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SOIL EROSION IN THE RIVER BASIN OF PROVALA, MONTENEGRO

ABSTRACT

Use of models in the research of soil erosion processes is at the moment a standard practice and models are necessary tool for better understanding of sediment production and runoff, although their interpretation is limited by large uncertainties, including model parameter uncertainties. In this research we studied the main ecological factors and anthropogenic influences in sediment yield on the Provala basin of Montenegro analyzing the relationships between the physical-geographical, geological, soil, land use, climate characteristics and soil erosion intensity. Real soil losses, G_{yr}, were calculated on 7541 m^3yr^{-1}, specific on 597 $m^3km^{-2}yr^{-1}$. The value of Z coefficient was calculated on 0.482 what indicates that the river basin belongs to the 3rd destruction category; erosion process is medium. There is a possibility for large flood waves to appear in the studied basin. The results presented in this paper can provide decision support for watershed managers about where the best conservation measures can be implemented effectively and at low cost in the studied area. The methods we used in this study can also be of interest in sediment modeling for other basins in the Region.

Keywords: Erosion, River Basin, Sediment yield, Runoff, IntErO model.

INTRODUCTION

Land degradation caused by erosion processes, combined with fast population growth, according to Stoffel and Huggel (2012), are ranked as the most important environmental problems in the world. The erosion is heavily affecting sustainable land management in various environments globally, having drastic consequences on soil productivity and fertility (Ballesteros-Cánovas *et al*, 2015; Stoffel *et al*, 2013).

The South and Southeast regions of Europe are significantly prone to water erosion. In Montenegro water erosion is the most important erosion type. The main forces of water erosion are precipitations and consecutive runoff; but not less important is fluvial erosion in water streams (Kostadinov *et al*. 2006).

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Water erosion has affected 95% of the total territory of Montenegro. Alluvial accumulation characterises the remaining area, where the deposition of sediments is also affecting agricultural land. Erosion caused by water is dominant in terrain with high slopes due to complex physical and geographical conditions paired with reckless logging (Spalevic, 2013a).

According to Blinkov (2015) the most erosive countries in Europe are the Balkan countries Albania and Montenegro, where the mean annual intensity of erosion is more than 10 t ha^{-1}. These findings are confirmed by Spalevic *et al* (2012) for the coastal area of Montenegro (1900 $m^3km^{-2}yr^{-1}$ for the Zeljeznica river basin of the Adriatic Watershed). On the other hand, for the Polimlje (North of Montenegro, the Black Sea Watershed), the calculated soil losses per km^2 for the 57 river basins were in average 331 $m^3km^{-2}yr^{-1}$ (Spalevic, 2011; Spalevic *et al*, 2013a). All the facts stated explains why erosion risk assessment and its quantification is an important question for this Region.

This contribution aims at providing a review of the main ecological factors and anthropogenic influences in sediment yield on the Provala basin of the Polimlje of Montenegro, as a case study, analysing the relationships between the physical-geographical, geological, soil, land use, climate characteristics and soil erosion intensity.

MATERIAL AND METHODS

The study was conducted in the Provala drainage basin (12.6 km^2), a right-hand tributary of the river Lim, located in the mountainous area of the north-eastern part of Montenegro (Figure 1).

Figure 1. Study area of the Provala drainage basin

Fieldwork was undertaken to collect detailed information on the intensity and forms of soil erosion, the status of plant cover, the type of land use, and the measures in place to reduce or alleviate the erosion processes. Morphometric methods were used to determine the slope, the specific lengths, the exposition and form of the slopes, the depth of the erosion base; the density of erosion rills.

We drew on the earlier geological (Zivaljevic, 1989) pedological (Djuretic and Fustic, 2000) research, who analysed all geological formations and soils of Montenegro including the studied area of the Provala watershed. Climatological data were received from the Institute of Hydrometeorology and Seismology of Montenegro.

Figure 2. Details from the studied Provala river basin (Mount Balj, the Village Seoce and the view on Andrijevica; photos Velibor Spalevic and Danilo Folic)

The general methodology for modelling soil erosion rates and related sediment yield involved several steps. First, a land use analysis through on-screen visual interpretation. Second, field work using morphometric methods for defining various parameters related to the erosion processes, land use, and the measures taken to reduce or mitigate erosion. Third, laboratory analysis competed. Finally, we applied prediction model to simulate soil erosion and sediment yield in the study area: the IntErO model (Spalevic, 2011).

The analytical equation is based on the following equation:

$$W_{yr} = T \cdot H_{yr} \cdot \pi \cdot \sqrt{Z^3} \cdot F$$

where W_{yr} is the annual erosion in m^3yr^{-1}; T, the temperature coeff.; $H_{yr,}$ the average yearly precipitation in mm; Z, the erosion coefficient.

The erosion coefficient, Z, was calculated as follows:

$$Z = Y \cdot X \cdot (\phi + \sqrt{I})$$

where, Y is Soil erodibility coefficient; X is Soil protection coefficient; ϕ is Erosion development coefficient (tables for Y, X and ϕ coefficients available at Gavrilovic, 1972). F is the watershed area in km^2.

The actual sediment yield was calculated as follows:

$$G_{yr} = W_{yr} \cdot R_u$$

where, G_{yr} is the sediment yield in m^3yr^{-1}; W_{yr} is the total annual erosion in m^3yr^{-1}; R_u is sediment delivery ratio.

The actual sediment yield was calculated as follows:

$$R_u = \frac{\left(\sqrt{O \cdot D}\right)}{0.2 \cdot (L + 10)}$$

where, O is perimeter of the watershed in km; D is the average difference of elevation of the watershed in km; L is length of the catchment in km.

The following required model input parameters were further generated by the IntErO model, receiving sediment yield and runoff predictions: i) Data from the Relief map, Physical-Geographical & Hydrological characteristics of the river basin; ii) Data from the Geological and Soil maps; iii) Land use iv) Meteorological data, including data on rainfall and temperatures.

This methodology is currently in use in: Austria, Bosnia, Brazil, Bulgaria, Croatia, Czech Republic, Iran, Italy, Macedonia, Montenegro, Morocco, Serbia, Saudi Arabia (Al-Turki *et al.*, 2015; Barovic *et al*., 2015; Barovic and Spalevic, 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*., 2014a; Spalevic *et al*., 2014b; Spalevic *et al*., 2014c; Spalevic *et al*., 2014d; Spalevic *et al*., 2013b; Spalevic *et al*., 2013c; Spalevic *et al*., 2013d; Tazioli *et al*., 2015; Tazioli, 2009; Kostadinov *et al*, 2014; Curovic *et al*., 1999; Vujacic & Spalevic, 2015).

RESULTS AND DISCUSSION

Climate. Various authors acknowledged the effects of climate on land degradation outlining the impacts of precipitations and temperature on soil erosion processes. According to Routschek *et al.* (2014), soil erosion is mostly the result of extreme but short rainfall events. Analysis of frequency and intensity of these extreme rainfall events are needed for the calculation of sediment yield, and will be more important in the future due to climate change. The impact of the climate change on frequency and extent of soil erosion processes has been estimated by several scientists (e.g. Klik and Eitzinger, 2010; Zhang *et al*., 2010; Mullan *et al*., 2012; Nunes *et al*., 2013). They emphasized fundamental limitations of several previous studies: the spatial and the temporal scale at which climate changes are represented; changes in land use and management.

The climate in the studied area of the Provala drainage basin is continental (absolute maximum air temperature of 35°C; min. -29.8°C). In order to receive the results on sediment yield and runoff for the studied river basin we analysed torrential rains, annual air temperatures, average annual precipitations.

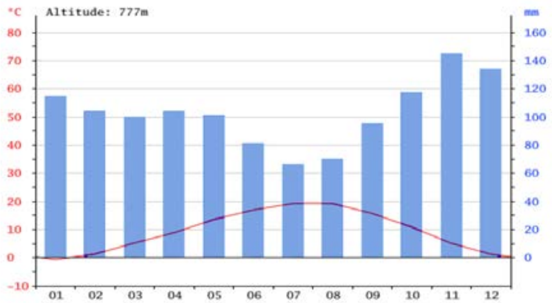

Figure 3. Climate graph

This location is classified as Dfb by Köppen and Geiger.

The amount of torrential rain, hb, is calculated on 115 mm. The average annual air temperature, t0, is 9 °C. The average annual precipitation, Hyr, is 1183 mm. The temperature coefficient of the region, T, is calculated to be 1.00.

Geology and soils. 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 consists mainly of Paleozoic clastic, carbonate and silicate volcanic rocks and sediments of the Triassic, Jurassic, Cretaceous – Paleogene and Neogene sediments. The coefficient of the region's permeability, S1, according to the analysis of geological substrate is calculated on 0.98.

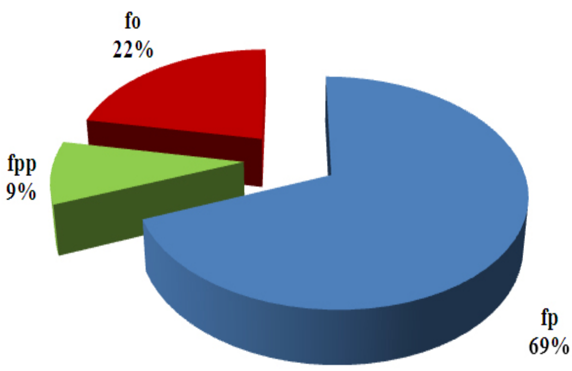

Figure 4: The structure of the river basin, according to bedrock permeability (fp: very permeable; fpp: medium; fo: low permeability).

Sediment yield is also a function of basin soils structure. Based on the results of pedological research (Fustic & Djuretic, 2000; Spalevic, 2011; Spalevic, 1999), and our own research, the most common soil types in the watershed are: *Dystric Cambisols, Kalkomelanosols, Eutric Cambisols, Fluvisols and Colluvial Fluvisols.*

The structure of the river basin, according to the soil types is presented at the figure 5.

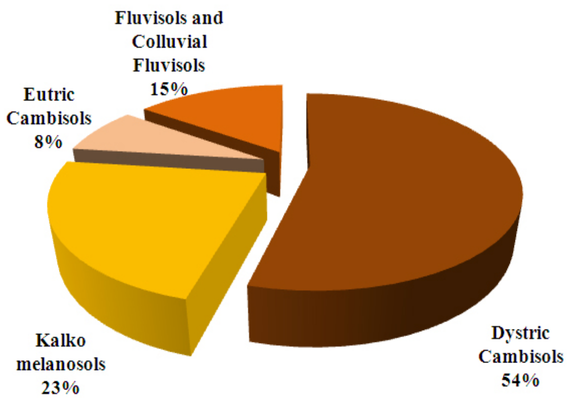

Figure 5: The structure of the river basin, according to the soil types

Land use. Soil erosion assessment is taking into consideration high dependencies and interactions between hydrogeomorphic processes and vegetation. Stoffel and Wilford (2012) highlighted the role of vegetation in the initiation of hydrogeomorphic processes and its impact on stream morphology.

Furthermore, acknowledged climate change forces land-use changes, e.g. alteration of land-use structure, crop variety, and time shift in tillage and harvest. This was the reason of our detailed analysis on land use and vegetation cover. According to the data of land use and vegetation cover, received from the Institute of Forestry of Montenegro (IoFoM), Statistical Office of Montenegro (MONSTAT), Google Maps and our own research, the Provala drainage basin is mainly covered by grass, covering the area of 51% of the studied river basin.

The diverse forms of forests cover about 45% of the watershed, leaving mainly valley plains and the top of the mountains unwooded. Forest vegetation is consisted of broadleaf tree species. On northern exposures are mainly beech forests - *Fagetum montanum,* while the southern exposures characterize forests of sessile oak and Turkish oak - *Quercetum petraea-cerris.* Beech forests are characterized by the high value of the tree layer canopy, 0.7-1.0, which is characteristic for the most of beech forests in northern part of Montenegro (Curovic *et al*., 2011). Most of beech forests of the river basin are low forests with coppice origin. At higher altitudes there are areas with the higher site index and which are covered by high beech forests.

Forest of Sessile and Turkish oak: Quercetum petraeae-cerris are dominated by *Quercus cerris* followed by *Quercus petreae, Carpinus betulus* and other xerophytes tree species. The shrub layer is composed of thermophilous shrubs, mainly Crataegus spp., Cornus mass, Prunus spinosa, Rosa canina, etc. The herb layer is typically dominated by *Poa angustifolia, P. nemoralis, Festuca sp.* etc. These forests are characterized by slightly less value of the tree layer canopy than beech forests.

Arable land covers a total surface area of only 4%, concentrated in the areas with low slope gradients. The detailed structure of the river basin, according to the land use is presented at the Figure 6.

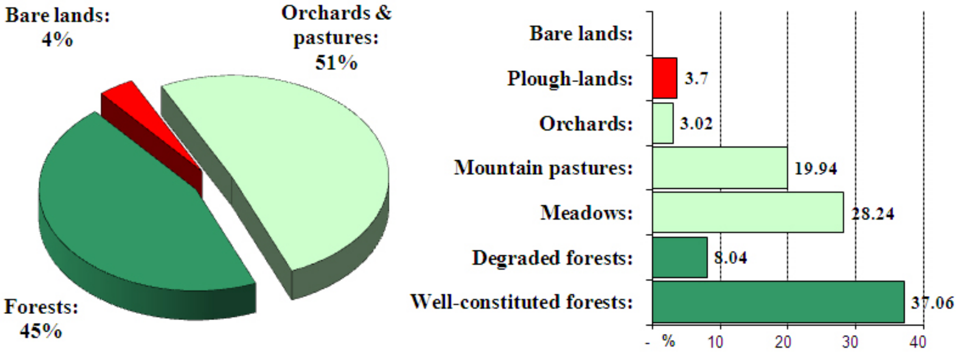

Figure 6: The structure of the river basin, according to the land use

Soil erosion characteristics. 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 small amount of material is washed through the soil, but more important erosion processes take place at the surface. Some problems of overgrazing and livestock traces are recorded also, in the areas close to the village Seoce. Material is detached by raindrop impact and flow traction and transported by overland water flow. Final results of the combinations of these detachment and transport processes are presented in the Table 1.

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

Inputs			
River basin area	F	12.62	km²
The length of the watershed	O	20.73	km
Natural length of the main watercourse	Lv	1.24	km
The shortest distance (fountainhead and mouth)	Lm	1.2	km
River basin length measured by a series of parallel lines	Lb	7.31	km
The area of the bigger river basin part	Fv	7.5	km²
The area of the smaller river basin part	Fm	5.12	km²
Altitude of the first contour line	h0	800	m
The lowest river basin elevation	Hmin	726	m
The highest river basin elevation	Hmax	1601	m
Very permeable products from rocks	fp	0.69	
Medium permeable rocks	fpp	0.09	
Poor water permeability rocks	fo	0.22	
A part of the river basin under forests	fš	0.45	
A part under grass, meadows, pastures and orchards	ft	0.51	
A part under bare land and ground without grass	fg	0.04	
The volume of the torrent rain	hb	115	mm
Average annual air temperature	t0	9	°C
Average annual precipitation	Hyr	1183.7	mm
Types of soil products and related types	Y	1.3	
Coefficient of the river basin planning	Xa	0.35	
Numeral equivalents of visible erosion process	φ	0.38	

Results			
Coefficient of the river basin form	A	3.27	
Coefficient of the watershed development	m	0.1	
Average river basin width	B	1.73	km
(A)symmetry of the river basin	a	0.38	
Density of the river network of the basin	G	0.1	
Coefficient of the river basin tortuousness	K	1.03	
Average river basin altitude	Hsr	1078	m
Average elevation difference of the river basin	D	352.01	m
Average river basin decline	Isr	48.17	%
The height of the local erosion base of the river basin	Hleb	875	m
Coefficient of the erosion energy of the basin's relief	Er	147.78	
Coefficient of the region's permeability	S1	0.56	
Coefficient of the vegetation cover	S2	0.72	
Analytical presentation of the water retention in inflow	W	1.3957	m
Energetic potential of water flow during torrent rains	2gDF^½	295.18	m km s
Temperature coefficient of the region	T	1	
Coefficient of the river basin erosion	Z	0.482	
Production of erosion material in the river basin	Wyr	15684	$m^3 yr^{-1}$
Coefficient of the deposit retention	Ru	0.481	
Real soil losses	Gyr	7541	$m^3 yr^{-1}$
Real soil losses per km^2	Gyr (km^2)	597	$m^3 km^{-2} yr^{-1}$

The coefficient of the river basin form, A, is calculated on 3.27. Coefficient of the watershed development, m, is 0.1 and average river basin width, B, is 1.72 km. (A)symmetry of the river basin, a, is calculated on 0.38 and indicates that there is a possibility for large flood waves to appear in the river basin. The height of the local erosion base of the river basin, Hleb, is 875 m. Coefficient of the erosion energy of the river basin's relief, Er, is calculated on 147. The value of Z coefficient of 0.482 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 Provala catchment on 7541 m^3 yr^{-1}, specific: 597 $m^3 km^{-2} yr^{-1}$.

CONCLUSIONS

The overall aim of this research was to investigate the soil erosion risk within the Provala drainage basin as one of the exemplary drainage basin from the region of Andrijevica valley, close to the Prokletije Massif, by means of modelling techniques implemented in a computer-graphics environment.

With 7541 $m^3 yr^{-1}$ of annual sediment yield, corresponding to an area-specific sediment yield of 597 $m^3 km^{-2} yr^{-1}$, the Provala drainage basin belongs to the Montenegrin basins with the medium sediment discharge. The value of Z coefficient was calculated on 0.482 what indicates that the river basin belongs to the 3rd destruction category (of five); erosion process is medium. There is a possibility for large flood waves to appear in the studied basin.

The application of the IntErO model in the Provala catchment confirms the suitable performance of this approach to predict sediment yield. The authors can state that the application of this model allows a simple risk assessment of soil erosion processes. The results presented in this paper can provide decision support for watershed managers about where the best conservation measures can be implemented effectively and at low cost in the studied area. The methods we used in this study can also be of interest in sediment modeling for other basins in the Region of Southern East Europe.

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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.

Ballesteros-Cánovas JA, Czajka B, Janecka K, Lempa M, Kaczka R.J, Stoffel M. (2015): Flash floods in the Tatra Mountain streams: Frequency and triggers. Science of the Total Environment 511: 639–648.

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

Barovic, G., Spalevic, V. (2015): Calculation of runoff and soil erosion intensity in the Rakljanska Rijeka watershed, Polimlje, Montenegro. Agriculture and Forestry 61(4): 109-115.

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; 5/2015.

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.

Blinkov, I. (2015): The Balkans: The most erosive part of Europe? Glasnik Sumarskog fakulteta. 111: 9-20. DOI: 10.2298/GSF1511009B

Curovic, M., Stesevic, D., Medarevic, M., Cvjeticanin, R., Pantic, D. and Spalevic, V. (2011): Ecological and structural characteristics of monodominant montane beech forests in the National park “Biogradska Gora”, Montenegro. Archives of Biological Sciences 63 (2), 429-440.

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

Klik, A., Eitzinger, J., 2010. Impact of climate change on soil erosion and the efficiency of soil conservation practices in Austria. J. Agric. Sci. 148, 529–541.

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.

Kostadinov S, Zlatic M, Dragovic N, Gavrilovic Z. (2006): Soil Erosion in Serbia and Montenegro, Soil Erosion in Europe, p.p. 271-277; Editors: John Bordman and Jean Poesen; John Wiley &Sons, Ltd; London.

Mullan, D., Favis-Mortlock, D., Fealy, R., 2012. Addressing key limitations associated with modelling soil erosion under the impacts of future climate change. Agric. For. Meteorol. 156, 18–30.

Nunes, J.P., Seixa, J., Keizer, J.J., 2013. Modeling the response of within-storm runoff and erosion dynamics to climate change in two Mediterranean watersheds: a multi-model, multi-scale approach to scenario design and analyses. Catena 102, 27–39.

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.

Routschek, V., Schmidt, J., Enke, W., Deutschlaender, Th. (2014): Future soil erosion risk — Results of GIS-based model simulations for a catchment in Saxony/Germany. Geomorphology 206: 299–306.

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., Vujacic, D., Barovic, G., Simunic, I., Moteva, M. and Tanaskovik, V. (2015b): 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. (2015c): 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. (2015d): 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. (2015e): 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. (2015f): 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, Curovic M, Borota D, Fustic, B. (2012): Soil erosion in the River Basin Zeljeznica, area of Bar, Montenegro. Agriculture and Forestry, 54 (1-4): 5-24.

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, p.1-131.

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.

Stoffel, M., Wilford, D.J. (2012): Hydrogeomorphic processes and vegetation: disturbance, process histories, dependencies and interactions. Earth Surface Processes and Landforms 37: 9-22

Stoffel M, Huggel C. (2012): Effects of climate change on mass movements in mountain environments. Progress in Physical Geography 36, 421 – 439.

Tazioli A., Mattioli A., Nanni T., Vivalda P.M. (2015): Natural hazard analysis in the Aspio equipped basin. Engineering geology for Society and Territory, Vol. 3:431-435. Doi 10.1007/978-3-319-09054-2_89.

Tazioli, A., (2009): Evaluation of erosion in equipped basins: preliminary results of a comparison between the Gavrilovic model and direct measurements of sediment transport. Envir. Geology 56, no. 5: 825-831.

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.

Zhang, Y., Nearing, M.A., Zhang, X.J., Xie, Y., Wei, H., 2010. Projected rainfall erosivity changes under climate change from multimodel and multiscenario projections in Northeast China. J. Hydrol. 384, 97–106.