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RESEARCH ARTICLE

APPLICABILITY OF SLOPE LENGTH AND SLOPE STEEPNESS (LS) FACTOR IN THE PATHRO RIVER BASIN, JHARKHAND INCORPORATING WITH GIS ENVIRONMENT

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ABSTRACT

Soil erosion has emerged as a global environmental challenge, intensified by growing population pressures and increasingly intensive land use. Even minor soil loss can trigger significant ecological and socio-economic consequences. Erosion occurs through both natural processes and human-induced activities, making its assessment essential for sustainable land management. Among the widely applied models, W. H. Wischmeier's Universal Soil Loss Equation (USLE) and Reynard's Revised Universal Soil Loss Equation (RUSLE) provides a robust framework for estimating soil erosion. Both the models incorporate key factors such as rainfall intensity, soil erodibility, vegetation cover, slope length and slope steepness, and land conservation practices. Slope length and Slope steepness (LS factor) plays a critical role in identifying zones most vulnerable to erosion. Reliable estimation of Slope Length and Slope Steepness can be achieved using slope map from Digital Elevation Model with the help of Arc GIS platform which mainly identify the zone of soil loss when other factors remain constant. In the Pathro River basin, the main objective how slope length and steepness factor affect the soil erosion and its intensity offering valuable insights for prioritizing conservation measures and mitigating land degradation.

KEYWORDS

Environmental Challenge, USLE, RUSLE model, Digital Elevation Model, Land Degradation.

1. INTRODUCTION

The developing world under the threshold of food insecurity. According to Food and Agricultural Organization if the global population reaches 9.1 billion by 2050, the FAO says that world food production will need to rise by 70%, and food production in the developing world will need to be doubled. Unscientific use and mismanagement led to soil degradation, which is an important global issue causing huge impact on agricultural productivity and environmental quality (Maji, 2010; Lakkad, 2025). Topography is the main factor affecting soil erosion (Koo, 2016). Terrain factors associated with curvature, topographic relief, and slope steepness, length, and direction (MengWang, 2018). Mainly slope length and slope steepness control the amount of soil erosion. Generally steep and longer slope length leads to more soil erosion. Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE) are most widely used Equation to calculate soil erosion (Wischmeier, 1978; Renard, 1997; Liu, 2015).The objective of the study is to calculate Slope length and Steepness factor for soil erosion estimation for better management of soil and its conservation.

2. MATERIAL AND METHODS

2.1 Study area

The Pathro River Basin is situated in Jharkhand. Its latitudinal extension is 24º 9' N to 24º 29' N, and longitudinal extension is 86º 15' E to 86º 48' E. Pathro River is tributary of the Ajay River. This basin has an area of almost 709 Sq. km. Topographically this River Basin falls within the elevation ranges of 177 m to 461 m above mean sea level. The whole River Basin is a part of Choto Nagpur Plateau region. This basin falls under moderate to steep slope with low vegetation and high intensity rainfall from mainly July to September; therefore, it is more probable to soil erosion

2.2 Digital Elevation Model (DEM)

A Shuttle Radar Topography Mission (SRTM) Digital Elevation Model with a spatial resolution of 30 meters was downloaded from NASA Earth Explorer. The Digital Elevation Model was processed using ArcGIS 10.5 to derive essential topographic parameters.

2.3 Terrain and Hydrological Analysis

Key terrain and hydrological layers—including Fill, Flow Direction, Flow Accumulation, Slope, and LS Factor—were generated using tools available in Arc Toolbox. The LS factor was computed using the Raster Calculator within the Map Algebra toolbox.

2.4 LS Factor Calculation

Both the USLE and the RUSLE equations are written as follows: A=RKLSCP

Where, A represents total soil loss (t ha^{-1} y^{1}); R represents rainfall-runoff erosivity factor; K is a soil erodibility factor; LS is a combined slope length and slope steepness factor; C is a cover management factor; and P is a support practice factor (Renard, 1997; Hongming Zhang, 2013).

The LS (Length-Slope) factor was calculated using the empirical formula

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proposed by Moore and Wilson (Moore, 1992):

$$LS = (\frac{A_s}{22.13})^m \times (\frac{\sin\theta}{0.0896})^n$$

Where:

- $LS$is the slope length and steepness factor
- $A_s$is the upslope contributing area derived from flow accumulation
- $\theta$is the slope angle in degrees
- m and n are empirical exponents based on slope gradient

In this study, the values used were $m = 0.4$ and $n = 1.3$, which are suitable for moderate to steep terrain. Slope reclassification was performed to represent actual ground area distribution across slope categories.

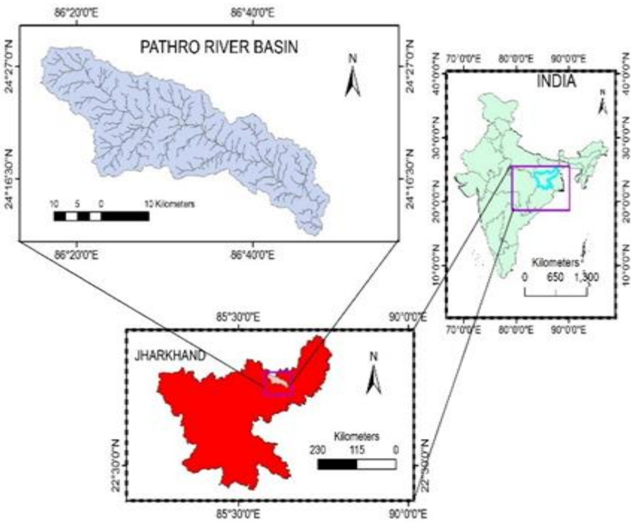

Figure 1: Location Map

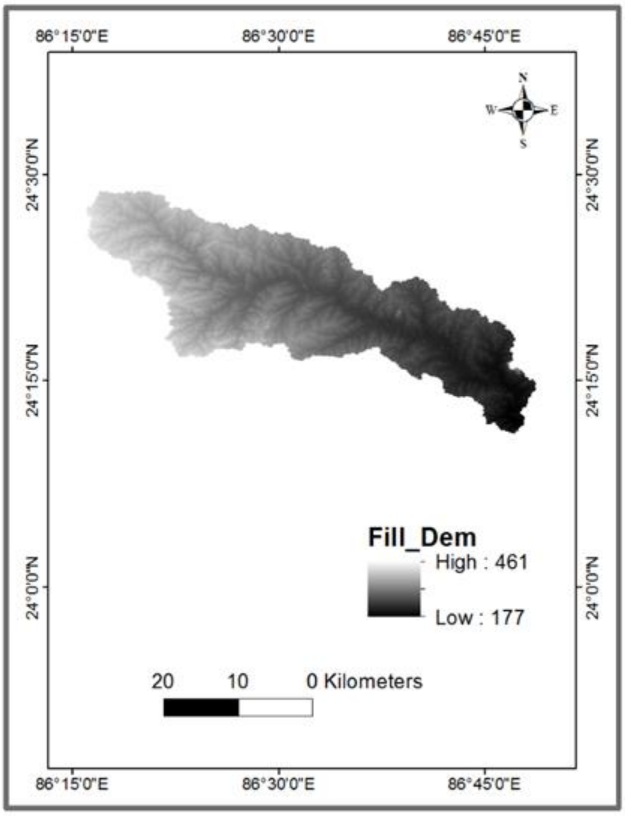

Figure 2: Digital Elevation Model

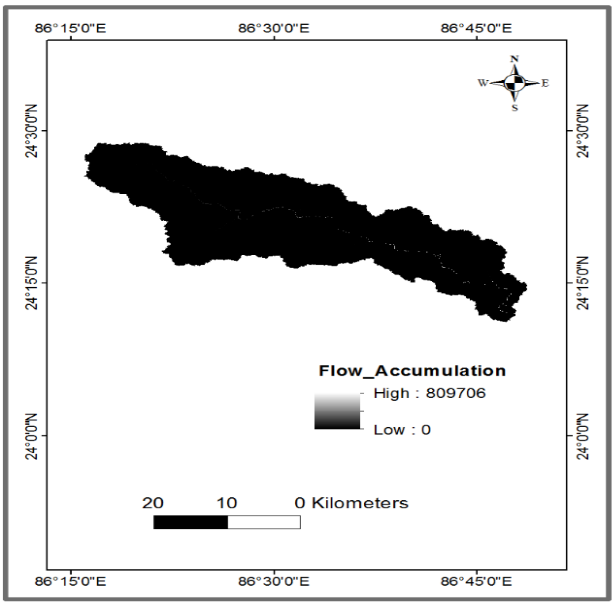

Figure 3: Flow Accumulation

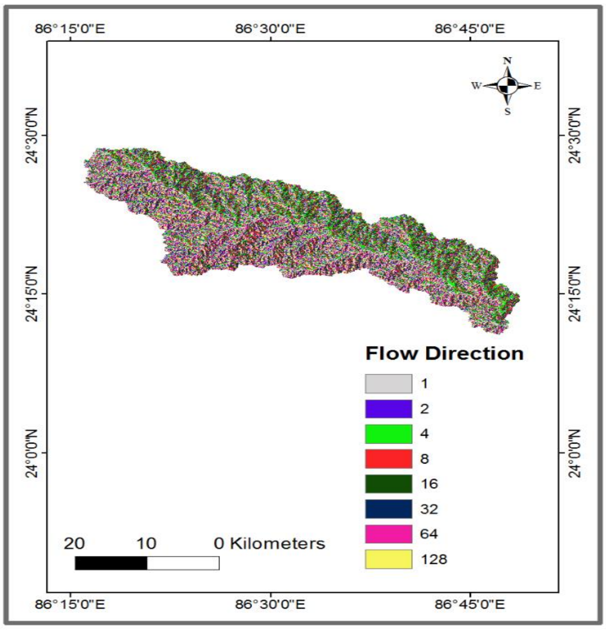

Figure 4: Flow Direction

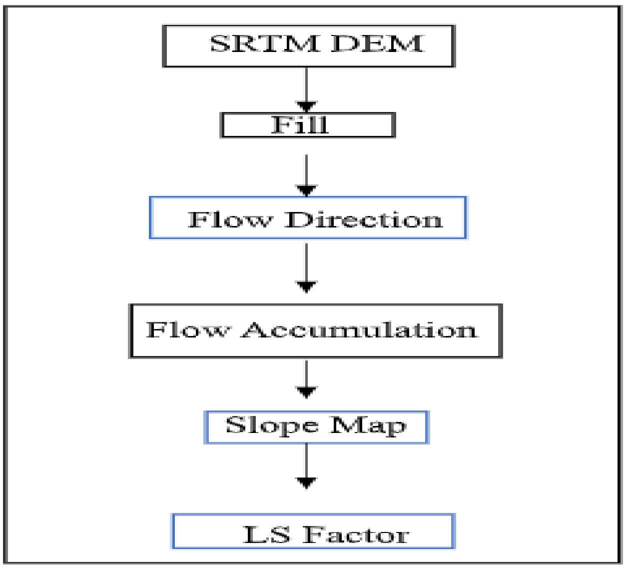

Figure 5: Flow Diagram showing LS factor

3. Result And Discussion

3.1 Digital Elevation Model (DEM)

The Digital Elevation Model (DEM) of the Pathro River Basin provides a comprehensive representation of the terrain morphology. The elevation of the study area ranges from a maximum of 461 meters to a minimum of 177 meters, showing a relative relief of approximately 284 meters across the river basin. Such considerable variation in elevation highlights the rugged nature of the landscape. The Steep slopes and sharp elevation gradients of the basin are particularly evident in the upper catchment areas, which significantly influence the hydrological processes. Such type of terrain characteristics enhances the velocity of surface runoff, thereby increasing the susceptibility of the basin to intense soil erosion. The DEM of the study area thus serves as a critical input for geomorphological and hydrological modelling, offering insights into slope instability, erosion potential, and watershed management strategies.

3.2 Flow Direction

Flow direction analysis delineates the path of water movement across the terrain, assigning each raster cell a downslope direction toward its steepest descent. This spatial representation of hydrological pathways reveals the stream flow pattern within the basin. The results indicate that most streams originate in the northwestern highlands and progressively drain toward the eastern and southeastern sectors of the basin. This directional flow pattern reflects the structural control of the terrain and provides a basis for understanding the connectivity of sub-watersheds, stream ordering, and potential zones of concentrated runoff.

3.3 Flow Accumulation

Flow accumulation analysis quantifies the number of upslope cells contributing runoff to each downslope cell, thereby identifying areas of concentrated flow and potential stream channel formation. High accumulation values correspond to major drainage lines, while low values represent interfluves and ridges. In the Pathro River Basin, the flow accumulation map distinctly outlines the primary drainage network, with channels converging toward the eastern and southeastern outlets. This spatial concentration of flow underscores the drainage intensity of the basin and highlights critical zones where erosion hazards are most pronounced. Such information is indispensable for prioritizing soil and water conservation measures, particularly in regions where agricultural activities intersect with steep slopes and high runoff potential

3.4 Slope map

The highest slope within the study area is almost more than 64 degrees. The slope has been categorized into five distinct classes, as presented in the accompanying table. Each class has been reclassified to reflect the area it covers. The first, second, and third slope classes encompass approximately 169.54 sq.km, 270.81 sq.km, and 239.95 sq.km, respectively. These regions are relatively less susceptible to soil erosion due to their gentle slopes. In contrast, the fourth and fifth slope classes cover 29.25 sq.km and 0.03 sq.km, respectively. These areas are more prone to intense soil erosion, primarily because of their steep slope characteristics. In figure-6 the red patches cover most steep slope mainly small hilly track. The green patches cover plain and riverine valley.

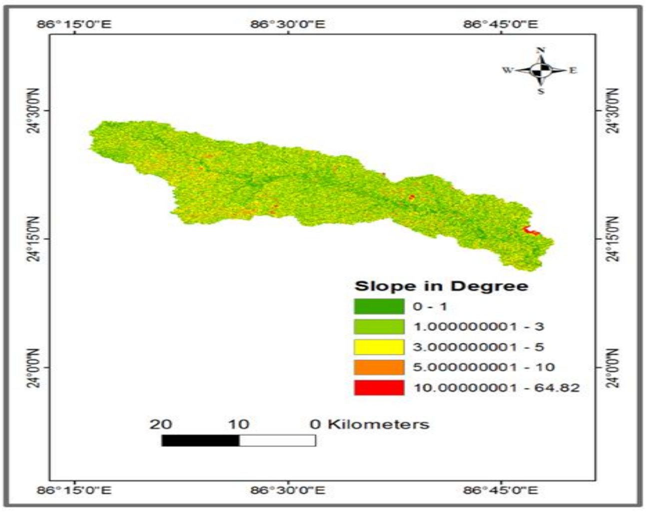

Figure 6: Slope in degree of the Study area

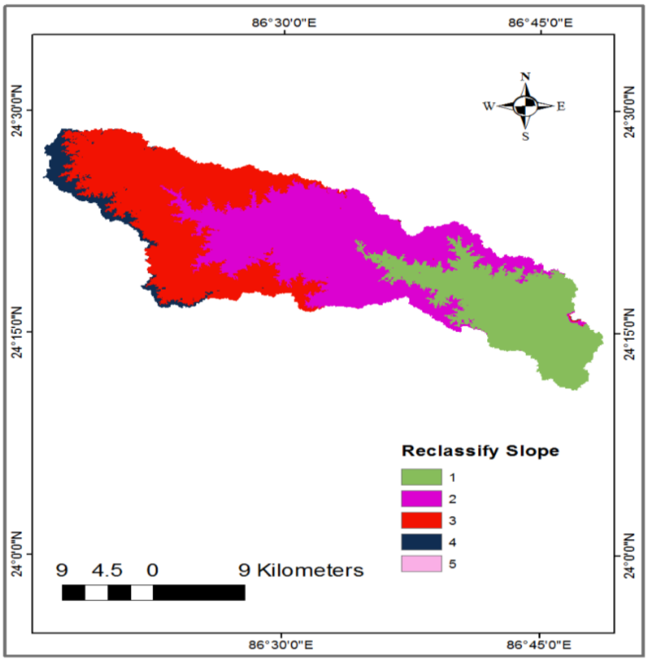

Figure 7: Reclassification of the Slope

Table 1: Slope classification with area	
Slope Classification (in degree)	**Area (in sq.km)**
0 - 1	169.54
1.000000001-3	270.81
3.000000001-5	239.95
5.000000001-10	29.25
10.00000001-64.82	0.03

3.5 LS Factor

The LS (Length-Slope) factor value of the study area reaches up to 31.01 which represent very steep and lengthy slope exposed to intense soil erosion by intense surface runoff. A significant portion of the area (Figure 8) around almost 169.54 sq.km—falls within the LS factor range of 0 to 1, indicating relatively gentle slopes. In contrast, about 270.81 sq.km of the area exhibits LS factor values almost 1 to 3. The third zone almost 239.95 sq.km represents LS factor of 3 to 5. The remaining segment mainly almost 30 sq.km represents LS value of 5 to almost 31. This segment primarily corresponds to steeply sloped terrain, which is highly vulnerable to soil erosion due to its topographic characteristics. In figure-9 the white patches represent highest LS value and black patches represents low LS value.

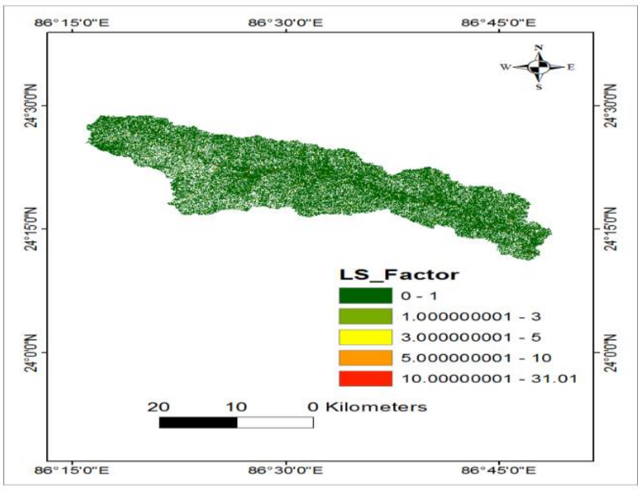

Figure 8: Classification of LS factor

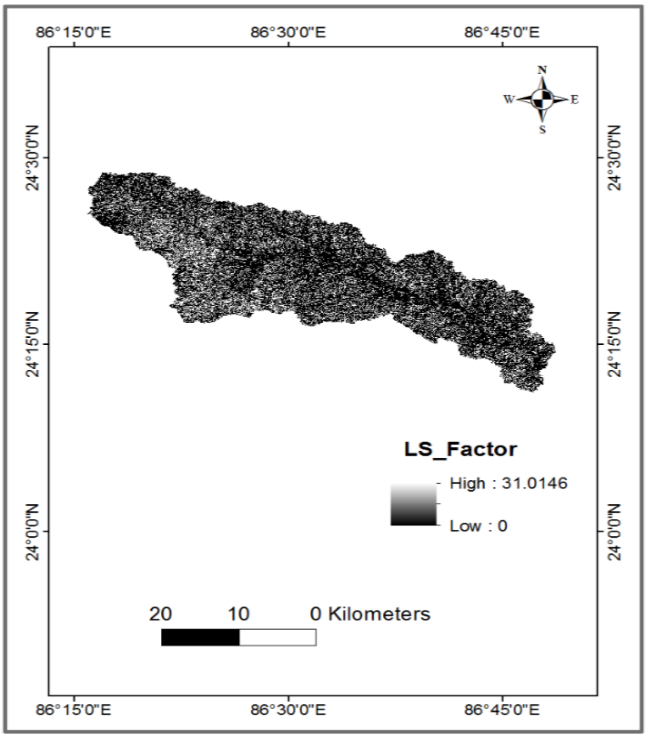

Figure 9: LS factor

4. Conclusion

The study area is predominantly characterized by high hillock-like landforms, with most of the part is undulating plateau surface. The relief ranges from a minimum elevation of 177 meters to a maximum of 461 meters, indicating significant topographic variation. Slope reclassification reveals that areas with the highest LS (slope length and steepness) values are primarily concentrated in zones of steep gradient. This spatial correlation suggests that LS values are strongly influenced by slope steepness and slope length. Assuming other factors of the USLE/RUSLE Model such as rainfall erosivity (R), soil erodibility (K), vegetation cover (C), and conservation practices (P)—remain constant across the landscape, the LS factor becomes a dominant determinant of erosion intensity. In such a scenario, higher LS values directly correspond to steeper with longer slopes, which in turn imply greater susceptibility to soil erosion.

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