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SPECIAL EDITION

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The theme of the Congress:

PROTECTION OF SOIL AS A FACTOR OF SUSTAINABLE DEVELOPMENT OF RURAL AREAS AND IMPROVEMENT OF ENVIRONMENT

The Congress is being organized for the first time since gaining independence of Bosnia and Herzegovina in the 1992, to mark the 2015 as International Year of Soils designated by the United Nations. Congress has provided a unique opportunity to point out to an inadequate recognition of significance of soil and raise awareness on crucial role of this natural resource for environmental quality. This Special Edition of the 9th Congress of the Soil Science Society of Bosnia and Herzegovina is an effort of our Society and community to contribute this initiative.

The journal is abstracted and indexed in CAB abstracts, Index Copernicus and EBSCO. The manuscripts are reviewed by at least two reviewers.

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C O N T E N T

FOREWORD

Soil has numerous functions that are indispensable for life on Earth. It provides food, biomass, raw materials, habitats and gene pools; it stores, filters and exchanges nutrients, carbon and water.

In Bosnia and Herzegovina, but also in the wider region, soil as a natural and economic resource is not properly recognized. Damage and loss of fertile (agricultural) land during the transitional period in the past two decades are becoming an increasingly huge problem. The land use and protection policy that is implemented at the national level is not in compliance with European or global level of requirements for and concerns about this natural resource. It is obvious that the golden age of agriculture in this region is over. In this regard, there is an ever growing concern that along with agricultural the soil science will get abandoned as well. However, many publications dealing with sustainable development and survival of civilization on Earth prove exactly the opposite - a large part of humanity is still affected by hunger and the soil has a broader socio-economic and environmental significance. Pedologists have to address all these issues and try to resolve them in connection with other associated scientific areas they normally rely on.

Pedology and soil related knowledge has a rich history in this area. The soil science in B&H as well as in the wider region has been successfully developed for a long time which is evident in a number of very significant scientific conferences and published papers.

The 9th Congress of the Soil Science Society of Bosnia and Herzegovina held in Mostar was a chance to present the status of soil quality, to review the severity of threats the soil is exposed to and exchange the information on soil protection activities in the European Union and some neighboring states.

Since the *United Nations* have designated 2015 as the *International Year of Soils* and December 5th as the *World Soil Day*, which will be observed every year, the 9th Congress of the Soil Science Society of Bosnia and Herzegovina, organized for the first time since gaining the independence in 1992, is an effort of our Society and community to contribute this initiative.

We wish to *thank you all* for *contributing* to the success of the *Congress.*

Prof. dr. Hamid Čustović
President of the Soil Science Society
of Bosnia and Herzegovina

PREDGOVOR

Zemljište je nosilac brojnih funkcija neophodnih za život na Zemlji. Osigurava hranu, biomasu, sirovine, staništa i rezerve gena, skladišti, filtrira i izmjenjuje hranjive materije, ugljik i vodu.

U Bosni i Hercegovini, ali i na području šireg regiona, zemljište kao prirodni i privredni resurs ne prepoznaje se na pravilan način. Oštećenja i gubici plodnog (poljoprivrednog) zemljišta tokom tranzicijskog perioda u posljednjih dvadeset godina poprimaju sve veće razmjere. Politika zaštite i korištenja zemljišta koja se vodi na nacionalnom nivou nije u skladu ni sa evropskim, ali ni sa globalnim nivoom potreba i zabrinutosti za ovaj, jedan od najvažnijih prirodnih resursa. Očigledno je da je na našim prostorima zlatno doba poljoprivrede prošlo. S tim u vezi, sve je veća bojazan da će se zajedno s poljoprivrednom naukom zapustiti i nauka o zemljištu/tlu. Međutim, u mnogim publikacijama koje se bave održivim razvojem i opstankom civilizacije na Zemlji dokazuje se upravo suprotno, obzirom da veliki dio čovječanstva još uvijek gladuje i zbog toga što tlo ima širi društveno-ekonomski i ekološki značaj. Pedolozi se moraju baviti svim tim problemima i pokušati da ih riješe zajedno sa povezanim, drugim naučnim područjima na koja se inače oslanjaju.

Pedologija i znanje vezano za zemljište imaju u ovoj regiji dugu istoriju. Nauka o zemljištu u BiH, ali i u širem regionu, dugo se veoma uspješno razvijala što pokazuju održani, veoma značajni naučni skupovi i objavljeni radovi u prethodnom periodu.

IX Kongres Udruženja za proučavanje zemljišta/tla u Bosni i Hercegovini, koji je održan u Mostaru, predstavljao je šansu da se prezentira stanje kvaliteta tla, procijeni ozbiljnost prijetnji kojima su tla izložena, te da se razmijene informacije o aktivnostima na zaštiti tla u zemljama Evropske unije i nekim susjednim zemljama.

Obzirom da je kalendarska 2015. godina proglašena je od strane UN-a *Svjetskom godinom zemljišta/tla*, a 05. decembar *Svjetskim danom zemljišta/tla*, koji će se obilježavati svake godine, IX Kongres Udruženja za proučavanje zemljišta/tla u Bosni i Hercegovini, organizovan po prvi put od sticanja nezavisnost 1992. godine, je doprinos našeg Udruženja i zajednice obilježavanju *Svjetske godine zemljišta/tla*.

Zahvaljujemo se svima koji su doprinijeli da Kongres bude uspješan.

Prof. dr. Hamid Čustović

Predsjednik Udruženja za proučavanje zemljišta/tla u Bosni i Hercegovini

EUROPEAN LAND QUALITY AS A FOUNDATION FOR THE SUSTAINABLE INTENSIFICATION OF AGRICULTURE

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Introductory lectures UDK 631.41(4)

ABSTRACT

Based on 3 large European sets of soil and land data 6 land indicators for soil resilience and soil performance were chosen for defining land and soil surfaces in Europe, on which sustainable agricultural production can be achieved and under which conditions. In this context, also desintensification on specific areas was proposed in order to achieve sustainability and environmentally safe conditions. On this basis data for arable land in 25 states of the EU 28 could be established, indicating that on 41% of the arable land a sustainable intensification is possible, on 4% extensification is needed, and on the remaining 55% no intensification is possible or only with restrictions.

Keywords: *arable land, agricultural intensification, sustainability, soil and land indicators, soil resilience, soil performance, Europe*

INTRODUCTION AND DEFINITION OF THE AIMS

By 2050, the world population will reach more than 9 billion according to actual UN projections (Alexandratos and Bruinsma, 2012). Besides the growth of population, higher per-capita income, and increasing demand for meat/ fish and dairy products, the total demand for food will increase (Godfray *et al*., 2010). The “green revolution” starting in the 1960s allowed an enormous increase of yield in the past 40 years mainly due to greater inputs of fertilizers, irrigation, new crop strains, agricultural machineries and other technologies (Tilman *et al*., 2002). However, studies show that the increase of yields at the current state would not meet the future demand for food (Ray *et al*., 2013). To meet the needs of agricultural products by 2050, further intensification of food production will be necessary. It has to be considered, that high input production needs more energy, fertilizer and irrigation. This has adverse effects on soil and

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environmental quality such as biodiversity, groundwater and surface water quality, and air due to greenhouse gas emissions.

An agricultural production, where “yields are increased without adverse environmental impact and without the cultivation of more land”, is defined as “Sustainable intensification” SI (The Royal Society London, 2009). This form of production combines energy flows, nutrient cycling, population-regulating mechanisms, and system resilience to intensify existing arable land without harm to the environment or other economic or social factors (Pretty, 2008).

As food security is intimately related to soil security and sustainable agriculture (The Royal Society London, 2009), the resilience (the capacity of systems to return to a (new) equilibrium after disturbance) and performance (the capacity of systems to produce over long periods) of soil under intensification must be considered (see also Blum and Eswaran, 2004).

Soils perform environmental, social, and economic functions (Blum, 2005): (1) biomass production for different uses; (2) buffering, filtering, biochemical transformation; (3) gene reservoir; (4) physical basis for human infrastructure; (5) source of raw materials and (6) geogenic and cultural heritage. Sustainable land use has to harmonize the use of these six soil functions in space and time, minimizing irreversible uses like sealing, excavation, sedimentation, acidification, contamination or pollution, and salinization (Blum, 2005).

To define the capacity of soil systems to provide goods and services for a long term, indicators have been chosen which are comprehensive enough to characterize the intrinsic potential of soils to level out or to reduce negative impacts of agricultural intensification. Fertile soils with specific characteristics have a high resilience against physical, chemical and biological disturbances such as erosion, compaction, contamination of air, plants and water, and against loss of biodiversity. They can therefore protect the groundwater against contamination, maintain biodiversity and reduce or minimize erosion and compaction. Soils with these characteristics also show a high performance and can produce a maximum of agricultural commodities if managed accordingly.

The main objective of this work was to identify the most important soil intrinsic parameters (indicators) which determine soil resilience and performance according to the ecological functions of soil.

MATERIAL AND METHODS

The suitability for SI is based on intrinsic soil quality parameters such as ‘resilience’ against adverse ecological impact and ‘performance‘ in the sense of long lasting productivity and was defined with 6 soil parameters (= indicators). The indicators presented in Table 1 were chosen based on available literature and expert knowledge. They were scored according to defined threshold levels in terms of poor (1), medium (2), good (3) and in some cases excellent (4) conditions.

	excellent	*good*	*medium*	*poor*	*unit*
SOC %	*≥ 4*	*2-4*	*1-2*	*≤ 1*	*%*
Clay+Silt	*≥ 50*	*35-50*	*15-35*	*≤ 15*	*%*
pH		*6.5-7.5*	*5.5-6.5; 7.5-8.5*	*≤ 5.5; ≥ 8.5*	*in H_2O*
CEC		*>25*	*10-25*	*≤ 10*	*cmol/kg*
Depth*		*≥ 60*	*30-60*	*≤ 30*	*cm*
Slope**		*≤ 8*	*8-15*	*15-25*	*%*

** Estimated according to WRB 2006 (see Schiefer et al., 2015)*
*** Sites with slopes>25% were excluded from calculations*

Data for these indicators have been taken from the Land Use/Land Cover Area Frame Survey 2009 (LUCAS), i.e. soil organic carbon (SOC) content, clay+ silt content, soil pH, and cation exchange capacity (CEC), which was carried out in 25 member states, and the European Soil Data Base (ESDB) 2.0 1:1,000,000 (i.e. slope and depth) provided by IES/JRC European Commission. To exclude sites not under agricultural cropping, a map of arable land from Corine Land Use Cover (CLC 2000) was used. All analysis was carried out with ArcGIS 10.2.

By summing up all the scores, a minimum value of 6 and a maximum value of 20 (4 points for SOC content as well as for clay + silt content and 3 points for pH, CEC, depth and slope, respectively) could be attributed to a land unit. The total score points were separated into four different categories of SI potential.

Land with lowest quality has only a final score between 6 and 10 (category 1). This means that the soil has intrinsic properties, which cannot support environmentally friendly intensification and therefore even extensification is suggested. Land in category 2 can show medium or good conditions (score >10), but one or even more indicators are in a "poor" condition (see table 1) and therefore an intensification is only possible with a high risk. A total score of 11 to 15 represents the medium category 3, where a low potential for SI is given, meaning that intensification should only be done with much caution. Land which can be recommended for SI (category 4) presents soils, which can compensate environmental impacts, show good agricultural production, and have a total score from 16 to 20. This land was recommended for intensive agriculture under the precondition that it is managed in a sustainable way.

This classification scheme was also applied at a local scale in Rutzendorf/Marchfeld in the eastern part of Austria (Figure 1). Data were taken from the soil quality index for cropping which was elaborated by the Austrian Soil Taxation using a very detailed raster for soil sampling (40-60 meters).

RESULTS AND DISCUSSION

This work is a conceptual approach in order to identify soils with a potential for SI based on existing data. Because of a lack of data, not all arable land could be covered by this study. The results show for an analyzed area of 671.672 km^2 of arable land in Europe, that almost half of it (49%; class 1 + 2) is not suitable for sustainable intensification. Out of this, 4% have such bad intrinsic soil qualities that intensification cannot be considered (class 1). It is recommended to rather de- intensify and to reduce land use intensity in order to avoid environmental harm. 12% of the area is in medium conditions, which means that a sustainable intensification on this land is not possible at the present state. This land should be used with precaution. Intensification without environmental risks can only be implemented at 41% of the analyzed land, because this land has a high resilience against negative impacts from intensive agricultural production and showing a high performance at the same time.

The most frequent limiting factor for sustainable intensification is the cation exchange capacity (CEC). Clay content, pH and soil organic carbon (SOC) cause similar constraints in many areas. These soil properties influence each other and are also linked to the CEC.

Portugal, Poland, Greece and Spain are examples for countries with limited soil resources for intensive agriculture. Soils in regions around river basins in general show positive resilience and persistence. It is also found that proportionally seen, agricultural land suitable for SI counts for more than 60% in Belgium, Slovak Republic, the United Kingdom, Latvia, the Netherlands and Hungary.

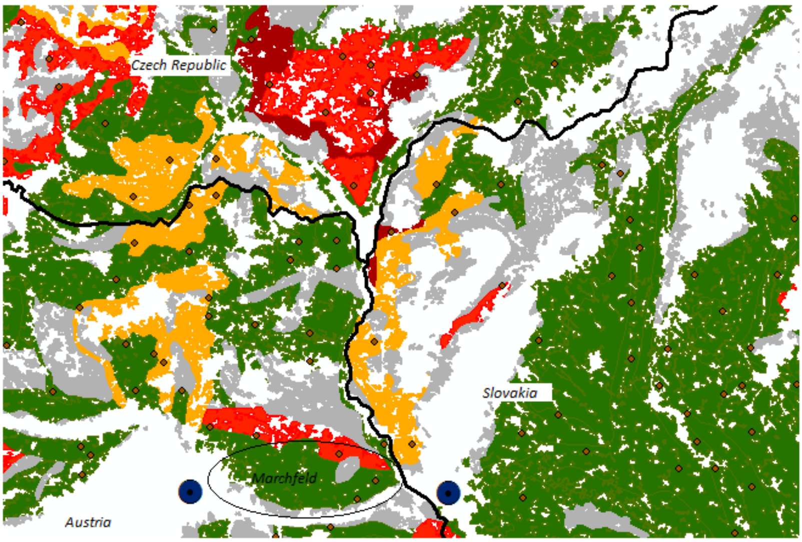

Figure 1. Land suitability for SI in Austria (Marchfeld), Czech Republic and Slovakia

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SOILS WITHIN THE POST-2015 SUSTAINABLE DEVELOPMENT AGENDA

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Introductory lectures UDK 631.4:502.1

ABSTRACT

Soils are considered across the Rio Conventions and while some advances have been made in the past two decades, implementation remains lacking and soil-related issues persist. This calls for a more integrated approach for the implementation of the Conventions. Similarly, soils will play a key role to achieve the post-2015 development agenda and can be found across the proposed Sustainable Development Goals (SDGs). This cross-cutting role is not being sufficiently acknowledged in the negotiations. Putting soils on the policy agenda will depend on a major shift in the discussion to recognize that soils underpin a wide range of services and should, therefore, be protected for future generations. Concerted efforts for advocacy within the post-2015 development agenda need to focus on keeping soils on the agenda and on making proposals for the effective implementation and monitoring of the SDGs.

Keywords: *soils, political advocacy, sustainable development goals, UNCCD, UNCBD, UNFCCC*

INTRODUCTION

Albeit being essential to sustainable development, soils have never been the specific focus of a Multilateral Environmental Agreement (MEA). However, as a crosscutting theme they are considered within the three Rio Conventions as they can contribute to climate change mitigation, they hold a large pool of biodiversity and are continuously affected by desertification. The three "Rio Conventions" are the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD). These MEAs were negotiated at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. As the main binding global environmental agreements they are considered the framework in which the countries of the world can implement sustainable development initiatives aiming at the

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reduction of human induced climate change, the protection of biological diversity and the limitation of desertification processes in drylands.

Putting soils on the agenda of these MEAs has involved a long process that required a large effort of awareness-raising and communication of issues related to the degradation of soils and land by scientists, civil society organizations and policy-makers. The convention texts of CBD and UNFCCC leave out soils but they are addressed in the text of the UNCCD and on the actions prescribed by the tree conventions such as the development of national action plans and the definition of specific targets and indicators for the monitoring of these resources at national level.

Twenty years after the conference in Rio we could take stock of the achievements at the Rio+20 meeting on sustainable development in 2012 in Rio de Janeiro. Indeed, some progress has been made but we are still observing extensive land and soil degradation processes in the world and we are rapidly depleting fertile soil resources that can be used for food production [1]. Conscious of these alarming trends, countries participating at the Rio+20 sustainable development conference agreed in the outcome document "The Future We Want" that we should "*strive to achieve a land-degradation-neutral world in the context of sustainable development*" [2]. A wide discussion on the definition of this concept and the concern of it potentially leading to the offsetting of land degradation in one place by restoration actions in another was triggered amongst scientists and on the political level amongst Member States in the framework of the process to set a Post-2015 development agenda and the proposed Sustainable Development Goals (SDGs) [3] to be signed off by the UN General Assembly in 2015. This soft law process follows the premise of the preceding Millennium Development Goals [2] and goes beyond by corresponding to the growing interest in the development of a universal and transformative agenda that provides a framing and a global vision for sustainable development that links environmental and development issues.

The aim of this article is to provide a review of current approaches of the three Rio Conventions to address soils and land and efforts to integrate soils and land in the Post-2015 process and the SDGs. We aim towards addressing the scientific community as well as the policy makers, attempting to bridge between policy and science by translating available scientific knowledge to potential policy recommendations. Some reviews of the provisions that address soils in international and national law have been made [4] [5] [42-44], but there has not been a comprehensive assessment of their integration in the political debate at the global level, in particular in the three Rio Conventions and especially linked to their role in the Post-2015 development agenda and the proposed SDGs. The following sections will discuss the links between soil resources and the conventions on climate change, biodiversity and desertification. These resources should be integrated in the conventions but are only partially or indirectly addressed. It seems that the SDGs offer an important opportunity to highlight the underpinning role of soil resources for sustainable development across the different themes.

SOILS AND CLIMATE CHANGE

Soils hold the second largest carbon pool on earth after the oceans. Estimates of the organic carbon pool vary globally between 1463 and 2011 Gt in the top 1 m of soil. This is due to the lack of reliable and updated global soil data since not all countries have monitoring systems, there are difficulties presented by the lack of comparability, temporal variability and the costs associated to obtaining the data [6]. This large carbon pool is in a constant equilibrium with the other pools and is highly sensitive to land use changes [7]. Any disturbance of the soil that increases mineralization rates of the carbon pool will cause a decrease of the carbon in the soil and the emission of carbon dioxide to the atmosphere [8]. For instance, agricultural practices that involve tillage will cause a rapid decrease of soil organic carbon levels. Lal [9] provides a comprehensive overview of the relevance of the soil organic carbon pool for climate change and potential implications of land use changes on greenhouse gas emissions.

The UNFCCC, adopted in 1992, aims to stabilize greenhouse gas emissions ‘‘at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system’’ [10]. According to fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC) [11], an important mitigation measure is to increase the size of existing carbon pools, thereby extracting CO_2 from the atmosphere (e.g., afforestation, reforestation and carbon sequestration in soils).

Overall, protecting and building-up the carbon stock of soils to avoid its release into the atmosphere can substantially contribute to climate change mitigation. Unfortunately, during the UNFCCC negotiations and the subsequent adoption of the Kyoto protocol the soil organic carbon pool has remained rather neglected. Only in recent years has there been a growing attention to peatlands, and very recently [45] to the potential of agricultural soils for climate change mitigation. The strong interest in peatlands and organic soils is because they account for the largest proportion of soil organic carbon and because these soils are particularly sensitive to climate change and land use changes [12]. Organic soils in boreal areas, mainly in Russia and Canada, are of major concern. This is due to the changes in permafrost-affected areas and the related possibility of rapid mineralization of large organic carbon pools within peatlands under permafrost conditions. Permafrost underlies 24 per cent of the northern hemisphere, can be over 2.5 million years old and up to 1,600 m deep [13]. It has an active layer which freezes and thaws each year. Warming is causing increased permafrost thaw, and the depth of the active layer in carbon-rich regions is projected to increase, causing land subsidence and coastal erosion, and ultimately increased release of carbon. Although there are large uncertainties involved in current thermal models estimating permafrost extent and thaw, there is clear agreement that permafrost coverage will decrease this century, and fluxes of carbon from thawing permafrost by 2100 are estimated between 1.2 and 1.6 Gt C/year (equivalent to half of all fossil fuel emissions from the industrial age to today). Of particular concern in this context is obviously the possibility of large methane emission, a gas with much higher greenhouse potential then carbon dioxide [14].

Parties to the UNFCCC agreed to take precautionary measures, to develop and implement policies and programs to reduce greenhouse gas emissions, to provide support to developing countries and to report annual inventories of emissions [11]. Under the Kyoto protocol [15], industrialized nations (except the US) agreed on reductions on emissions. In addition, Parties recognized the importance of addressing unsustainable land use changes but unfortunately soils were not defined as a priority. Article 12 of the Kyoto Protocol further sets a Clean Development Mechanism through which countries in Annex I earn ‘‘certified emissions reductions’’ through projects implemented in developing countries. These include projects for afforestation and reforestation.

The Conference of the Parties (COP) has over the years struggled to achieve concrete commitments and the implementation of measures that force Parties to cut back their greenhouse gas emissions to a level equal or below the levels in the year 1990. Some stakeholders in this process complain about the, so far, rather shallow provisions and commitments made by States. Many were disappointed when Parties met in Bali in 2007, Copenhagen in 2009, Cancun in 2010 and again in Durban in 2011 [16] [17] only to produce more ‘hot air’ provisions and commitments [16]. The so-called breakthrough climate agreement between the US and China to curb carbon emissions seems to show a new leadership from the highest emitting countries, largely uncommitted in the negotiations until now. In addition, recent discussions in Lima, Peru which shifted the focus from emission caps to ‘voluntary contributions’, are believed to have renewed momentum for the negotiation of a new global climate agreement to limit the temperature rise to 2°C which is expected to be reached at COP21 meeting in Paris 2015. Soils should play a role in these discussions for their potential role in global mitigation efforts. The French Government has recently announced [45], in preparation of COP 21 of UNFCCC, the *‘establishment of an international research program, which aims to develop agronomic research to improve organic matter stocks at an annual rate of 4 per 1000. Such an increase would offset emissions of greenhouse gases on the planet’* and it was also mentioned in a press conference that this research program would lead to an *‘action plan contributing to the agenda of solutions promoted by COP21’* helping to *‘reconcile food security objectives and the fight against climate change’*.

SOILS AND BIODIVERSITY

Reductions in soil biodiversity make soils more vulnerable to other degradation processes. Therefore, soil biodiversity is often used as an overall indicator of the state of soil health. Although the complexity of soil biodiversity dynamics is not yet fully understood, there is evidence that biological activity in soils is largely dependent on the occurrence of appropriate levels of organic matter. The quantification of soil biodiversity is extremely limited and confined to projects of local relevance. As the main effects of loss of biodiversity are indirect, the estimation of its economic costs is still rather difficult, but nevertheless some recent estimates [18] are available. These conservative estimates show the annual value of ecosystem services provided by soil biodiversity to be $1.5 trillion. This amount rises to $13 trillion once ecosystem good such as crops and timber are included. This demonstrates the vast economic benefits of soil biodiversity and its conservation. Preventing the decline of soil biodiversity must therefore be of paramount importance and it has understandably continuously gained relevance in dialogues connected to the CBD.

The CBD, which came into force in 1993, aims at the conservation of biological diversity, the sustainable use of its components and the fair, equitable sharing of the benefits arising from the utilization of genetic resources. The convention in its preamble frames the conservation of biodiversity as a common concern for humankind [19], which lays the foundation for the conservation of soil biodiversity globally. The role of soils in the convention text is almost non-existent which is surprising since soil is the habitat for an enormous variety of living organisms [20]. One gram of soil in good condition can contain up to 600 million bacteria belonging to 15,000 to 20,000 different species. In a pasture, for each 1 to 1.5 tons of biomass living on the soil (livestock and grass), about 25 tons of biomass (bacteria, earthworms and so on) are in the first 30 cm of soil underneath. Soil bacteria, fungi, protozoa and other small organisms play an essential role in maintaining the physical and biochemical properties needed for soil fertility. Larger organisms, worms, snails and small arthropods break up organic matter which is further degraded by microorganisms, and both carry it to deeper layers of soil, where it is more stable. Furthermore, soil organisms themselves serve as reservoirs of nutrients, suppress external pathogens and break down pollutants into simpler, often less harmful components [21] [22].

Actions prescribed under the CBD, however, do provide the basis for the protection of soil biodiversity. Under the convention, countries must develop national programmes strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plan or programmes [19]. This is important as the convention recognizes soils as the most important source of land-related biodiversity. Additionally, under article 7 of the Convention [19], a member country needs to identify activities likely to have adverse effects on biodiversity and monitor their impacts through sampling and other techniques in order to establish an information management system. Article 8 [19], also sets provisions that help achieve the Convention’s conservation goals. Here, Parties are required to establish a system of protected areas where special measures need to be taken to conserve biological diversity. These provisions can be used to put areas of ecological importance under special conservation regimes. Also, under article 8f, Parties are to rehabilitate degraded ecosystems and article 10d requires Parties to support local populations to develop and implement remedial action in degraded areas where biological diversity has been reduced. These provisions foster the implementation of sustainable land management practices, especially in geographical areas where soil biodiversity has been negatively affected.

Several initiatives have put soils on the biodiversity agenda. The COP of the CBD at its 6th meeting in Nairobi April 2002 decided (COP decision VI/5, paragraph 13) "to establish an International Initiative for the Conservation and Sustainable Use of Soil Biodiversity as a cross-cutting initiative within the programme of work on agricultural biodiversity, and invites the Food and Agriculture Organization of the United Nations, and other relevant organizations, to facilitate and coordinate this initiative". Following this decision, a series of activities where initiated by FAO. More recently the European Commission, as one of the priority actions took up the topic for the EU Soil Thematic Strategy [23]. As a contribution to the 2010 International Year of Biodiversity the first Atlas of European Soil Biodiversity [20] was published by the European Commission and presented at the CBD COP 10 in Aichi, Japan, October 2010. This first comprehensive regional assessment on soil biodiversity has generated large interest and triggered the establishment of the Global Soil Biodiversity Initiative (GSBI) [24]. The GSBI is currently completing a Global Soil Biodiversity Atlas planned to be released during the International Year of Soils 2015. In addition, at its COP 10, the CBD launched a ten-year framework for action and a set of 20 biodiversity targets called Aichi targets [25] in order to renew and strengthen national efforts towards the conservation of biodiversity. Two of the Aichi targets have a direct link to the protection of soils. Target 7 deals with the sustainable management of areas under agriculture, aquaculture and forestry and target 15 aims to enhance ecosystem resilience and the contribution of biodiversity to carbon stocks through conservation and restoration, including the restoration of at least 15 per cent of degraded ecosystems.

SOILS AND DESERTIFICATION

The UNCCD is certainly the Rio Convention closest to the issue of global soil protection; however, it addresses a subset of soil issues and only in particular regions. The role of soils within the convention has been well recognized in the original version of the convention text which came into force in 1996, identifying the process of land degradation as "*a reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as soil erosion caused by wind and/or water; a deterioration of the physical, chemical, and biological or economic properties of soil; and a long-term loss of natural vegetation*" (article 1f) [26].

The UNCCD was the global response to the pressing need to address severe desertification processes in Sub-Saharan Africa and in other drylands of the world and was expressively negotiated to address land degradation, including soil degradation, in those regions with a focus on social and economic as much as on environmental issues. Land degradation is estimated to affect 10–20% of the world's drylands [27]. Its limited focus on drylands has been perceived already in its early stage of implementation as a serious limitation, especially in view of the objective difficulty of describing in stringent and quantitative terms the area of applicability and the scope of the convention.

Drylands are shifting due to climate change and land degradation is by now perceived as a global problem extending well beyond the original scope of the convention. Expanding the scope of the convention to cover other issue areas has been met by resistance from member states and parallel discussions on the possibility of creating a standalone convention for soils have not gained sufficient momentum.

The UNCCD does not include provisions nor does it offer guidelines for the development of national legislations for the protection of land. Altogether, it focuses on project implementation and a bottom-up approach, the building of partnerships and capacity building which includes the support of non-affected parties to countries suffering from desertification. Parties to the UNCCD that have declared themselves as affected by desertification are required to develop National Action Programs (NAPs) to combat desertification (articles 9-10, 19) which should focus on underlying causes, especially socioeconomic factors (article 5 para c) [26].

The consistent application of the convention in the affected countries should result in a measurable reduction of land degradation. Unfortunately, 20 years after ratification we are still struggling with serious soil degradation processes, not only in affected countries, but in most parts of the world. There is therefore an urgent need to review the implementation of the convention and move towards a new strategy of implementation.

A positive outcome of the discussions at the Rio+20 Conference, which can be attributed to awareness raising efforts made by the UNCCD Secretariat and its partners, was the proclamation of the common wish to achieve a "land degradation neutral world" [28]. This agreement has triggered a lively debate [29] in the context of the post-2015 implementation of the convention with the setting up of an intergovernmental working group to work on a definition for land degradation neutrality and to develop strategies for its implementation within the framework of the convention [30] [31]. Moreover, within the negotiations for the emerging post-2015 development agenda and the SDGs, land and soils play a role.

SOILS AND THE POST-2015 DEVELOPMENT AGENDA

The Rio+20 sustainable development conference launched a process to develop a post-2015 development agenda [2]. This agenda is expected to provide an umbrella vision for sustainable development, define clear means of implementation and set structures and tools for the effective monitoring of sustainable development-related actions. A key element of this process is the development of a set of SDGs. The SDGs aim to integrate the three dimensions of sustainable development (economic, social and environmental) and to consider different national circumstances [2]. The post-2015 development agenda can contribute to awareness-raising and the implementation of the principles addressed in, inter alia, the MEAs discussed in the previous sections. A positive outcome of the Millennium Development Goals, amongst some not so positive results, was their ability to raise awareness for key development issues and catalyse actions and resources to address these issues [32] [33]. Furthermore, non-binding or "soft law" instruments "embrace a broader range of actors (including scientific organizations, academic specialists, NGOs, and industry)" and often act as an essential step in consensus-building" [34].

In addition to the involvement of a wide range of actors, the process of putting soils on the post-2015 development agenda and the SDGs provides the opportunity to address soils within the frame of a wide set of sustainable development issues i.e. with a nexus approach. Soils are one of the main elements of sustainable development [35] and are highly interlinked with the achievement of food, water and energy security, amongst others. The role of soils for sustainable development was recognized by article 206 of the Rio+20 Outcome Document "The Future We Want" in the agreement to "*strive to achieve a land degradation neutral world in the context of sustainable development*" [2]. As a limited and (in human terms) non-renewable natural resource we need to manage soils in a sustainable way for future generations. It is therefore imperative that these resources are coherently integrated across the SDGs. The Open Working Group formed to draft SDGs published a set of 17 proposed goals and 169 targets [36]. Soils and land will underpin the achievement of the SDG agenda as a whole and play a direct role in at least 7 of the proposed SDGs:

Draft Sustainable Development Goals (SDGs) as proposed by the United Nations Open Working Group (OWG) on SDGs in July 2014 highlighting the SDGs with a direct link to soils and land:

1. **End poverty in all its forms everywhere**
2. **End hunger, achieve food security and improved nutrition, and promote sustainable agriculture**
3. Ensure healthy lives and promote well-being for all at all ages
4. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all
5. **Achieve gender equality and empower all women and girls**
6. **Ensure availability and sustainable management of water and sanitation for all**
7. **Ensure access to affordable, reliable, sustainable, and modern energy for all**
8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
10. Reduce inequality within and among countries
11. **Make cities and human settlements inclusive, safe, resilient and sustainable**

12. Ensure sustainable consumption and production patterns
13. Take urgent action to combat climate change and its impacts
14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
15. **Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss**
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: Outcome document of the Open Working Group on SDGs [34]

Soils and land are addressed, amongst others, under goals for food security, sustainable agriculture and the protection of terrestrial ecosystems. The goals address, for instance, the need to ensure equal access and control over land, especially for poor and vulnerable populations. Issues of soil quality and halting land degradation are covered but will need to be managed together with targets that aim to double agricultural productivity, which could lead to an intensified use and to further degradation. The protection of soils in the SDGs can at the same time support goals, for instance, for climate change through the conservation of soil carbon stocks, for biodiversity conservation, for water availability and for poverty reduction though the support of livelihoods of people working in agriculture. These resources are found across the agenda, but there will be potential conflicts and trade-offs that should be addressed in a cross-cutting manner. Furthermore, addressing soils in the SDGs will require knowledge-based development of appropriate indicators that can be applied locally without increasing the data collection burden of Member States. But beyond indicators, which can be very costly and difficult to monitor, there is the need for innovative monitoring systems around the world. It will be crucial for this process to include different stakeholders and scientific disciplines.

Several initiatives are advocating for soils to be a part of the post-2015 development agenda. This issue has been highlighted for example in the communication of the European Commission (EC) outlining Europe's development aspirations for the new SDGs [37]. The Institute for Advanced Sustainability Studies (IASS) in Germany and partners have been working for the integration of soils and land in the SDGs with a 'people-centred' and transdisciplinary approach [38]. Several country governments are also supporting the issue, for instance, Namibia and Iceland formed an informal interest group called "*friends of desertification,"* which aims to maintain the momentum generated by Rio+20 around desertification, land degradation and drought in the context of post-2015 development agenda [39]. In order to have an impact on the official post-2015 process, it will be crucial that these organizations and groups cross-reference and present coordinated proposals, including collaboration with other stakeholders and initiatives.

CONCLUSIONS

Soil resources are covered across the Rio Conventions either in the text or through the implementation of actions prescribed by the conventions. This has contributed to increasing the momentum to speak about soils at the global level. However, even with the implementation of the conventions, we are still dealing with major challenges related to the degradation of land and soil resources. This is in part due to a lack of a cross-cutting and integrated approach.

The SDG process further highlights the need for an integrated approach as soils and land are found across several goals and will play a key role for the achievement of the agenda. The underpinning role soils and land will play across the SDGs needs to be recognized. Putting soils on the agenda of the existing MEAs and the post-2015 development agenda requires a major shift in the discussion around soils as a limited, non-renewable, natural resource. There is the need to recognize that soils are underpinning a wide range of services crucial for sustainable development and should, therefore, be protected for future generations.

The main difficulty in introducing soils within such a global sustainability agenda is that soils are in large majority in private ownership and are perceived by most countries of the world a topic strictly limited to national sovereignty. Accepting globally binding targets and regulations affecting national soil resources is still perceived by some governments as a major interference. The transnational dimensions of soil protection and sustainable soil management are still not sufficiently understood and the objective evidence of such interlinkages is still limited [40]. Some of the first considerations around the bioenergy debate in relation to Indirect Land Use Changes (ILUC) have triggered some research [41] into the interlinkages between national decision-making and their effects on the soil resources of other nations, but detailed data are still lacking for a comprehensive assessment of such interlinkages.

Moving forward, there is a need to focus on improving the implementation of the Rio Conventions with regards to soils. This will include further developing and strengthening synergies amongst the conventions. Additionally, soil scientists need to exchange with different stakeholders from other scientific disciplines, policy-making and civil society to link soils to key sustainable development issues such as water and food security and sustainable agriculture, climate change, biodiversity and ecosystem protection. Concerted efforts for advocacy within the post-2015 development agenda need to focus on keeping soils and land on the agenda and looking beyond 2015 towards an effective implementation and monitoring of the SDGs.

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List of Abbreviations

MEA	- Multilateral Environmental Agreement
UNFCCC	- United Nations Framework Convention on Climate Change
CBD	- United Nations Convention on Biological Diversity
UNCCD	- United Nations Convention to Combat Desertification
UNCED	- United Nations Conference on Environment and Development
SDGs	- Sustainable Development Goals
IPCC	- Intergovernmental Panel on Climate Change
COP21	- 2015 Paris Climate Conference
COP	- Conference of Parties
GSBI	- Global Soil Biodiversity Initiative
NAPs	- National Action Programs
OWG	- Open Working Group for the SDGs
EC	- European Commission
IASS	- Institute for Advanced Sustainability Studies
ILUC	- Indirect Land Use Changes

SOIL RELATED REASONS AND CONSEQUENCES OF EXTREME HYDROLOGICAL SITUATIONS (FLOODS, WATERLOGGING – DROUGHTS)

György VÁRALLYAY[1]

Review article UDK 631.432.2(439 Carpathian Basin)

ABSTRACT

The most important elements of sustainable development in the Carpathian Basin are the rational use and conservation of soil and water resources, maintaining their favourable "quality" and desirable multi-functionality. These are the main factors of multipurpose biomass production and environment protection: may help to prevent, eliminate or reduce extreme moisture situations (floods, waterlogging vs. droughts), unfavourable soil degradation processes limiting soil fertility/productivity, and their harmful economical/ecological/environmental/social consequences [9, 11, 14, 16].

Keywords: *soil moisture regime, water storage, waterlogging hazard, drought sensitivity, soil moisture control*

INTRODUCTION

The **natural conditions** (climate, water, soil and biological resources) **of the Carpathian Basin** (particularly lowlands and plains) are *generally favourable* for rain fed biomass production. These conditions, however, show extremely *high,* irregular, consequently hardly predictable spatial and temporal *variability;* often *extremes;* and sensitively react to various natural or human-induced stresses. The main constraints are: extreme moisture regime; soil degradation processes; and unfavourable changes in the biogeochemical cycles of elements, especially of plant nutrients and environmental pollutants [2, 7, 10].

The Carpathian Basin is a greatly **"water-dependent" region***,* where the soil–water relationships considerably influence, sometimes determine the type and rate of weathering, soil formation and soil degradation processes; the moisture and substance regimes; the abiotic and biotic transport and transformation; mass and energy regimes in the „geological formation–soil–water–biota–plants–near surface atmosphere"

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continuum; soil fertility/productivity; the yields and yield fluctuation of crops; and environmental conditions [17,18].

According to the meteorological/hydrological/ ecological forecasts the risk, probability, frequency, duration and intensity of **extreme meteorological and hydrological events** will be increasing in the future and their unfavourable economical, ecological and social consequences will be more and more serious, sometimes catastrophic [4, 5, 12]. Consequently, water will be the determining (hopefully not limiting) factor of food security and environmental safety and the **improvement of water use efficiency** (including soil moisture control) will be the key issue of multipurpose biomass production, environment protection and sustainable social development.

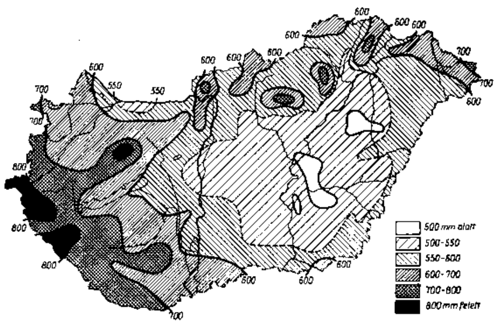
LIMITED WATER RESOURCES AND THEIR HIGH VARIABILITY

The Carpathian Basin is *generally rich* in water resources, especially in the low-lying parts of the Pannonian Plains, as the bottom of this large water catchment area. On the contrary, during certain "critical periods" in some "critical areas" the water resources are *limited* and **"extreme" hydrological situations**:

- *surplus* amount of water: flood, water-logging, "over-moistening" hazard;
- *shortage* of water: drought sensitivity is characteristic [4, 12, 14].

The average 450–600 mm annual **atmospheric precipitation** in the Pannonian Plains may cover the water requirement of the main crops even at high yield levels, and it gives reality for efficient "rain fed" biomass production. But the average shows *extremely high territorial* (Fig. 1A) *and temporal* (Fig. 1B, 1C and 1D) *variability*–even at micro-scale.

A



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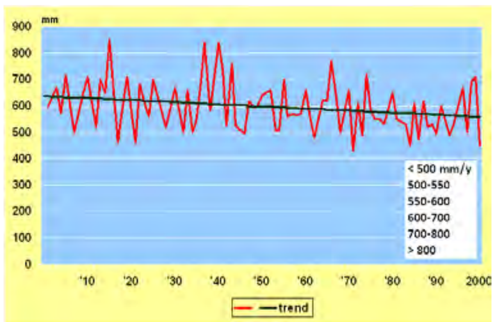

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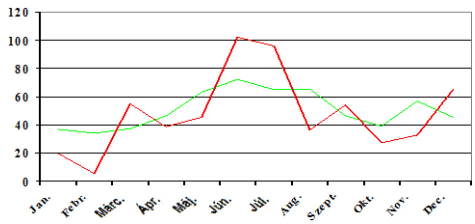

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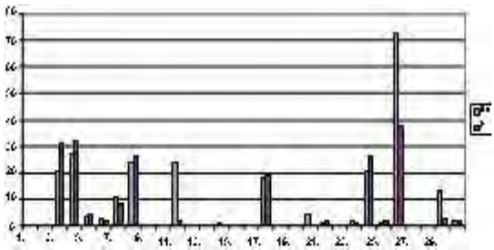


Figure 1. Territorial and time distribution of atmospheric precipitation in Hungary. A. Territorial distribution of the 100-year average annual precipitation. B. Average annual precipitation in Hungary in the 20th century. C. Monthly distribution of the long-term average and 2008 annual precipitation. D. Daily distribution of monthly precipitation (May 2008) at two nearby meteorological stations.

A certain part of the atmospheric precipitation falls as highly intensive rain or hail. Their frequency, duration and intensity have considerably increased during the last years, resulting in serious environmental consequences: intense surface runoff and erosion (soil losses and sedimentation hazards) or even landslides; infrastructure damages, etc. In such cases only a limited (reduced) part of the rainwater is stored in the soil and is available for the biota, natural vegetation and cultivated crops, and giving additional water (irrigation) or draining the surplus amount of water (drainage) would be necessary. Both are faced with serious limitations in the Carpathian Basin: limited quantity of good quality water for irrigation; relief; poor horizontal and vertical drainage conditions. Therefore, all efforts have to be taken to collect, store and rationally use *rainwater* and to reduce its evaporation, surface runoff and deep filtration losses [3, 7, 12, 13].

The average quantity of incoming **surface waters** (rivers) is about 110-115 km^3/year in Hungary and it will not increase in the future, particularly not in the critical low-water periods, and a certain quantity and quality of transboundary surface waters must be guaranteed for the lower Danube Basin countries (at present this outflow is about 115-120 km^3 [4, 5].

The “available” quantity of **subsurface waters** is also limited.

The average depth and fluctuation of the groundwater table shows great territorial variability. The possibility of capillary transport from the groundwater to the overlying soil horizons, and to the active root zone can be significant only in the lowlands [20]. This capillary transport – in the case of good-quality groundwater – may considerably contribute to the water supply of plants, decreasing drought sensitivity, as in the Small Hungarian Plain (NW Hungary). But a considerable part of subsurface waters (especially in the poorly drained East Hungarian Plain) is of poor quality (high salinity, alkalinity, sodicity) and in such cases this capillary solute transport threatens with harmful salinization/sodification processes.

Another part of the subsurface waters cannot be used or (over)exploited because of the sink of the water table and its unfavourable ecological consequences, like the serious "desertification symptoms" in the Danube–Tisza Interfluve sand plateau [9, 12].

In addition to the hardly predictable water resources, there are two more reasons of **extreme soil moisture regime**:

- the heterogeneous *micro relief* of the „flat" lowland;
- the highly variable, sometimes mosaic-like *soil cover* and the unfavourable physical and hydro physical properties of some soils (mainly due to heavy texture, high clay and swelling clay content, or high sodium saturation: ESP) [8].

SOIL RESOURCES, SOIL AS THE LARGEST POTENTIAL NATURAL WATER STORAGE CAPACITY

As a result of the combined influence of the highly variable soil forming factors and soil processes a highly – even on micro-scale! – heterogeneous, **mosaic-like soil cover** developed in the Carpathian Basin.

Under the given environmental conditions, it is an important fact that **soil is the largest potential natural water reservoir** (water storage capacity). The 0-100 cm soil layer potentially may store more than half of the average annual precipitation (500-600 mm). About 50% of it is „available moisture content", which may satisfy the water requirement of the natural vegetation and cultivated crops – even at high biomass production and yield levels [2, 12, 16].

This favourable fact is quite contrary with the high and increasing risk, hazard, frequency and duration of **extreme hydrological events** (floods, waterlogging, over-moistening vs. drought) sometimes in the same place in the same year, which are characteristic features of the Pannonian Plains [4, 5, 9, 11]. Their *main reasons* are the high territorial and temporal variability of atmospheric precipitation; rain: snow ratio and snowmelt characteristics; relief (including micro relief); soil conditions; vegetation; land use practices. And their *main consequences* are water losses (evaporation, surface runoff, seepage, deep filtration); soil (organic matter and nutrients), biota, vegetation and yield losses; energy losses [7].

What are the main reasons of this "huge water storage capacity" – "extreme moisture situation" contradiction*?*

1. Only (?) 31% of Hungarian soils represent an "ideal case" for the efficient use of the potential water storage capacity, having "favourable" hydro physical properties, but 43% of the soils have unfavourable and 26% moderately favourable water management characteristics, because of various limiting factors, as it can be seen in Figure 2 [16, 21].

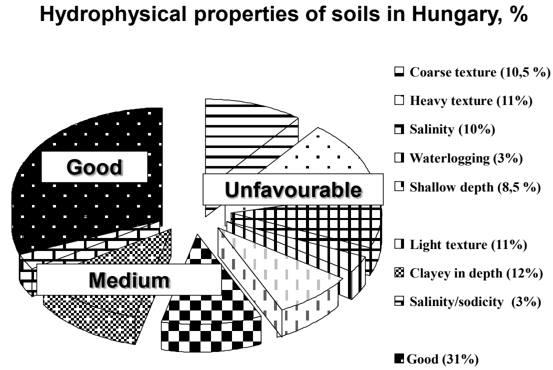


Figure 2. Water management characteristics of soils in Hungary and their reason

In the last years a comprehensive soil survey–analysis–categorization–mapping–monitoring system was developed for the exact characterization of *hydro physical properties*, modelling and forecast of the *water and solute regimes* of soils. The digital soil physical/ hydro physical database includes a 1:100 000 scale map of the hydro physical characteristics of soils. The map is shown in Figure 3 [13, 14, 21].

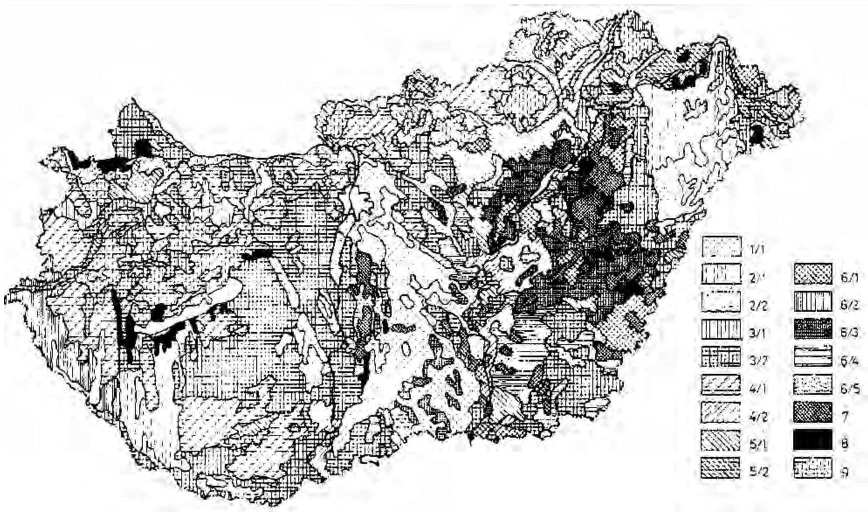


Figure 3. Hydro physical characteristics of soils in Hungary

1. Soils with very high IR, P and HC; low FC; very poor WR: **10.5%**.
2. Soils with high IR, P and HC; medium PC; and poor WR: **11.1%.**
3. Soils with good IR, P and HC; good FC; and good WR: **24.8%**.
4. Soils with moderate IR, P and HC; high FC; and good WR: **19.1%**.
5. Soils with moderate IR, poor P and HC; high PC and high WR: **6.2%**.
6. Soils with unfavourable water management: very low IR and K: **14.9%.**

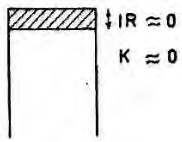
7. Soils with extremely unfavourable water management due to high salinity/sodicity: extremely low AMR, IR and K:**3.6%.**
8. Soils with good IR, P and HC; and very high FC (organic soils: **1.3%.**
9. Soils with extreme moisture regime due to shallow depth: **8.4%.** The main profile variants: (1) texture becomes lighter with depth (soils formed on relatively light-textured parent material): 2/1, 3/1. (2) uniform texture within the profile: 1/1, 2/2, 3/2, 4/2, 5/2. (3) relative clay accumulation in the horizon B: 4/1, 5/1. Profile variants of category 6: 6/1: highly compacted, heavy-textured soils with poor structure; 6/2: pseudogleys; 6/3. deep meadow solonetzes and solonetzic meadow soils; 6/4: soils with salinity/sodicity in the deeper horizons; 6/5: peaty meadow soils

2. The potential water storage capacity is not (or only partly) utilized because of the following reasons [9, 12, 16, 18]:
   - The pore space is not "empty": it is filled up by a previous source of water (rain, melted snow, capillary transport from groundwater, irrigation etc.): "*filled bottle effect";*
   - The infiltration of water (rain, melted snow) into the soil is prevented by the frozen topsoil: "*frozen bottle effect";*
   - The infiltration is prevented or reduced by a nearly impermeable soil layer on, or near to the soil surface: "*closed bottle effect"* (Fig. 4 (1));
   - The water retention of soil is poor and the infiltrated water is not stored in the soil, it only percolates through the soil profile: "*leaking bottle effect"* (Fig. 4 (2)).

The main reasons and consequences of these limiting factors are summarized in Figure 4.

1. Limited infiltration

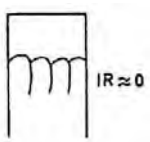
A. Impermeable layer (crust) on the soil surface



a) cemented by salts
- Na salts
- gypsum

b) compacted by improper soil management
- over-tillage, heavy machinery
- improper irrigation methods

B. Shallow wetting zones (low water storage capacity)



a) solid rock

b) hardpans (fragipans, duripans, orstein, ironpan etc.)

c) layer cemented by exch. Na^+, clay, $CaCO_3$ and other factors (clay-pan, concretionary horizons, petrocalcic horizons, etc.)

d) layer compacted by improper soil manage-ment (plough pans, etc.)

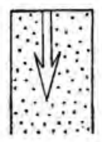
↓

extreme water regime

→ oversaturation (aeration problems)
waterlogging problems
surface runoff – water erosion

→ drought sensitivity

2. Limited water retention



IR, HC > FC → drought sensitivity

Figure 4. Limitations of utilizing the potential water storage capacity of soil

The soil moisture regime strongly influences, sometimes determines other soil ecological properties, such as air, heat and nutrient regimes, biological activity; soil fertility; the environmental sensitivity and tolerance limits of soil against various natural and human-induced stresses, including climate change, point source or quasi point source and diffuse soil pollution; and the soil technological indices for soil tillage and other agrotechnical operations [6, 13, 15, 19].

Sustainable soil management and moisture control

Rational land use and sustainable soil management are greatly water dependent in the Carpathian Basin [2, 3, 13, 14, 17].

As the direct moisture control actions, irrigation and drainage are faced with serious limitations (limited quantity of good quality irrigation water, relief; poor horizontal and vertical drainage conditions) all efforts have to be taken for the improvement of “rainwater efficiency” by a “two-way” (“double face”) moisture control, which basic concept is the preference of “storage” instead of “drainage” (transport away)! The most important elements of such rational and sustainable soil moisture control are:

- help the infiltration of water into the soil;
- help the useful storage of infiltrated water within the soil without any unfavourable environmental consequences;
- reduce the immobile (strongly bound, “dead”) fraction of the stored water;
- reduce evaporation, surface runoff and deep filtration losses of atmospheric precipitation and irrigation water;
- drain only the harmful surplus amount of water from the soil profile and from the area, improving vertical and horizontal drainage conditions (prevention of over-saturation and/or water-logging).

There are many possibilities for the practical realization of these basic objectives. Some of them are summarized in Table 1, indicating their potential environmental impacts [1, 12, 13, 17].

Scientific and technical development offer more and more new tools, techniques and technologies for such activities on the basis of our comprehensive digital soil physical/hydro physical database, which can be quantitatively interpreted for soil layers, soil profiles; physic-geographical, administrative, farming or mapping units (e.g. ecological region, water catchment area, county, settlement, farm, agricultural field etc.). Our task is to select and implement **proper and efficient site-specific technologies**. As it is clear from Table 1 most of these „moisture management actions" are – at the same time – efficient environment control measures and reduce the risk and unfavourable consequences of various natural and human-induced stresses (as soil degradation processes, nutrient stress, pollution hazard, etc.) [10, 14, 19].

Table 1. Elements and methods of soil moisture control with their environmental impacts

	Elements	**Methods**	**Environ-mental impacts***
Reducing	surface runoff	Increase in the duration of infiltration (moderation of slopes; terracing contour ploughing; establishment of permanent and dense vegetation cover; tillage; improvement of infiltration; soil conservation farming system)	1,1a 5a, 8
	Evaporation	Helping infiltration (tillage, deep loosening) Prevention of runoff and seepage, water accumulation	2,4
	feeding of ground-water by filtration losses	Increase in the water storage capacity of soil; moderation of cracking (soil reclamation); surface and subsurface water regulation	5b, 7
	rise of the water table	Minimization of filtration losses (↑); groundwater regulation (horizontal drainage)	2,3 5b,5c
Increasing	Infiltration	Minimization of surface runoff (tillage practices, deep loosening) (↑)	1,4,5a, 7
	water storage in soil in available form	Increase in the water retention of soil; adequate cropping pattern (crop selection)	4,5b,7
Irrigation		Irrigation; groundwater table regulation	4,5c,7, 9,10
Surface } drainage Subsurface		Surface } moisture control (drainage) Subsurface	1,2,3,5c, 6,7, 11

* Referring numbers: See below

Favourable environmental effects	**Unfavourable environmental effects**
Prevention, elimination, limitation or moderation of: – water erosion (1) – sedimentation (1a) – secondary salinization, alkalization (2) – peat formation, waterlogging, over-moistening (3) – drought sensitivity, cracking (4) – plant nutrient losses by: – surface runoff (→ surface waters eutrophication) (5a) – leaching (→ subsurface waters) (5b) – immobilization (5c) – formation of phytotoxic compounds (6) – “biological degradation” (7) – flood hazard (8)	– over moistening, waterlogging, peat and swamp formation, secondary salinization/ alkalization (9) – leaching of plant nutrients (10) – drought sensitivity (11)

CONCLUDING REMARKS

Soil management and soil moisture control have distinguished significance in rational land use and sustainable soil and water management in the Carpathian Basin. The present and expected increasing risk, frequency, duration and intensity of extreme (and irregular, consequently hardly predictable) climatic and hydrological events and moisture situations may result in serious (or even catastrophic) environmental damages and their unfavourable economical, ecological and social consequences [19]. **Proper and efficient soil and water management** may help to prevent, eliminate or reduce these extreme hydrological situations (floods, waterlogging vs. droughts), unfavourable soil degradation processes, and their harmful consequences. The proper control measures may satisfy the preconditions of soil resilience, the “quality maintenance” of this multifunctional, conditionally renewable natural resource, which are important elements of sustainable development, multipurpose biomass production and environment protection [2, 10, 19].

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POSSIBILITIES TO USE THE "LAND DEGRADATION NEUTRALITY" APPROACH FOR SUSTAINABLE LAND MANAGEMENT MEASURING AND MONITORING

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Introductory lectures UDK 631.452(470)

BSTRACT

Key messages of the paper include the following: (i) Land Degradation Neutrality (LDN) is a new paradigm reflecting the cross-linked aspirations and demands of land-related sustainable development goals; (ii) LDN is politically sounding and attractive, it has a good background to be economically evaluated; (iii) LDN is a part of "Land-based approach" and might be considered as an operational platform for overlapping issues of 3 Rio conventions; (iv) LDN state can serve as a SLM target and overall criteria at different levels (local, subnational, national); (v) Spatial and temporal changes in land cover are measurable by indicators of land quality balance; (vi) LDN is not equally measured and is a site-specific (national-specific) matter, although global indicators of land quality can be considered as common platform for coordination; (vii) LDN concept needs advanced scientific development

Keywords: *Land Degradation Neutrality, Sustainable Land Management, Climate Change Adaptation*

INTRODUCTION

Present land degradation processes are growing globally, so that soil degradation is even named as a "silent crisis of the planet" (Dobrovolskiy and Kust, 1995). The sustainable land management (SLM) concept is widely considered to be the main approach to prevent, avoid, mitigate and restore land degradation. In spite of SLM became a strong-advocated basic idea for many land use projects in different countries, it is still a big gap between announcement of the need for SLM and real SLM practices, because the SLM targets are very different, mostly site- and national-specific, and indicators are not well defined and case-sensitive in many cases.

The possible decision can be discovered through application of the idea of the Land Degradation Neutrality, which grew up from the concept of Zero Net Land Degradation

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(so-called Changwon initiative), has been already promoted by the UNCCD (2012) and adopted as an overall UNCCD target in 2015 (COP12) and was widely discussed in recent scientific literature (Chasek *et al*., 2013; Tal, 2015, Stavi and Lal, 2015; EC JRC, 2014).

The will to 'strive towards a Land Degradation Neutral World" was expressed in the resulting document of the Rio+20 conference (The Future We Want, 2012). Land degradation neutrality was also addressed in the discussions held on formulating the post-2015 Sustainable Development Goals (SDGs) in the goal 15.3: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". The target of this goal sounds as: "by 2030, combat desertification, and restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation neutral world".

In spite of all these discussions, it is however felt by many that this is still a vague target with inherently lots of unknown aspects of land degradation neutrality. Thus it is necessary to explore the links of the LDN and SLM concepts and possible solutions for the application of the LDN target to reach SLM objectives.

SLM AS AN EVOLVING KEY APPROACH. SLM VERSUS LAND DEGRADATION

SLM as a concept appeared in late 90-s and was not "sustainable" at the beginning. It grew from the matters of "effective" land management and/or "rational" or "efficient" land management used in different countries at national level. In turn a brief history of the SLM concept development at global level which can be traced clearly throughout its definitions shows its development from the Land Management as a process to sustain land resources and people well-being, to the key investment area for strengthening resilience to environmental changes and disasters, including changes of climate. The definitions provided below show that the SLM can be considered either as a "concept", or "approach", or "method and procedure", either "process", "goal", "successful story/good practice", or even as an investment.

*SLM is **the use of land** resources, including soils, water, animals and plants, **for the production of goods** to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions (UN Earth Summit, **1992**).*

*<u>Land management</u> is the **process** by which the resources of land are put **to good effect**. It covers all activities concerned with the management of land as a resource both from an environmental and from an economic perspective (UNECE, **1996**).*

*The GEF **mandate to combat land degradation** focuses on sustainable land management (SLM) as it relates primarily to desertification and deforestation (as a result of unsustainable practices (GEF, **2003**).*

SLM is a knowledge-based ***procedure*** *that helps integrate land, water, biodiversity and environmental management (including input and output externalities) to meet rising food and fiber demands while sustaining ecosystem services and livelihoods (World Bank,* ***2005****).*

SLM is the ***adoption of land use systems*** *that, through* ***appropriate management practices****, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources" (TerrAfrica,* ***2005****).*

*WOCAT (****2007****) for its platform selected the definition suggested by the UN Earth Summit (1992), and underlined that "SLM" is the better thinking than Land Degradation, as it shifts the concept from "bad news" to "good news"*

SLM has been recognized as ***a key investment area*** *for strengthening resilience to the impacts of climate change under the Pilot Programme for Climate Resilience, paving the* ***way for*** *the integration of SLM into* ***core development planning*** *and implementation (PPCR,* ***2009****).*

SLM is land managed in such a ***way*** *as to maintain or improve ecosystem services* ***for human well-being****, as negotiated by all stakeholders (UNCCD,* ***2009****).*

During last decades a soil science made a big input in the development of the concept of SLM. Having no possibilities to discuss this in small paper, we need to emphasize a number of ideas conceived by soil scientists. There are: the idea of soil functions in biosphere and human life, which in turn developed into the concept of ecosystem services, the idea of "soil health", the global assessment of land a soil degradation, and some others, which are based on the platform that soils are the basis for many productive biophysical terrestrial systems of the globe. It is so, because in comparison to living organisms soil is a product of biophysical interactions of hundreds and even thousands years, and its recovery needs much more time than the recovery of communities of plants and animals in case of their loss.

The modern SLM concept in this connection considers the difference between land (as a piece of territory) and land/soil (as a biophysical productive system performing important environmental functions/ ecosystem services). Considering some good agronomic practices as SLM at local level, one should not forget the indirect links within watersheds, or that the use of fertilizers supports the productivity but can promote the loss of the overall soil fertility, etc.

The land and its healthy soils allow agricultural production and contribute to poverty reduction and food security. Land's and soil's functional aspects include vegetation cover providing nutrient regulation and physical protection from e.g. erosion; natural drainage or water retention providing water regulation services including prevention from flash and mud floods; biodiversity habitat protection; land / surface interactions (gas, water and energy exchange) as part of the climate and meteorological systems. A healthy well-structured soil is the nutrient engine of the land; it can regulate vast amounts of carbon and provides an incredible amount of biodiversity. Preserving the good condition of land and all its functional structures, with soil as a main component, is required to continue to provide ecosystem services in a sustainable way and to avoid land degradation (EC JRC, 2014).

METHODS AND BASIC APPROACHES

Here we present the results of the study and understanding the concept of LDN for its scientific development and practical application, basing on our experience in the East Europe, Central Asia, the development of the Russian "Healthy Soil" initiative for the Group of Eight presented in 2014 (which unfortunately was not realized due to certain political circumstances), and also preliminary results of the discussion of this concept in the UNCCD Intergovernmental Working Group on the follow-up to Rio+20 (IWG) which worked on the elaboration of the internationally recognized science-based definition of the land degradation neutrality (LDN).

PARADIGM SHIFT?

THE VARIETY IN CONSIDERATIONS OF THE LAND DEGRADATION NEUTRALITY (LDN) CONCEPT

In practical terms the LDN concept is clear enough: SLM actions should not allow reducing the existing balance between "not yet degraded" and "already degraded" lands with persistent desire for the restoration of the last. Thus, the LDN can be considered as a practical tool to balance processes of land degradation and restoration/rehabilitation/recovering at global, regional, national and local levels.

It is also transparent, that according this common practical understanding the LDN has two linked dimensions: (i) reducing the rate of degradation of non-degraded land; (ii) increasing the rate of restoration of degraded land. Various fora have highlighted the risk of using one dimension to offset the other in the form of a trade system – this offsetting is to be avoided.

Also, rather than a global equilibration, global neutrality should be considered the sum of neutrality achieved by local communities and nations around the globe.

Other views and opinions on "What is the LDN about?" differ, but we tried to collect the various opinions from different sources on what the LDN should address for. Consequently, the basic vision and bedrock of the LDN concept consider the following matters:

- *changes in the LDN state has two co-linked dimensions: available land quantity/quality up and down alterations*
- *scattered effects related to both dimensions/directions can occur in synergy*

- *consequently, LDN promotes an ecosystem-based approach with two umbrella pathways of action: (i) addressing current and future LD (avoiding/preventing /minimizing LD): e.g. transition to SLM; (ii) redressing past LD: e.g. rehabilitate working landscapes and restore natural ecosystems*
- *the LDN concept considers spatial and temporal scales of actual manifestations and changes in land quantity/quality pari-passu with increase and mitigation of DLDD risks/threats*
- *land quality (both natural inherited and man-made artificial) is a multilateral term, which could mean productivity, functions, ecosystem services and their resilience, regeneration capacity, soil and ecosystem health, land potential, etc., or their combinations*
- *LDN recognizes the different uses of land and considers various approaches and methodologies to reach the LDN target, and as such it is about negotiating trade-offs and taking advantage of synergies in the management of these resources for multiple benefits*
- *recording changes in the LDN state needs baseline for its assessment and evaluation*
- *key LDN indicators should be easily monitored*
- *each country can declare their level of ambition*
- *the LDN should address links to biodiversity and climate change, poverty eradication and food security issues*
- *LDN requires an enabling environment in which all stakeholders participate and accept responsibility and voluntary commitments. This may include new legal frameworks that foster improved governance; technical and institutional capacity building for communities and individuals; increased investments and other incentives; etc.*

The scientific study of different explanations of the LDN concept withdrew three main constituents of the issue that let us emphasizing three approaches available to define the LDN:

- as a concept of land use/land management contributing/favouring to sustainable development at global/regional/national/local levels to meet the needs of future generations,
- as a phenomenon of equilibrium/homeostasis/constancy of land system in terms of the balance between deterioration and improvement of terrestrial ecosystems' qualities, functions and services; LDN occurs when ecosystem services are balanced artificially or naturally,
- as an SLM target to be adopted at national, sub-national or local level to sustain and improve natural resources for economic, social and environmental benefits, and food security.

The discussion of the term at various fora shows there is still a lack of commonly agreed scientific approaches to address the LDN definition. Scientists are still requiring the following answers: *What is the scientific base behind the concept? What science do we need to develop the concept (incl. social, economic, natural sciences, others)? What scientific studies and methods should be developed/undertaken to support policy decisions, and on the nexus of Rio conventions, in particular? What encouragement efforts ought to be undertaken in this case?* (Global Soil Week, 2015)

In spite of this a few of political solutions are already in place. For example, it is not strongly debatable already, that LDN strategy is not a "license to degrade" or a grand compensation scheme to restore the productivity of one area of land to offset degradation that has taken place elsewhere. It was also mutually agreed that while addressing achieving LDN each country can declare their own level of ambition and the steps undertaken depending on available national resources and/or international assistance. LDN is not a global target which requires a new protocol or international agreement.

Basing of these fundamental agreements, and taking into account the variety of approaches addressing LDN, the UNCCD recommended the following definition of the LDN as a consensus of policy makers, civil society, business, land users and scientists approaches:

Land Degradation Neutrality is a state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales, and ecosystems.

LDN AS AN INDICATIVE TOOL

Being defined as a "state", the LDN is likely to serve as a universal indicator for different modern concepts, such as SLM, either Climate Change (or disaster risk) Adaptation, ecosystem resilience and/or vulnerability, or some others, which are not clear enough, and sound mostly as slogans without concrete and simple content. The application is obvious and could be interpreted as the achieving LDN within specified spatial and temporal limits means that this land is managed in "sustainable" way or "adapted" to any possible environmental changes within the same limits.

The upcoming issue in this case is **what are the indicators for LDN itself**?! Some ideas can be realized from a conceptual definition of LDN suggested by us (Kust, Andreeva, 2014): LDN is an ecosystem-based target when healthy land resources remain environmentally, socially and economically available and sustainable, and provide raising opportunities for application of sustainable land and water management practices and their dissemination through mitigating degradation risks and land rehabilitation measures.

Anyway, it must be noted that there are different approaches to indicate LDN state, existing at present time, which needs coherent harmonization.

One is what we name as an "Anti-Degradation call", which sounds in general like "(Eco) system(s) overall harmony needs safety". This call is coming from the "environmental" community, and mainly corresponds to the global environmental issues and ecosystem services. Another is a "Production-defensive call" sounding like "Sustainability of resources and bioproductivity required", and it is coming mainly from "food security", agricultural, and "natural resource management" communities. If the first is oriented on the environmental safety, another is oriented on the production and economic matters.

This means in general, that to the moment there are two main groups of indicators to be considered as possible indicators for LDN as a state. Both groups relate to the issue of "***What matters do we measure for LDN?***" First of them is "measuring land degradation", which contains different possible options discovered and developed to different degrees: land quality, land quantity, scores of "relative fertility", land availability, soil/environmental health, etc. Second group explore the possibilities of measuring what the land produces, and consist of different and numerous biophysical and also economic and social parameters, such as bio-productivity, yield, vegetation cover, NDVI, income, economic and social benefits, ecosystem services, and others.

In view of the current and expected global pressures on the land to keep feeding an increasing world population, the "second group" is a bit more developed as a significant aspect is pointed to the importance of land productivity, its preservation or sustainable increase, and the knowledge on the current rates of land productivity. This has three key consequences (EC JRC, 2014): (i) a baseline has to be established against which to measure changes in land productivity; (ii) commitment to specified targets have to be agreed, (iii) mechanisms to monitor and assess the state of the land, and land productivity, at all scales have to be realized. It was emphasized, that although the targets can be set, but progress can only be measured against a baseline. Indicators need to be agreed that represent land productivity and/or related aspects that can be measured in a consistent, uniform and transparent manner. Also understanding of the interaction and the underlying drivers of land productivity change needs to be expanded if degradation has to be reduced or restoration has to be done successfully.

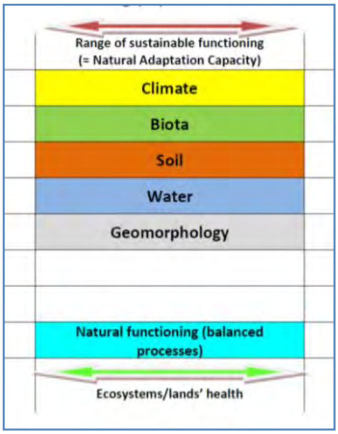
It is likely to note that all these aspects related to land productivity indicators fully correspond to other indicators including those from the "first group", that provides a good operational platform for their harmonization, taking into account the different traditions and approaches used in different countries and regions. It is essential to note, that probably the areal assessments (evaluations based on areal measures) will be a priority at the first steps of the LDN practical application, but further development for a qualitative assessment, and here the concept of soil health, ecosystem services, food security, social stress, water stress, etc. will be essential.

Another operational platform to harmonize the indicators system in different countries is the shortlist of internationally agreed land and soil indicators, which follow a tiered approach (see graphic below) and can be enriched at the national and sub-national level.

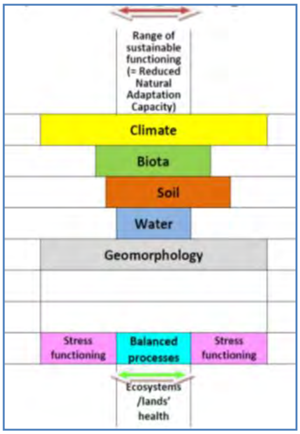
The list of global land and soil indicators encompasses: 1) land cover/land use change, 2) land productivity change and 3) soil organic carbon change (GLII, 2015). These indicators are measurable and essential in capturing a minimum of land characteristics that are globally comparable. Land cover/land use serves as an 'umbrella indicator' that allows stratification/disaggregation of the land productivity and soil organic carbon indicators. Land cover classes (e.g. forestry, agriculture, urban) will vary in importance depending on the context. Changes in land cover/land use give a first indication of the loss or degradation and restoration of land and soil quality. Land productivity addresses the net primary production per unit of area and time. Changes in land productivity, interpreted together with additional data, may give an indication on the loss or degradation, as well as on the restoration of land and soil quality. Soil organic carbon is relevant to estimate carbon fluxes and can be an important indicator of overall soil quality. The same set of three biophysical indicators were proposed by the UNCCD Secretariat for reporting on land-based adaptation, within a monitoring and evaluation framework (UNCCD, 2015).

One more issue of the application of LDN as an indicator addresses the question on "***What balance do we measure for LDN?***" To answer this question, the following points are critical.

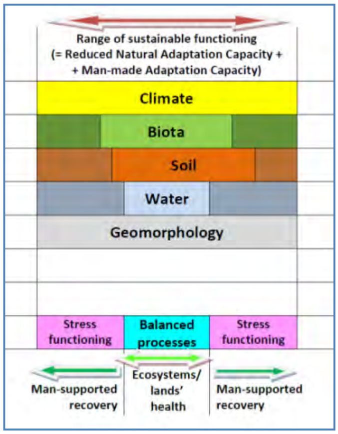
As it has been mentioned earlier, the LDN dynamics can be measures as a balance, which in turn requires a baseline for further monitoring. There are almost no doubts that for this purpose the state of the land and degradation/restoration processes (in terms of national- and site-specific indicators selected from the options described above) to the date of the last evaluation within a specific spatial scale can be determined as a necessary baseline.



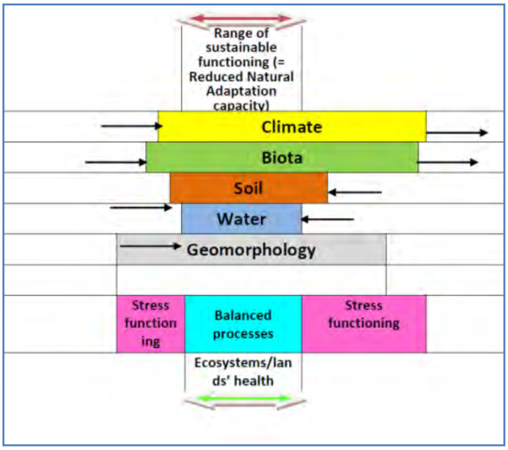
Natural sustainable functioning (equilibrium in constituents)



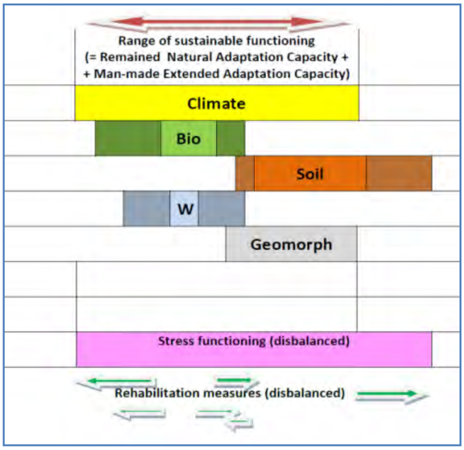
"Consumption-style" land use/management
(e.g. traditional agro cosystems)



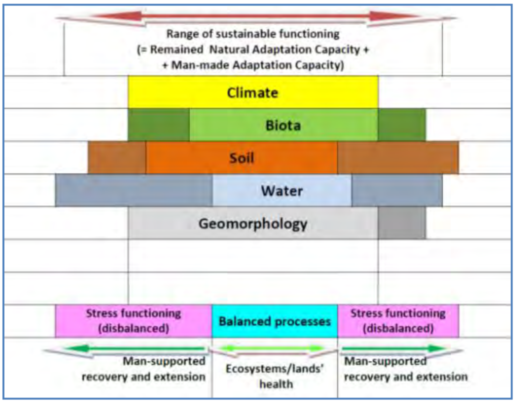
SLM functioning (adequate compensations required)



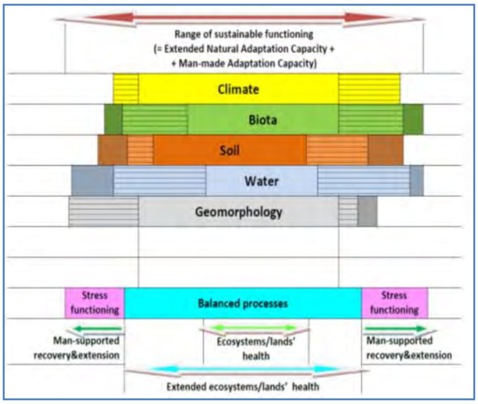
Stress affected functioning in traditional land use/management



Land/ecosystem degradation



Extended land use/management (man-made extension of resources/capacities)



Environmental land management (man-supportive extension of environmental services/externalities: new crops, artificial soils, irrigation, etc.)

In this case evaluation of the LDN progress can be measured by the ratio between land degradation (or risk of) and restoration (or avoiding/ preventing), which should not exceed '1' temporarily and spatially in terms of their areas. Indicators and/or metrics to reflect this ratio/balances can include different approaches based on the comprehensive assessment of available land quantity, land qualities and land degradation risks adaptive to various countries and areas, e.g.: between degraded/restored, destroyed (or alienated)/rehabilitated, between productive/unproductive, contaminated/recovered, etc. It can include not only the indicators of land and soil quality, but also indicators of land grabbing, soil contamination, land availability, changes in land use/land cover, economic and social benefits, etc.

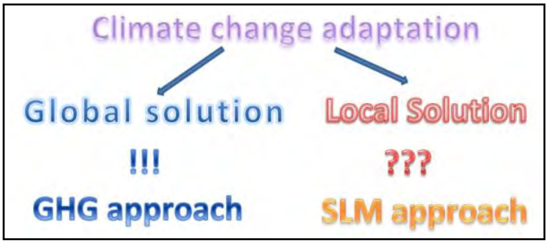
Another perspective approach, which can be practically more useful for monitoring LDN because of possibility to merge different indicators an assessment of the homeostasis of the soil/land cover is: a state when a set of components and ratio between them in terms of their areas remains constant within the ecosystem although internal mutual replacements can occur. The scientific basis for the development of this approach was discovered earlier and can rely on the ideas of the dynamics of soil cover in desertification affected areas (Kust, 1999) and of the invariants of soil cover changes (Goryachkin, 2006).

Some additional ideas on the understanding land dynamics and degradation states as well as the methodological approaches to achieve equilibrium and homeostasis in land degradation (=LDN) are reflected in a set of pictures above.

SLM, LDN AND CLIMATE CHANGE ADAPTATION ISSUES

A number of new concepts and paradigms appeared during last decades, such as sustainable land management (SLM), climate change (CC) adaptation, environmental services, ecosystem health, and others. All of these initiatives still not having the common scientific platform although some agreements in terminology were reached, schemes of links and feedback loops created, and some models developed. Nevertheless, in spite of all these scientific achievements, the land related issues are still not in the focus of CC adaptation and mitigation. The last did not grow much beyond the "greenhouse gases" (GHG) concept, which makes land degradation as the "forgotten side of climate change".

The possible decision to integrate concepts of climate and desertification/land degradation could be the considering of GHG" approach as providing global solution, and "land" approach as providing local solution covering other "locally manifesting" issues of global importance (biodiversity conservation, food security, disasters and risks, etc.) to serve as a central concept among those.



SLM concept is a land-based approach, which includes the concepts of both ecosystem-based approach (EbA) and community-based approach (CbA). SLM can serve as in integral CC adaptation strategy, being based on the statement "the healthier and resilient the system is, the less vulnerable and more adaptive it will be to any external changes and forces, including climate".

For these reasons the land-based approach using the LDN indicator and a tier of land-based indicators can serve as an operational tool for climate change adaptation assessment, as it was stated above in relation to the SLM assessment.

KEY MESSAGES:

- LDN is a new paradigm reflecting the cross-linked aspirations and demands of land-related SDG
- LDN is politically sounding and attractive, it has a good background to be economically evaluated
- LDN is a part of “Land-based approach” and might be considered as an operational platform for overlapping issues of 3 Rio conventions
- LDN state can serve as a SLM target and overall criteria at different levels (local, subnational, national)
- Spatial and temporal changes in land cover are measurable by indicators of land quality balance
- LDN is not equally measured and is a site-specific (national-specific) matter, although global indicators of land quality can be considered as common platform for coordination
- LDN concept needs advanced scientific development

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SENSITIVITY OF LAND TO CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT IN THE SUBMEDITERRANEAN KARST AREA OF BOSNIA AND HERZEGOVINA

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ABSTRACT

The value of the landscape in the karst region of Bosnia and Herzegovina (B&H) is the foundation of its existence and the key role in its appearance and formation is played by geomorphology and the soil. Through history the man has created a „cultural landscape" which is completely adapted to the natural conditions. He further enriches the space and makes it more appealing. Soils in B&H karst are extremely heterogeneous and form a real pedological mosaic. Found on the Mesozoic sediments of limestone and dolomite of the Middle and Upper Jurassic and Early and Late Cretaceous are Bare rocks (barren land), Rocky grounds (Lithosol), Limestone-dolomite Black soil (Calcomelanosol) and Brown soil on limestone and dolomite (Calcocambisol). A specificity of these rocks are the screes that are transported down the hillside. A series may occur on them in which, if shale materials are contained, Rendzina appears as a calcareous soil. In addition to the above mentioned limestone and dolomite, there are marly limestones of Jurassic and Cretaceous age and Quaternary sediments on which Alluvial soils (Fluvisol) developed as well as the soils of karst fields which are sometimes very porous and skeletal and sometimes heavy and clayey on impermeable substrate (hydromorphic soils).

The paper will provide an overview of characteristic soil types in the Sub-Mediterranean upper and lower karst region of B&H taking into account a range of properties that make them sensitive and vulnerable within the ecosystem. These should include a lack of water on the surface and large fluctuations in the amount of water during the rainy and dry seasons and whimsicality of climate in general, which has a huge impact on the state of biodiversity and human lives in this region.

Keywords: *karst, relief, soil types, climate change, aridity index*

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INTRODUCTION

Sub-Mediterranean Region of B&H is characterized by a variable suite of surface landforms and subsurface features due to the dissolution of soluble rock such as limestone, gypsum or salt. Karst features include sinkholes, caves, springs, sinking streams, cavities, dissolution-enlarged joints and/or bedding planes, and cutter-pinnacle zones, not all of which may be present or obvious. The proper characterization of karst conditions is of vital importance for groundwater flow and structural stability models of a site. Its complexity and variation from site to site pose a significant challenge to site characterization efforts. In B&H karst fields occupy about 100,000 ha.

Almost one half of the total territory of B&H is accounted for by karst area (limestone-calcareous terrains). The main characteristics of that area are the processes of desertification, floods and soil erosion. Soil erosion and torrent processes were very high in the past and today. The uneven pluviometry regime, very steep slopes of relief, destructive human activities and historical precedent of tectonic intensity have been the main drivers of erosions and flood processes. Such processes have transformed the natural landscape into limestone gray desert, exposing the nude stones on the surface. Long ago these zones were known as "passive areas" (unproductive zones) and the term "karst" was a synonym for poverty (Aley, 1992). The karst fields have been only potentially fertile but effectively unfertile "oasis" in the surrounding karstic grayness.

The condition of ecological balance in the area of Mediterranean karst is complicated by the climate change phenomenon. This is best shown in the drought index analysis which indicates that the highest increase of the Index during the vegetation period occurred in the area of Mediterranean karst, i.e. Mostar. The increase was determined at the level of vegetation period, seasonal period as well as at monthly level. During the vegetation period the coefficient of increase averaged between 0.08 and 0.2, and during the summertime between 0.02 and 0.20. Capriciousness of the climate and effects of drought on biodiversity of the area further complicate the karstic character of the area which developed mostly shallow skeletal soils, inclined relief affected by erosion and very porous geologic substrate which cannot retain water on the surface.

This area is severely affected by soil erosion and desertification (Čustović, 2007). The scarcity of soil functions in terms of agriculture and biodiversity, combined with a previous period of industrial development caused depopulation which became particularly apparent after the recent war. Now, in some karst areas population has been drastically reduced, in some places by more than 60% and in many areas by as much as 100% (parts of the municipalities of Glamoč, Bosansko Grahovo, Petrovac, Nevesinje, Gacko, etc.). This situation affects the condition of land as well as change in functions of soil in the ecosystem. Depopulation leads to the abandonment of traditional forms of agriculture which directly threatens the preservation of biological diversity and supports rapid succession (Marković, 2011).

Soil formation process on karst terrain, with limestones and dolomites is very slow. In view of the importance of soil and its multi-functionality, this paper is aimed at analyzing the extent and nature of soil in this part of B&H, vulnerability of shallow and skeletal soil exposed to the different types of erosion and anthropogenic pressures. Adaptation, adaptive capacity and vulnerability of soil to climate change in the Sub-Mediterranean Region of B&H is the aim of this paper.

MATERIAL AND METHODS

Drought index for B&H was obtained using the SPI method. To calculate the SPI index we analysed the 1961-2012 reference data series for various time scales and compared it with the area of Mediterranean karst, i.e. weather station Mostar.

Based on Aridity Index, i.e. P/PET ratio, the extent to which the evaporation is compensated by precipitation was calculated for each month and season as well as for annual average on the entire territory of B&H. Determined were monthly, quarterly (June, July and August) and annual levels of the average index for the reference period 1961-1991, and the account was taken of data on precipitation and PET from 53 weather stations across B&H.

Table 1. Classification of aridity/humidity

Zone	UNEP (1992) P/PET (Thornthwaite method)
Very arid	< 0.05
Arid	0.05 – 0.20
Semi-arid	0.20 – 0.50
Sub-humid	0.59 – 0.65
Humid	> 0.65

The analysis of land cover/land use and their change was performed using the CORINE Land Cover methodology for B&H.

To define the types of soil we used the Basic Soil Map M 1:50 000.

RESULTS

Karst area

Based on the relief forms, soil properties, land use, drought occurrence and the like, B&H can be divided in four agro-ecological areas: the area of high karst with karstic fields; the area of low Herzegovina (to include the upper course of the Neretva and karstic fields); the central hilly-mountainous area with river valleys, and; the plain hilly area (including serpentine and flysch zones) (Čustović *et al*., 2015).

In this paper, the focus is placed on the area of high karst with karstic fields and the area of low Herzegovina.

The area of high karst with karstic fields is a mountainous region situated at 800 m above sea level, which encompasses a significant number of high mountains extending in the Dinaric direction (NW-SE) and with pronounced relief forms and inclinations. Basic features of the Dinaric relief include deep river valleys and canyons, vast karstic fields and mountain ranges whose altitude goes from 1,000 to the highest peak of Maglić at 2,386 m (Čičić, 2002). Karstic fields (such as Bosansko Petrovačko, Glamočko, Livanjsko, Duvanjsko-Šuičko, Kupreško, Gatačko, Nevesinjsko) are enclosed karst valleys resembling green oasis in the karstic grey. Sloped terrain of the surrounding mountains is covered mostly by very shallow soils with pasture vegetation, shrubbery and degraded forests, which is exposed to strong erosion and denudation processes. Activities in the higher areas have a direct effect on the state of soil in karstic fields and ground waters.

The area of low Herzegovina (including the upper course of the river Neretva and karstic fields), in terms of geomorphology is known as low Mediterranean Herzegovina which encompasses the upper course of the river Neretva, the hinterland reaching Posušje, Stolac, Bileća and Livanjsko field which is the world largest karst field and is located at the transition zone towards the high karst. The entire area is criss-crossed by hillocks, hills and other relief forms at an altitude ranging between 500 and 700 ma.s.l. It accounts for about 10% of the total area of B&H and is surrounded by mountains such as Trtla, Viduša, Ivan, etc., and karstic fields on the upper terraces such as Mostarsko blato, Bekijsko polje, Kočerinsko, Dabarsko and many other smaller fields and plateaus. In the canyon of the river Neretva, represented are the sediment alluvial and colluvial-diluvial deposits in the Bijelo and Bišće fields, Hutovo Blato, as well as some smaller fields in the delta of the Neretva in Metković. In the very south of B&H, in the valley of the Trebišnjica river there are Trebinjsko and Popovo fields. This area, just like the above mentioned one, is characterized by pronounced karstic erosion along with other karst phenomena. Fields are semi-enclosed or enclosed, and their hydrological regime is regulated by the capacity of sinking zones to receive surplus rainfall in the fall and winter period. Droughts are a frequent occurrence related to the growing season when the water is most needed by plants, which reflects negatively on agricultural production. On the other hand, there is the problem of flooding and long-term waterlogging from fall to spring, which further aggravates the situation. Agriculture is relatively intensive, especially along the rivers Trebišnjica and Neretva, where irrigation causes sporadic occurrence of secondary salinization.

Land cover/land use

The area of high karst with karstic fields covers an area of 1,177,465 ha, and the area of low Herzegovina (including the upper course of the river Neretva and karstic fields) an area of 468,297 ha.

According to the CORINE 2012 data (Table 2), the most represented category of land cover/land use is the category of „Forest and semi natural areas“ which accounts for 1,274,599.4 ha or 77.4% of the entire observed territory. This category is predominant in both areas. In the area of high karst with karstic fields, this category covers 969,632.7 ha or 82.3%, and in the area of low Herzegovina 304,966.7 ha or 65.1%. The second most represented category is the category of „Agricultural areas“ which accounts for an area of 338,927.2 ha (20.6%) of the total observed area, of which 203,157.7 ha (17.3%) in the area of high karst, and 135,769.5 ha (29%) in the area of low Herzegovina. In the area of both zones, the artificial surface category covers 12,928.1 ha (0.8%), Wetlands 4,293.5 ha (0.3%) and Water bodies 15,013.8 ha (0.9%).

Table 2. Land cover/use in the karst area of B&H

CLC category	Surface (ha)	%
1 Artificial surfaces	12,928.1	0.8
2 Agricultural areas	338,927.2	20.6
3 Forest and semi natural areas	1,274,599.4	77.4
4 Wetlands	4,293.5	0.3
5 Water bodies	15,013.8	0.9
Total	1,645,762.0	100.0

Total changes in land cover/land use in the karst area (high karst and low Herzegovina) in the period 2000-2012 amount to 23,595.23 ha, with 82.6% of changes recorded in the period 2000-2006. The biggest changes were identified in the forest vegetation amounting to 17,967.58 ha which is 76% of the totally identified changes in land cover/land use in karst areas. When it comes to agricultural land, total changes in this category amount to 5,168.10 ha or 21.9% of the identified changes.

Pronounced depopulation of the karst area is a consequence of the extreme depopulation politics in the past as well as the fact that during the war it was mostly occupied and sustained extreme demographic changes (Marković, 2011). Analysis of data from the 1991 Census as well as preliminary data of the 2013 Census shows that the population in rural areas has been drastically reduced, e.g. Glamoč municipality where the population was reduced by as much as 68% or the municipality of Bosansko Grahovo whose population was reduced by 63%. Such trends are also characteristic for other rural areas of the region.

„The landscape surrounding the karst fields above 500 m altitude were traditionally linked to extensive livestock production, mainly sheep and goats, less cattle. However, due to depopulation, lack of fresh water for households and animals, lack of appropriate agricultural machinery and improvement of pastures, lack of civilization events in these areas, the number of livestock was dramatically reduced and the area almost deserted“ (Čustović, 2007).

The phenomenon of poverty in this region is not just a simple lack of income to purchase the basket of basic goods. Poverty is a form of insecurity and exposure to uncertainty. It consists of increasingly present phenomenon of climate change, the inability to access elementary needs such as adequate good, drinking water and sanitary services, education and health care, employment and entrepreneurial opportunities. In a nutshell, this is a condition where basic opportunities for a dignified life are lacking.

Climate changes

The Sub-Mediterranean region is also affected by climate changes. Drought index by the SPI method was applied for the Mostar station (Figure 1). The Standardized precipitation index (SPI_{12}) in the weather station Mostar displays a negative linear trend, which indicates the occurrence of a drought increase. The coefficient of determination R2 equals 0.055 and this is the biggest negative trend in B&H. The main disadvantage of this method is that it can observe changes only in precipitation patterns of a specific region.

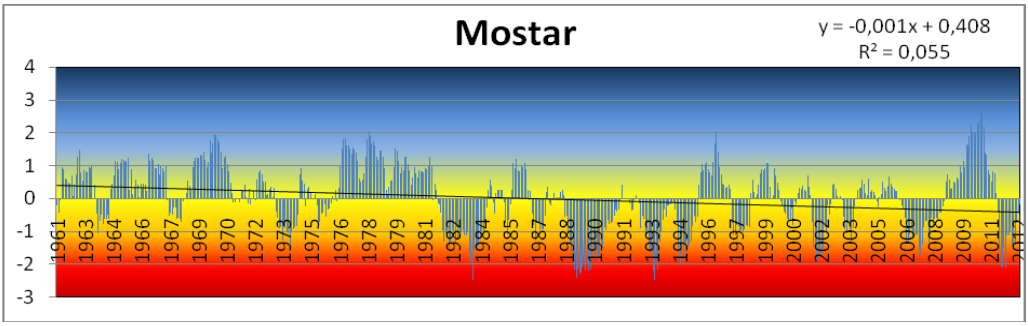

Chart 1. SPI_{12} in the area of Mostar (1961 – 2012)

Different aridity indices are applied to perceive drought from several aspects such as the Aridity index based on P/PET ratio presented below.

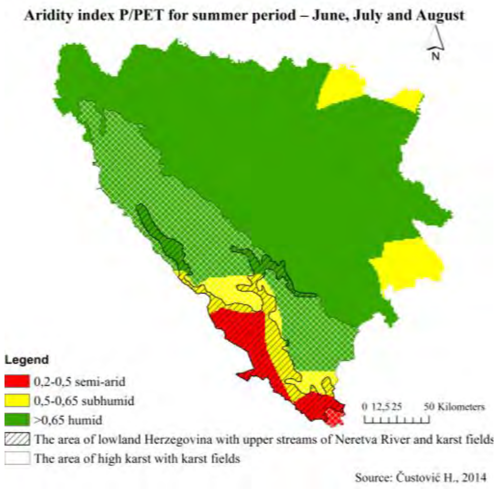

Figure 2. Aridity index P/PET for summer period – June, July and August

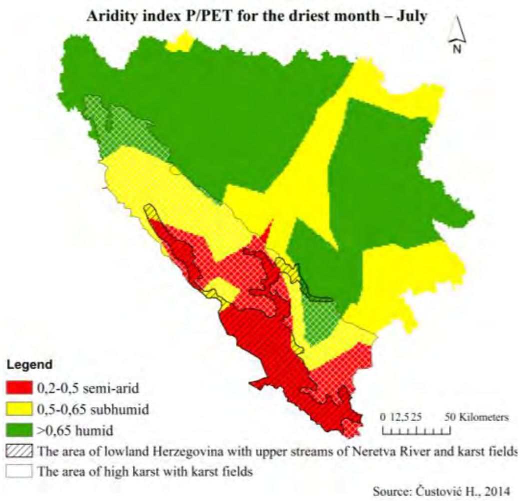

Figure 3. Aridity index P/PET for the driest month – July

As shown on the map of average values for summer period (June, July and August) within the period 1961-1991, semi-arid zones in our conditions represent the most vulnerable areas to drought and water deficit. They are typical of the southernmost part of the country, namely the area of the southern Sub-Mediterranean part of B&H. Summer period is driest in the area of Herzegovina where average Aridity index amounts 0.50. In the area of Herzegovina, on a monthly level, the Aridity index is lowest in July and August, when it varies from 0.26-0.63 (semi-arid to semi-humid). Also, a comparative analysis of multi-year series of data was made for the periods 1961-1991 and 2000-2012. A comparison of the two series indicates an increase in the Aridity Index level or precipitation deficit, which is particularly acute during the growing season. The increase in the Aridity Index that is present at all the shown meteorological stations or locations, was determined at vegetative, seasonal and monthly levels. During the growing season this increase ranged from 0.08 to 0.2, and during the summer from 0.02 to 0.25. The largest increase in the growing season was established for the area of Mostar (the difference between the periods amounted to 0.2).

It is necessary to point out that mean values for a longer period of time are used to develop Aridity index, so the extremes and high oscillations are not observed by this method. Finally, we need to say that the foreseen changes in precipitation and its distribution patterns (spatially and seasonally), combined with a rise in temperature and evaporation, resulting in increased precipitation deficit, will likely continue to cause extreme events (drought) and lead to the lack of access to water during summer when most needed by plants. The area of Herzegovina particularly stands out (most severely in lime and karst areas) as these changes are most pronounced there. As a consequence of the aforementioned, we are going to have decreased yields in the future due to reduced precipitation, increased evaporation and decreased soil moisture supplies.

Soil characteristics

The formation of soils is primarily affected by physical and geographical factors, first and foremost by geological structure, relief, climate, vegetation and especially water. Their impact leads to decomposition of the surface layer of rocks and minerals on which different soil types are formed. Each soil type at a specific site brings special features into the vegetation cover of natural vegetation, and if used in agriculture, into the possibility of growing various crops of special quality. As shown on the map provided below (Figure 4), there are six major types of soil in the researched area. In terms of production as well as the environment, these are the most important but also the most vulnerable types of soil of this ecosystem. Provided below is a description of soil types and their major characteristics within the ecosystem.

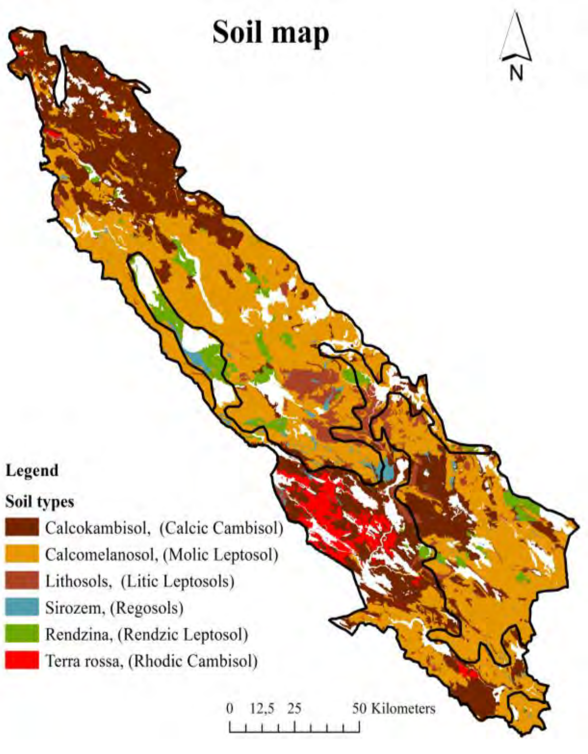

Figure 4. Soil map

Lithosols, (Litic Leptosols)

In this area, Lithosols developed on limestone and dolomite. So, these are the bare rocks or areas where rockiness level goes up to 90%. As these are extremely dry habitats, their scarce vegetation is mainly xerothermic. The total area of these soils amounts to 89,533.6 ha or 5.4% of the total observed karst area. Although these soils are important in terms of biodiversity, one must not lose sight of the fact that Lithosol is a result of destructive processes in the pedosphere. Effective protection of this soil through growing natural vegetation cover and allowing pedogenesis to progress to a stage which enables growth and maintenance of the grass or forest vegetation cover should be a permanent goal. The stabilization and linkage of creeps or screes is of special environmental importance. This is the preferred direction of management. Protection against erosion by water and wind should certainly be envisaged as a required measure. On the pastures this role could be played by dry stone walls. When it comes to natural vegetation, the most common is the community of *Coridaletumliospermae* (Fukarek, P., 1962). It should be noted that overgrazing on Lithosol opens the way to the destructive processes, but plant roots strongly hold on to the soil protecting it from erosion. Additionally, the hooves of sheep or goats can „cut into "the soil thus opening the way to erosion as well as some other human activities such as excavation. Figures 5. and 6. are the best examples of the mosaic pattern of soil cover even in a very small area, caused by topography – Rocky ground (Lithosol) alternates with limestone dolomite black soil (Calcomelanosol) in a mosaic pattern. Such a sequence of soils is called toposequence as the (micro- and meso-) topography determines the structure of the soil cover, i.e. the „achievements "of soil formation.

Figure 5 and 6. Lithosol is a substrate for poor pastures with xerothermic species resistant to drought as predominant (Bašić, F., 2012)

Sierozem, (Regosols)

Regosols are undeveloped or poorly developed soils on loose substrates which are generally not skeletal. They are formed by erosion of previously formed soils and initial processes of pedogenesis which have not yet resulted in the formation of humus A horizon due to its young age, erosion or human impact. Depending on the relief situation and geological substrate they occur in association with Lithosols and Calcomelanosols. These initial soils are rather important in crop production as the biologically active zone, represented by undeveloped Ai initial horizon, is deepened by loose C horizon which is also environmentally suitable for higher plants as it is porous, retains water and has enough air thus enabling rooting of plants. The most suitable for crop production are carbonate-silicate Regosols, especially its variants formed on marl. These soils occupy the foot of the slope and more stable positions in relation to Lithosols. Such topographic position at the foot of the mountains allows for soil to remain in the initial stages of development. These are most commonly the areas of pasture and forest association. Forest species particularly favour Regosols as the substrates of these soils are soft so the penetration of roots is without difficulties and they also retain water well. Pastures are somewhat more suitable than those on Lithosols. When it comes to the guidelines for the management of these soils, they should involve actions similar to those for Lithosols. Regosols are poor in humus, phosphorus and potassium so they respond well to the application of manure and mineral fertilizers. If used in agriculture, Regosol is particularly suitable for the cultivation of root crops where a high quality of products can be achieved. In the Sub-Mediterranean and Mediterranean zone these are the soils on which grapes and olives are successfully grown. Erosion control is the only way for ensuring evolution of these soils; Lithosol will evolve into Calcomelanosol and ultimately to Calcocambisol, while Regosol will gradually evolve into Rendzina. Total area of these soils amounts to 21,832.3 ha or 1.3% of the total observed area.

Calcomelanosol, (Molic Leptosol)

This type of soil belongs to the class of calcaric humus-accumulative soils with A-R and A-C structure of profile. It is formed on hard limestones and dolomites, on reliefs prone to erosion. The presence of limestone and dolomite parent substrate, pronounced relief and high altitude have a decisive influence on the development of this type of soil. Soil reaction mostly ranges within limits, pH slightly acid to alkaline. These limestone-dolomite black soils have a rather high content of humus. In terms of textural composition they are mostly loamy loose sandy soils and sandy clays. Thus, it can be stated that these are light soils with favourable properties when it comes to the rooting of plants. The total porosity (pore volume) exceeds 50%, and the level of water capacity is also high (over 50%), which implies that these soils are porous but also with a large absolute water capacity thanks to the high percentage of organic matter and humus. From the aspect of physical and chemical properties, limestone-dolomite black soils could be characterized as favourable soils provided there are no other limiting factors (shallow profile, rockiness and stoniness, etc.) causing their unsuitability for any intensive crop production; therefore, they are mainly used as pastures, while colluvial deposits of black soil in depressions are used for growing potato. The total area of these soils amounts to 752,695.9 ha or 45.7% of the total observed area.

Rendzina, (Rendzic Leptosol)

This is a humus-accumulative type of soil. It is developed on loose carbonate substrates (on loess, loess-like sediments, fluvioglacial sediments, soft limestones with a lot of silicate component, lake sediments, etc.). The parent substrate has a significant impact on pedogenesis. First and foremost, these are the substrates consisting of already fragmented clastic sediments or are quite easily physically weathered so that the process of pedogenesis takes place at a deeper carbonate regolith. Rendzina has a mollic, humus-accumulative horizon which is formed on loose carbonate substrate (IC). Usually a transitional AC horizon can be distinguished, so the profile structure is Ah-IC. Parent substrate has a high content of carbonates (over 20%), and the whole profile is carbonate except for the variety of leached and brownised Rendzina. It most often occurs in association with Regosols which are formed from Rendzinas after they have been affected by erosion. The vegetation on these soils is considerably different from the surrounding one as it has a larger share of calciphile and xerothermic species, and erosion „reveals "its hot spots if the vegetation has failed to cover the area and protect the soil. Rendzina is a very fertile soil with exceptionally favourable physical and chemical properties which requires abundant application of organic fertilizers for the successful production. They also require protection from erosion and permanent vegetation cover. The total area of these soils amounts to 68,089.5 ha or 4.1% of the total observed area.

Calcocambisol, (Calcic Cambisol)

These soils of Dinaric karst, usually situated at an altitude ranging from 500 to 1200 m above sea level, account for 461,520 ha or 28% of the total observed area. They belong to the class of cambic soils, on calcaric/dolomitic substrates with mollic *Amo* or ochric *Aoh* humus horizon, which lies directly on cambic Brz horizon of characteristic brown colour. The process of soil formation takes place in situ on unaltered natural substrate. Morphological structure of the profile is $Ah\text{-}B_{rz}\text{-}Cn$. This cambic horizon is of somewhat heavier textural composition, more pronounced structure and significantly less humic compared to the surface horizon. Since limestone weathers very slowly, formation of soil on these substrates is slower, thus the higher risk of erosion. Depth of the solum varies, however, these are mainly shallow to medium deep soils. Soil reaction in the surface horizon ranges from slightly acid to neutral and slightly alkaline. They are rather humus rich soils in the first horizon, but the content of humus rapidly decreases with soil depth. By its texture the surface horizon generally belongs to loams. The entire depth of the soil is mainly non-carbonate or slightly carbonate. According to the physical and chemical properties these soils are good for various types of production, however, due to the often occurrence of surface rockiness and stoniness, the shallowness of the soil and the altitude at which they are formed (short vegetation period), they are not always suitable for intensive crop production. Therefore, they are mostly used as meadows and pastures, i.e. under the vegetation that is already adapted to the specific environmental conditions. These soils are characteristic for the processes which increase demineralization of humus and the accumulation of mineral component in residual horizon. They are as favourable as garden and arable soils. Arable land and gardens used to be the dominant type of land use, their size was much bigger with only rare meadows and pastures. Today, it is the other way around: arable land and gardens are rare and meadows and pastures are predominant though insufficiently used due to depopulation. Dry stone walls remain as a kind of landmark from the past, Figure 7. These soils are most threatened by wind or water erosion so that all measures to protect forest and agricultural soils are welcome. It is very risky to expose plowed soil on the slopes to the impact of rainfall, so the vegetation cover should therefore be preserved and maintained.

Figure 7. Dry stone walls (on the left) remain silent witnesses of past times, and the new buildings of what awaits us (on the right) (Bašić, F., 2012)

Terra rossa, (Rhodic Cambisol)

In B&H, red soils are widespread on hard Mesozoic karstified limestone and dolomites in the Mediterranean karst area on flat positions and depressions rising to a maximum of 500 m above sea level. These are typical climatozonal soils of Ah-Brz-C type of profile. The main limitation of these soils is their depth and rockiness. The depth is determined by internal lithological structure and stratification of limestone as well as the inclination. These are also the most important limiting factors in agricultural production. Large areas in the low area of Herzegovina karst are covered by shallow red soils, spottily scattered and intersected by highly rocky areas which further complicates their use and protection. The red soils are rather similar to calcocambisols for their environmental and production properties. The total area of red soils amounts to 49,110.2 ha or 3% of the total observed area. Although the red soil is mostly clay soil, this property is corrected by good structure and favourable water-air regime. Neutral to slightly acid reaction is a very suitable property for growing the widest range of crops. However, this is the best soil for growing grapes and Herzegovina type of tobacco. It responds positively to fertilization with the most important macro-elements, especially nitrogen and phosphorus. Red soil in larger homogeneous areas can be moderately favourable for production, but in highly rocky and steep areas production is limited to small terraces built by human hands and protected from water and wind erosion by dry stone walls. These areas used to be covered by forest which is now destroyed either naturally or anthropogenically. Because of this, they are in many places eroded or completely destroyed (bare karst on the surface) with spots of red soils. Anthropogenic red soils are mainly related to terraced positions and sinkholes. Another significant problem is the deep karst erosion being the worst form of erosion. Thus, limitations in red soils, just like in calcocambisols, are determined by rockiness, the situation in relief, surface rockiness and depth of the soil. The red soils are also subject to the processes leading to an increased depth of mineral component and decreased humus content due to intensive mineralization.

CONCLUSIONS

The process of pedogenesis in the karst area of the Mediterranean region or mountain heights is characterized by dissolution of the Mesozoic limestones and dolomites, calcium and magnesium carbonates containing 0,1 up to maximum 5% of the so-called insoluble residue.

Another important process in the formation of soil pertains to the formation and transformation of organic matter, i.e. the process of humification. The content of humus in the soil depends on the intensity of two opposite microbiological processes: formation or humification and decomposition (mineralization) which results in the release of all biogenic elements embedded in the biomass from which humus is formed. In the researched area there are two „breaks “in the microbiological activity - the winter one due to low temperatures and the summer one due to drought, so that the processes at higher altitudes result in the predominant accumulation of organic matter, whereas at lower positions the process of accumulation and mineralization is balanced. For this reason, humus-accumulative soils such as Calcomelanosol and Rendzinas are prevalent in the pedosphere of high karst, and Calcocambisols and Red Soils in the pedosphere of low karst. Rocky grounds (Lithosols), Regosols (Sierozem) occur throughout the area in very steep relief positions, particularly on the southern and south-western exposures.

Almost all Mediterranean countries have enough rainfall at the annual level to cover evapotranspiration needs. Similar situation is in B&H and the Sub-Mediterranean region as well. But the distribution of rainfall during the year is very uneven in terms of space and time and is not in harmony with evapotranspiration distribution. The soil-water imbalance is the main limitation in agricultural production. Climate change has a very strong influence on all aspects of the ecosystem functions, particularly on the soil during the dry period of the year. During the cold part of the year there is too much rainfall when the evapotranspiration needs are very low. On the contrary, during the warm part of the year there is not enough rainfall and drought is often very acute.

In such conditions, farmers in rain-fed agriculture must be timely and accurately informed about the rainfall and soil water regime. In this way they can choose crops suitable for the specific rainfall distribution or make a better planning and production orientation. This could improve the protection of soil as one of the most important natural resources for humans.

The aim and task of comprehensive protection of the soil is to continuously maintain its main roles in a way that preserves natural ecosystems, all plant species and natural forests, makes the agro-ecosystem stable, ensures that agricultural production is at an acceptable level, without jeopardizing in any way the natural ecosystem – water, air and biological resources – flora and fauna. Agricultural production along with natural biodiversity and abundance of medicinal herbs, livestock and wild animals, should provide an aesthetically acceptable landscape, appealing to modern man. Soil protection is therefore a *conditio sine qua non* of the foundation, survival and improvement of this area. This effort requires activities on making an inventory of the condition of soils and establishing a continuous monitoring and appropriate information system.

Type of land use is an important issue not only for the establishment, but also for a sustainable survival and protection of the environment. In once different social and economic conditions of this area, the land that used to be cultivated is now abandoned and more or less left to nature – spontaneous vegetation..., and even in the parts that are still in use, the predominant type of use is again close to nature, namely grassland – mountain pastures and meadows. Livestock production is focused solely on natural sources of fodder as it is not cultivated. The possibility of growing vegetables and medicinal herbs of exceptional quality has not yet been recognized due to potentially small yields. The conversion of this land to organic farming is one of the options for sustainable management of this area. For this reason, sustainable agriculture, with special emphasis on animal husbandry combined with sustainable management of grasslands – meadows and pastures, as well as the cultivation of vegetables, represents a realistic direction of development.

In order to stop further degradation of all components of the environment, i.e. soil, water, air, biodiversity, landscape, economic and historical heritage and to reverse the process towards improvement, it is necessary to:

- support the economic viability of traditional farming systems and products and to contribute to the maintenance of landscape and biodiversity;
- foster regional management of natural and cultural resources to ensure long-term conservation of biodiversity (through important natural karst systems); and
- contribute to sustainable rural development by building a specific tourism product (brand).

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SPECIFIC ROLES OF SOIL IN AGROECOSYSTEMS OF NERETVA AND TREBIŠNJICA RIVER BASIN

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ABSTRACT

The diversity of soils and climate in the Neretva and Trebišnjica River Basin spreads from the lower, higher, high to very high zone over 2,000 meters above sea level. The most important agricultural land is in river valleys and karst poljes of belonging zones. Ameliorative systems are mostly out of function while actual systems are comprised of very intensive farming; vegetable growing, modern fruit plantations on the open field and protected areas (greenhouses), but also of the low-intensity farming system in a mountainous area. The current climate changes obviously are not a temporary phenomenon, but are a specific one; there are no more "dry" or "rainy years" as it was in the past -now we have both in the same year. In spring, the soil needs quick and efficient drainage of the sufficient water by drainage system, but in dry – vegetation period, compensation of water deficiency by irrigation is needed. Therefore, today's generation of decision-makers and users of soil as a public treasure cannot avoid the question as to which soil/land areas and at which way to focus investments. We propose the construction of multi-purpose water accumulation, to collect (excess) precipitation in autumn-winter season for irrigation in dry summer vegetation period, but it is necessary to focus land management on (pedo) biological properties and activity.

Keywords: *Neretva and Trebišnjica River Basin, changing climate conditions, karst polje*

INTRODUCTION AND OBJECTIVE OF RESEARCH

Important territory of agro sphere of Bosnia and Herzegovina (B&H) is the Neretva and Trebišnjica River Basin with associated karst poljes. The Neretva River is the longest (230 km) and the most water abundant river with annually discharge of 11,900 km^3 of high quality fresh water into the Adriatic Sea. Water springs of this river is in Zelengora and Lebršnik Mountains on 1,095 m.a.s.l., at first it flow as alpine river with deep, wild

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canyon, than wide water valley and is 203 km long in B&H, but the last 22 km of Neretva River is in Croatia, forming a wide picturesque delta on the mouth. Longer and water-richer tributary stream of Mediterranean Sea is only Nile River. The second largest watercourse of B&H is the Trebišnjica River 96.5 km long, having the spring on the foot of Vlajinja mountain near Bileća on 392 m.a.s.l., naturally sinks in ponor of Popovo polje and flows into the Adriatic Sea, but also partly flows underground to Hutovo blato and Neretva River.

The objective of research was to define and explain two specific soil-related services in environmentally sensitive area of Neretva and Trebišnjica River Basin: much more known food- and less known non-food or ecosystem-regulatory roles or services of soil. Because of these, soil-related services going to be more and more important in the light of predicted and expected climate changes. The other objective was to analyse tendencies of climate changes. The special aim was to define water balance and requirements tendencies of requirements of water for irrigation in conditions of intensive agriculture of low (5-100 m.a.s.l.), higher (100-300 m.a.s.l.) and high karst *poljes* (300-700 m.a.s.l.), as well as low intensity farming systems of very high *poljes* (more than 700 m.a.s.l.) and surrounding area.

MATERIAL AND METHODS

For general analyse and evaluation of climate, soils and biological resources, the results obtained in the study of Mišetić *et al*. (2005) for this territory were used.

Characterization of climatic conditions was made according to the data of Meteorological stations Mostar (h = 99 m.a.s.l.), φ = 43°20´53˝ N,λ = 17°47´38˝E) and Ivan Sedlo (h = 967 m.a.s.l. φ = 43°45´04˝ N,λ = 18°02´10˝E) of Federal Hydro meteorological Institute of Federation of B&H in Sarajevo, both for the same series of meteorological data; past series (1961-1990) and recent series of data (2000-2015).

Based on these data, the *Lang's* rain factor (KF) and *Gračanin's* monthly rain factor (KFm) was calculated. Water balance was calculated according to Thorntwhite method and drought conditions were described by monthly index of aridity by UNEP. For the same usable were also published data on this topic of Vlahinić *et al*. (2013), as well as the data from neighbouring county (Mesić, 2009). For characterization of soil, the data of own research in protected areas of Hutovo blato (Bašić, 2012) and Blidinje (Bašić, 2012; Bašić, Herceg 2015), as well as data on soil genesis and evolution on limestone and dolomite (Resulović *et al*. 2008, Bašić 2013, Husnjak, S., 2014) were used. Soil taxonomy was made using the criteria of International soil classification system IUSS Working Group WRB (2015), as well as soil classification according to criteria of Husnjak (2014). For agro ecological valorisation, the own experiences of neighbouring county (Poljak *et al*., 2009; Kisić 2009) were used. Very useful were also results obtained in research of Livanjsko polje (Čustović, Bašić, 2009; Čustović, Herceg, 2013), and data on policy of nature protection in B&H (Herceg *et al*., 2010).

RESULTS AND DISCUSSION

Climate of basin

On entire area two types of climate meet collide, chaotic intertwined and mixed influences of the Mediterranean in the south and the continental climate of the north. Warm, maritime air masses from Adriatic crosses Neretva valley and penetrates by numerous canyons penetrate into the interior. Southern slopes of all mountains in the Basin are exposed to its direct impact As consequence, for example, on Čvrsnica Mountain the Mediterranean flora penetrates very high (Bjelčić, Šilić, 1971; Šilić 2003; Martinić *et al*., 2010; Šaravanja *et al*., 2010). Collision and mixing of air masses cause the sudden change of weather and abundance of snow in winter.

Area of Mostar is located in the circulation zone of mid-latitude during the most of the year. It is under the influence of the subtropical high pressure zone during summer, with dry and warm weather. According to the Köppen climate classification, the location of Mostar has Cfsa climate.

In contrast to the Neretva River valley, the location of Ivan Sedlo in the central mountain region has a sub mountainous climate with maritime characteristics, which are primarily reflected in the annual rainfall regime and moderating air temperature extremes. According to the Köppen climate classification, the location of Ivan Sedlo has Cfsb climate.

Air temperature

According to the data of the past (1961-1990) series at Mostar meteorological station in the Neretva River valley, the annual cycle of air temperature monthly averages has maritime characteristics with autumn being warmer than spring by 1.6°C on average.

In the recent series all analysed indicators of monthly and annual temperatures increased in relation to series from past century (Table 1).

Table 1. Basic statistics of air temperature (°C) for Mostar

	1961-1990						2000-2015					
	MAM	JJA	SON	DJF	VEG	ANN	MAM	JJA	SON	DJF	VEG	ANN
avg	13.7	23.5	15.3	5.9	20.4	14.6	14.9	25.6	15.9	6.6	21.9	15.7
sd	1.0	0.8	1.0	1.0	0.7	0.4	0.7	1.2	0.8	1.0	0.9	0.5
max	15.2	25.0	17.2	7.6	21.5	15.6	16.4	27.8	17.6	8.8	23.3	16.2
min	11.4	21.7	13.0	3.3	18.8	13.6	13.8	23.4	14.0	4.8	20.3	14.6

**MAM: March, April, May; JJA: June, July, August; SON: September, October, November; DJF: December, January, February; VEG: vegetation period; ANN: annually; avg-average; sd-standard deviation; cv-coefficient of variation; max-maximum; min-minimum*

Considering the ten warmest years and warmest growing seasons in past and recent, all of them (both years and growing seasons) are recorded in the 21st century (Figure 1).

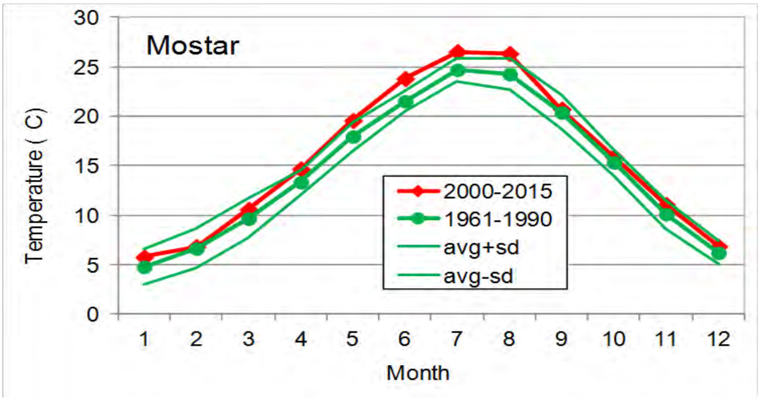

Figure 1. Monthly air temperature of series 2000-2015 and 1961-1990 - Mostar meteorological station

Considering the ten warmest years and warmest growing seasons in both series (46 years), all of them (both years and growing seasons) are recorded in the 21st century. Similar results were obtained by Majstorović (2015), which show an increase of average annual air temperature in B&H in last 100 years for 0.6°C.

According to the data of the Ivan Sedlo during the recent series summer months were warmer and consequently mean summer temperature and mean temperature of the growing period year were higher than in past series of last century (Table 2, Figure 2).

Table 2. Basic statistics of air temperature (°C) for the Ivan Sedlo

Indicators	Past series of data 1961-1990*						Recent series of data 2000-2015					
	MAM	JJA	SON	DJF	VEG	ANN	MAM	JJA	SON	DJF	VEG	ANN
avg	6.8	15.6	8.2	-1.6	13.0	7.2	7.7	16.9	8.9	-0.9	13.9	8.1
sd	1.2	0.8	1.2	1.6	0.6	0.5	0.7	1.1	1.1	1.7	0.8	0.6
max	8.8	17.3	10.1	1.2	14.0	8.3	8.9	19.2	10.8	2.8	15.2	9.0
min	4.0	13.8	6.0	-5.5	11.6	6.4	6.5	15.3	6.0	-3.2	12.9	6.8

**MAM: March, April, May; JJA: June, July, August; SON: September, October, November; DJF: December, January, February; VEG: vegetation period; ANN: annually; avg-average; sd-standard deviation; cv-coefficient of variation; max-maximum; min-minimum*

Of ten warmest years in both - past and recent series means 46 years, nine of them are recorded in the 21st century and of ten warmest vegetation periods of both series, eight of them are recorded in the recent - 21st century, indicated climate warming.

Maritime influence in the annual cycle is reflected in the warmer autumn than spring for 1.4°C. During the year, average monthly temperature begins to decline from mid-summer to the coldest month in the annual cycle (January, -2.7°C) and then increase to the warmest, means July with 16.4°C. It can be expected August as the hottest month as frequently.

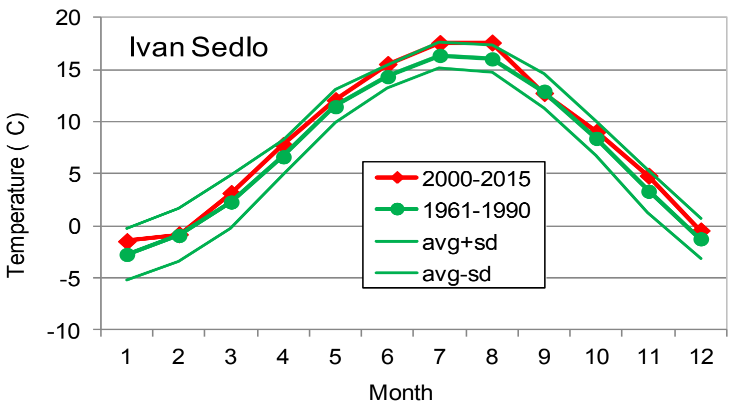

Figure 2. Monthly air temperature of series 2000-2015 and 1961-1990 –Ivan Sedlo meteorological station

Mean temperatures of July ranged 14.7°C - 19.7°C, both are warm (w) and mean January temperatures from -7.8°C - 0.9°C, means from nival (n) to cold (c). Temperature conditions are more stable in the warm part of the year (April to October) than in the cold one (November-March). This is evident from the annual course of temperature variability, expressed by standard deviation, which is the smallest in June and July (1.1°C namely 1.2°C), and the biggest one from January to March (1.8°C, 1.9°C, 2.0°C respectively). During the recent 16-year series 2000-2015, summer months were warmer than long term average, and consequently mean summer temperature and mean temperature of the growing (vegetation) period, as well as for the year were higher than long term average.

In support of theory of "climate warming" are data that of ten warmest years in both of series (46 years), nine of them are recorded in the 21st century and of ten warmest growing seasons eight of them are recorded in the 21st century.

Precipitation – quantity and distribution

According to the 30-year past series of climatic data, Mostar in the Neretva River valley has the maritime annual cycle of mean monthly precipitation. During the cold half-year receives in average 66% more precipitation than in the warm half (Table 3). This water is useful for irrigation in dry and hot summer season, as precondition of vegetable growing in a reasonable intensive farming system on the open field and/or in plastic houses.

Table 3. Basic statistics of precipitation regime for Mostar

Indica-tors	Past series 1961-1990*						Recent series 2000-2015					
	MAM	JJA	SON	DJF	VEG	ANN	MAM	JJA	SON	DJF	VEG	ANN
avg	379.4	196.5	449.8	495.3	522.2	1522.5	343.6	182.6	466.0	529.0	530.3	1494.5
sd	116.7	77.4	156.8	200.3	143.8	287.4	157.7	88.5	163.1	189.8	186.6	425.0
cv	0.31	0.39	0.35	0.40	0.28	0.19	0.46	0.48	0.35	0.36	0.35	0.28
max	748.1	384.9	747.9	873.7	915.6	1987.2	802.1	388.7	873.0	948.3	871.1	2490.7
min	213.0	76.2	172.1	114.1	315.8	840.5	137.4	77.9	168.1	187.3	289.6	872.5

**MAM: March, April, May; JJA: June, July, August; SON: September, October, November; DJF: December, January, February; VEG: vegetation period; ANN: annually; avg-average; sd-standard deviation; cv-coefficient of variation; max-maximum; min-minimum*

Precipitations are in the form of rain, snow is rare and short-lived. There is no clear tendency in precipitation regime, but the tendency of increase of maximal rainfall (more torrential rains). Analysis of precipitation regime shows that there is no clear grouping of "dry" and "wet – rainy" years in the 21st century. Of ten driest years and vegetation periods in the both series (46 years), five of them (both years and growing seasons), are recorded in the 21st century.

According to the past series 1961-1990, mountain meteorological station Ivan Sedlo on average receives 1,469 mm of precipitation (Table 4, Figure 5).

Table 4. Basic statistics of precipitation regime - Ivan Sedlo station

Indica-tors	Past series 1961-1990*						Recent series 2000-2015					
	MAM	JJA	SON	DJF	VEG	ANN	MAM	JJA	SON	DJF	VEG	ANN
avg	370.8	287.7	412.0	402.4	633.6	1469.0	348.4	275.3	482.2	439.6	653.9	1527.0
sd	105.1	106.1	120.5	152.7	144.3	237.3	94.9	96.8	139.0	170.9	198.5	333.9
cv	0.28	0.37	0.29	0.38	0.23	0.16	0.27	0.35	0.29	0.39	0.30	0.22
max	627.8	561.8	691.0	657.3	957.5	1781.5	493.4	402.2	779.1	827.4	1020.6	2510.2
min	205.4	150.9	181.8	80.5	393	976.4	182.6	90.7	210.5	154.2	313.5	1041.1

**MAM: March, April, May; JJA: June, July, August; SON: September, October, November; DJF: December, January, February; VEG: vegetation period; ANN: annually; avg-average; sd-standard deviation; cv-coefficient of variation; max-maximum; min-minimum*

The distribution of rainfall during the year is under the maritime influence, having the primary maximum in late autumn (November, 169 mm), but from February to April a spreading secondary maximum of about 135 mm. In the recent series small changes in mean annual and seasonal regime has occurred in relation to series of data of past century (from 6% to 9%) except in autumn when an increase of 17% is recorded.

Our analyse shows that of ten driest years and growing seasons in analysed 46 years, such a three years and growing seasons are recorded in this century as well as two of ten rainy years and five of ten growing seasons are also recorded in the 21st century. Speaking on precipitation tendency, truth to say, there is no humidity increasing tendency of climate.

Results of hydrological analyse of Brilly *et al*. (2015) suggest the frequent flood as indicator of precipitation regime.

According to Lang's rain factor, as visible in Table 5, area of Mostar is characterised by humid climate (H) in both studied series, but with lower rain factor – KF in recent series.

Table 5. Rain factors as indicator of humidity – Mostar station

Analysed series	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1961-1990	34.3	23.1	15.5	9.5	5.7	3.6	1.8	3.0	4.7	10.0	19.8	28.8	104.3 – H
	ph	ph	ph	h	sh	sa	a	a	sa	h	ph	ph	-
2000-2015	30.8	21.7	13.0	8.3	4.3	3.0	1.8	2.3	6.8	9.8	15.2	25.6	95.0 - H
	ph	ph	h	h	sa	a	a	a	h	h	ph	ph	-

Abbreviations: ph-per humid; h-humid; sh-semi humid; sa-semiarid, a-arid

Comparing the *Gračanin's* monthly rain factors (KFm) in studied series, it is visible that KFm of all months is lower in recent serie compared to past serie June became arid and along with July and August there are three months with arid characteristics. Contrary, September is the only month more humid in the recent serie compared to past one.

Contrary of situation in Mostar according to *Gračanin's* monthly rain factors (KFm), area of Ivan Sedlo has per humid climate in both of studied series of data (Table 6).

Table 6. Rain factors as indicator of humidity – Ivan Sedlo station

Analysed series	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1961-1990	-	-	58.5	20.0	9.1	7.4	5.0	6.2	8.5	15.9	51.0	-	204.0 - PH
	-	-	ph	ph	h	h	sh	sh	h	ph	ph	-	-
2000-2015	-	-	37.9	14.9	9.3	7.1	5.1	4.2	11.8	18.7	33.8	-	187.6 - PH
	-	-	ph	ph	h	h	sh	sa	h	ph	ph	-	-

Abbreviations: ph-per humid; h-humid; sh-semi humid; sa-semiarid, a-arid

Comparing the monthly rain factors in studied periods, it's visible that one month (August) only has become more arid and September more humid in the recent serie.

Thresholds of cardinal temperatures and vegetation period

Minimal temperature by which starts the biological activity of continental crops/plants, in the spring and stops in autumn is 5°C, for thermophilic plants vegetation starts at 10°C, but for Mediterranean cultures the threshold is 15°C (Mesić, 2009).

Table 7 presents the start, end and duration of periods with selected cardinal temperatures of 5, 10, and 15°C in Mostar.

Table 7. Thresholds and duration of cardinal temperatures in Mostar

Analysed series	Thresholds of temperatures, °C								
	5°C - vegetation period of continental cultures, date of:			10°C - vegetation period of termophilic cultures, date of:			15°C - vegetation period of Mediterranean cultures, date of:		
	Start	End	Duration	Start	End	Duration	Start	End	Duration
1961-1990	18.I	8.I	355 days	18.III	16.XI	244 days	26.IV	17.X	175 days
2000-2015	01.I	31.XII	365 days	11.III	23.XI	258 days	17.IV	21.X	188 days

The mentioned indicates that vegetation periods with temperatures above 5, 10, and 15°C in Mostar prolonged respectively by 10, 14, and 13 days in the recent period compared to past century.

Table 8 presents the start and end of vegetation periods for plants with cardinal temperatures of 5, 10, and 15°C of area of Ivan Sedlo meteorological station.

Table 8. Thresholds and duration of cardinal temperatures in Ivan Sedlo

Period	Thresholds of temperatures, °C								
	5°C - vegetation period of continental cultures, date of:			10°C - vegetation period of termophilic cultures, date of:			15°C - vegetation period of Mediterranean cultures, date of:		
	Start	End	Duration	Start	End	Duration	Start	End	Duration
1961-1990	3.IV	4.XI	216 days	6.V	4.X	152 days	25.VI	25.VIII	62 days
2000-2015	27.III	13.XI	232 days	1.V	7.X	160 days	10.VI	31.VIII	83 days

The period with temperatures above 5, 10 and 15°C in Ivan Sedlo prolonged by 16, 8 days and 21 days respectively in recent series compared to the past one. Means in the area of Ivan Sedlo there are thermic conditions for grass, some cryophilic plants, like rye, potato, cabbage and some shorter FAO groups of maize, but "late frost" is permanent risk for spring crops.

Water balance by Thornthwaite method

Calculation of water balance by Thornthwaite method of Mostar area during the series 1961-1990, shows the average actual evapotranspiration of 679 mm, total annual water surplus 844 mm, while deficiency is 126 mm and occurs in vegetation period during July and August (Figure 3 left).

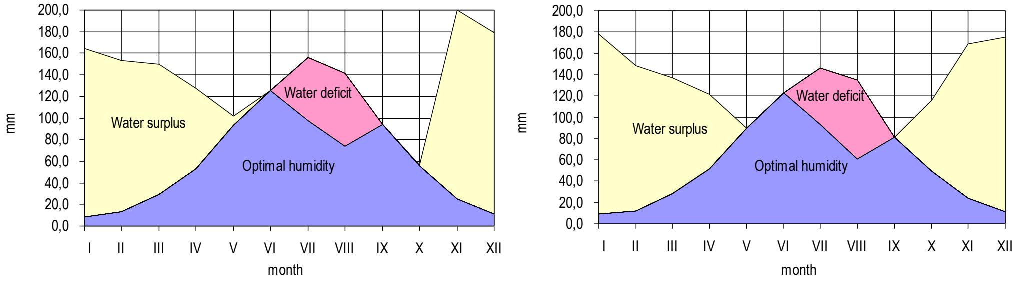

Figure 3. Water balance by Thornthwaite for Mostar 1961-1990 (left) and 2000-2015 (right)

Comparing the surpluses and deficiencies it is visible that there is no significant difference.

For Ivan Sedlo, during the past series actual evapotranspiration amounts 560 mm and the soil water reserves decrease during July and August. The total average annual water surplus is 909 mm while water deficiency is not registered (Figure 4 left).

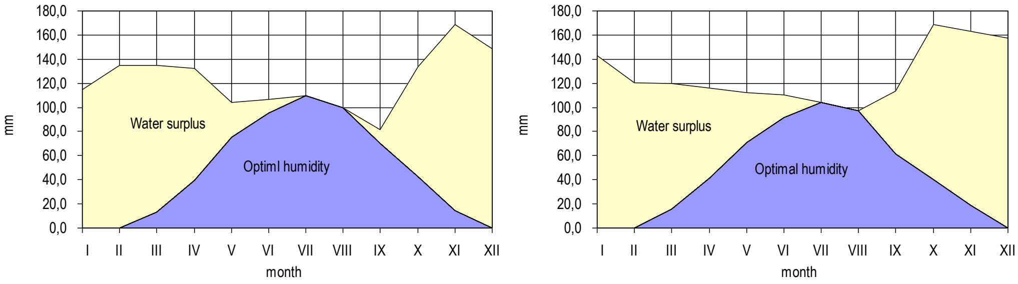

Figure 4. Water balance by Thornthwaite for Ivan Sedlo 1961-1990 (left) and 2000-2015 (right)

In recent series actual evapotranspiration is 542 mm and soil water reserves decrease during July and August. The total average annual water surplus is 985 mm while water deficiency is not registered (Figure 7 right).

Index of aridity according UNEP

We used monthly index of aridity - IA_U = rainfall (mm)/potential evapotranspiration created by FAO/UNEP for numerical identification of desertification (Tsakiris, Vangelis 2005).

Table 9. Indicators of water balance - Mostar

Series of meteorological data		Month AI_U = P*/PET						Annually mm		
		IV	V	VI	VII	VIII	IX	P*	D	S
Past series 1961-1990.	Average	-	-	0.62	0.29	0.52	-	1,522.0	126	843.7
	Dry 1983	-		0.33	0.13	0.44	-	840.5	265	308.5
	Rainy 1979	-	0.44	0.55	-	-	-	1,987.2	81	1,271.0
Recent series 2000-2015.	Average	-	-	0.59	0.33	0.45	-	1,494.5	127	861.1
	Dry 2011	0.58	0.91	0.25	-	0.16	0.35	872.5	187.0	318.7
	Rainy 2010	-	-	0.17	0.34	-	-	2,490.7	156	1,865.2

**P – Precipitations in mm, PET - potential evapotranspiration in mm D – water deficiency in mm S – water surplus in mm*

sub humid (0.50< AI_U <0.65)	*semiarid (0.20< AI_U <0.50*	*arid (0.05< AI_U<0.20)*

In dry years of recent series dry period begins in April and ends in September, July were not dry but August was the driest. In rainy year June was the driest. Problem is surplus from 18,650 m^3 water, causing soil erosion and floods on one, but drought on the other side.

Situation in Ivan Sedlo (Table 10), compared with long-term average, has surprisingly been changed. Usually humid area has become arid in dry, but semiarid in July and sub humid in in August in rainy year.

Table 10. Indicators of water balance – Ivan Sedlo

Series of meteorological data		Month AI_U = P*/PET			Annually mm		
		VI	VII	VIII	P	D	S
Past series 1961-1990.	Average	-	-	-	1,469.0	0	909.3
	Dry 1990	0.60	0.58	0.61	976.4	25	441.2
	Rainy 1984	-	0.50	-	1,781.5	0	1,205.5
Recent series 2000-2015.	Average	-	-	-	1,527.0	0	985.2
	Dry 2011	-	-	0.10	1,041.1	0	506.1
	Rainy 2010	-	0.27	0.71	2,510.2	9	1,976.4

**P – Precipitations in mm, PET - potential evapotranspiration in mm; D – water deficiency in mm, S – water surplus in mm*

sub humid (0.50< AI_U <0.65)	*semiarid (0.20< AI_U <0.50*	*arid (0.05< AI_U<0.20)*

Water surplus in recent series is higher than in past one, even extremely high.

Climatic conditions of the of Neretva and Trebišnjica River Basin are strongly influenced by winds, especially in autumn, winter and early spring. The most frequent winds are bura and jugo. Bura is northern and north-eastern, but jugo is the southern wind. Citing the other authors Ćorić (2009) states that winds decrease the temperature, quickly dries the soil and significantly decrease air saturation with water Which means that the area is much drier than it express analysed and presented indicators of climate.

The unfavourable distribution of precipitation during the year, with a large surplus in the cooler and deficiency in the warmer part of the year is the main characteristic of precipitation regime and water balance in the Basin. The rational and reasonable solution is to collect water surplus in (mini)multi-purpose accumulation and use this water for irrigation in dry period. Agriculture should be protected of both extremes - drought and floods.

SOILS OF NERETVA AND TREBIŠNJICA RIVER BASIN

Specifics of soil genesis and evolution

Dominant parent rocks generating mineral component of soil in Neretva – Trebišnjica Basin are hard Mesozoic, on southern part dominantly cretaceous but in northern older - Triassic and Jurassic) limestone and dolomites, typical for B&H karst. Loose parent materials are localy widespread (Ljubuški, Dubrave) as flysh (layers of marl in change with thin layers of sandstones), soft Miocene limestones, marly limestones and marl.

Soils are formed in complex long-lasting processes of soil genesis as interaction of climate (atmosphere), rock (lithosphere) fauna, flora - vegetation and living macro and microorganisms (biosphere) described in numerous references of B&H famous older and active soil scientists (Resulović, Vlahinić 1972; Resulović 1999; Resulović *et al*., 2008; Ćorić 2009). The duration of soil genesis depends mainly on the characteristics of the parent rock or substrate from which originate mineral component of soil. On the limestone, as the most widespread rock in the Basin, soil formation takes a long time as process of dissolution of limestone and accumulation of non-soluble residue. Time that is necessary for formation of a 1 cm thick soil layer (in the absence of wind/water erosion) is at least 8 000 years. Mentioned above means that for formation of a 100 cm thick soil layer, which would to be a good agricultural soil, approximately is necessery one million, but for Feralsol $_{\textbf{rhodic}}$ - Tera rossa, according to Durn (1996*)* even two millions years!!!

If there is no interruption, soil genesis and evolution on hard limestones and dolomites shows the sequence of soil types and subtypes, as members of soil evolution series as follows:

LITHOSOL$_{\textbf{calcaric/dolomitic}}$ (starting - initial accumulation of humus) →**LEPTOSOL** $_{\textbf{calcaric/dolomitic}}$, **UMBRISOL**$_{\textbf{leptic/skeletic}}$ - **MELANOSOL**$_{\textbf{calcaric}}$ – humus-accumulative soils**;**

organogenic (humus accumulation with small mineral component – insoluble residue of limestone or dolomite) →**organomineral** (along with humus accumulation of mineral component – insoluble residue) →**cambic** (increased mineralization of humus and the accumulation of mineral component in residual horizon)→**CAMBISOL$_{\mathbf{calcaric/dolomitic}}$** or – **FERRALSOL$_{\mathbf{rhodic}}$ (**or **TERRA ROSSA** according of Resulović *et al*. 2008, and Husnjak 2014 classification**)** (increased depth of mineral component, decreased humus content because of intensive mineralization) →**LUVISOL on limestone** (along with decreased humus content, elluvial-illuvial migration of clay and differentiation of clay content in soil profile).

All members of series are described in cited literature we could find for territory of Neretva-Trebišnjica Basin, but with different distribution in concrete zone. Because of geomorphological condition, soil genesis can be interrupted mostly by wind and/or water erosion, soil material can be removed to stable topographic position and settled to the foothill or in karst *poljes,* as multi-layers Colluvium. Soil genesis on the parent rock starts again – till the new interruption or till vegetation covers and protects from erosion.

In regularly recently flooded valleys of Neretva, Trebišnjica and tributaries there are Fluvisols, as multilayer soils transported by river water and deposited in floodplain. These soils are in rule very favourable and fertile, but with limited choice of crops – exclusive spring crops sown after regularly winter-spring floods, but on protected and drained land this type of soil is very favourable. Under influence of permanent stagnation of shallow water, as in Hutovo blato there are formed soils reach by organic matter accumulated in anaerobic – water condition – Histosol, with luxuriant specific hydrophilic plant cover. In wider valleys under influence of underground and/or flood water - Gleysols, with typical horizon of bluish colour.

Colluvial soil is a heterogeneous mixture of different soil material that, as a result of gravitation has moved down a slope and settled at its base, in depressions or above a barrier on a low-grade slope (natural or human-made, like hedge walls) or in karst *polje*. It has been transported across and redeposited on slopes as a result of erosional wash but may also be translocated by ploughing. It has been formed in relatively recent times (mostly Holocene), may show some stratification but it is not a typical feature due to the diffuse or chaotic nature of the deposition process.

SOIL-ORIGINATED TERRESTRIAL ECOSYSTEM EFFECTS

Soil is an essential part of all terrestrial ecosystems and milieu whence life (plant) originates and ends, or "an active biochemical factory fundamental for the Earth's food chain" (Arnalds, 2009), means agriculture and forestry as branches of economy crucial for sustainable development. The "Soil-originated terrestrial Ecosystem Effects - SOTEE" arise from soil functions affect the quality of life as the basis of FFFT effects (Food, Fibre, Fuel, Timber, means food security, food safety, source of fiber, biofuels and timber), determine the regional characteristics of the Multifunctional Character of Agriculture and Land

(MFCAL), on which the modern civilization bases sustainable development and formulates its attitude to soil as a natural resource (Bašić 2012, 2013). Concept of MFCAL places equal importance on the productive and ecological regulatory effects-roles of soil. On some areas (agricultural and forest land of high quality) prevalent would be organic matter (FFFT)-productive SOTEE, maximal respected in creation of land management system. On other areas, like protected one (national parks, parks of nature, water protecting area) prevalent SOTEE would be environment regulatory functions - services. The first one is known from very beginning of Soil science, rising within agricultural/forestry sciences, but environment regulatory is of recent origin.

SOTEE arise from interaction of members of so known ecological triad: soil-water-air, as components of terrestrial ecosystems (Varallyay, 2005). In spite of its importance as a unique natural body soil is in a special position in this triad. Namely, air and water are undoubtedly protected as "public properties", but soil (land) is traditionally one of basically private property. "Demand of the time" is protection of soil and ecosystems by regulation and direction of all practices on land and other resources management on a sustainable way. International, regional, state and local agreements, declarations, regulations, directions, rules and acts are so numerous that property rights of land owners and/or users are reduced on »rights« to work and be responsible for own work according to obligation arise from "out-farm" created decisions. It means; public regulation and legislation but private ownership and responsibility, or; own risk and responsibility for public interest and regulations! Our generation is on global level, on certain crossway where is necessary to find new – better and sustainable relation of land-owners on one, and public interest on the other side, which would reconcile profitability and sustainability in land management. Of course, with awareness of decision makers (politician) and public that there is no sustainable development without sustainable land management on the way which guarantee long-term SOTEE on desired level, including the awareness that tomorrow can be (too) late!

SOTEE in organic matter (Food) production – FFFT

Agriculture, forestry and land management directly affect the appearance of the landscape, the possibility of tourism development and the use of natural resources of the Basin. As stressed by Čustović (2012) and Vlahinić *et al*. (2003) karst *poljes* are with an area of 123,556 ha crucial for agriculture in Herzegovina, divided on the base of latitude:

<u>Low karst *poljes* (19,299 ha)</u>

This category includes karst *poljes* of the altitude 5 to 100 m.a.s.l.: Ljubuški (6,362 ha), Hutovo Blato (4,357 ha), Gabela (1,070 ha), Stolac - Vidovo polje (320 ha) and Mostar polje (4,000 ha). Ameliorative and flood protection systems are more or less in poor condition, some are totally destroyed and of any function (Ćorić 2009; Ćorić *et al*. 2013).

Higher karst *poljes* (25,865 ha)

Tthis category includes karst *poljes* of the altitude zone 100 – 300 m above sea level: Mostar blato (4,140 ha), Imotsko-Bekija *polje* (5,100 ha), Plateau Brotnjo (3,745 ha), Mokro (260 ha), Popovo (4,415 ha) - Construction of HPP, Trebišnjica river-bed trough the *polje* is regulated. Done complex reclamation of soil with irrigation on about 900 ha of land, described by Lučić (2012) Dubrave (7,000 ha), Trebinje-Dživar (1,205 ha).

Generally, land reclamation and floods protection systems are in-complete. The land is threatened by frequent floods and lack of water in dry summer. Existing facilities are unable to protect against the floods.

High karst *poljes* (10,689 ha)

In this category we can find karst *poljes* of the altitude zone 300 - 700 m above sea level: Kočerin (685 ha), Vir – Posušje (3,840 ha), Dabar (3,300 ha), Fatničko (564 ha), Bileća (640 ha), Ljubomir (810 ha) and Ljubinje (850 ha).

The predominant is an extensive crop - animal production as a consequence of unregulated water regime. In spite of water deficiency in soil, especially in summer, irrigation is not practice. According of criteria of EU this area can be designated as “less-favoured area” because of natural handicaps, e.g. unfavourable climatic conditions, short growing season due to the high altitude, steep slopes in mountain areas, and/or low soil productivity. Due to these handicaps there is a significant risk of agricultural land abandonment and thus a possibility of loss of biodiversity, desertification, forest fires and the loss of highly valuable rural landscape. To mitigate these risks, the Less Favoured Areas (LFA) payment is an important tool. Payments should contribute to continued use of agricultural land, maintaining the countryside, maintaining and promoting sustainable farming systems (Bašić, Herceg 2013; Kisić 2009).

Very high karst *poljes* (67,703 ha)

Very high are karst *poljes* of the fourth altitude – over 700 m above of sea level: Gatačko (3,183 ha), Nevesinje (17,000 ha), Livno (34,810 ha) and Duvno (12,710 ha).

Irrigation system was built. Completed flood protection to approximately 3000 ha of land, without irrigation in the building is a system for 900 ha system for basic and detailed drainage. There is a requirement for irrigation, basic and detailed surface drainage pipe drainage. And this zone can be designated as LFA.

Generally, all karst fields in Basin need investment in flood protection, drainage and irrigation system. The main limited factor in plant growing on the whole territory is unfavourable distribution of water, with deficiency in vegetation period but surplus in rest of the year. Building of multipurpose water accumulation offers rational solution (Tomić *et al*. 2013).

Environment regulatory (Non-food) SOTEE - Soil is a regulator!

Soil as a receptor and collector (accumulator) of different substances

With regard to position "between" the lithosphere and atmosphere, direct contact with the hydrosphere and anthrophosphere - biosphere, soil is acceptor of substances falling on it (acid rain and dry deposition - dust) or residues of pesticides, nitrates used in agriculture, that are environmentally relevant for all members of the biosphere and environmental components, especially water.

Soil as natural transformator!

All organic substances in the soil are exposed to (micro) biological destruction, transformation, and synthesis of new compounds, or degraded and immobilized to substances with which photosynthesis begin, means CO_2 and water, as the first and last link in the cycle of small or biological cycling of matter and energy. Similarly, in a harmless form, soil is transforming all organic pollutants such as polycyclic aromatic hydrocarbons (PAH), residues of pesticides and petrochemicals. Soils immobilize organic pollutants.

Soil as natural filter of water – Soil preserves drinking water!

The function of soil as universal cleaner (filter) is to filter rainwater and protects underground drinking (potable) water from pollution. Practically all waters in Neretva and Trebišnjica basin are drinking waters, protection of which is of extremely high importance (Bašić, 2013; Bogunović, Ćorić, 2014; Čustović, 2012; Herceg ,2013).

Climate regulatory SOTEE – Soil is source and sink of glasshouse gases!

Soil is a source of emissions of greenhouse gases, primarily CO_2. Namely, soil is the final link in the chain of biotransformation of organic carbon, which results is CO_2 and water as final products – the same one which starts in process of plant photosynthesis. It means that soil is also the sink of CO_2! Layers of the soil completely saturated with water in the absence of oxygen, carbon transformations finished with formation of methane – CH_4, as greenhouse gas more effective than CO_2. Although the total content of organic matter – humus in the soil (humosphere) is low – negligible (1-3%) humus is a public treasure of the most importance. Humus regulates chemical and biological processes, the food and energy source of soil microorganisms or “fuel” for “biologically fire”, as the basic factor of sustainable agriculture intensification. Its positive impact on soil structure strongly influences the water-air relation and hydrothermical conditions of soil, with high influence on soil fertility (Bašić, 2013).

Soil as buffer system

Working as a powerful buffer system, soil inactivates all substances that rapidly enters its mass or were released by mineralization of organic matter and prevent the stress of change in the soil, shocks to the biosphere.

Soil (land) as the space of natural and anthropogenic structures

Pedosphere provides space for agriculture, forestry, expansion of settlements, urban areas, roads, recreational area, and finally space for waste management. When making decisions on trace of roads – highways in Neretva and Trebišnjica Basin, solution should be the shortest possible route intersect karst *poljes* or river valleys with fertile soils. Faulty decisions on location can cause permanent and far-reaching consequences for the use of these facilities.

Soil as medium for waste disposal – On/in soil terminates all wastes!

Waste disposal is one of the spatial functions of soil**.** The choice of location is very delicate and absolutely highly professional matter. Regarding the soil, the basic requirement for good accommodation is the location of the landfill in Neretva and Trebišnjica river basin which excludes the possibility of pollutant emissions into the environment, especially water, but also air or biosphere - the plant life at the landfill or around it. Landfills take space - an agricultural land, a discharge from the landfill can be a source of contamination of soil, water and air pollution, which threatens human health, livestock and wildlife (Bašić, 2013).

SOTEE as foothold of biodiversity!

Soil is a habitat and gene reserve of number of micro-and macro-organisms, starting and ending points of the biological cycling, gene reserve and the foundation of biological diversity one of the major factors in the balance of nature. Means: soil diversity – biodiversity!

The number of living organisms below the surface is many times higher than on the soil surface, which is eloquently illustrated by the fact that good, fertile soil in the arable layer contains about 25 tones/ha of living organisms, including a number of extremely useful, such as symbiotic (genus *Rhizobium*) and non-symbiotic nitrogen fixing bacteria (*Azotobacter, Clostridium pastorianum*) that are using elemental nitrogen from the air and transforming it into a plant available form. What is more fertile soil, the total number of organisms and their diversity increases. Biotechnology is seeking the way to manage beneficial soil biological processes in the desired direction.

SOTEE in landscape shaping – the base of natural beauties!

The man in the natural landscape "impressed" their "messages". Changing the natural vegetation, and entering into the space created by agriculture is the "cultural landscape" due to natural conditions and enriches the space and makes it even more beautiful, affordable and attractive for rural tourism. Anthropogenic influence may be so radical (for example terracing of surface) that natural landscape completely changes in anthroscape.

Soil as a source of raw materials

Soil is an important source of raw materials, especially for the construction industry, such as the excavation of stone, soil for brick, then digging clay for ceramic crafts and industry, the use of sand and gravel as building materials, bauxite from Terra rossa, or the use of peat as a raw material for the production of substrates for closed spaces (greenhouses).

The archival SOTEE – Soil is conservator of natural and human heritages!

Conserving various geogenic and soil genesis shaping, soil keeps information on the conditions during the soil genesis that are useful for interpretation of soil evolution. Means; soil is containing the archaeological evidence of the history of humanity and is an information source for the reconstruction of human life and its activities witnessed by the archaeological remains covered by soil and protected from devastation and destruction.

Taking all in account, shortly described food- and non-food effects of soil-generated terrestrial ecosystems it can be understandable at first that soil as indeed the most complex system known to science is the medium which supports life in its broadest sense. Soil is more than (public) good; it is heritage of past generations, which obligate us ahead of coming generations. Soil science is a Life-science! The frame of agricultural and forest sciences within which Soil science started and developed is going to be (to) narrow!

CONCLUSIONS

The Neretva and Trebišnjica River Bain is a kind of "arena" in which two contrast types of climate meet collide, chaotic intertwined and mixed influences of the Mediterranean in the south and the continental climate in the north.

The durations of vegetation periods in Mostar prolonged respectively by 10-14 days in the recent compared to past century.

As these changes are chaotic and unpredictable, irrigation should be obligate practice in the new climatic conditions, in spite of water surplus from 318 mm in dry year to 1865 mm in rainy one, which means 18,650 m^3/ha/year of water causes soil erosion and floods, but also drought is a regular event on the other side.

The vegetation periods with temperatures above 5, 10, and 15°C in Mostar prolonged respectively by 10, 14, and 13 days in the recent period compared to past century.

The unfavourable distribution of precipitation during the year, with a large surplus in the cooler and deficiency in the warmer parts of the year is the main characteristic of precipitation regime and water balance in the Basin. The rational and reasonable solution is collection of water surplus in (mini)multi-purpose accumulation and use of mentioned water for irrigation in dry periods. Agriculture should be protected of both extremes - droughts and floods.

On hard limestones and dolomites there is soil evolution series: Lithosol→ Leptosol, Umbrisol, Melanosol→ Cambisol, Ferralsol, Terra rossa → Luvisol.

On global level our generation is on certain crossway where is necessary to find new – better and sustainable relation of land-owners on one, and public interest on the other side, which will reconcile profitability and sustainability in land management.

Taking all into account, shortly described food- and non-food effects of soil-generated terrestrial ecosystems we can say; soil is more than (public) good; it is heritage of past generations which obligate us ahead for coming generations.

Soil science is a Life-science! The frame of agricultural and forest sciences within which Soil science started and developed is going to be (to) narrow!

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WILDFIRE INDUCED CHANGES IN FOREST SOILS IN SOUTHERN CROATIA

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ABSTRACT

This paper presents preliminary results on the alterations in the forest soil properties during an wildfires occurred in 2011 and 2012 in southern Dalmatia (Croatia). At three locations in 2012 different soil samples (0-5 cm) were taken from shrub lands, depending on vegetation characteristics. Samples were taken from burned and unburned areas in order to determine possible differences. The results showed significant statistical differences between burned and control soil samples for pH, EC, and several cations and anions ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$, SO_4^{2-}, Ca^{2+}, K^+ and Na^+). These investigated parameters are under the direct influence of fire intensity on the ground. Results show that there is no difference between sites burned in 2011 and those that burned in 2012. Further investigation will reveal how many years it will take for the soil to return to pre-burned conditions.

Keywords: *climate change, wildfire, chemical soil properties, Dalmatian region*

INTRODUCTION

Fire as one of important disturbances in a forest system can alter vegetation composition and even promote tree regeneration (Martínez-Sánchez *et al*., 1999; Cammeraat and Imeson, 1999). In areas with a Mediterranean climate, they are determinants of landscape structure (Trabaud, 1998). The climatic characteristics of the Mediterranean with warm dry summers and relatively wet winters make it tending to wildfire occurrence. On the other hand, the influence of climatic changes cannot be denied (Pinol *et al*., 1998; Pausas, 2004). Warm and dry conditions related with global change are expected to increase the area affected by fire in the future (Gillett *et al*., 2004), and countries in years with the drier summer, have larger burned area that year (Pausas, 2004). Also, 44,000 thunderstorms occur on the earth during any day (Hatten *et al*., 2005), and in combination with the irresponsible human behaviour makes a huge threat to the natural forest.

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In Dalmatian region, for instance, the number of large-scale fires has increased in last 50 years due to socio-economic changes, abandoning livestock raising and rural depopulation and major depopulation of the islands. This has resulted with land abandonment and a forestation with flammable species, that are fire-sensitive (e.g. pine woodlands), and have pushed up highly resilient to fire (shrublands and oak forest).

Forest soil physical and chemical characteristics can be changed during burning, such as soil structure, porosity, pH and available nutrients. Soil microbial activity and community structure are also bound to be affected by fire (Certini, 2005; Neary *et al*., 1999). Fire affects soil through its ability to transform soil and ecosystem components. These transformations include outputs in the form of volatilized and combusted material as well as the convection of ash material. Fire can also mineralize organically bound elements such as N, P, and base cations which are then available for uptake by plants or leaching from the soil (DeBano *et al*., 1998; citation by Hatten *et al*., 2005). Nevertheless, long-term effects of fire on the soils depend on each soil, its characteristics and the characteristics of the ecological areas.

Many researchers have investigated wildfire and their impact on biological and chemical soils characteristics. Hatten *et al*. (2005) analyzed pH, C, N and extractable P in Douglas-fir forests of Washington State (USA) on soils affected by fire. Results show very little difference in soil properties between sites burned by low-severity fires and those areas left unburned. And lead to conclusion of little change in soil processes. In contrast to that, Murphy *et al*. (2006) studied wildfire in Nevada (USA) and concluded that fire and post-fire erosion caused large losses of C, N, P, S, Ca, and Mg from the forest floor and an increase in pH in the surface horizon. In Spain Andreu *et al*. (1996) observed that K shows low variations after the fire. pH increased after the fire in the same manner by the mineralization processes and the contribution of ashes, but after a year the values are similar to the previous before the fire.

Nevertheless, ecosystems prone to wildfires may evolve by developing responses to them. Such adaptations include a wide spectrum of strategies, from a partial surviving of the fire to a quick germination by seed or resprouting thereafter. A restoration, at least partial, of C and N cycles can be achieved through vegetation regrowth, which can be particularly healthy in Mediterranean ecosystems (Ferran and Vallejo, 1992; Kaye *et al*., 2010).

The question posed by this paper is: How does the wildfire affect the conditions in soils, and how much time will it take for the properties of fire-affected soils to return to their pre-fire levels? The objective of this study was to evaluate the effect of wildfire on the Mediterranean flora regarding the pH and EC, as well as different extractable forms of N ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$) and other ions (SO_4^{2-}, Na^+, K^+, Ca^{2+}). The hypothesis that is being put forward is that chemical soil parameters in Dalmatian soil covered by natural flora will vary substantially, and fire disturbances will lead to marked changes.

MATERIALS AND METHODS

The study area is located on island Korcula and Peljesac peninsula in the southern Dalmatia (43°02'- 42°45' N, 16°37'-17°46' E). Climate is Mediterranean and characterized by long, dry and hot summers. Winter is mild and humid. The area is covered with Mediterranean flora, and sometimes pine trees. Flora contains coniferous trees of Aleppo pine (*Pinushalepensis*), pines (*Pinuspinea*), Dalmatian black pine (*Pinusnigra*), cypress (*Cypressus sp*.) etc. Maki covering part of the area. Samples (uppermost 5 cm), in three replicates, were taken with similar aspect, slope, elevation and vegetation characteristics from very healthy shrublands, never cropped, and which have been diversely affected by wildfires in recent decade (areas burned before one or two years). Controls were chosen by their similarity to the burned area in order to determine the differences between samples. The soil pH was measured using the electrometric method with the Beckman pH-meter Φ72, in KCl suspension. Water-extractable anions (F^-, Cl^-, SO_4^{2-}) and cations (Na^+, K^+, Mg^{2+}) in soil samples were extracted in ultra-pure water in 1:10 (w/v) ratio according to ÖNORM L 1092 norm. Observed data were subjected to analysis of variance (ANOVA) using SAS Institute 9.3 and mean values were separated by Fisher's LSD test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Statistically significant difference was found in all chemical variables measured in soils that have recently been under fire (burned plots) and those without fire (control plots). Detailed results are presented in Table 1.

Burned soil samples had neutral to alkaline pH which varied from 6.78 to 7.31. The median soil pH for control samples was 6.28 which were 12% lower than the average in the burned samples. Control samples were low acid to neutral and their soil pH varied from 5.97 to 6.67. Statistical differences between control and burned samples were observed in the pH in each location. It is expected that the pH increases after the fire and decreases over time, the rate at which it does so being dependent on precipitation. Even though the research areas were in the zones of mixed vegetation, forests, and low vegetation, the obtained results confirmed the above assertion. Pereira *et al*. (2013) found significantly higher pH values three days after the fire, while Yinghua *et al*. (2012) have recorded the highest pH eight months after the fire, after which the pH started to decrease. The soil pH values increase as a result of oxidation of soil organic matter by combustion of some organic acids (Certini 2005). Smokvice area burned in 2011 has recorded increased pH levels, as well as locations burned in 2012. These areas have an uneven precipitation distribution which is reflected in the long spring-summer dry season and rainy winters, and further research should provide insight into the time needed for the soil pH of return to pre-fire levels.

Burned samples had a higher value of extractable form of N ions. Significant differences were recorded in $N\text{-}NO_3^-$ and NH_4^+ in most of investigated locations (Table 1). Higher average quantities of N-NH_4^+ and N-NO_3^- were observed in burned samples, with 17.85 mg kg^{-1} and 5.58 mg kg^{-1} and lower in control samples, with 14.80 and 1.55 mg kg^{-1}, respectively. Fire can increase and decrease the amount of N in soil. Baird (1999) and Binkley *et al*. (1992) found a small amount of N in burned soil. Schoch and Binkey (1986) and Yinghua *et al*. (2012) observed minimal N loss from a fire, but decomposition of the forest floor was stimulated by fire, releasing additional N during the following growing season, after the regeneration of vegetation. Weston and Attiwill (1990) observed an increase of fire-induced inorganic N to three times the original concentration over the first 205 days post-fire, but after 485 days the level of N return to the pre-fire situation. Rovira *et al*. (2012) in a long-term study of soil after 2 wildfires recorded a 50% loss of N (from 0.34% to 0.17%) from the first 5 cm of soil, but Choromanska and DeLuca (2002) noticed 100% (from 1.3 to 2.6 g kg^{-1}) higher N content in soil that had been recently exposed to fire. N-NH_4^+ and N-NO_3^- content tends to immediately increase in the soil surface after burning (Wan *et al*. 2001). N-ion forms rapidly dissipated through plant assimilation and microbial activities, leaching, surface runoff and erosion (Wondzell *et al*., 2003).

Table 1. Dissolved soil cations and anions for burned and control sample locations (B-burned, C-control)

Sample code		pH	EC	N-NH_4^+	N-NO_3^-	SO_4^{2-}	Na^+	K+	Ca^{2+}
		-log(H^+)	µS cm^{-1}	mg kg^{-1}					
Korcula 1 2011	**B**	7.09**a**	266.0**a**	11.30**b**	5.26**a**	52.46**a**	55.42**a**	75.74**a**	542.79**a**
	C	6.20**b**	155.9**b**	15.14**a**	0.60**b**	21.91**b**	44.30**b**	38.20**b**	308.53**b**
Korcula 2 2012	**B**	6.78**a**	221.0**a**	14.18**a**	7.14**a**	65.97**a**	57.19**b**	77.72**a**	381.44**a**
	C	5.97**b**	146.5**b**	12.95**a**	0.28**b**	28.89**b**	67.91**a**	53.56**b**	245.64**b**
Peljesac 2012	**B**	7.31**a**	335.5**a**	28.06**a**	4.34**a**	327.66**a**	57.17**a**	140.74**a**	607.99**a**
	C	6.67**b**	173.5**b**	16.31**b**	3.77**b**	39.08**b**	42.13**b**	27.24**b**	374.96**b**

*different letters within a row for each location indicate significant differences ($p<0.05$)

In this study significant differences between burned and control samples were identified in SO_4^{2-}, Na^+, K^+ and Ca^{2+}, in all investigated locations (Table 1). The amounts of SO_4^{2-}, Ca^{2+}, K^+ and Na^+were significantly higher in burned samples than in the control. EC also showed significantly higher values in all investigated sites, with almost 58% higher average value (274.17µS cm^{-1}) in burned than in control samples (158.63 µS cm^{-1}). Pereira *et al*. (2013) also report significantly higher EC and amounts of water-extractable Ca^{2+}, Na^+, K^+ and S in burned samples than in the litter solutions. Sulfur record significant differences between burned and unburnt soil at all locations. Values ranged from 52.46 to 327.66 mg kg^{-1}at burned plots and from 21.91 to 39.08 mg kg^{-1}at control plots. Similar to this study Binkley *et al*. (1992) also finds a smaller amount of sulpfur in the burned samples than in the control. Sulphur cycles may be strongly affected by fire by loosening in gaseous forms (Tiedeman, 1987). The role of S in ecosystem productivity is not well understood, although its fluctuations in the soil appear to parallel that of inorganic N (DeBano, 1991).

Our data are the result of higher soil amount of base cations in burned samples as a consequence of ash material and fire suppression by sea water. There are a number of factors that influence the vulnerability of sites to salinization (Oster *et al*., 1996). These factors include the position of a site within a landscape (Manning *et al*., 2001), soil type and rainfall. Although we don't have particularly rainfall information's at each location and same soil type is dominant in all investigated locations it can be assumed that precipitation rate was similar at each location and was relatively high with 680±171 mm (Meteorological and hydrological institute of Croatia, Lastovo station) of rain annually. The annual amount of rain did not reduce the amount of base cations (salt) in the soil, not even in locations that burned two years ago. Furthermore, there is no difference between sites burned in 2011 and those that burned in 2012 (Table 1), although the sites burned in 2011 had one more rainy season. Therefore, it remains to been seen how many years it will take for the soil to return to pre-burned conditions.

CONCLUSIONS

This preliminary study results show that wildfire led to an important alteration in the chemical composition of the forest soil. Results show difference between burned and control samples at almost all investigate properties. Burned soil samples have been recorded higher values of pH, EC, SO_4^{2-}, Ca^{2+}, K^+ and Na^+. Burned samples also record a higher value of extractable form of N ions. Such changes, from these fires, in soil properties from fire suppression suggest there has also been change in soil processes. Furthermore, differences between plots that was burned in 2011 and those that was burned in 2012 were small and led to conclusion that is more than two rainy winter season necessary for returning chemical properties in pre-burned levels and hence warrants further investigation.

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MULTI-PURPOSE EVALUATION OF AGRICULTURAL LAND IN THE FEDERATION OF BOSNIA AND HERZEGOVINA

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ABSTRACT

Multi-purpose land evaluation is a method of assessing the quality and value of the land in the service planning and land management, and is the fundamental basis for the development and optimum use of land in general. The subject of the study was evaluation of multi-purpose suitability of land for agricultural use was made according to the Regulations on the uniform methodology for the classification of agricultural land in the class (Official Gazette of the Federation of B&H, No. 43/11), using FAO assessment methodology (FAO, 1976; Brinkman and Smyth, 1973). Based on the results of research was created a database and map of suitability of agricultural land for growing different plants in agriculture vegetable (gardening); arable farming (annual crops); fruits (fruits growing); wine-growing (viticulture) and grassland (pastures and meadows). It was determined the priority of agricultural use as well as dedicated map (1:200 000), which shows the distribution of 36 recommended agricultural and economic programs in the Federation of Bosnia and Herzegovina. It was found that the largest area of 429,685.4 ha or 40.45% of agricultural land in the Federation of Bosnia and Herzegovina is suitable for agricultural economic program of grassland. Follow the other agricultural economic programs: fruits-grassland 123,996.4 ha or 11.67%; then fruits-vegetable-annual crops with an area of 89,384.7 ha (8.41%) and grassland-fruits-vegetable occupying 66.562 ha or 6,26% and grassland-vegetable-annual crops with an area 62,136.3 ha (5.85%). Other agricultural economic programs individually occupy an area of less than 4% of land. We believe that the information obtained through this project contribute to the overall development of agriculture in the Federation of Bosnia and Herzegovina, especially in terms of creating a proper and balanced concept as part of sustainable land management and reasonable land use policy.

Keywords: *evaluation of land, land suitability, land use policy, agricultural economic programs*

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INTRODUCTION

Based on the Law of Agricultural Land (Official Gazette of the Federation of B&H, No. 52/09), multi-purpose land evaluation is obliged measure of the land policy of the Federation, cantons and municipalities which affects the functional and rational management of agricultural land as good of general interest.

Land evaluation for a multi-purpose use is process of assessing the quality and value of the land in the planning and land management adapted to agro ecological condition is the fundamental basis for the development and optimal multifunctional and environment-friendly use of land in general.

This paper presents results of the project entitled "Multi-purpose of land use in the Federation of Bosnia and Herzegovina". This project realized a team of experts of the Faculty of Agriculture and Food Technology, University of Mostar in co-operation with the Faculty of Agricultural and Food Sciences, University of Sarajevo in order to implement the regulations purchased by The Federal Ministry of Agriculture, Water and Forestry. Project is finalized in the form of study with maps in the scale 1:200 000 made in modern GIS technology serving as a professional scientific background of suitability of agricultural land for multipurpose use.

MATERIAL AND METHODS

The most update methods in the field of analysis and processing of soil data were used to prepare the project and this paper. The preparatory phase of the project was to collect the relevant information (in writing and cartographic digital form). The data are studied and analyzed, and additional identification, data processing (text and graphics), interpretation of data and preparation of studies and maps were made, following standard criteria of 1: 200 000 in GIS technology.

Basic characteristics of the agricultural soil and land of the Federation of Bosnia and Herzegovina and existing relevant agro-ecological characteristics are prepared based on the existing data and cartographic documents.

Climate features are presented based on data provided by the Federal hydro meteorological institute for the period of 1997th-2012th, from meteorological stations: Bihać, Bugojno, Gradačac, Ivan Sedlo, Jajce, Livno, Mostar, Sanski Most and Sarajevo.

Relief features present in this paper are based on data of altitude and slope angle, obtained by digital terrain model in the Federation of Bosnia and Herzegovina.

Land use was determined based on data from the Environment basis of Environment plan of the Federation of Bosnia and Herzegovina for the period of 2008th-2028th as well as data of the limits of agro-zone within the area of agricultural land (is the scope of the first, second and third agro-zone).

Soil Map of the Federation scales of 1:200 000 is the fundamental basis for the evaluation of a multi-purpose area, both for arable farming and for fruits and wine growing (viticulture), vegetable and grassland.

The map is obtained from the Federal Bureau of Agropedology and is made based on the data of The Basic Soil Map of Bosnia and Herzegovina in the scale of 1:50 000.

For each soil mapping unit are the data in the attribute base as following: number of mapping unit, dominant pedosystematic unit within mapping unit, parent material, participation of rocks on the soil/land surface (%), participation of stones on the soil/land surface (%), soil texture in surface horizon, permeability of soil, infiltration of water in the soil, slope of terrain and soil depth (cm) (FAO, 1976; Bogunović at al., 1988).

Preparing the soil map for the development of this project necessary further additions and corrections were made considering the geological maps, map of terrain slope, map of altitude of terrain and topographical map. Within the agricultural land of Federation of Bosnia and Herzegovina 22 soil types were identified along with a 91 lower pedosystematic units. The basic characteristics of particular types of soil are presented in detail in the existing literature (Resulović at al., 2008).

Assessment of suitability of land for multi-purpose agricultural use were made according to the Regulations on the uniform methodology for the classification of agricultural land in the class (P-1, P-2, P-3,N-1, N-2) (Official Gazette of the Federation of B&H, No. 43/11)*,* based on the FAO assessment criteria (FAO, 1976; Brinkman and Smyth, 1973), considering requirements of agriculture crops including characteristics of the soil, the features of the relief, and climate characteristics.

P-1 suitability class include areas without significant limitations or with limitations that will not significantly affect the productivity. P-2 suitability class include areas with limitations that moderately affect the productivity, and P-3 suitability class cover areas wit limitations that significantly compromise the productivity. Temporary unsuitable soils of the N-1 suitability class are areas with limitations that can be improved by certain agriculture engineering intervention. Permanently unsuitable soils of the N-2 suitability class cover areas with limitations that rule out any possibility of economically justified production.

Based on the assessment results, a database related to soil maps for specific agro-zone were made, on which the maps of benefits by individual industries are based, with the inventory area.

RESULTS AND DISCUSSION

The suitability of agricultural land for arable farming (annual crops) in the Federation of BiH

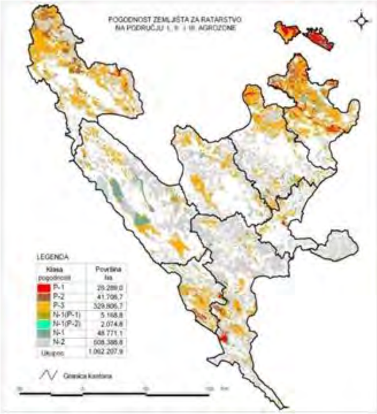

Figure 1. Map of suitability of agricultural land for arable farming in the F BiH

The largest part of agricultural land in the Federation of Bosnia and Herzegovina is permanently unsuitable (N-2) for arable farming (57.28%), within that is the smallest part of P-1 class of suitability (2.47%). The area of temporarily unsuitable land is of great importance for farming (N-1), that, after the specific agricultural measures can significantly raise the level of suitability for intensive arable farming. The main limiting factors for arable farming are: slope, land rockiness and stoniness and soil depth.

The suitability of agricultural land for vegetable growing in the Federation of Bosnia and Herzegovina

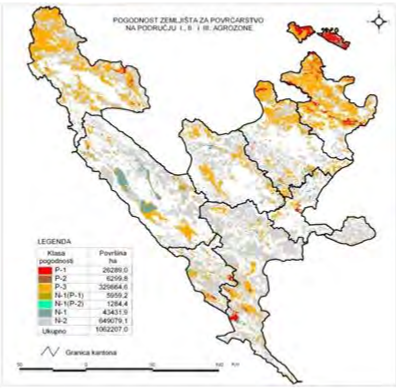

Figure 2. Map of suitability of agricultural land for gardening (vegetable growing) in the F BiH

Vegetable growing is the most challenging and demanding branch of the agriculture, because vegetable require the best soils, lowland flat, the optimal relative humidity, soil moisture, the good farmers knowledge and experience in order to have the successful gardening. The main limiting factors for vegetable are slope, soil depth, land rockiness, stoniness, and climate.

The largest part of agricultural land of Federation of Bosnia and Herzegovina is permanently unsuitable (N-2) for gardening (61.12%) within that is the smallest part of P-2 class of suitability (0.59%).

The land resources of area with soils temporarily unsuitable for vegetable growing (N-1 class) must be considered, which, after conducting the necessary agro- as well as hydro- technical regulation, can significantly raise the level of suitability for intensive gardening.

The suitability of agricultural land for fruits in the Federation of Bosnia and Herzegovina

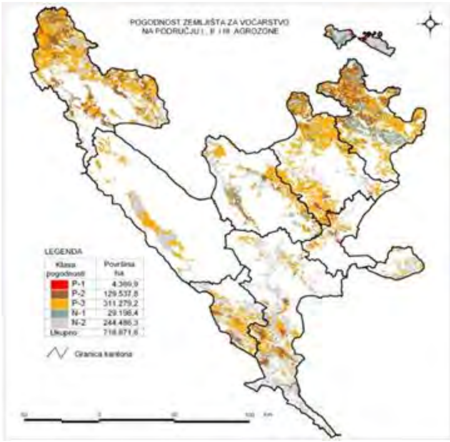

Figure 3. Map of suitability of agricultural land for fruit growing in the F BiH

The largest part of agricultural land in the Federation of Bosnia and Herzegovina (up to 800 m above sea level) is suitable for fruit production (61.93%), and within these areas is the largest part of the area P-3 (limited) class amenities (43.30%) and the lowest part of surface P-1 class amenities (0.61%).

The main limiting factors for fruits are climate, slope, soil depth and land rockiness.

The suitability of agricultural land for viticulture (wine-growing) in the Federation of Bosnia and Herzegovina

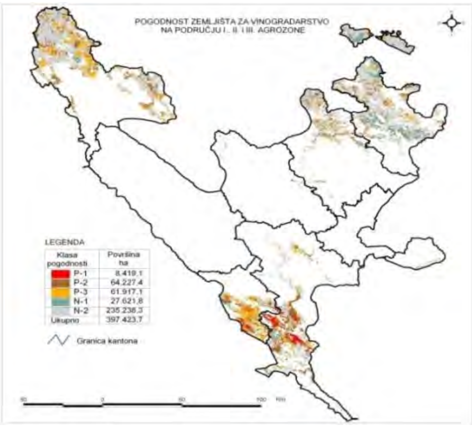

Figure 4. Map of suitability of agricultural land for viticulture in the F BiH

The viticulture - cultivation of vine and wine production in the Federation of Bosnia and Herzegovina is determined by the specific areas where is traditional occupation of farmers like in Neretva and tributaries river basins. Vine can grown in the Mediterranean area in all positions up to an altitude of 500-600 m, and in the continental part at specific southern, eastern and western expositions of 5 to 30%, at an altitude of 150 to 400 m above sea level. The main limiting factors for viticulture are climate, land rockiness, slope and soil depth.

Based on the assessments results of the agricultural land suitability for viticulture in the Federation of Bosnia and Herzegovina the largest part of agricultural land are permanently unsuitable (N-2) for viticulture (59,12%), with the smallest part of P-1 class amenities (2.19%), and the largest part of the area P-2 class amenities (16.16%).

Temporarily unsuitable land area for vineyards (N-1) is an important natural resource in the future, which after conducting the at first soil conservation follows by necessary agro- and hydro- technical measures, can be used in intensive viticulture.

The suitability of agricultural land for grassland production in the Federation of Bosnia and Herzegovina

Term grassland refers to the natural grass stands used as forage – pasture or meadows. Requirements of the grass roots are the smallest one. The main factor for the growth of grass is climate especially sufficient rainfall and temperatures freshers than for crops.

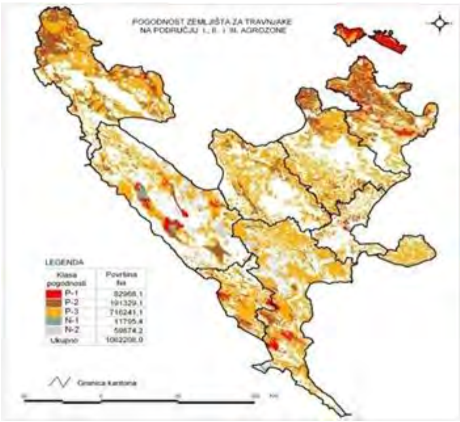

Figure 5. Map of suitability of agricultural land for grassland in the F BiH

In the Federation of Bosnia and Herzegovina, as it was expected, the largest share of agricultural land is suitable for grassland (93.25%), and among them the largest part is of the area P-3 class amenities (67.43%) and the lowest part is P- 1 class amenities (7.81%) for grassland.

The part of area under temporarily unfavourable class (N-1) is 1.11%, and the remaining area are permanently unsuitable soils for grassland (5.64%).

Priority of agricultural economic programs

Based on the results of research was created a database and map of suitability of agricultural land for growing different plants in agriculture vegetable (gardening); arable farming (annual crops); fruits (fruits growing); wine-growing (viticulture) and grassland (pastures and meadows). It was determined the priority of agricultural use as well as dedicated map (1: 200 000), including all three agrozone and all three altitudes in the Federation of Bosnia and Herzegovina. Based on data obtained it was determined of 36 recommended agricultural and economic programs.

The largest of agricultural land in the Federation of Bosnia and Herzegovina of 429,685.4 ha or 40.45% are suitably for agricultural economic programs of grassland. Follows the agricultural economic programs of fruits-grassland with 123,996.4 hectares or 11.67%; then fruits-vegetable-arable farming with an area of 89,384.7 ha (8.41%); programs and grassland-fruits-vegetable is occupying 66,562 ha or 6.26% and grassland-vegetable-arable farming with an area 62,136.3 ha (5.85%). Other agricultural economic programs individually occupy an area of less than 4%.

Reviewing the areas and distributions of priority economic programs to altitude zone, which inhibits or prevents certain ways of the agricultural economy, the situation is quite different.

In the first altitude zone up to 400 m above the sea level, there is a complete wine-growing economic program. The total area of land under agricultural and economic programs under this altitude zone is 397,423.8 hectares or 37.41% of the agricultural land of the Federation of Bosnia and Herzegovina, and number of priority agricultural economic program was reduced from 36 to 29. It is obvious that within this area the largest part is occupied by agricultural economic program grassland- vegetable- wine-growing (51,503.5 ha or 12.95%), fruits-grassland (40,142.2 ha or 10.10%) and fruits-wine-growing-vegetable (37,643.4 ha or 9.47%).

In the second altitude zone of 400-800 m above the sea level number of priority agricultural economic programs has been reduced from 29 to 17, with a total of slightly smaller area of land designated for agricultural and economic programs, and it is 321,448 ha (30.26%) of total area Federation of Bosnia and Herzegovina. In the framework of this highland zone the largest part is occupied by agricultural economic programs grassland (104,532.3 hectares or 32.52%), fruits- grassland (83,854.2 ha or 26.08%) and fruits-vegetable-arable farming (58,857.3 ha or 18.31%).

Finally, the third altitude zone higher than 800 m above the sea is a zone of grassland and partly arable farming-vegetable. There is eight mapping units only with recommended agricultural and economic programs. The total area of land under these programs is 343,336 ha (32.32%). Agricultural economic programs grassland (288,327 ha or 83.98%) and grassland-vegetable-arable farming (31,813.7 ha or 9.26%) occupy the largest part within this altitude zone.

CONCLUSIONS

In the area of agricultural land of the Federation of Bosnia and Herzegovina there is minimum suitable land (soil suitability class of P-1 to P-3) for viticulture (134,563.6 ha), for vegetable production (362,453.4 ha), followed by arable farming (397,804.4ha) and for fruit production (445,186.9 ha). The largest area of agricultural land is suitable for grassland (990,538.3 ha).

The temporarily unsuitable land (N-1) should be reduced because removing their inherent limiting factors, providing the investments in amelioration of this land are economically viable. It is possible to increase the level of suitability and the fund of suitable land, especially for wine-growing (to 6.95%), then for arable farming (5.27%), vegetable growing (4.77%), fruits (4.06%) and grassland (1.11%).

We believe that the information obtained through this project contribute to the overall development of agriculture in the Federation of Bosnia and Herzegovina, especially in terms of creating a proper and clear concept as part of actual land policy.

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DOES THINNING AFFECT THE SOIL RESPIRATION IN SILVER FIR, BEECH AND SPRUCE PREDOMINATING ADULT FOREST STANDS?

Matjaž ČATER[1]

Original scientific paper UDK 630*114:630*242(497.4)

ABSTRACT

In three high karst forest complexes, same spatial design was applied to observe the effect of silvicultural treatment - the degree of mature stand removal on soil efflux. In every forest complex nine subplots were established during the time of experiment according to predominating tree species in growing stock of the mature canopy stand - silver fir, Norway spruce and European beech. In 2012 silvicultural measures with different intensity - 50% and 100% removal of growing stock around the centre of the plot with minimal diameter of two tree heights were applied.

The seasonal pattern of CO_2 efflux rates was mostly accountable by changes in soil temperature. Spatial heterogeneity in CO_2 efflux rates was clearly reflected in management practice; release rates and recovery period were extreme in beech predominating sites, followed by the silver fir and norway spruce. It is our belief, that more oscillations may be expected in carbon release dynamics in the future, as the number of extreme weather events increases and the withdrawal of silver fir with its poor recruitment may have long-term consequences on these high karst high productive sites.

Keywords: *soil efflux, silviculture, carbon release, beech, silver fir, Norway spruce*

INTRODUCTION

The net flux of carbon (C) in terrestrial ecosystems results from the balance between photosynthetic CO_2 fixation and its release by ecosystem respiration. Northern forest ecosystems act as a carbon sink (Dixon *et al*., 1994; Goodale *et al*., 2002), but in the temperate forests respiration impacts the C balance more than photosynthesis (Valentini *et al*., 2000). Because the rate of C loss from soil is, to some extent, a function of temperature, the soil C balance is likely to be a sensitive indicator of climate change. The environmental and economic results from the balance between two large fluxes, CO_2 fixation (photosynthesis) and CO_2 release by ecosystem respiration benefits of this form

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of C sequestration are huge, but to date, there has been no scientific basis on which to judge the theoretical and practical validity of these ideas.

CO_2 movement or CO_2 flux out of the soil is the primary function of soil respiration; soil CO_2 flux is a significant component of the total atmospheric carbon balance. It is a physical process driven primarily by the CO_2 concentration diffusion gradient between the upper soil layers and the atmosphere near the soil surface.

Soil C is not only an important part of the global C cycle, but also a critical part of ecosystem energy and nutrient cycles. The soil CO_2 efflux consists of two components: soil organic matter (SOM)-derived CO_2 and root-derived CO_2 (Werth and Kuzyakov, 2008, 2010). Another important factor influencing the CO_2 transport is atmospheric CO_2, which diffuses into the soil. The abiotic carbonate-derived CO_2efflux has been considered of minor importance (Kuzyakov, 2010), but in semiarid and arid environments with carbonate-rich soils, efflux could be significant (Emmerich, 2003; Huxman *et al*., 2004). As soil temperature and soil moisture are among the most important factors controlling the CO_2 efflux (Raich and Potter, 1995; Davidson *et al*., 1998; Buchmann, 2000), they explain sometimes less than 60% of the day-to-day variations in soil respiration (Schlentner and Van Cleve, 1985; Toland and Zak, 1994; Moren and Lindroth, 2002) suggesting, that other factors such as root nitrogen concentration, soil texture, and substrate quantity and quality may be involved. Consequently, large spatial and temporal variations in soil respiration rates have been found both within and between most temperate ecosystems (Buchmann, 2000; Soe and Buchmann, 2005). Seasonal variations in soil CO_2 efflux have been observed in almost all ecosystems and have often been associated with changes in temperature, moisture, photosynthetic production and/or their combinations.

The main controlling factors may depend on the type of ecosystem and climate. Large spatial variability in soil CO_2 respiration results from a large variability in soil physical properties such as soil water content, thermal conditions, porosity, texture, chemistry, biological conditions (fine-root biomass, fungi and bacteria), nutrient availability (nitrogen mineralisation) and others (disturbed history and weathering) (Hanson *et al*., 1999; Fang *et al*., 1998; La Scala *et al*., 2000; Xu and Qi, 2001; de Neergaard *et al*., 2002; Shibistova *et al*., 2002). Shibistova *et al*. (2002) showed a close connection between tree density and the soil CO_2 efflux in an open boreal forest. Soil CO_2 efflux rates were about double in the areas in proximity to trees than in the open areas, indicating that the development stage of trees (e.g. age and height) can explain some of the spatial patterns in the soil CO_2 efflux in forests. Internal C fluxes within a forest ecosystem and their interaction with soil and atmosphere exchange processes may be addressed by using C isotopes.

The aim of our research was to identify differences in soil efflux before and after silvicultural measures (thinning) (1), to connect degree of carbon release according to the intensity of silvicultrural measure (2) and to compare soil effluxes in different stands with silver fir, Norway spruce and beech as predominating tree species (3).

MATERIALS AND METHODS

Research area is located in the Southern part of Slovenian Dinaric region, distributed along three forest management units: Trnovo, Snežnik and Rog. All studied forest complexes belong to *Omphalodo-Fagetum* with comparable structure, soil and climatic conditions (Table 1).

Table 1. Research area general features

	Trnovo	Snežnik	Rog
Area (ha)	70	70	70
Location (UTM-WGS84)	46° N, 13° E	45° N; 14 ° E	45° N; 15° E
Altitude (m a.s.l)	772 – 824	731 – 774	799 – 896
Landscape morphology	Karst terrain with sinkholes, ridges and slopes		
Bedrock	Limestone, dolomite		
Soil characteristics	Litosol, Rendzic Leptosol, Cambisol, Luvisol		
Temp $_{med}$ (°C)	9°C	8°C	8°C
Temp $_{max}$ (°C) (avg warm. month)		12.5°C	15.5°C
Temp $_{min}$ (°C) (avg coldest month)	4°C	2.5°C	2.5°C
Rainfall (mm)	2300 mm	1600 mm	1700 mm
Forest type	Mixed silver fir, beech and spruce high forests.		
Main management type	Uneven-aged forests.		
Cutting – harvesting method	Freestyle technique; irregularshelterwood; selective cutting		
Average living stock (m^3/ha)	292.0	442	351.6
Annual increment (m^3/hayr)	6.2	8.3	9.4
Basal area (average) (m^2/ha)	44.75	42.28	32.54
Stem density (N/ha)	415	379	443

In every forest complex nine subplots were established during the time of experiment according to predominating tree species in growing stock of the mature canopy stand - stands with silver fir, Norway spruce and European beech. In 2012, silvicultural measures with different intensity were applied with 50% and 100% removal of growing stock around the centre of the plot with minimal diameter of two tree heights (Figure 1).

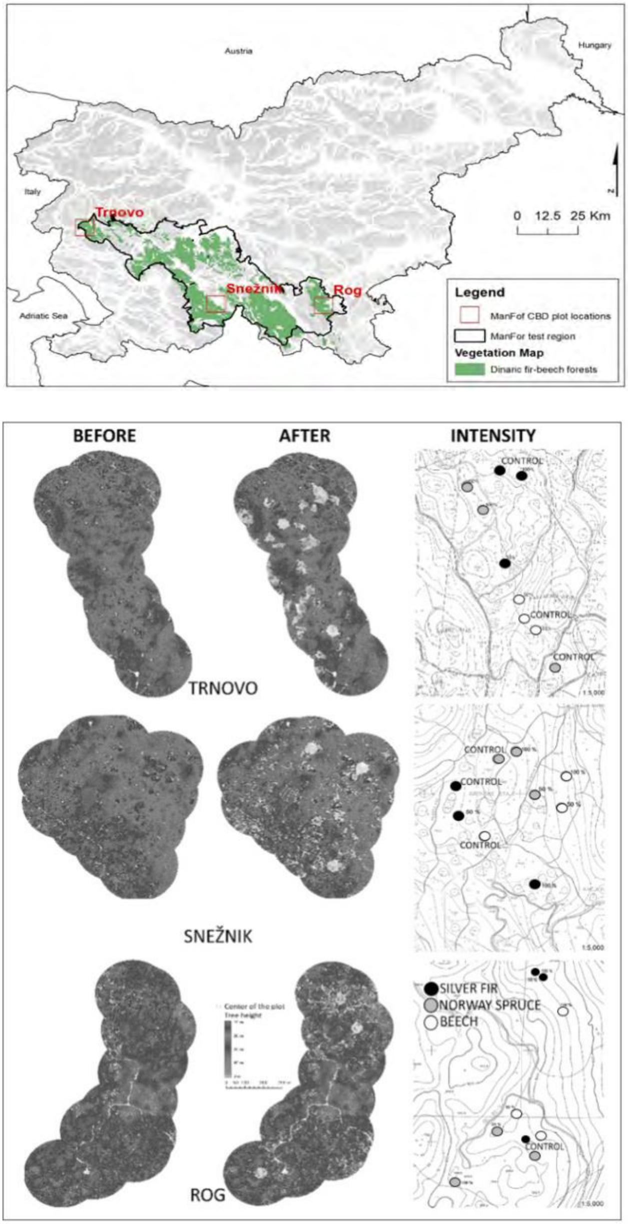

Figure 1. Location of research plots Trnovo, Snežnik and Rog - situation before and after silvicultural measure (100% intensity, 50% intensity and 0% - control with experiment design and equal share for every studied tree species (right). Tree height is presented with different colour (Author: A. Kobler, Slovenian Forestry Institute)

Soil efflux

Manual measurement of soil efflux included a LI-6400 console with battery pack, soil chamber and soil temperature probe, connected to the console, allowing the temperature measurements to be integrated into the data set. The chamber concentration was automatically scrubbed to just below an ambient target, and measured as it raised to slightly above ambient concentration. This maintained the CO_2 concentration gradient to within a few ppm of the natural, undisturbed value. Following each measurement, the intermediate flux data were fit with a regression, which is then used to compute the soil CO_2 flux at the target ambient CO_2 concentration (Čater and Ogrinc, 2011). Automated cycling ensures that CO_2 flux measurements are accurate and repeatable. A pressure equilibration tube was used to eliminate pressure differentials and avoid chamber leaks, while air inside the chamber was thoroughly mixed while maintaining a constant pressure to assure consistently accurate data (Čater and Ogrinc, 2011).

Soil efflux with soil temperature was measured prior to silvicultural measures and after the event every month during growing season in years 2012, 2013 and 2014. On every plot five permanent locations have been determined to acquire reliable measurement response. Mean soil CO_2 efflux (R_m) measurement was correlated with mean soil temperature (T_m) (separately for every tending intensity) using the exponential equation

$$R_m = \beta \cdot e^{\alpha \cdot T_m} \qquad [1],$$

With α and β as the regression coefficients.

The proportional change in CO_2 efflux from 10 °C increase in temperature, known as Q_{10} was calculated according to Lloyd and Taylor (1994):

$$Q_{10} = e^{10\alpha} \qquad [2],$$

with α as a regression coefficient from the first equation [1]. Q_{10} was calculated individually for every silvicultural intensity measure and normalized for the temperature of 10°C (R_{10}) according to following equation:

where R_S is the soil CO_2 efflux and T_S soil temperature measured at each position. Differences between response groups were defined by the analysis of variance with Statistic for Windows software.

RESULTS

Plots within forest complex were evaluated before and after silvicultural measures with light intensity at the forest floor as the criterial parameter using hemispherical photos. Before stem removal forest stands indicated similar forest cover all over three forest complexes, all lower than 12% ISF (Table 2).

Table 2. Light conditions before and after silvicultural measures

		Gap Fraction	Openness	Indirect Site Factor
Trnovo	before measure	7.5 ± 1.4	7.5 ± 1.4	11.4 ± 3.2
	control	5.6 ± 0.9	6.4 ± 0.9	9.2 ± 1.4
	50%	22.7 ± 6.7	25.2 ±7.6	40.6 ± 9.9
	100%	42.0± 6.5	46.8 ± 6.8	75.4 ± 8.5
Sněžnik	before measure	8.1 ± 2.9	8.2 ± 2.9	12.3 ± 4.7
	control	9.8 ± 1.5	10.7 ± 1.9	15.6 ± 5.3
	50%	18.2 ± 7.2	20.8 ± 8.0	36.3 ± 5.4
	100%	58.4 ± 3.3	58.5 ± 3.2	85.7 ± 8.3
Rog	before measure	6.4 ± 2.2	6.40 ± 2.2	9.2 ± 3.9
	control	5.9 ± 1.2	6.3 ± 1.3	8.1 ± 1.4
	50%	22.2 ± 4.8	23.3 ± 5.5	39.7 ± 9.6
	100%	49.3 ± 5.6	52.2 ± 8.7	65.2 ± 9.8

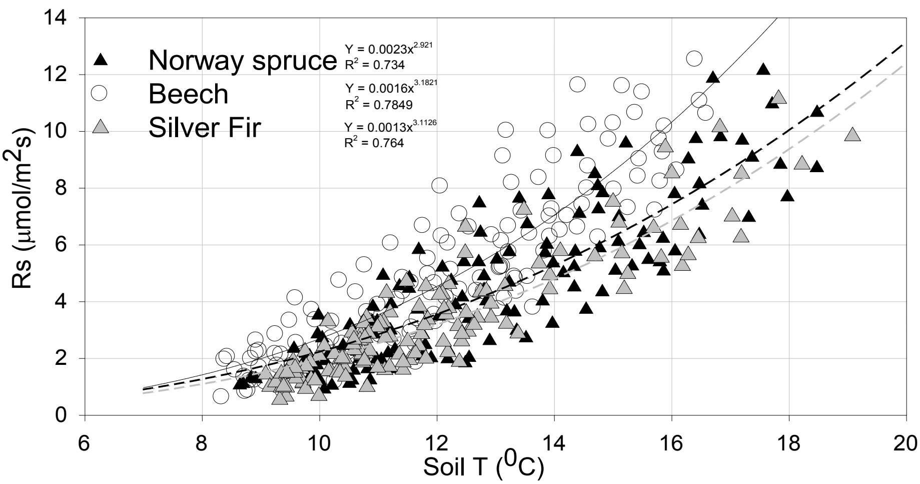

Figure 2. Soil efflux and soil temperature in different predominating tree species stands

Dependence between soil respiration (Rs) and soil temperature differed according to predominating tree species. Response was different between beech and both spruce and fir stamds, while no differences were confirmed between fir and spruce (Figure 2).

Soil efflux before and after silvicultural measures

Differences before and after silvicultural measures were mostly pronounced in the period of first month after the event and were gradually becoming insignificant. Merged data from all plots and sites confirmed biggest significant changes on plots with predominating beech, smaller responses on plots with silver fir and smallest on plots with predominating Norway spruce. Because of annual dynamics and change regarding the temperature, dependence it was more illustrative to present the average difference between plots with different tending activity compared to the reference (control) plot after the performed silvicultural measures. Differences between beech and other two tree species were highly significant in all forest complexes ($p \leq 0.001$***), while between fir and spruce differences were evident only for forest complex Trnovo ($p \leq 0.0429$*) (Figure 3).

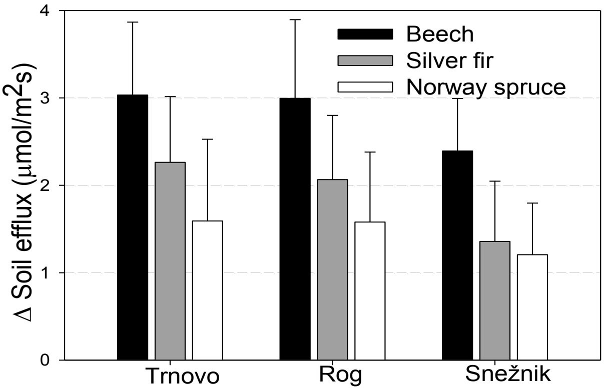

Figure 3. Difference in soil efflux - conditions before and after applied silvicultural measure according to predominating tree species; all plots included. Bars are standard errors.

Carbon release and intensity of silvicultrural measure

During the first month after applied measures the carbon release on all plots was significantly highest ($p \leq 0.001$***) on plots with biggest measure intensity (e.g. 100% removal of mature stand), regardless of the particular tree species and forest complex. Highest rates between forest complexes were evidenced in beech predominating stands, followed by silver fir and spruce. The absolute release rates were again highest in forest complex Trnovo and smallest on plots of Snežnik (Figure 4). Both forest complexes (Tolmin and Snežnik) also differed in their response within same and comparable tree species and silvicultural measure group:

Beech-100% intensity, p≤0.008**; Beech-50% intensity, p≤0.0521^NS^; Beech-Control,p≤0.0572^NS^;
Fir-100%, p≤0.000***; Fir-50%, p≤0.001**; Fir-Control, p≤0.0634^NS^ and
Spruce-100%, p≤0.0421*; Spruce-50%, p≤0.000***; Spruce-Control, p≤0.0591^NS^.

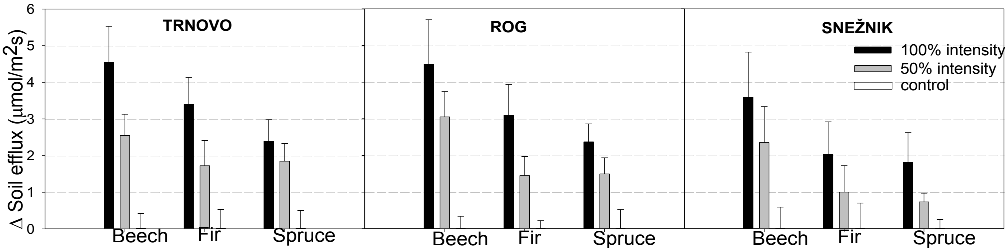

Figure 4. Intensity of silvicultural measure effect on soil efflux in stands with predominating beech, silver fir and spruce compared to control - referential stands without applied silvicultural measure. Bars are standard errors.

Situation between Trnovo and Rog was similar, butthe response of fir with 50% intensity measure indicated slightly smaller and insignificant carbon release rate compared to spruce plots in both forest complexes, while in plots of Snežnik rates on plots with 50% silver fir measure were higher than those of 50% spruce, respectively.

Response in time

According to decreasing differences in efflux on plots with applied measures in time, the estimation about the time when effux would return to comparable control values was evaluated. In general, the shortest recovery rate was estimated for the beech predominating sites (within 15 months), followed by the silver fir (approximately 24-25 months) and spruce sites (over 27 months), respectively (Figure 5).

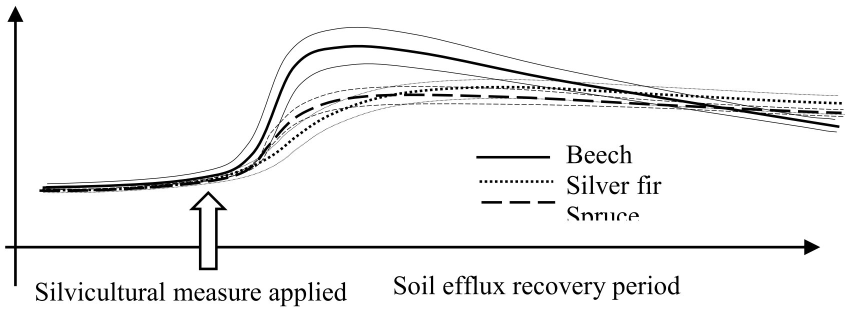

Figure 5. Schematic recovery period for different tree species reaching referential values

DISCUSSION

Our study was conducted across three replicated sites harvested at the operational scale, and, while this undoubtedly increased the overall spatial and treatment variability, it increases the applicability of presented results to realistic forest management scenarios. The ecosystem respiration rates observed in our study (5.0-10.µmol CO_2/m^2s) may be comparable to those reported for other beech forests in Europe (Epron *et al*., 2004; Søe and Buchmann, 2005; Knohl *et al*., 2008), as evaluated light conditions well described the intensity and also the efflux rate before and after applied measures on all plots. In our case, the seasonal variation in soil respiration is thought to be explained largely by soil temperature alone or a combination of soil temperature and water content (Davidson *et al*., 2006). The temporal variation in soil respiration in our study was well described by simple exponential functions (of temperature alone).

Spatial heterogeneity was affected by management practice, with a highest respiration rates on plots with 100% measure intensity, followed by the plots with lower management intensity. Higher respiration rates were related to lower average temperatures and microclimatic conditions in Snežnik than in Rog or Trnovo forest complex. Changes that were evidenced within same groups between forest complexes may be explained with different microclimatic conditions, in particular average air temperatures, as they were lowest in Snežnik, compared to other two forest complexes, while responses on Trnovo and Rog plots were more comparable.

Recovery period-comparison between control and managed plot-response indicated highest carbon release on plots with predominating beech, but also fastest recovery rate to the level of controlled plots with same tree species. Release rates of silver fir and spruce were smaller, but their recovery interval was significantly longer. In general, release differences in fir predominating stands were slightly higher to those in spruce dominated stands and were becoming gradually insignificant in time.

CONCLUSIONS

The seasonal pattern of CO_2 efflux rates was mostly accountable by changes in soil temperature. Simple exponential functions including temperature alone accounted relatively well for the spatial variability over the investigated forest stands.

Spatial heterogeneity in CO_2 efflux rates was clearly reflected in management practice.

Release rates and recovery period were extreme in beech predominating sites, followed by the silver fir and Norway spruce.

The amount of above ground litter may be a good indicator of soil respiration, as the high decomposition rate of litter associated with microbial respiration was a major component of soil respiration in a natural old growth forest reserve (Čater and Ogrinc 2011). It is our belief, that more oscillations may be expected in carbon release dynamics in the future, as the number of extreme weather events might increase and the withdrawal of silver fir with its poor recruitment may have long term consequences on this high karst high productive sites.

Acknowledgement

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SOILS PROPERTIES AND CARBON CONTENT AT RESEARCH OBJECTS IN FIR-BEECH FORESTS ON CALCAREOUS BEDROCKS OF THE DINARIC MOUNTAIN CHAIN: A CASE STUDY FROM SLOVENIA AND BOSNIA

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ABSTRACT

Large areas of European fir-beech forests are characteristic for the Dinaric Mountains and represent one of the most important forest ecosystems in the region. Such forests extend in high karst plateaus from the eastern Alps in SE Slovenia to the N Albanian massifs at the altitudes from 700 to 1200 (1500) m a.s.l. This is the area with a diverse landscape configuration. The bedrock is consisted of limestone, occasionally of dolomite limestone and dolomite. There are various soil conditions, where in a small area, a mosaic of Leptosols, Rendzic Leptosols, Chromic Cambisol, Calcaric and Chromic Luvisols occur. As climate conditions are very favourable for the growth of forests (high precipitation and air humidity), production function of wood is much more emphasized. Very little is known about the long-term effects of forest management and intensity of logging on soil organic matter quality and carbon stocks in these forest soils. Therefore, with an objective to understand better variations in soil properties, both in space and time, aiming to minimize the uncertainties of the SOC (soil organic carbon) and TN (total nitrogen) stocks, we have set up a research objects in silver fir-beech forests, in Slovenia (research plots in Kočevje, Snežnik and Trnovo) and Bosnia and Herzegovina (research plots on MT Bjelašnica). We analysed soil properties of the unmanaged and managed sites studying differences between treatments and also changes for the two years period of observations. Preliminary results from Slovenian sites show that the high intensity of logging (50 and 100% cut of growing stock) causes a decrease in SOC and TN contents, wider C/N ratio and higher

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pH values, with the largest level of alternations in the organic part of the soils. The study in Bosnia gave information on inherent SOC and TN concentrations in the organic and surface mineral soil, and also indicated no differences in soil properties between unmanaged and managed sites characterized by low (14-18%) intensities of logging.

Keywords: *forest management, organic matter, calcareous bedrocks, C stocks*

INTRODUCTION

Fir-beech forests (*Omphalodo-Fagetum*, syn.: *Abieti-Fagetumiliricum,* Horvat 1938, 1957 in Puncer 1979, 1980) in the Dinaric mountain region are recognized as uneven aged, self-regenerative and attributed to diverse soil and climate conditions highly favourable for forest growth, due to the abundant precipitations and high air humidity. This is the area with a diverse landscape configuration. The bedrock is predominantly consisted of limestone, dolomitic limestone and dolomite, on which a mosaic of Rendzic Leptosols, Chromic Cambisol, Calcaric Cambisol and Chromic Luvisols occur. Such forests extend in high karst plateaus from the eastern Alps in SE Slovenia to the northern Albanian massifs at the altitudes from 700 to 1200 (1500) m a.s.l. Herein, the applied management system favourites preservation of genuine forest structure, with least changes in canopy openings and site microclimatic conditions. In Slovenia, fir-beech forests have been recognized by Natura 2000 as one of the most extensively managed forest systems (Kutnar *et al*., 2011). Considering the number of one stand entries per ten year's rotation period, also in Bosnia they match the same category and they have been described by high biodiversity and unstable ratios the mixture of their major species (Ćirić *et al*., 1971; Stefanović *et al*., 1983).

In mountain regions, characterized mainly by shallow soils, organic matter (SOM), in both organic and mineral soil is found in substantially high concentrations (Baritz *et al*., 2010). This characteristic is crucially important for ecosystem functioning and forest productivity, as it is a major reservoir of carbon, nutrients and water. It is known that the forest soils on limestone and dolomites are highly heterogeneous, and thus they may vary considerably in a small area in their depth, bulk soil amounts, gravel content, etc. Also, the concentrations of SOC and TN vary considerably in karst areas (Schrumpf *et al*., 2011). Natural factors, which alter on a site level in relation to complex karst hydro-geological features, along with anthropogenic disturbances, which are comparable to natural disturbances, influence great spatial diversity of soil properties. Such spatial variability of soil properties limits the precision of measurement of changes in soil carbon and hence, the ability to detect changes (Homann *et al*., 2008).

Changes in SOC and TN concentrations for understanding alterations in forest soil productivity are broadly investigated and documented (Johnson and Curtis, 2001, Lal, 2005). The accumulation and quality of SOM is controlled by site factors and anthropogenic activities (Schoenholtz *et al*., 2000). Under the adjacent site conditions logging operations are usually generating differences in the SOM such as fresh litter accumulation at some places, but extracting major fraction of the organic material and associated elements (nutrients) from others, which may affect SOM on a long term (Schulze, 2000). In addition to SOM, authors report negative, positive or no influence of forest management activities (Prescott, 2002; Bauhaus *et al*., 2004), which can be explained by different intensities of selective logging, site differences and sampling strategy. Therefore, detecting variability in soil properties in space and time is of vast importance for quantification of differences between treatments in SOC and TN stocks (Homann *et al*., 2008).

In Slovenia effort was made in detecting and quantifying changes in SOC stocks, which are relevant for the purposes of reporting sources and sinks of C in regard to Kyoto obligations. Examining the impact of forest management system to SOC stock, as an important indicator of sustainable management practice is understudied topic in Bosnia and the data are also needed for filling the gap for South-eastern European regions, especially if considering climate change scenarios and their influence on beech forests on Balkan Peninsula. Investigations of variations in SOC concentrations are still scarce and actual data are needed for the purpose of assessing forest management impacts (Luyssaert *et al*., 2011).

The objective of this study was to understand better variations in soil properties, both in space and time, with an aim of minimizing the uncertainties of the SOC and TN stocks estimations. For that purpose, this study combined two approaches applied in the Dinaric fir and beech forests in Slovenia and Bosnia. We analysed soil properties of the unmanaged and managed sites studying differences in soil properties between sites with different logging intensities.

MATERIAL AND METHODS

Study sites

Three study sites were selected in Slovenia (Kočevski rog, Snežnik, and Trnovo) and one site in Bosnia (Mt Bjelašnica) (Table 1). The criteria for choosing study plots in each of the study sites were similar ecological factors: altitude, slope positions, inclination, soil properties, forest species composition and structure. Prior to sampling, in each study site we made a survey using a spade and 1 m auger (Pürckhauer auger) to address soil type according to WRB classification (IUSS WRB, 2015) for site level (Christophel, 2013).

Table 1. Site characteristics in Slovenia (Kočevski Rog, Snežnik, Trnovo and Bosnia (Bjelašnica)

Study site	Kočevski rog	Snežnik	Trnovo	Bjelašnica
Position	south-eastern Slovenia; 45.668°N, 15.033°E	southern Slovenia; 45.672°N, 14.460°E	western Slovenia; 45.989°N, 13.759°E	central Bosnia 43.4484°N 18.1541°E
Elevation	831-902 m a.s.l.	753-815 m a.s.l.	801-869 m a.s.l.	1350-1500 m a.s.l.
Area	70 ha	70 ha	70 ha	70 ha
Relief	high karst range with diverse terrain with numerous sinkholes, ridges, and slopes	high karst range with diverse terrain with numerous sinkholes, ridges, and slopes	high karst plateau with diverse terrain with numerous sinkholes, ridges, and slopes	high karst range with diverse terrain with numerous sinkholes, ridges, and slopes
Geology and soil	limestone and dolomite; Leptosol, Chromic Cambisol and Luvisol	limestone and dolomite; Leptosol, Chromic Cambisol and Luvisol	limestone and dolomite; Leptosol, Chromic Cambisol and Luvisol	limestone and dolomite; Rendzic Leptosol, Chromic Cambisol, Calcaric Cambisol and Luvisol
Meal annual precipitation	approximately 1700 mm	approximately 1700 mm	approximately 2000 mm	approximately 1200 mm
Mean annual temperature	8°C	8°C	9°C	1,4°C
Average annual increment of the whole management unit	9.4 m^3/ha/yr	8.3 m^3/ha/yr	6.2 $m^{3/}$ ha/yr	6.1 m^3/ha/yr
Forest management history	First forest management plan devised by Hufnagelintroduced close-to-nature management and suspended clear-cutting; some virgin forest remnants were protected in this region.	Systematic and organized forest management planning since the beginning of the 20^{th} century	First forestry plans in the 18th century; individual edicts for regulating forests as early as the 15^{th} century	Systematic and organized forest management planning since the beginning of the 20^{th} century

Note: The data for Slovenian sites are cited from Kutnar *et al*. (2015)

Plot selection, soil sampling, soil analysis

First approach applied in Slovenia involved 27 investigation plots which were selected in karst sinkholes in three study sites: Kočevski rog, Snežnik, Trnovo (Table 1). Circular plots of 0.4 ha were established in the central/bottom part of the selected sinkhole. At each of the site three logging intensities were provided:1) 1/3 of control plots: without any measures-0%, 2) 1/3 plots: 50% of growing stock logged, 3) 1/3 plots: 100% of growing stock logged. Samples were collected on a systematic sampling grid at the top, middle and on the bottom of sinkholes. Second approach applied in Bosnia, involved selection of four plots 0.5 ha which were selected with two intensities of silvicultural measures 1) control plot: without any measures-0% and 2) three plots with 14-18% of growing stock logged in different after-logging chronosequences (two, three and ten years). Samples were collected following restricted random sampling, which considered excluding disturbed sites and positions close to tree trunk. At each sampling point in Slovenian and Bosnian sites the organic layers of soil (Ol-litter layer, Of-fragmented or ferment zed layer and Oh-humified) were sampled with a wooden frame (25 cm x 25 cm). Mineral soil in Slovenia was sampled up to the depth of 80 cm and in Bosnia down to 10 cm of depth which represented mostly Ah (humus enriched mineral) horizon. The minimum sample size was 25, where 4 subsamples represented one composite sample (Cools and De Vos, 2010).

Organic and mineral soil samples were air dried. Rocks and roots were separated from the soil samples. Rocks were measured for mass and volume and dry roots were measured for mass. Dried samples were then grinded and samples with pH values ≥7.0 were analysed for mineral carbon content. Total organic C and total N were analysed using Element Analyser (LECO) and pH values were determined in 0.01M $CaCl_2$ solution. Basic statistical analysis encompassing T-test and ANOVA analysis were applied.

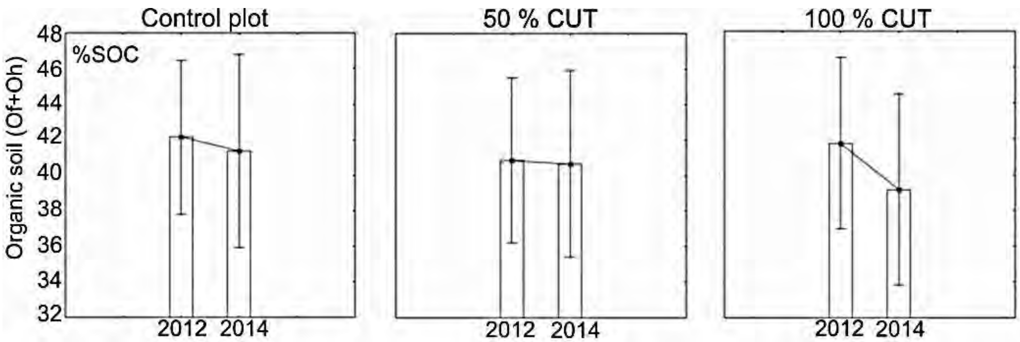
RESULTS

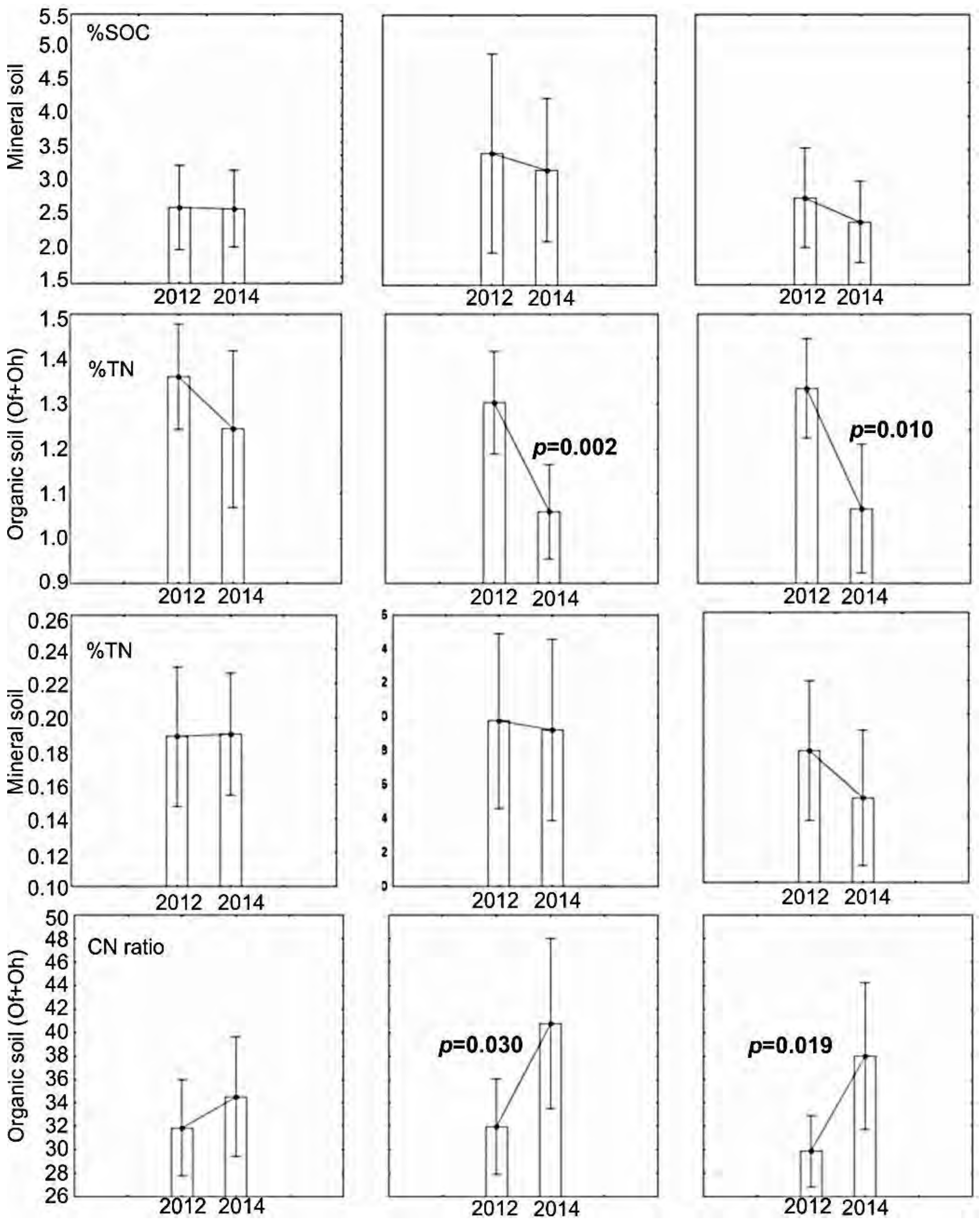
Organic and mineral soil analysis in Slovenian and Bosnian sites

Results of the site surveys, made with a Pürckhauer auger, indicated dominant presence of Chromic Cambisol for the compared sites in Slovenia (Kočevski rog, Snežnik, Trnovo) and Calcaric Cambisol, Chromic Cambisol following with Rendzic Leptosol. This part of the site survey gave only limited results considering estimation of soil horizon depth and humus characteristics, due to high content of gravel, stone and root which interfere the process of augering.

Analysed soil properties in Slovenia show insignificant and inconsistent differences between treatments control plot vs. 50 and 100% of cut (Figure 1). Values of SOC, TN and CN ratio were more variable for mineral soil compared to organic soil layer (Of+Oh). The repeated measurements (in 2012 and 2014) inferred to insignificant changes in SOC concentrations, which was markedly noticed in 100% of cut of total growing stock, in both organic (Of+Oh) and mineral soil. However, statistically significant decline ($p<0.002$, $p<0.010$) was detected in TN values only in organic horizons for the repeated measurements, for both intensities of logging (50 and 100% of cut). Also, significantly wider CN ratio ($p<0.030$, $p<0.019$) indicating changes in humus quality occurred in the organic soil for both intensities of logging (50 and 100% of cuts), observed in spotted periods. Soil pH values differed insignificantly between treatments for Slovenian plots (Figure 2), although significant ($p<0.034$) changes occurred again for plots with 100% logged growing stock in the organic horizons (Of+Oh).

Compare to Slovenia, Bosnian site was attributed to larger amounts of SOC, TN and higher pH values in both organic and mineral soil. In Bosnia, analysed soil properties indicated either no, or insignificant differences between treatments representing different chronosequences after last cut (2011, 2012, 2014 and control). Concentrations of the SOC and TN in the litter layer (Ol), fragmented (Of) and humified organic layer (Oh) were more or less the same among the treatments (Figure 3). Lower level of variability with less than 20% of standard deviation was observed in SOC and TN in the organic soil horizons compare to surface mineral soil characterized with higher standard deviations (exceeding 50%). Differences were not found between treatments in pH values.




%SOC
Mineral soil
%TN
Organic soil (Of+Oh)
p=0.002
p=0.010
%TN
Mineral soil
CN ratio
Organic soil (Of+Oh)
p=0.030
p=0.019
2012 2014

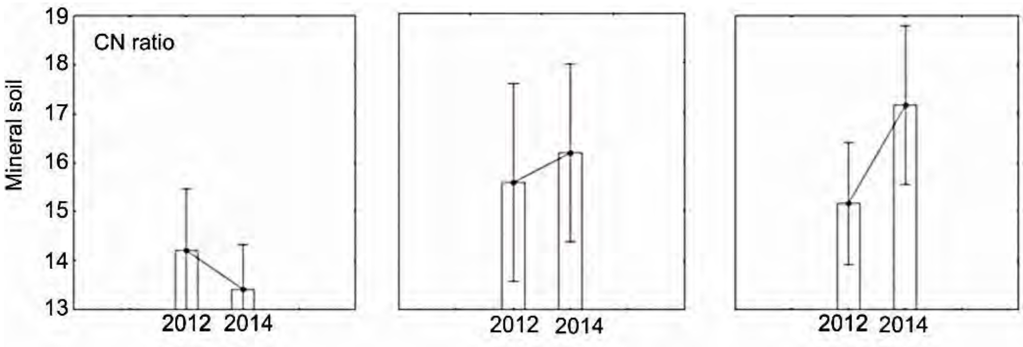


Figure 1. Soil organic carbon, total nitrogen and CN ratio (SOCC, TN, CN ratio) in the organic (Of+Oh) and mineral soil in control, 50% and 100% cut of growing stock plots examined in 2012 and 2014 in Slovenian sites

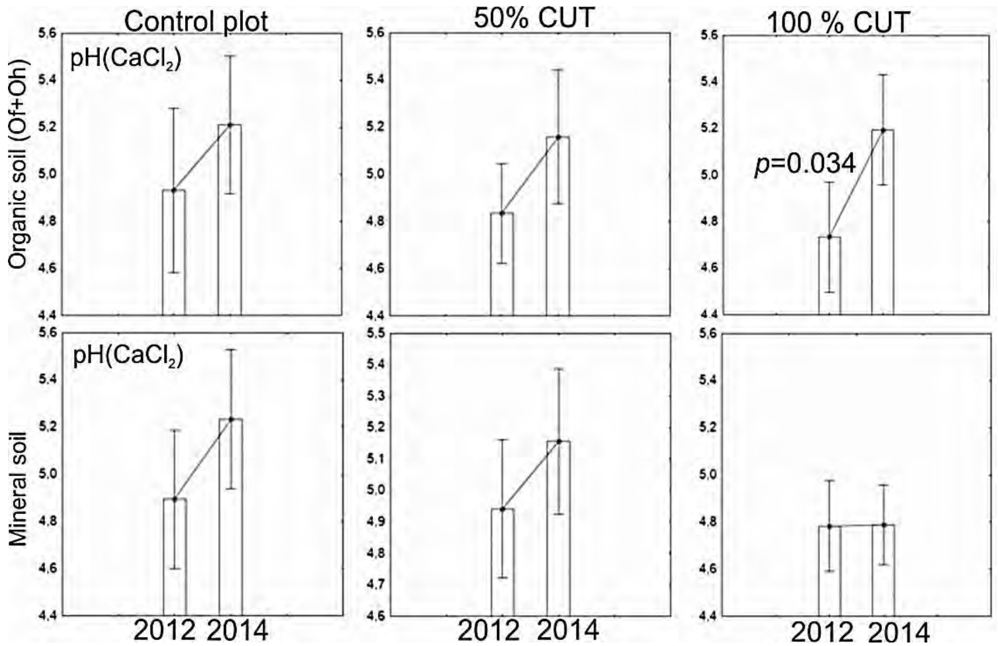


Figure 2. pH ($CaCl_2$) values in the organic (Of+Oh) and mineral soil in control-0%, 50% cut and 100% cut of growing stock plots examined in 2012 and 2014 in Slovenia

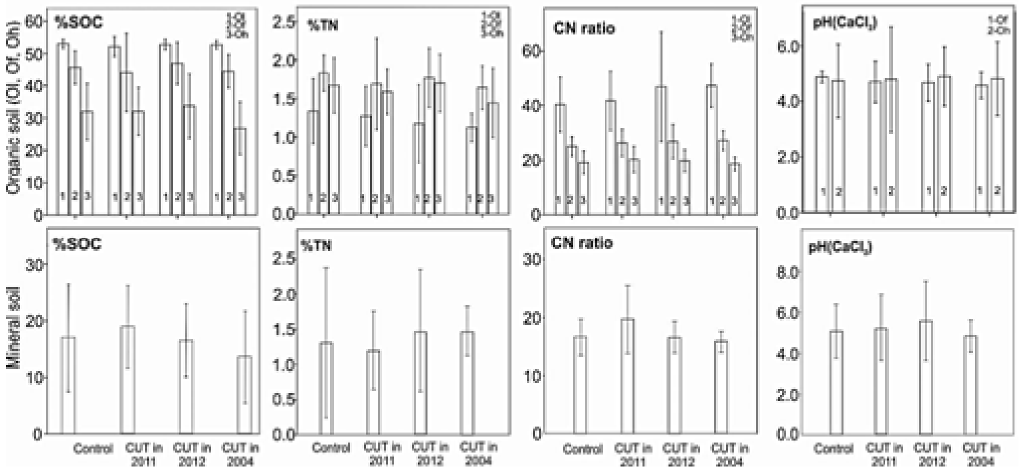


Figure 3. Quantity of soil organic carbon (C), total nitrogen (N), CN ratio (C/N) and pH values (pH ($CaCl_2$))in different organic (Ol, Of, Oh) and mineral soil layers (0-10 cm) in control vs. managed forest (14-18% cut of growing stock) analysed in different chronosequences (three, four and eleven years) after harvest in Bosnia

DISCUSSION

As expected for a mountainous region, soils at the study sites in Slovenia and Bosnia showed large small-scale (<1 m) variability of morphological features under the same soil unit. A Pürckhauer auger survey provided only limited insight into soil morphology because soils found on Jurassic-Cretaceous limestones are attributed to large proportion of gravel, stones and roots, which makes difficult to estimate soil horizon depth, presence of horizons when they are under stones and also discriminate humus horizon. Variability in SOM at site level influences a possibility to detect differences between treatments in quantities of SOC and TN. Such findings indicate the issue of treatments comparability (Yanai *et al.*, 2003), which was addressed (in study) by following the criteria, while choosing plots, of identical parent material, soil types, forest association, climate and managing system. Also, selection of appropriate sampling techniques and soil variables (in this study large soil cores and small soil pits of known area and volume were used), allow minimal changes and differences to be detected comparing to other area-based approaches (Johnson *et al.*, 1990; Ellert *et al.*, 2002). Differences in relief are restricting comparison between Slovenian and Bosnian plots. As an example, the hydrology of karst sinkholes, specific for Slovenian sites, influence more intense processes of leaching and lower pH values compare to Bosnian sites. Also, higher altitudes in Bosnia may have affected higher SOC concentrations.

Comparison between treatments (unmanaged vs. managed forest) in Slovenia and Bosnia pointed to different results. Regarding the differences in treatments, both studies showed insignificant differences. However, the decrease in concentrations of SOC and TN found in Slovenian sites corresponds to changes obtained by repeated measurements (2012 and 2014), indicating the influence of logging intensity on these parameters. Large opening of the forest canopy after logging may lead to increased solar radiation, which may have influenced to intermittent periods of temporarily increased decomposition and mineralization of forest floor organic matter of managed stands (Prietzel, 2010). In Bosnia, SOC and TN concentrations cannot be connected to logging operations, since no differences in treatments were detected. Low intensity of logging applied in selectively managed forests, also applied in this region, is usually connected with insignificant changes in quantities of SOC and TN (Bauhus *et al*., 2004; Jurgensen *et al*., 2012). Some recent studies made in forest soils on calcareous bedrock of Bavarian Alps show on one hand insignificant differences in concentrations in both organic and mineral horizons, but on the other significant differences in stock values between treatments (Christophel *et al*., 2013).

Higher level of changes that occurred in TN, C/N ratio and pH values in Slovenian sites, found in the organic layer, is considered to be influenced by higher concentration of light fraction in humus and higher sensitivity to changes in site factors (Currie, 1999). While abundance of Ca ion and bioturbation processes inherent to soils formed on calcareous bedrock could explain greater resistance of SOC in surface mineral soil (von Lützow *et al*., 2006).

CONCLUSIONS

Exploring the heterogeneity of soil properties is one of the initial steps for estimating SOC stocks. Approaches applied to detect soil properties and differences between unmanaged and managed mountainous fir-beech forests in Slovenia and Bosnia indicate to negative influence of high (clear cutting)-, and no influence of low-intensity selective logging. Significant changes which were detected include: a) in Slovenia, a significant reduction in the proportion of nitrogen, and a significant increase of CN ratio and pH values, and b) in Bosnia, no differences in soil features between unmanaged and managed forest. Alternations in the stand microclimate which may affect humification and mineralization processes can consequently increase the amount of CO_2 emissions from the soil, and therefore these consequences are important to be addressed in regard to organic matter functional roles stored in mountain forests.

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CHANGES IN THE ADSORPTION COMPLEX OF REKULTISOL UNDERNEATH THE SEEDED GRASSLANDS

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Original scientific paper UDK 631.41(497.6)

ABSTRACT

The research was conducted on deposol and rekultisol (technosols) in lignite mine Stanari. The main task of the formed grasslands is to improve the mechanical, chemical and biological properties of the rekultisol and deposol in the reclamation process. The fertility of Stanari deposol is extremely low in comparison to the natural soil. Grassland seeding through direct type of reclamation was conducted in 2008, 2011 and 2012 year. The conducted researches include the changes in the adsorption complex in the surface layer of the treated deposol in the reclamation process. Laboratory analysis of this technogenic soil were carried out before the reclamation and sowing started, and then in the process of reclamation at the end of 2012. On the experimental plots where reclamation measures were implemented, there is a slight improvement in most of the chemical characteristics of the rekultisol. Adsorption capacity and saturation degree of base cations in rekultisol were increased. Proper selection of the agromeliorative and other measures is required in the reclamation process. Well based seeding grasslands contribute to the creation of quality rekultisol.

Keywords: *deposol, reclamation, chemical properties, Stanari*

INTRODUCTION

Main objective of the reclamation of degraded areas, caused by open pit mine exploitation of the ore reserves, is to establish the management functions on these newly created technogenic soils (technosols). In order to achieve this objective, it is necessary to implement a number of activities envisaged by the reclamation project. In addition to detailed design, adequate results of previously conducted surveys are extremely important for the successful implementation of reclamation. From this

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reason arises the importance of various field and laboratory studies in biological reclamation of degraded soil.

Deposol (mine soil) in Stanari have middle favorable physical and mechanical characteristics, while their chemical characteristics are bad (Malic, 2010; Malic and Markovic, 2012). Previously projected reclamation methods for Stanari coal basin deposols (of a very low fertility) at formed overburden (unfertile) disposals, were agriculture and forest plantations. The main task of all these man-built terrestrial ecosystems is to stabilize and revive production and ecological functions of a technogenic soil. A significant part of the agricultural reclamation refers to the establishment of artificial grassland. Studies on the methods of grassland establishment in the reclamation process and potential yields have started in 2008 at the deposols of Raskovac open pit external disposal area in Stanari (Malic and Lakic, 2011). Pioneer species in agricultural reclamation include species from the families of *Poaceae* and *Fabaceae*.

Seeding grasslands establishment through seeding grass-leguminous mixtures and pure cultures of certain grass species is significantly present at mine in Bosnia and Herzegovina, Serbia and abroad. Since the earliest reclamation works in the USA, a vast expanse of recultivated areas has been under seeding meadows and pastures (Thorne, 2010; Skousen and Zipper, 2010; Lyle, 1987; Vogel and Berg, 1968).

Normally, most commonly sown species during reclamation process are grasses (family *Poaceae*) because they are producing a large amount of biomass and quickly adapt to specific and harsh environmental conditions. For biological reclamation most commonly used grass species are from the following genuses: *Poa, Festuca, Lolium, Panicum, Agrostis, Phleum, Dactylis* (Malic and Lakic, 2011; Smith *et al*., 2002).

Participation of leguminous in mixtures depends on the type and characteristics of deposols used for reclamation. In addition to the potential yields of forage and hay, multiple significance of all types of grasslands is reflected in the changes of basic physical, chemical and biological properties of deposol through increasing its fertility.

In previously conducted studies, growing annual field crops (sudan grass, rye, wheat and rapeseed) has shown that some positive changes have been identified in deposols, during the reclamation process of technogenic soil in Stanari area (Malic, 2010; Malic and Markovic, 2012; Markovic *et al*., 2012). Such research through agrotechnical phase of reclamation has continued where it was insisted on forming the more fertile surface layer of disposed overburden. A greater production of green mass directly affects increase of content of organic matter in the surface layer of deposol in the reclamation process and rekultisol at overburden disposal (Malic, 2010; Malic, 2015).

The main task of research conducted on the effects that established grasslands had on chemical properties of deposols in the reclamation process, is to condition targeted implementation of the most optimal agrotechnical methods and measures for the purpose of creation of quality rekultisol in the agroecological conditions of Stanari mine. Basic goal of the researched deposols is to increase the organic matter and humus content in the surface layer, as a foundation for successful reclamation.

MATERIAL AND METHODS

Research the intensity of changes of some chemical properties of rekultisol was carried out on soil samples from the individual experimental plots and surfaces reclamated through grassland establishment. All the deposol and rekultisol samples belong to the disposals formed at Raskovac open pit and Dragalovci zone of the coal mine: "EFT - Rudnik i Termoelektrana Stanari", municipality of Stanari, The Republic of Srpska, B&H.

Laboratory analysis of four average control samples was carried out before the start of biological reclamation, during 2007, 2009 and 2011. The fifth average control sample was taken from the natural soil of the grassland near Stanari mine.

Establishment of the seeding grassland was performed through direct type of reclamation by grass-leguminous mixtures and pure cultures seeding in the processed deposol. Seeding was carried out during the spring sowing period (2008, 2011 and 2012 year). Seeding rate amounted from 30 to 40 kg/ha. During the sowing period, application of fertilizers was performed through the average use of 70 kg/ha NPK, while during the vegetation period supplemental recharge of 50-80 kg/ha N was conducted. When the crops reached their maximum growth, mowing - lawn mulcher was performed.

According to the random schedule, resampling of rekultisol was carried out at the end of the vegetation period in 2012. Six average soil samples were taken from the plots where the seeding grasslands were established during the reclamation process.

Sampling was performed in accordance with the methodology specified for such kind of materials (Resulovic, 1986). The depth of sampling was 0-20 cm. Laboratory analysis of the samples were carried out at the Agricultural Institute of Republic of Srpska in Banjaluka. Characteristics of the soil adsorption complex were determined by the Kappen's method.

Edaphic conditions. Researched substrates belong to deposol before the start of biological reclamation phase and to deposol during the reclamation process (rekultisol). These types were systematized into the first technogenic soil subclass (Resulovic *et al.*, 2008), and according to the WRB (2006) reference groups as *Anthropogeomorphic soil material* - nonconsolidated mineral material or *Technosols* (anthropogenic technogenic soil). Samples were collected from two types of disposed material (deposol): sandy-loamy texture with quartz mineralogical composition and clay texture (bentonite clay dominance) with parts of clayish coal. Based on the control results of active and potential soil reactions, deposol samples are classified into a category of highly acidic and moderately acidic reaction. On the basis of organic matter content, deposols samples can be classified into a soil category of weak and medium content, while pure humus practically does not exist, except for the samples from clayey substrate. According to the available phosphorus (P_2O_5) and potassium (K_2O) content in deposol samples at the beginning of the research, these control samples classify deposol into a category of very poor content of these elements. Sandy loam samples of deposols can be classified into a category of extremely poor total nitrogen content.

Climatic conditions. The average rainfall of the investigated area for the seven-year period (2006-2012) amounted 751,84 l/m^2. The average annual air temperature for the same period was 11,23°C.

RESULTS

Results of the analysis of soil adsorption complex deposols before the biological reclamation, rekultisol, and natural soil are shown in Tables 1–2. Control results of parameters are presented in Table 1. Deposol samples before the start of biological reclamation and natural soil sample were analyzed.

Table 1. Control analysis of soil adsorption complex of deposol before biological reclamation, and of natural soil

Number of samples and subtype of deposol			***Soil Adsorption Complex Analysis***				***Degree of saturation of base cations***
			S	**H**	**T**	**V (%)**	
			cmol/kg				
1.	**sandy loam**	**deposol**	19.60	20.13	39.73	49.33	*moderately unsaturated*
2.			23.60	15.75	39.35	59.97	*moderately saturated*
3.			19.40	14.00	33.60	58.33	*moderately saturated*
4.	**clayey**		17.20	7.47	24.67	69.72	*moderately saturated*
5.	**natural soil**		29.20	1.13	30.33	86.27	*highly saturated*

From the Table 1, shown above it is concluded that based on the total adsorption capacity (T) all the analyzed samples of deposols (samples 1–4) are classified into a category of moderate or inadequately saturated (low to moderate degree of saturation of soil base cations - V). Low adsorption capacity is inherent to all acidic and sandy soils. The natural soil sample has the highest saturation (V) of base cations (S), and very low saturation of adsorbed Hydrogen ions (H), which is a good characteristic.

Results of the analysis of soil adsorption complex - rekultisol after the biological reclamation and during the reclamation process are shown in Table 2.

Table 2. Analyses of soil adsorption complex of rekultisol at the end of 2012

Number of samples and subtype of deposol			***Soil Adsorption Complex Analysis***				***Degree of saturation of base cations***
			S	**H**	**T**	**V (%)**	
			cmol/kg				
1.	2008	**sandy-loamy**	2.40	2.55	4.95	48.48	*moderately unsaturated*
2.	2011		8.00	2.10	10.10	79.21	*highly saturated*
3.	2011		6.40	1.20	7.60	84.21	*highly saturated*
4.	2011		1.60	1.28	2.88	55.56	*moderately saturated*
5.	2011		8.40	1.43	9.83	85.45	*highly saturated*
6.	2012	**clayey**	6.00	1.88	7.88	76.14	*highly saturated*

Reanalysis of soil adsorption complex (Table 2) indicates some positive changes during the period of biological reclamation by methods of seeding grassland establishment. Through the reduction of total amount of adsorbed base cations, reduction of initially adsorbed acidic (Hydrogen) ions is evident.

DISCUSSION

The implementation of biological reclamation gradually leads to the improvement of basic soil characteristics of deposol (both chemical and physical), through the evolution into the ameliorated deposol (Malic, 2010), and the formation of rekultisol, which is the main goal of reclamation of degraded areas. Similar studies confirm this theory on deposols of mine basins (Skousen and Zipper, 2010; Resulovic *et al*., 2008; Lyle, 1987).

It is precisely this difference between the ratios of adsorbed base cations and Hydrogen ions that is highly expressed in this research, particularly among the samples of sandy deposols in relation to clay and natural soil. It is evident that hydrogen ions can predominate over the adsorbed base cations (Table 1, sample no. 1), which implies that such types of soil (in this case sandy deposol with lack of colloids) with their current fertility, practically do not have sufficient adsorption capacity of all the necessary elements of mineral nutrition, which requires the implementation of full agrotehnical measures during the reclamation process. Similar studies indicate that in extremely acidic deposols adsorptive complex of soil is saturated with acidic cations (H, Al, Fe), which explains the high degree of hydrolytic acidity of some samples at copper mine disposals - Bor in Serbia (Golubovic Curguz *et al*., 2010).

Saturation degree of rekultisol with adsorbed base cations (V) shows the growth towards the increase of saturation (Table 2). Applied agromeliorative measures influenced the release of hydrogen ions from the surface of colloidal particles on samples from both types of deposol textures in reclamation, in a way that these values came closer to the values typical for natural soils. Positive effects on the adsorption of cations are expressed at higher clay content (especially montmorillonite and bentonite clay). The improvement of adsorption conditions on colloidal particles is achieved during research on reclamation with annual field crops on the same deposols (Malic and Markovic, 2012).

In accordance with this research are also studies conducted by Spoljar *et al*. (2006) on the revitalization of Djurdjevac sands, where the higher saturation degree of adsorption complex of the soil with bases, maximum adsorption capacity of base cations and larger amount of bases capable to be replaced on the degraded soil, are explained as a result of increasing the humus content which was accumulated during the implementation of revitalization-reclamation of sandy substrates for a long period of time. Through the application of bentonite and other similar materials, neutralization of the acidity can be conducted, which increases the amount of adsorbed base cations and soil saturation degree (Boskovic Rakocevic, 2003), which was indicated in the results of research performed on the pseudogley soil. This claim can be used for the enrichment of Stanari sandy deposols by the bentonite clay which is partly located at the geological profile of the overburden at the Raskovac open pit.

CONCLUSIONS

In comparison to the natural soil, depending on the type of substrate at specific locations, Stanari mine deposols are more or less of low fertility. In the reclamation process, artificial grasslands are being established to a significant extent, as a part of the agricultural reclamation method. Very important function of the grassland is the improvement of pedological - chemical properties of a technogenic soil. Conducted laboratory analysis before and during the biological reclamation phase indicate the positive changes in the surface layer of rekultisols and deposols in the reclamation process. Enrichment of the organic matter in the surface layer of rekultisols and implementation of other agromeliorative measures induced an increase in the saturation degree of adsorbed base cations, and a decrease in the adsorption of acidic cations.

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THE STATE OF SOIL ORGANIC MATTER IN DIFFERENT PHYSICAL FRACTIONS DEPEND ON LAND USE TYPE

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Original scientific paper UDK 631.417(497.6)

ABSTRACT

Known fact is that arable soils compared with correspondent native soils differ in the state of soil organic matter (SOM) and that agricultural practices halved content of soil organic carbon in last decades. Further, soil structure or aggregation mediates many biological and chemical processes in soil and influence on protecting of SOM. The objectives of this paper is to analyze how the different land use (forest, grassland and arable soil) effects on quality and quantity of SOM in different physical fraction. In particular, it is important to determine what pool (physically separated fraction) of SOM is most sensitive on cultivation and what pool is more resistant to mineralization.

The research is carried out on two soil type with different texture, Pseudogley and Terra rossa, in condition of different climate and soil management. Two groups of SOM analysis are singled out: 1) quantify SOC and N storage, and $\delta^{13}C$ by horizons; and 2) quantify the SOC and N in the following physically separated fractions of SOM: a) coarse and fine particulated organic matter (POM) density <1.8 gcm^{-3}; b) occluded POM in stable microaggregates 53-250 μm; and c) SOM in small microaggregates <53 μm.

Keywords: *soil organic matter, physical fractions, type of land use*

INTRODUCTION

Quantitative and qualitative inventory of soil organic carbon (SOC) is one of the main fields of research in soil science, spatially after increasing interest for biogeochemical cycles of carbon. The type of land use is an important factor controlling soil organic matter (SOM) storage since it affects the amount and quality of litter input, the litter decomposition rates and the processes of organic matter stabilization in soils (Six *et al*., 2002a). When a forest soil is brought under cultivation, the SOC content start declining (in same time release of CO_2 to the atmosphere), and the rate of declining depends upon climatic factors, soil type (structure and texture) and intensity of cultivation. Historically, agricultural ecosystems have lost more than 50 PgC (Lal *et al*., 2004). Some of this carbon lost can be recovered through improved management, thereby

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withdrawing atmospheric CO_2. Enhancing SOC content is important to improving soil quality, reducing risks of pollution and contamination of natural waters, and decreasing net gaseous emissions to the atmosphere. By J. Six *et al*., (2002b), the relationship between soil physical characteristics and the ability of soils to stabilize SOM is a key element in understanding the sequestration of organic C in soils and to illuminate the effects of land use changes on soil organic matter storage. According to Six *et al*., (2002b), Christensen (1996) and Stevenson (1994) describes three main mechanisms of stabilization SOM: i) chemical stabilization as the result of a chemical or physical chemical linkage between SOM and silt and clay, ii) physical protection where aggregates physically protected SOM forming a physical barrier between the microbe and organic substrates, and iii) biochemical stabilization that implies the existence of components in the organic substrate which are more resistant to decomposition. There is still considerable uncertainty about the effects of different land use and soil management on organic carbon storage in soil (B. John *et al*., 2004).

Two approaches are used to determine the impact of land management on the storage of carbon: a) measuring the change in carbon content in soils under different management (Campbell *et al*., 1995, 1996; according to D. Curtin *et al*, 1998) and b) measuring the flux of CO_2 from the soil and in the soil (Rochette *et al*., 1992; according to D. Curtin *et al*., 1998).

The objectives of this paper is to analyse how the type of land use, in the condition of different texture and soil management, affects on quality and quantity of SOM in different physical fraction and to identify SOC pools that preferentially stabilize SOC in the long term.

MATERIALS AND METHODS

The research was carried out on the two types of soils: i) Pseudogley (Albeluvisol stagnic) on diluvial clay from Sprečko polje in northern Bosnia, Tuzla vicinity, and ii) Terra rossa (Chromic Cambisol, Chr. Luvisol) from Dubrava plateau in Herzegovina, Mostar vicinity. Three soil profiles were opened per site, on arable land, grassland and forest. It was important that the land use types have a long constant history (at least several decades of permanent cropping or permanent grassland or permanent forest) and that within a site soil parent material and soil texture are identical. In Sprečko polje on Pseudoglay the arable land is on a large farm which was a big Agricultural Complex in state-owned, with silage corn and oat in rotation, grassland represented 17 years abandoned arable soil and the forest was consisting of oak (*Quercus sp*.) In Dubrava platou on Terra rossa, arable land is on a farm in private-owned, with cattle raising and agricultural production with 4-6 crops in rotation, and forest is degraded and consisting of oak (*Quercuspubescens*) and ash (*Fraxinusornus*). On both plots on arable land was applicated manure, and in Tuzla in arable land and grassland were calcification (liming) done.

In Tuzla (Pseudoglay), the climate is temperate continental. Average precipitation is 923 mm yearly, and average yearly temperature 10.2ºC. Mostar vicinity (Terra rossa) have a Mediterranean climate. Average precipitation is 1,459 mm yearly, and average yearly temperature 15ºC. Despite high precipitations mediterranean climate have arid characteristic rather than humid, because season (periodical) percipitations. Very important role on soil process have strong and dry wind “bura” which draying soil surface and take away small particles fine soil (wind erosion).

A soil profile samples has taken from the horizons (4 horizons per profile). Disturbed soil samples, which represents the horizons (3 replicates per horizon) have sieved <2 mm (remove all stones and all plant residues >2 mm), and then the sample has split in two parts: i) milled subsample, are used for analyses of total SOC and N in CN elementary analyzer; and ii) 2 mm sieved sample are used for analyses of pH, CEC (repeated washing of the sample with NH_4Cl, pH at the start of washing is 4.6), and finally for physical fractionation and quantification off and N_{fr} in different soil physical fractions (density fractions and particle size fractions). Undisturbed samples in Kopezcky rings V=100 cm^3, (3 replicates per horizon) are used to determine soil bulk density necessary to determine SOC stocks. At the forest plots the organic layer has to be sampled (n=3, and 25x25 cm plots) to determine SOC and N stocks of the forest floor.

The research strategy adopted was to compare, in the same soil unit, plots with different land use (arable soil with conventional tillage, and native soils under grassland and forest) and to evaluate the long term impact of cultivation on SOM stocks in the soils. Three group objectives are singled out:

- quantification of total SOC and N and the analysis C/N and $\delta\ ^{13}C$ per horizons until 10 and 30 cm depth, as an indicator of the impact anthropogenisation;
- The main work on Institute of Soil Science and Forest Nutrition in Goettingen was the physical fractionation of the soil organic matter pools by modified method Six *et al*. (2002b) (density fractions and particle size fractions) in 2 mm sieved samples taken from 10 cm topsoil. That means to quantify the SOC and N in the following five physically separated fractions of SOM:
- three size fraction of light particulated organic matter (POM) density <1.8 gcm^3: free light fractions, coarse >250 µm (cPOM) and fine 53-250 µm (fPOM) which are unprotected from decomposition, and occluded/intra POM which is physically protected in stable microaggregates 53-250 µm (iPOM). Fractionation of particulated organic matter (POM) were done on the basis floating in sodium polytungstate (SPT) specific gravity of 1.8 gcm^{-3},

- two fraction heavy SOM chemically protected by associated with silt and clay in small microaggregates (<53 µm) density>1.8 g cm^{-3}: SOM associated with free silt and clays (f silt+clay) separated after breaking macroaggregates, and occluded (intra) SOM associated with silt and clays physically protected in small microaggregates <53 µm (and silt+clay), separated after breaking microaggregates;
- discussion of affects soil texture and soil management on the storage soil organic carbon.

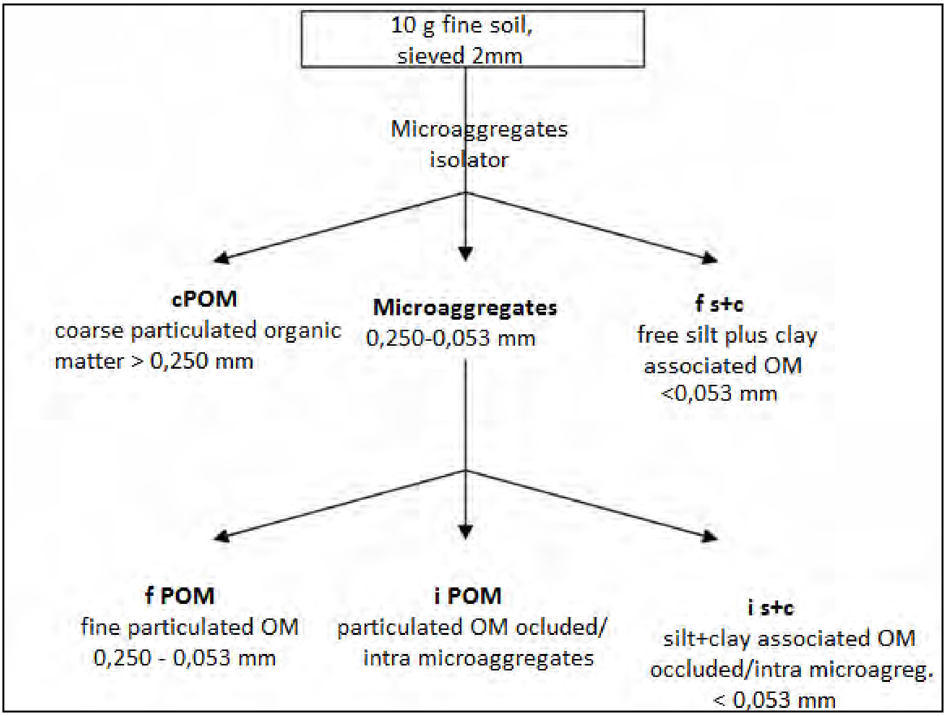

Figure 1. Scheme of fractionation

RESULTS

Table 1. Physical and chemical properties 2 mm sieved samples: Texture, Bulk density (BD), pH (1M KCl), Cation exchange capacity (CEC), Base saturation (BS): Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} in CEC, Soil organic carbon (SOC), Nitrogen (N), C/N ratio and $\delta^{13}C$ under different type of the land use

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Site/ land use	**Depth (cm)**	**Clay (%)**	**Silt (%)**	**Sand (%)**	**BD gcm^{-3}**	**pH (KCl)**	**CEC $cmol_+kg^{-1}$**	**BS %**	**C %**	**N %**	**SOC kgm^{-2}**	**C/N**	**$\delta^{13}C$ (‰PDB)**
Pseudoglay/Albeluvisol (stagnic)													
Arable land	0-12	25.6	45.2	29.2	1.47	3.7	6.5	61.7	1.24	0.12	2.18	10.1	-25.01
	12-30	25.6	44.5	29.9	1.45	3.7	6.5	60.8	1.16	0.12	3.03	9.8	-24.82
	30-52	24.8	47.5	27.7	1.54	3.6	6.6	59.6	0.99	0.10	3.35	9.6	-24.93
	52-99	41.6	35.9	22.5	1.57	3.3	15.6	70.3	0.27	0.05	2.03	5.7	-25.40*
Grassland	0-15	20.8	29.7	49.5	1.46	3.9	6.7	74.5	2.12	0.20	4.72	10.8	-26.10
	15-30	21.2	30.1	48.7	1.30	3.9	6.1	71.6	1.76	0.16	3.42	11.1	-26.19
	30-50	24.8	28.4	46.8	1.51	3.5	6.3	45.7	0.79	0.08	2.38	9.7	-26.25
	50-99	40.4	18.8	40.8	1.47	3.2	13.8	53.0	0.35	0.05	2.57	6.7	-25.68*
Forest	O_L								17.7	1.11	2.20	16.0	-27.90
	0-15	20.4	45.5	34.1	1.19	3.5	6.1	14.7	2.49	0.21	4.42	11.7	-27.39
	15-30	18.8	44.1	37.1	1.24	3.5	4.9	24.3	0.98	0.09	1.80	10.7	-27.18
	30-50	24.4	43.1	32.5	1.58	3.3	8.9	54.4	0.29	0.05	0.90	5.5	-25.95*
	50-99	39.2	33.2	27.6	1.53	3.3	16.1	74.3	0.25	0.05	1.88	4.7	-25.46

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Terra rossa /Chromic Cambisol													
Arable land	0-13	27.6	32.7	39.7	1.36	4.2	10.1	95.7	1.51	0.15	2.66	10.2	-25.42
	13-23	28.0	31.7	40.3	1.25	4.3	9.8	97.1	1.47	0.14	1.84	10.4	-25.33
	23-47	43.2	34.6	22.2	1.52	4.7	10.4	98.9	1.21	0.12	4.41	9.8	-23.62
	47-78	39.6	33.4	27.0	1.54	4.7	12.8	99.5	1.25	0.12	5.99	10.5	-24.11
Grassland	0-10	31.6	37.4	31.0	1.31	4.7	12.0	98.3	2.05	0.18	2.69	11.6	-23.74
	10-20	39.2	27.3	33.5	1.46	4.5	10.4	97.6	1.26	0.12	1.84	10.7	-22.95
	20-40	46.0	22.4	31.6	1.52	4.4	12.0	97.4	0.82	0.09	2.50	9.3	-22.64
	40-78	56.4	20.0	23.6	1.49	4.6	17.8	99.3	0.63	0.09	3.55	7.3	-22.42
Forest	O_L								19.1	0.92	0.32	20.8	-26.68
	0-11	33.2	44.4	22.4	1.27	4.6	12.9	96.6	2.63	0.22	3.67	11.7	-26.21
	11-23	37.6	38.0	24.4	1.38	4.2	10.0	88.4	1.65	0.15	2.75	10.7	-24.70
	23-38	44.0	26.5	29.5	1.43	4.1	9.9	88.4	0.98	0.10	2.10	9.6	-23.36
	38-78	43.6	29.5	26.9	1.48	4.1	10.5	89.8	0.63	0.07	3.70	8.3	-23.30

* signal less than 300 mV results with uncertain results

Pseudogley has a loam soil texture and Terra rossa clayey-loam texture (US Soil Taxonomy). According by Schefer-Schactschabel (pH in 1M KCl) Pseudoglay has a very strong acidity pH and Terra rossa strong acidity. Furthermore, a rate of decomposition SOM increase throughout the soil profile. Data shows that upper layers of Terra rossa contains the higher values of CEC (10-13 $cmol_{+}$ kg^{-1}) as well as to impermeable clayey horizon in Pseudoglay. In Terra rossa total percent base saturation are in range 88.4-99.3%. Lowest values of CEC are recorded in topsoil in pseudoglay in forest where recorded total percent base saturation less then is 50%. In arable land and grassland on Pseudoglay where liming is made, records show higher values of total percent base saturation (60-70%) than in forest.

Depend of the type of land use examined soils has been tested by the analysis of the complete C storage in kg m^{-2} within 10 cm and 30 cm of depth.

Table 2. SOC storage within 10 and 30 cm

Depth (cm)	SOC storage (kg m^{-2})					
	Pseudogley			Terra rossa		
	Arable	Grassland	Forest	Arable	Grassland	Forest
within 10 m	1.82	3.15	2.95	2.04	2.70	3.34
within 30 cm	5.21	8.14	8.42	5.78	5.78	7.71

The SOC stock to 10 cm depth in Pseudoglay in mineral soil is greater in grassland than in the forest, which is in accordance with the suggestions of Collins *et al*., 2000, and Kononova, 1996 (according to J.Six *et al*., 2002b) that grassland have a highest potential for storage SOC due to their higher base saturation, as is the case in this soil.

SOC storage in kg m^{-2} within 30 cm of depth is a good indicator of the impact cultivation on the SOC content. The average difference in SOC storage within 30 cm between forest and agricultural soils is 2.58 kg m^{-2} for both soils. Pseudogley makes the biggest proportion, with 3.21 kg m^{-2} more SOC in forest than in arable soil.

This analysis showed too, that natural soils on Pseudogley (grassland which is converted arable land and forest) have a higher content of organic carbon than natural soils of the Terra Rossa. Probably the most effective way of restoring the stock of carbon in cultivated soils is the restoration and maintenance of perennial vegetation (Bruce *et al*., 1998). However, in Terra rossa on the cultivable land were found higher content SOC than in arable land on Pseudoglay and the same storage of SOC as well as on the nearby grassland. The level of carbon in natural soils reflects the balance of the input C and loss of C under natural conditions, but in any case does not represent the upper limit of the carbon content of the soil (J. Six *et al*., 2002a).

It is interesting to compare the results from Pseudoglay in Tuzla with the research John *et al*. (2004) at Stagnic luvisol (silty loam) in Rotthalmuenster (mean annual rainfall of 886 mm and a temperature of 8.7°C, spruce forests)

Table 3. SOC storage (kg m^{-2}) whit in 30 cm in Tuzla and Rotthalmuenster

	Arable land	Grassland	Forest (mineral soil +O)
Stagnic Albeluvisol/Psudoglay,Tuzla	5,211	8,142	6,220 + 2,200
Stagnic luvisol, Rotthalmuenster	5,269	6,006	4,886 + 4,108

Results of SOC stocks in the arable land for both sites are equal, while in the natural soil under meadow in Tuzla have accumulated more organic carbon than inRotthalmuenster. Furthemor, in the mineral soil in oak forest in Tuzla were found larger stocks SOC, while in Rotthalmuenster the O horizon in spruce forest have a larger SOC stocks.

Table 4. Physical fraction: concentration soorganic carbon (C) and nitrogen (N), ratio C/N, storage of C in fractions gC$_{fr}$m^{-2}, yield C$_{fr}$(gm^{-2}) in total SOC (gm^{-2} within 10 cm depth), storage of C in fractions in gC$_{fr}$kg^{-1}soil

1	2	3	4	5	6	7	8
Site/land use	**Physical fraction**	**C_{fr} %**	**N_{fr} %**	**C_{fr}/N_{fr}**	**$gC_{fr}m^{-2}$**	**Yield (%) C_{fr} in C_t**	**C_{fr} $gC_{fr}kg^{-1}$**
Pseudoglay/Stagnic Albeluvisol							
Arable land	c POM	32.45	1.52	21.41	80	4.39	0.55
	f POM	26.15	1.50	17.42	58	3.18	0.39
	i POM	19.8	1.31	15.17	59	3.24	0.40
	i silt + clay	1.28	0.15	8.59	477	26.19	3.25
	f silt + clay	1.02	0.12	8.72	944	51.89	6.45
Grassland	c POM	30.39	1.81	17.01	183	5.82	1.25
	f POM	27.47	1.85	14.87	126	4.00	0.87
	i POM	25.12	1.79	14.12	195	6.19	1.34
	i silt + clay	2.79	0.28	9.84	695	22.05	4.74
	f silt + clay	1.54	0.17	9.25	1.587	50.39	10.87
Forest	c POM	34.18	1.24	27.55	157	5.32	1.32
	f POM	27.64	1.42	19.27	53	1.81	0.45
	i POM	23.43	1.46	16.1	119	4.03	1.01
	i silt + clay	3.05	0.31	9.9	767	25.99	6.53
	f silt + clay	2.07	0.21	10.04	1.555	52.71	13.04

1	2	3	4	5	6	7	8
Terra rossa/Chromic Cambisol							
Arable land	c POM	27.81	1.60	17.43	103	5.05	0.76
	f POM	27.02	1.47	18.35	88	4.30	0.65
	i POM	30.55	1.78	17.1	120	5.89	0.89
	i silt + clay	1.49	0.15	8.24	661	32.40	5.11
	f silt + clay	1.43	0.16	9.14	973	47.71	7.19
Grassland	c POM	27.61	1.10	25.32	148	5.49	1.12
	f POM	19.02	0.99	19.16	99	3.67	0.75
	i POM	30.85	1.45	21.31	109	4.02	0.83
	i silt + clay	2.11	0.23	9.14	1.146	42.43	8.70
	s silt + clay	1.86	0.20	9.48	1.127	41.74	8.53
Forest	c POM	31.56	1.42	22.23	192	5.74	1.51
	f POM	25.15	1.43	18.56	75	2.24	0.60
	i POM	29.05	1.52	19.12	218	6.53	1.73
	i silt + clay	2.65	0.28	9.45	1.076	32.22	8.50
	f silt + clay	2.1	0.21	9.95	1.635	48.94	12.75

Concentration of C_{fr}, in both soils, is higher in light fractions - particulated organic matter compared with heavy fractions - OM associated with silt and clay. The concentrations of C_{fr} in Pseudoglay come in following order cPOM>fPOM>iPOM>i s+c>f s+c. These results for Pseudoglay can be considered the opposite of the conclusions Golchin *et al*. (1994) who report that occluded within the micro aggregate light fraction (iPOM) had a higher concentration of C and N than the free light fraction (cPOM and fPOM), what in generally confirmed results from Terra rossa.

C_{fr}/N_{fr} ratio also show higher values in light fractions POM (less decomposed SOM) than in mineral associated OM which was actually a biochemical processed organic material, what is in accordance with studies John *et al*. (2004). The fraction particulated organic matter having a high C/N ratio and low potential net mineralization of nitrogen (N_{min}) (Catroux and Schnitzer, 1987; Chichester, 1969; Ford and Greenland, 1964; Sollins *et al*., 1984; Tiessen and Stewart, 1983; and Turchenek Oades, 1979 - according to J.Six *et al*., 2002).

The major part of the SOC in both soils was associated with the mineral fractions fs+c and is+c, in Pseudoglay 76% and in Terra rossa 81%.

In Pseudoglay, absolute differences in SOC storage between forest and arable land is the most evident in fractions fs+c (difference 611 gC_{fr} m^{-2}) and is+c (difference 415gC_{fr} m^{-2}). Relative difference between arable and native soils is most the evident in the iPOM fraction where values of C_{fr} storage in arable soil (59 gC_{fr} m^{-2}) is more than three times lesser than in grassland (195 gC_{fr} m^{-2}) and in fraction cPOM where is content of SOC in arable land halved. Six *et al*. 2002a in a study conducted at the Wildlife area in Ohio - USA, on the silty clay soil were found more than three times higher the amount of C in iPOM fraction in the forest ecosystem with walnut and oak than in agriculture. Many studies have found that the light fractions of particulate organic matter, particularly cPOM (> 250 microns), are relatively easily and widely decompose under cultivation indicating their relatively unprotected (biochemical and physical) status (Cambardela and Elliott, 1992; Six *et al*., 1999; Solomon al., 2000, according to Six *et al*., 2000).

In Terra rossa, SOC storage in all separated fractions has highest values in forest compared to arable land and grassland. Exceptions arei s+c fraction where values C_{fr}storage for forest and grassland are balanced, and fine POM fraction, which in all ecosystems have a similar values C_{fr} storage.

Table 5. The degree of stability of microaggregates (the percent of carbon from fraction intra microaggregates silt plus clay (i s+c) in total chemically protected SOC associated with total silt and clay (f s+c plus i s+c)

	Pseudoglay			Terra rossa		
	arable land	**grassland**	**forest**	**arable land**	**grassland**	**forest**
C_{fr}- free silt+clay ($g\ m^{-2}$)	944	1587	1555	973	1127	1635
C_{fr}- intra microaggregates silt+clay ($g\ m^{-2}$)	477	695	767	661	1146	1076
% C from stable microaggregates	34	30	33	40	50	40

The share of carbon from fraction intra micro aggregate silt plus clay (i s+c) in the total chemically protected SOC associated with silt and clay (C from f s+c plus i s+c) represents the degree of stability of microaggregates. Data show higher percent stable microaggregates in Terra rossa than in Pseudglay. Kemper Koch (1966) note that the stability of the aggregates increases to the maximum level with increase of clay content and the content of Fe-oxide (according to Six *et al*., 2002a).

CONCLUSIONS

In both types of soil, significantly lower storage of SOC within 30 cm on arable soils compared to forests (as well as to meadow in Pseudoglay) was recorded. The forest proved to be the most favorable for the accumulation of SOC in the form of organic matter both on the surface (O horizon) and in mineral soil.

Mostly part of SOM in both soils is chemically protected by associated with silt and clay fractions. These values are for Pseudoglay with loam texture 76% and in Terra rossa with clayey loam texture 81%. The degree of stability of microaggregates (the share C from intra silt + clay) is also higher on Terra rossa. It can connect with the present of Fe-oxides in the Terra rossa, which are connected with a positive impact on the stability of microaggregates (Kemper and Koch, 1966, according to Six *et al*., 2002). Furthermore, on acid topsoil of Pseudoglay were recorded low value CEC what can be connected with leeching bases, and it is well known a positive effect of Ca^{2+} (dominant in cation composition of CEC Terra rossa) on the aggregation.

In Pseudoglay, lower storage of C in arable soils related to natural ecosystems is evident in each separated fractions, spatially in iPOM and cPOM. Compared with Pseudoglay in Terra rossa different in SOC stocks between natural ecosystem and arable land in POM fractions is not so pronounced what indicated a good management with arable soils.

The example of managing agricultural soils on smaller farms (in private property) with cattle raising and agricultural production (Terra rossa) compared to large farms which was a big Agricultural Complex in state-owned (Pseudoglay), has shown that the way of managed with agricultural soil can significantly influence the trend of organic matter storage both in positive way (by decreasing cultivation, increasing the use of organic fertilizers, using different cultures in crop rotation; arable land on Terra rossa example) and in negative way (by intensive cultivation, fixed crop rotations, poor managing of manure; arable soil on Pseudoglay example). In Pseudoglay, by converting a abounded arable soil into a meadow, in the period of 17 years SOC storage within 30 cm became equal to the storage SOC in forest, while, compared to 50 m distant arable soil, 2.93kg m^{-2} more SOC was accumulated in meadow. This is a good example that managing soil can increase storing C in soil, in other words, it shows what kind of positive effects can be produced by using mixture of clover-grass in crop rotation.

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MICROBIOLOGICAL PROPERTIES OF REKULTISOL UNDER DIFFERENT CULTURES AT STANARI COAL MINE

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ABSTRACT

This paper studied the number of physiological and systematic groups of microorganisms in rekultisol under the different cultures at Stanari Coal Mine, and in variants of rekultisol where mineral fertilization and calcification were applied and in variants of rekultisol where only mineral fertilization was applied. The trial was set in the field conditions at the location of the internal part of overburden deposition site, near open pit Raskovac which is the part of Stanari coal mine. Mineral fertilizers were used as starter fertilizer and supplementary nutrition in the amount of 100-140 kg/ha of N and 40-60 kg/ha P_2O_5 and K_2O and calcification was completed by adding 4 t/ha $CaCO_3$. Microbiological analysis of the rekultisol determined the total number of bacteria, *Azotobacter sp*., ammonifiers, oligonitrophyls, actinomycetes and fungi. The aim of the research is to determine microbiological properties of rekultisol under small grains, potatoes, and grass-clover mixture at “Stanari” coal mine as well as to determine the effect of mineral fertilizers and calcification on the number of microorganisms in the rekultisol under different cultures. The total number of bacteria, oligonitrophyls, sporogenic ammonifiers, *Azotobacter sp.* and actinomycetes was higher in rekultisol under all of the tested cultures in the variant fertilizers + $CaCO_3$ comparing to the variant without $CaCO_3$, while the number of ammonifiers and fungi in rekultisol under all of the tested cultures was higher in the variant without $CaCO_3$ in relation to the variant mineral fertilizers + $CaCO_3$. In rekultisol under grass-clover mixture, higher total number of bacteria, oligonitrophyls and fungi was recorded in both tested variants, in relation to their number in rekultisol under potatoes and small grains. The number of actinomycetes was higher in rekultisol under potato in both variants, in relation to the number of actinomycetes in rekultisol under small grains and grass clover mixture. In rekultisol under small grains in variant mineral fertilizers + $CaCO_3$ number of

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ammonifiers was the lowest (182 x $10^4 g^{-1}$ absolutely dry soil), while the highest number of ammonifiers was recorded in rekultisol under grass-clover mixture in the variant without $CaCO_3$ (1778 x $10^4 g^{-1}$ absolutely dry soil). *Azotobacter sp.* count was lowest in rekultisol under grass clover variant without $CaCO_3$ (68 x $10^2 g^{-1}$ absolutely dry soil), while the highest *Azotobacter sp.* count was recorded in rekultisol under small grains in the variant with fertilizers + $CaCO_3$ (123 x $10^2 g^{-1}$ absolutely dry soil).

Keywords: *rekultisol, microbiological properties, mineral fertilizers, calcification*

INTRODUCTION

Reclamation of the damaged surface mine areas represents an important part of sustainable development strategies of many countries (Sheoran *et al*., 2010). Intensification of mining operations in the Raškovac open-pit mine and future open-pit mine Ostružnja, in order to provide sufficient quantities of coal for Stanari thermal plant, significantly accelerated the degradation of the environment and the whole ecosystem. Therefore, it is necessary to conduct reclamation of the damaged area (Loncar *et al*., 2009; Malic *et al*., 2012).

Surface coal mining disrupts the primary structure and composition of land and it causes deposition of different geological materials (Resulovic, 1982). Deposols have extremely low production value, lack of or very low humus content (Dželetovic *et al*., 1995) and nutrients (Filipovic *et al*., 1981), which results in changes in the quantitative and qualitative composition of microbial populations and their biochemical activity (Golic *et al*., 2014).

Biological reclamation is the old technology for the restoration of lands damaged by human activity. During reclamation of surface mine sites, soil microorganisms are extremely important for the sustainable ecosystem function. They themselves are involved in major soil processes, such as humification, recycling, and mineralization of organic residues, leading to the plant availability of nutrients. Thus, they represent an important link in the soil-plant system and contribute to the enhancement of soil fertility (Emmerling *et al*., 2002; Kourtev *et al*., 2002; Golic *et al*., 2006).

Mineral fertilization has the strongest influence on field crops yield. However, results of trials carried out by Barabasz *et al*. (2001) have shown that mineral fertilization also strongly affects a number of microorganisms and qualitative selection of whole communities of soil microorganisms. The universal system of fertilization is very difficult to achieve on acid soils due to numerous problems with nutrition, as well as the application of mineral nutrients, because it is difficult to specify needs of plants for certain nutrients in acid soils, as a result of very uneven both physical and chemical properties of soil (Bennett, 1993).

Adequate application of limestone material in combination with mineral and organic nutrients is the most effective way of avoiding adverse characteristics of acid soil (Jelić *et al*., 2008).

The aim of the research is to determine microbiological properties of rekultisol under small grains, potatoes and grass-clover mixture at “Stanari” coal mine as well as to determine the effect of mineral fertilizers and calcification on the number of microorganisms in the rekultisolunder different cultures.

MATERIAL AND METHODS

This research with different crops was performed in three years period (2011/2013), on the experiment plot of technogenic soil of the mine, within the inside part of overburden deposition site, near Raskovac pit, which is the part of Stanari coal mine. Stanari coal mine is located in north of the Republic of Srpska and Bosnia and Herzegovina.

Small grains were sown manually, during the autumn sowing date, with 250-280 kg/ha of seed. Seeding rate for potato and for grass-clover mixture was 40-45 kg/ha.

In variants of rekultisol where mineral fertilization and calcification were used, mineral fertilization used as starter fertilizer and supplementary nutrition in the amount of 100-140 kg/ha of N and 40-60 kg/ha P_2O_5 and K_2O, and calcification was completed by adding 4 t/ha $CaCO_3$. Same amount of mineral fertilization were used variants of rekultisol where only mineral fertilization were applied.

Before seeding these crops, implementation of sudangrass growth (one year) was performed with the green manure fertilization of deposol and it represents an agro-technical phase of reclamation process within the mine.

Samples were collected from deposol without measures of biological reclamation (deposol control) and deposol in the reclamation process. Chemical analysis of deposol determined the parameters as follows: pH values (determined in a 1:25 ratio of soil/distilled water and in KCl), humus content (dichromate method by Tjurin in modification by Simakov), availability of potassium and phosporous (Al-method by Egner-Riehm-Domingo).

Microbiological analyses involved determination of the number of particular systematic and physiological groups of microorganisms using the method of dilution on specific solid media. The following was determined: total number of bacteria (on the 1/10 strength Trypton Soya agar), soil fungi (on Czapek-Dox agar), actinomycetes (on the synthetic agar, Krasilljnikov, 1965), ammonifiers (on the nutrient agar), oligonitrophilic bacteria (Fyodorov's medium, Anderson and Domasch, 1958), count of *Azotobacter sp.* (Fyodorov's medium by the fertile drop method, Anderson, 1965). Incubation was followed by identification and counting of the colony forming units per 1 g of absolutely dry soil.

RESULTS

Chemical properties

Results of the basic chemical properties analysis of deposol (control) and deposolin the reclamation process are shown in Table 1.

Table 1. Results of chemical analysis of the deposol (control) and deposol in the reclamation process

Nº	Species	Phase of deposol (substrate) and fertilizing		pH H_2O	pH KCl	Organic matter	Humus (%)	Plant available P_2O_5 mg/100g	Plant available K_2O mg/100g
1.	-	**Deposol (control)**		5.2	4.1	1.60	0.0	0.0	1.0
2.	**Small grains and potato**	**Deposol in the reclamation process**	**Mineral fertilizer**	6.3	5.0	3.98	0.2	2.3	5.9
3.			**Mineral fertilizer + $CaCO_3$**	6.7	5.9	4.70	1.0	1.1	7.4
4.	**Grass-clover mixture**		**Mineral fertilizer**	6.1	5.0	3.01	0.0	1.0	5.4
5.			**Mineral fertilizer + $CaCO_3$**	7.2	6.2	3.5	0.1	1.6	5.5

Deposol (control) belongs to very acid soils (pH in KCl 4,1) with organic matter content of 1.6%, while the humus content and available phosphorus is below the level of detection. The content of readily available potassium is 1 mg/100 g soil.

Deposol in the reclamation process, under all cultures in the variant with the mineral fertilizer, had the 5.0 pH value in KCl, whereas in the variant with fertilizers + $CaCO_3$ pH value of the soil under small grainsand potatoes was higher 5.9 and in the soil under grass-clover mixture 6.2.

The content of organic matter in deposols in the process of reclamation has increased in relation to deposols-control. The land under small grainsand potatoes, the variant with mineral fertilizer, had the organic matter content of 3.98%, and in variant with fertilizers + $CaCO_3$ it was 4.7%. In soil under the grass-clover mixture the organic matter content was much lower with 3.01% in the variant with mineral fertilizer, and in variant mineral fertilizers + $CaCO_3$, the content of organic matter was 3.5%.

The humus content is very low in both variations, and it ranges from 0%, in the soil under grass-clover mixture, and in variants with mineral fertilizers up to 1% on the land under small grainsand potato crops in variant with mineral fertilizer + $CaCO_3$.

In all the tested variants the soil is poorly provided with readily available phosphorus. The content of readily available potassium is slightly higher in relation with the contents of available phosphorus, but is still poorly provided with potassium regarding the plant production.

Microbiological properties

Microbiological properties of this deposol (control) and deposol in the process of reclamation are shown in Table 2. The number of microbial groups is much lower in deposols (control) comparing to the deposols in the reclamation process.

The total number of bacteria and their composition is one of the indicators of the biological value of the land. The minimum total number of bacteria was recorded in soil under small grains and in the variant withthe mineral fertilizer only (54 x 10^6 g^{-1} of absolutely dry soil), while a slightly higher number of bacteria was recorded in the variant with the mineral fertilizer + $CaCO_3$ (97 10^6 g^{-1} absolutely dry soil). In the soil under the grass-clover mixture, the total number of bacteria was the highestin the variant with fertilizers + $CaCO_3$ and was 351 x 10^6 g^{-1} of absolutely dry soil.

Table 2. The number of the microbial groups in deposol control and deposol in the reclamation process

Species of Microorganisms		Phase of the deposol						
		Deposol (control)	Deposol in the reclamation process					
			Small grains		Potato		Grass-clover mixtures	
			MF	MF+ $CaCO_3$	MF	MF+ $CaCO_3$	MF	MF+ $CaCO_3$
Total number of bacteria x $10^6 g^{-1}$		4.7	54	97	128	194	158	351
Ammonifying bacteria	**Totalx 10^4 g^{-1}**	96	296	182	1120	766	1778	1069
	Sporogenicx 10^3 g^{-1}	7	63	126	167	233	34	53
Oligonitrophilic bacteriax 10^4 g^{-1}		96.1	751	1292	1171	1291	1361	1600
***Azotobacter sp.* x 10^2 g^{-1}**		5	83	123	93	109	68	110
Actinomycetes x $10^3 g^{-1}$		0	47	70	306	548	21	38
Fungi x 10^4 g^{-1}		36.5	233	168	337	248	461	391

The number of ammonifiers in deposols in the reclamation process under all tested cultures is lower in the variant with fertilizers + $CaCO_3$ compared to the variant with only mineral fertilizers. The highest number of ammonifiers was recorded in soil under grass-clover mixture in variant only with mineral fertilizers (1778 x 10^4 g^{-1} of absolutely dry soil), and the lowest in the soil under small grains variant with fertilizers +$CaCO_3$ (182 x 10^4 g^{-1} of absolutely dry soil).

In the soil under all of the cultures, the number of sporogenic ammonifiers was lower in variant with only mineral fertilizer in relation to the variation with mineral fertilizers + $CaCO_3$. Minimum number of sporogenic ammonifiers was recorded in soil under grass-clover mixture in variant with mineral fertilizer and was 34 x 10^3 g^{-1} of absolutely dry soil, while the highest number of sporogenic ammonifiers was recorded in the soil under potato, variant with fertilizers and $CaCO_3$ and it was 233 x 10^3 g^{-1} of absolutely dry soil.

Oligonitrophyls represent a dominant physiological group of microorganisms in the analyzed samples. Presence ofoligonitrophyls in soil under all of the cultures is greater in variation with mineral fertilizers + $CaCO_3$ compared to variants with only mineral fertilizers. The soil under grass-clover mixture contains higher number of oligonitrophyls in both variations, compared to the number of oligonitrophyls in soil under other cultures.

Applying calcification with mineral fertilizer, the number of *Azotobactersp.* and actinomycetes in the soil under all the tested cultures increased. The highest number of *Azotobactersp.* is recorded in the soil under small grains (123 x 10^2 $g^{-1}$of absolutely dry soil - a variant with fertilizers + $CaCO_3$), and the lowest number is in the soil under grass-clover mixture (68 x 10^2 g^{-1}absolutely dry soil - variant with mineral fertilizer). The number of actinomycetes is the highest in the soil under potato (548 x 10^3 g^{-1} absolutely dry soil - variant mineral fertilizers + $CaCO_3$), and the lowest in the soil under grass-clover mixture (21 x 10^3 g^{-1} absolutely dry soil - variant with mineral fertilizers).

The number of fungi in the soil under all tested cultures was higher in variant with only mineral fertilizer in relation to the number of fungi in variant with fertilizers + $CaCO_3$. The highest number of fungi, in both variations, is recorded in the soil under grass-clover mixture in variant with mineral fertilizer where the recorded number of fungi was 461 x 10^4 g^{-1} of absolutely dry soil, and in variant with fertilizers +$CaCO_3$ it was 391 x 10^4 g^{-1} absolutely dry soil. The minimum number of fungi in both variations was recorded in the soil under small grains. In this soil, invariant with mineral fertilizer, the number of fungi was 233 x 10^4 g^{-1} of absolutely dry soil, and in variant with fertilizers + $CaCO_3$ in the amount of 168 x 10^4 g^{-1} of absolutely dry soil.

DISCUSSION

The number of microorganisms in certain ecosystem is a definite indicator of soil fertility (Tabatabai, 1982). Soil fertilization with mineral fertilizers has a positive effect on increasing the biological productivity of various ecosystems, as well as the microbial activity in the soil (Barabasz, 2002). Results of basic chemical characteristics point to an acidic reaction of the tested deposol. The pH values directly affect the mobility of nutrients and enable their accessibility for the plants, but also cause the composition of soil microbial populations and affect the formation of certain species of plant-covers (Tintor *et al*., 2008). As most of cultivated plants require a slightly acidic, neutral to slightly alkaline soil reaction, a small number of crops can tolerate the conditions in acid soils. Neutralizing the acid soils by introducing limestone material is a measure that is regularly recommended in order to improve the physical, chemical and biological properties and to increase the level of soil fertility (Jelic *et al*., 2008).

Within the total number of microorganisms in the soil, the largest share belongs to bacteria. Bacteria are the most numerous in the neutral soils. By reducing the acidity, the conditions for increasing bacterial activity is created (Jarak *et al*., 2003), which was confirmed in this study. The total number of bacteria in the soil under all tested cultures is increased by application of $CaCO_3$ with mineral fertilizer.

Ammonifiers, as consumers of organic nitrogen and protein decomposers, are the most abundant group of microorganisms in the soil (Bogdanović, 1990). The size of this group of microorganisms is least sensitive to changes in physical and chemical parameters in soil and negative impacts (Tintor *et al*., 2009). Number of ammonifiers in soil under all tested cultures was higher in the variant with only mineral fertilizer in relation to the variant of mineral fertilizers + $CaCO_3$.

Free nitrogen-fixing bacteria, that can fix atmospheric nitrogen, play an important role in maintaining soil fertility. In the tested soils, the number of oligonitrophylsin the soil under all tested cultures was greater in variations with fertilizers + $CaCO_3$ compared to variants with only mineral fertilizer. In the soils under all tested cultures, there are modest reserves of nutrients, which is more acceptable for oligonitrophyles in comparison to the other groups of microorganisms. Dominance of oligonitrophilic bacteria compared to ammonifiers indicates the presence of mineral nitrogen.

Actinomycetes require alkaline environment and sufficient organic matter (Jarak and Govedarica, 2003), while the number of actinomycetes in the acid soil is low (Williams and Wellington, 1982). With the decrease of soil acidity, by calcification with mineral fertilizers, there was an increase in the number of actinomycetes in the soil under all tested cultures.

Azotobacter sp. is one of several soil bacteria important as nitrogen fixers that convert atmospheric nitrogen into forms available to plants and is very important parameter for determination of soil biogeny. This group of bacteria is very sensitive to all changes occuring in the soil and responds to them by its abundance and vigorous activities. According to Jarak and Čolo (2006), *Azotobacter sp*. in acid soils is either absent or present in very small numbers. Based on the results of this study, it can be concluded that increasing the pH value of the soil in the tested soil samples, due to the calcification with mineral fertilizer, had influenced on increase of *Azotobactersp*. number in the soil.

Fungi live in communities with a wide range of pH value (1.7-3.0 to 9.0). In environments with a low pH value, which is not suitable for bacteria and actinomycetes, fungi are the dominant microbial flora, which in such circumstances is particularly active in biochemical transformations. Due to the increased pH of the tested soil by applying calcification measures, a lower number of fungi are expected in variants with fertilizers + $CaCO_3$.

CONCLUSIONS

Based on the study of the effect of the mineral fertilizer applications and calcification on the number of microorganisms in deposols under small grains, potato crops and grass-clover mixtures, we can conclude the following:

- The application of mineral fertilizers and calcification showed improvement of chemical properties of deposol in the reclamation process.
- In the soil undergrass- clover mixtures, the total number of bacteria, the total number of ammonifiers, oligonitrophyls and fungi in both variants was higher than in soils under other tested cultures.
- Number of actinomycetes is the highest in the soil under potato in both studied variants.
- Number *Azotobacter sp*. was the lowest in soil under grass-clover mixtures in the variant with only mineral fertilizer, while the highest number of *Azotobacter sp*. was recorded in soil under small grains in variant with mineral fertilizer + $CaCO_3$.
- The total number of bacteria, oligonitrophyls, sporogenic ammonifiers, *Azotobacter sp*. and actinomycetes was higher in deposols in the reclamation process under all tested culture in variants with fertilizers + $CaCO_3$ compared to variant without $CaCO_3$, while the number of ammonifiers and fungi in deposols in the reclamation process under all tested cultures was higher in the variant without $CaCO_3$ compared to variant with fertilizers +$CaCO_3$.

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COMPARISON OF ALLUVIAL SOILS OF DIFFERENT LAND USE IN THE AREA OF THE NATIONAL PARK "UNA" WITH SPECIAL EMPHASIS ON THE DISTRIBUTION OF CADMIUM, NICKEL AND ARSENIC

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ABSTRACT

The paper presented results of a comparison of alluvial soils of different land use at two sites within the National Park "Una". The sites were related to a natural meadow (BUK) and artificial meadow (KLISA). The main objective of the research, in addition to the physical and chemical parameters of soil quality, was to determine the distribution of the total content of cadmium (Cd), nickel (Ni) and arsenic (As). The total content of these elements were observed in composite samples at two depths of 0-10 cm and 0-20 cm and horizons profile. Their total content was measured by atomic AAS. The results were analyzed using Kruskal – Wallis test ($p \leq 0.05$) using coefficient χ^2. The results showed a single legality of the distribution of Cd, Ni and As in samples of soil profile, while the average soil samples showed unique legality of the distribution of observed elements.

Keywords: *alluvial soil, distribution, cadmium, nickel, aresenic*

INTRODUCTION

In recent decades the area of the National park „Una" has stirred the interest of many scientists and researchers (Alibabić and Bašić, 2005; Bašić and Čustović, 2005; Muhamedagić, 2010, etc). In particular, the issues of distribution of toxic elements in the soil have been dealt with, both in our country and the world, by many researchers coming from different functional areas: industrial (Shakeri *et al*., 2009; Dheeba and Sampathkumar, 2012, etc.), urban (Romić and Romić, 2003, etc.), landfills (Dellantonio *et al*., 2007, etc.) and protected areas (Maksimović *et al*., 2013; Muhamedagić, 2015, etc.).

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This paper presents the results of a comparison of alluvial soils of different use with in the National Park „Una“. The study has placed a special emphasis on the distribution of the total content of cadmium (Cd), nickel (Ni) and arsenic (As) in the average samples (0-10 and 0-20 cm) and by depth of the soil profile. Selected research sites were located in the extensions of alluvial plains along the river Una. The first site of BUK (altitude: 284 m) and the second site of KLISA (altitude: 301 m) (Figure 1-2).

Figure 1 – 2. The sites of soil sampling BUK (left) and KLISA (right)

MATERIAL AND METHODS

This paper presents results of the field research, sampling and laboratory testing. All analyzes of soil samples were determined according to standardized methods: Mechanical composition (ISO 11277); Structure (Method by Sekera); The rights specific gravity, Porosity (ISO 11508); The volume specific gravity (ISO 11272); Actual humidity, Capacity of soil for water and Air capacity (ISO 11465); Humus (ISO 10694); $CaCO_3$ (ISO 10693); pH (ISO 10390); El. conductivity (ISO 11265); P_2O_5 and K_2O (ISO 19730) and The total content of metals and metalloids in the soil (ISO 11466).

A total of two pedological profiles were opened at the sites of research and average samples were taken from two soil depths: 0-10 cm and 0-20 cm.

Preparation of soil samples was carried out at the Biotechnical Faculty of the University of Bihać. All analyses of soil samples were carried out in the laboratory of the Institute of Soil Science, Agrochemistry and Reclamation of the Faculty of Agricultural and Food Sciences, University of Sarajevo, except for the content of arsenic that was carried out at the Faculty of Agriculture, University of Zagreb, and the Institute for Medical Research and Occupational Health in Zagreb. Statistical analysis was performed by the Kruskal-Wallis test at the level of significance of $p \leq 0.05$. To determine the relation and distribution of Cd, Ni and As in the soil we used the correlation coefficient (χ^2) (Kruskal and Wallis, 1952). Data were statistically analyzed using SPSS 17. The maximum allowable amounts of total contents were determined in accordance with the current regulations (Official Gazette of the Federation of B&H, No. 72/90) in relation to the soil texture (MRL) and the use of soil in organic farming (MRL-OF). Used are orthophoto imagery in the scale of 1: 5000 and 1: 75000, topographic maps and GIS.

RESULTS AND DISCUSSION

Results of the study on the comparison of alluvial soils with different use provide:

Description of the alluvial soil profile at the site of BUK (Figure 3)

- Site: alluvial plain – BUK (N 44° 39.042´, E 16° 01.938´);
- Vegetation: meadow;
- Use: natural meadow no cultivation;
- Parent substrate: alluvium

I 0-11 cm: surface layer intertwined with roots, brown in colour, with fine granular structure and sandy loam texture (sand = 68.8%, powder = 16.5%, clay = 14.7%).

II 11-51 cm: abrupt transition to a yellowish-brown layer with evident penetration of roots, with fine granular structure and sandy loam texture (sand=69.0%, powder=15.2%, clay=15.8%).

III 51-110 cm: gradual transition to a greyish-brown layer, with very fine granular structure and sandy clayey loam texture (sand=59.8%, powder = 21.0%, clay=19.2%).

IV > 110 cm: emergence of groundwater.

Description of the alluvial soil profile at the site of KLISA (Figure 4)

- Site: alluvial plain – KLISA (N 44° 35.115´, E 16° 04.487´)
- Vegetation: meadow;
- Use: artificial meadow – cultivated;
- Parent substrate: alluvium.

I 0-24 cm: surface layer is less overgrown with meadow vegetation with shallow root system, brown in colour, with fine granular structure and sandy loam texture (sand = 65.4%, powder = 18.7%, clay = 15.9%).

II 24-82 cm: this layer shows evident traces of rotten plant parts, its structure is finely granular, colour is yellowish brown, and texture sandy loam (sand = 56.9%, powder = 22.5%, clay = 20.6%).

III 82-115 cm: abrupt transition to a layer of grayish-brown colour with evident traces of rotten plants, fine granular structure and sandy clayey loam texture (sand = 55.2%, powder = 23.0%, clay = 21.8%).

IV > 115 cm: emergence of groundwater.

Figure 3 – 4. Profiles of soil at the sites BUK (left) and KLISA (right)

Physical properties of soil

The stability of structural aggregates in the depth of the profile was very good, good to unstable. Mechanical composition in the surface layer was lighter– sandy loams, and heavier in deeper layers – sandy clayey loams. The soils were porous (KLISA: 51.48 ± 0.42; BUK: 47.51 ± 0.91), with medium soil water (KLISA: 42.36± 0.70; BUK: 38.72 ± 0.52) and moderate soil air capacities (KLISA: 9.14 ± 0.44; BUK: 8.57 ± 1.01).

Chemical properties of average samples of soil 0-20 cm

In average samples the reactions of pH values of BUK and KLISA ranged from slightly to very alkaline with an upward trend with the profile depth. The contents of P_2O_5, K_2O and humus were low and deteriorated rapidly with the depth. Total content of $CaCO_3$ was high with a tendency of increase with the profile depth. Mean values of measured electro-conductivity of the soil were not indicative of soil salinity at the profile. Results of the observed chemical parameters in samples (0-20 cm) are shown in Table 1.

Table 1. The chemical properties in average samples (Σn = 3)

Parameters		$X_{mv} \pm X_{se}$	min	max	V	σ
pH in H_2O	BUK	8.27 ± 0,03	8.14	8.35	0.01	0.07
	KLISA	8.35 ± 0,04	8.20	8.47	0.01	0.09
pH in KCl	BUK	7.43 ± 0,02	7.35	7.51	0.00	0.05
	KLISA	7.46 ± 0,01	7.42	7.50	0.00	0.02
K_20 (mg/100g tla)	BUK	9.83 ± 1,41	6.20	14.50	12.05	3.47
	KLISA	7.25 ± 0,28	6.50	8.20	0.46	0.68
P_2O_5 (mg/100g tla)	BUK	4.82 ± 0,41	3.76	6.03	1.10	1.00
	KLISA	5.63 ± 0,20	5.00	6.34	0.24	0.49
Humus (%)	BUK	2.33 ± 0,29	1.64	3.04	0.50	0.71
	KLISA	1.54 ± 0,01	1.53	1.57	0.00	0.01
$CaCO_3$ (%)	BUK	62.79 ± 0,77	60.84	65.97	3.58	1.89
	KLISA	33.35 ± 0,49	31.52	35.18	1.44	1.20

Designation: „BUK" – natural meadow, „KLISA" – artificial meadow, n – number of samples, X_{mv} – mean value, X_{se} – statistical error, min – minimal value, max – maximum value, V – variance, σ – deviation

Distribution of the total contents of Cd, Ni and As in average samples

In average samples at the sites of BUK and KLISA (0-10 and 0-20 cm), a significant difference ($p \leq 0.05$) in the total content of Cd, Ni and As was established (Table 2).

Table 2. Distribution of the total contents of Cd, Ni and As in average samples

Observed		$X_{mv} \pm X_{se}$	min	max	V	Σ	χ^2	p
Depth0 – 10 cm (Σn = 3)								
Cd (mg/kg)	BUK	0.70± 0.01	0.69	0.71	0.00	0.01		
	KLISA	0.94 ± 0.00	0.94	0.95	0.00	0.01	3.95	p ≤ 0.05
Ni (mg/kg)	BUK	39.54 ± 0.01	39.52	39.55	0.00	0.01		
	KLISA	36.01 ± 0.02	35.99	36.05	0.00	0.03	3.97	p ≤ 0.05
As (mg/kg)	BUK	4.40 ± 0.01	4.39	4.42	0.00	0.01		
	KLISA	5.89 ± 0.00	5.89	5.90	0.00	0.01	3.97	p ≤ 0.05

Observed		$X_{mv} \pm X_{se}$	min	max	V	Σ	χ^2	p
Depth 0 – 20 cm (Σn = 3)								
Cd (mg/kg)	BUK	0.52 ± 0.07	0.33	0.71	0.03	0.18		
	KLISA	0.95 ± 0.00	0.94	0.96	0.00	0.01	3.95	$p \leq 0.05$
Ni (mg/kg)	BUK	34.87 ± 1.90	30.20	39.55	26.13	5.11		
	KLISA	39.33 ± 1.35	35.99	42.66	13.22	3.63	2.09	$p \leq 0.05$
As (mg/kg)	BUK	4.30 ± 0.04	4.20	4.42	0.01	0.11		
	KLISA	6.15 ± 0.11	5.89	6.41	0.07	0.27	8.48	$p \leq 0.05$

Designation: „BUK“ – natural meadow, „KLISA“ – artificial meadow, n – number of samples, X_{mv} – mean value, X_{se} – statistical error, min – minimal value, max – maximum value, V – variance, σ – deviation, χ^2 – Kruskal – Wallis coefficient; p – level of significance

In the average samples at the sites of BUK and KLISA (0-10 cm), total mean contents of Cd and As were lower than the permitted levels of MRL-OF and MRL (Cd_{BUK} = 0.70 mg/kg; Cd_{KLISA} = 0.94 mg/kg; As_{BUK} = 4.40 mg/kg; As_{KLISA} = 5.89 mg/kg), while the content of Ni was bordered MRL and exceeded MRL-OF (Ni_{BUK} = 39.54 mg/kg; Ni_{KLISA} = 36.01 mg/kg). In the samples from the site of BUK (0-20 cm), total mean contents of Cd and As were below the level of MRL-OF and MRL (Cd_{BUK} = 0.52 mg/kg; As_{BUK} = 4.30 mg/kg), while Ni had a tendency of slight decrease compared to the average samples 0-10 cm (Ni_{BUK} 39.54 to 34.87 mg/kg). In the samples from the site of KLISA (0-20 cm), total content of Cd remained the same (0.95 mg/kg) while the contents of Ni and As were slightly increased compared to the average samples 0-10 cm (Ni_{KLISA} 36.01 to 39.33 mg/kg; As_{KLISA} 5.89 to 6.15 mg/kg). Given that these alluvial plains were formed by deposition of allochthonous matter from the surrounding areas and affected by frequent, it is generally difficult to define a single tendency of increase or decrease of total content of Cd, Ni and As in the analyzed average samples (Figure 5 – 7).

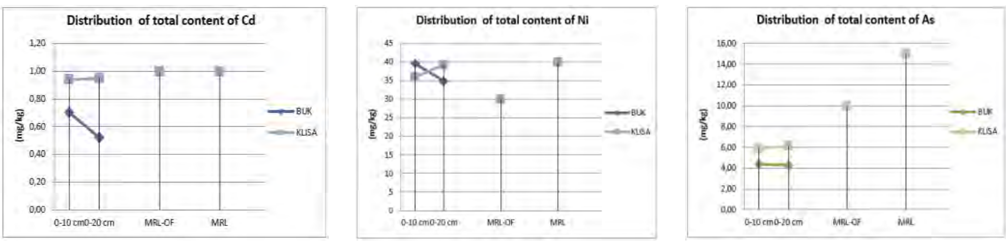

Figure 5 – 7. Distribution of the total content of Cd, Ni and As in average samples

Distribution of the total content of Cd, Ni and As in the soil profiles

Results of the analysed profiles at BUK and KLISA sites of different use (natural and artificial meadow) have shown significant differences ($p \leq 0.05$) in concentrations of Ni and As, and no differences ($p > 0.05$) in Cd (Table 5).

Table 5. Distribution of the total content of Cd, Ni i As in the soil profiles

Observed ($\Sigma n_{BUK-KLISA} = 18$)		$X_{sr} \pm X_{sg}$	min	max	V	σ	χ^2	p
Cd (mg/kg)	BUK	0.32 ± 0.13	<0.01	0.96	0.17	0.41	0.88	p > 0.05
	KLISA	0.41 ± 0.08	0.17	0.74	0.05	0.24		
Ni (mg/kg)	BUK	48.87 ± 1.00	44.86	51.12	9.02	3.00	7.76	p ≤ 0.05
	KLISA	41.16 ± 1.99	34.60	48.44	35.99	5.99		
As (mg/kg)	BUK	4.94 ± 0.14	4.38	5.40	0.18	0.43	3.96	p ≤ 0.05
	KLISA	5.41 ± 0.19	4.69	6.10	0.34	0.58		

Designation: „BUK" – natural meadow; „KLISA" – artificial meadow, n – number of samples, X_{mv} – mean value, X_{se} – statistical error, min – minimal value, max – maximum value, V – variance, σ – deviation, χ^2 – Kruskal – Wallis coefficient; p – level of significance

In the studied profiles at the sites of BUK and KLISA, the total mean contents had a downward trend (Cd_{BUK} 0.96 to < 0.01 mg/kg, Cd_{KLISA} 0.74 to 0.17 mg/kg, Ni_{BUK} 51.12 to 44.86 mg/kg, Ni_{KLISA} 48.44 to 34.60 mg/kg, As_{BUK} 5.40 to 4.38 mg/kg, As_{KLISA} 6.10 to 4.69 mg/kg). In both profiles of the alluvial soil of different use a single tendency of decline of total contents with the increase in depth, i.e. from the surface to the bottom of the profile, was observed in all three analysed elements (Figure 8 – 10).

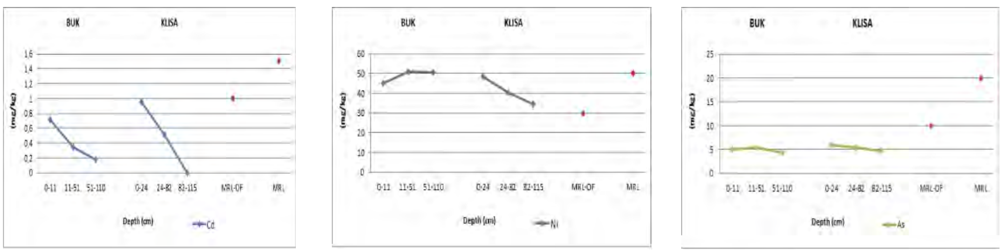

Figure 8 – 10. Distribution of the total content of Cd, Ni and As in soil profiles

CONCLUSIONS

At the sites of BUK and KLISA, according to the physical and chemical parameters of soil, stability of structural aggregates declines from very good to unstable; mechanical composition of the soil in the surface layer – sandy loams, and in the deeper ones – sandy clay loam. The soils are porous and with medium water and moderate air capacity. In the average samples at the sites (0-10 cm and 0-20 cm), total mean contents of Cd and As were lower than the permitted levels of MRL-OF and MRL ($Cd_{BUK} = 0.70$ mg/kg; $Cd_{KLISA} = 0.94$ mg/kg; $As_{BUK} = 4.40$ mg/kg; $As_{KLISA} = 5.89$ mg/kg), while the content of Ni was bordered MRL and exceeded MRL-OF ($Ni_{KLISA} = 36.01$ mg/kg; $Ni_{BUK} = 39.54$ mg/kg). In general, the pH levels established at the sites of BUK and KLISA ranged from slightly to very alkaline with an upward trend with the profile depth ($pH_{BUK\ in\ H20}$ 8.09 to 8.45; $pH_{BUK\ in\ KCl}$ 8.18 to 8.52; $pH_{KLISA\ in\ H20}$ 7.35 to 7.56; $pH_{KLISA\ in\ KCl}$ 7.42 to 7.60). In the surface layer, contents of P_20_5, K_20 and humus were low and decreased with the depth of soil. The content of calcium carbonate was high with a tendency to increase with depth ($CaC0_{3BUK}$ 31.52 to 65.97%; $CaC0_{3KLISA}$ 20.52 to 41.78%). The measured levels of soil electrical conductivity were not indicative of the soil salinity. In the distribution of Cd, Ni and As in the average samples taken from the sites of BUK and KLISA a significant difference ($p \leq 0.05$) was established in the total content of Cd, Ni and As. Generally, in average samples it was difficult to define a single tendency of distribution (increase or decrease) of the total content of Cd, Ni and As. In the profiles at the sites (BUK and KLISA), significant differences ($p \leq 0.05$) were determined in the total content of Ni and As, and no significant difference ($p>0.05$) for Cd. Generally, for the sites of BUK and KLISA it was established that the distribution of the content of Cd, Ni and AS in the profiles decreased in relation to the depth (Cd_{BUK} 0.96 to < 0.01 mg/kg; Cd_{KLISA} 0.74 to 0.17 mg/kg; Ni_{BUK} 51.12 to 44.86 mg/kg; Ni_{KLISA} 48.44 to 34.60 mg/kg; As_{BUK} 5.40 to 4.38 mg/kg; As_{KLISA} 6.10 to 4.69 mg/kg).

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CHANGES IN LAND COVER AND LAND USE IN THE KARST AREA OF BOSNIA AND HERZEGOVINA

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ABSTRACT

Natural characteristics of karst areas (lack of water on the surface, scarce soil and vegetation) are rather specific and because of them they are often viewed as unsuitable for human habitation. They are often described as inhospitable and passive areas, and Aley (1992) states that karst areas in America are correlated with areas of rural poverty. A large part of Bosnia and Herzegovina consists of karst areas (karst land extending northwest-southeast) which on average are quite sparsely populated. The scarcity of nature, and especially of soil functions in terms of agriculture, as well as the previous period of industrial development caused depopulation which became particularly apparent after the recent war. This contributed to the fact that in some karst areas population has been drastically reduced, in some places by more than 60%, which affects the condition of land cover and land use as well as change in functions of soil in the ecosystem.

Given the fact that the soil formation process on karst terrain is very slow (these are mainly shallow and skeletal soils) and in view of the importance of soil and its multi-functionality, this paper is aimed at analyzing the extent and nature of changes which occurred in land cover and in land use in this part of BiH, namely at analyzing the causes and effects. In order to be able to make such analysis, we used land cover databases, aerial photographs as well as orthophoto maps of the terrain.

Keywords: *land cover, land use, karst area, Bosnia and Herzegovina*

INTRODUCTION

According to FAO (URL), land cover (LC) is "the observed (bio) physical cover on the earth's surface." In the narrow sense includes vegetation and anthropogenic forms, while in a broader sense includes bare soil and water surfaces. At the same time, land

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use (LU) "is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it." Changes in land cover and land use are a reflection of the interaction between society and the environment and are particularly pronounced when economic and social systems are changing (Cvitanović, 2014).

Karst areas are specific for their natural characteristics, primarily scarcity of water, vegetation and soil. In such conditions adaptation of man is difficult. It is the level of man's adaptation to the specific natural features of karst that development of these areas is dependent on. Information on the type of land cover, extent of change and the purpose it is used for can be used for the assessment of sustainability, vulnerability and resilience of the land system (Han *et al*., 2004), which is particularly important in sensitive natural systems such as karst.

Bosnia and Herzegovina has undergone - and is still undergoing – significant social change and effects on space are enormous. This being said, the objective of the paper is to analyze the way and extent to which social processes influenced changes in land cover and land use in the isolated karst areas.

MATERIAL AND METHODS

In Bosnia and Herzegovina, the karst region extending from the northwest to the southeast has two distinctive areas – the predominantly mountainous part (belt of high karst) and the area of low Herzegovina (karst plateaus and the valley of the Neretva river and its tributaries). The low-Herzegovina area is more densely populated due to more favorable natural conditions (fertile soil, mild climate, water) as well as to better road connections which enabled a better economic development. The area of high karst has always been sparsely populated. Major settlements are situated mostly around the karst fields that represent oases of life. The population was traditionally involved in livestock farming and growing crops suited to harsh climate conditions. Today, particularly in the highest parts, the population is drastically reduced.

For the purpose of this study, selected were three municipalities in which the analysis of change in land cover/land use was made: Glamoč, Široki Brijeg and Gacko. Selected municipalities are located in geographically different areas and undergoing different social changes.

Analysis of changes in land use/land cover was carried out according to the CORINE Land Cover data for BiH.

RESULTS AND DISCUSSION

Total change in LU/LC in karst areas (high karst and low-Herzegovina) in the period 2000-2012 amounts to 23,595.23 hectares (Figure 1) of which more than 19,500 hectares are related to changes that occurred in the period 2000-2006. In the area of high karst, changes are recorded on an area of 14,867.6 hectares, and in low-Herzegovina on an area of 8,727.64 hectares (Figure 1).

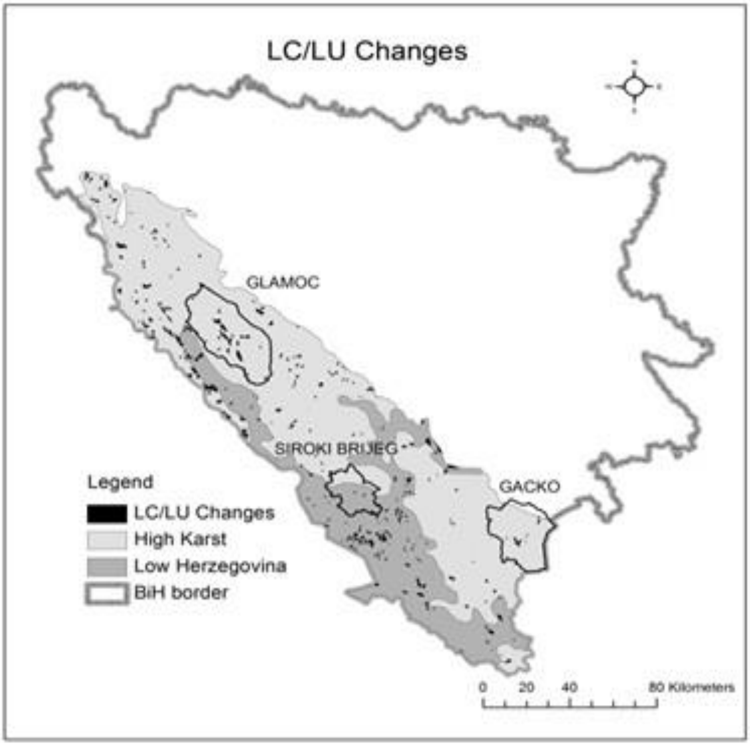

Figure 1. Changes in LC/LU in karst area (2000-2012)

The biggest changes are related to forest vegetation and account for 76% (17,967.58 hectares) of recorded changes in LU/LC in karst (Table 1). The analysis of change in the category of forest vegetation and other natural areas shows that a smaller part of the total change pertains to the transition to artificial (5.7%) or agricultural areas (2.2%). Changes within categories account for a total of 16,538.22 hectares or 92%, of which 69.7% are areas affected by the fires. Most of these changes are related to the area of high karst (11,495.68 hectares).

Total changes in the category of agricultural areas in the period 2000-2012 amount to 5,168.10 hectares or 21.9% of the total change in LU/LC in karst areas (Table 1). 66.5% of changes occurred within the category (transition to the groups of arable land parcels, non-irrigated fields and to some smaller extent to vineyards and orchards), 19.6% or 1,014.25 hectares in artificial surfaces and 12.8% or 662.13 hectares in succession of forest vegetation and natural grassland. The loss of agricultural areas in favor of artificial surfaces and the category of forest vegetation and natural grassland is slightly higher in low-Herzegovina (totaling 963.47 ha).

In the period 2000-2012, the category of artificial surfaces increased by 2,032.31 hectares, mostly in urban areas, construction sites and mineral resources exploitation sites. The expansion of artificial surfaces largely occurred at the expense of the loss of agricultural areas (loss of 1,014.25 ha).

Table 1. Changes in LC/LU (ha) in karst areas of BiH (2000-2012)

		LC/LU changes (ha)		
		2000-2006	**2006-2012**	**2000-2012**
Low Herzegovina	Artificial surfaces	286.24	0.00	286.24
	Agricultural areas	1649.15	320.36	1969.51
	Forests and semi-natural areas	4314.54	2157.33	6471.87
	Total	**6249.95**	**2477.69**	**8727.64**
High Karst	Artificial surfaces	42.81	90.88	133.69
	Agricultural areas	2893.92	304.67	3198.59
	Forests and semi-natural areas	10431.46	1064.22	11495.68
	Wetlands	8.85	0.00	8.85
	Water bodies	30.79	0.00	30.79
	Total	**13407.83**	**1459.77**	**14867.60**
Karst	Artificial surfaces	329.05	90.88	419.93
	Agricultural areas	4543.07	625.03	5168.10
	Forests and semi-natural areas	14746.00	3221.55	17967.55
	Wetlands	8.85	0.00	8.85
	Water bodies	30.79	0.00	30.79
	Total	**19657.77**	**3937.46**	**23595.23**

Most of the changes in LU/LC are those in the category of forest which was expected given the sparsely populated area, especially in the high karst belt. Although this area has always been sparsely populated, the process of depopulation the ageing of the population started 50 years ago as a result of social change. According to Čustović *et al*. (2013), changes in the demographic structure and the abandonment of rural areas have the following effects: the loss of biodiversity, degradation of ecosystem as a whole and the destruction of natural and cultural heritage.

The analysis of the three selected municipalities (Glamoč, Široki Brijeg and Gacko) was intended to determine the differences in changes in LU/LC with respect to different geographic location and demographic characteristics. Of the three studied municipalities, only Široki Brijeg recorded an increase in population, both in the pre-war and post-war period (Table 2). Unlike it, the municipalities of Glamoč and Gacko record a continuous population decline, where the decline in the municipality of Glamoč amounted to 67% in the period 1991-2013. Changes in population before 1991 are definitely related to the geographic location (mountainous area of high karst and more favorable climate and better road connections in low-Herzegovina) and socio-economic changes that occurred at that time (industrialization, deruralization, depopulation), but those after 1991 were significantly influenced by the war activities in BiH. The geographic location and demographic trends are directly related to the economic activities of the observed area as evidenced by the fact that Široki Brijeg municipality has significantly better economic indicators compared to the other two municipalities.

Table 2. Population of the municipalities of Glamoč, Široki Brijeg and Gacko in 1961, 1991 and 2013

Municipality	Area (km^2)	Population			Change in population 1961-1991 (%)	Change in population 1991-2013 (%)
		1961	1991	2013		
Glamoč	1096	17250	12593	4038	-27,0	-67,9
Široki Brijeg	388	24732	27160	29809	+9,8	+9,8
Gacko	736	14033	10788	9734	-23,1	-9,8

The biggest changes in LU/LC in the 12-year period were recorded in the municipality of Glamoč, totaling 2,846.38 hectares. Changes occurred in the categories of agricultural and forest areas, mainly within the categories. In the municipality of Gacko, changes were recorded on an area of 504.17 hectares, while smallest change was recorded in the municipality of Široki Brijeg (271.87 ha of which 225 ha in the category of forest vegetation and other natural surfaces). In both municipalities, the majority of changes occurred in the categories of agricultural and forest areas. The analysis indicates that changes in LU/LC affected about 2.6% of the territory of the municipality Glamoč, and about 0.7% of the territory of the municipalities Gacko and Široki Brijeg.

Recognizing that the population is one of the main factors of changes in space, the question is why are those the smallest in the municipality of Široki Brijeg, despite an increase in population and substantial economic activity? The fact is that most of the population and economic activities are related to the area of Široki Brijeg, therefore the biggest changes, i.e. most of them, occurred there before 2000, which is the reference year for CORINE. Changes are clearly visible on the maps in Figure 2.

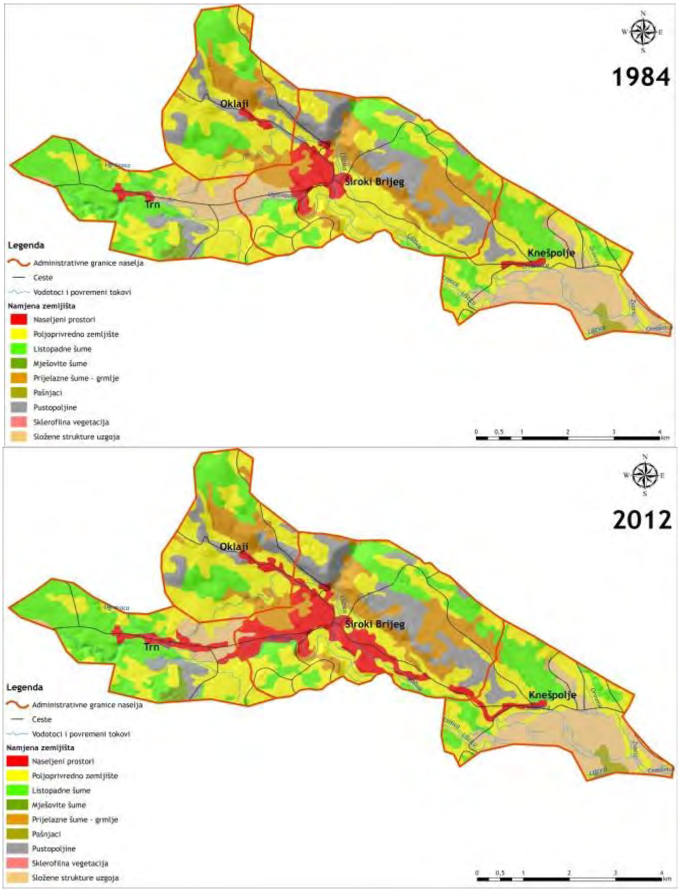

Figure 2. Changes in LU/LC in the wider area of Široki Brijeg (1984-2012)

CONCLUSIONS

Karst area, due to its natural features, has always been sparsely populated. Further depopulation was boosted by socio-economic changes both in the pre-war and post-war period. Natural and demographic characteristics of this area proved to be crucial for changes in land use/land cover. The most significant changes in building artificial surfaces took place before 2000, so that the biggest changes in LU/LC were recorded in the category of forest and other natural surfaces – they account for 76% of total recorded changes. Particularly pronounced here is the effect of forest fires to which poorly accessible mountainous areas of high karst are exposed (the areas affected by fire account for 70% changes in the category of forest). Karst as a whole, but mountainous areas of karst in particular, due to steep inclination, shallow soil and climate characteristics, is naturally susceptible to erosion. The fire affected areas are additionally exposed to this type of soil degradation.

Lengthy process of depopulation and aging population of the karst areas associated with processes of deruralization and urbanization accelerate the trend of land abandonment and neglect in general. Particular attention should be paid to the conversion of agricultural land into artificial surfaces which, in the above stated circumstances, has been simplified.

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THE EFFECT OF SOIL SELENIUM FERTILIZATION TREATMENT ON THE CONTENT OF SOME IONS (Cd, Fe, Zn and Se) AND YIELD OF TWO CORN HYBRIDS

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ABSTRACT

The concentration and form of some metals and metalloids in soil is governed by many chemical and physical properties of soil as pH, redox, Fe, Al ions and soil composition. The paper studied presents influence of chemical soil properties, environment conditions and selenium fertilization rate applied on ions status of zinc, cadmium, selenium and iron in soil and plant material, as well as specific adsorption of these ions in two different maize hybrids. The study was conducted at the farm Vita-Vi Višići (Čapljina). The experiment design was a completely randomized design with two hybrids, four different fertilization treatments in four replications. The experimental area was implemented standard agricultural management practices of preparation, tillage, fertilization, application of protective agents. Hybrid NP Pako is selected in order to achieve a high yield, and M34 hybrid for quality yield. The test results and statistical analysis revealed no significant difference in the yield of hybrids combined with different fertilization treatments. Accumulation of selenium, zinc, cadmium and iron in upper ground plant part of maize was not affected by fertilization treatments or selected hybrid. The highest yield was achieved by hybrid M34 Pioneer of 37.6 t $ha^{-1}$and the highest yield was obtained in application of third fertilization treatment 20 kg $NaSeO_4ha^{-1}$, but without statistically significant differences comparing to other hybrid or applied treatments. The highest content of selenium in the plant was found in hybrid NP PAKO 0.06 mg Se kg^{-1} of dry matter of maize applying the fourth liquid fertilization treatment (20 kg $Na_2SeO_4ha^{-1}$) but also without statistically significant difference comparing to other hybrid or fertilization treatment. Content of zinc, cadmium and iron in soil or plant material had not shown significant differences due to the applied fertilization or used maize hybrids, but some fluctuations were observed. Selenium

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fertilization did not have a limiting effect on the formation of the yield and tested elements, but its mobility and availability in soil and plant depends also on other factors as soil properties and climatic conditions of growing season.

Keywords: *selenium fertilization, maize hybrid, metals, metalloids, soil properties*

INTRODUCTION

In the past decades, European crop production including the southeastern European (SEE) countries has largely focused on securing food and feed production and maximizing yield in terms of biomass production per hectare. To meet the growing food demand due to ever increasing population, food policy was focused toward the consumption of food rich in calories and proteins. The consumption of food rich in micronutrients (minerals, vitamins, secondary metabolites) hasn't increased proportionally. Today 40% of the world population suffers from micronutrient deficiencies. Also on other hand soil pollution by heavy metals has become a critical environmental concern due to its potential adverse ecological effects.

Trace elements (TE) contents in soils can be locally rather high and are still increasing owing to many human activities, resulting in risk to human health and the environment. The total metal load on agricultural soils is the sum of metal input from atmospheric deposition, and input from the addition of fertilizers (mainly phosphate fertilizers), metal-containing pesticides, biosolids (for example sewage sludge, industrial wastes), emissions and wastewater (Adriano, 2001; Kabata-Pendias and Pendias, 1992). On the other hand, (TE) deficiency in plants has been found in regions of SEE countries. For example Zn and Fe deficiency in eastern part of Croatia (Jug *et al*., 2008), Cu deficiency in pasture and blood of sheep at Niksici Plateau (B&H) (Muratović *et al*., 2005), and selenium (Se) deficiency in almost whole SEE region (Maksimovic *et al*., 1992; Antunović *et al*., 2005; Muratović *et al*., 2007) have been observed. The soil-plant barrier limits transmission of many trace elements through the food chain, although Cd (an important human health concern) can bypass the soil-plant barrier. Results from many studies that support these key concepts provide a basis of our understanding of the relationship between trace element chemistry and soil chemical properties.

The paper objective was to enhance the bioavailability trace elements in soils and check the uptake level of Fe, Zn, Se and Cd in upper ground parts of maize to provide solutions for increasing their content by 2 to 3- fold in fodder crops.

MATERIAL AND METHODS

Experimental Site

Field trials experiments with different fertilization treatments of maize were set on Farm Vita VI, Višići, Čapljina. Two types of silage maize hybrids were selected according to the duration of vegetation stages one from FAO group 490 and other FAO group 380, NP Pako Singenta and M34 Pioneer. During vegetation season 2012 trials was set up on the experimental area of 1120 m^2 using a complete randomized block design statistical model. The experiment included three fertilization treatments and control treatments in four replications. The basic plot size was 20 m^2. On base of the soil analysis it was recommended to apply basic fertilization of 140 kg N ha^{-1}, 70 kg $P_2O_5ha^{-1}$ and 130 kg K_2O ha^{-1}. Basic NPK fertilization was same for all treatments and other treatments included control, 10 kg Na_2SeO_4 ha^{-1}; 20 kg Na_2SeO_4 ha^{-1} (these treatments were incorporated in soil in spring) and fourth treatment 20 kg $Na_2SeO_4ha^{-1}$ (liquid soil application in the phase of intensive growth along with additional nitrogen fertilizers).

Sample collection and chemical analysis

After the harvest of five randomly selected maize hybrids per plot in middle rows the whole plant material was weight, chopped, dried and prepared for chemical analyses. The plant material samples were analyzed after microwave digestion using 9 mL 65% (v/v) HNO_3 and 2 mL 30% (v/v) H_2O_2 (Kingstone and Jassie, 1986). Concentration of trace element Se was determined by inductively coupled plasma IICP), optical emission spectrometry (OES) technique.

Four average soil samples were collected from experimental site. The soil samples were prepared for analyses by drying and milling and basic chemical analyses were done: soil pH_{H2O} and pH_{KCl} (ISO 10390), soil organic matter by sulfochromic oxidation (ISO 14235), plant available phosphorus and potassium extracted by ammonium-lactate (Egner *et al*., 1960). Determination of trace elements selenium was extracted by aqua regia (ISO 11466) and the fraction extracted by aqua regia was considered as soil total content. Trace elements concentrations were determined using a Perkin Elmer Optima 5300 DV Inductively Coupled Plasma Optic Emission Spectrometer (ICP-OES).

Weather conditions on experimental sites

During vegetation seasons weather conditions were observed (average precipitation and average air-temperature) and are shown in Table 1.

Table 1. Weather condition on experimental site in trail with bio fortification of silage maize by selenium

Year		May	June	July	August	September	Total (L/m^2)	Mean (°C)
Višići (Mostar), B&H								
2012	**Pecip. L/m^2**	96.1	28.3	1.8	0.4	151.8	278.4	
	Max. °C	30.5	37	39	41	35.5		36.6
	Min.°C	7.2	12	16.5	13.5	6.5		11.1
	Humidity (%)	74	69	49	49	62		60.7

Data for summer of 2012 show extremely dry weather, with 0.4 l/m^2 of precipitation in August and it had affected on lower yields of green matter. Average minimal and maximal temperatures for maize growing period from May to September varied from 11.1°C till 36.6°C. Relative humidity for this five month of maize growth has also varied from 74 to 49%.

Data analysis

Data used for this paper work arise for selenium fertilization of maize and reflection on absorption on selenium, iron, zinc and cadmium and the aim of the research was primarily to provide a practical and basic knowledge of agronomic technologies and physiology of selenium and other metals in maize plant. The main investigation was to evaluate the bioavailability of selenium, content of trace element in maize plant and yield, as this could be reflected on the health and productivity of people and animals.

Obtained values were analyzed by ANOVA for find the differences in total selenium content, iron, zinc, cadmium in plant material for two types of maize hybrids fertilized with increasing rates of selenium fertilizer. For statistical data processing the GenStat 7 software (Laws Agricultural Trust, Rothamsted Experimental Station) was used.

RESULTS

Results of the analysis of agrochemical properties of soil from the site Višići indicate mild acid (in 1M KCl) to neutral (in H_2O) soil reaction, good humus which is moderate supplied with phosphorus and potassium (Table 2).

Table 2. The basic agrochemical soil properties on experimental locations

Location name Farm Višići	Soil sampling depth	pH		Humus (%)	Potassium mg K_2O/100 g	Phosphorus mg P_2O_5/100 g
		H_20	KCl			
1	0-30	6.56	5.69	3.95	32.2	16.9
2	0-30	6.84	5.91	3.65	31.6	14.3
3	0-30	6.49	5.34	3.08	18.1	13.7
4	0-30	6.36	5.19	3.52	28.5	16.2

Soil selenium content varied from 0.6047-0.9854 mg per kg of soil at our experimental site while Fe soil content varied from 28320-31800 mg per kg of soil. Cadmium content has varied 0.6130-0.6634 mg per kg of soil and zinc content varied form 89.89-103.40 mg per kg of soil (Table 3).

Table 3. Trace element analysis of soil samples on experimental site

Location name Farm Višići	Soil sampling depth	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Cd (mg kg^{-1})	Se (mg kg^{-1})
1	0-30	30980	99.76	0.6284	0.8879
2	0-30	28320	89.89	0.6130	0.9854
3	0-30	31380	99.41	0.6634	0.6471
4	0-30	31800	103.40	0.6556	0.6047

Soil type on experimental site is Fluvisol at elevation of 0 m. Fluvisols are found typically on level topography that is flooded periodically by surface waters or rising groundwater, as in river flood plains and deltas and in coastal lowlands. These soils exhibit a stratified profile that reflects their depositional history or an irregular layering of humus and mineral sediments in which the content of organic carbon decreases with depth.

According to the presented results in Table 4 there no differences between the fertilization treatments for tested elements iron, cadmium, zinc, selenium and yield. These results means that applied selenium fertilizers in different doses has not provide differences in result of measured parameters. Even without significant differences yield was highest by application of soil selenium doses 10 kg and 20 kg Na_2SeO_4 ha^{-1} while control was lowest. Cadmium, iron and zinc content variation has not been in relation to applied fertilization but selenium in plant material has shown slight increments as selenium treatment has increased.

Table 4. Difference in obtain average values for some elements and yield regarding the applied four fertilization treatments for the vegetation season 2012 for two type of maize hybrid

Variants	Control	10 kg Na_2SeO_4 ha^{-1}	20 kg Na_2SeO_4 ha^{-1}	20 kg Na_2SeO_4 ha^{-1} liquid applic.+additional fert.	LSD=0.05
Cd mg kg^{-1}	0.0539	0.0548	0.0535	0.0431	0.02
Fe mg kg^{-1}	81.1	84.6	68.4	74.9	15.35
Zn mg kg^{-1}	54.1	62.6	57.7	59.2	12.94
Se mg kg^{-1}	0.0467	0.0516	0.0502	0.0602	0.01
Yield t ha^{-1}	29.3	37.2	37.6	35.6	4.01
Significance	NS	NS	NS	NS	

NS-no significant differences between fertilization treatments

As the there is no significant differences for fertilization treatments for tested parameters two type of maize hybrids had also showed no difference for the same traits. Without significant differences the M 34 Pioneer cultivar has shown 15% higher yield than cultivar NP PAKO Syngenta. For named trace elements slight increment was visible for cultivar NP PAKO Syngenta comparing to M34 Pioneer (Table 5).

Table 5. Difference in obtain average values for some elements and yield regarding the selected maize hybrids for the vegetation season 2012

Variants	Yield t ha^{-1}	Cd mg kg^{-1}	Fe mg kg^{-1}	Zn mg kg^{-1}	Se mg kg^{-1}	Significance
M34	37.6	0.0509	74.6	56.2	0.0499	NS
NP PAKO	32.2	0.0517	79.9	60.6	0.0545	NS
LSD=0.05	8.33	0.01	10.85	9.15	0.008	

NS-no significant differences between fertilization treatment

Regarding the correlation between trace elements and yield some positive relation has been found (Table 6). This means that increment one of trait is strongly or medium followed by other measured traits or that correlation is not found. Iron had strong positive correlation with cadmium and zinc and moderate correlation with selenium and yield. Cadmium had strong positive correlation with iron and zinc, modern positive correlation with selenium and no correlation with yield. Zinc had strong positive correlation with iron and selenium, and moderate correlation with cadmium but no correlation with yield. Selenium has also positive affected trace elements included in trial, but no correlation has been found with yield.

Table 6. Correlation coefficients between tested traits

	Cd mg kg^{-1}	Zn mg kg^{-1}	Se mg kg^{-1}	Yield t ha^{-1} FW
Fe mg kg^{-1}	0.51**	0.52**	0.35*	0.35*
Cd mg kg^{-1}		0.36*	0.22*	-0.06^{ns}
Zn mg kg^{-1}			0.50**	-0.11^{ns}
Se mg kg^{-1}				-0.002^{ns}

** Strong to very strong correlation; *weak to medium weak correlation; ns-no correlation

DISCUSSION

Balanced nutrition of the plants is one of the main factors that affect the yield and quality of the plants. Significant impact of applied selenium fertilization on tested trace element and yield has not been found but some correlation relation between elements explains connection between them in combinations with chemical component of experimental soil and weather condition. According to Chaney (1988) the climate strongly influences soil types; these two factors largely control element (metals and metalloids) mobility and availability. Heavy metals and metalloids can be involved in a series of complex chemical and biological interactions. The most important factors which affect their mobility are pH, sorbent nature, presence and concentration of organic and inorganic ligands, including humic and fulvic acids, root exudates and nutrients (Violante *et al*., 2010). Accumulation of metal ions and metalloids in different compartments of the biosphere, and their possible mobilization under environmentally changing conditions induce a perturbation of both the structure and function of the ecosystem and might cause adverse health effects to biota (Fedotov and Mirò, 2008). Anthropogenic processes include inputs of heavy metals through use of fertilizers, organic manures, and industrial and municipal wastes, irrigation, and wet and/or dry deposits. These processes contribute with variable amounts of heavy metals to the agro-ecosystem (Violante *et al*., 2010).

In alkaline, well-drained soils, selenium tends to form selenates (Se^{+6}) which are highly available to plants and may sometimes lead to their accumulation at toxic levels. Although soil reaction plays a major role in determining Se solubility and availability, its influence lessens as the contents of clay and organic matter in the soil increase. Regarding the high content organic matter and clay soil particulates on our experimental site could affect the solubility and availability of selenium and its interaction with other TE's elements. But in acid and more poorly-drained soils, a ferric iron-selenite complex may form, which is only slightly available to plants (Gustafsson and Johnsson, 1992). Acid pH soil reaction on experimental site and moderate content of iron in soil could provide forming the iron-selenite complex or the low effect of fertilization on selenium content in soil and plant material could be provided by very low applied fertilization amount of Na_2SeO_4 per basic plot.

Although most soils contain adequate total iron, amounts that are available to plants might be inadequate dependent in various soil factors such as very high or low soil temperature, high humidity, poor soil aeration and compaction, high pH, HCO_3^- and $CaCO_3$ contents. Beside the bad physical properties of the soil Fe chlorosis is also related with PO_4^- and NO_3^- anions and other heavy metal concentrations such as Zn, Cd, Mn, Co, Cu and Ni (Basar, 2000; Lucena, 2000).The typical iron concentrations in soils range from 0.2% to 55% (20.000 to 550.000 mg kg^{-1}) (Bodek *et al*,. 1988) and concentrations can vary significantly even within localized areas due to soil types and the presence of other sources. According to our results variation of iron content at experimental site around 0.3% was moderate. Iron can occur in either the divalent (ferrous or Fe^{+2}) or trivalent (ferric or Fe^{+3}) states under typical environmental conditions. Iron is absorbed by plants as the ferrous ion (Fe^{+2}) which is necessary for the formation of chlorophyll and functions in some of the enzymes of the plant's respiratory system (Schneider *et al*., 1968).

Soil pH reaction, aeration and organic matter affect iron availability. The concentrations of iron in soil solution decrease sharply as the soil pH increase with minimum around pH 7.4-8.5. Poor soil aeration caused by flooding or compaction can increase or decrease iron availability depending on other soil conditions (Schulte, 2004). According to the same author the reduction in fixation and precipitation results in higher concentration of iron remaining in the soil solution available for root absorption. Iron plant analysis interpretation for maize impute deficiency iron at <10 mg kg^{-1}; low content 10-50 mg kg^{-1} and sufficient from 51-250 mg kg^{-1}. If we look at iron soil content at experimental site the moderate supply had result in sufficient content of iron in maize plant material showing the values of 74.6-79.9 mg per kg. Regarding not only the iron soil content but also low pH values that favors sufficient uptake level of iron in plant material. The formation of solid organic matter reduces the mobile forms of iron and its absorption by plants (Kabata-Pendias and Pendias, 1992), even our soil were rich in organic matter, nitrogen and phosphorus and potassium content this was not limiting factor for iron availability to soil or plant. Iron is very abundant element in Earth's crust and exists mainly as ferric oxides and hydroxides in soil under aerobic conditions. On floated land with very high underground water and love altitude during the rainy years as was experimental year with maize Fe (III) oxides undergo reductive dissolution and Fe (II) concentration is increased in soil solution (Neubauer *et al*., 2007). The biogeochemical transformation of Fe is very important as it affects not only solubility and speciation of Fe, but also bioavailability and toxicity of other metal contaminants such as cadmium (Cd) in soil (Neubauer *et al*., 2007).

Regarding the Cd in soils available for plant uptake and subsequent human uptake presents in the environmental poses a significant health risk. Cadmium is nonessential heavy metal that does not have any metabolic use (Samantaray and Rout, 1997). Generally zinc application decrease Cd uptake and accumulation in plants (McLaughin *et al*., 1994). Cadmium is of great environmental concern because it is highly toxic to plants and animals and it is highly mobile in the terrestrial environment. Atmospheric input and the use of phosphate fertilizers are the major sources of Cd for total plant concentration of agricultural crops. Low-molecular-weight organic acids present in the rhizosphere soil influenced the solubilisation of particulate-bound Cd into soil solution and accumulation by plant (Cieslinski *et al*., 1998). According to the Pavlikova *et al.* (2007) the content of cadmium at luvisol had ranged 0.287±0.107 mg $kg^{-1}$and on chernozem 8.101±4.799 mg kg^{-1} for maize experiment planted in pot. Regarding the Cd content at fluvisol from experimental site soil content is very low around 0.6 mg kg^{-1} and also there was a low content in plant material of maize 0.05 mg per kg without difference in selected cultivars. In anoxic environments, nearly all particulate cadmium is complexed by insoluble organic matter or bound to sulfide minerals (Kersten, 1988). Cadmium concentrations in non-polluted soils increase with clay concentration, but are generally lower than 1 µg g^{-1} dry soil (Mengel *et al*., 2001). Cadmium is concentrated in the topsoil, where it is associated with organic matter.

Hart *et al*. (2002) obtained the competitive interaction between Cd and Zn for uptake to the existence of a common transport system on plasma membranes. The effects of zinc application on Cd uptake and accumulation in plant are not consistent. Hart *et al*., (2002) found in durum and bread wheat that decreases in Cd uptake by roots with increasing Zn treatment is possibly due to a competition between Zn and Cd for uptake. Cadmium toxicity in plants become more severe under Zn deficient condition and this effect was not related to increasing Cd concentration in plant (Adiloglu *et al*., 2005). It is important to mention that the zinc and iron are in antagonistic relations, and high level of iron in the soil reduces the absorption of other metals by plants (Goletić, 2005). Uptake of zinc by the plants can be inhibited by the high iron content in the plant (Kovačević *et al*., 2004). In general, Zn in soil could varied between 10-300 mg Zn kg^{-1} (Kiekens, 1995). However, total Zn in soil is not good enough indicator of amount of Zn readily to uptake by plants. Total concentrations of metals in soils are a poor indicator of metal toxicity since metals exist in different solid-phase forms that can vary greatly in terms of their bioavailability (Huang and Gobran, 2005).

CONCLUSIONS

Fertilization with different selenium rate has not affected the yield or the selected hybrid had significant differences in yield. Also, fertilization with different selenium rate has not provide significant effect on Fe, Zn, Cd and Se in plant material or the hybrids showed significant differences between them.

Some strong positive correlation has occurred between Fe vs. Cd; Fe vs. Zn; Fe vs. Se and some moderate positive correlations were between Cd vs. Zn; Cd vs. Se and Zn vs. Se indicating the relations between them.

TE's element reactivity and bioavailability depends not only on its total content in soil but also on its chemical form in soil. For further research speciation of TE in soli could provide better defining influence of soil condition on their reactivity and bioavailability and identify the species that are more available for plants and microorganisms.

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LAND CAPABILITY STUDY AND MAP IN FUNCTION OF LAND PROTECTION, SPATIAL PLANNING AND AGRO-ECOLOGICAL ZONING

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ABSTRACT

The main act to consider the value of land from the perspective of various sectors and their needs (urban planning, agriculture etc.) in the Federation of B&H is the Decree on unique methodology for preparation of the spatial planning documents (Official Gazette of the Federation of B&H, No. 63/04 and No. 50/07), which prescribes the obligation of making the Land capability study as a segment of spatial basis. Land capability study projects are being implemented by the Institute of Soil, Agro chemistry and Melioration (PAM) of the Faculty of Agricultural and Food Sciences University of Sarajevo. By using defined soil bonity categories, land capability study defines the natural potential of soils in terms of agricultural production and food production, and defines the zones for various land use types. From the rational land use point of view, it means adequate spatial planning, urban development and environmental protection. This paper aims to present the importance, characteristics as well as use of the Land capability study at the municipality level using municipalities of Tuzla Canton as example. Agricultural areas of on the territory of five municipalities in Tuzla Canton (Gradacac, Gracanica, Kalesija, Zivinice, Sapna) account for 44,356.1 ha or 42.6% of the total area. Represented in these areas are soil bonity categories that range from II to VII. The first four bonity categories that are determined exclusively as agricultural land account for 28,739.91 ha or 63.1% of the total area. Within this group, the most represented is the IVb category with 17,229.8 ha. The best quality bonity categories II and III account for 7,514.3 ha or 16.5% of the total area. Analysis of the orthophoto images has identified a significant dynamics of change in space in the period 2008-2012 in four municipalities (Gradacac, Kalesija, Zivinice, Gracanica). Analysis has established that artificial areas (developed)

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increased by 737 ha, agricultural areas without orchards decreased by 1,136.72 ha, while the areas under orchards increased by 283.13 ha. The largest expansion of developed areas and settlements was recorded within the bonity categories IVb (47% of the total change) and III (27%).

Keywords: *land capability, land protection, spatial planning, agro-ecological zoning*

INTRODUCTION

Change in land cover/land use in B&H is very dynamic. According to the CORINE data in the period 2000-2012, total change amounted to 67,672.05 ha of which 28.4% pertain to change within agricultural land. The most significant change is the conversion of agricultural land into artificial surfaces which accounts for 8,658.5 ha (Ljuša, 2015; Ljuša *et al*., 2015).

Spatial planning is a highly multidisciplinary task where within the process of defining real space we meet with: natural characteristics of the area (land, climate, morphology, etc.), economic (level of production, employment), social (population characteristics), technical (infrastructural systems) and super-structural systems (Bublin, 2000).

Spatial planning was introduced in B&H rather late. The first B&H Spatial Plan 1981-2000 was adopted in 1982. Projections of this spatial plan required about100,000 ha of land for construction. After the adoption of the B&H Spatial Plan, municipality spatial plans were developed in a way which provided the protection of agricultural and forest land.

The basis for the adoption of municipal spatial plans were the land use value maps. According to available data, before September 1985 only four out of a hundred and five municipalities had the adopted spatial plan: Bugojno, Cazin, Lukavac and Mostar. On the other hand, the land use value maps being one of the main bases for the adoption of spatial and urban plans, were by that time either completed or in the phase of completion in fifty municipalities. For most municipalities that were significant in terms of agricultural production, these maps were not developed.

The lack of adequate policies and planning solutions are particularly evident in the recent history of B&H, from 1992 to this day. The system of spatial planning has evolved in a different direction than expected. The reasons include numerous social and political, economic and cultural changes as well as the lack of a state level authority for spatial planning, given that the Constitution of B&H does not address spatial planning and development as an explicit state jurisdiction. The situation is the same in the area of land policies.

Although the spatial planning activities in the entities are related to the laws governing this area, the existing legislation on spatial planning in general is not satisfactory and does not comply with the EU regulations. Namely, B&H has to comply with EU principles of spatial planning contained in the European Commission's European Spatial

Development Perspective-1999 (ESDP) and the guiding principles of the European Conference of Ministers responsible for Regional Planning-2000 (CEMAT) as well as other EU directives concerning spatial planning. When it comes to harmonization, in addition to lack of a state level ministry responsible for spatial planning, there is also a problem relating to the fact that spatial planning involves activities that are performed by other ministries (environment, transport, etc.) whose regulations also need to be harmonized with the EU. The problem is the lack of financial analyzes and linkage with the plans of economic and social development as well as the lack of criteria and indicators for monitoring and evaluating the implementation of spatial plans which is very important when it comes to trans-boundary areas (GAP, 2012).

In the Federation of B&H land use in the physical planning documents is determined based on the land use value maps. Decree on unique methodology for preparation of the spatial planning documents (Official Gazette of the Federation of B&H, No. 63/04 and No. 50/07) prescribes the obligation of making the Land capability study as a segment of spatial basis. The land use value map exists in just a few municipalities in the Federation of B&H.

Main objectives of this study are to prepare thematic databases and maps and to explore and analyze land resources of certain municipality by using Geographic Information System (GIS) and remote sensing source of information (ortho-photos). Based on this database, the further objective is to determine the distribution of different land use types, as well as to perform valorization of soil through its quality (bonity) categories and analysis of pedological characteristics of the present soil types. The adoption of the Law on agricultural land (Official Gazette of the Federation of B&H, No. 52/09) and the Instruction on professional criteria for the classification of land into bonity categories (Official Gazette of the Federation of B&H, No. 78/09) has protected the most valuable agricultural land used for food production from other consumers. According to these regulations, the areas of agricultural land could not be reduced or used for non-agricultural purposes until the adoption of spatial and urban plans.

MATERIAL AND METHODS

This paper aims to present the importance, characteristics as well as use of the Land capability study at the municipality level in Tuzla Canton. To analyze the presented data we used the Studies on land use value for the following municipalities: Gradacac, Gracanica, Kalesija, Zivinice and Sapna.

Land quality evaluation is used to determine the level of its suitability for agricultural production based on the scoring of natural conditions for crop production (soil, climate, relief). Land quality evaluation is performed by awarding points to the land rating properties in the way that the highest-quality land of the I rating category is awarded 100 points and the lowest quality land of the VIII rating category 10 points. Land quality rating is calculated using the following formula:

$$B = \sqrt{\mathbf{Tx\ x\ Kx\ x\ Rx\ x}\ \left(\mathbf{1} - \frac{\sum\%\ posebni\ efekti}{\mathbf{100}}\right)}$$

B-bonity score; T-soil properties score; K-climate properties score; R-relief properties score; ∑% special effects *(posebni efekti)*

Soil bonity categories are identified in accordance with the Law on Agricultural Land and based on field research and laboratory tests of soil samples taken from the field as follows:

- Land classified as I to IV cadastral, i.e. bonity category shall be determined solely as agricultural land;
- Land classified as V and VI cadastral, i.e. bonity category shall be determined as agricultural and exceptionally as land for other purposes;
- Land classified as VII and VIII cadastral, i.e. bonity category shall be determined as land that will be used for other purposes as required.

On the basis of orthophoto images an analysis of the existing use value of the land and spatial dispersion of agricultural, forest and barren land as well as water surfaces was made. The analysis of orthophoto images from 2008. and 2012. established the dynamics of change in space, i.e. land cover and land use, and associated it with the bonity categories.

Agro-ecological zoning i.e. assessment of suitability for the cultivation of individual crops is determined based on the FAO agro-ecological zones methodology.

RESULTS AND DISCUSSION

Tuzla Canton comprising 13 municipalities is located in the north-eastern part of B&H . Total area of the Canton amounts to 2,730 km^2 which accounts for 5.3% of the total area of B&H. Area of the five studied municipalities (Gradacac, Kalesija, Zivinice, Gracanica, Sapna) amounts to 104,225.42 ha or 1,042.25 km^2, which is 38.2% of the total area of the Canton.

When it comes to the land bonity (rating) categories, the most represented category in these five municipalities is IVb (17,229.83 ha), whereas the least represented is VII bonity category (225.85 ha) (Table 1, Figure 1). The best rating categories II and III account for 604.35 ha and 6,909.91 ha respectively. The largest areas of the II bonity category were identified in the municipality of Gradacac, amounting to 376.79 ha, while the smallest ones were recorded in Gracanica (5.53 ha). As for the III bonity category, the largest areas were identified in Kalesija (3,369.57 ha) and the smallest in Sapna (7.4 ha). As an illustration, Sarajevo Canton (surface 1,276.9 km², 9 municipalities) has only 3,159 ha of agricultural land of the I-III bonity categories (Čustović *et al.*, 2015). IVa bonity category is most represented in Zivinice (2,518.90 ha), and least represented in

Gradacac (190.9 ha). On the other hand, Gradacac has the largest area of the IVb ctegory (6870. ha), and Gracanica of the V (3,635.64 ha) and VI (2,349.17 ha) bonity categories. The VII bonity category has been identified in the area of Zivinice (143.2 ha) and Gracanica (82.65 ha).

Table 1. Overview of land bonity categories in the selected municipalities of Tuzla Canton

Bonity categories	Score	Gradacac	Kalesija	Zivinice	Gracanica	Sapna	Total	%
II	80-90	376.79	63.63	122.8	5.53	35.6	**604.35**	**1.3**
III	60-80	1,629.66	3,369.57	1,234.40	668.88	7.4	**6,909.91**	**15.2**
IVa	40-60	190.9	349.87	2,518.90	445.55	490.6	**3,995.82**	**8.8**
IVb	40-60	6,870.2	3,437.37	2,647.80	2,737.56	1,536.90	**17,229.83**	**37.8**
V	30-40	2,345.14	2,185.66	1,526.50	3,635.64	1,126.70	**10,819.64**	**23.8**
VI	20-30	1,322.01	859.29	1,179.20	2,349.17	38.1	**5,747.77**	**12.6**
VII	10-20	0	0	143.2	82.65	0	**225.85**	**0.5**

Source: Faculty of Agricultural and Food Sciences, PAM Institute, 2015

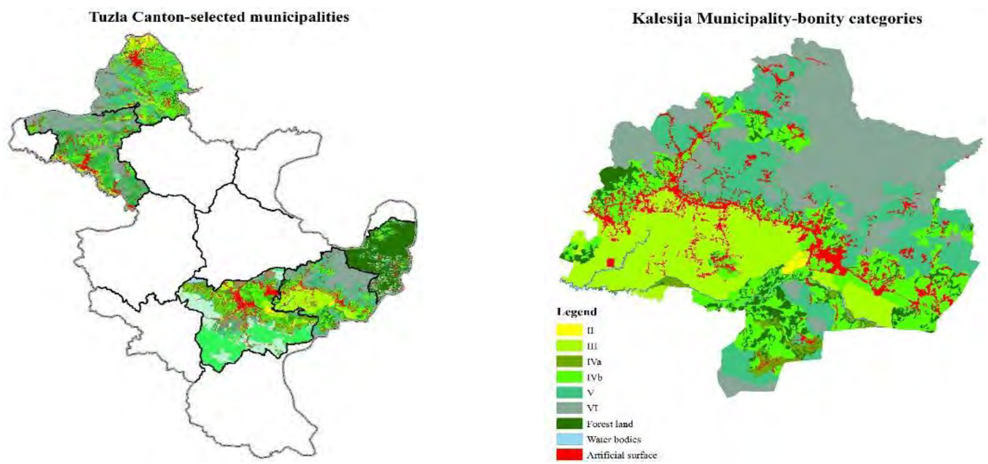

Figure 1. Bonity categories-example of Kalesija municipality

The Republic of Croatia also uses the land bonity system that is determined based on the value (bonity) of soil, climate and relief characteristics and other corrective factors such as rockiness, stoniness, floods and the like, according to the formula $B = \sqrt{TxKxR}$, where B stands for bonity of land without corrections, T-for bonity score of the soil; K-for bonity score of climate and R-for bonity score of relief (Kovačević, 1992; Bogunović, 2009).

According to Kovačević, thus defined bonity indicates versatile possibilities for land use, while the land quality evaluation method along with the determination of the economic conditions of agricultural production could replace the previous method of land classification and serve as a basis of the value of land in land consolidation assessment.

The analysis of land cover/land use, based on orthophoto images from 2012, has identified seven major categories of coverage (Table 2). The results of the analysis show that the largest areas in these five investigated municipalities are covered by the category of forest vegetation and other natural surfaces which account for 45,104.32 or 43.3% of the total area of the subject municipalities. The second most represented category is agricultural land without orchards which accounts for 41,530.58 ha (39.8%). Orchards occupy an area of 2,825.56 hectares so it can be stated that the total agricultural area accounts for 42.5% of the total area. Artificial surfaces, water bodies and quarries/mines account for 10.4% of the total area. Succession comes rather high on the list when it comes to the coverage and it covers an area of about 3,895 hectares or 3.7% of the total area.

The area of agricultural land ranges from 9,336 ha (Zivinice) to 9,895.11 ha recorded in Gradacac. The exception is the municipality of Sapna which has a total of 3.142,5 hectares of agricultural land, which is understandable considering that the total area of the municipality is two times smaller than the other municipalities. The municipality of Gradacac significantly excels when it comes to the area under orchards which amounts to 2,084.85 ha.

Table 2. Overview of the land cover/land use in the selected municipalities of Tuzla Canton (2012)

Category	Gradacac	Kalesija	Zivinice	Gracanica	Sapna	Total
Artificial surfaces	1,949.30	1,469.83	3,026.70	1,943.74	348.9	**8,738.47**
Agricultural land without orchards	9,895.11	9,726.80	9,336.00	9,427.17	3,145.50	**41,530.58**
Orchards	2,084.85	116.09	36.9	497.82	89.9	**2,825.56**
Forest vegetation and other natural surfaces	6,860.56	7,301.34	14,095.80	8,964.62	7,882.00	**45,104.32**
Succession	754.37	1,078.06	715	619.27	727.8	**3,894.50**
Water surfaces	73.27	79.07	711.6	51.83	40.1	**955.87**
Quarries/mines	0	7.36	1,140.7	28.07	0	**1,176.13**
Total	**21,617.45**	**19,778.55**	**29,062.70**	**21,532.52**	**12,234.2**	**104,225.42**

Source: Faculty of Agricultural and Food Sciences, PAM Institute, 2015

Analysis of changes in coverage in the period 2008-2012 shows that in four municipalities (Gradacac, Kalesija, Zivinice, Gracanica) artificial surfaces (developed land) have increased by 737 ha, agricultural land without orchards have decreased by 1,136.72 ha, while the areas under orchards have increased by 283.13 ha (Figure 2).

The biggest increase of the category of artificial surfaces was identified in the municipality of Zivinice amounting to 363.9 ha. Analyzes indicate a significant reduction of agricultural land without orchards (333 ha), therefore it can be stated that these surfaces have been converted into artificial surfaces (Figure 1). Succession is recorded in an area of 97.3 ha.

The situation in the municipality of Kalesija is significantly different. Namely, artificial surfaces have increased by 183 ha, while agricultural areas without orchards have reduced by slightly over 513 ha. However, in the context of the change there is an increase in the areas under orchards amounting to 5.14 ha as well as a significant occurrence of succession of agricultural areas amounting to 374.18 ha. This is an indication of a serious problem of abandonment of rural areas and agricultural activities.

In the municipality of Gracanica, artificial surfaces have increased by 115.48 ha, whereas agricultural areas have reduced by 271.13 ha. However, there is a large increase in areas under orchards of 165.55 ha which indicates the intensification of agricultural production in this fruit production region. The municipality of Gradacac has experienced the smallest increase in artificial surfaces amounting to 74.61 ha. It also recorded the least reduction in agricultural areas amounting to approximately 19 ha. Gradacac, just like Gracanica had a significant increase in orchards by 117.54 ha.

Figure 2. State of land cover (2008) and the increase in artificial surfaces (2012)
Source: Faculty of Agricultural and Food Sciences, PAM Institute, 2015

In view of these changes the question of identifying what bonity categories were affected by the expansion of developed or artificial areas has been raised. To answer to this question, we used the municipality of Kalesija as an example (Chart 1). The analysis shows that the largest expansion of developed surfaces and settlements occurred within the bonity category IVb (47% of total change). However, there is a rather worrying information that exceptional and valuable agricultural land of the III bonity category (soils on flat relief and slope up to 3% in the plains, or up to 16% on hilly terrain, medium deep or deep soils with depth over 60 cm, with a humus-accumulative horizon over 30 cm deep, pH reaction 6-8,5 etc.) for which the law provides that they must be protected against use for non-agricultural purposes, was to a large extent used for the expansion of artificial surfaces (27%). A significant expansion of artificial surfaces was also recorded in the area of V bonity category.

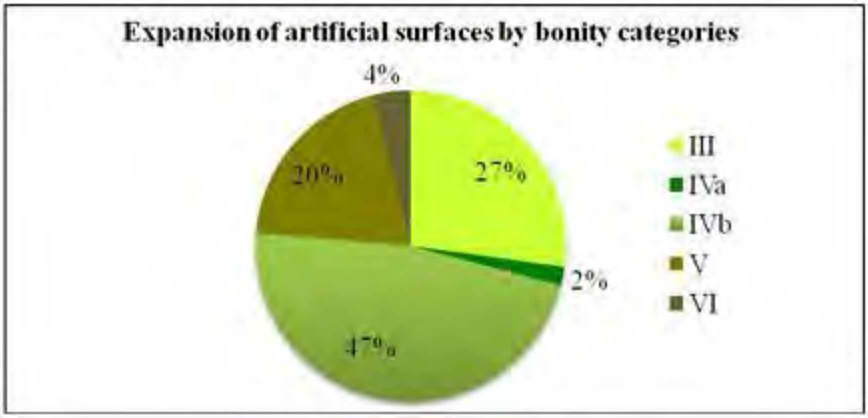

Chart 1. Expansion of artificial surfaces by bonity categories in the municipality of Kalesija

CONCLUSIONS

„Spatial planning is critical for delivering economic, social and environmental benefits by creating more stable and predictable conditions for investment and development, by securing community benefits from development, and by promoting prudent use of land and natural resources for development. Spatial planning is thus an important lever for promoting sustainable development and improving quality of life“ (UN, 2008).

The presented data show a significant dynamics in land use which considerably differs from one municipality to another. There is an evident pressure on agricultural land in terms of its use for construction. A significant reduction in the highest quality agricultural land over a period of just four years suggests that there is a large discrepancy between the spatial planning and the protection of agricultural land from being used for non-agricultural purposes (Ljuša, 2015).

Data on the number of spatial and urban plans in the municipalities of the Federation of B&H are not accessible to the public, which speaks for itself when it comes to their existence, obsolescence and compliance with other spatial planning documents (NAP, 2014). On the other hand, a few municipalities have the land use value maps.

Given the current situation regarding the lack of basis for spatial planning, we can rightfully ask how a municipality or any other administrative level in general can even begin the process of spatial planning without not only the updated layouts but also the basis of the quality of the land necessary for making adequate decision on the use of certain land area. There is also the question of land evaluation methods performed without adequate bonity layouts, in the context of determining its price in the process of conversion. According to Čustović *et al*. (2013a) the lack of analyses of bonity categories, information on land quality and spatial maps, give enough room for speculations and manipulations concerning this resource.

One of the consequences of the above stated problems and shortcomings is illegal construction. Facilities are first built without permits and then legalized. Massive illegal construction testifies to a failure to develop a coherent and comprehensive urban planning and zoning policy (Tsenkova, 2005). As stated by Čustović and Bajramović (2005), monitoring of illegal change of use of agricultural land and its actual use is very scarce, penalties are generally uncollectible, and municipalities and cantons do not have the capacity to fully implement the legal provisions.

However, despite the fact that agricultural land is being destructed, new buildings are literally scattered across the area which prevents rational equipping of such neighborhoods with infra- and super-structure. The key consequence of illegal construction and/or bad planning is a change of economic, environmental or aesthetic value of the landscape which is almost never discussed in B&H , though we are all well aware of it.

Yet, something that should be particularly insisted upon in B&H is the distinction between urban and rural space, considering the need of rural areas to be planned consistent with lifestyle, as well as the evaluation of the landscape which is particularly important to us as B&H is a rural country (Ljuša, 2015).

The significance of the landscape is especially pointed out in the European Landscape Convention (ratified by B&H) which, among other things, states that each party (signatory) undertakes "to incorporate landscape in their regional and urban planning policies and in policies relating to culture, environmental protection, agriculture, social, economic and any other policies which could directly or indirectly affect landscape". In this regard, we must not forget the abandoned rural areas and land which results in loss of biodiversity, degradation of ecosystems in general and the destruction of natural and cultural heritage (Čustović *et al*., 2013b).

The issue of adequate planning and management of the landscape is reflected in the fact that all the programs of rural development, according to the new EU agricultural policy, must include measures to protect and preserve the landscape in rural areas. The aspect of landscaping and the protection of land and natural resources within it, is definitely an issue which has to be included in the rural development strategies at all levels.

The use of land for non-agricultural purposes is not a problem exclusive to B&H. For example, in Germany in the period 1998-2000, the use of land for non-agricultural purposes accounted for 131 ha/day; later on there was a slight decrease but in 2004 it moved back to 131 ha per day (Progress Report on the 2012 National Sustainable Development Strategy). Change of land use particularly affected rural areas and about 50% of land was turned into concrete (*soil sealing*) (Loehr, 2012). One of the pilot measures to reduce the areas intended for construction which is undertaken in municipalities across Germany is urban permit trading. Each municipality has certain number of certificates which determine the area for construction. If the amount of open space on which the municipality wants to build exceeds the amount of open space provided by their certificates, the municipality can purchase additional certificates from other municipalities. Potential buyers of certificates tend to be economically growing municipalities that want to strengthen their growing economy. Examples of good practice such as this measure can be of great help in the development of measures, policies and specific projects at municipal level in B&H whose funding could be provided by EU funds.

One of the basis for spatial planning in the Federation of B&H is the development of land use value map which along with the supporting GIS database provides the spatial distribution and representation of land, which allows observation and commitment of a large land area to various purposes based on its status and environmental conditions. This is especially important in view of making decisions as to what land and parts of space can be excluded from their primary function and use them for other purposes. On the other hand, GIS provides the possibility of continuous updating, i.e. monitoring the changes in space, analysis and application of various models with the aim of assessing the use of an area.

One such approach is the agro-ecological zoning which, among other things, point to phenomena that are typical of land types or possible difficulties that are likely to be expected from the perspective of cultivation of some crop (Figure 3). This type of assessment and analysis facilitates the definition and implementation of measures aimed at mitigating or completely eliminating certain limitations and phenomena or possibly giving up on certain plans in the event that measures are not technically and economically justified. This approach allows for farmers who want to invest to be more objective while analyzing what type of the production to select or whether to apply certain agricultural practices which could improve soil condition and make it more suitable for a particular crop (Figure 4).

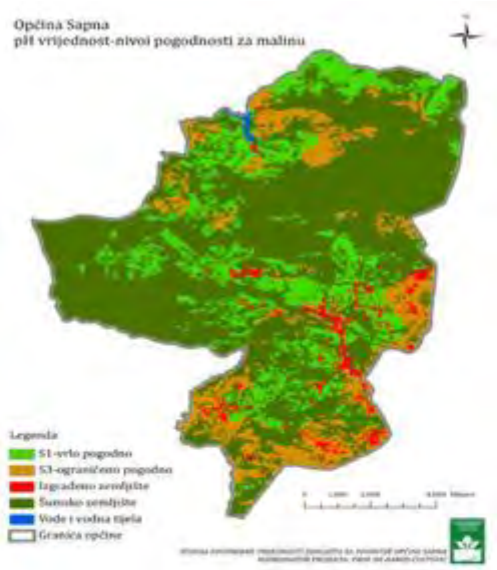

Image 3. pH-level of suitability for growing raspberries

Image 4. Suitability of soil for growing raspberries from the point of pH, humus, $CaCO_3$ and texture

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THE AGRICULTURAL LAND SUITABILITY AND AGROECOLOGICAL ZONING AS THE MAIN FACTORS FOR RURAL SPATIAL PLANNING IN KOSOVO

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ABSTRACT

The soil is an important non-renewable resource that is vital to human life. It supports terrestrial ecosystems such as biodiversity, fresh air and water, food security, cultural heritage and the built environment, representing a natural and an economical asset of a country. Appropriate scientific information is crucial for sustainable soil management by local, national and regional governing institutions. Productive land is a critical resource for food and biomass production. In a broader sense land resources, management is the implementation of land use planning, as agreed between and with the direct participation of stakeholders. It is achieved through political decisions; legal, administrative and institutional execution; demarcation on the ground; inspection and control of adherence to the decisions; solving of land tenure issues; settling of water rights; issuing of concessions for plant and animal extraction (timber, fuel wood, charcoal and peat, non-wood products, hunting); promotion of the role of women and other disadvantaged groups in agriculture and rural development in the area, and the safeguarding of traditional rights of early indigenous peoples. Land suitability categorization and the agro-ecological zoning are of essential importance for the decision making for justified developments in many policy areas including agriculture and spatial planning.

Keywords: *land suitability, agro-ecological zoning, rural spatial planning, Kosovo*

INTRODUCTION

Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the

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near-surface climate the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.). According to MAFRD data[4], Kosovo is characterised as a rural region whereby approximately 60% of the population is living in rural areas with an approximated 35% of the entire labour force involved with farming activities. Therefore, agriculture represents a key strategic sector for employment and economic activity. Compared to the 1990s, agricultural production has increased in the third millennium through government's commitment to improve the overall agricultural development.

Currently, in Kosovo, a land categorization system is used, which is based on the soil analysis undertaken fifty years ago and it was primarily used for the visual mapping of land use for land taxation purposes. It is based on the fundamental principle that a specific land use type is associated with a particular land quality class. Land suitability categorization and the agro-ecological zoning are of essential importance in decision making for justified developments in many policy areas including agriculture and spatial planning. Kosovo has good quality soils[5], which could be the foundation for a thriving agricultural industry that could sustain a significant impact on the country's GDP. However, because of the lack of spatial planning documents related to rural zones, the prime agricultural land was used for other purposes and construction that resulted in an immense loss of arable land.

This paper is intended to describe the role of the land suitability categorization and the agro-ecological zoning in the rural spatial planning process in Kosovo. The primary objective of the paper is to identify the relationship between land suitability categorizations, the agro-ecological zoning and land tenure on rural spatial planning and environmental impact in Kosovo.

The paper also aims to ensure widespread awareness among all stakeholders on the prevailing challenges of resource rural spatial planning and the importance of participatory and interactive intervention process for the rural land sustainable management. A systems approach is used to describe land suitability categorization and agro-ecological zoning in Kosovo, addressing the complex and dynamic nature of the relationships among the subject matter areas.

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[4] Ministry of Agriculture, Forestry and Rural Development (2014), *Green Report 2014*, Prishtina Kosovo.

[5] EULUP Project Number 2010/230-489, Further Support to Land Use - Eulup, Agricultural Land Suitability Classification, Technical Report No.3, Prishtina, 2011

MATERIAL AND METHODS

Agriculture Land Suitability Classification methodology is described in details in Administrative Instruction No. 02/2012 On Classification of Suitability of Agriculture Land, prepared by Ministry of Agriculture Forestry and Rural Development, Kosovo[6]

The agro-ecological zoning methodology has been refined by FAO for within-country level zoning applications[7], where socio-economic conditions were also taken into account. These conditions figure even more prominently in the programmes for (agro-)Ecological and (socio-)Economic Zoning EEZ - of whole and mainly natural ecosystems, such as the Amazon forest region or "biome". In these latter two cases, the zoning *sensustrictu* is a delineation of areas of rural lands, which could be earmarked for one or another use or non-use, based on identical physio-biotic conditions and prevailing socio-economic infrastructure. The resulting units can be defined as Resource Management Domains, RMDs, defined as areas within a broad physio-biotic zone that have at present the same socio-economic conditions.

Agricultural land suitability classification is crucial information set for spatial planning. A land suitability categorization is of essential importance in decision making for planning justified developments in many policy areas including agriculture and rural spatial planning in general. Land suitability classes from 1st to 8th are used as a basis for policy implementation and management in many sectors such as agriculture, forestry, construction, environment, real estate market, taxation, spatial planning, and development. Kosovo has widespread good quality soils, which could form the basis of a thriving agricultural industry which could constitute an important part of the country’s GDP. However because of unplanned developments that have not been sanctioned by the state this area of prime quality land is rapidly reducing. Furthermore, the segregation of land parcels, the small average farm size restraints land reform and directly affects the economic value and effectiveness of the agricultural sector.

These are the primary arguments why Kosovo needs to implement a refined and updated system of assessing land suitability for agriculture, which can also be used as a tool to inform policy decisions in the agricultural sector and spatial planning. This system is based on all currently available data and takes account of physical land properties. Bearing in mind the urgently pressing issues facing Kosovo, in order to ensure rapid integration into policy systems, the new land suitability classification[8]is straight forward, clear, transparent and easy to apply.

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6 http://www.mbpzhr-ks.net/repository/docs/982__UA_Nr.022012.pdf,

7 FAO, 1996. Agro-ecological Zoning. FAO Soils Bulletin 73, Food and Agriculture Organization of the United Nations, Rome, Italy

8 http://www.mbpzhr-ks.net/repository/docs/982__UA_Nr.022012.pdf,

It is the first time that the Kosovo municipalities will do integrated zoning planning for the rural areas within their territories[9].

RESULTS AND DISCUSSION

Physical planning is the designing of the optimal physical infrastructure of an administrative land unit, such as transport facilities - roads, railways, airports, harbours; industrial plants and storage of produce; mining and power generation, and facilities for towns and other human settlements - in anticipation of population increase and socio-economic development, and taking into account the outcome of land use zoning and planning. It has both rural and urban development aspects, though the latter usually predominates. Physical planning is generally carried out by the state, or by local government organizations for the general good of the community. The purpose is to take a more nearly holistic or overall view of the development of an area that can or would be taken by individuals. Physical planning has two main functions: to develop a rational infrastructure, and to restrain the excesses of individuals in the interests of the community as a whole. This latter function usually leads to physical planning being associated with a system of laws and regulations.

Land use planning is mainly related to rural areas, concentrating on the utilization of the land in the broadest agricultural context (crop production, animal husbandry, forest management/silviculture, inland fisheries, safeguarding of protective vegetation and biodiversity values). However, peri-urban areas are also included where they directly impinge on rural areas, through expansion of building construction onto valuable agricultural land and the consequent modification of land uses in the adjoining rural areas.

In a broader sense land resources, management is the implementation of land use planning, as agreed between and with the direct participation of stakeholders. It is achieved through political decisions; legal, administrative and institutional execution; demarcation on the ground; inspection and control of adherence to the decisions; solving of land tenure issues; settling of water rights; issuing of concessions for plant and animal extraction (timber, fuel wood, charcoal and peat, non-wood products, hunting); promotion of the role of women and other disadvantaged groups in agriculture and rural development in the area, and the safeguarding of traditional rights of early indigenous peoples.

The agriculture land suitability classification system is based on the assumption that land is used for conventional mechanized arable agriculture without irrigation. Agricultural land suitability takes account the spatial variation of all soil properties, landscape settings and climate conditions across the whole of Kosovo.

The key soil properties that determine ALSC are those that influence: (i) workability of land-that is the ability to produce a good seed bed at the correct time of year for the crop and to allow harvesting in conditions that will not damage soil structure, and (ii) crop water

[9] Assembly of Republic of Kosovo, Law No. 04/L-174, on Spatial Planning, 2013 Prishtina, Kosovo

availability- that ensures there are sufficient water reserves in the soil at key times of the year to allow optimum crop growth. Soil texture, soil depth, stoniness, available and retained water capacities and the depth and duration of waterlogging in the soil, therefore, are the main soil properties determining the suitability of land for arable cropping. The most important terrain factor is slope angle, though length and shape of the slope are also relevant. Regarding climate, rainfall, temperature, potential transpiration and derived water balance information are the most important factors.

This simple pragmatic methodology has been developed for Kosovo and it is based on all available data and carefully adjusted to the scale suitable for municipal spatial planning. The mapping methodology can be readily applied and more importantly – it can be accurately replicated by non-specialist staff in all municipalities or throughout Kosovo.

This ALSC methodology is suitable for national and municipality scale and to all readily available data. It comprises three ‘Key Datasets’ describing soil, terrain and climate. Four ALSC factors were selected from the soil data, two from climate data and one factor represents terrain. As it is the general case elsewhere in Europe, the geology substrate has not been considered in the ALSC model. Geological deposits act as parent material in soil formation process, but soil layers themselves are of utmost importance for ALSC because arable agriculture activities are usually done in 30-40 cm depth and are not possible in deeper laying parent material.

Some of these seven factors are more important than others in determining ALSC. The table of the relative importance of ALSC factors has been compiled (Table 1). Collective well experienced international expertise suggests that the main driver of this ALSC model is soil information (the 4 soil factors together represent 0.65 points of total importance, where maximum sum of points is equal to 1), and supplemented by factors describing terrain - slope (representing 0.25 points of importance) and climate - annual average rainfall and altitude (each representing 0.05 points of overall importance)[10].

Table 1. Factors for calculation of Agricultural Land Suitability Classification ALSC

Key Datasets	Factors	Relative importance of factors for ALSC
Soil	Soil type	0.45
	Soil texture	0.05
	Soil depth	0.10
	Soil drainage	0.05

[10] Administrative Instruction No. 02/2012 on Classification of Suitability of Agriculture Land, Government of Kosova, Ministry of Agriculture, Forestry and Rural Development Prishtina, 2012.

Key Datasets	Factors	Relative importance of factors for ALSC
Terrain	Slope	0.25
Climate	Altitude	0.05
	Av An Rainfall	0.05
	Total	**1,00**

Table 2. Table of Agriculture Land Suitability Classification

Classes SAL	The points SAL	Suitability of Agriculture Land	Group of Agriculture Land
1	85-100	Very good	Kept particularly for agriculture production
2	76-85	Good	
3	66-75	Above average	
4	56-65	Average	
5	46-55	Below average	Decisions to protect the agriculture must be taken based on the value
6	36-45	Poor	Weak land: mainly forestry zone and meadows; it is not reasonable to be kept for agriculture
7	01-35	Very poor	
8	0	Unsuited	Mechanized agriculture ploughing is not possible

Calculation of the SAL points is explained in details in Administrative Instruction No. 02/2012 On Classification of Suitability of Agriculture, in which case applies logarithm:

$$ALS= A * Wa + B * Wb + C* Wd +D * Wd +E* We + F * Wf+ G * Wg$$

A = points for factor “Soil type”
B = points for factor “Soil texture”
C = points for factor “Soil depth”
D = points for factor “Soil drainage”

E = points for factor “Slope”
F = points for factor “Altitude”
G = points for factor “Av An Rainfall”
W[a..g] = assessment of factors (Relative importance of factors for ALSC)

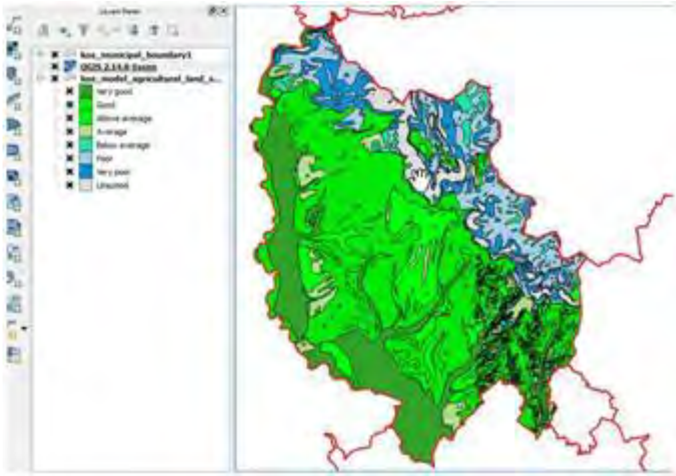

Figure 1. Map of ALSC of Rahovec Municipality

Agro-ecological Zoning (AEZ) refers to the division of an area of land into smaller unites, which have similar characteristics related to land suitability, potential production, and environmental impact[11]. It uses the agricultural land suitability classification ALSC as input and uses an additional set of data in its analysis. The output is an information set for the area involved, where the land is divided into land units (see Figure 2), according to their optimal land use regarding productivity, about socio-demographic and environmental factors. From the AEZ framework contains three essential elements:

(i) selected agricultural production systems with defined input and management relationships, and crop-specific environmental requirements and adaptability characteristics (these are termed land utilization types (LUT); (ii) geo-referenced climate, soil and terrain data which are combined into a land resources database, and (iii) procedures for the calculation of potential yields and for matching crop/LUT environmental requirements with the respective environmental characteristics contained in the land resources database, by land unit and grid-cell.

[11] Ministry of Environment and Spatial Planning Kosovo (2015), A Guide for Rural Spatial Planning in Kosovo, Prishtina, Kosovo.

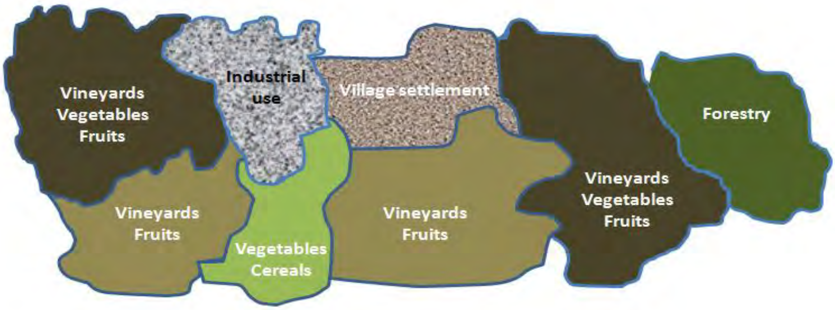

Figure 2. Examples of land units

Based on such methodology, each municipality has the potential area suitable for the cultivation of specific crops. Definition of the manner of land use in each unit should be done through socio-economic analysis of the needs of the population of the municipality and making an analysis of market requirements. After these two analyzes based on the potential of the soil, have to decide for what the defined surfaces during agro-ecological zoning would be exploited. Besides, creating an inventory and planning a sustainable development of agricultural land, one of the main objectives of the Agro-ecological zoning in Kosovo is to inform the potential investors about the agricultural potential of the land that is situated in the respective municipalities. In turn, the potential investors would have an important impact in the future land tenure and consolidation of the agricultural land, which is determined by increasing the agricultural productivity.

CONCLUSIONS

Kosovo has widespread good quality soils, which could form the basis of a thriving agricultural industry which could constitute an important part of the country's GDP. However because of unplanned developments that have not been sanctioned by the state this area of high-quality land is being rapidly reduced. Furthermore, the segregation of land parcels and the small average farm size restraints land reform and directly affects the economic value and effectiveness of the agricultural sector. A land suitability categorization is of basic importance in decision making for planning justified developments in many policy areas including agriculture and spatial planning.

The use of agro-ecological zoning is a good manner to identify the actual potential of agricultural land for development of specific annual crops and livestock in Kosovo. It consists of zoning the agricultural land into smaller units that have similar characteristics based on their land suitability attributes potential production and environmental impact. Through using the agro-ecological zoning, we can create an inventory of agricultural land that would provide valuable data related to agricultural assets of the municipality to potential investors that are interested in cultivating specific crops. Agro-ecological zoning is not a regulatory tool that determines a legally-binding land use. It is a guiding tool that exposes the true potential of specific zones in relation to its agricultural yield and according to climate, soil and terrain parameters that have a direct impact on agricultural production of specific crops. This type of zoning consists of the development of a standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production. In this context, the concepts of Length of Growing Period (LGP) and of latitudinal thermal climates have been applied in mapping activities focussing on zoning at various scales, from sub-national to the global level.

The agricultural land suitability and agro ecological zoning are the main factors, which should take into consideration during the rural land management planning RLMP. This process incorporates integrated environmental planning into land use management, and at the same time is a highly flexible planning methodology that focuses on the economic and social needs of the local stakeholders.

Agricultural land is a production commodity, and farmers need sufficient flexibility to adapt to the demands and opportunities of the agricultural (local, regional and global) markets. At the same time, the management of environmental resources – like an available river- or ground water – requires detailed fine-tuning and locally integrated solutions. That is where rural land management planning serves to complement the (strategic) rural development planning and spatial planning zoning.

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SUITABILITY OF AGRICULTURAL LAND OF THE HERZEGOVINA-NERETVA COUNTY FOR CULTIVATION OF SOME FRUIT SPECIES

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ABSTRACT

This paper presents the evaluation of benefits of the agricultural land for the cultivation of cherry, sour cherry, plum and apple in the area of Herzegovina-Neretva County (HNC). The evaluation of the land suitability was carried out according to the FAO method (FAO, 1976, Brinckman and Smith, 1973), according to the agro zone (up to 800 m above sea level) and taking into account the features of the soil, climate and topography and the requirements of these fruit cultures. The results of the research are shown with text and graphics (maps of benefits of the agricultural land). Based on the conducted research, the existence of significant and valuable land resources is established for development of fruit cultivation in Herzegovina-Neretva county.

For the cherry and sour cherry cultivation in the agricultural area of Herzegovina-Neretva county (up to 800 m above sea level) exists 29,682 hectares (28.55%) of suitable land, for the plum and apple cultivation exist 38,345 hectares (36.89%). The convenience of the class structure of the soil for the cherry, sour cherry, plum and apple is the smallest share of the P-1 class benefits. The largest proportion of the land P-3 class benefits for growing cherries, sour cherries, apples and plums with benefits in the soil for growing cherries have less difference between the surfaces of the P-2 and P-3 class suitability. The main limitations are the slope of the terrain, the depth of profile, rockiness and stoniness. Temporarily unsuitable soils had occupied significant area for these fruit species cultivation. Plots of this class can be with adequate, economically justified measures led to a certain class of convenience

Keywords: *agricultural land, facility, cherry, sour cherry, climate, relief*

INTRODUCTION

A rational use of the pomological and ecological potential of a production area is the foundation for sound growth and abundant and regular yield of fruit trees. To plan the

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development of fruit growing in a certain area, it is important to evaluate and define the degree of suitability of ecological conditions for cultivation of fruit trees, because fruit trees remain in the same place for many years. The Herzegovina-Neretva County (HNC) has a tradition in the production of fruits. Different climatic conditions, from Mediterranean to continental, provide the possibility of producing all types of continental and certain types of mediterranean fruits. The aim of this study was to determine the characteristics of soils, climate and relief in the area of agricultural soil/land of the Herzegovina-Neretva County as ecological factors of fruit production, and taking into consideration the criteria and requirements of the studied fruit species (sweet cherry, cherry, plum, apple), to evaluate the suitability of agricultural soils/land for their cultivation.

MATERIAL AND METHODS

The compilation soil map of agricultural land of the Federation of BiH at the scale 1:200,000 was used as the basis for preparation of this paper. This map was used as a basis to make a soil map excerpt for the Herzegovina-Neretva County (HNC), based on which the characteristics of soils/land are presented in this paper.

Well suitable soils of the P-1 suitability class include areas without significant limitations for cultivation of particular fruit species or with limitations that will not significantly affect the productivity and profits of production. Moderately suitable soils of the P-2 suitability class cover areas with limitations that moderately affect the productivity and profits of production of particular fruit species. The P-3 suitability class soils, suitable to a limited degree, cover areas with limitations that significantly compromise the productivity and profits of production of particular fruit species. Temporarily unsuitable soils of the N-1 suitability class are areas with limitations that can be improved by certain agricultural engineering interventions. Permanently unsuitable soils of the N-2 suitability class cover areas with limitations that rule out any possibility of economically justified production of those fruit species.

Data on climate were obtained from the Federal Hydrometeorological Institute. The requirements of particular fruit species were determined on the basis of the existing literature. For cultivation of apples, the best an average air temperature is 20°C during the growing season. The necessary precipitation for cultivation apples is about 600 mm during the growing season. For cultivation of plums the best average air temperatures are between 16°C and 20°C during the growing season. The necessary precipitation for cultivation plums is between 400-500 mm during the growing season. Cherry is growing in areas where an average annual air temperature ranges from 10°C to 17°C. Minimum precipitation for cultivation cherries is about 500 mm during the growing season. For cultivation sour cherries, temperature requirements are similar to requirements cherry, except that the lower limit for growing cherries is 650 mm of precipitation per year (Miljković, I., 1991; Šoškić, M. M., 2008).

Slightly hilly terrains (with slopes up to 10%) are the most favorable for the production of fruits. Slope gradients for fruit production should certainly not exceed 15%. Costs of terracing are significantly increased if slope gradient is greater than 15%, while positions with slopes greater than 30% are considered unsuitable for cultivation of fruit trees. Deep soil, fine textured soil, good physical and chemical properties, biologically active, neutral to slightly acid reaction are suitable soil for the fruit cultivation. Unsuitable soils for the fruit cultivation are shallow soils, very rocky and stony soils and heavy, dense, calcareous or acid soils with impermeable lower horizons (Miljković, I., 1991; Šoškić, M. M., 2008).

The land suitability evaluation was carried out according to the FAO method (FAO, 1976; Brinckman and Smith, 1973) for agricultural land in the area of HNC, specifically for the area up to 800 m above sea level. Based on results of the suitability evaluation of dominant soil types in mapped units, a special-purpose interpretation of the soil map of agricultural land was conducted, on the basis of which a map of suitability for cultivation of particular fruit species was made.

RESULTS AND DISCUSSION

Climate characteristics

The fundamental factors that determine the selection of fruit species to be grown in a particular area and affect the profitability of fruit production in that connection are the natural conditions, that is climate, relief, altitude and slope, and soil or land (depth, physical and chemical properties, participation of rocks on the soil/land surface, participation of stones on the soil/land surface, soil texture in surface horizon, permeability of soil, infiltration of water in the soil).

The area of HNC is an exceptionally heterogeneous area the agroecological conditions of which are defined by the proximity of the sea, articulated mountainous relief and river flows. The mountainous, moderately continental and mediterranean belt, each with its specificities, alternate in this area. According to data obtained from the Federal Hydrometeorological Institute for the period 2004-2013, the coldest month was January with an average air temperature of 4.3°C, and the warmest month was July with an average air temperature of 26.1°C. The average annual air temperature ranged from 10.6°C to 16.2°C. The average annual precipitation for the observed period was 1,580.2 l/m^2, and the average monthly precipitation ranged from 42.1 l/m^2 in July to 175.22 l/m^2 in November.

Relief characteristics

The maps of terrain altitude and slope were made for the purpose of evaluating the suitability of agricultural land for cultivation of fruit species. Considering that slope and height above sea level of the terrain (area) may represent major limitations for fruit growing, certain areas are treated as permanently unsuitable for fruit growing.

Analysis of the data of individual terrain altitude classes (Figure 1) shows that in the Herzegovina-Neretva County altitudes of more than 1,200 m occupy most of the terrain area (109,459.4 ha), while the area of altitudes from 1,000 to 1,200 m occupies the smallest part (30,011.5 ha). The terrain of altitudes up to 800 m in HNC covers the area of 255,153 ha.

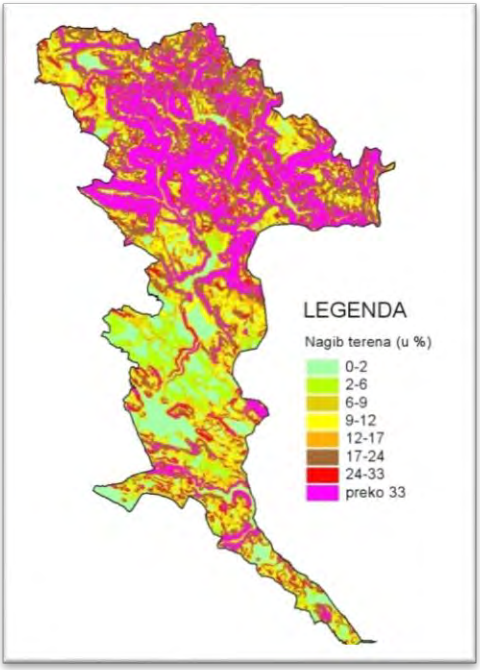

Figure 1. Terrain altitudes of the HNC area

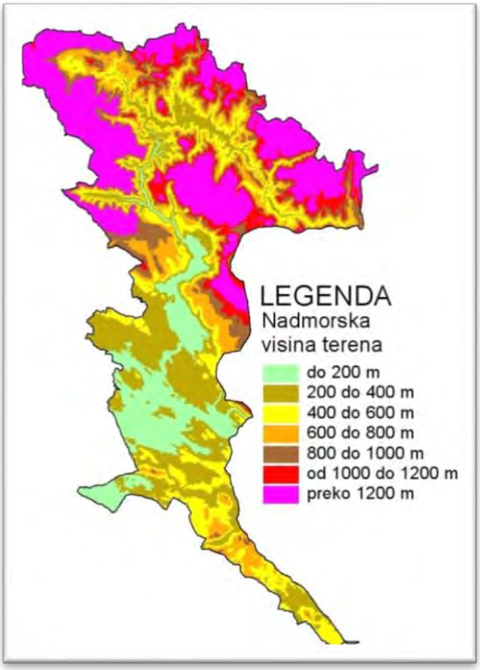

Figure 2. Terrain slopes of the HNC area

Source F1 & F2: Ćorić et al., 2013

Arable areas are mainly limited to sinkholes, depressions, clearings, plateaus, mild slopes protected from erosion and valleys of rivers and watercourses provided that there is no danger of flooding. Special arable resources are related to karst fields and karst plateaus (Ćorić *et al*., 2013).

Hillsides with their slopes are an important element of the relief (Figure 2). In the area of HNC, it is visible that the area with slope gradient from 17 to 24% occupies 109,457.9 ha, and the terrain with slope gradient from 24 to 33% covers the smallest area of 19,978.8 ha. The terrain with slope gradient from 0 to 17% occupies the area of 204,930 ha.

Soil characteristics

An excerpt of the soil map of agricultural land in the area of HNC (Figure 3) was made on the basis of the soil map of BiH at the scale 1:200,000 (Source: Federal Institute for Agropedology, Sarajevo) and the altitude map. In geological terms, the area of HNC is very complex. Consistent with the set of pedogenetic factors, different types of soil are developed in the area of Herzegovina-Neretva County. They are classified into two divisions, specifically the division of automorphic and the division of hydromorphic soils. The division of automorphic soil types that are found in the area of HNC includes the following: sierozem (regosol), colluvium, lime dolomite black soil (calcomelanosol), humus silicate soil (ranker), rendzina, eutric brown soil (eutric cambisol), distric brown soil (cistric cambisol), red soil (terra rossa), brown soil on limestone and dolomite (calcocambisol) and loessivized soil (luvisol). The hydromorphic division includes these types of soil: alluvial (fluvial) soils, marshy-gleyic soil (eugley), fluvial meadow (humofluvisol) and peat soil. Automorphic soils are all soils the formation and development of which is characterized by wetting only by precipitation, and percolation of rainwater is free and without long retention in the soil profile. Hydromorphic soils are characterized by regular or occasional wetting by excess underground, flood or flow water from higher terrains. The basic characteristics of particular types of soil are presented in detail in the existing literature (Škorić, A., 1986). For the purposes of soil suitability evaluation, characteristics of mapped units (up to 800 m asl) were established, which include: terrain slope, stoniness, rockiness, altitude, soil texture, drainage, mode of wetting, ecological depth and parent substrate, which more fully characterize individual systematic and mapped soil units.

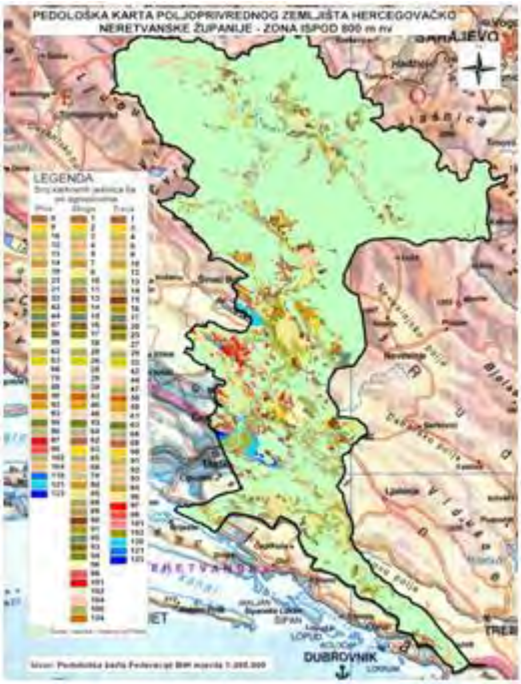

Figure 3. Soil map of agricultural land of HNC
Source: Federal Institute for Agropedology, Sarajevo

The evaluation of suitability of agricultural land in the area of HNC for the cultivation of sweet cherry, cherry, plum and apple trees

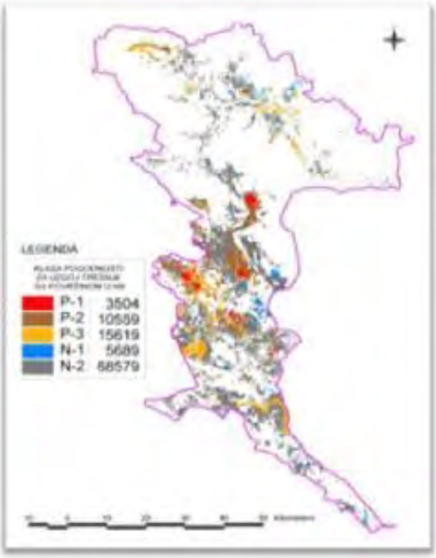

Figure 4. Sweet cherry cultivation suitability map

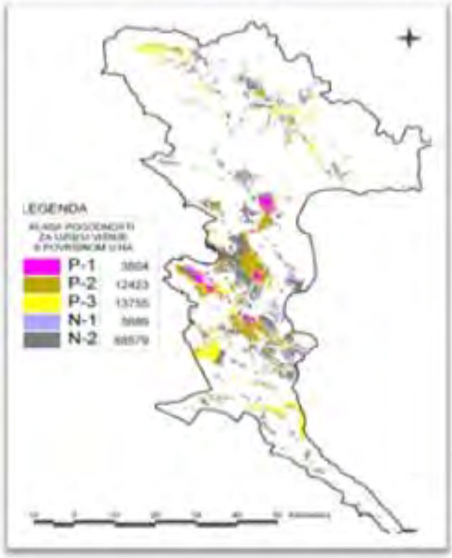

Figure 5. Cherry cultivation suitability map

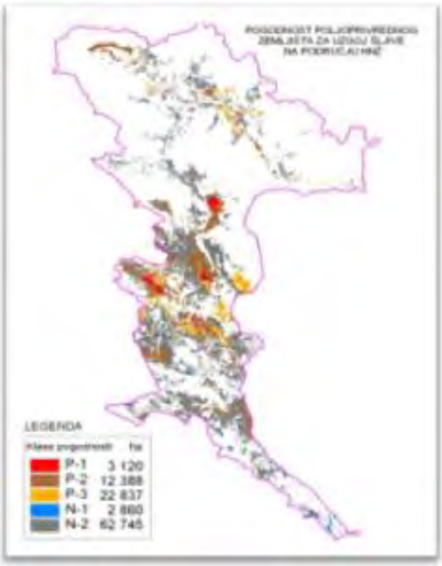

Figure 6. Plum cultivation suitability map

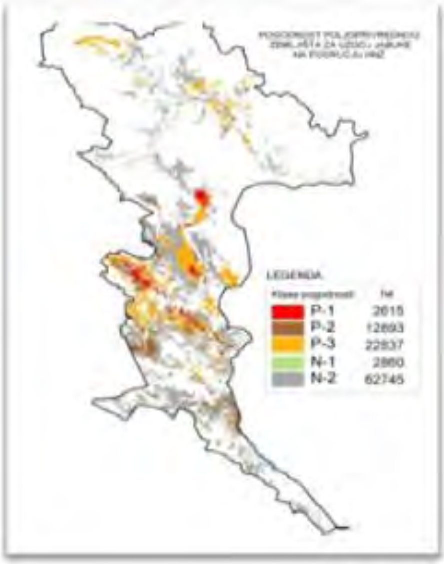

Figure 7. Apple cultivation suitability map

Source: Ćorić et al., 2013

Based on results of the evaluation of suitability of only and/or dominant soil type in mapped units and ectomorphological characteristics, evaluation of suitability of agricultural land for the cultivation of sweet cherry, cherry, plum and apple trees was carried out, and then the inventory of areas by suitability orders and classes was conducted. Spatial distribution of individual classes is shown on the suitability maps for cultivation of these fruit species in the area of Herzegovina-Neretva County (Figures 4., 5., 6., and 7.).

Analysis of the obtained data shows that in the total area of agricultural land of HNC (up to 800 m asl) the P-1 class soils for the cultivation of sweet cherry and cherry trees occupy the area of 3,504 ha (3.37%), and for the cultivation of plum trees 3,120 ha (3.00%) and apple trees 2,615 ha (2.51%).

In the area of HNC, the P-2 suitability class land for the cultivation of sweet cherry trees occupies 10,559 ha (10.16%), for the cultivation of cherry trees 12,423 ha (11.95%), for the cultivation of plum trees 12,388 ha (11.92%) and for the cultivation of apple trees 12,893 ha (12.40%). These areas for the cultivation of sweet cherry trees cover 15,619 ha (15.03%), for the cultivation of cherry trees 13,755 ha (13.23%), for the cultivation of plum trees 22,837 ha (21.97%), and for the cultivation of apple trees 22,837 ha (21.97%).

In the studied area, these soils for the cultivation of sweet cherry and cherry trees cover 5,689 ha (5.47%), for the cultivation of plum trees and apple trees 2,860 ha (2.75%). Most of these areas are found for the cultivation of sweet cherry and cherry trees, 68,579 ha (65.97%), for the cultivation of plum trees and apple trees 62,745 ha (60.36%), Table 1.

The main limiting factors for the cultivation fruits are: climate (occurrence and frequency of the spring and autumn frosts, low temperatures during flowering and fructification, excessive temperature during the growing period, insuficiency of water especially during the growth and development of the fruit), slope (positions with slopes greater than 30% are considered unsuitable for cultivation of fruit trees), soil depth (shallow soils), stoniness, rockiness (soils with a high percentage of rocks and/or stones).

Table 1. Inventory of areas (ha) of soil suitability classes for the studied fruit species

Class	sweet cherry	cherry	plum	apple
P-1	3,504	3,504	3,120	2,615
P-2	10,559	12,423	12,388	12,893
P-3	15,619	13,755	22,837	22,837
N-1	5,689	5,689	2,860	2,860
N-2	68,579	68,579	62,745	62,745

CONCLUSIONS

The conducted research established the presence of significant land resources for the development of fruit production in the area of the Herzegovina-Neretva County. In the area of the county (up to 800 m asl), there are 29,682 ha (28.55%) of land of various suitability degrees for the cultivation of sweet cherry and cherry trees, and for the cultivation of plum trees, and apple trees 38,345 ha (36.89%).

Thus, the total suitability areas for the cultivation of sweet cherry and cherry trees are the same primarily because of very similar requirements of the studied fruit species for agro ecological factors. In the structure of suitability classes for cherry trees, there is a slightly larger proportion of the P-2 suitability class primarily due to somewhat more modest requirements of this fruit species. The P-3 suitability class soils for the cultivation of sweet cherry, cherry, apple trees and plum trees have the highest occurrence. The P-1 suitability class soils have the lowest occurrence for all the studied fruit species. For the cultivation of sweet cherry trees and cherry trees the P-1 suitability class soils have the highest occurence than compared to all the studied fruit species, which greatly contributes to the high presence of calcareous soils in this area.

In fruit growing, specific agro ecological and soil conditions, as well as selection of the most appropriate cultivar for specific cultivation areas, can significantly increase the productivity of this branch of economy. Therefore this type of research should help improve production of fruits in the Herzegovina-Neretva County.

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WHOLE FARM NITROGEN BALANCE ON POULTRY FARMS IN CENTRAL BOSNIA REGION

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ABSTRACT

At livestock farms most part of nitrogen arrives as purchased products (fertilizer, animal feed and purchased animals). Within the boundaries of the farm, nitrogen recycles between the livestock and crop components. Finally, nitrogen exit a livestock operation unit preferably as managed outputs (meat, crops and manure) sold off the farm. Difference between the inputs and the managed outputs represents an itrogen balance that can be an indicator of environmentally sustainable production. Nitrogen (im)balance consider only amount of the nutrient that cross the border of the farm. In ideal conditions the nitrogen input/output ratio should be 1:1. Some nitrogen exits the farm as losses to the environment (nitrates in groundwater, ammonia volatilized into the atmosphere, and nitrogen into groundwater and surface water).

A study was conducted on five small poultry farm in order to determine whole farm nitrogen balance as difference between total nitrogen inputs (one day chickens, litter, animal feed) and outputs (meat, dead animals and manure). Selected farms differ according to capacity (ranging from 5,000 to 40,000 birds), producers of poultry feed, type and length of manure storage as well as other sensible farming practice which could influence on nitrogen balance.

Collection of data on all farms is done using a questionnaire. Nitrogen content in all substrates (feed, manure, litter) was determinate by Kjeldahl procedure. The results of the whole farm nitrogen balance with the recommendations of its balancing in order to reduce the negative environmental implications are presented in the paper.

Keywords: *whole farm nitrogen balance, broiler farms*

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INTRODUCTION

In the last few years, the poultry industry presented a significant increase in the animal production sector in Bosnia and Herzegovina. Awareness of the implications of poultry farming activities such as contamination of soil, surface and groundwater and air, have increased over the years. One of the major challenges in the modernization of poultry production is the need to reduce of the polluting effects on the environment and at the same time providing animal welfare demands and maintaining a profitable business.

Nutrients are transported along multiple pathways and in a variety of forms on a poultry operation. When it comes to environmental issues nitrogen plays an important role. At livestock farms most part of nitrogen arrives as purchased products (fertilizer, animal feed and purchased animals). Within the boundaries of the farm, nitrogen recycles between the livestock and crop components. Finally, nitrogen exit a livestock operation unit preferably as managed outputs (meat, crops and manure) sold off the farm. Difference between the inputs and the managed outputs represents a nitrogen balance that can be an indicator of environmentally sustainable production. Nitrogen (im)balance consider only amount of the nutrient that cross the border of the farm. In ideal conditions the nitrogen input/output ratio should be 1:1, but in the most farms practice nitrogen balance is far worse. Some nitrogen exits the farm as losses to the environment (nitrates in groundwater and surface water, ammonia volatilized into the atmosphere). Consequences include surface water and ground water pollution, eutrophication, increase of greenhouse effect, odor and acidification. Feed program and manure export practices are the most significant indicator of N balance variation. Purchased animal feeds are often the most significant source of the N inputs. The primary route of N excretion is fecal. Properly formulated ration that precisely meets the chicken's requirements for meat production and maintenance will minimize excessive N excretion.

In Bosnia and Herzegovina none study regarding whole poultry farm nitrogen balance conducted yet. Taking into account considerable number of poultry farm, knowledge of nitrogen flow at farms level could be basic step for improvement of N management at the farm.

MATERIAL AND METHODS

A study was conducted on five small poultry farms in central Bosnia region. The investigation was performed during the growing cycle that ran May – June 2015. Collection of data on all farms was done using a questionnaire. Questions referred to producers included: the hybrid and number of purchased and sold chickens and animal's products (meat), farm size, production of crops on the farm, the quantity of purchased feed (starter, grower, finisher), the quantity of purchased fertilizer, the amount of manure produced and sold, manure storage method. All data (information, questions) were related to the period of one production cycle (lasting from 35 to 38 days, depending of farm).

Compound feeds of two commercial producers were used in the experiment. Chicken feeding was *ad libitum*. Feed samples were collected and analyzed to determine nitrogen, crude protein, crude fiber, ether extract and crude ash. Feed samples were taken randomly from several different points of the broiler sheds on each farm. Subsequently the samples are then mixed to a single blend to produce a collective sample, which again is divided into several representative laboratory samples for crude nutrient analysis. The feed samples were initially dried at 105°C for 3 hours. The weight loss of the sample is determined and the water fraction is calculated. Ashing the sample at 550°C for 4 hours all organic compounds are removed. Calculating the weight loss of the feed sample during ashing, mathematically determined the organic matter fraction. The nitrogen content of the feed was determinated using the Kjeldahl method on a Foss Kjeltec^{TM} 2200 analyzer. Multiplying the nitrogen content in % obtained via Kjeldahl analysis with 6.25 gives an approximate crude protein (CP) content of the sample. Fats and lipids are extracted continuously with ether. After evaporation of the solvent the residue remaining was the ether extract (EE) fraction. Crude fiber (CF) was determined as the fraction, which is not soluble in a defined concentration of alkalis and acids.

Metabolisable energy (AME) content in compound feed was calculated according to Alvarenga *et al*. (2013):

AME_n=4164.187+51.006EE-197.663ASH-35.689CF-20.593NDF (average literature data was used for neutral detergent fiber contents in diets).

The litter consisted of wheat straw were weighed than placed into broiler sheds and leveled to obtain an approximate depth of 10 cm. Samples of straw were collected and analyzed for dry matter and nitrogen content before the start of production.

Litter sampling: At the end of the trial representative fresh poultry litter samples were collected from broiler sheds according to Best Management Practice procedure, before the litter was totally removed (Lavergne at al. 2011). Samples were dried in forced draft oven at 65ºC for 24 hours, ground and stored in plastic bottles at room temperature till their analysis. Nitrogen and dry matter content in the litter were analyzed as described above.

The same hybrid (Cobb 500) was used in all five farms. One-day old chicks were received from a commercial hatchery. Chicks were weighed and determined their average weight at each farm. Literature data (Strakova *et al*. 2015, Von Bobrutzki *et al*. 2013) was used for calculating nitrogen content in whole bodies (including feathers) of one-day old chicken, dead birds end broiler chickens at the end of fattening period. One-day old chicken nitrogen content was determined by multiplying average nitrogen content in whole bodies with average body weight. The content of nitrogen in the dead birds and broilers was determined by the same principle.

Whole-farm nitrogen balance was estimated as difference between total nitrogen inputs (one-day old chickens, straw, feed) and total nitrogen outputs (broilers, dead chickens and litter). This balance is interested only in the nitrogen that cross the border of the farm. It is not concerned with nitrogen recycled within the farm.

RESULTS AND DISCUSSION

Length of the production cycle was ranged from 35-38 days (38 days - Farm 1, 35 days – Farm 2, 3, 4 and 5).

Number of broiler chickens on farms involved in the study, ranged from 5,030 to 40,000. Initial number of chickens, number of living and dead birds, average body weight (one-day old, living and dead birds) is summarized in Table 1.

Table 1. Number of chickens and average body weight of broilers

	Number of chickens			Average body weight (BW), g		
	1-day old	Dead birds	Final	1-day old	Dead birds	Final
Farm 1	5030	75	4955	41	1075	2150
Farm 2	40000	1400	38600	39	1147	2255
Farm 3	9700	145	9555	41	1054	2150
Farm 4	9850	147	9703	42	1091	2225
Farm 5	20150	302	19848	42	1078	2198

Chickens on the Farm 1 were fed with compound feed-D_2, while on the other farms chickens were fed with a compound feed-D_1. The content of crude nutrients in both compound feeds is presented in Table 2.

Table 2. Content of crude nutrients in compound feeds (as feed basis)

Variable	Compound feed (D_1)			Compound feed (D_2)		
	Starter	Grower	Finisher	Starter	Grower	Finisher
Dry matter, %	91.13	91.18	90.35	90.37	90.33	90.04
Crude protein, %	21.43	20.66	15.56	20.27	19.01	18.26
Crude fat, %	4.93	6.32	7.78	4.81	7.36	8.93
Crude fiber, %	1.95	1.67	1.86	1.90	2.00	2.64
Ash, %	6.50	6.05	5.15	6.55	5.55	5.40
N, %	3.43	3.31	1.49	3.24	3.04	2.92
AME, kJ/kg	12050.03	12724.45	13738.19	11977.61	13295.98	13650.04
AME, kcal/kg	2880.02	3041.22	3283.50	2862.72	3177.82	3262,44

Crude protein and dry matter content in wheat straw and litter is presented in Table 3. Data for nitrogen are expressed in dry matter bases. Litter nitrogen content in fresh litter ranged from 1.67% to 2.77%. All nitrogen, in excess of the bird's requirement, is excreted. It basically means that reducing concentrations of nitrogen, in poultry litter/ manure can be achieved through feed supplements and feeding programs (Sutton and Lander, 2003). Using free amino acids or a diet with a lower protein content, nitrogen excretion through feces can be reduced by 10-27%. The same source states that the use of enzymes (general) and phytases, highly digestible feedstuffs and phase feeding decreases nitrogen excretion by 5%, 5% and 10-33% respectively. According to Powers and Angel (2008) applying 6-phase feeding program to broiler chickens, litter nitrogen content was decreased 16.6%.

Table 3. Straw and litter characteristics

Variable	Farm 1		Farm 2		Farm 3		Farm 4		Farm 5	
	straw	litter	straw	litter	straw	litter	straw	litter	Straw	Litter
Dry matter, %	92.32	41.64	94.57	53.76	93.94	58.22	90.61	66.59	93.82	60.95
N, % of DM	0.47	4.02	0.57	4.24	0.33	3.78	0.43	4.17	0.52	4,11

Nitrogen inputs, nitrogen outputs and nitrogen input/output ratio at investigated farms are summarized in the Table 4. Nitrogen arrived on the investigated broiler farms in the form of purchased feed, imported chicken and imported straw. The greatest input of nitrogen to the all five farms, was purchased by feed (99.24% (F_1), 98.80% (F_2), 98.71% (F_3), 98.68% (F_4), and 98.67 (F_5) of total nitrogen inputs.

The largest output of nitrogen from the farms was achieved through the sale of broiler chickens (100% (F_1), 100% (F_2), 76.65% (F_3), 99.27% (F_4), and 99.27 (F_5) considering nitrogen which crossed the farms boundaries.

Table 4. Average whole-farm nitrogen balance per farm

Variable	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5
N inputs, kg					
Imported chicken	5.28	39.94	10.18	10.59	21.66
Imported feed					
Starter	58.97	696.29	166.35	169.78	346.43
Grower	290.62	2287.21	546.15	554.42	1145.26
Finisher	394.20	759.90	159.43	161.66	330.78
Imported straw	0.35	5.46	1.16	1.29	2.86
Total inputs	749.43	3788.80	883.28	897.75	1846.99

N outputs, kg					
Broilers	303.62	2480.73	585.48	615.29	1243.34
Manure (litter)	0	0	174.07	0	0
Dead birds	0	0	4.28	4.49	9.12
Total outputs	303.62	2480.73	763.83	619.78	1252.45
Inputs-outputs	445.81	1308.07	119.45	227.97	594.54
Inputs/outputs : 1	2.45	1.53	1.16	1.45	1.47
Output/input, %	40.51	65.47	63.31	69.04	67.81

Inputs/outputs N ratio ranged from 1.15:1 (F_3) to 2.45:1 (F_1). The best nitrogen balance was found on a farm (F_3), then on farms (F_4), (F_5), (F_2), (F_1) and amounted 1.16; 1.45; 1.47; 1.53 and 2.45 respectively. The reason for this balance was satisfactory system for disposal of dead birds on (F_3, F_4 and F_5) farms. An unsatisfactory system of dead birds removal, during the production cycle, was applied at the other farms. On those farms dead birds were buried near broiler houses, which is unacceptable from an environmental standpoint. Also, removing the manure from the farm immediately after the end of fattening was applied on the farm (F_3). Although the production practice at all farms was cleaning out broiler houses after every batch, only one farmer (F_3) have been sold their manure after batch, what is positively reflected on the balance of nitrogen. On the other farms, manure was stored up to one year in inadequate locations. According to investigations conducted in Louisiana nitrogen input/output ratio amounted 2.7:1 if the manure stays on the farm. According to Chastain *et al*. (2003) nitrogen losses from litter storage ranged from 17% (covered pile) to 30% (uncovered pile).

The results indicate that birds given Diet 1 had a similar (and better) nitrogen balance ratio (Table 4) and feed conversion ratio-FCR (Table 5) compared to the birds consuming Diet 2.

Table 5. Basic production characteristic at investigated farms

	Live weight gain, g/bird	Total feed intake, kg	Feed intake, g/bird	Feed conversion ratio, FCR
Farm 1	2109	24880	5020	2,38
Farm 2	2216	140400	3637	1,64
Farm 3	2109	32050	3354	1,59
Farm 4	2183	32550	3355	1,53
Farm 5	2156	66900	3371	1,56

Poorer live weight gain (LWG) and higher FCR at the Farm 1 might be explained by unbalanced protein/energy ratio in grower and finisher diet. According to Domaćinović *et al*. (2015) the optimal protein/energy ratio in starter diet should be 1: 570-590 kJ, while the preferred ratio in the grower diets is 1:630-650 kJ. Protein/energy ratio in grower and finisher diets by which were fed the broilers on the Farm 1 was 1:699 (grower) and 1:747 (finisher).

Consequently, feed intake decreased as the dietary content of energy increased and the protein intake decreased as well. As a result, live weight decreased and FCR was impaired. On the other hand starter diets had balanced protein/energy ratio, but protein and energy content were slightly above the Cobb and NRC (1994) recommendations. A direct consequence of shortage of protein and energy content in diets is increasing feed intake. Taking into account that the largest input of nitrogen to the farms is achieved through the broiler diets, an unfavorable balance (2.45) could have been expected.

Crude protein content in starter and grower diet used at farms F_2, F_3, F_4 and F_5, was in line with the Cobb recommendations, while in the finisher diets was below recommendations. Protein/energy ratio in starter diet was balanced. Energy content in starter and grower diets was nearly optimal, only in the finisher diets was slightly higher. Considering this, as well as the shorter fattening period, a better nitrogen balance and FCR in these farms is understandable. A feed efficiency is much better in the first weeks of broiler production and then declines with increased target market weight. Since the feed efficiency declines as broilers get older, this fact should be taken into consideration when comparing different age flocks.

CONCLUSIONS

Farm nitrogen balances are a useful indicator for nitrogen losses and the potential for improving N management. The investigation has shown that poultry feed has a crucial impact on the nitrogen balance on the farm. Improving the whole-farm nitrogen balance can be achieved by applying nutrition strategies focused on reducing nitrogen excretion. Broiler chickens generally digest about 85 to 90% of the dry matter of the feed. One of the most important tasks is to formulate diets which improve the efficiency of nutrient retention by animals and decrease their excretion in urine and feces. To achieve this it is necessary to harmonize the amount of protein in the diet with the real broiler requirements, or apply phase broilers feeding. Also, the amount of energy in diets should be in line with the recommendation. Diets must be high enough in energy, provided from fat and carbohydrates, otherwise, dietary protein will be used by the bird to meet a substantial part of its energy requirement. It should emphasize a balanced protein/energy ratio in diets. For instance the use of free amino acids and highly digestible feedstuffs is a very efficient way to improve dietary protein quality and reduce nitrogen excretion.

Microclimatic conditions in the broiler house should be managed in a way that minimize litter moisture and improve litter quality. Wet litter is the primary cause of ammonia emissions. Therefore, the proper litter management is also important factor for optimal whole farm nitrogen balance.

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SOIL LOSS ESTIMATION USING THE INTERO MODEL IN THE S1-2 WATERSHED OF THE SHIRINDAREH RIVER BASIN, IRAN

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ABSTRACT

Soil erosion is one of the main problems of land degradation of agricultural land, especially in the mountainous areas. This negative process is one of the key problems to the environment and water resources in Iran. Using the computer-graphic modelling, we calculated sediment yield and peak discharge of the S1-2 catchment, of the Shirin-Dareh Basin of the Caspian Sea watershed. The area characterized cold winters (the minimum of 24.4°C) and warm, dry summers (the absolute maximum air temperature of 34.6°C; the average annual precipitation of 328 mm). The coefficient of the region's permeability, S1, is calculated on 0.84. The structure of the river basin, according to water permeability, is the following: f0, poor water permeability rocks, 53%; fpp, medium permeable rocks, 41%; fp, very permeable products from rocks: 6%. The most common soil type in the studied area is Inceptisols with Calcic horizon. The river basin is under the mountain pastures (51%) and the rest (49%) is the ground without grass vegetation and plough-lands. The coefficient of the river basin planning is calculated on 0.75. The coefficient of the vegetation cover is calculated on 0.9. We calculated the soil losses from the S1-2 catchment on 20404 $m^3 yr^{-1}$ and the peak discharge on 209 m^3s^{-1} (for the incidence of 100 years). The value of the Z coefficient of 0.917 indicates that the river basin belongs to the second destruction category, where the strength of the erosion process is high. With this study we provided new information about the recent state of the sediment yield of the S1-2 catchment, of the Shirin-Dareh Basin in the North Khorasan province of Iran in formats that can simplify the management in the watersheds, demonstrating the possibility of Soil Loss Estimation using the IntErO Model.

Keywords: *soil erosion, IntErO Model, sediment yield, ShirinDareh watershed*

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INTRODUCTION

Various environmental problems are involving the destruction of the natural balance as a result of the misuse or abuse of nature. Soil is one of the basic elements of nature and its problems are essential environmental problems (Dengiz and Akgül, 2005).

Soil degradation caused by erosion, together with rapid population increase, are ranked as the most important environmental problems in the world (Pimentel, 2006; Nikkami, 2012, Stoffel and Huggel, 2012, Ristic *et al.*, 2001) where the erosion is a key driver of land degradation heavily affecting sustainable land management in various environments worldwide (Stoffel *et al.*, 2013; Verheijen *et al.*, 2009); the biggest threat to the conservation of soil and water resources (Bayramin *et al.*, 2003).

Soil erosion is a growing problem globally and is serious problem in Iran. The off-site impact of loss of reservoir capacity is increasing in this Region. Quantitative information on soil loss is needed for erosion risk assessment. The modelling of the erosion process has progressed rapidly, and a variety of models have been developed to predict both runoff and soil loss. The authors of this study used the computer - graphic models (Spalevic, 2011; Spalevic, 1999a) for prediction of soil erosion intensity from the catchment area – IntErO model (Spalevic, 2011).

The objective of this research was characterization of the erosion processes in relation to the recent state of the sediment yield in the S1-2 Watershed of the Shirindareh River Basin. The results, consistent with previous researches on the neighbouring river basins, presented in formats that may be further used for the efficient management and protection, illustrating the possibility of modelling sediment yield by the IntErO model.

MATERIAL AND METHODS

The study was conducted in the area of the S1-2 watershed of the Shirindareh River Basin of the Caspian Sea Watershed (Figure 1).

Figure 1. Study area of the S1-2 watershed, the Shirindareh River Basin, Iran

The studied river basin is placed in the mountainous area of the north-eastern part of Iran. The river dam has been constructed on the main river of the basin; surface runoff is used for supply of water for drinking and agriculture and it is important to keep the reservoir in good condition, decreasing sedimentation and controlling the runoff at the upstream watersheds (Behzadfar *et al.*, 2015).

The S1-2 watershed is covering an area of 56 km^2. It is one of the medium to big sized watersheds of the natural entity of the Shirindareh region. During the field work, using a morphometric methods, various data on intensity and forms of soil erosion, land use, and the measures taken to reduce or mitigate erosion were recorded.

Figure 2. Details from the filed visit on the Shirindareh River Basin, Iran V. Spalevic & M. Behzadfar (Feb. 2015): Problems with overgrazing and livestock traces

According to our calculations, the shortest distance between the fountainhead and the mouth, lv, is 7.5 km; and the total length of the main watercourse with tributaries is 129 km. The relief has very pronounced dynamics; the average slope gradient in the river basin, Isr, is calculated on 26% what indicates that in the river basin prevailing steep slopes. The average river basin altitude Hsr, is calculated on 1700 m; the average elevation difference of the river basin, D, on 274 m.

The analysis of the geological structure and soil characteristics of the area was based on the research of the National Geological Survey Organization (NGS) led by Bolourchi (1987), who analysed the physical and chemical properties of all geological formations of North Khorasan province, including those in the study area of the S1-2

Basin. Climatological data were received from the North Khorasan Meteorological stations of Iran.

For obtaining data on forecasts of sediment yield and peak discharge from the basin we used the IntErO model (Intensity of Erosion and Outflow - program package; Spalevic, 2011), with the Erosion Potential Method – EPM (Gavrilovic, 1972) embedded in the algorithm of this computer-graphic method.

The basic analytical equation for the calculation of erosion-induced soil losses, as developed by Gavrilovic (1972), is as follows:

$$G_{yr \times sp^{/1}} = T \times H_{yr} \times \pi \sqrt{Z^3} \times R_u$$

where: $G_{yr\ sp}^{-1}$– specific annual total erosion-induced sediment yield reaching the confluence, m^3 yr^{-1} km^{-2}; T – temperature coefficient of the catchment; H_{yr} – amount of rainfall, mm; π – 3.14; Z– coefficient of erosion; R_u– coefficient of retention of soil in the catchment.

This methodology is currently in use in: Bosnia & Herzegovina, Brazil, Bulgaria, Croatia, Czech Republic, Italy, Macedonia, Montenegro, Morocco, Serbia, South Africa and Slovenia (Gazdic *et al.*, 2015; Spalevic *et al.*, 2015a, 2015b, 2015c, 2015d, 2015e, 2015f, 2015g, 2015h, 2015i, 2015k; Kostadinov *et al.*, 2014, Curovic *et al.*, 1999). In Iran have been successfully used in the regions of Chamgardalan, Kasilian, Kermanshah, Razavi Khorasan (Barovic *et al.*, 2015; Behzadfar *et al.*, 2015; Behzadfar *et al.*, 2014a; Behzadfar *et al.*, 2014b; Sadeghi, 2005, Sadeghi, 1993; Yousefi *et al.*; 2014; Zia Abadi & Ahmadi, 2011; Amiri, 2010) and other regions.

RESULTS AND DISCUSSION

The climate in the studied area is continental, with the absolute maximum air temperature of 34.6°C and the negative -24.4°C. The average annual air temperature, t0, is 10.2°C. The average annual precipitation, H_{yr}, is 328.4 mm (Source: Data from the North Khorasan Meteorological stations of Iran).

The temperature coefficient of the region, T, is calculated on 1.06; the amount of torrential rain, hb, on 35.61 mm.

Vegetation and land use. The studied area is located in Middle- East of the Kope-Dagh geographical region. According to the available literature and the analysis using the Google maps and Google Earth, including the records from the field visits, the pastures and meadows are covering the area of 51% and non-arable land of 49%. The coefficient of the river basin planning, Xa, is calculated on 0.75. The coefficient of the vegetation cover, S2, is calculated on 0.9.

Soil erosion and runoff characteristics. The dominant erosion form in this area is surface erosion and is the most pronounced on the steep slopes without vegetation cover. Problems with overgrazing and livestock traces are recorded also all over the studied area.

Processing the input data by the IntErO model we received the results in relation to the sediment yield of the S1-2 Watershed of the Shirindareh River Basin of Iran. The results are presented at the Table 1.

Table 1. The IntErO report for the S1-2 watershed river basin

River basin area	F	56.06	km²
The length of the watershed	O	40.28	km
Natural length of the main watercourse	Lv	7.54	km
The shortest distance between the fountainhead and mouth	Lm	6.59	km
The total length of the main watercourse with tributaries of I and II class	ΣL	128.97	km
River basin length measured by a series of parallel lines	Lb	11.81	km
The area of the bigger river basin part	Fv	31.64	km²
The area of the smaller river basin part	Fm	24.42	km²
Altitude of the first contour line	h0	1500	m
The lowest river basin elevation	Hmin	1426	m
The highest river basin elevation	Hmax	2189	m
A part of the river basin consisted of a very permeable products from rocks	fp	0.06	
A part of the river basin area consisted of medium permeable rocks	fpp	0.41	
A part of the river basin consisted of poor water permeability rocks	fo	0.53	
A part of the river basin under grass, meadows, pastures and orchards	ft	0.51	
A part of the river basin under plough-land and without vegetation	fg	0.49	
The volume of the torrent rain	hb	36.16	mm
Average annual air temperature	t0	9.8	°C
Average annual precipitation	Hyr	335	mm
Types of soil products and related types	Y	1.1	
River basin planning, coefficient of the river basin planning	Xa	0.75	
Numeral equivalents of visible and clearly exposed erosion process	φ	0.59	
Coefficient of the river basin form	A	1.04	
Coefficient of the watershed development	m	0.28	
Average river basin width	B	4.75	km
(A)symmetry of the river basin	a	0.26	
Density of the river network of the basin	G	2.3	
Coefficient of the river basin tortuousness	K	1.14	

Average river basin altitude	Hsr	1700.45	m
Average elevation difference of the river basin	D	274.45	m
Average river basin decline	Isr	26.01	%
The height of the local erosion base of the river basin	Hleb	763	m
Coefficient of the erosion energy of the river basin's relief	Er	88.76	
Coefficient of the region's permeability	S1	0.84	
Coefficient of the vegetation cover	S2	0.9	
Analytical presentation of the water retention in inflow	W	0.4838	m
Energetic potential of water flow during torrent rains	2gDF^½	549.42	m km s
Maximal outflow from the river basin	Qmax	209.29	m^3/s
Temperature coefficient of the region	T	1.04	
Coefficient of the river basin erosion	Z	0.917	
Production of erosion material in the river basin	Wyr	53820.52	m^3/yr
Coefficient of the deposit retention	Ru	0.379	
Real soil losses	Gyr	20404.44	m^3/yr
Real soil losses per km^2	Gyr/km^2	363.98	m^3/km^2yr

The coefficient of the river basin form, A, is calculated on 1.04. Coefficient of the watershed development, m, is 0.28 and average river basin width, B, is 4.75 km. (A)symmetry of the river basin, a, is calculated on 0.26 and that indicates that there is a possibility for large flood waves to appear in the studied river basin. The value of G coefficient of 2.3 indicates there is very high density of the hydrographic network.

The height of the local erosion base of the river basin, Hleb, is 763 m. Coefficient of the erosion energy of the river basin's relief, Er, is calculated on 88.76. According to the erosion type, the dominant process is surface erosion.

The value of Z coefficient of 0.917 indicates that the river basin belongs to II destruction category. The strength of the erosion process is high, and according to the erosion type, it is intrusive erosion. We calculated the soil losses from the S1-2 catchment on 20404 m^3 yr^{-1} and the peak discharge on 209 m^3s^{-1} (for the incidence of 100 years).

CONCLUSIONS

Sediment yield and peak discharge of the S1-2 catchment of the Shirin-Dareh Basin of the Caspian Sea watershed were calculated using the computer-graphic modelling. The results of the processing of the inputs, using the IntErO model, are the following:

- The structure of the river basin, according to water permeability, is the following: f0, poor water permeability rocks, 53%; fpp, medium permeable rocks, 41%; fp, very permeable products from rocks: 6%. The coefficient of the region's permeability, S1, is calculated on 0.84.

- The most common soil type in the studied area is Inceptisols with Calcic horizon.
- The river basin is under the mountain pastures (51%) and the rest (49%) is the ground without grass vegetation and plough-lands.
- The coefficient of the river basin planning is calculated on 0.75.
- The coefficient of the vegetation cover is calculated on 0.9.
- Calculated soil losses from the S1-2 catchment are 20404 m^3yr^{-1} and the peak discharge is 209 m^3s^{-1} (for the incidence of 100 years).
- The value of the Z coefficient of 0.917 indicates that the river basin belongs to the second destruction category, where the strength of the erosion process is high.

With this study we provided new information about the recent state of the sediment yield of the S1-2 catchment, of the Shirin-Dareh Basin in the North Khorasan province of Iran in formats that can simplify the management in the watersheds, demonstrating the possibility of Soil Loss Estimation using the IntErO Model. For more reliable conclusions measurements are needed for the model verification, including additional analysis in relation to the land use changes.

This study further confirmed the findings of Barovic *et al.*, 2015; Behzadfar *et al.*, 2015, 2014a, 2014b; Amini *et al.*, 2014; Yousefi *et al.*, 2014; Moradi *et al.*, 2015; Zia Abadi & Ahmadi, 2011; as well as Amiri, 2010; Khaleghi, 2005; Maleki, 2003; Nadjafi, 2003; Sadeghi 1993 in possibility of implementing the Erosion Potential Method in Iran, what leads to the conclusion that the IntErO model may be a useful tool for researchers in calculation of runoff and sediment yield for the river basins of the Caspian Sea Watershed with the similar physical-geographical characteristics like the Shirindareh river basins. We would like to highlight that the team of authors have the same good experience about the simplicity in operation and practicality in use of the IntErO also in the Saudi Arabia (Al-Turki *et al.*, 2015) and in the Western Balkans (Barovic & Spalevic, 2015; Vujacic & Spalevic, 2015; Spalevic *et al.*, 2014a, 2014b, 2014c, 2014d, 2013a, 2013b, 2013c, 2013d, 2013e, 2003a, 2003b, 1999b, 1999c).

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CALCULATION OF SEDIMENT YIELD USING THE INTERO MODEL IN THE S1-3 WATERSHED OF THE SHIRINDAREH RIVER BASIN, IRAN

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ABSTRACT

Soil erosion is a natural process caused generally by the force of water (running water and raindrops) or wind. The process involves not only the detachment of soil particles (on-site), but also their transfer and deposition elsewhere in the river basin and out of the catchment (off-site). The assessment of soil erosion may be performed using and analyzing measurements data (sediment discharge series and soil erosion measurements) or applying various analytical models. It is well known fact that the measurements results are available only in a few experimental catchments in most of the countries all over the World and as a consequence the researchers are frequently using the analytical models. For calculation of the Sediment yield in the S1-3 Watershed of Iran we used the IntErO model (Spalevic, 2011) based on EPM method (Gavrilovic, 1972). Calculated peak discharge from the S1-3 Watershed was 87 m^3s^{-1} for the incidence of 100 years and the net soil loss was 5,574 m^3km^{-2}, specific 194 m^3 km^{-2} per year. Taking into consideration the results of this study and previous experiences of the other researchers, it was concluded that the IntErO Model may be applied to the other regions similar to Shirindareh basin for calculation of sediment yield and identification of critical areas in watersheds.

Keywords: *soil erosion, IntErO Model, sediment yield, ShirinDareh watershed*

INTRODUCTION

Soil degradation and desertification risk is a globally acknowledged issue with ecological, socioeconomic, cultural and political implications at both the regional and local scales. Those processes occur in both developed and emerging countries and affect arid, dry and even sub-humid areas (Strijker, 2005; Koulouri and Giourga, 2007; Helming *et al.*, 2011).

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Soil degradation caused by erosion, together with rapid population increase, are ranked as the most important environmental problems in the world (Stoffel and Huggel, 2012; Ristic *et al.*, 2001) where the erosion is a key driver of land degradation heavily affecting sustainable land management in various environments worldwide (Ballesteros-Cánovas *et al.*, 2015; Stoffel *et al.*, 2013; Verheijen *et al.*, 2009). Every year, soil erosion leads to the loss of about ten million hectares of cropland, which reduces the limited amount of arable land available for food production, thereby contributing to malnourishment in millions of people (Pimentel, 2006). In addition, the accumulation of large volumes of sediment can cause severe sedimentation in reservoirs and channel beds, resulting in the loss of various functions in these hydraulic projects. Thus, it is important to determine the sediment yield rates in watersheds, which can provide a good basis to facilitate soil erosion control and river basin management (Zhao *et al.*, 2015).

Soil erosion is a growing problem globally and is serious problem in Iran. Quantitative information on soil loss is needed for erosion risk assessment. The modelling of the erosion process has progressed rapidly, and a variety of models have been developed to predict both runoff and soil loss. The authors of this study used the computer - graphic models (Spalevic, 2011; Spalevic, 1999a) for prediction of soil erosion intensity from the catchment area – IntErO model (Spalevic, 2011).

The objectives of the present study were: (1) to quantify the sediment yield in the studied S1-3 Watershed of the Shirindareh River Basin on the north-eastern part of Iran; (2) testing the possibility of application of the IntErO model in the conditions of the Caspian Sea Watersheds.

MATERIAL AND METHODS

The study was conducted in the area of the S1-3 watershed of the Shirindareh River Basin of the Caspian Sea Watershed (Figure 1).

Figure 1. Study area of the S1-3 watershed, the Shirindareh River Basin, Iran

The studied river basin of the S1-3 watershed is located in the north-eastern part of Iran and encompasses an area of 28.6 km^2. In terms of geomorphology and climate, it is part of the natural entity of the Shirindareh River Basin of the Razavi Khorasan that lies between steep slopes and plains bordering with Turkmenistan on Chaat region, draining to the Caspian Sea Watershed in the Gulf of Hasan Ghuly.

Shirindareh river basin area has the important strategic values for North Khorasan province. Because of quality and quantity of surface runoff and need to supply of drinking water and agriculture a rock fill dam has been constructed on the main river. The management of upland areas is very important to increase performance of the dam (Behzadfar *et al.*, 2015).

The shortest distance between the fountainhead and the mouth, lv, is 7 km; and the total length of the main watercourse with tributaries is 47.7 km. The average slope gradient in the river basin, Isr, is calculated on 23.50% what indicates that in the river basin prevailing steep slopes. The average river basin altitude Hsr, is calculated on 1,798 m.

Figure 2. Details from the filed visit: Problem with overgrazing (February 2015)

Fieldwork was undertaken to collect detailed information on the intensity and the forms of the soil erosion, the status of the plant cover, the type of land use, and the measures in place contributing to the reduction or alleviation of 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, the density of the erosion rills, the degree of the rills, and other relevant parameters. Different forms: the shape of the slope, the depth of the erosion base and the density of erosion rills were determined.

Climatological data were received from the North Khorasan Meteorological stations of Iran. Pedological survey was based on the research of the National Geological Survey

Organization (NGS) led by Bolourchi *et al*. (1987), who analysed the physical and chemical properties of all geological formations of North Khorasan province, including those in the study area of the S1-3 Basin.

For the obtaining data on forecasts of peak discharge from the basin and the intensity of the soil erosion we used the program package Intensity of Erosion and Outflow - IntErO (Spalevic, 2011) that is an integrated, second-generation version of the program "Surface and Distance Measuring" (Spalević, 1999) and the program "River basins" (Spalević, 2000). The Erosion Potential Method – EPM (Gavrilovic, 1972) is embedded in the algorithm of this computer-graphic method.

The model is currently in use in all the countries of Western Balkans, but also used by some researchers from Czech Republic and Italy (Gazdic *et al.*, 2015; Spalevic *et al.*, 2015a, 2015b, 2015c, 2015d, 2015e, 2015f, 2015g, 2015h, 2015i, 2015k; Kostadinov *et al.*, 2014, Curovic *et al.*, 1999). The EPM and/or the IntErO model have been successfully used in some regions of Iran: Chamgardalan, Kasilian, Kermanshah, Razavi Khorasan (Barovic *et al.*, 2015; Behzadfar *et al.*, 2015; Behzadfar *et al.*, 2014a; Behzadfar *et al.*, 2014b; Sadeghi, 1993; Amiri, 2010).

RESULTS AND DISCUSSION

The geological structure and soil characteristics of the area. Our analysis, extracting the geological data from the Geological map of Iran (Bolourchi *et al*., 1987), shown that the poor water permeability rocks prevails. The geological structure of the studied river basin is presented at the Table 1.

Table 1. The geological structure of the S1-3 watershed of the Shirindareh River Basin

A part consisted of a very permeable products from rocks	fp	0.07
Apart of the river basin area consisted of medium permeable rocks	fpp	0.42
A part of the river basin consisted of poor water permeability rocks	fo	0.51

The coefficient of the region's permeability, S1, is calculated on 0.83. The most common soil type in the studied area is Inceptisols with Calcic horizon.

There is a highly variable climate and human pressure on the land in the studied area of the S1-3 Watershed of the Shirindareh River Basin. The climate is continental, with cold winters and warm, dry summers. The Basic climatological data needed for calculation of Soil erosion intensity are presented at the Table 2.

Table 2. Basic climatological data needed for calculation of Soil erosion intensity

The absolute maximum air temperature	34.6 [°C]
The absolute negative air temperature	-24.4 [°C]
The average annual air temperature (t0)	10.2 [°C]
The average annual precipitation (H_{year})	328.4 [mm]

Source: The North Khorasan Meteorological stations of Iran

The temperature coefficient of the region, T, is calculated on 1.01; the amount of torrential rain, hb, on 36.84 mm.

Vegetation and land use. Good vegetation cover reduces overland flow velocity and increases infiltration by protecting the soil against rain drop impact and reducing the erosive capacity of the rain (Asfaha *et al.,* 2015; Molina *et al*., 2007) whereas deforestation leads to increased peak discharge (Bonan *et al*., 2004).The studied area is located in Middle-East of the Kope-Dagh geographical region. According to the available literature and the analysis using the Google maps and Google Earth, including the records from the field visits almost all the studied area is used for the pastures and meadows (Table 3).

Table 3. Land use structure at the S1-3 watershed of the Shirindareh River Basin

A part of the river basin under forests	fs	0
A part of the river basin under grass, meadows, pastures and orchards	ft	0.98
A part under bare land, plough-land and ground without vegetation	fg	0.02

The coefficient of the river basin planning, Xa, is calculated on 0.61. The coefficient of the vegetation cover, S2, is calculated on 0.8.

Soil erosion and runoff characteristics. The dominant erosion form in this area is surface erosion. Problems with overgrazing and livestock traces are recorded also all over the studied area.

The coefficient of the river basin form, A, is calculated on 0.81. Coefficient of the watershed development, m, is 0.37 and average river basin width, B, is 3.63 km. (A)symmetry of the river basin, a, is calculated on 1.1 and that indicates that there is a possibility for large flood waves to appear in the studied river basin. The value of G coefficient of 1.66 indicates there is very high density of the hydrographic network.

The height of the local erosion base of the river basin, Hleb, is 578 m. Coefficient of the erosion energy of the river basin's relief, Er, is calculated on 79.5. According to the erosion type, the dominant process is surface erosion.

The value of Z coefficient of 0.748 indicates that the river basin belongs to II destruction category. The strength of the erosion process is high, and according to the erosion type, it is intrusive erosion. We calculated the soil losses from the S1-3 catchment on 5574 m^3 yr^{-1} and the peak discharge on 87 m^3s^{-1} (for the incidence of 100 years).

Processing the input data using the IntErO model we received the results in relation to the sediment yield for the S1-3 Watershed of the Shirindareh River Basin of Iran (Table 4).

Table 4. Part of the IntErO report for the S1-3 Watershed River Basin

Input data			
River basin area	F	28.68	km²
The length of the watershed	O	29.16	km
Natural length of the main watercourse	Lv	7.03	km
The shortest distance between the fountainhead and mouth	Lm	6.43	km
The total length of main watercourse with tributaries of I & II class	ΣL	47.7	km
River basin length measured by a series of parallel lines	Lb	7.91	km
The area of the bigger river basin part	Fv	22.22	km²
The area of the smaller river basin part	Fm	6.46	km²
Altitude of the first contour line	h0	1700	m
The lowest river basin elevation	Hmin	1611	m
The highest river basin elevation	Hmax	2189	m
The volume of the torrent rain	hb	36.84	mm
Incidence	Up	100	years
Average annual air temperature	t0	9.3	°C
Average annual precipitation	Hyr	343	mm
Types of soil products and related types	Y	1.1	
River basin planning, coefficient of the river basin planning	Xa	0.61	

Results			
Numeral equivalents of visible and clearly exposed erosion process	φ	0.64	
Coefficient of the river basin form	A	0.81	
Coefficient of the watershed development	m	0.37	
Average river basin width	B	3.63	km
(A)symmetry of the river basin	a	1.1	
Density of the river network of the basin	G	1.66	

Results			
Coefficient of the river basin tortuousness	K	1.09	
Average river basin altitude	Hsr	1798.79	m
Average elevation difference of the river basin	D	187.79	m
Average river basin decline	Isr	23.5	%
The height of the local erosion base of the river basin	Hleb	578	m
Coefficient of the erosion energy of the river basin's relief	Er	79.5	
Coefficient of the region's permeability	S1	0.83	
Coefficient of the vegetation cover	S2	0.8	
Analytical presentation of the water retention in inflow	W	0.4934	m
Energetic potential of water flow during torrent rains	2gDF^½	325.07	m km s
Maximal outflow from the river basin	Qmax	86.79	$m^3 s^{-1}$
Temperature coefficient of the region	T	1.01	
Coefficient of the river basin erosion	Z	0.748	
Production of erosion material in the river basin	Wyr	20284.32	$m^3 yr^{-1}$
Coefficient of the deposit retention	Ru	0.275	
Real soil losses	Gyr	5574.57	$m^3 yr^{-1}$
Real soil losses per km2	Gyr km²	194.37	$m^3 km^2 yr^{-1}$

CONCLUSIONS

The study was conducted in the area of the S1-3 Basin of Shirindareh region, the main tributary of the river Atrakin Iran. Many factors have influenced the development of erosion processes in the studied territory. 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.

We calculated the soil erosion intensity and runoff using the IntErO model. According to our findings, it can be concluded that there is a possibility for large flood waves to appear in the studied S1-3 river basin.

Calculated peak discharge was 87 $m^3s^{-1}$for a return period of 100 years. The value of Z coefficient of 0.748 indicates that the river basin belongs to the second destruction category out of five. The calculated net soil loss from the river basin was 5574 m³ per year, specific 194 m^3km^{-2} per year.

This study further confirmed the findings of Barovic *et al.*, 2015; Behzadfar *et al.*, 2015, 2014a, 2014b; Amini *et al.*, 2014; Moradi *et al.*, 2015; as well as Amiri, 2010; Khaleghi, 2005; Maleki, 2003; Nadjafi, 2003; Sadeghi 1993 in possibility of implementing the

Erosion Potential Method in Iran. That leads to the conclusion that the IntErO model may be a useful tool for researchers in calculation of runoff and sediment yield for the river basins of the Caspian Sea Watershed with the similar physical-geographical characteristics like the Shirindareh River Basins. The team of authors have the same good experience about the simplicity in operation and practicality in use of the IntErO also in Saudi Arabia (Al-Turki *et al.*, 2015) and in the Western Balkans (Barovic & Spalevic, 2015; Vujacic & Spalevic, 2015; Spalevic *et al.*, 2014a, 2014b, 2014c, 2014d, 2013a, 2013b, 2013c, 2013d, 2013e, 2003a, 2003b, 1999b, 1999c).

Because of high erosion rate, complex measures must be taken for soil conservation and environmental protection in the studied area. That is key requirement for better socio-economic growth in the future.

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RELATIONS BETWEEN SOIL CHEMICAL PROPERTIES AND CADMIUM CONTENT IN GREEN MASS OF SILAGE MAIZE

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ABSTRACT

Cadmium content in soil is an important factor which determines the content of this heavy metal in plants. However, many other factors including soil pH, content of organic matter, other trace minerals in soil which could reduce or enhance cadmium uptake by roots of plants as well as anthropogenic routes of cadmium contamination (mining, superphosphates and industry) can have an influence on the cadmium concentrations in plant tissue. A three years study was conducted to evaluate cadmium content in green mass of silage maize in certain areas of Central Bosnia region. A multiple linear regression (MLR) model was developed to predict maize tissues cadmium concentration as function of different factors such as soil cadmium content, pH of soil, organic matter in soil as well as phosphorus, potassium, zinc and iron content in soil. The results indicate huge variability of cadmium content in soil (maximum value was more than 3fold greater than the minimum value) and green mass of maize (maximum to minimum ratio greater than 100). Cadmium concentration in all investigated samples of maize was below maximum tolerable levels in ruminant nutrition. Using a stepwise multiple linear regression method, a significant model emerged ($F_{2.14} = 55.193$, $p<0.001$; $R^2 = 0.887$). Significant variables were phosphorus (Beta = 0.813, $p<0.001$) and potassium (Beta = -0.401, $p<0.005$) content in soil. Soil pH, organic matter, cadmium, zinc and iron were not significant in this model. Insignificant correlation between soil and plant cadmium content ($r=0.374$, $p=0.07$) indicates that the presence of cadmium in the soil may not be the main determinant of its content in plants.

Keywords: *cadmium, soil chemical.properties, silage maize, MLR*

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INTRODUCTION

Cadmium (Cd) accumulates in plants grown in high-cadmium soils. Natural cadmium levels found in phosphates from sedimentary rocks range from 3 to 100 $mgkg^{-1}$ depending on their location (Singh, 1994). Additionally, annual application of phosphorus fertilizers is a significant source of Cd in the agricultural soils. Phosphate fertilizers, among all mineral fertilizers, are generally the major source of cadmium (McLaughlin *et al*., 1996). Also, atmospheric deposition of cadmium on the surface of soil and plants are recognized as important factor of food chain contamination. Data copied from EU risk assessment report implies that the cadmium atmospheric deposition ranged between 0.15 and 4 g/ha/year for 2002 (EU, 2007). Total soil cadmium content is not a good indicator of cadmiums migration possibility into plant tissue. The amounts of cadmium uptake by plants depends on many factors including soil texture, content of organic matter, pH of soil and the amount of rainfall (Jeng and Singh, 1995). Namely, these factors combined determine the ratio of cadmium leaching from soil and its uptake by plants. Additionally, it seems that the plant genotype can have an influence on the cadmium accumulation in plant tissue (Lehoczky and Kiss, 2006). Cadmium mostly accumulates in kidneys, but higher concentration can be found in liver, testes, pancreas and spleen of animals (and humans) as well, expressing cumulative toxic effect (NRC, 2005). Short term assessing of cadmium concentrations in food chain does not offer a valid picture of cadmium food contamination. Many factors influence the long-term accumulation of cadmium in the body making it difficult to evaluate the effect of different factors that contribute to cadmium contamination in different areas. Therefore, the aim of this study was to discriminate the most important factors (fertilizer, soil, pH and organic matter) that influence the cadmium content in maize.

MATERIAL AND METHODS

The research was conducted in four areas of the Central Bosnia region (Figure 1) which differ in agricultural practice, level of industrialization, urbanization and soil properties.

The crops chosen for this study were maize and green mass of natural pastures which serve as the major feedstuff at local dairy and sheep farms. Periodically, during three years, soil and animal feed samples were collected from each of the selected areas. Soil samples were taken using a stainless steel shovel from the depth of 0-20 cm, in which the roots of crops mainly distribute. Each soil sample consisted of up to ten subsamples taken from an area of ca 500 m^2. Five whole plants of maize per locality were ground and mixed after which the biomass sample was taken. The samples were dried and sifted prior to the determination of pH, potassium, phosphorus, iron and zinc as well as organic matter content in the soil and total cadmium content in soil and plants.

Figure 1. Map of selected localities

Soil pH was determined in a water solution (ISO 10390, 1994). SOC was determined by wet combustion of organic matter in H_2SO_4 and $K_2Cr_2O_7$- dichromate method (Mineev *et al*., 2001). Soil potassium and phosphorus content were determined according to AL by ammonium lactate-acetic acid extraction described by Egner *et al*. (1960). The content of extracted phosphorous is measured calorimetrically and the content of potassium by flame photometry. Inductively Coupled Plasma Mass Spectrometer (ICP-MS) was used to determine total cadmium content in substrates, while the total content of iron and zinc in soil was determined by Inductively Coupled Plasma Optic Emission Spectrometer (ICP-OES) after wet digestion of samples in ultra-pure HNO_3.

A multiple linear regression (MLR) model was created using the software package SPSS 17 in order to predict maize tissues cadmium concentration as function of different factors such as soil cadmium content, pH of soil, organic matter in soil as well as phosphorus, potassium, zinc and iron content in soil.

RESULTS AND DISCUSSION

Results of the soil properties and concentration of trace minerals in soil and whole plants of maize are presented in Table 1.

Table 1. Some indicators of soil quality and trace elements content in soils and plants at investigated localities

	Locality				Average
	Kalesija	Vitez	Kakanj	Butmir	
pH (H_2O)	5.96±0.60	7.00±0.28	7.93±0.08	6.45±0.21	6.83±0.29
pH (KCl)	4.77±0.67	6.05±0.35	7.22±0.05	5.07±0.28	5.77±0.34
P_2O_5, mg/100 g	1.27±1.27	7.95±9.12	2.99±2.14	16.79±1.22	7.25±3.44
K_2O, mg/100 g	37.33±19.33	56.60±48.79	36.37±14.26	17.64±1.32	36.98±20.92
O. matter, %	2.9±0.66	2.80±0.71	3.38±0.58	4.30±0.01	3.34±0.49
Cd soil, mg/kg	0.56±0.04	1.09±0.52	0.51±0.06	0.62±0.09	0.70±0.18
Zn soil, mg/kg	71.18±13.49	91.82±41.12	95.43±24.53	68.75±3.28	81.79±20.60
Fe soil, mg/kg	35846±12658	30845±2821	31910±7110	23740±1364	30585±598
Cd plant, mg/kg	0.001±0.000	0.006±0.006	0.023±0.013	0.098±0.013	0.032±0.08

Soil pH ranged from 5.96 to 7.93, mean value 6.83±0.29. It varied from alkaline to slightly acidic. The organic matter content was also variable and generally all the soils had moderate content of humus whereby the soils at Butmir and Kakanj were much richer in humus comparing to soils at Vitez and Kalesija sites. Content of phosphorous varied widely in the studied soils indicating different agronomic practice (intensity of fertilization) among investigated sites. Cd, Zn, and Fe contents in the studied soils differed markedly between sites. The Pearson correlation matrix for all investigated parameters is shown in Table 2.

Table 2. Pearson correlation matrix for total soil and plant properties

	Cd plant	pH	P_2O_5	K_2O	O. matter	Cd soil	Zn soil	Fe soil
Cd plant	1,000							
pH	-0.233	1,000						
P_2O_5	0.854***	-0.334	1,000					
K_2O	-0.483*	0.194	-0.101	1,000				
O. matter	0.753***	-0.025	0.675***	-0.261	1,000			
Cd soil	0.374	-0.49*	0.28	-0.488**	0.077	1,000		
Zn soil	-0.169	0.503*	-0.073	0.317	0.302	-0.404	1,000	
Fe soil	-0.398	0.191	-0.41	0.145	0.064	-0.265	0.646**	1,000

***; **; * Correlation is significant at the 0.001, 0.01 and 0.05 level respectively

Phosphorus and organic matter content in soil increase cadmium content in maize ($p<0.001$) and these strong associations are in line with the statement that the cultivated areas were contaminated by cadmium through different agricultural practice. This is opposite to findings of Ramachandran and D'Souza (1998) who stated that organic matter can regulate the availability of heavy metals through chelation reaction and that the complex compounds of trace elements with organic material are unavailable for plants. In this case positive organic matter and Cd relationship could be explained by the fact that the increase of organic matter in the soils is accompanied by intense adding of P fertilizers. Strong correlation ($r=0.575$, $p<0.001$) between organic matter and phosphorus content in soil is in line with this statement. At the same time, negative moderate correlation ($r=-0.483$; $p<0.05$) was observed between potassium content in soil and cadmium concentrations in the plant.

Using the stepwise method, a significant model emerged ($F_{2.14}=55.193$, $p=0.000$, Adj.$R^2=0.871$). Significant variables are shown in Table 3. Organic matter, pH, as well as soil trace elements content were not a significant predictor in this model.

Table 3. Stepwise logistic regression model predicting the cadmium content in the whole maize plant.

	Beta	**P**
Variables included in the model		
Constant	0.03	0.002
P_2O_5	0.813	0.000
K_2O	-0.401	0.001

Two primary factors that influenced the variability of cadmium content in the plant are the presence of phosphorus and potassium in the soil. 87.1% of total cadmium variability in maize plants could be explained by these two elements. Increasing phosphorus in the soil led to increase of cadmium content in plants which is in line with many earlier findings (Jeng and Singh, 1995; McLaughlin *et al*., 1996; Andresson and Siman, 1991). Nziguheba and Smolders (2008) showed that in 2008 the Cd concentration in the P fertilizers used in Europe had an average value of 36 mg Cd (kg $P_2O_5)^{-1}$. Therefore, the application rate of the mentioned mineral fertilizer (kg P_2O_5 ha^{-1} yr^{-2}) is a crucial parameter in determining the Cd input from fertilizers.

Results of potassium and cadmium correlation (Table 2 and Table 3) indicate that increasing K_2O content in soil led to the decrease of cadmium content in the plants. Although this relationship is weak ($r=0.483$ and Beta = -0.401) it seems that presence of potassium in soil cold interference cadmium uptake by plants.

Ciećko *et al*. (2004) found that soil contamination with cadmium caused an increase or a decrease in the content of potassium, depending on the plant species and organ, which indicates a possible correlation between these two elements, but it seems that this also depends on the physical and chemical properties of the soil. Namely, solubility of cadmium is associated with pH of soil and according to Sauve *et al*. (2000) 60% of the cadmium variability in soil solution phase could be explained by soil pH. In this study significant negative correlation coefficient (r=-0.49) between soil pH and cadmium content in the soil was observed (Table 2).

CONCLUSIONS

Although that the research was based on a limited number of inputs (localities, number of samples, limited factors indicating soil quality), soil phosphorus and potassium content are the factors that could be used for prediction of cadmium content in plants. Significant negative correlations were observed between soil pH and soil Cd content which implies that the availability of Cd for its uptake by roots of plant could become lower with the increase of soil pH. On the other hand, significant positive correlation between organic matter and Cd content in soil indicates that increased fertilizer application could lead to Cd contamination.

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THE TOTAL AND AVAILABLE CONCENTRATIONS OF ESSENTIAL TRACE ELEMENTS IN AGRICULTURAL SOILS OF EASTERN CROATIA

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ABSTRACT

The research objective was to determine the influence of basic soil chemical properties on total concentration and available fractions of essential trace elements in the soil. Agrochemical soil analysis were conducted at two localities of different soil properties Berak and Vinogradci in eastern Croatia. The soil at the site Berak was eutric cambisol of neutral reaction (pH average (H_2O) 7.20), while the soil in Vinogradci was luvisol of slightly acid reaction (average pH (H_2O) 5.87). Both soils were poor in organic matter and well supplied with phosphorus and potassium. As expected, at both analyzed sites the highest average concentrations were determined for total Fe, Mn and Zn followed, and the lowest concentrations were for total Cu. Higher total concentrations of analyzed microelements were recorded at the Berak site. The total concentrations of Zn and Cu in all analyzed soil samples were below the maximum permissible concentrations. The highest average concentration of available microelements fraction by EDTA Extraction, were at the Berak site determined for Mn (50.52 mg/kg), then Fe (21.77 mg/kg), Cu (4.78 mg/kg), and the lowest for Zn (1.47 mg/kg). At the Vinogradci site average concentrations of available fraction of microelements determined by EDTA extraction were the highest for Fe (77.09 mg/kg), then Mn (30.75 mg/kg), Cu (4.36 mg/kg), and the lowest for Zn (1.76 mg/kg). Identical order of average concentrations at both sites was also recorded for extraction with DTPA solution. Comparing available fraction of microelements by localities, higher average concentrations of Mn and Cu were found at the site Berak, while on site Vinogradci higher average concentrations were of Fe and Zn. At both sites the DTPA method extracted more of Fe and Mn, an average of 51.06% and 6.39% more than the EDTA method, but the method EDTA extracted more Zn and Cu, an average of 127.10% and 100.40% than DTPA method. The smallest share of the available fraction of the total concentration was recorded for Fe (0.06% by EDTA -

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0.09% by DTPA), followed by Zn (1.20% by DTPA - 2.74% by EDTA) and Mn (5.93% by EDTA – 6.31% by DTPA), while the largest share was observed for Cu (10.92% by DTPA and 21.84% by EDTA).

Keywords: *microelements, total concentrations, available fractions*

INTRODUCTION

Soil reaction affects the soil chemical properties in wide range, especially soil nutrients mobility and plant availability. Furthermore, soil acidity and elemental toxicities or deficiencies associated with it, affects crops growth and restricts yields through the world (Rengel *et al*., 2003). The increase in cultivation intensity with the increasing demand for higher yields with better quality has resulted in increasing demand for microelements.

Microelements such as Fe, Mn Zn and Cu play an essential role in the assimilation and dissimilation processes of plants in terms of activators and inhibitors of metabolic processes. Availability of micronutrients in agricultural soils is defined with pH as main factor. Changes of soil reaction impacts to the Fe, Mn, Zn and Cu soil status turnover. Increase of fertilization may cause some negative effects because of changes in micronutrient availability (Györi, 2006). Zn and Fe deficiency are currently listed as major risk factors for human health globally (Cakmak, 2008). Micronutrient deficiency in general can noticeably reduce the performance and profitablity of agroecosystem (Fisher, 2008).

Soil extraction techniques to measure the status of available micronutrients for plants are important in the diagnosis of deficiency or toxicity (Garcia at all, 1997). Threfore, the aim of this paper was to was to determine the influence of basic soil chemical properties on total concentration (aqua regia) and available fractions (EDTA and DTPA) of essential trace elements (Fe, Mn, Zn Cu) on acid and neutral soils of continental part of Croatia.

MATERIAL AND METHODS

Soil samples for conducted research were collected from arable soils (0-30 cm depth) on location Vinogradci, from luvisol soil in type Osijek-baranja county and location Berak, eutric cambisol soil in Vukovar-srijem county. Both locations are situated in eastern part of continental Croatia. A total of 106 soil samples of arable soils were taken on both localities for agrochemical analysis. The basic methods of soil analysis included determination of soil pH in a suspension of soil and water as well as soil and KCl solution, humus content, content of available forms of phosphorus and potassium, hydrolytic acidity and $CaCO_3$ content.

The total concentration of mineral elements in the soil, including the analyzed microelements are determined by various methods of partial or complete digestion of the soil (hydrofluoric acid, nitric acid, aqua regia). Soil samples for this investigation were digested in aqua regia according to method ISO, 1995b using freshly prepared mixture of 1/3 HNO_3 + 2/3 HCl.

For determination of plant available Fe, Mn, Zn and Cu concentrations in soil the different extraction solutions (EDTA, DTPA, AA-EDTA, HCl and water) are used, and for this study extraction methods with a solution of EDTA (ethylenediaminetetraacetic acid) and DTPA solution (dietientiaminpentaoctena acid) were used. The extraction method with EDTA (Trierweiler and Lindsay, 1969) is commonly used in the Republic of Croatia.

RESULTS AND DISCUSSION

Basic agrochemical soil properties as soil pH, humus content, plant available phosphorus and potassium and carbonate content were analyzed in all soil samples (Table 1). The soils at the site Berak were in average neutral (pH average (H_2O) 7.20), moderately supplied with organic matter and well supplied with phosphorus and potassium, moderately calcareous and according to hydrolytic acidity liming was not required. The soils in Vinogradci were in average moderately acid (average pH (H_2O) 5.87), poor in organic matter and also poorly supplied with phosphorus and potassium, moderately calcareous and liming was not obligate but it could be beneficial.

Table 1. Basic soil properties

	pH_{H_2O}	pH_{KCl}	AL-P_2O_5 mg/100 g	AL-K_2O mg/100 g	humus (%)
Berak	7.20a	6.38a	20.99a	24.31a	2.08a
Vinogradci	5.87b	4.95b	14.09a	17.79b	1.66b
Mean	6.51	5.64	17.41	20.92	1.86
St. dev.	1.13	1.22	20.47	6.67	0.36

As expected, at both analyzed sites the highest average concentrations of total concetrations of essential trace elements were determined for total Fe, Mn and Zn followed, and the lowest concentrations were for total Cu (Table 2).

Table 2. Total concentrations of microelements in soil (mg/kg)

	Fe	Mn	Zn	Cu
Berak	30.134a	839.5a	62.82a	21.75a
Vinogradci	26.469b	659.9b	53.92b	15.94b
Mean	28.233	746.3	58.21	18.73
St. dev.	3.051	163.3	7.59	3.78

Higher total concentrations of all analyzed microelements were recorded at the Berak site compared to Vinogradci site. It is important to point out that total concentrations of Zn and Cu in all analyzed soil samples (Berak and Vinogradci) were below the maximum permissible concentrations, which are for Zn 150.00 mg/kg and for Cu 90 mg/kg.

The highest average concentration of available microelements fraction by EDTA extraction (Table 3) were at the Berak site determined for Mn (50.52 mg/kg), then Fe (21.77 mg/kg), Cu (4.78 mg/kg), and the lowest for Zn (1.47 mg/kg). At the Vinogradci site average concentrations of available fraction of microelements determined by EDTA extraction were the highest for Fe (104.62 mg/kg), then Mn (38.60 mg/kg), Cu (3.46 mg/kg), and the lowest for Zn (1.69 mg/kg).

Table 3. Available concentrations of microelements in soil by EDTA extraction

	Fe	**Mn**	**Zn**	**Cu**
Berak	21.77b	50.52a	1.47a	4.78a
Vinogradci	104.62a	38.60b	1.69a	3.46b
Mean	64.76	46.95	1.58	4.10
St.dev.	67.42	21.40	0.94	1.10

Identical order of average available concentrations at Berak site (Mn>Fe>Cu>Zn) and at Vinogradci site (Fe>Mn>Cu>Zn) was recorded for extraction with DTPA solution (Table 4).

Table 4. Available concentrations of microelements in soil by DTPA extraction

	Fe	**Mn**	**Zn**	**Cu**
Berak	43.44b	51.13a	0.68a	2.28a
Vinogradci	107.31a	43.07b	0.71a	1.81b
Mean	76.58	44.40	0.69	2.03
St.dev.	53.11	21.15	0.44	0.51

Analysed neutral and acid soils significantly differed in soil pH, soil organic matter content and plant available potassium. Average total concentrations of microelements for all soils significantly differed in decreasing order Fe (28233 mg/kg) > Mn (746.3) > Zn (58.21 mg/kg) > Cu (18.73 mg/kg) according to all samples mean. Significant difference between neutral (Berak) and acid soils (Vinogradci) in total concentrations of microelements was recorded for all analysed essential trace elements where significantly higher total concentrations were observed in neutral soils (Berak site).

Comparing available fractions of microelements by localities, plant available fractions of Fe and Zn extracted with EDTA or DTPA were significantly higher in acid soils (Vinogradci site), while on neutral soils (Berak site) significantly higher average concentrations in the same extractants were observed for Mn and Cu (Table 5). At both sites the DTPA method extracted more of Fe and Mn, an average of 51.06% and 6.39% more than the EDTA method, but the method EDTA extracted more Zn and Cu, an average of 127.10% and 100.40% than DTPA method.

Table 5. Total and available microelements content in neutral and acid soils

	Neutral soils (Berak)					Acid soils (Vinogradci)				
	Total mg/kg	**EDTA mg/kg**	**EDTA % of T**	**DTPA mg/kg**	**DTPA % of T**	**Total mg/kg**	**EDTA mg/kg**	**EDTA % of T**	**DTPA mg/kg**	**DTPA % of T**
Fe	30134	21.77	0.07	43.44	0.14	26469	104.62	0.39	107.31	0.40
Mn	839.5	50.52	6.02	51.13	6.09	659.9	38.60	5.85	43.07	6.53
Zn	62.82	1.47	2.34	0.68	1.08	53.92	1.69	3.13	0.71	1.32
Cu	21.75	4.78	21.98	2.28	10.48	15.94	3.46	21.71	1.81	11.35

In all analysed soils and in both extraction solutions the lowest share of available fraction in total content were determined for Fe, follows Zn, then Mn and Cu had the highest share of the available fraction in total content. According to all samples mean, share of the available fraction of the total concentration was for Fe 0.06% by EDTA and 0.09% by DTPA extraction, for Zn 2.74% by EDTA and 1.20% by DTPA solution, for Mn 5.93% by EDTA and 6.31% by DTPA extraction, and for Cu 21.84% by EDTA and 10.92% by DTPA method.

Although acid soils had lower total concentrations of all analyzed microelements compared to neutral soils, the share of available fractions of the total concentrations were higher in acid soils than in neutral soils for all analyzed microelements.

Significant correlations between total concentrations of microelements and amounts extracted by EDTA or DTPA were not observed. On the other hand, very significant correlations were determined for plant available Fe, Mn, Zn and Cu between EDTA and DTPA (Table 6).

Table 6. Correlation coefficients between EDTA and DTPA solution for analysed microelements

	all soils	neutral soils	acid soils
Fe	0,832	0,877	0,741
Mn	0,848	0,808	0,919
Zn	0,957	0,855	0,974
Cu	0,748	0,351	0,829

Three extracted microelements by EDTA and by DTPA extraction solution were the most comparable in acid soils (Mn r=0,92, Zn r=0,97, Cu r=0,83; n=55). The highest correlation among EDTA and DTPA method for Fe was obtained in neutral soils (r=0,88; n=51). There was no significant correlation between EDTA and DTPA extracted Cu in neutral soils.

CONCLUSIONS

It can be concluded that EDTA solution extracted higher plant available concentrations of Zn and Cu than DTPA solution regardless of soil pH. Lončarić *et al*. (2008) reported for soils in Croatia that the ratio of available and total concentrations of micronutrients was strongly impacted by soil pH and all analysed elements had higher plant available concentrations in acid soils compared to calcareous soils. At the same time, DTPA solution resulted with higher concentrations of plant available Fe and Mn compared to EDTA method. Higher portion of available fractions of the total concentrations were observed in acid soils than in neutral soils for analyzed microelements. The highest ratio of available fraction of total content was recorded for Cu and the lowest for Fe in neutral and acid soils. Very significant correlations were determined between EDTA and DTPA method, and available Mn, Zn and Cu showed the highest correlation in acid soils, while Fe showed the highest correlations in neutral soils.

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ASSESSMENT OF Cu, Fe AND Zn CONTAMINATION IN AGRICULTURAL SOILS AROUND THE MEFTAH CEMENT PLANT, ALGERIA

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Original scientific paper UDK 631.453:666.94(65)

ABSTRACT

An attempt was made to investigate the concentrations of Cu, Fe and Zn in agricultural soils around the Meftah cement plant, Algeria. Forty soil samples were collected at two soil depths, 0-10 cm and 10-20 cm. The soil samples were digested with the EPA method and the concentrations of heavy metals were determined by atomic absorption spectrometry. The concentrations ranged from 7.22 to 55.75 mg kg^{-1} for Cu, 16160.8 to 19742.2 mg kg^{-1}for Fe and 44.46 to 200.26 mg kg^{-1}for Zn. The magnitude of the mean concentration values indicated the following order: Fe >> Zn > Cu for both horizons. In accordance with the European guidelines, the mean concentrations of the analyzed metals did not exceed the threshold values for agricultural soils. Concentrations of Cu, Fe and Zn in surface soils were higher than in subsurface soil samples. The enrichment factor (EF) was applied to assess the soil contamination. The enrichment factor values of Cu and Zn in studied soils ranged from 0.75 to 5.03 and 1.79 to 6.68, respectively. Up to 75% and 5% of soil samples were moderately to highly contaminate with regard to Zn and Cu respectively, compared to the upper continental crust concentrations.

Keywords: *heavy metals, soil, enrichment factor, cement industry*

INTRODUCTION

Amongst soil degradation processes, soil contamination by heavy metals is one of the major problems of our time. The accumulation of such elements in the soil in concentrations which exceed the threshold values recommended by international standard scan result in a loss of its qualities, which will influence the productivity, the ecosystem and the refore the human health. Sources of these elements in soils mainly include natural occurrence derived from parent materials and anthropogenic activities

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such as mining, cement industry, the use of untreated wastewater, and agricultural practices (Elbana *et al*., 2013; Ogunkunle and Fatoba, 2012). Cement industry through the release of air pollutants such as heavy metals, generated in the process of crushing limestone, bagging, and transportation of cement are carried by wind and deposited on soil, plants and water bodies (Princewill and Adanma, 2011). Addo *et al*. (2013) reported that gases and chemical products emitted by the cement industry may contain soil heavy metals such as Pb, Cd, Cr, Fe and Zn, and soils close to the cement factory have the highest level. To our knowledge little information exists on the content of soil heavy metals around Meftahcement plant in Algeria. The main objective of this research is to assess soil contamination and determine the concentrations of Cu, Fe and Zn in agricultural soil around to this cement plant.

MATERIALS AND METHODS

Study area: The study area is located between latitude 36° 37′ 00″ N and longitude 3°14′00″ E with a total land area of 2.500 ha. It has a subhumid Mediterranean climate, a mean annual temperature of 18.1 °C and a mean annual rainfall of 600 mm. The main agriculture uses of the area are the production of vegetable crops, cereals and fruit trees. The geological setting of the area is mainly characterized by sedimentary formation. These formations consist of alluvial deposit. The soil types are mainly weakly developed soils, vertisols and calcimagnesic soils (CPCS, 1967).

Soil sampling and preparation: A total of forty soil samples were collected from 20 locations around Meftah cement plant (Figure 1). Soil samples were obtained at two depths, 0-10 cm and 10-20 cm, with hand auger and then were transferred into well labelled polyethylene bags for storage and laboratory analyses. The samples were air-dried at room temperature (approximately 20°C) and passed through a polyethylene sieve with 2 mm openings to remove stones, coarse materials and other debris.

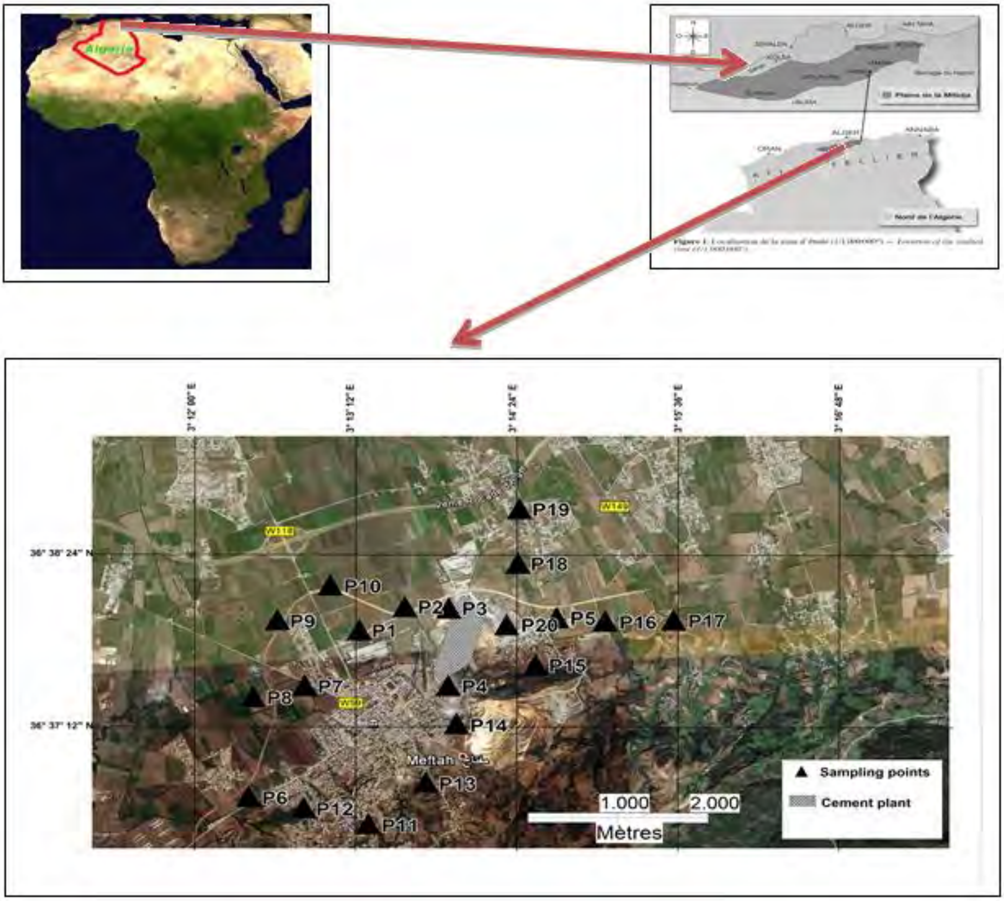

Figure 1. Distribution of sampling sites

Analytical procedures: The particle size distribution was determined by the pipette method. The pH was determined in water with a 1:2.5 soil to solution ratio, electrical conductivity in 1:5 extract, total carbonate by dissolution with HCl, and titration of the excess with NaOH using the Bernard calcimeter method. The percentage of organic matter in the soil samples was determined by the titration method, which is based on the oxidation of organic matter with $K_2Cr_2O_7$. Cation exchange capacity was obtained by extraction with 1M CH_3COONa (Jackson, 1958). Total concentration of metal was determined by a mixture of nitric acid and hydrogen peroxide method (USEPA, 1996). This process was carried out by direct digestion of 1 g of soil sample with repeated addition of HNO_3 and H_2O_2. The extract is then filtered and made to a volume with distilled water. The concentrations of Cu, Fe and

Zn in the extracts were determined by Atomic Absorption Spectroscopy (Perkin Elmer AAnalyst 100).

Assessment of soil contamination: The assessment of soil contamination by heavy metals was carried out by enrichment factor (EF) (Lu *et al*., 2009). The EF is expressed bellow as:

$$\mathrm{EF} = \frac{\left[\frac{\mathrm{Cx}}{\mathrm{CFe}}\right] Sample}{\left[\frac{\mathrm{Cx}}{\mathrm{CFe}}\right] Background}$$

Where (Cx/CFe) sample is the metal to Fe ratio in the sample of interest; (Cx/CFe) reference soil is the natural background value of metal to Fe ratio. As we do not have metal background values for our study area, we used the values from the upper continental crust (UCC). According to Acevedo-Figueroa *et al*. (2006)seven contamination categories are generally recognized on the basis of the enrichment factor: EF<1, no contamination; 1<EF<3, deficiency to minimal enrichment; 3<EF<5, moderate enrichment; 5<EF<10, moderate to high enrichment; 10<EF<25, high enrichment; 25<EF<50, very high enrichment; EF> 50 extremely high enrichment.

All statistical analyses in this study were performed using Past 3 software. Data were subjected to descriptive statistic.

RESULTS AND DISCUSSION

Physico-chemical parameters

The main physico-chemical parameters determined for the studied soil samples are given in Table 1. The pH values ranged from 7.12 to 7.86, which suggests neutral to alkaline conditions. The soil total carbonate ranged from 0 to 14.94% and EC values ranged from 0.16-0.62 dS/m indicating non saline conditions. The total organic matter in the soil ranges from 0.48 to 3.23%, with a mean value < 2%. Cation exchange capacity of the soils ranged from 16.71 to 31.9 $Cmolkg^{-1}$. The clay contents of the soil were considerable from 9.29 to 78.55%.

Table 1. Range, standard deviation (SD) and mean for the selected soil properties

Parameters	0-10 cm			10-20 cm		
	Range	**SD**	**Mean**	**Range**	**SD**	**Mean**
pH	7.12-7.86	0.19	7.52	7.26-7.81	0.13	7.64
EC (dS/m)	0.16-0.38	0.06	0.23	0.16-0.62	0.14	0.34
OM %	0.48-3.23	0.66	1.55	0.55-2.92	0.58	1.35
$CaCO_3$%	0-14.94	5.16	4.66	0-14.94	5.25	4.81
CEC (Cmol.kg^{-}1)	16.71-31.9	4.43	23.54	17.21-29.76	4.03	23.11
Clay %	9.72-76.83	16.44	48.3	9.29-78.55	17.68	51.36
Silt %	1.55-77.38	17.90	32	6.95-72.76	17	33.46
Sand %	2.77-51.72	12	19.42	2.82-30.09	7.1	13.61

EC: electrical conductivity, OM: organic matter, CEC: cation exchange capacity.

Heavy metal concentrations

The concentrations of the heavy metals in both depths are listed in Table 2. Copper concentrations in upper soil (0-10 cm) were in the range of (7.22-55.75 mg kg^{-1}), with the mean concentrations of 31.5 mg kg^{-1}. The highest Cu value (55.75 mg kg^{-1}) in the upper horizon was recorded to the west of the cement plant. The concentrations in the lower soil (10-20 cm) were in the range of 7.23-53.6 mgkg^{-1}, with the mean concentration of 30.7 mg kg^{-1}. The highest concentration of Cu (53.6 mg kg^{-1}) in the lower horizon was observed to the east of the cement plant. Compared to the international guidelines, the mean concentrations of Cu were lower than the threshold value of 100 mg kg^{-1} (Gawlik and Bidoglio, 2006), but higher than the upper continental crust value of 25 mg kg^{-1} (Wedepohl, 1995). The concentration of Cu were correlated with pH ($r=-0.52$, $p<0.05$) and OM ($r=-0.46$, $p<0.05$) for surface horizon and only with OM ($r=-0.47 p<0.05$) for subsurface horizon. Iron is reported, in studies focusing on soil heavy metal contamination, as reference element to establish the anthropogenic metal enrichment. In the study area the highest concentration of 19742.2 mg kg^{-1} (0-10 cm) was observed to the south of the cement plant. This value is in the range of normal values (19785-21794 mgkg^{-1}) found in agricultural soils (Ondo *et al.*, 2013). The mean and range values for Zn in surface (0-10 cm) and subsurface (10-20 cm) soils samples were 143.5, 46.35-200.26 and 132.9, 44.46-195.1 mgkg^{-1}respectively. The mean concentrations of Zn in the studied area exceeded the mean metal concentration of 65 mgkg^{-1}in the upper continental crust (Wedepohl, 1995) but remain below the threshold value of 200 mgkg^{-1} suggested by Gawlik and Bidoglio (2006) in European soils. The highest concentration of Zn was observed to the west of the cement plant. In respect to the influence of pedological parameters on Zn distribution, the statistical analysis showed a significant correlation with only clay ($r = 0.53$, $p<0.05$) for surface horizon.

Table 2. Range, standard deviation (SD) and mean for analyzed soil heavy metals (mg kg^{-1})

Para-meters	0-10 cm			10-20 cm		
	Range	SD	Mean	Range	SD	Mean
Cu	7.22-55.75	16.99	31.50	7.23-53.6	14.63	30.7
Fe	16361-19742.20	735.70	17675.38	16160.8-18799	618.30	17547.6
Zn	46.35-200.26	37.92	143.50	44.46-195.1	40,00	132.9

Moreover, a significant correlation was observed between Zn and Fe ($r=0.45$, $p<0.05$) for surface horizon and between Zn and Cu ($r=0.52$, $p<0.05$) for subsurface horizon. These results could be attributed to the similar dissolution-precipitation pattern. The magnitude of the mean concentration values for analyzed metals indicated the following order for both horizons.

$$\mathrm{Fe} \gg \mathrm{Zn} > \mathrm{Cu}$$

Based on mean concentrations, surface horizons showed higher concentrations of metals compared to subsurface horizons (Figure 2).

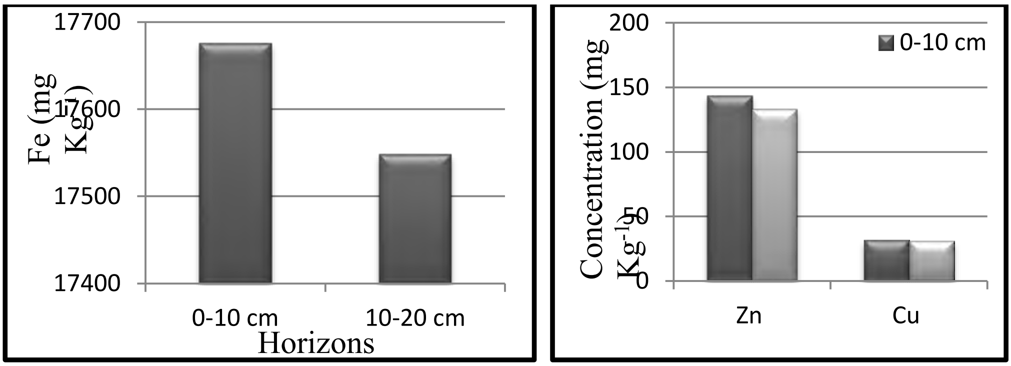

Figure 2. Concentrations of Cu, Fe and Zn in surface and subsurface soil samples

The results of EF corresponding to the two metals measured in the study area are given in Table 3. The lowest values of EF indicate that the occurrence of heavy metals in soils is due to natural process, while high values indicate enrichment by anthropogenic activities.

Table 3. Minimum, maximum and mean of EF in the studied area

Parameters	Min	Max	Mean
Zn	1.79	6.68	5.17
Cu	0.75	5.03	3,00

The EF of heavy metals in soils ranged from 0.75 (Cu) to 6.68 (Zn) (Figure 3). Mean value of EF was 3 for Cu, indicating moderate contamination. The mean EF value of Zn was 5.17, indicating moderate to highly enrichment in this element. The results revealed that up to75 and 5% of soil samples showed moderate to high enrichment for Zn and Cu respectively. In addition, 20 and 45% of soil samples showed a moderate enrichment for Zn and Cu.

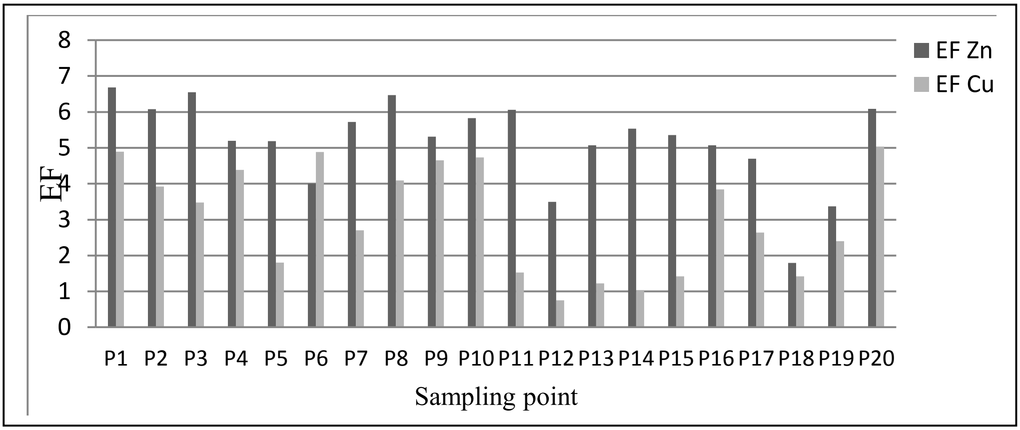

Figure 3. Spatial distribution of enrichment factor (EF) for Zn and Cu in the studied area

CONCLUSIONS

Although the results of this work showed an anthropogenic contribution compared to the upper continental crust, however the concentrations of Cu and Zn were below the European threshold values. Dust emissions from the cement plant activities are probably the cause of such enrichment with heavy metals in agricultural soils surrounding cement plant. Further studies with intensive sampling are needed to assess the distribution and contamination of other metals such us Cd, Ni and Pb in the studied area.

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TOTAL AND PLANT AVAILABLE TOXIC TRACE ELEMENTS (Cd, Cr, Co AND Pb) AT FARMS OF EASTERN CROATIA

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Original scientific paper UDK 631.453(497.5)

ABSTRACT

It is well known that soil properties, metal speciation and plant species, especially soil-plant interactions, determine the availability of metals in soils. Therefore, various one-step extraction methods such as EDTA and DTPA have been used to represent the available fraction. In present study we observed the total (*aqua regia*) and available fraction (EDTA and DTPA) of toxic trace elements (Co, Cd, Cr and Pb) from soil on two farms (Berak and Vinogradci) in eastern Croatia that have different soil properties. The study included 106 soil samples from soil depth 0-30 cm that were collected during 2013-2014. Samples were analyzed for standard soil properties (pH, organic matter, AL-P, AL-K) as well as for total and available fractions of toxic trace elements. Analyses of main soil properties show vide variety of soils. Soil pH (in H_2O) was in range 4.4-8.6 (avg: 6.5), thus sampling sites included range from very acid to alkaline soils. Farm in Berak (average pH was 7.2) had more alkaline soils while farm in Vinogradci was acidic (average pH was 5.9). Organic matter varied from 1.1-2.8% (avg: 1.9), average phosphorous was 17.4 mg/100g and potassium 20.9 mg/100g. Total concentration of trace elements extracted by *aqua regia* show satisfactory results as not one sample had elevated levels of toxic trace elements (Co, Cd, Cr and Pb). In that regard all sites satisfy Croatian regulation on pollutants in agricultural fields. However, EDTA and DTPA extractions show higher availability of Cr, Co and Pb for both extractions (EDTA and DTPA) at farm in Vinogradci where soils are more acidic compared to farm Berak. Only available Cd was shown to be higher in Berak than in Vinogradci.

Keywords: *availability, aqua regia, DTPA, EDTA, trace elements*

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INTRODUCTION

In most legislation maximum permissible concentrations (MPC) of trace elements are defined by total concentrations in soil. However, large number of studies has shown that plant uptake and potential toxicity are not so dependent on total concentrations as much as on available fractions. Soil properties, metal speciation and plant species, especially soil-plant interactions, determine the availability of metals in soils (Ehlken and Kirchner, 2002). Therefore, numerous one-step extraction methods such as EDTA, DTPA, $CaCl_2$, $NaNO_3$, water extraction etc. have been used to represent available fraction. The most widely used extraction methods are EDTA and DTPA extractions. Both of these methods have been used due to their ability to form very stable, water-soluble and well-defined complexes with metal cations (Norvell, 1984; Brun *et al*., 2001; Hammer and Keller, 2002; Chaignon *et al*., 2003; Feng *et al*., 2005). Previous studies of trace elements in this area have shown that there is a significant correlation between available factions (EDTA) and total concentrations (HCl extraction) (Lončarić *et al*., 2008). In addition, soil pH have shown to have a significant impact on available fraction of trace elements (Ivezić *et al*., 2012; Lončarić *et al*., 2008) therefore in present study we have observed relationship between total concentration, extracted by *aqua regia*, and available fractions, represented by EDTA and DTPA extraction methods, on two farms with different soil properties (acid and alkaline soils). The aim of our study was to investigate two extraction methods of available fractions under different soil pH conditions.

MATERIALS AND METHODS

The study was conducted on two farms (Berak and Vinogradci) in Danube basin of eastern Croatia where 106 samples from soil depth 0-30 cm were collected during 2013-2014. Sampling locations had different soil properties so both, acid and calcareous soils, were represented in the study. Soil samples were analyzed for standard soil properties (pH, organic matter, ammonium lactate phosphorous (AL P_2O_5), ammonium lactate potassium (AL K_2O)) as well as for total (*aqua regia*), EDTA and DTPA extractable toxic trace elements (Co, Cd, Cr and Pb). In addition to soil samples, 18 plant samples of wheat and corn grain were collected as well. Statistical analysis was done in Minitab statistical software and Microsoft Excel.

RESULTS AND DISCUSSION

Standard soil properties show significant differences ($p<0.001$) of main soil properties between two farms for pH, organic matter and available potassium (Table 1). Soil pH (in H_2O) was in range 4.4-8.6 (avg: 6.5), thus sampling sites included range from very acid to alkaline soils. Berak site had more alkaline soils while Vinogradci site had more acidic soils (Table 1). Organic matter (OM) varied from 1.1-2.8% (avg: 1.9), again Berak site had significantly ($p<0.001$) higher concentrations. Average available phosphorous was 17.4 mg/100g and available potassium 20.9 mg/100g, Berak had higher concentrations of both elements (P and K) although only concentrations of available K were significantly higher ($p<0.001$).

Table 1. Main soil properties of sampling sites

	Location	n	Mean	StDev	Min.	Max.
pH (H_2O)	Berak	51	7.2[a]	0.999	5.3	8.6
	Vinogradci	55	5.9[b]	0.847	4.4	8.4
pH (KCl)	Berak	51	6.4[a]	1.082	4.5	7.7
	Vinogradci	55	5.0[b]	0.907	3.9	7.7
OM	Berak	51	2.1[a]	0.2506	1.6	2.8
%	Vinogradci	55	1.7[b]	0.3383	1.1	2.7
AL P_2O_5	Berak	51	21.0[a]	24.7	5.6	100.0
mg/100g	Vinogradci	55	14.1[a]	15.05	3.5	95.2
AL K_2O	Berak	51	24.3[a]	4.573	15.7	35.6
mg/100g	Vinogradci	55	17.8[b]	6.81	9.9	44.1

[a,b] indicate significant differences at $p<0.001$, OM-organic matter, AL P_2O_5 - available P, AL K_2O – available K

In addition to mineral fertilizers, farm in Berak was also using organic fertilizers while farm in Vinogradci was only using mineral fertilizers, which is probably the reason for slightly better soil quality at Berak site. Organic fertilizers can improve soil fertility in a long term, primarily organic matter content but also the bioavailability of phosphorus and potassium as well (Lončarić *et al*., 2005).

Total concentration of trace elements extracted by *aqua regia* show significantly ($p<0.001$) higher concentrations for all four investigated toxic elements at Berak site (table 2.), however the concentrations were below the MPC for all analysed samples. In that regard all sites satisfy Croatian regulation on pollutants in agricultural fields (Official Gazette, 2010).

Available fractions of trace elements show higher availability of Cr, Co and Pb (although only Cr (EDTA) was significantly higher) for both extractions (EDTA and DTPA) at farm in Vinogradci where soils are more acidic than at farm Berak, while available Cd was shown to be significantly higher at Berak site compared to Vinogradci. This can be explained by higher total concentrations of Cd at Berak site as well as by Cd dependence on pH at Berak site in contrast to Vinogradci site where there was no such correlation (Table 3). Vinogradci had lower soil pH but the total Cd concentration was also significantly lower than at Berak site so we can argue that the pool from which the EDTA and DTPA were extracting Cd was much smaller at Vinogradci site. Soil pH influences the availability which is confirmed by correlation analysis of available fraction of trace elements (EDTA and DTPA) with pH (Table 3) from which we can see that most of the available fractions are highly correlated with pH.

Table 2. Trace element concentrations (*aqua regia*, EDTA and DTPA)

	Location	n	Mean	StDev	Min.	Max.
Co(AR)	Berak	51	14.5[a]	1.068	11.4	16.4
	Vinogradci	55	12.6[b]	1.548	9.2	16.2
Cr(AR)	Berak	51	45.9[a]	3.517	35.15	54.11
	Vinogradci	55	36.3[b]	3.601	28.53	44.01
Cd(AR)	Berak	51	0.34[a]	0.06464	0.21	0.47
	Vinogradci	55	0.27[b]	0.06577	0.11	0.41
Pb(AR)	Berak	51	15.7[a]	1.625	9.9	17.6
	Vinogradci	55	13.3[b]	1.425	9.5	16.1
Co(EDTA)	Berak	51	0.16 [a]	0.0714	0.05	0.33
	Vinogradci	55	0.18 [a]	0.0692	0.07	0.46
Cr(EDTA)	Berak	51	0.10 [b]	0.03288	0.04	0.21
	Vinogradci	55	0.18 [a]	0.07382	0.06	0.34
Cd(EDTA)	Berak	51	0.11 [a]	0.01456	0.07	0.15
	Vinogradci	55	0.08 [b]	0.02615	0.05	0.19
Pb(EDTA)	Berak	51	2.36 [a]	0.4157	1.65	3.45
	Vinogradci	55	2.54 [a]	0.845	1.45	7.45
Co(DPTA)	Berak	51	0.16 [a]	0.06675	0.061	0.293
	Vinogradci	55	0.18 [a]	0.06697	0.052	0.388
Cr(DPTA)	Berak	51	0.015 [a]	0.006981	0.005	0.028
	Vinogradci	55	0.017 [a]	0.006006	0.003	0.027
Cd(DPTA)	Berak	51	0.069 [b]	0.01124	0.036	0.098
	Vinogradci	55	0.043 [a]	0.01633	0.014	0.115
Pb(DPTA)	Berak	51	1.14 [a]	0.2906	0.70	2.30
	Vinogradci	55	1.19 [a]	0.316	0.59	2.07

*** indicates significant differences at $p<0.001$

Table 3. Correlation matrix

	Vinogradci $pH(H_2O)$	Berak $pH(H_2O)$
Co(EDTA)	-0.514***	-0.616***
	0.001	0.001
Cr(EDTA)	-0.74***	-0.754***
	0.001	0.001
Cd(EDTA)	-0.221	-0.323*
	0.105	0.021
Pb(EDTA)	-0.369**	0.041
	0.006	0.775
Co(DPTA)	-0.749***	-0.888***
	0.001	0.001
Cr(DPTA)	-0.777***	-0.875***
	0.001	0.001
Cd(DPTA)	-0.178	-0.71***
	0.194	0.001
Pb(DPTA)	-0.636***	-0.331*
	0.001	0.018

*** indicates significant correlation

Relationship between extraction methods representing available fractions show that EDTA and DTPA were highly correlated (Table 4), but EDTA shows significantly higher values for Cr, Cd and Pb. However, since both extraction methods were highly correlated we can easily predict values of one method by using the values of the other. Correlation between available fractions with total concentrations of investigated trace elements was reported only for some elements (Table 4). On the other hand, correlation of EDTA and DTPA with soil pH was present for most of the elements (Table 3). Therefore, we can argue that pH was influencing the mobility and availability of investigated toxic trace elements in a greater extent than the total concentrations did on both sites, Berak (alkaline site) and Vinogradci (acidic site).

Table 4. Correlations between extraction methods (*aqua regia*, EDTA and DTPA)

Berak	EDTA with *aqua regia* for: Co ($p<0.001$) and Cr ($p<0.05$)
	DTPA with *aqua regia* for: Co ($p<0.001$), Cr ($p<0.01$) and Pb ($p<0.001$)
	EDTA with DTPA for: Co, Cr, Cd and Pb ($p<0.001$)
Vinogradci	EDTA with *aqua regia* for: Cd ($p<0.001$)
	DTPA with *aqua regia* for: Co ($p<0.01$), Cd ($p<0.001$) and Pb ($p<0.001$)
	EDTA with DTPA for: Co, Cr, Cd and Pb($p<0.001$)

CONCLUSIONS

Total concentrations of all four investigated toxic trace elements (Cd, Co, Cr and Pb) were bellow maximum permissible concentrations prescribed by Croatian legislation. Two extraction methods, EDTA and DTPA, are most commonly used for determination of available trace elements. In our study they were correlated between each other for all investigated trace elements, regardless of the investigating site (Berak or Vinogradci), which indicates that if we have the results from one method we can still predict the values of the other one. The difference in soil pH between the sites did not affect this relationship, EDTA showed higher values for Cd, Cr and Pb at both sites. Further analysis of plant material is necessary to investigate the relationship of plant uptake and EDTA and DTPA extraction methods on such sites with different pH levels.

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SUITABILITY OF AGRICULTURAL LAND FOR THE CULTIVATION OF CABBAGE IN THE AREA OF HERZEGOVINA-NERETVA COUNTY

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ABSTRACT

Purpose of this paper was to perform inventory of areas and features of agricultural land in the field of the Herzegovina-Neretva County based on existing data and to assess benefits of agricultural land for cultivation cabbage according to the characteristics of the soil, relief and climate. The evaluation of the land suitability was carried out in line with FAO method (FAO, 1976) according to the agro zone.

Based on conducted research, it was established that the studied area is very suitable for the production of cabbage. There are 23,249.3 ha (11.68%) suitable land for the production of cabbage and temporarily unsuitable 5,201.2 ha (2.61%) while permanently unsuitable land for intensive production of cabbage are on 170,451.8 ha (85.7%). The main limitations for intensive production of cabbage in the studied area are the slope, the depth of profile and rockiness.

According to official data on the state of the current production of cabbage in the studied area and data of suitable land and temporarily unsuitable land, the conclusion is that there are basic prerequisites in the form of land resources to expand the production of cabbage in this field.

Keywords: *agricultural land, climate, relief, suitability, cultivation of cabbage*

INTRODUCTION

The area of Herzegovina is a region in which vegetables are traditionally and successfully produced. Potatoes, cabbage and onions occupy largest production areas. In most cases, production is organized on smaller areas in relation to the real possibilities of production on available arable land. According to data from the Federal Bureau of Statistics, the total area where cabbage is grown in the Herzegovina-Neretva

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County (HNC) is 334 ha (39.06%) in 2010, 277 ha (32.34%) in 2011, and 244 ha (28.54%) in 2012. In the period from 2010 to 2012, the highest production of cabbage was found in the areas of the municipalities of Čapljina, Mostar and Konjic, while the lowest production was in the areas of the municipalities of Neum, Ravno and Stolac. The highest production of 5,400 t was recorded in the area of the municipality of Čapljina in 2011. The yield of cabbage was from 8.0 t/ha in the municipality of Neum to 48 t/ha in the municipality of Čapljina. The microclimate of the cultivation area is the biggest factor for the cabbage growing period. By combining production in climatically different regions of HNC, it is possible to continuously supply the market with cabbage throughout the year. Early spring, late autumn, winter and overwintering cabbage are grown in lower warmer areas, while mountainous and hilly areas are favorable for the summer and early autumn production.

In accordance with agro-ecological characteristics and specific biological properties of cabbage, the paper presents an evaluation of suitability of agricultural land for cultivation of this vegetable crop in the area of Herzegovina-Neretva County. When dealing with suitability of land, we essentially talk about grouping into specific zones with distinct characteristics for the method of use, which leads to the division of land into specific categories in terms of its suitability (Brinkman & Smith, 1973). As a subject of evaluation, land includes soil, physical space (relief), climate, hydrological conditions, geological substrate and vegetation, as well as past and present human activities with the option of including economic relations (FAO, 1976).

MATERIAL AND METHODS

Basic characteristics of soil in the area of the Herzegovina-Neretva County were determined from the soil map of FBiH at the scale 1:200 000. In addition to characteristics of soil, climate and relief, agro ecological conditions for the production of cabbage were analyzed as well.

Evaluation of suitability of soil for the cultivation of cabbage was carried out according to the criteria and standards set out in the framework of the FAO land evaluation method (FAO, 1976). Evaluation of suitability by agricultural zones was carried out based on characteristics of the only and/or dominant type of soil in the mapped unit, as well as ectomorphological characteristics. Limit values, types and degrees of limitations for cultivation of cabbage were established: climate, terrain slope, soil depth, rockiness, skeletal structure, soil pH, nutrient availability, drainage, humidity regime, verticity.

Map of the suitability of agricultural land for cultivation of cabbage in the area of HNC is developed on the basis of the suitability evaluation results.

RESULTS AND DISCUSSION

Climate

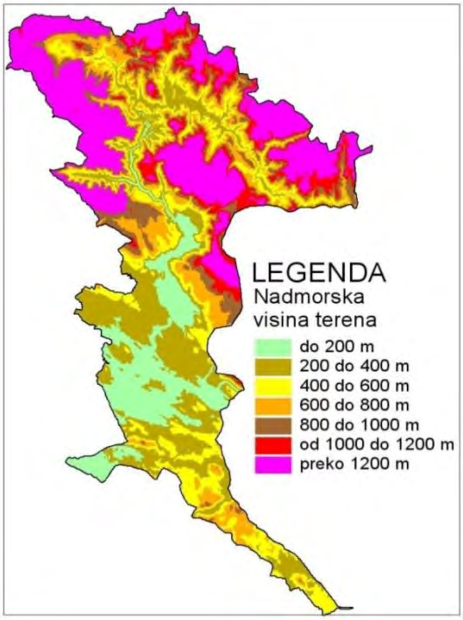
Two types of climate are typical for the area of the Herzegovina-Neretva County: mediterranean and continental with certain subtypes. The lower Mediterranean part of the municipalities of Neum, Stolac, Capljina, Ravno, Citluk and Mostar is characterized by mild and rainy winters with small amounts of snowfall, while summers are long, warm and hot with high daily temperatures. Hilly and mountainous parts of the municipalities of Jablanica, Konjic and Prozor/Rama are under the influence of harsh continental climate. Climate is much milder at lower altitudes, in areas along lake shores, and areas situated along rivers. In this area, precipitation is significant and ranges between 1,100 and 1,500 l/m^2.

Relief

The relief in the area of HNC can be characterized as a typical karst relief, with all fully developed types of karst formations: sinkholes (swallow holes), sinter pools, striations, grikes, chasms, springs, depressions, caves, karst fields (poljes), subterranean rivers, karst mounds, plateaus, ridges, canyons and others. The main visual and the most distinctive relief element of the entire HNC area is the Neretva River with its canyon and valley, which extends through and along the entire county from its far northeast to the far southwest where it enters the Republic of Croatia. Agricultural production is developed only in the valleys of the Neretva River and its tributaries, and to a degree on flat karst plates of lime dolomite rocks, and flysch and other tertiary sediments on which deep soils, suitable for agriculture, have developed.

By analyzing the altitude map, (Figure 1) it was established that altitude of the terrain varies in the range from under 200 m to over 1,200 m. Of the total area of HNC, which is 437,284.6 ha, the terrain with altitudes over 1,200 m covers the largest part with 25.03% (109,459.4 ha), while the terrain with altitudes from 1,000 to 1,200 m covers the smallest part with 6.86% (30,011.5 ha). The terrain with altitudes of up to 200 m extends over an area of 11.86% (51,859.5 ha).

By analyzing the terrain slope map (Figure 2), it was established that slopes 17-24% occupy the largest area of 25.03% (109,457.9 ha), while slopes 24-33% cover the smallest area with 4.57% (19,978.8 ha) in the area of HNC. There is 11% (48,060.60 ha) of flat and nearly flat terrain with gradient 0-2%. The presented maps show that the relief in the area of HNC is predominantly hilly and mountainous, which prevents and aggravates the conditions for agricultural production.



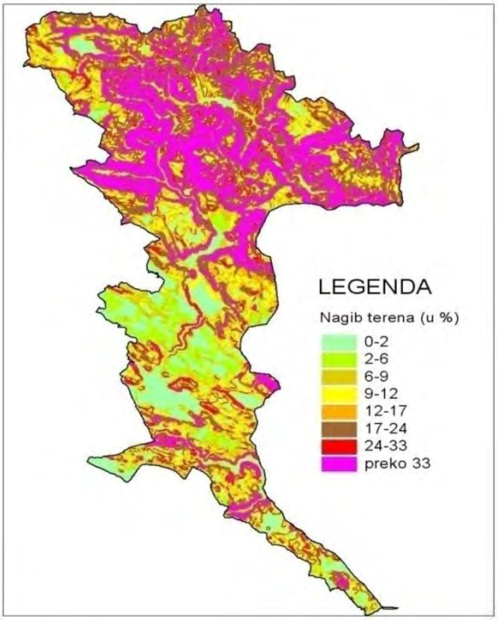


Figure 1. Terrain altitude map of the HNC

Figure 2. Terrain slope map of the HNC area

Source: Ćorić et al., 2013

Soil

Based on the soil map of F BiH at the scale 1: 200,000 the spatial distribution of soil types in the area of HNC is shown by agricultural zones (Figure 3). The area of HNC is characterized by 15 types of soil, out of which 11 are automorphic soils (sierozem, colluvium, calcomelanosol, rendzina, ranker, vertisol, calcocambisol, terra rossa, eutric cambisol, luvisol, distric cambisol) that are beyond the reach of flood water and groundwater, and 4 types of soil (alluvial, humofluvisol, marshy gleyic and low peat) are hydromorphic soils characterized by excessive wetting by rainwater or extraneous waters of different origins (capillary, flood, underground and seepage water). The most widespread soils are black soil on limestone and dolomite (calcomelanosol), and brown soil on limestone and dolomite, or calcocambisol. They are followed by rendzina, terra rossa, acid brown soil and colluvial soils (Ćorić *et al*., 2013).

The area of HNC has very little high-quality arable land for field production, and expansion of cities and settlements is mainly associated with lowland areas where relatively good soils are found, and so arable land has constantly been decreasing.

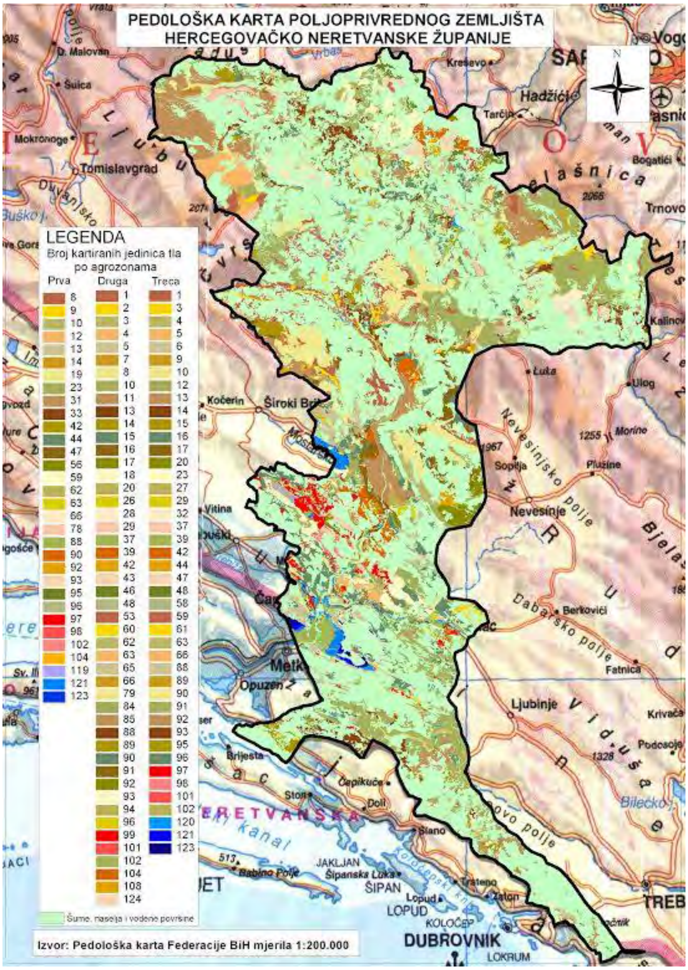


Figure 3. Soil map of agricultural land in the Herzegovina-Neretva County

Source: Federal Institute for Agropedology, Sarajevo

Agro ecological conditions for the cultivation of cabbage

Selection of species and varieties of vegetables and technology of their cultivation need to be adapted to climatic factors and the characteristics of available soil.

Although extending over a wide range, cabbage is grown most successfully in cool and humid areas. The most favorable temperatures for growth and development of cabbage plants are 15-20°C, while its growth stops at temperatures 25°C and 0°C. Cabbage can tolerate short-term cold spells of even up to -12°C without significant damage, but if such low temperatures occur suddenly and affect plants at the stage completely formed heads, they can completely destroy them. The optimum relative humidity of air for the cultivation of cabbage is 85-90%. Because of its need for high air humidity, the best yields are achieved by growing cabbage in river valleys and along major watercourses (Matotan, 2004). Alluvial, medium-heavy, deep soils rich in humus are the most suitable for cultivation of cabbage. Lighter soils that warm up sooner are more favorable for spring production, while heavier soils are more favorable for autumn production (Lešić *et al.*, 2002). The most favorable are mildly acid to neutral soils with pH of 6.0-6.5. On acid soils cabbage can be grown only with abundant application of manure. The root neck disease often occurs on such soils (Parađiković, 2002). Production of cabbage and other vegetable crops require selection of level to mildly sloped areas. For the production of vegetables in hilly areas, it is desirable to use southern or southwestern positions and avoid surfaces shaded by natural barriers for extended periods (Matotan, 2004).

Evaluation of suitability of agricultural land in the area of HNC for the cultivation of cabbage

The evaluation of suitability of land in the Herzegovina-Neretva County for the cultivation of cabbage was carried out on the basis of the presented data on characteristics of soil, climate, relief and specific requirements of cabbage.

According to the FAO methodology, evaluation of soils classifies individual mapped land units into suitability orders, classes and subclasses. The inventory of areas of all orders and classes of soil suitability for the cultivation of cabbage, obtained by evaluating the suitability of the only and/or dominant soil type in mapped units and the area of mapped soil units within the agricultural land, is shown in Table 1, and their spatial distribution is shown in Figure 4.

Table 1. Inventory of areas of suitability classes for cultivation of cabbage (ha)

Suitability class	Area (%)	%
P-1	821.70	0.41
P-2	7,667.40	3.85
P-3	14,760.20	7.42
N-1	5,201.20	2.61
N-2	170,451.80	85.70
TOTAL	**198,902.30**	**100,00**

Source: Marić, 2014

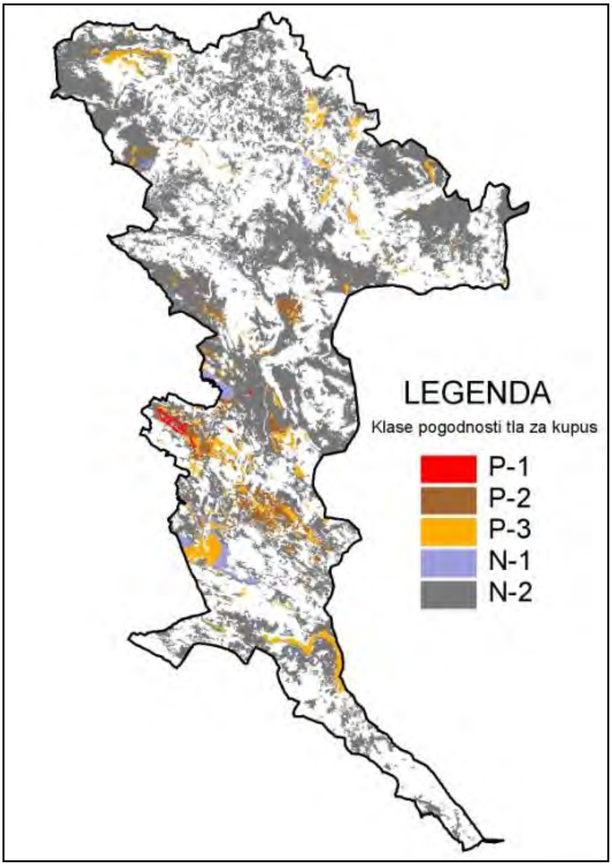


Figure 4. Suitability of agricultural land in the Herzegovina-Neretva County for cultivation of cabbage

Source: Ćorić et al., 2013

Analysis of the data (Table 1) shows that the Herzegovina-Neretva County area has the least soils of the P-1 suitability class for the cultivation of cabbage, which are without any significant limitations or with limitations that will not significantly affect the productivity and profits in production. They occupy only 821.7 ha, which accounts for 0.41% of the total area of agricultural land in HNC. The class of moderately suitable soils of the P-2 suitability class for cultivation of cabbage, which represents soils with limitations that moderately affect the productivity and profits in production of cabbage, occupies 7,667.4 ha or 3.85%. Soils of the class P-3, suitable to a limited degree, which are the soils with limitations that significantly compromise the productivity and profits in cultivation of cabbage, cover the area of 14,760.2 ha, or 7.42%. So, the total area of soils suitable for the cultivation of cabbage is 23,249.3 ha or 11.68% relative to the total studied area of agricultural zones in HNC. Temporarily unsuitable soils of the class N-

1, which can be upgraded to a certain class of suitability for cabbage by using adequate improvement measures, occupy 5,201.2 ha or 2.61%. Permanently unsuitable soils of the class N-2, which represent soils with limitations (stony, rocky, very steep and shallow soils) that rule out the possibility of growing cabbage, are by far the most abundant, occupying the area of 170,451.8 ha or 85.7%.

CONCLUSIONS

Based on the evaluation of suitability of agricultural land for the cultivation of cabbage, we can conclude that the area of Herzegovina-Neretva County has 23,249.3 ha (11.68%) of land suitable for the production of cabbage and 5,201.2 ha (2.61%) of temporarily unsuitable land. Areas permanently unsuitable for the production of cabbage, of the class N-2, occupy the area of 170,451.8 ha, or 85.7% of agricultural land in the area of HNC. The main limitations for intensive production of cabbage are terrain slope, rockiness and stoniness.

Cabbage is one of the most economically important species of vegetables, so it is necessary to carry out land improvement measures in order to increase areas and create higher-quality conditions for growth and development, which will ultimately result in high and quality yields. The presented evaluation of agricultural land will certainly promote its purpose-oriented use and help intensify the production of cabbage in the area of the county.

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PHYSICAL-CHEMICAL CHARACTERISTICS OF HERBICIDES USED FOR MAIZE PRODUCTION IN BIH AS FACTORS OF POTENTIAL HERBICIDE LEACHING IN GROUNDWATER

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ABSTRACT

The aim of the study is to present the elements which must be considered while determining the risk of the mobility of the herbicides. Herbicides used for maize production have the special eco toxical significance and special risk because some are potentially mobile, they are used on the large surfaces during the rainy period and near rivers.

Behaviour of the herbicides in the environment, particularly in the soil is very complex. It does not depend only on the characteristics of the herbicide, but on the many factors of the environment which are very variable. Regardless of this fact, there are experimentally determined physical-chemical indicators for each herbicide that show the possible behaviour of herbicides in the environment. Studied physical-chemical indicators of herbicide behavior are: Distribution Coefficient (Kd); Organic Carbon Partitioning Coefficient (Koc); Time of the Semi-Decomposition (DT_{50}); Water Solubility (S); Groundwater Ubiquity Score (GUS); Henry's Law Constant (Kh), Vapor Pressure (PV) and the Dissociation Constant (pK_a).

Namely, herbicides, in larger or smaller measure, have "*leaching potential*", which is ability to reach the underground water. One of the basic criteria for evaluating the herbicide ability to reach the underground water is related to indicators of mobility and persistency (DT_{50}) herbicides, but neglecting some other criteria in that evaluation such as the amount of applying, characteristics of the soil and the aim of the crop growth. According to the EPA criteria, for the herbicides used in maize production in Bosnia

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and Herzegovina (BiH), the “trigger“ value will indirectly indicate if the herbicides have large leaching potential.

Keywords: *herbicides, leaching, indicators, risk, maize*

INTRODUCTION

Maize (*Zea mays* L.) is a plant that is grown on the largest agricultural area in the Bosnia and Herzegovina (BiH) and Republic of Srpska compared to the other crops. Maize is grown on between 190,000 and 200,000 ha (Table 1) in the past years in BiH. Majority of maize production of BiH, between 140,000 and 150,000 ha each year, is in Republic of Srpska in the valley of Vrbas and Sava river. In these areas groundwater level is high and the risk of potentially contamination is more expressed. Paris *et al*. (2013) were doing monitoring of surface and groundwater in Italy and they found that herbicides, with the highest frequency in most of groundwater are: Terbuthylazine, Atrazine, Metolachlor and Bentazone.

Table 1. Area harvested (ha) cereals, total (Source: FAOSTAT)

Countries	Item	Area harvested (ha)			
		2010	2011	2012	2013
Bosnia and Herzegovina	Barley	18,637	20,745	20,453	20,678
	Buckwheat	553	584	564	633
	Maize	**188,752**	**195,970**	**196,504**	**189,554**
	Oats	9,958	10,007	10,280	9,838
	Rye	2,947	3,295	3,456	3,704
	Triticale	11,299	11,207	9,963	11,500
	Wheat	54,623	58,400	60,713	67,630

Maize production in this area is characterized with intensive use of herbicides to combat weeds. Some of the herbicides that are used in large quantities are potentially very mobile, and in addition to the relatively high quantity and mobility, herbicides are used at the end of April and the first half of May, when the precipitation is high, presenting an additional factor that may contribute to the mobility and leaching of herbicide sin to river sand groundwater. On the other hand, Janjic *et al*. (2005) emphasize that the sulfonylurea herbicides, were less mobile in the soil and does not exist real risk of their leakage into groundwater.

MATERIAL AND METHODS

In this study, physical-chemical characteristics of the herbicides used for corn production were analyzed. Those physical-chemical herbicide characteristics indicate partitioning behaviour and environmental persistence. Some of herbicides exceed the "trigger" value, and that indicate their possible mobility in the soil. Particularly important indicators of the herbicide behaviour in the soil are: Distribution Coefficient-Kd ($ml\cdot g^{-1}$), The Organic Carbon Partitioning Coefficient-Koc ($ml\cdot g^{-1}$), Time of the Semi-decomposition-DT_{50} (days), Water Solubility-S (mg/L) and Groundwater Ubiquity Score (GUS).

Distribution coefficient - Kd ($mL\cdot g^{-1}$). Distribution Coefficient is defined as the ratio of equilibrium concentrations C of a dissolved test substance in a two phase system consisting of a sorbent (soil or sewage sludge) and an aqueous phase; it is a dimensionless value when concentrations in both phases are expressed on a weight/weight base. In case the concentration in the aqueous phase is given on a weight/volume base then the units are $ml\cdot g^{-1}$. The Kd is relevant to understanding pesticide transport since chemicals remaining in soil solution can leach or become available in the water of a pond or stream. Because pesticides in soil solution are subject to leaching, the extent of sorption as measured by the Kd serves as a predictor of mobility: the higher the Kd, the lower the tendency to move in soil. For example, if a Kd is lower than 2, the molecule is termed highly mobile; if it's between 2 and 5, the molecule is considered mobile; and if the Kd is greater than 5, it's deemed immobile with respect to leaching (Whitford *et al.*).

The Organic Carbon Water Partitioning Coefficient - Koc ($mL\cdot g^{-1}$). For nonpolar pesticides, sorption is primarily related to associations with organic materials in the soil and sediments. A Koc value greater than 500 is usually associated with immobile pesticides (Wilson, 2009).

Time of the Semi-Decomposition - DT_{50} (days). Pesticide persistence often is expressed in terms of Time of the Semi-Decomposition in soil (see Table 2). This is the length of time required for one-half of the original quantity to break down (Kerle *et al*., 2007).

Table 2. Categories pesticides based Time of the Semi-Decomposition - DT_{50} (Kerle *et al*., 2007)

Categories based on half-lives	Time of the Semi-Decomposition DT_{50} (days)
Non persistent pesticides	< 30 days
Moderately persistent pesticides	30-100 days
Persistent pesticides	>100 days

Water Solubility- S (mg/L). Water Solubility describes the amount of pesticide that will dissolve in a known amount of water. It usually is measured in milligrams per litter of water (mg/L) or parts per million (ppm).

Groundwater Ubiquity Score (GUS). The Groundwater Ubiquity Score, or GUS, frequently is used to rate pesticides for their potential to move toward groundwater (see Table 3.). The GUS is a number that relates pesticide persistence (Time of the Semi-Decomposition - DT_{50}) and Sorption (Koc) in soil (Gustafson, 1989).

$$GUS = log(DT_{50}) \times [4 - log(K_{OC})]$$

Table 3. Pesticide movement ratings and their GUS equivalents (Kerle *et al*., 2007)

GUS values	Pesticide Movement Rating
< 0.1	Extremely low
0.1-1.0	Very low
1.0-2.0	Low
2.0-3.0	Moderate
3.0-4.0	High
>4.0	Very high

Screening Pesticides for Potential to Leach into Ground Water- *Trigger Values.* Trigger values are based strictly on laboratory data. Further refinements of ground water assessment of the pesticide should consider additional field parameters such as application rate, soil, and target crops. Trigger values are determined from a group of reference pesticides which have a history of use and extensive ground water monitoring. The following values may be used by regulators as an initial step to identify pesticides most likely to leach to ground water (Whitford *et al*., 1996):

Trigger Values Related to Persistence:

1. Aerobic soil metabolism half-life of greater than two to three weeks;
2. Field dissipation half-life of greater than two to three weeks;
3. Photolysis half-life greater than one week; or
4. Hydrolysis half-life greater than 60 days in sterile water.

Trigger Values Related to Mobility:

1. Koc usually less than 300;
2. The pesticide is a weak to moderate acid which would not be attracted to most soil particles; or
3. Water solubility greater than 30 parts per million (ppm).

The Groundwater Ubiquity Score:

1. GUS greater than 2.8 are more likely to leach to ground water;
2. While those with GUS values between 1.8 and 2.8 are somewhat less likely to leach;
3. Pesticides with GUS values less than 1.8 are unlikely to leach to ground water.

Screening Pesticides for Runoff Potential - *Trigger Values*. Herbicides can arrive into the water also by the runoff. Three factors are important for the runoff: type of soil; slope of terrain; and the intensity and timing (with respect to pesticide application) of rainfall. In evaluating surface runoff potential, pesticides are assigned based on their half-lives and sorptive Koc (Whitford *et al*., 1996).

Sorptive Koc ($mL \cdot g^{-1}$):

1. Low sorption: Koc less than or equal to 1000;
2. Intermediate sorption: Koc greater than 1000 and equal to or less than 10,000;
3. High sorption: Koc greater than 10,000.

Persistence (DT_{50}**)** in Soil**:**

1. Short: Time of the Semi-Decomposition equal to or less than 2 weeks;
2. Intermediate Time of the Semi-Decomposition greater than 2 weeks but less than or equal to 2 months;
3. Long: Time of the Semi-Decomposition greater than 2 months.

RESULTS

Weed control in maize production in BiH is done with an herbicides application. Non-chemical approach to combat weeds in maize production are present in the mountainous regions, but there sporadically performed and in very small areas. Number of herbicide which is registered for application in maize production is enormous. The Table 4. below presents the review of commercial herbicides used in maize production in BiH.

Table 4. Review of the registrated herbicides for maize production in BiH (Official Gazette of BiH, No. 49/2004 and Official Gazette of the Republic of Srpska, No. 66/2014)

ACTIVE INGREDIENT	PRODUCT TRADE NAME	APPLICATION TIME Pre/Post Emergent
2,4-D	Monosan herbi	Post EM
2,4- D + Floramsulam	Mustang	Post EM
Bentazon	Basagran	Post EM
Bentazon + Dicamba	Cambio	Post EM
Clopyralid	Lontrel- 100	Post EM
Dicamba	Banvel 480- S	Post EM
Dimethenamid-P	Frontier SUPER	Pre EM
Dimetenamid+ Terbuthylazine	Akris	Pre/Post EM
Flumioksazin	Pledge 50 WP	Pre EM
Fluroxypir meptyl	Starane 250	Post EM
Foramsulphurone + Izoxadiphen-etyl	Equip	Post EM
Foramsulphurone + Izoxadiphen-etyl + Iodsulphuron-methyl sodium	Maister- OD	Post EM
Isoxaflutole	Merlin 750 WG	Pre/Post EM
Isoxaflutole + Ciprosulfamid	Merlin flex	Pre EM
Linuron	Linurex 50- WP	Pre EM
Mesotrione	Callisto	Post EM
Nicosulfuron	Motivell	Post EM
Nicosulfuron + Rimsulfuron	Cordus 75- WG	Post EM
Nicosulfuron + Sulcotrione	Talisman	Post EM
Pendimethalin	Stomp 330-E	Pre EM
Prosulfuron	Peak 75- WG	Post EM
Prosulfuron + Dicamba	Casper 55 WG	Post EM
Rimsulfuron	Tarot 25- WG	Post EM
Rimsulfuron + Dicamba	Tarot plus WG	Post EM
Rimsulfuron + Thifensulfuron-methyl	Grid 75 WG	Post EM
S-metolachlor + Terbuthylazine + Mesotrione	Lumax	Post EM
S-metolachlor	Dual GOLD 960 EC	Post EM
Sulcotrione	Tangenta	Post EM

ACTIVE INGREDIENT	PRODUCT TRADE NAME	APPLICATION TIME Pre/Post Emergent
Tembotrione + Izoksadifen-etilen	Laudis	Post EM
Terbuthylazine	Radazin TZ- 50	Pre/Post EM
Terbuthylazine + Bromoxynil	Zeagran 340- SC	Post EM
Terbuthylazine + Isoxaflutole	Merlin DUO	Pre/Post EM
Thifensulfuron-methyl	Harmony 75 WG	Post EM
Topramezon	Clio	Post EM

Whereas maize is grown on large areas near rivers, where groundwater level is high, the potential mobility of herbicides used in the cultivation of maize is taken into consideration, and shown in Table 5. Characteristics of the herbicides which are used at corn according to the Partitioning Behaviour and Environmental Persistence and their "trigger" of the value are shown in Table 5.

Table 5. Physical and chemical properties of herbicides used in maize production (Source: EU Pesticides data base; EPA; EXTOXNET; PAN Pesticides Database-Chemicals; California Environmental Protection Agency and Cabrera, A. at al., 2007)

Active Ingredient	CAS No	DT_{50} Soil (days)	Water solubility (mg/L)	Koc ($ml \cdot g^{-1}$)	GUS* (calculated)
2,4-D Acet Acid	94-75-7	20	23180 mg/L (at 25°C; pH 7)	5-212	2.17-4.29
Bentazone	25057-89-0	4-21	570 mg/L (at 25°C; ~pH 7)	13-176	1.73-2.32
Dicamba	1918-00-9	7-28	6500 mg/L (at 25°C)	31.6	2.10-3.63
Dimethenamid-P	163515-14-8	4,7-16	1449 mg/L (at 20°C)	129-474	1.26-3.21
Linuron	330-55-2	13 - 82	63.8 mg/L (at 25°C; pH 7)	410-463	1.54-2.54
Mesotrione	104206-8	3-7	160 mg/L (at 20°C)	29-390	0.68-1.18
Nicosulfuron	111991-09-4	26	70 mg/L (at 20°C)	15.4-78.8	2.96-3.96
Pendimethalin	40487-42-1	27-186	0.33 mg/L (at 20°C; pH 7)	6,700-29,400	-1.06-0.25
Prosulfuron	94125-34-5	5-36	4000 mg/L (at 25°C; pH 6.8)	4-41	2.38-3.72
Rimsulfuron	122931-48-0	21	3750 mg/L (at 20°C)	49	3.04
S-metolachlor	(S-isomer) 87392-12-9 (R-isomer) 178961-20-1	11-31	480 mg/L (at 25°C; pH 7.3)	110-369	2.04-2.13

Active Ingredient	CAS No	DT_{50} Soil (days)	Water solubility (mg/L)	Koc ($ml \cdot g^{-1}$)	GUS* (calculated)
Tembotrione	335104-84-2	83	28300 mg/L (at 25°C; pH 7.3)	110	3.76
Terbuthylazine**	5915-41-3	34.3-110	8.5 mg/L (at 20°C; pH 7)	153-611	2.47
Thifensulfuron-methyl	79277-27-3	3-20	2.24 g/L (at 25°C; pH 7)	46-226	1.12-2.14

*GUS calculated by authors

EPA=United States Environmental Protection Agency (www.epa.gov); **EU Pesticides data base** (http://ec.europa.eu/food/plant/pesticides/eu-pesticides-atabase/public/?event=homepage&language=EN); **EXTOXNET**= The Extension Toxicology Network (http://extoxnet.orst.edu/); **PAN Pesticides Database-Chemicals** (http://www.pesticideinfo.org/Search_ Chemicals.jsp); **California Environmental Protection Agency** (http://www.calepa.ca.gov/); **Cit. Cabrera, A. *et al.* (2007);

DISCUSSION

Analysis of the physical-chemical characteristics of the herbicides that are used for maize production and their comparison with the “trigger“ value which point at potential to leach into groundwater indicate that Bentazone, Linuron, Nicosulfuron, Pendimethalin, Rimsulfuron, S-metolachlor, Tembotrione, Terbuthylazine have or can have Time of the Semi-Decomposition (DT50) in aerobic soil conditions longer than two or three weeks. If we observe water solubility and consider that trigger values related to mobility is greater than 30 parts per million (ppm), then almost all herbicides used for maize production, besides Pendimethalin, Terbuthylazine and Thifensulfuron-methyl satisfy this value. If we take value Koc ($mL \cdot g^{-1}$), and as “trigger” values usually less than 300, we conclude that most herbicides which are used for maize production have Koc<300. If theGUS valueis greater than 2.8, it is more likely that herbicides will leach to ground water, and that value can occur for: 2,4-D Acet Acid, Dicamba, Dimethenamid-P, Prosulfuron, and it is always achieve for Nicosulfuron (GUS=2.96-3.96), Rimsulfuron (GUS=3.04) and Tembotrione (GUS=3.76).

CONCLUSIONS

The largest areas under the maize production in BiH are near river valleys where the herbicides are used for weed control.

Physical-chemical characteristics of the herbicides that are used for maize production and their comparison with the “trigger“ value, indicate that the possibility of groundwater contamination exists.

Our research indicate that it is necessary to conduct: Special Studies to Evaluate Leaching Potential, Screening Pesticides for Runoff Potential, Assessment of Runoff Potential, Surface Water Contamination and Spray Drift Studies. Therefore, it is necessary to develop a public policy and strategy for soil and water protection through the controlled and restricted use of herbicides.

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MOBILITY OF IMAZETHAPYR DEPENDING ON THE CHARACTERISTICS OF SOIL

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ABSTRACT

The aim of the study was to research the mobility of imazethapyr in three types of soil in the disturbed conditions (laboratory labels KDIL, PILKD and PILKE), whose pH in H_2O varied from 4.55 to 7.01 using the methods of biological testing. In the study it was used PIVOT-M which contains 100 gl^{-1} of imazethapyr as ammonium salt and is formulated as the concentrated solution (SL).

Imazethapyr was washed out through the PVC columns, with the inner diameter of 45 mm and 20 cm long (4x5 cm). The amount of water used for eluting of the deposit amount of the herbicide suited the amount of 50, 100 and 200 l of water/m^2 and deposite amount of herbicide was 1.0 lha^{-1}. After the washout and draining of the column, the soil column was extruded and divided into the segments of 5cm. On the soil extract of 5 cm, 10 g of dry and noncontaminated soil of the same type was added to drain the extract and prepare for planting. Soil sample of 110 g of soil (110 g of the soil from the column + 10 g of the "pure" soil) is placed into the pot with the diameter of 5 cm and 8 seeds of oats were planted. Such formed pots are placed into the greenhouse in order to measure biometric indicators after 21 day (fresh mass of the shoot and root, dry mass of the shoot and root).

The mobility of imazethapyr depends on the chemical characteristics and mechanical content of the soil. In this study, placing in the regressive dependence of the soil characteristics [humus content (%), clay (%) and sand (%)], as an independent variable, with the amount of water required for elution, as dependent size, they could not demonstrate dependency relationships observed through a linear regression. However, when you observe pH dependence of soil and water volume (CV) required for elution of imazethapyr from the first 5 cm through the exponential regression of the first line, so that inhibition of oats growth, which is grown in the soil from that part of the column, was 10%, and which corresponds values of NOEL, it can be drawn a conclusion that

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functional dependency is established $KV = 98.545 + 3.228 \cdot 10^{8} \cdot e^{-\left(pH/0{,}335\right)}$ statistically significant, with a coefficient of determination 0.987. It tells us that the mobility of imazethapyr in the soil is greater as the pH of the soil is greater, which means that imazethapyr is very mobile in the neutral or soils with the weak basis.

Keywords: *herbicide, imazethapyr, soil, mobility, pH soil*

INTRODUCTION

Imazethapyr [IUPAC: 5-etil-2-[(*RS*)-4-isopropil-4-metil-5-oxo-2-imidazolin-2-il]-nikotinik acid] is a systematical herbicide from the class imidazolinone. Imezathapyr is herbicide which was greatly applied in weed control in the crops of soybean, beans, green beans, peas, lucerne and birds-foot trefoil.

The researchers have paid a great attention to studying the influence of soil pH on the model of the adsorption of imazethapyr, as well as the adsorption dependence on the clay type and its content and the content of the organic substances in the soil. Imazethapyr is an amphoteric compound (Stougaard *et al*., 1990) because of the presence of the carboxid-acid (pKa = 3.9) as well as base hinolgroup (pKa = 2.1). When pH decreases, an imazethapyr molecule will be alternatively negatively charged (COO, N) neutral (COOH, N), and then positive (COOH; NH+). Because of that, many authors examined dependence between pH of soil at one hand and adsorption of imazethapyr on colloid of the soil on the other hand. There are different opinions about that relevance. Some authors (Gennari *et al*., 1998; Loux *et al*., 1989; Gan *et al*., 1994; Oliveira *et al*., 2001) consider that pH of the soil has not any greater influence on the adsorption of imazethapyr. There are more authors who have the different opinion, that adsorption depends on the pH of the soil (Renner *et al*., 1998; Loux *et al*., 1989; Loux and Reese, 1992; Sakaliene *et al.,* 2007; Vischetti *et al*., 2002; Johnson *et al*., 2000; Nègre *et al*., 2001). It is determined that there is the greater sorption of imazethapyr when the pH of soil decreases from pH 8 to 3, probably because of the influence on ionization of the different ionizing functional groups (Goetz *et al*., 1986;. Renner *et al*., 1988;. Stougaard *et al*., 1990). However, considering the span of pH of the agricultural soils, then the ionization of the acid group should have the greater influence on the sorption because the pKa values are very low. Loux *et al*. (1989, cit. Kah, Melanie, 2007) studied the sorption of imazaquin and imazethapyr in 22 different types of soil and 6 samples of sediment, whose pH varied from 4.2 to 8.3, but they varied in many other aspects. The mentioned author used linear regression and established that there is a positive correlation between adsorption of imazakquin and the content of the organic carbon, but there is a negative correlation with pH value. Renner *et al.* (1998) established that the adsorption of imazaquin and imazethapyr was significantly decreased when pH was increased from 5.5 to 8.0. Stougard *et al.* (1990) also confirmed that imazaquin and imazethapyr adsorb better at lower pH, they are less mobile and less efficient, and it results at lower pH when protonation (reduction) of the basic functional groups of the herbicide molecules appear.

Ahmad *et al.* (2001) established by studying the sorption of imazethapyr in 25 samples in Pakistan and Australia, that Kd value for imazethapyr moves from almost 0 (0.02) to 6.94 lkg-^{1}. Generally, the alkali soil in Pakistan has the significantly lower Kd value than the soil in Australia. Considering sorption, on one hand, with pH of the soil and the content of the organic carbon in soil, on the other hand, it can be established that there is a strong correlation between the pH value of the soil and Kd and it is r=0.75. The research showed that sorption of imazethapyr in the alkali soil of Pakistan is low, and there is considerable risk to contaminate the underground water. The same authors claim that correlation between Kd and the content of the organic carbon is low, only r=0.35. Sakaliene *et al.* (2007) claim that there is no correlation between Kd value of the herbicide and the clay content in the soil, which means that the coefficient of the linear correlation (r) is only 0.10.

Johnson *et al.* (2000) established the strong dependency of Kd value on soil pH, so while measuring Kd in 7 different types of soil, it was determined the high negative correlation between Kd value and belonging pH of soil, while the coefficient of correlation is r=0.966 (p+0.000385). In the study of the given authors the pH of soil varied from 3.8 to 7.8.

MATERIAL AND METHODS

Mobility of imatethapyr in the soil was studied by the method of the biological testing, and imazethapyr was washed out through the PVC colons with the in inner diameter of 45mm, which were filled with the soil sample and sand in the compromised condition. Studying the mobility of imazethapyr by the bioassay method in the colons with the compromised samples was done by the combination of methods which were applied by Woondimagegnehu Marsie and Chester (1986), Janjic *et al*. (1992). The characteristics of the used soil are given in the Table 1 and 2.

Table 1. General data about chemical characteristics of soil

Type of soil (mark)	**Reaction (pH)**		**Humus (%)**	**P_2O_5 (mg/100g)**	**K_2O (mg/100g)**
	H_2O	**KCl**			
PILKE	7.01	6.41	1.8	6.1	23.1
KDIL	4.55	3.89	1.4	4.6	14.0
PILKD	4.81	3.88	1.8	3.9	38.4

Tabele 2. Grain structure and type of soil

Type of soil (mark)	% Grain sizes			Texture	Type of soil
	Sand 2.0-0.06 mm	Silt 0.06-0.002 mm	Clay < 0.002 mm		
PILKE	26.38	51.53	22.09	Silty loam	Eutric cambisol
KDIL	36.03	40.96	23.01	Loam	Dystrict cambisol
PILKD	14.79	67.05	18.16	Silty loam	Dystrict cambisol

Colons were filled with the soil samples so the soil profile of 20 cm was formed. Soil was "jammed" to get density of ostensible soil of 1.2 g/cm^3. Since the colon was 20 cm long, and diameter was 45 mm, the volume of the colon was 318.08 cm^3 so the mass of a colon was 381.70 g per colon or 400/colon approximately. Surface of the colon, the inner surface of the PVC tube was 15.9 cm^2 (or 0.00159 m^2), so the amount of the preparation of 1.01 l/ha matched to the amount 0.00016 ml of preparation/colon. Preparation was applied in the amount of 0.2 ml of the working solution on the top of colon, but 0.2 ml of the working solution of the preparation is mixed with 1.5 quartz sand which is equally and carefully distributed on the top of the colon. Such a colon is covered with the filter paper and then the elution is done. The amount of water that was used for elution of the deposit amount of herbicide matched the amount of 50, 100 and 200 l of water/m^2, which were 80, 160 and 320 ml of water per colon. The mentioned amount of distilled water was poured into the separation funnel, and then the washout process was undertaken. After the leaching-out, the colon was held to leach for 48 hours. After that the soil column was pushed out and divided into the segments of 5 cm, starting at 0-5 cm. The clipping of 5 cm was added 10 g of dry and non-contaminated soil of the same type to dry the clipping easily and prepare for sowing. Soil sample of 110g of soil (100g of soil from the column + 10g of "pure" soil) was placed into the pot whose diameter is 5 cm. Eight seeds of the oats were placed and those pots were placed in the greenhouse. Biometrical indicators were measured after 21 day.

RESULTS

The comparative analysis of mobility of imazethapyr in the examined soil is possible to do by comparing the regressive dependency between the amount of water that passed through the column as well as the size, and the percentage of the inhibition of the oats growth as the depending measure. The following conclusion can be drawn, the inhibition of the oats growth in segment from 0 to 5 cm, but in the segment from 5 to 10 as well is decreasing constantly as the amount of water increases (Figure 1 and 2). Therefore, it is possible to make regressive dependency between the amount of water that passed through the soil from the upper segments of the colon (0-5 cm) and the fall of the inhibition of the oats growth, due to leaching out the imazethapyr on the depth lower than 10 cm (Table 2). The following question can be asked. What amount of water is necessary to wash out imazethapyr in the given soil from the upper segments of the colon to make the inhibition of the oats growth, which we grow in the soil from that part of the colon, is 10% which matches to the NOEL value (Table 3).

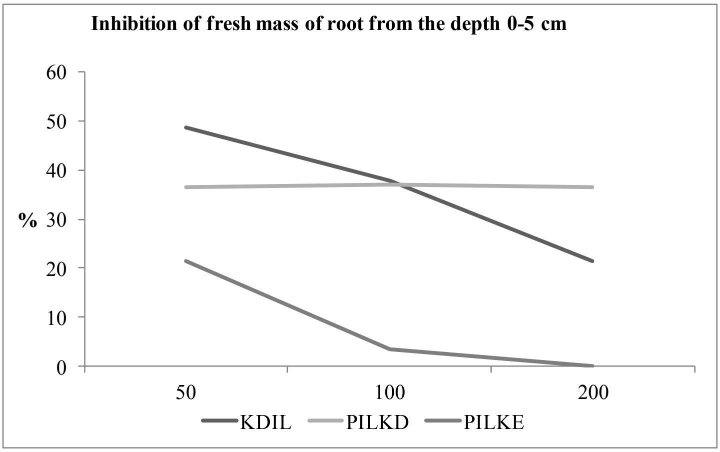

Figure 1. The comparative graph of inhibition dependency of the fresh mass of the root and the amount of the passed water on the depth of 0-5 cm

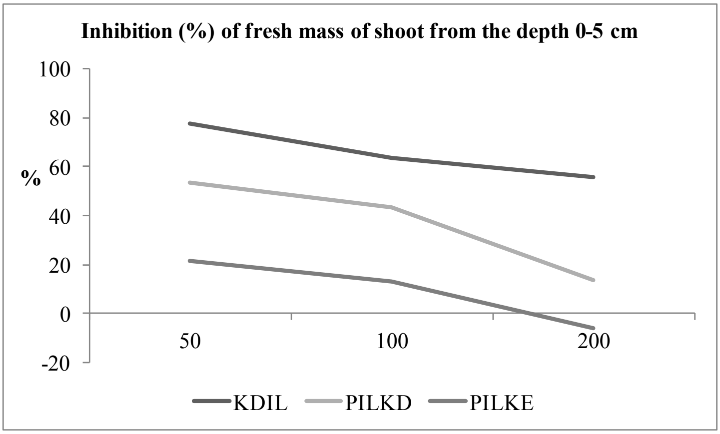

Figure 2. The comparative graph of inhibition dependency of the fresh mass of the shoot and the amount of the passed water on the depth of 0-5 cm

Table 3. Regressive dependency between the growth inhibition (In) of the fresh mass of shoot and the fresh mass of the oats root in the soil at the depth of 0-5 cm depending on the amount of water (AW) which passes through the colon (50, 100, 200 l/m^2)

Biometric indicators	Deep	Type of soil	The function of the linear regression with a coefficient of determination
FMS	0-5 cm	KDIL	$In_{(0-5)} = 81.315 - 0.136 \times AW$ (r^2=0.884)
		PILKD	$In_{(0-5)} = 56.875 - 0.1796 \times AW$ (r^2=0.994)
		PILKE	$In_{(0-5)} = 31.075 - 0.186 \times AW$($r^2$=0.935)
FMR	0-5 cm	KDIL	$In_{(0-5)} = 56.875 - 0.180\times AW$ (r^2=0.994)
		PILKD	$In_{(0-5)} = 36.705 - 0.0002 \times AW$ (r^2=0.0018)
		PILKE	$In_{(0-5)} = 23.215 - 0.128 \times AW$ (r^2=0.710)

Legend: FMS= Fresh mass of the shoot; FMR= Fresh mass of the root; In= Inhibition (%); AW= The amount of water

The amount of water necessary for leaching out the deposit amount of imazethapyr from the lay on the depth of 5 cm, actually 10 cm, so that imazethapyr in the soil of that segment stays so long to cause the inhibition of the fresh mass of the shoot and the fresh mass of the root at 10% which is shown at the table 4.

Table 4. The amount of water sufficient for elution of imazethapyr from the soil lay 0-5 and 5-10 cm on the concentration in the soil which id on the NOEL level

Biometric indicators	Deep	Type of soil	The amount of water sufficient for elution of imazethapyr on the concentration in the soil which id on the NOEL level
FMS	0-5 cm	KDIL	524.4 l/m^2
		PILKD	261.0
		PILKE	113.3
FMS	5-10 cm	KDIL	414.6
		PILKD	187.0
		PILKE	187.3
FMR	0-5 cm	KDIL	260.4
		PILKD*	-
		PILKE	103.2
FMR	5-10 cm	KDIL*	-
		PILKD	196.7
		PILKE	143.3

*NOTE: Because of the small coefficient of determination, calculating the amount of water necessary for leaching out the herbicide to make the inhibition of the oats growth less than 10% would be unreliable

According to the table 3 and regressive dependences (Table 4), we conclude that imazethapyris the most movable in the soil such as “PILKE”, and the least movable in the soil of the type “KDIL”.

Mobility of imezathapyr in soil also depends on the chemical characteristics and mechanical content of the soil. However, in this paper it cannot be proved the relations of dependency observed through the linear regression by putting characteristics of the soil into the regressive dependency [humus content (%), clay (%) and sand (%)], as independent variable with amount of water necessary for elution as dependent variable. However, when the pH of soil is observed through the exponential regression of the first line and amount of water necessary for leaching out of imazethapyr from the first 5 cm, the interesting conclusion can be drawn. Namely, such established functional dependency $KV = 98.545 + 3.228 \cdot 10^{8} \cdot e^{-\left(pH/0.335\right)}$ (Figure 3) is statistically significant, with coefficient of determination of 0.987. It tells that mobility of imazethapyr in soil is greater if the pH of soil is larger, which means that imazethapyr is very mobile in neutral and weakly base soil what is proved in many quotations. In other words, in the soil of neutral and base reaction, the less amount of water is necessary to move imazethapur than it is necessary in the acid soil, which means the soil with less pH. From the above, it can be concluded that pH of the soil is a dominant factor at mobility of imatethapyr.

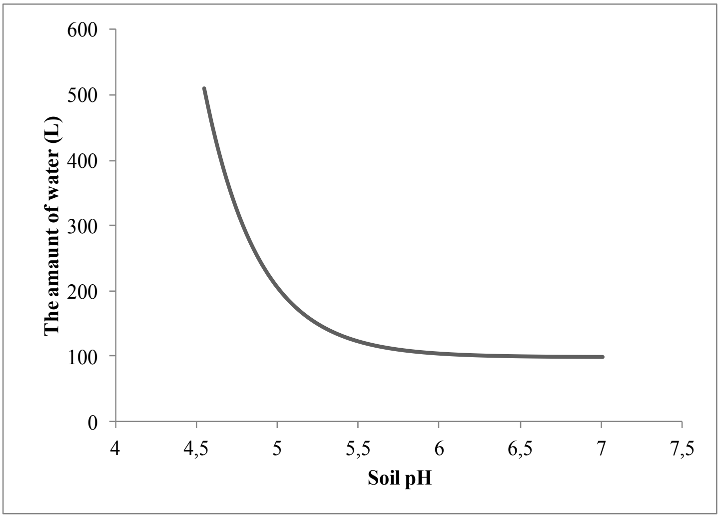

Figure 3. Regressive relation between soil pH and amount of water necessary for leaching out of imazethapyr

DISCUSSION

By studying the mobility of imazethapyr and its leaching out through the colons, it can be generally said that indicators of oats growth significantly vary due to the influence of imazethapyr, and considering the amount of water used for leaching out as well as the depth of the soil layer it reached. The amount of water which is necessary to move deposit amount of imazethapyr and wash out under 5 cm so that it stays in segment from 0 to 5 cm in the amount that cause the growth inhibition of 10% is 524.4 l/m^2 at “KDIL” soil type. At “PILKD” soil type it is 261.0 l/m^2, while at ‘PILKE’ it is 113.3 l/m^2 of water. Mobility of imazethapyr in soil also depends on chemical characteristics and mechanical content of soil. However, in this paper it cannot be proved the relations of dependency observed through the linear regression by putting characteristics of the soil into the regressive dependency [humus content (%), clay (%) and sand (%)], as independent variable with amount of water necessary for elution as dependent variable. Because of that, quotations of Stougaard *et al.* (1990) can be confirmed where it was established that the herbicides are the least mobile in the clay loam soil with the larger content of clay and organic matter. However, when the pH of soil is observed through the exponential regression of the first line and amount of water necessary for leaching out of imazethapyr from the first 5 cm, the interesting conclusion can be drawn. Namely, such established functional dependency with the coefficient of determination of 0.987.

CONCLUSIONS

There mobility of imazethapyr in soil is greater if the pH of soil is larger, which means that imazethapyr is very mobile in neutral and weakly base soil what is proved in many quotations. From the above it can be concluded that pH is dominant factor at mobility of imazethapyr.

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EDUCATION ON WORLD REFERENCE BASE FOR SOIL RESOURCES (WRB) - EXAMPLE OF GOOD PRACTICE

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Review article UDK 631.44:37

ABSTRACT

The World Reference Base for Soil Resources (WRB) research work started back in 1980. under the program named International Reference Base for Soil Classification (IRB). World Reference Base for Soil Resources was established in 1998., and its design provide easier communication between scientists to whom soil systematic is primary area of research. International Field Course of the World Reference Base for Soil Resources, held in Gödöllő, Hungary, from 01st to 05th of September, 2015.was organized to celebrate the International Soil Year. Soil Judging Contest of WRB was organized during the course. Students from Bosnia and Herzegovina, primarily students of Faculty of Agricultural and Food Sciences, University of Sarajevo and Faculty of Agriculture, University of Banja Luka attended the course. The above mentioned course and the contest were unique opportunity for students, young scientists and experts as well as those who have been already involved or interested in identification and characterization of the basic soil types all around the world to share information and experience. The unique field study program provided an opportunity to participants to gain new knowledge on Anthrosols, Calcisols, Chernozems, Kastanozems, Phaeozems, Gleysols, Luvisols, Solonetz and Vertisols in accordance to the World Reference Base for Soil Resource. Importance of the continuation of good practices and implementation of this type of field learning about WRB classification is crucial not only at the global level, but also at the regional one. This paper aims to stress the importance of education about WRB classification in order to improve and adapt the national classification system, importance of applied soil science in society in general and to increase the communication with other related disciplines globally.

INTRODUCTION

Soil is defined as the 3-dimensional top layer of the earth's crust. It is formed by the organic matter, mineral particles, water, air and living organisms. Soil has the properties that reflect the impact of the vegetation, fauna, climate, man and topography on the

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soil's parental material over a variable time span. It is in fact a complex, variable and living medium, where each of the five soil forming factors varies in time and space. A soil formation or pedogenesis is an extremely slow process and soils are still changing where it is shown in their soil profile.

Opposed to the taxonomy in the biology, which identify and separate all organisms and give it taxonomic rank, the world's soil cover is a continuum. In the early days of soil science, soil classification was based on the genesis of the soil. It is interesting that even after more than hundred years of modern soil science, since recently there was not developed and accepted unique system for the classification of the soils. Many soil classification where developed over the years which reflect different views held on concepts of soil formation and minor differences of opinion about criteria to be used in the classification. Today it can be said that The World Reference Base for Soil Resources (WRB), which was established in the 1998., is thankful for the great effort of the development and classification of the soils in the world on the and also creating and refining a common and global language for the soil classification. The great number of countries accepted this classification and many national classifications correlate with WRB (Deckers *et al*.).

The World Reference Base (WRB) is based on the Legend (FAO-Unesco, 1974) and the Revised Legend (FAO, 1988) of the Soil Map of the World (FAO-Unesco, 1971-1981). In 1980, the International Society of Soil Science (ISSS, since 2002 the International Union of Soil Sciences, IUSS) formed a Working Group 'International Reference Base for Soil Classification' for further elaboration of a science based international soil classification system. This Working Group was renamed 'World Reference Base for Soil Resources' in 1992. The Working Group presented the first edition of the WRB in 1998 (FAO, 1998) and the second edition in 2006 (IUSS Working Group WRB, 2006). In 1998, the ISSS Council endorsed the WRB as its officially recommended terminology to name and classifies soils (IUSS Working Group WRB, 2015).

To celebrate the International Year of Soils (IYS), an International Field Course and Soil Judging Contest was organized from 01st to 05th September 2015 in Gödöllő, Hungary. This occasion was the great opportunity for students, researchers and people interested in the soil classification from around the world to interact and experience the nature, landscapes and soils of the Danube Basin and Hungary.

International Field Course and Soil Judging Contest was organized by the Hungarian Soil Science Society (HSSS), SzentIstvan University (SZIU), International Union of Soil Sciences (IUSS), European Commission – Joint Research Centre (JRC), Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences (HAS – RISSAC), University of Miskolc (UNIMIS) and professor Erika Micheli (HSSS, SZIU) as the chair of organizing committee.

International Field Course and Soil Judging Contest was opportunity for the participants to learn more and to use their previous knowledge and practical skills to describe, understand and interpret soil characteristics in the field. Participants where describing a series of profiles using basic filed tools, selected standards and guidelines and expand their ability to correctly describe each soil, evaluate potential soil functions and interpret their capacity to perform under different land use and management practices.

Under the sponsorship of JRC, students from Bosnia and Herzegovina (BiH), primarily students of Faculty of Agricultural and Food Sciences, University of Sarajevo and Faculty of Agriculture, University of Banja Luka had opportunity to attend the course. Students from BiH where in one team named “Team of BiH” where the coaches were Dr. Arwyn Jones and Dr. Endre Dobos.

RESULTS

For the International Field Course and Soil Judging Contest participants registered and came from all continents, 28 countries (Afghanistan, Albania, Armenia, Australia, Bosnia and Herzegovina, Brazil, Croatia, Germany, Hungary, Japan, Kenya, Kosovo, Laos, Montenegro, Nigeria, Philippines, Rwanda, Serbia, South Africa, South-Korea, Spain, Sudan, Tajikistan, Tunisia, Turkey, Uganda, United Kingdom, USA). Including the instructors and local supervisors, 120 people participated in the event.

Figure 1. Team of BiH with their coach Arwyn Jones

The course was consisted from theoretical and field practical part. For the theoretical part the team of international soil experts gave an overview of the site and pointed out about soil functions, profile description and soil classification standards. Later on, local experts introduced the landscape and soil condition of Hungary.

For the field session each team had necessary equipment for field that consist of:

- 10% HCl dropper bottle
- Soil knife/digging tool
- Hand lens
- Water bottle
- Container for soil samples
- Clinometer
- Clipboard
- Plastic bags (for collection of standard soil samples for texture determination)
- Calculator
- Munsell Soil Color Chart books

Each team receive an official handbook and World Reference Base for Soil Resources (IUSS Working Group WRB, 2014) that was kindly provided by the organizers.

For the pits there were certain rules that need be followed and typical section was selected and clearly designated as the control section by the organization officials. The control section was used for measurements of horizon depths and boundaries and had to remain undisturbed and unblocked. A measuring tape was placed in the each control section at all pits. Up to seven horizons where described within given depth. At each site, a card was given the profile depth to be considered, the number horizons to be described and chemical or/and physical data that may be required for classification.

Figure 2. Pit with the control section

Every participant got one scoresheet/team. Following the instructions of the coaches, considering the information on the card and instruction of the handbook the scoresheets were filled.

SCORESHEET **I use WRB □** **Soil Taxonomy □**

International Field Course and Soil Judging Contest

Site number _____ Contestants ID _______ Describe ____ horizons within a depth of ______ cm

I. SITE CHARACTERISTICS

Land use	Slope	Slope	Parent material	Erosion		Surface cracks			Salt characteristics	
Type (1)	*Position (1)*	*% (1)*	*Consol./Unconsol (1)*	*Category (1)*	*Degree (1)*	*Width (cm) (1)*	*Depth (cm) (1)*	*Dist. (m) (1)*	*Cover (%) (1)*	*Thickness (mm) (1)*

II. SOIL DESCRIPTION

Horizon				Boundary			Soil color			Carbonates		Texture			Structure		Redox feat.	Coatings
Master		*Suffix (3)*	*No (2)*	*Lower depth (cm) (2)*	*Dist. (2)*	*Topo. (2)*	*HUE (1)*	*Value (2)*	*Chroma (2)*	*Content (2)*	*Forms (2)*	*Clay (%) (2)*	*Sand (%) (2)*	*Class (2)*	*Type (2)*	*Grade (2)*	*Type (2)*	*Nature (2)*
Prefix (1)	*Letter (2)*																	

III. SOIL PROFILE CHARACTERISTICS

Hydraulic conductivity (3)		Effective soil depth (3)	Type of the restrictive layer(s) (3)	AWHC (3)	Soil Wetness (3)
Surface	*Limiting*	Very deep (>150 cm)	Bedrock	VL	Class 1
H	H	Deep (100-150 cm)	> 25% $CaCO_3$	L	Class 2
M	M	Mod. deep (50-99 cm)	Natric horizon	MO	Class 3
L	L	Shallow (20-49 cm)	Salic horizon	H	Class 4
		Very shallow (<20 cm)	SiC, C or SC, structureless + massive		Class 5

IV. INTERPRETATIONS

Potato Production (3)	Irrigated Corn Production (3)	Local Roads for Comm. Planning (3)
Class 1 Optimal	Class 1 Optimal	Class 1 Optimal
Class 2 Suitable	Class 2 Suitable	Class 2 Suitable
Class 3 Unsuitable	Class 3 Unsuitable	Class 3 Unsuitable

V. DIAGNOSTICS AND SOIL CLASSIFICATION

World Reference Base for Soil Resources (2014)				
Diagnostics			Reference Soil Group (15)	Principal qualifiers (5)
Horizons (10)	Properties (5)	Materials (5)		
Argic	Abrupt textural difference	Albic materials	Anthrosols	Luvic
Calcic	Gleyic properties	Colluvic material	Solonetz	Calcic
Cambic	Lithic discontinuity	Fluvic material	Vertisols	Haplic
Chernic	Protocalcic properties		Solonchaks	Gleyic
Histic	Reducing conditions		Gleysols	Mollic
Hortic	Shrink-swell cracks		Chernozems	Stagnic
Mollic	Stagnic color patterns		Kastanozems	Vertic
Natric			Phaeozems	Hortic
Salic			Calcisols	
Umbric			Luvisols	
Vertic			Cambisols	
			Arenosols	
			Fluvisols	

Soil Taxonomy (12th Edition, 2014)					
Epipedon (10)	Subsurface horizon (5)	Diagnostic characteristics (5)	Order (10)	Suborder (5)	Great group (5)
Anthropic	Albic	Abrupt textural change	Vertisol	Ustic	Argi
Mollic	Argillic	Identifiable Secondary carbonates	Ultisol	Aquic	Calci
Ochric	Calcic	Lithologic discontinuity	Mollisol	Udic	Natr
Umbric	Cambic	Slickensides	Alfisol	Psamm	Hapl
	Natric	Aquic conditions	Inceptisol		Usti
	Salic		Entisol		

Figure 3. Draft of the score sheet

As it can be seen on the Figure 3. these are the score sheets for the each pit that need to be filled. Scoresheet was divided into five parts, as follows:

I. Soil characteristic, where it was observed land use, slope, parent material, erosion, surface cracks and salt characteristic.

II. Soil description which contains horizon, boundary, soil colour, carbonates, texture structure, redox features and coatings

III. Soil profile characteristic where was hydraulic conductivity, effective soil depth, type of the restrictive layer(s), AWHC (Available Water-Holding Capacity) and soil wetness marked

IV. Interpretation for the suitability of potato production, irrigated corn production and local roads for community planning

V. Diagnostic and soil classification where it could be used 2 types of classification: WRB and Soil taxonomy.

DISCUSSION

International Field Course and Soil Judging Contest was a great opportunity to learn more about classification, field procedures and techniques. During the four day course young people could learn from the prominent soil scientist of the today about classification of Hungarian soils and Danube basin. But the thing that made this course even more demanding was the opportunity to test your knowledge of World Reference Base of Soil Resources on the last day. Many of the participants had not had the chance to go in to the pit and do one of the techniques and field procedures that was required for the WRB classification or they lacked the experience. But till the end all of them carried valuable field knowledge to their countries and it can be said that they understood and gain need experience.

This course is also an example of the good learning practice and implementation of this type of field learning about WRB classification. Even though many of the contestants of this course were not experience in the WRB classification, not only in their country where they use national classification but also with the soils of Hungary, local team of experts introduced it and made an effort to all participants to understand pedogenesis and to distinguished between all different types of soils in Hungary and Danube basin. Because of that this method of learning is the best practice of teaching WRB.

After this course it can be said that WRB is complete classification system that gives accommodation to national soil classification systems. Also what was learned during this course is that WRB cannot be substitute for national soil classification systems, but to serve as a common ground for the communication on the international level. Also to add WRB can serve as a bridge between existing national classifications and to serve as communication tool for gathering soil databases for the monitoring of the world's soil resource. As it is known with strong database the biggest problem of today in the soil science would be easier to tackle.

This type of event has a goal to integrate students, teachers from Soil science area through challenging and dynamic activities outside the classroom. It is really important that faculties and universities apply this approach of learning Pedology because it interactive and valuable skills in professional life. Because of all of this is important to the continuation of good practices and implementation of this type of field learning about WRB classification. With this course young people, next soil scientist are educated and introduced into classification of soils on the global level. It is crucial to have this even not only at the global level, but also at the regional or national level where young soil scientist would gain skills to describe and classify soils and this experience and knowledge will be carried into the workplace, from agriculture to industry.

CONCLUSIONS

Translation of the WRB classification can be easily introduced to any language in the world, the nomenclature is defined precisely and some of the terms are retained from the traditional nomenclature. So it is important to educate about WRB classification in order to improve and adapt the national classification system according to WRB and update it with current changes of the soil science. BiH is using national classification system that is adapted from Yugoslavian national classification system. The need to correlate BiH classification system with WRB is expressible special now when BiH have tendency to join European Union. All the ministries and scientist that are responsible for this matter will need as soon as possible to start with field and laboratory soil investigations, as specified by criteria and normative given by WRB. International Field Course and Soil Judging Contest it giving the opportunity for young scientist from BiH to learn WRB from international expert and in the future to apply their gain knowledge in correlation of national systems with WRB. In that sense not only to have better communication with soil scientist around the world, then also to help to improve and bring up to date soil science in BiH.

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CONTAMINATION WITH HEAVY METALS AND PAH's IN SOIL IN THE CANTON SARAJEVO IN PERIOD 2009-2015

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ABSTRACT

In accordance with the role and importance of which in the world and in our country is attached to soil as a bio production factor, the need to examine and protect soil from contamination is imposed. Heavy metals are very common contaminants of soils. Highly toxic and carcinogenic PAHs are natural components of raw petro chemical compounds. Due to their negative influence on plants and animal world as well as on human population, it is necessary to evaluate and determine heavy metals and PAHs content in soils, especially in ones intended for agricultural production.

In this work, we have examined agricultural and urban soils in the Canton Sarajevo, for content of heavy metals and polycyclic aromatic hydrocarbons. Analyzed samples were in scattered state, taken from a depth of 0-30 cm. The total number of determined soil samples was one hundred and twenty (120), in the period of 2009-2015.

According to determined general chemical characteristics, soils are from slightly acetous to slightly alkaline. According to mechanical texture composition, examined soils have showed the following texture marks by Ehwald: clay and sandy loam.

Using flame/electrothermal atomic absorption spectrometry and gas chromatography with FID detection we have established the content of seven heavy metals and polycyclic aromatic hydrocarbons. In determining the content of heavy metals following methods were used: BAS ISO 11466:2000 and BAS ISO 11047:2000, and for PAHs the method was BAS ISO 18287:2008. Results were compared with the limit values from "Regulation on determining the allowable amounts of harmful and dangerous substances in soils and methods of their examination" specified in Official Gazette of the Federation of B&H, No. 72/09.

Keywords: *contamination, heavy metals, PAHs, AAS method, GC-FID*

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INTRODUCTION

It is a well-known fact that the land is a natural wealth, but unlike other resources such as mineral resources, forests, flora and fauna, his reserves, along with reserves of water and air, were considered to be inexhaustible. However, with the increase in urbanization, we have witnessed a disturbing degree of threat and soil contamination in all spheres of the environment. So, the land did not receive any necessary attention, although symposiums of pedologists have warned the public about the land care, as one of the most important parts of the ecosystem (plant - animal - man - water - air). A modern system of land management as a multifunctional medium, underlines that, in addition to the primary production of biomass, it has a set of other functions/roles, that are the foundation of establishing a balanced system and sustainability. All soil functions are inherent and equally important, and they include: ecological-regulation functions of the soil (receiver, collector and exchanger of various defects), such as: climate-regulation, spatial function, carrier of infrastructure, water purifier, source of genetic resources and biodiversity, landscape design, and the role of soil as a historical media-the development of civilization.

MATERIAL AND METHODS

Our research included the field and laboratory examination and data processing. Researches were carried out in 2009, 2010, 2012, 2013, 2014/15 year. 120 soil samples, from a depth of 0-30 cm, were taken from agricultural and urban land. The main task of the research was to determine the level of contamination of agricultural and urban land with inorganic pollutants: lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), chromium (Cr), cobalt (Co) and copper (Cu), and with (PAHs) polycyclic aromatic hydrocarbons as organic pollutants. The limit values were determined in accordance with the Regulation on determining the allowable amounts of harmful and dangerous substances in soils and methods of their examination (Official Gazette of the Federation of B&H, No. 72/09).

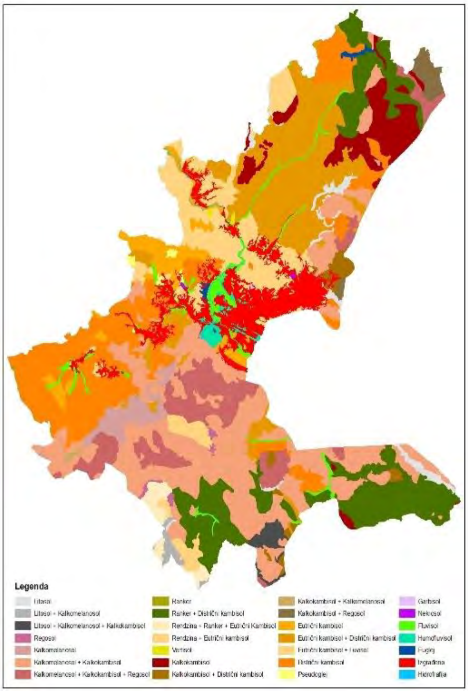


Figure 1. Pedological map of Canton Sarajevo
Source: Čustović et al., 2011

Sarajevo Canton occupies area of 126,994.59 ha, of which agricultural land is 48,118.97 ha, forest is 10,287.38 ha and unfertile land is 10,287.38 ha. The most represented with 90% are the automorphic soils (lithosols, regosols, rendzinas, rankers, mould, calcocambisols, distric cambisols and eutric cambisols). Hydromorphic soils are represented with 10% (fluvisol, pseudogley, semigley and eugley) A study of the use value of the land of the Canton Sarajevo are presented in Figure 1. The climate is continental, semi-humid with an annual average temperature of 9,5°C, and annual average precipitation of 961 mm (according to Lange's rain factor).

RESULTS

Some agricultural and urban soils in the Canton Sarajevo were examined for the content of heavy metals and PAHs. 120 soil samples, taken from a depth of 0-30 cm, were analysed in scattered state. We have shown the average values of the results of the heavy metals content in the soil, analysed by atomic absorption spectrometry (flame/graphite furnace), and the results of the PAHs determination, analyzed by gas chromatography with FID detection. BAS ISO11466:2000 and BAS ISO11047:2000 were used for heavy metals while BAS and ISO18287:2008 for the PAHs determination Values of the results are presented in Tables 1-7 and Graphs 1-5.

Table 1. The textural composition of the soil

Year	**The percentage content of soil particles with diameter in mm**				**Texture mark by Ehwald**
	Rough sand 2-0.2	**Fine sand 0.2-0.02**	**Fine Silt 0.02-0.002**	**Clay < 0.002**	
2009	0.38	62.30	23.89	13.42	Sandy loam
2013	13.21	59.82	10.69	9.22	Loamy sand soil
2014/15	8.20	65.71	13.19	12.70	Loamy sand soil

According to the above test results, textural composition of the soil shows no major differences per year, and Loamy sand soil mainly prevails.

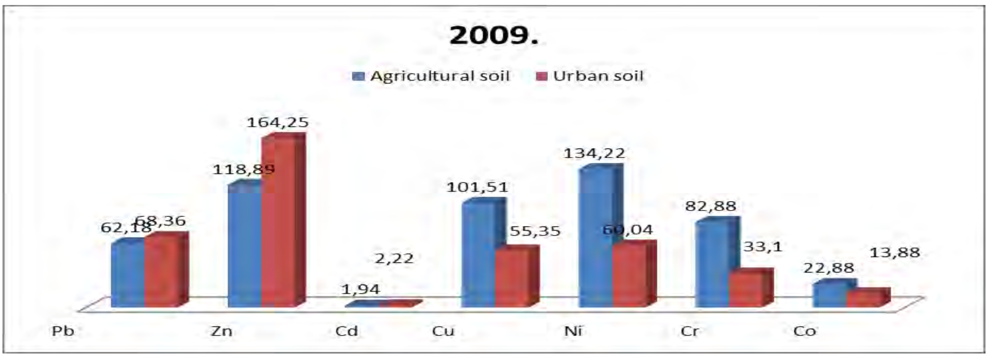
Table 2. General chemical properties of the soil

Year	Type of soil	pH values in		Humus content	$CaCO_3$ content
		H_2O	KCl	in %	in %
2009	Agricultural and urban	6.62	5.66	3.27	0.93
2010	Agricultural and urban	6.40	5.60	2.90	0.45
2012	Agricultural and urban	6.97	5.75	2.78	0.82
2013	Agricultural and urban	6.80	5.67	3.21	0.57
2014/15	Agricultural and urban	8.45	6.87	2.35	0.98

The pH value in H_2O is in the range from 6.40 to 8.45, while in 1MKCl ranges from 5.60 to 6.87. According to Schefter-Schatschabela limit values, soil is mildly acidic to mildly alkaline. The humus content ranges from 2.27% to 3.21%, and according to Gračanin the soil has low to medium humus content. The content of calcium carbonate is from 0.45% to 0.98% and it is a poorly calcareous soil.

Table 3. Average results (in mg/kg) of heavy metals and PAHs in 2009

year	Soil type	Pb	Zn	Cd	Cu	Ni	Cr	Co	PAH
2009	agricultural	62.18	118.9	1.94	101.5	134.2	82.88	22.88	n.d.
	urban	68.36	164.3	2.22	55.35	60.04	33.10	13.88	n.d.
	Limit values	***<150***	***< 300***	***< 1***	***< 100***	***< 60***	***<100***	***< 50***	***< 2***



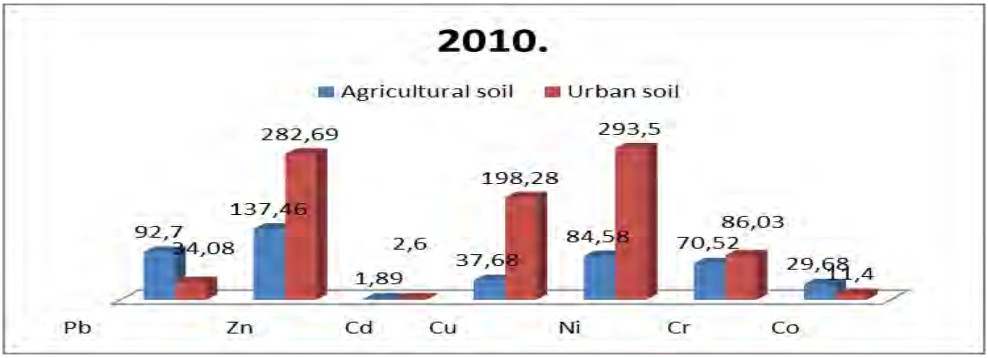
Graph 1. Average results of heavy metals for 2009

- Cadmium content is above the limit value, ranging from 1.94 mg/kg on agricultural soils, and 2.22 mg/kg in urban soils.
- Copper content is above the limit value, ranging from 101.51 mg/kg on agricultural soils, and 55.35 mg/kg in urban soils.
- Nickel content is above the limit value, ranging from 134.22 mg/kg on agricultural soils, and 60.04 mg/kg in urban soils.

The content of other heavy metals: lead, zinc, chromium and cobalt, and PAHs are below the limit values.

Table 4. Average results (in mg/kg) of heavy metals and PAHs in 2010

year	Soil type	Pb	Zn	Cd	Cu	Ni	Cr	Co	PAH
2010	agricultural	92.70	137.5	1.89	37.68	84.58	70.52	29.68	0.19
	urban	34.08	282.7	2.60	198.3	293.5	86.03	11.40	0.34
	Limit values	***<150***	***< 300***	***< 1***	***< 100***	***< 60***	***<100***	***< 50***	***< 2***

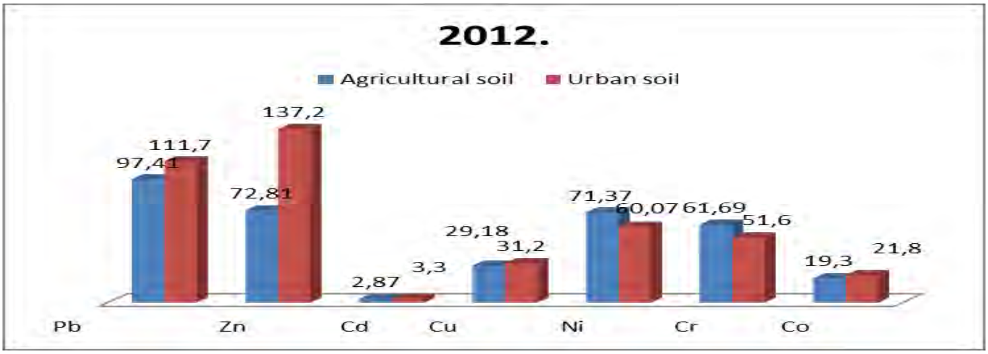


Graph 2. Average results of heavy metals for 2010

- Cadmium content is above the limit value, ranging from 1.89 mg/kg on agricultural soils, and 2.60 mg/kg in urban soils.
- Copper content is above the limit value, ranging from 198.28 mg/kg on agricultural soils, while is below the limit value in urban soils.
- Nickel content is above the limit value, ranging from 84.58 mg/kg on agricultural soils, and 293.5 mg/kg in urban soils. PAHs are below the limit values.

Table 5. Average results (in mg/kg) of heavy metals and PAHs in 2012

year	Soil type	Pb	Zn	Cd	Cu	Ni	Cr	Co	PAH
2012	agricultural	97.41	72.81	2.87	28.18	71.37	61.69	19.3	0.13
	urban	111.7	137.2	3.3	31.2	60.07	51.6	31.8	0.46
	Limit values	***< 150***	***< 300***	***< 1***	***<100***	***< 60***	***<100***	***< 50***	***< 2***



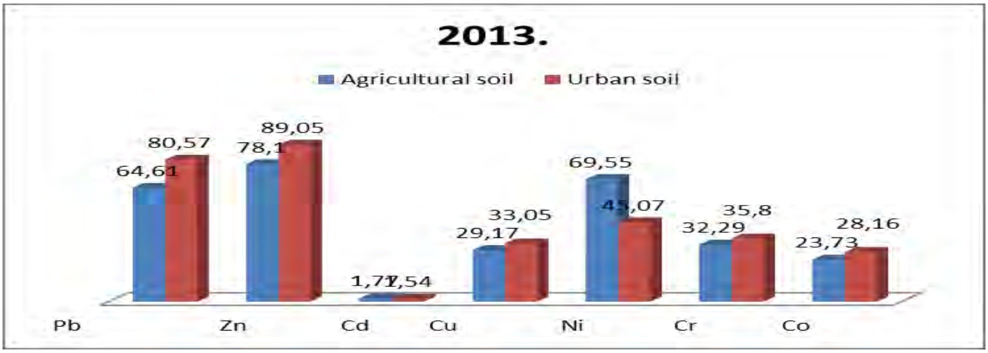
Graph 3. Average results of heavy metals for 2012

- Cadmium content is above the limit value, ranging from 2.87 mg/kg on agricultural soils, and 3.3 mg/kg in urban soils.
- Nickel content is above the limit value, ranging from 71.37 mg/kg on agricultural soils, and 60.07 mg/kg in urban soils.

The content of other heavy metals: lead, zinc, copper, chromium and cobalt, and PAHs are below the limit values.

Table 6. Average results (in mg/kg) of heavy metals and PAHs in 2013

year	Soil type	Pb	Zn	Cd	Cu	Ni	Cr	Co	PAH
2013	agricultural	64.61	78.1	1.77	29.17	69.55	32.29	23.73	0.12
	urban	80.57	89.05	1.54	33.05	45.07	35.8	28.16	0.45
	Limit values	***< 150***	***<300***	***< 1***	***< 100***	***< 60***	***<100***	***< 50***	***< 2***



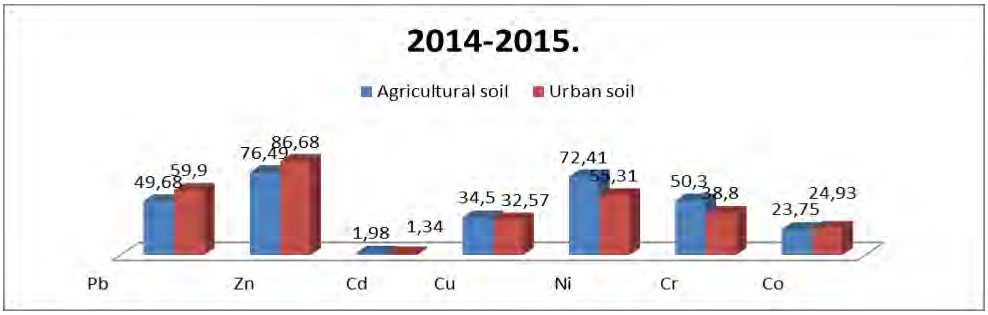
Graph 4. Average results of heavy metals for 2013

- Cadmium content is above the limit value, ranging from 1.77 mg/kg on agricultural soils, and 1.54 mg/kg in urban soils.
- Nickel content is above the limit value, ranging from 60.55 mg/kg on agricultural soils, while 45.07 mg/kg in urban soils is below the limit value.

The content of other heavy metals: lead, zinc, copper, chromium and cobalt, and PAHs are below the limit values.

Table 7. Average results (in mg/kg) of heavy metals and PAHs in 2014/15

year	Soil type	Pb	Zn	Cd	Cu	Ni	Cr	Co	PAH
2014-2015	agricultural	49.68	76.49	1.98	34.0	72.41	50.3	23.75	0.21
	urban	59.9	86.68	1.34	32.57	55.31	38.8	24.93	0.31
	Limit values	***< 150***	***< 300***	***< 1***	***100***	***< 60***	***<100***	***< 50***	***< 2***



Graph 5. Average results of heavy metals for 2014/15

- Cadmium content is above the limit value, ranging from 1.98 mg/kg on agricultural soils, and 1.34 mg/kg in urban soils.
- Nickel content is above the limit value, ranging from 72.41 mg/kg on agricultural soils, while 55.31 mg/kg in urban soils is below the limit value.

The content of other heavy metals: lead, zinc, copper, chromium and cobalt, and PAHs are below the limit values.

DISCUSSION

Investigations were carried out in the period from 2009 to 2015, on agricultural and urban soils in Canton Sarajevo. Analysis of the soil contamination in the studied period is presented in tables and graphs. Based on the comparison of the obtained average values of heavy metals and PAHs with a limit values, it can be established that the soil of the Canton Sarajevo is slightly exposed to contamination with heavy metals cadmium, nickel and partly with copper. The average concentration of other heavy metals and PAHs do not exceed the permissible limits.

Research conducted in 2009 and 2010 had determined the contamination of urban soil with nickel, copper and cadmium, while in agricultural soils higher contents of cadmium and nickel were found. The data obtained of cadmium content indicate slight contamination in agricultural and urban soils, while data from urban localities indicate intensive contamination with pollutants nickel and copper, whose average values are twice the permissible. The average copper content in urban soils ranged in value of 198.28 mg/kg, and the average nickel content was 293.5 mg/kg.

In the period from 2012 to 2015 the land of Canton Sarajevo was subjected to mild contamination with cadmium and nickel. In agricultural soils the average concentration value was 1.98 mg/kg for cadmium and 72.41 mg/kg for nickel.

On investigated localities of the Canton Sarajevo, contamination with other heavy metals was not established. The lead content ranged from 34.08 to 97.41 mg/kg, zinc content from 72.1 to 282.69 mg/kg, chromium content from 32.29 to 86.03 mg/kg and the content of cobalt ranged from 11.4 to 29.68 mg/kg.

Based on the results of the polycyclic aromatic hydrocarbons content, a slight increase in values in the period from 2010 to 2015 can be observed. The higher content of PAHs was found in urban localities, and lower content on agricultural soils, which seems to be a result of industrialization. The values of the PAHs content in urban soils ranged from 0.314 to 0.461 mg/kg, and for agricultural soils from 0.119 to 0.216 mg/kg. Taking into account that the examined samples are slightly acid to slightly alkaline, this is supported by the fact that in this range of pH values, heavy metals are less accessible to plants.

CONCLUSIONS

Field and laboratory studies were conducted from 2009 to 2015, on agricultural and urban soils in Canton Sarajevo for the presence of heavy metals: lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), chromium (Cr), cobalt (Co) and copper (Cu), and the content of PAHs in soil.

In 2009 there was an increased content of cadmium 1.94 mg/kg in agricultural soils and 2.22 mg/kg in urban soils, copper 101.51 mg/kg in agricultural soils and 55.35 mg/kg in urban soils and nickel 134.22 mg/kg in agricultural soils, and 60.04 mg/kg in urban soils.

In 2010 there was an increased content of cadmium 1.89 mg/kg in agricultural soils and 2.60 mg/kg in urban soils, copper 198.28 mg/kg in urban soils and nickel 84.58 mg/kg in agricultural soils and 293.50 mg/kg in urban soils.

In 2012 there was an increased content of cadmium 2.87 mg/kg in agricultural soils and 3.3 mg/kg in urban soils and nickel 71.37 mg/kg in agricultural soils and 60.07 mg/kg in urban soils.

In 2013 there was an increased content of cadmium 1.77 mg/kg in agricultural soils and 1.54 mg/kg in urban soils and nickel 69.55 mg/kg in agricultural soils and in urban soils the content was below the limit value.

In 2014/15 there was elevated cadmium content of 1.98 mg/kg in agricultural soils and 1.34 mg/kg in urban soils and nickel of 72.41 mg/kg in agricultural soils, while in urban soils the content was below the limit value.

We can observe in 2013, 2014 and 2015 a slight decrease in the content of cadmium and nickel. Elevated concentrations of the se metals in agricultural soils are most likely of the lithological origin; while in urban soils are both lithological and anthropogenic origins.

The concentrations of lead, zinc, nickel, chromium and cobalt are below the limit values. The same can be applied for PAHs compounds. Higher content of PAHs was found in urban localities, while lower was present on agricultural sites as a result of most likely anthropogenic impact.

Since increased concentrations of cadmium, nickel, and copper have a toxic affect on plants, and through them on the animals and humans, it is necessary to conduct more detailed researches of elevated concentrations of cadmium, nickel and copper in Canton Sarajevo.

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DISTRIBUTION OF JERUSALEM ARTICHOKE (*Helianthus tuberosus* L.) N THE CANTON SARAJEVO AREA

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ABSTRACT

Invasive plant species which also include Jerusalem artichoke (*Helianthus tuberosus* L.), are plants which come from other floral-geographical areas and in process of competition they suppress autochthonous gene by conquering available ecological systems. The spread of foreign species is becoming serious threat to the conservation of natural and semi-natural biotopes. Jerusalem artichoke belongs to the family *Asteraceae* and it originates from America. İt is perennial plant with highly developed root in form of irregular tubers from which emerges each year more perennial stalks. İt grows up to 3 m height. İn our conditions it does not produce seed, it is reproducing vegetative by tubers. İt is used for production of alcohol, in the pharmaceutical and food industry, as fodder and medicinal plant for more than 100 years. İn the second half of 20th century it has become serious invasive species in all parts of Europe. On the EPPO list Jerusalem artichoke belongs to 34 dangerous invasive species. İt is considered as weed of natural areas but it can occur on the agricultural soils and ruderal lands. The aim of this paper is to examine the prevalence of Jerusalem artichoke in the area of Sarajevo Canton. The obtained data can be used for its adequate and more successful suppression.

Keywords: *invasive species, Jerusalem artichoke, Sarajevo*

INTRODUCTION

Jerusalem artichoke belongs to the family *Asteraceae*. It is used for the alcohol production, forage crop, in the pharmaceutical and food industry (Seiler, 2007), as well as a medicament in the home medicine. Healing properties of this species are scientifically proven (Šilić and Abadžić, 2000). It originally comes from North America where American Indians were using it as a food and medicament and from the 16th century it is grown in many countries

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of Central Europe (Šilić and Abadžić, 2000). Today, it is cultivated and escaping, often invasive, in many temperate areas in Europe, Asia, New Zealand, and tropical South America (Weber, 2003). Despite the aforementioned benefits Jerusalem artichoke is considered as weed in the natural areas, but it can also occur on the arable land and ruderal areas. Labant-Hoffmann and Kazinczi (2014) said that in the second half of 20th century it became serious invasive species in every part of Europe. On the EPPO (European Plant Protection Organization) it is placed on the 34th place of dangerous invasive species.

Jerusalem artichoke is perennial plant with well-developed root in the form of irregular tubers. It grows up to 3 m height. It has strong, upright, one-year stalk. Raw tuber has a taste of hazelnuts and cooked one has a taste of artichoke. It grows in warm and continental climate. Often it is found near rivers and brooks and sometimes as a decoration in gardens. It is perennial plant and in our region it multiplies by tubers. Tubers are spindle-shaped and elongated and in contrast of potato they contain inulin instead of starch. Often it is found on fertile and moist soil, but it can also grow on the poor soil such as near the roads, on the edges of the forest, on the forest clearings, near the embankments and on the abandoned soils. It grows all the time because it is self-regenerated so we can say that it is indestructible. In Bosnia and Herzegovina it appears on the large number of regions in Central Bosnia (by the river Bosna) and in Herzegovina (by the river Neretva). It is also found by the river Spreča, but it already spread on abandoned ruderal habitats and also on crops. It was found in corn, sunflower, small grains and alfalfa (Bećar *et al*., 2009). Radovanović *et al*. (2013) for *Helianthus tuberosus L.* said that it grows on the wide territory of Serbia and Romania.

This plant species has a unique chemical composition and as the most precious ingredient stands out inulin. Inulin has a favorable impact on a human health and includes reduced risk for cardiovascular diseases, probiotic effect, prevention and/or reduction of osteoporosis. Terzić *et al*. (2007) consider Jerusalem artichoke as a food source. It is recognized as a potential source of resistance on some diseases that occur in sunflowers (Terzić *et al*., 2011).

Jerusalem artichoke is considered as a dangerous weed on agricultural and non-agricultural soils, so its repression has been a topic for a large number of researchers. Geophytes are the weeds that are hard to control and this species is one of them. Mowing it two times per year can significantly reduce it. Other researchers suggest that it should be mowed many times per year, every time when the plants height reaches 50 cm. Chemical repression is the best just before blooming and the efficiency is than 100%. The biggest problem for chemical control is that this species is mainly found in natural regions where this type of control is not allowed. The complete destruction of tillers and significant reduction of underground parts of the plant happened when the chemical and mechanical repression was made. According to the mentioned, best type of control is combination of chemical and mechanical treatments (Labant-Hoffmann and Kazinczi, 2014). Schittenhelm (1996) examined Jerusalem artichoke as a crop. After removing the tubers, significant number of them remains in soil. These tubers can make serious problems as a weed in the next crop. In the corn it can reduce yield by 91% and in the sugar beet by 81%. Control of Jerusalem artichoke is also possible by burning. Chemical and burning control is not recommended in the urban areas and near rivers.

There are no detailed data on distribution of Jerusalem artichoke in the Sarajevo Canton, so it was impossible to follow the dynamics of its spread and development over past years. The aim of this paper is to map populations of Jerusalem artichoke in area of Sarajevo Canton in order to ensure its monitoring and control in the future.

MATERIAL AND METHODS

The area of studying this invasive species is Canton Sarajevo. Canton Sarajevo is located in central part of Bosnia and Herzegovina based in city of Sarajevo. The area of the Canton Sarajevo is 1,276.9 km^2. Canton Sarajevo is under the influence of middle-europe continental climate from the north and mediterian climate from the south. Intertwining of these impacts and diversity of relief give this area feature of moderately continental climate. Average annual temperature is 9.5°C. Average annual precipitation is 1,000 to 1,200 mm. Snow can be heavy in this area, especially on higher altitudes.

Presence and distribution of invasive weed species was recorded by square method (0.25 m^2) (Novak *et al*., 2009).This method implies on the identification of species, number of stalks, height of plant, and phase of growing and development. Research was conducted in the period from April to October because it is the period of active vegetation. Ruderal areas, meadows and agricultural areas were examined.

All Jerusalem artichoke stands were photographed, mapped and assigned size classes (0-10 plants per m^2, 10-50 plant per m^2 and >50 m^2).

RESULTS AND DISCUSSION

In this research 42 habitats of Jerusalem artichoke were found. The highest number of locations was found in the west part of Canton Sarajevo, municipality Ilidža. Municipalities Hadžići, Novi Grad and Vogošća comes after Ilidža, while in other municipalities only 1 or 2 locations were found (Table 1).

Table 1. Number and size of locations of Jerusalem artichoke in Canton Sarajevo by municipalities

Municipality	Number of plants per m²			TOTAL
	0-10	10-50	>50	
Ilijaš	0	1	0	1
Ilidža	3	11	6	20
Hadžići	0	7	0	7
Trnovo	0	0	1	1
Novi Grad	0	4	0	4
Stari Grad	0	2	0	2
Novo Sarajevo	1	0	0	1
Centar	1	0	1	2
Vogošća	0	4	0	4
TOTAL	**5**	**29**	**8**	**42**

Figure 1. Surveyed area and position of registered Jerusalem artichoke stands

In the municipality Ilijaš Jerusalem artichoke was recorded on the ruderal area. In the municipality Ilidža it was found on 20 locations. In the Butmir settlement it was recorded on the seven locations, mostly along the road from municipality building to the junction Soković Kolonija – Hrasnica. On the location near municipality building on the ruderal soil this species takes area around 2,000 m^2. Number of plants per 1 m^2 on this location is 95, while the plant height in blooming phase was to 200 cm. Žgančikova *et al.* (2012) found location with 265 plants per m^2. On the ruderal area Jerusalem artichoke was recorded in Butmir settlement – bus station near the bridge on the river Tilava. It was recorded on the agricultural soil on the stubble in the area of Federal agricultural institute. Also it was found in the corn on four locations. At the experimental field of Faculty of Agriculture and Food Sciences it was recorded 80 plants per m^2 with average height of 1.3 m. This species was also recorded in other parts of this municipality, in the Osjek and Bojnik settlements. However, given that Jerusalem artichoke likes moisture soils it is located along sides of river Bosna and Željeznica with the high density.

In the municipality Hadžići Jerusalem artichoke was found on the sides of river Zujevina. Mostly those are communities with 13 to 35 plants per m^2.

From the aspect of invasive weed species municipality Trnovo was mostly examined along regional road Sarajevo - Goražde. Jerusalem artichoke was found in the valley of river Željeznica.

In the Novi Grad municipality Jerusalem artichoke was found on ruderal area and on the sides of river Bosna in Rajlovac settlement.

In the Stari Grad municipality Jerusalem artichoke was recorded on the part of child playground near bridge Kozija ćuprija and in Sedrenik settlement near the road.

Municipality Novo Sarajevo is in the center of the city so only one location of Jerusalem artichoke was found and it is in Vraca settlement, road to Lukavica.

In the Centar municipality Jerusalem artichoke was found on two locations and it is in Nahorevo and Pionirska dolina settlements. The abundance of Jerusalem artichoke is particularly striking in the Pionirska dolina settlement near the Koševski stream. On this abounded and moisture soil it has height over 150 cm with 55 plants per m^2.

In the center of municipality Vogošća, where the areas are orderly maintained, there are no recordings of any locations with this species. Going to the Sarajevo from Vogošća through Hotonj and Kobilja Glava settlements there are some locations of this weed. Near the gas station El-Tarik one big location of Jerusalem artichoke was recorded with 40 plants per m^2 and height up to 170 cm. Jerusalem artichoke was also found near river Vogošća which was expected since this weed likes moisture soils especially near waterways. In the Hotonj settlement there was also one location recorded (across gas station Hifa) with 15 plants per m^2. Jerusalem artichoke (*Helianthus tuberosus* (L.)) was found mainly on the riverbanks in dense populations (Žgančikova *et al*., 2012). On the road to Tuzla several locations of Jerusalem artichoke were found, near the river Ljubina. There was up to 50 plants per m^2 with the height up to 140 cm.

In order to develop effective eradication measures of this invasive weed, it is necessary to conduct more detailed research, especially on the agricultural land that has limited access. In nine municipalities in Canton Sarajevo only in municipality Ilidža it was found on the agricultural areas.

CONCLUSIONS

- Research conducted during one vegetation season in nine municipalities in Canton Sarajevo confirms the existence of Jerusalem artichoke in all municipalities. In total it was found on 42 locations with the biggest number in Ilidža municipality.
- In all municipalities this weed species was found on ruderal area, while only in municipality Ilidža it was found on stubble and in corn. The highest number of Jerusalem artichoke on rudereal area is also because of the fact that access to this area is undisturbed, while entering private areas was a problem which happened in this research.
- The highest number of plants per m^2 was recorded in Ilidža municipality – 95. On the eight locations number of plants per m^2 was bigger than 50, while the biggest number of locations were from 10 – 50 plants per m^2.
- In order to develop effective eradication measures of this invasive alien, it is necessary to conduct more detailed research as well as on non-agricultural and agricultural areas, but the focus should still remain on removal of vegetative growth.

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