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ANALYSIS OF THE IMPACT OF FRUIT GROWING DEVELOPMENT ON THE INTENSITY OF SOIL EROSION AND RUNOFF: CASE STUDY OF KRUSEVO, BIJELO POLJE, MONTENEGRO

SUMMARY

The research has been conducted to analyse the effects of land use change of the impact of fruit growing development on the intensity of soil erosion and runoff in the Study area of Krusevo, Bijelo Polje, Montenegro by using the Intensity of Erosion and Outflow – IntErO model of Spalevic. The required spatial maps, land use, soil and geology were prepared and analysed in GIS environment. The climatic data such as the volume of the torrential rain, average annual air temperature and average annual precipitation were calculated based on meteorological data received from the State Hydrological Institute for the region of Bijelo Polje (Montenegro). The results of land use change between these two periods (2011-2020) shown that the forest increased in the studied region by 1.57%. Specifically, degraded forests increased by 1.02%; Well-constituted forests increased by 0.55%. For the studied area we calculated forested area on 57.26% (2011), and 58.83% (2020). The values for Meadows in the studied area decreased from 2011 to 2020 for 1.67%; and for Pastures for 1.40%. Plough-lands decreased for the observed period for 1.59%. On the other hand, the surface under the Orchards increased by 3.09%, and that represented the shift from the Meadows to the Orchards; the shift from the Pastures to the Forests. This denser vegetation at the studied region for the observed period (increase of the forests and orchards) has led to higher water infiltration rate into the soil and at the same time to decrease of the sediment yield. The value of Z coefficient of 0.462 (2011); 0.461 (2020) indicates slight decrease of erosion processes because of the fruit growing development with shifting the meadows to orchards categorising the processes to the 3rd destruction category. The strength of the erosion process

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is medium, and according to the erosion type, it is surface erosion. Production of erosion material in the river basin, W year, is calculated on 11327 m^3year^{-1} for 2011; and 11278 m^3year^{-1} for 2020, what shown the decrease of erosion processes because of the subject fruit growing development. Coefficient of the deposit retention (sediment delivery ratio) is calculated as 0.299 what means that 30% of the total eroded material reaches to the outlet point. Real soil losses, G year, are calculated on 3392 m^3year^{-1} (2011), and 3377 (2020); Real soil losses per km^2, G year km^{-2}, are 262 $m^3km^{-2}year^{-1}$ (2011), and 261 $m^3km^{-2}year^{-1}$ (2020), with the same conclusion in relation to the fruit growing initiatives and the values indicates that the river basin belongs to 5th destruction category; it is a region of very weak erosion. The results showed that the appropriate land management and planning with implementing fruit growing in this area decreases maximum flow rate and also sediment yield. The application of the IntErO model may also be further used to understand the effect of land use change with new establishing of the fruit growing in the river basins on hydrological behaviour, soil erosion and sediment yield process and can be used as a useful tool in similar for fruit growing and soil conservation research.

Keywords: IntErO model; Land management; Fruit growing; Sediment yield; Montenegro.

INTRODUCTION

Soil erosion is one of the most significant causes of land degradation and an important environmental hazard throughout the world, especially in developing countries.

Sediment yield and soil erosion are two main constraints on sustainable management of water resources and soil. The quantification of these processes is crucial to design any scientifically based soil and water conservation plan and integrated land management. The acceleration of soil erosion due to human activities on a global scale has led to an increased sediment flow in many parts of the world. Unwanted complementary effects of soil erosion, such as loss of soil fertility, reduced water quality, alteration of the hydrological systems, and environmental contaminations, have been identified as a serious problem for human sustainability (Turner *et al*, 1990; Eswaran *et al*, 2001; Dabral *et al*, 2008.; Wang *et al*, 2013; Efthimiou *et al*, 2016; Khaledi Darvishan *et al*, 2016; Ferreira *et al*, 2016; Li *et al*, 2016; Kavian *et al*, 2018).

Many studies have shown that there is a significant relationship between land use change and soil erosion. Land use change may result in an increase of sediment and nutrient supply to rivers and may affect the water balance in the watershed and its variability, which must be assessed on a local scale (IntErO model, www.geasci.org/IntErO).

The main purpose of this study is the application of the IntErO model to evaluate the effects of fruit growing development on the intensity of soil erosion and runoff in the studied area of Krusevo, Bijelo Polje, Montenegro. With this study we try to create one of the sustainable forms of modelling that would be calibrated and validated in the close region of the studied catchment and afterwards used to evaluate how fruit growing is influencing local community, eco sectors, and agricultural production in relation to this subject matter.

MATERIAL AND METHODS

Study area

North Montenegro is mainly mountainous, with the presence of deep valleys incised into limestone ranges, and some parts are hilly and underlain by Palaeozoic rocks. The area is densely populated. The rivers in this region belongs to the Danube watershed and drain to the Black Sea. The location of the studied area is presented in the Figure 1 and panoramic view on the Figure 2 and 3.

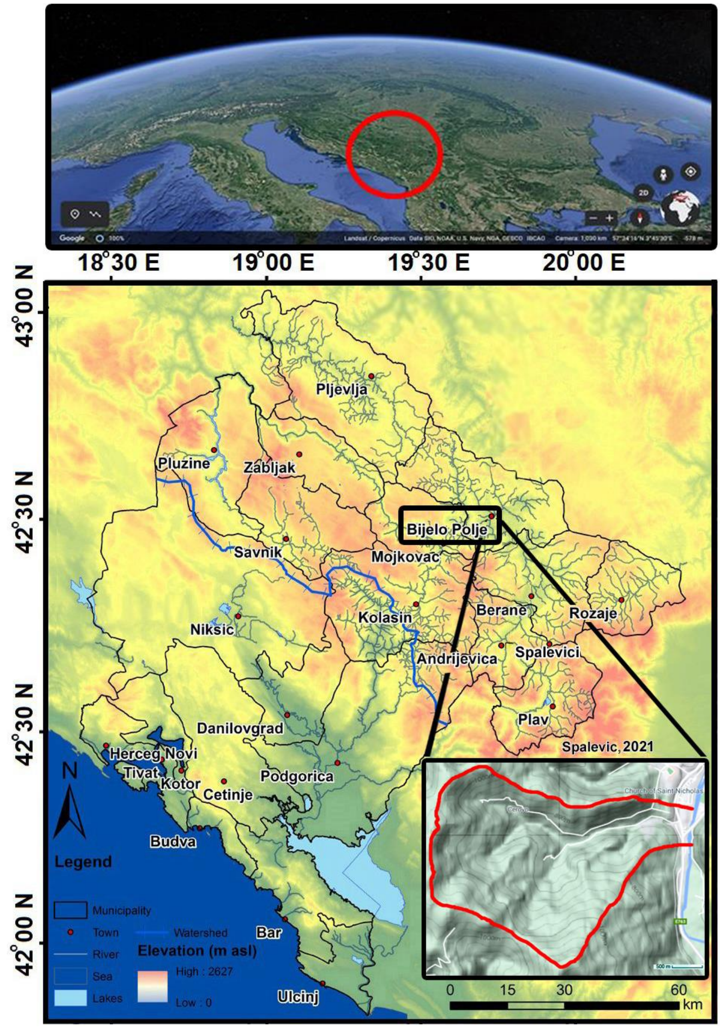

Figure 1: Location of the study area in Krusevo (43°00'12.1"; N 19°44'28.8"E)

Figure 2. Panoramic view on the studied area of Krusevo, Bijelo Polje

Figure 3. Some details on Land Use patterns of the studied area (2021)

The studied area of Krusevo (Bijelo Polje, North Montenegro) is a part of the Pepica River Basin, a left-hand tributary of the river Lim (43°00'12.1"; N 19°44'28.8"E; 43.003358, 19.741339). The basin stretches from its confluence with the Lim (lowest elevation, H min, of 578 m a.s.l) up to the tops where the highest elevation (Hmax) is 1264 m a.s.l. This watershed encompasses an area of 8.1 km^2, and the natural length of the main watercourse, Lv, is 4.4 km.

A flat area occurs around the village of Krusevo in the lower reach, where the fruit growing is established, and steep slopes make up the upper part of the watershed. The average gradient of the catchment, Isr, is 37.53 % and indicates that very steep slopes are present in the river basin. The average river basin altitude, Hsr, is 857.46 m a.s.l; the average elevation difference of the basin, D, is 279.46 m. The drainage density is low indicating a rather permeable substrate.

Climate

The study area is characterized by a mountain Mediterranean climate with rainy autumns and springs, cold winters, and a deficit of precipitation in the summer months. Basic data on the area needed for the calculation of soil erosion intensity and runoff are presented in Table 1.

Table 1. Precipitation and temperature for the period 1948–2020, Bijelo Polje.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max. daily precipitation in mm												
Max.	68.6	92.8	73	93.3	42.6	58.5	97.8	55.8	95.6	157.6	101.6	79.4
Aver.	23.4	22.8	21.5	24	21.9	20.6	21.7	21.1	25.3	29	29	23.5
St.D.	15.6	18.6	13	15	9.9	12.4	15.2	11.9	17.2	24.6	16.2	14.7
Mean monthly temperatures in °C												
Max.	2.9	5.8	7.8	12.6	15.8	18.2	20.8	20.9	17.7	12.6	8.6	4.4
Min.	−5.6	−5.2	−0.7	6.1	9.8	14.1	16.2	14.3	11.3	6.2	−1.6	−4.7
Aver.	−1.6	0.8	4.6	8.9	13.3	16.3	18.1	17.7	14.3	9.4	4.5	0.1
St.D.	2.2	2.7	2.1	1.3	1.3	1	1.1	1.4	1.5	1.4	2.1	2.2
Max. daily temperatures in °C												
Max.	15.4	20.9	25.6	28.1	32.4	35.5	36.8	39.2	36	29.5	23	19.2
Aver.	11.7	14.5	20.1	23.6	27.6	30.4	32.8	32.8	29.4	24.8	18.6	13.6
St.D.	2.8	3	3.1	2.3	2.2	2.5	2	2.5	2.6	2.6	2.8	3.3
Min. daily temperatures in °C												
Min.	−27.6	−24.5	−16.5	−7.5	−4	0	1.2	2.6	−4	−7.2	−15.4	−21.7
Aver.	−15.1	−13	−8.4	−2.8	0.9	4.8	6.5	6.1	2.3	−2.5	−7.3	−12.6
St.D.	5.3	4.7	4.1	1.8	2	1.8	2.1	1.5	2.5	2.3	3.7	4.6

Source: Data from the Hydrometeorological Institute of Montenegro and the Biotechnical faculty of the University of Montenegro (Spalevic *et al*, 2020).

The absolute maximum air temperature ever recorded was 39.2°C. Winters are severe, with negative temperatures as low as −27.6°C. The average annual air temperature, t0, was 8.9°C. The average annual precipitation, H year, was 873 mm. The temperature coefficient for the region, T, was calculated at 0.99. The torrential rain, hb, was calculated at 84.7 mm. (Spalevic *et al*, 2020).

Geology and soils

The broader study area consists of various types of sediment, magmatic and metamorphic rocks generated in the long, Palaeozoic to Quaternary, interval. Most of the terrain is underlain by Mesozoic formations of carbonate composition, while magmatic and silico-clastic rocks are substantially less present. The main rocks outcropping in the area are clastic and subordinate carbonate rocks from the Paleozoic, Triassic clastites, volcanites, tuffs, limestone and dolomites, Jurassic clastic rocks with diabasic effusions and metamorphic rocks and Quaternary, mainly alluvial and colluvial deposits.

In order to define the permeability of the rocks of the study area, we used the Geological Atlas of Serbia (Dimitrijevic, 1992) and extracted a geological map of the studied region from the Geological map of Montenegro (Zivaljevic, 1989). The region consists of Devonian-Carboniferous (D+C) and Permian (P) phyllites, argyllo-phyllites, metasandstones, and conglomerates.

The coefficient of the region's permeability, S1, was calculated to be 0.96, having semi permeable class of rocks, fpp, of 13%, with predominant rocks of poor permeability (class fo, 87%). According to the results of the field visits and supplementary laboratory analysis, but also using the previous research data of the project Soils of Montenegro (1964–1988) carried out by the team of the Biotechnical institute of the University of Montenegro (Fustic & Djuretic, 2000) and Spalevic (2011), the most common soil types in the study basin were: Dystric Cambisols, Fluvisols and Colluvial Fluvisols in the lower alluvial plain.

Vegetation and Land Use

Forests dominate this river basin accounting for 57% of the total vegetation cover and beech forests (*Fagetum montanum*) prevail. The degraded forests are located near settlements and roads because of the firewood harvesting. These forests are characterized by a terminate canopy and by a large number of species of ground flora, shrubs, and lower trees. They differ from beech forests in the inner parts of the basin, characterized by a dense canopy which is the main characteristic especially of the sub-association *Fagetum montanum typicum*, (Milošević *et al*. 2019). On some positions forests of Sessile oak and Turkish oak (*Quercetum petraeae cerridis* Lak.) is recorded. In the lower part of the basin, a narrow belt along the river channel is covered with hydrophilic forest (*Alnetea glutinosae, Salicetea herbacea*).

IntErO model application

The Intensity of Erosion and Outflow - IntErO model (Spalevic, 2011) was used for the analysis of the impact of fruit growing development on the intensity of soil erosion and runoff in the region of Krusevo, Bijelo Polje, Montenegro. The IntErO model is based on Erosion Potential Method – EPM (Gavrilovic, 1962; Gavrilovic, 1972) and is widely used in different environments of the Balkans (Gavrilovic, 1988; Globevnik *et al*, 2003; Blinkov & Kostadinov, 2010; Spalevic *et al*, 2012; Kostadinov *et al*, 2014; Barovic *et al*, 2015; Vujacic *et al*, 2015; Vujacic *et al*, 2017; Dragicevic, 2017; Spalevic *et al*, 2017; Kostadinov *et al*, 2018; Spalevic *et al*, 2019; Gocic *et al*, 2020; Spalevic *et al*, 2020) and internationally: Brazil (Tavares *et al*., 2019; Ayer *et al*, 2020; Bolleli *et al*., 2020; Sakuno *et al*., 2020); Greece (Efthimiou *et al*, 2016); Iran (Behzadfar *et al*, 2014; Gholami *et al*, 2016; Khaledi Darvishan *et al*, 2019; Khaledi Darvishan *et al*, 2018; Mohammadi *et al*, 2021); Italy (Milanesi *et al*, 2015); Morocco (El Mouatassime *et al*, 2019; Ouallali *et al*, 2020); Nepal (Chalise *et al*, 2019)...

The IntErO model, an upgrading of the programs "Surface and Distance Measuring" and "River Basins" of Spalevic and can be used for handling a large number of data with the processing of 27 inputs, returning, after the calculations, 22 final result parameters (Coefficient of the river basin form, A; Coefficient of the watershed development, m; Average river basin width, B; (A)symmetry of the river basin, a; Density of the river network of the basin, G; Coefficient of the river basin tortuousness, K; Average river basin altitude, Hsr; Average elevation difference of the river basin, D; Average river basin decline, Isr; The height of the local erosion base of the river basin, Hleb; Coefficient of the erosion energy of the river basin's relief, Er; Coefficient of the region's permeability, S1; Coefficient of the vegetation cover, S2; Analytical presentation of the water retention in inflow, W; Energetic potential of water flow during torrent rains, 2×gDF^½; Maximal outflow from the river basin, Qmax; Temperature coefficient of the region, T; Coefficient of the river basin erosion, Z; Production of erosion material in the river basin, W year; Coefficient of the deposit retention, Ru; Real soil losses, Gsp; Real soil losses per km^2. The input data and maps prepared for the IntErO model application are presented in the Table 2.

Table 2. Input data need for the IntErO analysis

Inputs	Amount / Unit
River basin areas (F)	12.92 km^2
The length of the watershed (O)	16.3 km
The area of the bigger river basin part (Fv)	8.9 km^2
The area of the smaller river basin part (Fm)	4.02 km^2
Natural length of the main watercourse (Lv)	3.82 km
The shortest distance between the fountainhead and mouth (Lm)	3.46 km
The lowest river basin elevation	578 m
The highest river basin elevation	1264 m
A part of the basin area consisted of medium permeable rocks (fpp)	0.13
A part of the basin consisted of poor water permeability rocks (f0)	0.87
The volume of the torrent rain (hb)	157.6 mm
Average annual air temperature (t0)	8.9 °C
Average annual precipitation (H year)	893.3 mm

RESULTS AND DISCUSSION

Land use changes (2011-2020)

Previous field research from 2011 and recent Landsat satellite images and maximum likelihood method were used to prepare land use map for the studied area. The study area consists of six (of seven) classes (Tab. 3, Fig. 4) including: (2) Plough-lands, (3) Orchards, (4) Pastures, (5) Meadows, (6) Degraded forests, and (7) Well-constituted forests (No bare land recorded – class 1).

Table 3: Land use classes of the studied area in % and km^2

Land use 2011	**%**	**km^2**	**Land use 2021**	**%**	**km^2**
Degraded forests	37.22	4.80	Degraded forests	38.24	4.93
Well-constituted forests	20.04	2.59	Well-constituted forests	20.59	2.66
Meadows	19.32	2.49	Meadows	17.65	2.28
Pastures	9.24	1.19	Pastures	7.84	1.01
Orchards	8.67	1.12	Orchards	11.76	1.52
Plough-lands	5.51	0.71	Plough-lands	3.92	0.51
Total	**100**	**12.92**	**Total**	**100**	**12.92**

Table 4: Trends of Land use classes' changes of the studied area (2011-2020)

Land use class	%	km^2
Degraded forests	1.02	0.13
Well-constituted forests	0.55	0.07
Pastures	(1.40)	(0.18)
Plough-lands	(1.59)	(0.21)
Meadows	(1.67)	(0.22)
Orchards	3.09	0.40

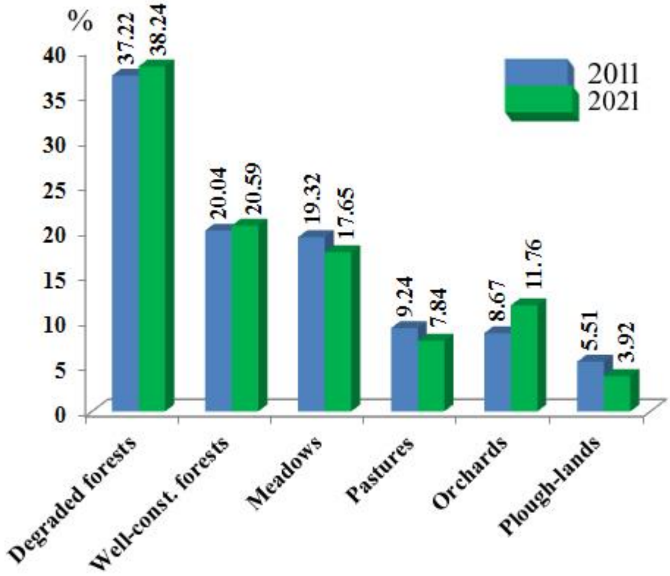

Figure 4. Graphical presentation on land use changes for the period 2011-2020

The results of land use change between these two periods (2011-2020) shown that the forest increased in the studied region by 1.57% (0.2 km^2) for a decade. Specifically, degraded forests increased by 1.02% (0.13 km^2); Well-constituted forests increased by 0.55% (0.07 km^2) for the period 2011-2020. That is in line with findings of Nyssen *et al* (2014) for Montenegro who stated that in the mountainous region of Montenegro, the wooded areas increased slightly, where dense vegetation increased from about 35% in the early-20th century to 56%. Our results for forest land of the studied region were about 1.7% (2011) to 2.8 (2020) percent's higher than those of Nyssen *et al* (2014); for the studied area; we calculated forested area on 57.26% (2011), and 58.83% (2020).

The values for Meadows in the studied area decreased from 2011 to 2020 for 1.67% (0.22 km^2); and for Pastures for 1.40% (0.18 km^2). Plough-lands decreased for the observed period for 1.59% (0.21 km^2).

On the other hand, the surface under the Orchards increased by 3.09% (0.40 km^2), and that represented the shift from the Meadows to the Orchards; but also shift from the Pastures to the Forests.

This denser vegetation at the studied region for the observed period (increase of the forests and orchards) has led to higher water infiltration rate into the soil, and at the same time to decrease of the sediment yield (Tab. 5, Figure 5).

Table 5. The outputs of IntErO model for the Studied are of the watershed

Output variables		**2011**	**2020**	**Unit**
Coefficient of the river basin form	A	0.83	0.83	
Coeff. of the watershed development	m	0.30	0.30	
Average river basin width	B	1.96	1.96	km
(A)symmetry of the river basin	a	0.76	0.76	
Density of the river network of the basin	G	0.30	0.30	
Coeff. of the river basin tortuousness	K	1.11	1.11	
Average river basin altitude	Hsr	840.84	840.84	m
Average elevation difference of basin	D	262.84	262.84	m
Average river basin decline	Isr	31.73	31.73	%
The height of the local erosion base	Hleb	686	686	m
Coefficient of the erosion energy	Er	115.18	115.18	
Coefficient of the region's permeability	S1	0.96	0.96	
Coefficient of the vegetation cover	**S2**	**0.70**	**0.69**	
Analytical present. of the water retention	W	1.7251	1.7251	m
Energetic potential of water flow	2gDF^½	258.08	258.08	m km s
Maximal outflow from the river basin	**Qmax**	**247.37**	**245.07**	**m^3/s**
Temperature coefficient of the region	T	0.99	0.99	
Coefficient of the river basin erosion	**Z**	**0.462**	**0.461**	
Erosion production in the basin	**Wyear**	**11327**	**11278**	m^3/year
Coefficient of the deposit retention	Ru	0.299	0.299	
Real soil losses	**G year**	**3392**	**3377**	**m^3/year**
Real soil losses per km^2	**G yr/km^2**	**262.6**	**261.5**	**m^3/km^2 yr**

Coefficient of the river basin form (A), Coefficient of the watershed development (m) and Average river basin width (B) calculated 0.83, 0.30 and 1.96 km, respectively. The (a)Symmetry of the river basin calculated 0.76 indicate that there is a possibility for large flood waves to appear in the river basin. In the recent decades, anthropogenic influence such as urban development and agricultural land use changes have increased the hazard of flood events and watershed vulnerability to rainfalls and rain storms that lead to Peak flow (Spalevic *et al*, 2011; Chalise *et al*, 2019; Mohammadi *et al*, 2021).

The Density of the river network of the basin (G) obtained 0.3. The G index indicates there is a low density of the hydrographic network. Drainage density as an important factor affects erosion process. Therefore, its management can cause erosion control in the region. This index depends on soil type and amount of flow through the channel (Mohammadi *et al*, 2021; Ouallali *et al*, 2020). The index of average river basin decline calculated 31.73%. The value of this index indicates that in the river basin prevail very steep slopes.

The height of the local erosion base of the river basin and Coefficient of the erosion energy of the river basin's relief obtained 686.

Coefficient of the river basin erosion, Z, is 0.462 (2011); 0.461 (2020). The values of Z coefficient indicates that the river basin belongs to 3rd destruction category. The strength of the erosion process is medium, and according to the erosion type, it is surface erosion. Figure 5 shows decrease of production of erosion material and real soil losses, but also decrease of runoff under the land use change in the period from 2011 to 2020.

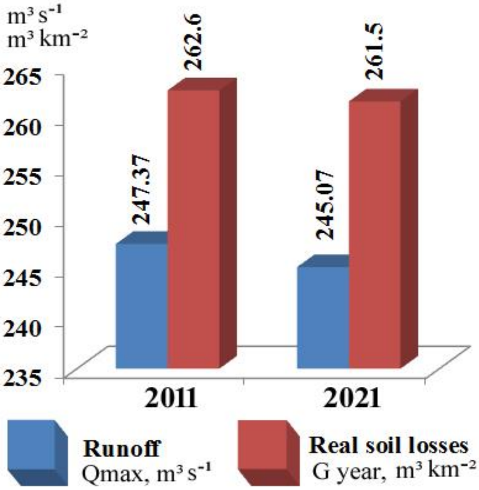

Figure 5. Graphical presentation of the Runoff and Soil losses (2011-2020)

Production of erosion material in the river basin, Wyear, is 11327 m^3year^{-1} (2011); 11278 m^3year^{-1} (2020). Coefficient of the deposit retention (sediment delivery ration) is calculated as 0.299. It means that 30% of the total eroded material reaches to the outlet point and deposit on slope and hydrological drainage system.

Real soil losses, G year, are 3392 m^3year^{-1} (2011); 3377 m^3year^{-1} (2020). Real soil losses per km^2, G year km^{-2}, are 262.6 $m^3km^{-2}year^{-1}$ (2011); 261.5 $m^3km^{-2}year^{-1}$ (2020) what indicates that the river basin belongs to 5th destruction category; it is a region of very weak erosion.

According to Grimes *et al* (2005), some marginal lands were cultivated again in the first decade of this century, as a consequence of the economic crisis in the region, but also on new initiatives of establishing new orchards on the places where we had before meadows. This trend was also confirmed by our research on land use in the small region in the North Montenegro.

CONCLUSIONS

In this study, the IntErO model was used to predict the effect of land use change on soil erosion and sediment yield in Krusevo from the Pepica watershed, from Bijelo Polje region of Montenegro. In the last decade, some parts of the meadows area of the studied region has shift to the orchards due to the new initiatives on fruit growing. Special attention was taken in Raspberry (*Rubus idaeus* L.) growing as one of the most important berry fruits in Montenegro.

The results of land use change between these two periods (2011-2020) shown that the forest increased in the studied region by 1.57%. Specifically, degraded forests increased by 1.02%; Well-constituted forests increased by

0.55%. For the studied area we calculated forested area on 57.26% (2011), and 58.83% (2020). The values for Meadows in the studied area decreased from 2011 to 2020 for 1.67%; and for Pastures for 1.40%. Plough-lands decreased for the observed period for 1.59%. On the other hand, the surface under the Orchards increased by 3.09%, and that represented the shift from the Meadows to the Orchards; the shift from the Pastures to the Forests. This denser vegetation at the studied region for the observed period (increase of the forests and orchards) has led to higher water infiltration rate into the soil and at the same time to decrease of the sediment yield. The value of Z coefficient of 0.462 (2011); 0.461 (2020) indicates slight decrease of erosion processes because of the fruit growing development with shifting the meadows to orchards categorising the processes to the 3rd destruction category. The strength of the erosion process is medium, and according to the erosion type, it is surface erosion. Production of erosion material in the river basin, W year, is calculated on 11327 $m^3 year^{-1}$ for 2011; and 11278 $m^3 year^{-1}$ for 2020, what shown the decrease of erosion processes because of the subject fruit growing development. Coefficient of the deposit retention (sediment delivery ratio) is calculated as 0.299 what means that 30% of the total eroded material reaches to the outlet point. Real soil losses, G year, are calculated on 3392 $m^3 year^{-1}$ (2011), and 3377 (2020); Real soil losses per km^2, G year km^{-2}, are 262 $m^3 km^{-2} year^{-1}$ (2011), and 261 $m^3 km^{-2} year^{-1}$ (2020), with the same conclusion in relation to the fruit growing initiatives and the values indicates that the river basin belongs to 5th destruction category; it is a region of very weak erosion.

The results showed that the appropriate land management and planning with implementing fruit growing in this area decreases maximum flow rate and also sediment yield. The application of the IntErO model may also be further used to understand the effect of land use change with new establishing of the fruit growing in the river basins on hydrological behaviour, soil erosion and sediment yield process and can be used as a useful tool in similar for fruit growing and soil conservation research.

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