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IDENTIFICATION OF MARGINAL LAND SUITABLE FOR BIOFUEL PRODUCTION IN SERBIA

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The use of biomass as a potential energy source has both advantages and disadvantages. Biomass is a potential source of fuel energy that provides economic and environmental benefits such as less expensive and less energy intensive production, carbon sequestration and soil preservation. However, the main concern associated with biofuels is that land needed for food will be used for biofuel crops. One potential solution is the use of marginal lands which are not suited for food production. Marginal lands generally refer to the areas not only with low production, but also with limitations that make them unsuitable for agricultural practices and ecosystem functions. This can be due to various forms of land degradation such as pollution, surface exploitation of mineral resources, erosion, overexploitation and others. We used remotely sensed data, environmental data and field survey data to identify possible marginal lands in Serbia. All gathered data was transferred to GIS in order to create maps and database of potential marginal lands which could be used for biomass production.

Keywords: biomass, biofuels, marginal land, GIS, degraded land, abandoned agricultural land

The use of biomass as a potential energy source has both advantages and disadvantages. Biomass as a potential source of fuel energy provides economic and environmental benefits. Technology for converting biomass into biofuel is more advanced with each passing year, thus making biofuels production cheaper and less energy intensive. Biomass could be considered as almost carbon neutral since growing biomass absorbs as much carbon as burning biomass releases. Also, some biomass crops can be less damaging to soil and more suitable as habitats for biodiversity than traditional agricultural crops. On the other side, critics point out that biomass crops will use land needed for food production and that biomass production could push lands currently under native cover into production, resulting in a carbon debt. Currently, many countries and regions in the world already feel pressure in land available for critical socioeconomic activities. Converting the existing cropland or developing new land for biofuel production raises immediate concerns including the food versus fuel debate, effects on the livelihoods of small-scale farmers, pastoralists and indigenous people, threat to nature conservation, and possible increase of carbon emissions. At the same time, land use change usually causes changes in water use, and consequently, biofuel production may aggravate water stress, which is already a growing worldwide issue (SERVICE, 2007). The question then remains whether it is possible to use biomass for biofuel production but without or with minimal negative impacts. More specifically, what types of land can be used for sustainable biofuel production, how much of that land is available, where is the land spatially located, and what is the land that has biofuel production potential currently used for. Possible solutions for this problem include using marginal, degraded and/or abandoned agricultural land as a source of biomass for biofuel production. Although the concept of marginal lands has evolved over time, this term most commonly refers to land with low productivity in the context of crop production or use limitations mostly due to reduced soil fertility, erosion, salinity, water excess or shortage (Kang et al., 2013). Marginal lands have received wide attention for their potential to biomass for biofuels production (Robertson et al., 2008). Since 1993, there have been an increasing number of papers addressing marginal lands, biofuels, GIS and any combination of these. Due to their characteristics, marginal lands are typically associated with low productivity and reduced economic return. Generally, they are also fragile and at high environmental risk. Potential using of marginal lands have also raised several concerns related to environmental impacts and ecosystem services (Searchinger et al., 2008). The discussion on marginal land use is ongoing and poses a serious trilemma associated with food security, bioenergy, and environmental concerns (Tilman et al., 2009). The concept of marginal land often includes waste lands, under-utilized lands, idle lands, abandoned lands and/or degraded lands. Abandoned agricultural lands are primarily related to lands where agricultural activities have ceased. These lands are widespread in parts of North America and Europe (Lambin, 2011), and using at least some of these lands as a source of biomass for biofuel production may help to reduce pressure on natural ecosystems. According to Campbell et al. (2008), abandoned land globally available for the production of bioenergy crops varies between 385 and 472 Mha. Land degradation is a widespread phenomenon. Degraded land, relevant to biomass for biofuel production,

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is primarily related to land which has been degraded due to over-intensified agricultural activities or some form of chemical pollution (such as heavy metals). In both cases, the land is not suitable for further crop production, and could be potentially used for energy crops. With this form of use, the added value could be the remediation of degraded land. Degraded land, defined as "areas where human activities have induced soil and/or vegetable degradation" (Hoogwijk et al., 2003), is assumed to have a potential between 430 and 580 Mha. Waste lands, such as various types of dumps, could also represent a potential source for bioenergy crops production. Ash dumps have been proven as suitable for *Miscanthus* × *giganteus* production (Milovanović et al., 2012). Also, further possible locations include sites of surface resource exploitation which are mandatory to be re-naturalized, and this could be done by planting of energy crops. Quantifying the biomass potentials for biofuel production from degraded and/or abandoned land and estimating potential yields of energy crops represents a challenging task. Major problems include limited availability of data and unclearly defined and synonymously used land categories. Consequently, only few potential assessments carried out the potential of biomass cultivation on degraded and/or abandoned land (Wolf et al., 2003; Hoogwijk et al., 2003; Moreira, 2006; Smeets et al., 2007; Campbell et al., 2008). In this paper, we analyze the potential of abandoned and degraded land in the Republic of Serbia with the focus on determining the quantity of such land.

Material and methods

Obtaining relevant data to assess the presence of abandoned agricultural and degraded land in the Republic of Serbia was done from multiple sources which include relevant literature, data from the Statistical Office of the Republic of Serbia, Corine Land Cover data, remotely sensed data, field data, etc. In 2012, the Statistical Office of the Republic of Serbia conducted a major agricultural census which was done according to the world program of agricultural census (RZS, 2012). This census included agricultural lands owned by both private and legal entities. Data from this census was essential in determining the amount of abandoned agricultural land. This was achieved by comparing data from previous agricultural censuses. Analysis of Corine Land Cover data was also used for determining the amount of abandoned agricultural land. Data for sizes and locations of land degraded through surface resource exploitation was obtained through remotely sensed data and with the use of Google Earth. For every site where determining of the precise location was possible, all data was transferred in GIS with ArcMap, and different maps were created. The data for ash dumps was obtained though Electric Power Industry of Serbia and Google Earth. For other types of land degradation and pollution, data was obtained from Report on state of soil in the Republic of Serbia conducted by the Ministry of Environment and Spatial Planning (MZSPP, 2009) and Degraded lands of Serbia project report (Fakultet za Primenjenu Ekologiju Futura, 2010).

Results and discussion

Data on total, used and unused agricultural land, as well as differences among different parts of Serbia are shown in table 1 and table 2. The total of 424.054 ha, which is about 5% of the territory of Serbia, represents agricultural land which is currently not being used. However, this is not uniformly spread across the country. Municipalities in the north part of the country have a high percentage of their territory as agricultural land and most of it is being currently used for agricultural purposes. On the other hand, municipalities in the southern part of the country have a much higher percentage of unused agricultural land. In the northern part of the country almost all municipalities have the percentage of unused agricultural land relative to the total territory of available agricultural land below 10%, while in the municipalities of eastern and southern part of Serbia this percentage is between 20 and 50%. The highest recorded percentage of unused agricultural land relative to the total agricultural land is 75% and it is found in the municipality of Crna Trava, located in the south of Serbia.

Table 2 Unused agricultural land in different parts of Serbia

Region	Unused Area in ha
Belgrade region	12 076
Vojvodina	72 313
Šumadija and Western Serbia	141 220
South and Eastern Serbia	198 445
Total	424 054

Table 3 Corine land cover changes between 1990–2000

Land cover type	Detected change
Artificial areas	increase of around 4000 ha
Agricultural areas	decrease of around 8000 ha
Forests and semi-natural areas	increase of around 2000 ha

Comparing previous available data with data from the recent agricultural census indicates that the percentage of unused agricultural land is rising. This is also evident

Table 1 Agricultural land usage in Serbia

	Total	Used	Unused
Area in ha	3 861 477	3 437 423	424 054
Percentage	100 %	89 %	11 %
Percentage of the territory of Serbia	49.8 %	44.3 %	5.5 %

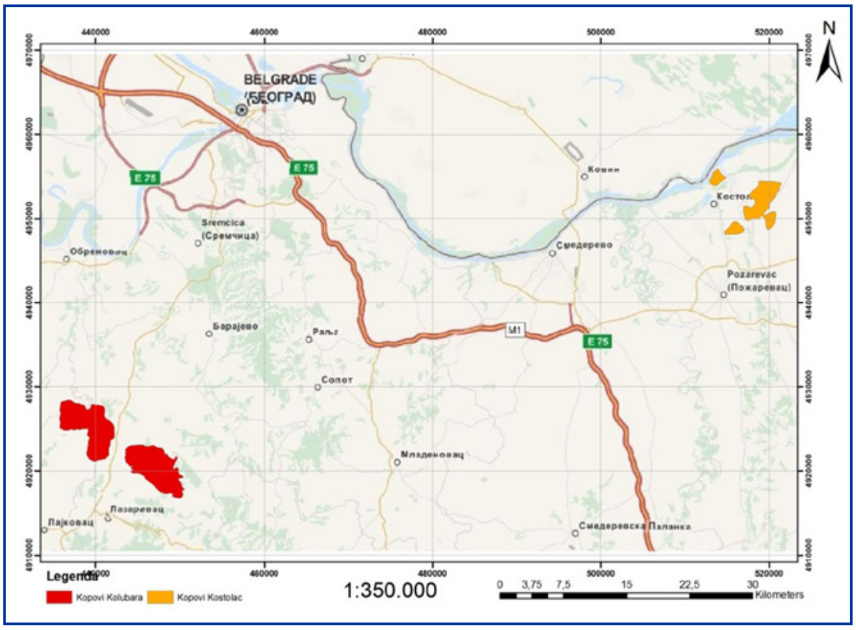

Figure 1 Locations of surface coal exploitation in Serbia

in data obtained from Corine land cover for years 1990 and 2000 (Table 3). Different causes, like remoteness, fragmentation, poor management, unprofitability and unfavorable demographic characteristics, can lead to abandonment of agricultural land. In Serbia, the most common cause is related to demographic reasons, since many young people are leaving rural for urban areas. According to the demographic data from population census done in 2002, almost all rural municipalities have a decrease in population, while the increase is detected in urban areas of the three biggest cities, Belgrade, Novi Sad and Niš. This increase is not caused by higher birth rate but rather by the relocation of people from rural to urban areas.

Locations of degraded land detected through remote sensing

Table 4 Ash dumps in Serbia

Power plant	Yearly average of ash amount in t	Year of formation	Total area in ha
Tent A	2,200,000–2,500,000	1974	400
Tent B	1,800,000–2,200,000	1984	600
Kostolac	550,000	1977	246
Kolubara	1,500,000	1976	78
Morava	90,000	1968	45
Kolubara Junkovac	old ash dumps	until 1976	40
Kostolac		until 1976	85
Total	around 6,500,000		1,494

Table 5 Degraded areas associated with surface coal exploitation

	Area in km²	Perimeter in km
Kolubara	53.045	52.473
Kostolac	17.899	34.888
Total	70.944	87.361

Table 6 Degraded areas associated with surface mineral exploitation

Location	Area in km²	Perimeter in km
Bela stena	0.132	4.435
Bor	9.669	39.398
Kadina luka	0.339	4.203
Krivelj	4.078	17.242
Lisa	0.17	3.725
Majdanpek	13.991	51.874
Negotin	0.167	3.396
Vencac	0.546	12.264
V. Majdan	0.134	2.641
Total	29.234	139.183

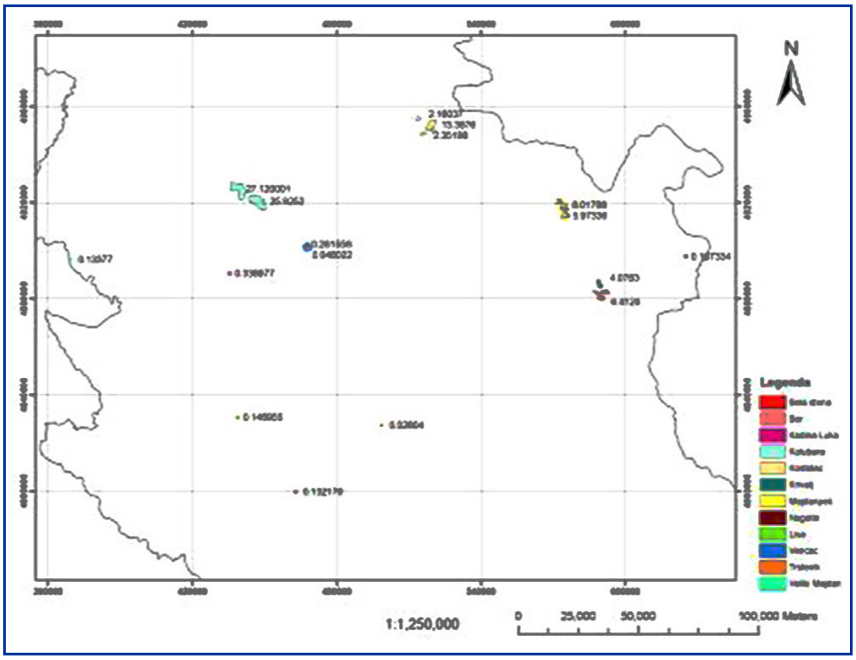

Figure 2 Locations of surface mineral exploitation in Serbia

include ash dumps and surface resource exploitation sites. There are 5 coal power plants in Serbia, located mostly near coal excavation sites. Each year, they generate around 6.5 million tons of ash and slag, 80 to 85% is ash and 15 to 20% is slag. Data on different ash dumps is in table 4.

Surface coal exploitation in Serbia is primarily done at two locations, Kolubara and Kostolac (Figure 1). Data on degraded areas associated with them is shown in table 5.

Besides coal surface exploitation, nine other locations of surface resource exploitation were detected (Figure 2). These are mostly related to different metallic ores and the degraded area associated with them is smaller than for coal surface exploitation, data is shown in table 6.

Land degradation caused by reduction of soil fertility and pollution

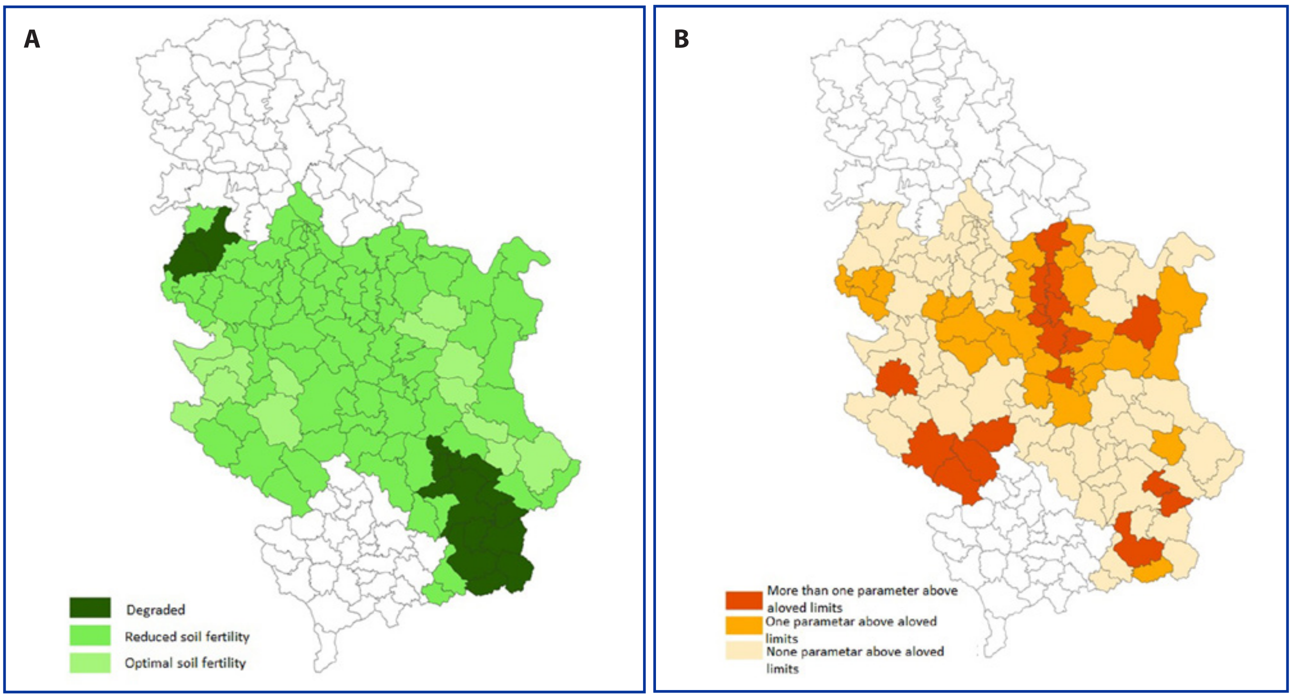

Figure 3 A – Soil fertility map of central Serbia; B – Soil contamination map of central Serbia

Table 7 Presence of heavy metals in soils of central Serbia

Heavy metal	Amount detected	Source
Nickel (Ni)	20% of samples have concentrations above allowed limit of 50 mg kg^{-1}	mostly natural in origin
Copper (Cu)	2% of samples have concentrations above allowed limit of 100 mg kg^{-1}	mostly near copper excavation sites
Chrome (Cr)	7.6% of samples have concentrations above allowed limit of 100 mg kg^{-1}	form natural and industrial sources
Cadmium (Cd)	1.3% of samples have concentrations above allowed limit of 3 mg kg^{-1}	mostly near industry and roads
Lead (Pb)	3.4% of samples have concentrations above allowed limit of 100 mg kg^{-1}	near roads
Arsenic (As)	5% of samples have concentrations above allowed limit of 25 mg kg^{-1}	mostly near mining sites

was analyzed based on data from different reports (MZSPP, 2009; Fakultet za Primenjenu Ekologiju Futura, 2010). Data from 5000 samples across the central parts of the country was analyzed. The total of 60% of samples from agricultural lands have at least one parameter of fertility reduced; 30% of samples have high acidity, pH below 4.5; 29% of samples (mostly related to agricultural land) have very low humus content, below 3%. Presence of heavy metals is shown in table 7.

Based on this data two maps were created in GIS. The first one is a map of soil fertility of central Serbia (Figure 3A) and a map of soil contamination of central Serbia (Figure 3B).

For soil fertility map, three classes were established: optimal soil fertility, reduced soil fertility and degraded soil. Most of municipalities have reduced soil fertility class. This is due to the reduction of one soil fertility parameter (pH, humus content, etc.). Degraded soils have more than one soil fertility parameter reduced, and municipalities within this class are mostly located in the south of Serbia, with the exception of two municipalities in the northwest part. For soil contamination map, three classes were created based on the number of parameters that are above the permitted limit. Classes include none, one and more than one parameter above the permitted limit. Municipalities with one and more than one parameter above the permitted limit are mostly located in central and southern part of the country.

Conclusion

The largest identified areas suitable for agro-energy crops in Serbia are unused agricultural lands, degraded land, which could also be used as a source of biomass for biofuels is also present but in significantly lower amount (Table 8). There is also a tendency for increase of unused agricultural land, which can also be expected to continue in the future since more and more people are relocating from rural to urban areas. For this land to be used as a source of biomass for biofuels it is necessary to determine their spatial characteristics, more precisely their exact locations and sizes of specific sites. This can be achieved through further and more detailed remote sensing with field validation.

Table 8 Total possible available land for agro-energy crops in Serbia

Type of land	Area in ha
Unused agricultural land	424 054
Degraded land from surface exploitation	10 918
Ash dumps	1 494
Total	436 466

Despite the fact that degraded lands are not significantly comparable in size to unused agricultural land, they can also be used for agro-energy crops cultivation. The added benefit is the remediation of polluted soils and minimizing of degradation caused by surface resource exploitation.

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