Application of the Erosion Potential Method in Vithkuqi Watersheds (Southeastern Albania)

Oltion Marko[1], Joana Gjipalaj[1*], Neritan Shkodrani[2]

[1] Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, Rruga Muhamet Gjollesha Nr. 54, 1023, Tirana, Albania

[2] Department of Civil Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, Rruga Muhamet Gjollesha Nr. 54, 1023, Tirana, Albania

* Corresponding author's e-mail: joana.gjipalaj@fin.edu.al

ABSTRACT

Soil erosion is one of the most important phenomena affecting land composition and settlement. Among all natural causes of soil erosion such as rainfall intensity, temperature and wind, the human activity; massive deforestation and intensive agriculture, including the latest climate changes are considered as very important factors, especially nowadays. Thus, calculating the soil erosion coefficient appears very important in order to prevent the phenomena. Many methods are used to calculate such coefficient but in the presented research, the Erosion Potential Method was chosen. In this study, eight watersheds in southeastern Albania were evaluated. Results show that erosion is present in all considered watersheds. In one case (Panariti watershed) the erosion coefficient was very high; excessive, while in others it varies from heavy to very slight erosion. In conclusion, it can be stated that the Erosion Potential Method can be applied in the Albanian contest, same as in other neighbor countries. The results from Panariti, Roshani and Gianci should be further investigated due to the high quantity of soil eroded.

Keywords: erosion potential method, watershed, Albania, sediment yield, soil erosion.

INTRODUCTION

Quantitative displacement and transportation of different portions of the land resulting in soil degradation are commonly considered as erosion [Joy et al. 2002]. Intensity of soil erosion phenomena is mainly dependent on natural factors and human influence. Progress of such phenomena can be defined as slow, high or even very high in the cases where the factors causing it are very consistent. Landscape properties which support erosion, such as rainfall, wind and temperature changes, can be listed as natural factors. However, nowadays climate changes are thought to be one of the main natural factors affecting soil erosion [Borelli et al. 2020; Nearing et al. 2004].

On the other hand, the intensive agricultural use of the land, large deforestation process, the increasing number of the population and other human activities represent the main factors in land erosion [Cono-Rwanda et al. 2016; Wenger et al. 2018, Zhao et al. 2019]. The volume of material involved during the erosion can be relevant and with great consequences regarding the land degradation process. Since materials can move through long distances, pollution of water bodies in terms of nutrients can occur [Sthiannopkao et al. 2006; Issaka et al. 2017; Camara et al. 2019]. Furthermore, sediment yields may cause major damages, such as influencing the flow rate when they settle at one final point. The complexity of the land degradation causes has made it difficult to predict the exact impacts on soil erosion. Considering all these factors, generation of land erosion and sediment yield maps would be an important step to oppose the process. The methodology for evaluation of sediment yield and erosion has been described by many authors and authorities. The first model used was the universal Soil Loss Equation (USLE) [Wischmeier

et al. 1965]. Following this, several models were developed and are still used nowadays to evaluate soil erosion, such as RUSLE (Revised Universal Soil Loss Equation) [Kenneth et al. 1991], MUSLE (Modified Universal Soil Loss Equation) [Williams 1975], PSIAC (Pacific Southwest Interagency Committee) [Pacific Southwest Inter Agency Committee 1968] and EPM (Erosion Potential Method) [Gavrilovic 1988].

The EPM method was initially proposed by Gavrilovic for former Yugoslavia conditions and then applied in many similar situations [Gavrilovic 1988]. The method aims to estimate the amount of sediment production and transportation by indicating the areas potentially threatened by the erosion phenomena. The methodology proposed by Gavrilovic represents a semi quantitative analysis that can be applied in arid and semi-arid areas to estimate erosion. This approach has been widely used to estimate the erosion in many countries [Haghizadeh et al. 2009; Milanesi et al. 2014; Milanesi et al. 2015], especially in the Balkan region [Blinkov et al. 2010; blinkov et al. 2013; Vujacic et al. 2015; Spalevic et al. 2015; Vujacic et al. 2016]. On the basis of the immediate need to assess erosion in Albania, the use of the Erosion Potential Method (EPM) was proposed in this paper.

In Albania, the erosion phenomena are consistently present, especially in specific regions where natural conditions and are most affected by human activity [Marko et al. 2011]. It is presumed that application of such methodology in specific areas of our country can help in identifying the erosion scale and in preventing the phenomena to prosper. Since in Albania and in the specific area proposed the most significant issue is the erosion caused by the water, this phenomenon will be focused on in this study.

MATERIALS AND METHODS

Model description

The Erosion Potential Method (E.P.M), was designed by Gavrilovic [Gavrilovic 1988] and used for the estimation of sediment production and transportation, as well as the erosion coefficient and its classification. This methodology was firstly applied to the erosion problems in Serbia, then in most of the Balkan countries, and nowadays worldwide, e.g. Italy, Switzerland, Croatia,

Iran, etc. [Haghizadeh et al. 2009; Milanesi et al. 2014; Milanesi et al. 2015; Blinkov et al. 2010; blinkov et al. 2013; Vujacic et al. 2015; Spalevic et al. 2015; Vujacic et al. 2016]. According to the original description of the method, these parameters of the Vithkuqi watershed were calculated: the annual volume of detached soil W_a (Equation 1), the temperature coefficient T (Equation 2), the erosion coefficient Z (Equation 3), the actual sediment yield G_y (Equation 4), and the sediment delivery ratio D_r (Equation 5). Equations and detailed description of the parameters used for the Erosion Potential Method are given below.

The annual volume of detached soil W_a (m³/year) has been determined using the following equation:

$$W = \mu \times S \times T \times h \times \sqrt{Z^3} \qquad (1)$$

where: S – is the watershed area (km²);
T – is the temperature coefficient (-);
h – is the mean monthly precipitation (mm);
Z – is the erosion coefficient (-).

The temperature coefficient T (-) depends on the mean annual temperature t (°C), and has been calculated using the following equation:

$$T = \sqrt{\frac{t}{10} + 0.1} \qquad (2)$$

The erosion coefficient Z (-) has been estimated using the following equation and the detailed information of Table 1.

$$Z = x \times y \times \left(\varphi + \sqrt{i_m}\right) \qquad (3)$$

where: x (-) indicates the protective nature of the land cover and is a function of land use;
y (-) describes soil erodibility and is a function of geological characteristics;
φ (-) shows the observed active erosion processes; i_m (%) is the mean slope of the studied area.

The total volume of sediments produced does not fully reach the outlet. A portion of it is redeposited in streams or other areas of the basin; therefore, it is important to calculate the real sediment production G (m³/year) by the following equation:

$$G = W \times D_r \qquad (4)$$

where: W_a (m³/year) is the annual volume of detached soil, and Dr (-) is the sediment delivery ratio, which represent the quantity of sediments that reach the downstream.

Table 1. Descriptive variables used in the Erosion Potential Model (EPM). Classification based on Zemljic [Zemljic 1971]

Coefficient of land cover	*x*
Mixed and dense forest	0.05–0.20
Thin forest with grove	0.05–0.20
Coniferous forest with little grove, scarce bushes, bushy prairie	0.20–0.40
Damaged forest and bushes, pasture	0.40–0.60
Damaged pasture and cultivated land	0.60–0.80
Areas without vegetal cover	0.80–1.00
Coefficient of soil erodibility	**y**
Hard rock, erosion resistant	0.2–0.6
Rock with moderate erosion resistance	0.6–1.0
Weak rock, schistose, stabilized	1.0–1.3
Sediments, moraines, clay and other rock with little resistance	1.3–1.8
Fine sediments and soils without erosion resistance	1.8–2.0
Coefficient of type and extent of erosion	**φ**
Little erosion on catchment	0.1–0.2
Erosion in water ways on 20 to 50% of the catchment area	0.3–0.5
Erosion in rivers, gullies and alluvial deposits, karstic erosion	0.6–0.7
50 to 80% of catchment affected by surface erosion and land slides	0.8–0.9
Whole catchment affected by erosion	0.9–1.0

The equation for *Dr*, is as follows:

$$D_r = \frac{\sqrt{H \times P}}{0.25 \times (L + 10)} \qquad (5)$$

where: H – is the mean height distance of the basin (or sub unit), (km); P – is the perimeter of the basin (or sub unit), (km); L – is the length of the basin (km)

Study area

The Vithkuqi area is located in the Korca district, at the South-East of Albania (Figure 1a). The study area is one of the most typical areas of Albania in terms of erosion development phenomenon due to its slope, especially in the upper part of the watersheds, and degradation of forest vegetation. The study area with a total surface of 22392 ha or 223.92 km² is divided into eight watersheds: Panariti, Shera, Rungaja, Katundi, Vithkuqi, Lubonja, Gjanci, and Roshanj, as it is shown in (Figure 1b). The data regarding the surface and perimeter of each watershed is given in Table 2.

The application of the Erosion Potential Method in this area were based on the data gathered from different field surveys and satellite sources.

Geological maps of the Albanian Geological Service were used to determine the geological structure and the coefficient of soil erodibility (*y*) of the studied area, as it is shown in Table 2.

The information about land use and cover type of each watershed was obtained using CORINE Land Cover maps. For the evaluation of the land cover coefficient *x* (data on Table 2), the coverage level map was used (Figure 1d).

Another important parameter for the determination of the erosion coefficient is the mean slope of the watershed i_m (data on Table 2), which was derived from the slope maps of each watershed generated by a Digital Elevation Model (DEM).

The mean elevation of the watersheds, varying from 1140 to 1700 m a.s.l., was derived from the elevation map of the studied area, as it is shown in Figure 1f.

The spatial distributions of precipitation and temperature, expressed as monthly rainfall (h, mm) and monthly temperature (t, °C), for the time period 1990–2018, were obtained from the meteorological stations of the area, situated at 1250 m a.s.l. and 1600 m a.s.l., respectively, as it is shown in Table 3.

RESULTS AND DISCUSSION

In the current work, a very large dataset comprising the surface and perimeter, the coefficient of soil erodibility, land cover, mean slope and mean elevation of the watersheds was collected using sources from a variety of academic, governmental and non-governmental institutions.

Detailed information about the above mentioned dataset, used for the application of Erosion Potential Method in Vithkuqi area is given in Table 2.

The study area, almost all of its surface, is crossed by the Osumi River, in the West-East direction. This river comprises the water inflows of all watersheds of the area, which are also its main source suppliers. Some of the suppliers are the Lisec stream, Qafe Kumbulla stream, Shen Thanas stream, etc. The map of the hydrographic network of the studied area is shown in Figure 1b and its density varies from 1.97 km/km² to 5.77 km/km².

The geological structure of Vithkuqi area consists mainly on magmatic rocks of the Jurassic
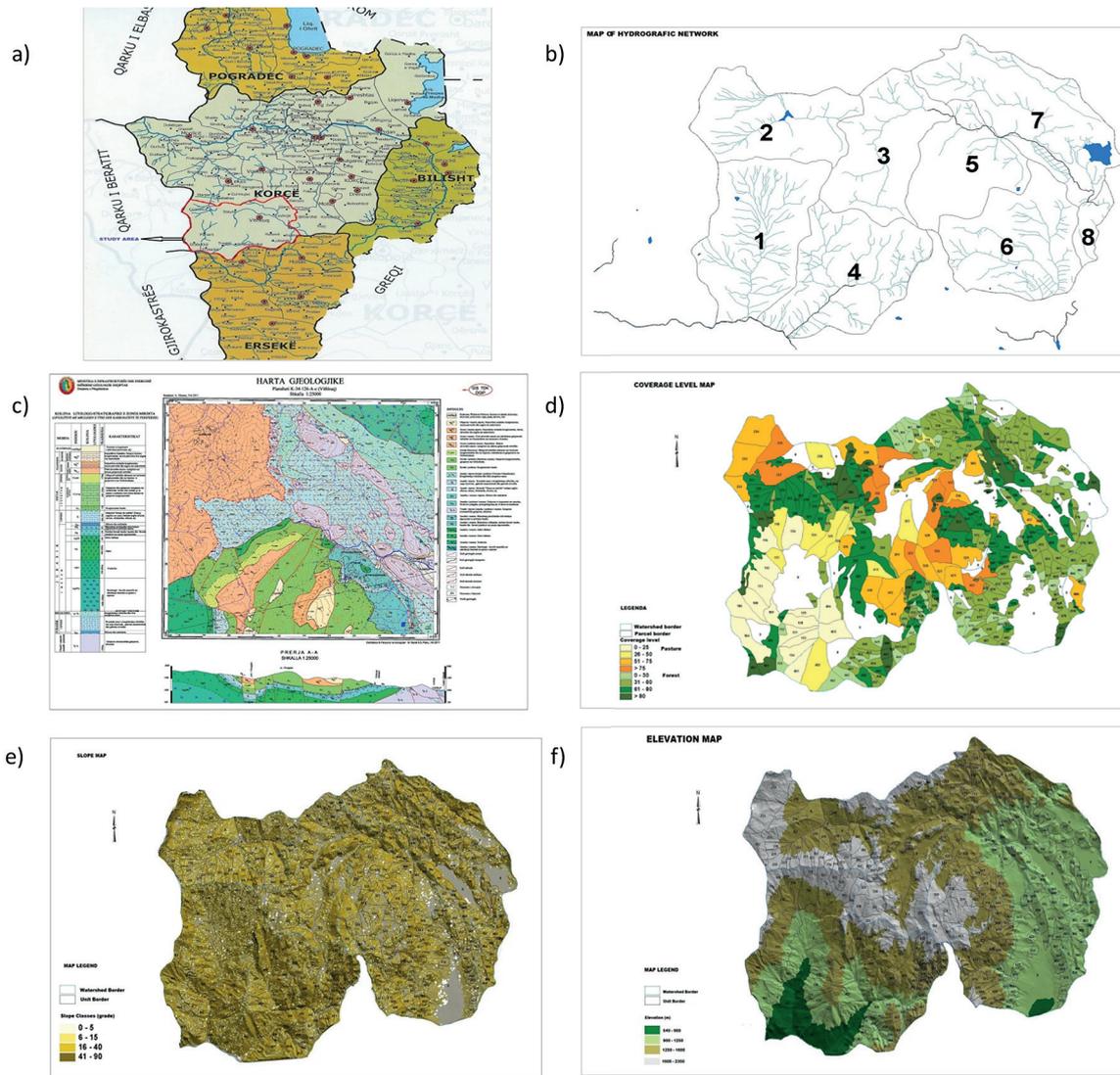
Figure 1. Vithkuqi area, Albania: location (a), hydrographic network (b), geological map (c),
land cover distribution (d), slope mean in percentage (e), and elevation map (f)

Table 2. Values of different parameters needed for the application of EPM in the study area

Name of watershed		Surface S		Perimeter P (km)	Coefficient of soil erodibility (y)	Land cover coefficient (x)	Mean slope i_m (%)	Mean elevation H (m a.s.l)
		ha	km²					
1	Panariti	3 670	36,7	16	1.5	0.8	25	1220
2	Shera	2 756	27,56	13	1.0	0.1	30	1700
3	Rungaja	2 766	27,66	13.5	0.9	0.5	33	1680
4	Katundi	3 426	34,26	15.6	0.9	0.6	28	1210
5	Vithkuqi	2 390	23,90	12.3	0.9	0.5	34	1500
6	Lubonja	3 168	31,68	14.8	0.9	0.6	23	1310
7	Gjançi	3 794	37,94	16.5	1.2	0.6	24	1370
8	Roshanj	422	4,22	3.2	1.3	0.6	27	1140

system, and sedimentary rocks of the Cretaceous, Paleogene and Triassic systems. The most common soil types of the studied area are Humic Cambisols and Humic Nitisols.

On the basis of the information gathered from the maps of the coverage level, forest covers the largest area (42%), followed by the pasture (26%), bare soil (15%), cultivated land (12%),

bare rocks (4%), and urban area covers only 1% of the Vithkuqi area. The data collected in the field showed that the main tree species covering the land are *Pinusnigra, Abies alba, Fagus sylatica, Quercussp* etc.

According to the climatic indicators of the area, the Vithkuqi area is classified in the mountain Mediterranean climate zone, South-East sub-zone, characterized by relatively high temperatures during summer, and quite low during winter (Table 3), as well as low rainfall during the summer period, and higher during the months of November – February (Table 3), in most cases as snowfall. Average annual temperatures and precipitation of the area are respectively: 13.2 °C and 1174.5 mm for the meteorological station at 1250 m a.s.l.; and 11.1 °C and 1443.4 mm for the meteorological station at 1600 m a.s.l.

As mentioned previously, all the parameters of Tables 2 and 3 were used for the application of the Erosion Potential Method (explained in section 2.1), obtaining the results for the erosion coefficient, the amount of eroded sediment, the sediment delivery ratio, and the sediment yield of the watersheds. Table 4 present the results obtained from the calculations performed according the equations 1, 2, 3, 4, and 5 of the Erosion Potential Method. Moreover, the results about the specific eroded sediment per each watershed, calculated as report of eroded material and the surface of the watershed expressed in ha, are shown in Table 4.

The erosion coefficient Z of the studied area varies between 0.11 and 1.56. According to the Gavrilovic classifications [14], the results of Table 4, shows excessive erosion (I erosion category) for Panariti watershed ($Z = 1.56$); heavy erosion (II erosion category) for Roshanji ($Z = 0.95$) and Gjanci ($Z = 0.78$) watershed; medium erosion (III erosion category) for Katundi ($Z = 0.66$), Lubonja ($Z = 0.58$), Rungaja ($Z = 0.57$), and Vithkuqi watershed ($Z = 0.53$); and very slight erosion (V erosion category) for Shera watershed ($Z = 0.11$).

As it is shown in Table 4, the application of EPM estimated a volume of 272513.3 m³/yr of eroded sediment for the Panariti watershed, as the highest value, followed by 100510.1 m³/yr of eroded sediment for the Gjanci watershed, 70478.9 m³/yr of eroded sediment for the Katundi watershed, 53603.9 m³/yr of eroded sediment for the Lubonja watershed, 50783.0 m³/yr of eroded sediment for the Rungaja watershed, 39247 m³/yr of eroded sediment for the Vithkuqi watershed, 14921.9 m³/yr of eroded sediment for the Roshanj watershed, and 4520.1 m³/yr of eroded sediment for the Shera watershed.

On the basis of other studies, the parameter which mostly affects the value of the eroded sediment W, is the coefficient of soil erodibility y, where the Panariti watershed with the largest amount of eroded material has the highest value, equal to 1.5 as can be seen in Table 2. According to the sensitive analyses performed

Table 3. Average monthly and annual temperatures and precipitation of the meteorological stations at 1250 m a.s.l and 1600 m a.s.l.

Parameter	Meteorological station (m a.s.l)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Precipitation (h mm)	1250	119.3	130.7	96.5	94	80.9	56.5	31.9	32.8	61.1	125.5	172	172.2	1174.5
	1600	133.6	145.1	106.7	106.2	140.8	88.5	63.8	48.3	86.1	105.0	203.3	178.1	1443.4
Temperature (t °C)	1250	4.1	4.1	7	11	17.3	20.9	22.9	23	19.8	13.3	9.6	5.3	13.2
	1600	2.0	2.0	4.9	8.9	15.2	18.8	20.8	20.9	17.7	11.2	7.5	3.2	11.1

Table 4. Results of the EPM method for all watersheds of Vithkuqi area

	Watershed name	T (°C)	Z (--)	W (m³/yr)	E (m³/ha/yr)	D_r (--)	G (m³/yr)
1	Panariti	13.2	1.56	272513.3	74.3	0.88	240800.7
2	Shera	11.1	0.11	4520.1	1.6	0.99	4473.5
3	Rungaja	11.1	0.57	50783.0	18.36	0.98	49609.5
4	Katundi	13.2	0.66	70478.9	20.6	0.88	61859.8
5	Vithkuqi	11.1	0.53	39247	16.4	0.93	36647.7
6	Lubonja	13.2	0.58	53603.9	16.96	0.91	49035.6
7	Gjanci	13.2	0.78	100510.1	26.5	0.88	88906.5
8	Roshanj	13.2	0.95	14921.9	35.4	0.65	9661.1

by Dragicevic et al. [2017], another parameter that affects the amount of eroded sediment W, is the land cover coefficient *x* (values in Table 2), where the Panariti watershed has the highest value 0.8 and the Shera watershed the lowest value 0.1, as reflected in the results of the eroded material.

In this study, the specific eroded sediment values *E* were also calculated. The Panariti watershed has the largest amount of eroded sediment per hectare per year, followed by the Roshanji, Gjanci, Katundi, Rungaja, Lubonja, Vithkuqi, and Shera watersheds. It was already mentioned that the results for this parameter (*E*) are calculated as a report of the amount of eroded material and the surface of each watershed. The results for the specific eroded sediment (*E*) are not in the same order as those for the eroded sediment (*W*), due to the fact that even the surface of the watersheds does not follow that order. Considering the results obtained by the calculations of specific eroded sediment (*E*), it is reconfirmed once again that the Panariti watershed is the area with the highest risk of erosion.

Since these watersheds have different sediment delivery ratio values, as it is shown in Table 4, their sediment yield is 240800.7 m³/yr; 88906.5 m³/yr; 61859.8 m³/yr; 49035.6 m³/yr; 49609.5 m³/yr; 36647.7 m³/yr; 9661.1 m³/yr; and 4473.5 m³/yr for the Panariti, Gjanci, Katundi, Lubonja, Rungaja, Vithkuqi, Roshanj and Shera watersheds, respectively. The differences between the volume of eroded material and their sediment yield are shown in Figure 2 for all watersheds of Vithkuqi area.

As it is shown in Figure 2 and in the absolute values of Table 4, there are differences between watersheds in terms of sediment yield and eroded material. The connection that exists between *Dr* and the transported material *G* is clearly noticed, since the watershed which has the largest amount of deposited material is exactly Shera (98.96% of eroded sediment) which has the highest value of sediment delivery ratio *Dr*, followed by Rungaja (97.68%), Vithkuqi (93.37%), Lubonja (91.47%), Gjanci (88.45%), Panariti 88.36%), Katundi (87.77%) and finally Roshanji (64.74%). Dragicevic et al. [25] conducted a sensitivity analysis of the EPM method and classified the sediment delivery ratio *Dr* as a very high sensitive parameter that affects only the sediment yield *G*. It is also worth mentioning the contribution of another parameter affecting the sediment yield of the Shera watershed, which – having the smallest amount of eroded material, has transported almost all of its quantity as it has the lowest land cover coefficient *Xa*. As it can be seen from the data used for the EPM evaluation, the first three watersheds (Shera, Rungaja and Vithkuqi) that have transported almost the entire amount of eroded material, are precisely the ones with the highest altitudes above sea level and with the most pronounced slopes. As mentioned above, the watershed that has transported the smallest amount of eroded material is Roshanji which has the smallest *Dr*, as it has the lowest value of both mean elevation (1140 m a.s.l.) and the perimeter of the watershed, only 3.2 km.
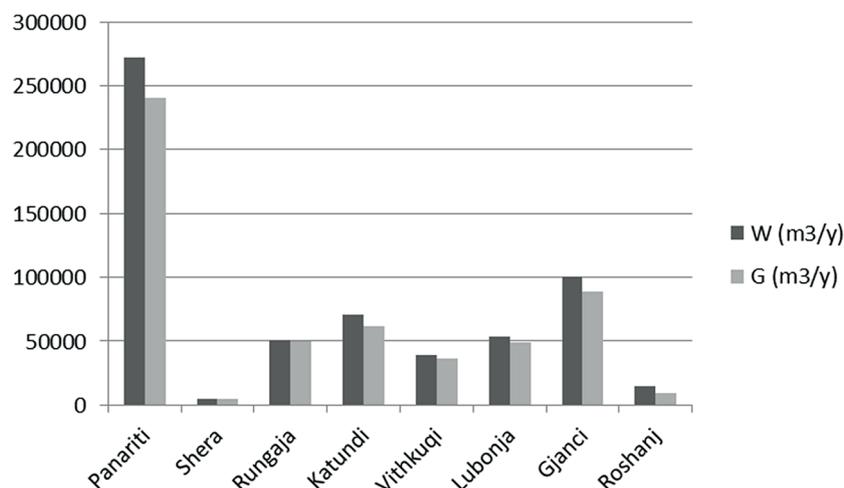

Figure 2. Comparison between the quantity of eroded sediment *W* and the sediment yield *G* for all watersheds of Vithkuqi area

CONCLUSIONS

In this work, the application of the Erosion Potential Method in an Albanian watershed was proposed for the first time. The EPM method provides and estimates the amount of sediment production, specific eroded sediment, the sediment yield, erosion coefficient and the erosion intensity and risk. The EPM method was applied to 8 watersheds of Vithkuqi area, in southeastern Albania. The results for the study area show that the overall sediment production is 606578.2 m^3/yr; the overall specific eroded sediment is 210.12 m^3/ha/yr, and the overall real sediment production 540994.4 m^3/yr. The major contributor in all the three values obtained from the applications of the EPM method is the Panariti watershed. The erosion coefficient Z of the watersheds was calculated and it varies between 0.11 (Shera watershed) and 1.56 (Panariti watershed). According to the Gavrilovic classifications, the study area shows excessive erosion (I erosion category) for the Panariti watershed (Z = 1.56); heavy erosion (II erosion category) for the Roshanji (Z = 0.95) and Gjanci (Z = 0.78) watershed; medium erosion (III erosion category) for the Katundi (Z = 0.66), Lubonja (Z = 0.58), Rungaja (Z = 0.57), and Vithkuqi watershed (Z = 0.53); and very slight erosion (V erosion category) for the Shera watershed (Z = 0.11).

In conclusion, it can be said that the application of the Erosion Potential Method is feasible for the specific study area. Moreover, this method can be applied in other country areas presenting the same situation contest with erosion problems. Results from this paper can be used by the policy makers in order to take measures for the prevention of the erosion in the study area, and not only. However, further studies focusing on other areas of the country with high erosion risk should be performed in order to better determine the efficacy and applicability of the proposed method.

REFERENCES

1. Blinkov I., Kostadinov S., Marinov I. 2013. Comparison of erosion and erosion control works in Macedonia, Serbia and Bulgaria. International Soil and Water Conservation Research.

2. Blinkov I., Kostadinov S. 2010. Applicability of various erosion risk assessment methods for engineering purposes, BALWOIS conference, Ohrid, Macedonia.

3. Borrelli P., Robinson D.A., Panagos P., Lugato E., Yang J.E., Alewell C., Wuepper D., Montanarella L., Ballabio C. 2020. Land use and climate change impacts on global soil erosion by water (2015–2070). PNAS.

4. Camara M., Jamil N.R., Abdullah A.F.B. 2019. Impact of land uses on water quality in Malaysia: a review. Ecol Process.

5. Congo-Rwanda D.R, Karamage F., Shao H., Chen X., Ndayisaba F., Kayiranga L.N.A., Omifolaji J.K., Liu T., Zhang C. 2016. Deforestation Effects on Soil Erosion in the Lake Kivu Basin, Forests.

6. Dragičević N., Karleuša B., Ožanić N. 2017. Erosion Potential Method (Gavrilović Method) Sensitivity Analysis. Soil & Water Res.

7. Gavrilovic Z. 1988. The use of empirical method (erosion potential method) for calculating sediment production and transportation in unstudied or torrential streams (Editor White W.R. In: International Conference on River Regime). John Wiley & Sons, 411–422.

8. Haghizadeh A., Teang L., Godarzi E. 2009. Forecasting Sediment with Erosion Potential Method with Emphasis on Land Use Changes at Basin. The Electronic Journal of Geotechnical Engineering, 14.

9. Issaka S., Ashraf M.A. 2017. Impact of soil erosion and degradation on water quality: a review. Geology, Ecology, and Landscapes.

10. Joy T.J., Foster G.R., Renard K.G. 2002. Soil erosion: Processes, prediction, measurement and control. John Wiley and Sons Inc.

11. Renard K.G., Foster G.R., Weesies G.A. Porter J.P. 1991. RUSLE: Revised universal soil loss equation. Journal of Soil and Water Conservation, 46(1) 30–33.

12. Marko O., Lako A., Çobani E. 2011. Evaluation of soil erosion in the area of Kallmet Lezha District. Geotechnical Special Publication, 1474–1482.

13. Milanesi L., Pilotti M., Clerici A., Gavrilovic Z. 2015. Application of an improved version of the erosion potential method in alpine areas. Italian Journal of Engineering Geology and Environment, 1.

14. Milanesi L., Pilotti M., Clerici A. 2014. The Application of the Erosion Potential Method to Alpine Areas: Methodological Improvements and Test Case. Engineering Geology for Society and Territory. DOI: 10.1007/978-3-319-09054-2_73

15. Nearing M.A., Pruski F.F., O'neal M.R. 2004. Expected climate change impacts on soil erosion rates: A review. Journal of Soil and Water Conservation, 59(1), 43–50.

16. Psiac. 1968. (Pacific Southwest Inter Agency Committee) report of the water management subcommittee.

17. Spalevic V., Barovic G., Mitrovic M., Hodzic R., Mihajlovic G., Frankl A. 2015. Assessment of sediment yield using the Erosion Potential Method (EPM) in the Karlicica watershed of Montenegro.

Conference Paper.

18. Sthiannopkao S., Takizawa S., Wirojanagud W. 2006. Effects of soil erosion on water quality and water uses in the upper Phong watershed. Water Sci Technol.

19. Vujacic D., Barovic G., Tanaskovikj V., Kisic I., Song X., Silva M.L.N., Spalevic V. 2015. Calculation of runoff and sediment yield in the Pisevska Rijeka Watershed, Polimlje, Montenegro. Agric. For., 61, 225–234.

20. Vujacic D., Spalevic V. 2016. Assessment of Runoff and Soil Erosion in the Radulicka Rijeka Watershed, Polimlje, Montenegro. Agric. For., 62, 283–292.

21. Wenger A.S., Atkinson S., Santini T., Falinski K., Hutley N., Albert S., Horning N., Watson J., Mumby P., Jupiter S. 2018. Predicting the impact of logging activities on soil erosion and water quality in steep, forested tropical islands. Environmental Research Letters, 13(4).

22. Williams J.R. 1975. Sediment-yield prediction with Universal Equation using runoff energy factor. In: Present and Prospective Technology for Predicting Sediment Yield and Sources. U.S. Dept. Agrie., 244–252.

23. Wischmeier W.H., Smith D.D. 1965. Prediction Rainfall Erosion Losses from Cropland East of the Rocky Mountains: A Guide for Selection of Practices for Soil and Water Conservation. Agricultural Handbook, 282.

24. Zemljic M. 1971. Calcul du debit solide - Evaluation de la vegetation comme un des facteurs antierosifs. In: International Symposium Interpraevent, Villach, Austria.

25. Zhao L., Hou R. 2019. Human causes of soil loss in rural karst environments: a case study of Guizhou, China. Sci Rep 9, 3225.