

Full Length Research Paper

Bank erosion as a factor of soil loss and land use changes in the Kolubara River Basin, Serbia

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The channel morphology of the Kolubara river was changed during the last century, mostly because of the lignite exploitation. In the research area, bank erosion is widespread and causes processes of soil loss and land use changes. This is an agricultural area and people used to farm their land parcels at the river banks. In the area of the three villages, which are situated on the Kolubara River banks, there are 208 land parcels at risk from the bank erosion. The changes in the area with endangered land parcels were analyzed using the cadastral maps from 1967 and aerial photographs from 2004. On the research sector, the Kolubara river length was 7.7 km in 1967 and 10.36 km in 2004. The research shows that 60.37 ha was lost and degraded by the bank erosion. The loss of land comprises 49.43% of the land parcels from 1967. The aim of this paper is to analyze the influence of the bank erosion rate on the changes of the Kolubara river course, soil loss and land use. The results of this research are important for the water and land management, as well as for the protection of intensive bank erosion.

Key words: Human impact, bank erosion, channel morphology, loss of land, land use changes.

INTRODUCTION

Bank erosion is a major geomorphological process in the alluvial floodplain and can be the result of natural factors and anthropogenic activities. Anthropogenic activity affecting river flows may cause changes in river morphology (Hook, 2006; Li et al., 2007; Kiss et al., 2008; Dragicevic et al., 2008a) and river regime as well as in rate of deposition of sediments (Surian and Rinaldi, 2003; Dragicevic et al., 2010).

Human impacts on the Kolubara river course were numerous and the alterations were made in several phases. The first huge intervention in Kolubara river system has been done in 1959, when Kolubara's riverbed was diverted into its right tributary Pestan river. Those

construction works were done for the purpose of lignite exploitation. The process of fluvial erosion was changed; bank erosion became stronger and resulted in larger amounts of sediment load deposition (Dragicevic, 2002). Pestan's riverbed was not predisposed for the flow of a stronger kinetic energy, and it caused many morphological changes in the lower part of Kolubara's river valley (Dragicevic et al., 2007b). Digging up the river banks leads to collapsing of the land surface. In the previous research reported by Dragicevic et al. (2008b), it was indicated that total length of the most degraded river banks extends over villages of Drazevac, Konatice and Poljane is 5.15 km.

The economic activity of residents of the villages in Donja Kolubara river basin is mostly based on agriculture. The environmental changes and the land loss have influenced the agricultural production of the owners of parcels at risk. Some of them quit farming the parcels

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at risk and the remains became the fallow land. According to cadastral maps the degraded land extends over three villages: Drazevac, Konatice and Poljane. However, these three villages have far more drastic reduction in the number of farmers. According to the 1961 and 2002 Population Censuses, total decrease of agricultural population was approximately 60%. The main factor for such a high ratio of decline in a relatively short period is river bank erosion.

There have been so far a lot of papers investigating negative effects of erosion on crop productivity; however small number of them is dealing with the impact of erosion on land use change through decrease in crop productivity (Baboule et al., 1994; Roose, 1996; Van Rompaey et al., 2002; Dragicevic and Stepic, 2006). Land use structure changes are complex so collecting and processing the data can take a long time. Landscape studies using aerial photographs, satellite images and different scale paper maps are useful for environmental changes determination in the area of alluvial zones of the rivers (Hook, 1977; Brizga and Finlayson, 1990; Vanacker et al., 2005; Li et al., 2007; Ayalew, 2009; Zawiejeska and Wyzga, 2010). It is also a valuable tool for estimating loss of land in a degraded area. Therefore, there was a need for better data source, like remote sensing data collection (Fazal, 2000; Weng, 2002).

This research showed a significant impact of river bank erosion on socio-economic and land use changes in the settlements located in the lower part of the Kolubara river basin. However, reversible process needs to be considered as well.

MATERIALS AND METHODS

Study area

The Kolubara river basin encompasses the western part of Serbia and covers 4.12% of Serbia's surface area (Figure 1). The Kolubara river is classified as a middle-sized river in the territory of Serbia according to the flow length (86.4 km) and the basin surface (3641 km²). The lower part of the Kolubara river basin is called Donja Kolubara river basin (area of 1810 km²) and is situated in the municipality of Obrenovac. The study area of soil loss and land use changes comprises three villages: Drazevac, Konatice and Poljane (Figure 1). In this paper the parcels on the river banks were researched. They are exposed to Kolubara's river bank erosion (Figure 2) and causes land loss. Diminishing of the land parcels has the consequences in landscape and environmental changes of the studied area. The main type of soil is alluvial soil. According the nearest meteorological station in Obrenovac, this area is characterized by continental climate, the average temperature is 11°C, and the mean annual precipitation is 647.2 mm (Dragicevic 2007b).

GIS environment and remotely sensed data collection are essential for studying land use changes. Land use/land cover (LULC) is an important part of the environment, and changes in this system often reflect the impacts of human activities on local terrestrial environment (Lin et al., 2009). Analysis of changing river channel course based on aerial photographs and maps are widely applied (Hook and Redmond, 1989; Downward et al., 1994; Large and Petts, 1996; Ollero, 2010; Blanka and Kiss, 2011). Hydrological

map series could be used to show the evolution of the river course and the developments of meanders, to specify the alterations of river channels induced by human impact, and combined with GIS environment to predict the further development of river processes.

Comparative analysis has been made on the base of Cadastral maps scale 1:2500 from 1967 and aerial photographs from 2004; reconstruction of the hydrological system has been done for the periods from 1967 to 2004. In each data source the position of the Kolubara River course was marked. By comparing the data from two periods, we determined the evolution of the Kolubara river course in 37 years. River bank lines were digitized and the extent of bank erosion was calculated under ArcGis 9.3. The same software was used for the estimation of the Kolubara river lateral migration rate. This rate was estimated using the calculated area between river positions in 1967 and in 2004 (area of river migration), which was divided by the total length of the river course in 1967. The loss of land (*S*) is expressed as the ratio between area of endangered land parcels in 1967 (*P*₁₉₆₇) and area of endangered land parcels in 2004 (*P*₂₀₀₄):

$$S = \frac{P_{1967} - P_{2004}}{P_{1967}} * 100 .$$

Land use structure in the area of villages: Drazevac, Konatice and Poljane are characterized by: arable land (which people used for farming mostly wheat and corn-crop rotation practice), forests (alluvial forests of willows and poplars) and few pastures. Since this is an alluvial zone with intensive river dynamics, there are sandbanks, mostly on the concave side of the river. By statistical analysis of a land use structure (official cadastral register of the Municipality of Obrenovac) in the three villages with degraded land parcels on the river banks, we obtained the results which show significant reduction in arable land. And by analysis of the questionnaire carried out among the owners of degraded land parcels in the villages Drazevac, Konatice and Poljane, it can be concluded that there was a significant decrease in the agricultural production. The risks from the floods and further soil loss influenced the land owners' decision making about farming the degraded land parcels.

RESULTS AND DISCUSSION

There were many changes in a fluvial landscape of Donja Kolubara river basin. They caused the environmental changes and the changes in a land use structure. Due to natural and human induced factors the Kolubara river course have migrated through the landscape and influenced agricultural production in the area. On the research sector (Figure 1) the Kolubara river length in 1967 was 7.7 and 10.36 km in 2004. This fact appoint to the river course evolution through the landscape. The rate of the Kolubara river lateral migration along the research sector is 47 m in average for the period of 37 years, which means 1.27 m per year. At the most endangered part (in the area of Drazevac village) the most intensive migration rate of the river channel was 224 m in 37 years, with the average of 6.05 m per a year).

People were always connected to the nature, and each alteration in the natural environment is followed by changes in socio-economic indicators. Fluvial processes

Table 1. Land use structure in Drazevac, Konatice and Poljane.

Land use	Total	Arable land	Woods	Pastures	Meadows	Sand banks	Other (roads...)
Drazevac							
Number of endangered parcels	89	36	14	2	5	32	-
Area in 1967 (ha)	54.31	32.52	4.28	0.36	2.93	14.22	-
Area in 2004 (ha)	24.55	19.53	1.19	0.03	1.3	2.5	-
Loss of land (ha)	29.76	12.99	3.09	0.33	1.63	11.72	-
Konatice							
Number of endangered parcels	74	51	1	2	-	19	1
Area in 1967 (ha)	40.74	34.45	0.31	1.02	-	4.88	0.08
Area in 2004 (ha)	23.55	21.64	0.18	0.55	-	1.15	0.05
Loss of land (ha)	17.19	12.81	0.13	0.47	-	3.73	0.03
Poljane							
Number of endangered parcels	45	26	3	-	-	15	1
Area in 1967 (ha)	27.08	21.84	0.82	-	-	4.18	0.24
Area in 2004 (ha)	13.66	13.19	0.19	-	-	0.26	0,02
Loss of land (ha)	13.42	8.65	0.63	-	-	3,92	0.22

of more intensive bank erosion and land degradation caused the loss of fertile soil in the studied area. Farmers who have land parcels on the Kolubara river bank cannot farm them in whole, because the river has changed its course and took some parts of the land parcels away (Figure 2).

In the three villages Drazevac, Poljane and Konatice, total number of the parcels at risk is 208 and the area of those land parcels was 122.13 ha in 1967. The results of calculated area of the same land parcels in 2004 showed that 60.37 ha was lost and degraded by the river bank erosion, which means that the land loss is 50.57 % of the land parcels from 1967 (Figure 3).

Land use characteristics of the parcels that were diminished have been changed as well. According to the cadastre, in 1967 on the parcels at river banks it was 5.41 ha of woods, 88.81 ha of arable land, 1.38 ha of pastures and 2.93 ha of meadows. Today, there is 1.56 ha of woods, 54.36 ha of arable land, 0.58 ha of pastures and 1.30 ha of meadows. Area of the woods (only parcels on the river banks) was decreased from 71.16%, area of the arable land decreased from 38.79%, area of the pastures decreased from 57.97% and area of the meadows was decreased from 55.63% (Table 1).

In the area of Drazevac village there are 89 degraded parcels, 3 are public and 86 land parcels belong to the private owners. Total surface area was 54.31 ha in 1967, and soil loss is 29.76 ha, which means that 54.8% of soil was lost and degraded. Konatice village has 74 degraded land parcels on the river banks and their area used to be 40.74 ha. After calculation of a soil loss (17.19 ha) the area of the degraded land parcels in Konatice village is 42.19% smaller than 1967. Total area of the 45 degraded

land parcels in the village Poljane was 27.08 ha in 1967, it is diminished by 49.56% and soil loss in this village is 13.42 ha (Table 1).

There is a significant decrease in arable land in the three villages (Table 1). The 113 parcels of arable land are degraded and it represents more than a half (54.3%) of all degraded land parcels. This is mainly an agricultural area, and the loss of 34.45 ha of arable land has an influence on the agricultural production.

There are 90 totally degraded parcels (area of 31.68 ha), which means they could not be used for any purpose. Regarding the land use structure, there are 25 totally degraded parcels of arable land (11.30 ha), 8 of woods (2.46 ha), 3 of pastures (0.74 ha) and the remaining belongs to sand banks (Table 1). Since Kolubara river changed its course by migration to the East, sandbanks marked on the cadastral map from 1967 were diminished. On the other side, the new point bars and the new sand banks were formed because of silt material accumulation and this brings it to the new environmental changes. Rivers are dynamic features, and their evolution through landscape is characterized by changing its course and alluvial zones on the river banks.

According to the 1961 Population Census, the agricultural population prevailed (90%) in those three villages. Since late 1960's, there was a drastic reduction in the number of farmers. Agricultural population represents 24, 28 and 31% of the total population in Drazevac, Konatice and Poljane respectively, according to the 2002 Population Census. The main factor for such a high ratio of decline, besides the processes of industrialization and urbanization, is river bank erosion. This is also one of the conclusions of an interview, which appoint that only 46%

of the interviewed owners still farm their degraded parcel, 31% do not farm the degraded parcels and 23% of them lease their degraded land parcels.

Those changes had significant influence in the activities of population. According to the 1961 Population Census, 91.1% of the active population was employed in a primary sector of activities (agriculture and forestry). Participation of employees in other sectors of activities was minimal – less than 5% per each sector. Latest Population Census data shows that 49.8% of the active population was employed in primary sector of activities in 2002. At the other hand, 27% was employed in second sector of activities (industry and construction) and 23.2% in third and fourth sector of activities.

We have carried out the questionnaire about farming degraded parcels, and the reasons for not doing it. Many of the owners do not farm their land on the river banks because of the risk of flooding, bank erosion, further degradation and soil loss. It should be mentioned that some of the degraded parcels are totally destroyed by the river bank erosion, and as such, it is not possible to farm them anymore. In the Drazevac village 51% of the interviewed owners do not farm their degraded parcels of arable land, 13% of them still farm the degraded parcels and 36% of them lease their land parcels. In the Poljane village the situation is similar, 66% of the interviewed owners do not farm their degraded parcels of arable land, 8% farm the degraded parcel, and 26% of them lease the land. Only 74% of the interviewed owners in the Konatice village farm the remains of their degraded parcels on the river bank, 10% of them do not farm the degraded parcel, and 16% of them lease their degraded parcel. The remains of the degraded land parcels which are no longer farmed becomes a fallow land.

Conclusion

Bank erosion, silt accumulation and floods are major environmental problems in the Kolubara river basin which could be aggravated by land-use changes. In the lower part of the Kolubara River basin there are 113 degraded arable land parcels, which represent more than a half (54.3%) of all degraded land parcels (208 land parcels) and 34.45 ha of arable land was lost, which is very important since this is mainly an agricultural area.

Bank erosion indirectly influences socio-economic indicators in those three villages. Because of the flood risks (Dragicevic et al., 2007a) and further land degradation process in the researched area, the remaining of arable land became uncultivated and have transformed into the fallow land. The interview carried out among the owners of degraded land parcels, appoint that only 46% of them still farm their degraded parcel, 31% do not farm the degraded parcels and 23% of them lease their degraded land parcels.

For further research, it is necessary to link fluvial processes with socio-economic factors in order to predict

the future development of the fluvial landscape. Due to the fact that Konatice and Poljane are located at the area which is planned for the expansion of Kolubara mining basin, it can be an important factor for the future development of fluvial and socio-economic landscape.

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