**SECTION 7:** NATURAL RESOURCES MANAGEMENT AND ENVIROMENT PROTECTION

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**Review paper**

# ESTABLISHMENT OF SOIL MONITORING SYSTEM IN REPUBLIC OF MACEDONIA

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**Abstract**
Soil is a finite natural resource. Land and soils deliver key ecosystem services and are pillars of the green economy. They support human well-being and provide sustenance for all including the poor, and are a source of new employment and economic progress. Unfortunately, their degradation is a serious global problem because of its adverse impact on their properties, on agricultural productivity, on food security, climate change, and sustainability of the ecosystem. In the Republic of Macedonia there has not been established monitoring of soil properties and soil degradation and therefore monitoring of the condition and changes of soil properties is necessary for soil protection, preservation of its natural functions and prevention of degradation processes. Soil monitoring implies continual monitoring of certain parameters of soil with purpose of gathering information on changes of the condition and characteristics of soil, and identifying the form and intensity of soil degradation. Without the development of the system by which information on negative changes in the soil would be continually gathered, there can be no timely response to prevent or alleviate such changes.
**Key words**: soil, monitoring, soil properties, soil degradation, soil protection.

## Introduction
*"Because it's everywhere, we tend to overlook the fact that soil is a limited natural resource"* (Rio + 20: Goals for Healthy Soils and the Role of the Global Soil Partnership). All soil researchers emphasize that soil is a finite natural resource. Technically, the soil is a renewable natural resource, because its formation goes on perpetually. However, due to the fact that pedogenesis is a very slow process, the soil is non-renewable for all practical purposes, which is why according to (Varallyay 2000 and Montanarella 2007), cit. Ličina V. et. al. (2011), scientists classify it as a conditionally renewable resource. Soil formation and restoration on the geological substrate take thousands of years, whereas the processes of soil degradation and soil loss are sometimes much more rapid and might occur in a matter of seconds or minutes, such as is the case with soil erosion or other kinds of natural or anthropogenic accidents.
As a dynamic polydisperse system with its many functions, the soil provides support for the entire ecosystem. It is a reactor, transformer and integrator of material and energy from other natural resources (solar radiation, atmosphere, surface and subsurface waters, biological resources). Soil is

the foundation of agricultural development and ecological sustainability, provide the basis for food, feed, fuel and fiber production, clean water availability, nutrient cycling, organic carbon stocks, one quarter of global biodiversity, and serve as a platform for construction and construction material. These functions are performed on different levels and are determined by inherent soil characteristics (e.g. texture, organic matter content, pH, cation exchange capacity, porosity etc.) and external environmental (climate, terrain, hydrological, biological) and anthropogenic (soil-use and management) factors (Georgely T. et.al 2007).

"The Father of India's Green Revolution", M. S. Swaminathan said that *"Soil anaemia also breeds human anaemia. Micronutrient deficiency in the soil results in micronutrient malnutrition in people, since crops grown on such soils tend to be deficient in the nutrients needed to fight hidden hunger. (...) Managing our soil and water resources in a sustainable and equitable manner needs a new political vision."*

However, despite the essential role that soil plays in the life of people, there is increasing degradation of soil resources due to inappropriate practices, burgeoning population pressures and inadequate governance over this essential resource. These include: decline in biodiversity and organic matter, erosion, compaction, floods and landslides, contamination (local and diffuse), sealing and salinization (Margareta Cvetkovska, Tatjana Mitkova.et.al 2007, Татјана Миткова et.al 2009). Therefore, the issue of the maintenance of soil resources is not merely an academic question, it is also an obligation owed to nature by both the individual and society as a whole.

Soils are often perceived as a second-tier priority and no international governance body to support coordinated global action on their management exists. For these reasons, FAO and a group of partners have launched the Global Soil Partnership (GSP) to improve global governance of the world's soil resources in order to guarantee healthy, productive soils for a food secure world - and to work together to sustain other essential ecosystem services on which our livelihoods and societies depend. Soil monitoring is an integral part of environment protection system and a major instrument of decision-making for the sustainable management and cost-efficient utilization of this resource (Sekulic et al. 2011).

Monitoring is the process of repeated observing, for defined purposes, of one or more elements of the environment according to pre-arranged schedules in space and time and using comparable methodologies for environmental sensing and data collection. It provides information concerning the present state and past trends in behaviour of the soil, or according to Bašić (2002), the soil protection strategy can be represented as shown below:

4M + 2P or 4M = Monitoring + Measuring + Mapping + Modeling + 2P = Predicting + Prevention

The significance of soil monitoring was emphasized by the European Union which, by Decision No 1600/2002/EC, raised the significance of soil protection to the level of water and air protection. In 2006, the European Commission gave a Proposal for a Directive of European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC, COM (2006)232) whose goal is to ensure soil protection based on principles of protection of soil functions, prevention of soil degradation, alleviation of effects of degradation and repair of degraded soils.

**Where we are?**

Macedonia has a long tradition of monitoring environmental quality, particularly in the fields of water and ambient air. Monitoring of biosphere, waste and noise are in the initial stages. The most important institutions involved in monitoring are the Ministry of Environment and Physical Planning (MEPP), the Hydrometeorological Administration (HMA), Institute for Public Health of the Republic of Macedonia (IPHRM) and the corresponding regional bodies (Environmental Monitoring Strategy, 2004).

Due to the fact that R. Macedonia is an agricultural country, it is important understand the role of the soil as an indispensably resource for this practice. However, in our country the process of monitoring soil properties and soil degradation has not been implemented yet, i.e. the current legislation does not cover soil monitoring. According to the Law on Agricultural Land, the Ministry for Agriculture, Forestry and Water Supply should define the substances that are harmful to the agricultural land and their maximum allowed concentration in the soil. However, the corresponding book of regulation has not been prepared. Soil monitoring is done within different projects, but without coordination between the projects. That is why establishing a monitoring system for the soil properties conditions and changes is more than necessary for their protection, as well as for protection of the natural functions of the soil and prevention of the degradation processes. Total area of the Republic of Macedonia (25,713 km$^2$), 44,04% is still an important agricultural area (source: map CORINE Land COVER, Environmental Indicators of the Republic of Macedonia, 2008). Land use distribution in the R Macedonia (in %) and land distribution by bonity classes in % are given in Table 1 and Figure 2.

Following trends can be distinguished: around 17,35% of the territory is classified as unproductive land; only one-half of agriculture land is arable land. This represents one-fourth of the territory; only 8 % of the arable land belongs to the higher land use classes. The reduction of the arable surfaces continues in its most fertile sections as the result of different types of degradation.

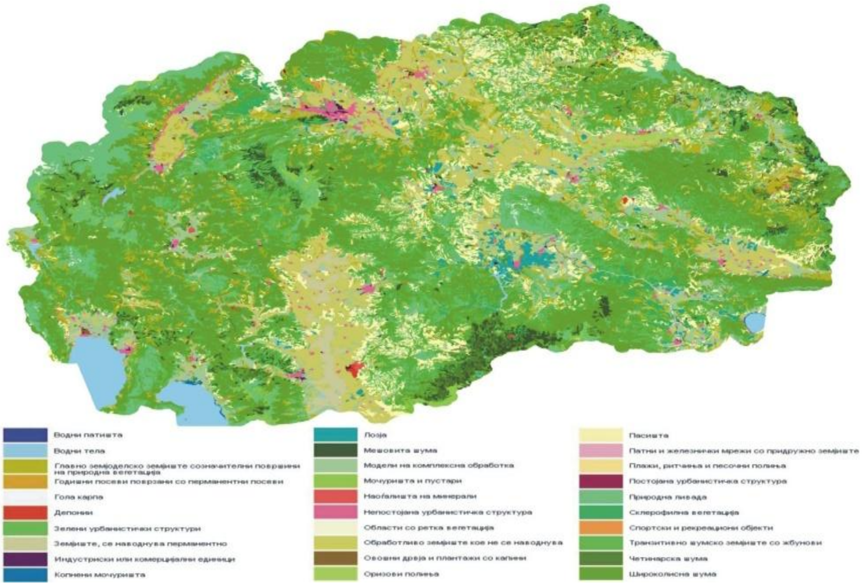



Figure 1. Map CORINE Land COVER, source: Environmental Indicators of the Republic of Macedonia, 2008

Table 1. Land use distribution (ha and %)

| Land use distribution | Area in ha | Total land percentage | Arable land percentage; unproductive land percentage |
|---|---|---|---|
| Total land | 2.543.216 | 100,00 | - |
| 1. Productive land | 2.101.812 | 82,64 | - |
| 1.1. Forest land | 981.812 | 38,60 | - |
| 1.2. Agriculture land | 1 120.000 | 44,04 | - |
| 1.2.1. Pastures | 608.000 | 23,90 | - |
| 1.2.2. Arable land | 511.000 | 20,09 | 100,00 |
| 1.2.2.1.Ploughlands and vegetable gardens | 415.000 | 16,32 | 81,21 |
| 1.2.2.2. Orchards | 14.000 | 0,55 | 2,74 |
| 1.2.2.3. Vineyards | 21.000 | 0,82 | 4,11 |
| 1.2.2.4. Natural meadows | 61.000 | 2,40 | 11,93 |
| 2. Unproductive land | 441.404 | 17,35 | - |

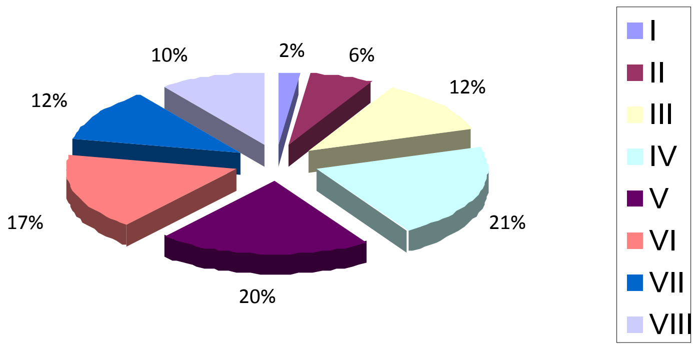



Figure 2. Land distribution by bonity classes in %

**What we have to do**

Following the Stabilization and Association Agreement between the Republic of Macedonia and the European Communities and their Member States, Macedonia is contract-bound to approximate its national legislation to the relevant EC legislation. This process of approximation includes approximation to a large number of EC legal obligations in the environmental sphere. Monitoring, in the comprehensive EC sense of the word, plays an important role in most of the relevant environment-related EC directives as well as the transposed Macedonian draft laws.

Structural changes in the Republic of Macedonia in the recent decade have given rise to overlaps concerning the responsibilities for monitoring and the activities of different institutions. Many activities are regulated by laws that are more than 30 years old. The monitoring responsibilities have varied for different environmental media. Since there was no overall national strategy or institution that integrated and coordinated the monitoring activities, the responsibilities and activities have been split between different Ministries or other institutions. There are overlaps regarding the institutional responsibilities and activities for some of the environmental media and gaps for others.

For successful and efficient management with its natural resources, each country must prepare its inventory by preparing appropriate maps (foundation) in a modern digital format, as well as establish adequate databases where the graphic (charts, maps, satellite images etc.) will be stored and interconnected with the appropriate tables where numerical data are contained defining and quantifying the natural resources (attributive data).

The preparation and printing of the Soil Map of the Republic of Macedonia will represent not only a sublimation of the efforts that have been put in the course of several decades by a pleiad of experts in the field of the study of soils, but also creation of a powerful toll in the country's economic development planning process especially in agriculture, forestry, rural development, protection of the environment (especially soils under degradation), prevention of any changing of the agricultural soils' application, realization of land consolidation and arrondation, preparation of the agricultural bases of certain areas, spatial planning, organization of the organic agricultural production etc.

**Establishment of soil monitoring system**

Soil quality varies with site conditions and management practices. Soil quality monitoring may be performed at several levels, from global estimates for the entire country or its parts to estimates for a single production plot.

Monitoring programmes, as part of the entire concept, must be agreed upon beforehand by the monitoring partners. Data, information and decisions constitute part of a strategy. Such monitoring programmes are the outcome of communication between the experts involved in designing such systems together with the decision-makers (or the population) making use of the information. Monitoring programmes aim to yield relevant information at reasonable costs. The monitoring should be viewed and implemented as:

– monitoring and protection of agricultural land (systemic control of the soil fertility, testing the soil's heavy metal content and other hazardous substances, examining the effect of fertilizers on crop quality and yield and examining the changes in the soil's chemical properties as well as the irrigation water quality) and

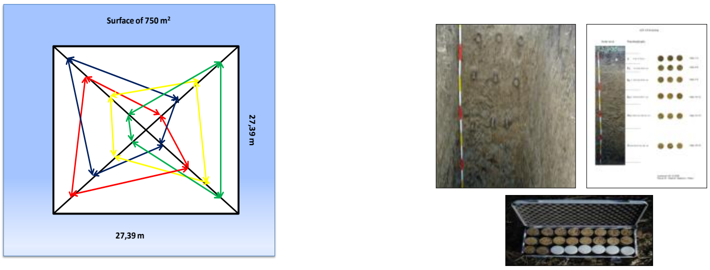
– soil monitoring for environmental protection and sustainable development (systemic observation of soil quality through observing the soil degradation assessment indicators, as well as undertaking and implementing remedial measures to eliminate the consequences of soil contamination and degradation regardless of whether they occur naturally or as a result of anthropogenic degradation).

Technical aspects of monitoring (networks, parameters and methods). The soil monitoring will be realized in 3 phases:

– field survey including collection of soil samples for laboratory analysis (ISO 10381-1:2002 and ISO 11464:2006);

– laboratory analysis (chemical, physical, physical-mechanical, biological, productive properties, etc.) are in accordance with the ISO standards

– statistical processing of the results.




Soil sampling sheme

Soil sampling of the profile in undisturbed condition

Figure 3. Soil sampling sheme and soil sampling of the profile in undisturbed condition

**As a conclusion**

Why monitoring?

Set up one single monitoring system at the state level.

Manage and maintain the data base for soil quality.

Provide information for the management of soil quality regarding soil quality control, identification of priorities, information of the public about soil quality and alert situations

Fulfill international obligations.

Such system will enable the different applications regarding food security, climate change mitigation and adaptation, provision of ecosystem services, soil suitability analysis, soil degradation assessment, etc.

The system will also allow the integration of soils with other disciplines and will be fundamental for monitoring the status of soils as per human interventions though land use changes and climate change impacts.

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## ВОСПОСТАВУВАЊЕ НА МОНИТОРИНГ СИСТЕМ НА ПОЧВИТЕ ВО РЕПУБЛИКА МАКЕДОНИЈА

Татјана Миткова, Миле Маркоски

**Апстракт**
Почвата е ограничен природен ресурс. Во екосистемот, земјиштето и почвите обезбедуваат клучни функции и се столбови на зелената економија. Тие се подршка за благосостојбата на човечката цивилизација во насока да се обезбеди храна за сите, вклучително и за сиромашните, и се ресурс за нови вработувања и економски напредок. За жал, нивната деградација е клучен глобален проблем бидејќи има негативно влијание на нивните својства, врз продуктивноста на земјоделското производство, врз безбедноста на храната, климатските промени и одржливоста на екосистемот. Во Република Македонија не се спроведува мониторинг на почвените својства, ниту за почвената деградација. Затоа, воспоставувањето на мониторинг на состојбата и промените на почвените својства е повеќе од потребно за нивната заштита, за заштита на нејзините природни функции и за превенција од процесите на деградација. Мониторингот на почвата подразбира континуирано следење на одредени параметри на почвата со цел собирање информации за промените на состојбата и карактеристиките на почвата, и идентификување на формата и степенот на нејзината деградација. Без развој на систем со кој постојано ќе се собираат информациите за негативните промени во почвата, не може на време да се одговори односно да се преземат мерки за да се спречат или намалат ваквите промени.

**Клучни зборови**: почва, мониторинг, почвени својства, почвена деградација, заштита на почвата.

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**Original scientific paper**

# TOBACCO STALKS AS RENEWABLE RAW MATERIAL FOR AGRO-INDUSTRIAL UTILIZATION

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**Abstract**
Tobacco stalks as agricultural waste are renewable raw material that can be converted into useful products and energy. It is noteworthy that, at 40 % moisture content, about 5 tons of tobacco stalks per hectare and year are produced only in six months duration. The objective of this study was to determine the morphological properties and chemical composition of stalks of Burley tobacco, variety B 98/N (cellulose, *Klason* lignin and acid soluble lignin, ash, total nitrogen and dry matter) and to evaluate its suitability for agro-industrial utilization. After harvesting of the leaves, part of the stalks were collected and air-dried in greenhouse and the rest were left to dry in field, under atmospheric conditions. The stalks were analyzed according to ASTM standard methods for the determination of moisture, ash, and lignin. The *Kurshner-Hoffer* method was used for determination of cellulose. The average values of length, diameter, and weight of dried tobacco stalks were determined as 170 cm, 8.5 cm, and 210 g, respectively. Content of cellulose was found to be 38.5 % in air-dried stalks and 36.4 % in field dried stalks. Contents of total lignin, *Klason* lignin and acid soluble lignin in air-dried stalks were 22.5 %, 20.7 % and 1.80 %, respectively. The results indicate that cellulose and lignin content in air-dried stalks are slightly higher, compared to those dried in field. It was found that 30 % of the nitrogen, 18 % of the ash, and 35 % of the organic matter may be lost from tobacco stalks if they are dried in field.
**Key words**: tobacco, stalks, cellulose, lignin, utilization.

## Introduction

Tobacco (*Nicotiana tabaccum* L.) is an annual plant of 0.8-2.5 meters in height depending on the variety. It is grown and culturally managed for high quality grade leaf for manufacturing a number of tobacco products. Every year, large amounts of tobacco stalks are produced, most of them being disposed of as wastes, incorporated into soil or burned in the field (Agrupis and Maekawa, 1999). This agricultural waste from harvesting of tobacco farms are useful substitute for traditional wood raw materials in the pulp and paper industry and xylose (Shakhes *et al.*, 2011; Akpinar *et al.*, 2011). Agricultural residues such as tobacco stem are renewable sources of energy (Sun and Cheng, 2002; Martin, *et al.*, 2008). Tobacco waste presents an alternative to inorganic fertilizer. It is possible to use tobacco stalk as a soil amendment due to its high organic matter and low toxic element content (Okur, *et al.*, 2008; Chaturvedi *et al.*, 2008).

Tobacco stalk is composed largely of cellulose, a polymer of glucose; hemicellulose, a complex polymer of which the main chain consists primarily of xylans or glucomannans; and lignin, a complex phenolic polymer (Agrupis *et al.*, 2000; Kajita *et al*., 2002). They are consisting of phloem and xylem cells and its hardening begins as floral initiation occurs. Delaying topping till full bloom allows the stalks to harden and accumulated lignin, cellulose and hemicellulose (Palmer and Perace, 1999; Flower, 1999). Cellulose and lignin are crucial for structural integrity of the cell wall and stiffness and strength of the tobacco stalk and root. In addition, lignin waterproof the wall enabling transport of water and solutes through the vascular system, and they play a role in protecting plants against pathogens. The secondary cell wall thickenings that form the spiral rings of the tobacco xylem elements are rich in lignin in addition to cell wall materials. Lignin is concentrated in the xylem elements of the vascular bundle in the leaf tissue and xylem elements of the stalk tissues. Cellulose along with hemicellulose and pectin are deposited in the primary and secondary cell walls of the various cell types (Esau, 1967; Hepworth and Vincent, 1998). Commonly used method for the quantitative determination of cellulose in hardwood and softwood materials is Kurshner-Hoffer method. This gravimetric method involves multi step extraction of noncellulosic compounds from plant material (Browning, 1967, ASTM, 1993).

Unlike the other cell wall components of tobacco plant, the lignin is mostly insoluble in mineral acids. A method developed by the ASTM is the most commonly employed method for determination of the lignin in wood and non wood samples (Agrupis and Maekawa, 1999). The approach, a modification of the Klason process consists of treating the stalk samples with 72% sulphuric acid, followed by a dilute acid step, to hydrolyze the polysaccharides, extracting of the majority of the lignin as an insoluble residue. This acid insoluble lignin is quantified gravimetrically after extraction and filtration. This value, however, does not represent the total lignin content of the sample. A small portion of the lignin is solubilized during the hydrolysis and its remaining dissolved in the filtrate from insoluble lignin preparation. This lignin fraction is referred to as acid soluble lignin and may be quantified by ultraviolet spectroscopy, which relies on the acid soluble lignin's adherence to Beer's law (Agrupis and Maekawa, 1999, Akpinar *et al*., 2011). An absorptivity (extinction coefficient) value of 110 $L/mol^{-1}cm^{-1}$ is used to calculate the amount of acid-soluble lignin present in the hydrolysate. The 205 nm absorptivity reported for most woods fall in the range of 88 to 113 $L/mol^{-1}cm^{-1}$. (Kaar and Brink, 1991). Together, the acid insoluble and soluble determination quantify the total lignin content of a sample.

Tobacco is an important crop in the Republic of Macedonia and significant efforts are made to restart production of Burley tobacco. About 5 tons of stalks from this tobacco type per hectare in year are produced in only six months duration. The literature findings showed that stalks and other tobacco waste could be used in various products, in the production of pulp and paper, bio-ethanol, as well as, inorganic fertilizer (Sun and Cheng, 2002; Chaturvedi *et al*., 2008; Martin, *et al*., 2008; Shakhes *et al*., 2011).

The objective of present work was to determine the usability of dried tobacco stalks. The morphological properties and chemical composition of stalks of Burley tobacco type (B 98/N variety) were investigated to evaluate its agro-industrial usability. Also, considered the influence of the manner of drying on chemical composition of stalks was evaluated.

## Material and methods

*Plant Material*. The field and laboratory research was set up in Scientific Tobacco Institute-Prilep in 2010 and 2011 years. Tobacco variety B 98/N was grown according to the standard agriculture practice for tobacco type Burley, on plant spacing of 50 cm within and 90 cm between rows, i.e. at planting density of about 22 000 plants per ha. Six tobacco harvests were harvested according to the conventional regime. The morphological traits of forty stalks of the middle plot row, i.e. length, diameter, and weight, as well chemical composition of stalks were determined.

*Stalk Drying Treatments*. After harvesting the leaves, forty stalks were marked. Twenty of marked stalks were air-dried in greenhouse until achieving moisture content of 15-20 %. Other twenty tobacco stalks were left to dry in field one month, under atmospheric conditions. Ten stalks from the two manner of drying were analyzed whole and ten were cut into upper, medium and lower leaf position. First, stalks were cut into smaller pieces to about 3-5 cm length and then ground by a Retsch ZM1 mill (Germany) to pass a 110 mm screen. Final sizing of powdered samples was done through the use of a sieve of 0.5 mm.

*Chemicals*. For cellulose and total nitrogen determination of stalks reagent grade 96 % ethanol, sodium hydroxide, Kjeldahl catalyst (Cu-Se), 0.1 mol/L hydrochloric acid, 65% nitric and boric acid (Merck, Germany) were used. Determination of acid insoluble and acid soluble lignin was done with analytical grade 72% sulphuric acid purchased from Merck (Germany).

*Characterization of stalk*. The moisture content was determined by drying at 105 $^{o}$C till constant mass. The ash content in stalk was determined by dry oxidation at 575 $^{o}$C till constant mass achievement. The nitrogen content (N) was determined by *Kjeldahl* method (Veverka *et al.,* 1993). The nitrogen was quantified by mineralization within a strong acid medium, containing 98% sulphuric acid, followed by steam distillation and titrimetric determination of $NH^{+4}/NH_3$.

*Determination of cellulose*. The cellulose content was determined following *the Kurshner-Hoffer* approach, by treating 2 g of sample with 50 mL of alcoholic nitric acid solution under reflux, during four cycles per 1h. After each cycle, the alcoholic nitric acid solution was removed and a fresh amount was added. At the end of the four cycles, the cellulose was filtered, washed, dried and weighed.

*Determination of Klason acid insoluble lignin*. The mixture of ground tobacco stalk (0.3 g) was mixed with 72% sulphuric acid (3 mL) was heated at 30 $^{o}$C, 1h with stirring. After adjusting of acid concentration to 4 % w/w by adding deionised water, the mixture was autoclaved at 125 $^{o}$C and 15 psi pressure, for 1h. Acid insoluble lignin was defined as the residue corrected for acid-insoluble ash, retained on a medium porosity filter crucible after the primary 72% and secondary 4% $H_2SO_4$ hydrolysis steps.

*Determination of acid soluble lignin*. Acid soluble lignin was determined by measuring the absorbance of the hydrolysate at 205 nm wavelength on a Varian Cary Scan 50 spectrophotometer (Switzerland) in 1cm quartz cells, at 25 $^{o}$C. Acid soluble lignin content was calculated using the extinction coefficient of 110 $L/mol^{-1}cm^{-1}$ (Kaar and Brink, 1991). The total lignin content was obtained by the addition of acid insoluble or Klason lignin and soluble lignin obtained by both methods.

*Statistical analysis*. Statistical analysis was performed using STATISTICA 8 software (StaSoft, Inc., Tulsa, USA).

**Results and discussion**

The dried stalks of Burley tobacco type (B 98/N variety) were characterized with 179 cm length, diameter of 8.5 cm and 210 g weight (mean values). The air dried stalks were with good shape and free from fungal attack or other degradation. Darker color and signs of degradation caused by exposure to water and wind were determined at the stalks left to dry in the field.

The chemical analysis of whole tobacco stalks, air and field dried stalks, is presented in Table 1. Each presented data stands for the average values of the two years survey. The cellulose was determined as major component, followed by acid insoluble lignin.

Table 1. Chemical composition* of the air dried (A) and field dried (F) tobacco stalks.

| | Cellulose | | Total lignin | | Acid insoluble lignin | | Acid insoluble lignin | |
|---|---|---|---|---|---|---|---|---|
| | A | F | A | F | A | F | A | F |
| Average value (%) | 38.53 | 36.38 | 22.47 | 21.32 | 20.72 | 19.43 | 1.77 | 1.90 |
| Standard deviation | 0.12 | 0.15 | 0.16 | 0.12 | 0.12 | 0.15 | 0.05 | 0.06 |
| Relative standard deviation (%) | 0.31 | 0.40 | 0.73 | 0.55 | 0.56 | 0.77 | 2.92 | 3.33 |

*Calculated to the corresponding dry matter weight.

The average cellulose content of 38.53% determined in air dried stalks was higher than cellulose content of 36.38% found in field dried stalks. The air dried and field dried stalk were characterized with the total lignin content of 22.47% and 21.32%, respectively. The acid insoluble content in air dried stalks (20.72%) was more than eleven times higher that soluble lignin content in it (1.77%). Content of acid soluble lignin content in field dried stalks was found to be 1.90%, which was slightly higher than of air dried.

The published data highlighted that the genetic makeup and cultural management conditions have the primarily influence on morphological characteristics and chemical composition of tobacco plant (Flower, 1999). The cellulose content in the tobacco stalk, stem and mid-rib portion of the leaf is higher than its content determined in the lamina portion of leaf. In the process of drying the absolute content of cell wall polymers does not change. Due to the reduction of the content of the other organic materials in the stalk and steam, the content of cell wall polymers increases (Tso, 1990; Agrupis and Maekawa, 1999).

In Table 2 is presented the quantity of cellulose, lignin and ash determined in the air dried and filed dried tobacco stalks.

Table 2. Comparison of chemical composition of tobacco stalks.

| Constituent | Tobacco stalk | | Tobacco stalks (Shakhes *et al.*, 2011) | Tobacco stalks (Akpinar *et al.*, 2011) |
|---|---|---|---|---|
| | A | F | | |
| Cellulose (%) | 38.53 | 36.38 | 39.20 | not analyzed |
| Total Lignin (%) | 22.47 | 21.32 | 18.90 | 24.50 |
| Acid insoluble lignin (%) | 20.72 | 19.43 | not analyzed | 23.00 |
| Acid soluble lignin (%) | 1.77 | 1.90 | not analyzed | 1.50 |
| Ash (%) | 5.90 | 4.84 | 6.86 | 6.40 |

The cellulose contents determined in B 98/N tobacco variety were slightly lower than cellulose content established by Shakhes *et al*. (2011). In relation to the content of lignin in stalks, Akpinar *et al*. (2011) determined content of acid insoluble lignin of 24.50% and 23.00 % acid soluble lignin. The total lignin content of 18.90% confirmed by Shakhes *et al*. (2011) was lower, compared with the data obtained from this research and from Akpinar *et al*. (2011). The ash content of 5.90 % and 4.84 % determined in air and field dried stalks was lower that ash content published in literature (Akpinar *et al*., 2011; Shakhes *et al*., 2011). According to the obtained results for cellulose content determined in the different parts of stalks, exactly, in the lower, the middle and in the upper part, can be concluded that the cellulose content is highest in the lower part of the stalk, 39.3% in air dried and 37.9% on field dried stalks (Figure 1). In both variants of stalks, in the upper part quantity of cellulose content is the lowest, compared with the cellulose quantity in lower and middle part of stalks. The differences in the determined quantities of lignin in the examined parts of the stalks, in air dried and filed dried stalks, were insignificant. The biggest quantities of lignin of 23.00 and 21.80% were determined in the upper part of air dried and field dried stalks, respectively. In relation to the content of lignin in different part of Burley stalk, Agrupis and Maekawa (1999) determined higher content of acid insoluble lignin of 17.9% in lower and 17.2% in upper part. The content of acid soluble lignin in lower part was 3.1% and 3.3% in upper. They found higher cellulose content in lower and upper part of stalk (40.1% and 39.5%, respectively) in comparison to our results (39.30% and 37.90%, respectively).

In terms of chemical composition (Figure1) the lower part of the stalks contains higher cellulose and lignin than the middle and upper part which is expected since the latter is less mature, hence, less fibrous and less lignified.

On the other hand, the upper part of the stalks contains more ash and total nitrogen than the lower one. Ash content increasing from the lower to the upper part of the air dried stalk and was 5.13%, 5.88% and 6.69%, respectively (Figure 2).

Identical dynamics of ash content is noted in field dried stalk, but that variant has smaller values. In relation to the content of ash, Agrupis and Maekawa (1999) determined higher content (7.9% and 10.2%, respectively) in comparison to our results.

The nitrogen content determined in field dried stalk (low, middle and upper part) differed significantly from the air dried stalk (Figure 2). In the low and medium part of air dried stalks, total nitrogen quantities of 0.84% and 0.92% was established. In upper part the ash content in the highest and reaches 1.25%.

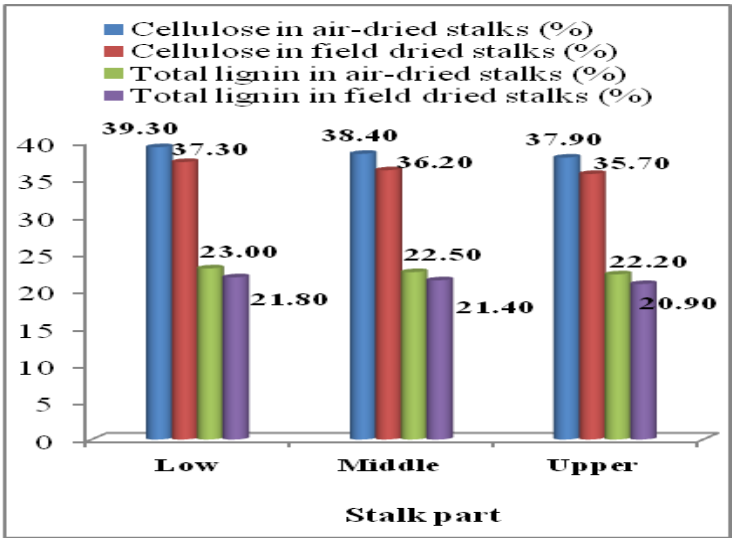


Figure 1. Cellulose and total lignin dynamics in relation to the stalk position

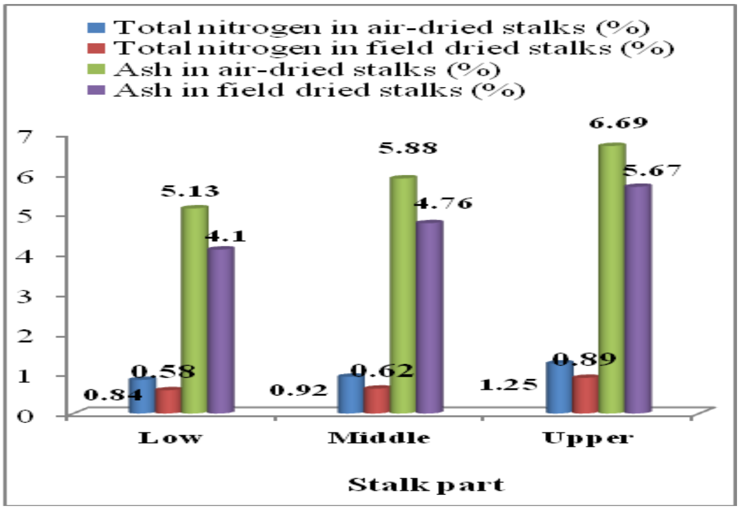


Figure 2. Total nitrogen and ash dynamics in relation to the stalk position

Method for lignin determination is optimized for tobacco stalks, and consists of two steps. The first step performs the determination of acid-insoluble lignin, and the filtrate is used to determine acid soluble lignin. This enables the content of insoluble and soluble lignin to be determined in the same sample. A reliable analysis of total lignin can be accomplished on as little as 300 mg of sample with a relative standard deviation of 0.73 and 0.55.

High cellulose content and lignin are considered desirable for pulp and paper industry because it have been correlated with high pulp yield (Agrupis et al., 2000; Shakhes et al., 2011). For bioethanol production, the efficiency of cellulose hydrolysis had been found to be positively correlated with materials which have high cellulose and low lignin content (Martin, et al., 2008; Sun and Sheng, 2002). This means that due to the higher value of lignin and lower cellulose field dried stalks have lower usability for pulp production. The higher ash content has negative impact to pulp yield (Shakhes et al., 2011). Increasing the rate of nitrogen fertilizer (up of 300kg N/ha) increases the amount of ash, and concentration of nicotine, total and protein nitrogen (Pospišil et al., 1998). Although the content of the ash was sufficiently high, because the lower nitrogen content the stalks haven't potential for application as soil fertilizer.

## Conclusions

The results of this work show that the analyzed components in dried stalks of tobacco variety B 98/N are present in quantities comparable with the literature data.

The proposed analytical methods are suitable for the reliable characterization and quantification of cellulose and lignin in tobacco stalks.

Tobacco stalks posses high cellulose content and lignin are considered desirable for pulp and paper industry.

Although the content of the ash was sufficiently high, because the lower nitrogen content the stalks haven't potential for application as soil fertilizer.

The utilization of this material for pulp and ethanol production does not only solve the proper disposal of these wastes, but also provides an opportunity to use tobacco for unconventional purposes.

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# ТУТУНСКИТЕ СТРАКОВИ КАКО ОБНОВЛИВА СУРОВИНА ЗА АГРО-ИНДУСТРИСКО ИСКОРИСТУВАЊЕ

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**Апстракт**

Тутунските стебла како земјоделски отпад претставуваат обновлива суровина што може да се преработи во корисни производи и во енергија. Може да се забележе дека околу 5 тони тутунски стебла по хектар со 40% содржина на влага се произведуваат за само шест месеци. Целта на овој труд е да се утврдат морфолошките својства и хемискиот состав на стеблата од тутунот од типот Берлеј, сорта Б 98/ N (целулоза, Klason лигнин, лигнин растворлив во киселина, пепел, вкупен азот и сува материја) и да се оцени нивната соодветност за агро-индустриска употреба. По бербата на листовите, дел од стеблата се собрани и воздушно сушени во стаклара, а останатите се оставени да се сушат во поле, под дејство на атмосферските услови. Во стеблата се одредени содржината на влага, пепел и лигнин според ASTM стандардни методи. Метод по Kurshner-Hoffer е употребен за утврдување на застапеноста на целулозата. Просечните вредности за должина, дијаметар и тежина на исушените тутунски стебла изнесуваат 170 cm, 8,5 cm и 210 g, соодветно. Содржина на целулоза изнесува 38,5% во воздушно исушените стебла и 36,4% во стеблата сушени во полски услови. Содржината на вкупниот лигнин, Klason лигнинот и во лигнинот растворлив во киселина во воздушно исушените стебла изнесува 22,5%, 20,7% и 1,80%, соодветно. Резултатите покажуваат дека вредностите за целулоза и лигнин во воздушно исушените стебла се малку повисоки, во споредба со сушените во полски услови. Исто така, може да се каже дека кога тутунските стебла се сушат во полски услови има губиток од 30% од азотот, 18% од пепелта, и 35% од органските материи.

**Клучни зборови**: тутун, стебла, целулоза, лигнин, употреба.

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**Original scientific paper**

# THE WATER FOOTPRINT AS A MEASURE OF THE AGRICULTURAL WATER CONSUMPTION AND POLLUTION

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## Abstract

The world's water resources are under increasing pressure due to consumption and pollution associated with different human activities. Around 70% of the current water withdrawals are for agricultural production. This quantity refers to the volume of water withdrawn from various sources and generally used for crop cultivation during dry periods of year. The water footprint is an indicator that gives a new dimension to the analysis of the global water consumption and pollution patterns. This is an indicator that incorporates not only the "traditional" water consumption as a result of water withdrawals (blue water), but also consumption of water that is readily available in the nature (green water), as well as the "consumption" of water that is required to assimilate the pollution discharged (grey water). The total water footprint in agricultural production in the world is 8,363 km$^3$/yr, out of which 7,404 km$^3$/yr is the water footprint of crop production. The share of animal production in the total agricultural water footprint is 29% or 2,422 km$^3$/yr. Considering the total global water footprint of humanity of 9,087 km$^3$/yr, agricultural production has the largest share of 92.0%. The agricultural production consumes the entire green water component of the global water footprint of humanity, whereas its share in the blue water component is 92.2%. Because of its considerable share in the grey water footprint of humanity (65.6%), the agricultural production can be considered the largest water polluter in the world.

**Key words**: water consumption, agriculture, water footprint.

## Introduction

The available fresh water resources are distributed unevenly on the planet. The average global renewable water resources, which are in most part comprised of the surface water flows, reach a total of 42,780 km$^3$/yr (Shiklomanov, 2000). The largest available quantities are found in Asia and South America (13,510 and 12,030 km$^3$/yr respectively), and the least in Australia and Oceania (2,400 km$^3$/yr) and Europe (2,900 km$^3$/yr). The average global renewable water resources per capita are around 7,600 m$^3$/person/yr (Vučijak *et al*., 2011). Australia and Oceania have the largest available volume (83,700) and in Asia water is the least available (3,920 m$^3$/person/yr). The presented numbers are constantly changing due to the population growth in the world. Based on the UN estimates, the global population of around 1.65 billion at the beginning of the 20th century increased to over 6 billion by the end of the century (Vučijak *et al*., 2011). The UN predicts that the population will reach 9 billion by 2050. The population growth between 1970 and 1994 caused diminution of available water resources from 12,900 to 7,600 $m^3$/person/yr (Shiklomanov, 2000). The largest decline rates were observed in Africa (around 2.8 times), Asia (2.0 times) and South America (1.7 times), whereas in Europe the available water resources per capita declined by only 16%.

Data on the global water consumption indicate that the largest share (around 70%) is used in agriculture (Appelgren, 2004) for the irrigation of approximately 250 million hectares of arable land in the world. This is only 17% of the global arable land, but it provides more than 1/3 of the world's harvest. In order to provide food for increasing population, more and more land has to be cultivated and irrigated. Livestock farming has been increasingly using water in the recent years as well. In many countries over 90% of water withdrawn is used for irrigation, and in many European countries (e.g. Spain, Portugal, Greece) this share is over 70% (Saejis and van Berkel, 1996). Irrigation is essential particularly in developing countries, which strive to secure enough food for their populations.

The afore-mentioned consumption is mostly related to water withdrawn from the environment and delivered to crops in dry seasons in order to secure their growth and development. These interventions offset the water deficit in the soil, which cannot be achieved by natural processes, e.g. by precipitation, surface or ground water recharge, etc. The volume of water required for irrigation is typically quantified based on the crop evapotranspiration rate $ET_c$ (e.g. Hoekstra and Hung, 2005), which is a complex process of transferring moisture by evaporation of water from wet surfaces – soil and water, and transpiration from plants (Ćerić *et al*., 2003).

The volume of water used for irrigation is a typical indicator of the water consumption in agriculture. Although this indicator gives some useful information, it does not provide full picture in regard to the total water requirements for the production of agricultural products. This paper presents the agricultural water consumption expressed as the water footprint, which is an indicator introduced in 2002 with the aim to comprehensively assess the volume of water used in production or in different human activities.

## Material and methods

Numerous human activities consume or pollute water – e.g. irrigation, swimming, cleaning, washing, cooling, processing, etc. Until recently, the total consumption or pollution of water were considered as the sum of consumption or pollution from each individual activity. However, Hoekstra (2003) introduced an idea that the consumption and pollution of water should be considered in the entire production and consumption chain, and should be measured by the water footprint.

The water footprint is defined as the total volume of freshwater that is used to produce the goods and services consumed by an individual or community (Hoekstra and Chapagain, 2008). It is an indicator that considers not only the volume of water that is directly used in a production or consumption process, but indirect use of water as well. In this context, direct consumption refers to the use of water in any particular process, whereas indirect (virtual) consumption is the volume of water used for products or services that are inputs in the considered process (Figure 1). The water footprint is therefore the total volume of water used in all phases of the production or consumption of any product. For example it includes water consumed for the growth of crops that are used in a production process, water used in all phases of the production chain, including the volume of water that is required to dilute the pollution discharged from the process to environmentally acceptable level.

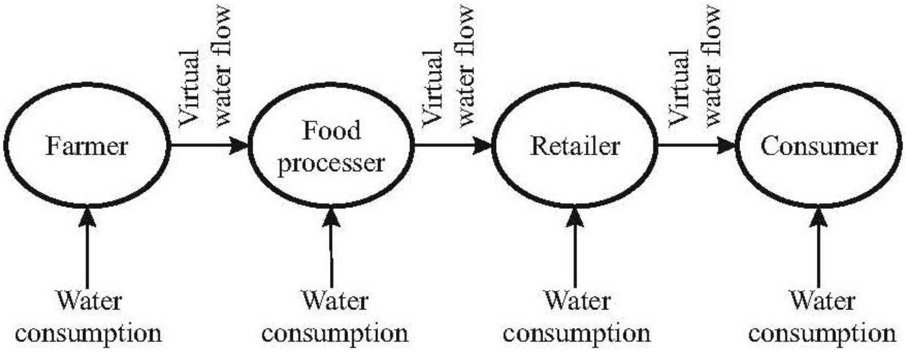


Figure 1.The virtual water chain

The concept of the water footprint is similar to the ecological footprint which was introduced in 1990's (Rees, 1992; Rees and Wackernagel, 1994; Rees, 1996) and which represents a surface of land and water that is required for the production of resources necessary for the population and reception of pollution being discharged. Thus, whereas the ecological footprint quantifies the surface of the land required to sustain the human population, the water footprint indicates the quantity of water used for the same purpose (Hoekstra, 2009). The water footprint considers three components (Figure 2): (i) consumption of water available in soil and plants as moisture (green water footprint), (ii) consumption of water withdrawn from surface and ground water bodies (blue water footprint), and (iii) consumption of water required to receive the pollution discharged (grey water footprint). Traditionally, only the blue water footprint is considered as the actual water consumption. However, plants use available moisture in the soil and the green water footprint should not be ignored in the global analysis of the water consumption. The grey water footprint is also important as it refers to the pollution of water resources. This component, however, does not represent the volume of discharged wastewater, but is rather defined as the volume of water required to assimilate the pollution to the existing water quality standards (Hoekstra, 2009).

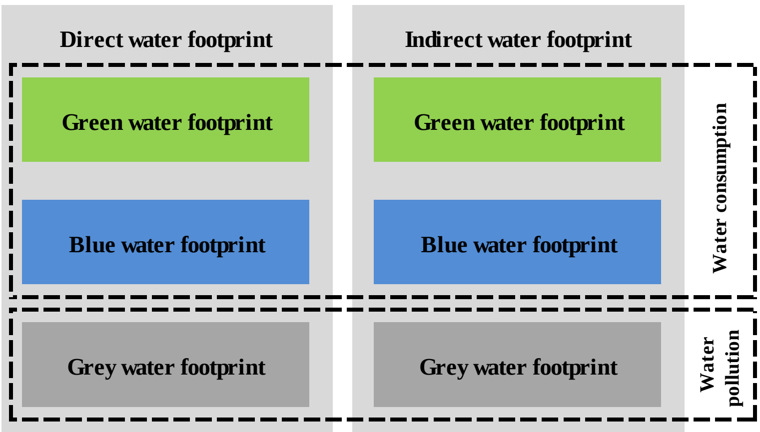


Figure 2. Components of the water footprint (Source: Hoekstra *et al.*, 2009)

The water footprint can be assessed for any product, but also for any group of consumers (e.g. person, family, city, country, etc.) or for a producer or group of producers in a sector, in which case it is defined as the sum of the respective water footprints.

When the water footprint of a group of consumers in an area (e.g. country) is considered, a new spatial dimension can be introduced in the analysis. Specifically, the import and export of products lead to import and export of virtual water that is embedded into the product. In this case the consumers of the products are spatially disconnected from the processes that produce the products (e.g. Naylor *et al*., 2005). Countries that import the products are actually externalizing their water footprint, thus creating pressure on exporting regions and not in the area of consumption. Cotton clothes are an example of products that typically create the virtual water trade from one region to another. The production of a cotton T-shirt has the water footprint of approximately 2,000 liters, and this water footprint is generated by the final user. The water footprint however is transferred to countries in which different stages of the production cycle are located – e.g. China, India and Pakistan, which are cotton producing countries, and Malaysia where the T-shirts are produced (Chapagain *et al*., 2006). If the cotton T-shirts are exported to Europe, it can be asserted that the European consumers actually use the water resources from other countries.

## Results and discussion

*Water Footprint in Agriculture*

The water footprint in agriculture depends on the type of agricultural product. For example, lattice has the water footprint of 130 liters for a kilogram of the product, whereas the water footprint of 1 kg of chocolate is as much as 24,000 liters (Table 1). The numbers presented in Table 1 are the global average, and they vary significantly in different regions in the world according to the type of production process and some other factors (Hoekstra, 2008). If we consider the production of beef, the water footprint is calculated based on the parameters of an industrial production system – an animal is grown for three years before it is slaughtered to produce approximately 200 kg of boneless meat. In this period the animal consumes around 1,300 kg of grains (wheat, barley, oats, corn, soybean, and other grains), 7,200 kg of roughages (pasture, hay, silage and other roughages), 24 $m^3$ of water for drinking and 7 $m^3$ for servicing (Hoekstra, 2008; Hoekstra, 2010). In order to produce 1 kg of boneless meat, 6.5 kg of grains is used, also 36 kg of roughages and 155 liters of water for drinking and servicing of the animals. As 15,300 liters is used to produce the animal feed, the water footprint of one kilogram of beef equals to 15,500 liters.

From the afore-mentioned example one can understand the difference between the assessment of the traditional water consumption and the water footprint. The traditional calculation shows that 155 liters of water is used for the production of 1 kg of beef, which is actually the volume used in the production process for drinking and maintenance of the animals and facilities. However, this is only direct consumption which makes 1% of the total water consumption (the water footprint), whereas the remaining 99% is virtual water.

Table 1. Water footprint of some agricultural products*

| Agricultural product | Unit | Water footprint (liter) | Agricultural product | Unit | Water footprint (liter) |
|---|---|---|---|---|---|
| Apple, pear | 1 kg | 700 | Maize | 1 kg | 900 |
| Beef meat | 1 kg | 15,500 | Milk | 250 ml | 250 |
| Beer | 250 ml | 75 | Olives | 1 kg | 4,400 |
| Wheat bread | 1 kg | 1,300 | Orange | 1 kg | 460 |
| Cabbage | 1 kg | 200 | Peach, nectarine | 1 kg | 1,200 |
| Cheese | 1 kg | 5,000 | Pork | 1 kg | 4,800 |
| Chicken | 1 kg | 3,900 | Potato | 1 kg | 250 |
| Chocolate | 1 kg | 24,000 | Rice | 1 kg | 3,400 |
| Coffee | 125 ml | 140 | Sugar (sugar cane) | 1 kg | 1,500 |
| Cucumber, pumpkin | 1 kg | 240 | Tea | 250 ml | 30 |
| Dates | 1 kg | 3,000 | Tomato | 1 kg | 180 |
| Lettuce | 1 kg | 130 | Wine | 125 ml | 120 |

*Source: Hoekstra, 2008

*Water Footprint of Crop Production*

The global water footprint of crop production is estimated at 7,404 $km^3$/yr for the period from 1996-2005 (Mekonnen and Hoekstra, 2010), which is around 17% of the renewable water resources in the world. The largest water footprint comes from the production of wheat (1,087 $km^3$/yr), rice (992 $km^3$/yr) and corn (770 $km^3$/yr), so these three crops consume more than 38% of the global water footprint of crop production. Other significant crops are fodder crops, soybeans, sugar cane, cotton, barley, sorghum, oil palm, coconuts, millet and coffee, which consume another 34% of the global water footprint of crop production. All other crops consume the remaining 28% of the water footprint.

Around 78% of the global water footprint of crop production is the green water footprint, 12% is the blue water footprint, and the remaining 10% the grey water footprint. For most of the crops the share of the green water footprint in the total consumptive water footprint (green and blue) is more than 80%. However, wheat and rice have large blue water footprints, and they contribute with more than 45% in the global blue water footprint of crop production. The grey water footprint in the crop production is related to the use of fertilizers. Wheat, rice and corn together account for about 56% of the global grey water footprint. For most of the crops the consumptive water footprint (green and blue) is smaller for irrigated crops than for rain-fed crops. The reason is that irrigated crops have better yields than rain-fed crops. For example, the water footprint of apple produced in a rain-fed farming system is 883 $m^3$ per ton (Table 2), as compared to 734 $m^3$/t in an irrigated farming system.

It can also be observed that shifting from rain-fed to irrigation farming system will reduce the total consumptive water footprint (green and blue) from 717 to 694 $m^3$/t, which is also true for the grey water footprint (reduced from 167 to 71 $m^3$/t). For some crops, however, the introduction of an irrigation farming system will increase the total water footprint per ton, which is the case e.g. with soybeans, sugar cane and rapeseed (Table 2).

Table 2. Water footprint of rain-fed and irrigated crops*

| Crop | Farming system | Yield (t/ha) | Global water footprint ($km^3$/yr) | | | | Unit water footprint ($m^3$/t) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Green | Blue | Grey | Total | Green | Blue | Grey | Total |
| Wheat | Rain-fed | 2.48 | 610 | 0 | 65 | 676 | 1,629 | 0 | 175 | 1,805 |
| | Irrigated | 3.31 | 150 | 204 | 58 | 411 | 679 | 926 | 263 | 1,868 |
| | Global average | 2.74 | 760 | 204 | 123 | 1,087 | 1,278 | 342 | 208 | 1,828 |
| Rice | Rain-fed | 2.69 | 301 | 0 | 30 | 331 | 1,912 | 0 | 190 | 2,102 |
| | Irrigated | 4.67 | 378 | 202 | 81 | 661 | 869 | 464 | 185 | 1,519 |
| | Global average | 3.90 | 679 | 202 | 111 | 992 | 1,146 | 341 | 187 | 1,673 |
| Apple | Rain-fed | 8.93 | 24 | 0 | 6 | 30 | 717 | 0 | 167 | 883 |
| | Irrigated | 15.91 | 8 | 8 | 2 | 18 | 343 | 321 | 71 | 734 |
| | Global average | 10.92 | 33 | 8 | 7 | 48 | 561 | 133 | 127 | 822 |
| Soybean | Rain-fed | 2.22 | 328 | 0 | 5 | 333 | 2,079 | 0 | 33 | 2,112 |
| | Irrigated | 2.48 | 24 | 12 | 1 | 37 | 1,590 | 926 | 85 | 2,600 |
| | Global average | 2.24 | 351 | 12 | 6 | 370 | 2,037 | 70 | 37 | 2,145 |
| Rapeseed | Rain-fed | 1.63 | 62 | 0 | 12 | 74 | 1,783 | 0 | 356 | 2,138 |
| | Irrigated | 1.23 | 4 | 9 | 1 | 14 | 1,062 | 2,150 | 181 | 3,394 |
| | Global average | 1.57 | 66 | 9 | 13 | 88 | 1,703 | 231 | 336 | 2,271 |

*Source: Mekonnen and Hoekstra, 2010

Although the yields are better with the irrigation systems, this happens because the actual evapotranspiration increases and approaches potential evapotranspiration. The data suggest that the irrigation apparently increases the water consumption; however, the consumption per ton of yield is typically smaller. From this one can understand the significance of the irrigation farming systems, which contribute not only to better crop yields, but also to more sustainable use of water resources.

*Water Footprint of Animal Production*

An increasing consumption of animal food, such as meat or milk, is present in the last decades as a consequence of an economic development and the growth of the population income. The global meat production doubled from 1980 to 2004, due to increase of the meat, milk or milk products consumption of 5% annually in developing countries (FAO, 2005). These products have large unit water footprints, which has caused an increase in the global water footprint of animal production. For the period from 1996 to 2005 the global water footprint of animal production was 2,422 $km^3$/yr (Mekonnen and Hoekstra, 2010a). A major portion comes from the livestock feed, around 98% of the total water footprint. The volume of water that is used for drinking, servicing or feed preparation is relatively small and amounts to 1.1%, 0.8% and 0.03% respectively.

The water footprint by animal categories shows that the growth of beef cattle consumes 33% of the global water footprint of animal production (Table 3). Another significant animal categories are dairy cattle (19%), pig (19%) and broiler chicken (11%).

Dairy cow has the largest average annual water footprint per animal of 2,056 $m^3$/yr, which is more than for an average human (Mekonnen and Hoekstra, 2010a). On the other hand, the broiler chicken generates an average annual water footprint of only 26 $m^3$ per animal. The distribution of the total water footprint of animal production to green, blue and grey component greatly depends on the type of production system (Table 4), and significantly varies across the countries. Table 4 also shows that the water footprint of meat increases from chicken (4,300 $m^3$/t), goat (5,500 $m^3$/t), pork (6,000 $m^3$/t), and lamb (10,400 $m^3$/t) to beef, which has the largest water footprint of 15,400 $m^3$/t (Mekonnen and Hoekstra, 2010a). The main cause of such variation is different feed conversion efficiency – beef production requires eight times more feed per kg of meet produced than pork production and as much as 11 times more feed than chicken production. Another significant reason is the feed composition, particularly the share of concentrate feed that has a significantly larger water footprint than roughages. The portion of the concentrate feed for chicken broiler is much higher (the global average 73%) as compared to beef (only 5%).

Table 3. Total water footprint by livestock categories*

| Livestock | No. of animals in the world (millions) | Average water footprint ($m^3$/animal/yr) | Annual water footprint | |
|---|---|---|---|---|
| | | | ($km^3$/yr) | (%) |
| Beef cattle | 1,267 | 630 | 798 | 33 |
| Dairy cattle | 228 | 2,056 | 469 | 19 |
| Pig | 880 | 520 | 458 | 19 |
| Broiler chicken | 9,923 | 26 | 255 | 11 |
| Horse | 112 | 1,599 | 180 | 7 |
| Layer chicken | 5,046 | 33 | 167 | 7 |
| Sheep | 1,052 | 68 | 71 | 3 |
| Goat | 750 | 32 | 24 | 1 |
| Total | 19,258 | | 2,422 | 100 |

* Source: Mekonnen and Hoekstra, 2010a

Dairy cow has the largest average annual water footprint per animal of 2,056 $m^3$/yr, which is more than for an average human (Mekonnen and Hoekstra, 2010a). On the other hand, the broiler chicken generates an average annual water footprint of only 26 $m^3$ per animal. The distribution of the total water footprint of animal production to green, blue and grey component greatly depends on the type of production system (Table 4), and significantly varies across the countries. Table 4 also shows that the water footprint of meat increases from chicken (4,300 $m^3$/t), goat (5,500 $m^3$/t), pork (6,000 $m^3$/t), and lamb (10,400 $m^3$/t) to beef, which has the largest water footprint of 15,400 $m^3$/t (Mekonnen and Hoekstra, 2010a). The main cause of such variation is different feed conversion efficiency – beef production requires eight times more feed per kg of meet produced than pork production and as much as 11 times more feed than chicken production. Another significant reason is the feed composition, particularly the share of concentrate feed that has a significantly larger water footprint than roughages. The portion of the concentrate feed for chicken broiler is much higher (the global average 73%) as compared to beef (only 5%).

*Impact of Crop and Animal Production on the Global Water Footprint*

The total global water footprint of agriculture amounts to 8,363 $km^3$/yr (Mekonnen and Hoekstra, 2010a), out of which 7,404 $km^3$/yr is related to the water footprint of crop production (Table 5). As explained earlier, the water footprint of animal production is composed of the water footprint of animal feed (98%) and the volume of water consumed for drinking, livestock servicing and feed preparation. Out of the water footprint of animal feed, which amounts to 2,376 $km^3$/yr, the volume of 1,463 $km^3$/yr is related to the cultivation of crops used for animal feed, and the remaining volume to pasture. This shows that as much as 20% of the total water footprint of crop production (7,404 $km^3$/yr) is actually related to the animal feed. The share of the animal production in the total water footprint of agriculture is 29%.

As the total global water footprint of humanity is estimated at 9,087 $km^3$/yr (Hoekstra and Mekonnen, 2012), the share of agriculture is as much as 92.0%. The industrial sector contributes with 4.4% to the global water footprint, while the remaining 3.6% is related to the population water supply. The data show that the agriculture is the major contributor to the global water consumption. The agriculture consumes the entire water from the global green water footprint (Figure 3), while its share in the global blue water footprint is 92.2%.

According to this indicator, the agriculture is also the largest water polluter because of its share of 65.6% in the global gray footprint.

Table 4. Green, blue and grey water footprint of animal products (global average)*

| Product | Farming system | Water footprint ($m^3$/t) | | | Product | Farming system | Water footprint ($m^3$/t) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Green | Blue | Grey | | | Green | Blue | Grey |
| Beef | Pasture | 21,121 | 465 | 243 | Chicken | Pasture | 7,919 | 734 | 718 |
| | Mixed | 14,803 | 508 | 401 | | Mixed | 4,065 | 348 | 574 |
| | Industrial | 8,849 | 683 | 712 | | Industrial | 2,337 | 210 | 325 |
| | Average | 14,414 | 550 | 451 | | Average | 3,545 | 313 | 467 |
| Lamb | Pasture | 15,870 | 421 | 20 | Eggs | Pasture | 6,781 | 418 | 446 |
| | Mixed | 7,784 | 484 | 67 | | Mixed | 3,006 | 312 | 545 |
| | Industrial | 4,607 | 800 | 216 | | Industrial | 2,298 | 205 | 369 |
| | Average | 9,813 | 522 | 76 | | Average | 2,592 | 244 | 429 |
| Goat | Pasture | 9,277 | 285 | 0 | Milk | Pasture | 1,087 | 56 | 49 |
| | Mixed | 4,691 | 313 | 4 | | Mixed | 790 | 90 | 76 |
| | Industrial | 2,431 | 413 | 18 | | Industrial | 1,027 | 98 | 82 |
| | Average | 5,185 | 330 | 6 | | Average | 863 | 86 | 72 |
| Pork | Pasture | 7,660 | 431 | 632 | Cheese | Pasture | 5,371 | 293 | 241 |
| | Mixed | 5,210 | 435 | 582 | | Mixed | 3,903 | 463 | 377 |
| | Industrial | 4,050 | 487 | 687 | | Industrial | 5,078 | 500 | 406 |
| | Average | 4,907 | 459 | 622 | | Average | 4,264 | 439 | 357 |

*Source: Mekonnen and Hoekstra, 2010a

Table 5. The global water footprint of agriculture

| Water footprint category | Water footprint | | | |
|---|---|---|---|---|
| | Green | Blue | Grey | Total |
| Water footprint of agricultural production | | | | |
| Water footprint of crop production | 5,772 | 899 | 733 | 7,404 |
| Water footprint of grazing | 913 | – | – | 913 |
| Direct water footprint of livestock* | – | 46 | – | 46 |
| Total | 6,685 | 945 | 733 | 8,363 |
| Water footprint of animal production | | | | |
| Water footprint of feed crop production | 1,199 | 105 | 159 | 1,463 |
| Water footprint of grazing | 913 | – | – | 913 |
| Direct water footprint of livestock* | – | 46 | – | 46 |
| Total | 2,112 | 151 | 159 | 2,422 |
| * drinking, servicing and feed mixing | | | | |
| Source: Mekonnen and Hoekstra, 2010a | | | | |

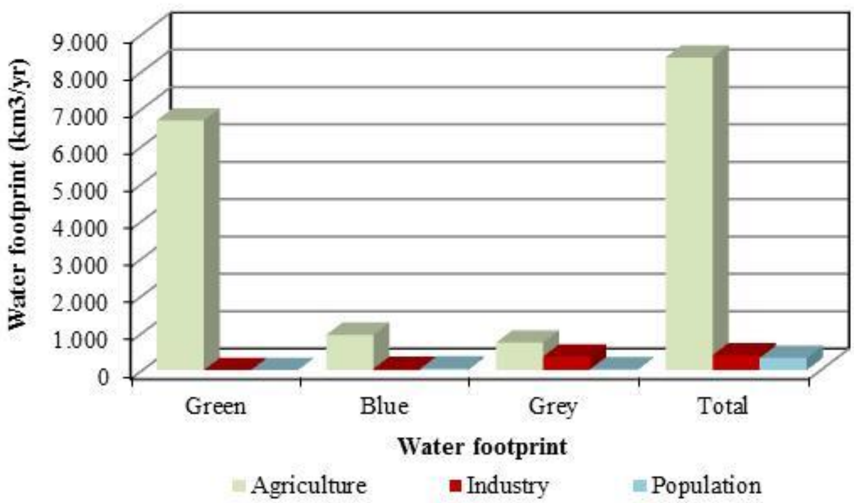


Figure 3. Distribution of the global water footprint per main categories

**Conclusions**

The world's water resources are under increasing pressure due to consumption and pollution associated with different human activities. The total consumption or pollution of water are often considered as the sum of consumption or pollution from different activities, and until recently little attention has been paid to the consumption and pollution of water in the entire production or consumption chain. The approach which takes into account the use of water in the entire production and consumption chain has gained more attention after the concept of the water footprint was introduced at the beginning of the century. The water footprint is a comprehensive, multi-dimensional indicator of the water use, which covers not only the direct water consumption of a producer or consumer, but also indirect water consumption. The water footprint thereby incorporates not only the "traditional" water consumption as a result of water withdrawals (blue water), but also consumption of water that is readily available in the nature (green water), as well as the "consumption" of water that is required to assimilate the pollution discharged (grey water).

Agriculture is a particularly significant water user at the global scale. Measured by the water footprint, agriculture consumes about 92% of the water resources that mankind use for its needs. It is commonly perceived that the reduction of the agricultural water footprint can be achieved by the introduction of good agricultural practices, which is an approach that will for most part impact the gray water footprint. This is accomplished by reducing the quantity of chemicals used, introducing better techniques and taking care of the timing of their implementation. In theory the gray water footprint can be reduced virtually to zero by switching to organic farming, but in reality this is difficult if not impossible to achieve. The green and blue water footprint of agriculture ($m^3$/t) can be reduced by increasing the water use efficiency, e.g. by introducing more efficient irrigation techniques (drip, sprinkler irrigation etc.) as compared to traditional ones (surface irrigation). One possible way of reducing the global agricultural water footprint is to replace products that have large water footprint with products of a similar nutritional value but smaller water footprint. In this regard, a general conclusion can be made that it is more efficient to obtain calories, protein and fat through crop than animal products, since the water footprint per calorie and gram of protein and fat is larger for animal than crop products.

Regardless of the available options, reducing the global water footprint of agriculture will be a major challenge in the future because of the rapid population growth on the planet and the growing food demand. To achieve this goal it is necessary to involve not only farmers but also consumers of agricultural products, as well as all other stakeholders.

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# ТРАГИ ОД ВОДА КАКО МЕРКА ЗА ОПРЕДЕЛУВАЊЕ НА ПОТРОШУВАЧКАТА НА ВОДА И ЗАГАДУВАЊЕТО

Ќериќ Адмир, Вучијак Бранко

**Апстракт**
Водните ресурси во светот се под постојан притисок, пред се поради зголемената потрошувачка и загадување на истите поврзани преку различни активности на човекот. Околу 70% од денешната потрошувачка на вода отпаѓа на земјоделското производство. Ова количество се однесува на волуменот на вода потрошен од различни извори и генерално користен за одгледување на земјоделските култури во сушните периоди од годината. Трагите од вода е еден вид индикатор кој дава една нова димензија во анализата на глобалната потрошувачка на вода и загадувањето. Ова е индикатор кој ја вклучува не само традиционалната потрошувачка на вода (сина вода), но исто така и потрошувачката на вода која е лесно достапна во природата (зелена вода), како и потрошувачката на вода која е неопходна за испуштање и ослободување на загадувањето (сива вода). Вкупните траги од вода во земјоделското производство во светот се 8,363 $km^3$/годишно, од кои 7,404 $km^3$/годишно се од растителното производство. Учеството на анималното производство во вкупните траги од вода е 29% или 2,422 $km^3$/годишно. Земајќи ги вкупните траги на вода од 9,087 $km^3$/годишно од човечки активности, може да се види дека земјоделското производство го има најголемото учество со 92%. Земјоделското производство ја користи целата компонента од зелена вода од вкупните траги на вода за луѓето, поради што неговото учество во компонентата сина вода изнесува 92%. Поради значајното учество во сивата вода (65,6%), земјоделското производство може да се вбори во најголемите загадувачи во светот.
**Клучни зборови**: потрошувачка на вода, земјоделство, траги од вода.

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**Original scientific paper**

# DETERMINATION OF EVAPOTRANSPIRATION UNDER DIFFERENT IRRIGATION AND FERTILIZATION TECHNIQUES IN GREEN PEPPER CROP PRODUCTION

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**Abstract**
The field experiment was conducted with green pepper crop *Bela dolga* grown in experimental plastic house near by the Faculty of Agricultural Sciences and Food in Skopje, during the period of May to October in 2005, 2006 and 2007. The main aim of this investigation was to determine evapotranspiration (ETP) in two-stem pruned ("V"system) green pepper crop under different irrigation and fertilization techniques and regimes. Also, the evapotranspiration coefficient was determined during this investigation, which can be used as parameter for indirect calculation of total crop water requirements during the vegetation. Therefore, four experimental treatments were applied in this study. Three treatments were irrigated by drip irrigation and drip fertigation (KK1, KK2, KK3), while the last one was irrigated by furrow irrigation with conventional application of fertilizer (control treatment $Ø_B$). From the average results obtained in three years of investigation, it can be concluded that there are negligible differences in ETP and ETk between the treatments KK1 and KK2 (drip fertigation every 2 and 4 days), what is result of closer irrigation interval of these two treatments. As a result of longer frequencies between the irrigations, the treatment KK3 (drip fertigation scheduled by tensiometers) showed 4,5-5,5% higher evapotrasnpiration in comparison with KK2 and KK1, and from 24 to 25,5% higher ETk in comparison with KK1 and KK2. The results for ETP and ETK in treatments KK1 and KK2 showed statistically significant differences in comparison with treatment KK3. The effect of the irrigation and fertilization techniques on evapotranspiration and ETk are presented by the results from the treatment KK3 and $Ø_{B.}$ Namely, the control treatment showed 15% higher ETP, or almost 30% ETk in comparison with KK3. The results are statistically significant at 0,01 level of probability.
**Key words**: potential evapotranspiration, evapotranspiration coefficient, drip fertigation, furrow irrigation, green pepper.

## Introduction
Evapotranspiration represents the water loss from a combined surface of vegetation and soil (Hatfield *et al.*, 1990). Generally, evapotranspiration (ET) is referred as a combination of two separate processes whereby water is lost from the soil surface by evaporation and from the crop by transpiration. Evaporation and transpiration occur simultaneously and there is no easy way of

distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process (Allen *et al.*, 1998).

The term potential evapotranspiration (ETP) was introduced by Thornthwaite in 1948, and was defined as the maximum rate of water loss by crop through the transpiration and evaporation under ideal conditions of soil moisture and vegetation. In natural conditions, evapotranspiration is presented by ETa, or actual evapotranspiration (Iljovski, 1992; Iljovski and Cukaliev, 1994; Bošnjak, 1999). The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ETo. The reference surface is a hypothetical grass reference crop with specific characteristics.

As is well known, the factors who affects of the evapotranspiration are: weather parameters, crop characteristics, soil conditions, irrigation techniques, applied agro-technical measures, etc. Allen *et al.*, (1998) reported that the only factors affecting ETo are climatic parameters. Consequently, ETo is a climatic parameter and can be computed from weather data. ETo expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. The FAO Penman-Monteith method is recommended as the sole method for determining ETo.

Crop evapotranspiration can be measured or calculated using a variety of approaches. Generally, in irrigation practice, the methods for measuring and estimation of ET can be classified as direct and indirect methods (Evett, 2007; Howell and Meron, 2007; Iljovski and Cukaliev, 2002; Dragović, 2000; Bošnjak, 1999). The indirect methods are based on empirical and mathematical models, where the climatic parameters are of primary importance, and most of them do not consider the crop characteristics or soil factors. Therefore, for greater precision the direct methods are characterized, because most of them simulate natural conditions or ET is determined directly in the field. The most used direct methods in irrigation practice for measuring of ETP are lysimeters, soil water balance method, method of field conditions with experimental trials and etc. (Iljovski and Cukaliev, 2002; Dragović, 2000; Bošnjak, 1999). Therefore, the main objectives of this study were to determine and compare evapotranspiration (ETP) under different techniques and regimes of irrigation and fertilization in green pepper crop production in Skopje region and to evaluate evapotranspiration coefficient as affected by methods of application of water and fertilizers. The determination of crop evapotranspiration in our investigation was realized by soil water balance method.

## Material and methods

The field experiment was conducted with two-stem pruned (“V” system) green pepper crop ‘Bela dolga’ grown in experimental plastic house near by the Faculty of Agricultural Sciences and Food in Skopje ($42^{o}$ 00' N, $21^{o}$ 27' E), during the period of May to October in 2005, 2006 and 2007. The soil type is coluvial (deluvial) soil (FAO Classification) disturbed with urban activities. The soil chemical characteristics of the experimental field are presented in Table 1.

Table 1. Soil chemical characteristics of the experimental field

| Layer cm | $CaCO_3$ % | Organic matter % | pH | | ECe dS/m | Available N mg/100 g soil | Available forms mg/100 g soil | |
|---|---|---|---|---|---|---|---|---|
| | | | $H_2O$ | KCl | | | $P_2O_5$ | $K_2O$ |
| 0-20 | 3,24 | 0,90 | 8,02 | 7,30 | 2,40 | 3,10 | 17,79 | 32,15 |
| 20-40 | 3,80 | 0,84 | 8,08 | 7,26 | 2,28 | 2,47 | 13,36 | 19,38 |
| 40-60 | 3,59 | 0,56 | 8,03 | 7,35 | 2,25 | 2,80 | 8,40 | 16,10 |

According to the recommendations and literature data for the region (Maksimović, 2002; Lazić *et al.*, 2001; Jankulovski, 1997), green pepper planted in our condition and yields up to 60 t/ha, needs the following amount of nutrients: N 485 kg/ha, $P_2O_5$ 243 kg/ha and $K_2O$ 585 kg/ha. The application of the fertilizer for the treatments was done in two portions (before planting and during the growing season), what is common practice in our country. For all treatments, the first portions of the fertilizers was done before planting of green pepper, while the rest of the fertilizers needed for achieving the targeted yield was applied through the fertigation system for drip fertigation treatments (Table 2) and conventional fertilization on soil for control treatments (spread in two portions, flowering and fruit formation). All investigated treatments have received same amount of fertilizers, but with the different methods and frequencies of application of water and fertilizers. The idea was to investigate the influence of irrigation and fertilization method on ET and ETk in green pepper crop production.

Table 2. Type and amount of fertilizers in drip fertigation

| N 485 | $P_2O_5$ 243 | $K_2O$585 | kg/ha | N:P:K | |
|---|---|---|---|---|---|
| | | 48 | 318 kg/ha | 15:15:15 | before replanting |
| / | 195 | 128 | 375 kg/ha | 0:52:34 | drip fertigation |
| / | / | 411 | 802 kg/ha | 0:0:51+18S | drip fertigation |
| 437 | / | / | 952 kg/ha | 46:0:0 | drip fertigation |
| 485 | 243 | 585 | | | |

Remark: the same amounts and quantity of fertilizers were used for furrow irrigation treatment

The fertigation equipment for drip fertigation treatments was Dosatron 16, with a plastic barrel as reservoir for concentrated fertilizer. The whole amount of fertilizer was dissolved in the barrel and barrel was sealed to avoid evaporation of the water. The source of water was the water supply system for the city of Skopje (very high quality of water).The irrigation of the experiment (treatment KK1, KK2 and $Ø_B$) was scheduled according long-term average daily evapotranspiration for green pepper crop for Skopje region (Table 3). Long term average evapotranspiration was calculated by FAO software CROPWAT for Windows 4.3 using crop coefficient (kc) and stage length adjusted for local condition by Faculty of Agricultural Sciences and Food. Because the use of drip irrigation and application of the water was only on part of the total surface, the daily evapotranspiration of drip irrigation treatments was decreased for 20% (coefficient of the coverage). In each experimental year, the irrigation and fertigation regime have occurred from 20-25 May until

10-15 October. The irrigation scheme used in the experiment was designed according to randomized block design for experimental purposes with four treatments in three replications.

Table 3. Daily and monthly crop water requirements for green pepper crop for the Skopje region

| Months | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|
| mm/day | 1.9 | 3.6 | 5.5 | 5.0 | 3.7 | 1.8 |
| mm/monthly | 59 | 108 | 171 | 155 | 111 | 54 |

Generally, the experimental treatments were set up according to the daily evapotranspiration rate. The idea was to investigate not only irrigation and fertilization techniques, but also irrigation and fertilization frequency and their effect on ETP and ETk.

Treatment 1 (KK1): Drip fertigation according to daily evapotranspiration with application of water and fertilizer every two days;

Treatment 2 (KK2): Drip fertigation according to daily evapotranspiration with application of water and fertilizer every four days;

Treatment 3 (KK3): Drip fertigation according to tensiometers measurements;

Treatment 4 ($Ø_B$): Furrow irrigation according to daily evapotranspiration with application of water every seven days and classic fertilization (spreading of fertilizer on soil).

The size of each plot (replication) was 6.6 $m^2$ (25 plants in 0.75 m of row spacing and 0.35 m plant spacing in the row). Each plot (replication) was designed with five rows of crop. There were five plants in each row.

The crop evapotranspiration was determined by direct measurement with soil water balance method at soil layer 0-100 cm depth (Tanaskovic *et al.*, 2006; Dragović, 2000; Bošnjak, 1999; Allen *et al.*, 1998; Cukaliev, 1996). The method consists of assessing the incoming and outgoing water flux into the crop root zone during the vegetation. In our investigation, the main parameters for estimation of ETP were irrigation (I) and initial or active soil moisture at the beginning of vegetation (Wi) as incoming water flux and active soil moisture on the end of vegetation (We) as potential outgoing water flux. As was mentioned above, our investigation was realized in experimental plastic house, where precipitations (P) were ignored. Also, as a result of controlled irrigation practice, surface runoff (RO) and deep percolation (DP) were excluded from this estimation. The subsurface water and water transported upward by capillary rise (CR) didn't have influence on water income in the root zone, and they were ignored. Therefore, crop evapotranspiration (ETP) was determinate under equation ETP = (I+Wi)-We. The crop evapotranspiration coefficient ETk was estimated as ratio between ETP and dry matter yield. Collected data were subjected to statistical analysis of variance and means were compared using the least significant difference (LSD) at the 1 and 5% level of probability ($P<0.01$ and $P<0.05$) test.

## Results and discussion

*The meteorological conditions during the research*

The pepper crop has exceptional requirements according to the climatic conditions. If climatic conditions are unfavorable or if they vary, the productivity and yield of the pepper crop can be significantly decreased. The pepper crop needs a lot of heat during whole growing period, what is connected with its native place of origin, the tropical zone (Gvozdenović, 2004; Jankulovski, 1997).

If the temperature is below 15°C, there are possibilities to increase the falling of flowers (Gvozdenović, 2004; Lazić *et al.*, 2001). Also, the flowers and fruits can fall if the temperature goes up to 35°C (Đurovka *et al.*, 2006). The optimal temperature for growing of pepper in controlled environment is 20-25°C during the day time and 18-20°C during the night (Đurovka *et al.*, 2006). Bosland and Votava (2000) reported that the best pepper yields can be obtained when the air temperature during the day time is between 18-32°C, especially in the stage of fruit formation. The average seasonal temperature in our investigation for the experimental plastic house (average in the growing period) during 2005, 2006 and 2007 was 22.83°C, 22.95°C and 24.1°C respectively (Table 4). During the period of the biggest fructification (June-August) the average temperature in all three years was in the frame of the optimum values recommended by Bosland and Votava (2000).

Table 4. Monthly average air temperature (°C) in Skopje region (according to the National Hydro-meteorological Service) and in the experimental plastic house (by our measurements), during the green pepper vegetation

| Year / Months | Average temperature (°C) in Skopje region | | | Average temperature (°C) in the experimental plastic house | | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2005 | 2006 | 2007 |
| V | 18,0 | 17,8 | 18,6 | 20,9 | 20,5 | 21,6 |
| VI | 20,9 | 20,6 | 23,9 | 24,1 | 23,6 | 27,1 |
| VII | 24,1 | 23,4 | 27,1 | 28,2 | 27,2 | 31,0 |
| VIII | 22,1 | 23,3 | 25,1 | 26,1 | 26,9 | 28,9 |
| IX | 19,1 | 19,5 | 17,7 | 22,2 | 22,7 | 20,6 |
| X | 12,7 | 14,0 | 12,7 | 15,5 | 16,8 | 15,4 |
| Average | 19,48 | 19,77 | 20,85 | 22,83 | 22,95 | 24,10 |

Generally, pepper crop has great crop water requirements during the vegetation period, which is the result of the poorly developed root system and huge biomass exposure to strong transpiration (Lazić *et al.*, 2001; Jankulovski, 1997; Iljovski and Cukaliev, 1994). It is well known that pepper crop is most sensitive to water shortage (drought) during the flowering and fruit formation. The Skopje area in that period is characterized with highest temperatures and insolation, so the evapotranspiration is at its highest rate. Usually rainfalls are down to a minimum in that period.

Data presented in Table 5 shows that all three years of testing were characterized as very wet years with a lot of rainfall in the growing season. As was mentioned above, our testing was conducted in a controlled environment (plastic house), where water income does not have any influence on the crop evapotranspiration, which means that the total water income was presented by irrigation water requirements (almost 75%) and initial or active soil moisture at the beginning of vegetation (almost 25%).

For normal pepper crop growing and for high and quality yields, the optimal relative humidity should range from 60 to 70%. Gvozdenović (2004) reported that lower relative air humidity followed by high temperature can affect flower and fruit falling. Jankulovski (1997) reported that relative air humidity in plastic houses should be around the 70%.

With the exception of October, the average relative humidity during all three years of our investigation was close to recommended values for the plastic houses.

Data for relative air humidity during the investigation are shown in Table 6.

Table 5. Monthly precipitation (mm) in Skopje region

| Year | 2005 | 2006 | 2007 |
|---|---|---|---|
| Months | Precipitation (mm) | Precipitation (mm) | Precipitation (mm) |
| V | 72,4 | 19,2 | 96,2 |
| VI | 38,4 | 94,7 | 34,8 |
| VII | 36,9 | 39,0 | 1,2 |
| VIII | 73,3 | 29,2 | 52,7 |
| IX | 34,2 | 43,3 | 27,2 |
| X | 50,1 | 56,9 | 140,0 |
| Average | 305,3 | 282,3 | 352,1 |

In any case, it should be pointed out that our investigation was realized in a controlled environment of an elementary type (plastic house), where the temperature and relative air humidity were heavily controlled and regulated, only with manual opening of side vents. In this relation, Jankulovski (1997) reported that regulation of microclimate condition in plastic houses is harder than in green houses.

Table 6. Monthly average relative humidity (%) in Skopje region (according to National Hydro-meteorological Service) and in the experimental plastic house (by our measurements), during the green pepper vegetation

| Year / Months | Average relative humidity (%) in Skopje region | | | Average relative humidity (%) in the experimental plastic house | | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2005 | 2006 | 2007 |
| V | 63 | 59 | 65 | 72 | 74 | 73 |
| VI | 56 | 64 | 56 | 63 | 71 | 61 |
| VII | 55 | 59 | 38 | 60 | 63 | 53 |
| VIII | 65 | 57 | 51 | 71 | 60 | 60 |
| IX | 68 | 60 | 58 | 74 | 66 | 68 |
| X | 71 | 70 | 75 | 81 | 80 | 83 |
| Average | 63 | 61,5 | 57,2 | 70,2 | 69 | 66,3 |

*Influence of irrigation and fertilization techniques on ETP, ETk and green pepper yield*

As was mentioned above, the crop evapotranspiration (ETP) was determined by direct measurement with soil water balance method at soil layer 0-100 cm depth, under permanent content of soil moisture and nutrients, as well as permanent agro-technical measures. The water balance method in our investigation was realized by assessment of the water income and active soil moisture at the end of vegetation into the crop root zone. The water income was estimated through the irrigation water requirements and initial or active soil moisture at the beginning of vegetation. Irrigation water requirement for the treatments KK1, KK2 and $Ø_B$ is presented as water quantity applied during the vegetation (read on the volumetric meter); with periodic soil samplings for controlling of momentary soil moisture and realized irrigation regime. The irrigation water requirement for the treatment KK3 was obtained by tensiometers readings installed in the soil. The Initial or active soil moisture at the beginning of vegetation is presented as the difference between field capacity (FC) and permanent wilting point (PWP). Cukaliev (1996) has calculated initial or active soil moisture at the beginning as a difference between momentary soil moisture and permanent wilting point, but in our case we refilled the soil moisture up to field capacity before starting with the irrigation regime. The active soil moisture at the end of vegetation is calculated as a difference between momentary soil moisture at the end of vegetation and permanent wilting point. The difference between water income (irrigation water requirements and active soil moisture at the beginning) and active soil moisture at the end of vegetation is the potential evapotranspiration. The results for water balance and ETP, separately by year of investigations are presented in Table 7, 8 and 9. From the results shown in Table 7, it can be concluded that the content of active soil moisture at the end of vegetation in the treatments KK1 and KK2 is from 53 to 71% higher in comparison with KK3.

Table 7. Water balance and ETP ($m^3$/ha) for 2005

| Treatment | Wi | I | Total income | We | ETP | Comparison with KK1 (%) | Comparison with KK2 (%) |
|---|---|---|---|---|---|---|---|
| KK1 | 1824 | 4882 | 6706 | 1903 | 4803 | 100 | 102,3 |
| KK2 | 1824 | 4999 | 6823 | 2126 | 4697 | / | 100 |
| KK3 | 1824 | 4510 | 6334 | 1242 | 5092 | 106,0 | 108,4 |
| $Ø_B$ | 1824 | 5819 | 7643 | 1829 | 5814 | 121,1 | 123,8 |

The main reason for higher content of active soil moisture at the end of vegetation in the treatments KK1 and KK2 is irrigation application rates scheduled according to the average daily evapotranspiration with continuous keeping of soil moisture in the frame of field capacity (short irrigation frequencies, 2 or 4 days). Tanaskovik *et al.*, (2006) reported similar results in drip fertigation treatments at two and four days in tomato crop production. On the other hand, the treatment with tensiometers readings (KK3) and drip irrigation frequency every 8 or 10 days (which is not the typical frequency for drip irrigation), presented lower active soil moisture at the end of vegetation. Generally, it can be concluded that the final irrigation application rates (2-3 rates) at the end of vegetation in the treatments KK1 and KK2 couldn't be applied, in order to decrease the participation of irrigation water requirement (I) in total water income, without negative effects on the yields. If the results for ETP in 2005 are presented in comparative values, then potential evapotranspiration in the treatments KK2 and KK1 is lower by 23,8 and 21,1 % in comparison with $Ø_B$, while in comparison with KK3 ETP it is about 8,4 and 6% lower.

Table 8. Water balance and ETP ($m^3$/ha) for 2006

| Treatment | Wi | I | Total income | We | ETP | Comparison with KK1 (%) | Comparison with KK2 (%) |
|---|---|---|---|---|---|---|---|
| KK1 | 1824 | 4517 | 6341 | 1548 | 4793 | 100 | 102,3 |
| KK2 | 1824 | 4543 | 6367 | 1680 | 4687 | / | 100 |
| KK3 | 1824 | 4176 | 6000 | 1100 | 4900 | 102,2 | 104,5 |
| $Ø_B$ | 1824 | 5328 | 7152 | 1512 | 5640 | 117,7 | 120,3 |

In 2006, as result of proper controlling of the final irrigation application rates, the active soil moisture at the end of vegetation in the treatments KK1 and KK2 was lower by 22,9 to 26,5% when compared to the previous year. The potential evapotranspiration in treatments with drip fertigation was lower by 15 to 20,3 % compared to the treatment with furrow irrigation and spreading of fertilizers.

The decreasing trend of active soil moisture at the end of vegetation continued in following year, which can be connected to a higher temperature in comparison with 2005 and 2006. Also, the results for potential evapotranspiration in all treatments are connected with the temperature. Various researchers indicate the direct influence of temperature on ET (Evett 2007; Iljovski and Cukaliev 2002; Allen *et al.*, 1998; Doorenbos *et al.*,1986; Doorenbos *et al.*, 1984). Namely, the results for ETP in 2007 are almost for 275 to 543 $m^3$/ha higher compared with 2006, when the least evapotranspiration was registered.

Table 9. Water balance and ETP ($m^3$/ha) for 2007

| Treatment | Wi | I | Total income | We | ETP | Comparison with KK1 (%) | Comparison with KK2 (%) |
|---|---|---|---|---|---|---|---|
| KK1 | 1824 | 4550 | 6374 | 1306 | 5068 | 100 | / |
| KK2 | 1824 | 4716 | 6540 | 1400 | 5140 | 101,5 | 100 |
| KK3 | 1824 | 4489 | 6213 | 880 | 5333 | 105,2 | 103,6 |
| $Ø_B$ | 1824 | 5517 | 7331 | 1142 | 6189 | 122,1 | 120,4 |

Table 10. Average results for ETP, yield and ETk, for all three years of investigation

| Treatment | ETP $m^3$/ha | ETP comparison with KK2 (%) | Yield (t/ha) | D.M. yield (t/ha) | ETk | ETk comparison with KK1 (%) |
|---|---|---|---|---|---|---|
| KK1 | 4888 | 101 | 73,15 | 12,24 | 399,3 | 100 |
| KK2 | 4842 | 100 | 69,18 | 11,98 | 404,2 | 101,2 |
| KK3 | 5108 | 105,5 | 63,42 | 10,19 | 501,3 | 125,5 |
| $Ø_B$ | 5881 | 121,5 | 56,99 | 9,07 | 648,4 | 162,4 |
| LSD: 0,05 | 56,45 | | 1,80 | 0,72 | 34,09 | |
| LSD: 0,01 | 76,16 | | 2,43 | 0,98 | 46,85 | |

From the results presented in Table 10, it can be concluded that there are negligible differences in ETP and ETk between the treatments KK1 and KK2 (drip fertigation every 2 and 4 days), what is a result of closer irrigation interval of these two treatments. Statistically, there is no significant difference in ETP and ETk between treatment KK1 and KK2. So, in this case, the decision for the frequency of drip fertigation in a range of two to four days should be made according to the yield, not according to the ETP and ETk. Drip fertigation frequency every two days achieves a yield that is significantly higher than the yield if fertigation is applied with four day frequency (KK2). Bar Yosef (2003) reported better pepper yields in treatment with drip fertigation 2 or 3 times a day (71 t/ha) compared with every day (68 t/ha) or every 2 day drip fertigation (66 t/ha). Also, various researches reported better yields in pepper and other crops by using of high-frequency surface drip irrigation and fertigation in comparison with low frequency surface drip irrigation and fertigation (Tanaskovik, 2011; Iljovski *et al.*, 2003; Tekinel and Kanber, 2002; Phene, 1995; Oğuzer *et al.*, 1991; Topçu 1988). On the other hand, as a result of longer intervals between the applications, the treatment KK3 (drip fertigation scheduled by tensiometers) showed 4,5-5,5% higher evapotrasnpiration in comparison with KK2 and KK1, and from 23,9 to 25,5% higher ETk in comparison with KK1 and KK2. The results for ETP and ETK in treatments KK1 and KK2 showed statistically significant differences in comparison with treatment KK3. According to the results of the average green pepper crop yields presented in Table 10, it is clear that the high drip fertigation frequency create better environment for increasing of yields in comparison with low drip fertigation treatment (KK3). So, our results show that the time difference between two applications of water and fertilizers higher than four days will significantly decrease the yield and increase ETP and ETk of green pepper crop due to increased water stress. Metin Sezen *et al.*, (2006) in their investigations with different irrigation regime in pepper crop, reported the best yield in the treatment with drip irrigation frequency of 3 to 6 days with average ET from 519,5 mm, while in the drip irrigation treatment with irrigation frequency from 6 to 11 days and 9-15 days yield and water use efficiency decrease. Doorenbos *et al.* (1986) reported that prolonged water deficit limits growth and reduces yields in tomato crop.

The effect of irrigation and fertilization techniques on ETP is presented by the achieved results in treatments KK3 (drip fertigation with tensiometers readings) and $Ø_B$ (furrow irrigation and spreading of fertilizers). Namely, in almost the same irrigation intervals, the treatment KK3 obtained almost 15% lower ETP compared with $Ø_B$, which is a result of the application of fertilizers through the drip irrigation system. The results are statistically significant at 0,01 level of probability. Also, the drip fertigation treatment showed a statistically significant higher yield compared with furrow irrigation and spreading of fertilizer. The effect of the drip fertigation can be explained by the fact that with drip fertigation the root zone is simultaneously supplied with water and readily available nutrients. Haynes (1985) reported that if nutrients are applied outside the wetted soil volume they are generally not available for crop use. Hagin *et al.*, 2002 reported that in a fertigation system, the timing, amounts, concentrations and ratios of the nutrients are easily controlled and compared by a conventional fertilizer application and irrigation. Dasberg and Or (1999) reported that increased yields using drip irrigation can be attributed to several factors: higher water use efficiency because of precise application directly to the root zone and lower losses due to reduced evaporation, runoff and deep percolation; reduced fluctuations in the soil water content resulting with avoidance of water stress etc. A number of other investigators give reports with higher yields, efficient use of water and fertilizers and lower ETP in different crops when fertilizers were injected through the drip system in comparison with conventional application of fertilizers (Tanaskovik *et al.*, 2011; Cukaliev *et al.*, 2008; Tanaskovik *et al.*, 2006; Halitligil *et al.*, 2002; Al-Wabel *et al.*, 2002; Castellanos *et al.*, 1999; Petrevska K. J. 1999; Papadopoulos, 1996).

The total dry matter yield in drip fertigation treatments, show the same pattern as a fresh fruit yield. The results are statistically significant at 0,01 level of probability. Halitligil *et al.*, (2002) reported that with the same quantity of fertilizer but different methods of application, drip fertigation shows higher dry matter yield in comparison with treatment with spreading of fertilizers on soil.

The positive effect of drip fertigation on ETk is presented by the differences between the treatments KK3 and $Ø_B$. From the results, it can be concluded that the treatment KK3 has an almost 30% lower ETk coefficient in comparison with furrow irrigation and spreading of fertilizers on the soil. The average ETk coefficient achieved in treatments KK1 and KK2 are pretty close to average transpiration coefficient of 330 presented by Lazić *et al.*, (2001). Tanaskovik (2005) and Petrevska (1999) achieved a lower ETk coefficient in tomato crop with drip fertigation in comparison with furrow irrigation and spreading of fertiliser.

Generally, the obtained results for ETP in our investigation are lower than those recommended by Iljovski and Cukaliev (1994), from 7000 to 8000 $m^3$/ha and Doorenbos *et al.*, (1986), from 600 to 900 mm. This is a result of the proper and controlled irrigation and fertilization regime during all three years of investigation, especially in drip fertigation treatments. It is important to mention that our results are connected to proper water management in agricultural production, especially in the forthcoming period when the climate changes are expected to have an influence on water resources in our country.

**Conclusions**

The least average potential evapotranspiration (ETP) is achieved in the treatments with drip fertigation at 2 (4888 $m^3$/ha) and 4 days (4842 $m^3$/ha). Statistically, there is no significant difference. On the other hand, as a result of longer intervals between the applications, the treatment KK3 (drip fertigation scheduled by tensiometers) showed 4,5-5,5% higher evapotrasnpiration in comparison with KK2 and KK1. The results for ETP in the treatments KK1 and KK2 showed statistically significant differences in comparison with treatment KK3 (5108 $m^3$/ha). The effect of irrigation and fertilization techniques on ETP is presented by the achieved results in treatments KK3 and $Ø_B$. Namely, in almost the same irrigation intervals, the treatment KK3 obtained almost 15% lower ETP compared with $Ø_B$ (5881 $m^3$/ha), which is a result of the application of fertilizers through the drip irrigation system. The results are statistically significant at 0,01 level of probability.

The highest average yields are achieved in treatments KK1 and KK2 with 71,11 t/ha and 68,40 t/ha, while in treatment KK3 the average yield was almost 6-9 t/ha lower (62,61 t/ha). The results are statistically significant at 0,01 level of probability. It is clear that the high drip fertigation frequency creates a better environment for increasing of yields in comparison with low drip fertigation treatment. The least average yield is achieved in treatment $Ø_B$ (54,74 t/ha). The treatments with drip fertigation statistically showed a significantly higher yield compared with furrow irrigation and spreading of fertilizer. Also, the total dry matter yield in drip fertigation treatments, show the same pattern as a fresh fruit yield. The results are statistically significant at 0,01 level of probability.

The treatments KK1 and KK2 show the best ETk coefficient or 400 in average. The highest ETk was achieved in treatment $Ø_B$ almost 650, which is a result of improper irrigation and fertilization technique. The positive effect of drip fertigation on ETk is presented by the differences between the treatments KK3 and $Ø_B$. From the results, it can be concluded that the treatment KK3 has an almost 30% lower ETk coefficient in comparison with $Ø_B$. Statistically, the results are significant at 0,01 level of probability.

Generally, the obtained results for ETP and ETk in our investigation are lower than those recommended by the literature. This is as result of the proper and controlled irrigation and fertilization regime during all three years of investigation, especially in drip fertigation treatments. It is important to mention that our results are connected to proper water management in agricultural production, especially in the forthcoming period when the climate changes are expected to have an influence on water resources in our country.

Finally, from our research we can conclude that the optimal frequency for irrigation and fertigation of green pepper crop in similar conditions is from two to four days. The final decision of the frequency of drip fertigation in a range of two to four days should be done according to the yield, not according to the ETP and ETk.

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# ОПРЕДЕЛУВАЊЕ НА ЕВАПОТРАНСПИРАЦИЈА КАЈ ПИПЕРКА ПРИ ПРИМЕНА НА РАЗЛИЧНИ НАЧИНИ НА НАВОДНУВАЊЕ И ЃУБРЕЊЕ

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**Апстракт**

Истражувањето беше спроведено во периодот од мај до октомври во 2005, 2006 и 2007 година, кај пиперка од сортата Бела долга, одгледувана во заштитен простор-пластеник на опитните површини на Факултетот за земјоделски науки и храна во Скопје. Главна цел на истражувањето беше да се определи потрошувачката на вода (ETP) кај пиперка одгледувана со контролиран раст на стеблото (V-систем), при примена на различни начини и режими на наводнување и ѓубрење. Покрај главната цел, во истражувањето беше определен и транспирациониот коефициент (ETk), кој исто така како параметер може да послужи за индиректно утврдување на потрошувачката на вода. За таа цел, четири варијанти беа поставени во истражувањето. Три варијанти (КК1, КК2, КК3) беа залевани со систем капка по капка и истовремена апликација на хранливите материи преку системот (фертиригација), додека една варијанта беше наводнувана со бразди и класично ѓубрење (контролна варијанта $Ø_Б$). Од добиените просечни резултати за сите три години на истражување, може да се заклучи дека разликите во ETP и ETk помеѓу КК1 и КК2 (фертиригација на 2 и 4 дена) се многу мали, дури и незначителни, што се должи на блискиот интервал на залевање на двете варијанти. Варијантата КК3 (фертиригација со помош на тензиометри), како резултат на подолгиот интервал на залевање покажа 4,5-5,5% повисока евапотранспирација во споредба со КК2 и КК1, односно од 24 до 25,5% повисок ETk во споредба со КК1 и КК2, а разликите се високо статистички значајни. Ефектот на техниката на наводнување и ѓубрење врз евапотранспирацијата и ETк, може да се види при споредба на варијантите КК3 и $Ø_Б$, каде ETP и ETk се за 15, односно 30% повисоки кај контролната варијанта. Резултатите се високо статистички значајни на ниво на веројатност од 0,01.

**Клучни зборови:** потенцијална евапотранспирација, евапотранспирационен коефициент, фертиригација, наводнување со бразди, пиперка.

**UDC:631.67:556.18 (560.8)**
**Review paper**

# APPROACHES ON EFFICIENT WATER USE FOR IRRIGATED AGRICULTURE IN GAP REGION OF TURKEY

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## Abstract
Use of water in agriculture is very important for agricultural production and decreasing the impacts of drought. Global water use in agriculture is approximately 70% in not only Turkey but also in the world. Due to the fact that there has been a competitive among domestic, industrial and agricultural sectors in terms of water use, the most pressure is on the irrigated agriculture. Use of water in agriculture plays the important role in terms of negative effects of climate change and inappropriate irrigation applications. The amount of irrigation water of 5 000-6 000 $m^3$ per ha are used in the modern irrigation systems while the amount of irrigation water more than 10 000 $m^3$ per ha are used for conventional irrigation. Additionally to use a large amount of water causes risks of salinity and erosion for irrigated lands. There has not been only one way to overcome these problems. These could be technical and institutional approaches. The precautions must be applied as integrated with all the applications. Technical precautions could be using modern irrigation systems, improving irrigation scheduling for efficient water use, water harvesting, using wastewater, terracing, building small dams, mulching and less soil ploughing. Institutional precautions are to improve the functional structures of water user associations and irrigation cooperatives. In this article, due to risk of climate change and drought especially in Southeastern Anatolia Region of Turkey, irrigation problems and the precautions for the effective use of water in agriculture are discussed.

**Key words**: irrigation, efficient use of water, water management, Southeastern Anatolia Region, Turkey.

## Introduction
Agriculture has the greatest potential for solving the problems of global water scarcity and effective use of water. Thus, irrigation is the most input in increasing crop production especially for arid and semi arid regions. Considering food demand and human life, irrigation investments have become more important in all over the world. Over 70% of available water in the irrigated areas is used for agriculture; however competition for the limited water resources in the dry areas is increasing with domestic and industrial demand reinforced by high population growth rates, improvements in living conditions and changing expectations, depriving agriculture of substantial amounts. There will be new water allocation between sectors and water currently available to agriculture is likely to decrease further (Cetin et al., 2009).

Water scarcity is a situation where there is insufficient water to satisfy normal requirements (Winpenny, 2009). Many of the causes for water scarcity are inter-related and are not easily distinguished. These may be population growth, food production, climate change and variability, land use, water quality, water demand, sectoral resources and institutional capacity, poverty and economic policy, water resource management, international waters, political realities and sociological issues. Southeastern Anatolia Project (GAP), that is an integrated regional development project was laid in 1980, in Turkey. GAP, was initially undertaken as a program to develop water and land resources of the region and consequently planned as a package comprising 13 projects envisaging irrigation schemes and hydraulic power plants in the basins of the Euphrates and the Tigris. The surface area of the region is 75,358 square kilometers constituting 9.7 % of the total surface area of the country (Figure 1). Turkey has 8.5 million hectares of irrigable land in near future and about 20 % of this land is in Southeastern Anatolia. The GAP region has a share of about 10 % in both the total population and geographical area of Turkey.

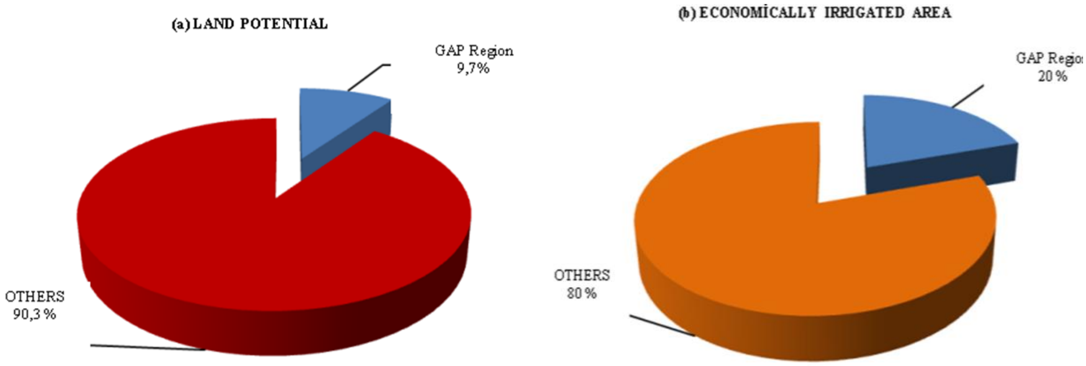


Figure 1. Land potential of GAP Region (a), **e**conomically irrigated area of GAP Region (b)

GAP, is one of the world's largest and most ambitious regional development projects, which includes not only a giant water resources development plan, but also large-scale investment in a wide range of development-related sectors such as agriculture, energy, transportation, telecommunications, health care, education as well as urban and rural infrastructure. GAP as it is presently conceived, is a US$32 billion multi-sectoral, integrated regional development program, which primarily aims at strengthening economic, environmental, cultural, social, institutional aspects of human development in this economically disadvantaged region by significantly raising the prevailing living standards and quality of life.

GAP package included 22 dams, 19 hydraulic power plants and irrigation covering an area of 1.7 million hectares. The main components of the GAP project were the Atatürk Dam, Sanliurfa Tunnels, and Sanliurfa-Harran irrigation system. Presently, area of 189 951 ha are irrigated by Ataturk Dam, in the near future, area of 882 000 ha will be irrigated (Cetin, 2011). With the preparation of GAP Master Plan in 1989, the project transformed into an integrated regional development effort also covering such diverse fields as rural and urban infrastructure, housing, transportation, communication, agricultural and industrial development, tourism, education and health. Later on, parallel to developments taking place in the world, the philosophy of sustainable human development was adopted in the context of GAP activities upholding the principles of human development, participation, equality and fairness. At present, besides its water resources development program, the GAP is implemented as an integrated regional development project based on sustainable human development covering many other sectors as well.

*Effects of Irrigation on Regional Development*

In the GAP Region, 1.822 million hectares is planned to be irrigated. By the end of 2009, a total of 300 397 ha were irrigated in Euphrates and Tigris Basin. Almost 72 093 ha of irrigation network construction is still underway while in the planning stages are 1,448,556 ha. Around 16,5% of irrigation projects are operated. It has shown irrigated areas in the GAP Region on the Table 1.

Irrigation has changed crop pattern in GAP Region, and the farmers have started to use new agricultural techniques. Considering development and increasing life standard in the region by means of irrigation, the beneficial impacts of irrigation will be (i) increased crop production and increased farm income, (ii) increased cropping intensity and crop diversification, (iii) increased farm employment and (iv) increased farm consumption and increased permanent wealth (Cetin, 2011). Crop pattern before GAP and planned crop pattern in the part of named Lower Euphrates of GAP including Harran Plain are given in Table 2 and 3. According to dry conditions, the highest crop ratio is winter wheat and barley (51 %) and legumes (31 %). According to the crop pattern of GAP Project, the ratio of cotton will have been the highest (34.3 %) and the second highest ratio of the crops were winter wheat and barley (27,9%).

Table 1. Irrigated area in the GAP Region according to the years (Anonymous, 2012)

| Years | Irrigated Area (ha) | Net irrigated area opened during the year (ha) |
|---|---|---|
| 2002 | 198.854 | 4.758 |
| 2003 | 206.954 | 8.100 |
| 2004 | 224.604 | 17.650 |
| 2005 | 245.613 | 21.009 |
| 2006 | 262.335 | 16.722 |
| 2007 | 272.972 | 10.637 |
| 2008 | 287.295 | 14.323 |
| 2009 | 300.397 | 13.102 |

Realized crop pattern in the areas before GAP and starting irrigation of GAP is given in Table 4. Cotton grown ratio was 50.0-69.0 % and 59.0-79.0 % in Ceylanpınar and Akçakale Irrigation Schemes before GAP. Although there were no any cotton crops for the dry areas in Harran Plain, the ratio of cotton has reached dramatically through 91-96%.

Table 2. Crop pattern before GAP in Harran Plain of GAP (Fakioglu, 1989)

| Crops | Area Sown (%) |
|---|---|
| Wheat + Barley | 51 |
| Lentil + Chick Pea | 31 |
| Sesame + Sun flower | 3 |
| Fallow | 13 |
| Others | 2 |
| Total | 100 |

Table 3. Planned crop pattern according to irrigation conditions of Harran Plain (Fakioglu, 1989)

| Crops | Area (%) |
|---|---|
| Cotton | 34.3 |
| Wheat + Barley | 27.9 |
| Tuber crops | 8.1 |
| Vegetables | 7.5 |
| Fruits | 4.5 |
| Forages | 4.7 |
| Grapes + Pistachio | 2.5 |
| Poplar tree | 3.8 |
| Others | 6.7 |
| Sub Total | 100.0 |
| Second crops (Sesame, corn, groundnut and soybean) | 16.5 |
| Total | 100.0+16.5 |

Table 4. Realized crop pattern in some of irrigations schemes in GAP (DSI, 1997)

| Crops | Irrigation Schemes Name | | | | | |
|---|---|---|---|---|---|---|
| | Ceylanpınar* | | Akçakale* | | Harran | |
| | 1994 | 1995 | 1994 | 1995 | 1995 | 1996 |
| Cotton | 50.0 | 69.0 | 59.0 | 79.0 | 96.0 | 91.0 |
| Wheat + Barley | 37.0 | 25.0 | 37.0 | 20.0 | -- | -- |
| Horticultural crops | 13.0 | 6.0 | 2.0 | 1.0 | 1.0 | 2.0 |
| Corn | -- | -- | -- | -- | -- | 3.0 |
| Others | -- | -- | 2.0 | -- | 3.0 | 4.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

*Started irrigation projects by ground water (wells) before GAP

This situation has increased the incomes of the farmers. However, besides use of over irrigation, undesired crop pattern applied on the contrary planned crop pattern is the most important problems. These applications indicate that more irrigation water can be consumed or used.

Farmers' incomes have increased with starting irrigation in this region. For example, the value added per person was 596 USD in the region before irrigation in 1995; it was 1241 USD in 2008. This is significantly increased for human life. Considering all the sectors development, especially irrigation investments and increasing agricultural production will be play enormous role for the development in near future (Anonymous, 2012).

*Applications and Approaches for Irrigation on Efficient Water Use*

When soil and water resources have not been managed considering the characteristics of soil and water resources, it can not be stated on sustainability of soil and water resources. On the other hand, many problems might occur; such as soil and water loss, soil and water pollution, soil erosion, soil salinity. Considering different irrigation methods, surface irrigation methods are widely used in Turkey. In this respect, the main problem is the use of excessive irrigation water. According to some of the research results, average 900-1000 mm irrigation water is enough to get maximum yield on cotton in Harran Plain. At the beginning of irrigation years, the farmers have applied irrigation water between 1200-1500 mm. Considering the last research result, the affected area by salinization increased from 11 430 ha in 2000 to 17 767 ha within 10 years showing 55 of increment. Salinization and high ground water levels increased by means of irrigation (Cullu et al., 2010). Also, over irrigation has resulted drainage problems. There is no only one way to overcome these problems. Efficient water use could be achieved using the integrated approaches or applications of technical and institutional approaches.

*Technical Approaches and Applications:* Efficient water use might be considered as different applications. These could be using modern irrigation systems for irrigated agriculture, improving irrigation scheduling for efficient water use, water metering, water harvesting, using wastewater, terracing, building small dams, mulching and less soil ploughing. The most important issue in terms of irrigation is not to apply considering volumetric measurements per area. Thus, some sanctions must be applied to the farmers who use exceed water and for other inappropriate applications. Some precautions for preventing irrigation problems and inappropriate applications must offer to the decision makers and the government. The precautions must be applied as integrated with all the applications.

The sustainable use of water resources under aridity may imply effective adoption and implementation of integrated land and water resources planning, improving of water distribution and irrigation systems, valuing the water as an economic, social and environmental good, adoption of appropriate water and irrigation technologies, the users participation in water resources and system management and education and training of water managers, operators and users. For example, there are no sanctions to provide irrigation water to farmers on the basis of volume. If it is applied, the farmers and irrigation unions will have an effective and efficient use of irrigation water.

*Institutional Approaches and Applications:* In Turkey, allocation of irrigation water to the farmers in irrigation schemes performed by means of Water User associations (WUAs) and Irrigation Cooperatives (ICs). These establishments, WUAs and ICs, are directed by democratic rules under the framework of the present laws. However, there are practically some mismanagement in these establishments. There are many different reasons for this. These are habits and education level of the farmers, local conditions, history, customs, local or national politicians, social structure of the region. Thus, these authorities, WUAs and ICs, must be controlled by decision makers and/or governments to get more appropriate in terms of efficient management. In this way, an effective water management and water saving can be achieved. For that reason, the Law (Law No: 6172) for Water User Associations has been enacted nowadays.

**Conclusions**

Use of micro-irrigation systems especially drip irrigation plays significant role on water saving for irrigated agriculture. Thus, use of pressurized irrigation systems should be supported directly or indirectly by governments. Fortunately, this was started by 2007 in Turkey initiated in our country by the end of the year 2007. In addition, the present large-scale surface irrigation projects, and farm irrigation networks must be converted to the pressurized irrigation systems.

Another main problem is not to use amount of irrigation water considering volumetric basis. For that reason, over or exceed irrigation in Turkey is one of the major problems. These applications cause deterioration on soil conditions. The farmers have believed that the more water is equal to more crop yield. Thus, they have not been considered the deterioration of soils, and particularly soil salinization and alkalinity.

The sustainable use of water resources may imply with implementation of integrated land and water resources planning, improving of water distribution and irrigation systems, considering the water as an economical, social and environmental resource. In addition, use of appropriate water and irrigation technologies, the participation of the users in water resources and system management, and education and training of water managers, operators and users are the other factors affecting irrigation management. On the other hand, there are many different direct or indirect ways to be considered in use of efficient water. These may be surface water harvesting, terracing, building small dams, using non-conventional water resources, water conservation and water saving practices and management, water metering, water pricing, to develop new crop varieties resistant to water stress, improving irrigation systems, improving irrigation scheduling and deficit irrigation.

As a result, there is no only one way to overcome this problems but an integrated management in irrigated agriculture must be planned and implemented. Thus, regional, national and/or international new approaches and mechanisms on water and irrigation management should be organized.

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# ПРИСТАП ЗА ЕФИКАСНО КОРИСТЕЊЕ НА ВОДАТА ЗА НАВОДНУВАЊЕ ВО ЗЕМЈОДЕЛСКОТО ПРОИЗВОДСТВО ВО GAP РЕГИОНОТ ВО ТУРЦИЈА

Неше Узен, Онер Цетин, Мурат Караер

**Апстракт**

Водата има големо значење за земјоделското производство и влијае на намалување на негативните ефектите од сушата. Глобалното користење на водата во секторот земјоделството во Турција, но и на светско ниво е приближно 70%. Поради фактот дека денес постои постојана конкуренција во поглед на користење на водата помеѓу домашниот сектор, секторот индустрија и земјоделското производство, очигледно е дека најголемиот притисок се јавува токму во земјоделството, односно наводнувањето на земјоделските култури. Исто така, водата во земјоделството има важна улога во поглед на намалување на негативното влијание на климатските промени и неправилното наводнување. Кај модерните техники на наводнување, нормата на наводнување изнесува од 5 000 до 6 000 $m^3$/ha, додека кај традиционалните техники на наводнување таа се движи дури и над 10 000 $m^3$/ha. Дополнителен проблем при користењето на поголемо количество на вода преставува ризикот од засолување или ерозија на површините кои се наоѓаат под наводнување. Генерално, во праксата не постојат единечни мерки за решавање на овие проблеми. Потребен е технички и институционален пристап за решавање на истите, преку интегрирање на сите мерки. Техничкиот пристап потребно е да опфаќа мерки како модерни системи за наводнување, подобрување на режимот на залевање за поефикасно користење на водата, конзервација на водата, користење на отпадни води, терасирање, изградба на мали вештачки акумулации, мулчирање и помала обработка на почвата. Институционалниот пристап опфаќа мерки за подобрување на структурата на функционирање на водните заедници и кооперативите за наводнување. Оттука, поради ризикот од влијанието на климатските промени и сушата во југо-источниот регион на Анатолија во Турција, во овој труд се изложени проблемите од праксата на наводнување, како и мерките за поефикасно користење на водата во земјоделското производство.

**Клучни зборови:** наводнување, ефикасно користење на водата, управување со водите, југо-источен регион на Анатолија, Турција.

**UDC:631.48 (497.7)**
**Original scientific paper**

# FORMATION, GENESIS, EVOLUTION AND CLASSIFICATION OF SOILS ON LIMESTONES AND DOLOMITES MOUNTAIN JABLANICA

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**Abstract**
In this paper are presented the results of research conditions of formating, the genesis, evolution and classification of calcomelanosols and calcocambisols on Jablanica mountain. On different localities of the Jablanica mountain were excavated 18 basic pedological profiles of calcomelanosols with subtypes: organogenic (5) organomineral (12) and brownized (1) and 4 profiles brown soils on limestone and dolomites with a typical subtype. In addition, data were collected for conditions of soil forming factor (parent material, relief, climate, vegetation and human impact). Surveyed soils are formed only on pure limestones, dolomitised limestone and silicated limestone, mountainous terrain at an altitude of 900-1990 m. Investigated soils are formatted under variety of oak and beech communities, but in subalpine belt under alpine grassland communities. Examined soils on Jablanica mountain are extend into four climate-vegetation belts. By cutting and burning the forest erosion process is intensified. Calcomelanosols are the first stage in the evolution of soils on compact limestone and dolomites. Jablanica mountain evolutionary series has following order: organogenic –organomineral – brownized calcomelanosol - calcocambisol (brown soil on limestone and dolomite).
**Key words**: soil, conditions for forming, genesis, evolution, classification.

## Introduction

Calcomelanosols and calcocambisol formation on limestones and dolomites are highly spread out in the Republic of Macedonia. By Filipovski (1996), calcomelanosols comprising 220 000 hectares and occupy 8.6% of the territory of the Republic of Macedonia. According to the same author Filipovski (1982) calcocambisols formation on limestones and dolomites cover about 92 944 ha of the territory of the Republic. Taking into account highly spread out of calcomelanosols and calcocambisols formation on limestones and dolomites as well as the possibility of greater use in agriculture and forestry purpose of this paper came out. Mountain Jablanica, by its geological structure is built around the same of silicate rocks and limestone.
The subject of this paper are soils formation only on pure limestones and dolomites. On Mountain Jablanica we found two soil types formation on pure limestone: calcomelanosols and calcocambisols. Soil cover is intermittent and is bordered by limestone and dolomite rocks. Depth profile of these soils changed to the little distance. Calcomelanosols overgrown with grass and

forest vegetation. Grassland vegetation is mainly used for grazing cattle, and the lower part is used as meadows of which gets hay. Calcocambisols are deeper soils compared to calcomelanosols and mainly are under forest vegetation, lower part under grassland vegetation and favorable habitats for development forest and grassland vegetation.

## Material and methods

On mount Jablanica were excavated, studied and described morphologically 22 profiles on limestones and dolomites of which 18 calcomelanosols with subtypes: organogenic (5), organomineral (12) and brownized (1) and 4 profiles brown soils on limestone and dolomite (calcocambisols) with a typical subtype (Petkovski, et al., 1993). In addition, data were collected for conditions of soil forming (parent material, relief, climate, vegetation and human impact). Since these profiles were colected soil samples for laboratory analysis. Field trials are conducted according to generally accepted methodology in our country (Filipovski, edit. 1967).

## Results and discussion

Review of soil forming factors that affect the formation of calcomelanosols and calcocambisols on Jablanica Mountain is shown in Table 1.

*Geographical conditions and relief*

Jablanica Mountain extends in a north-northwest and south-southeast. The mountain is widespread in the region of 41˚05 'to 41˚30' north latitude and 20˚30'to 20˚40' eastern longitude. Morphological notes with several tops over 2000 meters high. The highest of which is the Black Stone with 2257 m. Its eastern slopes cut through with more narrow and deep valleys and very steep down in Struga field and valley of the Black Drim.

Investigated soils are formed in mountainous landscapes Jablanica mountain at an altitude of 900 - 1990 m. The highest parts of the investigated area extend organogenic calcomelanosols. In the lower parts of the mountain extend organomineral and brownized calcomelanosols. Calcocambisols are extend with previous, on flatly relief forms.

*Geological composition*

Jablanica is a silicate and carbonate mountain prevalence carbonate rock. Investigated soils are mainly formed on pure limestone and less on silicated limestones and dolomitized limestones (Table 2).

*Climate and vegetation*

Investigated soils occur in more climate vegetation belts, because parent material is crucial soil forming factor. Republic of Macedonia can be divided into 8 vertical climatic vegetation belts (Filipovski *et al.,*1996). Investigated soils extend down into 4 climatic vegetation belts and because it is inhabited by different plant communities. Calcocambisols of mountain Jablanica prevalent at an altitude of 1000-1380 m. Warmer exposures and lower altitudes are found under plant communities oak and hop hornbeam, and higher altitudes and colder exposures under community submountain and mountain beech. Calcomelanosols encountered at an altitude of 900-1990 m. Organomineral and brownized calcomelanosols extends on smaller altitude are covered under xerophilous plant communities, while those at higher altitudes and colder expositions under mezophytic associations. Organogenic calcomelanosols are spread out highest in investigated area and can be found under the subalpine grassland associations and mesophytic forest communities.

*Human impact*

In the past, the cutting and burning of the forest was particularly intense in the subalpine region.With it's enhanced erosion and impact of forest vegetation is replaced by grass vegetation. Also with excessive grazing and trampling causes erosion.

Table 1. Some Soil forming factor of soil forming on limestone and dolomites on Jablanica mountain

| Prof Nº | Horizon and depth in cm | Parent material | Altitude m | Exposition | Inclination % | Stoniness % | Rockyty % | Phytocenosi |
|---|---|---|---|---|---|---|---|---|
| Calcomelanosol – *Organogenic* | | | | | | | | |
| 9 | A (0-25) | Limestone | 1400 | Northeast | 40-50 | 20-30 | 30-40 | as. Aceri obtusati-Ostryo-Fagetum Em at Riz.1988 |
| 38 | A (4-24) | Dolomite with layers of limestone | 1300 | Northeast | > 50 | 60-70 | 50-60 | as.Festuco heterophyllae-Fagetum Em 1965* |
| 8a | A (0-22) | Limestone | 1550 | East | > 50 | 40-50 | 70-80 | as. Aceri obtusati-Ostryo-Fagetum Em at Riz.1988 |
| 60 | A (0-10) | Limestone | 1950 | Northwest | 45-50 | 35-40 | 45-50 | as. Onobrychi-Festucetum syllenicae Ht. 1936 |
| 61 | A (0-12) | Limestone | 1970 | North | > 50 | 60-65 | 50-60 | as. Onobrychi-Festucetum syllenicae Ht. 1936 |
| Calcomelanosol – *Organomineral* | | | | | | | | |
| 3 | A (3-28) | Limestone | 1200 | Northeast | 40-50 | 20-30 | 30-40 | as.Querco-Ostryetum carpinifoliae Ht.1938 |
| 4 | A (4-40) | Limestone | 1350 | North | 30-40 | 20-30 | 30-40 | as. Aceri obtusati-Ostryo-Fagetum Em at Riz.1988 |
| 5 | A (3-26) | Limestone | 1500 | Northeast | 50-60 | 10-20 | 20-30 | as. Aceri obtusati-Ostryo-Fagetum Em at Riz.1988 |
| 7 | A (0-21) | Dolomitised limestone | 1500 | Northeast | 50-60 | 10-20 | 20-30 | as. Aceri obtusati-Ostryo-Fagetum Em at Riz.1988 |
| 11 | A (0-27) | Limestone | 1000 | North | 30-40 | 30-40 | 30-40 | as.Querco-Ostryetum carpinifoliae Ht.1938 |
| 20 | A (0-18) | Limestone | 1400 | East | 30-40 | 60-70 | 50-60 | as. Juniperetum oxycedri-communis Riz.prov. |
| 22 | A (0-30) | Limestone | 1300 | Northeast | 15-20 | 20-25 | 30-35 | as.Querco-Ostryetum carpinifoliae Ht.1938 |
| 30 | A (0-29) | Limestone | 1250 | West | 35-40 | 40-45 | 35-40 | as.Festuco heterophyllae-Fagetum Em 1965* |
| 33 | A (0-36) | Limestone | 900 | North | 40-50 | 10-20 | 10-20 | as.Querco-Ostryetum carpinifoliae Ht.1938 |
| 35 | A (0-27) | Limestone | 1500 | Southeast | 50-60 | 50-60 | 20-30 | as.Pteridio-Asphodeletum albae Em 1976 |
| 4a | A (0-25) | Limestone | 1200 | North | 30-35 | 20-30 | 20-30 | as.Querco-Ostryetum carpinifoliae Ht.1938 |
| 62 | A (0-18) | Limestone | 1990 | North | 50-55 | 40-45 | 50-55 | as. Onobrychi-Festucetum syllenicae Ht. 1936 |
| Calcomelanosol – *Brouwnized* | | | | | | | | |
| 8 | O (0-8)<br>A (8-36)<br>(B)rz36-52 | Limestone | 1500 | East | 40-50 | 30-40 | 40-50 | as. Calamintho grandiflorae-Fagetum Em.1965** |
| Calcocambisols (typical) | | | | | | | | |
| 1 | A(2-21)<br>(B)rz21-55 | Dolomitised limestone | 1000 | West | 30-40 | 10-20 | 20-30 | as.Querco-Ostryetum carpinifoliae Ht.1938 |
| 2 | A (3-20)<br>(B)rz20-35<br>(B)rz35-70 | Silicated limestones | 1140 | South | 30-35 | 20-30 | 30-40 | as.Querco-Ostryetum carpinifoliae Ht.1938 |
| 10 | A (0-24)<br>(B)rz24-58<br>(B)rz58-70 | Silicated limestones | 1200 | Northeast | 40-45 | 20-25 | 30-40 | as.Festuco heterophyllae-Fagetum Em 1965* |
| 21 | A (2-21)<br>(B)rz21-73 | Silicated limestones | 1380 | North | 50-60 | 20-30 | 20-30 | as. Calamintho grandiflorae-Fagetum Em.1965** |

*syn as. Fagetum submontanum macedonicum Em 1965** syn as. Fagetum montanum macedonicum Em 1965

*Genesis*

According to Filipovski (1996) influenced by the factors described in calcomelanosols occur following three soil forming processes: 1. Dissolving $CaCO_3$ and $MgCO_3$ from limestone and dolomite and their rinsing; 2. Accumulation organic matter and the formation of humus horizon and 3. Forming (B)rz horizon in brownized calcomelanosols.

The genesis of brown soils on limestone and dolomites (calcocambisols) are characterized by the following processes: 1. Accumulation mull and half row humus; 2. Decarbonization; 3. Slight acidification; 4. Slight chemical weathering by weak clay formation; 5. Fixation and hydratation $Fe_2O_3$ and 6. Releasingon the clay residuum of limestone (Filipovski 1984).

*Evolution*

Calcomelanosols are the first stage in the evolution of soils on compact limestone and dolomites. Jablanica Mountain evolutionary series has following order: organogenic – organomineral – brownized calcomelanosol - calcocambisol (brown soil on limestone and dolomite).

*Classification*

Investigated soils (Table 3) are classified according classification of Former Yougoslavia (Škorić *et al.*, 1985)

Table 2. Parent material of investigated soils

| Parent material | Profile N$^o$ |
|---|---|
| Limestone | 9,8a,60,61,3,4,5,11,20,22,30,33,35,4a,62,8 |
| Dolomite with layers of limestone | 38 |
| Dolomitised limestone | 7,1 |
| Silicated limestone | 2,10,21 |

Table 3 Classification of calcomelanosols and calcocambisols on Jablanica mountain

| Soil types | Subtypes | Varieties | Forms | Profiles |
|---|---|---|---|---|
| Calcomelanosols | Organogenic | Lithic | Mollic horizon | 9, 38, 8a, 60, 61 |
| | Organomineral | Lithic | Mollic horizon | 3, 4, 5, 7, 11, 20, 22, 30, 33, 35, 4a, 62 |
| | Brownized | | | 8 |
| Calcocambisols | Typical | Deep | Clayey | 1, 2, 10, 21 |

**Conclusions**

Soils that are aim of investigation are formed in mountainous landscapes Jablanica mountain at an altitude of 900 -1990 m. The highest parts of the investigated area extend organogenic calcomelanosols. In the lower parts of the mountain extend organomineral and brownized calcomelanosols. Calcocambisols are extend with previous, on flatly relief forms. Investigated soils are formed predominantly on pure limestones, less on dolomitised limestone and silicated limestone.

Calcomelanosols and calcocambisols of mountain Jablanica extend down into 4 climatic vegetation belts and because it is inhabited by different plant communities. They are developed under various oak and beech associations, while in the subalpic region under high-mountain grass associations.

The genesis of calcomelanosols are characterised three soil forming processes:

1. Dissolving $CaCO_3$ and $MgCO_3$ from limestone and dolomite and their rinsing; 2. Accumulation organic matter and the formation of humus horizon and 3. Forming (B)rz horizon in brownized calcomelanosols.

The genesis of calcocambisols are characterized by the following processes:

1. Accumulation mull and half row humus; 2. Decarbonization; 3. Slight acidification; 4. Slight chemical weathering by weak clay formation; 5. Fixation and hydratation $Fe_2O_3$ and 6. Releasing on the clay residuum of limestone.

Jablanica Mountain evolutionary series has following order: organogenic – organomineral – brownized calcomelanosol – calcocambisol.

In our investigation we found three subtype calcomelanosols: organogenic, organomineral and brownised, and one typical subtype calcocambisol.

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# ГЕНЕЗА, ЕВОЛУЦИЈА И КЛАСИФИКАЦИЈА НА ПОЧВИТЕ ОБРАЗУВАНИ ВРЗ ВАРОВНЦИ И ДОЛОМИТИ НА ПЛАНИНАТА ЈАБЛАНИЦА

Марјан Андреевски, Душко Мукаетов, Миле Маркоски

**Апстракт**
Во овој труд се изнесени резултатите од истражувањата на условите за образување, генезата, еволуцијата и класификацијата на варовнично-доломитните црници и кафеавите почви врз варовник и доломит на планината Јабланица. На различни локалитети на планината Јабланица беа ископани 18 основни педолошки профили на варовнично-доломитни црници со поттиповите:органогени (5), органоминерални(12) и браунизирани (1) и 4 профили на кафеави почви врз варовници и доломити со еден поттип типични. Притоа, беа собрани податоци за условите на почвообразување (матичен супстрат, релјеф, клима, вегетација и влијание на човекот). Испитаните почви се образуваат само на чисти варовници и доломити, на планински релјеф на надморска височина од 900-1990 м. Образувани се под разни дабови и букови заедници а во субалпскиот појас под високопланински тревни заедници. На планината Јабланица испитуваните почви се простираат во четири климатско- вегетациски појаси. Со сечење и палење на шумата засилена е ерозијата. Варовнично-доломитните црници претставуваат прв стадиум во еволуцијата на почвите врз компактни варовници и доломити. На планината Јабланица еволуционата серија го има следниот редослед: органогена – органоминерална – браунизирана варовнично доломитна црница – кафеава почва врз варовник и доломит.

**Клучни зборови**: почва, услови за образување, генеза, еволуција, класификација.

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# IMPACT OF PRECIPITATION UPON NITRATE LEACHING AND CROP YIELD AT DIFFERENT PIPE DRAINAGE SPACING

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**Abstract**

The goal of three-year investigations was to determine the influence of precipitation upon drainage discharge and its duration, concentration of nitrates in drainage water, amount of nitrates leached and yields of crops grown: winter wheat, oilseed rape and soybean, at four different pipe drainage spacings (15 m, 20 m, 25 m and 30 m) on pseudogley-gley soil. Investigations were carried out at the experimental amelioration site "Jelenščak" near Popovača, in the period from 1 October 2008 to 30 September 2011.Winter wheat (2008/09), oil seed rape (2009/10) and soybean (2011) were grown at the experimental site. Identical agricultural management practices were applied in each year in all pipe spacing variants. Total nitrogen rates applied amounted to 183.6 kg. $ha^{-1}$ (2008/09), 175.5 $kg.ha^{-1}$ (2009/10) and 130 $kg.ha^{-1}$ (2011).Research results show that drainage discharge and its duration depended on the amount and distribution of precipitation during the study period. The highest drainage discharge was determined at the narrowest pipe spacing (15 m), while its longest duration was observed at the widest spacing (30 m). No drainage discharge was registered in the growing season of the dry 2011. The highest nitrate concentration in drainage water, in all pipe spacing variants, was recorded with the occurrence of the first drainage discharges and was higher than MAC (10 $mg.L^{-1}$ $N0_3$ - N). It was only after the autumn crop harvest that nitrate concentration was below MAC. The amount of nitrates leached, in each year and at each pipe spacing, depended on the drainage discharge and nitrate concentration in drainage water. Crop yields in the production year were statistically significant between the set pipe spacings (2008/09 and 2009/10), while they were not statistically significant in 2011. Effect of pipe drainage in draining surplus water from soil was positive in humid years while no effect of pipe drainage was recorded in the dry year.

**Key words**: precipitation, pipe spacing, drainage discharge, nitrate leaching, crop yield.

## Introduction

In the Republic of Croatia, hydromorphic soils caver an area of 1,789,070 ha. Hydroameliorative systems of surface drainage have been completed on 600,054 ha (33.5 %) of the said area, surface drainage systems have been partially built on 518,830 ha (29.0 %), while there are no surface drainage systems on 670,186 ha (37.5 %). Areas on which surface water had to be regulated by subsurface drainage (pipes) amounted to 820,350 ha. Thus far, subsurface drainage has been installed at an area of 161,530 ha (19.7 %), so subsurface drainage still remains to be provided on 658,820 ha (80.3 %) (Marušić, 1992).

Agricultural production is very risky on such developed/undeveloped agricultural areas, especially when surplus and/or deficit of precipitation occurs before or during the growing season. Such conditions make production planning very difficult and/or almost impossible, because production, and thereby also yield, depends on the weather conditions, making yields of field crops and their quality highly variable. This is the reason why most agricultural producers and part of the general public speak about the so called natural disasters, caused by floods or droughts.

Besides yields achieved and quality of agricultural products, we hear everyday discussions about the environment and its protection, namely, how much agriculture with all its inputs (mineral fertilizers and protection agents) influences the pollution of the natural resources soil and water, or about what should be done to act according to the principles of sustainable management, which implies production cost-effectiveness, environmental conservation, that is, its protection and prevention of further excessive pollution of ground and drinking water, notably by nitrates. Due to easy leaching of nitrates and its harmful consequences for people, the EU Nitrates Directive (91/676/EEC) was issued on water protection against pollution caused by nitrates of agricultural provenance due to inadequate and excessive nitrogen fertilization and incorrect storage of stable manure. The directive defines the responsibilities of the EU member countries regarding introduction of protection and supervision measures, and prescribes the conditions and measures for protection against nitrate pollution to be applied at farms. As part of the EU accession process, the Republic of Croatia has adopted this directive and incorporated it in its national legislation. Application of the Nitrates Directive will start after Croatia becomes a full member of the EU.

The goal of three-year investigations was to determine the influence of precipitation upon drainage discharge and its duration, concentration of nitrates in drainage water, amount of nitrates leached and yields of crops grown: winter wheat, oilseed rape and soybean, at four different pipe drainage spacings (15 m, 20 m, 25 m and 30 m) on pseudogley-gley soil.

## Material and methods

Investigations were conducted from 1 October 2008 to 30 September 2011 at the experimental amelioration site "Jelenščak" in the central Sava Valley (in the vicinity of Popovača) on hydroameliorated pseudogley-gley soil. The wider terrain area, including the experimental site, is situated in an area of relatively flat relief (I<1‰) at the average height above sea-level of 95.0–96.0 m. Prior to the application of hydroamelioration, the terrain was utilized for extensive public pastures, which were also covered by typical hydrophilic vegetation (Šimunić, 1995). The terrain on which the trial was set up is situated in the peripheral part of the Nature Park Lonjsko polje (Fig.1).

The shape of the terrain and the position of the experimental amelioration site (table) within it are shown in Figure 2. The experimental amelioration site comprises four different pipe spacings (15 m, 20 m, 25 m and 30 m) laid out in four replications (Figure 3). Pipe length is 95 m in all spacing variants, pipe diameter is 65 mm, average slope is 3 $^{0}/_{00}$ and average is depth 1 m. Drainage pipes are combined with contact (hydraulic) material gravel and drain directly into an open detailed canal. Pipe spacing of 25 m (with the said pipe length of 95 m) has an appertaining area of 1425 $m^2$; pipe spacing of 20 m has an area of 1900 $m^2$; pipe spacing of 25 m has an area of 2375 $m^2$ and pipe

spacing of 30 m has an area of 2850 $m^2$. Drainage discharge in each pipe spacing variant was continuously measured with the aid of a limnigraph, installed at the pipe outlet to the canal.
Climatic data used were provided by the weather station at Sisak, at ca. 15 km distance from the experimental amelioration site.


Figure 1. Location of the experimental amelioration site

The same crop was grown in each year in all pipe spacing variants and identical agricultural management practices were applied. Winter wheat was grown in the first year, oilseed rape in the second year, while soybean was produced in the third year.
Winter wheat was sown in October 2008. Total nitrogen rate applied was 183.6 kg.ha$^{-1}$. The crop was harvested at the beginning of July 2009. Oilseed rape was sown in mid-September 2009 and total amount of nitrogen added with fertilization was 175.5 kg.ha$^{-1}$. The crop was harvested at the beginning of July 2010. Soybean was sown at the beginning of April 2011 and a total of 135 kg.ha$^{-1}$ nitrogen was added with fertilization. Crop was harvested in mid-September 2011. Crop yield was measured at each pipe spacing and was expressed at 13% grain moisture level. Drainage water was sampled during drainage discharge, each ten days on average. Drainage water samples were taken separately for each pipe at the pipe outlet to the canal. Concentration of nitrates in drainage water was determined spectrophotometrically with 2.6-dimethylphenol (HRN ISO 7890-1:1998).
The amount of nitrates leached (at each pipe spacing) was calculated from the data on average monthly concentration of nitrates in drainage water and total monthly amount of drainage discharge. The annual value was obtained by summing up the monthly values of nitrates leached at each spacing.
ANOVA was applied for drainage discharge, its duration, nitrate concentration and crop yield in the tested pipe spacing variants; in the case of $p \leq 0.05$, Duncan's Multiple Range Test was performed.


Figure 2. The terrain and the position of the experimental amelioration site (table) "Jelenščak" – within the red frame (www.googlemaps.com)

To facilitate interpretation of research results, site factors (soil) and climate (precipitation) were taken into consideration.

*Pseudogley-gley and its characteristics*

As per textural composition, hydroameliorated pseudogley-gley soil (Figure 4) is silty clay to 75 cm depth, silty clay loam at 75 cm to 115 cm depth, and silty clay from 115 cm to 130 cm (Table 1). It belongs to the class of porous soils (average porosity 49 vol.%), on the borderline between medium and high water retention capacity (average water capacity 45 vol.%) and of very low air retention capacity (average air capacity 4 vol.%), as well as of very low water permeability (average water permeability 0.011 m/day). According to the MKCl reaction to 75 cm depth, the soil has acid reaction; according to humus content to 35 cm depth, it is fairly humus-rich; according to the supply of available phosphorus and potassium (to 35 cm depth), it is in the poor availability class.

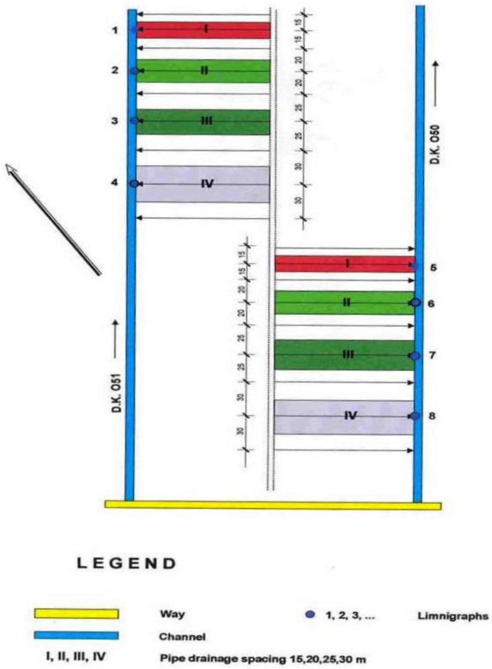


Figure 3. Scheme of the experimental amelioration site "Jelenščak"

*Climate (precipitation)*

According to its general climatic characteristics, the Sisak region belongs to the central-European temperate climate, warm climate zone, moderately rainy climate with expressly continental traits. In the twenty-year period (1986 - 2005), an average of 925 mm of precipitation fell in the Sisak region, which fluctuated from 614.8 mm to 1086.9 mm. The growing seasons had 523.4 mm or 56.6 %, which is a characteristic of the continental precipitation regime. Monthly precipitation maxima were recorded in late spring and late summer parts of the year (June and September). The multiyear average and distribution of precipitation over the year allow the conclusion that the precipitation regime is favourable for agricultural production. However, to get a better insight into monthly and annual precipitation and its distribution, probability of its occurrence should be calculated (Table 1) as well as the occurrence return period (Table 2).

Figure 4. Pseudogley-gley soil profile

Based on the multiyear precipitation average, the Sisak region is on the borderline between semi-humid and humid climate (Kf = 81.9) pursuant to Lang's rain factor, whereas pursuant to the monthly heat index of Gračanin, the region belongs to moderately warm climate (T=11.3°C).
Climatic and hydrological characteristics of the studied region are some of the indispensable indicators for the planning and designing of drainage systems, since multiyear precipitation, its monthly or seasonal distribution or maximum daily precipitation and its intensity define the key characteristic of climate and determine the type of agriculture and management on ameliorated areas.
Table 1 presents the probability of monthly precipitation occurrence for the weather station Sisak, which was calculated according to the formula:

$$Fa = \frac{2n-1}{2y} \times 100$$

Fa - occurrence probability (%)

n - number of equivalent occurrences or observations
y – total number of occurrences or observations

Return period of precipitation occurrence was calculated according to the formula:

$$P = \frac{y}{n}$$

P – Return period

It is evident from Table 1 that the probability of precipitation occurrence in 50 % cases was 948.3 mm (value taken from Fa=52.5 %), while the probability of precipitation occurrence was 1005.9 mm in 22.5 % cases. It is evident from Table 1 that the listed sums of annual precipitation (1005.9 mm and higher) were allocated to class I and that their occurrence can be expected every 4th year.

Table 1. Occurrence probability of monthly and annul precipitation (Fa) (mm), WS Sisak, 1986-2005

| Entry | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Sum | Fa (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 90.7 | 114.1 | 95.8 | 151.9 | 198.6 | 190.4 | 151.5 | 182.3 | 229.9 | 178.2 | 196.5 | 136.4 | 1086.9 | 2.5 |
| 2 | 84.9 | 79.4 | 84.4 | 125.8 | 176.5 | 178.6 | 148.1 | 160.6 | 228.3 | 147.2 | 172.5 | 133.8 | 1038.7 | 7.5 |
| 3 | 84.5 | 77.8 | 80.8 | 91.2 | 172.7 | 153.6 | 124.4 | 158.1 | 147.3 | 131.5 | 137.3 | 129.7 | 1023.4 | 12.5 |
| 4 | 79.0 | 71.7 | 68.4 | 83.7 | 107.0 | 152.7 | 114.2 | 150.3 | 140.7 | 123.9 | 136.8 | 104.3 | 1008.1 | 17.5 |
| 5 | 73.4 | 69.6 | 63.8 | 82.1 | 98.9 | 129.3 | 105.8 | 117.5 | 130.0 | 114.9 | 134.8 | 103.7 | 1005.9 | 22.5 |
| 6 | 71.2 | 64.2 | 63.1 | 79.9 | 97.7 | 127.9 | 105.1 | 105.9 | 121.3 | 109.9 | 124.5 | 84.7 | 992.8 | 27.5 |
| 7 | 67.6 | 62.7 | 63.0 | 78.3 | 89.7 | 127.3 | 103.6 | 93.0 | 115.0 | 98.9 | 122.4 | 76.2 | 977.7 | 32.5 |
| 8 | 66.8 | 57.3 | 59.7 | 76.6 | 83.4 | 119.6 | 85.9 | 92.9 | 105.2 | 93.1 | 121.9 | 70.4 | 960.1 | 37.5 |
| 9 | 66.6 | 48.4 | 55.9 | 75.5 | 81.4 | 102.5 | 77.2 | 83.2 | 103.2 | 78.7 | 104.5 | 69.9 | 958.7 | 42.5 |
| 10 | 57.4 | 48.4 | 54.9 | 73.7 | 75.9 | 102.5 | 73.3 | 82.3 | 95.4 | 72.8 | 89.3 | 64.9 | 948.5 | 47.5 |
| 11 | 55.9 | 47.7 | 54.1 | 73.0 | 75.8 | 94.0 | 64.4 | 82.1 | 86.0 | 71.4 | 88.3 | 56.4 | 948.3 | 52.5 |
| 12 | 55.9 | 43.3 | 52.6 | 65.7 | 65.0 | 91.9 | 63.8 | 76.5 | 83.5 | 70.1 | 85.9 | 55.6 | 938.8 | 57.5 |
| 13 | 55.1 | 36.5 | 52.5 | 65.5 | 63.9 | 89.0 | 51.3 | 68.7 | 82.5 | 68.8 | 72.2 | 50.5 | 925.1 | 62.5 |
| 14 | 42.8 | 34.8 | 38.7 | 65.0 | 63.9 | 81.9 | 50.1 | 65.6 | 80.1 | 61.8 | 71.2 | 44.5 | 923.9 | 67.5 |
| 15 | 42.3 | 31.3 | 37.6 | 61.3 | 54.8 | 63.7 | 45.1 | 60.6 | 79.4 | 60.9 | 63.5 | 43.8 | 912.3 | 72.5 |
| 16 | 41.6 | 30.7 | 35.5 | 55.6 | 44.1 | 51.4 | 44.6 | 47.1 | 58.8 | 46.3 | 57.7 | 39.8 | 879.5 | 77.5 |
| 17 | 29.1 | 21.3 | 29.6 | 46.9 | 35.0 | 47.4 | 41.9 | 24.9 | 41.6 | 35.6 | 55.8 | 32.1 | 868.7 | 82.5 |
| 18 | 22.7 | 12.3 | 27.6 | 46.7 | 32.5 | 47.4 | 40.8 | 22.7 | 38.2 | 30.0 | 30.8 | 28.1 | 865.1 | 87.5 |
| 19 | 17.5 | 11.1 | 26.7 | 46.2 | 26.0 | 42.5 | 37.7 | 20.3 | 33.9 | 20.3 | 25.8 | 24.8 | 829.2 | 92.5 |
| 20 | 13.0 | 4.5 | 5.1 | 29.6 | 25.8 | 40.0 | 30.5 | 10.5 | 25.4 | 12.8 | 17.2 | 18.7 | 614.8 | 97.5 |

Table 2. Return period of annual precipitation sums, WS Sisak

| Class | Precipitation (mm) | Number of equivalent occurrences (n) | Return period (P) |
|---|---|---|---|
| I | 1100-1000 | 5 | 4 |
| II | 1000-900 | 10 | 2 |
| III | 900-800 | 4 | 5 |
| IV | 800-700 | 0 | 0 |
| V | 700-600 | 1 | 20 |

**Results and discussion**

Research results are presented in Tables and Graphs.

*Drainage discharge and its duration*

Table 4 provides monthly and total precipitation amounts during the studied period as well as monthly and total drainage discharge in the growing seasons for the different pipe spacings.

Table 3. Precipitation during the growing season (mm), Weather Station Sisak

| Year | IX | X | XI | XII | I | II | III | IV | V | VI | VII | VIII | IX | Σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008./09. | *** | 88.1 | 86.1 | 101.1 | 113.2 | 40.4 | 53.6 | 31.3 | 44.2 | 153.2 | *** | *** | *** | 711.2 |
| 2009/10. | 30.2 | 88.4 | 102.2 | 94.8 | 105.4 | 88.6 | 66.3 | 59.0 | 156.9 | 146.2 | 64.9 | *** | *** | 1002.9 |
| 2010./11. | *** | *** | *** | *** | *** | *** | *** | 31.2 | 31.7 | 125.0 | 88.3 | 42.0 | 30.2 | 348.4 |

*** Non-growing season

Table 4. Monthly and total drainage discharge for different drainpipe spacings (mm)

| Year | Pipe spacing (m) | IX | X | XI | XII | I | II | III | IV | V | VI | VII | VIII | IX | Σ (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008/09 | 15 | *** | 11 | 26 | 64 | 67 | 19 | 24 | 7 | 0 | 32 | *** | *** | *** | 250 |
| | 20 | *** | 11 | 24 | 64 | 65 | 18 | 25 | 7 | 0 | 31 | *** | *** | *** | 245 |
| | 25 | *** | 12 | 25 | 63 | 66 | 20 | 24 | 8 | 0 | 29 | *** | *** | *** | 247 |
| | 30 | *** | 12 | 25 | 63 | 65 | 18 | 23 | 7 | 0 | 27 | *** | *** | *** | 240 |
| 2009/10 | 15 | 0 | 0 | 25 | 63 | 67 | 56 | 28 | 5 | 33 | 47 | 0 | *** | *** | 324 |
| | 20 | 0 | 0 | 23 | 62 | 65 | 55 | 28 | 5 | 32 | 47 | 0 | *** | *** | 317 |
| | 25 | 0 | 0 | 20 | 60 | 62 | 52 | 25 | 4 | 32 | 47 | 0 | *** | *** | 302 |
| | 30 | 0 | 0 | 20 | 59 | 60 | 52 | 25 | 4 | 31 | 46 | 0 | *** | *** | 297 |
| 2010/11 | 15 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 20 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 25 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 30 | *** | *** | *** | *** | *** | *** | *** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*** Non-growing season

Table 5. Total drainage discharge (mm), % of precipitation and duration of drainage discharge for different drainpipe spacings (days) in winter wheat and oilseed rape production

| Year | Drainpipe spacing (m) | Total drainage discharge (mm) | | % of precipitation | Duration of drainage discharge (days) | |
|---|---|---|---|---|---|---|
| 2008/09 | 15 | 250 | a | 35.2 | 98 | A |
| | 20 | 245 | b | 34.4 | 102 | B |
| | 25 | 247 | bc | 34.7 | 105 | Bc |
| | 30 | 240 | d | 33.7 | 114 | D |
| | | F=19. 38 c=3.49 | | | F= 25.42 c=3.49 | |
| 2009/10 | 15 | 324 | a | 32.3 | 118 | A |
| | 20 | 317 | b | 31.6 | 124 | B |
| | 25 | 302 | c | 30.1 | 132 | C |
| | 30 | 297 | d | 29.6 | 140 | D |
| | | F=131.08 c=3.49 | | | F=116.09 c=3.49 | |

Values marked with different letters are statistically significant, according to Duncan's Multiple Range Test

Precipitation amount, distribution and time of precipitation occurrence during the investigation period influenced the drainage discharge and its duration (Tables 4 and 5), both at the annual and monthly levels, as well as the differences between the tested pipe spacings. No drainage discharge was recorded in any pipe spacing variant in the growing season of 2011.

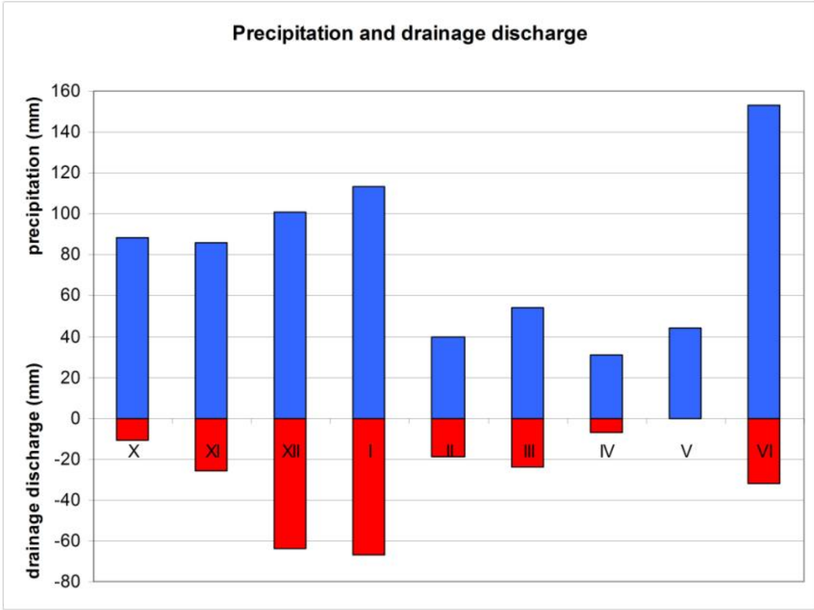


Figure 1. Monthly precipitation values and monthly drainage discharge values, for the drainpipe spacing of 15 m in winter wheat production (2008/09)

In winter wheat production in 2008/09, the first drainage discharges in all pipe spacing variants were recorded in October (Graph 1 represents the graphic precipitation and drainage discharge flowchart for pipe spacing of 15 m), whereas the first drainage discharges in 2009/10 were recorded in November (Graph 2).

Drainage discharge was recorded after the soil water supply was filled up with precipitation from the preceding months. In the winter-spring period, monthly drainage discharge in all pipe spacing variants followed the monthly amounts of precipitation, that is, the higher the monthly amount of precipitation, the higher was the drainage discharge, and vice versa. In the late spring and summer months, due to intensified growth and development of plants, the amount of drainage discharge was not proportional to precipitation. Namely, evapotranspiration was increased at later plant development stages due to higher spring and summer air temperatures, so that lower drainage discharge was recorded in all pipe spacing variants.

In years in which drainage discharges were registered, the highest drainage discharge was determined at the narrowest pipe spacing (15 m), whereas the lowest was recorded at the widest pipe spacing (30 m). As regards drainage discharge duration, Table 5 shows that the shortest duration was determined at the narrowest pipe spacing (15 m), and the longest at the widest pipe spacing (30 m). Thus, the discharge and its duration are inversely proportional values, which may be attributed to the drainage system efficiency.

According to the investigations conducted by Šimunić (1995), Petošić et al. (1998) and Tomić et al. (2002), narrower pipe spacing is more efficient for draining surplus water from drained soils, since larger amounts of water are drained in s shorter period of time and better water-air relationships in soil are created faster, which is a prerequisite for timely application of agricultural management practices on hydroameliorated arable areas.

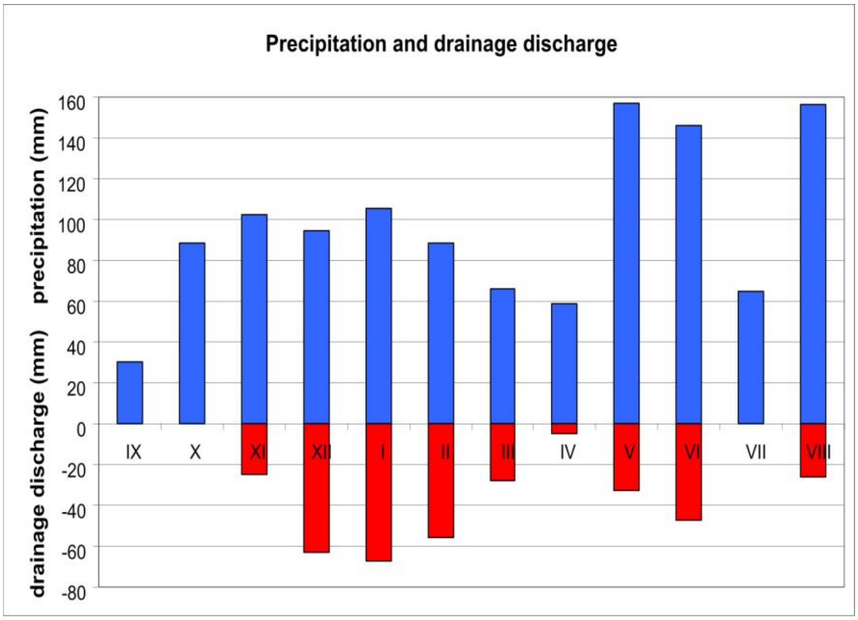


Figure 2. Monthly precipitation values and monthly drainage discharge values, for the drainpipe spacing of 15 m in oilseed rape production (2009/10)

*Nitrate concentration in drainage water*

Maximum and average concentrations of nitrates in drainage water were higher than MAC (10 mg. $L^{-1}$) in all pipe spacing variants while minimum values were below MAC (Table 6; Graphs 3 and 4). The highest nitrate concentration was recorded in October (2008), and in November (2009), after sowing and basic fertilization, when the first higher precipitation occurred and caused drainage discharge, as seen in Graphs 3 and 4.

Nitrate concentration deceased in subsequent months in all pipe spacing variants, and then it increased in March 2009 and in February 2010, also in all spacing variants (post fertilization–topdressing of crops with 54 $kg.ha^{-1}$ nitrogen).

Table 6. Maximum and average concentration of nitrogen ($mg.dm^{-3}$) in drainage water

| Drainpipe spacing (m) | October 2008-June 2009 | | | September 2009-June 2010 | | |
|---|---|---|---|---|---|---|
| | Max | Average | | Max | Average | |
| 15 | 23.12 | 13.90 | a | 47.85 | 21.84 | a |
| 20 | 23.18 | 13.71 | a | 50.13 | 21.47 | a |
| 25 | 24.59 | 12.57 | b | 48.59 | 21.14 | a |
| 30 | 23.53 | 12.65 | b | 43.53 | 20.37 | a |
| | | F=6.37 c=3.49 | | F=0.013 c=3.49 | | |

Values marked with the same letter are not statistically significant, according to Duncan's Multiple Range Test.

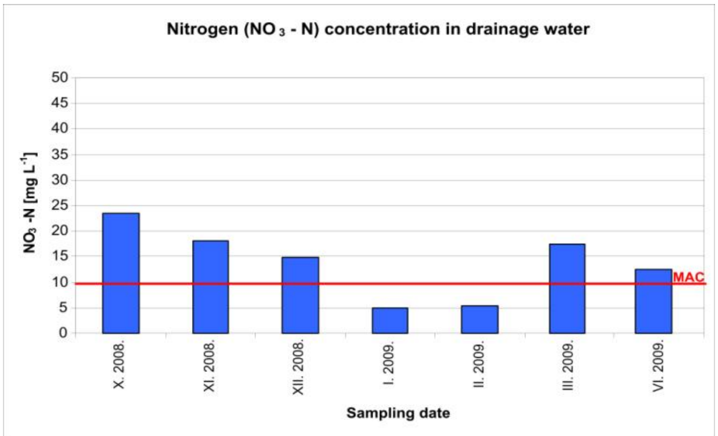


Figure 3. Fluctuation of nitrogen concentration in drainage water, for the drainpipe spacing of 15 m in winter wheat production (2008/09)

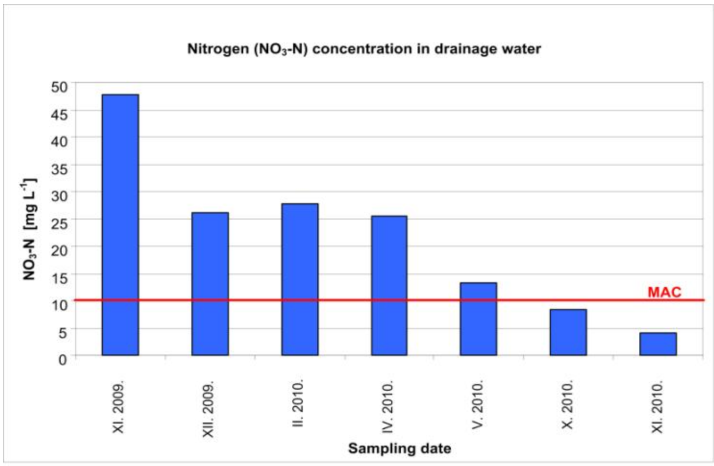


Figure 4. Fluctuation of nitrogen concentration in drainage water, for the drainpipe spacing of 15 m in oilseed rape production (2009/10)

In subsequent months, nitrate concentration decreased despite the second nitrogen application (40.5 $kg.ha^{-1}$) (2010). This reduction in nitrogen concentration can be explained by the fact that in later spring months crops have a well-developed habitus, which enables higher nitrate uptake, and thereby its lower leaching. Nitrate concentration in May 2010 and June 2009 was still above MAC. It was only in the autumn that nitrate concentration values were below MAC in all pipe spacing variants. The difference in nitrate concentration between pipe spacings was statistically significant in 2008/09, whereas it was not significant in 2009/10. Similar results for nitrate concentration in drainage water were obtained by Rossi et al. (1991), Šimunić et al. (2002; 2011) and Bensa et al. (2007).

*Leaching of nitrates with drainage water*

Amounts of nitrates leached at different pipe spacings are given in Table 7.

Table 7. Nitrate leached with drainage water ($kg.ha^{-3}$) and percentage of nitrogen leached relative to total N added with fertilization

| Drainpipe spacing (m) | October 2008- June 2009 | | September 2009-June 2010 | |
|---|---|---|---|---|
| | $Kg.ha^{-1}$ | % | $Kg.ha^{-1}$ | % |
| 15 | 34.8 | 19.0 | 70.8 | 40.3 |
| 20 | 33.6 | 18.3 | 68.1 | 38.8 |
| 25 | 31.0 | 16.9 | 63.8 | 36.4 |
| 30 | 30.4 | 16.6 | 60.5 | 34.5 |

As can be seen from Table 7, there are differences in the amount of nitrates leached both between investigation years and pipe spacings. In both years, the highest amount of nitrates leached was found at the pipe spacing of 15 m, while the least nitrates were leached at the pipe spacing of 30 m. In fact, highest leaching occurred at the pipe spacing of 15 m, where the highest drainage discharge was measured and vice versa, while leaching was the lowest at the pipe spacing of 30 m, where the lowest drainage discharge was measured. According to Mesić et al. (2007), the amount of nitrogen leached is linearly correlated with the amount of drainage discharge. The difference in the amount of nitrates leached in 2009/10 and 2008/2009 is also attributed to the above listed findings. As already mentioned, there was only a small difference in the amount of nitrogen added with fertilization, so the amount of nitrogen added could not affect the twice larger amount of nitrogen leached. The lower impact on the amount of nitrogen leached could be ascribed to crop requirements for nitrates at particular development stages.

*Crop yields*

Crop yields per pipe spacing are presented in Table 8.

Table 8. Winter wheat, oilseed rape and soybean yields ($t.ha^{-1}$)

| Drainpipe spacing (m) | Winter wheat ($t.ha^{-1}$) | | Oilseed rape ($t.ha^{-1}$) | | Soybean ($t.ha^{-1}$) | |
|---|---|---|---|---|---|---|
| 15 | 5.30 | a | 3.30 | a | 2.32 | a |
| 20 | 5.10 | b | 3.03 | b | 2.40 | a |
| 25 | 4.95 | b | 2.69 | c | 2.39 | a |
| 30 | 4.75 | c | 2.38 | d | 2.29 | a |
| | F=15.6 c=3.49 | | F=49.38 c=3.49 | | F=2.61 c=3.49 | |

Values marked with different letters are statistically significant, according to Duncan's Multiple Range Test.

As can be seen from Table 8, there are differences in crop yields achieved in the tested pipe spacing variants both between years and between pipe spacings. Highest wheat and oilseed rape yields were achieved in the 15 m pipe spacing variant, while the highest soybean yield in 2011 was obtained at the pipe spacing of 20 m. Lowest yield in all investigation years was that of the 30 m pipe spacing variant. Differences in winter wheat yield determined in 2008/09 were statistically significant at the tested spacings, except for the spacing of 20 m and 25 m. In the second investigation year, oilseed rape yields were statistically significant in the tested pipe spacing variants, while no statistically significant differences between pipe spacings were found for soybean production in the dry 2011. Very similar results were reported by Tomić et al. (2002) and Tomić et al. (2007.a 2007.b ), Mesić et al. (2008) and Šimunić et al. (2011), who maintain that the effect of the drainage system (pipe spacing) influences the yield, since system functionality is reflected in hydrological parameters such as drainage discharge and its duration. In the dry 2011, the different pipe spacings were not in the function of drainage, so they had no influence on soybean yield. At the same experimental site, Tomić et al. (2002) and Šimunić et al. (2011) determined statistically significant differences in wheat and maize yields in some years, with the highest yields in the pipe spacing variants of 15 m and 20 m. Further, these authors think that crop yield and differences between the pipe spacings tested could also be caused by fertilizer rates and fertilization dynamics, weather conditions at sowing and other agricultural management practices applied.

## Conclusions

Three-year investigations of the influence of precipitation upon drainage discharge, concentration and leaching of nitrates, and crop yields in different pipe spacing variants on hydroameliorated soil in the central Sava Valley point to the following conclusions:

The highest drainage discharge and its longest duration were determined at all pipe spacings in the oilseed rape growing season, i.e., in the period with the largest amount of precipitation (2009/10). Lower drainage discharge was recorded in all pipe spacing variants in the winter wheat growing season, i.e., in the period with less precipitation (2008/09), while drainage discharge was not recorded in any pipe drainage variant in the growing season of soybean, i.e., in the period with the lowest precipitation (2011).

The recorded maximum and calculated mean values of nitrate concentration in drainage water were higher at all pipe spacings in the oilseed rape growing season, in the period with the highest precipitation and highest drainage discharge (2009/10), compared to the wheat growing season, when lower precipitation and lower drainage discharge were recorded (2008/09).

The calculated amount of nitrates leached in all pipe spacing variants was higher in 2009/10 than in 2008/09 (the amount of leached nitrates is the product of multiplication of monthly drainage discharge at each pipe spacing by nitrate concentration at each pipe spacing).

The recorded winter wheat yield (2008/09) at each pipe spacing was statistically significant between pipe spacings, except between 20 m and 25 m spacings. The oilseed rape yield recorded at the set pipe spacings was statistically significant between all pipe spacings, whereas soybean yield was not statistically significant at the tested pipe spacings.

The results indicate that the draining of hydromorphic pseudogley-gley soil by pipe drainage (combined drainage) is justified, but also call for caution in the management of ameliorated areas because of the altered pedophysical and pedochemical properties of hydroameliorated soil.

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# ВЛИЈАНИЕ НА ВРНЕЖИТЕ ВРЗ ИСПИРАЊЕТО НА НИТРАТИТЕ И ПРИНОСОТ НА ОДГЛЕДУВАНИТЕ КУЛТУРИ ПРИ РАЗЛИЧНИ РАСТОЈАНИЈА ПОМЕЃУ ЦЕВКИТЕ ЗА ОДВОДНУВАЊЕ

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**Апстракт**

Целта на тригодишното истражување беше да се утврди влијанието на врнежите врз дренажното оттекување и неговото траење, концентрацијата на нитратите во дренажната вода, количината на испраните нитрати и приносот од пченица, маслодајна репка и соја одгледувани на почвен тип псевдоглеј (поттип глејна почва), при четири различни растојанија помеѓу дренажните цевки (15 м, 20 м, 25 м и 30 м). Истражувањата се спроведени на мелиорациското експериментално поле "Јеленшчак" во близина на Поповача, во периодот од 1 октомври 2008 до 30 септември 2011 година. Експерименталните истражувања со озимата пченица беа поставени во 2008/09 година, со маслодајната репка во 2009/10 година, додека експерименталните истражувања со сојата беа извршени во 2011 година. Во секоја експериментална година беа поставени исти агротехнички мерки кај сите варијанти со различни растојанија помеѓу цевките. Вкупната количина на аплициран азот изнесуваше183.6 $kg.ha^{-1}$ (2008/09), 175.5 $kg.ha^{-1}$ (2009/10) и 130 $kg.ha^{-1}$ (2011). Резултатите од истражувањето покажуваат дека дренажното оттекување и неговото траење зависат од количината и распоредот на врнежите во периодот на истражувањето. Најголема количина на дренажно оттекување е забележана кај најтесно поставените цевки (15 m), додека најдолго траење на оттекувањето е утврдено кај најширокото растојание (30 m). Во сушната 2011 година за време на вегетацискиот период не е регистрирано дренажно оттекување. Максималната концентрација на нитрати во дренажната вода, кај секое растојание помеѓу цевките е утврдена со појавата на првите дренажни оттекувања и беше повисока од максимално дозволената концентрација - МДК (10 $mg.L^{-1}$ $N0_3$ - N), а дури на есен по жетвата на културите концентрацијата била под МДК. Количината на испраните нитрати во секоја година и кај секое растојание помеѓу цевките зависи од дренажното оттекување и концентрацијата на нитратите во дренажната вода. Приносот од екпериментираните култури во 2008/09 и 2009/10 година беше статистички оправдан помеѓу различните растојанија на цевките, додека во 2011 година, разликите не беа статистички оправдани. Од истражувањата, утврдено е позитивно влијание на одводнувањето во похумидните години во споредба со посушните години.

**Клучни зборови:** врнежи, растојание помеѓу цевки, дренажно оттекување, испирање на нитрати.

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**Original scientific paper**

# THE LEVEL OF ACIDITY CHANGES AND CONTENT OF MOBILE ALUMINIUM AFTER LIMING

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## Abstract
Numerous chemical factors limit normal growth of plants on acid soils. Limited fertility of acid soils is caused by a high concentration of H- and Al-ions, some organic acids and heavy metals, as well as by a lower availability of significant group of nutritive elements (P, Ca, Mg, B, Zn, Mo). Particularly harmful effect is expressed by aluminum. Liming, as acid soils remediation measure, is successful in elimination of the above mentioned unfavorable soil properties. Field trials have been done on soil type Dystric cambisol. The trial was established as random complete block design (RCBD). The three doses of hydrated lime ($CaO$ x $H_2O$) have been applied in order to reduce acidity: the one was on the level of partial liming (1/3 $Y_1$ CaO and 1/2 $Y_1$ CaO), and the as full liming ($Y_1$ CaO). Liming strongly affected the studied parameters. The major changes caused by liming were observed in pH, hydrolytic acidity, level of base saturation percentage (V%), and mobile aluminum content. Full liming eliminated soil acidity and improved significantly the all properties of the soil adsorption complex. Partial liming gave a satisfactory result, especially in decreasing of mobile aluminum content.

**Key words**: liming, pH, hydrolytic acidity, aluminium, Dystric cambisol.

## Introduction
Primarily acidic soils create a number of difficulties in agriculture, especially in the production of high quality and biologically valuable food. There are many factors that limit fertility of the land. High concentrations of H and Al ions, and some organic acids and heavy metals, as well as a small number of available nutrients (P, Ca, Mg, B, Zn, and particularly Mo) are just some of these factors. At acid soils with pH $\leq$ 5.5 Al-toxicity is the main stress factor for plants (Merino-Gergichevich *et al*., 2010; Poschenrieder *et al*., 2008), and in such conditions it is linked to the prevailing pressure for adaptation of cultivated plants (Ryan and Delhaize, 2010).
Harmful effects of mobile aluminum can be viewed from two aspects. First, its indirect impact through the reduction of solubility is being noticed, as well as availability of nutrients. Namely, aluminum ions, among other things, block the adsorption of phosphorus and potassium, and cause disturbing crop growth and development (Zheng, 2010). In addition there are indirect and direct effects, when Al ions act toxic on the plant. The acidic environment increase presence of trivalent aluminum cations - $Al^{3+}$ (Lidon and Barreiro, 2002; Kochian *et al*., 2005), which is the most toxic of all types Al (Delhaize and Ryan, 1995). The best recognized Al-toxicity effects have been

noticed and are well described in the root (Barceló and Poschenrider, 2002, Ma, 2007; Panda and Matsumoto, 2007). A serious problem that appears at high concentrations of aluminum is the inhibition of root growth. It has been noticed that aluminum influences the formation of immature and poor root system, which has limited ability to adopt mineral nutrients and also increases the risk of stress caused by drought (Marcshner, 1991). More precise, toxic effect is being caused by the inhibition of lateral root and root hairs, interruption of feeding with P and Ca and inhibition of growth of shoots (Fageria *et al*., 1988; Foy, 1988). However, the upper parts of the plants may be damaged (Merino-Gergichevich *et al*., 2010), especially leaves, and about which is rarely known. Today, there are more evidences of the negative effects of aluminum on the light absorption, photosynthetic electron transport, gas exchange (Chen *et al*., 2005a, Chen *et al*., 2005b; Chen, 2006), photoprotective systems (Chen *et al*., 2005a; Ali *et al*., 2008), pigments (Chen *et al*., 2005a; Mihailoovic *et al*., 2008; Milivojević *et al*., 2000), as well as other elements associated with the structure or function of the photosynthetic apparatus. Calcification of acid soils is one of the key factors which can keep or even improve their productivity (Mao *et al*., 2008; Repšiene and Skuodiene, 2010). By using the materials containing Ca fundamentally are being changed: physical, chemical and biological properties of the soil, which creates good preconditions for high efficiency of agricultural practice. Therefore, this research has the aim to investigate use of different levels of calcification in an acid soils, such as the Dystric cambisols, defines its effect on the degree of change on acidity and content of mobile Al, as important factors which limit the fertility.

**Material and methods**

Studies were conducted on the soil Dystric cambisol near Leposavić (Kosovska Mitrovica) during two consecutive years (2009 and 2010 years). Test crop was wheat cultivar Pobeda.

Prior to the formation of experimental field, average samples of soil have been sampled for analysis of chemical properties of Dystric cambisols: pH ($H_2O$ and KCl), hydrolytic acidity (H), total adsorbed basic cations (S), cation exchange capacity (T), base saturation percentage ( V%) and mobile Al. The obtained data are being used to determine the level of calcification in terms of elimination of excess acidity and to evaluate the effect of pH on the improvement of mobile Al content in the soil. For calcification has been used CaO with high degree of purity. The material is applied in both years in September, precisely before primary treatment, so it has been properly distributed over the surface and entered into the soil by plowing.

The quantities of CaO which have been applied, were calculated according to the value $Y_1$ in the soil and the size of the experimental plots (50 $m^2$). Three variants of calcification have been determined and applied: 1/3 $Y_1$ CaO (V-3), 1/2 $Y_1$ CaO (V-4) and $Y_1$ CaO (V-5), and two variants without calcification: variant with NPK (V-2) and the variant without liming and fertilization - control (V-1). Fertilizers were applied with the variant performed with calcification. In all cases, the dose of active nutrients: nitrogen, phosphorus and potassium were the 120 kg N/ha for $P_2O_5$ and $K_2O$, 90 kg/ha ($N_{120}P_{90}K_{90}$). Fertilization has been done by the standard technology for the production of wheat.

The experiment has been performed as a randomized complete block design (RCBD) with four replications. The size of experimental plot was 50 $m^2$.

In both years, during the stage of wheat tillering (TL), 5 months after liming and after the harvest (AH), 10 months after liming, the pH was determined in distilled water and 1M KCl using a pH meter ISKRA MA 5740, and exchangeable Al or cell by the method of Sokolov in soil extract with 1M KCl, so it has been firstly determined by the total substitutional acidity, and then precipitation of Al with NaF and influence of Al-ions in forming of substitutional acidity. The hydrolytic acidity - H (by Kappen's method), total adsorbed basic cations - S (by Kappen's), cation exchange capacity - T (mathematically as S + H), base saturation percentage - V% (mathematically as S / T x 100) were detected only after harvesting wheat.

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

**Results and discussion**

The effects of different liming on active and substitutional acidity during these years are given in Table 1. Results from the table clearly indicate the very significant effect of applied CaO. The changes were evident in the first checking after 5 months of treatment (in the stage of wheat tillering), and the variant with the lowest amount of the calcification materials. Differences between treatments where no CaO has been applied (V-1 and V-2) and in which CaO has been applied (V-3, V-4 and V-5) are statistically highly significant.

There were clear differences between varieties with the calcification done. All differences were statistically significant, except for changes in the acidity of the active tillering stage (TL) 2009, when the differences between first (V-3) and second level (V-4) partial calcification, were at the level of statistical significance. Such changes of substitutional, as well as of the active acidity support the necessity of calcification of acid soils (Busari *et al*., 2008; Jelic *et al*., 2011, Mao *et al*., 2008; Repšiene and Skuodiene, 2010), in order to create favorable conditions for easy growth and development of plants. In particular, it refers to a group of plants that are not sufficiently tolerant to soil acidity.

It should be underlined changes of pH during one growing season. Specifically, during the period between the first (tillering stage) and other checks (after harvest), there was a small decrease of pH. This trend is expected since many processes in soil, above all, rinse, and the adoption of Ca by plants lead to loss of calcification materials, which leads to a decrease of pH. Therefore, often is being stated a time limited (temporality) effects of these measures (Brković and Petrović, 1995), so because of these reasons it is necessary to repeat after a certain time. Since the problem of acidity can not be definitively resolved, it is completely acceptable regular application of lime material that would soil acidity maintain at an acceptable level (Garscho and Parker, 2001).

In this way benefits would be multilateral. Smaller quantities calcification materials would be on one side, economically viable, and on the other side can ensure better availability of nutrients, as well as a more favorable environment for the growth and development of crops.

The changes were noticed with hydrolytic acidity (H), total adsorbed basic cations (S), cation exchange capacity (T), base saturation percentage ( V%), and the results of the influence of liming on these properties of Dystric cambisols are given in Table 2.

The intensity of changes depended on the level of calcification (partial, half, full), and the amount of applied Ca. As expected the highest changes have appeared in the treatment where full calcification has been done. Here hydrolytic acidity (H) has been very significantly reduced, while base saturation percentage (V%) has been increased compared to the variants where calcification has not been applied. Accordingly, with full calcification total adsorbed basic cations (S) has been increased, and cation exchange capacity (T) has been decreased, but the differences are statistically significant only related to V-1 and V-2. Changes of these calcification parameters on soil type – pseudogley, noted Dugalić *et al.*, 2002.

Table 1. The changes of pH in $H_2O$ and 1M KCl after liming

| | pH ($H_2O$) | | | | pH ( 1M KCl) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2009 | | 2010 | | 2009 | | 2010 | |
| Before the trial | 5.45 | | 5.52 | | 4.85 | | 4.87 | |
| In the trial | TL | AH | TL | AH | TL | AH | TL | AH |
| V-1 | 5.45 | 5.43 | 5.42 | 5.50 | 4.83 | 4.83 | 4.84 | 4,83 |
| V-2 | 5.50 | 5.51 | 5.41 | 5.47 | 4.75 | 4.79 | 4.79 | 4.82 |
| V-3 | 5.92 | 5.89 | 5.90 | 5.84 | 5.23 | 5.30 | 5.29 | 5.24 |
| V-4 | 6.17 | 6.15 | 6.18 | 6.14 | 5.57 | 5.56 | 5.60 | 5.58 |
| V-5 | 6.79 | 6.77 | 6.87 | 6.73 | 6.24 | 6.20 | 6.24 | 6.19 |
| LSD (0.05) | 0.24 | 0.08 | 0.10 | 0.09 | 0.12 | 010 | 0.14 | 0.09 |
| LSD (0,01) | 0.35 | 0.12 | 0.14 | 0.13 | 0.17 | 0.14 | 0.20 | 0.12 |

Table 2. Changes $Y_1$, S, T and V (%) after liming

| | H (m.eq · 100 $^{-1}$g) | | S (m.eq · 100 $^{-1}$g) | | T (m.eq · 100 $^{-1}$g) | | V (%) | |
|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 | 2009 | 2010 |
| Before the trial | 9.44 | 9.07 | 8.98 | 9.00 | 18.42 | 18.06 | 48.79 | 49.59 |
| In the trial | | | | | | | | |
| V-1 | 10.61 | 9.12 | 9.20 | 8.60 | 19.81 | 17.77 | 46.33 | 48.25 |
| V-2 | 9.31 | 9.46 | 8.62 | 9.42 | 17.94 | 18.89 | 47.81 | 49.87 |
| V-3 | 5.01 | 4.98 | 11.75 | 10.92 | 16.85 | 15.91 | 70.24 | 68.66 |
| V-4 | 3.39 | 3.50 | 11.60 | 11.54 | 14.77 | 15.12 | 77.82 | 73.54 |
| V-5 | 1.95 | 2.25 | 11.93 | 12.77 | 13.55 | 14.02 | 85.77 | 87.09 |
| LSD (0.05) | 1.10 | 1.02 | 1.73 | 1.38 | 2.56 | 1.76 | 5.21 | 4.58 |
| LSD (0,01) | 1.58 | 1.46 | 2.49 | 1.98 | 3.68 | 2.53 | 7.49 | 6.57 |

Partial (V-3) and half (V-4) calcification have also achieved satisfactory results, particularly in reducing hydrolytic acidity and increasing base saturation percentage. However it should be noted that the effect of both of these variants, when it comes to total adsorbed basic cations and cation exchange capacity, was very close to those results which were achieved by using the biggest quantity of CaO. This effect of small amounts of calcification material once again supports a findings that in this way can be successfully improved the unfavorable properties of acid soils.
Mobile aluminum, as one of the limiting factors for crop production on acid soils, at the Dystric cambisols was at the level which has been expected for depressing effect on crops. However, calcification in all the years of research and at all levels of melioration, radically changed a picture of mobile Al content, and the results are shown in Table 3.

Table 3. Changes of mobile aluminium content (mg · 100 $g^{-1}$) after liming

| | 2009 | | 2010 | |
|---|---|---|---|---|
| Before the trial | 12.26 | | 13.86 | |
| In the trial | TL | AH | TL | AH |
| V-1 | 12.28 | 12.21 | 13.62 | 13.80 |
| V-2 | 12.32 | 12.54 | 13.92 | 13.87 |
| V-3 | 5.26 | 5.56 | 6.25 | 6.39 |
| V-4 | 2.17 | 2.37 | 2.44 | 2.62 |
| V-5 | 0.48 | 0.40 | 0.47 | 0.42 |
| LSD (0.05) | 0.35 | 0.28 | 0.35 | 0.07 |
| LSD (0,01) | 0.50 | 0.40 | 0.50 | 0.10 |

Contents of mobile $Al^{3+}$, in both years, strongly changed in the entire variant with CaO. Thus, during the first phase of determining in the phase of tillering of wheat, in the variant with full calcification, it has been found Al content in trace amounts. According to results of other authors calcification had the same effect on other soil types, as pseudogley (Dugalić *et a*l., 2002, Jelic et al., 2011), Dystric albeluvisol (Repšiene and Skuodiene, 2010), rinsed pseudogley and cambisol (Pivić *et al*., 2011). At the same time, at the partial variant (V-3), and in particular the partial calcification, mobile aluminum content is reduced to a level when it significantly reduces the risk of its toxic effects on crops. In the treatments V-3 and V-4 during the growing season it has been registered a slight increase of the mobile Al content.

## Conclusions

Based on the result of trials and laboratory investigation of the influence of liming on acidity and aluminum content in soil type Dystric cambisols, the following conclusions can be drawn: applying of CaO has quickly acted and maximum changes before a determination has been made in the tillering phase of wheat. The biggest changes have been detected in the reduction of all forms of acidity and content of mobile Al, and increasing the base saturation percentage. The degree of reduction in content of mobile Al with partial (1/3 $Y_1$) and in half calcification (1/2 $Y_1$) justify and affirm these levels in calcification of acid soil. Main benefits of lower levels of calcification were lower investments in calcification material, and reducing the content of mobile Al below the level of toxicity.

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# НИВОТО НА КИСЕЛОСТ И ИЗМЕНАТА НА МОБИЛНИОТ АЛУМИНИУМ ПОСЛЕ КАЛЦИЗАЦИЈА

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**Апстракт**
Голем број на хемиски фактори го ограничуваат нормалниот раст на растенијата на кисели почви. Ограничената плодност на киселите почви е предизвикана од висока концентрација на H и Al-јони, некои органски киселини и тешки метали, киселоста влијае и на пониската достапност на значајна група на хранливите елементи (P, Ca, Mg, B, Zn). Особено штетно делува содржината на алуминиум. Внесувањето на варовник кај киселите почви како мерка за санација е успешна во елиминирањето на горенаведените неповолни почвени својства. Теренските испитувања се направени на почвениот тип Дистричен камбисол. Опитот беше поставен како случаен комплетен блок дизајн (RCBD). Трите дози од CaO x $H_2O$ беа применети со цел да се намали киселоста: едната беше на ниво на делумна примена на варовник (1/3 Y1 CaO и 1/2 Y1 CaO), и како целосна примена на варовник (Y1 CaO). Главните промени предизвикани од апликацијата на варовникот беа забележани во pH вредноста, хидролитичката киселост, нивото на заситеност со бази (V%), и мобилни содржина на алуминиум. Целосната доза од примена на варовникот ја елиминира почвената киселост и значително ги подобори и останатите својства на почвениот адсорптивниот комплекс. Делумната апликација на варовникот даде задоволителни резултати само во намалувањето на мобилната содржина на алуминиумот во почвата.
**Клучни зборови**: варовник, pH, хидролитичка киселост, алуминиум, Дистричен камбисол.

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**Original scientific paper**

# THE NUMBER OF MICROORGANISMS IN DEPTS IN ALLUVIAL SOIL IN SKOPJE REGION

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**Abstract**
The soil represents living and dynamic environment for different types of microorganisms. With their enzyme activity microorganisms participate in the creation of plant nutrients. Thus, microorganisms participate in the creation and maintenance of soil fertility and are considered as biogenic indicators. In this paper, the total number of microorganisms, actinomyces, diazotrophs, fungi and cellulolytic, denitrifying, ammonifying and nitrifying microorganisms was examined in alluvial soil in Jurumleri locality, Skopje. The number of microorganisms was studied at three different depths (0-10 cm, 10-20 cm and 20-30 cm). The examined soil has favorable physical and chemical properties for growth and development of microorganisms. It was found that most of the studied groups of organisms are present at a depth of 0-10 cm, while ammonifying bacteria are mostly present at a depth of 20 - 30 cm.
**Key words:** soil, bacteria, actinomyces, diazotrophs, yeasts, cellulolytic, denitrifying, ammonifying, nitrifying microorganisms, molds.

## Introduction

Soil represents a complex system composed of solid, liquid and gaseous phase. The solid phase consists of organic and mineral matters, liquid of water and substances dissolved in it, and the gaseous phase consists of oxygen, carbon dioxide, nitrogen, hydrogen, ammonia, etc. All three phases are interrelated and their relationship affects fertility and soil microbial activity (Filipovski G, 1974). The quantitative and qualitative composition of soil microorganisms is different in different types of soils and depends on abiotic (temperature, moisture, acidity, content of organic and mineral substances) and biotic factors (microorganisms, plants, animals and humans and their interaction). The number of microorganisms and their activities in the soil is an important indicator of soil fertility since in the soils with formed profile they maintain its structure, the level of organic matter and through the transformation of materials they provide plants with soil nutrients. Microorganisms in the soil are deployed in horizontal and vertical direction, depending on the latitude, climatic factors, soil type, type of microorganisms and according to the depth of the profile and the altitude. Target of this research is to examine the number of different groups of microorganisms by depth of the profile on alluvial soil in the region of Skopje.

**Material and methods**

Research are made on alluvial soil in the vicinity of Skopje, particularly in Jurumleri with geographical position of the soil profile on 41 ° 58'20, 84 "north and 21 ° 33'24, 44" east on 276 m altitude. Soil analysis are made for the mechanical composition (Table 1) and chemical properties of the soil (Table 2).

The mechanical composition of the soil depends from the subsoil and the processes that occur during soil genesis and the evolution of soil (Mitrikeski J., Mitkova T, 2006).

In terms of mechanical composition of the soil dominates the fraction sand and dust, which reflects very well on the physical properties of the soil. According to the classification of soils by Scheffer and Schachtschabel, examined soil belongs to the group of loam.

Table 1. Mechanical composition of the soil

| Depth in cm | Coarse sand 0,2-2 mm | Cramp (fine) sand 0,02- 0,2 | Total | Dust 0,02-0,002 | Clay <0,002 | Clay + dust |
|---|---|---|---|---|---|---|
| 0-20 | 2.87 | 56.53 | 59.40 | 34.60 | 6,00 | 40.60 |
| 20-40 | 3.46 | 60.24 | 63.70 | 34.30 | 2.00 | 36.30 |
| 40-60 | 3.09 | 50.11 | 53.20 | 42.40 | 5.00 | 47.40 |
| 60-80 | 5.18 | 41.72 | 46.90 | 45.66 | 7.44 | 53.10 |
| 80-115 | 1.78 | 42.15 | 43.93 | 45.95 | 10.12 | |

Table 2. Chemical composition of the soil

| Depth in cm | pH | | Total N % | Humus % | $CaCO_3$ | Readily available nutrients in the soil | |
|---|---|---|---|---|---|---|---|
| | $H_2O$ | n KCl | | | | $P_2O_5$ | $K_2O$ |
| 0-20 | 8.1 | 7.2 | 0.1698 | 2.83 | 9.9 | 16.47 | 20.10 |
| 20-40 | 8.2 | 7.2 | 0.0708 | 1.18 | 10.83 | 15.29 | 18.10 |
| 40-60 | 8.7 | 7.3 | 0.066 | 1.10 | 11.66 | 4.31 | 18.20 |
| 60-80 | 8.7 | 7.3 | 0.051 | 0.85 | 9.99 | 5.29 | 20.40 |
| 80-115 | 8.7 | 7.3 | 0.0378 | 0.63 | 10.83 | 3.72 | 22.10 |

Based on the presented data about the chemical composition of the soil was determined that the soil according to U.S. classification has neutral to moderately alkaline reaction of the soil solution and in the deeper layers (strata) alkalinity increases. The presence of carbonates in the soil is important because it strongly influences on the chemical composition of the soil, particularly on the reaction of the soil solution, so according to Penkov (1996) the soil belongs to carbonate rich soils.

Examined soil is poor to moderately rich with humus; total N content is in correlation with the level of humus in the soil and its presence decreases with increasing of the depth. The presence of $P_2O_5$ and $K_2O$ in the top layers shows that the soil is middle provided, and in the deeper layers these values are declining.

The samples for microbiological analysis of the soil are taken aseptically on depth of 0-30 cm. The soil samples are taken in spring and are analyzed in the microbiological laboratory of the Faculty of Natural Sciences and Mathematics.

In the soil are studied different groups of microorganisms according to standard methods (Jarak and Govedarica, 1997).

Tests are made with the method of sowing on adequate dilution of soil on selective nutrient substrates and incubation on temperature of 28 ºC and the total number of microorganisms and ammonia forming bacteria 3-4 days, nitrifying bacteria (nitric forming bacteria), nitrate forming bacteria and nitrate reducing bacteria 5-7 days, fungi and actinomyces 2-3 days.

The total number of microorganisms in the soil is examined on substrate of soil agar ($10^{-6}$); nitrifying bacteria (nitric forming bacteria) are grown on a substrate esbi agar ($10^{-6}$);

nitrate forming bacteria are determined on mineral substrate with composition: $(NH_4)_2SO_4$ 2g, $K_2HPO_4$ 1g, $MgSO_4$ 0,5 g, $FeSO_4$ 0,4 g, NaCl 0,4 g, $CaCO_3$ 1g, $MgCO_3$ 1 g, agar 1,5% ,distilled water;

nitrate reducing bacteria are studied on mineral substrate with composition: $KNO_3$ 2g, $K_2HPO_4$ 1g, $MgSO_4$ 0,5 g, $FeSO_4$ 0,4 g, NaCl 0,4 g, CaCO3 1g, $MgCO_3$ 1 g, agar 1,5%, distilled water; ammonia forming bacteria are examined by the method of titer on liquid substrate- nutrient broth, using a reagent- leaves soaked with Krupov reactive which is prepared from one part 3% $H_2SO_4$ and two parts aqueous solution of fuchsin; cellulose splitting microorganisms are studied using carboxyl methyl cellulose ($10^{-2}$); yeasts are tested on the substrate Czapek-Dox Agar with composition: $NaNO_3$ 2g, $KH_2PO_4$ 1g, $MgSO_4$ 0,5 g, KCl 0,5 g, $FeSO_4$ 0,1 gr, sucrose 300 g, agar 200 g) ($10^{-4}$); molds are determined on the substrate Czapek-Dox Agar with composition: $NaNO_3$ 2g, $KH_2PO_4$ 1g, $MgSO_4$ 0,5 g, KCl 0,5 g, $FeSO_4$ 0,1 g, sucrose 300 g, agar 200 g) ($10^{-4}$); actinomyces are determined on synthetic agar according to Krasiljnikov (composition: $K_2HPO_4$ 5g, $MgCO_3$ 5g, NaCl 5g, $KNO_3$ 10g, $FeSO_4$ 10 g, $CaC0_3$ 150g, sucrose 200 g, agar 160 g), ($10^{-5}$).

**Results and discussion**

The results from the microbiological tests are shown in Table 3.

in the surface layer, and with increasing of the depth their number decreases.

Bacteria are prokaryotic organisms that have a key role in the process of circulation of matter. Fertile soils contain between one hundred million and a billion bacteria in one gram of soil, their biomass is between 300 - 3000 grams per $m^3$ of soil, their presence entirely depends on the amount of organic matter, pH, the content of water, air, warmth, light, crop rotation and other agro-technical measures.

The average number of bacteria in the examined soil at a depth of 0-10cm is 88 per gram of soil, at a depth of 10-20cm is 132 per gram of soil and at depth of 20-30 cm is 64. Most bacteria per gram of soil are noted at a depth of 10-20 cm.

Actinomyces are heterotrophic organisms; saprophytes with developed digestive system with ability for decomposition of the organic complex such as humus, chitin, cellulose that for other organisms is difficult to decompose (Waksman, 1945).

Environmental conditions in the soil are suitable for the development of actinomyces and they are most numerous in the surface layer of 0-10 cm.

Table 3. Number of microorganisms by depth in alluvial soil ($10^x$ /g soil)

| Soil layer (strata) | Total no. of bacteria | Actinomyces | Nitrifying bacteria | Yeasts | Cellulose splitting microorganisms | Nitrate reducing bacteria | Molds | Ammonia forming bacteria | Nitrate forming bacteria |
|---|---|---|---|---|---|---|---|---|---|
| 0-10 first iteration | 81 | 139 | 230 | 70 | 144 | 221 | 16 | +++ | 184 |
| 0-10 second iteration | 61 | 193 | 111 | 95 | 180 | 213 | 38 | ++ | 228 |
| 0-10 third iteration | 122 | 161 | 150 | 95 | 134 | 233 | 33 | + | 195 |
| 10-20 first iteration | 79 | 22 | 57 | 30 | 77 | 102 | 16 | +++ | 137 |
| 10-20 second iteration | 110 | 35 | 80 | 24 | 53 | 110 | 18 | ++ | 107 |
| 10-20 third iteration | 209 | 20 | 88 | 14 | 42 | 82 | 5 | + | 83 |
| 20-30 first iteration | 15 | 42 | 74 | 34 | 83 | 93 | 6 | +++ | 59 |
| 20-30 second iteration | 36 | 15 | 102 | 45 | 107 | 83 | 11 | +++ | 97 |
| 20-30 third iteration | 141 | 66 | 100 | 87 | 52 | 82 | 6 | ++ | 65 |

Physiological groups of microorganisms - ammonia forming bacteria, nitrate reducing bacteria, nitrate forming bacteria and nitrifying bacteria (nitric forming bacteria) are important for the circulation of nitrogen, carbon, sulfur, phosphorus and other elements. The ammonia forming bacteria with a role to decompose organic nitrogen compounds are numerous in the examined soil, so at a depth of 0-10 cm and 10-20 cm the number of ammonia forming bacteria is equal, and their number is highest at a depth of 20-30 cm. Microorganisms that oxidize ammonia up to nitrates are nitrate forming bacteria and they are most numerous in the surface layer, with increasing of the depth their number declines. Nitrate reducing bacteria are microorganisms that reduce the nitrates up to elemental nitrogen. They are most numerous in the surface layer of the soil.
Cellulose splitting microorganisms decompose the cellulose in the soil, thus creating oxy-acids that enrich the soil with nitrogen substances. The number of cellulose splitting microorganisms is greatest in the surface layer of 0-10 cm (up to 152 per gram of soil).
Molds grow better in acidic soils, because they are acid-fast, although they are numerous in soils with neutral reaction. The number of molds in the examined soil is higher.

**Conclusions**

Based on the results of the research we concluded that:
The mechanical structure and chemical properties of the soil are favorable for development of all studied groups of microorganisms.
The depth of the soil affects the number of microorganisms.
The total number of microorganisms is highest in the soil layer at a depth of 10-20 cm.
The ammonia forming bacteria are most frequent in the soil layer of 20-30 cm, while all other groups of microorganisms – actinomyces, nitrifying bacteria (nitric forming bacteria), nitrate forming bacteria, nitrate reducing bacteria, yeasts, molds and cellulose splitting microorganisms are most numerous in the surface layer of 0-10 cm.

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## БРОЈНОСТА НА МИКРООРГАНИЗМИТЕ НА РАЗЛИЧНА ДЛАБОЧИНА ВО АЛУВИЈАЛНА ПОЧВА ВО СКОПСКО

Олга Најденовска, Даниела Димовска, Џоко Кунгуловски, Наталија Атанасова Панчевска

**Апстракт**
Почвата претставува жива, динамична средина во која живеат различни видови микроорганизми. Преку ензимската активност микроорганизмите учествуваат во создавањето на хранливите материи за растенијата. Оттука, микроорганизмите учествуваат во создавањето и одржувањето на плодноста на почвата и претставуваат индикатори на нејзината биогеност. Во овој труд се испитувани вкупниот број на микроорганизми, актиномицетите, азотофиксаторите, габите, целулолиотичките микроорганизми, денитрификаторите, амонификаторите, и нитрификаторите во алувијална почва, во н. Јурумлери, Скопско. Бројноста на микроорганизмите е испитувана во три различни длабочини ( 0-10 см, 10-20см, и 20-30см ). Испитуваната почва има поволни физичко - хемиски својства за живот и развиток на микроорганизмите. Констатирано е дека најголем број на испитуваните групи микроорганизми е на длабочина од 0-10 см, а амонификаторите на длабочина од 20 – 30 см.

**Клучни зборови**: микроорганизми, алувијални почви.

**UDC:631.95:581.131(497.115)**
**Origanal scientific paper**

# HYDROCARBON IMPACT & ITS CONSEQUENCES ON ENVIRONMENT AND FOOD CHAIN IN OILFIELDS

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**Abstract**
This study shows the presence of high levels of hydrocarbon pollution on flora, biological diversity and agricultural land in Fier area with an impact on agricultural development. Ecosystems in Fier district provide resources and opportunities for the economic development of society, offering natural wealth such as sea and land, tourism, biotic world such as forests, wetlands, etc. Mediterranean climatic and specific conditions of the aquatic ecosystem have identified a covered field and a diverse fauna. Flora is characterized by a long vegetation period, which may even exceed 10 months. Fauna is constantly shrinking as a result of vegetation cover damage due to hydrocarbon concentration, both in land, air and surface water.

**Key words:** Fluorescence parameters, photosynthetic activity, Phragmites Australis, Eucaliptus Camaldulensis, invasive species, vegetative stage.

## Introduction

Referring to the phyto-climatic point of view, the region under study extends to Mediterranean forests and shrub land belt and is characterized by a diversity of habitats and plant communities, such as riverbed vegetation, freshwater wetland or different stages of their degradation, natural, semi-natural and artificial or created by human activity. It is very rare to see pieces of natural vegetation. More often one can notice considerable surfaces covered by Rubus ulmifolius (thorns) and Paliurus spina-christi (bramble). Other indicators of this degradation are spread in a considerable degree of species such as invasive species as Dittrichia viscosa, and anthropogenic species, etc. Agricultural production provides 50% of all personal income in the region of Fier. Fier district has 17.5% or 122,241 hectares of agricultural land in the country and exports many agricultural and livestock products to other markets within Albania. Cultivation, including wheat, maize, vegetables, industrial plants and forages, cover nearly 86% of the agricultural district area, while forests cover 14%. Agriculture in Fier is more developed and there are more forests compared to other districts.

## Material and methods

Biological diversity is an indicator of environmental health in a certain area, including living beings of plant and animal origin. The richer is the diversity of living beings, the more diverse is the interaction between them and the fauna and flora world. Biologic balance degradation in the region under study is due to hydrocarbon pollution. The database collected in polluted areas is further examined in laboratory conditions and results are compared to standard values.

*Biological diversity assessment in agricultural environments due to hydrocarbon pollution*

Hydrocarbon negative impact is manifested differently. However, the fumigant action and asphyxia are probably the most serious. Field work has enabled an assessment of health and population density of plants and animals in the two comparative areas: both in hydrocarbon polluted areas and hydrocarbon-free areas. This has been achieved by:

1. Assessing wild plant populations, through remote observation and macro analyses, where 3-4 rectangular squares are assigned in the selected area, each square of 1000m2, with a distance of more than 1000 meters from each other. After the square is checked by naked eye, surfaces containing rare plants are marked. This is expressed in m2 per 1000m2;
2. Observing birds flying on the water, on trees or on the checked square, and indicating the number of birds that the naked eye might catch;
3. Performing an analytical check, for instance, in a 1000m2 square are checked five quadrates of 1m2 each, with regards to the plant species and their development;
4. Checking for rain worm density under the context that rain worm is the most active creature for earth hygiene. For this, 10 holes are dug in every 5 hectares, each with dimensions 50 x 50 x 50cm2. The soil is carefully burrowed and the number of earthworms and other creatures is recorded;
5. Checking water canals for living beings. To do this, some samples are taken from a liter of water. After the water is drained through cheesecloth the living creatures are numbered;
6. Checking the health status of agricultural plants in the selected sector, where 100 plants per 5ha are examined for the presence of aphids, mycosis, red apple, and main illnesses.

The present study is focused, both in hill and field areas, in main plants, as well as in lands which are distant from pollution sources.

*Assessment of pollution in agricultural lands caused by oil extraction*

Fier region is characterized by diversity in the cultivation of arable crops, like wheat, corn, vegetables, industrial plants and forages and covers over 20% of the national necessities of the country. Some industrial plants such as sunflowers and soy are concentrated in Fier and cover respectively 83.5 and 72.5% of the area at national level. The soils of this area are considered as problematic since they are often under the pressure of oil exploitation. One of the factors of such degradation is oil exploitation in 23,000 ha. Such lands show a high variability of pH, whose values range from 7.2 to 8.5, classifying them into lands of neutral to alkaline character. Furthermore, the ratio of Ni content in all these soils is relatively high. Its content stands between values from 215.9 to 284 mg/kg; which is a proof of toxic levels of such element found in soil (Table1).

With regards to Pb element content, it is found that such lands contain it in a significant level, but not as high as those accepted by EU. Whereas Vanadium (Vn) indicates values of high fluctuations from 48 to 108 mg/kg dry land, thus being an indicator of land contaminated by Vanadium. With regards to the content of hydrocarbon in soil, it is found that it appears at high values ranging from 117.2 to 454.3 mg/ per 100gr. We are of the opinion that the high content of heavy metals (Ni, Vn and Pb) in oilfields affects soil pollution. Moreover, the analysis of hydrocarbons in the area that result in high concentrations further reinforces the conclusion on oil extraction activity impact in soil pollution in this area.

Table 1. The contend of polluted elements in oilfields soil

| The monitories points and the sample site | pH | Ni (mg/kg), dry soil | Pb (mg/kg), dry soil | Vn (mg/kg), dry soil | Total hydrocarbon (mg/100gr) |
|---|---|---|---|---|---|
| Patos- Marinez P1 0-30cm | 7.2 | 250 | 114 | 92.1 | 246 |
| Patos- Marinez P2 0-30cm | 7.2 | 215 | 114 | 48 | 129 |
| Patos- Marinez P3 0-30cm | 8.5 | 284 | 126 | 108 | 454 |
| Patos- Marinez P4 0-30cm | 8.1 | 215 | 137 | 83 | 117 |
| Average | 7.75 | 241 | 122.7 | 82.7 | 236.5 |

*Assessment of pollution impact on agricultural land flora in oilfields*

Albanian flora stands out for its high diversity which is thought to be as a result of the geographical position of Albania, and that heavily depends on the topography and climate of the area. Such flora, apart from being rich in species, shows high levels of native species in the study area. The presence of high levels of pollution has serious consequences on the flora and fauna of this area. The analysis of chlorophyll fluorescence parameters and the assessment of the photosynthetic leaf activity are conducted through the appropriate fluorescence imaging equipment, namely FluorCam 700 MF, at the Institute of Biological Research. Herb samples are taken in Patos-Marinëz area. (Table 2) [1]

Table 2. The analysis of chlorophyll fluorescence parameters

| Place spread | Herbs | Fluorescence parameters | | | Assessment of the photosynthetic | | |
|---|---|---|---|---|---|---|---|
| | | Fo | Fm | Fv | Rfd | qN | NPQ |
| Zharrez Spring | Phragmites australis 1-1 | 126.71 | 357.29 | 230.58 | 1.479 | 0.855 | 1.087 |
| | Phragmites australis 1-2 | 120.01 | 362.91 | 242.9 | 1.552 | 0.834 | 1.124 |
| Zharrez Spring | Eucaliptus camaldulensis | 159.94 | 640.33 | 480.39 | 1.786 | 0.856 | 1.718 |
| | Eucaliptus camaldulensis 2-2 | 132.79 | 601.69 | 468.9 | 3.072 | 0.922 | 2.737 |
| Gjanice River | Phragmites australis 3-1 | 110.99 | 509.71 | 398.72 | 3.043 | 0.914 | 2.583 |
| | Phragmites australis 3-2 | 163.65 | 774.58 | 610.93 | 1.806 | 0.793 | 1.639 |
| Gjanice River | Eucaliptus camaldulensis 2-1 | 124.46 | 459.3 | 334.84 | 1.557 | 0.856 | 1.186 |
| | Eucaliptus camaldulensis 2-2 | 122.59 | 415.09 | 292.49 | 1.411 | 0.822 | 0.995 |

Based on the table data, fluorescence images and on the fluorescence kinetics curves, it results that the indicators of herb photosynthetic activity analyzed in such areas are low, expressed more clearly in leaves being under a fully developed vegetative stage (approximately 3-4 months). Leaves which indicate a higher photosynthetic activity (Eucaliptus camaldulensis 2-2, Phragmites australis 3-1) are leaves under a new vegetative stage (of nearly one month old). The low values of photosynthetic activity indicators as well as leaves chlorophyll fluorescence dispersion (gradient and non

[1] Analyzes were carried out in biological research institute, Academy of sciences during 2010

uniformity) indicate the negative impact of oil hydrocarbon pollutants found in this area. (Fig 1,2,3,4)

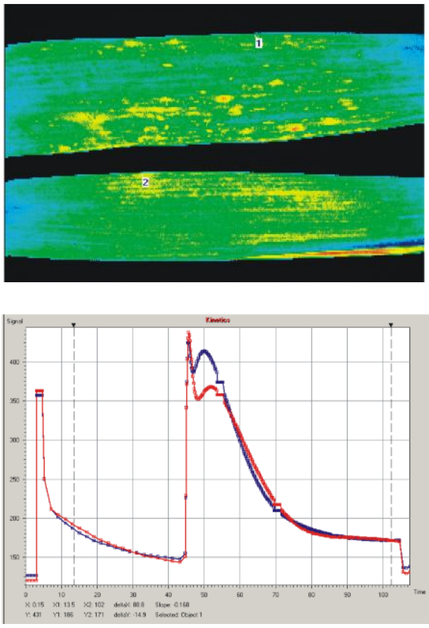

Figure 1. Fluorescence images and on the fluorescence kinetics curves. Phragmites australis, Zharrez Spring

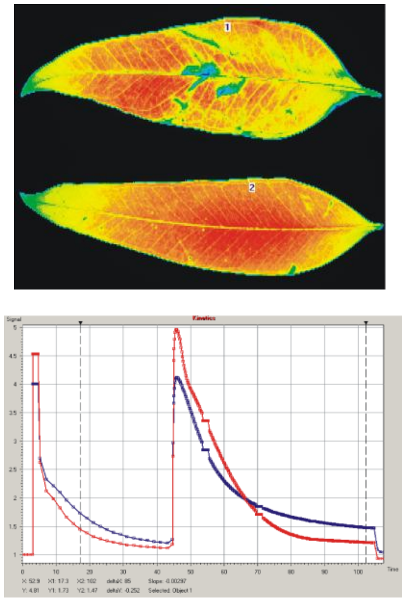

Figure 2. Fluorescence images and on the luorescence kinetics curves. Eucaliptus camaldulens, Zharrëz Spring

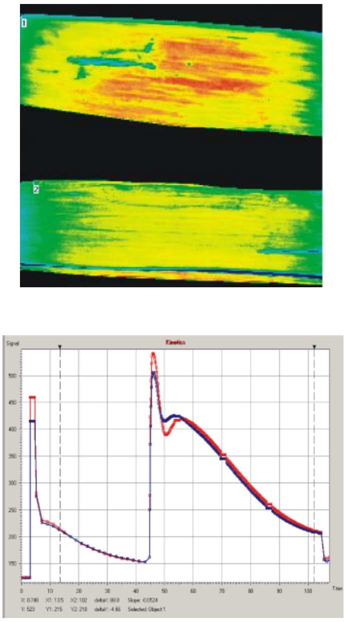

Figure 3. Fluorescence images and on the fluorescence kinetics curves. Phragmites australis, Gjanice river

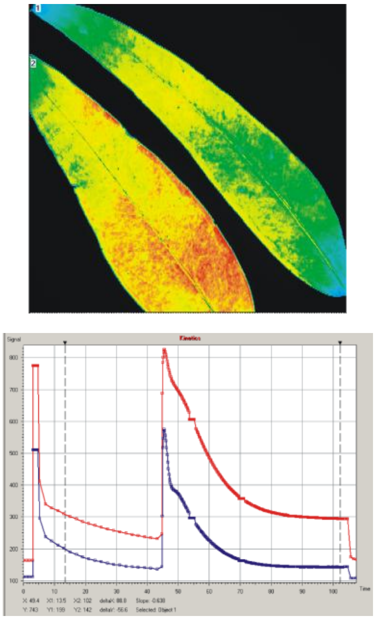

Figure 4. Fluorescence images and on the fluorescence kinetics curves. Eucaliptus camaldulensis, Gjanica river

Other indicators of such degradation are the considerate spread of such invasive species as *Dittrichia viscosa* and anthropogenic species as *Asphodelus aestivus, Andropogon ischaemum, Erigeron sp*. etc. Elements of Mediterranean forest and shrub belt in individual cases are encountered nearby or within such areas such as *Rubus ulmifolius* (bush), *Paliurus spina-christi* (shrub) or under areas covered by natural vegetation such as *Phlomis fruticosa, Quercus coccifera, Spartium junceum.*

**Conclusions**

As a conclusion we can say that the entire area represents a stage of native vegetation degradation (degradation that continues to this day) not in very high values in terms of biodiversity;

Oil extraction and processing activity in the region, besides anthropogenic activity, has caused a high level of pollution and considerable loss of biodiversity values. The following two are the most visible indicators of this activity:

1. Increase of morbidity from various diseases (Picture 1,2, 3, 4)
2. Higher morbidity by pests (Picture 5,6)

Picture 1. Pollution effects on Phragmites australis leaves

Picture 2. Pollution effects on Populus canadensis leaves

Picture 3. Pollution effects on Rubus ulmifolius leaves (necrosis)

Picture 4. Pollution effects on Calystegia sepium leave (necrosis

Picture 5. High presence of pests

Picture 6. High presence of pests

Hydrocarbon contamination consequences in the oil extraction area not only influence environmental pollution (water, air, land), but also the biodiversity of the area, and then further the food chain;
Arable agricultural lands, degraded and abandoned lands, occupy roughly more than half the area of the region under study;
Biodiversity is affected more than in all other ecosystems;
Repeated plow activity in such lands without protective measures has led to irreparable scale damage and currently a large part of the agricultural land area are abandoned;
Regardless the extension in this belt, the flora of such environments has almost nothing in common with the vegetation of this belt;
Degradation represents the highest stage of former primitive forest degradation (that may have existed in the area) dominated by ilqja (Quercus ilex), as a result of anthropogenic abusive activity through intensive deforestation, cutting, burning, grazing, repeated works and leaving such lands fallow for a long period of time, and what is more important, as a result of the high level of pollution caused by drilling and exploitation activities of the area for oil extraction purposes;
Soils of this area are physically eroded in large scale and in many cases has surfaced rock sole;
*Recommendations*
Improvement of infrastructure and technology in the oil extraction and processing industry;
Areas of highly oil hydrocarbon contamination must undergo a "Phyto-rehabilitation" process;
There is an urgent need for intervention for its improvement through forestation with native species;
Forestation intervention would rehabilitate the landscape, reduce the dust level and improve somewhat air quality.

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# ВЛИЈАНИЕ НА ЈАГЛЕВОДОРОДОТ И НЕГОВИТЕ ПОСЛЕДИЦИ ВРЗ ЖИВОТНАТА СРЕДИНА И СИНЏИРОТ НА ИСХРАНА ВО ОКОЛИНАТА НА НАФТЕНИТЕ ПОЛИЊА

Алма Шеху, Алфред Мулај, Сеит Шалари, Хазир Положани, Марјанти Гури

**Апстракт**

Во овој труд се анализира присуство на високо ниво на загаденост од јаглеводород во флората, биолошкиот диверзитет и земјоделско земјиште во областа Фиер и неговото влијание врз развојот на земјоделството. Еко-системите во областа Фиер обезбедуваат ресурси и можности за економски развој на општеството, нудејќи природни богатства како што се море и копно, туризам, шуми, мочуришта, итн. Медитеранските климатски и специфични услови на водните еко-системи го идентификуваат опфатеното поле и разновидната фауна. Флората се карактеризира со долг вегетациски период, кој може да надмине дури и 10 месеци. Фауната постојано се намалува како резултат на штета врз вегетациската покривка штосе должи на концентрацијата на јаглеводород во земјата, воздухот и површинските води.

**Клучни зборови**: Флуоресцентни параметри, фотосинтетска активност, Phragmites Australis, Eucaliptus Camaldulensis, инвазивни видови, вегетациски период.

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**Original scientific paper**

# THE IMPACT OF MINING INDUSTRIAL PROCESSES OF "TREPÇA" COMPLEX IN THE QUALITY OF RIVERS TREPÇA AND SITNICA

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## Abstract
Mitrovica a city that lies in northern part of Kosovo is recognized as the biggest center with the largest metallurgic and mining complex Trepça in Europe. The Mining activities in Mitrovica resulted with a dramatic environmental pollution. The ore processing until 2000 and the existence of three tailing damps contribute to the dissemination of hazardous material in air, soil and water. As a result of uncontrolled water discharge of industrial processes such as: discharged water from mining and flotation in Stan Terg and First Tunnel, Metallurgy and zinc battery factory in Mitrovica, rain waters from industrial landfills, water from drainage channels that flow directly into rivers without prior treatment show serious problem regarding to pollution of Trepca and Sitnica rivers, adding a high level of heavy metals concentration which exceed international standards. The main objective of the present investigation was to evaluate and analyze the impact of these industrial processes in the quality of water of Trepça and Sitnica rivers. The Atomic Absorption Spectrometry (Shimadzu AA-6300) was applied for the determination of lead, zinc, cadmium, copper and iron levels in Trepça Flotation Laboratory. It was found that the level of lead (0.6434 mg / L), zinc (2.08 mg / L), copper (0.1374 mg / L), iron(0.7132 mg / L) and cadmium (0.015 mg / L) concentration is relatively high. Pollution of rivers with heavy metals represents a permanent threat to flora, fauna and the population living in the region. Therefore in the conclusion the study presents recommendations for possibility of eliminating or reducing the concentration of heavy metals.
**Key words**: heavy metals, river pollution, Atomic Absorption Spectrometry.

## Introduction
Beside the use of water in many different branches of industry, river water is a subject to contamination from raw concentrated discharges of these industrial waters. (Dukovic, J, et al 2000).
By exploiting the natural resources man developed and diversified industrial production economy, but it increases the content of chemicals in aquatic environments, especially the heavy metals and organic micropollutants (pesticides, poliklor-difenilet, chlorinated organic substances, aromatic hydrocarbonspoliciklike, etc..), by discharges of solid, liquid and gaseous, urban, industrial, agricultural and mining. All these pose a threat to aquatic ecosystems, affecting the water quality. (Çullaj, A.2005).

Environmental pollution from industrial processes is great danger in the city of Mitrovica, although the chemical industries today are not operating. However, these industrial processes continue to have an impact on environmental pollution, especially in aquatic ecosystems where the problem is pollution of river Sitnica and Trepca. Impact on the pollution of revers Sitnica and Trepca have the dischargd and untreated water from the battery factory and chemical industry, drainage water from the tailings of jarosite and phosophogips. Flotation factory for the production and processing of ferrous metals in technological process uses the relatively large amounts of water. After completion of these technological process the water is discharged into rivers without any pollution with preliminary treatment. The main characteristics of Sitnica and Trepca river and Trepces is the pollution contaminated with heavy metals that often exceeds the allowed values??.Heavy metals are highly toxic in their compounds and some of them even in their basic form.

Heavy harmful metals are, mercury, arsenic, cadmium, kallai, chromium, zinc and copper.These metals are widely used in industry especially in metal galvanic wardrobe and some products like batteries and accumulators. These metals can be introduced into the environment wherever these products are produced, used and disposed.Heavy metals are extreme toxic because their corresponding compounds ions are soluble in water and can be absorbed immediately into the body.

It is clear that the earlier pollution in this area has been very heavy. 1980 Studies show that all vegetables and wheat planted in the Mitrovica area containing large concentrations of lead.People who feed on these plants are at risk to take the lead to three times more than the maximum allowed by the OBSH. (Rozaje D. et al 1983). Concentrations of lead in the blood of residents of Mitrovica were several times higher than the population of Pristina.

It is estimated that about 9,000 children in Mitrovica may have blood lead concentration of 40 ug / dL.In this case the determination of heavy metal concentraton is made by atomic absorption spectrometric method Shimadzu AA-6300, in the laboratory flotation Trepca tunnel first, and analysis results show that the contamination level of lead and zinc is several times higher than the allowed European standards.

**Material and methods**

First sample was taken in Frasher, approximately a mile and a half away from landfill.Second sample was taken 500 m away from the new bridge of French KFOR called ,,Verdunit Bridge".Third sample was taken at the beginning of the dump and the fourth sample was taken at the end of the industrial waste dump Mitrovica Industrial Park.While the first sample is picked in river Trepca on the mine of Trepca, the second sample was taken after the discharge of industrial wastewater from Flotation and the third sample was taken after Trepqes and Sitnicas union.

Water samples were placed in polyethylene containers, which have been cleaned with same water from which the sample was taken. (Korca,B. 2003). Samples are identified by serial number and place of receipt.In the taken samples it is determined the concentration of heavy metals, Pb, Cd, Zn, Cu and Fe, and pH.Ph-has been calculated with pH meter apparatus. 100 ml of sample of were placed in erlenmeyer and previously they were filtered to remove the insoluble substances. In every sample was added a 1 ml concentrated HNO3, and are placed in electrical roshon up to the boiling point.Samples were then cooled, and as a result of evaporation the amount of sample is reduced.Samples are placed in a normal container and are leveled with distilled water. Çiriq,J.,Vajgan,Peshiq, Hemisko Tehnoloski Prirucnik.

For each element after they optimized the respective conditions as wave length, lamp position, the position of fuzed , type of flame and the fissure spectral width the absorbance of standard solvents was measured and the calibration curves were constructed and parameters of lead,zinc, cadmium, copper and iron have been calculated.(Atomic Absorption Spectrometry, Method Manual, ISSME 3-010101, Thermo electron Corporation, Cambridge, Solaar House),Institut za Nuklearne Nauke, (1951).

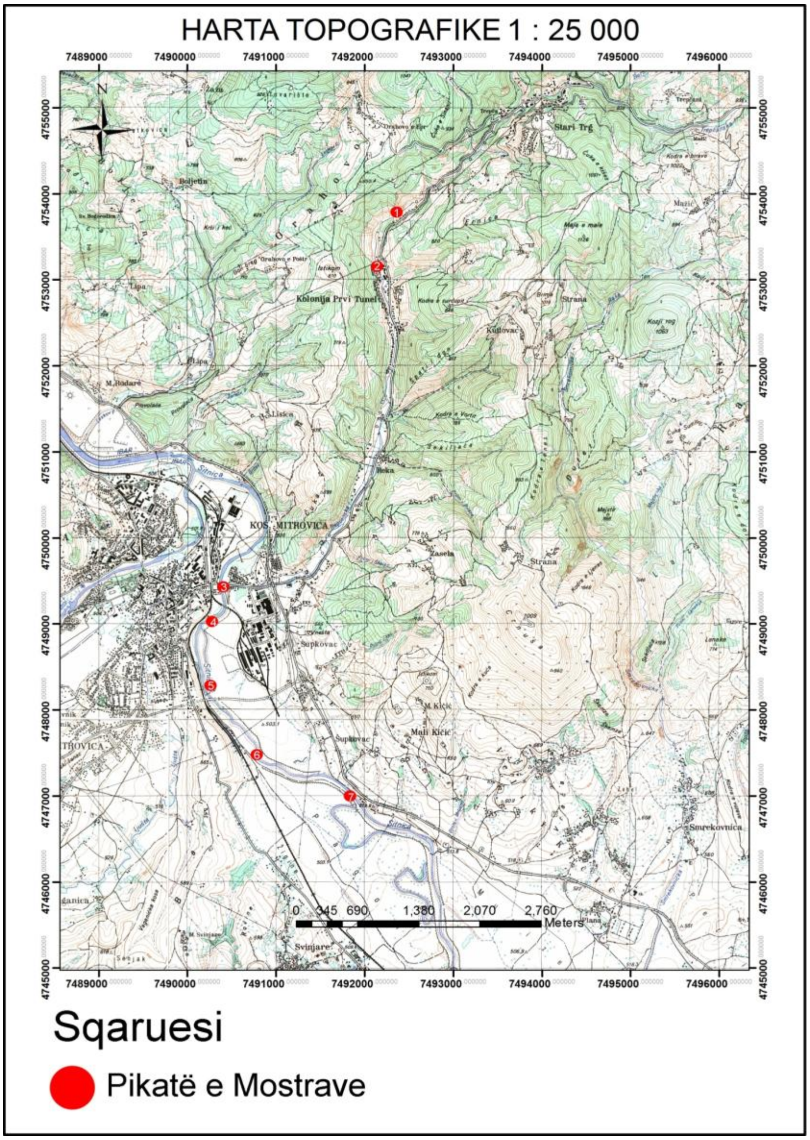



Figure 1. The topographic presentation of Sitnica River and Trepqe samples

**Results and discussion**

The following Table 1 shows the aty metals in the samples that were taken in the Sitnica River.

Table 1. Values of heavy metals and pH in Sitnica River

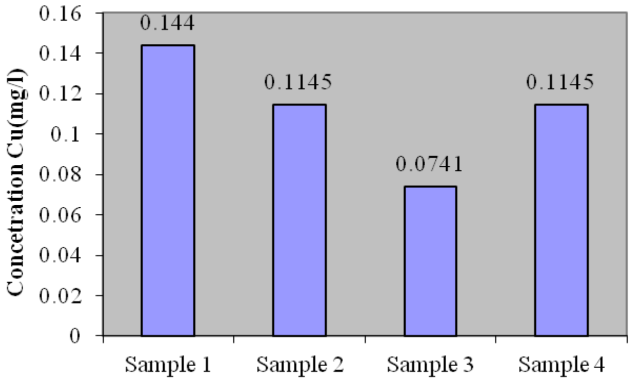
| | Europian Union Directive 98/83/EC | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|---|
| pH | 6-8.2 | 7.67 | 7.70 | 7.69 | 7.78 |
| Cu mg/L | 0.01-1.0 mg/L | 0.144 | 0.1145 | 0.0741 | 0.1145 |
| Cd mg/L | 0.005-0.01 mg/L | 0.0049 | 0.0056 | 0.0055 | 0.0036 |
| Zn mg/L | 0.2-1.0 mg/L | 0.017 | 0.0367 | 0.5136 | 1.3536 |
| Pb mg/L | 0.005-0.01 mg/L | 0.0293 | 0.1746 | 0.0696 | 0.1467 |
| Fe mg/L | 0.3-1.0 mg/L | 0.0877 | 0.6922 | 0.077 | 0.0306 |

Table 2. Values of heavy metals and pH in river Trepca

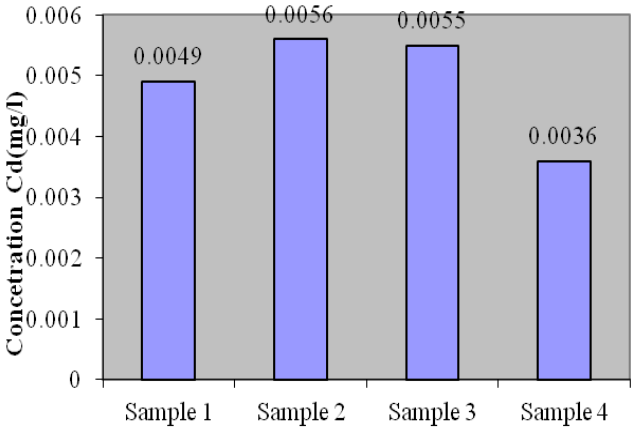
| | Europian Union Directive 98/83/EC | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|---|
| pH | 6-8.2 | 7.07 | 8.1 | 7.85 |
| Cu mg/L | 0.01-1.0 mg/L | 0.1276 | 0.1374 | 0.0549 |
| Cd mg/L | 0.005-0.01 mg/L | 0.0037 | 0.0048 | 0.0045 |
| Zn mg/L | 0.2-1.0 mg/L | 0.0546 | 2.08 | 1.2349 |
| Pb mg/L | 0.005-0.01 mg/L | 0.1311 | 0.6434 | 0.3178 |
| Fe mg/L | 0.3-1.0 mg/L | 0.1956 | 0.7132 | 0.1089 |

Based on the results obtained from the samples and analysis is clear that contamination is evident. Significant values of concentration of heavy metals mainly lead and zinc were observed in river waters Trepqes where comes the merging of river water and the discharging water that comes out of Flotation.

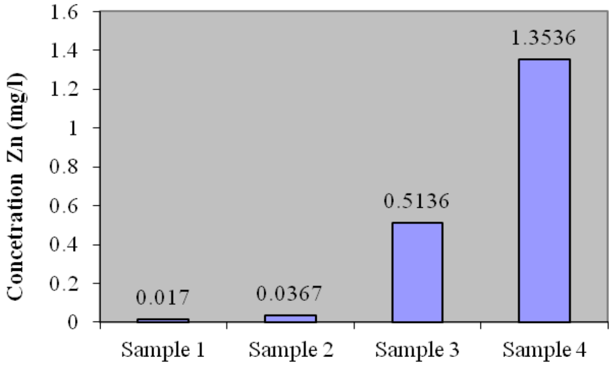
In the following figures it is shown the concentration of metals Cu, Cd, Zn, Pb and Fe.

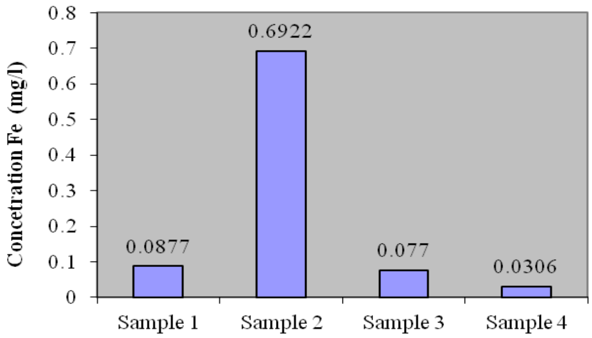


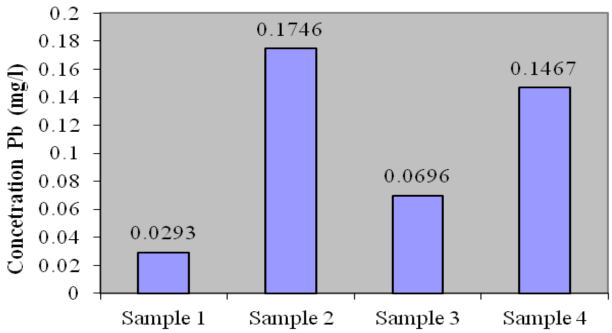

The pH values in all samples in Trepca and Sitnica rivers do not exceed the standard values. The figure shows that copper in the third sample does not exceed the standard values of pollution, otherwise the three other samples of the copper concentration exceeds the allowed values above 0.1 mg / L.



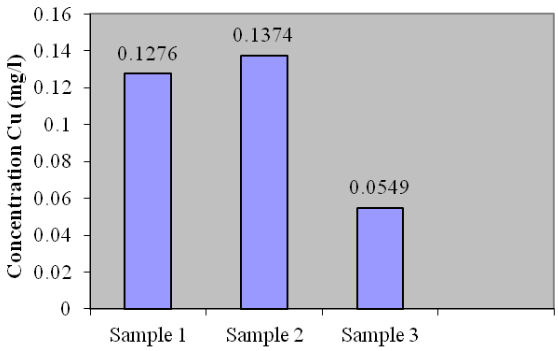

Based on the values obtained from the analysis no contamination with cadmium is present.

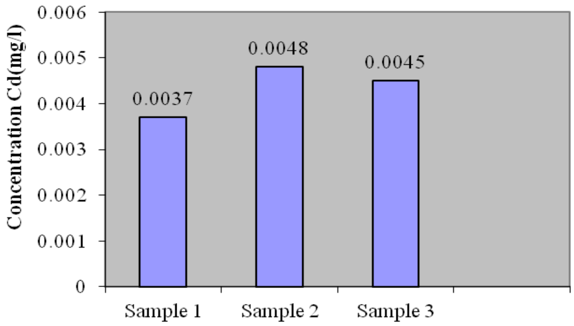


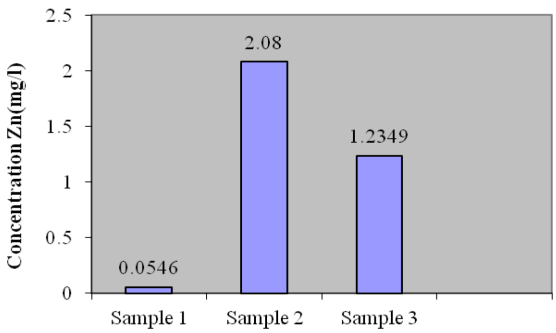



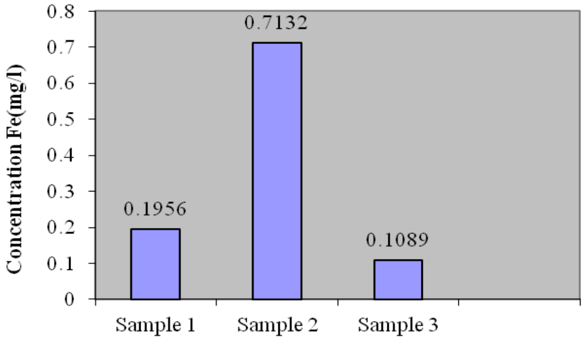



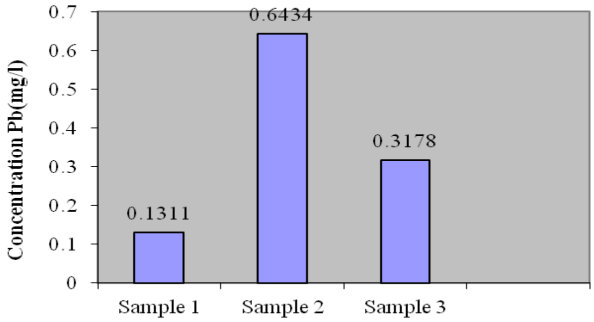

Based on the results obtained from sampling the contamination with heavy metals is evident. Significant values of concentration of lead and zinc were observed in river waters and exceed the standard values 0.2 mg / L, ie, 0.005 mg / L referred to by the European Union Directive 98/83/EC. The contamination with lead and zinc is result of wastewater discharges from drainage and industrial waste landfills (jarosite and phosphogyps). In the following figures it is shown the concentration of metals Cu, Cd, Zn, Pb and Fe.


Concentration Cu (mg/l)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.1276
0.1374
0.0549
Sample 1
Sample 2
Sample 3


Concentration Cd(mg/l)
0.006
0.005
0.004
0.003
0.002
0.001
0
0.0037
0.0048
0.0045
Sample 1
Sample 2
Sample 3


Concentration Zn(mg/l)
2.5
2
1.5
1
0.5
0
0.0546
2.08
1.2349
Sample 1
Sample 2
Sample 3




Values which are obtained as a result of analyzing of water samples in Trepca River are very high compared with the limited standard values. The sample taken in the discharged water from the flotation process show very high values of heavy metal, mainly with lead and zinc. As result of contamination with heavy metals this river is categorized in the fourth category.

**Conclusions**

Thanks to the research we conclude that contamination with heavy metals like lead, zinc is present in River Trepqe and Sitnica.The largest concentration of contaminants is observed in the vicinity of the point discharge of industrial wastewater of flotation.Since there was no industrial waste compacting and regular coverage of landfills in PIM, still these landfills continue to be a environmental pollutants of Sitnica River.

By ending this paper, we came to the conclusion that there are some possibility that in the future these pollutants can be removed or reduced to the allowable limit values:

1. Both industrial landfills should be covered with plastic fossils for reasons of environmental protection from pollutants.
2. The coverage of landfills with soil layers and their vegetation.
3. The Treatment of sewage and that industrial waste before they are discharged into the water of the river.

In recent times new technologies are discovered thanks to the scientific work and efficient processes devices which allow the removal of contaminants from polluted waters of acid derived from the mining. This process of treatment is possible with the use of less hazardous chemicals in such rechnology that will facilitate the application.

If we take proper handling of dumps, repairing the state of equipments in the cleaning facilities waste water from industries and the preliminary treatment of sewage flowing into the river the pollution will not exceed the allowed standard values of heavy metals pollution .

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# ВЛИЈАНИЕТО НА РУДАРСКИТЕ ИНДУСТРИСКИ ПРОЦЕСИ НА „ТРЕПЧА“ КОМПЛЕКСОТ ВРЗ КВАЛИТЕТОТ НА РЕКИТЕ ТРЕПЧА И СИТНИЦА

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**Апстракт**

Митровица, градот кој се наоѓа во северниот дел на Косово е признат како најголем центар со најголемиот металуршки и рударски комплекс Трепча во Европа. Рударските активности во Митровица резултираа со драстично загадувањето на животната средина. Преработката на руда до 2000 година и постоењето на рударски отпади придонесете во ширење на штетни материи во воздухот, почвата и водата. Како резултат на неконтролираното испуштање на вода од индустриските процеси како што се: испуштени води од рударството и флотација во Stan Terg и First Tunnel, фабрика за металургија и цинк батерии во Митровица, дождовници од индустриски депонии, вода од одводни канали кои истекуваат директно во реките без претходно управување, претставуваат сериозен проблем во однос на загадувањето на реките Трепча и Ситница, додавајќи високо ниво на тешки метали кои ги надминуваат меѓународните стандарди. Главната цел на ова истражување беше да се оцени и да се анализира влијанието на овие индустриски процеси врз квалитетот на водата на реките Трепча и Ситница. Атомска апсорпциска спектрометрија (Shimadzu AA- 6300) беше применета за одредување на нивото на олово, цинк, кадмиум, бакар и железо во лабораторијата за флотација во Трепча. Се покажа дека нивото на концентрација на олово (0,6434 mg/L), цинк (2,08 mg/L), бакар (0,1374 mg/L), железо (0,7132 mg/L) и кадмиум (0,015 mg/L) е релативно висока. Загадување на реките со тешки метали претставува постојана закана за флората, фауната и населението кое живее во регионот. Затоа во заклучокот на трудот се презентираат препораки за можноста за елиминирање или намалување на концентрацијата на тешки метали.

**Клучни зборови:** тешки метали, загадување на река, Атомска апсорпциска спектрометрија.