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SUSTAINABLE PRODUCTION OF BIOMASS THROUGH MISCANTHUS GIGANTEUS PLANTATION DEVELOPMENT

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ABSTRACT: *Energy crops offer clear ecological advantages over fossil fuels, such as a positive carbon balance which contributes to the reduction of greenhouse gases emissions and the low sulphur content, which contributes to the reduction of acidifying gases emissions. According to the results of miscanthus yield analyzes from field plots established on arable and degraded land in Serbia, and actual costs of plantation development, economic and energy efficiency of biomass production has been calculated. Experimental research results on miscanthus production in Serbia show that this kind of production is possible and can reach efficiency in country specific conditions.*
KEYWORDS: *miscanthus, plantation, energy efficiency, sustainable production*

INTRODUCTION

Energy crops offer clear ecological advantages over fossil fuels, such as a positive carbon balance (due to the photosynthesis of the biomass used as raw material) which contributes to the reduction of greenhouse gases emissions, to the low sulphur content and to the reduction of acidifying gases emissions [1]. The main encouragement to bio-energy crop production and development was the acceptance of Kyoto protocol (1997) related to climate changes and reduction of greenhouse gases emissions. High interest in bio fuels on global level could be explained with following facts: bio fuel is a potential which can make a country less dependant of fuel oil import; bio fuel usage contributes to CO_2 emissions reduction; bio fuel usage can significantly improve quality of life in rural areas. The ideal energy crop has to have good capacity for energy transformation from solar to harvestable biomass with maximum efficiency, minimal input requirements and favorable environmental influence. Energy biomass systems must be characterized with very positive energy balance, which means lower energy inputs than energy yield, especially because energy inputs are related to fossil fuels and carbon emissions to the atmosphere.

Annual or multiannual species of grass with high biomass yield, high efficiency in nutrients and water consuming and good quality of biomass combustion are very perspective as energy crops. Perennial grasses can often produce higher yield of biomass than forest trees. The most interesting for cultivation and with the highest bioenergy potential are: Switch grass (Panicum virgatum L.), Red canary grass (Phalaris arundinacea L.), Giant cane (Arundo donax L.) and Miscanthus (Miscanthus×giganteus Greef et Deu.).

Among the biomass crops, miscanthus is one of the most interesting, since it can transform solar energy into electricity, and due to its high content in cellulose it can also be used for paper pulp production [2]. Miscanthus x giganteus is perennial grass with 15-30 t/year/ha of harvestable biomass, depending on agri-environmental conditions, and with 16 MJ/kg of higher heating value. Miscanthus high level biomass production and possibility of cultivation on less quality soil [3] make this crop very suitable as annual renewable raw material for bio-fuel production.

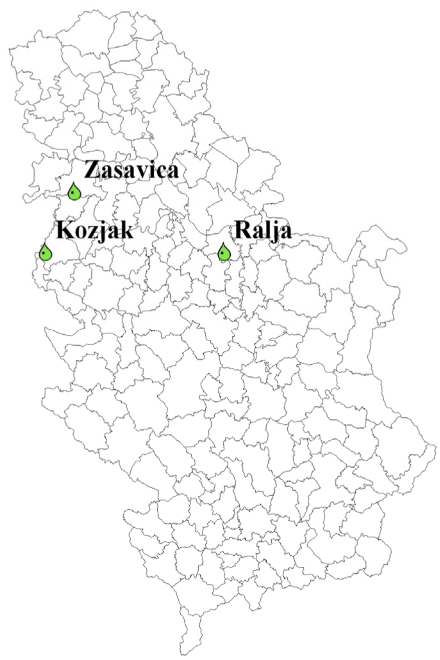
Commercial production of miscanthus based on maximization of above ground biomass yield requires selection of highly productive locally fully adapted varieties, fully mechanized farming operations, adequate use of fertilizer, chemical pest, disease and weed control [4]. In previous researches, several aspects of the sustainability of miscanthus biomass production in Serbia have been evaluated [5,6,7].

MATERIAL AND METHODS

Experimental sample plots of miscanthus have been established in Serbia at different locations (Ralja, Kozjak, Zasavica, Map 1) and comprise four different types of agri-environmental conditions:

a) A - arable land (Chernozem-black soil) with no fertilizer;
b) AF - arable land fertilized with 100 kg/ha of nitrogen fertilizer;
c) D - degraded soil (Calcaric Cambisols) with no fertilizer; and
d) DF - degraded soil with the same fertilizing regime.

Planting density of miscanthus rhizomes is 10 000 pieces per ha and yield calculations are related to the technologically dry biomass (with 15-20% of moisture content), harvested at the end of winter when the biomass quality is the most desirable. The content of water and nitrogen is the lowest during this time of the year and the biomass yield is only 30% lower than the peak value typical for the middle of autumn (October).



Map 1: Locations of miscanthus experimental plots in Serbia

Energy balance for perennial grasses with the aim of biomass production comprises entire queue of operations and materials applied for plantation establishment and its maintenance and, on the other hand, energy yield through dry biomass combustion. Direct energy input (fuel) and indirect energy inputs (mechanization, workers, chemicals, planting material etc.) can be expressed through energy equivalents necessary for the production. Table 1 shows general values of energy equivalents, according to literature sources which cover multiannual experimental results [8, 9, 10, 11].

Economic analyzes are conducted according to the calculated yield of technologically dry biomass of miscanthus from the sample plots, applying actual production costs relevant for the first year and plantation establishment.

Table 1 – Energy equivalents for energy crops production means and activities [12]

	Unit	Energy equivalent
Diesel fu	MJ l^{-1}	40.035
Guarding	MJ kg^{-1}	0.17
Briquetting	MJ kg^{-1}	1.0
Irrigation	MJ m^{-3}	1.02
Transport	MJ t^{-1} km^{-1}	9.22
Mechanization	MJ kg^{-1}	71.384
Workers	MJ h^{-1}	1.87

RESULTS AND DISCUSSION

Yield and energy parameters calculated for the second and third vegetation period of the miscanthus experiments in Serbia are presented in Table 2.

Table 2 – Yield and energy parameters of miscanthus cultivation for II and III vegetation period

Parameter Year Year	A II III	AF II III	D II III	DF II III	Ref. value [13]
Annual yield t/ha	2.50 9.93	4.48 14.24	4.30 8.44	7.68 12.50	10-30
Energy yield (EY) GJ/ha/year	40.0 158.9	71.68 227.84	68.8 135.4	122.88 200.00	< 360
Energy input (EI) GJ/ha	13.7 17.6	23.9 27.8	17.6 21.6	32.1 36.0	14 - 22
Net energy yield (EY-EI) GJ/ha/year	26.3 141.3	47.78 200.04	51.2 113.8	90.78 164.0	156 - 360
Energy ratio (EY:EI)	2.92 9.03	3.0 8.20	3.91 6.27	3.83 5.56	2.2 - 6.9
Cost of cultivation €/ha	200 180	270 250	225 205	295 270	II 186 III 172

Yield and energy balance values from experiments in other European countries are variable. Dry matter yields from miscanthus were studied in two series of UK trials from 1994 to 2003 at seven sites in England and from 2001 to 2006 at eight sites in Scotland and England and two in Northern Ireland. Calculated yield amounts from these studies varied between 10 and 25 t/ha for production period of 9 years, while yield amounts in Serbia can be predicted as significantly higher according to production *results for the first two years. Möller et al. (2007) [14] conducted a study to investigate the yield and economics of miscanthus production in several EU states. The mean biomass yield for M. giganteus from five EU states was between 11 and 20 t/ha, with the highest yield being recorded for production in Germany and Italy. The mean UK yield at 11.6 t/ha was the lowest of the countries included in the study.*

Clifton-Brown et al. (2000) [15] developed a model to predict the yield of miscanthus in Ireland, using data from trials conducted in 1994 and 1995. Predictions were based on the interpretation of field data and ten years of climatic data, to predict yield using a Geographical Information System (GIS). Highest predicted yields of miscanthus were for the South-West of Ireland with approximately 26 t/ha and the lowest yields for the North-East of Ireland with approximately 16 t/ha.

Miscanthus presented a clear positive energetic budget with energy ratio between 2.92 and 9.03, both for arable land with no fertilizer. Degraded soil trials showed higher request for energy inputs while, on the other hand, energy yield is also higher in comparison with arable land. From this point of research, it can be assumed that degraded areas are more suitable for miscanthus production from both aspects, reasonability of land use followed with energy ratio.

Data from Portugal showed energy balance value of 360 MJ ha^{-1}, while in Italy energy balance in 12-year-old plantation was 156 MJ ha^{-1}. Recent research by Clifton-Brown et al. (2004) [16] estimated peak yields of 25.8 t DM/ha in Belgium and 13 t DM/ha in Sweden and Finland. Having in mind this results, it is obvious that environmental conditions in Serbia are supportive for miscanthus cultivation and reaching of energy balance maximum, during the seasons without extreme drought and when planting is conducted in the right moment.

Mechanization used for cultivation is the major energetic input (according to energy equivalents), while productivity is the most important item considering outputs. So, all the conditions that could be improved in order to achieve a better yield should be applied, even if this implies an acceptable increase in the energetic inputs. The energy inputs increased with the level of nitrogen fertilizer but the increase of the energy output (derived from better yields) compensates largely the difference and the result is a much higher net energy gain. This statement is confirmed through the registered differences between energy ratio for arable and degraded soil experiments. However, long-term experimental monitoring is necessary for definition of the highest yields and energy balance values.

Costs of cultivation for the second and the third year are between 180 and 295 €/ha while the highest costs were registered for DF variant (degraded soil with fertilizer). These costs are higher than reference values taken from an estimation conducted by IPA Energy Consulting, Edinburgh (2005), but possible explanation could be differences in production period (reference value implies for a 10-year period), unit costs (fertilizer and machinery) between England and Serbia and calculating year (2005-2010).

Table 3 – Establishment costs of miscanthus plantation (€/ha)

	Establishment cost	€/ha	Ref. value [13]
1.	Import of rhizomes 0,18 eurcent x10.000 + costs	1.930	1.150
2.	Custom costs	16	0
3.	Transport costs	500	0
4.	Phyto-sanitary assessment	10	0
5.	Expedition costs	50	0
6.	Other administrative costs, taxes	24	0
7.	Soil preparation costs, seedling, tractor, fuel, seedling machine, fertilizer	400	270
	Total:	2.930	1.420

Establishment costs imply to the first production year and amount <3000 €/ha because rhizomes have to be imported (in this case from Austria) (Table 3).

The highest cost is accrued in Year 1 due to the planting material, expenditure on planting machinery and chemicals associated with initial establishment costs. In subsequent years, the average cost decreases from €2930/ha in Year 1 to app. €200/ha. However, further researches have to answer whether the production of miscanthus at these prices is considered viable.

CONCLUSION REMARKS

Experimental research results on miscanthus production in Serbia show that this kind of production is possible in country specific conditions. Miscanthus yield depends on agri-environmental conditions and long-term monitoring for experiments established on arable and degraded soil is necessary for decision making process in sustainable biomass production using this perennial grass. Energy balance values have to be calculated for a decade at least to establish a database which can be supportive tool for biomass production best practice guidelines development for country specific conditions. Very important precondition for sustainable production of miscanthus briquettes is that *processing capacities have to be close to the plantation, because high transport costs can jeopardize economic efficiency of the production process. Also, the production process has to be fulfilled with appropriate storage capacities close to the plantation equipped with electricity and water.*

However, if all these preconditions are fulfilled there is still a question on viability of miscanthus production in the absence of energy crop subsidies on national level.

Strong linkage between scientific-research and energy sectors is necessary through project activities and applications for investment funds, such as the case of miscanthus experimental researches in Serbia where the scientific institutions cooperate with public enterprise for electricity production with the aim of renewable energy sources usage improvement

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