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ASSESSMENT OF SOIL EROSION IN THE LIPNICA WATERSHED, POLIMLJE, MONTENEGRO

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Abstract

Assessment of soil erosion risk is of great importance for management of natural resources, allowing decision makers to modify land use properly implementing environmental strategies more sustainable in the long-term. Inappropriate land use and land management is often viewed as main cause of accelerated erosion rates. Modelling soil erosion rates is key to understand the impact of future land management and climate change on land degradation. Polimlje is one of five river basins in Montenegro that drains toward the Danube and is divided into fifty-seven sub basins. Lipnica watershed is one of them where we studied soil erosion processes using the IntErO model, with the Erosion Potential Method embedded in the algorithm of this computer-graphic method. For the current state of land use, calculated maximal outflow from the river basin is 58 m^3s^{-1} for the incidence of 100 years and the net soil loss is 469 m^3year^{-1}, specific 92 m^3 $year^{-1}$ per square kilometre. With the results obtained we were able to conclude that the river basin belongs in „Destruction Category V”, according to the classification system of Gavrilovic; the erosion process is very weak. This study has shown that the IntErO model and Erosion Potential Method are useful tools for researchers in calculation of sediment yield at the level of the river basins for the South East European region.

Key words: *Erosion, Soil erosion assessment, watershed, Land use, IntErO model.*

Introduction

Soil is one of our most precious natural resources. Proper soil management is a key to sustainable agricultural production. Soil management involves six essential practices: proper amount and type of tillage, maintenance of soil organic matter, maintenance of a proper nutrient supply for plants, avoidance of soil contamination, maintenance of the correct soil acidity, and control of soil loss – erosion (Simmons and Nafziger, 2014).

Watersheds are often affected by natural disasters, above all floods, overflows, inundations, erosion problems, landslides and pollution (Tazioli et al., 2015). The estimation of the erosion in a watershed is therefore essential to encompass a lot of environmental problems and to evaluate the amount of sediment moved, transported and deposited in and out of the basin.

Direct measurements of erosion in a watershed are possible with multi-years measurement of solid transport in the closing-section (Tazioli, 2009). Due to lack of sediment gauging station in some catchments, for anticipating and evaluating of catchment’s erodibility within catchment’s programming and making priority in soil conservation for evaluating erosion and sediment yield, it is necessary to use quantitative and qualitative models. By using models for calculation of erosion intensity we are able to locate erodible areas, but major problem is their

calibration and reliability which should be done with high precision (Zia Abadi and Ahmadi, 2011).
The authors of this study used the computer - graphic IntErO model (Spalevic, 2011) for prediction of soil erosion intensity and maximum outflow from the catchment area. This model is calculating inputs using analytics of the Erosion potential method (EPM), originally developed by Gavrilovic (1972). The method has been tasted earlier in many catchments area in Bosnia & Herzegovina, Bulgaria, Croatia, Czech Republic, Italy, Iran, Montenegro, Macedonia, Serbia and Slovenia (Behzadfar, et al., 2014; Kostadinov et al., 2006; Spalevic et al, 2012b). In Montenegro have been successfully used in the Region of Polimlje (Spalevic et al. 2014a, 2014b, 2014c, 2014d, 2014e, 2014f, 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2012a).
The goal of this research is the characterization of the erosion processes in relation to the recent state of the runoff and sediment yield in the Lipnica Watershed of the Polimlje River Basin.
The results are consistent with previous researches under similar conditions and it appeared that analytical output results are compatible with field observations of Kostadinov (2014), Tazioli (2009), Spalevic (2011), as well as Maleki (2003), Khaleghi (2005), what is leading to the conclusion that the modelling of the sediment yield by the EPM and IntErO model is one of the possible options for studying the river basins similar to the Lipnica watershed of Polimlje, Montenegro.

Material and methods

The study area refers to the Lipnica catchment a left-hand tributary of the river Lim located in Polimlje Region of Montenegro. The total area of the catchment, F, is 5.1 km^2; perimeter, O, is 12.59 km; with a natural length of the main watercourse, Lv, of 4.12 km; as well as a minimum elevation of 560 m and maximum of 1096 m above the sea level. The terrain type of the catchment is predominantly hilly with average slope of 29% indicating that in the river basin steep slopes prevail.
Using the data of the Hydro-meteorological Institute of Montenegro, station Bijelo Polje for the period 1948 – 2014 we concluded that the climate of the area is characterised by dry summers; rainy autumns and springs; and cold winters. The absolute maximum air temperature is 35°C and the low temperatures can fall to a minimum of -29.8°C. The amount of torrential rain, hb, is 84.7 mm. The average annual air temperature, t0, is 8.9 °C. The average annual precipitation, H_{year}, is 893 mm. The temperature coefficient of the region, T, is calculated on 0.99.
We drew on the earlier geological research of the Institute of Geology of Montenegro using the geological data from the Geological map of Montenegro (Zivaljevic, 1989) related to the structure of the river basin, according to bedrock permeability. 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. Our analysis shown that the structure of the river basin, according to bedrock permeability, is the following: f0, poor water permeability rocks, 86%; fpp, medium permeable rocks, 14%; fp. The coefficient of the region's permeability, S1, is calculated on 0.96.
Based on the previous results of soil research (Fustic and Djuretic, 2000; Spalevic, 2011), as well as the original fieldwork and laboratory analysis, we concluded that major soil types in the river basin are Dystric cambisol (91%); Calcomelanosol (8%) and some Fluvisol (1%), close to the confluence of Lipnica into the Lim River.
We used the program Intensity of Erosion and Outflow - IntErO (Spalevic, 2011) for calculation of soil erosion intensity and forecasting of maximum runoff from the river basin, a programme driven by the Erosion Potential Method (Gavrilovic, 1972).

The Erosion Potential Method calculates coefficient of erosion and sediment yield (Z) of a Catchment area by following equation:

$$Z = Y \times Xa \times (\varphi + I)^{1/2}$$

where:
Y is coefficient of rock and soil resistance to erosion ranging from 2 to 0.25;
Xa is a Land use coefficient, ranging from l.0 to 0.05;
φ is the coefficient, observed erosion processes ranges from 1.0 to 0.1, based on the severity of erosion;
I is the average land slope in percent.

Sediment production is estimated as:

$$W = T \times H \times \pi \times Z^{3/2}$$

where:
W is the average annual specific production of sediments per km^2 in $m^3 year^{-1}$;
T is a Temperature coefficient, calculated as:

$$T = (t/10 + 0.1)^{1/2}$$

with t, the mean annual temperature in degrees Celsius (°C).
H is the average yearly precipitation in mm.

Results and discussion

Soil erosion represents key environmental issue worldwide and primary driver of land degradation. Water-induced soil erosion is the result of the complex effect of a whole group of factors. In their research Curovic et al (1999), Djekovic et al. (2013), have shown that erosion intensity is commonly influenced by the land properties and use, increasingly so in the anthropogenius period of their evolution.
Over the last thirty years, anthropogenic factors have significantly increased pressure on agricultural and forest land, degrading the vegetation cover, which eventually results in serious degradation and loss of fertile soil.
We used the software IntErO to process the input data required for calculation of the soil erosion intensity and the maximum outflow. A complete report for the Lipnica river basin is presented in Table 1.

Table 1. Part of the IntErO report for the Lipnica river basin

River basin area	F	5.11	km²
The length of the watershed	O	12.59	km
Natural length of the main watercourse	Lv	4.12	km
Shortest dist. betw. the fountainhead and mouth	Lm	4.03	km
Basin length - by a series of parallel lines	Lb	5.85	km
The area of the bigger river basin part	Fv	3.04	km²
The area of the smaller river basin part	Fm	2.07	km²
The lowest river basin elevation	Hmin	560	m
The highest river basin elevation	Hmax	1096	m
A very permeable products from rocks	fp	0	
Medium permeable rocks	fpp	0.14	
Poor water permeability rocks	fo	0.86	
A part of the river basin under forests	fs	0.54	

grass, meadows, pastures and orchards	ft	0.42	
Bare land and plough-land	fg	0.05	
The volume of the torrent rain	hb	84.7	mm
Incidence	Up	100	years
Average annual air temperature	t0	8.9	°C
Average annual precipitation	Hyear	893.3	mm
Types of soil products and related types	Y	0.7	
Coefficient of the river basin planning	Xa	0.47	
No equival. of clearly exposed erosion process	φ	0.29	
Coefficient of the river basin form	A	0.6	
Coefficient of the watershed development	m	0.51	
Average river basin width	B	0.87	km
(A)symmetry of the river basin	a	0.38	
Density of the river network of the basin	G	0.81	
Coefficient of the river basin tortuousness	K	1.02	
Average river basin altitude	Hsr	765.54	m
Average elevation difference of the river basin	D	205.54	m
Average river basin decline	Isr	29.6	%
Height of the local erosion base of the river basin	Hleb	536	m
Coeff. of the erosion energy of the basin's relief	Er	113.47	
Coefficient of the region's permeability	S1	0.96	
Coefficient of the vegetation cover	S2	0.7	
Water retention	W	1.7216	m
Energ. potent. of waterflow during torrent rains	2gDF^½	143.58	m km s
Temperature coefficient of the region	T	0.99	
Coefficient of the river basin erosion	Z	0.275	
Production of erosion material in the basin	Wyear	2059	m^3year^{-1}
Coefficient of the deposit retention	Ru	0.228	
Real soil losses per year	Gyear	469.15	m^3year^{-1}
Real soil losses per km^2 per year	Gyear/km²	91.78	$m^3km^{-2}year^{-1}$

According to our analysis, the portion of the river basin under forest cover is 54%; grass, meadows, pastures and orchards covering 42%; bare land, ploughed land and ground without grass vegetation are less than 5%. The coefficient of the river basin planning, Xa, is calculated as 0.47. The coefficient of the vegetation cover, S_2, is calculated as 0.7. Structure of the land use in the Lipnica basin is presented in Figure 1.

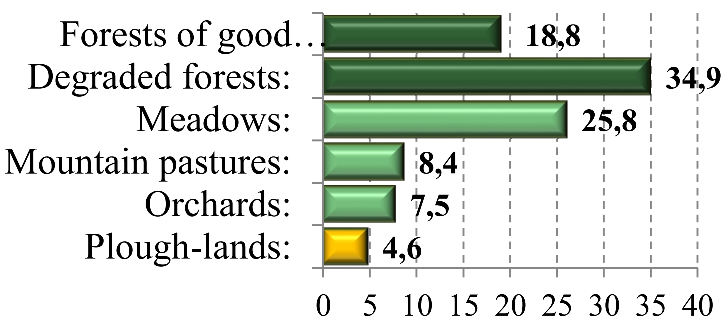

Figure 1. Land use structure of the Lipnica watershed (%)

The dominant erosion form in the studied river basin is sheet erosion with a removal of a relatively uniform thin layer of soil from the land surface by rainfall and largely un-channelled surface runoff (sheet flow).

(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 0.81 indicates that there is medium density of the hydrographic network. The value of Z coefficient of 0.275 indicates that the strength of the erosion process is weak, and according to the erosion type, it is mixed erosion. The production of sediments in the basin, W_{year}, is calculated as 2059 m^3 $year^{-1}$; and the Coefficient of the intra-basin deposition, Ru, at 0. 228. Sediment yield at catchment outlet (G_{year}) was calculated as 469 $m^3 year^{-1}$; and specific sediment yield at 92 $m^3 km^{-2} year^{-1}$, what indicates, according to Gavrilovic, that the river basin belongs to 5th category. It is a region of very weak erosion.

Conclusions

The study was conducted in the area of the Lipnica Watershed, a left-hand tributary of the river Lim in Montenegro. According to our findings, it can be concluded that there is a possibility for large flood waves to appear in the studied river basin. Calculated peak flow is 58 $m^3 s^{-1}$ for a return period of 100 years.

The value of Z coefficient of 0.275 indicates that the strength of the erosion process is weak, and according to the erosion type, it is mixed erosion. Sediment yield at catchment outlet (G_{year}) was calculated as 469 $m^3 year^{-1}$; specific sediment yield at 92 $m^3 km^{-2} year^{-1}$, what indicates, according to Gavrilovic, that the river basin belongs to 5th category, out of five. According to Gavrilovic classification (1972), the river basin is a region of very weak erosion.

Findings of this research lead to the conclusion that the Erosion Potential Method and the IntErO model is an efficient tool for computing erosion potential and sediment yield being useful tools for researchers in calculation of sediment yield at the level of the river basins for the South East European region.

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