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CALCULATION OF SOIL EROSION INTENSITY IN THE NEDAKUSI WATERSHED OF THE POLIMLJE REGION, MONTENEGRO

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ABSTRACT

Soil erosion on agricultural land is a growing problem in the South Eastern European Region and is a threat to soil quality and to the ability of soils to provide agricultural services. The negative impact of sediments on the environment and water resources is widely acknowledged with many watercourses in Montenegro. In this context risk-assessment procedures using of computer-graphic methods have been introduced in the Polimlje region of Montenegro to help policymakers to recognise sites where either certain crops should not be grown or anti-erosion measures are required. We used modelling of sediment yield and runoff for calculation of soil erosion intensity for a Nedakusi watershed. Physico-geographical inputs, which are the basis for the calculation of soil erosion intensity, are included in the IntErO simulation model, with the Erosion potential method embedded in the algorithm of this computer-graphic method. Our results shown that the net soil loss was calculated on 428 m^3 per year, specific 140 m3km-2 per year. The results of this study are the determination of erosion processes in the studied watershed; new information about the recent state of the runoff and a sediment yield in formats that can facilitate its efficient management and protection, illustrating the possibility of modelling of sediment yield with such approach.
KEYWORDS: Erosion, Soil erosion assessment, watershed, Land use, IntErO model.

INTRODUCTION

Soil erosion is a growing problem in South East Europe. Land degradation caused by soil erosion is especially serious in Montenegro (Spalevic et al., 2014a), affecting 95% of the total territory of Montenegro (Spalevic, 2011). The off-site impacts of runoff, sedimentation, loss of reservoir capacity, flooding is increasing in this Region.

Quantitative information on soil loss and runoff is needed for erosion risk assessment. The modelling of the erosion process has progressed rapidly, and a variety of models have been developed to predict both runoff and soil loss (Zhang et al. 1996). The authors of this study used the computer - graphic IntErO model (Spalevic, 2011) for prediction of soil erosion intensity and maximum outflow from the catchment area.

The objective of this research was characterization of the erosion processes in relation to the recent state of the runoff and sediment yield in the Nedakusi Watershed of the Polimlje River Basin. The results, consistent with previous researches on the neighbouring river basins, presented in formats that may be further used for the efficient management and protection, illustrating the possibility of modelling sediment yield by the IntErO model.

The objective has been met based on literature review, past experience and field measurements at the Polimlje River Basin. Such detailed set of information about the watersheds areas of this region are important for the development of soil protection strategies in the wider area. We showed that IntErO can be applied for the assessment of soil erosion at the national and/or regional scale and may be a useful tool for similar studies in the southern east Region of Europe.

MATERIAL AND METHODS

Study area

The study was conducted in the area of the Nedakusi River Basin, a left-hand tributary of the river Lim (Figure 1). The basin area lies on the slopes of Torine (828 m a.s.l.) on the west, above the Nedakusi, which is placed on the small flat area on the lower alluvial, close to the inflow of Nedakusi River to the Lim River (553 m a.s.l.).

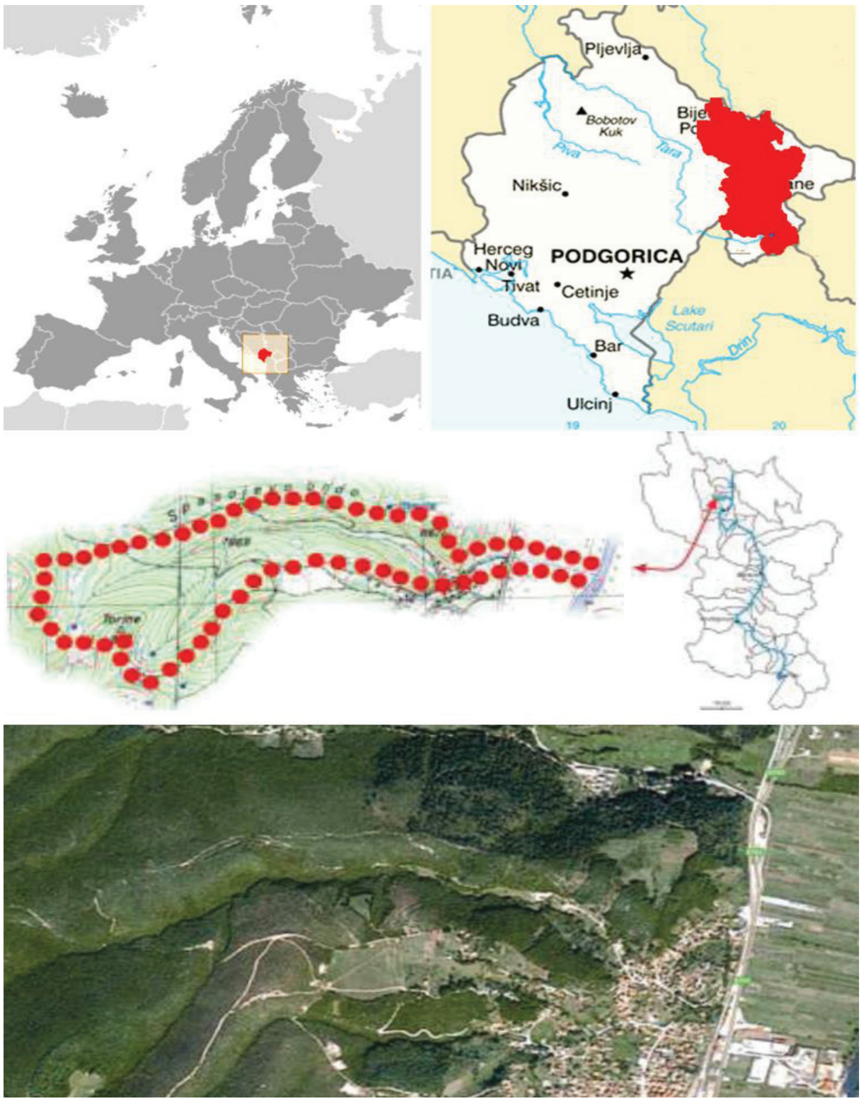

Figure 1. Studied area of the Nedakusi River Basin

The river basin encompasses an area of 3.1 km2 and is categorized in the group of the smallest watersheds of the natural entity of the Polimlje region. The average slope gradient in the river basin, Isr, is calculated on 18%, what indicates that in the river basin prevail medium inclined slopes. The average river basin altitude, Hsr, is calculated on 649.8m; the average elevation difference of the river basin, D, is 96.8m. The natural length of the main watercourse, Lv, is 1.2 km. The shortest distance between the fountainhead and the mouth, Lm, is 1.09 km (source: original).

Soil loss model application.

We used the Intensity of Erosion and Outflow (IntErO) program package (Spalevic, 2011) to obtain data on forecasts of maximum runoff from the basin and soil erosion intensity, with the Erosion potential method (Gavrilovic, 1972) embedded in the algorithm of this computer-graphic method.

This methodology is in use in: Bosnia & Herzegovina, Bulgaria, Croatia, Czech Republic, Italy, Iran, Montenegro, Macedonia, Serbia and Slovenia (Spalevic et al., 2014; Kostadinov et al., 2014). In Montenegro have been successfully used in the Region of Polimlje (Spalevic et al. 2014a, 2014b, 2014d, 2013a, 2013b, 2013c, 2013d, 2013e, 2012).

RESULTS AND DISCUSSION

Climatic characteristics

The climate in the studied area is continental. The absolute maximum air temperature is 37.8°C; the negative temperatures can fall to a minimum of -28.3°C. The average annual air temperature, t0, is 8.9°C. The average annual precipitation, Hyear, is 873.7mm (Source: Data from the Meteorological station Bijelo Polje, Institute of Hydrometeorology of Montenegro). The temperature coefficient of the region, T, is calculated on 0.99.

The geological structure and soil characteristics of the area

Our analysis, using the available data from the Geological Institute of Montenegro and the Geological map of Montenegro (Zivaljevic, 1989), shown that the structure of the river basin, according to bedrock permeability, is the following: f0, poor water permeability rocks, 0.58; fpp, medium permeable rocks, 0.42%. The coefficient of the region's permeability, S1, is calculated on 0.87 (source: original).

The most common soil type in the studied area are Dystric cambisol (60%); Calcomelanosol (40%); with small area of Fluvisol close to the inflow of Nedakusi River to Lim (Fustic and Djuretic, 2000; Spalevic, 2011) (Figure 2).

Figure 2. One of the profiles opened during the field work (Dystric cambisol)

Vegetation and land use

Most of the studied area is covered by beech forests (Fagetum montanum). Fagetum montanum differentiated into several associations of which the most characteristic are Fagetum montanum typicum, Luzulo - Fagion moesiacae, and Fagetum montanum drymetosum. Beech forests are characterized by dense canopy, especially association Fagetum montanum typicum in the upper part of the river basin on the slopes of Torine. Due to intensive harvesting of firewood beech forests near settlements and roads are degraded.

On the southern exposures there are forests of Sessile oak and Turkish oak (Quercetum petraeae-cerridis Lak.). A narrow belt near the river in the lower part of the river basin is covered with hygrophilic forest (Alnetea glutinosae, Salicetea herbacea). These forests are characterized by large number of species. In last decades climate changes affected on forest ecosystems in changes and to some extent movement of the Vegetation vertical layout belts (Curovic and Spalevic, 2010).

The coefficient of the river basin planning, Xa, is calculated on 0.51. The coefficient of the vegetation cover, S2, is calculated on 0.72. Structure of the land use in the Nedakusi River Basin is presented in Figure 3.

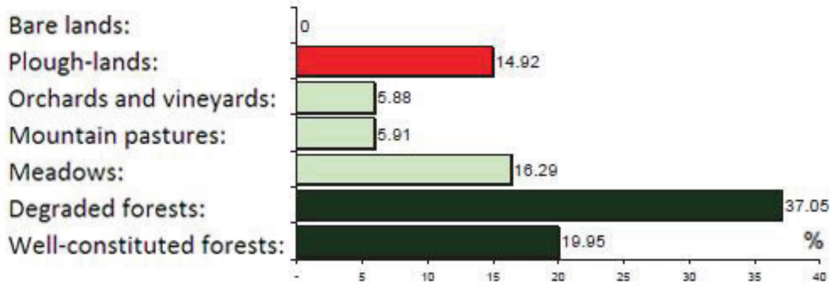

Figure 3. Land use structure of the Nedakusi watershed (%)

Figure 4. View on the Nedakusi placed on the alluvial terrace and an orchard close to the inflow of Nedakusi to the Lim River

Soil erosion and runoff characteristics

The dominant erosion form in this area is surface erosion and has taken place in all the soils on the slopes, with the effect that this erosion is the most pronounced on the steep slopes with scarce vegetation cover (Figure 4). Part of the IntErO report for the Nedakusi watershed is presented in the Listing 1, providing comprehensive summary on soil erosion processes of the studied river basin.

Listing 1. The IntErO report for the River basin: 51 (Nedakusi, 2014)

Input data: River basin area, **F**, is 3.05 km2; The length of the watershed, **O**, is 7.43 km; Natural length of the main watercourse, **Lv,** is 1.17 km; The shortest distance between the fountainhead and mouth, **Lm**, is 1.09 km; The total length of the main watercourse with tributaries of I and II class, **ΣL**, is 1.17 km; River basin length measured by a series of parallel lines, **Lb**, is 2.98 km; The area of the bigger river basin part, **Fv**, is 1.72 km2; The area of the smaller river basin part, **Fm**, is 1.33 km2; Contour line length, **Liz**: 2.24 km; 1.87 km; 1.4 km; The area between the two neighbouring contour lines, **f**: 1.47 km2; 0.66 km2; 0.66 km2; 0.25 km2; Altitude of the first contour line, $\mathbf{h_0}$, is 600 m; Equidistance, **Δh**, is 100 m; The lowest river basin elevation, **Hmin**, is 553 m; The highest river basin elevation, **Hmax**, is 828 m; A part of the river basin consisted of a very permeable products from rocks (limestone, sand, gravel), **fp**, is 0; A part of the river basin area consisted of medium permeable rocks (slates, marls, brownstone), **fpp**, is 0.42; A part of the river basin consisted of poor water permeability rocks (heavy clay, compact eruptive), **fo**, is 0.58; A part of the river basin under forests, **fš**, is 0.57; A part of the river basin under grass, meadows, pastures and orchards, **ft**, is 0.28; A part of the river basin under bare land, plough-land and ground without grass vegetation, **fg**, is 0.15; The volume of the torrent rain, **hb**, is 157.6 mm; Incidence, **Up**, is 100 years; Average annual air temperature, $\mathbf{t_0}$, is 8.9 °C; Average annual precipitation, **Hgod**, is 873.7 mm; Types of soil products and related types, **Y**, is 1.5; River basin planning, coefficient of the river basin planning, **Xa**, is 0.51. Numeral equivalents of visible and clearly exposed erosion process, **φ**, is 0.23.

Results: Coefficient of the river basin form, **A**, is 1.23; Coefficient of the watershed development, **m**, is 0.19; Average river basin width, **B**, is 1.02 km; (A)symmetry of the river basin, **a**, is 0.25; Density of the river network of the basin, **G**, is 0.39; Coefficient of the river basin tortuousness, **K**, is 1.08; Average river basin altitude, **Hsr**, is 649.87 m; Average elevation difference of the river basin, **D**, is 96.87 m; Average river basin decline, **Isr**, is 18.08%; The height of the local erosion base of the river basin, **Hleb**, is 275.00 m; Coefficient of the erosion energy of the river basin's relief, **Er**, is 66.25; Coefficient of the region's permeability, $\mathbf{S_1}$, is 0.87; Coefficient of the vegetation cover, $\mathbf{S_2}$, is 0.72; Analytical presentation of the water retention in inflow, **W**, is 1.7663 m; Energetic potential of water flow during torrent rains, $\mathbf{(2gDF)}^{1/2}$, is 76.10 m km s-1; Maximal outflow from the river basin, **Qmax**, is 103.65 m3 s-1; Temperature coefficient of the region, **T**, is 0.99; Coefficient of the river basin erosion, **Z**, is 0.486; Production of erosion material in the river basin, **Wgod**, is 2822.5948 m3 god-1; Coefficient of the deposit retention, **Ru**, is 0.152; Real soil losses, **Ggod**, is 428.57 m3 god-1; Real soil losses per km2, $\mathbf{Ggod}^{km-2}$, is 140.64 m3 km-2 god-1.

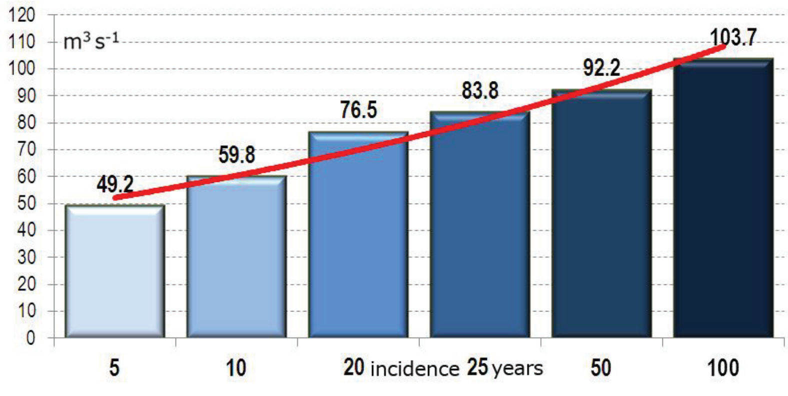

Figure 5. Calculated peak flow of the Nedakusi river basin for the incidence of 5, 10, 20, 25, 50 and 100 years

For the current state of land use, calculated peak flow is 103.7 m3s-1 for a return period of 100 years. Calculated peak flow of the Nedakusi watershed for the incidence of 5, 10, 20, 25, 50 and 100 years is presented on the Figure 5.

CONCLUSIONS

The objective of this research was characterization of the erosion processes in relation to the recent state of the runoff and sediment yield in the Nedakusi Watershed of the Polimlje River Basin. The results, consistent with previous researches on the neighbouring river basins, presented in formats that may be further used for the efficient management and protection, illustrating the possibility of modelling sediment yield by the IntErO model.

Several important facts were suggested by the model results:

- According to our findings, it can be concluded that there is a possibility for large flood waves to appear in the studied Nedakusi river basin;
- The value of G coefficient of 0.39, indicates there is low density of the hydrographic network;
- The value of Z coefficient of 0.486 indicates that the river basin belongs to III destruction category (range: from I to V);
- The strength of the erosion process is medium and according to the erosion type, it is surface erosion;
- Calculated peak flow is 103.7 m3s-1 for a return period of 100 years;
- Real soil losses, Ggod, is 428.57 m3 god-1;
- The value of 140.64 m3 km-2 god-1 indicates, according to Gavrilovic, that the studied river basin is a region of very weak erosion.

The objective has been met based on literature review, past experience and field measurements at the Polimlje River Basin. Such detailed set of information about the watersheds areas of this region are important for the development of soil protection strategies in the wider area. We showed that IntErO can be applied for the assessment of soil erosion at the national and/or regional scale and may be a useful tool for similar studies in the southern east Region of Europe.

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