**Original scientific article** **UDC: 551.3.053(497.11 Jablanica)**
Received: 10 Jun 2022; doi: 10.5937/zrgfub2270083K
Received in revised form: 20 Jun 2022;
Accepted: 24 Jun 2022;
Available online: 30 Jun 2022.

# CHANGES IN SOIL EROSION INTENSITY IN JABLANICA REGION

Filip Krstić[1]*, Stefan Paunović*

*University of Belgrade – Faculty of Geography, Studentski trg 3/III, 11000 Belgrade, Serbia

**Abstract**: The aim of the paper is to analyse the changes in erosion intensity in Jablanica region between 1971 and 2018, using the Gavrilović method. Study area covers the catchment of three left tributaries of South Morava river, which have vary unstable river regimes. Natural conditions have a negative impact on intensity of the erosion process with unfavourable geological and pedological structure, precipitation regime, high slope values and significant vertical dissection of the terrain. Changes in erosion process are caused by changes in agricultural production as well as anti-erosion works, that have been carried out during the second half of the 20th century.

**Keywords**: Jablanica, Pusta reka, Veternica, Gavrilović method, soil erosion

## Introduction

Soil erosion is the main degradation process of agricultural soils by antropogenic interference. Erosion process is influenced by the characteristics and distribution of rainfall, soil type, topography, soil cover and management, and by conservationist practices supporting agricultural production (Panagos et al., 2015).

According to Telles et al. (2013), erosion has contributed to the impoverishment and reduction of the sustainability of agroecosystems by causing the loss of soil, water, nutrients and organic carbon. Beside causing

[1] Corresponding author: F. Krstić, University of Belgrade – Faculty of Geography, Studentski trg 3/III, 11000 Belgrade, Serbia; e-mail: filip.krstic@gef.bg.ac.rs

the degradation of agricultural areas, erosion results in economic, social and environmental damages that can be minimized with the adoption of soil conservation practices important in the control of erosion. For such economically underdeveloped regions, such as Jablanica, soil erosion is one of the main natural limiting factors for future regional development.

Excessive erosion of the land surface can have limiting consequences on regional development, especially considering the use of natural resources such as agricultural land. In some regions of Serbia, excessive erosion represents a significant natural risk (Dragićević et al., 2011). Among the most endangered regions is South Serbia, located in the basin of South Morava river. Erosion affects increased soil degradation, reduction of its productivity, as well as the volume and quality of agricultural production. Anthropogenic factors that contribute to soil erosion are: intensive agricultural production, especially on steep agricultural areas, irrational logging and mining.

Serbia is covered with hard erosive processes and about 86% of its area is at some risk of erosion. More intensive erosion processes cover 35% of the territory of Serbia (Lazarevic, 1983), from the south of the Sava and the Danube (hilly-mountainous part of Serbia).

Soil erosion in the Jablanica region is the result of natural and anthropogenic factors. Since the 1950s, the Jablanica region has been identified since the 1950s as one of the areas most threatened by erosion in Serbia. The intensity of erosive processes was influenced by the unfavorable geological structure dominated by easily eroding crystalline schists on the mountain rim of the region and weakly bound sediments at the bottom of the Leskovac Basin. Intense rainfall and an unfavorable pluviometric regime, the great fragmentation of the relief as well as the destruction of the forest cover contributed to the development of erosive processes.

Vasović (1998) singled out several periods of intensive deforestation during the 20th century, which also affect the recent state of erosion. The long-term destruction of forests was in the period 1912–1928 during the Balkan Wars and the First World War, as well as due to the later immigration of the population and the creation of agricultural areas on barren land. The second period of deforestation (predominantly oak forests) was between 1930 and 1935. It was especially pronounced in lower basin of Jablanica river. The third period of deforestation was during the German occupation in the Second World War (mostly in the Šumanka river basin). Due to this sparseness of forests, the land was exposed to intensive denudation (Vasović, 1998).

## Materials and Methods

### Study area

Study area consists of three river catchments: Jablanica, Veternica and Pusta reka in the geographical region of Jablanica in South Serbia. All three rivers are left tributaries of South Morava. Study area covers 1624.1 $km^2$ and can be divided into five micro-regions: Pusta reka, Upper Jablanica, Lower Jablanica, Porečje and Poljanica. Administratively, area covers the municipalities of Bojnik, Medveđa and Lebane as well as parts of the City of Leskovac and the City of Vranje.

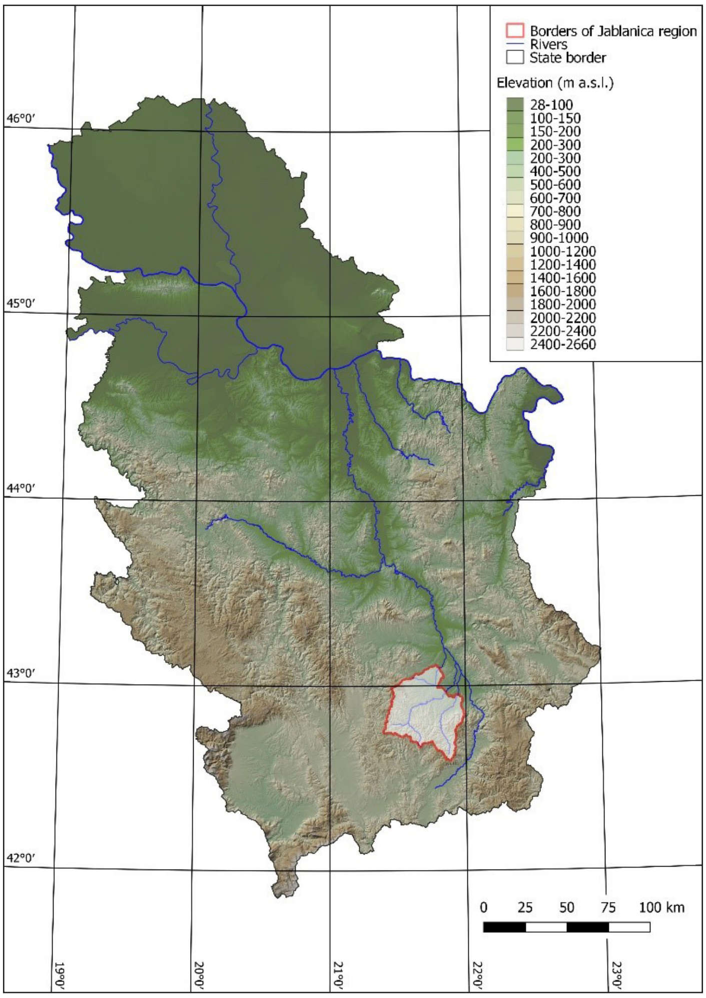


*Figure 1. Geographical position of Jablanica region within Serbia*

The Jablanica region is mostly located within the Serbian-Macedonian massif (Karamata, Dimitrijević and Dimitrijević, 1998). Several dominant lithological formations can be distinguished in the structure of the region. The largest area is occupied by crystalline slates and granitoids. Crystalline schists belong to the lower complex of the Serbian-Macedonian Mass, which forms its core, and are mostly of sedimentary origin. In the southern part of the region, in the area of Poljanica, deposits of Paleogene sediments were found. Volcanites are developed in the Lece andesite massif, in the west of the region. The northeastern part of the region, the Leskovac basin, is covered by Neogene and Quaternary sediments. The geological structure of the region also has a negative effect on erosive processes. Dominant crystalline schists (gneisses, micaschists, leptinolites, etc.), unbound pyroclastic material and Neogene sediments are subject to weathering and erosion. Due to the deforestation and removal of the pedological cover, they are exposed to the action of external forces.

The main valleys in the region have southwest–northeast orientation, and the elevation varies from 219 m a.sl. in the northeast part to 1445 m a.s.l. in the south (mountain Kukavica). Mean slope of the study area is 12.5°, while in the mountainous parts the maximum value of the slope is 50°, which has a significant impact on the intensity of the soil erosion.

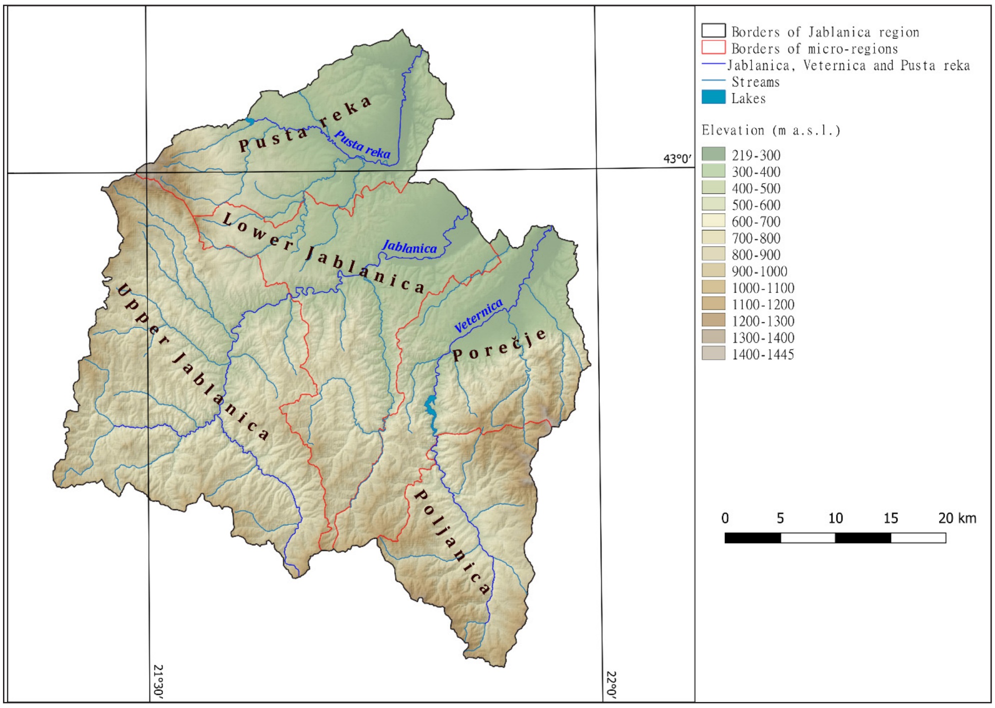


*Figure 2. Map of Jablanica region and its micro-regions*

Another factor that affects soil erosion is intense and short-term rainfall. This kind of precipitation causes the formation of torrential flows. The most dangerous torrential areas are the Šumanka river basin and the Veternica basin. In the mountainous part of the region, the mean annual temperature (period 1991–2018) was 6.2°C (Kukavica), while in the lowland north-eastern part it was significantly higher (11.5° - Leskovac). Mean annual precipitation varies from 661 mm in Leskovac to 1011 mm on Kukavica mountain.

## Methodology

Soil erosion represents a complex process, which is affected by a number of factors. One of the most accurate ways to combine DEM and satellite images regarding land erosion research is to correctly classify spatial parameters, which are represented through a smaller number of classes or units (Milevski et al., 2007). The Gavrilović method, which will be used in this paper, belongs to the group of regional methods, and has been characterized in the world literature as a semi-quantitative method (de Vente et al., 2005).

The erosion coefficient (Z) is calculated on the basis of the following formula (Gavrilović, 1972):

$$Z = Y \cdot X \cdot (\varphi + \sqrt{I}), \text{ where:}$$

Z - erosion coefficient; Y - coefficient of land resistance to erosion; X - coefficient of land protection from atmospheric factors and erosion; φ - coefficient of type of the erosion; I - average drop in surface area for which the erosion coefficient is calculated.

The coefficient of land resistance to erosion (Y) was obtained by digitizing and analyzing the sheets of the Pedological Map of the SFRY at a scale of 1:50,000. On the territory of the region, eutric and distric cambisols and rankers are the most dominate types of soil, and are also very susceptible to erosive processes.

*Table 1. Coefficients of land resistance (Gavrilović, 1972)*

| Erosion resistance coefficient of the substrate | Y |
|---|---|
| Fluvisol | 0.3 |
| Deluvium | 0.8 |
| Eutric Cambisols | 0.7 |
| Lithosol | 0.4 |
| Pseudogley | 0.9 |
| Dystric Cambisol on magmatic rocks | 0.7 |
| Dystric Cambisol on metamorphic rocks | 0.8 |
| Vertisol | 0.7 |
| Ranker | 0.7 |

The coefficient of the land protection from the atmospheric factors and erosion (X) was calculated by the processing and analysis of the Corine Land Cover Data, issued by the European Environment Agency (EEA). The lowest coefficients are represented in the areas that are most protected from weathering and erosive processes (coniferous forests, mixed forests and deciduous forests), while the areas of mineral exploitation, areas with scarce vegetation and irrigated arable agricultural areas have the highest coefficients. Forests are an important regulator of the erosive process, especially in the areas with high slope values.

*Table. 2. The coefficient of the land purpose*

| Substrate protection coefficient | X |
|---|---|
| Coniferous forest | 0,15 |
| Mixed forest | 0,15 |
| Broad-leaved forest | 0,2 |
| Discontinuous urban fabric | 0,25 |
| Transitional woodland shrub | 0,4 |
| Natural grassland | 0,4 |
| Fruit trees and berry plantations | 0,4 |
| Pastures | 0,5 |
| Land principally occupied by agriculture | 0,55 |
| Vineyards | 0,6 |
| Complex cultivation patterns | 0,7 |
| Non-irrigated arable land | 0,8 |
| Sparsely vegetated areas | 0,9 |
| Mineral extractions sites | 0,9 |

The coefficient of erosion type (φ) was determined by using the bare-soil index (BSI). For that purpose, the multispectral satellite images of the LANDSAT 8 satellite (United States Geological Survey - USGS) were used. Satellite images were downloaded from the website of the US Geological Survey (USGS) for July 26, 2018 (summer period during the maximum development of vegetation). The bare-soil index was calculated by the following formula:

$$BSI = \frac{((B6 + B4) - (B5 + B2))}{((B6 + B4) - (B5 + B2))} + 1$$

where B6 is the shortwave infrared spectral channel (SWIR 1), B4 is the red spectral channel, B5 is the near infrared spectral channel (NIR), and B2 is the blue spectral channel. The BSI index in the region ranges from 0.43 to 1.15.

The average surface slope (the terrain slope) (I) was calculated in GIS environment by using the 30 m DEM, in the form of a percentage expressed in decimal notations. As the slope increases, the stability of the slopes decreases, the intensity of erosion increases, and the likelihood of torrential floods rises (Novković, 2016).

## Results and Discussion

The erosion map of SR Serbia was made on the basis of field research conducted in the period 1966-1971 (on a scale of 1:500,000). Based on the erosion intensity coefficient, five categories were distinguished: excessive erosion, strong, medium, weak and very weak erosion. It was concluded that in that period, the beginning of decreasing and stagnation of erosive processes can be observed. As the authors of the map point out, such a tendency is a consequence of social changes, and to a lesser extent anti-erosion works that have been carried out (Lazarević, 1983). In the second half of the 20th century, there was a decline in livestock and a decrease in anthropogenic pressure on the soil of hilly and mountainous areas, which were exposed to the most intense erosion processes. The most intensive erosive processes in the region were recorded in the area of Porečje, i.e. in the lower Veternica basin (erosion coefficient 0.653), as well as in the Poljanica area, i.e. in the upper Veternica basin (0.596). In Upper Jablanica, the erosion coefficient was 0.405, and in Lower Jablanica 0.487. Pusta reka region had the lowest erosion coefficient of 0.327. Weaker erosive processes in this region are explained by smaller values of terrain slopes.

By analyzing the soil erosion map from 2018, it is concluded that there have been significant changes in the intensity of the erosive processes. The goal of applying the Gavrilović method was to gain insight into the recent state of erosion in the region by taking into account the current climate conditions and land use patterns. The biggest changes occurred in the way land is used (reduction of anthropopression), especially in the hilly and mountainous parts of the region. During the last three decades, the process of deagrarization has intensified. As a result, there was an increase in the area under deciduous forests and especially under vegetation that represents scrub and young forest. The degree of afforestation of the region in 2018 was 64% (excluding young forest and scrub, it is 57%). The spontaneous abandonment of agricultural production and the reforestation of former arable land had a most important impact.

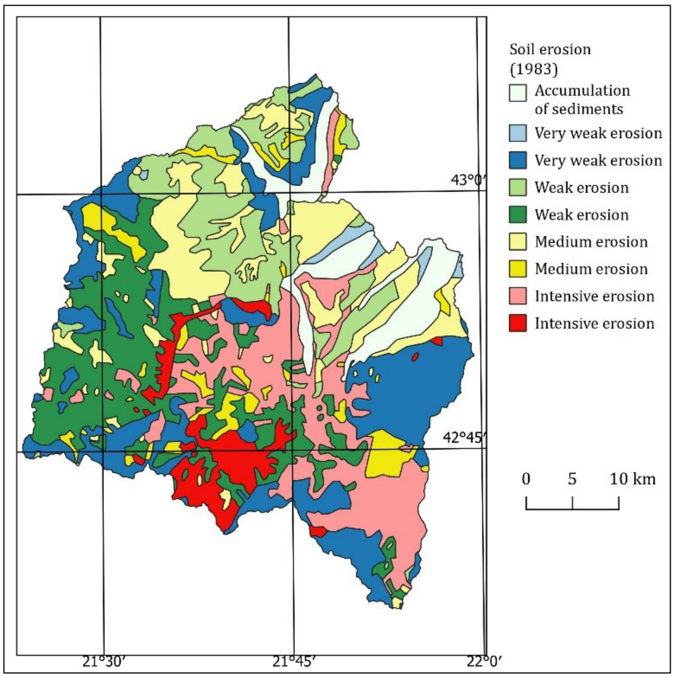


*Figure 3. Soil erosion intensity in Jablanica region in 1983*

According to the situation in 2018, very weak and weak erosion are most prevalent in the region (73.4% of the region's territory, compared to 51.2% in 1971). Medium erosion was recorded on 371.1 km2 (22.9%), and severe erosion on 60.6 km2 (3.7% of the territory). The Banjska river basin represents a good example of the reduction in the intensity of erosion in the period 1971–2018. According to Lazarevic (1983), this part of Upper Jablanica was affected by strong and moderate erosion. However, according to the current situation, low and medium erosion dominates. In this hilly-mountainous area, strong erosion is present only in the vicinity of Sijarinska Banja, i.e. in the smaller valley expansions of the Banjska river, where agricultural land is still cultivated. Despite the fact that erosive processes in the region are less intense, agricultural production did not develop. It is a consequence of depopulation and lack of labor force.

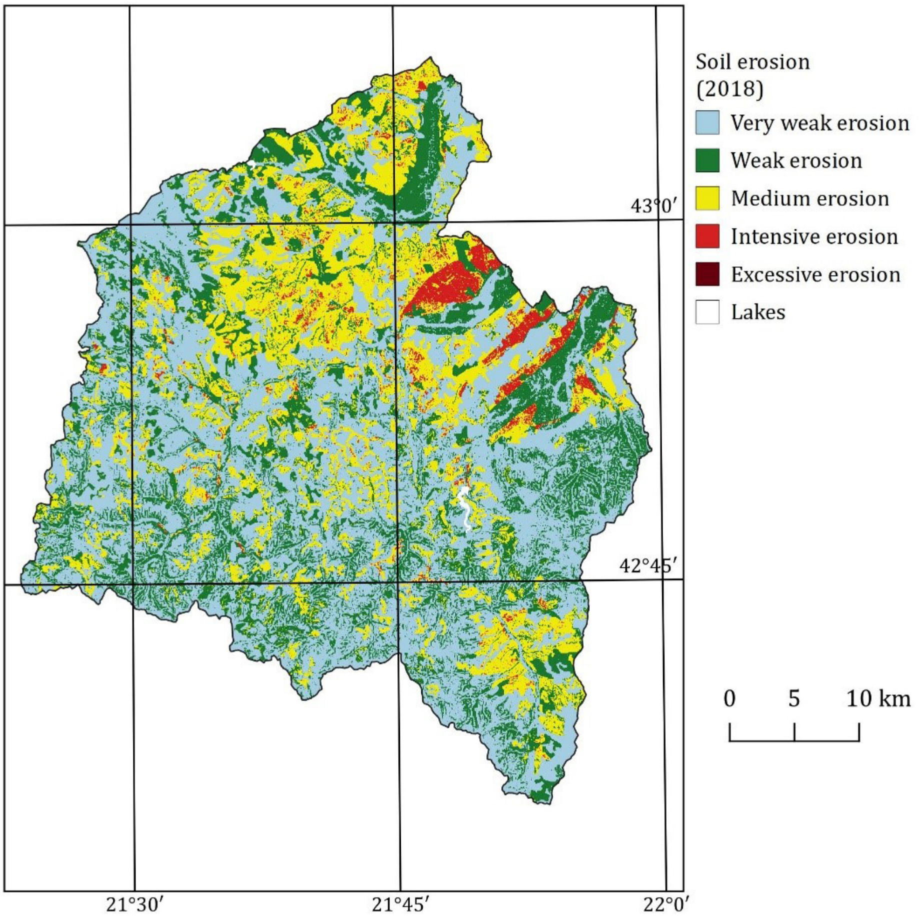


*Figure 4. Soil erosion intensity in Jablanica region in 2018*

Strong erosion is characteristic of low-lying parts of the region in the northeast, i.e. low slopes that form the watershed between Veternica, Sušica, Jablanica and Pusta Reka. These are areas of intensive agricultural production (farming and vegetable growing). In places, excessive erosion was recorded in this area, which was not the case in 1971 (although the areas under this category of erosion are negligible). Such data indicate that the process of soil erosion has stabilized in most of the region. Depopulation and cessation of agricultural production in the higher parts of the region are the main factors that have influenced the state of erosion and regional development. Natural conditions continue to influence the intensity of erosive processes. This is best seen on the example of the Poljanica basin, where processes of depopulation and deagrarization are the most intense. In addition, in this microregion, there is still moderate erosion with smaller areas under strong erosion (due to unfavorable natural conditions). The average erosion coefficient for 2018 in the area of the entire region is 0.293.

## Conclusion

In the second half of 20th century as well as in the first decades of 21st century significant changes have occurred regarding the intensity of soil erosion in the study area. In the Poljanica basin, Upper Jablanica and in the higher parts of the Pusta reka region, it is necessary to convert arable land that is threatened by erosion. By converting degraded arable land into meadows and pastures, the development of animal husbandry would be enabled. For this branch of agriculture, there are significantly more favorable natural resources and conditions. The most intensive erosion takes place in the lower parts of the region, in Porečje, Lower Jablanica and low areas of Pusta reka region. Intensive production of vegetables and industrial plants (tobacco and sunflower) leads to rapid soil degradation and loss of fertility. Degraded areas that are on higher slopes must be replaced with perennial agricultural crops. The high level of groundwater in the alluvial plains of the rivers leads to oversaturation of the surface layers of the soil and the initiation of landslides.

Therefore, it is necessary to carry out land melioration of landslides, regulation and maintenance of drainage channels. In the area of Porečje, it is necessary to increase the areas under grass vegetation (meadows and pastures), raise orchards and apply measures of afforestation, in order to improve the water regime of the soil. The mentioned measures would reduce the direct damage caused by the triggering of landslides. Indirectly, agricultural production in the region would improve, because agricultural crops would be grown on adequate areas, with an increase in total production.

## References

de Vente, J., Poesen, J. & Verstraeten, G. (2005). The application of semiquantitative methods and reservoir sedimentation rates for the prediction of basin sediment yield in Spain. *Journal of Hydrology*, *305* (1-4), 63-86.

Dragićević, S., Filipović, D., Kostadinov, S., Ristić, R., Novković, I., Živković, N., Anđelković, G., Abolmasov, B., Šećerov, V. & Đurđić, S. (2011). Natural hazard assessment for land-use planning in Serbia. *Int. J. Environ. Res., 5* (2), 71–380.

Gavrilović, S. (1972). Inženjering o bujičnim tokovima i eroziji. *Izgradnja*, Specijalno izdanje, Beograd, 1-292.

Karamata, S., Dimitrijević, M. i Dimitrijević, M. (1998). Okeanski prostori u središnjem delu Balkanskog poluostrva tokom mezozoika. U: Šućur, M. (ur.): XIII kongres geologija Jugoslavije – zbornik radova, knjiga 2 – regionalna geologija, stratigrafija i paleontologija, 119–123. Herceg Novi: Crnogorsko geološko društvo, Savez Geoloških društava Jugoslavije.

Lazarevic, R. (1983). *The Erosion Map of Serbia, 1:500,000*. Belgrade: Institute of Forestry and Wood Industry.

Milevski, I., Dragićević, S. & Kostadinov, S. (2007). Digital elevation model and satellite images an assesment of soil erosion potential in the Pčinja catchment. *Bulletin of the Serbian Geographical Society*, *87* (2), 12–19.

Novković, I. (2016). *Prirodni uslovi kao determinante geohazarda na primeru slivova Ljiga, Jošaničke i Vranjskobanjske reke*. Doktorska disertacija, Geografski fakultet, Univerzitet u Beogradu.

Panagos, P., Borrelli, P., Meusburger, K., Alewell, C., Lugato, E., Montanarella, l. (2015). Estimating the soil erosion cover-management factor at the European scale. *Land Use Policy*, 48, 38-50.

Telles, T.S., Dechen, S.C.F., Souza, l. G. A, Guimaraes, M. F. (2013). Valuation and assessment of soil erosion costs. *Scientia Agricola*, *70* (3), 209-216.

Vasović, M. (1998). *Gornja Jablanica*. Belgrade: Narodno delo.