DOI: 10.17707/AgricultForest.61.2.20

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CALCULATION OF RUNOFF AND SEDIMENT YIELD IN THE PISEVSKA RIJEKA WATERSHED, POLIMLJE, MONTENEGRO

SUMMARY

This paper presents the use of the computer-graphics model IntErO, based on the Erosion Potential Method of Gavrilovic, for calculation of runoff and sediment yield in the Pisevska Rijeka Watershed of Montenegro. Specific physical-geographical inputs needed for the calculation of soil erosion intensity we imported in the IntErO model, what allowed the quantification of the effects of soil erosion, sediment yield and runoff on the environment of the studied region. The value of Z coefficient of 0.370 indicates that the river basin belongs to 4th destruction category (of five). The strength of the erosion process is weak, and according to the erosion type, it is intrusive erosion. The calculated peak discharge from the river basin was 253 m^3s^{-1} for the incidence of 100 years. Production of erosion material in the river basin, Wyear, is 11031 m^3 yar^{-1}. The net soil loss for the studied river basin was 4903 m^3 per year, 372 m^3 per kilometer per year respectively. According to our calculations there is a possibility for large flood waves to appear in the studied river basin of Pisevska Rijeka. Having in mind this, but also the previous research experiences gained in the other neighboring watersheds of the North of Montenegro, the IntErO model is recommended for soil erosion modeling in other river basins similar to the studied watershed, because of its simple identification of critical areas affected by soil erosion.

Keywords: Soil erosion, Sediment yield, Runoff, Watershed, Polimlje

INTRODUCTION

Soil erosion is one of the biggest environmental problems and is a critical threat to food security and to the environment (Ebrahimpour *et al.* 2011).

According to Lazarević (1996), Spalevic (2011), water erosion has affected 13,135 km^2 of the total territory of Montenegro (13,812 km^2). Erosion initiated by water is a crucial problem in the landscapes with high slopes due to

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Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

the complex physical and geographical conditions, being a major challenge for mountainous soils of Montenegro (Spalevic, 2011).

Soil erosion can be controlled applying the best management practices of land management, collecting the data from the field, working in the laboratories and in parallel using predictive models for the evaluation of different management scenarios.

Field measurements of erosion and sedimentation using classical techniques are time-consuming and expensive (Bujan *et al.* 2000). Various software have been developed for calculation soil erosion intensity and runoff. The objective of this research was studying of soil erosion processes using a computer-graphic model IntErO (Spalevic, 2011), simulating runoff and sediment yield, providing new information about the erosion processes in formats that can simplify management, illustrating the possibility of modeling with such approach.

MATERIAL AND METHODS

The studied area is mountainous region close to the highest peaks of Montenegro: Komovi (2487 m a.s.l.) and Zla Kolata (2535 m a.s.l.) in the Prokletije Mountains (Frankl *et al.* 2015).

Rivers in this part of north Montenegro drain to the Black Sea. The main watercourse is the Lim River and the studied river basin of Pisevska Rijeka (Figure 1) is a right-hand tributary of the river Lim, which is 5.5 km upstream of the settlement Andrijevica, encompassing an area of 13.2 km^2. The length of the watershed (perimeter), O, is 17.68 km.

Using morphometric methods we determined various physical geographical characteristics, such as the slope, the specific lengths; Google Earth and Google maps was used to further investigate the morphology of the features that were not noted during the fieldwork.

Some pedological profiles were excavated, and soil samples were collected for physical and chemical analysis. The granulometric composition was determined by the pipette method (Karkanis *et al.* 1991). The soil samples were dispersed using sodium pyrophosphate; pH in H_2O and nKCl was determined with a potentiometer; total carbonates by the volumetric Scheibler method (Thun and Herrmann, 1949). The content of the total organic matter by the Kotzman method (Jakovljevic *et al.* 1995); easily accessible phosphorous and potassium by the Al-method (Egner *et al.* 1960), and the adsorptive complex (y1, S, T, V) was determined by the Kappen method (Kappen, 1929).

For calculation of sediment yield and runoff the most widely used model is American USLE (Universal Soil Loss Equation), developed by Wischmeier and Smith and Revised USLE (RUSLE).

In Montenegro, for calculation of sediment yield and runoff the Erosion Potential Method – EPM (Gavrilovic, 1962; 1970; 1972) is in use as the most suitable on catchment level for the watershed management needs and its modifications (Lazarević, 1968; 1985; Pintar *et al.*, 1986), which are similar to

USLE model (Mikoš *et al.*, 2006). In the region of Polimlje of Montenegro was repeatedly used by Spalevic *et al.* (2015a, b, 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2014g; 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2013g; 2012, 2011).

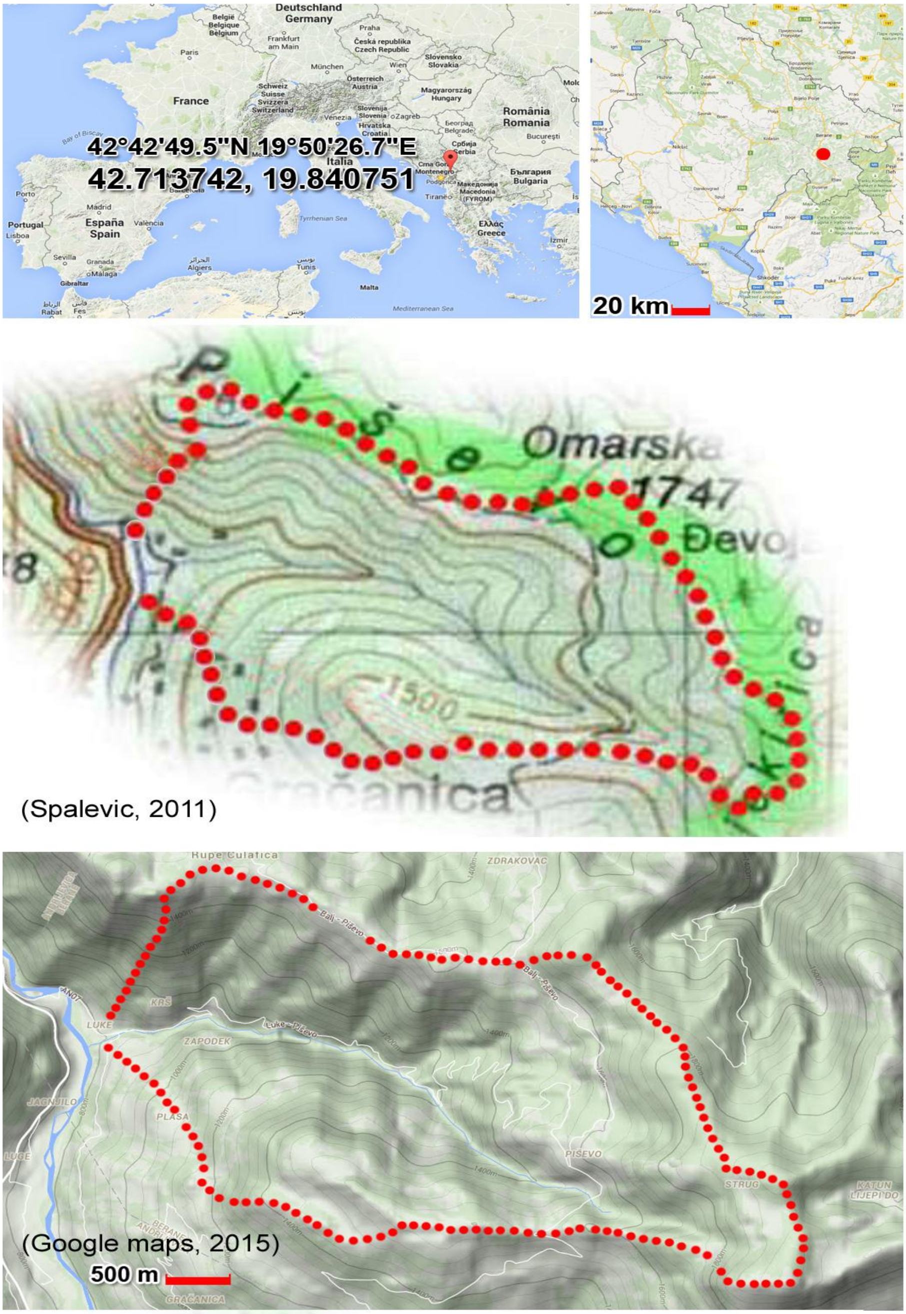

Figure 1: Study area of the Pisevska Rijeka Watershed

The advantage of the EPM compering to the American Erosion Model is that the EPM is not arranged for the calculation of soil erosion on arable lands primarily, but was developed also for the hydro-regulation needs. The equation is based on decades of measurements performed on around hundreds of erosion fields in central Serbia, a region similar to the studied region of Polimlje in Montenegro.

For this specific research of the calculation of runoff and sediment yield we used the IntErO model (Spalevic, 2011), which is based on the EPM method.

RESULTS AND DISCUSSION

Physical-geographical characteristics and erosion factors. According to the available literature sources, one of the first authors who called attention to the geographical individuality of this Region was Cvijic (1921). In the research of Knezevic and Kicovic (2004) natural characteristics of this area was described; Pavicevic (1956, 1957), Pavicevic and Antonovic (1976) and Spalevic (1999, 2011) characterized erosion processes of the upper part of the Polimlje Region.

Figure 2. View from Sjekirica
(Photo: Blagoje Saric)

The river basin of Pisevska Rijeka stretches from its inflow to the river Lim, where Hmin, is 775 m asl. (42.713498, 19.841147) to the tops of the Mt Balj, Omarska (1747 m) Strug, along the north and eastern watershed boundary, with the H max of 1988 m asl (Sjekirica).

The greater portion of the river basin, Fv, is 8.14 km^2; the smaller part, Fm, is 5.04 km^2. Coefficient of the river basin form, A, is 0.80; Coefficient of the watershed development, m, is 0.33; Average river basin width, B, is 1.70 km.

The average slope gradient in the river basin, Isr, is calculated on 46.77% what indicates that in the river basin prevails almost vertical slopes. The average river basin altitude, Hsr, is 1345.74 m; the average elevation difference of the river basin, D, is 570.74 m.

The length of the main watercourse, Lv, is 4.3 km. The shortest distance between the watershed boundary and the mouth, Lm, is 3.9 km. The total length of the main watercourse, with I and II class tributaries, ΣL, is 4.29 km. The density of the river network of the basin, G, is 0.33, what indicates there is low density of the hydrographic network.

Climatic characteristics. The area is characterized by dry summers; rainy autumns and springs; and cold winters. The absolute maximum air temperature is 35^{O}C and negative temperatures can fall to a minimum of -29.8^{O}C. The amount of torrential rain, hb, is 115 mm. The average annual air temperature, t0, is 9 °C. The average annual precipitation, Hyear, is 1183.7 mm.

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

A part of the river basin consisted of a very permeable products from rocks, fp, is 0.17; medium permeable rocks, fpp, is 0.09; poor water permeability rocks, fo, is 0.74. The coefficient of the region's permeability, S1, is calculated on 0.87.

Pavicevic (1956, 1957), Pavicevic and Tancic (1970), Fustic and Djuretic (2000), and Spalevic (2011) studied the soils of the region of Upper Polimlje, where the studied watershed belongs.

According to our analysis and taking into consideration the research of the other colleagues in this region, the most common soil type is Dystric Cambisol (Brown district, acid, soil). In some smaller areas in the river basin there are also soils such as Calcocambisol on limestone, Kalkomelanosols, Fluvisols, Colluvial Fluvisols close to the inflow of Pisevska River to Lim. The structure of the soils is resented on the Figure 3.

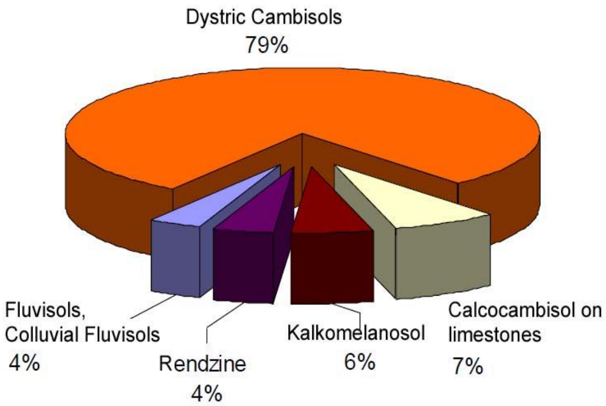

Figure 3. Soils of Pisevska Rijeka Watershed

One of the profiles
Dystric Cambisols

Characteristics of the Watershed in relation to Soil Erosion and Runoff. Soil erosion represents key environmental issues worldwide (Stoffel and Huggel, 2012) and major initiator of land degradation (Verheijen *et al.*, 2009). We used the software IntErO for calculation of the soil erosion intensity and the peak discharge. A detailed report for the Pisevska Rijeka watershed is presented in Table 1.

Table 1. IntErO report for Pisevska Rijeka Watershed

Input data:

River basin area	F	13.18	km²
The length of the watershed	O	17.68	km
Natural length of the main watercourse	Lv	4.29	km
The shortest distance between the fountainhead and mouth	Lm	3.87	km
The length of main watercourse with tributaries of I and II class	ΣL	4.29	km
River basin length measured by a series of parallel lines	Lb	7.74	km
The area of the bigger river basin part	Fv	8.14	km²
The area of the smaller river basin part	Fm	5.04	km²
The lowest river basin elevation	Hmin	775	m
The highest river basin elevation	Hmax	1988	m
A part of the river basin consisted of a very permeable products	fp	0.17	
A part of the river basin area consisted of medium permeable	fpp	0.09	
A part of the river basin consisted of poor water permeability	fo	0.74	
A part of the river basin under forests	fš	0.55	
A part under grass, meadows, pastures and orchards	ft	0.42	
A part under bare land, plough-land, ground without grass	fg	0.03	
The volume of the torrent rain	hb	115	mm
Incidence	Up	100	years
Average annual air temperature	t0	9	°C
Average annual precipitation	Hgod	1183.7	mm
Types of soil products and related types	Y	1.1	
River basin planning, coefficient of the river basin planning	Xa	0.31	
Numeral equivalents of visible erosion process	φ	0.35	

Results:

Coefficient of the river basin form	A	0.8	
Coefficient of the watershed development	m	0.33	
Average river basin width	B	1.7	km
(A)symmetry of the river basin	a	0.47	
Density of the river network of the basin	G	0.33	
Coefficient of the river basin tortuousness	K	1.11	
Average river basin altitude	Hsr	1345.74	m
Average elevation difference of the river basin	D	570.74	m
Average river basin decline	Isr	46.77	%
The height of the local erosion base of the river basin	Hleb	1213	m
Coefficient of the erosion energy of the river basin's relief	Er	202.65	
Coefficient of the region's permeability	S1	0.87	
Coefficient of the vegetation cover	S2	0.69	
Analytical presentation of the water retention in inflow	W	1.3626	m
Energetic potential of water flow during torrent rains	2gDF^½	384.13	m km s
Maximal outflow from the river basin	Qmax	253.96	m³/s
Temperature coefficient of the region	T	1	
Coefficient of the river basin erosion	Z	0.37	
Production of erosion material in the river basin	Wgod	11031.5871	m³/god
Coefficient of the deposit retention	Ru	0.445	
Real soil losses	Ggod	4903.68	m³/god
Real soil losses per km2	Ggod/km²	372.13	m³/km² god

Figure 4. Details from the Canyon of the Pisevska Rijeka, close to the inflow

The study area characterize hilly-mountainous topography with many steep slopes from which the water runs off and flows quickly. That is favorable for triggering the soil erosion process. The dominant erosion form in this area is surface runoff. We recorded and counted the surfaces with rills, gullies and ravines where erosion was the most pronounced on steep slopes with scarce or denuded vegetation cover in the Canyon of Pisevska Rijeka (3%). The areas under the forests, fs, (55%) and under the grass, meadows and pastures, ft, (42%) prevails (Table 1). Well-constituted forests are the most widespread plant form (48%). The proportion is as follows: mountain pastures (27%), meadows (15%), degraded forests (7%), bare-lands (3%). Coefficient of the vegetation cover, S2, is 0.69. River basin planning, coefficient of the river basin planning, Xa, is 0.31.

The height of the local erosion base of the river basin, Hleb, is 1213 m. Coefficient of the erosion energy of the river basin's relief, Er, is 202.65. Analytical presentation of the water retention in inflow, W, is 1.3626 m.

Sediment yields were calculated with the IntErO model on 347,273 m^3 per year for the 57 river basins of Polimlje in Montenegro (Spalevic, 2011), and 4903 m^3 per year for the study on Pisevska Rijeka; the calculations for the Polimlje region corresponded to the results of measurements on the Potpec dam downstream, 350,000 m^3 per year (Begic and Vranic, Potpec). This correspondence suggests that the assessment results of actual losses of soil erosion potential obtained by IntErO model are eligible for the study area.

CONCLUSION

The value of Z coefficient of 0.370 indicates that the river basin belongs to 4^{th} destruction category (of five). The strength of the erosion process is weak, and according to the erosion type, it is intrusive erosion. The calculated peak discharge from the river basin was 253 m^3s^{-1} for the incidence of 100 years. Production of erosion material in the river basin, W year, is 11031 m^3 yar^{-1}. The net soil loss for the studied river basin was 4903 m^3 per year, 372 m^3 per kilometer per year respectively. According to our calculations, there is a possibility for large flood waves to appear in the studied Pisevska Rijeka Watershed.

The calculations for the Polimlje region, where the studied watershed belongs, corresponded to the results of measurements on the Potpec dam downstream. This correspondence suggests that the assessment results of actual losses of soil erosion potential obtained by IntErO model are eligible for the study area and may be a useful tool for researchers in calculation of sediment yield for the other river basins in the regions of South East Europe, similar to the Polimlje basin.

ACKNOWLEDGEMENT

This research was funded by the Ministry of Science of Montenegro: The Study on Erosion processes of the Berane valley (1995-1999) and The Study on Erosion processes of the Polimlje Region 2001-2011.

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