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Contents

FOREST TERRACE SOILS OF THE FOREST-STEPPE OF CENTRAL RUSSIA AND ENVIRONMENTAL PROBLEMS IN THEIR AGRICULTURAL USE

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Abstract
In present time anthropogenic modification of landscapes are prevail in the forest-steppe of Central Russia. Therefore investigations of forming factors, of ecological problems of use of the terrace forest soils, of soil cover state are appear very actual. At use of terrace landscapes it is necessary to draw near differently.

Keywords: forest soils, terraces, agricultural use, humus, environmental issues.

Introduction

Research related to the study of biosphere functions of soils terraces, has always been important. Natural fertility and proximity to water sources give them special value, and their barrier function in the path of migration of elements – environmental significance. Terrace landscapes are distributed in narrow bands on the left banks of the river valleys of the Don and Voronezh, and is represented by a series of three or four terraces.

The patterns of distribution of soil cover of the terraces are closely associated with the factors of soil formation that differ by the terraces of different elevation levels. The greatest influence of soil-forming rocks, the level of groundwater, plant communities. Their diversity creates diversity and characteristic features of the soil cover of the terraces of different age.

Material and Methods

During the field stage of the study were used such methods as the route, the comparative-geographical landscape with the laying of the profiles from low to high floodplain terraces, a full-profile cuts with a selection of soil samples in layers every 10 cm. During the laboratory stage in the selected samples were analyzed by granulometric composition, reaction environment, the amount of exchange bases, hydrolytic acidity, humus, its fractional-group composition, the content of available forms of nitrogen, phosphorus, potassium according to standard techniques.

Results and Discussion

The first and second terraces from the surface of the stacked old alluvium sediments. Over them grow pine forests, which formed the sod-forest soil sandy and loamy-sandy composition. These soils have a humus horizon (15-20cm), brown, light brown or yellow layer of sand (up to 4,0-4,5 m). There is a lot of brown-gray interlayers of organic and mineral compounds. The total capacity of the horizons of 60-75cm.

Sod-forest sandy soils have poor structure in the humus horizons and unstructured in the rest of the profile. Structureless due to their low content of clay fraction particles, including organic colloids. The low quality of the granulometric composition of predetermined adverse physical-chemical properties and humus status of sod-forest soils of the low terraces of river valleys of the forest. They are characterized by low humus content of 0,2-1,5% throughout the profile. Only the upper 20-cm thickness stands out sharply in her humus is 4,5 to 5,1%. This distribution of organic matter due to its accumulation in the humus-accumulative horizon, which concentrated the main part of the root systems of herbaceous vegetation and forest litter. The same pattern in the distribution of humus in the profile is observed in sod-forest soils of the second terrace.

Sod-forest soils are characterized by low content of absorbed bases, which are distributed unevenly throughout the profile. In sandy soils the amount of absorbed bases is 30-46% over the whole profile. With the exception of sandy layers, in which the figure is 53% to 70%. In the humus-accumulative horizons the degree of saturation of the bases might increase to 77%. Sod-forest sandy loam soils of the second terrace above the floodplain the degree of saturation of bases different from their sandy counterparts on the first terrace. The profile is characterized by sandy loam soils moderately rich upper part (70-84%) and slightly saturated the rest of the profile (52-70%). The layers where there is some increase in hydrolytic acidity, unsaturated fats (48%). The reaction of sod-forest soils are acidic sandy throughout the profile Soils of the low terraces is poor in nutritional elements. Only in the small capacity of the humus horizon, the maximum content of mobile compounds of phosphorus reaches 11-16, minimum 3-4mg/kg of soil. In the rest of the profile content of P_2O_5 is 3-9mg/kg soil. The considered soil is better secured exchangeable potassium: 54-110мг/kg soil in the humus horizon, 8-46мг/kg soil in the rest of the profile.

Soil formation on the third terrace is in terms of the cumulative balance due to double soil-forming rocks (sand strata at shallow depth underlain by loam) and a large part in the pine forests of broad-leaved trees – oak, linden, ash, maple. This terrace is covered with a gray forest-steppe soils of light granulometric composition.

The fourth terrace of the Don and Voronezh from the surface cover is composed of loam and soil formation it has the features of processes occurring on watersheds. So here under the oak forests form the gray forest loamy soil. They have the most favorable physical-chemical and agrochemical indices and, therefore, more intensively involved in agricultural use. Change of vegetation, plowing of the soil lead to changes in morphological features (formed of the arable and subsurface horizons with less intense humic coloration disappears porosity; physical properties (granulometric composition, structural state, water and agro-physical properties); chemical and physical-chemical properties. Plowing of gray forest-steppe soils leads to a deterioration of the physical properties of the arable and subsurface horizons. They increase the value of the bulk density (0,05-0,06 g/cm^3), specific gravity (0,03-0,01) and decreases total porosity (1-3%), although the overall General physical properties remain good. The negative impact of limited soil layer of 0-40 cm and does not affect the deeper horizons. The development of these soils is accompanied by decrease in permeability of the plow layer. The absolute content of humus in the layer 0-20 cm is reduced by 1%. This is due to the mixing of soil horizons during plowing. Below the cultivated horizons of strong changes in the content and distribution of humus in the profile is not marked.

In the gray forest-steppe sandy loam ploughed soils throughout the profile decreased the content of exchangeable calcium, but especially sharply in the arable horizon (up to 3 mg-Eq/100g soil against 11 under forest). The development affected the content of exchangeable magnesium in the composition of absorbed bases. It decreased slightly throughout the profile in the soil on arable land and to a depth of 50 cm in the pasture. Deeper, the increase of magnesium content to 1,5-2,5 mg-Eq/100g of soil against 1,0-1,3 under forest. It is in this part of the profile it is noted the removal of the sludge, which confirms the connection of exchange of magnesium with fine part of the soil. In general, the amount of exchange bases decreased markedly only in the arable horizon of the soil.

The value of hydrolytic acidity in these soils was reduced in the arable horizon is 0,3-1,4 mg-Eq/100g of soil. In the soil in the pasture there was a decrease of this index by 1 mg-Eq/100g of soil in the layer of 0-40 cm. Respectively, with the change in the amount of absorbed bases and hydrolytic acidity in the development of gray forest-steppe sandy loam soils has changed and the degree of saturation of the soil. It decreased in the layer 0-30cm up to 60-67% in sandy soils on arable land against 77-89% under forest. In the rest of the profile, the figure is higher than in virgin soils and with depth the degree of saturation increases. Under meadow vegetation in the pasture soils are saturated with bases at 65-80% to a depth of 80 cm, deeper the degree of saturation is less than at the same depth under the forest. In cultivated soils throughout the profile increased pH. They become less acidic and closer to neutral and slightly acidic.

Pine forest on the terraces and groves of forest-steppe of Central Russia in the Holocene, occupied a huge space. Since then their appearance has changed several times, aided by climatic fluctuations and historic era human activity. Forest terraces experiencing intensive anthropogenic impact. There are many cases of deforestation, and then use freed from woody vegetation of soils in agriculture. Often, especially in agricultural turnover involved a more fertile soils of high terraces. The sandy soils of the terraces causes significant harm not only change forest vegetation, but also subsequent plowing, which leads to the development of erosion processes. When changing natural vegetation and crops can dramatically reduce the amount entering the soil organic matter. This is due to almost double reduction of the number of underground mass in cultivated cereals at the expense of exclusion from the field of their overground parts. In addition, the change of forest ecosystems by agricultural lands greatly affects water, air and thermal regimes of soils. In the spring under the forest soil moist is better than plowing. Temperature fluctuations between the seasons are less pronounced under natural vegetation than in the fields. Thus, the change of the forest ecosystems on the cultural changes the character and direction of soil formation. These changes are compounded by agrotechnical and reclamation techniques used in the cultivation of agricultural crops. Plowing leads to disruption of the structure of the profile, especially in soils with low capacity of genetic horizons (gray steppe-forest, sod-forest soils). The result of the processing is the mixing of the soil mass, making the upper layers of homogeneous structure is destroyed, the physical properties deteriorate.

Conclusions

The result of the destruction of natural forests and subsequent ploughing up of steel erosion, especially on sloping topography. Light soils of the terraces are exposed to water and wind erosion. Parts of the first terraces above the floodplain is covered with sand, which are easily overcome by the wind and transferred to the surrounding fields. These areas in need of afforestation. High erosion terraces great value oak. Forest belts of oak enhanced the slopes of gullies and ravines.

Anthropogenic factor leads to the development of new processes that are not typical in natural conditions (mechanical stirring of the plow layer, removal of nitrogen and mineral nutrients with the harvest, anthropogenic introduction of substances, the formation of the technogenic layer, etc.), which leads to the formation of anthropogenic soils options.

For a long time the soil was formed under the influence of natural factors of soil formation and their evolution was done in conjunction with the conversion of these factors. Human-influenced landscapes are formed. All changes in the landscape are reflected in the soil profile. Unreasonable interference in the life of nature violates the centuries-old dynamic equilibrium between interrelated elements of landscapes and the natural laws of their development, reduces water, reduces mineral and increases the population of harmful organisms. Conversely, thoughtful attitude to nature contributes to the preservation and enhancement of natural resources.

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PRODUCTIVITY BIOMASS AGRO-ENERGY CROPS – SORGHUMS – TOLERANTS BY ENVIRONMENTAL CONDITIONS

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Abstract
Sorghum as a crop species has specific physiological predisposition for tolerance to unfavorable environmental conditions and has the ability to convert solar energy into biomass with high efficiency. The average mass of stem was 175.16 g. Genotype Dale had lower mass of stem compared to genotype NS sweet corn. Average panicle length was 18.20 cm. Genotype Dale had a longer panicle compared to the genotype NS sweet corn. The difference in length panicle between the genotypes NS corn sweet and Dala was not statistically significant. There is an evident correlation between the components of morphological characteristics: mass of stem, panicle length and environmental conditions. Mass stem was positively correlated with the panicle length and the temperature and the poor negative correlation with precipitation.

Keywords: Genotypes, Sorghum, climatic factor, correlation, morphological characteristics

Introduction
Biomass energy production is a very wide term which, among alia encompasses all forms of organic matter such as wood, organic matter herbaceous plants, agricultural crops, agricultural residues, aquatic vegetation, animal fertilizers, and communal solid waste. There are lot of plants that have the ability to convert solar energy into biomass with high efficiency, including herbaceous crops, fast-growing woody crops, fodder crops (alfalfa, clover, canary grass and Miscanthus), sugar crops (sugar cane, sugar beet, fibrous and sweet sorghum), cereals (corn, barley and wheat), and oilseed crops (soybean, rapeseed, palm, sunflower, safflower, canola and cotton) to allegations Lewandowski (2000) and Kresovic et al. (2016).
According to botanical classification of summary named Sorghums means the more plant species belonging to the genus Sorghum (Clayton & Renvoize 1986). One of these species is *S. bicolor*, which author de Wet (1978) includes annual and perennial cultivated and wild forms. According to modern classification, all sorghum grown in our area belong to the plant species *S. bicolor*. Per agronomic classification based on the method of cultivation and the use of *S. bicolor* is divided into so-called agronomic forms: grain sorghum, sorghum broomcorn, sorghum, sweet corn and Sudan grass (Sikora, Berenji, 2010a, 2010b, Sikora et al. 2012, 2013, 2014, 2015).
Sorghum as a crop of tropical origin has specific physiological predisposition for tolerance to unfavorable environmental conditions. The genetic potential for grain sorghum yield is still significantly limited due to the influence of abiotic stress. Stress caused by lack of moisture is the most important abiotic influence coma plants can be exposed throughout the growing season. At sorghum is observed and described several physiological factors of drought tolerance (Sikora et al., 2013, 2014). The term stress was performed from the Latin word stringers, which meaning limiting force. From the aspect of plant production, Grime (1979) defines stress as an external constraint that limits the level of dry matter production during the whole or part of the vegetation

under genetic potential. Jones and Jones (1989) as the response of plants to stress in the definition of the term production of dry matter replaced by the term economic yield.

Contemporary humankind over the past twenty years, faced with growing problems of global warming. Approval of the Kyoto Protocol in Japan (1997), are set targets for the reduction of greenhouse effect gas emissions at the international level. On 21 conference on climate change held in Paris, adopted a new global agreement. On imperative to reduce greenhouse effect gas emissions, and allowable temperature the growth to 1.5 ° C, starting from 2020 with the entry into the power, committed themselves 196 Member States, including the Republic of Serbia. The obligation of our country is that by 2030 reduce emissions by 9.8% compared to 1990.

One of the main causes of drought, which manifests itself as an insufficient amount of water in the soil to meet the needs of plants for normal growth and development, is the lack of the total amount of rainfall during the year and their distribution during the vegetation period of the plants and the intensity of atmospheric evaporation precipitates (Maksimovic et al., 2016). Monitoring and analysis of weather and climate conditions are essential for the analysis of the achieved yield and the quality obtained (Popović, 2010, Maksimovic et al., 2016,). On the ability to retain water in the soil also affects a series of agricultural measures: the choice of previous crop and cultivated species of a certain genotype, sowing date, circuit, fertilization, inter-row cultivation, irrigation and use of the preparation for the conservation of water (Maksimovic et al. 2016).

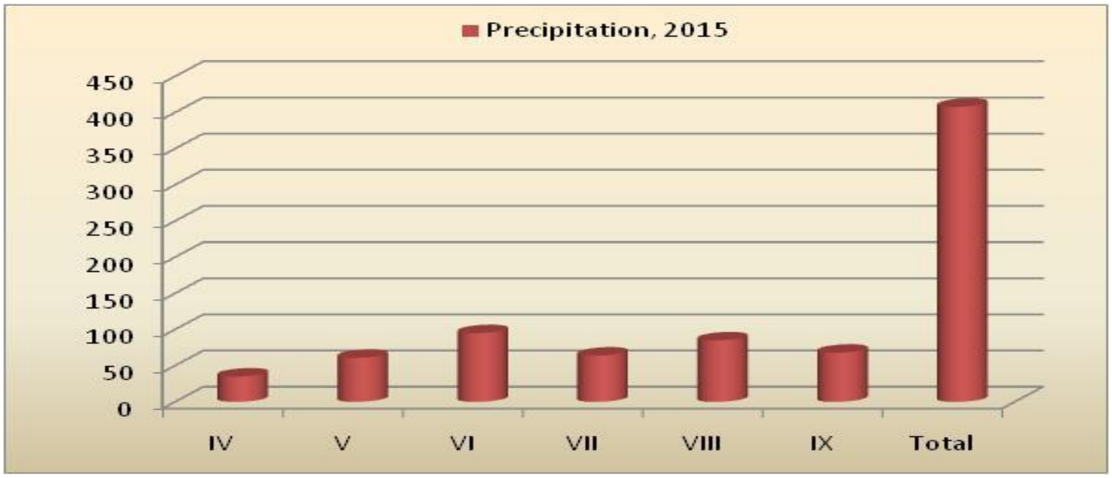
Due to the extremely high variability of the genus Sorghum is possible to create a hybrid for specific purposes, such as the high sugar content in the stem, and plants with high cellulose content are suitable for the production of bio-energy (renewable energy). With the intensification of agricultural production, part of the arable land is justified used to produce bioenergy (Pataki, 2012). The aim of this study was to determine the productivity of biomass sorghum on chernozem soil.

Material and Methods

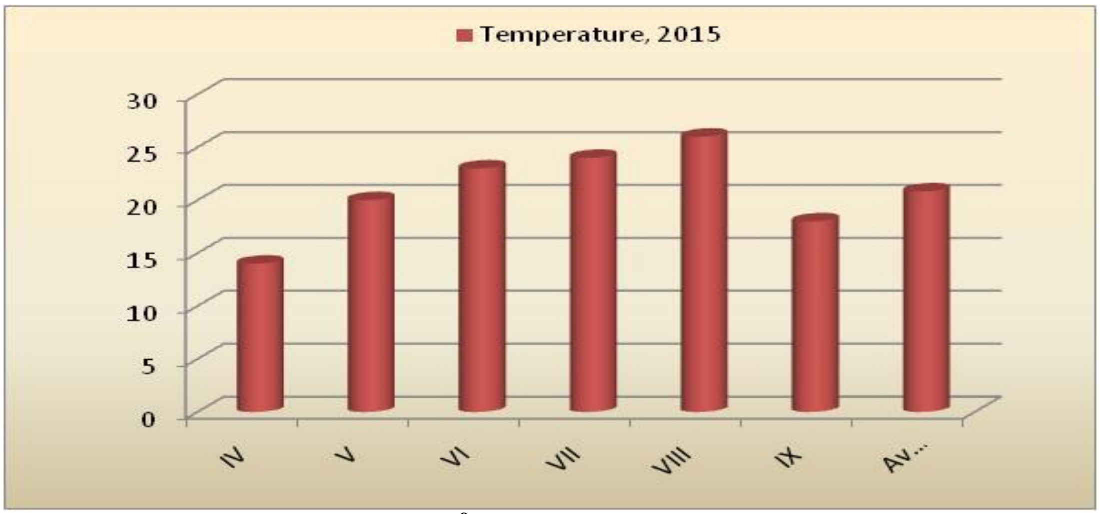
The experiment was carried out in 2015. was performed one factorial field experiment in Stara Pazova, Serbia, chernozem soil, according to a randomized block design with 5 replications. Basic plot size was 10 m^2 (5 m x 2 m). The subject of research were two genotypes of sweet sorghum: Dale and NS Sweet corn (NS Šećerac - In Serbian), created at the Institute of Field and Vegetable Crops in Novi Sad. Sowing was done in the third decade of April. Using standard cultural practices for growing grass. Mowing of plants was carried out at the stage start tasseling in the second decade of July. For the analysis of morphological characteristics (mass of stem and length of panicle) samples were taken from freshly mown biomass.

Meteorological data

Meteorological indicators - precipitation and thermal conditions during the vegetation period of the plants were obtained from the meteorological station Stara Pazova, graph 1 and 2. The quantity and distribution of rainfall varies from year to year, are unpredictable and changeable (Popovic, 2010, Glamoclija et al., 2015 Maksimovic et al, 2016). The total rainfall in the examined vegetation period was 408 mm while the average temperature amounted to 20.83 0C, graph 1 and 2.



Graph 1. Total precipitation, mm, IV-IX mount in 2015, Stara Pazova, Serbia



Graph 2. Average temperature, ^{0}C, IV-IX mount in 2015, Stara Pazova, Serbia

Results and Discussion

The average mass of stem was 175.16 g. Genotype Dale had lower mass of stem compared to genotype NS sweet corn. Difference in mass of stem between the genotypes NS sweet corn and Dala was not statistically significant, tab. 1 graph 3a. The standard deviation for the mass of stem was 9.14 and standard error 2.89, Table 1.

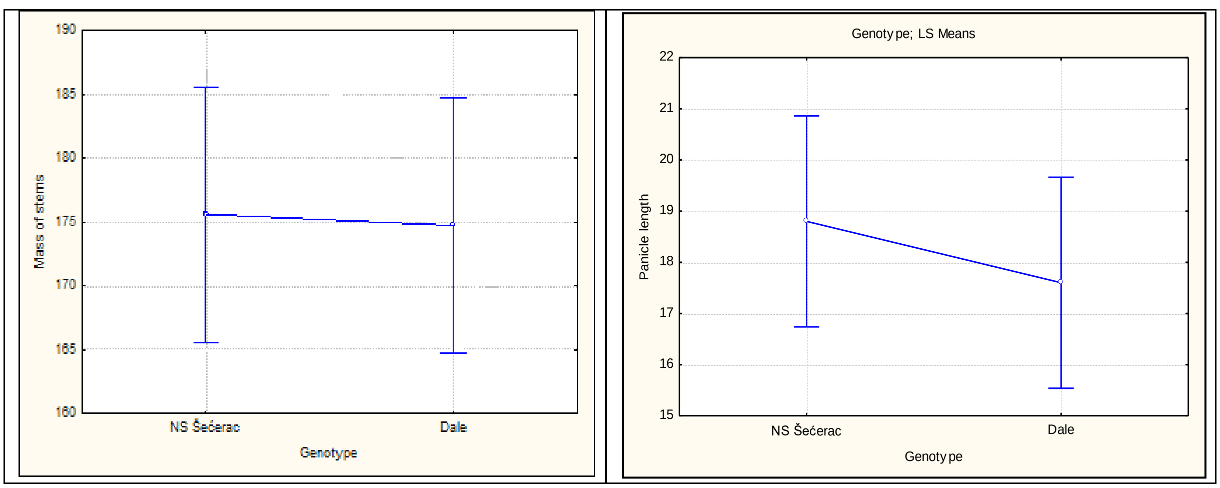
Average panicle length was 18.20 cm. Genotype Dale had a longer panicle compared to genotype NS sweet corn. Difference in the panicle length between genotypes NS sweet corn and Dala was not statistically significant, tab. 1 graph 3b. The standard deviation for the panicle length was 1.99 and standard error 0.62, Table 1.

Based on *Levene*'s Test for Homogeneity of Variances for genotypes had a significantly influence on the mass of stem, Table 2.

Table 1. The morphological traits of the genotypes of sorghum, Stara Pazova, Serbia

Parameters						
Mass of stems (g)						
Genotype	**No**	**Mean**	**Std. Dev.**	**Std. Err**	**-95.00%**	**+95.00%**
NS Sweet corn	5	175.59	12.37	5.54	160.22	190.96
Dale	5	174.72	5.85	2.62	167.46	181.98
Average	10	175.16	9.14	2.89	168.62	181.69
Panicle lenght (cm)						
Genotype	**No**	**Mean**	**Std. Dev.**	**Std. Err**	**-95.00%**	**+95.00%**
NS Sweet corn	5	17.60	1.64	0.73	16.76	20.84
Dale	5	18.80	2.30	1.03	14.74	20.45
Average	10	18.20	1.99	0.62	16.78	19.63

LSD Test	**Mass of stems**	**Panicle lenght**
0.5	14.12	2.92
0.1	20.54	4.25



a.) *b.)*

Graph 3. Average mass of stem (a) and Panicle lenght (b) of tested genotypes, Serbia

Table 2**.** Levene's Test for Homogeneity of Variances for Mass of stems and Panicle lenght

Levene's Test for Homogeneity of Variances; Degrees of freedom for all F's: 1, 8m; Effect: Genotype				
Mass of stems	***MS Effect***	***MS Error***	***F***	***p***
	79.953	*6.671*	*11.985*	*0.008*
Panicle lenght	*0.256*	*1.080*	*0.237*	*0.639*

Correlations of Mass of stem, Panicle length, Temperature and Precipitation

In order to improve sorghum production system, it is necessary to understand the relationships that exist between the individual factors and their impact on productive morphological characteristics of sorghum. It is evident that there is a correlation between the components of morphological characteristics: plant mass, length of panicle and environmental conditions. Mass stem was positively correlated with the panicle length and the temperature and the poor negative correlation with precipitation, table 3.

Table 3. Correlations between tested parameters

Parameter	***Mass of stem***	***Panicle length***	***Temperature***	***Precipitation***
Mass of stem	1.00	0.12 ^{ns}	0.23 ^{ns}	-0.39 ^{ns}
Panicle lenght	-	1.00	0.16^{ns}	-0.41 ^{ns}
^{ns} - non significant Marked correlations are significant at p < ,05000				

Similar results in experiments with broomcorn they had a Sikora et al., (2012, 2013, 2014, 2015). The authors allege that observed highly significant correlation between the components and the quality of panicle environmental conditions. Number of stems per panicle increases in conditions of higher daily air temperature, and decreases with increasing humidity. The authors state that the fineness is positively correlated with average daily air temperature and the total sum temperature during the growing season, while in humid conditions coefficient or smaller fineness.

Sorghum can be cultivated in different soil types (sandy soils, soil heavier texture), tolerates drought and high summer temperatures, better than most cultivated forage plant species. It has a strong root system strong suction power, which grows on those types of land for other plant species less suitable or have low yields. From land uses large amounts of nutrients to achieve high yield, yield responds well to fertilization and irrigation (Pataki, 2012).

Conclusions

The average mass of stem was 175.16 g. The genotype Dale had lower mass of stem compared to genotype NS sweet corn. Average panicle length was 18.20 cm. The genotype Dale had a longer panicle length compared to genotype NS sweet corn.

The recorded the relationship between the components of morphological characteristics: plant mass, panicle length and environmental conditions. Mass of stem was positively correlated with the panicle length and the temperature and the poor negative correlation with precipitation.

Sorghum as a crop species has specific physiological predisposition for tolerance to unfavorable environmental conditions and has the ability to convert solar energy into biomass with high efficiency.

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SIMILARITIES AND DIFFERENCES OF RURAL DEVELOPMENT IN THE REGIONS OF NORTHEASTERN CHINA AND FAR EAST OF RUSSIA

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Abstract
The impact of economic globalization on sustainable development has been more and more perceptible since the 21st century. Regions of Russia's Far East and Northeast China are the important regions affecting the sustainable development of the world because of their rich natural resources, good environment condition and large potential for economic development. Due to a number of historical and geopolitical reasons, the cooperation between Russia and China in the region of Northeast Asia is progressing, but at a quite slow speed and in unsustainable manner. The paper addresses some problems and challenges of sustainable rural development in the Heilongjiang Province, P.R.China and neighbor cross-border regions of Russia (Far Eastern Federal District and Siberian Federal District), investigates similarities and differences of rural way of life in those regions and discusses measures to promote the cooperation between two countries and ensure sustainable rural development in the selected regions.

Keywords: Far East, food security, Northeast Asia, rural development, rural territories

Introduction

Rural territories have strong natural, demographic, economic and cultural potential which rational usage may ensure sustainable development and high standards of life of rural dwellers in any country.

Over the transition period of 1990-2000s there were certain reforms implemented in agricultural production and land relations both in Russia and China, including in the sphere of rural development. According to Ivolga (2014), in Russia those reforms let to stabilize situation in rural areas during transition period. However, the globalized and urbanized world has brought social and economic sustainability of rural areas into increasingly challenged surroundings (Chen et al, 2016). In the case of China (as in many regions of Russia, especially those in the eastern part of the country), rural areas lag behind urban ones in terms of living standards and quality of life because of their low level of industrial development and urbanization. As of Heilig (2003), the economic boom in China during 200-2010s was mainly generated by urbanized coastal provinces in southern and eastern parts of China. Rural areas in the northern parts of the country, on the contrary, experienced little economic growth after the first wave of development in the early 1980s, when family farming was re-introduced after decades of centrally planned agricultural communes (Chen and Fleisher, 1996).

In Russia, too, gaps in infrastructural development between rural and urban (even suburban) areas are continuing to grow. Number of rural settlements in the eastern parts of the country, especially in the Far East, goes down because of huge migration outflow from rural areas to cities. Migration brings together related negatives: ageing of population, lack of labour of high qualification, degradation of population, growing social tensions, abandonment of rural settlements and agricultural lands, lowering effectiveness of agricultural production, and growing environmental load because of outdated machineries and low culture of farming.

Two countries, China and Russia, have much in common in the sphere of rural development, especially in those districts which are not very much industrialized and lay outside the economically developed southern and southeastern coastal provinces (in the case of China) and central regions of Russia. Contemporary rural development policies are much broader than they used to be in the early 2000s. They shifted from agriculture itself to a broader spectrum, which included social and economic situation in rural territories, development of rural infrastructure, employment and involvement of rural households into economic activities, rural tourism and other alternative sources of income, environmental and recreational issues, etc (Erokhin, 2014). Effectiveness of such policies directly affects living standards of rural people, social and demographic situation in rural areas, national food security, social and economic control over rural territories, and development of traditional cultures and rural way of life (Ivolga, 2014).

Material and Methods

Northern China can be divided into northeast, north, and northwest region. They are also considered as province-level administration areas and consist of fourteen provinces, including Heilongjiang, Jilin, Liaoning, Beijing, Tianjin, Hebe, Inner Mongolia, Shanxi, Shandong, Ningxia, Shaanxi, Gansu, Qinghai, and Xinjiang (Ma, 2011).

Russia's Far Eastern Federal District is composed of nine regions, which are Republic of Sakha (Yakutia), Kamchatsky Krai, Primorsky Krai, Khabarovsky Krai, Amurskaya Oblast, Magadanskaya Oblast, Sakhalinskaya Oblast, Jewish Autonomous Oblast, and Chukotsky Autonomous District.

For the purpose of this research we will study the Heilongjiang Province located in the northeast part of China, since the province directly borders with Primorsky Krai, Khabarovsky Krai, Amurskaya Oblast, Jewish Autonomous Oblast, and Zabaykalsky Krai of the Siberian Federal District of Russia (Figure 1).

Figure 1. Map of Far East of Russia and Northeastern China
Note: 1 is for Jewish Autonomous Oblast, Russia
Source: Author's development based on
https://upload.wikimedia.org/wikipedia/commons/8/82/Heilongjiang_in_China.svg

For the purposes of the current research we have primarily addressed the works related to analysis of local specifics of rural development and unique economic, social and environmental features of certain regions (Merzlov, Ovchintseva and Popova, 2012; Zhou et al, 2007). Regional specifics of sustainable development of rural areas in the northern and eastern parts of China are obtained from the works of Ma (2011), Chen and Fleisher (1996), and Chen et al (2016), while overview of contemporary issues of sustainable rural development in Russia in terms of existing differences between regions is made based on the works of Ivolga (2014) and Zhuplei (2015).

Data for Russia's regions of Far East are obtained from the State Council of the Russian Federation (2015) and www.regnum.ru. For China we have used two major online sources which are www.stats.gov.cn and www.statista.com.

Results and Discussion

Rural population in both Russia and China is decreasing. During the decade of 2004-2014, number of rural dwellers in Russia decreased by 1.7% (from 38.62 mln people in 2004 down to 37.98 mln people in 2014), in China – by 18.3% (from 757.05 mln people in 2004 down to 618.66 mln people in 2014) (Table 1).

Table 1. Rural population in China and Russia in 2004-2014, mln people

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
China	757.05	745.44	731.60	714.96	703.99	689.38	671.13	656.56	642.22	629.61	618.66
Russia	38.62	38.42	38.13	37.88	37.82	37.78	37.44	37.31	37.23	37.12	37.98

Source: State Council of the Russian Federation, 2015; www.statista.com

China is now experiencing the “rural flight”, when fewer people are needed to bring the same amount of agricultural output to market, and related agricultural services and industries are consolidated. Rural flight is exacerbated when the population decline leads to the loss of rural services (such as business enterprises and schools), which leads to greater loss of population as people leave to seek those features. surplus labor in rural areas due to higher average fertility rates, and improved living conditions all play a role in contributing to the flows of migrants from rural to urban areas

Until 1983, the Chinese government, through the hukou system, restricted the ability of the citizens to internally migrate. A hukou is a record in a government system of household registration required by law in mainland China and Taiwan, and determines where citizens are allowed to live. Since 1983, the Chinese government has slowly lifted the restrictions upon internal migration leading to a great increase in the number of internal migrants, especially from rural areas towards the urbanized regions.

Despite the easier regime, even today, the hukou system limits the ability of rural migrants to receive full access to urban social services at the urban subsidized costs. Share of rural population in total population in China is much higher in comparison to Russia (Table 2). Over 42% of population of Heilongjiang Province lives in rural areas, while in neighbor regions of Russia – only 24.64% (Far Eastern Federal District in total, average).

Table 2. Share of rural population in total population in the selected regions of China and Russia in 2014, %

Country / region	2014
China, total	45.23
Heilongjiang Province	42.60
Russia, total	26.03
Far Eastern Federal District of Russia, total	24.64
Republic of Sakha (Yakutia)	34.71
Kamchatsky Krai	22.45
Primorsky Krai	23.11
Khabarovsky Krai	18.17
Amurskaya Oblast	32.70
Magadanskaya Oblast	4.58
Sakhalinskaya Oblast	18.63
Jewish Autonomous Oblast	31.73
Chukotsky Autonomous District	31.45
Siberian Federal District of Russia, total	27.39
Zabaykalsky Krai	32.61

Source: State Council of the Russian Federation, 2015; www.regnum.ru; www.stats.gov.cn

Amid high birth rate which ensures reproduction of rural population on a progressively increasing scale, both Heilongjiang Province in China and regions of Far Eastern Federal District of Russia experience common problems related to low life expectancy in rural areas and outflow of employable population to more urbanized and developed territories. In Russia, despite the growing crude birth rates, number of regions with natural rural population increase is only 34, which is about 41%.

Table 3. Grouping of Russia's Far Eastern regions on natural increase (decline) of rural population in 2014.

Groups on natural increase/decline of population	Regions
Natural increase	Republic of Sakha (Yakutia); Zabaykalsky Krai; Khabarovsky Krai; Jewish Autonomous Oblast; Chukotsky Autonomous District
Natural decline	
Including mortality/birth rate:	
below 120%	Altaysky Krai; Amurskaya Oblast; Primorsky Krai
120-150%	Kamchatsky Krai; Magadanskaya Oblast; Sakhalinskaya Oblast

Source: Author's development based on State Council of the Russian Federation, 2015; Ivolga, 2014

Depopulation of rural areas is partly caused by unemployment. In China, about 40% of total employment is in rural areas. The poorest rural households tend to derive a large share of their income from agricultural activities, which often show low levels of productivity and net profits. In Russia, employment in agri-industrial sector had been decreasing during 2004-2014, while employment in non-agricultural industries had been increasing. Share of agriculture-related industries in rural employment is very much affected by natural and environmental factors. As environmental conditions for agricultural production get worsened, the share of agriculture in rural employment decreases.

Unemployment rates in rural areas in Russia's regions of Far East vary (Table 4). Some regions had 10% in 2014, while others ended up with 20%. Average unemployment rate in Russia in 2014 was 6%.

Table 4. Grouping of Russia's Far Eastern regions on unemployment in rural areas in 2014.

Level of unemployment in rural areas, %	Regions
Below 10	Kamchatsky Krai; Chukotsky Autonomous District; Magadanskaya Oblast; Sakhalinskaya Oblast
10-20	Republic of Sakha (Yakutia); Altaysky Krai; Zabaykalsky Krai; Khabarovsky Krai; Primorsky Krai; Amurskaya Oblast; Jewish Autonomous Oblast

Source: Author's development based on State Council of the Russian Federation, 2015; Ivolga, 2014

Merzlov, Ovchintseva and Popova (2012) developed the classification of Russia's regions, which included four types and nine subtypes of regions depending on the character of rural development, utilization of available agricultural and environmental resources, level of social and demographic development, and threats to sustainable development of rural areas. Far Eastern regions of Russia are included into the Subtype 3c ("poor social and natural conditions") and are characterized by a combination of unfavorable social and environmental conditions. Density of rural population is very low (2 inhabitants per square km in average). Agricultural production is not a predominant type of rural activities, since many people are involved into forestry and mining.

Republic of Sakha (Yakutia), Kamchatsky Krai; Chukotsky Autonomous District; Magadanskaya Oblast; Sakhalinskaya Oblast are related to Type 4 ("low level of territorial development"). Those are north-eastern parts of Russia with area of 62% of Russia's territory and population of only 6% of total population. The regions are not heavily involved in agricultural production, and their impact into the national gross agricultural production is very small. Rural people in those regions are employed in forestry and mining. Agricultural production is supported by regional and federal budgets. Bankruptcy of forest-industry enterprises, high unemployment and migration outflow create serious threats to development of rural areas.

According to this classification, northern-eastern provinces of China, namely Heilongjiang Province, can also be referred to as Type 3 ("relatively unfavorable conditions"), as Russia's regions of Far East. According to Zhou et al (2007) and Ma (2011), the land infertility is a severe issue and a plenty of land in the northern parts of China is in arid, semiarid or desert regions. Moreover, environment in northern China is vulnerable due to serious soil erosion, soil desertification, shortages of agricultural water resources and lowering of groundwater levels. Based on this kind of natural environment, agricultural productivity is comparatively low in comparison to than that of southern China (Ma, 2011).

Another problem in China's rural areas, pointed out by Heilig (2003), is the structure of agriculture. He indicates that the average farm size in China is extremely small, which limits market opportunities for farmers. As a consequence, rural people have very little monetary income and have to find nonagricultural labor in the urban areas to gain enough money. The problem is that a large part of China's agriculture is traditional subsistence farming, which contributes little to a modern economy (Heilig, 2003).

Experiencing unfavorable environmental conditions of agricultural production, suffering from a rural flight and high unemployment rates, facing a lot of internal structural problems, Russia and China have to make every possible effort to develop diversification of rural economy, support farmers and alternative forms of employment and self-employment, including local crafts and rural tourism. The set of measures has to include implementation of rural development issues into the national and regional development strategies; consideration of tasks of sustainable rural development in the rural area planning schemes; improvement of rural infrastructure, including transport and communications; analysis of environmental problems and existing threats to sustainable environmental development; elaboration of measures to secure biodiversity; expand special support measures, such as for young people and families, in order to retain them in rural areas; increase of investment attractiveness of rural areas in general and rural settlements in particular as local centers of rural development.

Conclusions

Diversification of rural economics and expansion of income opportunities for rural inhabitants are the key tasks on the way to increasing the sustainability of rural. Agricultural production in both Russia and China operates in rather complicated social, economic and environmental conditions. Elaboration and implementation of targeted development programs and regionalized state policies are required for ensurance of sustainable rural development of the Far Eastern regions of Russia of Subtype 3c ("poor social and natural conditions") and Type 4 ("low level of territorial development"), as well as Heilongjiang Province of China of Type 3 ("relatively unfavorable conditions").

Aims of such policies are:

- creation of favourable social and economic conditions for performance of national and territorial development functions by rural areas;

- stabilization of rural population size and creation of conditions for its sustainable growth by means of lower mortality, increasing life expectancy, and decreasing of migration outflow;
- development of employment opportunities, increase of social standards of living and welfare with due consideration of internationally recognized standards;
- performance increase of agricultural production and bigger impact of rural areas into the social and economic development of Far East of Russia and Northern East of China.

In our opinion, the relevant state policies in the sphere of ensurance of sustainable rural development in the considered regions of Russia and China have to be based on the following principles:

- approach to development of rural areas as entire territorial complexes which perform important social functions and impact to the social and economic development of Russia and China;
- assurance of rights of those people living in rural areas, including ensurance of access to state and municipal services of adequate quality;
- usage of various forms of state support for ensurance of favourable conditions of social and economic development of rural areas and utilization of existing economic, demographic and natural potential;
- partnership between the state, local authorities in the regions, business and rural dwellers;
- differentiated approach to development of rural areas in various regions of Russia's Far East and Chinese Northeast, consideration of local peculiarities and their effects on agricultural production and rural areas in general. The goal here is to minimize differences between regions in terms of living standards of rural dwellers, employment opportunities, development of infrastructure, etc.;
- development of links between rural areas and cities, integration of rural areas into a common economic system on a basis of agricultural and industrial cooperation, development of modern effective forms of agribusiness;
- investment projects in agricultural production coupled with development of social and engineering infrastructures in rural settlements;
- rational use of natural resources, preservation and development of agricultural landscapes, environmental protection of rural areas;
- creation of better living conditions in rural settlements.

Sustainable regional and rural development in both Russia's Far East and Chinese Northern East is only possible, if the regional diversity is taken into account in development concepts (Heilig, 2003). Like Russia, China has all possible extremes in climate, population, and infrastructure availability. It is therefore essential, that detailed regionalized analyses are undertaken for understanding the specific development constraints and options of various regions, their similarities and differences, and those social and economic conditions that determine a development potential of rural areas in those regions.

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MICROPROPAGATION AS AN INPORTATNT FACTOR IN THE GROWTH AND DEVELOPMENT OF *MISCANTHUS* SPECIES

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Abstract
Several grass species of the genus *Miscanthus* are considered to be outstanding candidates for a sustainable production of biomass to generate renewable energy. The purpose of this study was to investigate the effects of genotype, the developmental stage of the explant donor inflorescence and the induction medium on the success rate of micropropagation. The experiments were conducted on two genotypes of *Miscanthus* (*Miscanthus sinensis* × *giganteus* and *Miscanthus sinensis* TATAI). Explants from the youngest inflorescences (0.5–2.9 cm in length) showed a significantly higher callus induction rate than those from more developed inflorescences (3.0–5 cm in length). In addition, cultures initiated from explants from the youngest inflorescences showed significantly the highest rates of callus regeneration and the highest shoot regeneration rate. The best shoot regeneration was from calli initiated from the youngest inflorescences when cultured on the Murashige and Skoog basal medium (MS3) with 5 mg l^{-1} 2,4-dichlorophenoxyacetic acid (2,4-D) and 1,430 mg l^{-1} proline. In *M.* × *giganteus,* we have observed the maximum CIR value of 9.8, while the maximum genotypic CIR values for different accessions of *M. sinensis* TATAI ranged from 5.8. This demonstrates that, with some adjustments, efficient micropropagation of *Miscanthus* sp. is feasible.

Keywords: micropropagation, *Miscanthus* sp., medium cultivation, donor inflorescence

Introduction

Species from the genus *Miscanthus* are perennial giant grasses from East Asia, some of which were introduced to Europe from Japan in 1935 (Greef and Deuter 1993; Linde-Laursen 1993). Because of their C4 type photosynthesis and high water-use efficiency, they tend to offer a very high potential for biomass production. A *Miscanthus* crop is potentially an efficient, sustainable, multifunctional and environmentally friendly biomass producer, making it very suitable and promising for the production of biofuels and fibre in Europe (Lewandowski and Schmidt, 2006). In the near future, grasses from the genus *Miscanthus* will likely play an important role in sustainable agriculture (Christian et al., 2008, Jureková et al., 2012).
Within the genus, *M.* × *giganteus* and *M. sinensis* TATAI are considered to be the most valuable for biomass production. Of the two, *M.* × *giganteus* is a sterile triploid hybrid between diploid *M. sinensis* and tetraploid *M. sacchariflorus* (Linde-Laursen 1993); *M. sinensis* is fertile but self-incompatible and produces highly variable progeny. Hence, for both species, vegetative propagation is the only method for a commercial-scale multiplication of plants. Species of *Miscanthus* have been propagated by rhizome division or by in vitro micropropagation. Despite a number of reports on the in vitro culture of *M. x giganteus* (Holme and Petersen 1996; Petersen 1997; Petersen et al. 1999), there is, as yet, no well-established or recommended method for the in vitro micropropagation of various *Miscanthus* species that would be suitable for commercial production (Filová, 2015).

In the present study, the micropropagation effectiveness of *M.* × *giganteus* and *M. sinensis* TATAI genotypes were studied. The experiments conducted were performed using the existing micropropagation techniques for *M.* × *giganteus* with a range of modifications and with several newly established culture media for callus induction. In the process, the genotypic, developmental and culture medium effects were tested.

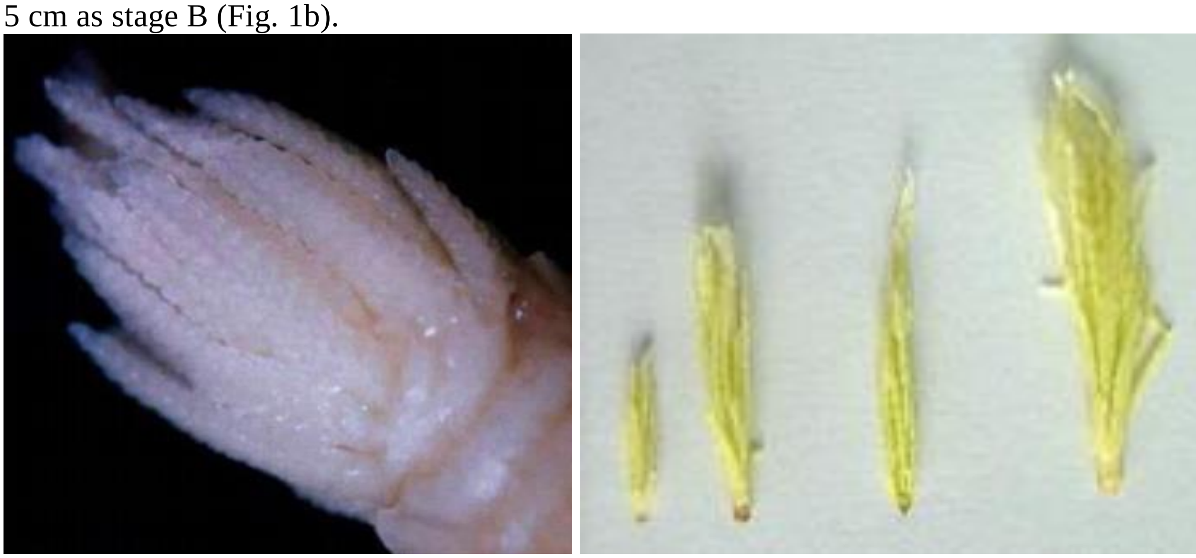
Material and Methods

Plant material

The experiments were conducted on two genotypes of Miscanthus (Miscanthus sinensis × giganteus Greef et Deu. and Miscanthus sinensis TATAI.

In vitro culture

Cultures were initiated between May and June from tillers collected from plants grown without fertilization. The tillers had inflorescences ranging in length from 0.1 to 5 cm. The uppermost stem segments were cut at 1–2 nodes below the base of inflorescences. All foliage, except for 3–4 leaves outside the inflorescence, was removed. Cut stem segments were surface-sterilized for 20 min with 10% commercial ACE bleach (0.45% sodium hypochlorite) and rinsed three times in sterile water. To test the efficacy of in vitro culture, 1-mm segments of immature inflorescences were used as explants. Immature inflorescences ranging in length from 0.5 to 2.9 cm were classified as developmental stage A (Fig. 1a, b) and those in the size range 3.0–5 cm as stage B (Fig. 1b).



(a) **(b)**

Fig. 1 Micropropagation of *Miscanthus* through inflorescences delivered callus: (**a**) and (**b**—first four on the *left*) inflorescences at the developmental stage A; (**b**—first on the *right*) inflorescences at the developmental stage B;

The explants were cultured on 4 callus induction media, labeled M1–M4 (Table 1). These were based on either the B5 medium of Gamborg et al. (1968), the SH medium of Schenk and Hildebrandt (1972) or the MS medium of Murashige and Skoog (1962). The M3 medium contained MS medium supplemented with 5 mg l^{-1} 2,4-dichlorophenoxyacetic acid (2,4-D) and 1,430 mg l^{-1} proline according to Holme and Petersen (1996). All media were adjusted to pH 5.70–5.75 prior to the addition of 0.8% agar and were autoclaved at 121°C for 20 min.

Table 1 Composition of the media used for the induction of callus

Medium	Basal medium	Plant growth regulator (mg l^{-1})			
		2,4-D	BA	KIN	Proline
M1	B5	2.5	1	–	–
M2	SH	0.75	–	0.5	–
M3	MS	5	–	–	1,430
M4	MS	5	0.1	–	–

Plant regeneration from callus occurred on the MS medium supplemented with 2 mg l^{-1} BA (Holme and Petersen 1996) under a 16-h photoperiod (100 µmol m^{-2} s^{-1}). Twenty percent of randomly chosen k1 callus pieces were transferred to the regeneration medium for 4 weeks, transferred to fresh medium for another 4 weeks and scored for the numbers of regenerated callus and shoots. For root induction, single shoots were transferred to the MS medium with 1 mg l^{-1} 1-naphthaleneacetic acid (NAA) and kept at a 16-h-photoperiod regime for at least 2 weeks.

After 12 weeks of callus induction, the number of callus pieces and the number of pieces of each of the four callus classes were scored. The callus induction rate was calculated as the number of callus pieces per number of explants (CIR). After 8 weeks of the k1 callus growth on the regeneration medium, the number of k1 calli showing regeneration was recorded, as well as the number of regenerated shoots per callus. These numbers were used to calculate two parameters of the regeneration success rate: callus regeneration percentage (CRP, the ratio of the number of calli with shoots vs. the number of calli transferred to the regeneration medium multiplied by 100) and the shoot regeneration rate (SRR, the number of shoots obtained per callus piece).

Results and Discussion

Given the absence of effective seed propagation in *Miscanthus*, an efficient micropropagation protocol is a prerequisite for its commercial biomass production. This study represents the first attempt to evaluate the genetic, developmental and media composition effects on the effectiveness of micropropagation in *M. sinensis*. The results appear promising. In *M.* × *giganteus*, we have observed the maximum CIR value of 9.8, while the maximum genotypic CIR values for different accessions of *M. sinensis* TATAI ranged from 5.8. The Newman–Keuls comparison of means showed that, among the studied genotypes *M.* × *giganteus* had significantly the highest CIP, by *M. sinensis* TATAI (Table 2).

Among the 4 tested induction media, M3 had the highest CIR, with 8.6 callus pieces/explant, while M1 and M4 had the highest frequency of shoot-forming callus.

In this study, a higher effectiveness of micropropagation was observed for younger inflorescences (0.5–2.9 cm in length). Such inflorescences are clearly an excellent source of explants, perhaps because of the proportionately larger amount of meristematic tissue. This is in agreement with a previous study on micropropagation in *M.* × *giganteus* (Lewandowski 1997), which also reported immature inflorescences of *M.* × *giganteus* to be the best organ for callus induction, with a relatively fast production of up to 280 explants per inflorescence. Additional advantages of the inflorescence explants are a low rate of contamination and little browning of the medium. The highest callus induction and shoot regeneration in our studies were observed for the explants from the youngest inflorescences (stage A).

Table 2 Influence of genotype, developmental stage of inflorescence and induction medium on the callus induction rate (CIR) and frequency of callus classes (k1, k2, k3 or k4)

Factor	CIR	Frequency of callus class (%)			
		k1	**k2**	**k3**	**k4**
Genotype					
M. sinensis TATAI	5.8 c[1]	16.7 a	5.6 b	27.6 b	0.5 c
M. × *giganteus*	9.8 a	25.1 c	10.1 c	16.9 c	25.4 a
Developmental stage of inflorescence					
A	6.4 a	50.9 a	5.8 a	24.9 a	18.4 b
B	5.6 b	42.1 b	4.8 a	27.6 a	25.5 a
Medium					
M1	3.4 c	60.3 a	1.9 c	8.8 c	28.9 a
M2	3.1 d	43.7 bc	13.7 a	29.5 b	13.0 c
M3	9.7 a	36.0 c	1.6 c	33.2 a	29.2 a
M4	6.3 b	52.2 b	6.0 b	21.0 b	20.7 b

[1]For the individual factors, mean values in each column marked with the same letter do not differ significantly ($P = 0.05$) according to the Newman–Keuls test

The combination of M3 (the MS medium supplemented with 5 mg l^{-1} 2,4-D and 1,430 mg l^{-1} proline) gave the highest CIR (9.7) of all the media tested, but other media, notably M4, also promoted good callus formation, with CIR values of 6.3 and 3.1, respectively. For both types of tested explants, medium supplemented with proline (M3 combination) noticeably reduced the excretion of the media-browning substances by the explants. Holme et al. (1997) noted the same effect in *M. x giganteus* when using the MS medium with 5 mg l^{-1} 2,4-D, supplemented with various concentrations of proline. Enzymatic browning in plant in vitro culture may be delayed or reduced by polyphenol oxidase inhibitors. Proline is thought to inactivate the polyphenol oxidase (Öztürk and Demir 2002). Additional organic components supplementing basal media with, e.g. proline, serine or casein hydrolysate, increased morphogenic callus induction in many grass species (Trigiano and Conger 1987; Wang et al. 2002). In this study, 12.5 mM proline (1,430 mg l^{-1}) was required to reduce medium browning. Supplementing the medium with proline, however, did not increase the frequencies of the k1 and k2 classes of callus. Similar studies in *M.* × *giganteus* with proline in the callus induction medium at concentrations of 12.5, 25 or 50 mM did, however, increase embryogenic callus formation in shoot apex and leaf explants (Holme et al. 1997). In contrast, no difference in embryogenic callus formation was observed when culturing immature inflorescences at proline concentrations ranging from 0 to 100 mM.

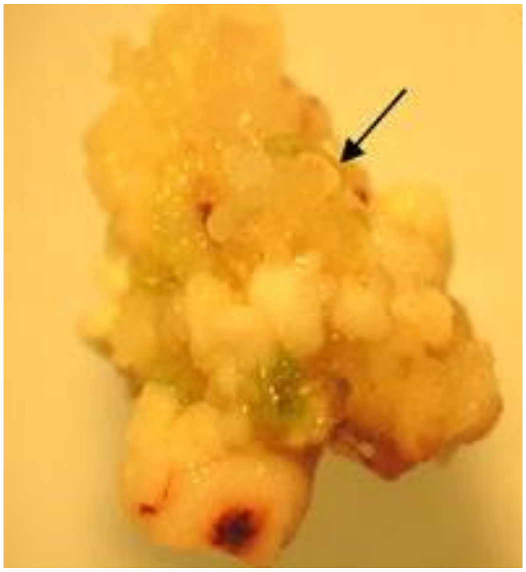
Callus regeneration

Among the 2 genotypes tested, *M. sinensis* TATAI gave the highest CRP (35.4%) and *M.* × *giganteus* 17.8 (Table 3). Callus from explants derived from relatively mature inflorescences (stage B) had a relatively poor regeneration ability. Additionally, the effectiveness of callus regeneration was also strongly affected by the callus induction medium used prior to shoot regeneration. Callus generated on the MS basal medium supplemented with 5 mg l^{-1} 2,4-D and 1,430 mg l^{-1} proline (M3) had the highest CPR (29.7%) and SRR (1.3). With the exception of M4, callus induced on all tested media had a higher regeneration capacity when young inflorescences were used.

Table 3 Influence of genotype, developmental stage of inflorescence and induction medium on the callus regeneration percentage (CRP), number of regenerated shoots and shoot regeneration rate (SRR)

Factor	**CRP**	**No. of regenerated shoots**	**SRR**
Genotype			
M. sinensis TATAI	35.4 a[1]	1,172	2.0 a
M. × *giganteus*	17.8 b	395	0.7 b
Developmental stage of inflorescence			
A	23.1 a	1,825	1.6 a
B	14.6 b	1,065	0.9 b
Callus induction medium			
M1	6.4 c	259	0.6 c
M2	17.8 b	273	0.7 c
M3	29.7 b	626	1.3 b
M4	12.9 b	329	0.7 c

[1]For the individual factors, mean values in each column marked with the same letter do not differ significantly ($P = 0.05$) according to the Newman–Keuls test



(a)

Fig. 2 Micropropagation of *Miscanthus* × *giganteus* delivered callus: (a) shoot-forming callus (arrow) – k1

Conclusions

This study has implications for the introduction of new *Miscanthus* genotypes to the commercial market. For *M. sinensis*, using 5-mm inflorescence explants in the developmental stage A and on the MS medium containing 5 mg l^{-1} 2,4-D and 0.1 mg l^{-1} BA, about 19 plants can be produced in 22 weeks from a single explant. Under the same conditions, one *M.* × *giganteus* explant is expected to yield about 4.8 plants. At these rates, to establish a 1 ha plantation of *Miscanthus* at the density of one plant per square meter, 519 or 2,070 inflorescence explants need to be cultured for *Miscanthus* genotypes, respectively.

Acknowledgements

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MULTIPLICATION OF MISCANTHUS GRASS BY *IN VITRO* TILLERING

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Abstract

Miscanthus ×giganteus is considered an interesting energy plant with high biomass production for the commercial use. Plants are able to be propagated by a vegetative way only, mainly by rhizome division. This method is slow and limits the expansion of plant cultivation. Propagation under *in vitro* conditions is a method that enables fast multiplication of plant material through the year. In this work, we optimised plant multiplication by the method of *in vitro* tillering. New shoots were developed from axillary buds and multiplied on media with cytokinins BAP or Thidiazuron. Rooting of shoots was positively affected by the addition of auxin NAA or IAA. Plants of miscanthus grass produced in explant culture were successfully acclimatised to field conditions and they did not differ from rhizome developed plants in biomass production.

Keywords: *Miscanthus × giganteus*, micropropagation, axillary bud, *ex vitro*

Introduction

Genus *Miscanthus* includes perennial giant grasses belonging to C4 plants with high photosynthesis efficiency. *Miscanthus × giganteus* Greef et Deu, which is the most valuable for biomass production (Xue et al., 2015), is naturally occurring triploid hybrid (2n=57) of *M. sinensis* (2n=38) and *M. sacchariflorus* (2n=76) sampled in 1935 by A. Olson in Yokohama, Japan, cultivated in Denmark and spread out over middle Europe (Greef et al., 1997). It is considered environmentally friendly producer of biomass, biofuel, lignin and lignocellulose. Due to low moisture content during harvesting, biomass is suitable for direct combustion without the need for drying. The yield potential of miscanthus grass exceeds the capabilities of the natural plant species in Slovakia, including fast-growing trees. *Miscanthus× giganteus* is a triploid hybrid which doesn't produce fertile seeds. Plants are usually propagated by rhizome division, but rhizomes production is slow and the success of establishment of new crops is strongly affected by the age of mother plant. Plant tissue culture is an alternative way to prepare necessary amount of propagules within a relatively short time. First works oriented to micropropagation of *M. × giganteus* via callus from immature inflorescence were published by Holme and Petersen (1996) and Lewandowski (1997). Recently, the method is used in praxis, however, multiplication by rhizomes is still predominant (Boersma and Heaton, 2014).

The aim of our work was the optimization of *in vitro* multiplication of miscanthus grass by the method of *in vitro* tillering, omitting the callus phase.

Material and Methods

The *in vitro* culture of *Miscanthus × giganteus* was initaited from nodal segments containing an axillary bud. Nodal segments were taken from one-year-old plants grown in pots with a garden substrate. Stem segments 4 cm long were rinsed under tap water for 10 min, then in 97% denatured EtOH for 2 min. Washed segments were sterilized in commercial bleach containing 4% of NaOCl and rinsed 4 times in sterile distilled water. Central parts of segments with axillary bud were cultivated in the MS medium (Murashige and Skoog, 1962) with 30 g l^{-1} sucrose and 0.4 mg l^{-1} BAP solidified with 2.5 g l^{-1} of Gelrite. L-cysteine HCl in dose 50 mg l^{-1} was added into the medium to prevent explant browning and the subsequent necrosis of the explants. Explants were cultivated in a cultivation room with a photoperiod 16 h light/8 h dark with (the light intensity 50 µmol m^{-2} s^{-1}) and the temperature 24/20°C.

Regenerated shoots were used in multiplication experiments. Three cytokinins – BAP, Thidiazuron (TDZ) and kinetin (KIN) in dose 1 mg l^{-1} were used to induce *in vitro* tillering of explants. The most effective dose of cytokinins BAP (1, 2 and 4 mg l^{-1}) and TDZ (0.5, 1 and 2 mg l^{-1}) was tested in the next experiment. For rooting of regenerated shoots, 1 mg l^{-1} of auxins NAA or IAA was added into the medium. Each experiment was evaluated after 6 weeks of cultivation under conditions mentioned above.

Rooted shoots were transplanted to soil and acclimatised to *ex vitro* conditions. First two week the plants were cultivated under the plastic cover at 15°C, during the third week the plants were gradually uncovered and the temperature was increased up to 20°C. Six weeks old plants were transplanted to the field in the locality Piešťany (west part of Slovakia). Growth parameters (number of shoots, shoot diameter, and plant height) and the biomass production were measured in the spring of the third year of cultivation and compared with rhizome-developed plants.
Experimental data were analysed by ANOVA and means were then separated by LSD test (the least significant difference) at $\alpha = 0.05$ using the statistical software STATGRAFICS Centurion XVI.II.

Results and Discussion

Isolated nodal segments with axillary bud regenerated shoots during 4 weeks on the induction medium. For shoot multiplication, three different cytokinins were compared. There were observed statistically significant differences among them. The highest multiplication coefficient was observed on the medium with TDZ (fig. 1A). Although a slightly lower number of shoots was produced on medium with BAP, the shoots were more robust and their fresh weight was higher in comparison with TDZ (fig. 1B). An effective dose of cytokinins was 0.5 mg l^{-1} of TDZ (fig. 2A) or 2 mg l^{-1}BAP (fig. 2B). An increase of these doses did not improve multiplication anymore. While several reports on miscanthus micropropagation via callus culture was published (Holme and Petersen, 1996; Lewandowski, 1997; Glowacka et al., 2010), the *in vitro* tillering was only seldom described (Nielsen et al., 1995; Lewandowski, 1997). Lewandowski (1997) described shoot regeneration from apical meristems and observed the highest multiplication of shoots on medium with 3 mg l^{-1} BAP combined with 0.45 mg l^{-1} IAA. Nielsen et al. (1995) described the positive synergic effect of BAP and TDZ on shoot multiplication and the uniform shoot size produced.

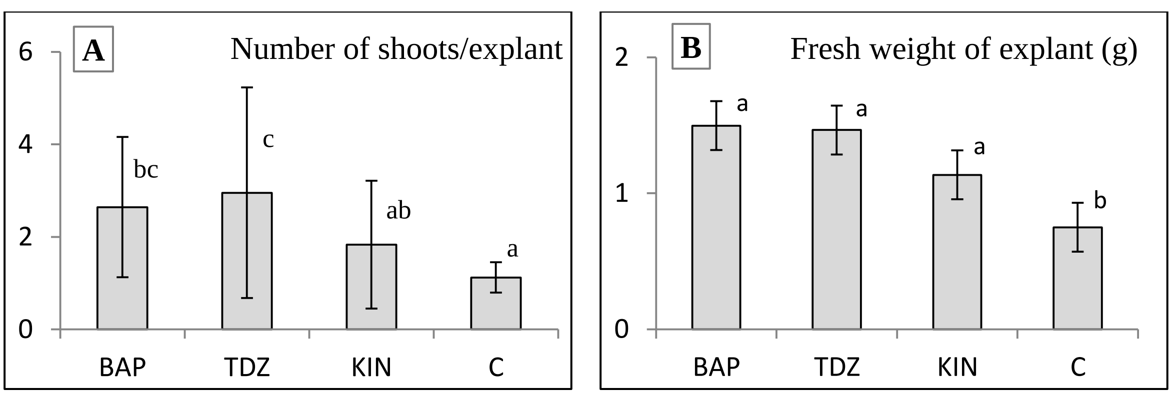

Fig. 1: Multiplication of *Miscanthus* × *giganteus* in explant culture. *A*) Number of shoots per explant and *B*) the fresh weight of explants (g) on media with different cytokinin: BAP, Thidiazuron (TDZ) and kinetin (KIN) in dose 1 mg l^{-1}, C – control medium without cytokinin. Means ± SD; different letters indicate statistically significant differences evaluated by LSD test at $\alpha = 0.05$.

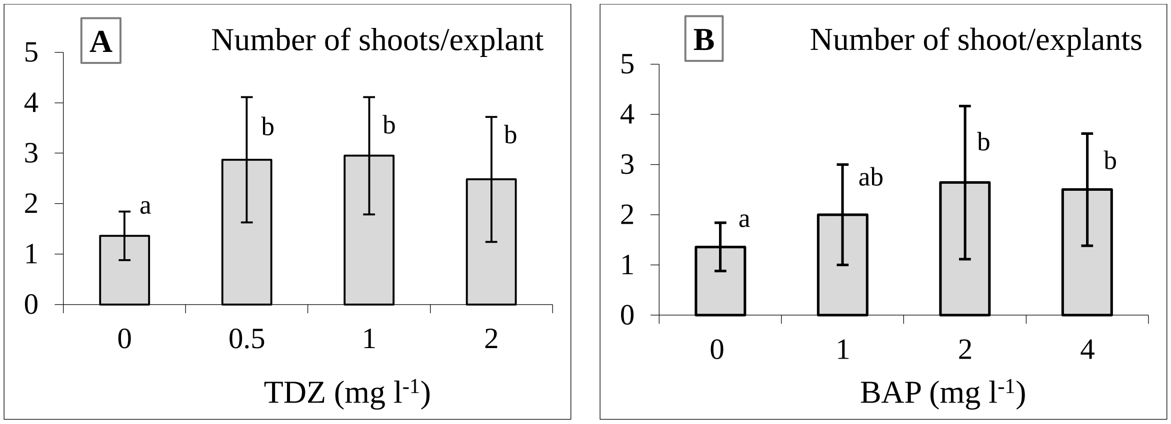

Fig. 2: Multiplication of *Miscanthus* × *giganteus* in explant culture. Number of shoots per explant on media with different concentration of cytokinin: *A*) Thidiazuron (TDZ) and *B*) BAP. Means ± SD; different letters indicate statistically significant differences evaluated by LSD test at α = 0.05.

Shoots rooted spontaneously in multiplication medium, however, the addition of auxins improved root formation. There were no statistically significant differences in the number of roots between used auxins NAA and IAA (fig. 3). Plants rooted in medium with auxins were acclimatised to *ex vitro* conditions with the frequency of 95.1 – 100%.

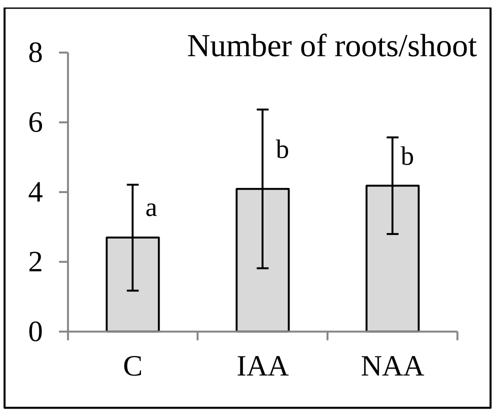

Fig. 3: Rooting of shoots in nutrient medium with auxins IAA and NAA in dose 1 mg l^{-1}, C – control medium without auxin. Means ± SD; different letters indicate statistically significant differences evaluated by LSD test at α = 0.05

All plants transplanted to the field condition survived acclimatisation. Although a lower winter-freeze survival was mentioned for *in vitro* plants (Lewandowski, 1998), there were not observed any losses during winter in our experiment. Plants propagated under *in vitro* conditions produced more shoots with significantly lower diameter. No significant differences were observed for plant height, as well as for the production of dry biomass per plant (tab. 1). Similar results were also described by Lewandowski (1998) and Clifton-Brown et al. (2007).

Table 1: Comparison of growth parameters and the biomass production of *M.* × *giganteus* plants propagated by rhizomes and *in vitro* culture.

	Number of shoots	Plant height (cm)	Diameter of shoots (mm)	Yield of dry biomass (kg/plant)
Rhizomes	54.0 ± 12.92^{a}	248.86 ± 36.12^{a}	9.43 ± 0.51^{b}	1.98 ± 0.56^{a}
In vitro	65.0 ± 12.82^{a}	256.56 ± 18.09^{a}	8.51 ± 0.68^{a}	2.10 ± 0.50^{a}

Means ± SD; different letters indicate statistically significant differences evaluated by LSD test at α = 0.05

Conclusions

Explant cultures offer an alternative way to multiply vegetatively-propagated plants. We can conclude that *in vitro* tillering is a method that can be effectively used for propagation of *Miscanthus* × *giganteus* plants. This method of direct regeneration is usable alone, or it can be combined with undirect regeneration, where shoot multiplication follows after plant regeneration from calli.

Acknowledgements

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PROVISIONING SERVICES OF ECOSYSTEM OF FAST-GROWING PLANTS (MISCANTHUS) IN SLOVAKIA REGION

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Abstract

Plantations of fast-growing plants are local agro-ecosystems that they play a leading production functions. They provide provisioning services in the form of phytomass, which in turn has the energy and non-energy use. This type of cultural ecosystem is an alternative to the cultivation of mainly unused agricultural soils. Research on the provisioning ecosystem services of plantations of fast-growing plants *Miscanthus* was carried out under conditions of field experiments on college farm in Kolíňany in Nitra region, Slovakia. After the fifth year of vegetation (2014) agro-ecosystem of the fast-growing plants achieved an average production of 28.60 t ha^{-1} of dry biomass (*Miscanthus* × *giganteus* 30.9 t ha^{-1} and *Miscanthus sinensis* Tatai 26.3 t ha^{-1}). Differences in biomass *Miscanthus* genotypes in each monitored vegetation period are statistically highly significant. The research results contribute to the knowledge of the cultivation energy plants in Slovakia as alternative energy resources providing mainly provisioning ecosystem services in the country.

Keywords: ecosystem services, provisioning services, agro-ecosystem, fast growing plants *Miscanthus*

Introduction

Cultural ecosystem is like a natural ecosystem complex and dynamic combination of plants, animals, microorganisms and natural (abiotic) environment, which exist together as a unit and individual components are interdependent.

Ecosystem Assessment is a tool for evaluating the many different aspects of ecosystem health and the provision of ecosystem goods and services. In 2000 the United Nations started a global initiative called the Millennium Ecosystem Assessment. The report from this assessment indicates that up to two thirds of ecosystem services on Earth are threatened or in decline (Millennium Ecosystem Assessment, 2005).

The general framework of ecosystem services division established the Millennium Assessment. MA divides ecosystem services to:

1. Provisioning services
2. Regulating services
3. Cultural services
4. Supporting services.

Agro-ecosystems consume and provide ecosystem services (Figure 1). People value cultural ecosystems primarily for their ability to provide benefits and they are designed to bring food and bio-energy (provisioning services). On the other hand, they are highly dependent on the system of ecosystem services provided by the nature. Negative human impact on these ecosystems is the loss of the ability of ecosystems to provide certain services, such as the loss of natural habitats for the conservation of biodiversity, loss of nutrients and the presence of pesticides in nature. However, appropriate intervention can prevent many negative effects of agro-ecosystems. Agricultural ecosystems can provide many other services, for example regulating services (flood control), monitoring of surface water quality, carbon balance and control of greenhouse gases. Cultural services these ecosystems are represented by the fact that these ecosystems complement the beauty of the landscape and provide opportunities for recreation and tourism. This type of ecosystems leads to a broad spectrum of goods and services. Since this is a cultural ecosystem, majority status has provisioning services - production of goods and services (Power, 2010).

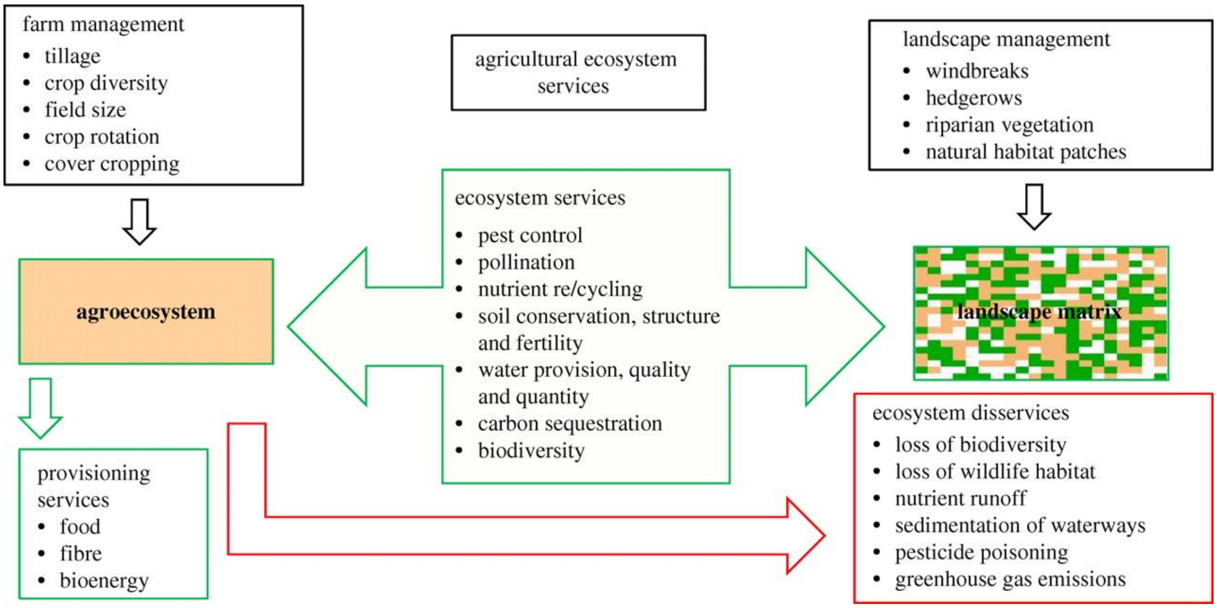

Figure 1 Interactions of ecosystem services in the cultural ecosystem (Power, 2010)

Traditionally, agroecosystems have been considered primarily as sources of provisioning services, but more recently their contributions to other types of ecosystem services have been recognized (MEA 2005). Influenced by human management, ecosystem processes within agricultural systems can provide services that support the provisioning services, including pollination, pest control, genetic diversity for future agricultural use, soil retention, regulation of soil fertility and nutrient cycling.

Agro-ecosystems are recognised in the international ecosystem services literature for their potential to contribute to the supply, of provisioning services, and also cultural, regulating and supporting services (Zhang et al., 2007 and Power, 2010). How agro-ecosystems contribute to, or impact on, the supply of ecosystem services depends on the management of those systems (Foley et al., 2005).

Plantations of fast-growing plants are local agro-ecosystems in regions where they have a major production functions. They provide provisioning services in the form of phytomass, which in turn has the energy and non-energy use. This type of cultural ecosystem is an alternative to the cultivation of mainly unused agricultural soils.

The aim of this paper is to quantify provisioning services of fast-growing plants plantations on a model example plantation of fast-growing herbs genus *Miscanthus*.

Material and Methods

Basic research of provisioning services evaluation two *Miscanthus* genotypes is based on research locality to the Slovak University of Agriculture in Nitra, in Kolíňany village. The research location is situated in the cadastral municipality of Kolíňany in Nitra region.

The exact definition of the research area was carried out using global positioning system – GPS60CS GARMIN. Selected characteristics of research stand are documented in Table 1.
The model plantations of two Miscanthus genotypes were established in 2010. Each genotype was planted on an area of 100 m2 in the planting density 1x1 m. Planting density is 10,000 plants per 1 ha.
As plant material was used: Miscantus × giganteus (Greef et Deuter, 1993) often used in the field experiments (Walsh, 1997). Planting material were rhizomes from Hannes Stelzhammer Austria. Miscanthus sinensis (Tatai) has been cross-pollination breeding genotypes of Miscanthus sinensis. Planting material were seedlings produced in vitro in Power-H Kft, Hungary.

Table 1 Selected characteristics of the research stand

Stand characteristic	Stand/locality
	Kolíňany
location	13 km north from Nitra town
altitude	199 m above sea level
GPS localization	48° 21' 21.6752115" N 18° 12' 23.8327789" E
average year air temperature / temperature in growing season	11.0 °C / 15.4 °C
average annual sum of precipitation / in growing season	594.22 mm / 429.88 mm
soils	fluvial gluey, medium weight soil

Source: Own Processing

The selected indicators of growth and organs of plants *Miscanthus* were studied in dynamic collection (weekly intervals during the growing season) in the years 2010 to 2015. In the paper are evaluated energy plants *Miscanthus* in term of their production capabilities in the process of adaptation to environmental conditions in the Slovak Republic.
Based on fundamental research was to determine the gross production of biomass suitable for energy and non-energy use.As a basis for assessment of the ecosystem services of agro-ecosystems - energy plants plantations, serve the methodology of the European Environment Agency (EEA) Experimental framework for assessment ecosystem services in Europe (EEA, 2011) and Methodology for mapping and evaluation of ecosystems and their services (Maes et al., 2013).

Results and Discussion
The cultural ecosystems have an important representative in all Slovak regions. They are located in an environment where for their growth are the best conditions (geomorphology, climate, soil, hydrology, as well as socio-economic). Within the cultural ecosystem it is dominated by the cultivation of crops that have utility in the context of food security in Slovakia.
Land resources in Slovakia are primary, secondary and other agricultural land. At primary farmland are localized agro-ecosystems to ensure food self-sufficiency. For non-food purposes it can be used secondary land. In Slovakia, a secondary land occupies 696,038 hectares, which represents 29%. Other land should be used in preference to alternative agricultural use, for energy crops, the various non-biological purposes (sports, tourist and recreational). In Slovakia, other agricultural land occupies 368,587 hectares, which represents about 15%.

For establishing plantations of fast-growing plants in Nitra region can currently be used 22% of the land fund of the region (Table 2). Most of this type of the agricultural land is unused. Unused agro-ecosystems do not contribute to the environmental quality of the region or the enhancement of the socio-economic sphere.

In the framework of the EU agricultural policy are presenting new solutions in connection with the temporary or permanent unused land for agricultural activities. One of the effective solutions using such localities is a fast-growing plant. These are the localities where the potential of biomass production guarantee farmers environmentally and economically acceptable effects than conventional production of agricultural products. For biomass as fuel is increasing demand. Therefore, farmers are a precondition for the marketing of energy crops in the region.

Table 2 Secondary agricultural land and other land in Nitra region

Region	SAL Area in ha	OAL Area in ha	SAL % from Agricultural land	OAL % from Agricultural land
Nitra	18 779	34 378	4	18

Legend: SAL – secondary agricultural land; OAL – other agricultural land

Source: Own Processing by data from Slovakia National Agriculture and Food Centre (2016)

Marišová et al. (2015, 2015b) in their work suggest that the establishment of plantations of fast-growing plants in Slovakia can be applied to soils that are temporarily or permanently unused agricultural, taking account of further legislative restrictions.

Climate represents an important growth factor in the biomass production. Daily temperatures and precipitation can be considered as limiting factors. Accumulated effective air temperatures exceeding the minimum of 10 °C are important for the growth of species of the genus *Miscanthus*. Average monthly precipitation and the average monthly air temperature with locations in Kolíňany in the Nitra region are shown in Table 3.

Table 3 The average monthly precipitation total and the course of the average monthly temperatures on research area in Kolíňany, Slovakia (2010 – 2014)

5 year average / month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
mm	44.44	31.76	33.84	34.67	73.63	65.63	60.62	52.68	55.42	38.88	40.54	36.42
°C	-0.04	0.62	6.08	11.65	16.42	19.55	22.26	21.29	16.31	10.52	6.82	0.88

Zdroj: Slovak Hydrometeorological Institute, own processing

Based on the analysis of climate indicators, it can be stated that in the research locality in the Nitra region are favourable climatic conditions for the growing of phytomass from this type of ecosystem, the appropriate temperature and rainfall conditions during the growing season for biomass production of the *Miscanthus* subjects.

As shown in Table 4, the annual productions of dry matter aboveground organs of studied genotypes are increasing every year. Age of the plants affects the ability of income and allocation of materials to individual organs. An individual in the growth gradually takes some living space. Individuals in the connected ecosystem plantations produce a sufficient quantity of underground organs, roots and rhizomes. These underground organs also serve as a storage organ. The next year at the beginning of the vegetation period the plant used storage organ for the benefit of growth processes and the initial formation of organic matter above-ground organs.

Table 4 Crop of the dry above-ground biomass energy plantations plant species (t $ha^{-1}.year^{-1}$) grown at a research base in Kolíňany in Nitra region

Energy plants / Year	2010	2011	2012	2013	2014
Miscantus × giganteus	11.10	18.10	27.10	30.30	30.90
Miscanthus sinensis Tatai	10.80	16.90	22.60	24.10	26.30
Miscanthus - average	10.95	17.50	24.85	27.20	28.60

Both observed *Miscanthus* genotypes create the amount of dry matter that can be considered as economically beneficial in the first year of cultivation.
In each subsequent growing year the crop of the dry matter increases. When comparing the two genotypes of Miscanthus we can be based on the results concluded that in terms of Nitra Region (research site Kolíňany) both genotypes produce annually a balanced production of dry matter, which is about the same, although higher production of dry matter aboveground authorities shall register for genotype Miscantus × giganteus (Greef et Deuter).
From the aspect of the biomass produced by aboveground organs, *Miscanthus* growth was observed since the establishment of plantations in 2010 (Table 4). After the fifth vegetation year (2014), the growth reached the average production of 28.60 $t.ha^{-1}$ of dry biomass (at harvest moisture) (*Miscanthus × giganteus* 30.90 t ha^{-1} and *Miscanthus sinensis* Tatai 26.30 t ha^{-1}) (Figure 2). Differences in biomass production of both *Miscanthus* genotypes are statistically highly significant in each monitored vegetation period. The results of studies on *Miscanthus* production in Europe and USA are presented by Heaton et al. (2010). The authors present a range of usable production starting at the amount of 5-55 t ha^{-1}. In optimal conditions of the southern Europe, the production of dry biomass of the aboveground organs is about 25-30 t ha^{-1} (Angeliny et al., 2009), while irrigated conditions in Portugal increased the production at level of the 36 t ha^{-1} (Clifton-Brown et al., 2001), 34-38 t ha^{-1} in Italy (Ercoli et al., 1999; Cosentino et al., 2007) and 38-44 t ha^{-1} in Greece (Danalatos et al., 2007).

Figure 2 The ecosystem of the fast-growing plant Miscanthus of a research area in Kolíňany (Nitra region, Slovakia) - autumn 2015 (the sixth year of vegetation)
Photo: author

Collection of appropriate types of energy plants is supplemented by willow and poplar. Demo et al. (2012, 2013) was devoted to the cultivation of willow and poplar plantation method. The results achieved in the Hungarian varieties Experess and Csala and Swedish variety Inger also confirmed the high adaptability of willows on the climatic conditions in the Slovak Republic, namely in the village Kolíňany (Nitra region). Cyclic provision of woody biomass energy willow and miscanthus too is a basic ecosystem services that plantation of energy crops can provide.
Production parameters monitored varieties of willow and poplar in the Slovak Republic reached the level economically advantageous production. Research was confirmed by Demo et al. (2014) and Prčík (2016). The research results contribute to the knowledge of the cultivation energy plants in Slovakia as alternative energy resources providing mainly provisioning ecosystem services in the country.

Conclusions

Agro-ecosystems consume and provide ecosystem services. Their main benefit is the provision of food and bioenergy. From the ecosystem goods and services have majority representation provisioning services. Ecosystems fast-growing plants are local agro-ecosystems in regions where they provide for the production of phytomass for energy and non-energy use.
Research on the provisioning ecosystem services of plantations of fast-growing plants *Miscanthus* was carried out under conditions of field experiments on college farm in Kolíňany in Nitra region, Slovakia.
The plantation of fast-growing grass *Miscanthus* (observed in 2010-2014) in terms of biomass production (both genotypes) create the average production of 24.85 t ha^{-1} in the third growing year (2012), which compared to 2011 increased by almost 60%. After the fifth year of vegetation (2014) agro-ecosystem of the fast-growing plants achieved an average production of 28.60 t ha-1 of dry biomass. The genotype *Miscantus × giganteus* appears to be more productive. The crop was established (planted) from rhizomes.
Studied genotypes fast-growing plant *Miscanthus* demonstrated the ability to adapt to the environmental conditions in the region and at the same time generate economically interesting production of dry matter aboveground organs.
The research results contribute to the knowledge of the cultivation energy plants in Slovakia as alternative energy resources providing mainly provisioning ecosystem services in the country.

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ANALYSIS OF DESCRIPTIVE STATISTICS FOR SELECTED WATER QUALITY PARAMETERS FROM THE ENVIRONMENTAL PERSPECTIVE

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Abstract

Environmental and water quality affects mainly anthropogenic influences that affect its individual components. Man has impact on water quality through different activities. Many activities pollute the environment, even the surface water, which then lead to many environmental problems. Although the waste water after cleaning contain substances that affect water quality in streams, regarding to the planned expansion of municipal sewage, the quality of water in streams should not deteriorate. Just completion of sewerage networks in the settlements is a precondition for reducing the pollution of surface waters. By adopting the Water Framework Directive, we are committed to meeting the commitments relating to sewage treatment in villages. As for technical unfeasibility we do not meet the so-called good water status, so the deadline for achieving good status has been shifted to 2021, respectively. 2027. Currently, it is necessary to take into account the needs of future generations, therefore attention was focused precisely on the environment and its sustainability.

Key words: water quality, water quality indicators, descriptive statistics

Introduction

Water is a necessary and essential condition for life on earth. Human is in connection with water and influence his life. Human causes anthropogenic changes such intensive use of the landscape, influencing the changes in the quality of watercourses. Kotrla and Prčík (2010, 2012) are dealing with the issue of water and living space or water as a factor affecting occurrence of vegetation in a natural environment.

In 2000 came into force Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy (Water Framework Directive), which significantly changed the way for monitoring and evaluation, as well as water management in most European countries. This Directive was transposed to the Water Act - Act no. 364/2004 Z.z. on waters and amending Act No. 372/1990 Coll. on misdemeanors, as amended. Pollution sources that adversely affect water quality, can be divided according to their nature and action essentially into two categories: point sources - significantly affect the quality of water in surface streams and the quality of groundwater in the alluvial sediments and surface sources - according to their origin operate permanently or occasionally, and their size and impact on water quality are still subject to a variety of interacting factors. Sources of diffuse pollution are mainly agriculture, landfills and ponds, runoff from paved areas, contaminated stormwater, contaminated irrigation water. Very important is to maintain an ecological stability in nature and in the field of waters. Ecological stability is one of the factors that are also in interest of Kotrla and Prčík (2014).

Member States under this Directive provides programs for monitoring of water on a coherent and comprehensive overview of water status within each river basin district. The Water Framework

Directive in the context of its objectives, states an achieving at least good status of waters to not be realizing without the purification of produced waste water (Krupová, 2009).

Material and Methods

Water quality assessment has been carried out on the basis of the research project VEGA 1/1170/11 anthropogenic impacts on the development and quality of surface runoff from small watersheds in the conditions of the altered climate through direct measurements at locations flows in the river basin Žitava. Sampling was carried out in the upper basin Žitava, Hostiansky potok, Širočina, Stránka, and Čerešňový potok. Samples were taken at different sampling sites in the municipalities of each subcatchments, directly in the villages, above the wastewater treatment plant, under the wastewater treatment plant or on sewage treatment plant discharges. In samples that were collected was monitored the content of nutrients, particularly nitrogen and phosphorus. Evaluated been selected water quality parameters: P-PO 4 - phosphate phosphor, N-NO3 - nitrate nitrogen and N-NH4 - ammonia nitrogen.

Stated water quality parameters were compared with values that are defined in Regulation of the Government of the Slovak Republic No. 269/2010 Coll. laying down the requirements to achieve good water status and determine the quality of water under I. and II. and III. ecological quality classes according to the type of water body. The categorization of watercourses in Slovakia was carried out under the Water Framework Directive. Evaluated been these types of water bodies: P1M, P2M and K2M. Žitava can be classified into water body type K2M, Hostiansky potok, Stránka and Čerešňový potok P2M, Širočina into the water body type P1M.

Selected water quality indicators P-PO4, NO3-N and NH4-N were analyzed by means of descriptive statistics. Used were the following characteristics:

• arithmetic average - characteristic position, it is the mean value, often used in practice,

$$\bar{x} = \frac{1}{n}\sum_{j=1}^{n} x_j = \frac{\sum_{j=1}^{n} x_j}{n}$$

• standard deviation - a measure of variability, the square root of the variance, represents the values that move around the average ± and expresses the variability of the group,

$$s_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} = \sqrt{s_x^2}$$

• median - characteristics of position that characterizes in terms of the size of the intermediate (central) value of the group, 50% of the value is above this value and 50% of the value is below this value,

$$\tilde{x}_{50}$$

• minimum value,

• maximum value.

Results and Discussion

The quality and quantity of water in streams depend primarily on human activity but important is also the location of flow with respect to their length.

It was found that the average value of the indicators meet the limits set in Regulation of the Government of the Slovak Republic No. 269/2010 Coll. Measurement at the Žitava and Hostiansky potok was held in 2011. For Horná Žitava was evaluated water quality in the stream Žitava, in Jedľové Kostoľany, above and below the Obyce and above and below Machulince. In the village Jedľové Kostoľany and Obyce is not built WWTP. Measurement in Obyce took place above and below the village. In the Machulince measurement took place over the village and under the wastewater treatment plant. The WWTP was built as a shared community for Machulince and Obyce, because Obyce have drainage networks, water treatment is not used. Selected water quality indicators were analyzed by means of descriptive statistics and results are showed in the following tables.

Water quality in the Horná Žitava with their average values for the parameter P-PO4 and NO3-N satisfies the second ecological quality class, indicator N-NH4 reached values falling in the first ecological quality class.

Table 1 Descriptive statistics for selected indicators of water quality in the basin of the Horná Žitava

Indicator	Average	Standard deviation	Median	Min. value	Max. value
$P\text{-}PO_4$	0.193	0.129	0.137	0.085	0.476
$N\text{-}NO_3$	2.257	0.669	2.1	1.5	3.7
$N\text{-}NH_4$	0.437	0.892	0.09	0.00	2.62

Source: own processing

The water quality in the Hostiansky potok its average value for the parameter P-PO4 and NH4- N was in second ecological quality class, while for the variable N-NO3 it was first class.

Table 2 Descriptive statistics for selected indicators of water quality in the basin of the Hostiansky potok

Indicator	Average	Standard deviation	Median	Min. value	Max. value
P-PO4	0.102	0.066	0.082	0.003	0.176
N-NO3	2.3	1.669	1.7	0.6	5.3
N-NH4	0.58	1.085	0.04	0.02	2.75

Source: own processing

Water quality in Širočina fulfills first ecological quality class in two cases, namely the variable P-PO4 and NH4-N. The N-NO3 in the average rate values that goes back to the third ecological quality class.

Table 3 Descriptive statistics for selected indicators of water quality in the basin of the Širočina

Indicator	Average	Standard deviation	Median	Min. value	Max. value
P-PO4	0.1428	0.059	0.166	0.036	0.199
N-NO3	5.083	1.926	4.75	2.0	7.7
N-NH4	0.103	0.182	0.025	0.00	0.51

Source: own processing

The water quality in the basin Stránka with average values included in the second ecological quality class, and that the two indicators. Indicator P-PO4 exceeded values and was placed in the third class of ecological quality.

Table 4 Descriptive statistics for selected indicators of water quality in the basin of the Stránka

Indicator	Average	Standard deviation	Median	Min. value	Max. value
P-PO4	0.235	0.154	0.155	0.120	0.550
N-NO3	2.5	1.573	2.15	0.8	4.6
N-NH4	0.505	1.005	0.045	0.01	2.75

Source: own processing

Water quality in Čerešňový potok assessed by descriptive statistics reached the same values as the Stránka.

Table 5 Descriptive statistics for selected indicators of water quality in the basin of the Čerešňový potok

Indicator	Average	Standard deviation	Median	Min. value	Max. value
P-PO4	0.765	0.746	0.41	0.042	1.790
N-NO3	4.667	2.255	5.1	0.5	7.0
N-NH4	0.495	1.009	0.045	0.0	2.75

Source: own processing

The assessment of descriptive statistics can be concluded that the water quality indicators achieved the worst results in the Stránka and Čerešňový potok, where indicators fall into the second and third class environmental quality.

The assessment of surface water quality in the river basin Žitava and its subcatchments conclude that the increased burden is caused mainly by natural influences or lower efficiency of the WWTP as documented in some cases. For monitored catchments degradation of water occurs away from the source. In some cases were recorded exceeded permitted levels, this was the case when were also recorded lower water levels. Furthermore, it is necessary to point out the need to review current procedures that are applied to agricultural practices, as agriculture affects the water quality in streams, which was also reflected in increased levels of phosphate in the selected sampling points.

The problem is the fact that some villages have no built sewage treatment plants, which are functional and villages then conducts sewage to flow directly without purification. Water quality in streams is also affected by the flow rate, which varies depending on the season. This was also confirmed by Ondr (2010) when, in their research found that the transport of nutrients in the flow affects the increased flow, especially at the time of the spring snow melt. McIsaac et al. (2003) in their research indicated that the increasing flow rate decreases in the water content of NO3. The concentration of total nitrogen depends on the type of the country, its concentration in the intensively cultivated land is higher, as confirmed by our measurements of water quality. In some flows surpassed authorized standards, usually they are elevated phosphorus as a result of the biological composition of the whole area. According to Kronvanga et al. (2005), phosphorus gets into water, in particular of the agricultural land as impact of erosion. Author stated that the excessive concentration of phosphorus in the water is one cause of the so-called eutrophication. Our observations confirm that the increased phosphorus content in the monitored flows is caused by discharge from agricultural areas that are fertilized with fertilizers containing phosphate. As stated Jurik (2007), nitrates in the waters in an amount of 0.1 to 10.0 mg.l-1 have been exceeded this amount, it usually indicates the load flow of waste water. Renwick (2008) also points out that the higher concentration of nitrates in water is seasonal and in winter is higher

Conclusions

Environmental and water quality affect mainly anthropogenic influences that affect its individual components. Man has impact on water quality through different activities. Many activities pollute the environment, even the surface water, which then lead to many environmental problems. The biggest polluter in the monitored area is district Zlaté Moravce. As mentioned above, the water quality is currently affected by demographic changes only in minimal way, because of that fact that most villages has built wastewater treatment plants and sewerage. It can be stated that the observed subcatchments have followed a similar trend as in whole Slovakia. Expectations regarding anticipated consumption of drinking water and the subsequent production of waste water regard to the demographic development in the river basin Žitava are not met. Although the waste water after cleaning contain substances that affect water quality in streams, regarding to the planned expansion of municipal sewage, the quality of water in streams should not deteriorate. Just completion of sewerage networks in the settlements is a precondition for reducing the pollution of surface waters.

By adopting the Water Framework Directive, we are committed to meeting the commitments relating to sewage treatment in villages. As for technical unfeasibility we not meet the so-called good water status, so the deadline for achieving good status has been shifted to 2021, respectively. 2027. Currently, it is necessary to take into account the needs of future generations, therefore attention was focused precisely on the environment and its sustainability. Only organic and sustainable agriculture and integrated water management are opportunities for sustainable development in Slovak regions.

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ENERGY CROPS IN ASPECT OF WATER RESOURCES IN POLAND

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Abstract

Problem of the impact of energy crops on water resources in Poland is presented in this paper. On the one hand, the presence of a large area of light soils unfavorable for intensive food production promotes the development of energy crops. On the other hand, water resources in Poland are relatively small. In this paper is characterized the current development of energy crops. In order to evaluate the impact of energy crops on water resources was performed using SWAT model comparison of water use on evapotranspiration and the outflow of water from the catchment in the case of three types of plants: tree stands, willow and bermuda grass. Results of calculation shows significant differences in the amount of evapotranspiration between tree stands and bermuda grass. Much smaller differences in evapotranspiration are between tree stands and willow. These results indicate that the decision about the location of energy crops with a large share in the catchment area should take into account the water needs of energy crops, because their cultivation can significantly affect the parameters of water balance. This analysis also showed that the SWAT model can be a good tool to evaluate changes in water resources due to changes in land use.

Key words: energy crops, water resources, SWAT model, evapotranspiration, catchment area

Introduction

The most important problems of environmental policy the European Union is undoubtedly the climate protection. The European Union obligation for Member States to take a series of measures to prevent warming of more than 2°C compared to pre-industrial levels. Among other things, it is assumed that to 2020 will be achieved growth of energy from renewable sources in overall EU energy consumption by 20% and by 27% to 2030 with comparison in 1990. Achieving these goals is a particular challenge for Poland, where about 90% of the energy is derived from coal and lignite. This situation is confirmed by the data in Figure 1, which shows the share of different types of sources in electricity production in the five selected countries in 2000 and 2015 (IEA Statistics 2016).

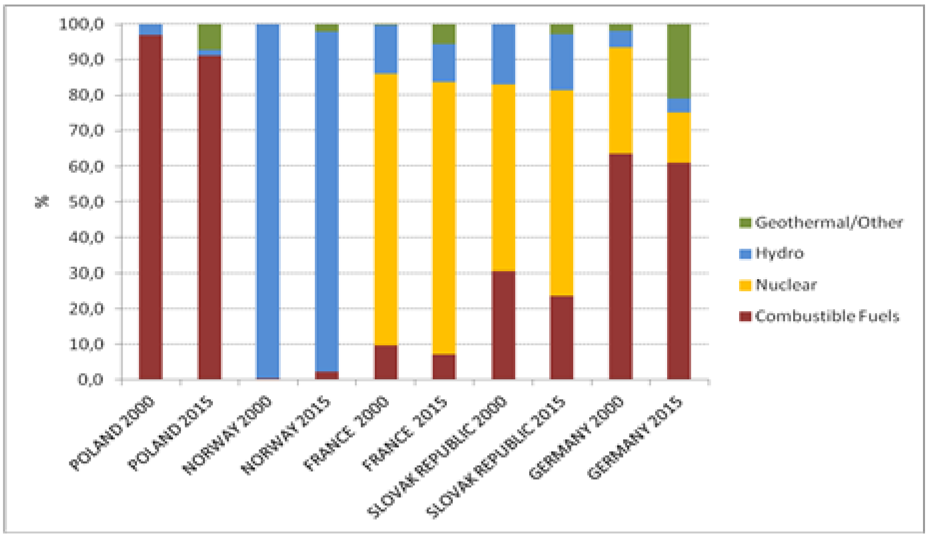

Fig.1. Share of various energy sources for electricity production in selected countries (IEA Statistics 2016).

Figure 1 show that in analyzed countries dominant source of energy for electricity production is: combustible fuels in Poland and in Germany, hydropower in Norway, nuclear energy in France and Slovakia. In the period 2000-2015 growth in the share in electricity production of geothermal and renewable energy sources also including energy crops was significant only in Germany (over 20%). In the other countries didn't exceed 7%.

A significant challenge for the energy sector in Poland is its decarbonisation. Coal constitutes the 55% of primary energy supply and 92% of electricity. This means that for Poland to achieve the objectives of the European Union in the field of climate protection requires significant development of renewable energy. One of the sources of renewable energy is energy crops. However, the development of production energy plants has serious environmental limitations related among others to the effect of such production on water resources and greenhouse gases. The use of large-scale energy crops can have significant impact on water resources both in the catchment area and on water management in the catchment area, and can also affect the water management in the neighboring areas.

The article deals with methodical problem of assessing the impact production of energy crops on water resources. An attempt to assess the possibilities to use the SWAT model to evaluate the components of the water balance in the catchment scale with different use of land is presented in the paper.

Cultivation of energy crops in Poland

Soil and water resources

In a series of studies predicts a significant increase in energy crops taking into account that a very good and good soil conditions suitable for food production covers in Poland only 30% of the country area. The most common soil types in Poland include brown soils, acid brown soils, grey brown podsolic soils, rusty soils and podsolic soils. A much smaller area is covered by chernozem soils, rendzina soils, black soils and alluvial soils. The soils in Poland are mainly of glacier origin and according to texture they are characterized by a great variability with the predominance of light sandy soils (47 % of total area) with low water holding capacity (Table 1). Loams cover approximately 25 % of the country. There is relatively high (8.5 %) share of organogenic soils (Pierzgalski, Jeznach 2006).

Table 1. Water retention of mineral soils

Soil texture	Water holding capacity [% of volume]	Effective soil moisture retention [% of volume]
Loose sand	6.3	4.2
Loamy sands	11.6 − 18.6	8.7 − 15.2
Loams	27.5 − 34.4	21,4 − 24,1
Silty clay	35.5	18.3

Energy crops could be located on the area with poorer soil and water conditions. It is estimated that energy crops can be allocated in Poland from 1 to 4 million hectares. Such a large increase in the area of energy crops, however, is dependent on water conditions. The characteristics of water conditions in the Polish soils are shown in Table 2.

Table 2. Water conditions of agricultural lands

Water conditions	Area [million ha]	Area [%]
Very frequent and long term excess of water	1.0	5
Periodical excess of water	2.9	16
Relatively good water conditions	8.9	48
Periodical deficit of water	4.9	27
Permanent deficit of water	0.7	4

The issue of the impact of energy crops on water resources undertook several authors (Bendes 2002, Borek et al. 2010, Dalla et al. 2010, Kowalik and Scalenghe 2010, Stone et al. 2014). This problem is particularly important in Poland, because Polish water resources are, on the background of European countries, relatively small. In addition, they characterized by high volatility in terms of time and space. Properties temperate climate and geomorphological conditions are the main causes of occurrence, diverse in terms of location, periodic shortages and surpluses of water, manifested in the form of droughts and floods. Average rainfall in a year amounts to little more than 600 mm, while in the central part of Poland they amount to only 500 mm, and in the high mountains in the south of Poland rising to 1500 mm. The sum of the average annual precipitation may in individual years vary considerably, e.g. In an extremely wet 1975 years the average annual precipitation for the whole country amounted to 780 mm, and a dry 1990 years only 420 mm. Contrast climate determines its spatial variability and thus means the spatial variability of water resources. The greatest water shortages occur in the central part of Polish, although there is also drought in the northern part of the country and even in mountainous areas. Extreme hydrological phenomena, resulting in, among others, floods occur throughout the country, but mostly on the south of the country. Multi-year average of surface water resources are estimated at approx. 1,660 m3 / capita / year, with average in the European countries of approx. 4560 m3 /capita / year (Borecki et al. 2003).

Climatic water balance analysis during the six month vegetation period (April-September) indicates the occurrence of negative-valued differences between the rainfalls and evapotranspiration in almost entire central part of Poland. Only in the southern territories of Poland, the water balance in this period is positive. It has been found that the central territories of Poland show a particular deficit of water and they are most threatened with becoming a steppe. Hence, this area requires the necessary protection of agriculture from the negative effects of water deficiency in the vegetation period. Water deficit occurs especially sharply on light soils with low water holding capacity.

The area cultivated energy crops

The basic criterion for energy crops production is economy profit, but also drought resistance and durability plantations. According to tests conducted on experimental plots highest energy yield among perennial plants were obtained from the willow, rose and miskanthus (Podlaski et al. 2010).

The area of permanent plantations of energy crops amounted in Poland to 13 000 ha in 2014. Although the cultivation of energy crops in the period from the year 2010 by the year 2014 increased more than doubled, it is still insignificant amount of energy production. The area of main important energy plants is showed in table 3 (Gajewski 2016).

Table 3. Area of most important energy crops in Poland in period 2008-2013

Year	Energy crops		
	willow	miscanthus	poplar
2008	5940	400	86
2009	6160	1834	647
2010	6757	1834	647
2011	6917	1834	1259
2012	7101	733	2463
2013	7728	733	3175

Material and Methods

Assess the impact of land use on water resources or water management is used in different models (Deelstra et al. 2010). This article attempts to use the SWAT model for this purpose.

The SWAT (Soil and Water Assessment Tool) model is well-known river basin hydrological model. It is systematically improved, and its description can be found in the work of Neitsch et al. (2010). Model SWAT is a model of the structure of the river catchment, which can be used to determine the impact of changes in the use in the catchment on water balance parameters (Abbaspour et al. 2007). This model can be used to simulate the long-term impact of the climatic and forest and agricultural management on the quality of water, loads of sediments and chemicals. These simulations can be performed for different catchment basin management practices and characteristics of the soil and the variety of spatial development. SWAT model allows for the various catchment management practices. So, management operations allow you to control the growth cycle of plants, the terms of fertilizers and pesticides, and removal of plant biomass. The calculations can be conducted in step, daily, monthly or annual modeling and runs continuously. SWAT is a physical model, so that the relationships between input and output parameters are described by the equations. This model is applicable to both the small and large catchments. Preparation of the model for calculation comprising:

- the division watershed into sub-catchments,
- reclassification of land cover map,
- develop a database of soils,
- preparation of meteorological data.

SWAT is one of the hydrological models that requires very huge amount of data about topography (Digital Elevation Model), soil types, land use and meteorological condition. The problem is in availability of these data in Poland in proper resolution, special for small catchments. For the paper purposes, we created a database with all data required for SWAT. Digital Elevation Model (DEM) was created from large lidar point collections. Created DEM has a pixel size of 1x1 m. Precipitation originated from the weather stations in Szklarnia and Flisy. Other missing data were obtained using the built-in model Weather Generator. The hydrographic data were obtained from Digital Map of Hydrographic Division of Poland (Institute of Meteorology and Water Management). Land use data were obtained from the CORINE Land Use/Land Cover (LULC) (2006) which afterwards has been converted to SWAT LULC. Unfortunately there was a problem with soil data and, additionally, with polish soil classification not complementary with the US one. In this situation, we obtained soils data from Harmonized World Soil Database (HWSD).

For the purposes of this article SWAT model used to determine the water evapotranspiration of the various plants in Czartusowa river basin. This watershed is located in the south eastern part of the Poland in Janow Lubelski Forest District. The catchment area to the cross hydrometric section in Szklarnia is 12.9 km^2, the average elevation of the area

203 m above sea level with the slope 8.9 m km. The average annual rainfall 674 mm and 406 mm in summer half year. The catchment area of the extent of forest cover 93% with a predominance of pine stand with parts of fir and alder.

SWAT model was calibrated on the base of measurement results of discharge in the period 2005-2007. With the calibration step adopted monthly calculation. Program SWAT-CUP was used for calibration. It allows modifying the parameters automatically, in the specified range. To assess the degree of fit of the model to real data were used:

• efficiency ratio model of Nash-Sutcliffe (NSE),
• coefficient of determination R^2,
• PBIAS factor.

After calibration, performed the validation of the model for the years 2008 - 2010 with a monthly time step and then the calculation of the evapotranspiration were carried out for three options of catchment use: the current forest, willow and bermuda grass.

Results and Discussion

SWAT-CUP (Calibration and Uncertainty Programs), was developed by Swiss Federal Institute of Bioscience and Biotechnology. SWAT-CUP provided four optimization algorithms including Sequential Uncertainty Fitting Version 2, SUFI-2; Generalized Likelihood Uncertainty Estimation, GLUE; Parameter Solution, ParaSol and Markov Chain Monte Carlo, MCMC (Tang, 2011). For the calibration, SUFI-2 optimization algorithm was used. SUFI-2 is a tool for sensitivity analysis, multi-site calibration and uncertainty analysis. It is capable of analyzing a large number of parameters and measured data from many gauging stations simultaneously. In SUFI-2, parameter uncertainty is described by a multivariate uniform distribution in a parameter hypercube, while the output uncertainty is quantified by 95PPU calculated at the 2.5% and 97.5% levels of the cumulative distribution function of the output variables. The results of the calibration of the SWAT model are given in Figure 2 and Table 4.

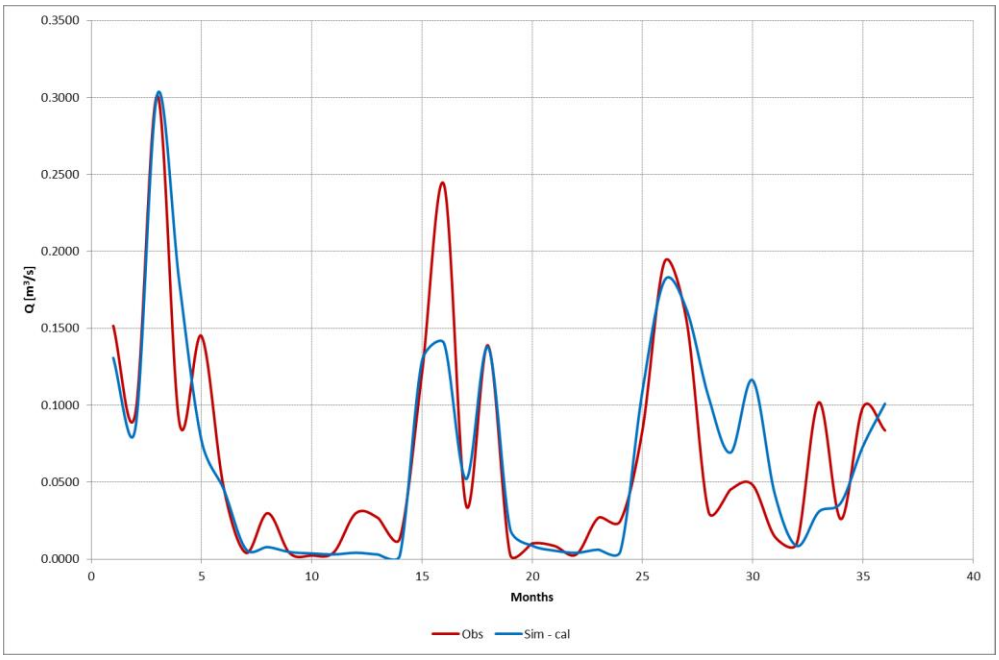

Fig.2. Results of SWAT model calibration on the base observation discharge in Czartusowa river

Table 4. The values of quality assessment's model obtained in calibration

Statistical parameter	Value	Evaluation of model
N_{SE}	0,75	good
R^2	0,76	very good
PBIAS	5,30	very good

The evaluation of hydrologic model behaviour and performance is commonly made and reported through comparisons of simulated and observed variables. Frequently, comparisons are made between simulated and measured discharge at the river. For objective evaluation, mathematical estimation of errors between observed and predicted values must be conducted by the use of different model evaluation statistics (Figure 3 and Table 5).

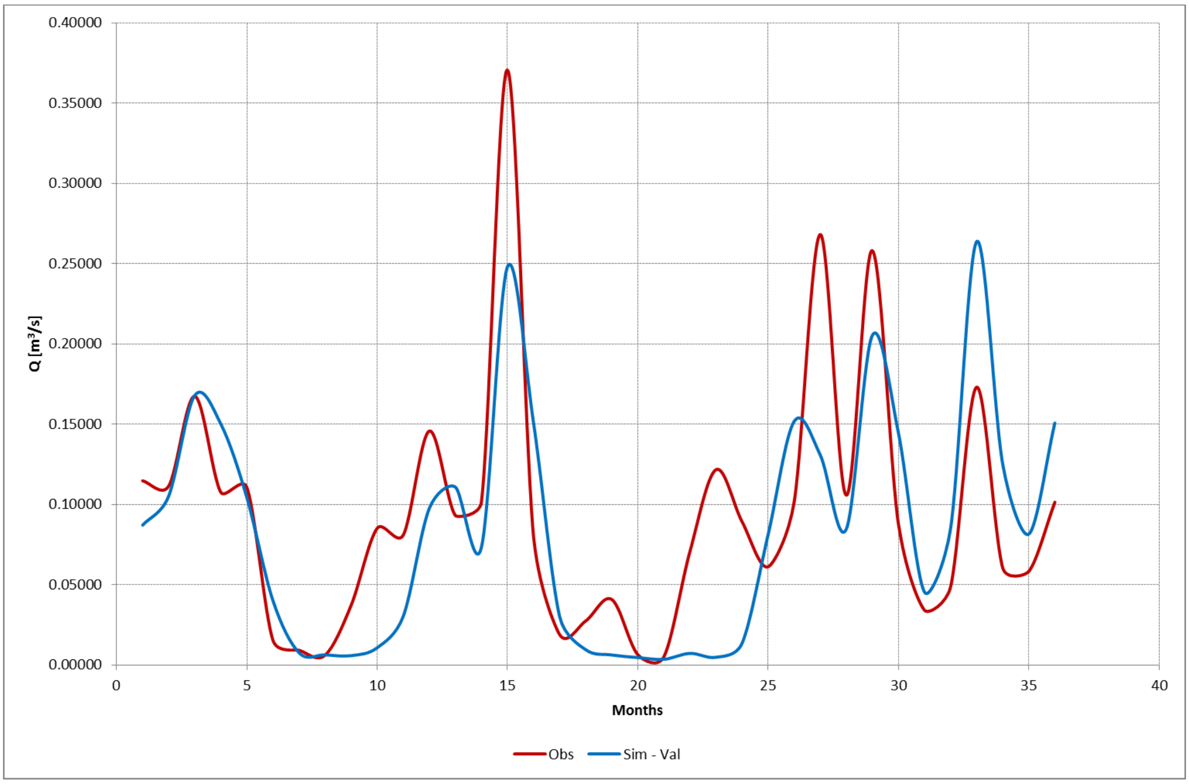

Fig. 3. The results of modelling for evaluation of calibrated model

Table 5. The values of quality assessment's model obtained in validation

Statistical parameter	Value	Evaluation of model
N_{SE}	0,50	satisfactory
R^2	0,55	good
PBIAS	10,40	good

Statistical parameters given in Tables 4 and 5 indicate a good fit of the model to empirical data, which justifies conducting simulation calculations.

Then, using the calibrated model was performed an analysis of the impact of land use on the evapotranspiration. Calculations were performed for three variants of development: the forest, willow and bermuda grass in the entire catchment area. The results simulation calculations are shown in Figure 4.

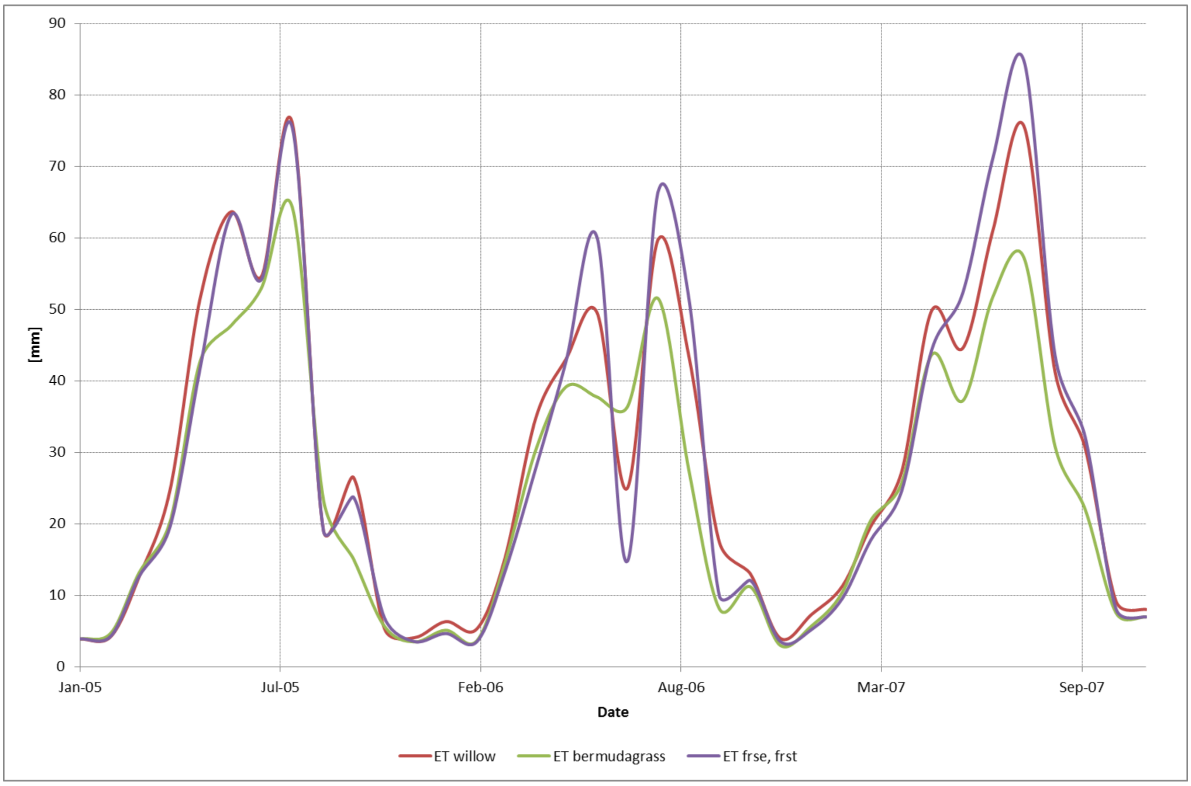

Fig. 4. Comparison of monthly evapotranspiration of tree stands (forest, willow and bermuda grass) in Czartusowa catchment area.

Figure 2 shows significant differences in the amount of evapotranspiration between tree stands and bermuda grass. Much smaller differences in ewapotranspiration are between tree stands and willow. These results indicate that when deciding on the location of energy crops should take into account local water conditions and water needs energy plants, because they vary greatly in terms of water requirements.

Conclusions

1. Implementation adopted by the European Union environmental policy relating to climate protection requires increasing cultivation of energy crops.
2. It is estimated that in Poland there is potential about 1 - 4 million hectares where energy crops can be grown. The condition limiting may be insufficient water resources. This points to the need for crops selection according to criterion of the water requirements.
3. SWAT model can be a good tool to evaluate the impact of energy crops on water resources in scale of watershed provided that a successful model calibration and verification.

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FAST-GROWING PLANTS: BIOMASS PRODUCTION IN A SUSTAINABLE WAY IN SLOVAKIA

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Abstract
The paper presents the issue of sustainable biomass production in the Slovak Republic. The research was conducted at the research base at the college farm in village Kolíňany, Nitra region. The production of dry biomass of Italian varieties of poplar (Monviso, Pegaso, AF-2 and Sirio) has been monitoring in the vegetation between 2011 and 2015. The highest yield of dry biomass in third vegetation year was in the variety Monviso (35.40 t ha^{-1}), the lowest variety Pegaso (6.18 t ha^{-1}) in which the disease *Dothichiza* was identified. The highest values of dry matter in the vegetation period 2014 reached a variety AF-2 (64.50 t ha^{-1}). The varieties in the vegetation period 2015 can be divided into two group in term of biomass production. In the first group are variety Monviso (89.70 t ha^{-1}) and variety Pegaso (67.13 t ha^{-1}) and in the second group are variety AF-2 (197.84 t ha^{-1}) and variety Sirio (185.87 t ha^{-1}). Experimental poplar varieties in different growing years exceeded the threshold of economic efficiency (12 t ha^{-1}).

Keywords: fast-growing plants, poplar, sustainable production, biomass

Introduction
Intensive cultivation of energy plants in Slovakia does not have a long tradition yet. Most of energy plants are little known, despite the fact that in the past, many of these species were cultivated in Slovakia. One group of the energy plants is energy grass *Miscanthus* (Kotrla, 2016). Biomass has the largest share of technically usable potential of renewable energy sources. Currently it uses approximately one third (Kotrla, 2011).
Among the fast-growing woody plants in Slovakia are classified mainly soft deciduous trees, among which we include poplar. The polar is the main tree species with a dominant economic interest in lowland and in particular floodplain areas of Slovakia (Kotrla, Prčík, 2010).
Demo et al. (2013) confirms cultivation rapidly growing energy poplars on farmland, as an alternative, especially in non-forest areas of Slovakia, on soils with a lower credit rating (5-9) and a high water table.
For optimum use of land for the cultivation of the fast-growing plants are recommended marginal land, localities economic unstable for conventional agricultural crops (Laureysens et al., 2004) and soil contaminated by human activity (Jandačka et al., 2007).
Analysis of land use human population and its impact on environment pollution have been studied by Mandalová (2013, 2015). The author classifies activities under conventional agricultural production as the most important negative effect.
The ecological value of energy plantations (diversification of agricultural production) depends on the country context to a significant extent, on the size of the growing area and specific regulatory measures. Other ecological benefits of the diversification of agricultural production: alternative crops increases the number of species in crop rotation, diversity is increases, fast-growing plants contribute to the promotion of sustainable agriculture with their biological and technology diversity and there is important size of growing area. Jureková et al. (2011) confirmed increase biodiversity in agricultural landscapes during cultivation of fast-growing willow at the smaller plantations.

Marišová et al. (2015, 2015b) in their work suggest that the establishment of plantations of fast-growing plants in Slovakia can be applied to soils that are temporarily or permanently unused agricultural, taking account of further legislative restrictions.
Cultivation of the energy crops on agricultural land creates a space for the use areas which are less suitable for growing traditional field crops. The plantation of the energy plants provide permanent cover land, their further use can also contribute to improved energy and economic balance of the agricultural system (Pospíšil, Vilček, 2000).
Green economy brings opportunities for business development, opening up new markets in the efficient and ecological use of natural resources. This transfer would mean increasing the use of natural resources and lead to increased demand for biomass. The increased demand for biomass opens new questions about the sustainability of the green economy (Scarlat et al., 2015).
The aim of this paper is to evaluate the dry matter production of the four varieties of poplar coming from Italy Breeder's Program at the conditions of the south-western Slovakia. The article points to the fact that on the basis of research pursued all varieties reach an economically efficient level of biomass production.

Material and Methods
The four varieties of poplar (*Populus* × *canescens*) from the Italian breeding program were included to the research:
Monviso: Populus × generosa × Populus nigra, origin: controlled hybrid, mother: Populus × generosa [P. deltoides 583 (Iowa – USA) × P. trichocarpa 196 (Oregon – USA)], father: Populus nigra 715-86 [P. nigra 12 (Piedmont – Italy) × P. nigra 7 (Umbria – Italy)], sex: female. AF-2: Populus × canadensis, origin: controlled hybrid, mother: Populus deltoides 145-86 (Illinois – USA), father: Populus nigra 40 (Piedmont – Italy), sex: female. SIRIO: Populus deltoides × Populus × canadensis, origin: controlled hybrid, mother: Populus deltoides 266 (Tennessee – USA), father: Populus × canadensis 4-85 [P. deltoides 1095 (Illinois – USA) × P. nigra 666 (Tuscany – Italy)], sex: male. PEGASO: Populus × generosa × Populus nigra, origin: controlled hybrid, mother: Populus × generosa [P. deltoides 80-16 (Iowa – USA) × P. trichocarpa 84-19 (Oregon – USA)], father: Populus nigra 4 (Piedmont – Italy), sex: male (Demo et al. 2013).
Research plantation of Italian varieties poplar was established in April 2009 to land resources Collage farm in Kolíňany village, Nitra region, Slovakia. Research area is located at an altitude of 180 m above sea level and it belongs to the warm climate of the region, very dry, lowland. The average annual temperature is 9.9°, the average annual rainfall for the period 1951-2000 is 547.6 mm. Soil on the research area is moderate (loam), fluvisol, pH of the soil is 7.26 and 1.8% soil humus.
Two methods of planting to two-line were used during planting of poplar varieties. In the first method of planting, 0.2 meters long cuttings of one-year old shoots with a diameter of 25 mm planted into the ground, leaving 30 mm length cuttings above the soil surface. In the second method, all cuttings planted to the soil up to the surface of the soil. The distance between two-lines was 2.0 m, 1.0 m in double rows and distance of the planted cuttings in the line 0.75 m. This type of planting ensure 8,889 individuals per ha (Demo et al. 2013). Rooted cutting with the aboveground cutting is presented in figure 1.

Figure 1 Rooted cutting with the aboveground cutting (07.06. 2009)
Photo: Demo, 2009

The harvest of the biomass at the end of the first and during the second three-year growing cycle was evaluated. The extracted biomass at harvest moisture was converted to an individual within the stand (kg per plant). The extracted biomass was dried in an oven at 105 ° C, and then converted per produced dry matter in t h^{-1}.

Results and Discussion

According by Porvaz et al. (2009) cultivates of the fast-growing tree species is economically efficient if the annual production of biomass is at least 12 t ha^{-1}. In terms of production, studied varieties (Table 2) represent a suitable biological material in soil-ecological conditions of southern Slovakia. The biomass production is economically efficient and it pan out balanced yield biomass that can be used in the energy and non-energy sector too.

Table 2 Biomass production in the third growing year (2011) in different varieties of poplar

Varieties	Planting methods	Average % of dry matter	Average dry weight of individual [kg]	Maximal dry weight of individual [kg]	Yield of dry biomass [t ha^{-1}]
Monviso	1	41.33	3.98	5.93	35.40
	2	41.33	2.50	3.30	22.25
AF-2	1	40.91	3.45	3.96	30.67
	2	40.91	2.55	3.14	22.71
Pegaso	1	40.84	2.15	4.70	19.12
	2	40.84	2.03	2.85	18.06
Sirio	1	41.76	3.42	5.09	30.42
	2	41.76	3.65	6.66	29.80

The evaluation of the achieved yields of biomass of different varieties (Table 2) show, that the highest harvest of biomass were obtained with the first method of planting for all varieties, in which 0.2 m long cutting from one-year old shoots in average 25 mm in diameter were planted in the soil, leaving a 30 mm length cuttings above the soil surface. The re-count average dry weight of the individuals 8,889 individuals per ha, the highest yield of dry biomass was achieved in a variety Monviso to a first method of planting (35.40 t ha^{-1}), the lowest of a variety Pegaso (19.12 t ha^{-1}). Very low harvest of dry biomass of a variety Pegaso was also due to attack of this variety during the growing by disease of poplars (*Dothichiza*) (Figure 2).

Figure 2 The gowth of Pegaso variety during the 2011 attack by the *Dothichiza*
Photo: Demo, 2011

As the first year after re-sectional (2011) the individuals of poplar varieties created of the canopied growth (Figure 3) and the cuttings formation was observed in all subjects, there was no need to pursue further research on the level of variations (in establishment of the growth).

Figure 3 The canopied growth of poplar in vegetation period 2011
Photo: Demo, 2011

The average yield of biomass experimental individuals of the grey poplar varieties in the year 2012 (Table 3) was in the range of 15.83 kg of a variety AF-2 to 21.16 kg of a variety Monviso. These differences in yield biomass in individuals were reflected in the biomass yield varieties as referred to in t ha^{-1}. The average yield of biomass in the experimental varieties at harvested moisture ranged from 140.74 t ha^{-1} in a variety AF-2 to 188.14 t ha^{-1} in a variety Monviso. At 44.76 and 47.91% dry matter were average yield of biomass in dry matter for each variety in the range of 67.42 t ha^{-1} in a variety AF-2 to 87.16 t ha^{-1} in a variety Monviso (Prčík, Kotrla, Hauptvogl, 2014).

Table 3 The yields of polar biomass (*Populus* × *canescens*) in the fourth vegetation year of the first growing cycle (2012) and in the first vegetation year of the second growing cycle (2013)

Varieties	Biomass yield					
	Average biomass yield of the studied varieties [kg]		Avarage biomass yield of the studied varieties a harvest moisture [t.ha-^{1}]		Average biomass yield of the dry matter of the studied varieties [t.ha-^{1}]	
	2012	2013	2012	2013	2012	2013
Monviso	21.16	6.03	188.14	53.56	87.16	21,92
Pegaso	18.83	3.75	167.40	33.34	76.90	14.09
AF-2	15.83	3.43	140.74	30.45	67.42	12.34
Sirio	19.76	4.00	175.70	39.78	78.64	15.51
Average varietes [t.ha-^{1}]					77.54	15.97
Average varietes [t.ha-^{1}.year^{-1}]					25.85	15.97

In the table 3 is the average yield of biomass experimental individuals of the grey poplar varieties in the year 2013 – the first year of the second growing cycle. The average yield was in the range from 3.43 kg variety AF-2 and 3.6 kg variety Monviso. These differences in yield biomass in individuals were reflected in the biomass yield varieties as referred to in t ha^{-1}. The average yield of biomass in the experimental varieties at the harvested moisture ranged from 30.45 t ha^{-1} in AF-2 variety and 53.56 t ha^{-1} in Monviso variety. At 38.98 and 42.25% dry matter were average yield of biomass in dry matter for each variety in the range from 12.34 t ha^{-1} in AF-2 variety to 21.92 t ha^{-1} in Monviso variety.

Table 4 The yields of poplar biomass (*Populus* × *canescens*) in the second vegetation year of the second growing cycle (2014) and in the third vegetation year of the second growing cycle (2015)

Varieties	Biomass yield					
	Average biomass yield of the studied varieties [kg]		Avarage biomass yield of the studied varieties a harvest moisture [t.ha-^{1}]		Average biomass yield of the dry matter of the studied varieties [t.ha-^{1}]	
	2014	2015	2014	2015	2014	2015
Monviso	11.1	22.41	98.67	199.16	44.44	89.70
Pegaso	14.9	18.10	132.45	160.67	55.34	67.13
AF-2	16.35	50.15	145.34	445.78	64.50	197.84
Sirio	12.75	45.53	113.34	404.67	52.05	185.87
Average varietes [t.ha-^{1}]					54.08	135.14
Average varietes [t.ha-^{1}.year^{-1}]					27.04	45.05

The fresh biomass (Table 4) in the vegetation period 2014 was ranged from 98.67 (Monviso) to 145.34 t ha^{-1} (AF-2). The dry biomass (calculated in t ha^{-1}) ranged from 44.44 t ha^{-1} (Monviso) to 64.50 t ha^{-1} (AF-2). In the vegetation period 2015, which represents the third vegetation year of the second three-year growing cycle, varieties can be divided in terms of production into two groups. In the first group are varieties Monviso (89.70 t ha^{-1}) and Pegaso (67.13 t ha^{-1}). The other one represents varieties which set up the order of double the output compared to the first group. Variety AF-2 developed 197.84 t ha^{-1} and Sirio 185.87 t ha^{-1}.
The annual production comparing for the growing years 2014 and 2015 indicate an increase of the biomass production on average by 66.6% (45.05 t $ha^{-1}.year^{-1}$).
The production of the fast-growing poplar biomass has a lot of positive aspects in term of the environment. It contributes to reducing the proportion of CO_2 in the atmosphere, positively affects the recycling of water and nutrients (Dobson et al., 1997) and poplar plantations increase the diversity of perspectives and aesthetic value of agricultural landscapes. Plantations have also joined a number of other positive functions in the non-forest woody vegetation in the landscape (noise barrier, erosion control, windbreaks and so on).
In terms of socioeconomic, plantations of the fast-growing plants represent new jobs, especially in rural areas, represent a domestic source of fuel whose price and production volume can quite accurately predict to the future (Mönnich et al., 2006), it is possible to make unused agricultural land and land unsuitable for arable crops (Pastorek et al., 2004).

Conclusions

The highest yield of dry biomass in third vegetation year was in the variety Monviso (35.40 t ha^{-1}) establish according first method of planting, the lowest variety Pegaso (6.18 t ha^{-1}) in the second method of planting, in which the disease *Dothichiza* was identified.
The highest values of dry matter in the vegetation period 2014 reached a variety AF-2 (64.50 t ha^{-1}).
In the vegetation period 2015, which represents the third vegetation year of the second three-year growing cycle, varieties can be divided in terms of production into two groups – the first group: variety Monviso (89.70 t ha^{-1}) and Pegaso (67.13 t ha^{-1}) and the second group: AF-2 (197.84 t ha^{-1}) and Sirio (185.87 t ha^{-1}).
Experimental poplar varieties in different growing years exceeded the threshold of economic efficiency (12 t ha^{-1}).

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POSSIBILITIES OF APPLICATION OF GIS AND MSPA METHOD TO IMPROVE INTEGRAL MANAGEMENT OF PROTECTED NATURAL AREAS AND FOREST ECOSYSTEMS

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Abstract

Fragmentation and connectivity of forest ecosystems plays a key role in their conservation, potential to represent habitat for other species, biodiversity associated with them and also their management related to spatial planning. Analysis of forest ecosystems, areas they cover, their fragmentation and connectivity can be done in different ways. MSPA (*Morphological Spatial Pattern Analysis*) is one of the relatively newer methods which can be used to accomplish this in a way which provides substantial and accurate data. MSPA is based on analysis of raster data using mathematical morphology methods. Before that it is necessary to spatially reference the raster data in some of the GIS software. In this paper raster data for Tara National Park was analyzed using MSPA methodology. This area was chosen because it represents a protected natural area which conservation is very important since it represents one of the few remaining habitats of Serbian spruce. Raster of this area, originally derived from remote sensing, were processed in GIS software and GUIDOS (*Graphical User Interface for the Description of image Objects and their Shapes*) Toolbox which enables MSPA. Results of this type of analysis represent a reclassification of each pixel which corresponds to a forested area regarding its spatial location and relation to its neighboring pixels. This paper shows the graphical and numerical MSPA results for the selected location as well as the importance for conservation efforts. The application of described technology represents a good starting basis for decision making in the fields of sustainable management of protected natural areas and integral forest management of forest ecosystems in Serbia. Results of this type of analysis also have potential to improve commercial aspects of forest and protected areas, as well as environmental protection management.

Keywords: inegral forest management, forest ecosystems, GIS, MSPA

Introduction

Forest management and conservation is currently focusing on the integrity and diversity of forest ecosystems. Because of that forest landscape connectivity is gaining increased acceptance as a key objective which plays a vital role in interactions in forest ecosystems and influence their ecological services [1]. This is, perhaps, most obvious in the case of biodiversity. Species dispersal and migrations, pollination, and genetic interchanges are just some examples of important processes which are influenced by the degree of present connectivity in a forest ecosystem [2]. Besides that, maintaining or contributing to an increase of forest connectivity may contribute to mitigation of potentially negative effects of habitat fragmentation and climate change.

Successful forest management also depends on monitoring ecological changes that are constantly happening either through natural processes or anthropogenic influences. Landscape pattern can reflect or influence ecological processes that operate at different scales, and a good way to analyze them is by applying some form of landscape metrics. Currently there is a wide range of methods which can be used to analyze landscape spatial pattern, and one of them is morphological spatial pattern analysis (MSPA) [3] which is based on mathematical morphology [4]. MSPA analyzes land cover patterns on raster maps in order to describe the geometric arrangement and connectivity of the map elements.

In this paper this methodology was applied to Tara National Park and its surrounding area, located in western part of Serbia. This area was chosen because it represents an important protected area with high biodiversity. Over 1.000 plant species, which is a third of total number of plant species in Serbia, are located in this area. Tara National park is also a home for over 135 bird species, among which there are several birds of prey with special conservation importance. Various mammal species, both large and small, also live in this area. This location is also very important because it is one of the few remaining places where Serbian spruce is present in the wild. Serbian spruce (Picea omorika Panč./Purkyne) is an endemic species of the Balkan Peninsula and a tertiary relic. Its widespread populations from the tertiary have been reduced to the refugia in east Bosnia and west Serbia. The conservation of this species is necessary not only for its rarity and vulnerability, but also on the account of its valuable pioneer qualities [5].this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

Material and Methods

In order to conduct MSPA it is necessary to acquire and prepare a raster with reliable information about the analyzed object. We obtained a forest type map of the analyzed area from the EU Joint Research Center website [6]. This map was crated based on satellite imagery data in 2006. Its spatial resolution is 25m and is spatially referenced in ETRS89 Lambert Azimuthal Equal Area projection. Relevant map classes show broadleaved forests (light green color), coniferous forests (dark green color), water (light blue color) and non-forested land (light yellow color). The original forest type map covered and area of Southeastern Europe with a size of 1.000km x 1.000km. Raster processing tools in GIS were used to obtain two smaller maps of the analyzed area, one in 1:100.000 scale, figure 1, and the other in 1:200.000 scale. The first map was used to analyze the state and fragmentation of forest cover in Tara National Park and the second one to analyze its connectivity with the surrounding areas. Next step in the MSPA methodology is to create a binary mask, figure 2, which is a raster that has pixels which can only have tree possible values, one for foreground (areas which are being analyzed), one for background (all other areas) and one for missing or irrelevant data. All forested area, both broadleaved and coniferous, was reclassified as foreground and all non-forested area was reclassified as background, while water areas were reclassified as missing data. This was done in GUIDOS Toolbox (Graphical User Interface for the Description of image Objects and their Shapes) [7], which was also used to conduct MSPA and connectivity analysis. MSPA is based on several morphological operations and the extent and direction of these operations is defined by the structuring element (SE), which is region of pixels of predefined size and shape. After that each pixel is analyzed regarded to the pixels adjacent to it and is reclassified as one of the following:

- Core: core forest pixels represent the inner part of a forested region, away a certain distance from the forest boundary. When determining the core pixels it is important to set the distance to non-forested area in pixels which is needed to be present in order for a pixel to be classified as core pixel. Since the spatial resolution of the input map is 25m the distance was set to 3 pixels. Usually, in forest ecosystems, conditions which are characteristic for inner forest (core forest) start approximately between 50m to 100m away from the edge of the forest depending on the forest ecosystem type.
- Islet: islet forest pixels are forest regions too small to contain core forest.
- Perforated: perforated forest pixels represent transition zone between core forest and a non-forest patch which is located within a core forest area

- Edge: edge forest pixels are the transition zone between core forest and core non-forest
- Loop: loop forest pixels represent a corridor which connects to the same core forest region where it originates
- Bridge: bridge forest pixels have no core forest and connect at least two different core forest areas
- Branch: branch forest pixels have no core forest and connect at one end only to a forest region

These classes represent various types of forest spatial patterns which can be important for forest conservation and management. Core forest areas are usually a sign of unfragmented habitat which suitable for species preferring forest interior areas, while forest edge is more likely to be suitable for species which require both forested and non-forested areas. Bridges can represent important corridors which need to be protected in order to conserve the connectivity of the forested areas, while branches can be used to identify the best stubs upon which forest restoration can build new corridors between different, previously not connected, forested regions. Once all MSPA analysis was completed obtained rasters were used to create maps in GIS software by overlying them with Tara National Park border, locations of Serbian spruce and areas of nature reserves.

Results and Discussion

Results of the MSPA are shown in figure 3 and table 1. Figure 3 shows the reclassified raster of the analyzed area after the MSPA in the 1:100.000 scale and table 1 gives the spatial statistics of MSPA (percentage of presence of each pixel type in the analyzed raster). Over a half of all the analyzed area, 53,75%, is covered by some type of forest. According to the MSPA of all the forested area almost a half, 43,28%, is considered as core forest. Forest fragmentation is relatively limited since only 4,25% of foreground pixels are classified as islets, while connectivity between forested areas is quite present, with 25,28% of pixels being assigned as bridge pixels. Difference between core to non-core pixels (all MSPA classes except core) is slightly in favor of non-core pixels with 56,72% of foreground pixels belonging to non-core classes.

Table 1. MSPA spatial statistics

MSPA class (color)	**% of pixels in foreground**	**% of pixels in whole raster**
Core (green)	43,28	24,04
Islet (brown)	4,25	2,36
Perforation (blue)	2,11	1,17
Edge (black)	11,54	6,41
Loop (yellow)	7,73	4,29
Bridge (red)	25,28	14,04
Branch (orange)	5,82	3,23
Background (grey)	- - -	44,45
Missing (white)	- - -	1,80

Once MSPA of a raster is complete GUIDOS Toolbox offers different types of further spatial analysis. One of them is a component analysis which can be used to assess the connectivity of the analyzed foreground.

Component analysis reclassifies foreground pixels and groups them in different components with different colors. One component represents a group of pixels which are connected among themselves but not with other pixels from different components. Results of the components analysis for the analyzed area are shown in figure 4. The map in figure 4 has a 1:200.000 scale because this scale is better to analyze connectivity of Tara National Park with the surround area. There is a total of 832 components in the analyzed area, however three are substantially larger than the rest. First one is located west of Tara National Park, in Bosnia and Herzegovina (pink color), second one is located in Tara National Park, but also south and east of it (yellow color), and the third one is located east of Tara National Park (green color).

Figure 1. Forest type map of the Tara National Park.

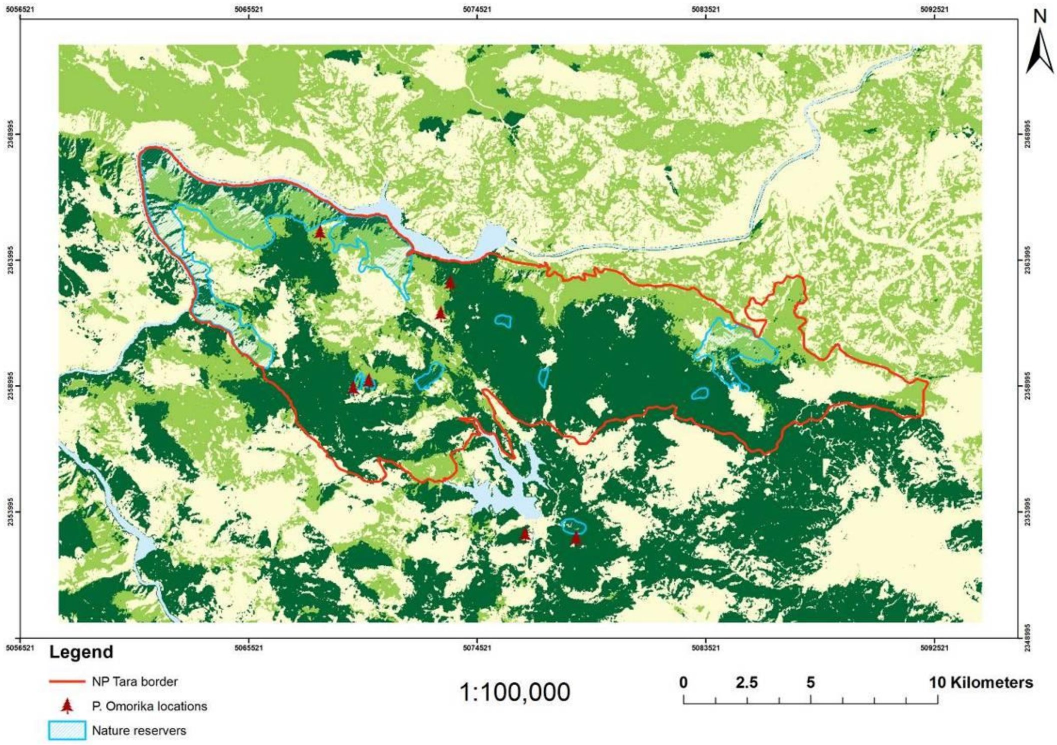


Figure 2. Binary mask of the Tara National Park

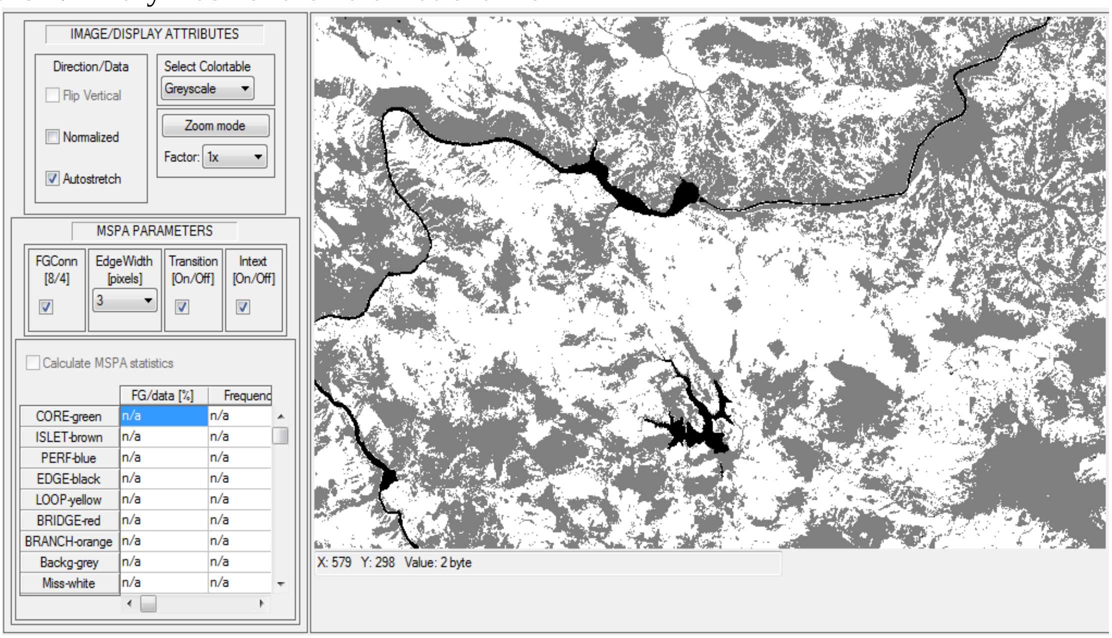


Figure 3. MSPA classification map of the Tara National Park

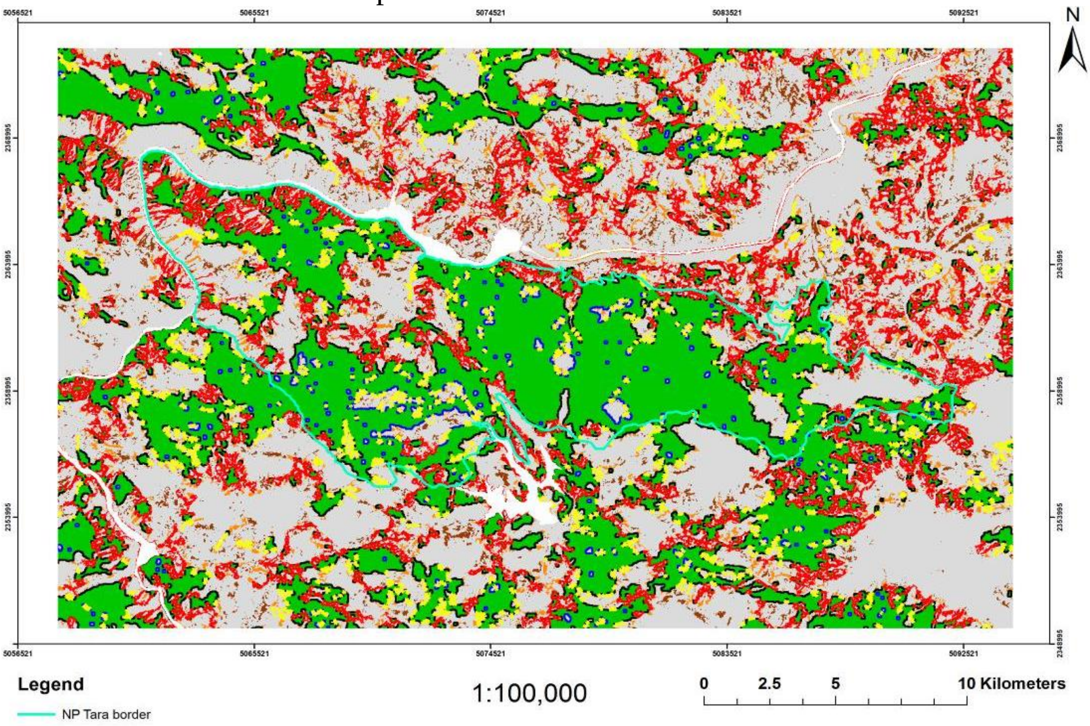
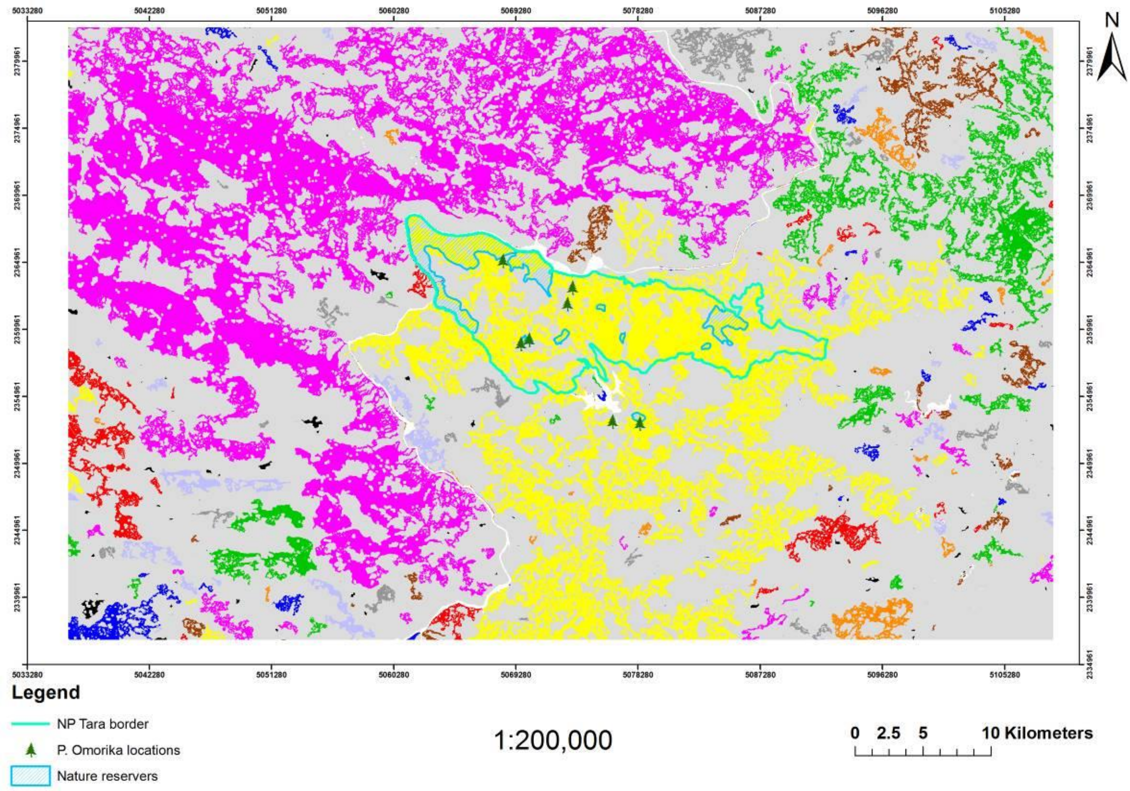


Figure 4. Connectivity analysis map of the Tara National Park



Conclusions

MSPA can provide new and insightful conclusions regarding forest ecosystems and their state. Because of that it has a potential to be useful in their management and conservation. In this paper MSPA was applied to the Tara National Park and its surrounding area. It was observed that Tara National Park has obvious large areas which are classified as core forest, mostly in its central part. Its western part has large areas of forest cover with edged characteristics (all non-core foreground pixels). By overlying Serbian spruce locations and nature reserves (which mostly have this status based on the presence of Serbian spruce) we can observe that is habitat is dominantly coinciding with edge forest areas. This confirms the fact that this tree species does not tolerate competition with other present tree species like Norway spruce, and prefers to pioneer non-forested areas. This example shows just one species which prefers edge of forested area. On the other hand core forest areas can be more suitable for large mammal predators which are also present in Tara National Park. The balance of these two types of forest habitats is quite good in Tara National Park with only a slightly more forest areas being classified as edge. Analysis of the connectivity of forested area of Tara National Park among itself and to its surrounding showed that almost all forest cover in it is connected. There is just one small unconnected fragment which is located in the western part of Tara National Park. River Drina represents a natural barrier on the western and northern side of the Tara National Park, however, the Park has good connectivity with the forest cover located south of it. There is a large number of forest fragments (some even quite large) not connected fragments not connected among themselves and also not connected to Tara National Park. Having that in mind, future forest management efforts could primarily focus on connecting these forest fragments to Tara National Park.

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