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ESTIMATION OF SLOPE LENGTH FACTOR (L) AND SLOPE STEEPNESS FACTOR (S) OF RUSLE MODEL IN THE OZAT RIVER BASIN BY REMOTE SENSING AND GIS

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ABSTRACT

The LS factor is important component of USLE and RUSLE. It represents slope length and slope steepness factor, which is used to estimate soil erosion of a given area. The S factor measures the effect of slope steepness and L factor defines the impact of slope length. The combined LS factor explains the topography on soil erosion. The major uncertainty of soil loss estimation studies is deriving from LS factor. For the present study, Ozat River basin was selected. LS factor was calculated by using the SRTM DEM of 30m resolution, which was downloaded from USGS earth explorer. The equation given by Wischmeier and Smith was used. The Slope length for the area was found between 40m to 2572.64m. LS factor value ranges from 1.76 to 32.56. The high values of LS factor were found in the area correspond with the locations of high elevations and very steep slopes.

Keywords: Erosion, RUSLE, Slope Length, Slope Steepness, SRTM DEM

Introduction

Soil is the upper most weathered and disintegrated layer of the earth's crust, which is composed, of minerals and the organic substances with the capability of sustaining plant life. The depth of soil varies from place to place; it may vary from practically zero *i.e.* no soil layer to several meters. However, the top 30 cm soil depth is very useful as concerned to the human being and wildlife. The top layer of soil is continuously exposed to the actions of atmospheric activities. Wind and water are the two main active forces, which are responsible for the dislodging of the top soil layer and transportation of them from one place to another, which can be referred as soil erosion.

Soil erosion losses are primarily caused by wind and water, which remove soil surface materials (Kirkby and Morgan 1980). Water is the primary factor influencing soil erosion; raindrop impact and flowing water process this agent, which includes particle detachment, movement, and deposition (Foster and Meyer 1977; Wischmeier and Smith 1978; Julien 2002). Soil erosion is a significant issue in agriculture and the management of natural resources because it lowers soil productivity, contaminates streams, and fills reservoirs (Fangmeier *et al.*, 2006). Numerous factors, including human activities such as building roads, highways, dams, or controlling streams and rivers, mining, and urbanization, can hasten the processes of erosion, transportation, and sedimentation. Soil erosion is the process by which raindrops strike the ground's topsoil and separate soil particles (sediments) by splashing. A thin overland flow carries the separated particles that cause sheet erosion or inter rill erosion laterally to the rills. Gully erosion, which is comparable to rill erosion but larger in scope, is the result of the rills progressively joining to form wide pathways. The Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) are two of the many empirical models used to quantify soil erosion losses. According to Renard *et al.*, (1997), the RUSLE equation is an improved version of the USLE model that retains the foundation of the original USLE equation while introducing enhancements in factors based on fresh data. Slope length factor L and steepness factor S indicate how topography affects soil erosion modelling in the RUSLE equation. Increased erosion results from a progressive build-up of runoff in the downslope direction as slope length L increases. The increasing the slope steepness factor S is increased the soil erosion to cause of increasing in the velocity.

In recent years, advancements in Remote Sensing and Geographic Information System (GIS) technologies have provided valuable tools for assessing and monitoring soil erosion on a larger scale. Remote sensing involves the acquisition of data about the Earth's surface from air borne or satellite sensors, while GIS integrates and analyses spatial information to derive meaningful insights. Remote sensing data, such as satellite imagery can provide essential inputs for the USLE model. Satellite sensors can capture information about land cover, vegetation density, topography and surface characteristics, which are crucial for accurately estimating soil erosion rates. By combining remote sensing data with GIS, spatial analysis techniques can be applied to model erosion susceptibility, identify vulnerable areas, and prioritize soil conservation efforts.

The Digital Elevation Model (DEM) is a quantitative representation of the Earth's surface that provides basic information about the terrain and allows for the derivation of attributes such as slope, aspect, drainage area and network, curvature, and topographic index (Mukherjee *et al.*, 2014). The DEM and the LS factor determine the spatial resolution (cell size) of the soil erosion model results, and incorporate the soil erosion potential due to surface runoff. The L-factor gives the impact of slope length while the S-factor accounts for the effect of slope steepness. The LS-factor is dimensionless, having values equal to and greater than 0. The main objective of this study is to compute the LS-factor based on a high-resolution DEM for the Ozat river basin.

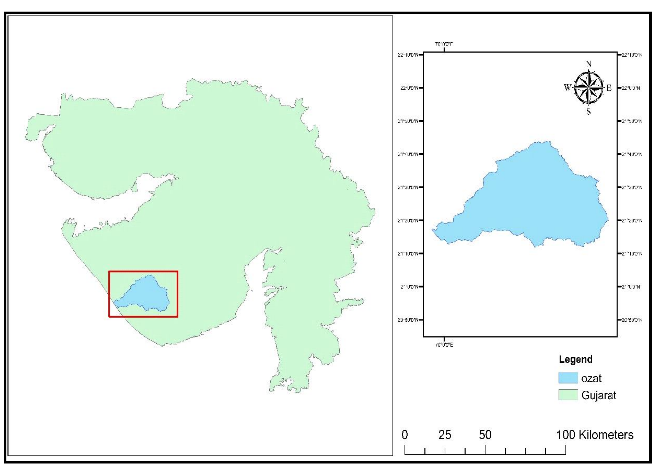

Fig. 1: Location of study area.

Material and Methods

Location

Ozat River originates from Visavadar and meets in Arabian sea. It is situated between latitude of 21° N to 22° N and longitude of 70° E to 71° E. The perimeter of a basin is 390.11 km having catchment area 3410 sq.km. Agriculture is the main occupation in the area. Groundwater is the main source of irrigation on study area. The study area is located in a semi-arid area, belonging to the south-Saurashtra Agro-climate area in Gujarat, India. The climate of the region is subtropical. (Paghadal *et al.*, 2014).

Data Collected

SRTM DEM (Shuttle Radar Topography Mission)

SRTM data have been enhanced to fill areas of missing data to provide digital elevation data with a resolution of 1 arc-second for global coverage. SRTM 1 Arc-Second Global-elevation data offer worldwide coverage of void filled data at a resolution of 1 arc-second (30 meters) and provide open distribution of this high-resolution global data set. Some tiles may still contain voids.

Estimation of Topographic Factor (LS)

In the RUSLE model, the slope length (L) and

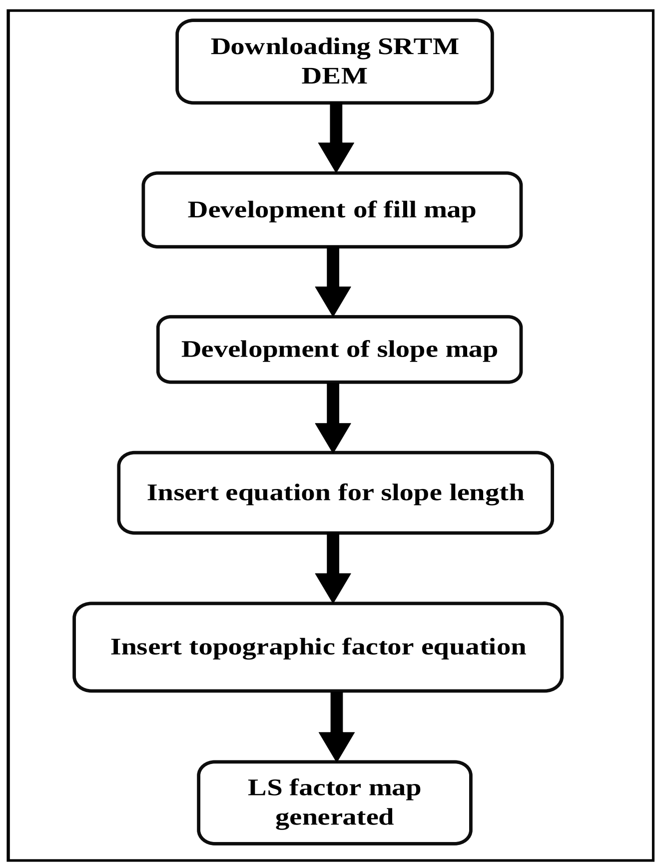

Fig. 2: Flow chart for estimation of LS factor.

steepness (S) were jointly estimated. Because the L and S of the slope directly affect the erosive force of water, soil erosion will be high if they are high and vice versa. Slope length and steepness for the study area derived from SRTM DEM downloaded from USGS Earth Explorer (https://earthexplorer.usgs.gov/). Shuttle Radar Topography Mission (SRTM) DEM with the resolution of 30 m was used.

The LS factor combines length and slope site characteristics into one variable using a standard equation. It is based on the belief that more erosion will occur on a steeper slope, and a longer slope will allow more opportunity for this erosion to occur. It is a unit less parameter relative to the standard conditions referenced above. Slope length and steepness factor (LS) accounts for the effect of topography on sheet and rill erosion. There are a number of methods available to find out LS and for the present study, two parameters that constitute the topographic factor, slope length and slope gradient factor, were estimated through a DEM. The LS is the expected ratio of soil loss per unit area from a field slope to that from a 22.13 m length of uniform 9 % slope under otherwise identical conditions (Shinde *et al.,* 2011). A slope length map was generated using the equation as follows;

$$L = 0.4 \times S_p + 40 \quad (1)$$

Where,

L is the slope length and

S_p is the slope steepness in percentage

For slopes up to 21 %, the following equation, modified by Wischmeier and Smith (1978), was used:

$$LS = \left(\frac{L}{22.1}\right) \times (65.41 \times Sin\,\theta)^2 \times 4.56\; Sin\,\theta + 0.065 \quad (2)$$

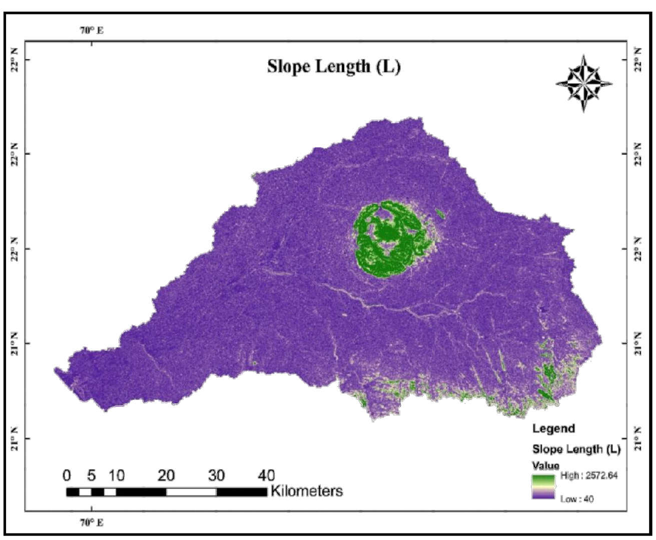

Fig. 3: Slope length map of study area.

For the slope steepness of 21% or more the equation used was:

$$LS = \left(\frac{L}{22.1}\right)^{0.7} \times (6.432 \times Sin\;\theta)^{0.77} \times 4.56\; Cos\;\theta) \quad (3)$$

Where,

LS is the slope length and gradient factor,

θ is angle of the slope and

L is sloping length in metres.

Results and Discussion

Slope length is the horizontal distance from the point of origin of overland flow to the point where either the slope gradient gets decrease enough to start deposition or the overland flow gets concentrate in a defined channel. In principle, longer the slope length the more runoff will be there; gathering the speed and gaining its own energy and thus resulting into rill erosion and formation of gully network. For the study area slope length was calculated by using the equation and the value for slope length ranges from 40m to 2572.64 m as shown in Fig. 3.

The SRTM DEM from the USGS earth explorer was used to create the slope map of study area. The slope was found in percentage. For the area whose slope is more than 21% the equation modified by Wischmeier and Smith (1978) was used. By using the raster calculator LS factor map was created in ArcGIS whose value ranges 1.76 to 32.56. The highest point from LS factor is 32.56 as shown in Fig. 4, those areas correspond with the locations of the high elevations and very steep slopes in the study area. Similar LS factor was found in the study done by Belasari and Lakhouili (2016).

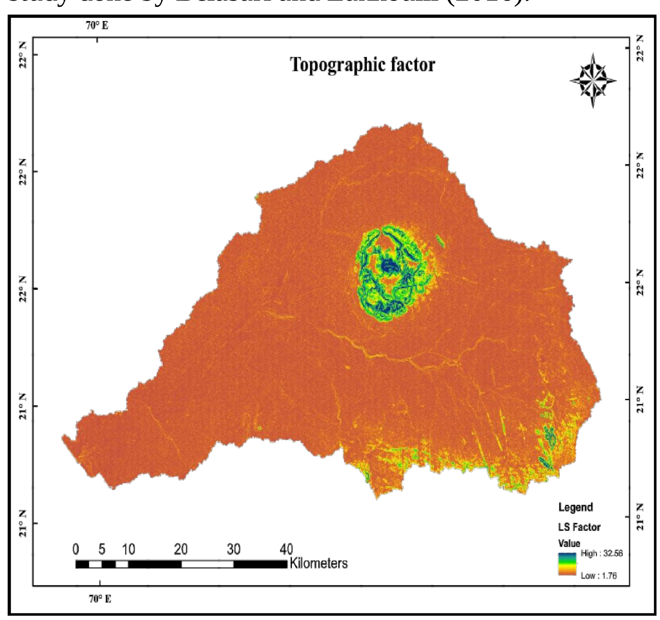

Fig. 4: Topographic factor map of study area.

Conclusion

Soil erosion is known as detachment, transportation and deposition of soil particles from one place to another while being influenced by gravity, wind, water forces. The most severe type of land degradation occurs due to soil erosion, particularly in developing nations like India. Soil erosion is serious issue in India, which reduces the productivity of agricultural land and avaibility of water. Natural factors such as topographic, rainfall, soil and land cover and human-induced factors such as land use, support practice factor, often cause soil erosion in a river basin. Slope and slope length were used to calculate topographic factor (LS). The value for slope length ranges from 40m to 2572.64m. The topographic factor of Ozat river basin was ranging between 1.76 to 32.56; these areas correspond with the locations of the high elevations and steep slopes in the study area.

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References

Belasri, A. and Lakhouili A. (2016). Estimation of soil erosion risk using the Universal Soil Loss Equation and Geo-Information Technology in Oued El Makhazine Watershed, Morocco. *Journal of Geographic Information System*, **(8)**, 98-107.

Fangmeier, D.D., Elliot W.J., Workman S.R., Huffman R.L. and Schwab G.O. (2006). Soil erosion by water. Soil and Water Conservation Engineering, 5th ed. Thomson Delmar Learning, New York. 134-158

Foster, G.R. and Meyer L.D. (1977). Soil erosion and sedimentation by water- an overview. Procs. National Symposium on Soil Erosion and Sedimentation by Water, American Society of Agricultural Engineering, St. Joseph, Mechigan, 1-13.

Haan, C.T., Barfield B.J. and Hayes J.C. (1994). Design hydrology and sedimentology for small catchments. Elsevier: Amsterdam, the Netherlands.

Julien, P.Y. (2002). River Mechanics. Cambridge University Press, New York, 31-78.

Kirkby, M.J. and Morgan R.P.C. (1980). Soil erosion. Chichester, New York. Bridsbane, Toronto, John Wiley and Sons Publications.

Mukherjee, S., Joshi P.K., Mukherjee S., Ghosh A., Garg R.D. and Mukhopadhyay A. (2014). Evaluation of vertical accuracy of open-source Digital Elevation Model (DEM). *International Journal of Applied Earth Observation Geoinformatics*, **21**, 205-217.

Paghadal, M. (2014). An assessment of surface and groundwater resources of Ozat river basin using remote and GIS.

Renard, K., Foster G., Weesies G., McDool D. and Yoder D. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). Agricultural Handbook 703, USDA-ARS.

Shinde, V., Sharma A., Tiwari K.N. and Singh M. (2011). Quantitative determination of soil erosion and prioritization of micro watersheds using Remote Sensing and GIS. *Journal of the Indian Society of Remote Sensing*, **39(2)**, 181-192.

USGS. USGS EROS Archive—Digital Elevation—Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global. Available online: https://earthexplorer.usgs.gov/

Wischmeier, W.H. and Smith D.D. (1978). Predicting rainfall-erosion losses from cropland east of Rocky Mountains: guide for selection of practices for soil and water conservation. USDA Agricultural Handbook, 282.