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CALCULATION OF RUNOFF AND SOIL EROSION INTENSITY IN THE RAKLJANSKA RIJEKA WATERSHED, POLIMLJE, MONTENEGRO

ABSTRACT

This paper presents the use of Erosion Potential Method (EPM) for the prediction of runoff and soil loss in the Rakljanska Rijeka Watershed, Polimlje, Montenegro. Physical-Geographical, Climate, Geological, Pedological and Land Use inputs, which are the basis for the calculation of soil erosion intensity, we included in the EPM model. Information on runoff and sediment yield from the Rakljanska Rijeka Watershed, located in North-East Montenegro are described. The value of the Z coefficient was calculated on 0.457, what 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. Our results suggest that the calculated peak discharge from the river basin was 78 m^3s^{-1} for the incidence of 100 years. According to our analysis there is a possibility for large flood waves to appear in the studied river basin. The net soil loss was 2438 m^3 per year, specific 210m^3km^{-2} per year. The Erosion Potential method we used in this study is highly recommended for soil erosion modelling in other river basins similar to the studied watershed, because of its simple and reliable identification of critical areas affected by the soil loss caused by soil erosion.

Keywords: Soil erosion, Runoff, watershed, EPM Method.

INTRODUCTION

Soil erosion is a key driver of land degradation and heavily affects sustainable land management in various environments worldwide. An appropriate quantification of rates of soil erosion and a localization of hotspots are therefore critical, as sediment loss has been demonstrated to have drastic consequences on soil productivity and fertility (Stoffel *et al*., 2013).

Soil erosion is a growing problem globally and is serious problem in the Balkans. Quantitative information on soil loss is needed for erosion risk assessment. The modelling of the erosion process has progressed rapidly, and a variety of models have been developed to predict both runoff and soil loss. The authors of this study used the Erosion Potential Method (Gavrilovic, 1972) for prediction of soil erosion intensity from the catchment area.

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The objective of this research was characterization of the erosion processes in relation to the recent state of the sediment yield in the Rakljanska Rijeka Watershed of the Polimlje River Basin of Montenegro. The results, consistent with previous researches on the neighbouring river basins, presented in formats that may be further used for the efficient management and protection, illustrating the possibility of modelling sediment yield by the EPM method.

MATERIAL AND METHODS

Montenegro is located in South-eastern Europe, between the Adriatic Sea and Serbia (Geographic coordinates: 42 30 N, 19 18 E). The total land boundaries are 680 km of which with Albania 186 km, Bosnia and Herzegovina 242 km, Croatia 19 km, Kosovo 76 km, Serbia 157 km. The total area is 13,812 sq km, of which land is 13,452 sq km and water is 360 sq km. Coastline line is 293.5 km, with narrow coastal plain backed by rugged high limestone mountains and plateaus.

The study was conducted in the Rakljanska Rijeka Watershed, located in the mountainous area of the north-eastern part of Montenegro (Figure 1).

Figure 1. Study area of the Rakljanska Rijeka Watershed, the Polimlje River Basin, Montenegro

The Rakljanska Rijeka Watershed is covering an area of 11.4 km^2. It is one of the medium sized watersheds of the natural entity of the Polimlje region. During the field work, using a morphometric methods, various data on intensity and forms of soil erosion, land use, and the measures taken to reduce or mitigate erosion were recorded.

According to our calculations, the shortest distance between the fountainhead and the mouth, lv, is 5.2 km. The relief has very pronounced dynamics; the average slope gradient in the river basin, Isr, is calculated on 32.5% what indicates that in the river basin prevailing very steep slopes. The average river basin altitude Hsr, is calculated on 857 m; the average elevation difference of the river basin, D, on 320 m.

The analysis of the geological structure and soil characteristics of the area were based on the research of the National Geological Survey led by Zivaljevic (1989) and Djuretic & Fustic (2000), who analysed all geological formations and soils of Montenegro including the Polimlje. Climatological data were received from the Institute of Hydrometeorology and Seismology of Montenegro.

For obtaining data on forecasts of sediment yield and peak discharge from the basin we used the Erosion Potential Method – EPM (Gavrilovic, 1972).

The basic analytical equation for the calculation of erosion-induced soil losses is as follows:

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

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 – retention.

This methodology is currently in use in: Austria, Bosnia & Herzegovina, Brazil, Bulgaria, Croatia, Czech Republic, Iran, Italy, Macedonia, Montenegro, Morocco, Serbia, South Africa and Slovenia (Al-Turki *et al.*, 2015; Barovic *et al.*, 2015; Behzadfar *et al.*, 2015; Behzadfar *et al.*, 2014a; Behzadfar *et al.*, 2014b; Gazdic *et al*, 2015; Ristic *et al*., 2001; Spalevic *et al*., 2015a; Spalevic *et al*., 2015b; Spalevic *et al*., 2015c; Spalevic *et al*., 2015d; Spalevic *et al*., 2015e; Spalevic *et al*., 2015f; Spalevic *et al*., 2015g; 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; Kostadinov *et al*, 2014; Curovic *et al.*, 1999; Vujacic & Spalevic, 2015).

RESULTS AND DISCUSSION

The coastal area of Montenegro is with Mediterranean climate and is characterized with hot dry summers and autumns and relatively cold winters with heavy snowfalls inland (the continental climate). The climate in the studied area located in the North of Montenegro is continental, with the absolute maximum air temperature of 39.2°C and the negative -27.6°C. The average annual air temperature, t0, is 8.9°C. The average annual precipitation, H_{yr}, is 873 mm (Source: Data from the Institute of Hydrometeorology). The temperature coefficient is calculated at 0.99. The torrential rain, hb, is calculated at 84.7 mm.

The study area belongs to the Durmitor geotectonic unit of the inner Dinarides of Northern and North - eastern Montenegro (Frankl *et al*., 2015). The geological structure of that part of Montenegro consists mainly of Paleozoic clastic, carbonate and silicate volcanic rocks and sediments of the Triassic, Jurassic, Cretaceous - Paleogene and Neogene sediments (Zivaljevic, 1989). Our analysis shows that the structure of the river basin, according to bedrock permeability, is the following: f0, poor water permeability rocks, 92%; fpp, medium permeable rocks, 8%. The coefficient of the region's permeability, S1, according to the analysis if geological substrate is calculated on 0.98.

Based on the previous results of pedological research (Fustic and Djuretic, 2000; Spalevic, 2011; Spalevic, 1999), and our own research, the most common soil types in the watershed are: *Dystric Cambisols* (89%), *Fluvisols* and *Colluvial Fluvisols* (8%) and *Eutric Cambisols* (3%).

Soil erosion and runoff characteristics. The dominant erosion form in this area is surface erosion and is the most pronounced on the steep slopes without vegetation cover. Some problems of overgrazing and livestock traces are recorded also. Processing the input data by the EPM method we received the results in relation to the sediment yield of the Rakljanska Rijeka Watershed. The results are presented at the Table 1.

Table 1. Listing of the EPM report for the Rakljanska Rijeka Watershed

River basin area	F	11.4	km²
The length of the watershed	O	14.59	km
Natural length of the main watercourse	Lv	5.21	km
The shortest distance (fountainhead and mouth)	Lm	4.07	km
The main watercourse with tributaries of I and II class	ΣL	5.21	km
River basin length measured by a series of parallel lines	Lb	6.52	km
The area of the bigger river basin part	Fv	5.73	km²
The area of the smaller river basin part	Fm	5.67	km²
Altitude of the first contour line	h0	600	m
The lowest river basin elevation	Hmin	537	m
The highest river basin elevation	Hmax	1212	m
Very permeable products from rocks	fp	0	
Medium permeable rocks	fpp	0.08	
Poor water permeability rocks	fo	0.92	
A part of the river basin under forests	fš	0.51	
A part under grass, meadows, pastures and orchards	ft	0.4	
A part under bare land and ground without grass	fg	0.09	
The volume of the torrent rain	hb	157.6	mm
Average annual air temperature	t0	8.9	°C
Average annual precipitation	Hgod	873.7	mm
Types of soil products and related types	Y	1.1	
Coefficient of the river basin planning	Xa	0.48	
Numeral equivalents of visible erosion process	φ	0.3	
Coefficient of the river basin form	A	0.55	
Coefficient of the watershed development	m	0.44	
Average river basin width	B	1.75	km
(A)symmetry of the river basin	a	0.01	
Density of the river network of the basin	G	0.46	
Coefficient of the river basin tortuousness	K	1.28	
Average river basin altitude	Hsr	857	m
Average elevation difference of the river basin	D	320	m
Average river basin decline	Isr	32.46	%
The height of the local erosion base of the river basin	Hleb	675	m
Coefficient of the erosion energy of the basin's relief	Er	116.9	
Coefficient of the region's permeability	S1	0.98	
Coefficient of the vegetation cover	S2	0.71	
Analytical presentation of the water retention in inflow	W	1.709	m
Energetic potential of water flow during torrent rains	2gDF^½	267.8	m km s
Maximal outflow from the river basin	Qmax	174.6	$m^3 s^{-1}$
Temperature coefficient of the region	T	0.99	
Coefficient of the river basin erosion	Z	0.478	
Production of erosion material in the river basin	Wgod	10276	$m^3 yr^{-1}$
Coefficient of the deposit retention	Ru	0.284	
Real soil losses	Ggod	2923	$m^3 yr^{-1}$
Real soil losses per km^2	Ggod (km²)	256	$m^3 km^{-2} yr^{-1}$

The coefficient of the river basin form, A, is calculated on 0.55. Coefficient of the watershed development, m, is 0.44 and average river basin width, B, is 1.75 km. (A)symmetry of the river basin, a, is calculated on 0.01 and that indicates that the river basin is completely asymmetric, what is decreeing a chances for large flood waves to appear in the studied river basin. The height of the local erosion base of the river basin, Hleb, is 675 m. Coefficient of the erosion energy of the river basin's relief, Er, is calculated on 117. According to the erosion type, the dominant process is surface erosion.

The value of Z coefficient of 0.478 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.

We calculated the soil losses from the Rakljanska Rijeka catchment on 2923 m^3 yr^{-1}, specific: 256 $m^3km^{-2}yr^{-1}$; the peak discharge on 174.6 m^3s^{-1} (for the incidence of 100 years).

CONCLUSIONS

Sediment yield and peak discharge of the Rakljanska Rijeka Watershed of the Polimlje Basin of the Black Sea watershed were calculated using the Erosion Potential Method of Gavrilovic. The most characteristic outputs acknowledged during the field visit, laboratory analysis, studying the available literature, and finally applying the EPM method are the following:

-The structure of the river basin, according to water permeability, is the following: f0, poor water permeability rocks, 92%; fpp, medium permeable rocks, 8%. The coefficient of the region's permeability, S1, according to the analysis of geological substrate is calculated on 0.98.

- The most common soil types in the watershed are: *Dystric Cambisols* (89%), *Fluvisols* and *Colluvial Fluvisols* (8%) and *Eutric Cambisols* (3%).

-The predominant vegetation formation for the river basin is forest (51%); surfaces under grass are covering 40% and the ground without grass vegetation and plough-lands, 9%. The coefficient of the vegetation cover is calculated on 0.71.

-The value of Z coefficient, calculated on 0.478, indicates that the river basin belongs to the 3rd destruction category (of five). The strength of the erosion process is medium, and according to the erosion type, it is surface erosion.

-We calculated the soil losses from the Rakljanska Rijeka catchment on 2923 m^3 yr^{-1}, specific: 256 $m^3km^{-2}yr^{-1}$; the peak discharge on 174.6 m^3s^{-1} (for the incidence of 100 years).

With this research we provided new information about the recent state of the sediment yield of the Rakljanska Rijeka Watershed, of the Polimlje Basin in the North of Montenegro in formats that can simplify the management in the watersheds of the Region, demonstrating the possibility of Soil Loss Estimation using the Erosion Potential Method. For more reliable conclusions measurements are needed for the model verification, including additional analysis in relation to the impact of land use changes on sedimentation and runoff.

REFERENCES

Al-Turki, A.M., Ibrahim, H.M., Spalevic, V. (2015): Impact of land use changes on soil erosion intensity in Wadi Jazan watershed in southwestern Saudi Arabia. Agrosym 2015, Jahorina, Bosnia and Herzegovina; 10/2015

Amiri, F., (2010): Estimate of Erosion and Sedimentation in Semi-arid Basin using Empirical Models of Erosion Potential within a Geographic Information System.Air, Soil and Water Research, 3: 37-44.

Barovic, G., Leandro Naves Silva, M., Veloso Gomes Batista, P., Vujacic, D., Soares Souza, W., Cesar Avanzi, J., Behzadfar M., Spalevic, V. (2015): Estimation of sediment yield using the IntErO model in the S1-5 Watershed of the Shirindareh River Basin, Iran. Agriculture and Forestry 61(3): 233-243

Behzadfar, M., Curovic, M., Simunic, I., Tanaskovik, V., Spalevic, V. (2015): Calculation of soil erosion intensity in the S5-2 Watershed of the Shirindareh River Basin, Iran. International Conference on Soil, Tirana, Albania; 4-7 May, 2015.

Behzadfar, M., Djurovic, N., Simunic, I., Filipovic, M. and Spalevic, V. (2014a): Calculation of soil erosion intensity in the S1-6 Watershed of the Shirindareh River Basin, Iran. International Scientific conference: Challenges in modern agricultural production, December 11, 2014, Skopje, Macedonia.

Behzadfar, M. Tazioli, A., Vukelic-Shutoska, M., Simunic, I., Spalevic, V. (2014b): Calculation of sediment yield in the S1-1 Watershed, Shirindareh Watershed, Iran. Agriculture and Forestry, 60 (4): 207-216.

Curovic, M., Spalevic, V., Dozic, S., Dubak, D. (1999): Proposal of Anti Erosion Regulation of Department 17 of Husbandry Unit Rudo Polje-Kovren. Agriculture and Forestry, 45 (3-4): 5-23.

Frankl, A., Lenaerts, T., Radusinovic, S., Spalevic, V., Nyssen, J. (2015): The regional geomorphology of Montenegro mapped using Land Surface Parameters. Zeitschrift für Geomorphologie, in press.

Gazdic, M., Pejovic, S., Vila, D., Vujacic, D., Barovic, G., Djurovic, N., Tanaskovikj, V., Spalevic, V. (2015): Soil erosion in the Orahovacka Rijeka Watershed, Montenegro. Book of Proceedings. Sixth International Scientific Agricultural Symposium “Agrosym 2015”. p: 1425-1432. DOI: 10.7251/AGSY15051425G

Kostadinov, S., Zlatic, M., Dragicevic, S., Novkovic, I., Kosanin, O., Borisavljevic, A., Lakicevic, M., Mladjan, D., (2014): Anthropogenic influence on erosion intensity changes in the Rasina river watershed - Central Serbia.

Ristic, R., Kostadinov, S., Malosevic, D., Spalevic, V. (2001): Erosion aspect in the assessment of soils of hydrologic classes and determination of CN number of runoff curve. Acta biologica Iugoslavica, A: Zemljište i biljka. 50(3):165-174.

Spalevic, V., Curovic, M., Barovic, G., Florijancic, T., Boskovic, I., Kisic, I. (2015a): Assessment of Sediment Yield in the Tronosa River Basin of Montenegro. The 9th International Symposium on Plant-Soil Interactions at Low pH. October 18-23, 2015, Dubrovnik, Croatia.

Spalevic, V., Curovic, M., Barovic, G., Vujacic, D., Tunguz, V., Djurovic, N. (2015b): Soil erosion in the River Basin of Provala, Montenegro. Agrosym 2015, Jahorina, Bosnia and Herzegovina; 10/2015.

Spalevic, V., Vujacic, D., Barovic, G., Simunic, I., Moteva, M. and Tanaskovik, V. (2015c): Soil erosion evaluation in the Rastocki Potok Watershed of Montenegro using the Erosion Potential Method. 2nd International Symposium for Agriculture and Food - ISAF 2015, Faculty of Agricultural Sciences and Food – Skopje, 7-9 October, 2015, Ohrid, Macedonia.

Spalevic, V., Frankl, A., Nyssen, J. Curovic, M. and Djurovic, N. (2015d): Calculation of soil erosion intensity in the Sutivanska Rijeka Watershed of Montenegro using the IntErO model. 2nd International Symposium for Agriculture and Food - ISAF

2015, Faculty of Agricultural Sciences and Food – Skopje, 7-9 October, 2015, Ohrid, Macedonia.

Spalevic, V., Curovic, M., Barovic, G., Vujacic, D., Djurovic, N. (2015e): Soil erosion in the River Basin of Kisjele Vode, Montenegro. International conference: Land Quality and Landscape Processes, Keszthely, Hungary; 06/2015

Spalevic, V., Barovic, G., Vujacic, D., Bozovic, P., Kalac, I., Nyssen, J. (2015f): Assessment of soil erosion in the Susica River Basin, Berane Valley, Montenegro. International Conference on Soil, Tirana, Albania; 4-7 May, 2015.

Spalevic, V., Barovic, G., Mitrovic, M., Hodzic, R., Mihajlovic, G., Frankl, A. (2015g): Assessment of sediment yield using the Erosion Potential Method (EPM) in the Karlicica Watershed of Montenegro. International Conference on Soil, Tirana, Albania; 4-7 May, 2015.

Spalevic, V., Curovic, M., Andjelkovic, A., Djekovic, V., Ilic, S. (2014a): Calculation of soil erosion intensity in the Nedakusi Watershed of the Polimlje Region, Montenegro. International Scientific conference: Challenges in modern agricultural production, December 11, 2014, Skopje, Macedonia.

Spalevic, V., Tazioli, A. Djekovic, V., Andjelkovic, A., and Djurovic, N. (2014b): Assessment of soil erosion in the Lipnica Watershed, Polimlje, Montenegro. The 5th International Symposium “Agrosym 2014”, Jahorina, 23-26 October 2014, Bosnia and Herzegovina, p 723-729.

Spalevic, V., Hübl, J. Hasenauer, H. and Curovic, M. (2014c): Calculation of soil erosion intensity in the Bosnjak Watershed, Polimlje River Basin, Montenegro. The 5th International Symposium “Agrosym 2014”, Jahorina, 23-26 October 2014, Bosnia and Herzegovina, p 730-738.

Spalevic, V., Curovic, M., Billi, P., Fazzini, M. Frankl, A., and Nyssen, J. (2014d): Soil erosion in the Zim Potok Watershed, Polimlje River Basin, Montenegro. The 5th International Symposium “Agrosym 2014”, Jahorina, 23-26 October 2014, Bosnia and Herzegovina, p 739-747.

Spalevic, V., Djurovic, N., Mijovic, S., Vukelic-Sutoska, M., Curovic, M. (2013a): Soil Erosion Intensity and Runoff on the Djuricka River Basin (North of Montenegro). Malaysian Journal of Soil Science, Vol. 17: p.49-68.

Spalevic, V., Curovic, M. Tanaskovik, V., Oljaca, M., Djurovic, N. (2013b): The impact of land use on soil erosion and run-off in the Krivaja river basin in Montenegro. The First International Symposium on Agricultural Engineering, 4th - 6th October 2013, Belgrade–Zemun, Serbia, VI: 1-14.

Spalevic, V., Nyssen, J., Curovic, M., Lenaerts, T., Kerckhof, A., Annys, K. Van Den Branden, J., Frankl, A. (2013c): The impact of land use on soil erosion in the river basin Boljanska Rijeka in Montenegro. In proceeding of the 4th International Symposium “Agrosym 2013”. p. 54-63.

Spalevic, V., Curovic, M., Uzen, N., Simunic, I., Vukelic-Shutoska, M. (2013d): Calculation of soil erosion intensity and runoff in the river basin of Ljesnica, Northeast of Montenegro. In proceeding of the 24th International Scientific-Expert Conference on Agriculture and Food Industry, Sarajevo, Bosnia and Herzegovina.

Spalevic, V. (2011): Impact of land use on runoff and soil erosion in Polimlje. Doctoral thesis, Faculty of Agriculture of the University of Belgrade, Serbia, p 1-260.

Spalevic, V. (1999): Application of computer-graphic methods in the studies of draining out and intensities of ground erosion in the Berane valley. Master thesis. Faculty of Agriculture of the University of Belgrade, Serbia (in Serbian). pp-131.

Stoffel, M., Corona, C., Ballesteros-Cánovas, J.A., Bodoque, J.M. (2013): Dating and quantification of erosion processes based on exposed roots. Earth-Science Reviews 123: 18-34.

Vujacic, D., Spalevic, V. (2015): Assessment of runoff and soil erosion in the Radulicka Rijeka Watershed, Polimlje, Montenegro. The 6th International Symposium Agrosym 2015, Jahorina, 15-18 October 2015, Bosnia and Herzegovina.