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SPATIAL ESTIMATION OF SOIL EROSION USING GEOSPATIAL TECHNIQUE – A CASE STUDY OF JANJEVA RIVER CATCHMENT (KOSOVO)

Valbon BYTYQI[1], & Tropikë AGAJ[2]
[1]*Department of Geography, FMNS, University of Pristina, Kosovo. orcid.org/0000-0002-8625-1470*
[2]*Poznan University of Life Sciences, Email: tropikaagaj@gmail.com (Corresponding author); orcid.org/0000-0001-8154-7013*

Abstract: The aim of the study is to analyse the spatial estimation of soil erosion in a small size river catchment of Janjeva (Kosovo). Soil erosion is becoming a serious threat and its spatial estimation is crucial for soil resource protection and management. The Revised Universal Soil Loss Equation (RUSLE) methodology integrated with GIS techniques was applied to estimate the annual erosion rate. Different datasets including open-source data were used to find main components of soil erosion. The results show different soil erosion classes depending on lithological settings, landforms, climate conditions, soil properties, land cover and soil conservation practices. By calculating RUSLE parameters for Janjeva River catchment (84 km^2), we found out that mean annual erosion rate is 1 t·ha^{-1}·yr^{-1}. Erosion rate class <5 t·ha^{-1}·yr^{-1} dominates the catchment's area with 92.5%, while other classes have 7.5% of catchments total area. Highest rates of soil erosion are found in volcanic rocks, steep slopes and soils without conservation practices. Soils located in western part of the catchment with adequate conservation practice have minimum erosion rate.

Keywords: land degradation, soil erosion; RUSLE model, input factors, Janjeva River catchment, Kosovo.

1. INTRODUCTION

Land degradation is a process influencing many activities and its quantitative assessment is very important (Panagos et al., 2015a). As a complex process, soil erosion contributes to the loss of soil production capacity (Várallya, 1987). Obviously as a process, it may occur in a short period of time, whereas, the final stage is the loss of soil capacity to produce agricultural products. Early assessment means adequate soil conservation practices.

With the increase of human population worldwide (Amundson et al., 2015), land degradation has become a significant phenomenon and widespread problem (Olsson et al., 2019), with nearly 1/3 of land degraded in planetary scale (Lal, 2015). In nature, land degradation is driven by natural processes and factors on Earth's surface, whereas, by human implications the process is accelerated. However, in most the cases, both factors act simultaneously (Nearing et al., 2017). During the 20th century, with anthropogenic activities like increase of agricultural production, urbanization, deforestation, and extreme weather events, land degradation has accelerated, where its biological production has been altered, and nature's capacity for restoration has been exceeded.

As soil degrades, soil erosion increases. Quantitative assessment of soil erosion is made by different models. Most used are USLE (Universal Soil Loss Equation, 1979) and RUSLE (Revised Universal Soil Loss Equation, 1997), which provide high-accuracy estimation, with acceptable results (Beskow et al., 2009).

A river catchment as main hydrographic unit is considered an area where natural processes are driven by surface and river erosion. Ozsoy et al., (2012), Prasannakumar et al., (2012), and Zhang et al., (2013), in their observation and quantitative assessment of soil erosion, stated that the RUSLE model showed good results in river basins' scale. However, the application of the model requires taking into consideration a lot of spatial data (Durães & De Mello, 2013), which can be carried out by applying GIS/RS techniques (Ozsoy et al., 2012; Pradhan et al., 2012). Application of different soil erosion models from 2001 predicted an increase of 2.5% of soil erosion in the world, and is attributed to land use changes (Borrelli et al., 2017). By integrating GIS techniques with open access data, the application of the RUSLE model, soil erosion can be estimated, whereas, the results serve as good tool to adapt the conservation practices for soil protection.

In Kosovo, systematic observations of soil erosion began in the 1970s of last century which resulted with compilation of first erosion map (Erosion map of Kosovo, 1983). Later, soil erosion assessments were made in small river catchment (Agaj & Bytyqi, 2022), municipality level (Maliqi et al., 2023). Other authors have analysed soil erosion as a process that affects sustainable use of agriculture land (Ramadani & Bytyqi, 2018), etc. As a country with small areas of agricultural land per capita, the assessment of soil erosion and its vulnerability is of high importance. Recently, in the hilly-mountainous terrains as the dominant landforms, there are abandoned representing regressive settlements, whereas conservation practices are absenting. With this study, we are presenting an approach of using the RUSLE model as a tool for the assessment of soil erosion in a small river catchment.

2. STUDY AREA AND METHODOLOGY

2.1. Study area

Kosovo is a landlocked country in the central part of the Balkan Peninsula. It is distinguished by a variety of geological formations, from Precambrian age to the youngest Quaternary age. Most of the country's territory belongs to the Dinaric arc of mountains (Pruthi, 2013a; Elezaj & Kodra, 2007). Even though the country has a small area (10,905 km²), it has a diverse morphology, consisting of tectonic plains surrounded by mid- to high-altitude mountains in its border zone (Pruthib, 2013). Since the beginning of the Upper Miocene until the present day, neotectonic movements have been very active. Along numerous fractures, tectonic movements have been restored and together with new fractures, subdividing the territory of Kosovo into blocks with deca- to hectokilometric size (Jovanović, 1975). The dominance of blocked tectonics in Kosovo has influenced the distribution of main rivers and their tributaries. While the main rivers have central position in plains, the tributaries have developed elongated shape catchments, like Janjeva River. Landforms hypsometry of the country varies from tectonic plains (400-600 m) to the high mountain ranges located in Kosovo's borders (Rudoka, 2,658 m), whereas most of the its area has continental climate featured with impact of Mediterranean air masses in the west (Pllana, 2015; Peneva et al., 2023). Mountainous terrains are distinguished by the cold climate with high amount of rainfall, dense drainage network and dissected relief.

As the study site is chosen Janjeva River catchment (84 km²). Characterized by two morphological units: Kosovo plain in the west and Eastern Mountains in the east, the river has developed an elongated river basin. The main river is a right tributary of the Sitnica River, which flows towards the Black Sea (Figure 1).

In a geological context, the Janjeva River catchment is located in the External and Central Vardari Subzone and consists of three geological units: Kosovo Cenozoic basin in the west with unconsolidated rocks (sand, clay and gravel), Gadime metamorphic unit with orthoschists, Badoc/Kishnica Cenozoic volcanic complex (andesite), and Vardar Lower Cretaceous flysch trough in the east (Elezaj & Kodra, 2006) (Figure 2). Two main morphological units are characterized by different geological settings, morphometric features, and different soil types. The western flat part of the catchment consists mainly of unconsolidated rocks, gently undulated (Figure 3), low drainage density, and vertisols (smonitsa) soil type, whereas alluvisols are found as small elongated patches through rivers valleys. Toward east hard rocks, strong and steep sloping, deep river valleys are dominating the catchment, whereas cambisols are main soil type. Land cover of the area is represented by deciduous forests and semi natural vegetation (Figure 4).

The average altitude of the catchment is 742 m, lower than Kosovo's mean altitude (807 m). Under 700 m altitude lies 50% of the catchments' area, 33.3% is between altitude class 701-900 m, and above 900 m are about 16.7% of the catchments' area. Altitude classes have different natural conditions indicating soil erosion rates.

Located in continental climate condition, through the catchment isotherm of 9°C and 10°C are found, whereas the yearly rainfall amount is 619 mm (Pllana, 2015). However, towards the east, rainfall amount increases to 700 mm (Map of rainfalls and temperature, 1983). Rainfall belongs to continental regime, nearly equally distributed in seasons, with summers distinguished by intensive rainfall accompanied by hail.

2.2 Materials and methods

Soil erosion assessment is carried out with various models, but the Revised Universal Soil Loss Equation (RUSLE) is the most frequently used. RUSLE is an empirical base approach to calculate the yearly rate of soil erosion (Saha et al., 2022). For the purpose of the analyses, different data are used. Digital Elevation Model with 10 m spatial resolution was used to calculate slope and altitude values. Soil map with 1:50,000 scale is used to determine main soil types distributed in the catchment, whereas geological map of scale 1:100,000 is used to interpret lithological settings. Rainfall data for Janjeva weather station, and Map of rainfall and air temperature are used to find rainfall values for the whole catchment. Whereas, land cover and land use data for the year 2018 downloaded from European Environment Agency are used to find main land use types over catchment (Table 1).

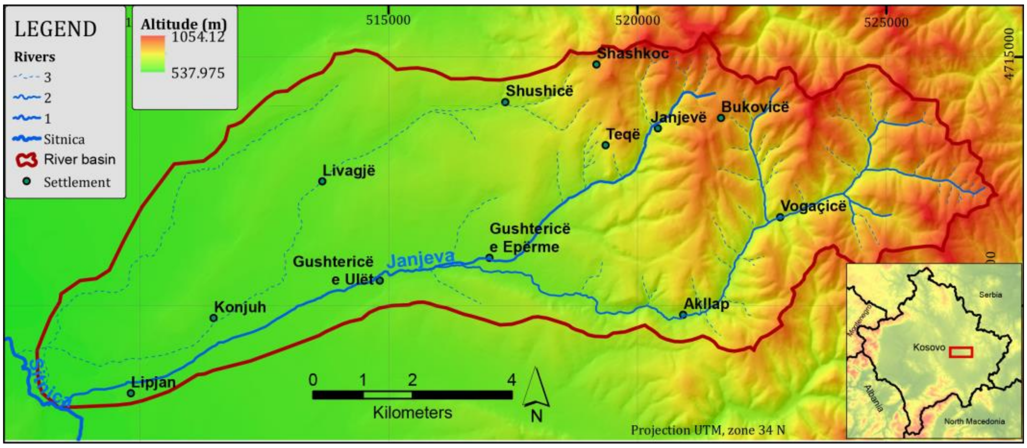

Figure 1. Location and physiographic map of the Janjeva River catchment

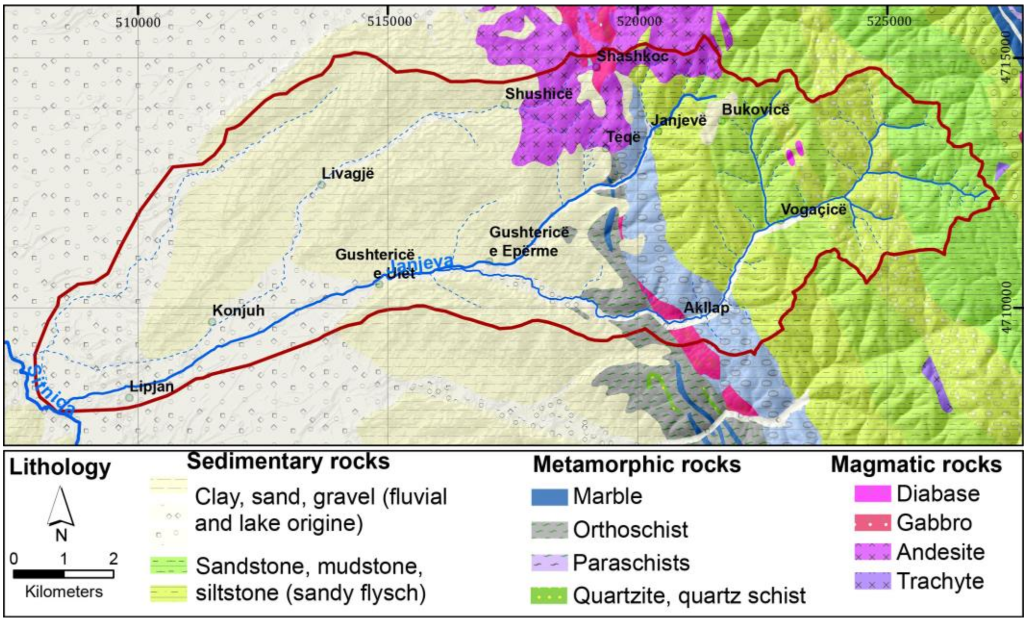

Figure 2. Lithological map of the Janjeva River catchment

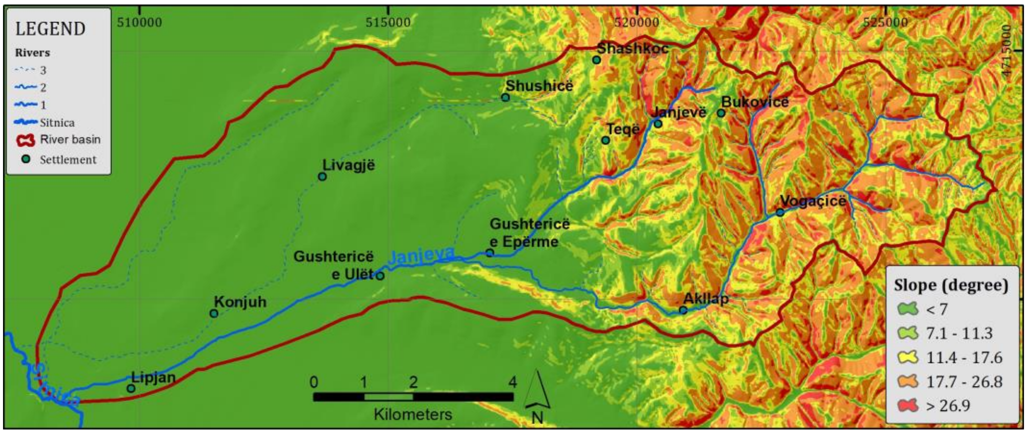

Figure 3. Slope map of the Janjeva River catchment

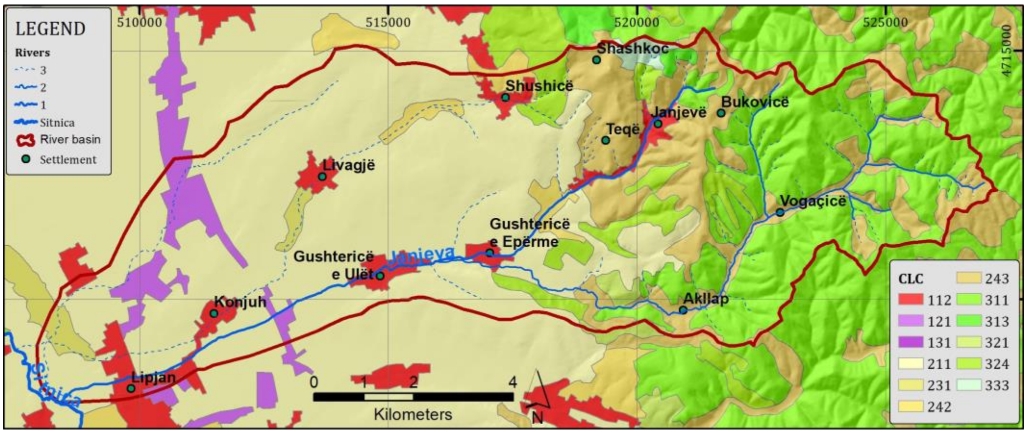

Figure 4. Land cover map of the Janjeva River catchment

Table 1. List of datasets used for calculation in RUSLE model

Data/maps	Resolution or scale	Source of dataset
DEM	10 m	Kosovo Cadastral Agency
Soil map	1:50,000	
Soil texture	250 m	soilgrids.org
Geology	1:100,000	KPMM
Rainfall data	1:200,000	Map of rainfalls and temperature of Kosovo
Land cover/land use	100 m	Copernicus Land Monitoring Service

All the assessments of RUSLE parameters were made using GIS/RS techniques, with ArcMap 10.8 as the primary evaluation tool for collecting, analysing, and representing different thematic maps.

In order to obtain the results from RUSLE model, the flow methodology has to be followed. Firstly, based on topographic map of scale 1:25,000 the catchment was delineated. A DEM with 10 m spatial resolution was filled to remove sinks and imperfections. Flow direction and flow accumulation was done to find the flow direction and its accumulation downslope, where the LS values were found. Based on the satellite images from Copernicus Satellites, the Land Cover was clipped. As secondary data, rainfalls, soil management practice and soil types were used to complete the RUSLE equation. All the data were intersected to find the soil erosion rates in the Janjeva catchment (Figure 5).

RUSLE equation has several parameters (Renard et al., 1997), which include climate and survey database, where using precipitation data and DEM model are necessary to compute erosivity factor (R), slope length, and steepness factor (LS); land cover to calculate cover management and practice controlling factor; and soil data especially soil texture to calculate erodibility factor. RUSLE is described by equation:

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

Where: A - soil loss ($t \cdot ha^{-1} \cdot yr^{-1}$), R – rainfall erosivity ($MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot yr^{-1}$), K – soil erodibility ($t \cdot h \cdot MJ^{-1} \cdot mm^{-1}$); LS – length and slope factor (dimensionless), C - soil use and management factor (dimensionless), P - soil conservation practice by locals (dimensionless).

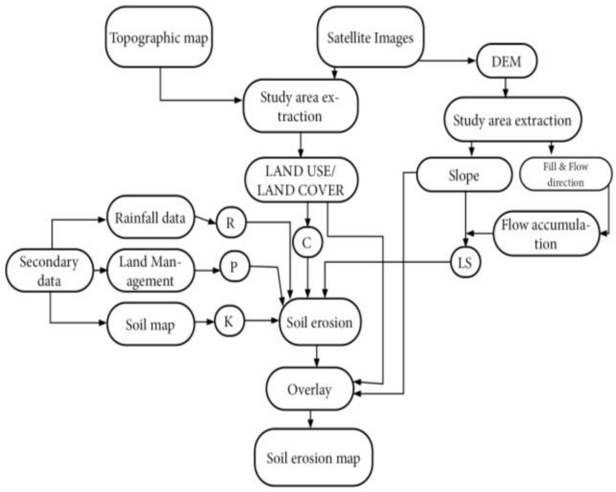

Figure 5. Flow chart methodology

3. RESULTS AND DISCUSSION

The rainfall erosivity (R) is one of the main parameters of RUSLE equation, which plays an essential role showing the potential of rain to cause soil erosion from exposed surfaces, especially unprotected. It is considered a product of a consecutive 30-minute intense rainfall (EI30) (Zhang et al., 2013; Ballabio et al., 2017). Rocks' reaction to rainfall erosivity depends on rock/soil type, where unprotected rocks/soils have a high possibility of being eroded and vice-versa. Some authors have proposed the correlation of EI30 with the Modified Fournier Index (MFI) in regions or catchments lacking detailed rainfall records. In these cases, rainfall erosivity can be calculated based on monthly and annual precipitation values as we did in our analyses. Rainfall erosivity for Janjeva catchment is calculated using yearly existing rainfall data with a formula proposed by Renard & Freimund (1994). Furthermore, it is applicable in a location where the mean annual precipitation is less than 850 mm.

$$R = 0.0483 * P^{1.61} \quad (2)$$

Rainfall erosivity values in the Janjeva River catchment range between 1,377 to 2,326, with highest values found in the eastern hilly-mountainous part of the catchment, which receives yearly, annual amount of rainfall of 800 mm, while the lowest values or rainfall erosivity are found in the western part of catchment (Figure 6).

Soil erodibility (K) factor is key component in the RUSLE model, which measures the susceptible soil types and their particles to be detached and transported by rainfall and runoff. While the soil erodibility factor is dependent from soil types, the K-factor values are influenced by soil texture and structure, organic matter, and permeability of soil profile (Erencin et al., 2000). The K-factor is the intrinsic susceptibility of the soil to erosion, which is a function of soil properties (Ozsoy et al., 2012; Pradhan et al., 2012). It is one of the most challenging factors to estimate in a model (Wang & Su, 2020). In soils with a high content of clay, soil erodibility values ranges from 0.05-0.15, but in soils with prevalent content of sand, the value is about 0.45. Destabilization of particles has a threshold for their occurrence and is a function of the area's hydrogeological features and geobiological characteristics (Covelli et al., 2020). Soil characteristics in the Janjeva River catchment have different evolutions, which show different K-values (Figure 7). The percentage of sand, silt, clay, and organic carbon are the main components of soil in response to soil erodibility. The clay percentage in flat slopes of Janjeva catchment is high (30-40%), while in eastern hilly-mountainous soils have low values (20-25%), while the distribution of sand percentage is vice versa. Soil erodibility factor in the Janjeva River catchment is calculated with formulas described by Williams Equation (1995) and FAO soil:

$$K = F_{sand} * F_{si-cl} * F_{orgc} * F_{hisand} * 0.1317 \quad (3)$$

And individual formulas are:

$$F_{sand} = \left(0.2 + 0.3 \cdot exp\left[-0.256 \cdot m_{sand} \cdot \left(1 - \frac{m_{silt}}{100}\right)\right]\right) \quad (4)$$

$$F_{clay} = \left(\frac{m_{silt}}{m_{clay} + m_{silt}}\right)^{0.3} \quad (5)$$

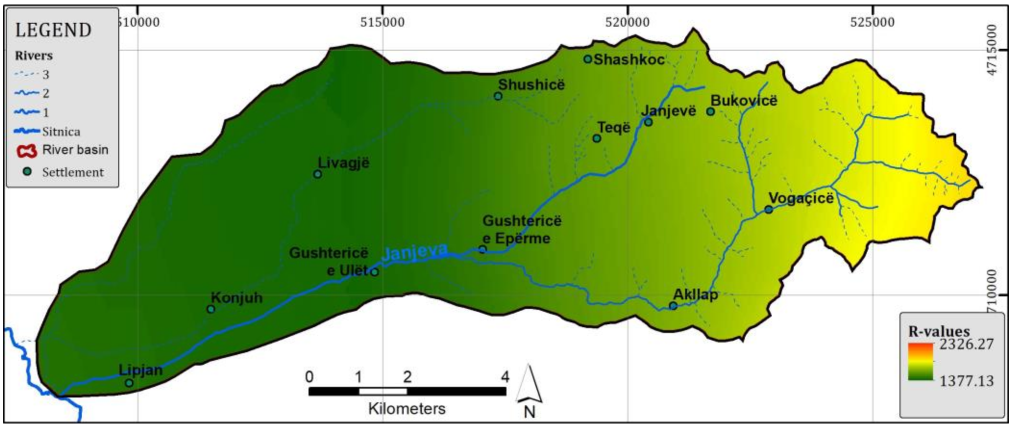

Figure 6. Map of R-values in the Janjeva River catchment

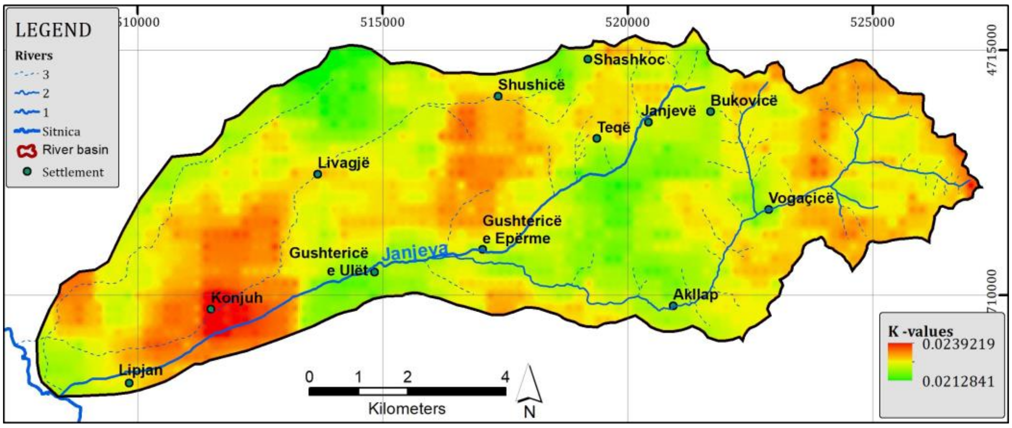

Figure 7. Map of K-values in the Janjeva River catchment

$$F_{orgC} = \left(1 - \frac{0.256 \cdot orgC}{orgC + exp[3.72 - 2.95 \cdot orgC]}\right) \quad (6)$$

$$F_{silt} = \left(1 - \frac{0.7\left(1 - \frac{m_{sand}}{100}\right)}{\left(1 - \frac{m_{sand}}{100}\right) + exp\left[-5.51 + 22.9\left(1 - \frac{m_{sand}}{100}\right)\right]}\right) \quad (7)$$

Where: m_{sand} is proportion of sand content (%); m_{silt} is proportion of silt content (%); m_{clay} is proportion of clay content (%); orgC is amount of organic carbon of the layer (%)

Soil erodibility values for Janjeva River catchment range between 0.0239 and 0.0212. The highest values are found throughout the valleys, and surface water divide between perennial streams. High soil erodibility values in valleys of the eastern part are associated with the slope steepness, while lowest values in western part are indicated by soil texture composed with loose sediments. Slopes values have played an important role in soil texture. In the eastern part of the catchment, soil has more sand, whereas in the west flat and gentle slopes are more clayey.

In the RUSLE model, the **LS factor** takes into consideration the effects of topographical factors (slope, curvature, aspect) (Zhang et al., 2013), where two components are analysed: length factor (L) and slope steepness factor (S). LS is considered to be a crucial factor in the quantification of erosion due to surface runoff (Alexakis et al., 2013). By using the ArcMap 10.8 software, slope, curvature, and aspect values for the Janjeva River catchment were obtained from the Digital Elevation Model with 10 m spatial resolution. Firstly, the DEM was filled to calculate the flow accumulation and flow direction. Slope and slope length factor were calculated by a formula proposed by Moore & Burch (1986) which contains a simplified equation using unit contributing area, generating the effects of surface runoff in soil loss:

$$L = \left(\frac{A_s}{22.13}\right)^{0.4} \quad (8)$$

$$S = \left(\frac{sin\beta}{0.0896}\right)^{1.3} \quad (9)$$

Where: A_s – specific contributing area (m^2/m)

β – slope angles (degrees)

LS factor is an indicator to predict soil deposition. The mapping of the LS factor (length and slope factor) has been conducted in European Union Countries (Panagos, 2015b) with a DEM of 25-m spatial resolution. The results show that high LS-factor values are observed in countries with a high percentage of mountainous areas, such as the Alps, Apennines, Carpathian, and Pindos. Countries characterized by flat topography have lowest LS-factor values.

Janjeva River is a small catchment that is located in hilly-mountainous areas in the east, and flat and gentle slopes of Kosovo plain in the west. Different landforms in the catchment have the LS-factor values ranging from 0 to 369 (Figure 8). The highest values are found in the upper part of the river catchment, especially in the floodplain and other valley of main tributaries.

Cover Management Factor (C) reflects the effects of cropping, where land cover plays an essential role in the field. Management practices are very important factor which affects soil erosion rate. It is dimensionless factor, and C-values ranges between 0 and 1, whereas lowest values indicate cover (protected) soil, while higher values indicate uncover with significant chances of soil loss.

Janjeva River catchment is located in two types of landforms, indicating different types of land cover. Western part of the catchment has agricultural land with high fertility rate, whereas eastern part of river catchment is mostly hilly-mountainous where population migration was very intensive in last decades, meaning the absence of soil conservation practice and intense soil erosion process. C-values were calculated based on literature indicated by land cover type (Lastoria et al., 2008). Forests in general have C-values of 0.004, pastures 0.05, whereas these two categories cover 20.5% of catchment total area. One of biggest classes of land cover is non-irrigated arable land that covers 47.7% of catchment's area indicating the highest

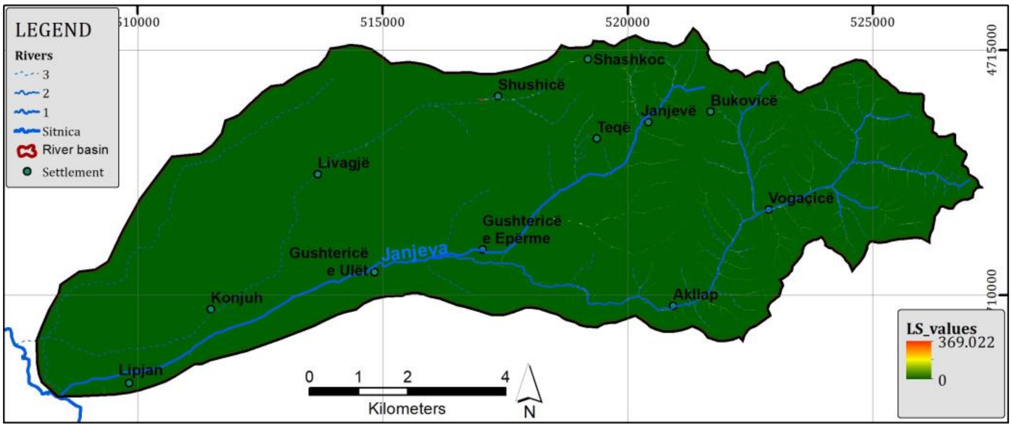

Figure 8. Map of LS-values in the Janjeva River catchment

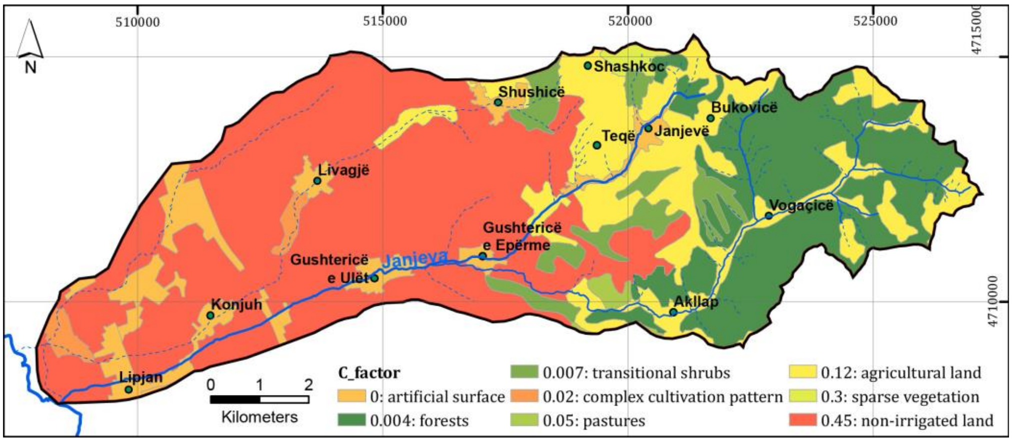

Figure 9. Map of cover management factor for the Janjeva River catchment

values of C-factor (Table 2). However, those classes, due to agriculture, have soil erosion control practices. The other category with lowest values is transitional shrubs covering 4.5% of the area (Figure 9).

Table 2. C-factor for different land cover classes

C-factor	Description	Area (ha)
0.000	Artificial surface	659.5
0.004	Forests	1,676.1
0.007	Transitional shrub	391.4
0.020	Complex cultivation pattern	96.0
0.050	Pastures	48.1
0.120	Agricultural land	1,476.4
0.300	Sparse vegetation	51.9
0.450	Non-irrigated land	4,010.9

Soil conservation practice (P) is the last of five input factors in the RUSLE model. It is a dimensionless factor which takes into account soil and water conservation measures in order to reduce soil erosion, and values varies between 0 and 1. Most river catchment areas show no erosion control practices, and the P-factor is considered equal to 1 (Beskow et al., 2009; Panagos et al., 2015). Different soil erosion control practices which include soil protection measures, reduces the P-value towards 0. P-factor values were calculated after Shin (1999), which takes into account the slope degree, which are main component of cultivating methods in slope conditions. Soil erosion control practices in the upper part of the Janjeva River catchment are not applicable because of population migration, whereas in agricultural land in flat and gentle slopes contour farming is applicable.

Land use values (C) are an essential factor in RUSLE equation. Land Use are as the results of interaction between human activities and conservation practices. C-values are determined by using the CORINE land cover map of Kosovo (Mbulueshmëria e tokës në Kosovë, 2018) and are compared with Land use data produced by Copernicus Land Monitoring Service. Agricultural lands are dominating the flat gentle slopes of western part, and nowadays are used for agricultural production. Their presence is related to high land capability soils, flat slopes, and agricultural machinery used for farming. Most of the settlements are found there. The eastern part of the river catchment is covered with deciduous and mixed forest, with some pasture above volcanic rocks. Irrigation lands have C-values of 0.45, whereas pastures, complex cultivation patterns, and other agricultural land have values between 0.02-0.12, and forest with transition zone or shrubs have 0.004-0.007 values.

Factors analysed in RUSLE model show different soil erosion classes in Janjeva catchment. As a model that incorporates several factors, using the GIS/RS technique makes it possible to calculate the variables to determine yearly soil erosion rates and future measures for conservation and protection to maintain its sustainable use of land.

The study reveals that most of the catchment's area lies in erosion rate class <5 t·ha^{-1}·yr^{-1}, where 7,783 ha of the catchment are found (Table 3). These are soils located in western part of the catchment, in flat slopes of Kosovo plain, with soil conservation practice like contour farming. The second class has soil erosion rates between 5-10 t·ha^{-1}·yr^{-1} and covers nearly 5% of catchment areas. Other subsequently classes cover small areas of the catchment.

Table 3. Erosion rate classes in Janjeva River catchment

Soil erosion classes (t·ha^{-1}·yr^{-1})	Area (ha)	%
< 5	7,783.42	92.48
5-10	418.93	4.98
10-15	103.37	1.23
15-20	37.09	0.44
20-25	25.54	0.30
>25	48.03	0.57
	8,416.38	**100.00**

According to soil erosion rates, scientist have agreed to determine the "tolerable" soil loss (TSL), as indicator to establish quantitative standards to measure the effectiveness of strategies and control erosion technique (Di Stefano et al., 2023). According to the Organization for Economic Co-operation and Development (OECD), have proposed a TSL value lower than 6 $t \cdot ha^{-1} \cdot yr^{-1}$, while Bazzoffi (2008) proposed halt of the OECD value (3 $t \cdot ha^{-1} \cdot yr^{-1}$), which in our study lies most of the catchment's area.

If soil loss estimates are mostly below 5 $t \cdot ha^{-1} \cdot yr^{-1}$, it suggests that soil erosion is quite moderate in the Janjeva watershed. Nevertheless, the significance of this degree of soil erosion is contingent upon several aspects, including the specific objectives of land use, environmental sensitivity, and long-term sustainability goals. From a certain standpoint, soil erosion rates that are below 5 t/ha*year may be seen acceptable or even preferable in specific situations, especially if they are in line with sustainable land management goals and do not jeopardise soil fertility, water purity, or the health of the ecosystem. Under these circumstances, the rates of soil erosion may fall within tolerable thresholds that are necessary for preserving soil health and sustaining agricultural productivity. Nevertheless, it is crucial to acknowledge that even apparently minimal rates of soil erosion can result in gradual and lasting effects on soil fertility, land productivity, and environmental quality. Thus, although soil loss values below 5 $t \cdot ha^{-1} \cdot yr^{-1}$ may not signify an immediate crisis, they should nonetheless be closely monitored and controlled to prevent erosion from worsening over time and resulting in negative consequences. Furthermore, it is essential to take into account the spatial distribution of soil erosion rates within the watershed. Although the average soil loss is often less than 5 $t \cdot ha^{-1} \cdot yr^{-1}$, some regions with higher erosion rates may still provide substantial difficulties and necessitate focused conservation efforts to address erosion and prevent soil degradation.

The modelled results compared to older data (Erosion map of Kosovo, 1983), and nearby catchment (Bed and sediment load erosion in main rivers in Kosovo, 2018), shows similar results, even there are limitations in resolution and scale, while bed and sediment load are measures in a river with a dam in it. Former data described for the catchment and divided in class, show the presence of erosion rates between 6-30 $t \cdot ha^{-1} \cdot yr^{-1}$, which are also detected by the application of RUSLE model, even in climate conditions in Kosovo.

The method is based on certain assumptions and correlations, such as calculating the erosivity of rainfall by using monthly and annual precipitation values in cases when precise rainfall records are not available. This may lead to mistakes, as it does not explicitly quantify the erosive nature of specific rainfall occurrences. Estimating soil erodibility values is difficult because of the intricate interaction between components such as soil texture, structure, organic content, and permeability. Differences in these factors throughout the catchment can impact the precision of soil erodibility estimations. The strategy presupposes specific land cover and management practices, which may not consistently correspond to the real conditions on the terrain. The presence of diverse land cover and management techniques within the catchment area may lead to uncertainties in the modelling outcomes. The technique may not adequately capture the spatial and temporal heterogeneity shown by soil erosion processes. Modifications in land utilisation, soil characteristics, and climate trends over a period of time may impact the precision of the simulated outcomes. Validation and calibration of the method using observed soil erosion data may be necessary to enhance accuracy and reliability. Insufficient validation may result in uncertainties regarding the estimated soil erosion rates. The process entails the amalgamation of diverse inputs and characteristics, each of which may possess its own uncertainties and restrictions. Dealing with the intricacy of these inputs can present difficulties in implementing and understanding the model. Due to variations in local physical conditions and land management techniques, it is necessary to make adjustments and contextualise the modelling methodology in order to accurately represent the specific local circumstances within the catchment area.

The determination of the precise threshold at which soil erosion becomes a substantial issue relies on multiple elements, such as land use goals, environmental vulnerability, and regulatory criteria. Although there is no universally agreed-upon threshold that applies to all cases, various parameters and benchmarks are routinely utilised to evaluate soil erosion rates and their consequences. Soil erosion rates that exceed 5 $t \cdot ha^{-1} \cdot yr^{-1}$are often seen as a reason to worry and may indicate the need for intervention. This threshold serves as a standard for sustainable soil management practices and is established on the assumption that soil loss beyond this level can result in the deterioration of soil productivity, depletion of topsoil, decline in water quality, and reduction of ecosystem services. Nevertheless, the importance of soil erosion rates above 5 $t \cdot ha^{-1} \cdot yr^{-1}$can differ based on variables such as land use, soil properties, slope steepness, and climate conditions. In locations with significant susceptibility to erosion or in environmentally fragile landscapes, even very low erosion rates can have harmful consequences and require rapid action.

Even the RUSLE model is worldwide accepted soil erosion methods, its limitations in terms of data validation, the complexity of erosion processes, sensitivity to scale and erosion should be considered when using it. The method simplifies the complexity of soil erosion, but in other hand, it is a useful tool to make an approximate assessment for further soil erosion control measures to be implemented in the field. Even though, the factors have a temporal change, like land cover and land use, climatic changes in terms of rainfall distribution, RUSLE is a good tool to make soil erosion assessment. Further study needs to take into account more data, like rainfalls, land use data, to present soil erosion rates in high resolution data, where the control measures can be implemented.

The modelled findings (Figure 10) are not actual observations, but rather estimations derived from empirical equations, data inputs, and assumptions inherent in the modelling process. The results offer interesting insights into probable soil erosion patterns within the Janjeva catchment. However, it is important to understand them as representations rather than actual observations of reality. Verification by comparison with empirical data and on-site measurements is essential to establish the precision and dependability of the simulated outcomes. Hence, although the modelled outcomes have useful prediction abilities, they should be seen as theoretical constructs that need to be validated and improved by empirical validation and continuous monitoring efforts.

4. CONCLUSIONS

The present study aimed at analysing different contributing factors in soil erosion. Janjeva River catchment was chosen because it represents a catchment model that has similar natural features with other small catchments throughout Kosovo. The study aims to establish a framework to identify soil erosion intensity in relation to parameters, topography, geological settings, land cover, demographic and agricultural practices. The analysed parameters in RUSLE equation shows the most contributing factors in soil erosion. By analysing them, we found that most of catchment's area lies under low values of erosion rates (1 $t \cdot ha^{-1} \cdot yr^{-1}$), the differences being created with different land cover, length and slope steepness, soil conservation practices etc.

The intricate nature of the Janjeva catchment's geographical terrain, which includes a variety of topographical features, land use patterns, soil compositions, and climatic fluctuations, requires careful modifications to the modelling approach. It is essential to include these specific local geographical conditions in the model framework in order to achieve a thorough comprehension of soil erosion dynamics. The improved model will provide more precise evaluations of soil erosion rates by considering the complexities of the catchment's topography, land cover, soil properties, and climate patterns. Hence, it will offer significant perspectives for formulating focused and contextually appropriate conservation strategies with the goal of safeguarding the integrity of the catchment's soil resources. Our study can serve as basis of understanding of soil erosion pattern over small catchments, while it can be used for other catchments to determine the patterns of soil erosion and apply soil protection practices, encouraging policymakers and responsible authorities to provide a baseline for sustainable land management. This approach shows great potential to use in other catchments with the aim of identifying

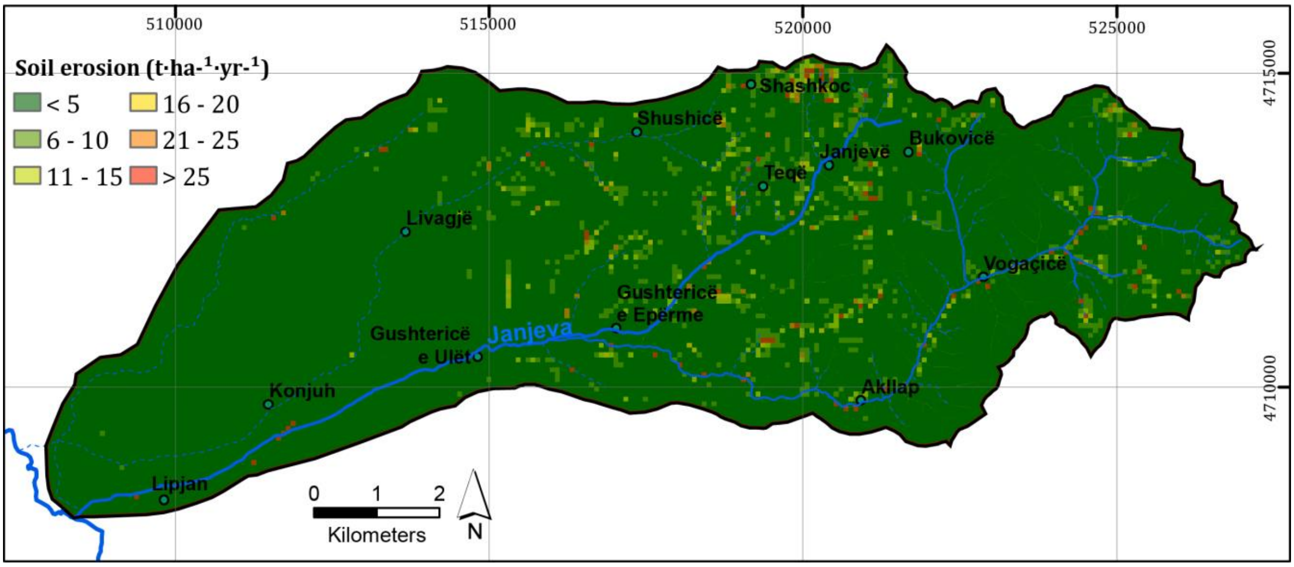

Figure 10. Soil erosion map of the Janjeva River catchment

potential risk areas. As socio-economic conditions could be changed, future analyses need to take into consideration their dynamics and apply measures for soil protection. Future monitoring could be implemented with usage of satellite images and new land cover/land use data to identify spatial and temporal changes.

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