republic, but has been recorded significant regional disparities

Protection against erosion on arable land realized by acceptable size of the parcel was used to a minor extent, only 0.3% from all measures (only 12 LPIS units of blocks).

Protection against erosion on arable land through an acceptable size of the parcel and greening of arable land are environmental measures with the highest environmental effects, but were carried out on a very small proportion of farmland SR and with large regional disproportion.

This fact significantly reduces the effectiveness of these measures in Slovakia.

The overall effectiveness of soil protection measures RDP was reduced due to the economic "inefficiencies" of certain compensatory payments.

The results of soil-conservation measures RDP evaluation by using GIS tools were limited, because the bas capabilities for applying basic spatial data unit- LPIS units of blocks.

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LEGAL PROTECTION OF AGRICULTURAL LAND IN THE SLOVAK REPUBLIC

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ABSTRACT

The quality of soil and land-use management is the basis for good conditions of life inhabitants. For this reason this issue should be at the core of any soil policy. Soil is the main natural resource, and the economic and social potential of each country. The way of farmland use must be adequate to natural conditions in given landscape and at the practical level of farming and must not threaten an ecological stability of the territory. The soil is a multifunctional phenomenon, which is part of the environment, allows the production of foodstuffs and raw materials filters and holds water, and ecologically compensated balance of substances found in nature. The limitations of the availability of soil resources are a critical issue when considering global food security. The soil quality issue is significant to policy makers because some aspects of soil degradation are only slowly reversible (decline organic matter) or irreversible (erosion) ones. Everybody who uses farmland for agricultural production is doing duty to utilize farmland in such a way, which conserves its natural fertility. The new law about agricultural soil protection has been approved in the year 2004 and amended in the year 2013. This law determinates protection properties and function of agricultural soil and protection environmental function of agricultural soil, which are production of biomass, filtration, and neutralization and transformation substance in nature.

Keywords: soil protection; soil service; laws about soil protection; environmental function; compaction; degradation

INTRODUCTION

The limitations of the availability of soil resources are a critical issue when considering global food security. High quality soils are rare and should be most protected. Although sustaining soil quality is recognized as an important issue by all countries, the extent and trends in soil degradation processes have yet to be determined for many countries. The soil quality issue is significant to policy makers because some aspects of soil degradation are only slowly reversible (decline organic matter) or irreversible (erosion). Given the importance of maintaining soil quality to ensure agricultural productivity, expenditure on soil conservation, both from private and government sources, is frequently a substantial share of total Agri-environmental expenditure. Government policies, dealing with a soil quality improvement, commonly provide a range of approaches, including investment and loans, to promote conservation practices, and advices on soil management. Enhancing soil quality and quality of land-use management is essential for maintaining agricultural productivity and basis for good conditions of inhabitants.

An important parameter quantitative assessment of the sources of agricultural land and the need to safeguard them for future generations is their acreage, per capita. Generally speaking, the higher the value, the more stable the region (region, state)-particularly in terms of ensuring the nutrient sufficiency. Conversely, the more built-up areas per capita, the area is ecologically less stable.

Statistically accounted for Slovakia to 9 115 m^2 per capita, of which agricultural land is 4 518 m^2 (2 653 m^2 arable land), forest land 3 731 m^2, 173 m^2 water surface, and other built-up area 692 m^2. The average for the European Union, these indicators was 3500 m^2 respectively 2 100 m^2. Well above average, Latvia (from 8 100 m^2 to 12 200 m^2), well below the average of the Netherlands and Belgium (1 200, respectively 700 m^2).

Council of Europe already in 1992 issued a recommendation to try to change the overall philosophy of looking at the ground. For the first time it recommended the Member States to protected only land area, but began also to the protection of its functions. Under the new directive the states should adopt programs and recovery of their lands. Another major point of the new directive is to increase people's awareness of the importance of land and its protection. People have little interest in the land. This applies not only ordinary citizens but also decisive and political workers. They cannot imagine that life without land on Earth is not possible.

The aim of this paper was the development of the legal protection of agricultural land in the Slovak Republic.

MATERIAL AND METHODS

The Slovak legal system for many decades gives greater attention to the protection of agricultural land. In terms of the development of legislation protecting farmland is important to note that in comparison with other countries was of the former Czechoslovakia adopted as one of the first the law about protection of agricultural land No. 48/1959. This act was replaced by law. 53/1966. These laws were focused only on protecting of the production ability and area of arable land. As overall in this period these laws have not paid site ecological protection, but only acreage and protect land resources against soil sealing and for non-agricultural purposes.

According the Law no. 48/1959 agricultural land is an indispensable basic means of production agricultural production. Therefore be agricultural land, especially arable land, under the provisions of this law has been to protect agricultural land and create conditions for its expansion and improvement. Although the legislation in question set out measures to mitigate the damage caused to agricultural land and agricultural production, it was not applied in practice. The lack of economic stimulus resulted in the permanent loss of arable land and, in particular, the total devastation of farmland.

For this reason, in 1966, was adopted a new law for the protection of agricultural land no. 53/1966. Agricultural land is the basic natural resource of our country, indispensable means of production for attaining self-sufficiency in the production of staple foods and is one of the main components of the environment. Protection of agricultural land, its enhancement, use and expansion were the main tasks. For this was issued Government Regulation no. 103/1979 on the rates charges for withdrawal of agricultural land agricultural production. Charges ranged from 35,000 crowns to 1 350 thousand crowns, according to the creditworthiness of land and natural habitats.

In 1992 was adopted new law No. 307/1992 on the protection of agricultural land, which had significant environmental impacts and was not restricted just to protect agricultural soil before soil sealing. The use of agricultural land fund must respect the natural conditions in any given territory, the ordinary management of the agricultural production in the area and importantly not threaten the ecological stability of the landscape. Anyone who uses agricultural land for agricultural production has to use the agricultural land to preserve its natural fertility. Charges for permanent withdrawal of agricultural soil from the agricultural land fund were set from 50 000 SK/ha to 11 300 000 SK /ha according to the quality of the soil.

Despite the fact that this law was prepared on high level, the protection of agricultural land has not been sufficiently accepted. In practice, the soil conservation has not received general attention, was not sufficiently respected and remained on the periphery of society.

Persistent disrespect for the land and its protection was the reason why the National Council of the Slovak republic adopted in 2004 a new law on the protection and use of agricultural land No. 220/2004. By this law had been protected first four groups of the highest quality soil without financial payments.

Act No. 219/2008 was re-provides for the obligation to pay charges for permanent and temporary withdrawal of agricultural land, but only the first four groups according to soil quality codes of pedo-ecological units (PEU). For permanent withdrawal of agricultural land charges are from 6 till 15 € per square meters, for temporary withdrawal of agricultural land 1th to 4th Group 1 €/m^2.

Until 2013 the protection of agricultural soils against soil sealing has been concentrated into the south-western Slovakia, where are our highest quality soils located. At the same time we have a large amount of regions with little or no protection of agricultural soils against soil sealing. The latest law about protection of agricultural land and its use is the law No. 57/2013, amending and supplementing Act No. 220/2004. This Act protects agricultural land in all cadastral territory of Slovakia.

RESULTS AND DISCUSSION

Method of use of agricultural land must be adequate natural conditions in a given area and the normal management of the farmland in particular the landscape area and must not jeopardize the ecological stability of the area. Anyone who uses the agricultural land for agricultural production is to use agricultural land as to preserve its natural fertility.

Change arable land cultivated on land differently without the permission of the executive body of the district national committee is forbidden.

Agricultural land can be degraded through degradation processes:

- Physical processes – erosion, compaction and waterlogging
- Chemical processes – acidification, salinization
- Biological processes – declines in organic matter
- Soil sealing – withdrawal of agricultural soils to non-agricultural using.

These degradation processes are linked to changes in farm management practices, climate and technology. There can be lags between the incidence of degradation, the initial recognition of a problem by farmers and the development of conservation strategies. The limitations of the availability of soil resources are a critical issue when considering global food security. High quality soils are rare and at risk of degradation and loss through degradation. Although sustaining soil quality is recognized as an important issue by all countries, the extent and trends in soil degradation processes have yet to be determined for many countries. The soil quality issue is significant to policy makers because some aspects of soil degradation are only slowly reversible (decline organic matter) or irreversible (erosion) ones.

Extensive investment activity, which in 1945 carried with us, significantly reduced the acreage of agricultural and arable land in particular. In the fifties of the last century there was no law to protect agricultural land. Only in 1959 a law was passed to protect agricultural land. Although the legislation provides for measures to mitigate the damage caused to agricultural land has not been used in practice. Lack of economic incentive has resulted in a steady decline mainly arable land and total devastation of farmland.

For this reason, in 1966, a new Act on the Protection, which has been supported by economic incentives? This Act contains provisions on the protection and use of agricultural land, as well as natural resources of our country to achieve self-sufficiency in the production of the basic means of production - food and is one of the main components of the environment. To download farmland were prescribed payments from 10 000 to 1 350 000 crowns per hectare based on soil quality.

From the year 1992 had law protection of agricultural land pronounced environmental in nature and was not restricted just to protect agricultural soil against soil sealing. The reason for the emergence of a new law on the protection of agricultural land fund No 307/1992 was the restoration of property ownership to land, formation of market relations in agriculture and in the interest of restoring or improving the function of ecological stability in agricultural land. The use of agricultural land fund must respect to the natural conditions in a given territory and in the ordinary management of the agricultural production in the area and must not threaten the ecological stability of the landscape.

In spite of the fact that this law was a good level, the protection of agricultural land has not been sufficiently accepted. In practice, soil conservation has not received general attention was not sufficiently respected and remained on the periphery of society. Persistent disrespect for the land and its protection was the reason why the National Council of the Slovak republic adopted in 2004 a new law on the protection and use of agricultural land. According the introductory provision of the new law, the agricultural soil is assessed as an irretrievable natural resource and unique component of an environment.

Everybody is obliged to protect soil natural functions and prevent any action that could lead to the farmland deterioration. The way of farmland use must be adequate to natural conditions in given landscape and at the practical level of farming and must not threaten an ecological stability of the territory.

The main principles of this law were:

- Protection of properties and functions of agricultural land and to ensure its sustainable management,
- Protection of agricultural land against illegal permanent or temporary soil sealing agricultural land
- Sanctions for breach of the obligations lay down by this law.

In terms of the principles of sustainable agricultural land use, land management and soil protection is primary:

- care for agricultural land,
- protection against degradation,
- protection against erosion,
- protection before compacting,
- balance of the soil organic matter,

- Protection against hazardous substances.

By the §4 this law has been installed a new activity „Soil service", which has been created on Soil Science and Conservation Research Institute (SSCRI) Bratislava. "Soil Service" conducting a survey of soil and recommends protective measures for soil degradation. Soil conservation represents a basic part of individual and social awareness of developed countries with accepting an axiom that "any soil degradation leads to degradation of welfare and perspectives for life“. Initial basis for back up the importance of Soil Service represents also very rich base of data and knowledge about gradual degradation of agricultural soils in the area of our country. In such context of activities in soil degradation not just in our country, but in each developed country worldwide the creation of Soil Service appears to be highly actual and commonly desirable also in Slovakia. The main objective of the Soil Service is to be a professional supervisor for any activities in the field of soil conservation, a preferred provider of information related to soil and soil quality and to formulate professionally justified measures for soil protection against degradation processes and damages.

Activities of the soil service The Soil Service is established within the frame of practical implementation of the law No. 220/2004 , but mainly as an apparatus helping to make information about the state of agricultural soils, their properties, need of reclamation, and possibilities of their use and conservation more transparent. Its function is not only restrictive, but helps to the land owners, land users and managers in rational way of soil use, soil protection from degradation with respect to the principles of sustainable resource management. In the portfolio of Soil Service following main activities are included:

- Analyze, evaluation and quantification of the state and trends in soil degradation
- Proposals and justification of solutions and projects development for the soil conservation and management at specific locations
- Creation and maintenance of the Information system of agricultural soils endangered by degradation, providing soil related information

These activities are carried by the Soil Service on its own initiative (as a result of own research), but also on request from the state soil conservation authorities, other state authorities, local authorities, other scientific and research bodies, foundations, enterprises or any legal or physical persons having information about soil degradation or any risk of such degradation.

In the case of permanent and temporary land delimitation out of the farmland there is a duty to cut humus horizon and accomplish some measures for optimal use of the spoil material. In the case of temporal land delimitation out of the farmland cited Act orders soil return back into original status. In the case the soil may be deteriorated (degraded), the Act charges recultivation measures with return the soil into the original status regarding the soil quality. By this law of the agricultural soil conservation and utilization had been protected first four groups of the highest quality soils without financial payments.

Act No.219/2008 was re-provides for the obligation to pay charges for permanent and temporary withdrawal of agricultural land, but only the first jour groups according to soil quality codes of pedo-ecological units (PEU).

Charges for the permanent withdrawal of agricultural land has been established for the best quality soil from 4 to 15 € per m^2. Till 2013 has been the protection of agricultural soils against soil sealing concentrated into the south-western Slovakia, where in terms of quality are our highest quality soils. At the same time we have a large amount of regions with little or no protection of agricultural soils against soil sealing.

Act No. 220/2004 and 219/2008 protect agricultural land, mainly in the South-western part of Slovakia, where there is high-quality soil (fig. 1). The latest law for the protection of agricultural land and use is the law no 57/2013, amending and supplementing Act No. 220/2004. This Act is protected agricultural land in all cadastral territory of Slovakia. The latest law about protection of agricultural land and its use is the law No.57/2013, amending and supplementing Act No. 220/2004. This Act protects agricultural land in all cadastral territory of Slovakia.

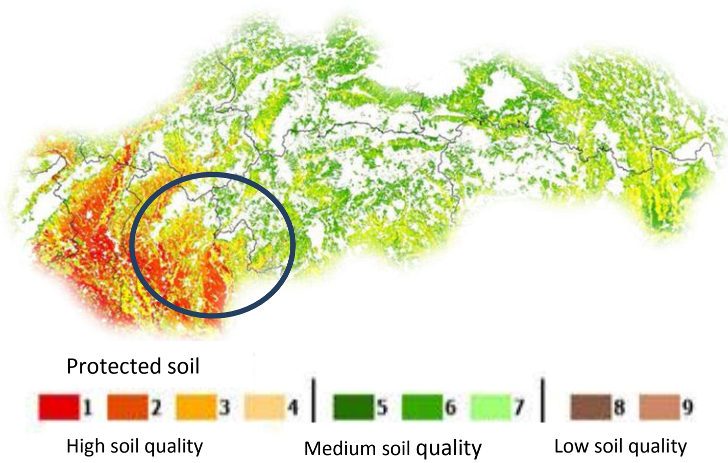


Fig. 1. Map of soil quality in Slovakia

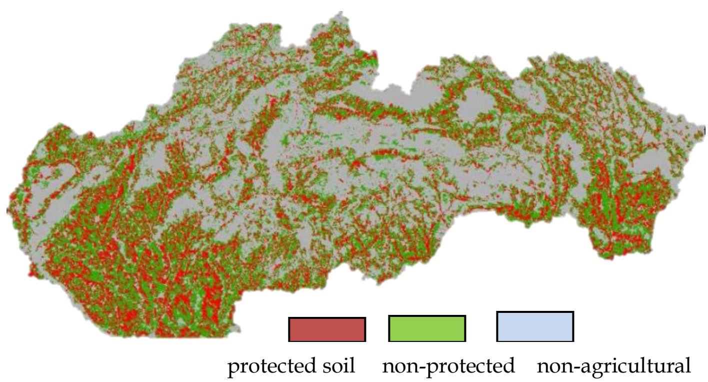
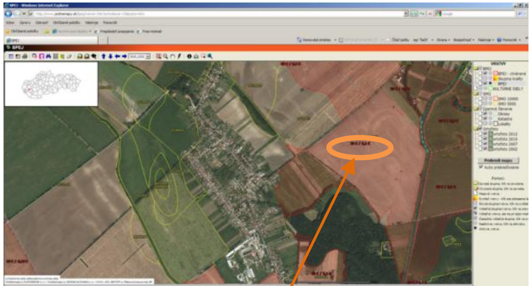


Fig. 2. Map of protected agricultural soil by the law no. 57/2013

Law concerning the charges for soil sealing of the high soil quality has been prepared that the best quality agricultural soils are protected in a particular administrative area and thus solves protection throughout the SR. According to this law, 37% of the total agricultural land of the Slovak Republic is protected, what represents approximately 937 222 ha. Protected agricultural land is evenly distributed throughout Slovakia and protection applies to all cadastral areas, except where the administrative area we registered minimum or no agricultural land. Procedure for the determination of protected lands for which there is a liability to pay the charges for permanent or temporary soil sealing is following:



Annex no. 1 of the Regulation Government's "Basic rate of levy for permanent and temporary soil sealing area under pedo-ecological units

Základné sadzby odvodov za trvalé a dočasné odňatie poľnohospodárskej pôdy podľa kódu bonitovaných pôdno-ekologických jednotiek (BPEJ)			
Skupina kvality	Kód BPEJ	Odvod za odňatie €/m²	
		Trvalé	Dočasné
1	0017002 0017005 0017012 0019002 0019005 0019012 0019015 0022002 0022005 0022012 0117002 0117005 0119002 0119005 0119012 0119015 0122002 0122005 0122012 0122015	20	0,20
2	0002002 0002005 0017032 0017035 0018003 0018013	15	0,15

Annex no. 2 of the Regulation Government's "List of highest quality agricultural land he relevant administrative area under pedo-ecological units

Zoznam najkvalitnejšej poľnohospodárskej pôdy v príslušnom katastrálnom území podľa kódu bonitovaných pôdno-ekologických jednotiek (BPEJ)

Kód KÚ	Názov KÚ	Kód BPEJ
800015	Ábelová	0865432 0871412 0911002 0961212 0961242 0961345 0961412 0961545 0965242 0965442 0971202 0971212 0971222 0971225 0971235 0971242 0971422 0971433 0972422 0972423 0977262 0979262 1061442 1065442 1071405 1094202
800040	Abovce	[illegible] 0406042 0407003 0426002
800058	Abrahám	0017002 0017005
800066	Abrahámovce	0611002 0669232 0669432 0670233 0671203 0671403 0769232 0769245 0769332 0769342 0769432 0769435 0770233
800074	Abrahámovce	1011012 1063442 1069242 1069342 1070243 1070343 1073312 1073442 1078262
800091	Abramová	0729002 0811002 0811005 0812003 0820003 0864003
800112	Abranovce	0757002 0757202 0761232 0771242 0771243
800121	Adamovské Kochanovce	0202002 0202042 0203003 0248212 0249003 0250002 0250202
800155	Adidovce	0611002 0612003 0614062 0657302
800163	Alekšince	0126005 0139002 0139005 0144002

Fig. 3: Map of pedo-ecological units

Necessity of effective national soil conservation policies with permanent soil resources inventory and maintained systematic soil research including international cooperation is also assumed to be of great importance. Soil conservation must be an interest of the state and whole society. The rules mentioned above were in May 1992 highlighted again and actualized by the Council of Europe in the „Recommendation on Soil Protection No. R (92)8, from which a unified definition of soil for the EC countries is derived: Definition of soil: Soil is integrated part of ecosystem of the Earth, situated between Earth surface and under-layer. Soil profile is partition to layers – horizons, with specific physical, chemical and biological properties and different function Recommendation of the EC "R (92) 8" on soil conservation is based on the appraisal of the main soil functions as follows:

• producing food,

• Storing, filtering and transforming minerals, water, organic matter, gases, etc.

• providing raw materials,

• being the platform for human activity.

Backordering to this document all the soil functions are of equal importance. Permanent conditions must be maintained for harmonized supplementation and protection of all soil functions. Harmonization of the Soil charter with Agenda 21 must respect principle, by which in case of conflict between economic and ecological interests the ecological ones has to be preferred. Soil conservation represents a basic part of individual and social awareness of developed countries with accepting an axiom that "any soil degradation leads to degradation of welfare and perspectives for life“. Initial basis for back up the importance of Soil Service represents also very rich base of data and knowledge about gradual degradation of agricultural soils in the area of our country. In such context of activities in soil degradation not just in our country, but in each developed country worldwide the creation of Soil Service appears to be highly actual and commonly desirable also in Slovakia.

Soil Service shall issue on yearly basis an information reports on the state and trends in soil degradation in Slovakia and about priorities in conservation of agricultural soils. Proposal of the Soil service structure Soil service as a particular and specialized unit represents an integral part of the Soil Science and Conservation Research Institute (SSCRI). Person responsible for the activities of Soil service is the director of the VÚPOP. Mandated by performance of the Soil service activities are the workers under professional management of the person nominated by the director (Soil service manager).

CONCLUSIONS

Charges are processed, that the best quality land are protected in a particular administrative area. Previous laws were designating the charges in the whole country; the amendment addresses the charges in the all cadastral territory. Thus you can identify land that are protected or the territory to which it can build. According to the quality of the soil is determined by the state charges. The law does not prohibit soil sealing, only is limiting sitting of buildings on the agricultural soil with highest quality. The best quality land in Slovakia can be found from the Danube plain. The amendment bill would just like to protect these sites. Even if an investor interested in these areas significantly occupy farmland, ideal would be if the focus was associated with the processing of agricultural products and food production of primary production. From dues for agricultural land should be exempt investors who want to occupy land on the breaks in the built-up area to 5,000 square meters or in sites that are linked to built-up area.

The laws are easier to accept and respect their need to explain to people only if society begins to understand that the protection of the land and its improvement is a fundamental need of the whole society, filled with the sense of the law on the protection and use of agricultural land.

Council of Europe already in 1992 issued a recommendation to try to change the overall philosophy of looking at the ground. For the first time it recommended the Member States to protected only land area, but began also to the protection of its functions.

It follows that in each territory must clearly identify the priority functions of the soil and on the basis that use it. Soils with high fertility potential should be used for food; others should serve as a source of non-commodity functions, in particular the protection of nature and life in general.

In Slovakia, the Act on the protection and use of agricultural land, which is the principle of the protection of soil functions adopted and developed. Unfortunately, enforcement of these principles is low.

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ZÁKON NR SR č.220/2004 o ochrane a využívaní poľnohospodárskej pôdy a o zmene zákona č.245/2003 Z.z. o integrovanej prevencii a kontrole znečisťovania životného prostredia a o zmene a doplnení niektorých zákonov.

ZÁKON NR SR č.57/2013 o ochrane a využívaní poľnohospodárskej pôdy a o zmene zákona č.245/2003 Z.z. o integrovanej prevencii a kontrole znečisťovania životného prostredia a o zmene a doplnení niektorých zákonov.

ZÁKON SNR Č. 307/1992 o ochrane poľnohospodárskeho pôdneho fondu.

ZÁKON SNR Č. 48/1959 o ochrane poľnohospodárskeho pôdneho fondu.

ZÁKON SNR Č. 53/1966 o ochrane poľnohospodárskeho pôdneho fondu.

International Congress: SOIL-WATER-PLANT

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WEBGIS APPLICATION IN SOIL SCIENCE USING GOOGLE FUSION TABLES AND GOOGLE MAPS TECHNOLOGYS

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ABSTRACT

Application of WebGIS allows designing, implementing, generating, delivering and analyzing interactive maps on the World Wide Web. Bearing in mind that the latest trend in databases and data warehouses is "floating in the cloud", the Google and other database service providers are applying cloud computing principles to database technologies. The Google developed a new online database called Fusion Tables that takes a new approach to database management, fusion Tables stores data on Google servers, which allows users from multiple locations convenient access to the data and powerful tools for data manipulation. The Google Maps is a web mapping service application and technology provided by Google, that powers many map-based services; also Google Maps API allows external developers to write applications that use Fusion Tables as a database. In this paper will be presented the advantage of using soil pH (KCl) and pedology layers of Cadastral municipalities Kostolac and Kostolac Village stored at Google Fusion Tables and soil pH (KCl) data interpolated by kriging method stored as KMZ layer at server side, as the end product all layers are displayed on the World Wide Web by employing Google Maps API.

Keywords: WebGIS, Google Maps, Google Fusion Tables, Cloud Computing, soil pH (KCl), pedology

INTRODUCTION

The latest trend in databases and data warehouses is "floating in the cloud" (Baldauf and Stair, 2011). Google and other database service providers are applying cloud computing principles to database technologies. The term Cloud computing can be define as follows: By using virtualized computing and storage resources and modern Web technologies, cloud computing provides scalable, network-centric, abstracted IT infrastructures, platforms, and applications as on-demand services (Baun *et al.*, 2011). Currently cloud vendors, researchers, and practitioners alike are working to ensure that potential users are educated about the benefits of cloud computing and the best way to harness the full potential of the cloud (Buyya, Broberg and Goscinski, 2011). The essential characteristics of cloud computing are (Baun *et al.*, 2011):

- On-demand self-service: Services can be provided unilaterally and on demand to consumers without requiring human interaction.
- Broad network access: Services are available over the network in real-time through standard mechanisms.
- Resource pooling: The resources are pooled to enable parallel service provision to multiple users (multi-tenant model), while being adjusted to the actual demand of each user.
- Elasticity: Resources are rapidly provisioned in various, fine-grained quantities so that the systems can be scaled as required. To the consumer, the resources appear to be unlimited.

Google developed a new online database called Fusion Tables that takes a new approach to database management, fusion Tables stores data on Google servers, which allows users from multiple locations convenient access to the data and powerful tools for data manipulation (Baldauf and Stair, 2011). Google Fusion Tables are launched in the northern hemisphere in the summer of 2009, and allow us to store, share, query and visualize data tables. Users can keep the data private, share it with a select set of collaborators, or make it public (Gonzalez, 2010). Fusion Tables is not a traditional database system focusing on complicated SQL queries and transaction processing. Instead, the focus is on fusing data management and collaboration: merging multiple data sources, discussion of the data, querying, visualization, and Web publishing (Halevy and Shapley, 2009). Also Fusion Tables API allows external developers to write applications that use Fusion Tables as a database (Gonzalez, 2010).

The WebGIS is a service which makes possible the display of spatial data via the Internet by using any web browser (Internet Explorer, Firefox, Opera, etc.), the user can collect and retrieve heterogeneous data sets through interactive maps in a simple and intuitive way, intended to different user groups (Jaramaz *et al.*, 2010). In June 2005 Google publically released the Google Maps API. The Google Maps is a web mapping service application and technology provided by Google, that powers many map-based services. The Google Maps API lets you harness the power of Google Maps to use in your own applications to display data in an efficient and usable manner (Svennerberg, 2010). Inside Google Maps can be displayed information stored in many formats, by using standard geometric primitives (point, line and polygon).

This paper describes the goals of integration of Google Fusion Tables and KML files with Google Maps technology, and the possibilities of their practical application in Soil Science.

MATERIAL AND METHODS

Fusion Tables enables us to upload files containing structured data. The currently supported formats include CSV (Comma Separated Values), different spreadsheet formats (Excel, Open Office, and Google Spreadsheets), and KML (Keyhole Markup Language) up to 100MB. The data can contain geographical objects such as points, lines and polygons. The Keyhole Markup Language (KML) is an XML-based language for managing the display of three-dimensional geospatial data (Fuller and Frazier, 2009). The KML files are very often distributed in KMZ files, which are zipped KML files with a .kmz extension.

Vector and raster data are created inside the ArcGIS software, and then saved in KML format. The vector layers are converted to KML format so they could be imported within the Fusion Tables, list of imported layers are displayed below:

- Location of Soil Sampling with pH in KCl value; contains geometric (point) and attribute data,
- Pedology layers of Cadastral Municipalities Kostolac and Kostolac Village; contains geometry (polygon) and attribute data, and
- Borders of Cadastral municipalities Kostolac and Kostolac Village; contains geometric (polygon) and attribute data (implemented only for the easier orientation of end-users).

Once the data is imported, Fusion Tables enables users to explore their data with a combination of data visualization and SQL-like querying. The Fusion Tables API supports querying of data through select statements, update of the data through insert, delete, and update statements, and data definition through a create table statement.

The raster layer is stored as a KMZ file directly on the server, and it is employed to display Interpolated pH in KCl values. Data are interpolated by utilization of Ordinary kriging method.

The next phase is the development of a webpage that uses the Google Maps API in order to display the data stored in the specified sources (Fusion Tables and KMZ).

The information that a user sees on Google Maps at any time is an overlay of multiple layers. Any query result that is to be displayed on a map is represented as a layer. When a user submits a request to view a map, a corresponding request is sent to the backend servers with information about the currently visible layers, the geographic coordinates of the window that is visible on the user's browser, and the current zoom level. The backend then creates tiles (small images) by putting together information in the different layers, and it serves the tiles as the response to the user's request.

The map tiles are images that are loaded from Fusion Table data source in the background with Ajax calls and then inserted into a <div> in the HTML page, which contains Google Maps. As user navigate the map, the API sends information about the new coordinates and zoom levels of the map in Ajax calls that return new images. The Google Maps API itself basically consists of JavaScript files that contain classes with methods and properties that you can use to tell the map how to behave.

It is important to note that Google Maps employ Word Geodetic System 84 (WGS 84), which is the same system the Global Positioning System (GPS) uses. The coordinates are expressed using latitude (y) and longitude (x).

RESULTS

Basic Google Maps contains Map and Satellite view with options for zoom in, zoom out and pan. Research area without displayed layers is represented at Figure 1.

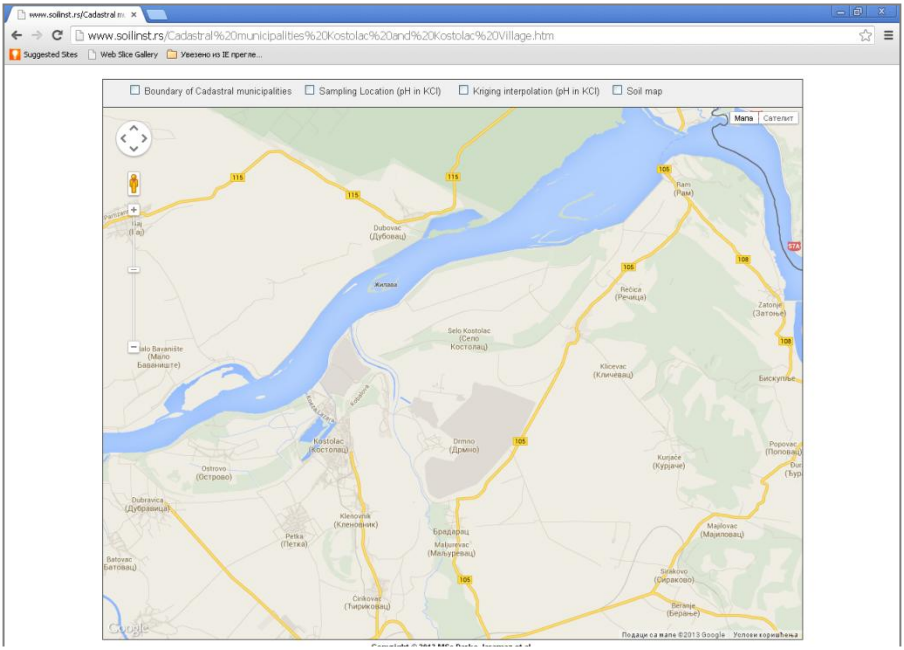

Fig. 1. Google Maps

Vector geometry and attribute data are stored inside Google Fusion Tables (Fig. 2), and from there will be retrieved inside webpage that contains Google Maps. Within the unique tables are stored following vector layers (as detailed explained earlier) with corresponding geometric and the attribute data:

- Location of Soil Sampling with pH in KCl value,
- Pedology layers of Cadastral Municipalities Kostolac and Kostolac Village, and
- Borders of Cadastral municipalities Kostolac and Kostolac Village.

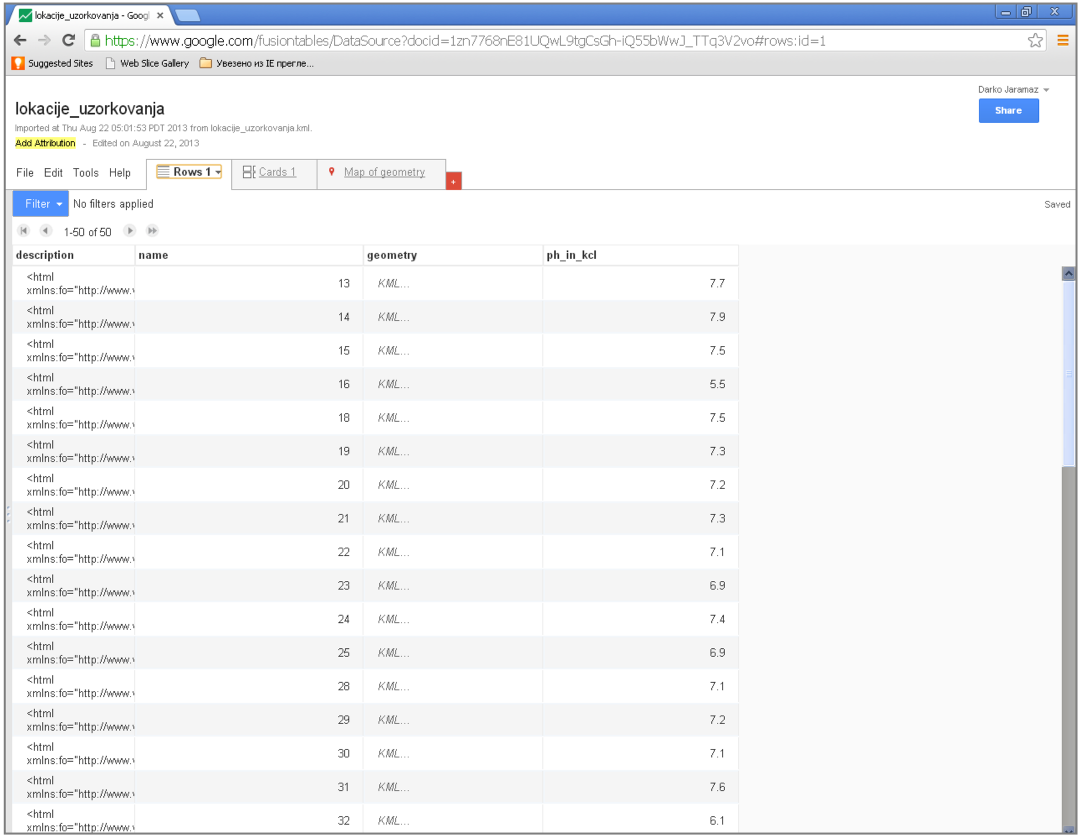

Fig. 2. KML file imported inside Google Fusion Tables

Google Maps with displayed Location of Soil Sampling are represented at Figure 3. Location of Soil Sampling layer (geometry and attribute data) is stored inside Fusion Tables. Every sampling location are displayed on the map with associated pH in KCl value, pH in KCl value can be easily retrieved by clicking of user side on the selected location point.

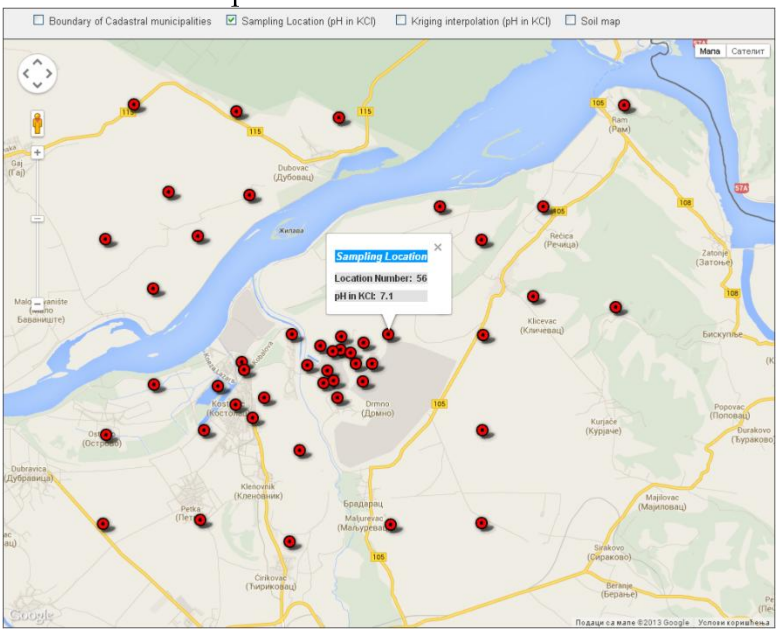

Fig. 3. Google Maps with displayed Location of Soil Sampling (pH in KCl)

Google Maps with displayed Interpolated data layer (pH in KCl values) with the layer that display Borders of Cadastral municipalities Kostolac and Kostolac Village (implemented only for the easier orientation of end-users) are represented at Figure 4. Interpolated data layer are in raster format (KMZ file) and it is stored at server side in its original form, and Borders of Cadastral municipality's layer is stored inside Fusion Tables. Colors of Interpolated data layer correspond to the following interpolated pH in KCl values:

- Red – pH in KCl value from 5.40 to 6.00,
- Orange – pH in KCl value from 6.01 to 6.50,
- Yellow – pH in KCl value from 6.51 to 7.00,
- Green –pH in KCl value from 7.01 to 7.50, and
- Blue – pH in KCl value from 7.51 to 7.90.

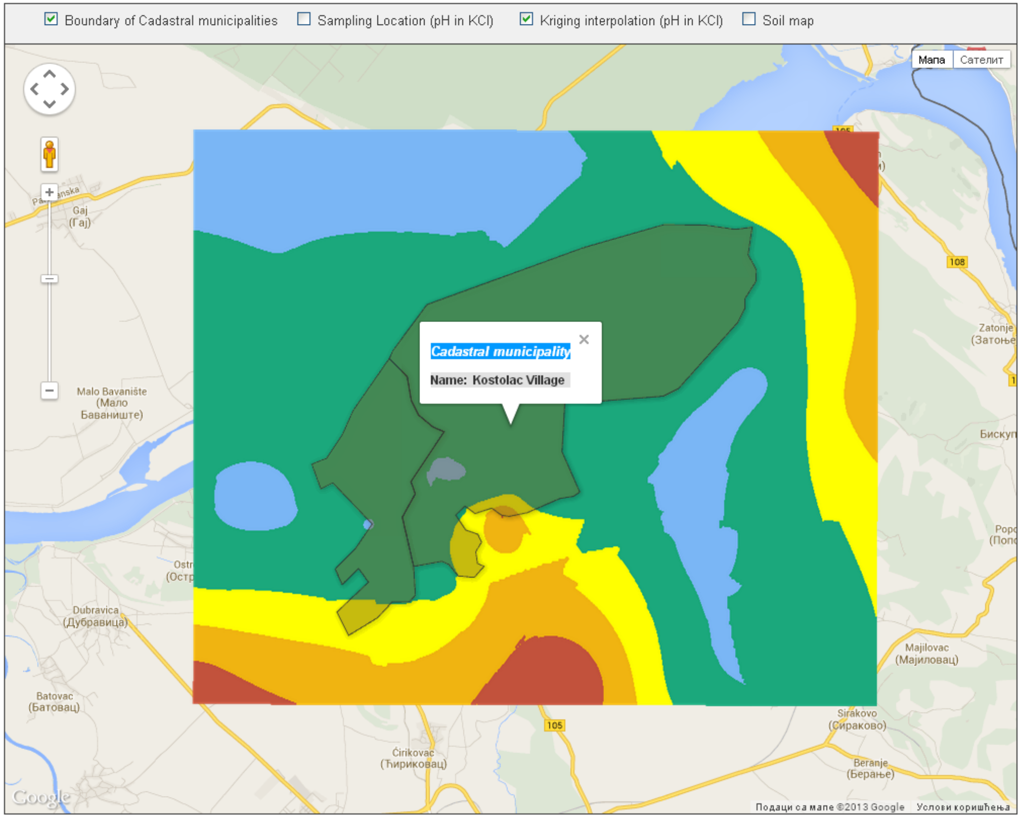

Fig. 4. Google Maps with displayed Interpolated data (pH in KCl)

Google Maps with displayed Soil map are represented at Figure 5. Soil map layer (geometry and attribute data) is stored inside Fusion Tables. Every polygon that represented soil type are displayed on the map with associated attribute value (name of the soil type), name of the soil type can be easily retrieved by clicking of the user side on the selected polygon.

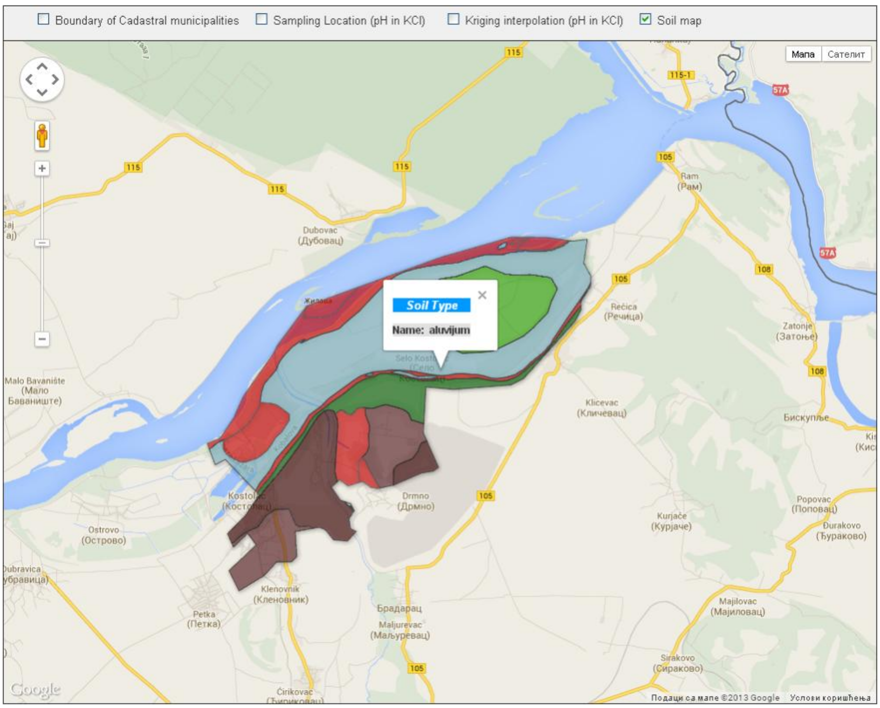

Fig. 5. Google Maps with displayed Soil map

Some of possibility of overlapping stored layers are represented on the Figure 6, where are displayed already previously mentioned Soil map layer and Interpolated data layer (pH in KCl values).

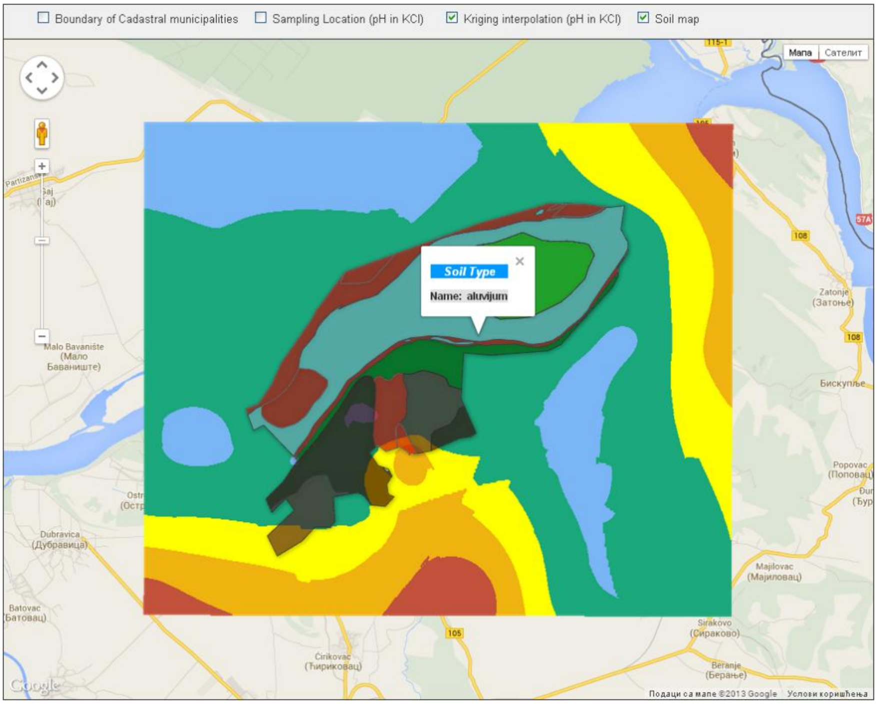

Fig. 6. Google Maps with displayed Soil map and Interpolated data (pH in KCl)

CONCLUSION

Data management and the Web need to be integrated data collection, presentation and visualization should be immediately compatible with the Web (Shneiderman, 2008; Viegas and Wattenberg, 2009). There is no doubt that cloud computing is a disruptive technology which has the potential to change our understanding of how to provision and leverage IT services in a fundamental and sustainable way; the effects might even be comparable to the introduction of the personal computer some 25 years ago. (Baun *et al.*, 2011).

The Google Fusion Tables represents a free online cloud service for managing large collections of tabular data (data in tables). Fusion Tables takes a new approach to database management; Fusion Tables stores data on Google servers, which allows users from multiple locations convenient access to the data and powerful tools for data manipulation (Baldauf and Stair, 2011). The goal of Fusion

Tables is not to replace traditional database management systems; the objective is to offer data management functionality that exploits today's computing environment in order to effectively enable new users and uses of data management technology. Fusion Tables performed server-side map rendering, and that is an advantage of this technology because almost all spatially oriented database performed data (map) rendering by client-side.

Cloud computing offers a multitude of opportunities, but also entails some risks. Perhaps the greatest concern is the safety and privacy of data as well as the vendor lock-in issue. But it is important to know that the desired degree of security can be achieved by data encryption. In some cases, encrypted data stored in the cloud are safer than unencrypted data located in the user's data center (Baun *et al.*, 2011).

Many extensions need to be integrated inside Fusion Tables, such as more expressive data modeling and expanded query capabilities and providing adequate performance on large datasets, but currently it represents one of most advantage free cloud service solution for data managing.

In the recent past the map solutions were expensive and required special map servers, yet they did not deliver the same level of interactivity. The Google Maps is a web-based service that provides detailed information about geographical regions and sites around the world. The Google Maps API lets you harness the power of Google Maps to use in your own applications to display your own (or others') data in an efficient and usable manner (Svennerberg, 2010). Displayed data (layers) can be stored in a standard relational database (e.g. Microsoft SQL Server, PostgreSQL, MySQL, etc.), XML format, KML format and in Google Fusion Tables.

ACKNOWLEDGEMENT

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International Congress: SOIL-WATER-PLANT

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THE USE OF HIGH RESOLUTION SATELLITE IMAGES FOR DEFINING CHANGES IN THE ECOSYSTEMS

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ABSTRACT

The adequate biodiversity protection at the species and genetic level is not possible without the adequate site protection. The climate change causes the increase in the air temperature (increased evapotranspiration), decrease in the quantity of precipitation, as well as the deterioration of the soil physical characteristics. The deterioration of the water-air soil characteristics will lead to the deterioration of the structure caused by the decrease of the nutrient content. The protective role of the vegetation will be reduced; the soil erodibility will increase, as well as the number of the wildfires, whereas the site conditions will deteriorate drastically. The global changes also affect the smaller regions, owning to which the monitoring of them is of a particular importance for the changes in the ecosystems. For this purpose we use the satellite photos of the high resolution, and by the use of GIS technology the method of the monitoring of the periodical changes in the ecosystems was developed. The collected data will enable the creation of the model which contains the dynamics of changes in the natural ecosystems. This paper analyzes cadastral municipality Djurašići. The classification based on EUNIS system of the site classification was applied. By the use of the satellite photos of the high resolution (pixel size 1m) for Djurašići area the spatial distribution of the sites was defined. By the periodical recording of the characteristic areas in Serbia the spatial distribution of the ecosystems, as well as the changes in their composition and structure, will be monitored.

*Keywords***:** ecosystem, biodiversity, climate change, site, GIS

INTRODUCTION

Climate is a natural condition that most directly affects forest ecosystems. On forest ecosystems affected by climate as:
- macroclimate (planetary)
- regional climate (regional impacts of climate) and
- microclimate (climate of small spatial units, and even point (eco climate - climate of flowers or plants, air tree crowns).

Effects of climate are:
- indirectly, through climate factors (latitude and longitude, the layout of land and sea, altitude, etc.)
- directly, through the elements of climate (radiation, air temperature and soil, air pressure, wind, humidity, cloudiness, precipitation, etc.)

In its development of forest vegetation, provided that the ecosystem cannot be seriously disturbed by a change in environmental factors, reaching its peak represented a stable community, in conformity with the regional climatic conditions. As a result climatogene or climate zonal communities occur, which are tailored to regional climate conditions and the most complete reflection of the natural conditions of a region. Community-specific mountain belts are climate regional. All of these communities caused by the general climatic conditions are now simply called the zonal vegetation, including the same concept climate zonal (in plain) and climate regional (in the high mountain belts).

Projections of climate change in the 21st century

Presented according to the latest estimates of regional climate change in Southern Europe Region which belongs to the Republic of Serbia, in addition to the trend of further increase in air temperature, in the coming period is expected to further decrease precipitation, followed by reducing the number of days with snow and snow cover, reducing runoff, soil moisture and availability water resources.

Climate change projections for Europe show a reduction of annual rainfall in South Eastern Europe by 1% per decade. This decrease of rainfall in South East Europe would be the most distinctive in the warm half of the year, and for a given scenario amounted to about 22% at the end of this century. Climate change in our cause of increased air temperature (evapotranspiration increased), reducing the amount of rainfall as well as the deterioration of physical properties of soil. Deterioration of water-air properties of soil will term deterioration of soil structure caused by the reduction of organic matter. Reduce the protective role of vegetation, soil erosion ability increase the number of forest fires, and will dramatically worsen living conditions for afforestation. A large part of the negative effects caused by climate change can be reduced by proper choice of ways to use the land, the replacement of cultures and species that are adapted to new conditions and other measures. Based on monitoring changes in temperature can be planned in future afforestation activities in terms of proper choice of species (species that are best submitted made changes), such as planting materials, choosing the appropriate method of soil preparation.

MATERIAL AND METHOD

Cadastral municipality Djurašići is located in the territory of Municipality of Prijepolje. It stretches from the bank of the river Lim or the very city of Prijepolje, and rises to 1,400 meters above sea level. It borders with the cadastral municipalities Izbičanj, Crkveni Toci and Gornje Babine (Fig. 1).

Climatic characteristics were determined based on data received from weather stations Priboj, Pljevlja and Bijelo Polje. Digital Model of Terrain (DMT) was done like one of the characteristics of the studied area, and it was used as the basis for making aspect - slope map (Fig. 2-5). The zones with different geologic substrate were cartographically identified. Determination on the satellite images was performed in combination with the scanned map of geologic substrate. The zones with different types of soil were cartographically identified. It was used the Classification of the soils of Yugoslavia (Škorić, A. *et al.*, 1985).

For determination of the erosion intensity it was used the Classification made by Gavrilovic (1972). The erosion map was made based on the available documentation, the data collected in the field, the application of adopted methodology and data provided by satellite images. Present erosion processes are classified into five categories: from the weakest form of erosion (Category V) to the greatest form of erosion or excessive erosion (Category I).

Habitat classification was performed using the EUNIS habitat classification as well as by determination of habitat on satellite images and testing of selected homogeneous units in the field. Based on all the data, the attributing of homogeneous units was performed using geoprocessing method.

RESULTS

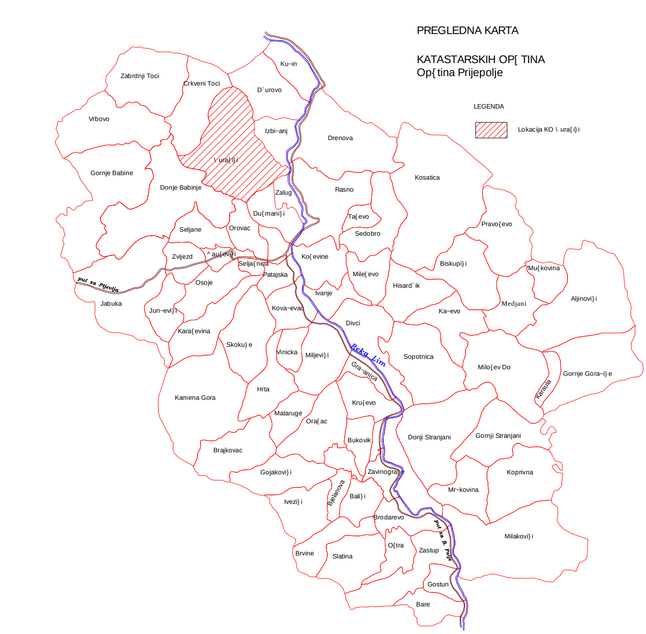

Fig. 1. Overview of the cadastral municipalities of Prijepolje

Because of the mountain nature and the flow of air masses from the south, in the studied area there are three climatic regions. These regions are mostly conditioned by relief, direction of extension and the aspect of terrain. Lowland region includes the valley of the Lim River and its tributaries, from 400 to 700 meters above sea level. In the river valley is moderate - continental climate, whose influence in this area is weakened, so the climate in river valleys is milder. On transient region there are plateaus at an altitude between 700-1300 meters. Here prevails moderate-continental climate with characteristics of mountain climate. Mountainous region is at more than 1300 meters above sea level, ie. these are the highest parts of the region where prevails mountain climate.

Djurašići cadastral municipality belongs to the basin of the river Ljupča that has the typical shape of an elongated fan. Based on the obtained values of the basin shape coefficient it can be seen that there are favorable conditions for the occurrence of high flood waters and their rapid concentration in the lower course.

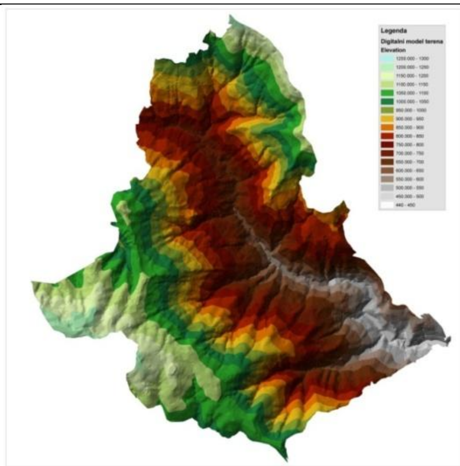

Fig. 2. Digital Model of Terrain

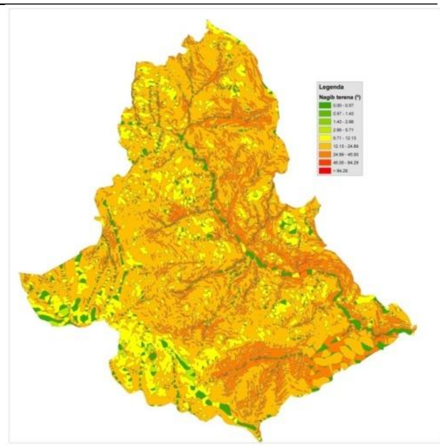

Fig. 3. Slope map

Fig. 4. Satellite image of DMT

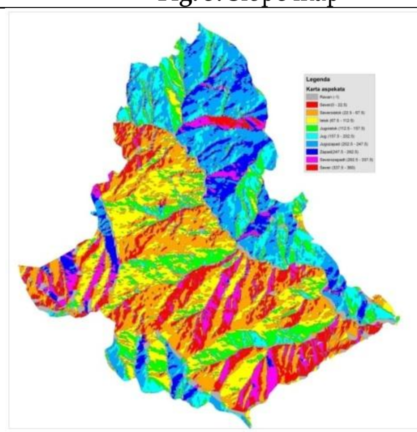

Fig. 5. Aspect map

Terrain configuration is stressed; the slopes are very steep and intersected by numerous ravines of very large longitudinal sides. Steep slope angles are typical for the flow of river Ljupča. River-bed width varies and in some places it is very narrow even below 10-15

m. Ljupča tributaries are deeply cut into the parent rock, cross-section of their basin often has the shape as the letter "V". Potential of Ljupča flow in the period of torrential rain P_{sl} is 608, which indicates the possibility of a very large flow in the period of torrential rain. In this area are presented non-classical sedimentary rocks, igneous rocks, metamorphic rocks and unconsolidated deposits (Fig. 6). Their share in the total area is shown in Tab. 1.

Table 1. Geologic substrate of cadastral municipality Djurašići

Geological substrate	Number of homogeneous units	Area (ha)	% share
alluvium	11	4,80	0,19
diabase	39	35,07	1,36
phyllite	772	2385,38	92,79
limestone	53	137,15	5,34
serpentinite	9	8,20	0,32
Total	884	2570,60	100,00

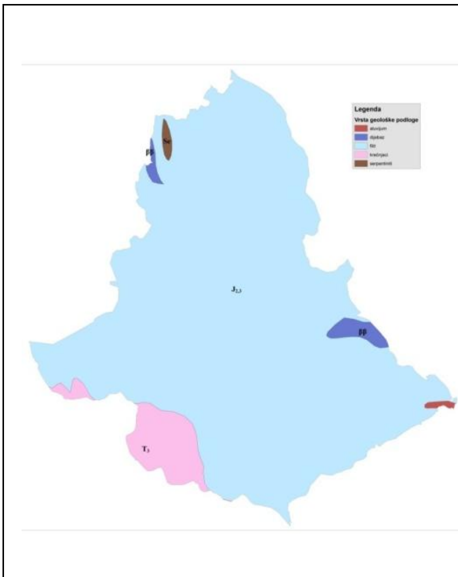

Fig. 6. Geologic map of cadastral municipality Djurašići

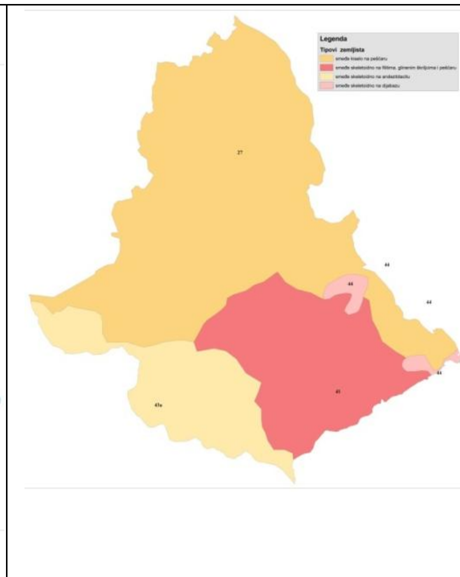

Fig. 7. Pedologic map of cadastral municipality Djurašići

The area Djurašići is characterized by hilly and mountainous relief which caused the formation of mainly shallow to moderately deep soil with different percentage of skeleton. The main types of soil registered in Djurašići area are shown in Table 2 and Figure 7.

Table 2. Represented soil types

Soil types	Number of homogeneous units	Area (ha)
acid brown on sandstone	566	1525,56
brown skeletal on andesite-dacite	106	406,87
brown skeletal on diabase	49	42,74
brown skeletal on phyllite, clay schist and sandstone	187	595,43
Total	908	2570,60

Erosion processes

Given that the hilly and mountainous land covers most of the area and that the existing geologic substrate favors the development of erosion, soil erosion processes have more or less overtook the whole area (Table 3).

Based on the data from the map, the mean value of the coefficient of erosion for the entire cadastral municipality Djurašići has been determined. Mean coefficient of erosion (Z) is 0.29, so the area is classified in IV category of destructiveness - low erosion (Figure 8).

Potential erosion endangerment. Factors that influence erosion are climate, soil type, slope, vegetation and land-use. The infiltration capacity of substrate influences the amount of surface water runoff. Surface runoff and erosion are increased with increasing of the slope degree, as well as with increasing of the slope length. The slope exposition may also influence the degree of erosion, indirectly, through the composition of the vegetation. The intensity of erosion largely depends precisely on the conservation and nature of vegetation. Forest ecosystems are characterized by high infiltration capacity and the presence of forest cover that has a high water holding capacity which affects the process of mitigating of water erosion. On the denuded areas there is increased surface runoff followed by soil depletion and erosion endangerment (Table 3, Figure 9).

Habitat classification

The concept of protection of biodiversity habitat becomes a central unit of protection. Habitat is defined as a "community of plants and animals (and other members of biocoenosis), which together with abiotic factors (soil, climate, water quantity and

quality, etc.) represents a unique functional unit" (Davies CE & Moss, D. 2002: EUNIS Habitat classification).
– European Habitats Classification System, European Environment Agency & European Topic Centre on Nature Protection and Biodiversity).

Table 3. Erosion intensity and potential erosion endangerment in cadastral municipality Djurašići

A. Erosion intensity	Num.of homogeneous units	Area of homogeneous units	%	B. Potential erosion endangerment	Homogeneous units	Area of Homog. units	%
Excessive	12	30,25	1,26	Area of very strong endangerment	13	30,82	1,28
Strong	134	229,55	9,53	Area of strong endangerment	134	246,07	10,21
Medium	125	701,62	29,12	Area of medium endangerment	128	736,03	30,54
Weak	69	166,57	6,91	Area of weak endangerment	71	120,75	5,01
Very weak	375	1281,66	53,19	Area of very weak endangerment	368	1275,91	52,95
Accumulation	-	-	-	Without endangerment	1	0,08	0,00

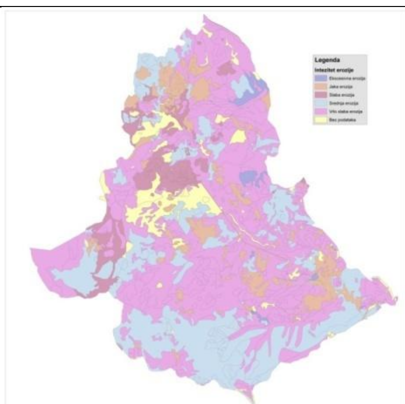

Fig. 8. Erosion map of cadastral municipality Djurašići

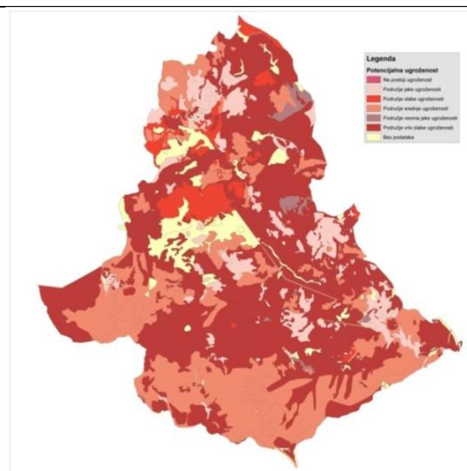

Fig. 9. Potential erosion endangerment, area of cadastral municipality Djurašići

The main documents that define the initial elements in the protection of habitat for:

- Convention on Biological Diversity - CBD - UNCED, Rio de Janeiro, 1992
- Berne Convention - Council of Europe, Bern, 1972 and
- Habitat Directive - the EU Habitats Directive 92/43/EEC.

Serbia habitat classification system is based on the EUNIS classification system (Lakušić, D. 2005). Most, but not all EUNIS habitats are actually biotopes or areas with equal environmental conditions enough to support a distinctive combination of organisms that inhabit them. All EUNIS habitats (except the smallest) include at least 100 m^2 surface, while the upper limit is determined.

At the low scale can be described and called "microhabitats" (which generally take up less than 1 m^2, and is significant for some small invertebrates and lower plants). Examples of this are dead trees from old forests, which are ideal habitats for many species decomposers. For larger scale habitat can be grouped in the so-called. "Habitat complexes" often occur in a typical mosaic, or a combination of individual habitat types, which may be in mutual dependence.

With the development of the classification itself, made the basis of parameters that includes the reference systems for climate, soil, water quality, vegetation, and typical physiographical elements, or the dominant plant and animal species

The aim of establishing this system is just creating a reference database on species, habitats and areas that forms the basis of the Directive on Birds and Habitats Directives of the NATURA 2000 network and its network of similar EMERALD Berne Convention, and is also used in the development of indicators (EEA Core Set and others) and create reports on the state of environment. Habitat types of cadastral municipality Djurašići (Table 4, Figure 10-13).

Table 4. Types of habitat in cadastral municipality Djurašići, digital processing of IKONOS satellite images

Types of habitat	No. of homogeneous units	Area of homogeneous units
C2.2 – Permanent, fast and turbulent watercourses whose levels do not change	1	3,37
E1.2B2 – Serpentine steppe on shallow rocky soil	3	11,01
E2.1 – Permanent mesophillic pastures and meadows for grazing after mowing	60	492,86
E2.13 – Abandoned pastures	6	10,21
E2.33 – Balkan high mountain meadows	131	165,50
E5.21 – Xero-thermophilic forest lanes	1	0,10
E5.22- Mesophilic forest lanes	4	2,57
F3.16 – Bushy habitats of common juniper (Juniperus communis)	12	43,44
G1.1211 – Mountain mono dominant gray alder galleries (Alnus incana)	1	0,79
G1.211 – Ash - Alder (Fraxinus) – (Alnus) forests along streams and springs	1	3,40
G1.6914 – Moesian mountain beech forests with Sessile oak (Quercus petraea)	16	141,42
G1.6926 – Moesian mono dominant acidophilous beech forests	7	18,25
G1.6931 - Moesian mountain beech forests with hornbeam (Ostrya carpinifolia)	1	1,79
G1.6941 – Moesian mono dominant mountain beech forests	7	10,60
G1.6C – Illyrian beech (Fagus) forests	5	16,18
G1.7511 - Moesian mono dominant Sessile oak (Quercus petraea) forests on limestome	5	9,09
G1.7512 - Moesian mono dominant Sessile oak (Quercus petraea) forests on serpentinite	1	3,94
G1.757 – Illyrian Sessile oak (Quercus petraea) forests	90	204,20
G1.7611 – Typical forest of Hungarian and Turkey oak	2	1,91
G1.761E – Forest of Hungarian and Turkey oak with beech (Fagus)	4	17,67
G1.871 – Moesian acidophilous Sessile oak (Quercus petraea) forests	203	751,62
G1.872 - Moesian acidophilous Turkey oak (Quercus cerris) forests	7	4,53
G1.91B – Balkan birch (Betula) forests on terrain that is not marshy	1	0,62
G1.923 – Moesian mountain beech forests with bilberry (Vaccinium myrthyllus)	5	1,11
G1.95 – Forest of European Aspen (Populus tremula) and birch (Betula) with elderberry	1	0,31
G1.D4 - Orchards	7	8,86
G1.D5 – Other orchards with high trees	2	0,80
G3.1E51 – Dinaric calciphile Common Spruce (Picea abies) forests	4	1,85
G3.1E52 - Dinaric acidophilous Common Spruce (Picea abies) forests	10	38,40
G3.F111 – Artificially established Spruce stand with naturally regenerated Sessile oak	1	0,60
G3.F14 - Artificially established Austrian pine stand	3	6,38
G3.F141 – Artificially established Austrian pine stand with naturally regenerated Sessile oak	2	0,37
G3.F16 - Artificially established Austrian and Scots pine stand	1	6,10
G3.F17 - Artificially established Spruce and Austrian pine stand	7	32,44
G4.611 – Mixed forests of beech and fir on silicate	1	0,92
G4.612 – Mixed forests of beech and fir on carbonate soils	4	59,44
G4.613 - Mixed forests of beech and fir on serpentinite	4	23,82
G4.62 - Mixed forests of beech, fir and spruce	7	16,41
G4.63 - Mixed forests of beech and spruce	41	189,13
G5.61 – Deciduous scrub forests	2	11,06
G5.71 – Coppice forests	9	26,03
G5.81 – Recently deforested areas	6	35,78
H3.2 – Basic and ultra-basic inland cliffs	4	1,53
H5.6 – Trampled areas	1	0,15
H5.61 – Bare ground	10	6,64
I1.13 – Small intensive monoculture (<ha)	3	6,61
J4.2 – Road network	1	0,10

In the area of cadastral municipality Djurašići noted the following habitats:

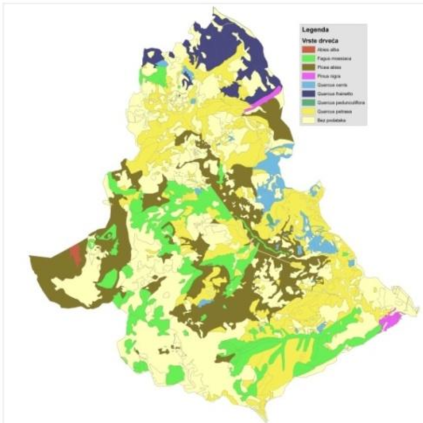

Fig. 10. Types of trees

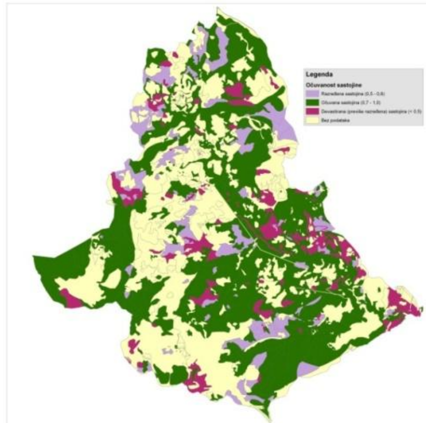

Fig. 11. Preservation of stand

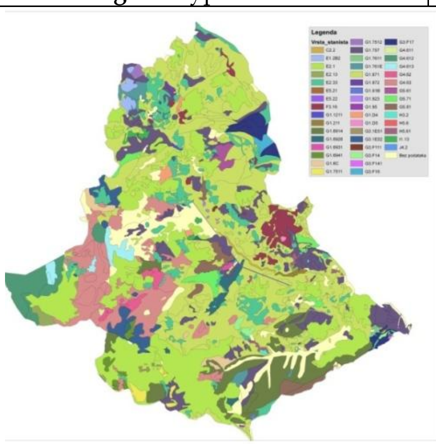

Fig. 12. Map of research habitat areas

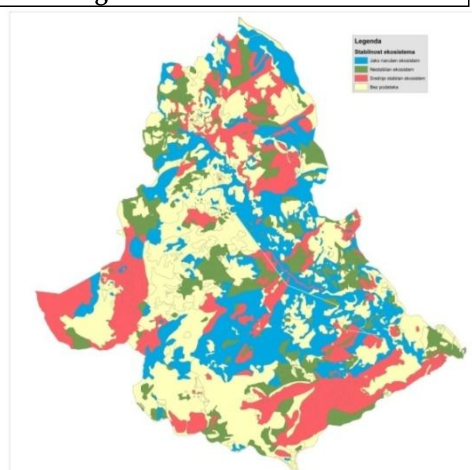

Fig. 13. Map of ecosystem stability made on the basis of satellite images

TYPES OF CHANGES HABITATS

The changes represent a translation of habitat area one category to another class of habitats. Conditions for the identification of categories of habitats using satellite imagery have changed the reflection spectrum. These changes recognize the changes in properties of elements are interpreted. On a methodological point of view it means that the Figures of two or more periods (time series) used to identify changes in land cover. They use two basic methods for the detection of changes in satellite images:

• Visual and computer-aided visual interpretation

• The method of digital identification changes

In order to monitor changes in habitat most used visual interpretation of satellite images. All necessary changes are performed at the initial (primary) layer of the data that changes only locally in the areas where they identified changes in the habitats. All unchanged polygons (homogeneous) keep the border areas from the previous period. Do not create the new database but the data supplement. This will minimize the occurrence of errors in the database during the change, which is common when comparing independently established database.

Significantly and reduced cost (drawing) polygons. On the use of high resolution satellite imagery database to form a homogeneous whole of the minimum area of 1 m^2. Changes in the habitats of the map if they reflect the actual evolution of changes in habitats (e.g. growth of settlements, clear cutting forests, etc.) rather than its seasonal changes.

Typical types of changes are:

• Changes in habitat on the entire surface of the polygon: Balkan high mountain meadows (E2.33) and abandoned pastures (E2.13);

• Exchange of land between two polygons: for example, small intensive monocultures (I1.13) with orchards (G1.D4);

• The appearance of the new polygons: for example Forest of European Aspen (Populus tremula) and birch (Betula) with elderberry (G1.95) within deciduous scrub forests (G5.61)

• The disappearance of the polygons: for example Bushy habitats of common juniper (Juniperus communis) (F3.16) with artificially established Austrian pine stand (G3.F14).

CONCLUSION

Global changes are reflected in the areas of smaller regions, so that their monitoring of great importance to changes in ecosystems. For this purpose we use high resolution satellite images, and using GIS technology developed is a method of monitoring the periodic changes in ecosystems. The collected data allow development of models that contain dynamic changes in natural ecosystems.

Periodic recording of the characteristic areas in Serbia will be followed by a spatial representation of ecosystems, as well as changes in their composition and structure.

ACKNOWLEDGEMENT

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SOIL FERTILITY AND CONTAMINATION BY HARMFUL SUBSTANCES IN RASKA AREA

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ABSTRACT

Area of Raska is situated in the south-west part of Serbia on the 3918 km2. There are two main towns Kraljevo and Novi Pazar and three municipalities: Raska, Vrnjacka Banja and Tutin. In the year 2005 the research of soil fertility, 315 soil samples were collected from that area. Samples were collected by greed system, on each 1000 ha from the depth of 0-25cm. The mostly of samples were collected from the woods, pastures and meadows as the whole area is situated on the slopes. The analyses of samples exhibit low content of lime (0-1%) and pH reaction acid to slow – acid (63 %). The content of organic matter (humus) is mainly on the high level. The content of easily –available K_2O is average to high, while easily-available P_2O_5 is low. There was not some serious contamination of the area by harmful substances as heavy metals. The content of Ni (38% of samples) and Cr (36 % of samples) was higher than MAC but it is originated from the parent rocks from the valley of Ibar which are mainly ultrabasic serpentines. In some soil samples higher content of As, Pb, Cd, Cu and Hg were observed.

Keywords: Raska district; soil fertility; heavy metals

INTRODUCTION

Agrochemical investigation conducted on the territory of Raska district are part of phase VI national macro-project "Control of fertility and levels of harmful and hazardous substances in the soil of the Republic of Serbia ", financed by the Ministry of Agriculture, Forestry and Water Management, for a period of 14 years (1993-

2007). This paper describes the characteristics and soil pollution in the Raška District.

Raska district is located in the southwestern part of the Republic of Serbia. It includes the towns Kraljevo (central district) and Novi Pazar and three municipality Raška, Vrnjacka Banja and Tutin. Relief of Raska region is mostly hilly-mountainous, with midly undulating Pester plateau.

On soil fertility and pollution is greatly affected by soil and geological composition, which in this area is different. In addition, inadequate agricultural practices, can often be a potential source of environmental pollution.

The aim of the study was to gain a realistic perception of soil fertility this region, and the state of their contamination by heavy metals.

The results allow a clear identification of areas at risk of crop production (in the case of high content of heavy metals). With the identification of contaminated areas, and determining the origin of pollution (particularly anthropogenic), it could be at the state level to enable appropriate action repairs and planned soil protection.

MATERIALS AND METHODS

Institute of Soil Science conducted a field study during 2005. At each location, the average soil sample wen taken from a depth of 0-25 cm. Samples were collected in a square grid of approximately 1000 ha (1 samples per 1000 ha). Most of the samples taken by forests, meadows and pastures.

In the prepared soil samples were conducted planned laboratory tests: pH - nKCl electrometrically, % $CaCO_3$ - volumetric, % humus - method of Kotzman, accessible P_2O_5 and K_2O - AL method according to Egner-Riehm. Available B is determined by the curcumin on spectrophotometer. F content was determined using a potentiometric ion -selective electrode for fluoride, along with previous melting Na_2CO_3. The content of total forms of heavy metals were determined by the procedure of cooking with HNO_3 and H_2O_2 and reading on the AAS.

Criterion for the assessment of soil contamination of these elements were the maximum allowed concentration (MAC) of agricurtural soil, according to the Regulation (SG RS 23/94, 1994).

Data were analyzed using descriptive statistics and correlations, and maps were drawn ArcView 8.3.

RESULTS AND DISCUSSION

Geological composition of the field Raska district is very different, which is present a great variety of soil types.

In northern areas, in the aluvium of West Morava river was formed fluvisol and humofluvisol, while on the river and lake terraces around the Kraljevo dominated pseudogley.

South is hilly mountainous area, where are at the different substrates formed rankers and, to a lesser extent, eutric and dystric Cambisols. On the mountains around the Ibar viver there are rankers on serpentines. A significant part of the area around Novi Pazar and Raska make eutric and distric cambisols on andesite and dacite and their tuffs. In the eastern part of the Raška area are two large granodiorite massif. Southwest of Novi Pazar there are rankers on shales and sandstones.

They are in the complex with hard limestone on which iz formed calcocambisol, Calcomelanosol and Lithosol. Because of the different geological composition and soil types, agro-chemical characteristics and heavy metal content in soil Raska district is quite uneven.

a) Acidity and basic chemical properties of the soil Raska district:

Measured soil pH varied from very acid (3,20) to alkaline (7,40). Class of highly acidic soil makes 20,4 % of the samples - they are rankers on granodiorit, shale and sandstone and some pseudogleys around Kraljevo. Other samples had favorable pH: medium acidic soil (the most common - 38% of samples), and slightly acid (25% of samples), and neutral soil (15% of samples). At least the samples is with an alkaline reaction (1,6%). Values pH are shown in Table 1. and map 1.

Raska district characterized mainly non-calcareous soils and very low calcareous soils (91% of samples< 1% $CaCO_3$), while the percentage of low and middle calcareous soil are low (6% and 3% of samples). In sporadic samples were measured and very high values of carbonates, and their maximum measured value was 33,6 %.

According to the humus content, soil are generally medium provided (61% of samples) and high provided (35%), while only 4%

of the samples are with low humus content. However, due to the sporadic samples were recorded large variations in humus, from 0.44% to 13.88 % (Tab. 1).

In the tested samples were found available phosphorus values ranged from 0.01 to 91,35 mg/100 g of soil (Tab. 1 and Map 2). In a significant percentage were found very low (80,3%) and low (6,3%) contents of the element (total 86,6%). The smallest proportion mapes samples with medium (3%), or high (5,4%) content of the element. About 5 % of the samples had a very high content of phosphorus, which occurs probably as a result of inadequate fertilization.

Poor supply of soil in Serbia with phosphorus was identified also in other studies (Mrvić *et al.*, 2010; Čakmak, 2009).

In terms of readily available potassium content in the samples are also measured a large variation from 3,60 to 55,00 mg/100g of soil (Tab. 1). About 63% of samples is medium to good supplied with potassium, while a small percentage (about 16% of the samples) has a high content of this element. Unlike phosphorus, class of very low potassium content is represented only about 14%, samples in the class of low content 8% of soil samples.

b) The contents of all forms of hazardous and potentially harmful substances and available boron

In addition to the basic indicators of soil fertility in the Raska region it was examined also the content of total forms of hazardous substances (As, Pb, Cd, Ni, Cr, Hg) and potentially harmful elements (Cu, Zn total and affordable B). Specified harmful elements also represent the biogenic elements, which in high concentrations can have negative effects on the plant and on other parts of the environment.

Presence of hazardous substances in the soil vary within wide limits, (Tab. 2 and 3). The increased value above the maximum allowable concentration (MAC, SG RS 11/90) were found in a significant percentage of Ni and Cr (38 % and 28 %), and considerably lower in Pb, As and Cd (9 %, 5 %, 3%), while those of Hg and Cu above the MAC were found only in one sample (0.3 %). Concentrations of total Zn and accessible B, in the samples do not exceed permissible levels.

The measured concentrations of Ni and Cr were significantly higher than MAC and in relation to the concentration of other dangerous and potentially harmful elements are fairly. Concentrations Ni in soil ranged from 0,4-793 mg kg^{-1} (average 109 mg kg^{-1}). The values of this element above the MAC (50 mg kg^{-1} were find in 38% of samples, and values above 100 mg kg^{-1} in 28% of samples. Concentrations of Cr ranged from 0,35-869 mg kg^{-1} (approximately 106 mg kg^{-1}), and the potential contamination of this element (above 100 mg kg^{-1}) was present in 28% of samples.

It is likely that such high contents of Ni and Cr are natural (geochemical origin) located in the bedrock of ultrabasic rocks, serpentine. Observed an increased content of these elements in the rankers on serpentine rocks, which occupy a large part of the territory around Ibra - mountain Goc, Stolovi, Cemerno, Rogozna, part to Studenica (also indicate increased concentrations of Mg, Fe and Co). The works of many researchers (Djordjević, *et al.* 2005; Jakovljević and Stevanović 2004; Mrvić *et al.* 2011; Adriano, 2001) also point to the increased content of Cr and Ni in the serpentine rocks.

In addition, in the West Morava river valley, in several samples were found high concentrations of Ni. That alluvial deposits in the river valleys, created under the influence of ultrabasic rocks have naturally high content primarily (Ni, Cr, Co and Mg) was also indicates by previous researches (Sikirić *et al*., 2010; Jakovljević *et al.* 1979).

On the geochemichal origin the pollution indicates the high correlation of Ni and Cr.

The concentrations of Pb in the studied soil samples ranged from 11-300 mg kg^{-1} (approximately 66 mg kg^{-1}), of which 29 samples (9%) exceeded the limit of MAC.

The total content of As ranges from 0,1-382 mg kg^{-1} (mean 14 mg kg^{-1}). Potential contamination of As is present in some samples (5%).

Higher levels of Pb and As were found in some samples of Raska, on the slopes of Kopaonik, in soil on andesite tuffs, and on the slopes Cemerno, mostly in rankers on schist.

Cd content varied in the range of 0,05-9,5 mg kg^{-1} and only 3% of the samples exceeded the MAC limit (3 mg kg^{-1}), in the interval of 2-3 mg kg^{-1} was also only 3% of the samples. Increased concentrations of this element occurring in different types of soil (usually calcocambisol, cambisol on diabase, schist, serpentine).

The values of Hg and Cu above the MAC were measured only in one sample (0,3%). Concentrations of total Zn and affordable B, in the samples do not exceed MAC (Tab. 3).
The maps 3 and 4 represents the territorial distribution of Ni and Pb.

Table 1. Basic chemical properties of the soil in the Raška District

Statistical parameter	CaCO	pH	Humus	P_2O_5	K_2O
Medium value	0.63	5.40	5.06	6.16	21.73
Median	0	5.30	5.16	2.07	19.20
Stand.deviation	3.23	0.99	1.10	12.72	11.26
Minimum	0	3.20	0.44	00.1	3.60
Maximum	33.6	7.40	13.88	91.35	55.00

Table 2. Total content of As, Cd , Cr, Ni and Pb in Raška District

Stat. parameter	As	Cd	Cr	Ni	Pb
Medium value	13.70	0.87	106.30	109.1	65.89
Median	7.90	0.60	44.20	23.3	63.10
Stand.deviation	32.81	0.16	143.01	179.1	31.22
Minimum	0.1	0.05	0.35	0.4	11.05
Maximum	382	9.50	869	793	300
% of samples with valuable. > MAC	16sampl. 5%	10sam. 3%	89sam. 28%	120sam. 38%	29sam. 9%

Table 3. The total content of Hg, Cu, Zn and B accessible in Raška District

Stat. parameter	Hg	Cu	Zn	B
Medium value	0.16	22.6	34.5	0.51
Median	0.09	19.2	30.9	0.48
Stand.deviation	0.37	19.7	20.0	0.16
Minimum	0.01	4.1	5.5	0.18
Maximum	5.71	214.9	216.6	1.32
% samples with valuable. > MAC	1sampl. 0.3%	1sampl. 0.3%	0%	0%

CONCLUSION

The Raska district have is a great diversity of soil types, with a uneven agrochemical properties. Very acidic soil present 20,4 % of samples, and other soils, with appropriate cultural practices may be favorable for agricultural production, it is mainly calcareous soils and very poorly calcareous soils (91 %), with intermediate (61 % of samples) and high (35 %) content of humus.

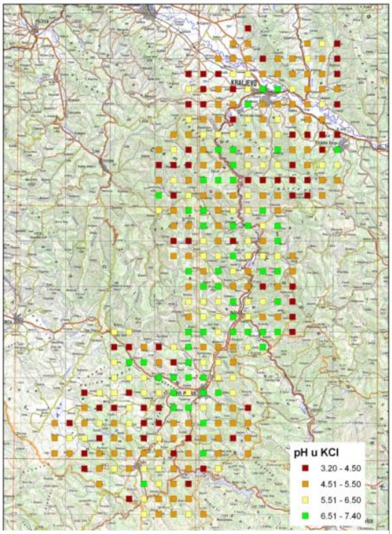

Image 1. Value pH in the territory of Raska district

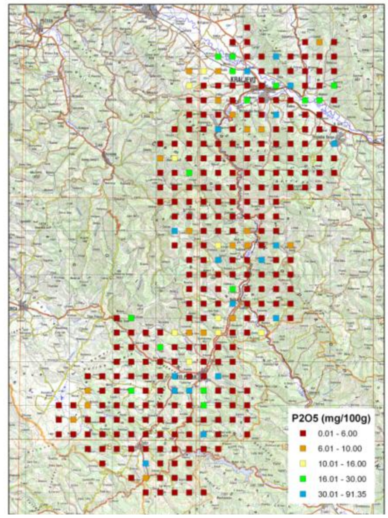

Image 2. Content of phosphorus in the territory of Raska district

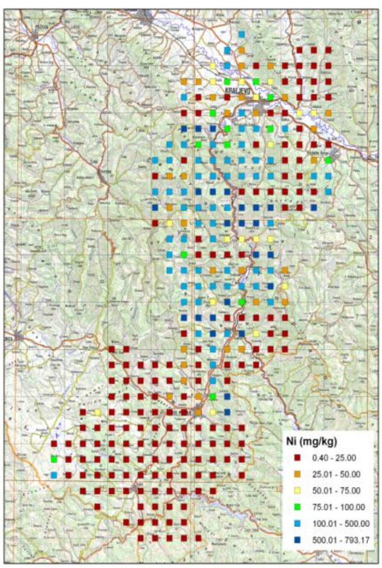

Image 3. The content of total Ni in the territory of Raska district

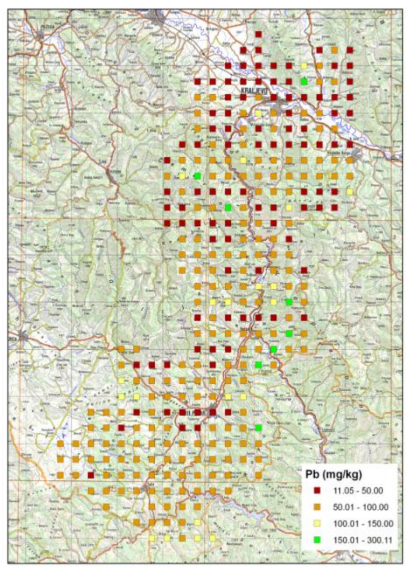

Image 4. The content of total Pb in the territory of Raska district

In a significant proportion was found very low and low available phosphorus content (87%) and medium to high content of available potassium (63% of samples).

The majority of soil samples were not contaminated with heavy metals. As the most common pollutants occur: Ni (38% samples above MAC) and Cr (28% of the samples exceeded the MAC), and much less Pb and Cd, Hg and Cu (9% and 3%), Hg and Cu values above the MAC are represented with 0,3%.

Conducted agrochemical analysis basically shows a relatively good of the overall condition soil pollution by heavy metals.

ACKNOWLEDGEMENT

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AUTHOR INDEX