

Analysis of Soil Erosion Risk in a River Basin – A Case Study from Hogoshti River Basin (Kosovo)

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ABSTRACT

Geological settings, climatic conditions, terrain characteristics especially slope angle and length, climatic condition, land cover and land use, other river system parameters like stream density, bifurcation ratio, stream length, drainage texture etc., are the main factors that contribute to soil erosion and potential risk. Land cover and land use plays an important role in soil erosion risk. Hogoshti River basin lies in eastern part of Kosovo. It is distinguished with two main terrains: hilly mountainous with metamorphic rocks of Neoproterozoic age in north, and plain with terrigenous rocks of young geological age in the south. Continental climate conditions with high intensity rainfall during summer, and a river system with average stream density, high bifurcation values, small values of stream intensity, elongated form of the basin in combination with high distribution in hilly-mountainous areas with seminatural vegetation have indicated dominantly low and moderate erosion risk to the basin, with potential to high rate. The Revised Universal Soil Loss Equation (RUSLE) is an important equation for soil erosion risk. With input of model factors soil erosion risk map was created, and results show that in Hogoshti River basin dominates soils with moderate and low erosion risk. In recent years, the area is depopulated which means land conservation techniques aren't practicing.

Keywords: soil erosion risk, RUSLE model, input factors, river basin indices, Hogoshti River basin

INTRODUCTION

Soil degradation is becoming a significant phenomenon all around the world. It is a serious and widespread problem [Olsson et al., 2019]. The latest estimation worldwide the land degradation is at rate of 33% [Lal, 2015]. Most case the soil erosion is a natural driven process [Khaleidian et al. 2016] and is referred mainly as human caused activity. The ecosystems in the world are altered since the spread of population around the globe [Amundson et al. 2015]. And, the changes in human landscape have occurred with adoption of agriculture [Guo et al., 2003]. Soils are suffering from biological production which in main cases is caused by anthropogenic and natural factors, or both of them [Nearing et al., 2017]. Land degradation happens when nature's capacity of restoration is exceeded by degradation process. Physical, chemical and biological properties of

the soil is often characterized by depletion of its quality. Based on the level of agricultural production, using of heavy techniques for agricultural land, management practiced etc., land degradation has its own temporal and spatial scales of development [Summary - Flash Flood Risk Assessment, 2012].

Different soil erosion models have been made with the main idea for high accuracy estimation. RUSLE model [Revised Universal Soil Loss Equation) is considered a simple and is used largely for estimation and soil erosion prediction. This model is evaluated as acceptable accuracy [Beskow et al. 2009]. RUSLE model provides estimation on soil displacement by water erosion.

River basins are used as areas for assessment of soils vulnerability to erosion, by taking into consideration its topographical features. Ozsoy et al. [2012], Prasannakumar et al. [2012], and Zhang et al. [2013] stated that the assessment

of the vulnerability of soils to erosion like river basins, can be made with the RUSLE model as its topographic factor was reformulated, improving the representativeness of it in basin's scale. However, it requires the use of tools able to collect, store, manipulate and display spatial data [Durães & de Mello, 2013]. Therefore, a Geographical Information System (GIS) has been used, especially by applying the technique of map algorithms [Ozsoy et al., 2012, Pradhan et al., 2012]. This technique has produced good results with the application of RUSLE, developing maps with the average spatial distribution of soil losses and its subsequent interpretation in the context of natural vulnerability. Different models predict that the average soil erosion has increased by 2.5% based on evaluation from 2001, and the main factor is assessed to be in land use changes [Borrelli et al., 2017].

Kosovo is situated in Balkan Peninsula and its relief is mostly hilly-mountainous [Ramadani and Bytyqi 2018]. In geological setting, Kosovo is made with different formations ranging from Precambrian until the Quaternary, and is divided in different zones, where most of them belongs to Dinaric arc of the mountains. The eastern part of Kosovo belongs to Dardania Massif [Pruthi 2013]. Territory of Kosovo is characterized by significant hypsometry ranging until 2658 m. It is individualized with different morphological units, and various genetic landforms [Pruthi, 2013]. Most of country has continental climatic conditions, with rainfall distribution to summer months which are intensive [Pillana, 2015].

The assessment of soil erosion and vulnerability in river catchment has a high importance for Kosovo, which in the future will apply broad research to estimate the values in other parts of the country as well. Because Kosovo is considered a country with dominantly hilly-mountainous, soil erosion calculations and potential conservations practice need to be considered as future plans and strategies to protects soils from erosion.

Nowadays hilly-mountainous areas in Kosovo are facing population migration towards plains [Bytyqi and Ramadani, 2017]. The abandoned areas are covered with forest and shrubs, and lately used by population as biomass and energy production for single houses. Thus, with the absence of soil management practices land degradation phenomenon is increased.

Systematic observations for soil erosion in Kosovo have been made during the 70s of last century, where the studies were finalized with Soil

Erosion Map [Erosion map of Kosovo, 1983]. Areas in map were described with isolines which present the annual average values of soil erosion in main river basin. Since then, many changes have happened in hilly mountainous areas, especially human migration, which in RUSLE model plays a role as an important factor by apply different soil conservation practices.

The paper presents an approach to a river basin where RUSLE model is used in combination with GIS/RS technique in order to made an assessment of soil erosion risk.

MATERIALS AND METHODS

Different models have been used to made assessment of soil erosion. In our case, the Revised Universal Soil Loss Equation (RUSLE) is used to estimate the annual soil loss in average, and Hogoshti River basin (Kosovo) was used as assessment area. The river basin is chosen because it lies in two different morphological unit, and represents two different areas where RUSLE factors are very different, and land use have different approach. The GIS/RS techniques provides an important tool to assess and evaluate the values obtained through the equation. Digital Elevation Model with 12.5 m pixel facing (downloaded in: asf.alaska.edu), orthoimages of different years were used and field studies were carried out. Geological, soil, erosion and land cover maps produced in the 80-s were used to identify the main features and to compare with our study results. Every element/factor is assessed individually, and the results in several parameters, which resulted with creation of different thematic maps.

RUSLE equation is described as follow:

$$A = R \times K \times LS \times C \times P \quad (1)$$

where: A – represents soil loss ($\text{tones} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$), R – is the erosivity from rainfalls ($\text{MJ} \cdot \text{mm} \cdot \text{ha}^{-1} \cdot \text{h}^{-1} \cdot \text{yr}^{-1}$), K – is erodibility of soil ($\text{t} \cdot \text{h} \cdot \text{MJ}^{-1} \cdot \text{mm}^{-1}$); LS – the topographic factor (–), C – represents the soil use and management factor (–), P – is calculated by soil conservation practice by locals and is an important factor (–).

The rainfall erosivity (R) shows the potential of rain which can cause soil erosion from exposed surfaces, especially from unprotected, and is a product for a consecutive 30-minute intense rainfall (EI30) [Zhang et al., 2013, Ballabio et al.,

2017]. The assessment of the climatic conditions of potential soil loss was carried out using factor of energy and rainfall intensity that are reflected in the erosion hazard using relative indices or rainfall erosion index (REI) [Dudiak et al., 2019]. Due to lack of detailed rainfall records for the river basin, many authors correlate the EI_{30} with the Modified Fournier Index (MFI), whose rainfall erosivity value can be obtained based on monthly and annual precipitation data set. In a basin with continental climate, the rainfall pattern shows the distribution mostly in summer, and is associated with high intensity rains with great potential of erosivity [Pllana, 2013].

The soil erodibility (K) is intrinsic susceptibility of the soil to erosion, which is a function of its pedologic, physical, and chemical characteristics of the soils, such as percentage of silt and sand, structure, permeability, organic matter, parental material and others [Ozsoy et al., 2012, Pradhan et al., 2012]. Soil erodibility values is most difficult factor in RUSLE model to determine [Wang and Su, 2020]. Typical values for soil erodibility range from about 0.10 for soils with high clay content, to 0.45 for soils with prevalent sand content. The interaction between physical and biological processes of stabilization and destabilization occurs within particles. These processes have a threshold for their occurrence and are a function of hydrogeological features and geobiological characteristics of the area [Covelli et al., 2020], in our case of river basin. The hilly-mountainous terrain in Hogoshti River basin consists of metamorphic rocks that are more resistant as the sedimentary rocks (clastic) in the plain areas. Land cover plays an important role in soil erodibility. The upper part of the river basin has a thin soil cover, but without using the conservation practice and deforestation soil erosion is more at risk.

In addition, in this model, LS factor takes into account the effects of topographical factors (slope, curvature, aspect) [Zhang et al., 2013]. Slope, curvature, and aspect values were obtained from DEM (asf.alaska.edu). The values were calculated using GIS software (ArcGIS and QGIS).

Land cover plays an important role in the field, and its management (land use) is very important, which can fasten or slow the soil erosion rate. The C factor can be managed due to soil conservation practice, and further to reduce the erosion in the slopes. There is a new situation created in Hogoshti River basin, it's all because of migration

towards plain, but the lack of humans to control the land cover and land use has led to changes in soil conservation practices (P). Recently, through cadastral areas of abandoned settlements, trees and shrubs are deforested for heating, especially with lack of control from authorities.

Soil conservation practice (P) is another input factor in RUSLE model. It is a dimensionless factor, and it varies from 0–1, and the show the ability of land management practice can reduce the soil erosion. As most of the river basins shows no erosion control practices, the factor was considered to be equal to 1 [Beskow et al., 2009, [Ozcan et al., 2008, Panagos et al., 2015]. The P values decreases by adopting soil conservation practices. Human influence in P factor in very important, because the erosion control is a local activity which can be held by farmers. By applying certain field practices along contours, the runoff erosion will be smaller. In Hogoshti River basin are few anti-erosion practices or rather extensive interventions such as planting, stone walls as engineering practices to slow down the river speed and to control the gully erosion. In recent years there are enormous number of inhabitants which have left the hilly-mountainous settlements and settle down in the flat areas or in the cities, which means fewer practices in the field.

RESULTS AND DISCUSSION

The study site for this paper is Hogoshti River basin which lies in eastern part of Kosovo, and belongs to Kamenica municipality (latitude 42.6°N; longitude 21.6°E) with a basin area of 94.5 km². The area of interest consists of two geological units: Dardania Massif in the north which has rocks of Neoproterozoic age consisting of metagranitic rocks, biotite gneiss, migmatic rocks, amphibolite and micaschist gneiss with an area coverage of 77% of basin; these rocks have low permeability, high stream density, with infiltration speed of 10⁻⁹ m/s. Southern part of river basin belongs to Kamenica basin, and consists of young rocks mostly of Middle Miocene age represented with marlstone and tuffstone, and calcareous flysch. Through the river banks can be found alluvium and some proluvium. These rocks have fissure and intergranular porosity with 10⁻⁵–10⁻⁹ m/s. [Terzin et al. 1976]

Tectonic settings have determined the morphographic features of the basin. The north part

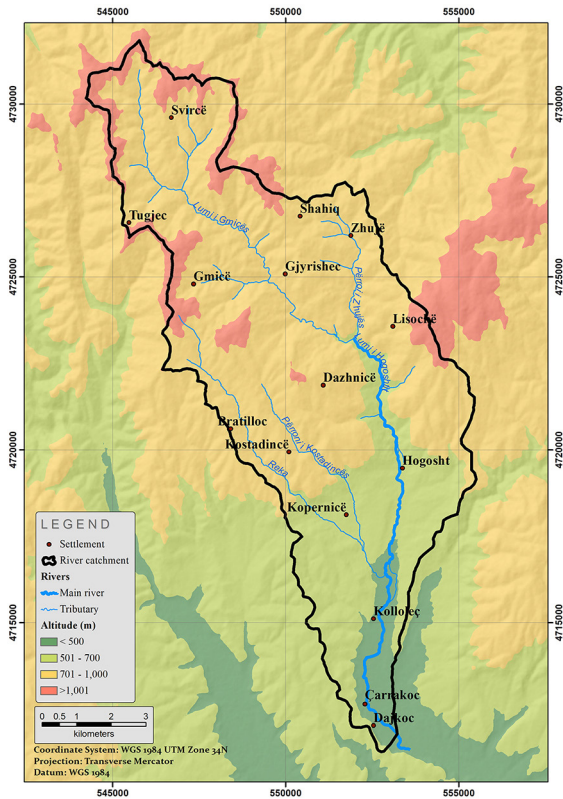


Fig. 1. Physiographic map of Hogoshti River basin

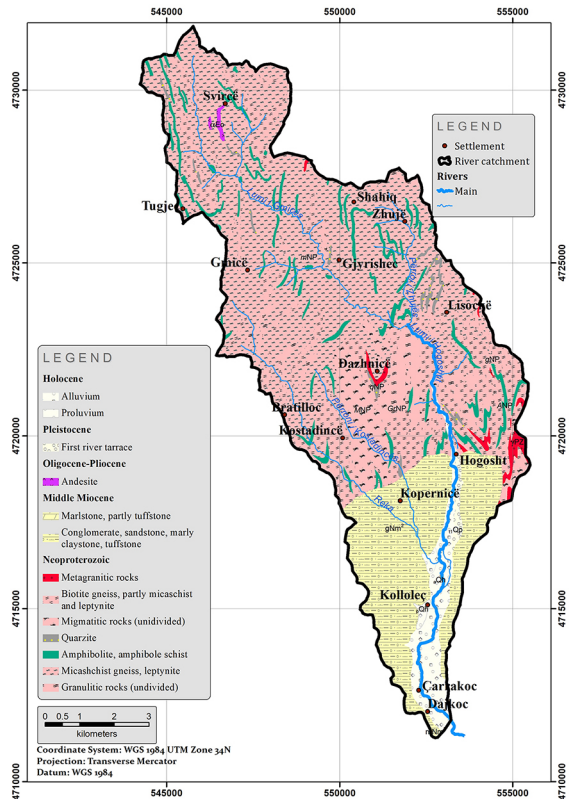


Fig. 2. Lithological map of Hogoshti River basin

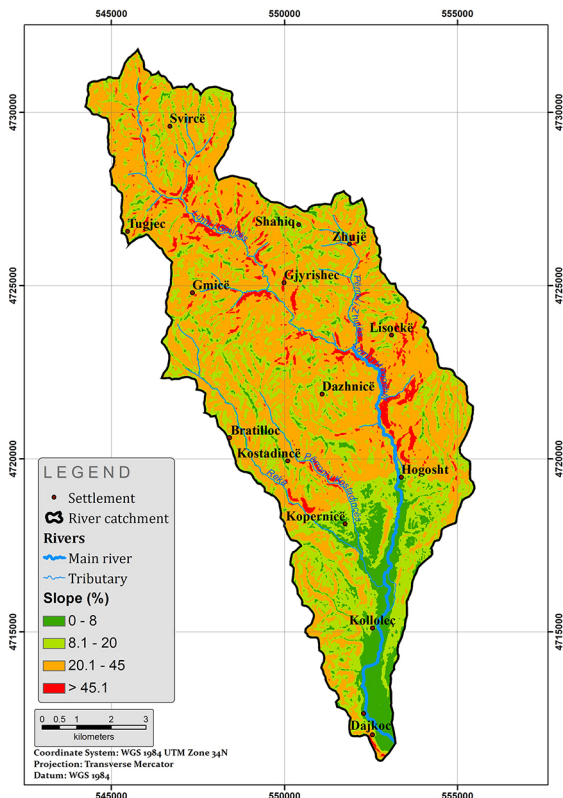


Fig. 3. Slope map of Hogoshti River basin

of basin with an area of 71.4% is considered as hilly-mountainous with altitude above 700 m a.s.l., only 5.1% of total area is plain with altitude

from 463–500 m a.s.l. The plain lies in southern part of basin and belongs to downfaulted block of Kamenica basin (tectonic graben). The basin has an average altitude of 738 m, which is calculated using DEM.

Climate is continental with more rains in the summer, and less in the winter. Temporary and spatially variable of low precipitation appears in the basin, with rainfall under 600 mm/y. Most of the basin has rainfall above 800 mm/y, and the lowest areas has rainfall between 600–700 mm/y. [Map of rainfalls and temperature, 1983]. By calculating with Thiessen polygons, the mean annual rainfall of the river basin is 771 mm/y. Temperature is calculated from the nearest weather station in Kamenica which show an annual temperature of 10.4 °C, with months like January with negative values. For the northern part which is mostly hilly mountainous average annual varies between 8 °C and 9 °C. Because of large continentality scale some years encounter semi-arid conditions.

The R values are estimated by using data from the nearest weather stations. Since in the river basin doesn't have any stations, the values are calculated by interpolation using IDW (Inverse Distance Weight). K is a quantitative indicator which is based on the soil texture. Soil texture in an important factor which indicate the intensity of

Table 1. Altitude classes in Hogoshti River basin

Altitude	Description	Area (km ²)	Percent of basin, %
< 500	Plain	4.8	5.10
501-700	Hilly	22.2	23.50
701-1000	Hilly-mountainous	60	63.40
> 1001	Mountainous	7.5	8.00
Total		94.5	100.00



Fig. 4. Southern part of Hogoshti River basin

erosion. Typical values for soil erodibility range from about 0.10 for soils with high clay content, to 0.45 for soils with prevalent sand content. LS values are ranging from 0 to 4.98. The biggest values are found on first tributaries of the main rivers and also in the upper part of the basin. But the main areas remain the upper sectors of main tributaries, which are eroded by rainfalls. Land use values (C) are determined by CORINE land cover map of Kosovo [Mbulueshmëria e tokës në Kosovë, 2018]. According to the data, more than the half of Hogoshti River basin is covered by deciduous forest which lies in the upper part of basin in hilly-mountainous areas. Shrubs covers 15%, and only 18.5% is land used for complex pattern and agriculture, and 9.8% are agricultural lands without irrigation system. Most of the basins consists of vertisols whom they cover the hilly mountainous areas of the basin. Alluviosols lies through the river banks, not far than 200 m from the river. Erosion in the past has washed the soils, making them shallow horizons with low quality soils [KPPM, 2006]. P values ranging from 0–1. Zero means good conservation practice and 1 means inadequate measures against erosion. Based on population data in the latest year the area is depopulating and the conservation practiced aren't happening. Deforestation can speed up the erosion in the field.

Some other indicator that contributes to erosion are also the number of streams, the length of the streams, bifurcation ratio. The numbers of rivers

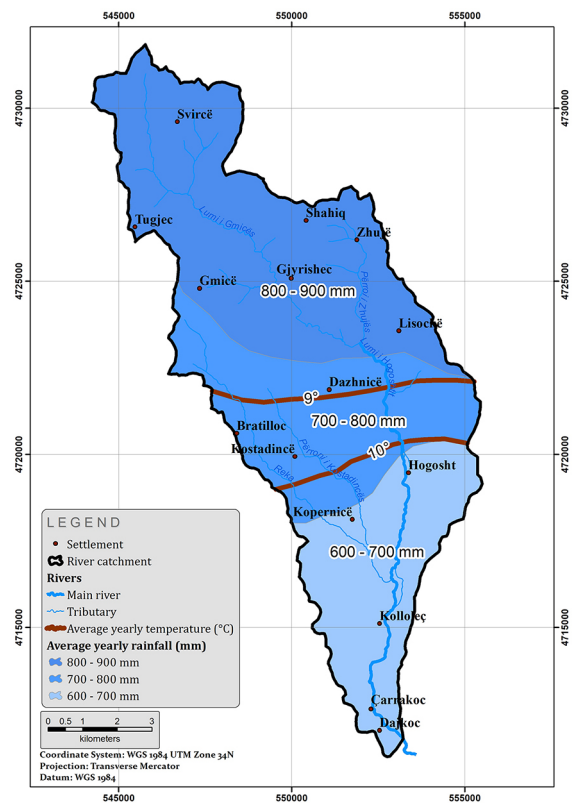


Fig. 5. Temperature and rainfalls in Hogoshti River basin

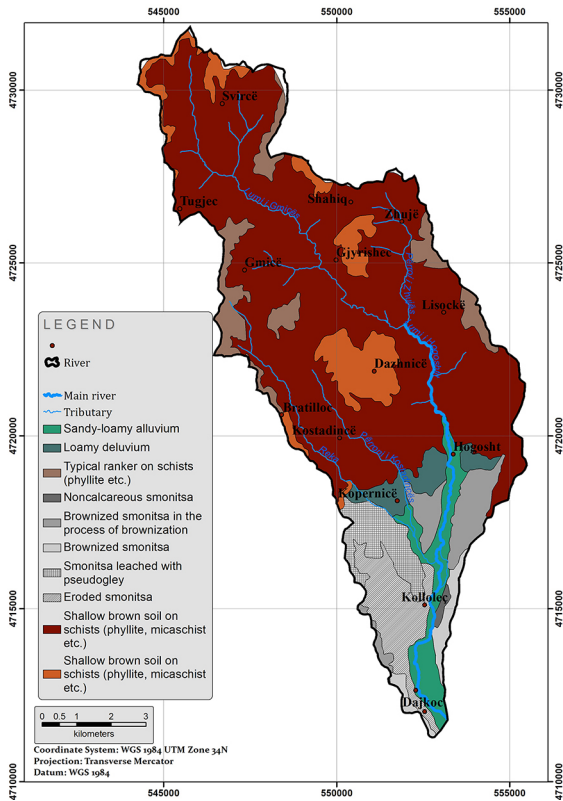


Fig. 6. Soil types in Hogoshti River basin

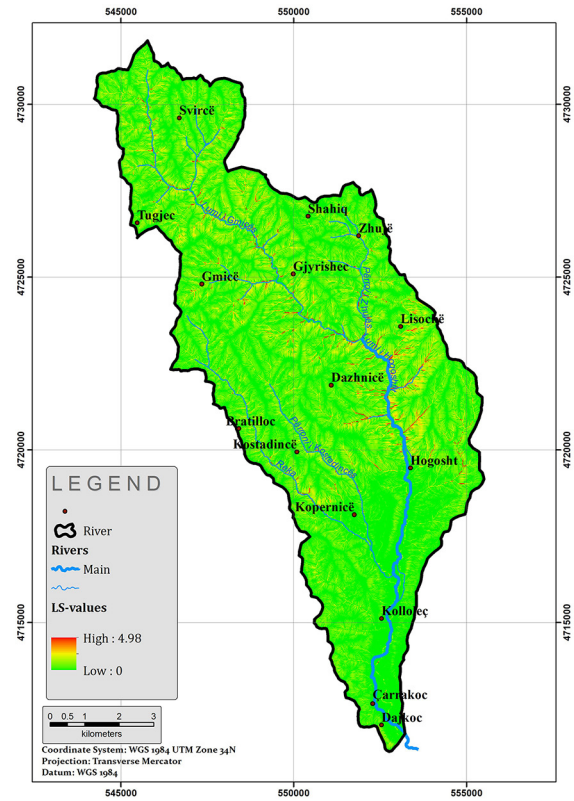


Fig. 7. Length and slope values

segments are related to rainfalls in the river basin. In Hogoshti River basin are 265 river segments with 201.7 km of long, with main river being 25.8 km long. Drainage density also contributes to soil erosion. Horton found that the regions with high rainfall values have bigger drainage density and erosion rate is high. Average drainage density in Hogoshti River basin is 1.9 km/km², with 2.32 km/km² in upper course of the river and 1.87 km/km² in lower course of the river. According to Flash Flood Risk Assessment over Kosovo [Flash Flood Risk Assessment over Kosovo, 2012]. Hogoshti River basin belongs to an area with high potential of flash floods, especially in lower part of the river. And based on bifurcation ratio of the streams (average 18.5 – very high), the high values indicate high potential for flash floods, because high number of low order streams discharge in short time of high intensity rains a lot of water which can't flow through river bed, and floods happens.

The total numbers of streams make drainage texture. In early stages of erosion makes, the drainage texture tends to be coarse, and in maturity age of basin it tends to be finest. If in the area of basin are found soft or weak rocks, and if they are uncovered by vegetation, it produces a fine texture, whereas massive and resistant rocks

(which are found in the northern part of basin) produce a coarse texture. The finer textures from sparse vegetation in arid climates compared to the same rocks in another climate (i.e., humid climate). Drainage texture for Hogoshti River basin is 4.45. High drainage texture means low infiltration, low permeability, and high stream density, which fits with metamorphic rocks in the basin. And, low drainage texture is suitable to coarse grained rocks with high permeability and infiltration rate which as a consequence is low stream density with small erosion rate.

Drainage intensity plays an important role in erosion. Based on calculation from topographic map of scale 1:25000, Hogoshti River basin has a value of 1.33.

Erosion rate in Kosovo terrains was made with final compilation of a map during the 80-s which estimates that the Hogoshti River basin belongs to “high (2.000 m³/km²/y) and very high (3.500 m³/km²/y) category of soil erosion” which consists mostly in hilly mountainous areas, and “weak (1.000 m³/km²/y) and very weak (400 m³/km²/y) category of soil erosion” [Erosion map of Kosovo 1983]. River basin has an average rainfall between 800–900 mm, with and continental regime with most of the rainfall occurs in summer season.

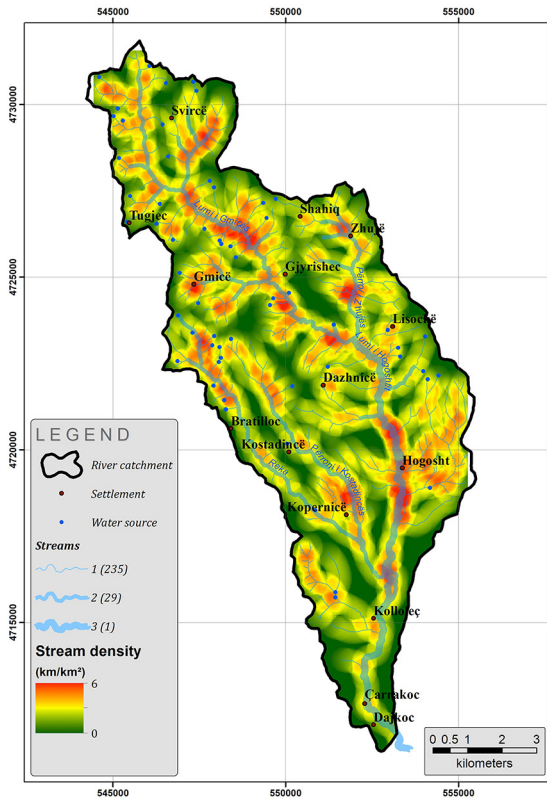


Fig 8. Stream density in Hogoshti River basin

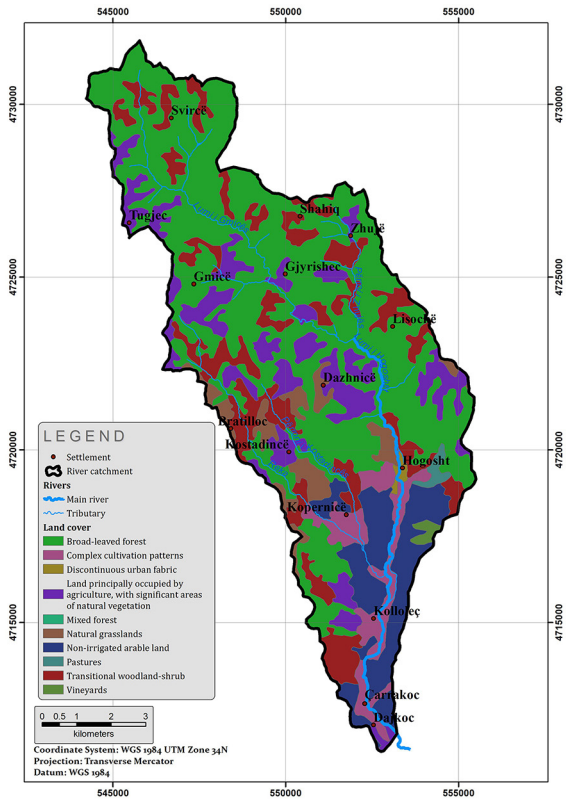


Fig. 9. Land cover map

Based on field observations and calculation made according to RUSLE model, the river basin map for soil erosion risk is created and soil erosion category are determined. Slope features (steepness and length) play an important role in soil loss. Run-off velocity is increased with steepness of slope, as it does in slope length. With slope increase surface waters will find the path to reduce infiltration and speed soil erosion. Extreme and high values of soil erosion risk are found in steep slopes, especially with sparse vegetation, and are covering in total 16.3% of basin's area (8.1 km²). The slopes are not even steep but also long with slopes, and as a result of forest degradation, the soil erosion is increased.

Most of the terrains have moderate soil erosion risk which consist of 45.8% of total area of the basin. Those areas are in hilly mountainous regions with low slope angle and are spread on smooth ridges which are stream divides. The slopes have pastures or sparse vegetation, and as seen in the field the land cover plays an important role on soil erosion. With human migration the slopes haven't the maintenance that was made before, and therefore the conservation practice are missing.

Low rate of soil erosion risk areas in hilly-mountainous terrains are found on the top of smooth ridges, at the bottom of stream valleys, and most of them are found in southern part of



Fig. 10. Soil erosion practice in the basin slopes

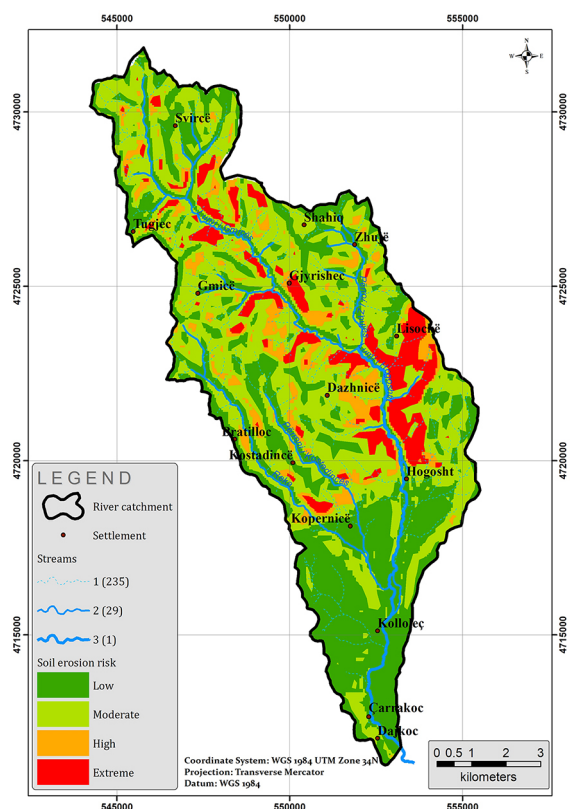


Fig. 11. Soil erosion categories in Hogoshti River basin

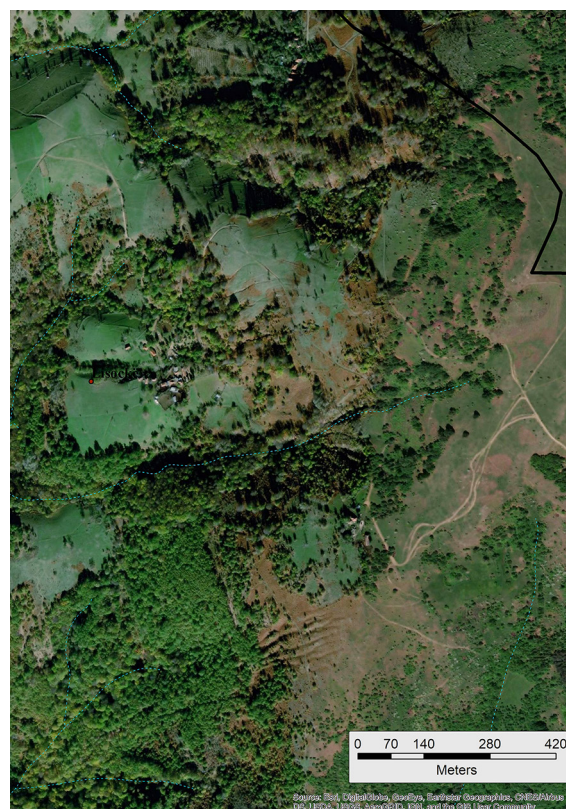


Fig. 12. An example of extreme soil erosion risk

Table 2. Soil erosion categories in Hogoshti River basin

Soil erosion risk category	Soil erosion risk (km ²)	Percentile, %
Extreme	8.1	8.60
High	7.3	7.70
Moderate	43.2	45.80
Low	35.8	37.90
	94.5	100.00

river basin, which belong to Kamenica plain. They are low angle slopes which consist of areas with land use for agricultural production, where soil conservation practices are found.

Soil erosion practices are made in the past in Hogoshti River basin. Engineering structures can be found in the field, but nowadays they lack in maintenance. For the future, other engineering practice should introduce in order to minimize the soil erosion even in areas where most of population have migrated.

CONCLUSIONS

Soil erosion risk in Hogoshti River basin was carried out using different GIS/RS techniques and

analysis on some variables calculated in order to determine the potential zone for the future land conservation and protection. Even the basin is lithologically characterized mostly with metamorphic rocks which are very resistant, steep slopes, deforested slope, weathered rocks are mostly exposed to soil erosion. Based on RUSLE model calculation, 45.8% of river basin has moderate soil erosion risk, 37.9% has low erosion risk, and 16.3% has high and extreme erosion risk. High and extreme erosion risk zones are found in steep and long slopes, deforested slopes, and in recent years with migration of population, soil erosion risk will increase because of the lack of conservation practices.

Sustainable land management should be involved in reducing the soil erosion risk. Forestation, engineering practices, terracing and other land conservation practices should be made in order to slow down the rate of erosion in the basin. The assessment of soil erosion and vulnerability in river catchment has a high importance for Kosovo, which in the future will apply broad research to estimate the values in other parts of the country as well. Because Kosovo is considered a country with dominantly hilly-mountainous soil

erosion calculations and potential conservations practice need to be considered as future plans and strategies to protects soils from erosion.

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