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BIOMASS AS A DRIVING FORCE FOR RURAL DEVELOPMENT - MISCANTHUS BEST PRACTICES

SUMMARY

In most countries, valorisation of biomass as a renewable energy is related to the traditional sources such as woody biomass and agricultural residues. Nevertheless, perennial grasses can often produce higher yield of biomass than forest trees, while existing mechanization of forest management units are at disposal. Perennial grasses require only one cultivation activity, preparation for planting, and low nitrogen inputs during 10-20 years of cultivation.

Poor rural population reliance on the functions of biomass production is rarely measured and is usually not included in valorization of total household potentials for entrepreneurship, which further leads to development of inappropriate strategies that do not appreciate the role of environmental protection in combating the poverty.

Miscanthus giganteus is a highly productive plant species, which has been cultivated in Europe for 20 years as energy crop. The remarkable adaptability of Miscanthus to different environments makes this novel crop suitable for establishment and distribution under a range of European and North American climatic conditions. It produces no seed and its plantations should be established using vegetative method of planting divided rhizome pieces, so there is no threat of natural ecosystems contamination by uncontrolled spreading of this allochthonous species.

This paper shortly reviews the role of perennial herbaceous crops in meeting the need for sustainable land use and development. Research results from field sample plots of Miscanthus, including biomass production potential and heat capacity, are explained with the aim of closer recognition of environmental contribution and influences and energy efficiency of this energy crop.

Keywords: Miscanthus, energy efficiency, biofuel

INTRODUCTION

Interests and attitudes of different stakeholders in biofuels production are variable and controversial and external factors can have significant influence in the process of national programming of biofuels production (Lakner, 2008). Bioenergy can contribute significantly to climate change struggle and rural

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development, but also can cause further degradation of soil and water resources, ecosystem instability, food safety problems and increasing of greenhouse gasses emissions, if human resources do not respect rules of sustainability during the production development (Sagar, Kartha, 2008). Having in mind these problems, main goals of national policies in energy management have to be energy consumption reduction, introduction of renewable energy sources, increasing of quality and quantity of agricultural production and environmental pollution reduction, followed by decreasing of production costs (Janic *et al*., 2009).

Intensive researches have to support policy framework development and provide baseline for decision making and modelling of scenarios of future environmental and socioeconomic influences of biomass production. Economic efficiency of bioenergy sources is still questionable and it has to be supported with exact measurements conducted within multiannual field and laboratory experiments, as a baseline for further cost-benefit analyzes (Milovanovic *et al*., 2011; Drazic *et al*., 2010). The price of biofuel on global market is still high and this type of energy is not available to wider population, while the producers have competitiveness problems with conventional plants production.

Supportive governmental measures for biofuels production in every country have to be planned and documentary by experimental research results from the field, because of many assets of this type of energy production: oil import decreasing, greenhouse gasses emission reduction, new employment offers and sustainable use of degraded lands.

From what has been said *above, it follows* that only intensive use of existing and new bioenergy crops can lead to multifunctional agriculture, as well as to price stability of agricultural products. These improvements will contribute to sustainable rural development of every country.

Literature data have shown that growth of Miscanthus is energy wise the most efficient one compared with other biomass producers as biofuel source (Bohemel *et al*. 2008). When growing this plant for industrial processing, strategy of increase of stem share with respect to leaf mass at vegetation end should be followed, because such biomass has more favourable combustion characteristics, higher caloric value and lower ash content (Monti *et al*. 2008.). It has been shown that this plant has extremely high potential for storage, exclusion from bio-geo-chemical carbon cycle, which makes it significant in combat against global warming (Cliftom-Brown *et al* 2007.).

Miscanthus (genotype whose growth as energy crop is mostly present in Europe (Lewandowski *et al*. 2000), is a sterile triploid hybrid (Linde-Laursen 1993) which originates from Southeast Asia. This means that: 1) its reproduction is possible only through vegetation way, 2) it is sensitive to low temperatures, 3) its development requires high isolation and relatively large quantity of water. As consequence of this the following occurs: 1) high price for planting material, thus establishment of stand, 2) freezing as consequence of low winter temperatures, particularly in absence of snow cover, 3) higher yields are achieved with watering (Ercoli *et al.*1999, Clifton-Brown and Lewandowski 2000, Cosentino *et al*. 2007) in southern parts of Europe.

In this study we investigate the possibility of production biomass of Miscanthus giganteus in Republic of Serbia as bioenergetic crop according EU experiences.

MATERIAL AND METHODS

Plant material was purchased from commercial supplier. Rhizomes were planted in the spring of 2007, 2008 and 2010. The examination of yield was performed in experiment fields at four locations in Republic of Serbia (Zemun municipality/chernozem, Ralja city/ etrustic cambisol, Loznica city/degraded cambisol, Zasavica town/ hydromorphic black soil) (Figure 1)

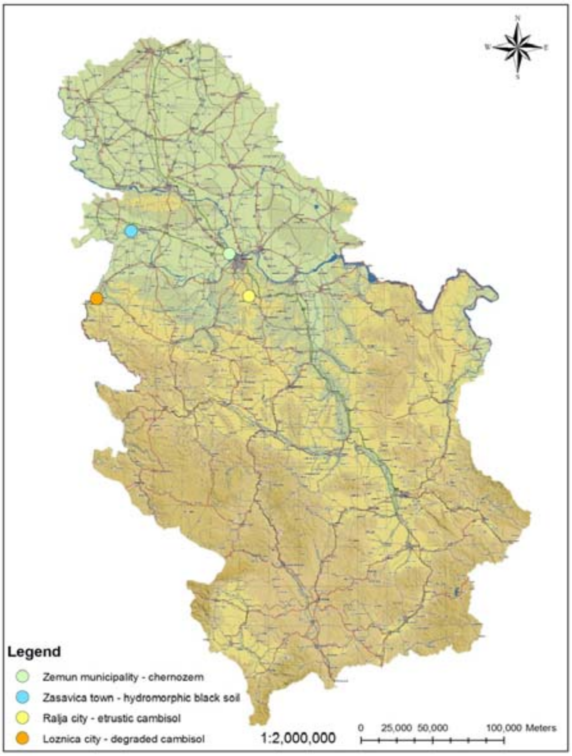

Figure 1. Four locations of experimental fields of Miscanthus

Rhizomes (100) were planted in plots of 10 x 10 m each in 3 repetitions. The experiment was conducted with fertilizer applied before planting (100kg/ha NPK) by watering. The yield was measured by harvesting all aboveground plant material per plot and calculated at 15% moisture content. Moisture contents were measured as 1 – dry biomass/harvested biomass x 100. Dry biomass was determined after drying at room temperature during 7 days and 24 h in oven at 50°C. Results are shown as arithmetic mean ±standard error.

RESULTS AND DISCUSSION

Miscanthus life-cycle. Miscanthus is a perennial rhizomatous grass with the C4 photosynthetic pathway. Its sterile hybrid witch cannot form fertile seeds as a consequence of its triploidy. (Lewandowski *et al*., 2000). As sterile hybrid Miscanthus spears naturally by means of underground storage organs (rhizomes) (Clifton-Brown and Lewandowski, 2000; Lewandowski *et al*., 1999). However, their spread is slow and there will not be any uncontrolled invasion of hedges or fields. These rhizomes can be split and the pieces re-planted to produce new plants. Due to their photosynthesis properties (C4 plant), Miscanthus species have a potential for very high growth rates.

Figure 2. Annual cycle of Miscanthus giganteus

In Europe it begins growing in April and continues until halted by frost in November (Ercoli *et al*., 1999). Miscanthus is planted in spring and canes produced during the summer are harvested in winter. This growth pattern is repeated every year for the lifetime of the crop, which will be at least 15 years. Literature data show that Miscanthus biomass increases by third year and remains constant for 15-20 following years (Cristian *et al.*, 2008). Figure 2 shows annual cycle of Miscanthus development at Zasavica town site in the first vegetation period.

Field experiment – losses during 1st year.

Table1. Losses of Miscanthus plants in the first year. Date represents averages of 3 samples by 100 plants in field experiments, without watering and fertilizer; interval of experimental data was done in parenthesis. * damaged but survive plants.

Results show that there are no significant losses during the first vegetation season even without application of agro-technical measures.

Table 1. presents results of monitoring survive of plantlets during 1st year of established canopy.

Experimental site	Degree of emergency %	Summer damage %	Winter freezing damage* %	Late frost damage* %
Zemun municipality	92 (72-96)	5 (2-10)	5 (3-7)	14 (5-20)
Ralja city	90 (85-95)	5 (2-9)	10 (5-12)	12 (5- 15)
Loznica city	86 (70-90)	7 (3-11)	2 (0-3)	3 (1-5)
Zasavica town	84 (80-92)	5 (3-12)	2 (0-3)	5 (0-11)

Field experiment - moisture contents

Table 2. Moisture content (%) in Miscanthus biomass harvested during 2nd year of canopy. O- control plots, WF plots with watering and fertilizing.

Experimental site	Moisture content EH 0	Moisture content EH WF	Moisture content LH 0	Moisture content LH WF
Zemun municipality	80±7	89±6	18±2	20±4
Ralja city	79±7	85±5	20±2	20±3
Loznica city	66±9	74±3	18±3	21±4
Zasavica town	82±4	86±5	24±2	27±4

Table 2 presents results of moisture contents in early harvest EH biomass (September) and late harvest LH (February) in experiment with watering and fertilizing (WF) and without them (0). The data refers to the second year of canopy.

Biomass harvested in September, when it is at its maximum during the year, contains high percentage of water so it is not suitable for incineration. Biomass harvested in February, after winter, contains 18-27% of moisture which characterises it as biofuel. Because of this, further experiments were conducted on a biomass harvested in the late winter.

Field experiment – yield

In table 3 were presented results of biomass production in 2nd year, late harvest, calculated at 15% moisture contents.

Table 3. Biomass (kg/ha) of Miscanthus straw harvested in early spring after 2 years of cultivation. 0 control, without agrotechnical measures, 0W only watering, F0 only fertilizing, WF watering and fertilizing.

Experimental site	00	0W	F0	WF
Zemun municipality	2834±250	3287±288	2900±346	3450±137
Ralja city	3445±327	4228±522	6180±352	6260±158
Loznica city	2577±316	2986±340	3466±402	3582±360
Zasavica town	3122±420	3566±358	4286±340	4323±286

Acquired results show that effect of watering and fertilising depends on soil on which Miscanthus is grown. On chernozem, irrigation contribution is more important because this is very fertile soil, while on canbisol fertilisation contribution has more importance, because this soil holds water from precipitation. Best yield was achieved on canbisol, but it is probably a consequence of the history of the experimental field on which vegetables was grown before Miscanthus. Good yields were achieved in Zasavica town which are not dependent on applied measures probably because of the marshland that matches the soil of origin of this plant.

Yield that was achieved in the second year of canopy development corresponds to literature information for canopies that after the third year have yields of 12-22 t/ha (Clifton-Brown *et al.*, 2007). At the experiment field, in Zemun municipality, that was established in 2007, yield after the third year was 14 t/ha and after the fourth 17 t/ha. At the experimental field in Loznica city, that was established in 2008, after three years yield was 7 t/ha for non-treated field or 15 t/ha for fields that were fertilised right after planting.

Miscanthus giganteus has not been previously grown in Serbia, except sporadically as a decorative species. European experience in Miscanthus cultivation (Ercoli *et al.*, 1999) shows many general advantages of Miscanthus biomass as an energy crop. Mineral content is low at the early-spring harvest: 0.09-0.34% N. 0.37-1.12% K, 0.03-0.21% Cl; CO_2 emission up to 90% lower in comparison with coal; gross heating value of 17-19 GJ/t; net energy content 15.8-16.5 GJ/t ; water content at harvest 15%; chopped density at harvest of 70-100 kg/m^3 ; compacted bale density 150-300 kg/m^3, holocellulose content of 64-71%; ash content of 1,5–4,5 % ; ash fusion temperature of 1090°C; and sulphur content of 0,1%; Ash remained after Miscanthus combustion contains about 30-40% SiO2. 20-25% K, 5% P2O5, 5% CaO and 5% MgO. High biomass productivity and high heating value, low SO_2 and NOx production in comparison with fossil fuels, annual renewing and low requirements for canopy maintenance indicate the advantages of the plant over fossil fuels and other biomass sources (Kahle *et al*., 2001).

At present giant grasses from the genus Miscanthus are considered to be key renewable raw materials for industry and energy production (Jeżovski, 2008). Miscanthus giganteus high level biomass production (20 t/ha/year) and possibility of cultivation on less quality soil (Heaton at al. 2004) make this crop very suitable as annual renewable raw material for bio-fuel production (Dražić *et al*., 2010). Biomass crops can provide renewable sources of fuel for heat energy and electricity generation, whilst making gainful use of excess agricultural land (Beale *et al*., 1999). It has been shown that this plant has extremely high potential for storage, exclusion from bio-geo-chemical carbon cycle, which makes it significant in combat against global warming (Clifton-Brown *et al*., 2007).

CONCLUSIONS

According to obligations emanating from the implementation of Kyoto Protocol and in accordance with the sustainable development priorities of Serbia in the period until 2015, provided in the National Strategy of Science Development and National Energy Development Strategy and Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, production and use of biomass is of crucial importance for provision of annually renewable domestic source of energy and for environmental protection. Integrated approach to the production of energy crops, both farming and forest ones, is the imperative, because estimated available biomass (as waste, harvesting remains and manure) is not satisfactory in terms of its quality and quantity.

Biomass of *Miscanthus* is characterized by high energy contents (about 16 GJ/t) and low production of ash and nitrogen oxides after combusting. The disclosed yield greatly varies depending on climate and agro-ecological conditions, as well as genotypes, so efforts are made to adapt the existing cultivation technology to local conditions. Investments into the production of biomass of perennial grass are limited to the first year (establishment of a plantation is the most expensive: preparation of land, protection against weed, procurement of seedling material and planting of rhizomes, irrigation, when necessary). Once planted it provides yield over the next twenty years with virtually no further investments (annual harvesting for perennial grass, every 3 years for fast-growing willows). Preliminary analyses show that it is necessary to achieve yield of technologically dry mass of 10-15 t/ha/year in order to make production cost-effective. Energy generation from this biomass is still considerably more expensive than energy generation from fossil fuels, but ecological parameters are far more favourable for biomass.

Systematic collection and critical analysis of the results obtained in experimental measurements of biomass production was gained from agro-industrial crops through field tests from the environmental, energy and economic efficiency aspects. The first category includes field tests previously established, currently in their development phase. The second one includes target tests which will be established at the beneficiary's research grounds and in other degraded areas. The third one includes field tests which will be established with other agro-energy crops which prove to be interesting for biomass production. The data collected through analyses performed by accredited laboratories with regard to field tests will be compared with literature data and other data obtained in the analyses of biomass from harvest remains and agricultural waste.

The beneficiary is provided with specific results related to production of agro-energy crops in degraded areas and agricultural land: the areas needed for achievement of biomass production of 10% of fossil fuels consumption with measured yields in the own tests for Miscanthus.

Special attention is paid to socioeconomic aspects of agro-energy crops production through the analysis of energy, ecological and economic incoming and resulting parameters through application of adequate methods. This analysis should serve to assist a decision-maker in estimating further development of production and use of agro-energy crops from the aspect of natural resources management in accordance with national and international standards in place.

Bearing in mind that this is a brand new area of study, it is also necessary to implement general awareness raising campaign about the necessity of energy crops production. With regard to that, it is planned to establish a network of institutions (scientific and educational) which will serve as consultants to the economic subjects that decide to produce and process biomass and energy crops and they will actively participate in adoption and harmonization of standards in this area.

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BIOMASA KAO POKRETAČ RURALNOG RAZVOJA - *MISCANTHUS* PRIMER DOBRE PRAKSE

SAŽETAK

U mnogim državama, valorizacija biomase kao obnovljive energije je vezana za tradicionalne izvore kao što su drvne biomase i poljoprivredni ostaci. Ipak, višegodišnje trave mogu često da proizvedu veće prinose biomase nego šumsko drvece, dok je postojeća mehanizacija jedinice za upravljanje šumama na raspolaganju. Višegodišnje trave zahtevaju samo jednu aktivnost kultivacije, pripremu za sađenje i malu količinu azota tokom 10-20 godina uzgajanja.

Oslanjanje siromašne ruralne populacije na funkcije proizvodnje biomase se retko meri i najčešće nije uključeno u valorizaciju ukupnog potencijala domaćinstva za preduzetništvo, što dalje dovodi do razvoja neprikladne strategije koja ne uvažava zaštitu životne sredine u borbi protiv siromaštva.

Miscanthus giganteus je veoma produktivna vrsta koja se već 20 godina u Evropi uzgaja kao energetski usev. Neverovatna prilagodljivost Miskantusa na različite uslove čini ovaj noviji usev prikladnim za sađenje i distribuciju u raznim evropkim i severno-američkim klimatskim uslovima. Ne proizvodi seme i njegovo sađenje se uspostavlja kroz vegetativni metod sađenja pojedinačnih rizoma, tako da ne postoji pretnja od zagadjenja prirodnih ekosistema kroz nekontrolisano širenje alohtonih vrsta.

Ovaj rad se ukratko osvrće na ulogu višegodišnjih travnatih useva u ispunjavanju potreba za održivu upotrebu i razvoj zemljišta. Rezultati istrazivanja uzoraka zemljista sa polja Miskantusa, uključujući i potencijale proizvodnje biomase i grejni kapaciteti, su objašnjeni sa ciljem bližeg prepoznavanja doprinosa za životnu sredinu, uticaja na životnu sredinu i energetske efikasnosti ovog energetskog useva.

Ključne riječi: Miskantus, energetska efikasnost, biogorivo