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SOIL EROSION: CAUSES AND EFFECTS WITHIN PERILO SMALL CATCHMENT (WESTERN SERBIA)

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Abstract

This study deals with the evaluation of soil erosion in a small catchment. Mean annual and total specific erosion-induced sediment yields in the Perilo Brook catchment are induced by both natural and anthropogenic factors. The catchment erosion factors evaluated in this study, viz. relief, geological substrate, soil, climate and vegetative cover, have contributed to the annual erosion intensity of 162.90 m^3 km^{-2} of soil in the catchment area of the Perilo, classified as a small torrential brook and a dry watercourse.

Keywords: *erosion factors, erosion intensity, soil, catchment*

Introduction

Land degradation and soil loss are global events. Human induced pressures on natural ecosystems are still in progress, along with conservation efforts (Hacisalihoğly et al., 2010). The main factor causing soil degradation worldwide is water erosion, which threatens 56% of the world's arable land (Oldeman et al., 1990).

Over 90% of the total land area in the Republic of Serbia suffers from different types and intensities of erosion (Djorović and Kadović, 1997). The erosion process can have both direct and indirect impacts, inducing permanent soil disappearance. The calculated value of the total annual sediment yield suggests that some 16.0 cm of soil are annually eroded off the 21,000 ha of land in Serbia (Spalević, 1997). In the Republic of Serbia (Central Serbia), there are 1.221 million ha of eroded soil, and 36,000 ha are in a steady state, now (Statistical Yearbook, 2008).

Erosion has mostly affected strongly sloping, deforested or cultivated shallow soils on slopes, formed on impermeable geological substrates, due to the effects of intense rainfall and fluctuating air temperatures (Spalević, 1997).

The tendency of air temperature to increase and of rainfall to decrease is quite evident in the region of Čačak (Šekularac, 2002). Climate change leads to degraded soil physical properties, increases soil erodibility and reduces the protective role of vegetation.

The above factors cause intensification of both surface and deep-cutting processes of erosion.

Given the above, the objectives of this study are quantitative assessment of soil erosion induced by a range of factors and estimation of sediment yield in one part of the catchment area of the Kamenica River (part of the Zapadna Morava catchment) i.e. its subbasin, including its first order left-hand tributary the Perilo.

Materials and methods

The Perilo is located near Čačak (43^0 $53^{'}$ N; 20^0 $21^{'}$ E), Western Serbia, and belongs to the catchment of the Zapadna Morava river.

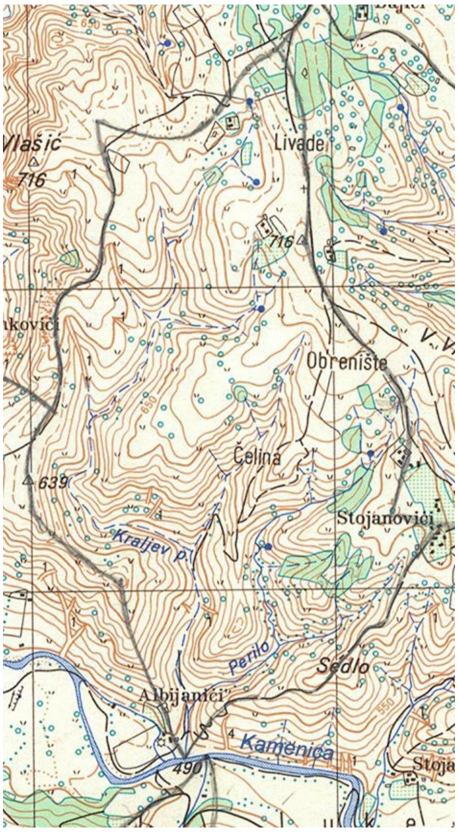

Figure 1. Perilo catchment

Natural characteristics of the Perilo Basin were studied using map data (hydrography, relief, geological substrate and soil), literature data (elements of climate: rainfall and air temperature) and data obtained through an immediate reconnaissance survey of the area (vegetation).

Maps of the studied area have the following scale: topographic map (1:25,000, Fig. 1; 1:50,000) by the Military Geographical Institute (1971), geological map (1:500,000) by the Institute of Soil Science (1966) and pedological map (1:50,000) by the Institute of Soil Science (1964).

Meteorological parameters for the catchment area were calculated using the method of interpolation of rainfall data (Republic Hydrometeorological Bureau, 1930-1961) by the rainfall gradient (Bonacci, 1984), and air temperature (Centre for Research in Agriculture, 1949-1995) calculations for any altitude (Dukić, 1984).

Erosion-induced soil losses can be predicted by various analytical models.

However, according to the experience of a number of researchers, the Erosion Potential Method – EPM (Gavrilović, 1972) is the most suitable on catchment level for watershed management purposes in this Region and is used in: Bosnia & Herzegovina, Bulgaria, Croatia, the Czech Republic, Italy, Iran, Montenegro, Macedonia, Serbia and Slovenia. This is why quantitative indicators of soil erosion in this research were calculated using the Erosion Potential Method - EPM.

The basic analytical equation for the calculation of erosion-induced soil losses, as developed by Gavrilović (1972), is as follows:

$$G_{yr \times sp^{/1}} = T \times H_{yr} \times \pi \sqrt{Z^3} \times R_u \qquad (1)$$

where:

$G_{yr\ sp}^{-1}$ – specific annual total erosion-induced sediment yield reaching the confluence, $m^3\ yr^{-1}\ km^{-2}$
T – temperature coefficient of the catchment
H_{yr} – amount of rainfall, mm
π – 3.14
Z – coefficient of erosion
R_u – coefficient of retention of soil in the catchment.

Results and discussion

The size, length, circumference and shape (perimeter) of a catchment area are among major catchment elements of importance for soil erosion. The Perilo catchment is 1.81 km^2 in area (F), 2.17 km in length (L), and 6.22 km in circumference (C).
The major physical and geographical elements of the Perilo catchment, viz. relief characteristics, geological substrate features, soil type and soil utilisation method, are quantitative parameters or soil erosion in the catchment.

Table 1. The basic parameters of the Perilo catchment relief

Catchment Name: Perilo	
The lowest point of the main watercourse and catchment (B), m	492
The highest point of the main watercourse (C), m	670
The highest point of the catchment (E), m	726
Average slope of the main watercourse in the catchment (I_a), %	10.8
Mean catchment altitude (M_{sl}), m	631.59
Mean catchment altitudinal difference (D), m	139.59
Mean catchment slope (I_m), %	23.2
Coefficient of catchment relief erosion energy (E_r), $m/km^{1/2}$	63.76

Table 1 presents the Perilo relief which plays a primary role in the occurrence of soil erosion. The mean altitude (A_m) of the Perilo is 631.59 m and the mean altitudinal difference (D) is 139.59 m. The mean slope (I_m) is 10.8%. Relief of a region can also be determined by the coefficient of relief erosion energy (E_r), the value thereof for the Perilo catchment being 63.76 $m\ km^{-1/2}$. An increase in relief parameter values results in increasing intensity of soil erosion in the catchment.
Geological substrates contribute significantly to the erosion process within the Perilo catchment area (Table 2). Erosion resistance of geological substrates is directly related to water permeability. The geological substrate of the Perilo catchment is serpentine (100.00% of the total catchment area) and exhibits poor permeability. The water permeability coefficient of the serpentine geological substrate (S_1) is 1.00, suggesting non-resistance of the geological substrate to the erosion process (Table 2).

Table 2. Geological substrate of the Perilo catchment, coefficient of water permeability (S_1) and erosion resistance

Catchment name: Perilo		
F_{ppr}-Poorly permeable rocks		
Serpentine	km^2	1.81
	%	100.00
Coefficient of geological substrate water permeability (S_1)	1.00	
Resistance of geological substrate to erosion	Non-resistant	

As an erosion agent, soil and its properties contribute, to a lesser or greater degree, to the erosion process. Due to the effect of pedogenetic factors, the soil type covering the Perilo catchment area is humus-siliceous soil on serpentine rock. It is classified as shallow soil. The profile of the humus-siliceous soil on serpentine is of A_h–C type. A strong degree of erodibility is found in the humus-siliceous soil on serpentine (Šekularac, 2000).

Table 3. The structure of the Perilo catchment according to type of land use and vegetative cover coefficient (S_2)

Catchment Name: Perilo			
F_f	Forests and coppice of good spacing	km^2	0.05
		%	2.76
F_g	Orchards	km^2	0.00
		%	0.00
	Meadows	km^2	0.12
		%	6.63
	Pastures and devastated forests and coppices	km^2	1.60
		%	88.40
Σf_g		km^2	1.72
		%	95.03
F_b	Arable land	km^2	0.04
		%	2.21
	Infertile soil	km^2	0.00
		%	0.00
Σf_b		km^2	0.04
		%	2.21
Vegetation cover coefficient (S_2)		0.80	

The most aggressive climate elements inducing and contributing to soil erosion include rainfall, air temperature, and soil temperature (indirectly, through air temperatures). This region has a temperate continental climate. The mean annual rainfall total (R) for the Perilo catchment is 784.2 mm, and the mean annual air temperature (T) is 8.5^{0}C. The data on rainfall reaching the catchment surface indicate an important role of rainfall as a climate element in soil erosion in the catchment area observed.

The contribution of the other soil erosion agents i.e. vegetation, both autochthonous and anthropogenic, and vegetative cover coefficient (S_2) is given in Table 3. The total area of land under forests and coppice of good spacing (F_f) in the Perilo catchment is 0.05 km^2 (2.76%), most of the land – 1.72 km^2 (95.03%) is under grass vegetation ($\sum F_g$), and 0.04 km^2 (2.21%) of land are under bare soil ($\sum f_b$). These forms of land-use facilitate the protection of the studied area against erosion (vegetative cover coefficient, $S_2 = 0.80$).
The devastating potential of the watercourse can be determined from the hydrographic and hydrologic traits of the region analysed. The traits pertaining to the family of the Perilo torrent (F_c) are as follows: F_c: D; IV; Z=0.37, meaning that the Perilo is a dry watercourse and a small torrential brook (D) classified as class IV of erosion category (a deep type of erosion) and having an erosion coefficient (Z) of 0.37 (weak erosion intensity).
The above traits of the erosion factors in the Perilo catchment result in sediment production and soil erosion of particular intensity.
The scale of erosion of the Perilo catchment is manifested through the mean annual erosion-induced sediment yield, W_{yr} of 951.11 m^3 yr^{-1}.
The mean annual volume of the total sediment yield (G_{yr}) reaching the Perilo confluence is 294.84 m^3 yr^{-1}, whereas the specific annual total erosion-induced sediment yield reaching the confluence with the Kamenica River ($G_{yr\ sp}^{-1}$) is 162.90 m^3 km^{-2} yr^{-1}. This finding regarding the weak erosion intensity is comparable to that on the low-intensity erosion of the Grliška River region (Eastern Serbia) of ($G_{yr\ sp}^{-1}$) 209.12 m^3 km^{-2} yr^{-1} (Stefanović et al., 2007). Using the method of EPM, in research of the Djuricka river basin (North of Montenegro), predicted that the soil losses were 645 m^3 km^{-2} per year (Spalevic et al., 2013). The said erosion intensity on the Perilo catchment is manifested through the relief erosion energy coefficient of 63.76 m $km^{-1/2}$, the erosion coefficient (Z) of 0.37, mean annual rainfall of 784.2 mm and average annual air temperature of 8.5^{0}C, with about 95.03% of land area under grass vegetation ($\sum F_g$), and the dominating humus-siliceous soil on serpentine rock.
The above data show that, in view of the annual sediment yield, about 0.48 ha of soil up to 20 cm depth are eroded off the Perilo catchment area i.e. about 0.71 t ha^{-1} of soil are lost annually. The amount of the eroded soil material can be categorised as class I (0-1 t ha^{-1} yr^{-1}) of permissible or tolerable erosion (Hacisalihoğly et al., 2010).

Conclusion

The Perilo is a dry watercourse during the summer and a small torrential brook at other times of the year. The value of Z coefficient of 0.37 indicates that the river basin belongs to destruction category IV. The strength of the erosion process is weak, and deep erosion dominates in the studied area. These and the other soil erosion agents analysed in the catchment area have resulted in the mean annual erosion-induced sediment yield of 951.11 m^3 yr^{-1}, and erosion intensity of 162.90 m^3 km^{-2} yr^{-1}. The erosion observed in this region is of weak intensity, and the anthropogenic factor is the key agent in the process governing soil utilisation, soil conservation and protection from further erosion-induced degradation.

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