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SOIL EROSION EVALUATION IN THE RASTOCKI POTOK WATERSHED OF MONTENEGRO USING THE EROSION POTENTIAL METHOD

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Abstract
Soil erosion is the most important factor of land degradation worldwide, causing significant environmental problems in the region of South East Europe also. We studied soil erosion processes in the RastockiPotok Watershed of Montenegro using the Erosion Potential Method (EPM) of Gavrilovic, which is created in Yugoslavia and is the most suitable on catchment level for the watershed management needs in this Region. The peak discharge (Qmax) is calculated on 150 m^3s^{-1} and there is a possibility for large flood waves to appear in the studied basin. According to our analysis, the coefficient fs, (portion under forest) is 0.45; ft (grass) is 0.41 and fg (bare land) is 0.14 and the coefficient of the river basin planning, Xa, is 0.52. Real soil losses, Gyr, were calculated on 1472m^3yr^{-1}, specific 250$m^3km^{-2}yr^{-1}$. The value of the Z coefficient of 0.488indicates that the studied watershed belongs in the Destruction Category III: the erosion process is medium. This study confirmed the findings of the other Balkan researchers that the EPM method of Professor Gavrilovic is a useful tool for calculating sediment yield in the South East Europe.

Keywords: Montenegro, watershed, soil erosion, runoff, Erosion Potential Method (EPM)

Introduction

Soil is an essential resource for the food chain and our society. Soil formation is a slow process, while soil destruction can be rapid. Hence, soil is considered a non-renewable resource, and its sustainability is important. Among the threats to soil is erosion, which is a natural phenomenon that can be impacted by global change (Paroissien, 2015).
The issue of sediment yield and runoff and their factors is one of the hot spots in hydrological science. Various studies show that sediment yield and runoff in a river basin are mainly affected by local natural conditions, such as precipitation, vegetation coverage, terrain, lithology, and soil structure, as well as human activities (Xu 2006). Quantitative information on sediment yield and runoff is needed for erosion risk assessment. Besides field and laboratory investigation, erosion risk models have proved to be good tools to understand these processes (Boardman, 2006).
This study aims to estimate the annual sediment yield, due to rainfall and runoff, at theoutlet of RastockiPotok River basin, which is located in north Montenegro. The main processes quantified in the study are runoff resultingfrom rainfall, soil erosion due to rainfall and runoff, inflow of soil erosion products intostreams, and sediment transport in streams. The quantification leads to the computation of sediment yield at the basin outlet.
Erosion Potential Method (EPM) of Gavrilovic (1972) was chosen for this study as it is widely used in different studies in the Region (Bosnia and Herzegovina, Macedonia, and Serbia). Blinkov and Kostadinov (2010) evaluated applicability of erosion risk assessment methods for the Balkan region, considering dependence on scale and different needs. The EPM was, according to them, the most suitable for the watershed management needs in this Region. The EPM model was earlier validated for simulating the processes of soil erosion and

sediment transport over the Polimlje River Basin in North of Montenegro (Spalevic, 2011).

The new detailed report about the state of the runoff and sediment yield in this format may be used further in watershed management sector of Montenegro, illustrating the possibility of modelling of sediment yield with such approach.

Materials and methods

We studied the area of the Rastocki Potok drainage basin (6 km^2), a right-hand tributary of the river Lim.In terms of geomorphology and climate, it is a part of the natural entity of the Bijelo Polje Valley of the Polimlje region, North of Montenegro (Figure 1).

Figure 1. Study area of the Rastocki drainage basin

The river basin of Rastocki Potok stretches from its inflow to the River Lim (H_{min}, 540 m) to the tops of the hills over the villages Cerovar and Krusev Do where the H_{max} is 1278m. There is a flat area on the lower alluvial terrace close to the inflow of the

RastockiPotok to the River Lim. The average river basin decline, I_{sr}, is calculated at 25.5% and indicates that steep slopes prevail in the studied river basin. The average river basin altitude, H_{sr}, is calculated at 840 m; the average elevation difference of the river basin, D, is 300 m.

The detailed information on the soil erosion processes were collected during the field visit. This includes also the analysis of the status of plant cover, the type of land use, and the measures to reduce the erosion processes, as well as determination of the slopes, specific lengths, the exposition, the depth of the erosion base and the density of erosion rills.

We used the data of Soils of Montenegro (Djuretic and Fustic, 2000) for the studied area of the RastockiPotok. Furthermore, some pedological profiles had been reopened, and soil samples were taken for physical and chemical analysis. The granulometric composition of the soil was determined by the pipette method; the soil samples were air-dried at 105°C and dispersed using sodium pyrophosphate. The soil reaction (pH in H_2O and nKCl) was determined with a potentiometer. The total carbonates were determined by the volumetric Scheibler method; the content of the total organic matter was determined by the Kotzman method; easily accessible phosphorous and potassium were determined by the Al-method, and the adsorptive complex (y1, S, T, V) was determined by the Kappen method (Spalevic*et al*., 2013).

Understanding of soil erosion processes is essential in appreciating the extent and causes of soil erosion and in planning soil conservation. According to the previous experience in the Region, the most reliable method for determining the sediment yields and the intensity of the erosion processes for the studied area is the Erosion Potential Method (EPM). This method was created, developed, and calibrated in Yugoslavia (Gavrilovic, 1972).

With the increased computing powers of the last 20to 30 years, there has been a rapid increase in the explorationof catchment erosion and sediment transportthrough the use of computer models (Merritt et al., 2003) and have also been demonstrated in Montenegro, specifically in the Region of Polimlje (Barovic and Spalevic, 2015; Fustic and Spalevic, 2000; Gazdic et al, 2015; Spalevic et al., 2015a; Spalevic et al., 2015b; Spalevicet al., 2015c; Spalevic et al., 2015d; Spalevic et al., 2015e; Spalevic et al., 2014a; Spalevic et al., 2014b; Spalevic et al., 2014c; Spalevic et al., 2014d; Spalevic et al., 2013a; Spalevic et al., 2013b; Spalevic et al., 2013c; Spalevic et al., 2013d; Vujacic&Spalevic, 2015). That approach was used in the research on the RastockiPotok river basin.

These methods involve several steps: data acquisition, model specification and estimation (Madureiraa et al., 2011). We used the program package Intensity of Erosion and Outflow - IntErO (Spalevic, 2011) in this research. This program is an integrated, more modern second-generation version of the program „Surface and Distance Measuring" (Spalevic, 1999) and the program "River basins" (Spalevic, 2000). We used this program to obtain data on forecasts of maximum runoff from the basin and the intensity of the soil erosion. The EPM is embedded in the algorithm of IntErO computer-graphic method.

Results and discussion

Climatic characteristics.The climate and human pressure on the land in the Rastocki Potok river basin is very variable. The area is characterised by short, fresh, dry summers; rainy autumns and springs, and cold winters. The absolute maximum air temperature is 39.2^{O}C. Winters are severe, so much so that negative temperatures can fall to a minimum of -27.6^{O}C.

The temperatures are highest on average in July, at 20.8 °C. January is the coldest month, with temperatures averaging -5.6 °C.

It is well well-known fact that the precipitations and runoff are direct driving forces of soil erosion and sediment transport. The least amount of rainfall occurs in July (and August). Most of the precipitation here falls in November (Figure 2).

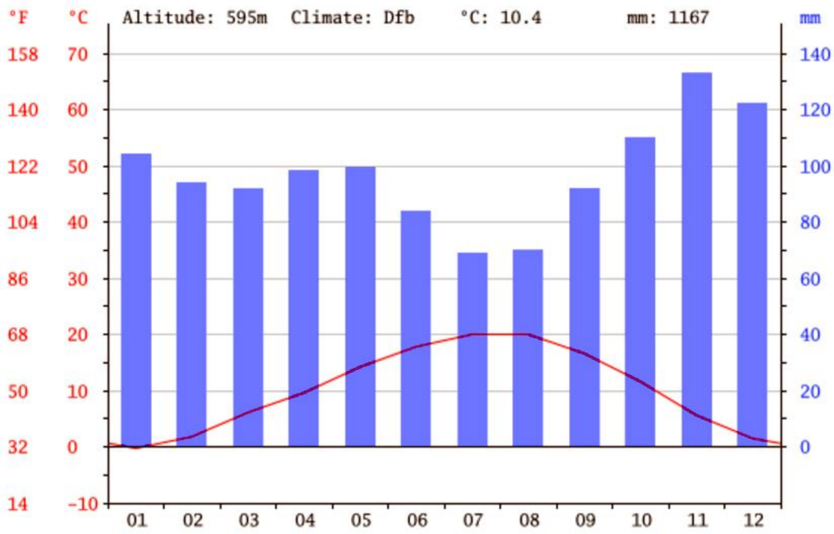

Figure 2. Climate graph

The average annual air temperature, t_0, is 8.9°C. The average annual precipitation, H_{yr}, is 873.7 mm. Temperature coefficients for the region, T, is calculated at 0.99. The torrential rain, hb, is calculated at 157.6 mm.

The geological structure of the area consists mainly of Paleozoic clastic, carbonate and silicate volcanic rocks and sediments of the Triassic, Jurassic, Cretaceous-Paleogene and Neogene sediments and Quaternary. In the structural-tectonic sense, the area belongs to the Durmitor geotectonic unit of the inner Dinarides of Northern and North-eastern Montenegro (Zivaljevic, 1989).

In order to define the permeability of the rocks of the studied area we used both: the Geological Atlas of Serbia (Dimitrijevic, 1992) and Geological Map of Montenegro (Zivaljevic, 1989) and extracted a map of permeability for the study area.

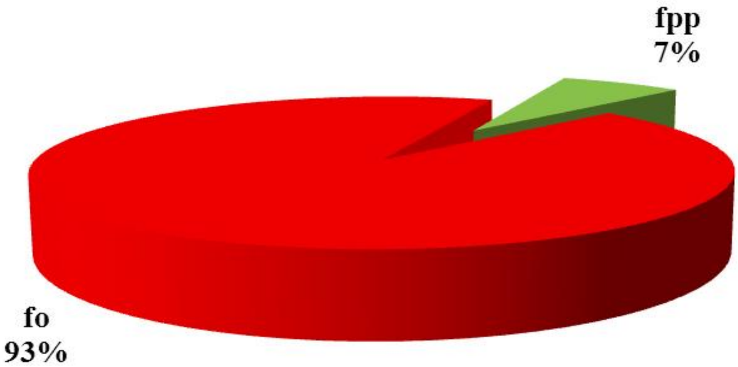

Figure 3: The structure of the river basin, according to bedrock permeability (fpp: medium; fo: low permeability)

The coefficient of the region's permeability, S1, is calculated to be 0.98. Within the studied basin, the area with medium permeable rocks (class fp) is 7% and the rest has poor permeability (class fo) is 93%.

Soil characteristics of the area. According to the results of the filed visits and supplementary laboratory analysis, but also using the previous research data of the project Soils of Montenegro (1964-1988) of the team of the Biotechnical faculty (Fustic & Djuretic, 2000), the most common soil types in the studied river basin are: Dystric Cambisols and Eutric Cambisols.

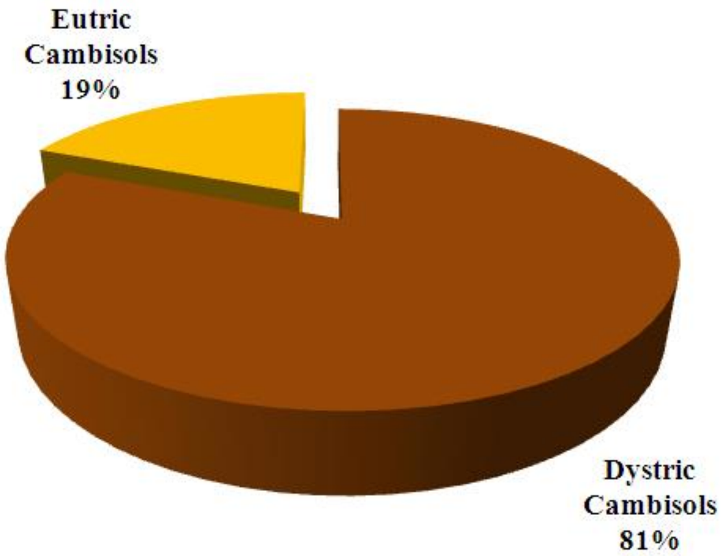

Figure 4: The structure of the river basin, according to the soil types

Land use. The structure of the Rastocki Potok watershed, according to the land use is presented in the Figure 5.

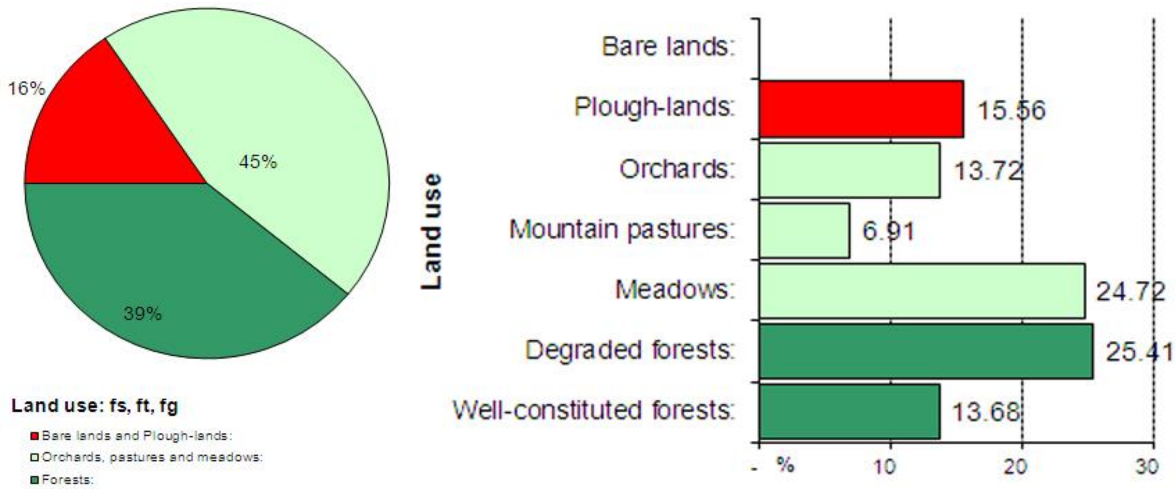

Figure 5: The structure of the river basin, according to the land use

According to our analysis, the coefficient f_s, (part of the river basin under forests) is 0.39, f_t (grass, meadows, pastures and orchards) is 0.45 and f_g (bare land, plough-land and ground without grass vegetation) is 0.16.

The coefficient of the river basin planning, X_a, is 0.54. Of the total river basin area, related to the river basin structure, degraded forests are the most widespread form (25.41%). The proportion is further as follows: Meadows, 24.72%; Plough-lands, 15.56%; Orchards and vineyards, 13.72%; Well-constituted forests, 13.68%; Mountain pastures, 6.91%.

Soil erosion. The dominant erosion form in the study area is sheet erosion with the uniform detachment and removal of soil and sediment particles from the soil surface by overland flow and raindrop impact distributed across slopes of the watershed. It has taken place in all soils on slopes, being the most pronounced on steep slopes with scarce or denuded vegetation cover.

We used the software IntErO to process the input data required for calculation of the soil erosion intensity and the peak discharge.

A complete report for the Rastocki Potok river basin is presented in Table 1.

Table 1. Part of the IntErO report for the RastockiPotok Watershed

Input data			
River basin area	F	5.88	km²
The length of the watershed	O	10.55	km
Natural length of the main watercourse	Lv	3.24	km
The shortest distance between the fountainhead and mouth	Lm	2.97	km
River basin length measured by a series of parallel lines	Lb	4.44	km
The area of the bigger river basin part	Fv	3.46	km²
The area of the smaller river basin part	Fm	2.42	km²
The area between the two neighboring contour lines	fiz	0.76	km²
Altitude of the first contour line	h0	600	m
Equidistance	Δh	100	m
The lowest river basin elevation	Hmin	540	m
The highest river basin elevation	Hmax	1278	m
Very permeable products from rocks	fp	0	
Medium permeable rocks	fpp	0.07	
Poor water permeability rocks	fo	0.93	
A part of the river basin under forests	fš	0.39	
Grass, meadows, pastures and orchards	ft	0.45	
Bare land, plough-land and ground without grass vegetation	fg	0.16	
The volume of the torrent rain	hb	157.6	mm
Incidence	Up	100	years
Average annual air temperature	t0	8.9	°C
Average annual precipitation	Hyr	873.7	mm
Types of soil products and related types	Y	1.2	
River basin planning, coefficient of the river basin planning	Xa	0.54	
Numeral equivalents of visible erosion process	φ	0.28	
Results:			
Coefficient of the river basin form	A	0.64	
Coefficient of the watershed development	m	0.38	
Average river basin width	B	1.32	km
(A)symmetry of the river basin	a	0.35	
Density of the river network of the basin	G	0.55	
Coefficient of the river basin tortuousness	K	1.09	
Average river basin altitude	Hsr	840.01	m
Average elevation difference of the river basin	D	300.01	m
Average river basin decline	Isr	25.49	%
The height of the local erosion base of the river basin	Hleb	738	m
Coefficient of the erosion energy of the river basin's relief	Er	150.86	
Coefficient of the region's permeability	S1	0.98	
Coefficient of the vegetation cover	S2	0.75	
Analytical presentation of the water retention in inflow	W	1.7325	m
Energetic potential of water flow during torrent rains	2gDF^½	186.03	m km s
Maximal outflow from the river basin	Qmax	150.81	$m^3 s^{-1}$
Temperature coefficient of the region	T	0.99	
Coefficient of the river basin erosion	Z	0.488	
Production of erosion material in the river basin	W yr	5476.8969	$m^3 yr^{-1}$
Coefficient of the deposit retention	Ru	0.269	
Real soil losses	G yr	1472.09	$m^3 yr^{-1}$
Real soil losses per km^2	G yr km²	250.39	$m^3 km^{-2} yr^{-1}$

(A) symmetry coefficient indicates that there is a possibility for large flood waves to appear in the river basin. The value of G coefficient of 0.55, indicates there is medium density of the hydrographic network.

The value of 25.49% indicates that in the river basin prevail steep slopes. The value of Z coefficient of 0.488 indicates that the river basin belongs to III destruction category. The strength of the erosion process is medium, and according to the erosion type, it is surface erosion.

The value of 250.39 m^3 km^2 yr^{-1}indicates, according to Gavrilovic, that the river basin is a region of very weak erosion.

Conclusion

Several factors influenced the erosion processes in the territory of the RastockiPotok river basin. The most significant factors are the area's climate, relief, geological substrate and pedological composition, as well as the condition of the vegetation cover and the land use. The peak discharge (incidence of 100 years) from the river basin, Q_{max}, is 150.81 m^3 $s^{-1}$and is suggesting the possibility of a large flood. The strength of the erosion process is medium, and the erosion type is surface erosion. The predicted soil losses were 1472 m^3 yr^{-1}, specific, 250m^3 km^{-2} yr^{-1}. According to Babic et al (2003) from the "Jaroslav Cerni" Institute for the Development of Water Resources (JCI), the leading research organization in Serbia's water sector, real soil losses are 350 m^3 km^{-2} $yr^{-1}$for the Lim river basin. By using the IntErO software to estimate the soil losses per km^2 in 57 river basins of Polimlje, the average value was331.78 m^3 km^{-2} yr^{-1}(Spalevic, 2011). This study confirmed the findings of the other Balkan researchers that the EPM method of Professor Gavrilovic is a useful tool for calculating sediment yield in the South East Europe. EPM is embedded in the algorithm of IntErO computer-graphic method.

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