

## Soil Erosion Intensity and Runoff on the Djuricka River Basin (North of Montenegro)

Spalevic, V.<sup>1</sup>, N. Djurovic<sup>2</sup>, S. Mijovic<sup>3</sup>, M. Vukelic-Sutoska<sup>4</sup> and M. Curovic<sup>1\*</sup>

<sup>1</sup>University of Montenegro, Biotechnical Faculty, 81000 Podgorica, Montenegro

<sup>2</sup>University of Belgrade, Faculty of Agriculture, 11070 Zemun, Belgrade, Serbia

<sup>3</sup>The State Audit Institution of Montenegro, 81000 Podgorica, Montenegro

<sup>4</sup>Cyril and Methodius University, Faculty of Agriculture Science and Food, Macedonia

### ABSTRACT

Ecological factors, which are the basis for the calculation of soil erosion, are included in the simulation model. Social aspects, such as the attitude of farmers towards practising environmentally sustainable land use techniques, are difficult to analyse because of lack of data and the level of difficulty inherent in connecting natural, economic, and social data together. At the level of the river basin, the use of an IntErO model allowed the quantification of the environmental effects of erosion and the land use planning measures. Maximal outflow (incidence of 100 years) from the river basin  $Q_{\max}$ , is 240 m<sup>3</sup>/s suggests the possibility of a large flood. The strength of the erosion process was medium, and the erosion type was mixed erosion. The predicted soil losses were 645 m<sup>3</sup>/km<sup>2</sup> per year. To support the faster renewal of the vegetation and slow down the erosion processes, biological protection measures need to be applied, together with technical ones, notably by using shoulders and ditches to partition water fluxes at the land surface. These would reduce runoff velocity and further support reforestation and the renewal of grass, shrubs and trees.

**Keywords:** IntErO model, land use, runoff, soil erosion, watershed

### INTRODUCTION

Soil erosion is as one of the biggest environmental problems the world faces. It is a critical threat to food security and to the environment (Ebrahimpour *et al.* 2011). In Europe, soil erosion is caused mainly by water. Rill- and inter-rill erosion affects the largest area, whereas gully erosion and landslides are relatively localised though often visually striking. Soil losses due to water erosion are high in southern Europe (Van Lynden 1995). According to Poesen *et al.* (2003) in this part of Europe, erosion has led to the formation of extensive degraded areas called badlands, in which high rates of soil loss is observed (Mathys *et al.* 2003). According to the expert-based GLASOD map (Oldeman *et al.* 1991), the area of human-induced soil erosion by water in Europe, excluding Russia, is roughly estimated to be 114 million hectares (17% of total land area), of which 80% is topsoil loss and 20% terrain deformation (Gobin *et al.* 2004).

\*Corresponding author : E-mail: velobor.spalevic@gmail.com

According to Spalevic (2011), Kostadinov *et al.* (2006), Kadovic (1999) and Lazarevic (1996), water erosion has affected 13,135 km<sup>2</sup> or 95% of the total territory of Montenegro (13,812 km<sup>2</sup>). Alluvial accumulation characterises the remaining area. Erosion caused by water is dominant in terrain with high slopes due to complex physical and geographical conditions alongside reckless logging (Spalevic *et al.* 2012).

The extent and distribution of erosion depend on the specific pattern of physical and geographical factors. The major drivers of water erosion are intense rainfall, topography, low soil organic matter content, percentage and type of vegetation cover, inappropriate farming practices, and land marginalisation or abandonment (Vukelic-Shutoska *et al.* 2011).

The exploitation of forests for the timber industry and the irrational use of land has caused a change in land use structure, and the quality of vegetation cover in the Djuricka river basin. The soil and geological substrate are more exposed to the impact of various agents, particularly water, wind, temperature, and gravity. Natural resources are consumed faster than they can be regenerated.

A field survey shows that forests are degrading. In many places, numerous ridges, gullies and ravines have appeared; and around the highest mountain peaks, sandbanks are present.

All these facts obtained in the process of the field survey led the authors to analyse the impact of land use on runoff and soil erosion intensity in this area using a computer-graphic method.

## METHODOLOGY

We studied the area of the Djuricka river basin, a right-hand tributary of the river Lim, which lies on the slopes of the massive mountain Prokletije in the South and Mount Kofiljaca on its North-East (*Fig. 1*). The river basin of the Djuricka rijeka encompasses an area of 69.5 km<sup>2</sup>. In terms of geomorphology and climate, it is a part of the natural entity of the Polimlje region (North-East of Montenegro). The natural length of the main watercourse, Lv, is 14.54 km. The shortest distance between the fountainhead and the mouth, Lm, is 12.12 km. The total length of the main watercourse, with tributaries of I and II class, ΣL, is 37.5 km.

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 and the density of erosion rills.

We drew on the earlier pedological work of the Biotechnical Faculty team (Fustic *et al.* 1988), who analysed the physical and chemical properties of all the Montenegrin soils including those in the study area of Djuricka rijeka. Furthermore, some pedological profiles had been reopened in the last five years, and soil samples were taken for physical and chemical analysis. The granulometric composition of the soil was determined by the pipette method (Gee and Bauder 1986; Karkanis *et al.* 1991); the soil samples were air-dried at 105 °C and dispersed using sodium

pyrophosphate. The soil reaction (pH in H<sub>2</sub>O and nKCl) was determined with a potentiometer.

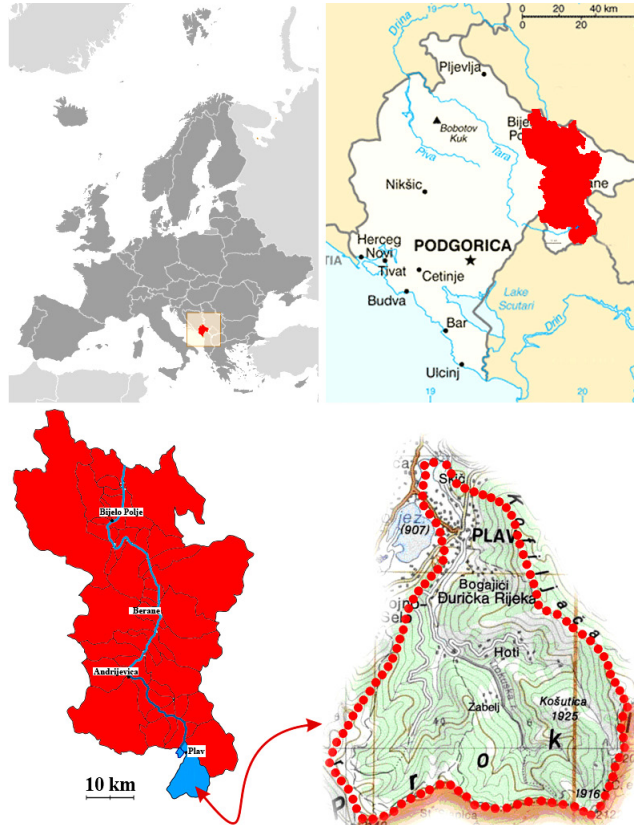


Fig. 1: Study area

*Polimlje:*

- 43.245703 N, 19.580383 E (North);
- 42.508046 N, 19.905853 E (South);
- 43.148092 N, 19.485626 E (West);
- 42.963960 N, 20.120087 E (East).

*Djuricka river basin:*

- 42.370071 N, 19.562838 E (North);
- 42.301407 N, 20.000849 E (South);
- 42.314508 N, 19.570517 E (West);
- 42.323475 N, 19.570517 E (East).

Total carbonates were determined by the volumetric Scheibler method (Thun and Herrmann 1949); the content of the total organic matter was determined by the Kotzman method (Jakovljević *et al.* 1995); easily accessible phosphorous and potassium were determined by the Al-method (Egner *et al.* 1960), and the adsorptive complex (y1, S, T, V) was determined by the Kappen method (Kappen 1929).

Understanding soil erosion processes is essential in appreciating the extent and causes of soil erosion and in planning soil conservation (Hashim *et al.* 1995).

Spatial modelling has emerged as an important tool in soil erosion studies, especially at the watershed scale (Memarian *et al.* 2012). The use of computer-graphics in research on runoff and the intensity of soil erosion have also been demonstrated in Montenegro, specifically in the Region of Polimlje (Spalevic 1999; Spalevic *et al.* 2013; 2012, 2011; 2007; 2004; 2003; 2001; 2000a; 2000b; 1999a). That approach was used in the research on the Djuricka river basin.

There are a number of relevant empirical evaluation methods. These methods involve several steps: data acquisition, model specification and estimation (Gavrilovic 1961; 1964; 1965; 1972; Madureira *et al.* 2011).

Most of those methodologies remain at the qualitative (descriptive) level, relying on empirical evidence and expert subjective evaluation of the conditions. In the South-Eastern European Region, two methodologies have achieved the required level of standardisation of research procedures to minimise subjective errors of the researchers which allows obtaining uniform results and in tracking the state of changes in erosion intensity over a period of time.

The first method is the 'Universal Soil Loss Equation–USLE', of the U.S. Soil Conservation Services. This method determines the intensity of erosion on agricultural land, but is also successful in very small catchments which are located on the surfaces with moderate slopes and on the nearly flat terrains.

Another method is the 'Erosion Potential Method–EPM' and is in use in watershed management. It was created, developed, and calibrated in Yugoslavia (Gavrilovic 1972).

Both of these methods are standard for use in agriculture and water management, according to its primary purpose, but it should be noted that the USLE method is not that accurate for surfaces with a slope of less than 7° as it is developed for determining erosion processes for agricultural production. The EPM covers a wide range of soil erosion intensities. Common to both methods is that they each have clearly defined procedures. Subjective evaluations are reduced to a minimum. Any trained expert will obtain matching data for the same area of the research. According to previous experience, and verifications (Spalevic 2011), the most reliable method for determining the sediment yields and the intensity of the erosion processes for the studied area is the EPM.

Blinkov and Kostadinov (2010) evaluated applicability of various erosion risk assessment methods for engineering purposes. Factors taken into consideration depended on scale, various erosion tasks as well as various sector needs. The EPM was, according to them, the most suitable on catchment level for the watershed management needs in this Region.

The use of computer-graphics in research on runoff and the intensity of soil erosion have been demonstrated in Montenegro, specifically in the Region of Polimlje (Spalevic *et al.* 2013, 2013a, 2013b, 2013c, 2013d, 2012, 2008, 2007, 2004, 2003, 2001, 2000, 2000a, 1999, 1999a), Fustic and Spalevic (2000). We used the Intensity of Erosion and Outflow (IntErO) programme package (Spalevic 2011) to obtain data on forecasts of maximum runoff from the basin and soil erosion intensity. IntErO - an integrated, second-generation version of the Surface

and Distance Measuring (Spalevic 1999) and River basins programmes (Spalevic 2000a) - is characterized by simplicity of use in calculating a large number of input data. EPM is embedded in the algorithm of this computer-graphic method.

## RESULTS AND DISCUSSION

### *Physical-Geographical Characteristics and Erosion Factors*

Many authors have studied the physical-geographical characteristics of this area. Cvijic (1921) called attention to the geographical individuality of the region, with special emphasis on the Prokletije mountain group where the Djuricka river basin is located.

Knezevic and Kicovic (2004) and Kicovic and Dragovic (2000) described the natural characteristics of Mount Prokletije in the Polimlje Region. Additional research elaborated on issues dealing with the influence of anthropogenic factors and the processes of soil erosion in the area.

The Djuricka river basin stretches from its inflow to Lim ( $H_{\min}$ , is 907 m) to the tops of the massive mountain of Prokletije in the South (*Fig. 2*), where the  $H_{\max}$  is 2149 m on Mala Scapica (Scapica Minor) (*Fig. 3*). The basin is hilly and mountainous.



*Fig. 2: Prokletije*

There are mild slopes around the village Bogajici and steep slopes surrounding the massive mountains. The average river basin decline,  $I_{sr}$ , is 39.26%; the average river basin altitude,  $H_{sr}$ , is 1476.40 m; the average elevation difference of the river basin,  $D$ , is 569.40 m.

There are not many places in the Polimlje region that are as steep as the area stretching from above the town Plav to the tops of Mt. Prokletije. The relief has very pronounced dynamics at the water-source zones of the Trokuska River and the tributaries.



*Fig. 3: Malo Selo (the Small village) in the river basin Djuricka rijeka*

#### *Climatic Characteristics*

The climate and human pressure on the land in the Djuricka river basin is very variable. The climate is determined by the proximity of one large water area (the Lake of Plav) and the Prokletije Mountain. It is characterised by short, fresh, dry summers; rainy autumns and springs, and cold winters. The absolute maximum air temperature is 35 °C. Winters are severe, so much so that negative temperatures can fall to a minimum of -29.8 °C.

In terms of rainfall, there are two characteristically rainy periods of the year: the first-cold period (October-March) and the second-warm period (April-September).

Basic data on the area needed for the calculation of soil erosion, intensity, and runoff are presented in Tables 1 - 6. The amount of torrential rain,  $h_b$ , is 89.4 mm. The average annual air temperature,  $t_o$ , is 8.1°C. The average annual precipitation,  $H_{year}$ , is 1345.4 mm.

#### *The Geological Structure of the Area*

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

The coefficient of the region's permeability,  $S_1$ , is 0.96. The structure of the Djuricka river basin, according to the permeable products from rocks is presented in *Fig. 4*.

TABLE 1  
Monthly precipitation sums in litres m<sup>2</sup> – Gusinje, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	304	270	235	259	231	162	165	165	329	553	393	398
Av	138	119	105	128	89	74	59	67	91	139	175	164
St.d.	104	80	55	57	47	37	39	43	68	117	92	112

Year = 1345.4

TABLE 2  
Monthly precipitation sums in litres m<sup>2</sup>- Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	404	246	167	240	240	246	190	147	214	405	435	311
Av	124	101	89	106	82	69	54	62	85	119	156	135
St.d.	101	68	46	55	46	52	40	36	56	94	97	82

Year = 1182.3

TABLE 3  
Daily maximum in litres m<sup>2</sup> - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	89	89	77	59	51	49	46	41	41	70	72	66
Av	28	31	30	32	25	19	17	18	25	30	36	34
St.d.	26	21	17	13	15	13	11	10	11	18	22	20

TABLE 4  
Monthly average air temperature in °C - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	1.9	2.9	5.8	9.8	14	16	20	20	16	11	6.3	3.4
Min	-5.2	-4.9	-1.9	6.1	10	13	16	16	10	7.5	-1.3	-3.2
Av	-1.4	-0.4	3.2	7.6	12	15	17	17	13	9.3	3.2	0.0
St.d.	2.2	2.2	2.3	1.1	1.1	1.0	1.2	1.3	1.5	1.2	2.2	2.0

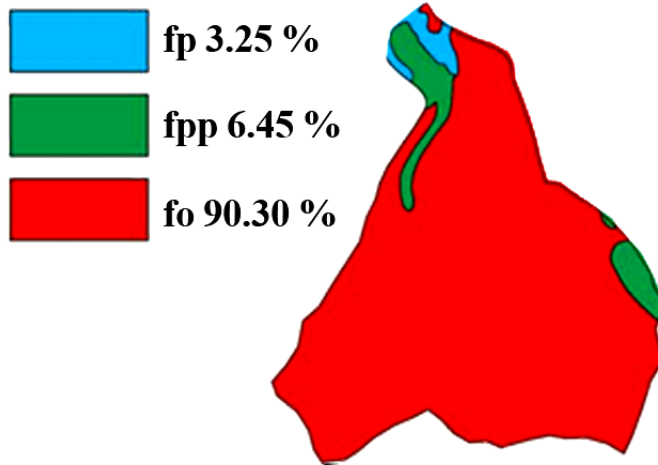
Annual average air temperature = 8.1

TABLE 5  
Absolute maximum of air temperature in °C - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	14	18	24	24	28	33	35	35	32	27	22	19
Av	12	12	18	21	26	29	32	31	28	24	18	13
St.d.	2.1	2.8	3.4	2.4	2.3	2.7	2.0	1.9	2.7	1.8	3.2	2.4

TABLE 6  
Absolute minimum of air temperature in °C - Plav, Montenegro

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	-30	-22	-18	-11	-1.6	0.0	0.0	1.0	-1.1	-6.4	-17.0	-21
Av	-16	-14	-9.2	-3.1	0.5	2.3	4.0	3.7	2.3	-3.1	-9.5	-14
St.d.	5.2	3.8	4.8	2.9	1.4	1.6	2.0	1.7	2.1	2.0	3.5	4.6

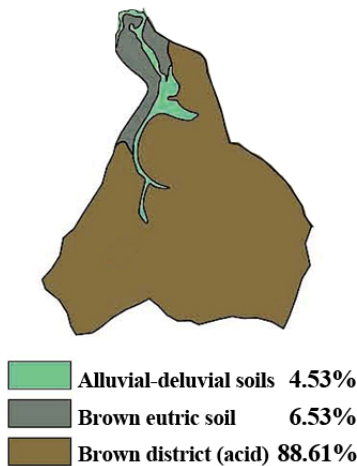


*A part of the river basin consisted of a very permeable rocks* fp  
*A part of the river basin area consisted of medium permeable rocks* fpp  
*A part of the river basin consisted of poor water permeability rocks* fo

*Fig. 4: Structure of the Djuricka river basin according to the permeable products from rocks*

*Soil Characteristics of the Area*

Several researchers (Pavicevic 1956, 1957; Pavicevic and Tancic 1970) studied the soils of the high mountains in Upper Polimlje, including the Djuricka river basin. Going from the inflow of the Djuricka River past Lim to the surrounding mountainous terrain, the most common soil types were alluvial-deluvial soils, brown eutric soils, and brown district (acid) soils. The structure of the Djuricka river basin, according to the soil types is presented in Fig. 5.



*Fig. 5: Map of soil types in the Djuricka river basin*



*Fig. 6: An example of the soil profile found (Brown district soils)*

### *Vegetation*

Large soil losses on sloping land can be attributed to high runoff rates which are generated on surfaces with no or little contact cover. Disturbance to the soil surface resulting in large supplies of easily entrainable material enhances the capacity of overland flow to cause erosion (Hashim *et al.* 1997).

For the purposes of calculating the maximum outflow from the Djuricka river basin ( $Q_{\max}$ ), we analysed the vegetative cover (ratio S2: part of the basin covered by forest, the grasses, orchards, as well as the barren land).

The composition of the geological substrate and the soil formed on this substrate are, for the most part, resistant to erosion where the area is well protected by adequate vegetation cover. However, in places where the terrain is free from vegetation, runoff is intensive. This terrain is characterised by rill erosion, gully erosion and other forms of deep erosion. The arrival of torrents erodes the substrate, causing soil slides, and in some situations, the substrate itself. Deep erosion occurs on the slopes of Prokletije and Kofiljaca, including the intersection of gullies and ravines.

The studied area is located in Dinaridi Province of the Middle-Southern-East European mountainous biogeographical region. The dominant type of vegetation is forests, accounting for more than half of the total vegetation cover.

Plant communities of the area are in the following classes of vegetation:

- a) *Quercio-fagetea* Br.-Bl. Et Vlieger 37.
- b) *Quercetea robori-petreae* br.-Bl. Et Tx. 43.
- c) *Erico-pinetea* Horvat 59.
- d) *Vaccinio-picetea* Br.-Bl. 39.
- e) *Betulo-adenostiletea* Br.-Bl. 48.
- f) *Epilobietea angustifolii* Tx. Et Prsc. 50.
- g) *Salicetalia purpureae* Moor 58.
- h) *Alnetea glutinosae* Br.-Bl. et Tx. 43.
- i) *Arhenanteretea* Br.-Bl. 47.
- j) *Festuco brometea* Br.-Bl. et Tx. 43.
- k) *Plantaginetea majoris* Tx. et Prsg. 50.
- l) *Secalinetea* Br.-Bl. 51.
- m) *Caricetea curvulae* Br.-Bl. 48.
- n) *Elyno-seslerietea* Br.-Bl. 48.
- o) *Salicetea herbacea* Br.-Bl. 47.
- p) *Thlaspetea rotundifolii* Br.-Bl. 47.
- q) *Asplenietea rupestris* Br.-Bl. 34.
- r) *Phragmitetea* Tx. et Prsg. 49.
- s) *Montio-cardaminetea* Br.-Bl. et Tx. 43.

On the vertical profile, the Djuricka river basin is differentiated from the following forest communities:

1. *Quercetum petraeae-cerridis*, Lak. Mostly in the southern exposure of the valleys on the main watercourse, and the lower parts of its tributaries.
2. *Quercetum petraeae montenegrinum*, Lak. On the hilly parts of the river basin.
3. *Fagetum montanum*. Differentiated into several associations of which the most characteristic is Luzulo - Fagion moesiaca.
4. *Abieti - Fagetum moesiaca* Blec and Lak.
5. *Picetum excelsae montanum*
6. *Picetum excelsae subalpinum*, above 1600m.
7. *Fagetum subalpinum* between 1500-1800m at all exposures and different geological substrates.
8. *Pinetum heldreichii* between 1500-2000m.
9. *Pinetum peuces*:
  - a. *Pinetum peuces montenegrinum* Blec. between 1800-2000 m;
  - b. *Pinetum heldreichii-peuces* Lak. between 1700-2000 m;
  - c. *Pinetum mughi* above 2000 m.



Fig. 7: Pioneer vegetation Endemic ass. *Euphorbio-Valerianetum bertiscei* Lksic (68) 70

In the upper part of the river basin, on the eastern slopes of Kosutic, and the western slope of Prokletije, close to the border with Albania, are forests of Macedonian pine. Going downstream to Kofiljaca on the southern exposures are forests of fir and spruce; in the lower regions, fir, spruce and beech are found. On the southern exposure of Kofiljaca, close to the village of Bogajici are forests of fir and spruce, and in the lower regions beech. On the slopes of the sub-basin of the Trokuska river is a beech forest. Below, close to the settlement of Hoti are mixed forests of fir, spruce and beech. On the slopes of Lovnocelo, there is a zone of pure beech forests.

In the Jasenicka sub-basin of the river, down the left tributary of the Djuricka River, on the slopes of Mala Sljapica and Podkobila, are the forests of Macedonian pine and mixed forests of beech and Macedonian pine. Going downstream, the area is covered with sub-alpine beech. Further down, on the slopes of Tumba, there are mixed forests of pine, fir, spruce, and beech.

According to our analysis, the coefficient  $f_s$ , (part of the river basin under forests) is 0.50,  $f_t$  (grass, meadows, pastures and orchards) is 0.47 and  $f_g$  (bare land, plough-land and ground without grass vegetation) is 0.03.

The coefficient of the river basin planning,  $X_a$ , is 0.45. Of the total river basin area, related to the river basin structure, ( $X_a$  is 0.45) mountain pastures are the most widespread form (35.48%). The proportion is as follows: degraded forests -25.24%; well-constituted forests - 25.24%; meadows - 10.96%; plough-lands - 2.6%; and orchards - 0.48%. The structure of the Djuricka river basin, land use is presented in Fig. 8.

The coefficient of the vegetation cover,  $S_{22}$ , is 0.70.

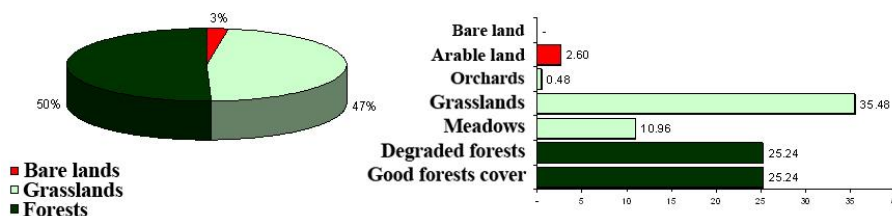


Fig. 8: Land use in the Djuricka river basin

#### Characteristics of the Basin in Relation to Soil Erosion and Runoff

Soil erosion represent key environmental issues worldwide (e.g., Green, 1982; Larson *et al.* 1983; Stoffel and Huggel 2012) and primary drivers of land degradation (Verheijen *et al.* 2009). Recent studies dealing with soil conservation subjects have discussed and sometimes questioned, the magnitude of land degradation in the Region, human responses, and the linkages with land use and cover (LUC) changes where water is one of the causes of positive but also negative effects on the land and environment (Nyssen *et al.* 2012).

Water-induced soil erosion is the result of the complex effect of a whole group of factors. Several studies (Curovic *et al.* 1999, Spalevic *et al.* 2013, 2013a, 2013b, 2013c, 2013d, 2012, 2008, 2007, 2004, 2003, 2001, 2000, 2000a, 1999, 1999a, Spalevic 2011; Fustic and Spalevic 2000) have shown that erosion intensity is always influenced by the properties and the use of soil, increasingly so in the anthropogenous 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.

The relief of the hilly-mountainous terrain is characterised by many steep slopes from which the water runs off and flows quickly, which is favourable for triggering the soil erosion process. The dominant erosion form in this area is

surface runoff, but more severe forms of erosion such as rills, gullies and ravines also occur.

The erosion activities affect some areas of agricultural and forest land, but they are mostly close to roads that connect small rural communities with the town Plav. The erosion causes some places to lose fertile land, resulting in sterile alluvial deposits on the fertile soils of the small alluvial terraces close to the main watercourse. It has also resulted in torrents which have flooded roads and interrupted travel and the migration of farmers from and to the *katuns* (seasonal/summer villages).

Massive surface runoff of soil results in denudation of slopes, followed by the occurrence of numerous gullies, ravines and landslides. Surface or runoff erosion has taken place in all the soils on the slopes, with erosion being most pronounced on steep slopes with scarce or denuded vegetation cover.

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 Djuricka river basin is presented in Table 7.

(A)symmetry coefficient (0.06) indicates that there is a possibility of large flood waves in the river basin.

The value of the G coefficient that was 0.54 indicates that there is a medium density of the hydrographical network. Maximal outflow (appearance of 100 years) from the river basin,  $Q_{\max}$ , is calculated on 240 m<sup>3</sup>/s.

The value of the Z coefficient was 0.554. According to the result of the value of Z, the river basin belongs to destruction category III. The strength of the erosion process is medium, and according to the erosion type, it is mixed erosion.

Sediment yields were calculated with the IntErO model on 347,273 m<sup>3</sup>/year for the 57 basins of Polimlje in Montenegro, and 44,902 m<sup>3</sup>/km<sup>2</sup> for the study on the Djuricka river basin (Spalevic 2011); the calculations for the Polimlje region corresponded to the results obtained by the engineers Muhidin Begic and Milosav Vranic (0.35 x 10<sup>6</sup>m<sup>3</sup>) for the Potpec accumulation, which is downstream from the study area. This correspondence suggests that the assessment results of actual losses of soil erosion potential obtained by IntErO model are eligible for the study area.

According to Babic *et al.* (2003) from the “Jaroslav Černi” Institute for the Development of Water Resources (JCI), the leading research organisation in Serbia’s water sector, real soil losses are 350 m<sup>3</sup>/km<sup>2</sup> per year for the Lim river basin (Polimlje, *Fig. 1*). By using the IntErO software to estimate the soil losses per km<sup>2</sup> in 57 river basins of Polimlje, we found the average value to be 331.78 m<sup>3</sup>/km<sup>2</sup> per year (Spalevic 2011), and 645.4 m<sup>3</sup>/km<sup>2</sup> year for the studied Djuricka river basin (Table 8 / N°1). This correspondence suggests that the results of the assessment obtained by IntErO model are eligible for the study area.

TABLE 7  
Part of the IntErO report for the Djuricka river basin

<b>INPUT DATA</b>			
River basin area	F	69.57	km <sup>2</sup>
The area of the bigger river basin part	Fv	35.87	km <sup>2</sup>
The area of the smaller river basin part	Fm	33.70	km <sup>2</sup>
Natural length of the main watercourse	Lv	14.54	km
The shortest distance between the fountain head and mouth	Lm	12.12	km
The total length of the main watercourse with tributaries	ΣL	37.5	km
River basin length measured by a series of parallel lines	Lb	15.86	km
Contour line length 1000m	liz	10.20	km
Contour line length 1100m	liz	20.73	km
Contour line length 1200m	liz	26.40	km
Contour line length 1300m	liz	28.33	km
Contour line length 1400m	liz	31.83	km
Contour line length 1500m	liz	32.88	km
Contour line length 1600m	liz	32.30	km
Contour line length 1700m	liz	29.52	km
Contour line length 1800m	liz	27.32	km
Contour line length 1900m	liz	19.02	km
Contour line length 2000m	liz	12.12	km
Contour line length 2100m	liz	2.53	km
The area between 907m and contour line 1000	fiz	5.35	km <sup>2</sup>
The area between the two neighbouring contour lines 1000-1100	fiz	4.65	km <sup>2</sup>
The area between the two neighbouring contour lines 1100-1200	fiz	5.92	km <sup>2</sup>
The area between the two neighbouring contour lines 1200-1300	fiz	6.33	km <sup>2</sup>
The area between the two neighbouring contour lines 1300-1400	fiz	6.57	km <sup>2</sup>
The area between the two neighbouring contour lines 1400-1500	fiz	6.8	km <sup>2</sup>
The area between the two neighbouring contour lines 1500-1600	fiz	7.37	km <sup>2</sup>
The area between the two neighbouring contour lines 1600-1700	fiz	7.5	km <sup>2</sup>
The area between the two neighbouring contour lines 1700-1800	fiz	6.75	km <sup>2</sup>
The area between the two neighbouring contour lines 1800-1900	fiz	6.15	km <sup>2</sup>
The area between the two neighbouring contour lines 1900-2000	fiz	4.06	km <sup>2</sup>
The area between the two neighbouring contour lines 2000-2100	fiz	1.83	km <sup>2</sup>
The area between the two neighbouring contour lines 2100-	fiz	0.3	km <sup>2</sup>
Altitude of the first contour line	h0	1000	m
Equidistance	Δh	100	m
The lowest river basin elevation	Hmin	907	m
The highest river basin elevation	Hmax	2149	m
A part of the river basin consisted of a very permeable rocks	f <sub>p</sub>	0.03	
A part of the river basin area consisted of medium permeable rocks	f <sub>pp</sub>	0.06	
A part of the river basin consisted of poor water permeability rocks	f <sub>o</sub>	0.91	
A part of the river basin under forests	f <sub>s</sub>	0.50	
A part of the river basin under grass, and orchards	f <sub>t</sub>	0.47	
A part of the river basin under bare land and without grass vegetation	f <sub>g</sub>	0.03	
The volume of the torrent rain	hb	89.4	mm
Incidence	Up	20	years
Average annual air temperature	t0	8.1	°C
Average annual precipitation	Hyear	1345.4	mm
Types of soil products and related types	Y	1.2	
River basin planning, coefficient of river basin planning	Xa	0.45	
Numeral equivalents of visible and clearly exposed erosion process	φ	0.41	

<b>RESULTS:</b>		
Coefficient of the river basin form	A	0.54
Coefficient of the watershed development	m	0.49
Average river basin width	B	4.39 km
(A)symmetry of the river basin	a	0.06
Density of the river network of the basin	G	0.54
Coefficient of the river basin tortuousness	K	1.2
Average river basin altitude	Hsr	1476.4 m
Average elevation difference of the river basin	D	569.4 m
Average river basin decline	Isr	39.26 %
The height of the local erosion base of the river basin	Hleb	1242 m
Coefficient of the erosion energy of the river basin's relief	Er	136.89
Coefficient of the region's permeability	S1	0.96
Coefficient of the vegetation cover	S2	0.7
Analytical presentation of the water retention in inflow	W	0.751 m
Energetic potential of water flow during torrent rains	2gDF <sup>1/2</sup>	881.61 m km s
Maximal outflow from the river basin	Q <sub>max</sub>	239.8 m <sup>3</sup> s <sup>-1</sup>
Temperature coefficient of the region	T	0.95
Coefficient of the river basin erosion	Z	0.554
Production of erosion material in the river basin	Wyear	115593 m <sup>3</sup> year <sup>-1</sup>
Coefficient of the deposit retention	Ru	0.388
Real soil losses	G year	44902 m <sup>3</sup> year <sup>-1</sup>
Real soil losses per km2	G year/km <sup>2</sup>	645 m <sup>3</sup> km <sup>2</sup> year <sup>-1</sup>

TABLE 8  
Calculated soil losses per km2 in 57 river basins of Polimlje (m<sup>3</sup>/km<sup>2</sup> year)

1	645,40	11	417,68	21	88,66	31	197,99	41	131,23	51	140,64
2	521,84	12	278,33	22	470,42	32	296,45	42	122,48	52	315,28
3	104,31	13	427,63	23	324,45	33	255,60	43	194,76	53	216,30
4	288,97	14	330,12	24	212,67	34	325,19	44	198,08	54	250,39
5	562,60	15	429,10	25	385,41	35	195,47	45	212,39	55	256,39
6	399,52	16	403,46	26	492,68	36	264,43	46	254,63	56	269,25
7	328,96	17	370,61	27	232,47	37	286,07	47	200,43	57	413,66
8	180,22	18	244,32	28	305,76	38	327,04	48	514,60	Average	
9	327,69	19	219,39	29	268,09	39	452,92	49	200,56	<b>331,78</b>	
10	298,19	20	286,90	30	266,21	40	210,32	50	247,93	m <sup>3</sup> /km <sup>2</sup> year	

Tazioli (2009) undertook a comparison between the Gavrilovic EPM model and direct measurements of sediment transport. The study was applied to different equipped basins in Italy and Africa. The numerical results obtained for some basins in the Marche region (Italy) were compared with the empirical formula of EPM for the calculation of erosion. Tazioli's research concluded that EPM is particularly useful for small and medium water courses (similar to those of the Apennine ranges in Italy, but also for the Djuricka river basin that was studied), allowing for an assessment of erosion in the whole watershed.

This methodology is in use also in Bosnia & Herzegovina, Croatia, Italy, Montenegro, Macedonia, Serbia and Slovenia. The EPM is distinguished by its high degree of reliability in calculating sediment yields as well as transport and

reservoir sedimentation (Ristic *et al.* 2011). EPM is embedded in the algorithm of IntErO computer-graphic method.

### CONCLUSION

Many factors influence the erosion processes in the territory of the Djuricka river basin. The most significant factors are climate, relief, geological substrate and pedological composition, as well as the condition of the vegetation cover and land use.

Maximal outflow (over 100 years) from the river basin,  $Q_{max}$ , is  $240 \text{ m}^3 \text{ s}^{-1}$ , suggesting the possibility of a large flood. The strength of the erosion process is medium, and erosion type is mixed erosion. The predicted soil losses are  $645 \text{ m}^3 \text{ km}^2 \text{ year}^{-1}$ .

This zone will experience intensive tourism in the future. There is therefore a need to take preventive measures against the possibility of increasing soil erosion processes. To support a more rapid renewal of the vegetation and slow down the erosion processes, biological protection measures need to be applied, together with technical measures, notably by using shoulders and ditches to partition water fluxes at the land surface. These would reduce runoff velocity and further support reforestation and the renewal of grass, shrubs and trees.

### ACKNOWLEDGEMENT

This research was funded by the Ministry of Science of Montenegro.

### REFERENCES

- Babic Mladenovic, M., Z. Obuskovic and Z. Knezevic. 2003. Zasipanje akumulacija u Srbiji – Problemi i pravci resavanja. *Vodoprivreda* 35: 387-393.
- Blinkov, I. and S. Kostadinov. 2010. Applicability of various erosion risk assessment methods for engineering purposes, *BALWOIS 2010 Conference - Ohrid*, Republic of Macedonia. 25 - 29 May 2010.
- Cvijic, J. 1921. Ledeno doba u Prokletijama i okolnim planinama. Glasnik Srpske Kraljevske Akademije, knj. XCI, Beograd, 1913, knj. XCIII, Beograd.
- Curovic, M., V. Spalevic, D. Dubak and S. Dozic. 1999. Suggestion for anti-erosion arrangement of compartment 17 form unit Rudo Polje – Kovren. *Agriculture and Forestry*. 45(3-4): 5-23.
- Ebrahimpour M., S. K. Balasundram, J. Talib, A. R. Anuar and H. Memarian. 2011. Accuracy of GeoWEPP in estimating sediment load and runoff from a tropical watershed. *Malaysian Journal of Soil Science*. 15: 25-33.

- Egner, H., H. Riehm and W.R. Domingo. 1960. Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nährstoffzustandes der Böden. II. Chemische Extraktionsmethoden zur Phosphor- und Kaliumbestimmung. *K. Lantbrukshoegsk. Ann.* 26:199-215.
- Gavrilovic, S. 1961. Proracun srednje godisnje kolicine nanosa prema potencijalu erozije. Glasnik Sumarskog fakulteta. Beograd.
- Gavrilovic, S. 1964. Nauka o eroziji zemljista i bujicnim tokovima. Knjiga prva. Beograd.
- Gavrilovic, S. 1965. Odredjivanje maksimalnih i godisnjih protoka voda u bujicnim slivovima i erozionim podrucjima. Izdanje dokumentacije za gradjevinarstvo i arhitekturu, sv 88. Beograd.
- Gavrilovic, S. 1972. Inzenjering o bujicnim tokovima i eroziji. Izgradnja. Beograd.
- Gee, G.W. and J.W. Bauder. 1986. Particle size analysis,. In: *Methods of Soil Analysis: Part I*, pp. 383–411( 2nd ed.). Madison: American Society of Agronomy (Agronomy 9).
- Hashim Ghulam M., W. Abdullah Yusoff and A.A. Cyril Ciesiolka. 1997. Overland flow and soil erosion in sloping agricultural land. *Malaysian Journal of Soil Science.* 1: 35-49.
- Hashim, Ghulam M., Cyril A.A. Ciesiolka, W. Abdullah Yusoff, A.Wahab Nafis, M. Radzali Mispan, Calvin W. Rose and Keppel J. Coughlan. 1995. Soil erosion processes in sloping land in the east coast of Peninsular Malaysia. *Soil Technology.* 8(3): 215–233.
- Fustic, B. and V. Spalevic. 2000. Characteristics of erosion processes in the river basin of Daspic river. *Agriculture and Forestry.* 46(1-2): 5-17.
- Fustic, B. 1988. Map of the Soils of Montenegro (scale 1:50,000). Vojnogeografski institut, Beograd, Poljoprivedni institut Podgorica.
- Green, C.P. 1982. Assessment of erosion. *Earth-Science Reviews* 18: 77–78.
- Gobin, A., R. Jones, M. Kirkby, P. Campling, G. Goversa, C. Kosmas and A.R. Gentile. 2004. Indicators for pan-European assessment and monitoring of soil erosion by water. *Environmetal Science and Policy.* 7:25–38.
- Jakovljević, M., M. Pantovic and S. Blagojevic. 1995. *Laboratory Manual of Soil and Water Chemistry* (in Serbian). Belgrade: Faculty of Agriculture.
- Kappen, H. 1929. *Die Bodenazidität.* 363p. Berlin: Springer Verlag.

- Kadovic, R. 1999. Protiverozioni agroekosistemi – Konzervacija zemljista, Sumarski fakultet, Beograd.
- Karkanis, P.G., K. Au and G. B. Schaalje. 1991. Comparison of 4 measurement schedules for determination of soil particle-size distribution by the hydrometer method. *Canadian Agricultural Engineering*. 33(2): 211–215.
- Kicovic, D. M. and R.M. Dragovic. 2000. Natural features and protection of Komovi. *Zastita prirode*. 52(1): 105-115.
- Knezevic, M. and D. Kicovic. 2004. Prirodne specificnosti polimskih Prokletija u svetlu aktivne zastite. Glasnik srpskog geografskog drustva. *Sveska LXXXIV* – Br.1. Beograd.
- Kostadinov S., M. Zlatic, N. Dragovic and Z. Gavrilovic. 2006. Soil Erosion in Serbia and Montenegro. In *Soil Erosion in Europe*, ed. John Bordman and Jean Poesen, pp. 271-277. London: John Wiley & Sons, Ltd.
- Larson, W.E., F.J. Pierce and R.H. Dowdy. 1983. The threat of soil erosion to long-term crop production. *Science*. 219: 458–465.
- Lazarevic, R. 1996. Erozija u Crnoj Gori. Erozija, strucno-inf. bilten, br.23. Beograd.
- Madureiraa, L., L. Nunesb, J. Borgesc and A. Falcãod. 2011. Assessing forest management strategies using a contingent valuation approach and advanced visualisation techniques: A Portuguese case study. *Journal of Forest Economics*. 17(4): 399–414.
- Mathys, N., S. Brochot, M. Meunier and D. Richard, D. 2003. Erosion quantification in the small marly experimental catchments of Draix (Alpes de Haute Provence, France). Calibration of the ETC rainfall-runoff-erosion model. *Catena*. 50: 527-548.
- Memarian, H., S.K. Balasundram, J. Talib, C.B.S. Teh, M.S. Alias, K.C. Abbaspour and A. Haghizadeh. 2012. Hydrologic analysis of a tropical watershed using KINEROS2. *Environment Asia*. 5(1): 84-93.
- Nyssen, J., J. Van den Branden V.Spalevic, A. Frankl, L. Van de Velde, M. Curovic and P. Billi. 2012. Twentieth century land resilience in Montenegro and consequent hydrological response. *Land Degradation & Development*. DOI: 10.1002/ldr.2143.
- Oldeman, L.R., R.T.A Hakkeling and W.G. Sombroek, W.G. 1991. GLASOD World Map of the Status of Human-induced Soil Degradation. ISRIC, Wageningen UNEP, Nairobi (second revised edition).

- Pavicevic, N. 1957. Osobine aluvijuma u dolini Lima. *Agriculture and Forestry*. 3(2): 35-52.
- Pavicevic, N. 1956. Soil erosion in the upper part of the Lim river basin. *Agriculture and Forestry*. 2(2): 1-18.
- Pavicevic, N. and N. Tancic. 1970. Smedja sumska zemljista u slivu Lima i sastav humusa u njemu. *Arhiv za poljoprivredne nauke*, N<sup>o</sup>. XXIII, Sv. 82. Beograd.
- Poesen, J., J. Nachtergaele, G. Verstraeten and C. Valentin. 2003. Gully erosion and environmental change: Importance and research needs. *Catena*. 50: 91-133.
- Ristic, R., B. Radic, N. Vasiljevic and Z. Nikic. 2011. Land use change for flood protection - a prospective study for the restoration of the river Jelasnica watershed. *Bulletin of the Faculty of Forestry*. 103: 115-130.
- Spalevic, V., M. Curovic, V. Tanaskovik, M. Oljaca, N. Djurovic. 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*, 4<sup>th</sup> - 6<sup>th</sup> October 2013, Belgrade–Zemun, Serbia, VI: 1-14.
- Spalevic, V., J. Nyssen, M. Curovic, T. Lenaerts, A. Kerckhof, K. Annys, J. Van Den Branden, A. Frankl. 2013a. 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"*, 3-6 October, 2013, Jahorina, Bosnia p. 54-63.
- Spalevic, V., M. Curovic, N. Uzen, I. Simunic, M. Vukelic-Shutoska. 2013b. 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., M. Curovic, V. Tanaskovik, R. Pivic, N. Djurovic. 2013c. In proceeding of the *1st International Congress on Soil Science, the 13th National Congress in Soil Science: SOIL – WATER – PLANT*, Belgrade, Serbia.
- Spalevic, V., I. Simunic, M. Vukelic-Sutoska, N. Uzen and M. Curovic. 2013d. Prediction of the soil erosion intensity from the river basin Navotinski, Polimlje (Northeast Montenegro). *Agriculture and Forestry*. 59(2): 9-20.
- Spalevic, V., W. Mahoney, N. Đurović, N. Uzen and M. Curovic. 2012. Calculation of soil erosion intensity and maximum outflow from the Rovacki river basin, Montenegro. *Agriculture and Forestry*. 58(3): 7-21
- Spalevic, V. 2011. Impact of land use on runoff and soil erosion in Polimlje. Doctoral thesis, 260p, Faculty of Agriculture of the University of Belgrade, Serbia.

- Spalevic, V., M. Curovic, D. Borota and B. Fuštić, B. 2008. Soil erosion in the River Basin Željeznica, area of Bar, Montenegro. *Agriculture and Forestry*. 54 (1-4): 5-24.
- Spalevic, V., M. Curovic, and A. Povilaitis. 2007. Conditions of soil erosion in the Komarača river basin, North-East of Montenegro. Paper presented at conference *Erosion and Torrent Control as a Factor in Sustainable River Basin Management*, Belgrade.
- Spalevic, V., M. Curovic, A. Povilaitis and S. Radusinović. 2004. Estimate of Maximum Outflow and Soil Erosion in the Biogradska River Basin. Monographs, No.1, *Biodiversity of the Biogradska Gora National Park*, ed. V. Pešić. pp. 1-20, Department of Biology of the University of Montenegro, Podgorica.
- Spalevic, V., G. Seker, B. Fuštić and Ristić R. Šekularac. 2003. Conditions of erosion of soil in the drainage basin of the Crepulja - Lucka River. Paper presented at, *Natural and Socioeconomic effects of Erosion Control in Mountainous Regions*, pp. 287-292, Banja Vrujci, Srbija, Faculty of Forestry, Belgrade, World Ass. of Soil&Water Conservation.
- Spalevic, V., B. Fuštić, S. Šoškić and R. Ristić. 2001. The estimate of maximum outflow and soil erosion intensity in the Vinicka river basin with application of computer graphic methods. *Agriculture and Forestry*. 47(3-4): 95-104.
- Spalevic, V., Fustic, B., Jovović, Z., Curovic, M., Spalevic, B., Popovic. V. 2000. Characteristics of erosion processes and proposal of land reclamation measures in the drainage basin of the Šekularska river. *Agriculture and Forestry*. 46(3-4): 2-18.
- Spalevic V., A. Dlabac , B. Spalevic, B. Fuštić and V. Popović. 2000b. Application of computer - graphic methods in the research of runoff and intensity of ground erosion - I program "River basins". *Agriculture and Forestry*. 46 (1-2): 19-36.
- 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. 135p.
- Spalevic, V., D. Dubak, B. Fuštić, Z. Jovović and R. Ristić. 1999a. The estimate of the maximum outflow and soil erosion intensity in the Kaludra River basin. *Acta Agriculturae Serbica* IV(8): 79-89.
- Stoffel, M., and C. Huggel. 2012. Effects of climate change on mass movements in mountain environments. *Progress in Physical Geography*. 36: 421-439.
- Thun, R. and R. Herrmann. 1949. Die Untersuchung von Boden. Neumann Velag, Radebeul und Berlin, pp 15-28.

- Van Lynden, G.W.J. 1995. European Soil Resources. Nature and Env. No. 71. Council of Europe, Strasbourg.
- Verheijen, F.G.A., R.J.A Jones, R.J. Rickson and C. J. Smith. 2009. Tolerable versus actual soil erosion rates in Europe. *Earth-Science Reviews*. 94: 23–38.
- Vukelic-Sutoska, M., T. Mitkova and M. Markoski. 2011. Management of waters and soils in Skopje valley according to sustainable agriculture, Opatija-Croatia. *Proceedings of 5th Croatian Water Conference: Croatian Waters Facing the Challenge of Climate Changes*, pp. 895-904.
- Zivaljevic, M. 1989. Tumac Geoloske karte SR Crne Gore, 1:200 000; Posebna izdanja Geoloskog glasnika, Knjiga VIII, Titograd.