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CALCULATION OF SOIL EROSION INTENSITY IN THE BOSNJAK WATERSHED, POLIMLJE RIVER BASIN, MONTENEGRO

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Abstract

Soil erosion is considered as one of the main processes of land degradation. These effects are often related to changes in land use e.g. deforestation, etc. Such land use changes are a major global environmental problem involving sedimentation, ecological degradation, and nonpoint source pollution. Understanding the processes of soil erosion, can help in identifying the erosion prone areas and the potential measures to alleviate the environmental effects. Most of the studies focus on small spatial units, while little attention has been given to the amount of sediment yield at the catchment scale. A small spatial unit approach neglects the transfer of sediment through catchments as well as the scale-dependency of erosion processes. Furthermore, approaches focusing on small spatial units do not consider important off-site impacts of soil erosion, such as sediment deposition in reservoirs, flooding as well as ecological impacts. The erosion response of catchments to changes in land use or climate often differ strongly from the responses resulting from changes at the plot scale. This study aims to illustrate the possibility in calculating the sediment yield at the catchment scale using the model IntErO which is based on the Erosion Potential Method of Garilovic. We apply the mode in the study region, the Bosnjak watershed. Our results suggest that the calculated maximal outflow from the river basin was 94 m^3s^{-1} for the incidence of 100 years and the net soil loss was 738 m^3 per year, specific 111 m^3km^{-2} per year, what indicates, according to Gavrilovic classification, that the river basin belongs to the V category; it is a region of very weak erosion. The method we used in this study can also be of interest for sediment modelling in other basins, because of its simple and reliable identification of critical areas of soil erosion in watersheds.

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

Introduction

The occurrence of natural and anthropogenic extreme phenomena all around the world makes us pay more attention to their environmental and economic impacts (Ristic *et al*., 2012; Schmidt *et al*., 2006; Lerner, 2007). Soil erosion is one of them and is a growing problem in South East Europe, especially in the Mediterranean countries. Land degradation caused by soil erosion is especially serious in Montenegro (Spalevic *et al*., 2014c). According to Kostadinov *et al.* (2006), water erosion has affected 95% of the total territory of Montenegro. The off-site impacts of runoff, sedimentation, loss of reservoir capacity, flooding is increasing in this Region.

Quantitative information on soil loss and runoff is needed for erosion risk assessment. This requires collection of field data and observations, various measurements by estimating the sediments accumulated in reservoirs or using suspended sediment yield data of rivers

(Bagarello *et al*., 2011; Della Seta *et al*., 2009; Zeng *et al*., 2009; de Vente *et al*., 2008; van Rompaey *et al*., 2005), laboratory experiments (Leone and Sommer, 2000; Piccolo *et al*., 1997; Torri and Poesen, 1992), as well as processing of those data through the predictive models.

During the past decades, research has primarily focused on the development and application of models able to indirectly predict the magnitude, frequency, scope and temporal spacing of soil erosion (Borrelli *et al*., 2014). Most of these studies are based on the Universal Soil Loss Equation - USLE (Wischmeier and Smith, 1978) and its revised and modified versions (e.g., MUSLE — Williams, 1975; RUSLE — Renard *et al*., 1997; SEDEM/WaTEM — van Rompaey *et al*., 2001). Many researchers reported good performances of these models in predicting soil erosion risk and quantifying of soil erosion rates in different environments (among others, Amore *et al*., 2004; Onori *et al*., 2006; Märker *et al*., 2008). However, despite the comprehensive number of variables considered by these models, their capability to predict the sediment yield on the watershed scale is still problematic (van Rompaey *et al*., 2005).

Blinkov and Kostadinov (2010) evaluated applicability of various erosion risk assessment methods for engineering purposes for the Southern east European region. Factors taken into consideration depended on scale, various erosion tasks as well as various sector needs. The Erosion Potential Method - EPM (Gavrilovic, 1972) was, according to their findings, the most suitable on catchment level for the watershed management needs in this Region.

Position of Blinkov and Kostadinov, but also our prior experience in the Region, leads the authors of this study to analyse the sediment yield for the studied area of Bosnjak River Basin using the Intensity of Erosion and Outflow - IntErO model (Spalevic, 2011), which is based on the Erosion Potential Method. The main outcomes are new specific information about the state of the runoff and sediment yield in formats that may be used in its efficient management and protection, illustrating the possibility of modelling of sediment yield with such approach.

Material and methods

Study area. The north eastern parts of Montenegro are very mountainous, with the presence of deep incised valleys (in Limestone Mountains) but also a rather hilly (Lenaerts, 2014). In this region the Prokletije mountains are the highest massive of the Dinaric Alps, reaching a height of 2694m (Maja e Jezercë) in Albania and containing Zla Kolata, the highest peak of Montenegro at a height of 2534 m, Dobra Kolata (2528 m a.s.l.) and Rosni Vrh (2525 m a.s.l.) although there is some discussion about this subject (Annys *et al*., 2014). Rivers in this region drain to the Black Sea. Some of these rivers form deep canyons in limestone formations, but further downstream they form broader valleys flowing through softer Paleozoic material (Boskovic and Bajkovic, 2002).

The study was conducted in the area of the Bosnjak River Basin, a left-hand tributary of the river Lim. The basin area lies on the steep slopes of Petrovo Brdo (1250m a.s.l.) and Crepuljska Kosa (1100 m a.s.l.) on the south; the Orlujak and Crkvine (1318m a.s.l.) on the north, above the villages of Gornje and Donje Zaostro. There is a small flat area on the lower alluvial terrace in the village of Donje Zaostro, close to the inflow of Bosnjak to the river Lim.

The river basin encompasses an area of 6.6 km^2 and is categorized in the group of the small watersheds of the natural entity of the Polimlje region. The average slope gradient in the river basin, Isr, is calculated on 33%, indicating that in the river basin prevail very steep slopes. The average river basin altitude, Hsr, is calculated on 937.6m; the average elevation difference of the river basin, D, is 282.6m. The natural length of the main watercourse, Lv, is 2.8 km. The shortest distance between the fountainhead and the mouth, Lm, is 2.5 km (source: original).

Fieldwork. During the field work, specific data, needed as inputs for the processing by the EPM methodology, were collected and later used for the calculation of the intensity of soil erosion; e.g. data on the status of plant cover, the type of land use, measures that are done to reduce or mitigate the erosion processes. Morphometric methods were used to determine the slope, lengths, exposure and slope shape, the depth of the erosion base and the density of erosion rills.

Soils. We drew on the earlier pedological research of the Agricultural Institute in Podgorica (Fustic and Djuretic, 2000), who analysed the physical and chemical properties of all Montenegrin soils, including those in the study area of the Bosnjak River Basin. Furthermore, some pedological profiles had been opened recently, and soil samples were taken for physical and chemical analysis.

Vegetation and land use. Estimating soil erosion and sediment yield requires comprehensive recognition of various factors, but identification of the parameters is difficult because of the complexity of soil erosion phenomena (Eisazadeh *et al.* 2012). Vegetation plays and important role in improving the soil quality, reduction of runoff and reduction in loss of soil (Thompson *et al.* 2005), that is, in increasing the infiltration capacity and reduction of soil erodibility (Bochet et al. 1999). It alleviates the destructive force of rain drops and their effect on soil. Plants pose an obstacle to the flow of water down the slope, so more water is absorbed by the soil, and one part of it is used by plants for their own needs. Thus, less water runs off the slope, and in such cases it usually does not cause erosion and it reaches brooks and rivers clear (Saric, T. *et al.* 1999). Analysis of the status of the plant cover, the type of land use in the catchment is part of the set of the required actions in defining the needed parameters for calculation of the parameters.

The land cover data were derived from satellite imagery. We drew on the earlier filed work of the Institute of Forestry of Montenegro in Podgorica (1998) who analysed the status of the plant cover, the type of land use of all the Montenegrin forests including those in the study area. All those data, together with official statistics from the MONSTAT (Statistical office of Montenegro) were further processed according to the EPM methodology and used to characterise the watershed, evaluating the intensity of runoff and soil erosion.

Soil loss model application. We used the Intensity of Erosion and Outflow - IntErO program package (Spalevic, 2011) to obtain data on forecasts of maximum runoff from the basin and soil erosion intensity, with the Erosion potential method (Gavrilovic, 1972) embedded in the algorithm of this computer-graphic method. This methodology is in use in: Bosnia & Herzegovina, Bulgaria, Croatia, Czech Republic, Italy, Iran, Montenegro, Macedonia, Serbia and Slovenia (Spalevic *et al*., 2014c; Kostadinov *et al*., 2014). In Montenegro have been successfully used in the Region of Polimlje (Spalevic *et al*. 2014a, 2014b, 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2012a, 2003).

Results and discussion

Climatic characteristics. The climate in the studied area is continental, i.e. with cold winters and warm, wet summers. The absolute maximum air temperature is 37.8°C; the negative temperatures can fall to a minimum of -28.3°C. The average annual air temperature, t0, is 9°C. The average annual precipitation, H_{year}, is 944mm (Source: Data from the Meteorological stations Berane & Bijelo Polje, Institute of Hydrometeorology of Montenegro). The temperature coefficient of the region, T, is calculated on 1.00; the amount of torrential rain, h_b, on 71.9 mm.

The geological structure and soil characteristics of the area. A geological map of Montenegro, extracted from the Geological Atlas of Serbia (Dimitrijevic, 1992) made known that the major part of Montenegro is covered by Mesozoic sedimentary rocks. Dimitrijevic has divided Montenegro into 5 geotectonic zones. The northernmost zone is the East Bosnian-

Durmitor block, where the studied river basin is located, representing different nappes - thrust sheets. These nappes consist of Late Palaeozoic and Lower Triassic clayey-marly-sandy beds, Middle Triassic eruptive rocks and Middle and Upper Jurassic diabase-chert formation rocks (Radulovic and Radulovic, 1997).

Our analysis, extracting the geological data from the Geological map of Montenegro (Zivaljevic, 1989), shown that the structure of the river basin, according to bedrock permeability, is the following: f_0, poor water permeability rocks, 78%; f_{pp}, medium permeable rocks, 9%; f_p, very permeable products from rocks: 13%. The coefficient of the region's permeability, S_1, is calculated on 0.89 (source: original).

The most common soil type in the studied area are Dystric cambisol (93%); Calcomelanosol (7%); with small area of Fluvisol close to the inflow of Bosnjak to Lim (Fustic and Djuretic, 2000; Spalevic, 2011).

Vegetation and land use. The studied area is located in Dinarid Province of the Middle-Southern-East European mountainous bio-geographical region. Most of the river basin is covered by beech forests (*Fagetum montanum*). *Fagetum montanum* differentiated into several associations of which the most characteristic are *Fagetum montanum typicum, Luzulo - Fagion moes*iacae, and *Fagetum montanum drymetosum*. Beech forests are characterized by dense canopy, especially association *Fagetum montanum typicum* (Curovic *et al*. 2011). Due to intensive harvesting of firewood beech forests near settlements and roads are degraded. On the southern exposures there are forests of Sessile oak and Turkish oak (*Quercetum petraeae-cerridis* Lak.). A narrow belt near the river in the lower part of the river basin is covered with hygrophilic forest (*Alnetea glutinosae, Salicetea herbacea*). At the higher parts of the basin there are mixed of broadleaves and deciduous tree species (*Abieti - Fagetum moesiacae* Blec and Lak.*)*. In last decades climate changes affected on forest ecosystems in changes and slightly movement of the Vegetation vertical layout belts (Curovic and Spalevic, 2010).

According to our analysis, portion of the river basin under forest cover is 60%; grass, meadows, pastures and orchards covering 31%; bare land, ploughed land and ground without grass vegetation 9%. The coefficient of the river basin planning, Xa, is calculated on 0.41. The coefficient of the vegetation cover, S2, is calculated on 0.70. Structure of the land use in the Bosnjak watershed is presented in Figure 3.

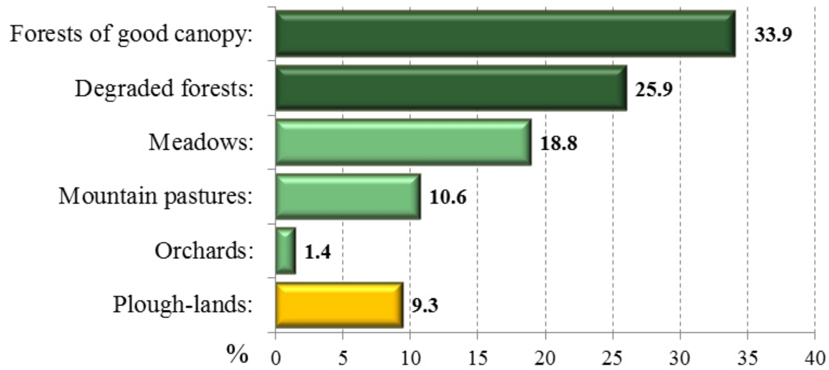

Figure 3. Land use structure of the Bosnjak watershed (%)

Soil erosion and runoff characteristics. Watersheds are in fact often affected by natural disasters, above all floods, overflows, inundations, erosion problems, landslides and pollution (Tazioli *et al.,* 2015). The dominant erosion form in this area is sheet erosion and has taken place in all the soils on the slopes, with the effect that this erosion is the most pronounced on the steep slopes with scarce vegetation cover. We used the software IntErO for calculation of the soil erosion intensity and the maximum outflow. Part of the detailed report for the Bosnjak river presented in the Table 1.

For the current state of land use, calculated peak flow is 94.86 m^3s^{-1} for a return period of 100 years. In addition, using the option of altering the incidence in the IntErO software, we received the information on the calculated peak flow for the return period of 5, 10, 20, 25, 50 and 100 years (m^3s^{-1}), presented in the Figure 4.

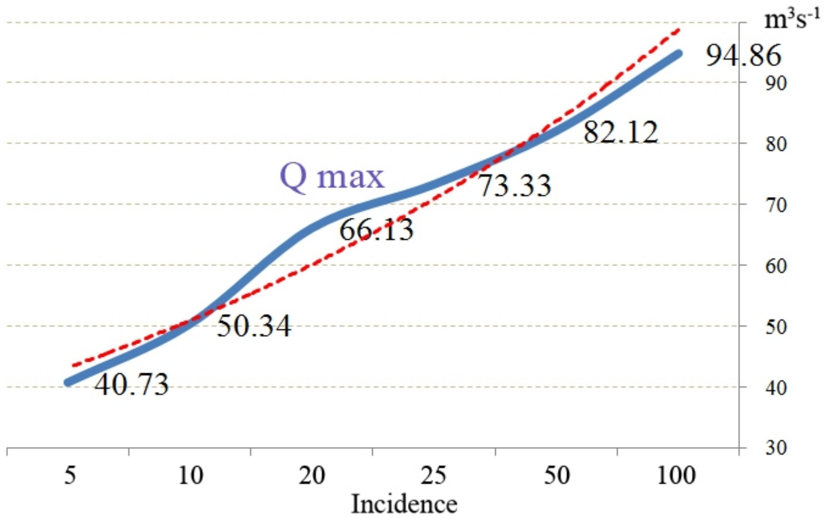

Figure 4. Calculated peak flow for the return period of 5, 10, 20, 25, 50 and 100 years (m^3s^{-1})

Analysis further shown that the coefficient of the river basin form, A, is 0.85. Coefficient of the watershed development, m, is 0.31 and average river basin width, B, is 1.16 km. (A)symmetry of the river basin, a, is calculated on 0.18 and indicates that there is a possibility for large flood waves to appear in the river basin. Drainage density, G, is calculated as 0.43 km km^{-2} which corresponds to low density of the hydrographic network. The height of the local erosion base of the river basin, Hleb, is 663 m. Coefficient of the erosion energy of the river basin's relief, Er, is calculated on 131.67.

The value of Z coefficient of 0.256 indicates that the river basin belongs to the fourth destruction category out of five. The strength of the erosion process is low, and according to the erosion type, it is mixed erosion.

The production of sediments in the basin, W_{year}, is calculated as 2537 m^3 $year^{-1}$; and the Coefficient of the intra-basin deposition, Ru, at 0.291.

Sediment yield at catchment outlet (G_{year}) was calculated as 738 m^3year^{-1}; and specific sediment yield at 111 $m^3km^{-2}year^{-1}$.

Conclusions

Relatively large river basins of the north of Montenegro, such as the Lim, Tara, Piva, Cehotina and Ibar consist of a great number of tributaries. A large variety of different geomorphologic and sedimentary processes are acting in its watersheds. Those complex and huge tributary systems need to be analysed individually because of the different responses to the different climate conditions, geological substrate, pedological composition and land use.

We calculated the soil erosion intensity and runoff in the area of the Bosnjak River Basin, a left-hand tributary of the river Lim in Montenegro, using the IntErO model (Spalevic, 2011). Several important points were suggested by the model results:

- According to our findings, it can be concluded that there is a possibility for large flood waves to appear in the studied Bosnjak river basin.
- The value of Z coefficient of 0.256 indicates that the river basin belongs to the fourth destruction category out of five. The strength of the erosion process is low, and according to the erosion type, it is mixed erosion.

- Calculated peak flow is 94 m^3s^{-1} for a return period of 100 years.
- The calculated net soil loss from the river basin was 738 m³ per year, specific 111 m^3km^{-2} per year, what indicates, according to Gavrilovic classification (1972), that the river basin belongs to the V category; it is a region of very weak erosion.
- The soil loss rates in the catchment (111 $m^3km^{-2}year^{-1}$) and in the wider Polimlje region (350 $m^3km^{-2}year^{-1}$) are very low in comparison to adjacent watersheds of the Coastal zone of Montenegro where the soil loss is around 1900 $m^3km^{-2}year^{-1}$ in some watersheds (Spalevic *et al.*, 2014c; Spalevic *et al.*, 2012b). This shows that vegetation cover and land management in northern Montenegro are effective in protecting the land from erosion as was also observed by Nyssen *et al*. (2014).

This study further confirmed the findings of Kostadinov (2014), Tazioli (2009), as well as Spalevic (2011), what leads to the conclusion that the Gavrilovic method as well as the IntErO model is a useful tool for researchers in calculation of runoff and sediment yield at the level of the river basins of south east Europe, similar to the Polimlje basin of Montenegro.

References

Amore, E., Modica, C., Nearing,M.A., Santoro, V.C., 2004. Scale effect in USLE and WEPP application for soil erosion computation from three Sicilian basins. J. Hydrol. 293, 100–114.

Annys, K., Frankl, A., Spalevic, V., Curovic, M., Borota, D., Nyssen, J., 2014. Geomorphology of the Durmitor Mountains and surrounding plateau Jezerska Povrs (Montenegro). Journal of Maps, 10 (4), pp. 600-611.

Boskovic, M, Bajkovic, I., 2002. Waters of Montenegro. Podgorica: Hydrometeorological Institute of Podgorica.

Bagarello, V., Ferro, V., Giordano, G., Mannocchi, F., Pampalone, V., Todisco, F., Vergni, L., 2011. Effect of plot size on measured soil loss for two Italian experimental sites. Biosyst. Eng. 108, 18–27.

Blinkov, I. and Kostadinov, S., 2010. Applicability of various erosion risk assessment methods for engineering purposes, BALWOIS 2010 Conference - Ohrid, Republic of Macedonia. 25 - 29 May 2010.

Bochet E, Poesen J, Rubio JL (2000): Mound development as an interaction of individual plants with soil, water erosion and sedimentation processes on slopes. Earth Surf Process Landf 25:847–867.

Borrelli, P., Märker, M., Panagos, P., Schütt, B., 2014. Modeling soil erosion and river sediment yield for an intermountain drainage basin of the Central Apennines, Italy. Catena 114, p. 45–58

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., 2010. Climate changes impacts on forests in Montenegro-mitigation and adaptation; International Scientific Conference: Forest ecosystems and climate changes, Proceedings, Volume 1, Institute of Forestry, March 9-10th, Belgrade, Serbia p.283-287.

De Vente, J., Poesen, J., Verstraeten, G., Van Rompaey, A., Govers, G., 2008. Spatially distributed modelling of soil erosion and sediment yield at regional scales in Spain. Glob. Planet. Chang. 60, 393–415.

Della Seta, M., Del Monte, M., Fredi, P., Lupia Palmieri, E., 2009. Space–time variability of denudation rates at the catchment and hillslope scales on the Tyrrhenian Side of Central Italy. Geomorphology 107, 161–177.

Dimitrijevic, M.D., 1992. Coloured map of the Geology of Serbia, with overlay and legend‖. In: Geological Atlas of Serbia, 1: 2,000,000. Belgrado: Grafimex.
Eisazadeh, L., Sokouti R., Homaee, M., Pazira, E. (2012): Comparison of empirical models to estimate soil erosion and sediment yield in micro catchments. Eurasian Journal of Soil Science. Volume : 1, Issue 1, Page : 28 – 33.
Fustic, B. and Djuretic, G., 2000. Soils of Montenegro. Biotechnical institute, University of Montenegro.
Gavrilovic, S., 1972. Engineering of torrential flows and erosion. Publisher: Izgradnja. Beograd.
Institute of Forestry of Montenegro, 1998. Special Forestry Management Plan for the unit "Crni Vrh - Rujiste"; Institute of forestry and wood processing, Podgorica.
Kostadinov S., Zlatić M., Dragićević S., Novković I., Košanin O., Borisavljević A., Lakićević M., Mlađan 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. In Boardman, J., Poesen, J. (eds), Soil Erosion in Europe. John Wiley & Sons, Ltd; London: 271-277.
Lenaerts, T., 2014. Geomorphological mapping of Montenegro: Landform genesis and present processes. Master thesis, University of Gent, Faculty of Geography, p128.
Leone, A.P., Sommer, S., 2000. Multivariate analysis of laboratory spectra for the assessment of soil development and soil degradation in the southern Apennines (Italy). Remote Sens. Environ. 72, 346–359.
Lerner, L. A., 2007. Assessing global exposure to natural hazards: Progress and future trends, Environ. Hazards, 7, 10–19.
Märker, M., Angeli, L., Bottai, L., Costantini, R., Ferrari, R., Innocenti, L., Siciliano, G., 2008. Assessment of land degradation susceptibility by scenario analysis: a case study in Southern Tuscany, Italy. Geomorphology 93, 120–129.
Nyssen, J., Van den Branden, J., Spalevic, V., Frankl, A., Van de Velde, L., Curovic, M. and Billi, P., 2014. Twentieth century land resilience in Montenegro and consequent hydrological response. Land Degradation & Development. 25: 336-349.
Onori, F., De Bonis, P., Grauso, S., 2006. Soil erosion prediction at the basin scale using the revised universal soil loss equation (RUSLE) in a catchment of Sicily (southern Italy). Environ. Geol. 50, 1129–1140.
Piccolo, A., Pietramellara, G., Mbagwu, J.S.C., 1997. Reduction in soil loss from erosionsusceptible soils amended with humic substances from oxidized coal. Soil Technol. 10, 235–245.
Radulovic, V., Radulovic, M. (1997) ―Karst of Montenegro‖. In: Stevanovic, Z. (Ed.) 100 years of hydrology in Yugoslavia. Belgrade: University of Belgrade.
Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., Yoder, D.C., 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Agriculture Handbook N.703.U.S. Department of Agriculture Research Service, Washington.
Ristic, R. Kostadinov, S., Abolmasov, B., Dragicevic, S., Trivan, G., Radic, B., Trifunovic, M., Radosavljevic, Z., 2012. Torrential floods and town and country planning in Serbia. Nat. Hazards Earth Syst. Sci., 12, 23–35.
Saric, T., Beus, V., Gadzo, D., Djikic, M. (1999): Land degradation and soil protection. Sarajevo.
Schmidt, T. P., Greiving, S., Kallio, H., Fleischhauer, M., and Jarva, J., 2006. Economic risk maps of floods and earthquakes for European regions, Quatern. Int.(Elsevier), 150, 103–112.

Spalevic, V., Railic, B., Djekovic, V., Andjelkovic, A., and Curovic, M., 2014. Calculation of the Soil Erosion Intensity and Runoff of the Lapnjak watershed, Polimlje, Montenegro. Agriculture and Forestry, Vol. 60. Issue 2: 261- 271.

Spalevic, V., Radanovic, D., Behzadfar, M, Djekovic, V., Andjelkovic, A., Milosevic, N., 2014. Calculation of the sediment yield of the Trebacka Rijeka, Polimlje, Montenegro. Agriculture and Forestry, Vol. 60. Issue 1: 259-272.

Spalevic, V., Curovic, M., Simunic, I., Behzadfar, M, Tanaskovic, V., 2014. Land degradation, land use and soil erosion: the case of Montenegro. CIHEAM, The Watch Letter: Land Issues in the Mediterranean Countries Vol. 28, Issue 1: 58-62.

Spalevic, V., Djurovic, N., Mijovic, S., Vukelic-Sutoska, M., Curovic, M., 2013. 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., Grbovic, K., Gligorevic, K., Curovic, M., and Billi, P., 2013. Calculation of runoff and soil erosion on the Tifran watershed, Polimlje, North-East of Montenegro. Agriculture and Forestry, Vol. 59, Issue 4: p.5-17.

Spalevic, V., Simunic, I., Vukelic-Sutoska, M., Uzen, N., Curovic, M., 2013. Prediction of the soil erosion intensity from the river basin Navotinski, Polimlje (Northeast Montenegro). Agriculture and Forestry, Vol. 59, Issue 2: p.9-20.

Spalevic, V., Curovic, M. Tanaskovik, V., Oljaca, M., Djurovic, N., 2013. 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., 2013. The impact of land use on soil erosion in the river basin Boljanska rijeka in Montenegro. Proceeding "Agrosym 2013". Key note papers, p. 54-63.

Spalevic, V., Curovic, M., Uzen, N., Simunic, I., Vukelic-Shutoska, M., 2013. 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.

Spalevic, V., Mahoney, W., Djurovic, N., Üzen, N. and Curovic, M. 2012. Calculation of soil erosion intensity and maximum outflow from the Rovacki river basin, Montenegro. Agriculture and Forestry, Vol. 58 (3): 7-21.

Spalevic, V., Čurović, M., Borota, D. and Fuštić, B., 2012. Soil erosion in the river basin Zeljeznica, area of Bar, Montenegro. Agriculture and Forestry, Vol. 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., Seker, G., Fustic, B., Ristic, R., Sekularac, G., 2003. Conditions of erosion of soil in the drainage basin of the Crepulja - Lucka River. Natural and Socioeconomic effects of Erosion Control in Mountainous Regions, pp. 287-292, Banja Vrujci, Srbija.

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.

Thompson DB, Walker LR, Landau FH, Stark LR (2005): The influence of elevation, shrub species, and biological soil crust on fertile islands in the Mojave Desert, USA. J Arid Environ 61:609–629.

Torri, D., Poesen, J., 1992. The effect of soil surface slope on raindrop detachment. Catena 19, 561–578.
Van Rompaey, A., Bazzoffi, P., Jones, R.J.A., Montanarella, L., 2005. Modelling sediment yields in Italian catchments. Geomorphology 65, 157–169.
Van Rompaey, A.J.J., Verstraeten, G., van Oost, K., Govers, G., Poesen, J., 2001. Modelling mean annual sediment yield using a distributed approach. Earth Surf. Process. Landf. 26, 1221–1236.
Williams, J.R., 1975. Sediment-yield prediction with universal equation using runoff energy factor. Present and Prospective Technology for Predicting Sediment Yield and Sources. ARS, S-40. US Gov. Print Office, Washington DC.
Wischmeier,W.H., Smith, D.D., 1978. Predicting rainfall erosion losses. Agriculture Handbook, n. 537. Agriculture Research Service, US Department of Agriculture, Washington.
Zeng, Q., Yue, Z., Yang, Z., Zhang, X., 2009. A case study of long-term field performance of check-dams in mitigation of soil erosion in Jiangjia stream, China. Environ. Geol. 58, 897–911.
Živaljević, M., 1989, Geologic map of SR Montenegro, 1: 200 000; Special Publication of the Geological Bulletin, Volume VIII, Titograd.