Determination of Soil Loss by Erosion in Different Land Covers Categories and Slope Classes in Bovilla Watershed, Tirana, Albania

Valmir Baloshi, Fran Gjoka, Nehat Çollaku, Elvin Toromani

Abstract**—**As a sediment production mechanism, soil erosion is the main environmental threat to the Bovilla watershed, including the decline of water quality of the Bovilla reservoir that provides drinking water to Tirana city (the capital of Albania). Therefore, an experiment with 25 erosion plots for soil erosion monitoring has been set up since June 2017. The aim was to determine the soil loss on plot and watershed scale in Bovilla watershed (Tirana region) for implementation of soil and water protection measures or payments for ecosystem services (PES) programs. The results of erosion monitoring for the period June 2017 - May 2018 showed that the highest values of surface runoff were noted in bare land of 38829.91 liters on slope of 74% and the lowest values in forest land of 12840.6 liters on slope of 64% while the highest values of soil loss were found in bare land of 595.15 t/ha on slope of 62% and lowest values in forest land of 18.99 t/ha on slope of 64%. These values are much higher than the average rate of soil loss in the European Union (2.46 ton/ha/year). In the same sloping class, the soil loss was reduced from orchard or bare land to the forest land, and in the same category of land use, the soil loss increased with increasing land slope. It is necessary to conduct chemical analyses of sediments to determine the amount of chemical elements leached out of the soil and end up in the reservoir of Bovilla. It is concluded that PES programs should be implemented for rehabilitation of sub-watersheds Ranxe, Vilez and Zall-Bastar of the Bovilla watershed with valuable conservation practices.

Keywords**—**ANOVA, Bovilla, land cover, slope, soil loss, watershed management.

I. Introduction

SOIL erosion has become a great concern on a global scale. The 12th International Soil Conservation Organization (ISCO) Conference held in Beijing, China, during 26-31 May 2002, noted that soil erosion remains one of the world's biggest environmental problems, threatening both developed and developing countries [1]. By removing the upper soil layer and organic matter that play a key role in plant growth, soil erosion becomes the main factor for soil degradation [2]. Any soil loss more than 1 t/ha/year may be considered irreversible within a period of 50-100 years [3]. The accelerated soil erosion caused by agriculture is the major threat to soil productivity and water quality in the hilly and mountain areas of Albania. According the European Environment Agency, Albania is part of the red zone [4]. This type of erosion is an undesirable process that adversely affects the conservation of water and soil [5]. Land use is one of the influential factors that affect soil erosion [6], making its optimization one of the most important issues that have a big effect on soil conservation [7] and erosion control [8]. In the Bovilla watershed (Tirana), inappropriate land use practices have stimulated soil erosion, generating sediments and pollutants that were deposited in the Bovilla reservoir from which the city of Tirana is supplied with drinking water. Sedimentation in Bovilla reservoir has caused many problems in water quality, decrease of storage capacity and water supply for population as result of turbidity raising. Information on the degree and extent of soil erosion obtained by RUSLE-GIS model is useful for the implementation of PES programs at the watershed scale [9]. Currently, a PES program supported from the World Bank & SIDA is implementing in Albania. This program is focused on erosion control in two watersheds, Bovilla and Ulza [10], [13]. It is hypothesized that the amount of soil loss in Bovilla watershed is affected by the current forms of land use. Therefore, changes in land use should be seen as an effective tool for soil erosion control and water resource conservation. Currently, there is a lack of information on the soil loss by the land cover categories and slope classes. The aim of this study was to provide information on soil loss on experimental erosion plot and watershed scale in Bovilla watershed (Tirana region) for implementation of soil and water protection measures (PES schemes).

II. Material and Methods

A. Study Area

The study area is located between 41°30' - 41°15' N latitudes and 19°50' - 20° 05' E longitudes, in the north-eastern part of Tirana city. Bovilla watershed area is 95 km^2, where 52.2 km^2 belongs to Tirana municipality and the rest to Kruja municipality. The Bovilla reservoir is 15 km far away from Tirana city with a maximum water filling capacity of 80 Million cubic meter. The total area of Bovilla reservoir is 4.6 km^2 and the maximal depth is 53 m. The climate of the study area is Mediterranean with relatively cold, wet winters, and warm, dry summers. Bovilla watershed has a wide altitudinal range affecting directly the local climate. The mean annual

Valmir Baloshi is PhD student with the Faculty of Forestry Sciences, Department of Forestry, Albania (phone: +355675656077; e-mail: rimlav_2004@hotmail.com).

Fran Gjoka is with the Faculty of Agriculture and Agro-environment, Department of Agro-environment (phone: +355696380759; e-mail: fgjoka2001@gmail.com).

Nehat Çollaku is with the Faculty of Forestry Sciences, Department of Forestry (phone: +355685756660; e-mail: nehatcollaku@ubt.edu.al).

Elvin Toromani is with the Faculty of Forestry Sciences, Department of Forestry (phone: +355699198055; e-mail: etoromani@ubt.edu.al).

temperature is 13.9 °C, the rainfall is 1718.6 mm [10] and the potential evaporation is 916 mm [14]. Rainfall data are characterized by a non-uniform monthly distribution. Most of the precipitation falls during autumn and winter months being the main source of water supplier for the hydrologic network in the Bovilla watershed. Geologically, the Bovilla watershed can be divided into two distinct areas: peripheral area of watershed consisting predominantly by carbonate deposits - limestones and dolomites and minor amounts of quaternary deposits - clays, alevrolites, sands; and central area of watershed consisting mainly of flysch. The study area has a dissected topography and contains a variety of landforms like mountains, hills and valleys. Based on the built DEM of the watershed, around 80% of the Bovilla watershed has an inclination from 15 to 30 degree. The elevation range in Bovilla watershed vary from 300 to 1800 m a.s.l. 80% of the basin area has an altitude from 300 to 1000 m a.s.l. The main soil groups in the study area are Leptosol, Cambisol and Phaeozem. The cambisol was found in the north and northeastern parts of the watershed on steep slopes and was developed especially on flysch formation and carbonate deposition, leptosol dominates the central-southern and southwestern parts of the watershed on relative steep slopes and was developed especially on flysch formation, and phaeozem in the northwestern part of the watershed on steep slopes and on flysch rocks and carbonate deposition. Land cover is dominated by broadleaves forest, pastures, riparian vegetation and agriculture lands.

B. Erosion Plot Layout

25 experimental erosion plots with regular and irregular shape were installed to monitor soil loss caused by water erosion. Erosion plots were installed in different land use categories (forest, pasture, agricultural, bare lands, degraded forest land and orchard) and slope classes (0-20%, 21-40%, 41-60% and more than 60%) in the frame of the project entitled “Study on sediment measurement and monitoring: Case study - Bovilla catchment” [10]. The study sites were situated near the farmer’s settlements in 2 villages (Zall Bastar & Mner i Siperm) Distribution of erosion plots in the study sites according to land use and slope are presented in Table I.

TABLE I
DISTRIBUTION OF EROSION PLOTS ACCORDING TO LAND USE AND SLOPE

Slope (%)	Land use					
	Agric. land	Forest land	Pasture land	Bare land	Deg. forest land	Orchard
0-20	3	-	1	-	-	-
21-40	-	3	4	-	1	1
41-60	-	1	1	2	-	1
> 61	-	2	2	3	-	-

C. Monitoring of Parameters

The parameters that have been monitored are: amount and distribution of rainfall, runoff volume, amount of sediment in runoff. After every rainfall event, the volume of water runoff together with sediments have been collected in the barrels with a capacity of 200 liters, installed in every sample plots. The volume of the collected surface runoff was estimated and recorded in the proper field forms, and afterwards the entire content of the barrels were carefully mixed until a homogeneous mixture was obtained. Three bottles of 0.5 L each were filled and labeled. The mixed content of water and sediments was left from 1 - 2 weeks, until the sediments were completely deposited in the end of the bottle. After removing water from the bottles, the sediment is quantitatively transferred to a 1000 ml beaker, where all events of one month are collected. One week later, when the sediment is clearly separated from the water, the sediment thickness (mm) in beaker is measured and recorded (knowing the beaker surface and sediment thickness the sediment volume is calculated, in cm^3). After removing water from the beaker, one-month sediments are quantitatively transferred to 1000 ml containers, where one-year monitoring sediments are collected. The whole sediments collected during the monitoring period were mixed together and sent to the Soil Laboratory of the Agriculture University of Tirana to determine the exact weight of sediments. The exact dry weight of sediments was measured by drying soil samples at 105 °C for 8 hours [10].

D. Soil Loss and PES Program

For the implantation of PES program for erosion control, firstly we have determined hotspot areas and analyzed if conservation of natural vegetation in areas with high erosion risk has great potential to justify PES programs. Determination of hotspot areas has been done using Revised Universal Soil Loss Equation (RUSLE) and GIS.

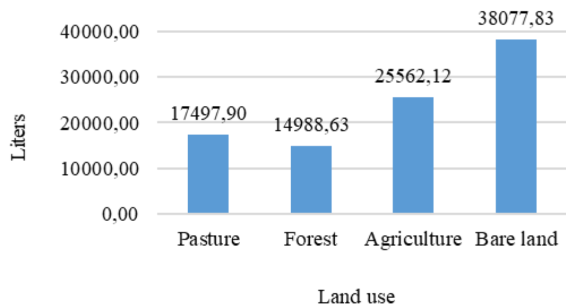

Fig. 1 Runoff amount (l/ha) according to land use and slope

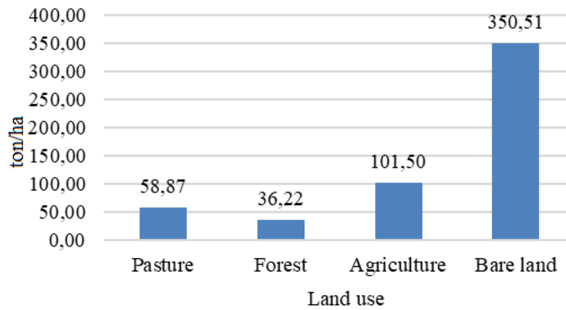

Fig. 2 Soil loss (ton/ha) according to land use and slope

E. Statistical Analysis

The data were elaborated using SPSS var. 20.0. ANOVA was used to analyze the differences in runoff and soil loss amounts between land use classes.

III. Results and Discussion

A. The Runoff

Surface runoff varied from 17497,9 liters in pasture land to 38077,83 liters in bare land (Fig. 1).

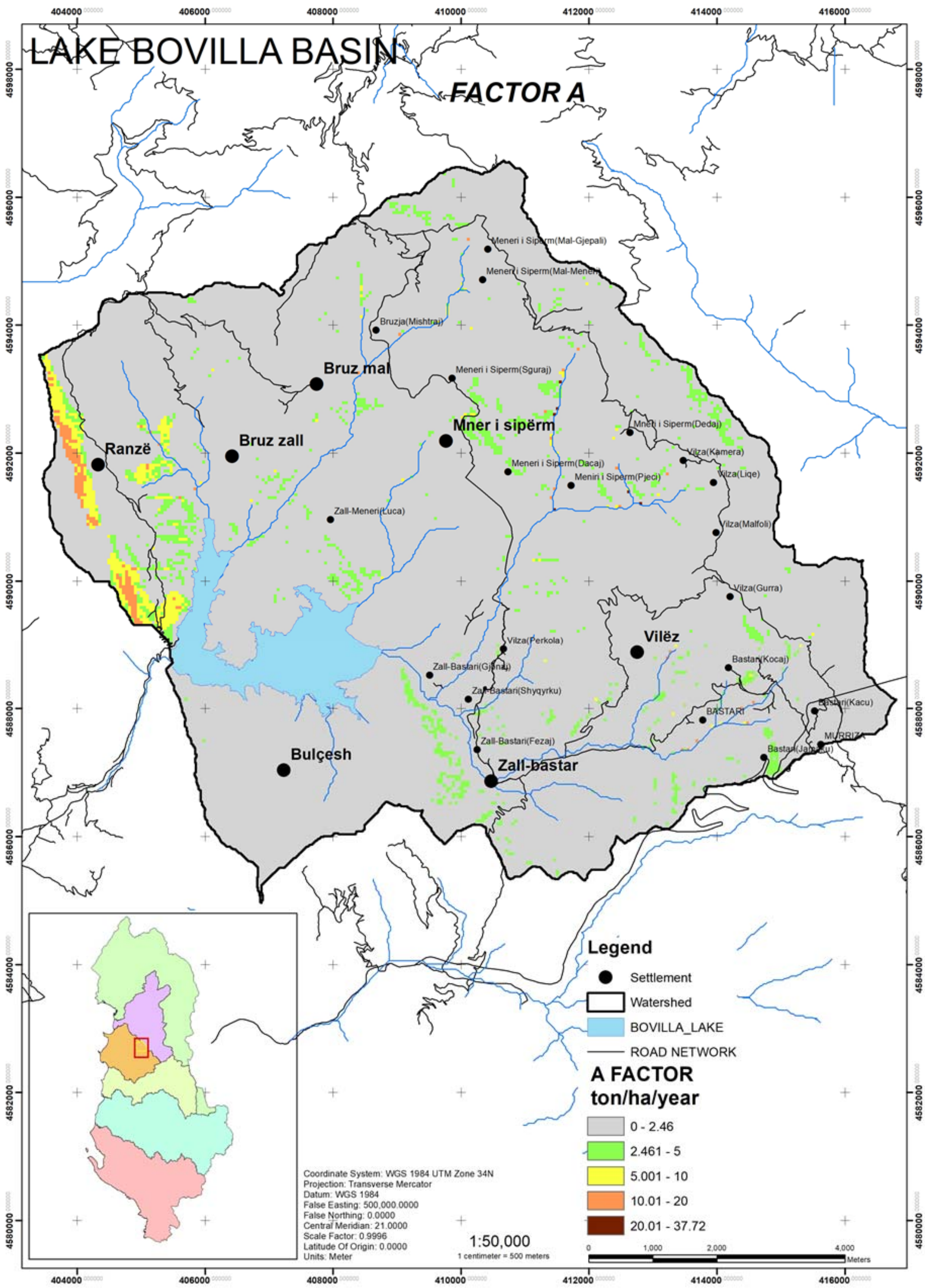

Fig. 3 Spatial distribution of soil loss in Bovilla watershed

The amount of runoff from pasture land tried to increase with the increase in inclination, from 17254.88 liters on slope of 13% to 17662.31 liters on slope of 65%. The amount of runoff from forest land varies from 13295.83 liters on slope of 28% to 12840.6 liters on slope of 64%. Reducing the volume of runoff by increasing the slope might be explained by the fact that forest land has different vegetation cover in different slope class. The surface runoff volume from agricultural land is 23023.82 liters on slope of 4.6% and reducing with inclination to 22979.1 liters on slope of 13.2%. This also can be explained by fact that agricultural land is maintained in different crops in different slope class. While the amount of runoff from bare land increases with increase in inclination from 36665.93 liters on slope of 43% to 38829.91 liters on slope of 74%.

Results of ANOVA are presented in Table II. As it seems, there is a significant difference in the mean runoff between land use categories (F>Fcrit).

TABLE II
ONE-WAY ANOVA FOR RUNOFF

Source of Variation	df	MS	F	P-value	F crit
Between Groups	3	6,18E+08	78,11	1,48E-11	3,072467
Within Groups	21	7917123			
Total	24				

B. Soil Loss

The soil loss values range from 36.22 ton/ha in forest land to 350.51 ton/ha in bare land (Fig. 2).

The soil loss in pasture land increases by increase in inclination from 30.75 t/ha on slope of 13% to 63.22 t/ha on slope 65%. The amount of soil loss in forest was 21.24 t/ha on slope of 28% and 18.99 t/ha on slope of 64%. Decreasing soil loss with increasing land inclination can be explained by argument that forest has different vegetation covers on different slope classes. Soil loss on agricultural land was 108.2 t/ha on slope of 4.6% and 58.55 t/ha on slope of 13.2%. Also here decreasing soil loss with increasing inclination explained that agricultural land is maintained different crops. In bare land, soil loss is increasing by increase in inclination from 127.74 t/ha on slope 43% to 595.15 t/ha on slope 62%. Results of ANOVA are presented in Table III. The data show significant difference in the mean soil loss between land use categories (F> Fcrit).

TABLE III
ONE-WAY ANOVA FOR SOIL LOSS

Source of Variation	df	MS	F	P-value	F crit
Between Groups	3	115469,1	10,271	0,000229	3,072
Within Groups	21	11242,09			
Total	24				

C. PES Program Implementation

The annual soil loss at the watershed scale varies from 2.46 to 37.72 tons/ha/year (Fig. 3) [11].

The maximum soil loss was found in the mountainous areas with LS Factor values greater than 15.2. Soil losses of more than 1 t/ha/year are considered irreversible within a period of 50-100 years [3], while the mean rate of soil loss in the EU is 2.46 t/ha/year [12]. Based on the sediment yield and drainage area, the sub-watersheds Ranxe, Vilez and Zall-Bastar were selected as critical erosion areas, which contribute to about 65% sediment yield of the watershed (Fig. 4) [11]. In these critical areas, the PES programs are necessary to apply.

Fig. 4 Relative contribution of sub-watersheds to total sediment yield

IV. CONCLUSION

The results of soil erosion monitoring (June 2017 – May 2018) showed that the amount of runoff and soil loss was different due to land use. The highest values of surface runoff were measured in bare land 38829.91 liters on slope of 74% and lowest values in forestry land 12840.6 liters on slope of 64%. The highest values of soil loss were measured in bare land 595.15 t/ha on slope of 62% and lowest values in forestry land 18.99 t/ha on slope of 64%. Runoff and soil loss are reducing from bare land and agricultural land to pasture and forest. This study shows that soil loss or erosion caused by water is very higher compare with European average soil loss which is 2.46 ton /ha/year.

Regarding slopes we found that the runoff and mean soil loss were increased by slope except agricultural land and forestry land where soil loss decreases in relation with increasing land inclination. This can be explained by the fact that agricultural land is maintained with different crops, and forest lands have different vegetation cover in the different slope classes.

As viewed from result, Bovilla watershed is endangered by higher values of erosion which directly indicate to drinking water quality and quantity for city of Tirana. The management must take preventive measurements' based on land-use changes or support practices to reduce soil loss in Bovilla watershed by implemented PES program.

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