

# POTENTIAL RISKS AND PROBLEMS IN THE CULTIVATION OF PERENNIAL ENERGY CROPS

## POTENCIJALNI RIZICI I PROBLEMI KOD GAJENJA VIŠEGODIŠNJIH ENERGETSKIH USEVA

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### ABSTRACT

Second-generation biofuel production systems are significantly better than first-generation systems. However, the size of areas in which the energy crops are grown depends on public support, and it decreases if public support is missing. Despite all the environmental and economic benefits, perennial energy crops do not currently play a significant role. It is believed that available land areas will be a basic limiting factor for cultivating biofuel crops in the EU. On the other hand, there is significant untapped potential for bioenergy production in abandoned and marginal land in Southeast Europe. At the same time, perennial energy crops are investments with certain risks. Economically viable production of dedicated energy crops will be difficult to achieve on most lands classified into V-VIII land capability classes. In terms of the risk of farming investments, maize has an advantage over all perennial energy crop systems. We have identified 10 types of risks for successful production of energy crops: (1) Crop water supply; (2) Weed infestation in crops; (3) Risks of frost damages; (4) Crop lodging; (5) Crop diseases and pests; (6) Short harvest periods and variable yields; (7) Economic viability of cultivation on land areas of lower land capability class; (8) Influences of agricultural practices and agro-ecological conditions on biomass quality; (9) Storage of harvested biomass and fire hazard; and (10) economic sanctions, war, and war surroundings. Although the cultivation of perennial energy crops has a perspective, it must be systematically planned and further improved.

**Keywords:** energy crops, marginal land, land capability classes, production risks.

### REZIME

Proizvodni sistemi druge generacije biogoriva su znatno bolji od sistema prve generacije. Međutim, veličina površina na kojima se gaje zavise od javne podrške i one opadaju kada izostane podrška. Uprkos svim mogućim životno-sredinskim i ekonomskim koristima, višegodišnji energetski usevi trenutno ne igraju značajniju ulogu. Tek treba da se razvije tržište za bioenergetsku biomasu. Smatra se da će u EU osnovni ograničavajući faktor za razvoj biogorivnih useva biti raspoložive zemljišne površine. U jugoistočnoj Evropi, pak, postoji veliki neiskorišćeni potencijal za proizvodnju bioenergije na napuštenim i marginalnim poljoprivrednim površinama. Kritičan faktor u prihvatanju novih useva, kao što su bioenergetski usevi, je njihova profitabilnost u odnosu na postojeće usevne sisteme. Pri tom, višegodišnji energetski usevi predstavljaju i rizične investicije. Ekonomski održiva proizvodnja namenskog energetskog useva biće teško ostvariva na većini zemljišta bonitetnih klasa V-VIII. U pogledu rizičnosti ulaganja poljoprivrednih proizvođača, kukuruz ima prednost nad svim višegodišnjim sistemima energetskih useva. Identifikovano je čak 10 vrsta rizika za njihovu uspešnu proizvodnju: (1) obezbeđenost useva vodom; (2) prisustvo korova u usevu; (3) opasnost od izmrzavanja useva; (4) poleganje useva; (5) bolesti useva i štetočine; (6) kratki žetveni rokovi i varijabilni prinosi; (7) ekonomičnost gajenja na zemljištima nižih bonitetnih klasa; (8) uticaj agrotehnike i agroekoloških uslova na kvalitet biomase; (9) skladištenje požnjevene biomase i opasnost od požara; i (10) ekonomske sankcije, rat i ratno okruženje. Trenutno se smatra da je tranzicija ka 100% obnovljivoj proizvodnji u sektoru električne energije nedostižna. Zbog toga, iako gajenje višegodišnjih energetskih kultura ima perspektivu, ona se mora sistemski planirati i dalje unapređivati.

**Cljučne reči:** energetski usevi, marginalne zemljišne površine, bonitetne klase zemljišta, proizvodni rizici.

### INTRODUCTION

The growth of bioeconomy implies the replacement of fossil sources with biomass, originating from plants, animals, or microorganisms. The current focus on renewable energy activates a combination of objectives, including reduction of carbon emissions (Schiermeier et al., 2008), enhancement of energy safety (Eaves and Eaves, 2007) and minimization of dependency on limited reserves of fossil fuels. The political support of bioenergy has justified itself by promises regarding the reduction of greenhouse gases and the increase of employment in rural areas. Bioenergy is an alternative to non-renewable and polluting fossil fuel. It is reported that 95–97% of the world's bioenergy is produced by direct combustion of biomass (Guldhe et al., 2017). Combustion of biomass as fuel

retards the net emission of CO<sub>2</sub> in the atmosphere making it a green fuel (as a subsequent amount of carbon has already been sequestered by the plant during photosynthesis when it was alive) (Johnston and van Kooten, 2016).

While support measures result in income increase in rural areas, several studies discovered low potentials of reduction of greenhouse gas emissions with liquid biofuels (Fargione et al. 2008; Searchinger et al., 2008). This is especially the case for biofuels produced by intensive management with oil, sugar, or starch crops, requiring large quantities of fertilization nitrogen (N). In addition, this so-called first generation of biofuels requires biomass which is also used for food or for animal feeds. This has a strong negative effect on their acceptance, and resulted in the discussion "food against fuel". The demand for raw materials from the first generation of biofuels has

encroached directly on food markets. This has influenced food prices along with other factors, such as speculations, possibilities for storage and below-average (poor) harvest (Lewandowski, 2016).

There is an apparent opposition that is not convinced of the benefit of biofuel for the environment. This group is concerned that biofuel is detrimental to the poor because it competes for food grain, raising prices and vying for land used for producing grain, leading to food shortage (Singh, 2013). The increase in food costs that coincides with a global increase in biofuel production leads to thinking that biofuel production is to blame for the increase in food costs (Mueller et al., 2011). Then, there is a concern that such a great range of soil conversion shall be opposed to food production and that it will affect the environment (Lovett et al., 2009). After more than a decade of strong political support for bioenergy introduction, especially liquid transportable biofuels, it became clear that restriction of resources is the major obstacle to acceptance and further expansion of bioenergy (Lewandowski, 2015). The objective of our research is to indicate briefly the key problems occurring in the growing and utilization of energy crops, as well as certain opinions and attitudes in the scientific community contesting the benefits from energy utilization thereof.

## MATERIAL

### Specific characteristics of bioenergy crops

Production systems of the second generation of biofuels (non-food and dedicated energy crop plants: miscanthus, switchgrass, giant reed, hemp, reed canary grass, poplar, black locust) are much better than the first generation system (rapeseed, sugar beet, corn). They contribute to a greater extent to decreasing emissions of greenhouse gases, they have much higher net energy yields and improved efficiency of resource utilization, while soil erosion and N rinsing are low (de Vries et al., 2014). Then, biomass production concerning perennial crops is characterized by numerous specific features:

1. Perennial crops for biomass have low input requirements and their cultivation is associated with very low emission of greenhouse gases. Due to its perennial growth and the possibility of recycling and storing nutrients during the winter in underground roots and rhizomes, perennial crops have relatively low fertilization requirements for biomass (McCalmont et al., 2017; Ozdogan and Geren, 2019).
2. Cultivation of perennial crops does not require ploughing for biomass every year, which leads to the melioration of soil fertility, carbon sequestration and biodiversity. The production period of perennial crops for biomass ranges from 10 to 25 years depending on the type of crop. In the long term, the soil remains protected from intensive cultivation, which is necessary for crop establishment. Together with the increased return of organic matter, this leads to sequestration (binding) of carbon in the soil, improvement of soil fertility and an increase in soil biodiversity (McCalmont et al., 2017).
3. Perennial crops for biomass are efficient in the utilization of water and soil area. The efficiency of utilization of water and nutrients of perennial energy C<sub>4</sub> crops (miscanthus, prairie millet) is higher than C<sub>3</sub> crops, such as wheat and rape (Zhu et al., 2010).
4. Perennial crops for biomass are more stress-tolerant than annual crops and can be produced under marginal conditions.

They have deep roots, and from the second season, they are not dependent on optimal conditions for establishment, such as sufficient amounts of precipitation or soil cultivation. Deep rooting and long-lasting residue on the soil provide protection from erosion on slopes (Lewandowski, 2016).

5. Perennial crops for biomass can be produced at low costs. They should be established only once for the growing cycle from 10-25 years. Low demand for agrochemicals leads to low prices of agricultural inputs and low operational costs (fertilization and harvest) (Lewandowski, 2016).
6. Perennial crops for biomass, producing non-edible lignocellulosic biomass are used for biofuel production, according to Mueller et al. (2011), and they have a relatively modest contribution to the increase of commodity prices of food, and according to McCalmont et al. (2017) do not affect food market.

### Status of production of perennial energy crops

Currently, 14% of the global energy demand is catered by bioenergy from biomass. Biomass can be converted to electricity, heat, or liquid biofuels with advanced technologies. The International Energy Agency has set its goal to achieve 25% of the global transportation fuel demand through biofuels by 2050 (Pandey et al., 2016). However, there are no real statistics on the production of perennial crops for biomass in Europe. According to Lewandowski (2016), until 2015 there were about 10.000 ha under miscanthus in Great Britain, 4000 ha in Germany, 4000 ha in France, 500 hectares in Switzerland and the same in Poland. However, the size of areas in which miscanthus is grown in Europe depends on public support and they are decreasing when there is no support, as has been recently noticed in Ireland. For example, the area in which energy willow is grown in Sweden has also been reduced from 14.000 ha in 2014 to 10.000 ha in 2015 (Lewandowski, 2016).

Several studies have shown that technical potential is great, but an actual offer of low-cost and sustainably produced biomass is presently still limited (Dornburg et al., 2010). According to Lewandowski (2015), the main reason for this is that these assessments of potential neither consider infrastructural and logistic costs and limitations, nor "real" production conditions on the terrain (Table 1). Briefly, the areas in which perennial crops are grown for biomass in the EU, are probably smaller than 60.000 ha, from what Lewandowski (2016) has drawn a conclusion that, in spite of all possible environmental and economic benefits, perennial crops for biomass do not at this time play an important role in the EU.

According to Mola-Yudego et al. (2014), stable policies and long-term contracts are key elements for the successful introduction of energy crops. In order to develop the production of biofuel, the following is necessary: price support, impetuses, import restrictions, corresponding authorizations, or a combination thereof (Singh, 2013). Simply, biofuels cannot compete successfully with fossil fuels. Even when they succeed in finding a stronghold in the environment in which the price of oil is high, they are under the grace of Organizations of Petrol Exporting Countries (OPEC), which are capable of full control of the market in their own way and drive away the competition, because their production costs are extremely low (Singh, 2013).

Table 1. Reasons for low production of perennial crops for biomass

Reason	Explanation
Production costs are too high, and yields can vary from year to year	Initial costs of establishing perennial crops for biomass are high, and the result is insufficient development of sorts and agricultural production technologies, together with high input costs for agricultural production, soil areas, and manpower (workforce) for relatively low biomass value.
Unstable market	The main use of lignocellulose perennial crops for biomass is for the production of thermal energy and electric power, the profitability of which is low. In Europe, with the exception of wood mass from forests and by-products of the timber and wood industry, bioenergy products require subsidies in order to be competitive in the energy retail markets.
Interest in this production is on a low level	For farmers, perennial crops for biomass are new and many of them have neither the knowledge nor technical equipment to produce them. Therefore, introducing perennial crops for biomass requires the development of efficient production technology and cooperative or tertiary utilization of machinery. Farmers hesitate to produce perennial crops for biomass because it has no appropriate subsidies and this means taking their land lots through long-term biomass production. They will be willing to do that only if the biomass market is stable or if they get long-term contracts.

## DISCUSSION

### Potential risks

Perennial energy crops are considered risky investments. The potential for adoption of these crops does not depend only on the average net income and on the tendency of farmers to take a risk (Skevas et al., 2016). According to Scarlat et al. (2015), 5 potential risks can result in the increased biomass production and biomass supply in Europe: (1) moving toward a bio-economy based on natural resources of soils and it will lead to a high increase in demand for biomass encroaching on the sustainability of biologically based economy; (2) additional utilization of land areas could lead to adverse effects by changing the mode of utilization of land areas, such as negative effects on biodiversity, soil carbon and loss of soil fertility; (3) the need to raise crop productivity may lead to enhanced utilization of fertilizers and pesticides, with additional problems associated with water and soil contamination; (4) additional pressure on water resources; and (5) increase of competition for resources between foodstuff crops and biomass crops.

Although there exist relatively favorable agroecological conditions for *Miscanthus* cultivation in Serbia (Figure 1), Dželetović et al. (2014a) have identified even 9 risks for its successful production, that we may deem important for other perennial energy crops too:

(1) Crop water supply. The impact of drought conditions on yield as well as plant biochemical functions is complex and different plant types, species, and genotypes may vary in their tolerance and responses to drought (Hoover et al., 2019). In the areas of South and East Europe, to which Serbia also belongs in a geographical sense, a negative impact on yields is present, first

of all, possible water deficits and possible extreme weather conditions. Besides, some parts of Serbia are considered steppe areas (Banat, Eastern and Southern Serbia), which are considered partly appropriate for *Miscanthus* growing (Dželetović et al., 2013a). In contrast, the short-term wetting (a two-week flood) does not cause visible damage to the *Miscanthus* crop and does not affect the yield (Figure 2).



Fig. 1. *Miscanthus* × *giganteus* (Experimental field in INEP, Zemun)

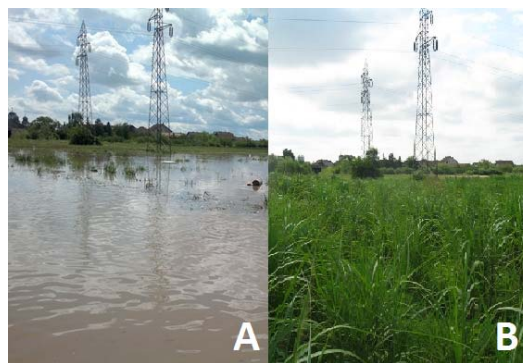


Fig. 2. *Miscanthus* field in Majur near Šabac: (A) Flood, May 2014; (B) July 2014.

(2) Weed infestation in crops. Due to slow establishment, some energy crops are poor competitors in the period after planting. Weed control during the period of establishment is of primary importance for their successful and economical cultivation (Maksimović, 2015).

(3) Risk of frost damage. In the first winter after planting, shallow planted and insufficiently developed rhizomes of certain energy crops have often been destroyed by the cold and/or excessive moistening. A snow blanket protects rhizomes from freezing efficiently in the first winter after planting. In the second and the following winters these problems concerning spending the winter have not been recorded (Plažek et al., 2011; Fonteyne et al., 2016). For example, compared to *M. × giganteus*, *Spartina pectinata* has superior tolerance to rhizome freezing, tolerance of leaves to freezing in spring and a higher success rate of establishment in the first year (Freisen et al., 2015).

(4) Crop lodging. Considerable losses in biomass yield in subsequent years can occur due to the breaking of stems caused by a load of big snow blankets (Figure 3). Strong winds, freezing rain and abundant snowfall may contribute to a more significant decrease in crop amount during autumn and scattered lay-down during winter. Under humid (moist) conditions flexible biomass is laid down up to losses by breaking of aboveground parts, especially under snow and ice.



Fig. 3. Breaking of *Miscanthus* stems caused by load of big snow blanket.

(5) Crop diseases and pests. *Miscanthus* is sensitive to pests and diseases in the areas of Asia, where it occurs naturally. In Europe, there were no reports of plant pests and diseases that significantly limit the productivity of *Miscanthus* (Cosentino et al., 2012), which is more favourable than the situation with forest crops of short rotation, such as willow and poplar (Karp and Shield, 2008). Potentially, the risk can be pathogenic fungus infections, virus diseases, leaf lice, common rural moths, larvae of ghostly moths, plant lice and parasite nematodes.

(6) Short harvest periods and variable yields. Dry biomass yields are often variable because they depend on: the duration of the growing season, air temperature, schedule of precipitation (Dželetović et al., 2013b) and harvest time (Dželetović et al., 2014b). Fertilization of some energy crops does not have a more significant impact on the amount of expected yields. Postponement of the harvest until winter or the beginning of spring leads to losses in biomass, due to loss of leaves and falling of crowns of a stem. Deciding on the harvest date represents a compromise between a yield that can be harvested and the quality thereof.

(7) Economic viability of cultivation and land areas of lower land capability class. The manifested differences in the yield amount recommend growing on more fertile soils. For example, sustainable production shall be economically profitable if *Miscanthus* biomass yield is  $>10$  tons  $\text{ha}^{-1}$  a year (Mishra et al., 2013). There are specific laws that regulate appropriate subsidies and privileged status for investors in the sector of energy production from renewable sources (Golusin et al., 2010). However, there are currently no subsidies for the production of energy crops. Lewandowski (2016) believes that such subsidies are necessary in order for it to be competitive in the energy market.

(8) Influence of agrotechnical and agroecological conditions on biomass quality. By the selection of a proper combination of time and method of harvest, biomass quality may be affected (Kapustyanichik and Yakimenko, 2020). Early harvest is useful if a crop is to be converted into ethanol in the biorefinery or in biogas. By postponing the harvest the content of mineral nutrients is reduced and the percentage of organic matter is increased, which is suitable for the utilization of produced biomass as a source of thermal energy (Bilandžija et al., 2020).

(9) Storing of harvested biomass and fire danger. The risk of fire on a field can be present only in dry crop harvest (Figure 4).

At moisture content above 25% in bales, the self-heating of stored material can occur, with the risk of spontaneous combustion in the absence of ventilation. The bales with lower density ( $<250$   $\text{kg m}^{-3}$ ) can be stored without fear of self-heating (El Bassam and Huisman, 2001). The bales with higher densities and limited airflow are subject to self-heating.



Fig. 4. Majur near Šabac, Serbia: A fire in April 2020, on a plot under *Miscanthus*, was caused by the negligence of the tractor driver.

(10) Economic and political sanctions, war and war surroundings. Since the beginning of 2022, this risk has imposed itself as additional and very influential. The war in Ukraine caused numerous disturbances in the market of energy and agricultural products. In countries exposed to unpredictable war events and/or sanctions, the risk of investment has multiplied. As a rule, farmers in the war and the war environment will primarily focus on food production. In the case of sanctions, the farmers' decision will depend on which economic sector will be most affected and how much it will affect agricultural production and the market for agricultural products.

### The issue of available land areas

Among social components, employment was one of the major trumps of support for biofuels in various periods of time. The issues concerning soil areas will become an important factor in the expansion of the biofuel industry, and the demand for the volume (bulk) of raw materials will be increased, requiring large areas. According to Singh (2013), the integration of restricted farmers' resources in the production of biofuel raw materials will be critical, especially in developing countries in which minor landowners are dominant. The discussion "food against fuel" broke out of the demand for corn, namely, ethanol, causing protests throughout the world.

The areas with the highest biomass yields coincide with areas in which food is produced, on highly-valuable soil areas (Lovett et al., 2009), first of all, because of making a higher profit (Dželetović et al., 2011). It is considered that the basic limiting factor for the development of biofuel crops shall be available soil areas. According to Lovett et al. (2009), when highly valuable soil areas and inappropriate areas are excluded, through the exploitation of only 4-28% lower value soil areas in Great Britain (depending on the region), shall not have inevitably a great impact on the safety of food production. The primary purpose of production of foodstuff crops, as always, should be for food, and biofuels should be obligatorily placed in a secondary position. The policy concerning exploitation of soil areas should exclude the low inclusion of biofuel crops in the crop rotation through which there are returns to a farm, are increased without impact on food production, should not be prohibited, namely, it must be stimulated (Singh, 2013).

The use of marginal soils for the production of energy crops is one of the strategies for achieving energy security and food production. Agricultural land is marginalized for economic or

biophysical reasons (Lewandowski, 2016). Biomass production in economically marginalized soil areas often gives low economic frameworks, mainly due to low yields. Biophysical marginalization can be the result of low soil quality, contamination, insufficient water supply, or steep slopes, and can be overcome only by stress-tolerant crops. Good limits (frameworks) can be attained on biophysically marginalized soil areas if marginal soils can be used productively with these crops, although the costs of the utilization of soil area are low (Lewandowski, 2016). However, an intensive use of poor soils for the cultivation of energy crops was not noticed, although they are the first to be used for this purpose (Jeziarska-Thöle et al., 2016).

In view of a high percentage of abandoned and marginal soil areas (mainly V-VIII land capability class) in some countries of the Western Balkans, the potential of available soil areas for growing of these crops is very high (Dželetović et al., 2016; Voća et al., 2019). However, on a majority of land capability classes V-VIII, economically sustainable production of specific-purpose energy crops will be difficult to realize. Namely, by the production of *Panicum virgatum* L. on the land of lower capability class, the costs for delivery of biomass (raw material) have been increased even up to 32%. For this reason, Gouzaye and Epplin (2016) consider that the needs of production of the second generation of energy crops, of capability classes III and IV, can be defined as marginal relative to capability classes I and II.

### Issue of production profitability

Among many factors, constantly increasing food production per inhabitant has been identified as a probable cause of low inflation of food costs (Shrestha et al., 2019). Thereby, among several variables tested as the reason for the increase in the food cost index, the highest correlativity was with crude oil cost (Shrestha et al., 2019). In addition to profitability (fixed cost of biomass, input costs and possible costs of agricultural soil area) and other aspects associated with agriculture, such as the size of farms or participation (share) regarding leased arable land, can have a strong impact on farmers' decisions.

A critical factor in the acceptance of new crops, such as energy crops, is their profitability relative to the existing crop systems. A majority of agricultural producers shall select soil areas for energy crops only if economic receipts from these plants are at least equal to the return of invested funds from the most profitable conventional alternatives (Kells and Swinton, 2014). While production costs can be anticipated with certain security, farmers are exposed to potentially high variabilities of biomass yield and price (Bocquého and Jacquet, 2010).

The results of Skevas et al. (2016) show that corn, with harvest of grain and 38% animal feed (animal feedstuffs, as cellulose bioenergy raw material), is the most profitable and minimum risk option for investment. Regarding the risks of farmers' investments, corn has the advantage over all perennial systems of energy crops. Although they are not currently attractive to farmers who are oriented toward profit, perennial energy crops have a higher potential for successfully competing with corn under marginal conditions for plant production (Skevas et al., 2016). Co-variant risk (risk changing by coordination through transfer from one to another crop growing system), according to Gillich et al. (2019), has a significant negative effect on the decision on growing of short rotation coppice (poplar, willow) period or miscanthus. On the contrary, Fewell et al. (2016) have established that farmers' attitude toward risk did not have a significant impact on the decision concerning growing prairie millet or miscanthus.

The data suggest that bumper costs of cereals need not be caused by the increase in biofuel production, but they can, due to the existence of a speculation "bubble" associated with: high oil prices, a weak dollar, and increasing instability due to commodity index of investment of financial resources (Mueller et al., 2011). Many factors can influence the increase of food costs, and they are associated with the cost of raw materials, enhanced demand, diminished supply and increased production costs, leading to higher energy costs and mineral fertilizers (Mueller et al., 2011).

According to Blazquez et al. (2018), promoting renewable energy sources, in liberalized markets of electric power, creates a paradox in that successful penetrating of renewable energy sources may become a victim (casualty) of own success. With regard to current market architecture, future applications of renewable energy sources will certainly be more expensive and with a smaller range. Moreover, Blazquez et al. (2018), are of the opinion that the transition toward 100% of renewable production in the electric power sector is unreachable. Paradoxically, in order that renewable technologies to continue to increase their market share, they have to co-exist with fossil fuel technologies. Ignoring these findings may slow down the adoption and increase the costs of introducing new renewable technologies. For this reason, Blazquez et al. (2018) indicate the incompatibility between the liberalization of electric power and the policy of renewable energy sources, regardless of the country, location, or renewable technologies.

### CONCLUSION

Despite all the possible environmental and economic benefits, perennial energy crops do not currently play a significant role. The market for energy biomass has yet to be developed. A crucial factor in accepting new crops, such as energy crops, is their profitability compared to existing crop systems. Then, perennial energy crops represent potentially risky investments. We have identified 10 types of risks for successful production of perennial energy crops. In addition to potential risks, we believe that the following are also important: the issue of available land and the issue of profitability of production of these crops. The transition to 100% renewable generation in the electricity sector is considered unattainable, at least for now. We think that it follows from the above that the cultivation of perennial energy crops must be systematically planned and further improved.

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