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EFFECT OF URBANIZATION ON SOIL EROSION

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ABSTRACT: Soil erosion is a serious problem faced at global and local level. The soil erosion rate increases at a faster rate due to urbanization. Urbanization involves expansion of urban related area and conversion of natural physical landscape to more economic land uses. Due to urbanization, water holding capacity of the soil decreases and runoff rate increases which in turn led to soil erosion. This study was conducted in Karamana river basin to determine the effect of urbanization on soil erosion in its watershed area, Thiruvananthapuram district. Universal Soil Loss Equation (USLE) was applied for the study and the spatial distribution of soil loss over the basin was obtained with the help of GIS. The maximum soil erosion rate of Karamana river basin in 1999 and 2008 is 36t/ha/yr and 39t/ha/yr respectively. Among the five USLE factors, the most prominent parameter crop and management factor (C) and erosion control practice factor (P) which is the function of land cover change, the ultimate result of urbanization.

Keywords: USLE; GIS; Remote sensing; Annual soil loss

1. INTRODUCTION

The way humans have used land and exploited its resources over time is a serious problem as it has altered land cover and impacted the functioning of the ecosystem. Its impacts can be seen in forms of uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of wetlands, and loss of fish and wildlife habitats everywhere on the earth. Urbanization is among the most evident aspects of human impact on the earth system. The process of urbanization produces radical changes in the nature of the surface and atmospheric properties of a region, because the natural vegetation is removed and replaced by non-evaporating and non-transpiring surfaces such as metal, asphalt and concrete. Also water holding capacity of the soil decreases and runoff rate increases which in turn leads to soil erosion. So it is necessary to determine the effect of urbanization on soil erosion of a river basin.

The Universal Soil Loss Equation (USLE) developed by Walter H. Wischmeier is the most widely used empirical model to estimate soil erosion. USLE computes soil loss as the product of five parameters: rainfall erosivity (R), soil erodibility (K), topographic factor (LS), crop and management factor (C), and erosion control practice factor (P).

Annual soil loss in an area if represented spatially gives a better visualization of the actual problem. GIS is a spatial analysis tool which allows simpler and faster data and parameter management, especially when repeated applications of similar and complex procedures are required.

1.1 Objectives of the study

The objective of the study is to determine the effect of urbanization on soil erosion by comparing the annual soil loss in the study area using USLE with the help of GIS and remote sensing.

2. METHODOLOGY

The overall methodology involves the use of USLE in a GIS environment.

2.1 Determination of USLE Factors

The parameters in the USLE model Rainfall erosivity (R), Soil erodibility (K), Topographic factor (LS), Crop and Management factor (C), and Erosion Control Practice factor (P) was determined.

2.1.1 Rainfall Erosivity Factor (R)

The rainfall data from the rainguage stations in the selected watershed is interpolated using Inverse Distance Weighted method and R Factor is estimated using the expression:

$$R = \sum_{i=1}^{12} 1.735 \times 10^{\left(1.5 \log \left(\frac{P_i^2}{P}\right) - 0.8188\right)} \quad \text{(Arnoldus, 1980)} \quad (1)$$

where R = rainfall erosivity factor (mm/ y) Pi = monthly rainfall (mm)
P = annual rainfall (mm)

2.1.2 Soil Erodibility Factor (K)

The K factor measures soil susceptibility to rill and interill erosion.

$$K = 7.594\{0.0034+0.0405 \exp[-.5((\log Dg+1.659)/0.7101^2)]\} \quad (2)$$

where Dg is the mean geometric particle size in mm obtained from USDA classification.

2.1.3 Topographic factor (LS)

The effect of slope length and gradient on the intensity of the erosion process is collectively known as the "Topographic factor, LS". LS Factor is estimated with the help of GIS using the expression:

$$LS = (\text{Flow accumulation x Cell size}/22.13)^{0.4} \times (\text{Sin slope}/0.0896)^{1.3} \quad (3)$$

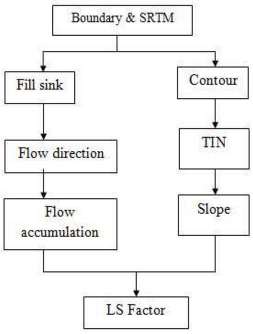

FIGURE 1. Flow chart for LS factor determination

2.1.4 Crop and Management Factor (C)

The C factor represents effect of cropping and management practices in agricultural management. C factor values obtained from NDVI map. NDVI is the Normalized Difference Vegetation Index. The NDVI map is obtained by processing the landuse map in the ERDAS Imagine software.

C factor = 1.02 – 1.21 x NDVI (4) [Hui et al. (2010)]

2.1.5 Erosion Control Practice Factor (P)

It is the ratio of soil loss with a given surface condition to soil loss with up-and-down-hill plowing. P factor is roughly determined from the P factor table that is based on interpolation from Wischmeier et al. (1978).

TABLE 1. P Factor

Landuse	P Factor
Agriculture	0.5
Built up	1
Forest	1
Wasteland	1
Waterbody	1

Individual raster layers were derived for each factor in USLE and processed in GIS. The raster factor maps are then multiplied to get the Annual Soil Loss map.

2.2 Study Area

Karamana river flows in southern direction through Thiruvananthapuram Corporation. Thiruvananthapuram is the second-most populous district in Kerala. According to State Urbanization report, in 2001 its census is 33.75% and it increased to 53.8% in 2012. So Karamana River basin is the selected study area.

Karamana River has its origin in the Chemmunji mottai and Agastyamalai of the Nedumangad hills. It joins Arabian Sea near Pachallur. It has a length of 68kms and basin area of 702km^2 . The basin lies between 8^0 3’36”N and 8^{0}30’52”N latitudes and 76^0 57’16”E and 77^0 44’E longitudes.

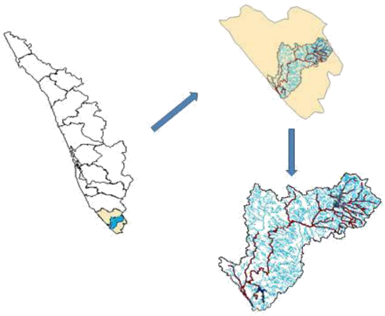

FIGURE2. Karamana river basin

2.3 Collection of Datasets

The monthly and annual amounts of precipitation of the basin were collected from the Indian Meteorological Department (IMD). Soil classes and the landuse map of 1999 were collected from Kerala State Landuse Board and the landuse map of 2008 from Bhuvan.

Sl no.	Station	RFactor (mm/yr)	
		1999	2008
1	Aryanad	1105	1619
2	Nedumangad	1188	516
3	Trivandrum City	683	358
4	Trivandrum Airport	710	360

3. RESULTS AND DISCUSSIONS

The various parameters in USLE were determined and is as shown below:

3.1 Rainfall Erosivity Factor (R)

The R factor for the basin for the year 1999 and 2008 and its spatial representation is shown below.

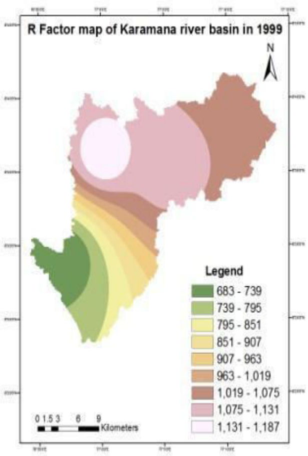

FIGURE 3. R Factor map in 1999

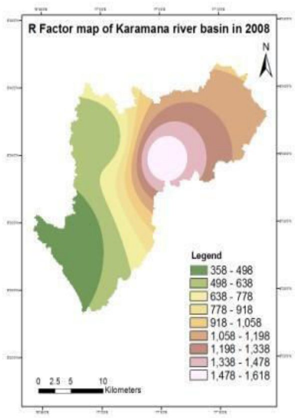

Figure 4.K Factor Map in 2008

3.2 Soil Erodibility Factor (K)

Based on the soil present in the Karamana river basin, K values were calculated as given in table. 3 and its spatial representation as shown in fig.5.

TABLE 3. Soil types and K values

Soil Type	Dg(mm) as per USDA classification	K Factor
Riverine alluvium	2	0.033
Red loam	0.1	0.226
Black soil	0.002	0.259
Coastal alluvium	2	0.033
Forest loam	0.05	0.297
Laterite soil	1	0.046

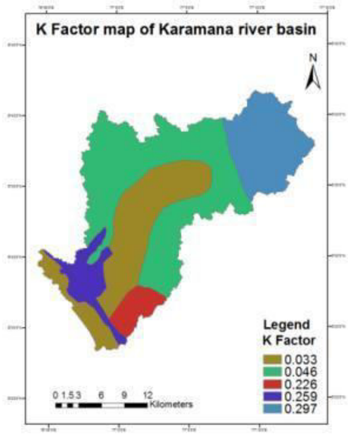

FIGURE 5. K Factor map

3.3 Topographic Factor (LS)

LS factor map was prepared in GIS and as shown in fig.6.

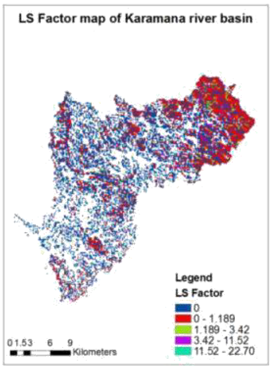

FIGURE 6. LS Factor map

3.4 Crop and Management Factor (C)

The C factor values for year 1999 and 2008 were obtained from prepared NDVI maps and are spatially represented in fig.7and fig.8.

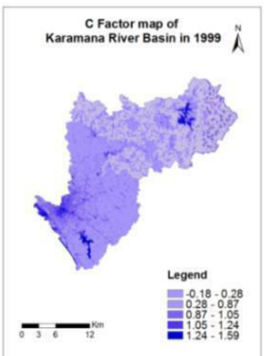

FIGURE 7. C Factor map in 1999

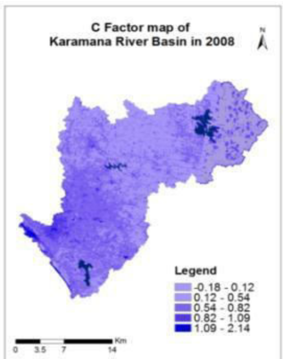

FIGURE 8. C Factor map in 2008

3.5 Erosion Control Practice Factor (P)

The GIS map of P factor for Karamana river basin for 1999 and 2008 is as shown below.

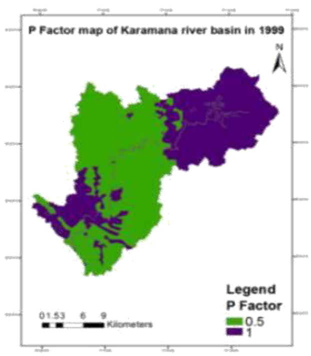

FIGURE 9. P Factor map in 1999

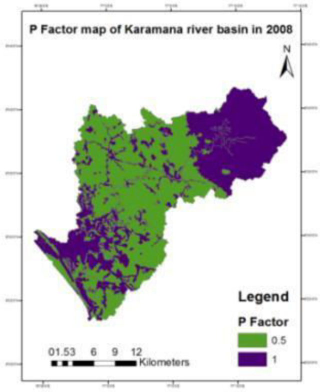

FIGURE 10. P Factor map in 2008

3.6 Annual Soil Loss in Karamana river basin

Annual soil loss map in GIS for Karamana river basin for 1999 and 2008 was obtained and as shown in fig.11 and fig.12. From the map the area susceptible for various rate of soil loss was determined.

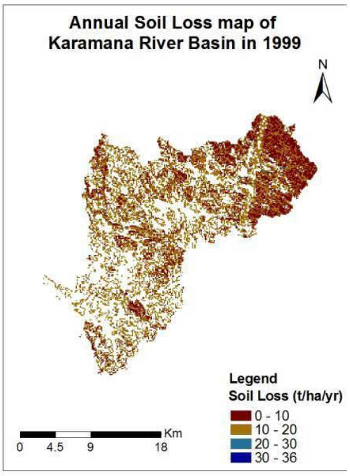

FIGURE 11. Annual Soil Loss map in 1999

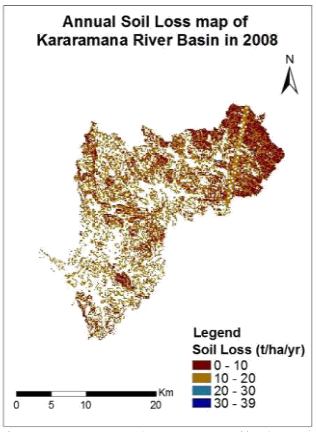

FIGURE 12. Annual Soil Loss map in 2008

TABLE 4. Change in rate of soil loss and corresponding area

Soil Loss (t/ha/yr)	Area (km^2)	
	1999	2008
0 - 10	88.14	90.82
10 - 20	1.68	1.79
20 - 30	0.22	0.41
30 - 40	0.09	0.15

4. CONCLUSIONS

The study shows there is an increase in rate of soil loss in the entire river basin. The maximum rate of soil loss in 1999 is 36t/ha/yr and in 2008 is 39t/ha/yr. Comparatively low erosion is observed in the western part and high erosion along the eastern side in the study which matches with the actual slope of the basin as it is steeper in eastern side and gentle in western side. Among the five USLE factors, the LS and K factor remains the same. Except for one station R factor was found to be less during 2008 when compared to 1999.Even then soil loss was found to be more during 2008. Hence that increase in the soil loss in the river basin may be due to change in C and P factor. These factors are directly linked to land cover change which is the ultimate result of urbanization.

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