RESEARCH ARTICLE (Open Access)

Estimated and measured soil loss in a sub-watershed of Ulza watershed (Estimated and measured soil loss in a sub-watershed)

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Abstract

Soil erosion is a serious threat to soil productivity and water quality in central part of Albania, where agriculture is applied on sloping land. In some sub-watersheds of Ulza watershed soil erosion has changed the soil chemical properties, particularly phosphorus and potassium levels. About 26% of agricultural land is cultivated with maize and 18% of local farmers conduct tillage along the *s*lope direction. Estimation of soil loss is useful in planning and conservation actions at the basin or watershed level. This study aims to compare estimated and measured soil loss values at sub-watershed level in Ulza watershed (Bulqizë). This was performed using soil loss data obtained by integrating RUSLE and GIS tools with C-factor values computed experimentally using monitoring erosion plots installed under different land cover and slope categories. The estimated rainfall erosivity (R), soil erodibilty (K), topography (LS) and land use/land cover (C) factors ranged from 135.6 to 177.3 MJ mm ha^{-1} h^{-1} y^{-1}, 0.39 to 0.56(t ha h)/(ha MJ mm), 0.029-339.7) and 0 to 0.075, respectively. Preliminary results indicated that the estimated potential mean annual soil loss is 24.12 t· ha^{-1} y^{-1} or aproximately 17% lower than soil loss measured on the erosion plots. This means that the RUSLE model applied to Ulza watershed conditions provides an underestimation of soil loss when is applied at small scale (sub-watershed level). Therefore, in the RUSLE model is better to use the K and R factors obtained from experimental measurements instead of using emprirical models developed in other studies.

Keywords: Soil loss; RUSLE model; GIS; experimental erosion plot; Ulza watershed.

1. Introduction

According to Oldeman [4], about 1094 mln ha of land areaffected by water erosion and 549 mln ha by wind erosion. In Albania, 350,000 ha of land are prone to water erosion and 14,000 ha are prone to wind erosion [10].Some areas have already been ruined. In several sub-watersheds of Ulza watershed soil erosion has reportedly changed the soil chemical properties, particularly phosphorus and potassium parameters. About 26% of agricultural land is cultivated with maize and 18% of local farmers conduct tillage along the *s*lope direction. Meanwhile, soil conservation practices are lacking in the entire Mati River Basin or farmers are not paying attention. Estimation of soil loss is useful in planning and conservation actions in the basin or watershed level. Although the RUSLE, as a quantitative method for assessment of soil erosion, gives detailed information on soil erosion risks [11], it does not provides specific information on the sediment yield from watersheds[14]. In Albania, recent studies on soil erosion have been carried out using the RUSLE model and erosion plots installed under different categories of land covers and slopes. But a comparison of results obtained by these two methods has not been performed yet. It is hypothesized that the use of the RUSLE model with C-factor computed experimentally, provides compatible data to those experimentally measured for the conditions of Ulza watershed. Therefore, this paper presents the preliminary results of a study aimed at comparing the measured values of soil loss through erosion plots with those modeled by RUSLE at small scale (sub-watershed level) at Ulza watershed (Bulqizë).

2. Material and Methods

2.1. Study area

Study area is a small sub-watershed inside the Mati River Basin, with an area of 2916 ha. The land cover is dominated by beech forests accounted to 1240 ha, followed by degraded areas (274 ha), mineral extraction sites (33 ha) and water bodies (37 ha). Land cover includes broad-leaved forest (beech), sclerophyllous vegetation, coniferous forests (siver fir) and herbaceous vegetation. Between 2000 and 2017, the area covered by coniferous and broad-leaved forests is declined, while transitional woodland/shrub forests area have been increased. During the field survey we didn't notice erosion control measures such as terraces, afforestation of steep slopes, etc.
The study area has a Mediterranean hilly climate in the lower parts and a Mediterranean Mountainous climate in the high elevation areas. The mean annual rainfall is 1128 mm, the mean temperature is 11.2°C and the potential evaporation is 794 mm. The geology of the area is mainly harzburgite - iherzolite and dunite with the formation of deep soils rich in clay. The local topography is characterized by slopes of varying lengths, where the predominant slope is from 31 to 40% and the average height is 1459.53 m above sea level (m a.s.l). The topography of the sub-watershed is mainly convex with steep slopes on the both sides. Such characteristics of the landscape increase the water runoff and their transportation. For these reasons, rill and gully erosions forms were present in the study area. The soils of the region are Vertic Cambisol, Haplic Cambisol, Dystric Cambisol and Haplic Luvisol, with the first two being the most prevalent in the study sub-basin.

2.2. Methods

To estimate the potential soil loss we applied the Revised Universal Soil Loss Equation (RUSLE) model because the study area is characterized by a very complex landscape configuration. The RUSLE model enable to estimate the gross erosion (the sum of rill erosion and inter-rill erosion) using the following equation [7].

$$A = R \cdot K \cdot LS \cdot P \cdot C$$

where:
A-annual soil loss (t ha^{-1} $year^{-1}$); R-rainfall erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}); K-soil erodibility factor (t ha h)/(ha MJ mm); LS-length-slope factor (dimensionless), C-land use/cover factor (dimensionless), P-support practice factor (dimensionless).
RUSLE parameters are generated by annual rainfall data from the CRU TS 3.24 climate dataset (R Facor), soil types and properties (K Factor), digital elevation model-DEM (LS Factor), soil loss data and other paremeters of erosion plots (C Factor). The P factor is selected 1.0 because in the area there is no agriculture land and management practices are not applied. Another apporach to estimate the soil loss was by using monitoring erosion plots. Monitoring of erosion process was carried out at 20 m^2 erosion plots under natural rainfall conditions (Figure 1).

Figure 1. Monitoring erosion plots installed in beech forests of the study area

Sample plots have been established based on three slope classes (1-20, 21-40 and >41%) and four land use categories (forest, degraded forest, pasture, bare land).

3. Results and Discussion

3.1. Estimation of soil erosion parameters

The RUSLE parameters are determined and respective data are estimated using different apporaches. Thus Rainfall erosivity factor (R) was estimated using the following equation because the data on rainfall intensity are not available for the study area. This equation gives the relationship between mean annual rainfall and rainfall erosivity factor [5].

$$R = I_{30} (9.28 P - 8383) / 1000$$

where:

I_{30} = 75 mm / h (value recommended by Wischmeier); P = average annual precipitation (mm) over the last 35years. Annual rainfall data over the last 35 years were provided from the CRU TS 3.24 climate dataset from the nearby rainfall stations within the study area. Considering the rainfall dataquite uniform in the study area the R values estimated ranged135.6 to177.3 (MJ mm/ha/h) (Figure 2).

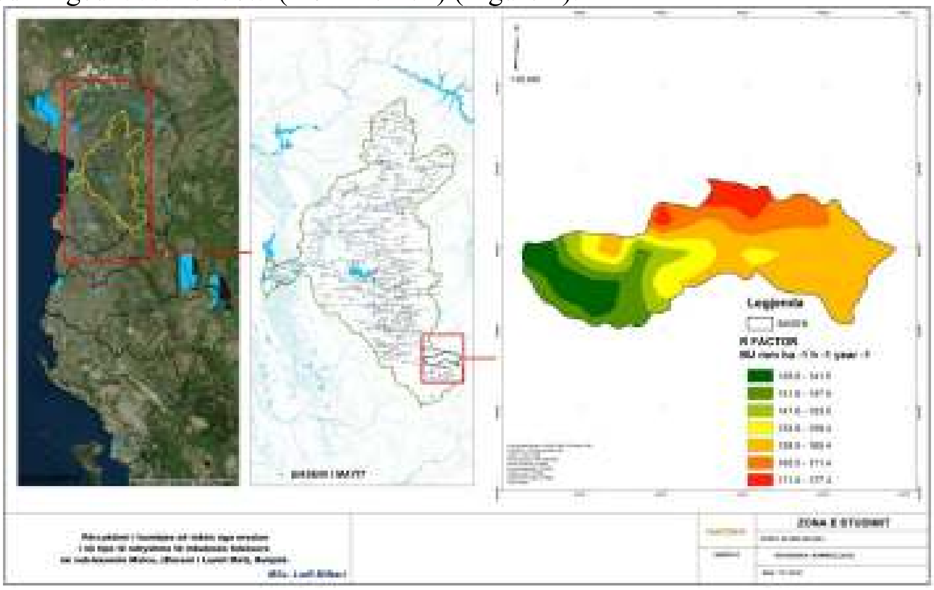

Figure 2. Rainfall erosivity factor map

The second factor in the RUSLE model is **Soil erodibility (K).** Soil erodibility is mainly function of texture, organic matter (OM) content, structure and permeability and is determined based on the following equation [6], using soil data provided from the soil samples collected from the study area (Table 1).

$$100K = \frac{[2.1 \cdot M^{1.14} \cdot (10^{-4}) \cdot (12 - OM) + 3.25 \cdot (S - 2) + 2.5 \cdot (p - 3)]}{7.59}$$

where:

where K- erodibility factor, in t ha h/(ha MJ mm); M-particle size parameter: [M= (%silt+%sand)*(100-%clay)]; OM-organic matter (%); s-soil structure code; p-permeability class.

Table 1. Field and laboratory measured properties of soils from the study area*

Soil type	Field estimate		Laboratory analysis				K Factor
	Texture	Structure	Organic matter	Sand	Silt	Clay	
			(%)				
Dystric Cambisol	Clay Loam	Fine granular	1.69	35,64	30,76	33,6	0,56

Vertic Cambisol	Clay	Medium subangular blocky	1.40	22,4	36,8	40,8	0,48
Haplic Luvisol	Clay Loam	Medium moderate granular.	9,39	32,44	35,66	31,9	0,39
Haplic Cambisol	Sandy Clay Loam	Fine granular	1.69	48,84	26,06	25,1	0,52

The calculated K values ranged from 0.39 in Luvisols to 0.48-0.56 (t ha h) /(ha MJ mm) in Cambisols (Figure 3).

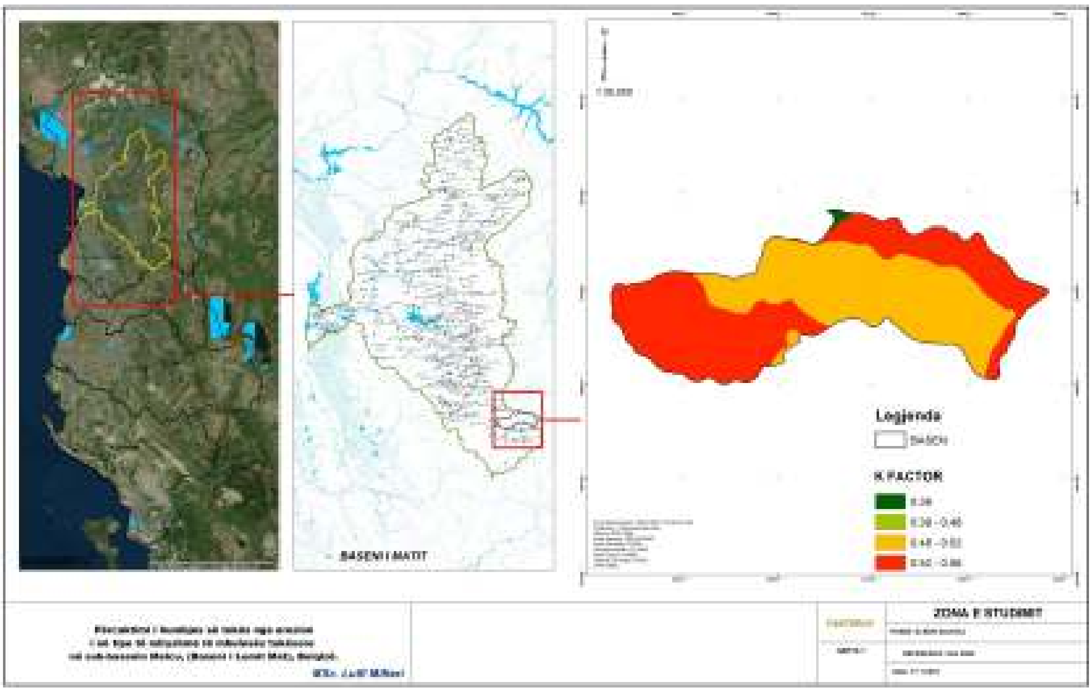

Figure 3. Soil erodibility factor map

The next factor in the model estimated was the **Length slope factor (LS).** To estimate the impact of terrain on soil erosion a detailed DEM for the study area was built using ArcGis. The following equation[8], was used to calculate the slope-length factor:

$$LS = [0.065 + 0.0456 \cdot Slope + 0.0065 \cdot (slope)^2] \cdot \left(\frac{slopelength}{22.1}\right)^{0.5}$$

The highest values of LS (339.7) were found in the most steep slopes (Figure 4).

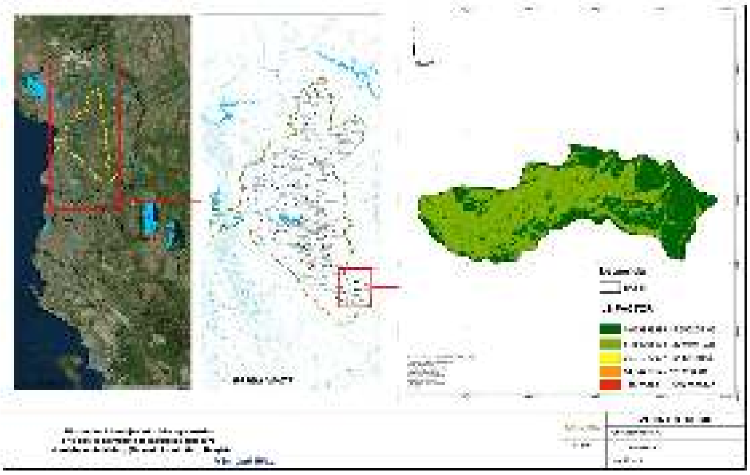

Figure 4. Length slope factor map

The **land cover factor (C)** of the model was determined using the annual soil loss data (t ha^{-1} $year^{-1}$) obtained from experimental measurements and other factors estimated using the above-mentioned approaches. The calculated C values ranged from 0.0017 to 0.075 (Figure 5).

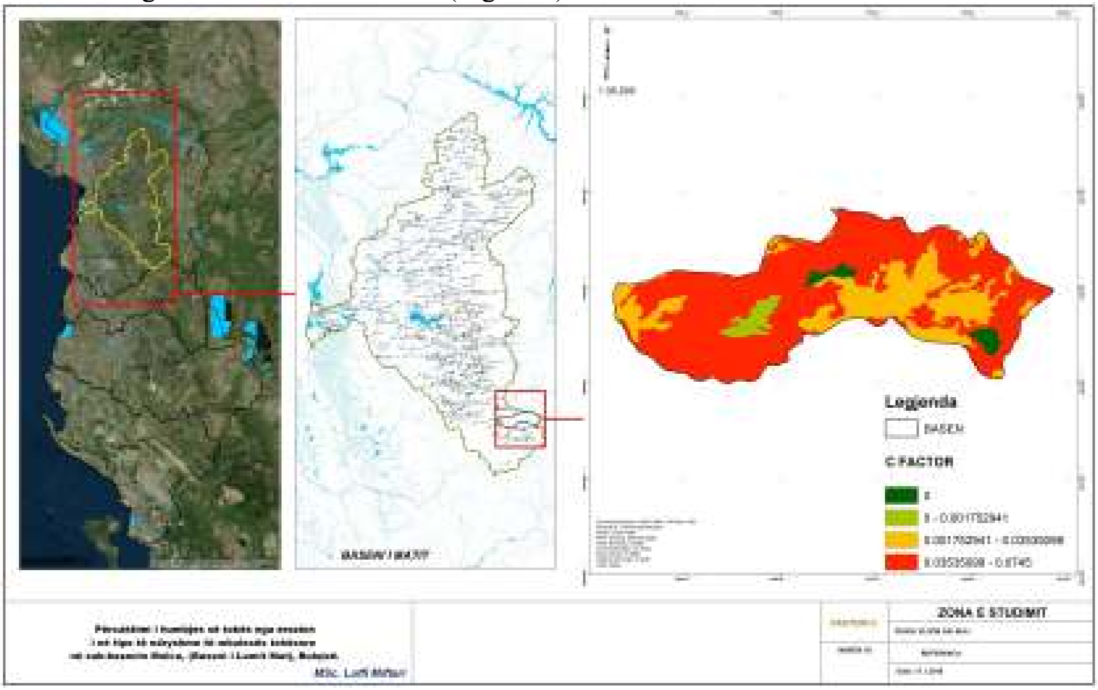

Figure 5. Land cover factor map

The last factor of the model was the **Support practice factor (P)**. It represents the ratio of soil loss with a specific support practice to that with up and downslope tillage [13]. The P factor is taken equivalent with 1.0, because there is no erosion control practices in the area.

3.2 Estimation of soil loss using RUSLE and Monitoring Sample Plots

Preliminary results indicated that the potential soil loss varies from 0 to 40 t· ha^{-1} y^{-1}, with an average of 24.12 t· ha^{-1} y^{-1} (Figure 6). The soil loss was much higher than around 1.4 t ha^{-1} yr^{-1} which is the upper limit of tolerable soil erosion in Europe [12]. Meanwhile, hot spots in the study watershed were considered areas with erosion > 10 t ha^{-1} yr^{-1}[2].

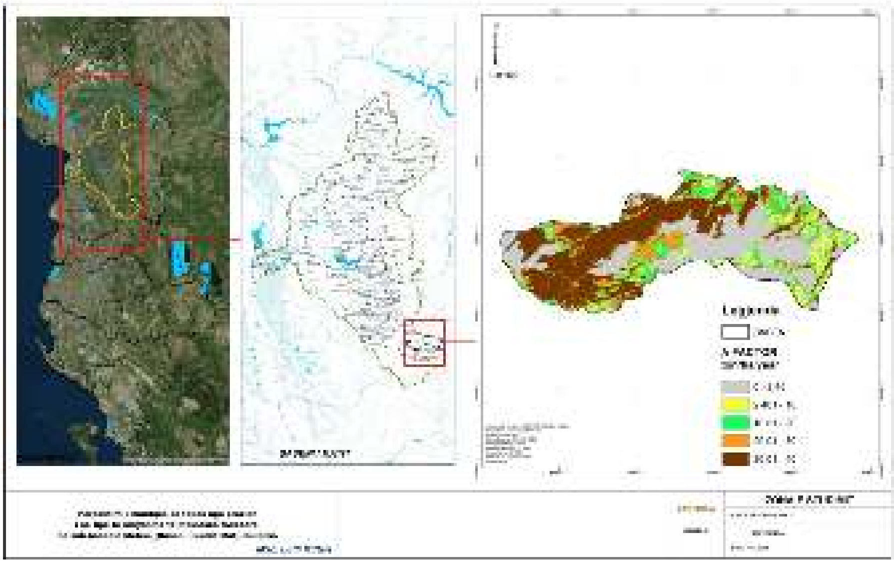

Figure 6. Annual potential soil loss (A) map in the study sub-watershed

Values of soil loss measured through experimental erosion plots (preliminary results) are presented in the Figure 6. Results indicated that the mean annual soil loss for all land cover categories is 28.92t· ha^{-1} y^{-1}. Estimation of RUSLE model applied to Ulza watershed conditions indicates an under estimation (-17%) of measured soil loss values for selected sub-watershed. The similar results are reported by [1; 8].

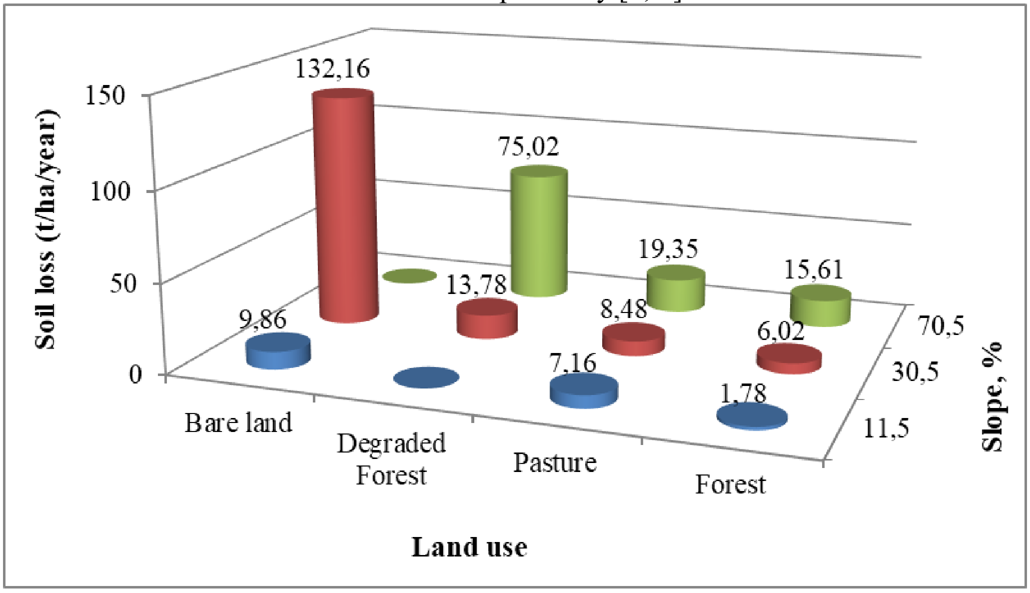

Figure 7. Measured soil loss according to land slope and land cover

4. Conclusions

The RUSLE model has been used as a tool to estimate potential soil loss and identify hot spots within a sub-watershed in Ulza watershed. However, the comparison of soil loss values estimated by RUSLE model under the conditions of Ulza watershed (Bulqizë) with those measured by erosion plots reveals that this model provides an under estimation of soil loss compare to monitoring sample plots. Therefore, in order to avoid under- estimation for soils of Ulza watershed, in the RUSLE model is better to use K and R parameters obtained from experimental measurements instead of statistical models. This comparative study among two methods of soil loss estimation is the first step towards a model adapted to local conditions.

5. Acknowledgements

This research was supported by the Agricultural University of Tirana.

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