Soil loss modelling in Himalayan region; A case of Tuirial Basin, Mizoram

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Abstract

Soil loss is most common phenomenon everywhere but it is more peculiar in the eastern Himalayan extension region like Mizoram due to its rugged terrain composed of sedimentary rock. As the region falls under moist tropical climate, erosion is assumed to be very high due to existence of steep slopes and loose sedimentary terrain, which needs attention for soil conservation and other management practices to check at least to minimize further erosion. An attempt was made in Tuirial watershed in the northeastern part of Mizoram based on the integration of the factors like R, K, LS and C in GIS environment. The estimated average annual soil loss ranges from 0.0 to 1519.52 thousand t $ha^{-1}y^{-1}$. Soil loss in this watershed was classified into seven zones of erosion intensity. Among all, high to very severe zones occupy large area of about 13027.53 ha. which is 9.35% of the total area. The use of geospatial technologies in the quantification of soil loss through the integration of R, K, LS, C and P factors for better resource planning in order to implement appropriate conservation measures is found to be effective.

Introduction

Soil erosion is one of the most severe environmental issues in Himalayan region, due to loose and fragile geological rock formation. The running water, surface run-off, wind, temperature, rainfall, landuse pattern and topography are the factors responsible for erosion. Mizoram is hilly area with short slope length favourable for the formation of v-shaped valleys. The loose and fragmented rock are transported down toward low valley soles by the gravitational forces. The mean annual rainfall in Mizoram is about 2500 mm received by moist tropical climate and south west monsoon. The high rainfall accelerates intensive run-off, over steep sloping terrain, which is aggravated by agricultural activities. Thus, the increased shifting cultivation practise in this area has led to dynamic changes in the forest cover. Thereby, the exposed bare ground with loose soil is prone to severe erosion.

The universal soil loss equation (USLE), modified universal soil loss equation (MUSLE) (Wischmeier and Smith, 1978), revised universal soil loss equation (RUSLE) (Renard et al., 1997), soil and water assessment tool (SWAT) (Arnold et al., 1998), and European soil erosion model (EUROSEM) (Morgan et al., 1998) are the most popular empirical methods for predicting soil erosion. The most widely used models to estimate soil erosion among empirical methods are USLE and RUSLE. The empirical approaches of both the RUSLE and USLE techniques are the same (Vanlalchhuanga et al., 2021). However, RUSLE has a few advantages over USLE. The RUSLE empirical approach is modified and upgraded, such as with monthly rainfall factors and an empirical equation for the computation of the slope length and steepness of slope (LS) factor (Renard et al., 1991).

In this study, RUSLE (Renard et al., 1997) empirical approach was used to estimate soil erosion in the Tuirial basin of Mizoram by integrating five parameters, such as soil erodibility factor (K), rainfall erosivity factor (R), cover management factor (C), conservation practice (P) factor, slope length and steepness factor (LS) (Renard et al, 1997). The advantage of RULSE model can accurately estimate annual soil loss

(Tessema, 2020). The number of scientific investigations have been performed to estimate annual soil loss using RUSLE and geospatial techniques globally, such as the upper Tuirial watershed (Barman at el., 2020), in the northeastern part of India, at Mahadevpur block (Vanlalchhuanga at el., 2021), the western Ghats of Kerala (Thomas at el., 2018), the lower Kulsi basin of Northeast India (Thakuriah, 2023). In other countries, like Sri Lanka, at the Sabaragamuwa basin (Senanayake at el., 2020), and in Malaysia, at the Pansoon sub-basin (Yusof at el., 2019). Thus, this method is widely used to predict soil loss. In the present study includes the details of thematic layer to compute LS factor like flow accumulation (λ), variable length-slope exponent (m), factor that varies with slope gradient (β), slope angle (θ), slope length (L), and the steepness of slope (S). These parameters give the accurate result of LS factor.

The Tuirial river basin is at high risk of soil loss due to high intensity rainfall, fast and heavy surface run-off on the hill slopes, in addition to the human intervention in the thick forest cover to satisfy economic needs. It is highly essential to assess soil loss in the basin for implementation of proper land and water resource management and conservation programmes. The present study aims to estimate the erosion risk zones resulted by severe soil loss within the Tuirial basin. Since the majority of the different land use and cover patterns, such as settlement, forest, water bodies, highways, fallow land, present cultivation, and settled cultivation, are associated with undulating topography in this fragile terrain, which promotes accelerated erosion.

Materials and Methods

Study Area

The Tuirial River Basin covers 1419.17 km^2 area of land and water, it lies between longitudes 92°42'E–92°52'E and latitudes 23°26'N–23°52'N. The highest elevation is 1690 m above MSL seen at Hmuifang hill in the south western corner of the water divide line, and about 23 m above MSL is the lowest at Saipum village north eastern corner of the watershed within the state of Mizoram. The river is about 117 kilometres long, from source to outlet. It originates from the eastern site of Chawilung village at an elevation of 1083 metres above MSL about 62 km from Aizawl city. It flows northward to join the Barak River in Assam. It also formed the district boundary between Kolasib and Aizawl districts on the eastern side. Important perennial streams like the Lungdai Lui, Tuisen Lui, Keitum Lui, Tuiritai Lui, and Hachhe Lui join the Tuirial river before it joins the confluence of the Barak river in the Cachar district of Assam. As the watershed is formed by the structural hills and valleys, it is elongated and spreads in a south-to-north direction. Clay, Loamy soil, Fine loamy, Loamy skeletal, and Coarse loamy are the soils found in the Tuirial watershed. The mean annual precipitation is about 2500 mm of which most of it is received during southwest monsoon in the months of early June to September. Dense, medium, open, and bamboo forests are the different forest types occur in this watershed.

Material Used

The Tuirial basin water divide was extracted from the survey of India's topographical sheets of 83D/14A, 83D/14B, 83D/15, 83D/16, 83H/3, 83H/3, 84A/12, 84A/13, 84A/14, 84A/15, 84E/1, 84E/2, and 84E/3 at 1: 50,000 scale, with reference to the Watershed Atlas of Mizoram using QGIS 3.22 software. The thirteen (13) topographical sheets covering the watershed area were rectified and mosaicted to transform the coordinate system to the WGS_1984_UTM_Zone_46N projection system before digitizing settlement and linear features like streams, and roads (Fig. 1). The rainfall data from seventeen rain gauge stations was collected from NASA power data. A soil texture map was generated using the soil texture data obtained from Mizoram Remote Sensing Application Centre (MIRSAC). The LULC types of the study area were classified from the satellite data (Sentinel 2C) based on-screen visual interpretation techniques in the GIS environment. Advanced Land Observing Satellite (ALOS) Phased Array Type L-band Synthetic Aperture Radar (PALSAR) digital elevation model (DEM) data at 12.5-metre spatial resolution was acquired from the ASF database for the generation of slope in degrees, flow direction, and flow accumulation (Table 1).

Table 1
Materials used

Source	Available at	Data
COPERNICUS	https://earthexplorer.usgs.gov/	SENTINEL 2C
ASF	https://search.asf.alaska.edu/#/	ALOS PALSAR 12.5m
MIRSAC	Directorate of Science and Technology, Mizoram	Soil Texture
NASA POWER	https;//Power/larc/data/access	Rainfall data
Google Earth	https://www.google.com/intl/en_in/earth/versions/	Study Area
Survey of India	Department of Geography and Resource Management, Mizoram University	83D/14A, 83D/14B, 83D/15, 83D/16, 83H/3, 83H/3, 84A/12, 84A/13, 84A/14, 84A/15, 84E/1, 84E/2, 84E/3

Methodology

The RUSLE (Renard et al., 1997) which is widely used approach was used to estimate average annual soil loss (A) and erosion risk zones in the Tuirial basin (Eq. 1). Also, the details methodological flow chart highlighted in Fig. 2.

$A = R \times K \times L \times S \times C \times P$, (1)

Where A means averages annual soil loss per unit area (t $ha^{-1}yr^{-1}$), R is the rainfall erosivity (MJ mm ha^{-1} yr^{-1}), K is the soil erodibility factor (ha hr. MJ^{-1} mm), L is the slope length factor, S is the slope steepness factor (dimensionless), C is the cover management factor (dimensionless), and P is the support and conservation practice factor (dimensionless).

Rainfall Erosivity Factor (R)

The Rainfall erosivity factor of soil loss depends on the amount and intensity of rainfall (Renard et al., 1991), and it is also the most important to determine soil loss (Thakuriah, 2023). The rainfall erosivity factor is determined by two rainstorm characteristics like kinetic energy (E) and the maximum 30-minute intensity (I) (Wischmeier, 1959). In the present study, thirty (30) years (1992–2022) of NASA power daily rainfall data of 413-metre resolution at seventeen rain gauge stations was downloaded to compute the R factor. The rainfall data was interpolated using the inverse distance weighted (IDW) tool as this method is suitable for smooth rainfall distribution due to the least error (Bakis et al., 2021). Thus, the rainfall erosivity factor (R) was estimated using (Eq. 2) the raster calculator in ArcGIS 10.4, after Chattopadhyay et al. (2014) and Vanlalchhuanga et al. (2021).

R = 79 + 0.363 x (2)

Where R is the rainfall erosivity factor (MJ.mm ha^{-1} hr^{-1} yr^{-1}), x is mean annual rainfall (mm).

Soil erodibility factor (K)

The susceptibility of soil loss is determined by the soil texture, grain size, organic content in the soil, surface run-off, and the amount and intensity of rainfall (Prasannakumar et al., 2011; vanlalchhuanga et al., 2021; Thakuriah, 2023). Soil texture and the attribute information were prepared by the data obtained from the Mizoram Remote Sensing and Application Centre (MIRSAC, 2015). K factors for each soil texture in the study were identified from the soil erodibility value after Barman et al. (2020). The K value of each soil texture was added to the attribute table and converted into a raster thematic layer using ArcGIS 10.4.

Slope Length and Slope Steepness (LS) Factors

Slope length (L) is the length of distance from the origin to where the slope gradually decreases to the extent that deposition begins and finally enters the river channel (Wischmeier and Smith, 1978). Slope steepness (S) is the angle of inclination of the slope and is a dimensionless factor. The higher the slope length and the angle of inclination, the higher the possibility of a higher risk for soil erosion (Renard et al., 1977; Wischmeier and Smith, 1978). In the initial period, the USLE and RULSE developed for gently slopes areas for one dimension however, in the rugged terrain region it becomes two-dimensional, making dimensional to estimate LS factor is difficult (Van Remortel et al., 2004). There are various methods of LS factor calculation, although, in this study we adopted LS factor computation after Van Remortel et al., (2004) and Moore and Wilson (1992). The LS factor was determined using ALOS PALSAR DEM data following the following equation.

$$\lambda = \left[\frac{FlowAccumulation}{3.1416}\right]^{0.5}$$

3

$$\beta = \frac{\sin\theta}{\left[3 \bullet (\sin\theta)^{0.8} + 0.56\right]}$$

4

$$m = \frac{\beta}{(1+\beta)}$$

5

$$L = \left[\frac{\lambda}{22.13}\right]^{m}$$

6

$$S = 10.8 \bullet \sin\theta + 0.03\theta < 9\%$$

7

$$S = 16.8 \bullet \sin\theta - 0.5\theta \geq 9\%$$

8

$$LS = \left[\left(\frac{"\ \lambda\ "}{22.13}\right)^{\wedge}\ "\ m\ "\right] \times\ "\ S\ "$$

9

where λ is flow accumulation, m is a variable length-slope exponent, β is a factor that varies with slope gradient, and θ is the slope angle, L is the slope length (m), S is the steepness of slope.

Cover Management Factor (C)

The cover management factor is defined as the ratio of soil loss to a specific land use land cover. The P factor ranges from 0 to 1, depending upon the types and patterns of land use and land cover. It also varies with the rate and amount of soil loss depending on the land use and land cover. The area where vegetation indirect contact with raindrops on the soil particles has less erosion. While the area with bare land has more soil loss due to the direct impact of raindrops on the soil surface (Prasannakumar et al., 2012; Rahaman et al., 2015), Sentinel 2-C multispectral satellite data of 10 metre spatial resolution acquired on March 3, 2023, was used to prepare a land use and land cover layer of the study area using ArcGIS 10.4 software. Settlement, current cultivation, fallow land, water bodies, bamboo, dense, medium, and open forest types were identified as land use types in the study area (Fig. 11). The C factor value corresponding to each land cover condition was assigned as per the study carried out by Barman et al (2020).

Practice Management Factor (P)

The practise management factor is the rate and amount of soil loss under the conservation practise compared with the up and down hill slope cultivation (Dabral at el., 2008; Das at el., 2018; Vanlalchhuanga at el., 2021; Thakuriah, 2023). Practise management factors such as contouring, terraces, proper drainage, and settled agriculture help to reduce the rate and amount of soil loss because they reduce surface run-off (Renard and Foster, 1983). As per the practise management factor, the numerical values from 0 to 1 are constant. The value close to zero denotes that the conservation practise is good, whereas close to 1 refers to poor practise management (Chatterjee et al., 2014; El Jazouli et al., 2017; Ozsahin et al., 2018). The *P* factor values were added to the attribute table and converted into a raster thematic layer using ArcGIS 10.4. The magnitude and the spatial distribution of *P* factor value ranges from 0.28 to 1.00 with a mean value of 0.97 (Fig. 12).

Thematic layer integration using Spatial Analyst tool

The computed values of R, K, C, P, and LS factors were converted into a thematic raster layer, which was integrated through a raster calculator using ArcGIS 10.4, to derive the soil erosion layer of the Tuirial watershed. The thematic layer was reclassified into seven erosion risk zones in terms of ton/ha^{-1}/yr^{-1} of soil loss by spatial analyst tools. Then, the raster layer of the soil erosion map was converted into a polygon to compute each soil loss area.

Results and Discussion

Rainfall erosivity factor (R)

The average annual rainfall distribution for the years 1992 to 2022 varies from 706 to 2112 mm (Fig. 13), and the R-Factor ranges from 956.10 to 1486.93 MJ.mm ha^{-1} hr^{-1} yr^{-1} with an average value of 1116.77 MJ.mm ha^{-1}hr^{-1}yr^{-1} (Fig. 14). The south at Siaksuk and north at Neibawi parts of the river basin are exposed to maximum rainfall, while the north western parts of Aizawl and Sairang experience low rainfall, and the rainfall erosivity is directly proportional to the amount of rainfall received in different parts of the river basin.

Table 2
Soil Texture and K-Factor

Sl.No.	Soil Texture	K-Factor	Area(km^2)	Percentage (%)
1	Fine Loamy	0.57	953.76	67.36
2	Loamy Skeletal	0.54	275.86	19.48
3	Clayey	0.25	66.57	4.70
4	Coarse Loamy	0.66	119.61	8.44

Soil erodibility factor (K)

The calculated K factor varies from 0.51 to 0.66 t ha $MJ^{-1}mm^{-1}$ with a mean value of 0.57 t ha $MJ^{-1}mm^{-1}$ (Table 2). A lower value of K indicates soils that are least prone to erosion, while higher values indicate soils that are highly prone to erosion by water (Barman et al., 2020; Vanlalchhuanga et al., 2021; Thakuriah, 2023).

Slope length and slope steepness factor (LS)

The LS factor varies from 0 to 16.75, with a mean value of 2.71 and a standard error of 1.58 (Fig. 8). Close to zero value are gently slope, the slope length also short. The spatial distribution map clearly shows the concentration of high LS values in steeper slope areas, where there is a sudden change in relief and slope angle (Table 3 and Fig. 9).

Table 3
Slope Angle

SI.No.	Angle (degree)	Area (km^2)	Percentage (%)
1	0–10	1251.94	88.53
2	10_20	20.43	1.44
3	20–30	23.84	1.68
4	30–40	22.47	1.58
5	40–50	23.30	1.64
6	50–60	22.28	1.57
7	60–70	18.66	1.31
8	70–80	18.42	1.30
9	> 80	12.65	0.89

Cover management factor (C)

The magnitude and the spatial distribution of cover management factor are found to be at the range of 0.004to 0.45 with a mean value of 0.16 which indicate medium of soil loss as per the cover management computation (Table 4 and Fig. 10).

Table 4
LULC and corresponding factor C and P factors

Sl.No.	LULC	Area(km^2)	Percentage %	C-Factor	P-Factor
1	Built-up land	28.46	2.01	0.25	1
2	Current Cultivation	13.31	0.94	0.45	0.5
3	Fallow Land	226.19	16.00	0.15	0.9
4	Bamboo Forest	315.68	22.33	0.12	1
5	Dense Forest	11.22	0.79	0.004	1
6	Medium Forest	659.35	46.64	0.12	1
7	Open Forest	122.96	8.70	0.1	0.8
8	Water Bodies	36.57	2.59	0.1	1

Average annual soil loss

The value of soil loss generated from the thematic map ranges from 0 to 1519.52 Mg ha^{-1} yr^{-1} (Table 5 and Fig. 17) The high value pixels are shown in areas such as barren land, Jhum fallows, agricultural land, and built-up areas, as well as in areas where the topography is highly dissected with steep slope. Therefore, current Jhum fallow land are found to be more affected and sensitive in terms of soil erosion in this region.

Table 5
Estimated average annual soil loss of Tuirial River Basin

Sl.No.	Class	Rate of soil loss	Area (ha.)	Percentage
1	very low	0–1	125941.00	90.24
2	low	1_5	112.09	0.08
3	slightly	5_15	110.54	0.07
4	moderate	15–30	358.62	0.25
5	high	30–60	471.40	0.33
6	severe	60–90	540.02	0.38
7	very severe	> 90	12016.10	8.61

Discussion

Based on the RUSLE parameters such as rainfall erosivity factor (R), soil erodibility factor (K), topography factor (LS), cover management (C), and practise management (P), the yearly soil loss of the Tuirial watershed was determined. There are many factors affecting soil erosion, such as rainfall, running water, surface run-off, wind, and solar energy. Of these factors, rainfall is one of the most important and triggering factor. The intensity, duration, and amount of rainfall affect the rate of infiltration. If the rainfall duration is longer, the hardness of soil particles reduces, resulting in the possibility of landslides and movement. In Mizoram surface run-off is found to be very high. The rainfall erosivity factor of the Tuirial basin ranges from 541 to 881 MJ.mm ha^{-1} hr^{-1} yr^{-1} (Fig. 14). The average annual rainfall during these periods varies from 1209 to 2104 mm (Fig. 13). The higher R-value indicates higher rainfall that contributes to soil erosion. The monsoonal rainfall with high intensity and longer duration result in higher surface runoff and was also susceptible to soil erosion on hill slopes and cause floods in the lowland area.

Clay, coarse loamy, fine loamy, and loamy skeletal are the predominant soils found in the Tuirial basin (Table 2, Fig. 15). The soil texture and corresponding K factor values were identified from the soil erodibility values after Barman et al. (2020). The value of K can varies on the basis of soil texture. The K value varies from 0.25 t hr. $MJ^{-1}mm^{-1}$ of clay to 0.66 t hr. $MJ^{-1}mm^{-1}$ of coarse loamy soil texture in the Tuirial basin (Fig. 16). The susceptibility to soil loss increases with a higher K factor. The K value of coarse loamy soil texture is more susceptible to soil loss than the lower K values of clay, fine loamy, and loamy skeletal soil texture in the Tuirial basin.

The steepness of the slope (S) and slope length (L) provide quantitative terrain analysis of the Tuirial basin. The topographic factor of the slope length (L) layer was prepared from the topographic parameters such as λ flow accumulation (Equation. 3, Fig. 3), β slope gradient (Equation. 4 and Fig. 4), variable length-slope exponent (Equation. 5 and Fig. 5), slope length (m) (Equation. 6 and Fig. 6), and the steepness of the slope layer was generated from the sin θ of a slope angle (Equations. 7, 8 and Fig. 7). The LS factor is integrated using (Equation. 9) raster calculator in the ArcGIS environment. The flow accumulation thematic layer is generated after the computation of the flow direction of the Tuirial basin ALOS PALSAR DEM using hydrology tools. The higher flow accumulation values denote that the area has the possibility of high runoff. The spatial variation of the topographic factor (LS) in the Tuirial basin varies from 0 to 16.75 (Fig. 8). The basin slope ranges from 0° to 81.34° (Table 3), and based on the angle of inclination resulted in soil loss (Fig. 9). A higher value of the topographic factor (LS) is more susceptible to soil loss.

The cover management and support practise factors are dimensionless parameters in the RUSLE model; both the C and P factors were derived from land use and land cover (LULC) classifications from the Tuirial basin. The LULC of the Tuirial basin is classified using supervised image classification by QGIS 3.22 from a sentinel 2-C satellite image at 10 metres' resolution after conversion into false composite colour (FCC). The C factor value close to zero means well protected, while the value approaches 1 for current and abandoned jhum cultivation (Fig. 11). The study area is classified into eight types of land use and land cover, such as settlement, current cultivation, fallow land, bamboo forest, open, medium, and dense forest, and water bodies (Fig. 10). The P value ranges between 0 and 1 (Fig. 12), where close or zero is good conservation management, and close to one is the area of poor conservation management

(Vanlalchhuanga et al., 2021; Thakuriah, 2023). The settlement, road construction-affected areas, current cultivation, and fallow land were assigned lower P values, due to bare soil and the cultivation practise on the hill slope, which removed the cover with accelerated high run-off.

The average soil loss of the Tuirial basin was estimated by integrating thematic layers of RUSLE factors using the raster calculator in ArcGIS environment. The average annual soil loss of the Tuirial river basin varies from 0 to 1519.52 thousand t $ha^{-1}yr^{-1}$. Seven zones of soil loss were classified into, low (0–1 thousand t $ha^{-1}yr^{-1}$) 125941 ha. slightly (1–5 thousand t $ha^{-1}yr^{-1}$) 112.09 ha. moderate (5–15 thousand t $ha^{-1}yr^{-1}$) 110.54 ha. high (15–30 thousand t $ha^{-1}yr^{-1}$) 358.62 ha. very high (30–60 thousand t $ha^{-1}yr^{-1}$) 471.40 ha. severe (60–90 thousand t $ha^{-1}yr^{-1}$) 540.02 ha. and very severe (≥ 120 thousand t $ha^{-1}yr^{-1}$) 12016.10 ha (Table 5, Fig. 17a & b). The large area of the basin was identified as erosion-free or with very low soil loss. These areas are covered by thick vegetation, low land, concrete infrastructure, clay, and other less surface run-off. The basin area of 12016 ha (8.61%) was identified as a very severe zone of soil erosion risk. Because of the built-up area, road construction, and current cultivation, exposed bare surfaces on hillslopes accelerate high run-off, as well as high P and LS factors. The high rate of soil loss in the Tuirial basin was identified in the built-up area, barren land, and current shifting cultivation, including cultivable fallow land (Figs. 18 and 19). The thick vegetation cover is found on the high degree slope, which is inaccessible and difficult for cultivation activities. Generally, the Mizo settlements are located on the hill slopes and edges, which contribute to high soil erosion rate along with rainfall and the LS factor (Fig. 18). The FAO estimates that the average soil loss rate in the tropical region is less than 10 t $ha^{-1}yr^{-1}$ (George et al., 2021). However, in the present study area, the average annual soil loss is estimated at 0–1519.52 t $ha^{-1}yr^{-1}$ the upper Tuirial watershed, it is estimated at 0–34323.3 t $ha^{-1}yr^{-1}$ (Barman et al., 2020); and in the northeastern part of India, at Mahadevpur block, the average soil loss is estimated at 0–16843.07 t $ha^{-1}yr^{-1}$ (Vanlalchhuanga et al., 2022). the western Ghats of Kerala experiencing the same tropical climate, it has been estimated at 0–105.578 t $ha^{-1}yr^{-1}$ (Thomas et al., 2018), 0 to 6453 t $ha^{-1}yr^{-1}$ in the lower Kulsi basin of Northeast India (Thakuriah, 2023). Whereas in countries, like Sri Lanka, at the Sabaragamuwa basin, the average annual soil loss is estimated at 0.0–50 t $ha^{-1}yr^{-1}$ (Senanayake et al., 2020), and in Malaysia, at the Pansoon sub-basin, it is estimated at 0–18473 t $ha^{-1}yr^{-1}$(Yusof et al., 2019). According to the literature and the previous study, India's average annual soil loss is far more catastrophic than that of other tropical climate countries.

Conclusions

It was observed that in the areas of settlements, road construction, and current cultivation soil loss was found high in the Tuirial basin. Fine to loamy soil contributes more than 80% of the total area, which is highly at risk of soil loss. Whereas near the main river, the dominant soil is clay, but there is less erosion because of the compact soil texture. Along the water dived settlements such as Hlimen, Bukpui, Thingthelh, North Chaltlang, Lungmuat Nisapui, Serkhan, Lungdai, Sihphir, Nausel, Aizawl, Falkawn, Sateek, Tachhip, Lamchhip, Baktawng, Thingsulthliah, Seling, Saitual, Mauchar, Ratu, and Saipum village experience severe to extremely severe soil erosion. Support practise (P) and topographic factor (LS) with cover management are the leading factors that contribute to massive soil loss even in the same rainfall erosivity (R) and soil erodibility (K) factors in the study area. The GIS-based RUSLE model has successfully estimated long-term average annual soil erosion in the Tuirial River Basin. The model offers a valuable means for identifying the susceptible areas of soil loss and planning and implementing soil and water conservation measures to reduce the soil loss. The results can be improved by improving the input data, like a high-resolution DEM, to extract a more accurate LS factor. More rainfall stations within the study area can improve the accuracy of the R factor and provide a more accurate assessment of soil erosion in the basin.

Declarations

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Author contributions

Imanuel Lawmchullova (Junior Fellow Research): Manipulation of data, Conceptualization, Methodology, Data analysis, Mapping, Writing original draft. Udaya Bhaskara Rao (Prof): Critical review, Supervision, Editing. Lalrinkimi: Editing, Investigation, Review.

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Data availability

The data supporting the findings of this study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no competing interests.

Ethics approval

All authors have read and understood and have complied as applicable with the statement on “Ethical responsibilities of Authors” as found in the Instructions for Authors and are aware that, with minor exceptions, no changes can be made to authorship once the paper is submitted.

Consent to participate

All participants provided informed consent to participate.

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Figures

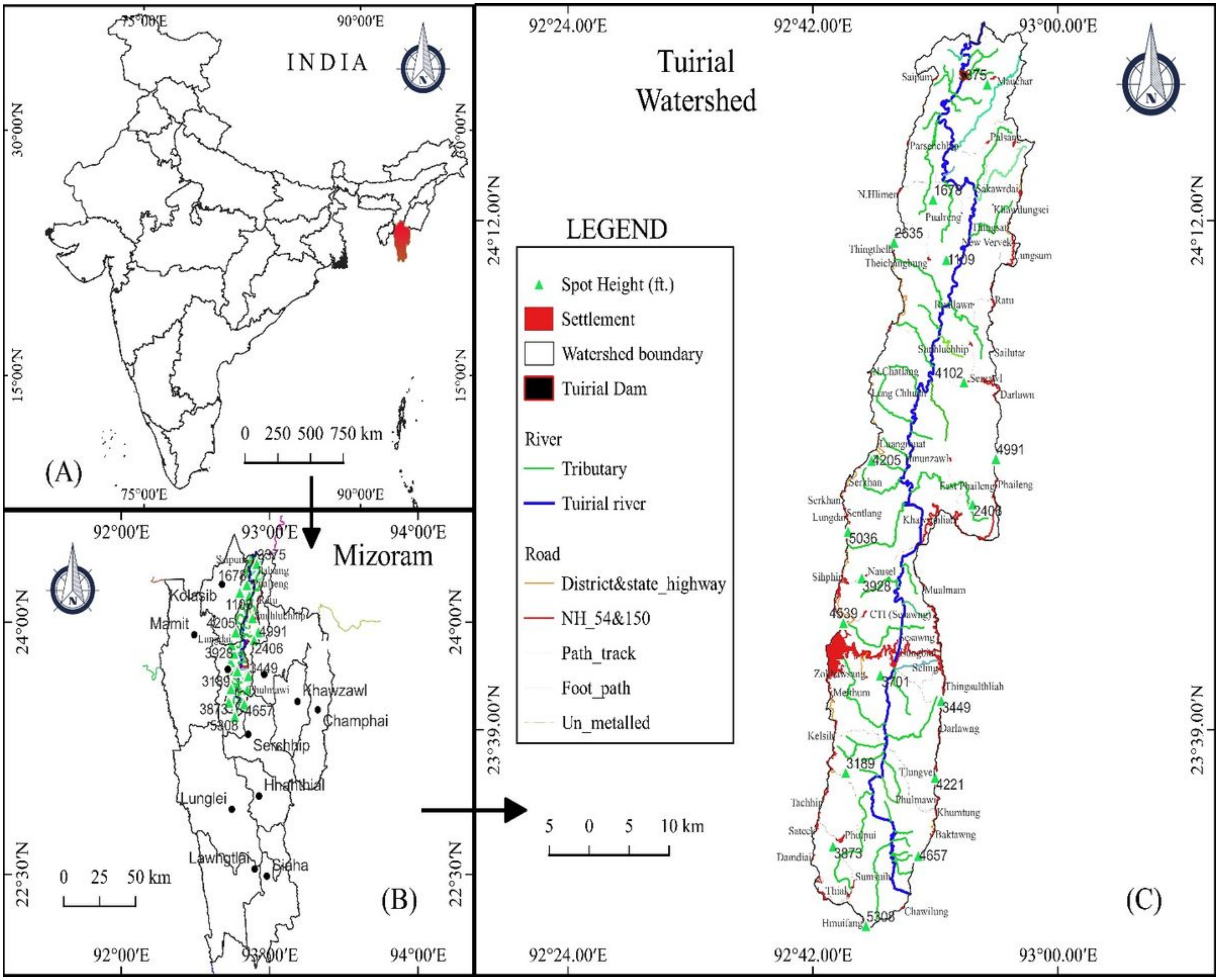

Figure 1

Location of study area

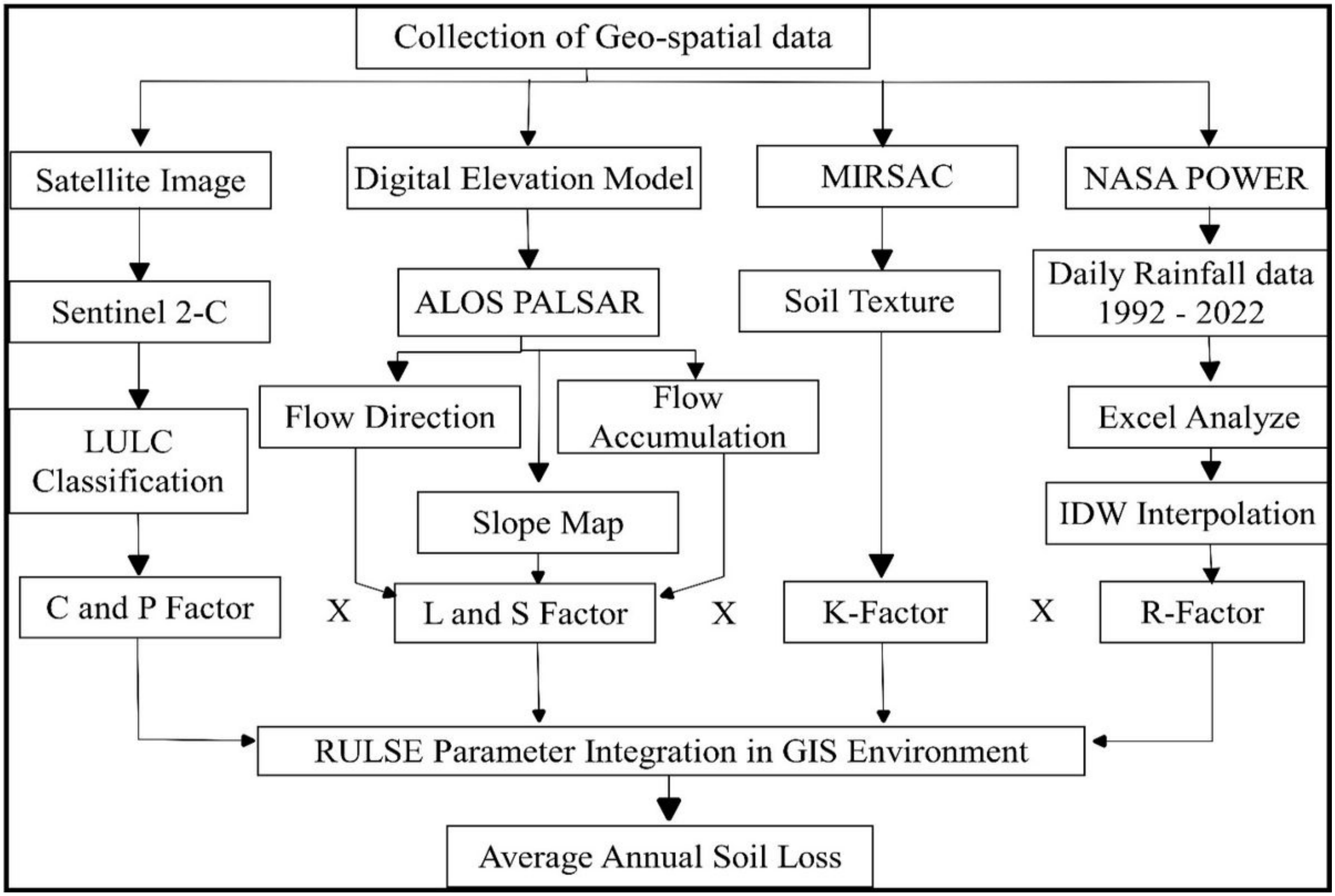

Figure 2

Work flow for estimation of annual soil loss

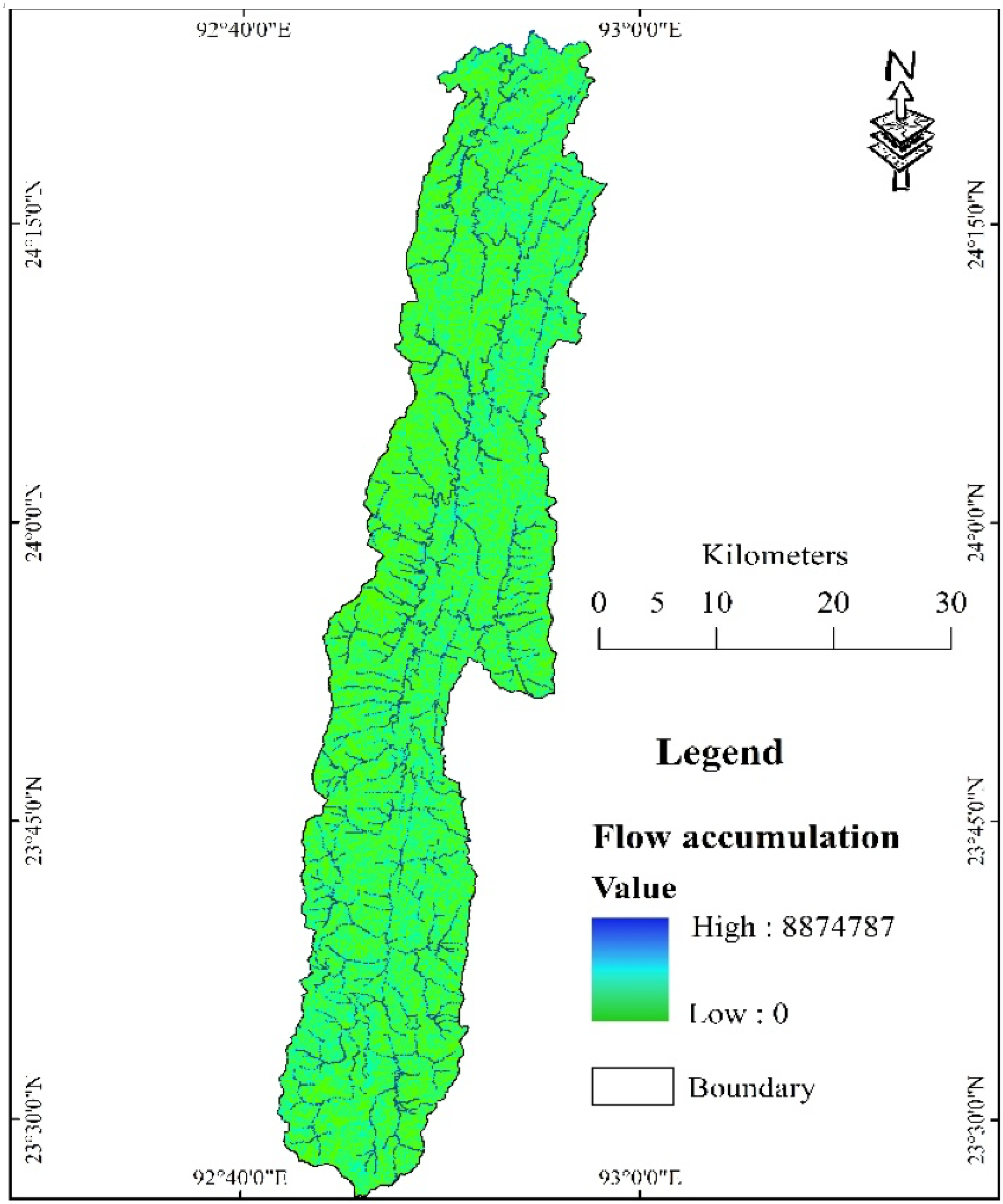

Figure 3

Flow Accumulation

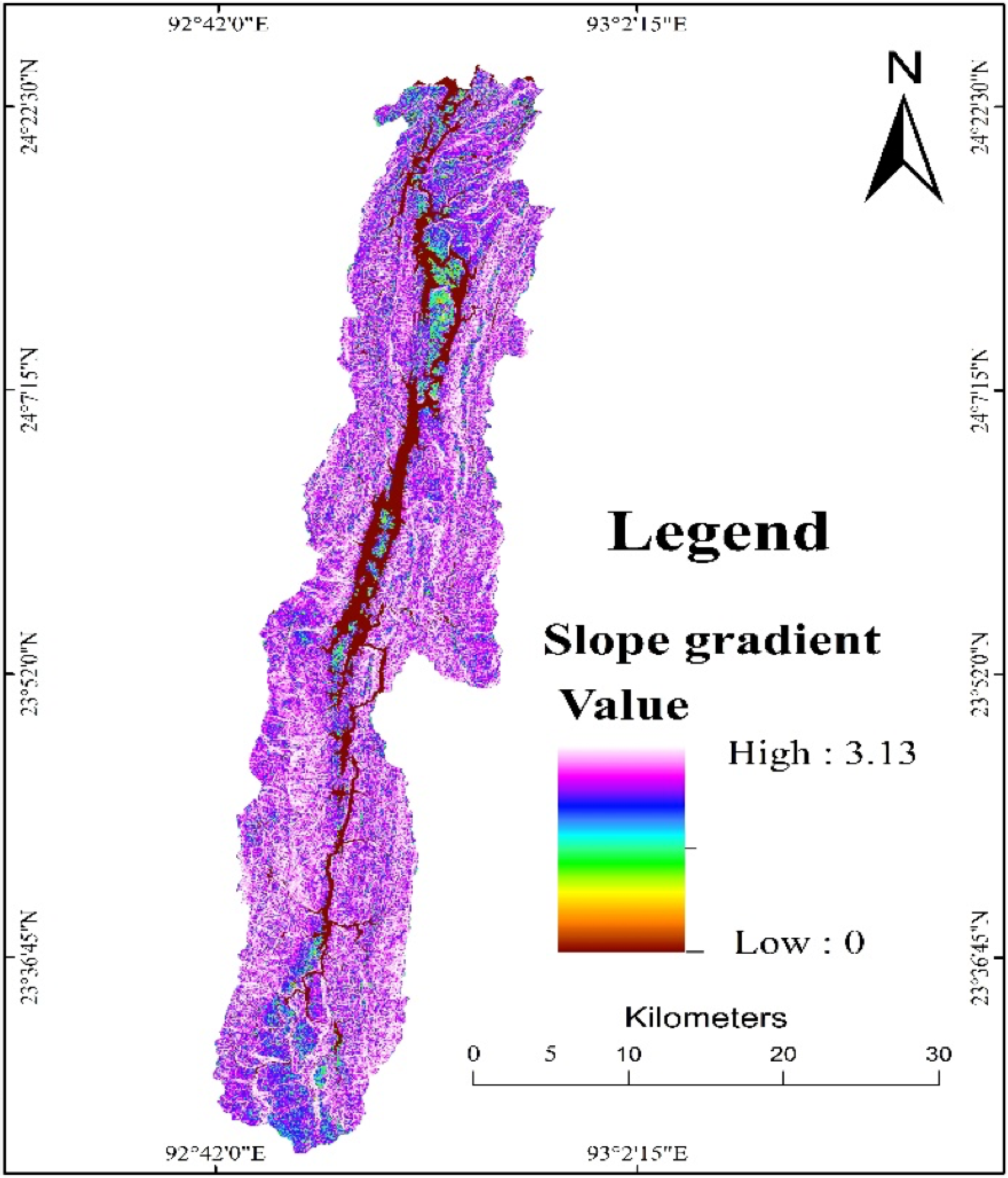

Figure 4

Slope Gradient

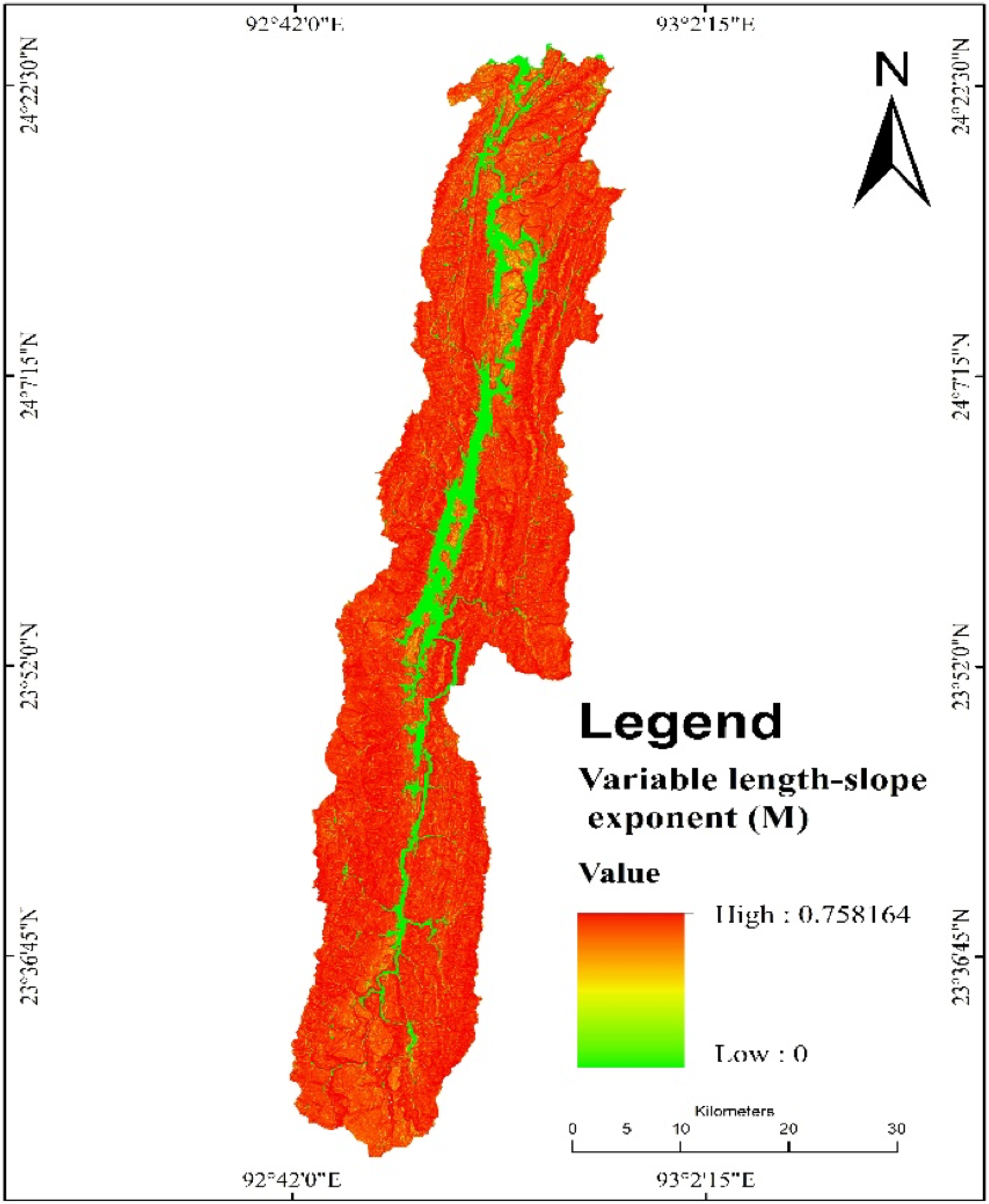

Figure 5

Variable length slopes exponent

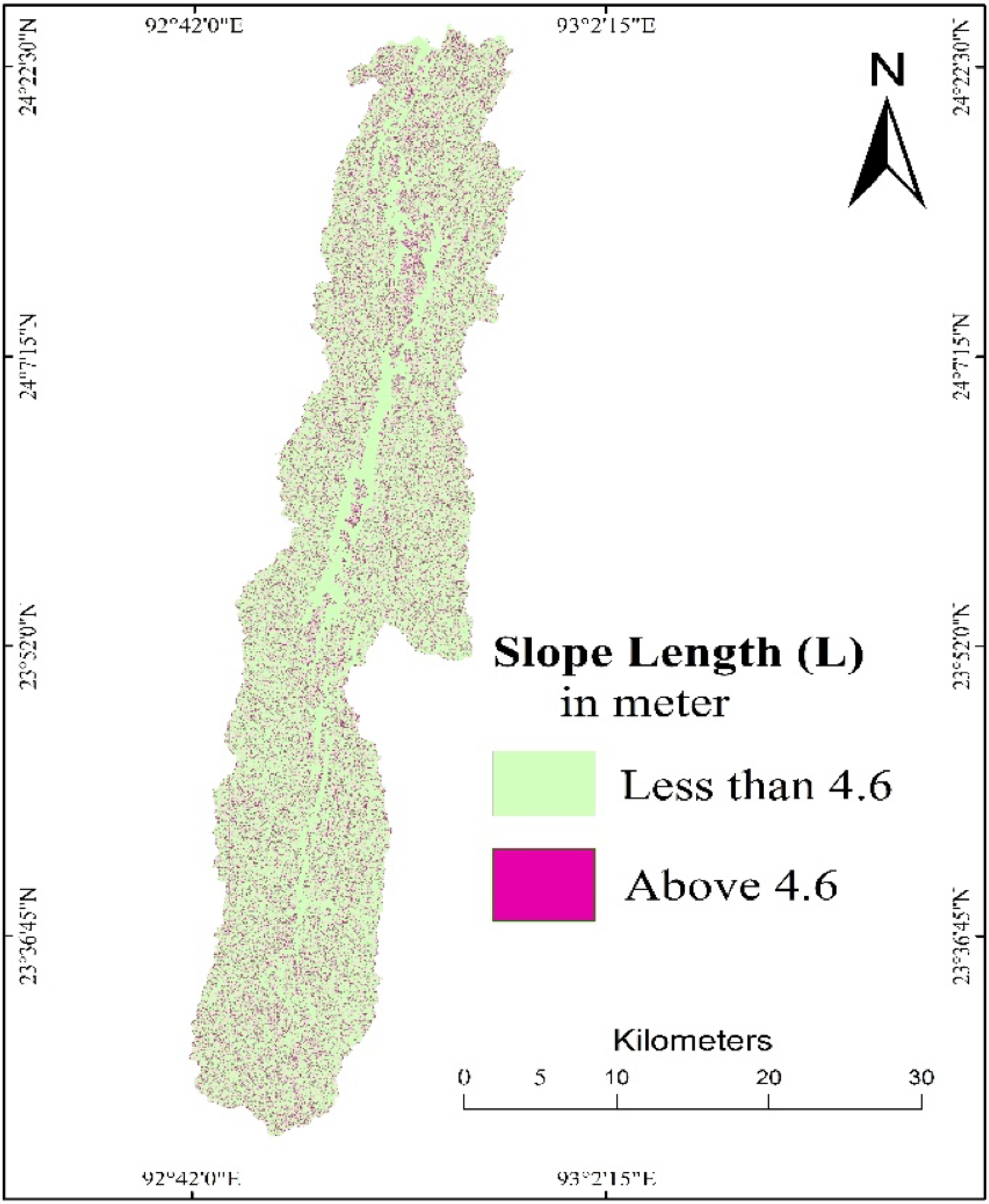

Figure 6

Slope Length

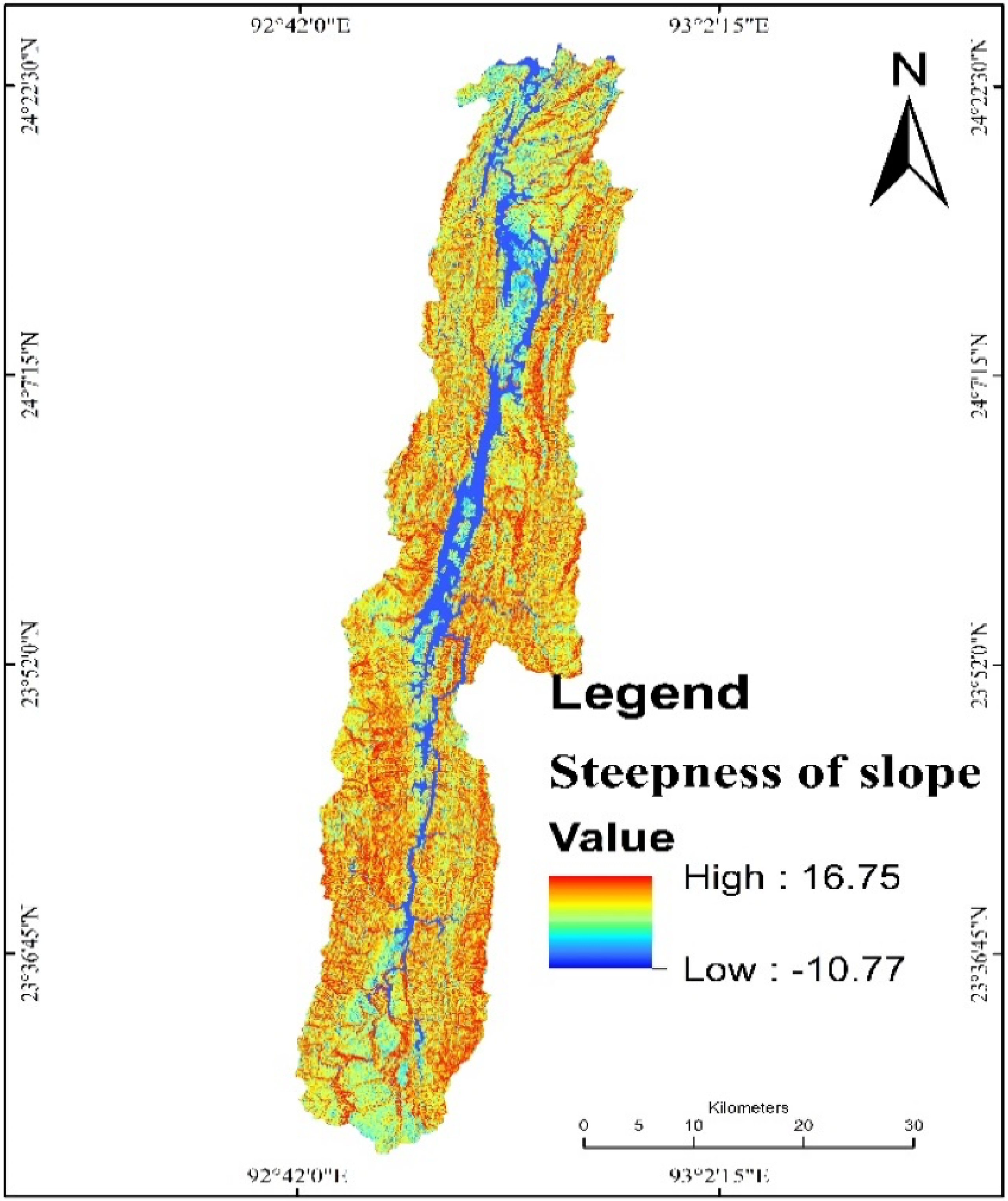

Figure 7

Steepness of slope

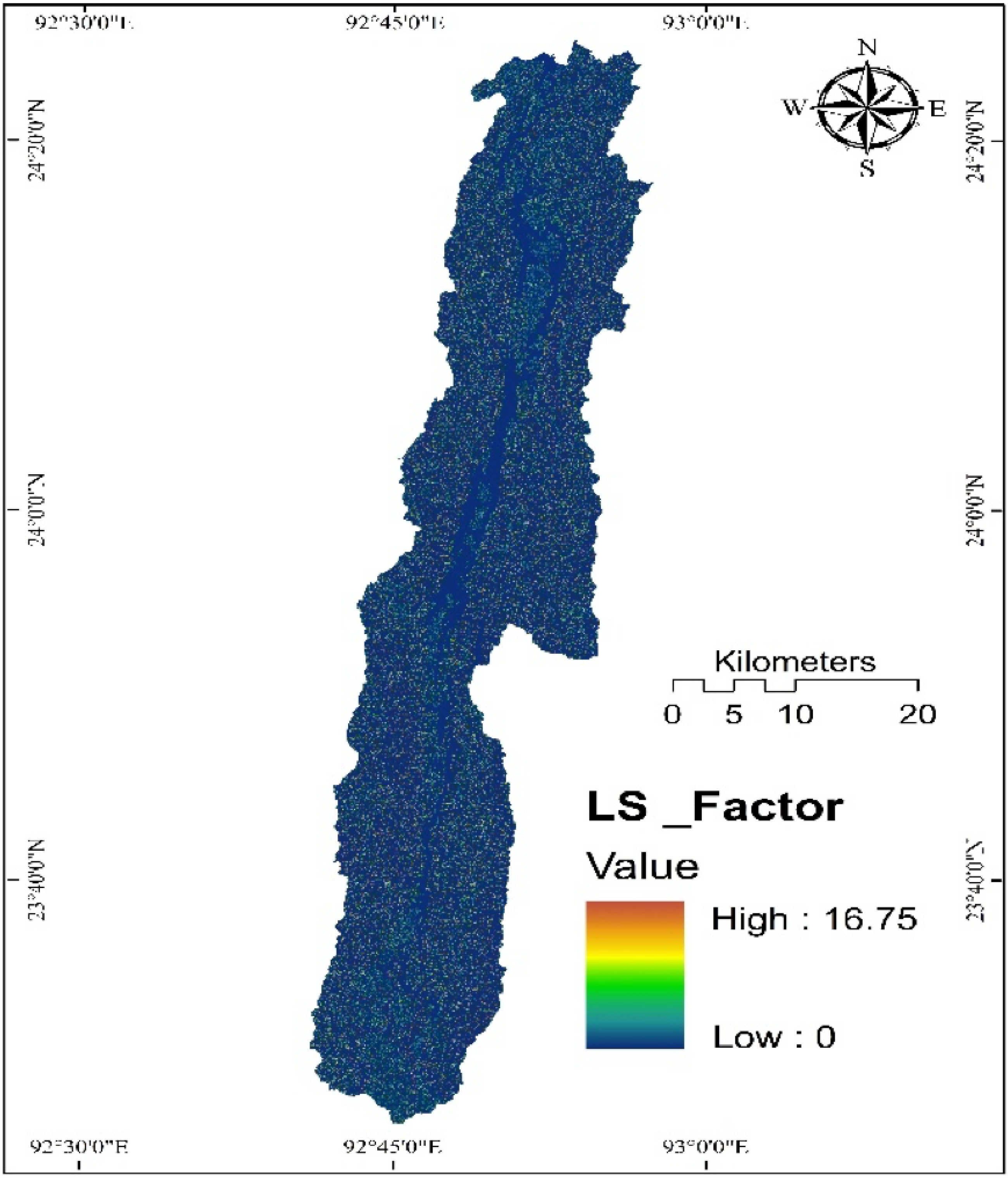

Figure 8

LS Factor

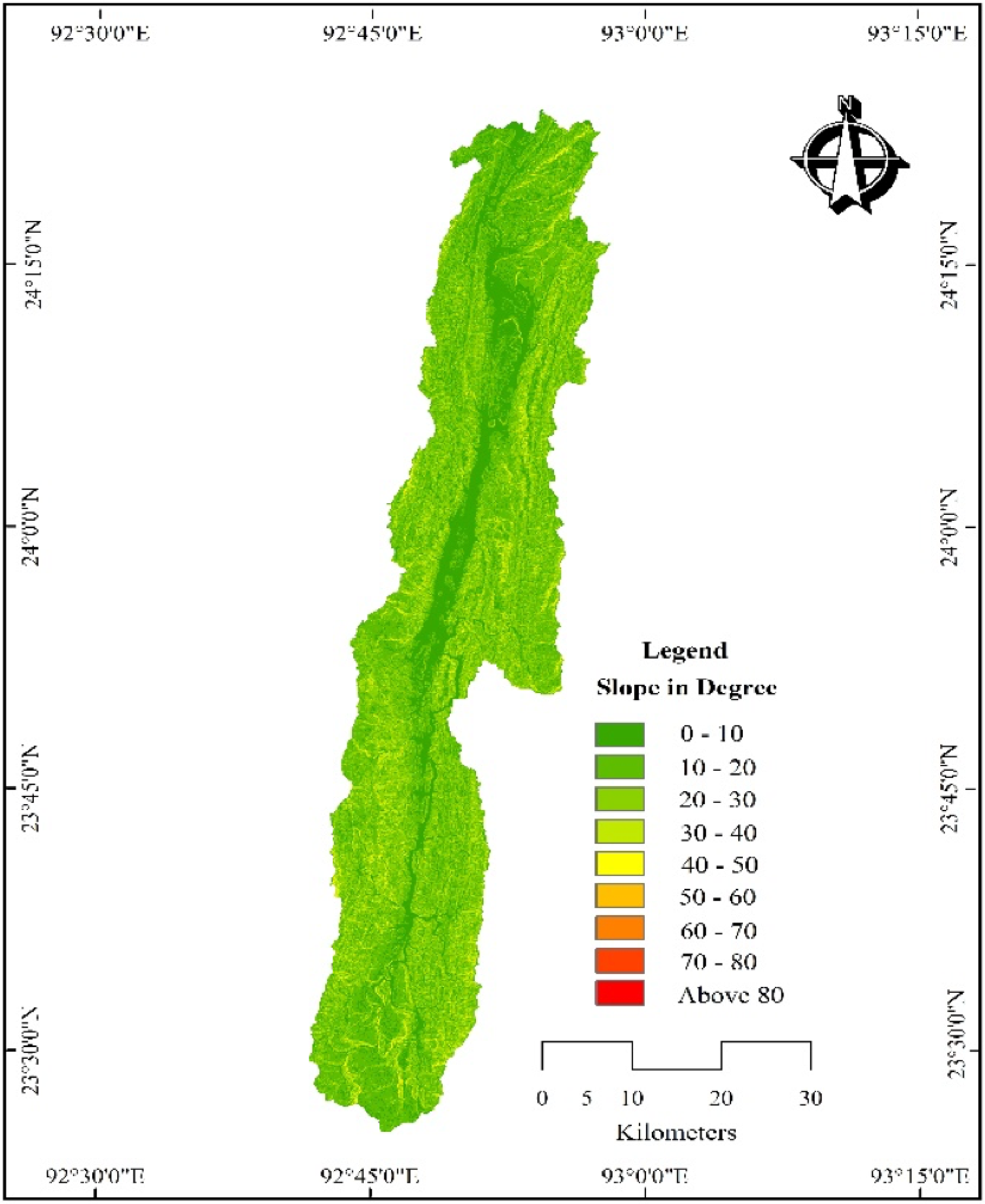

Figure 9

Tuirial basin slope

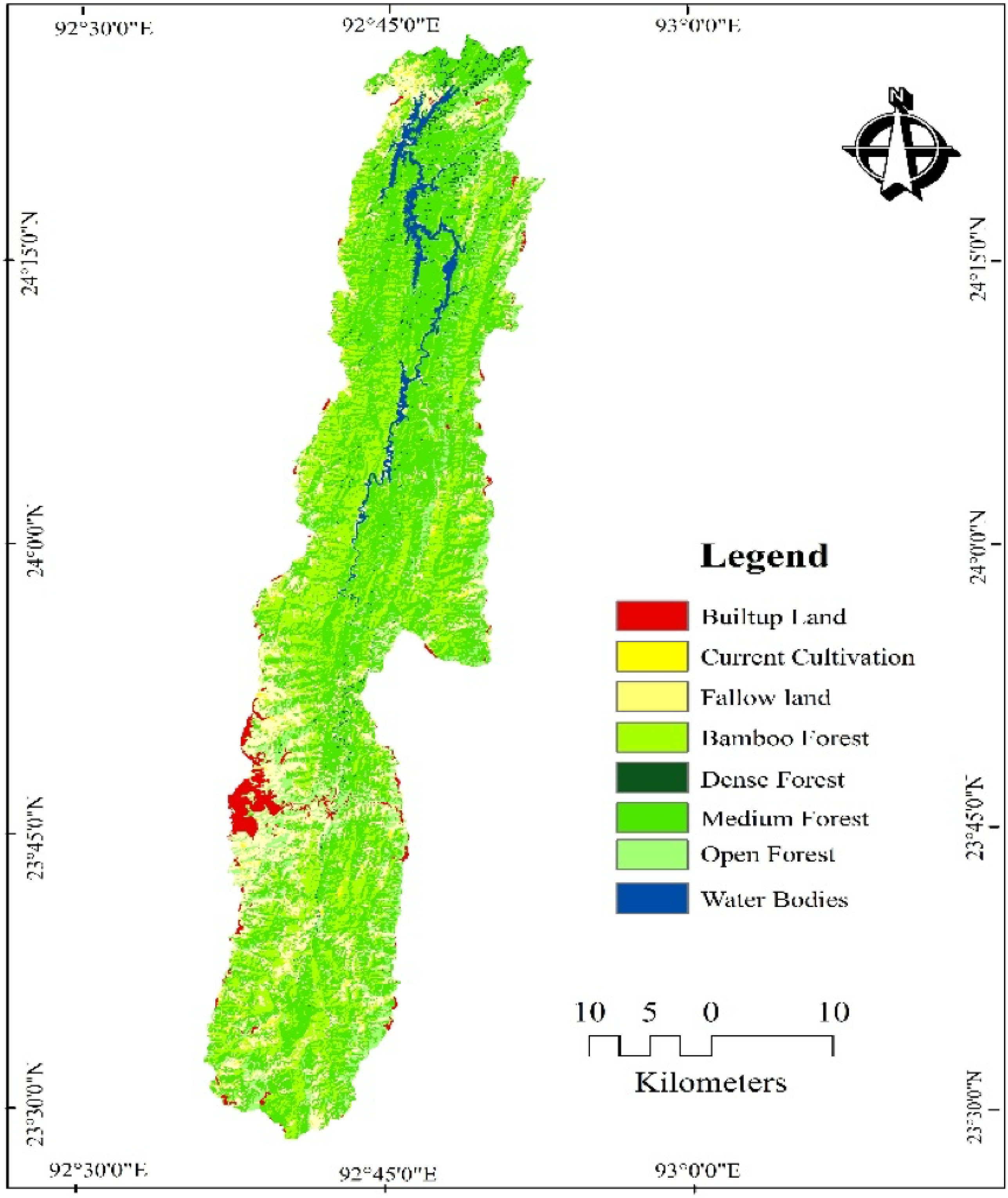

Figure 10

LULC of Tuirial basin

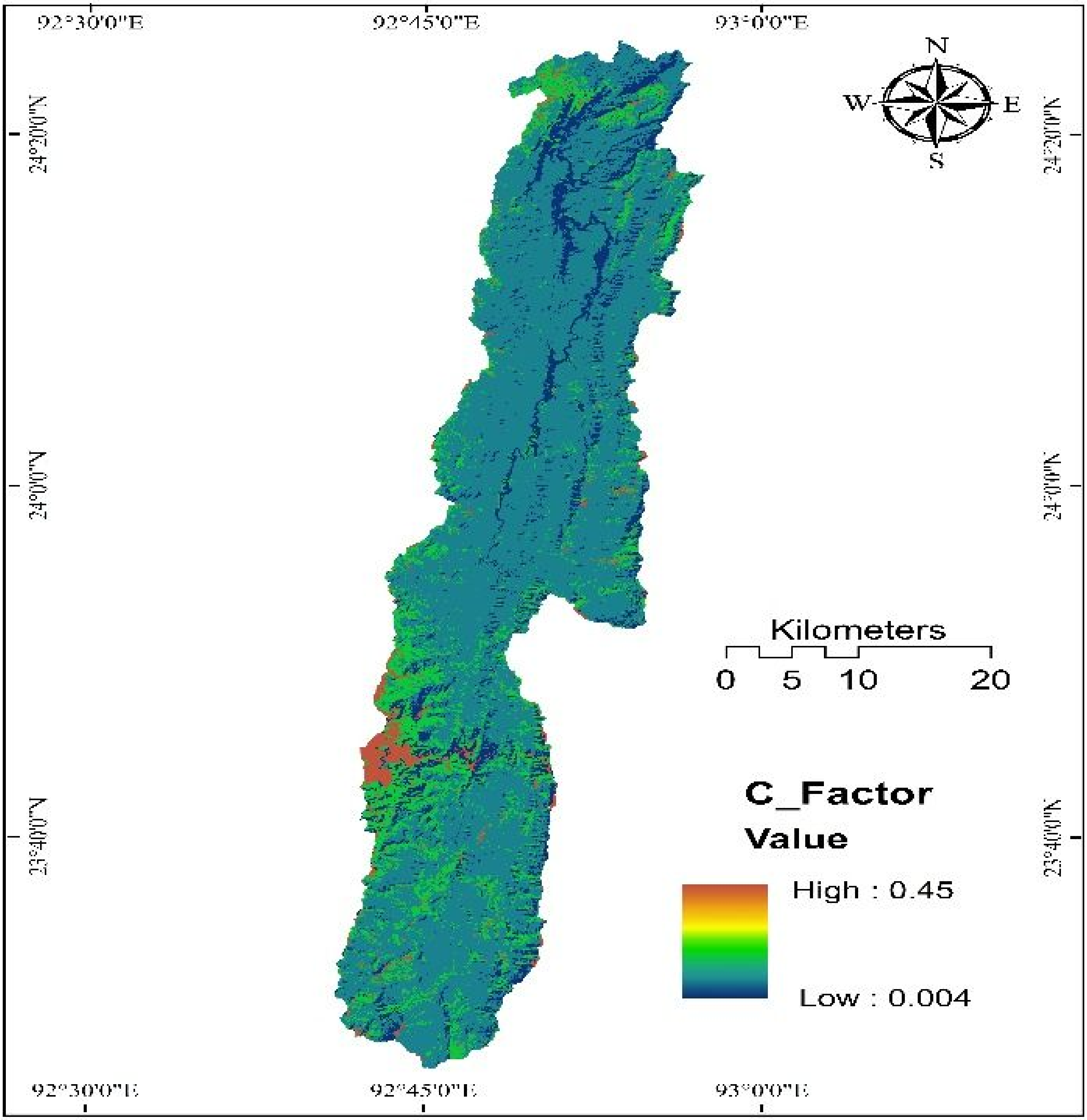

Figure 11

Cover Management Factor

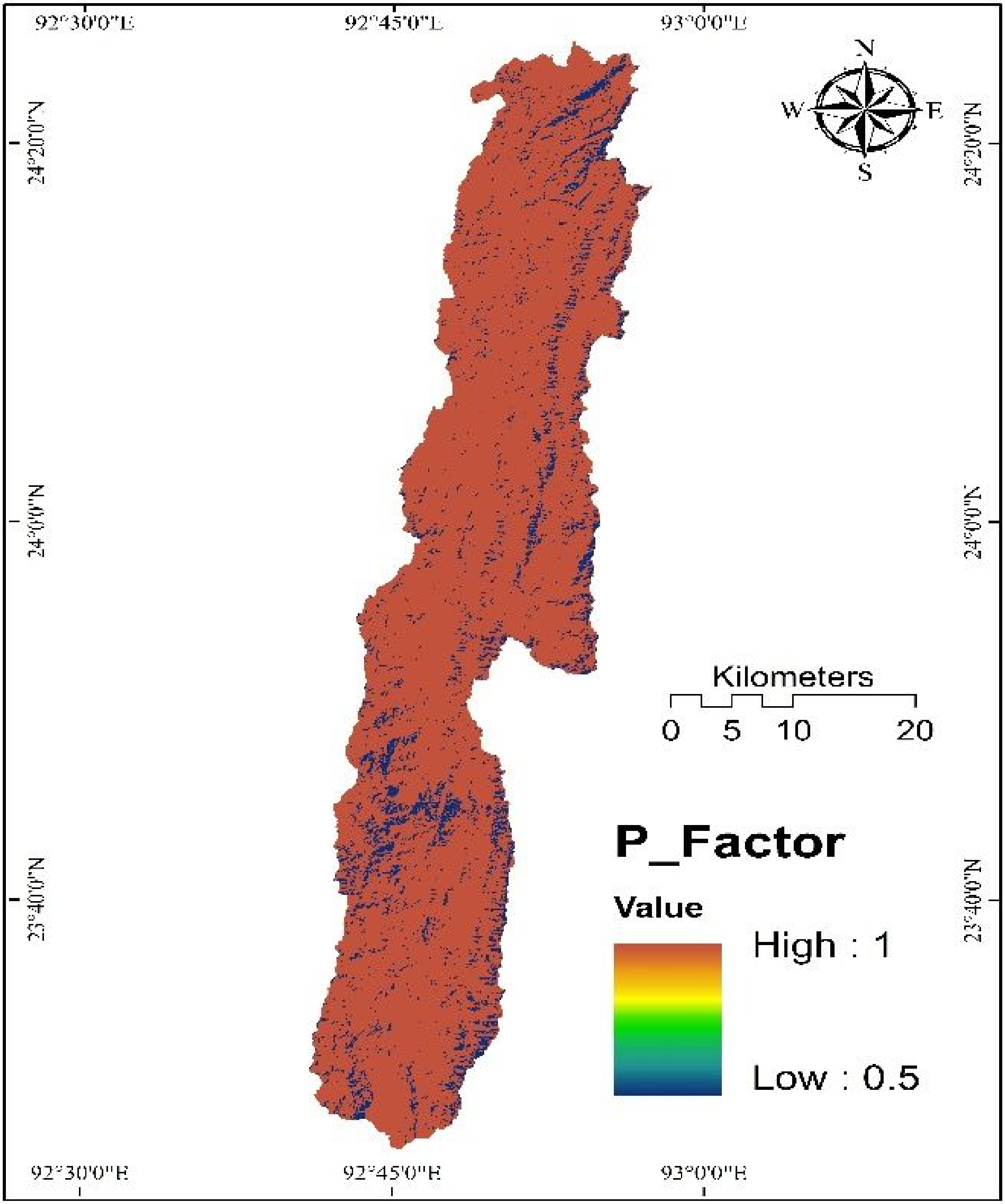

Figure 12

Practice Management Factor

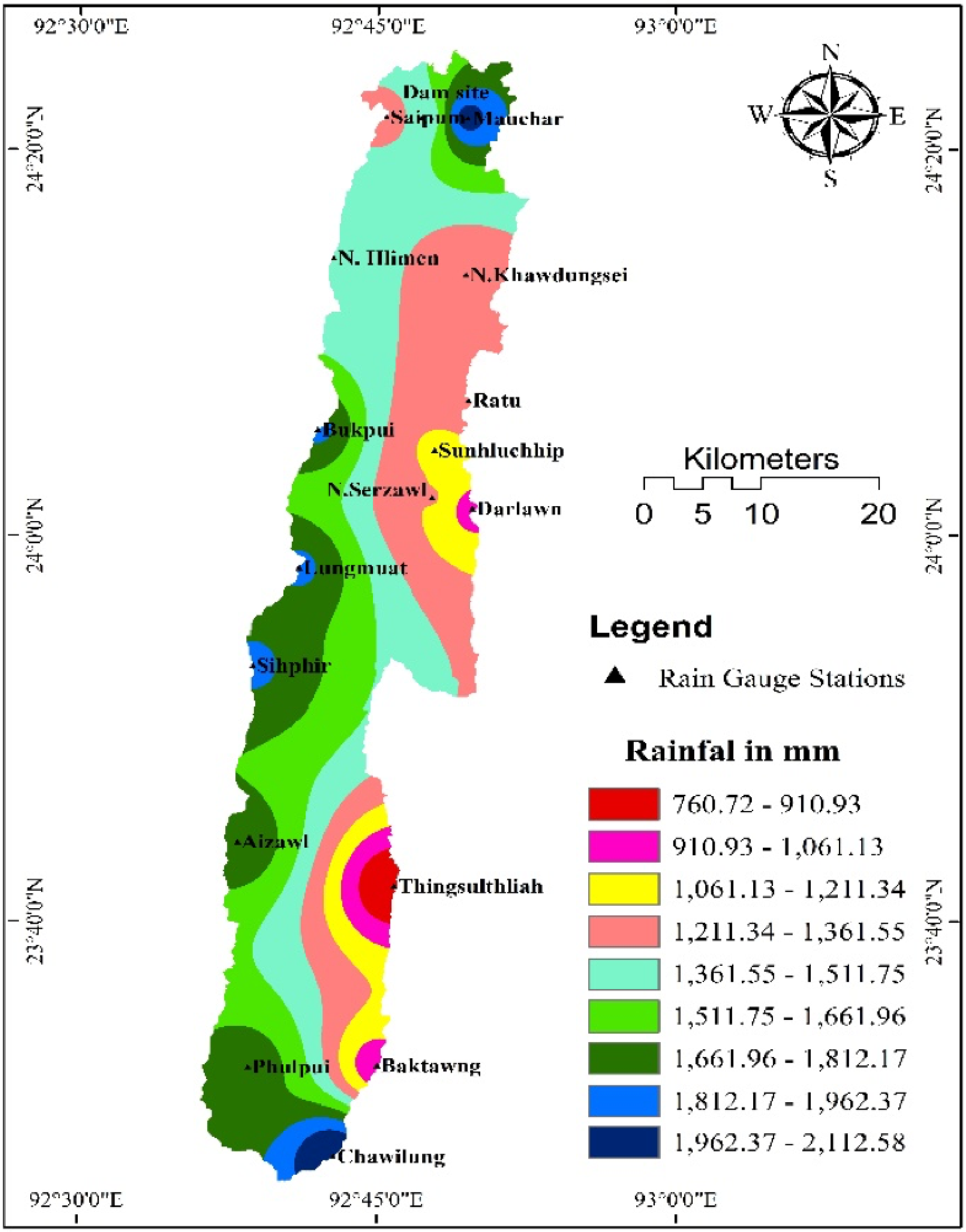

Figure 13

Rainfall distribution in Tuirial basin

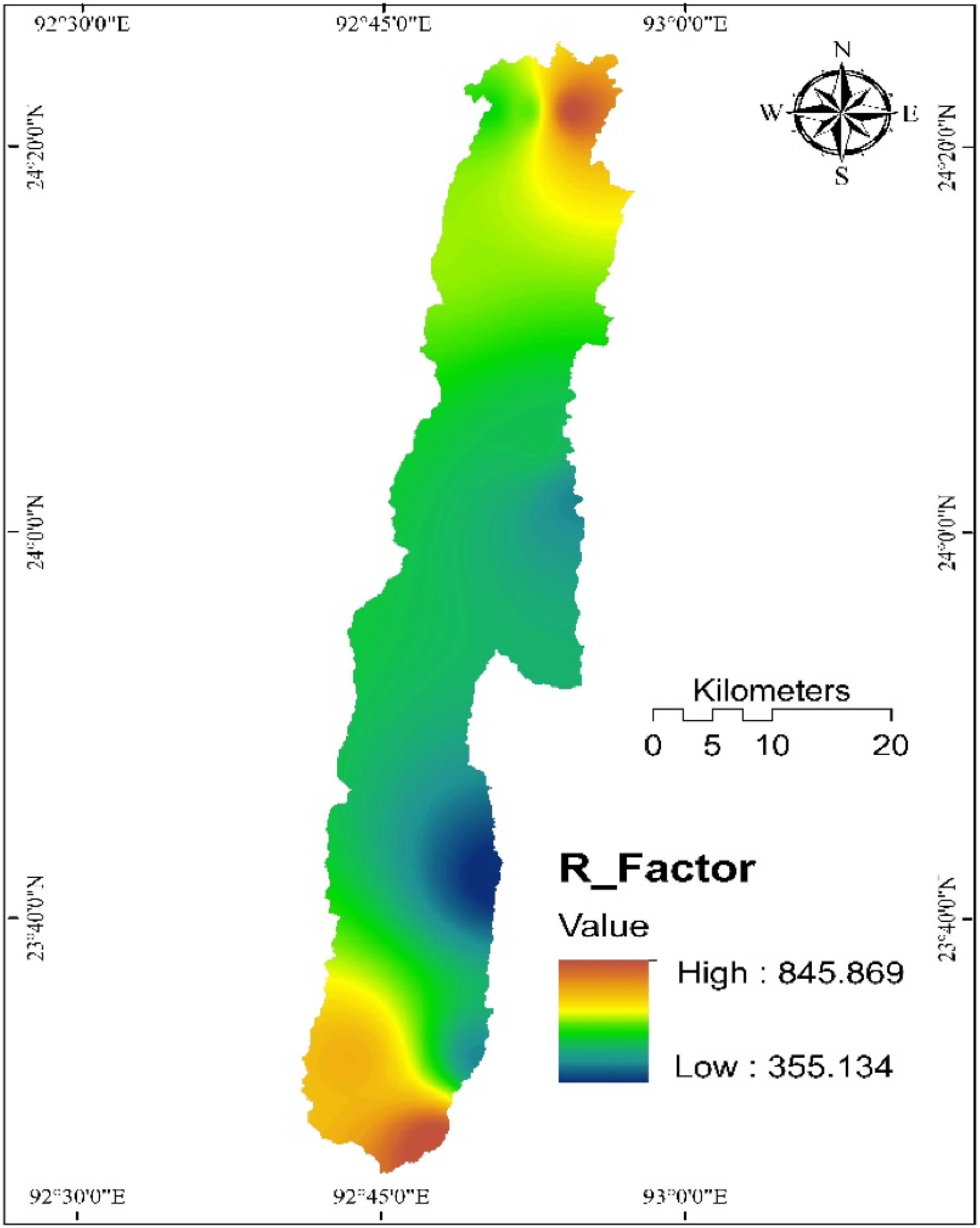

Figure 14

Rainfall Erosivity Factor

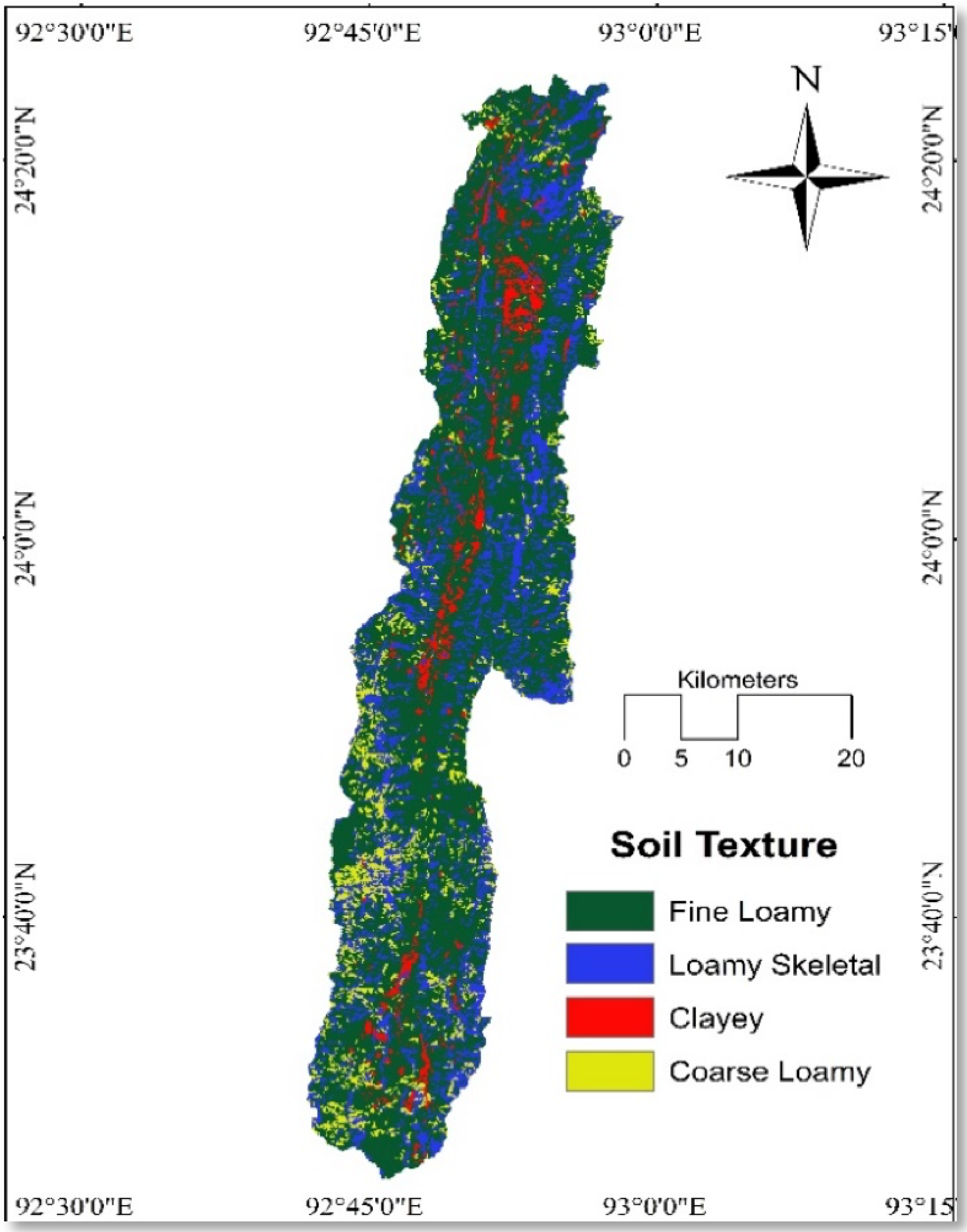

Figure 15

Soi texture distribution in Tuirial basin

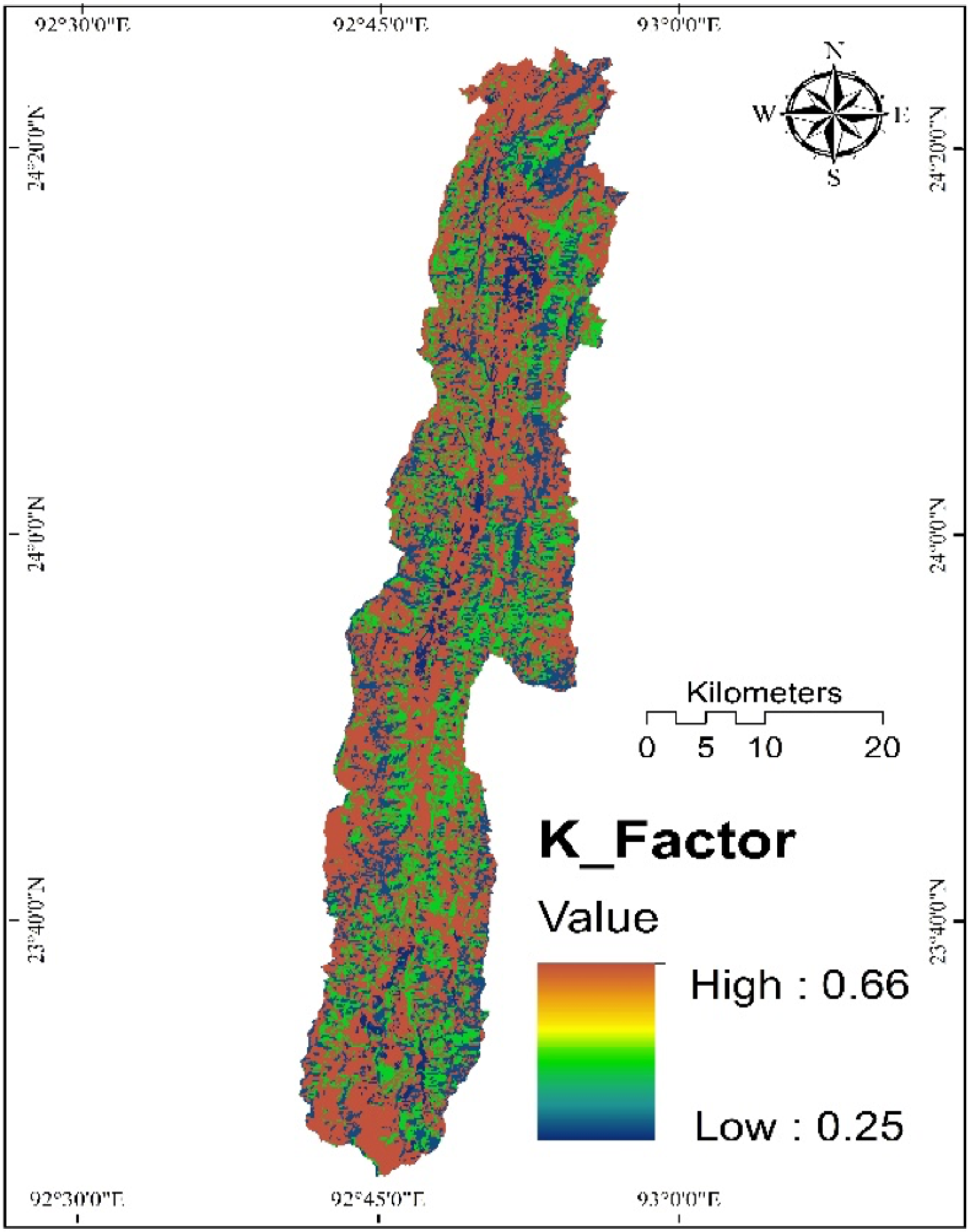

Figure 16

Soil Erodibility Factor

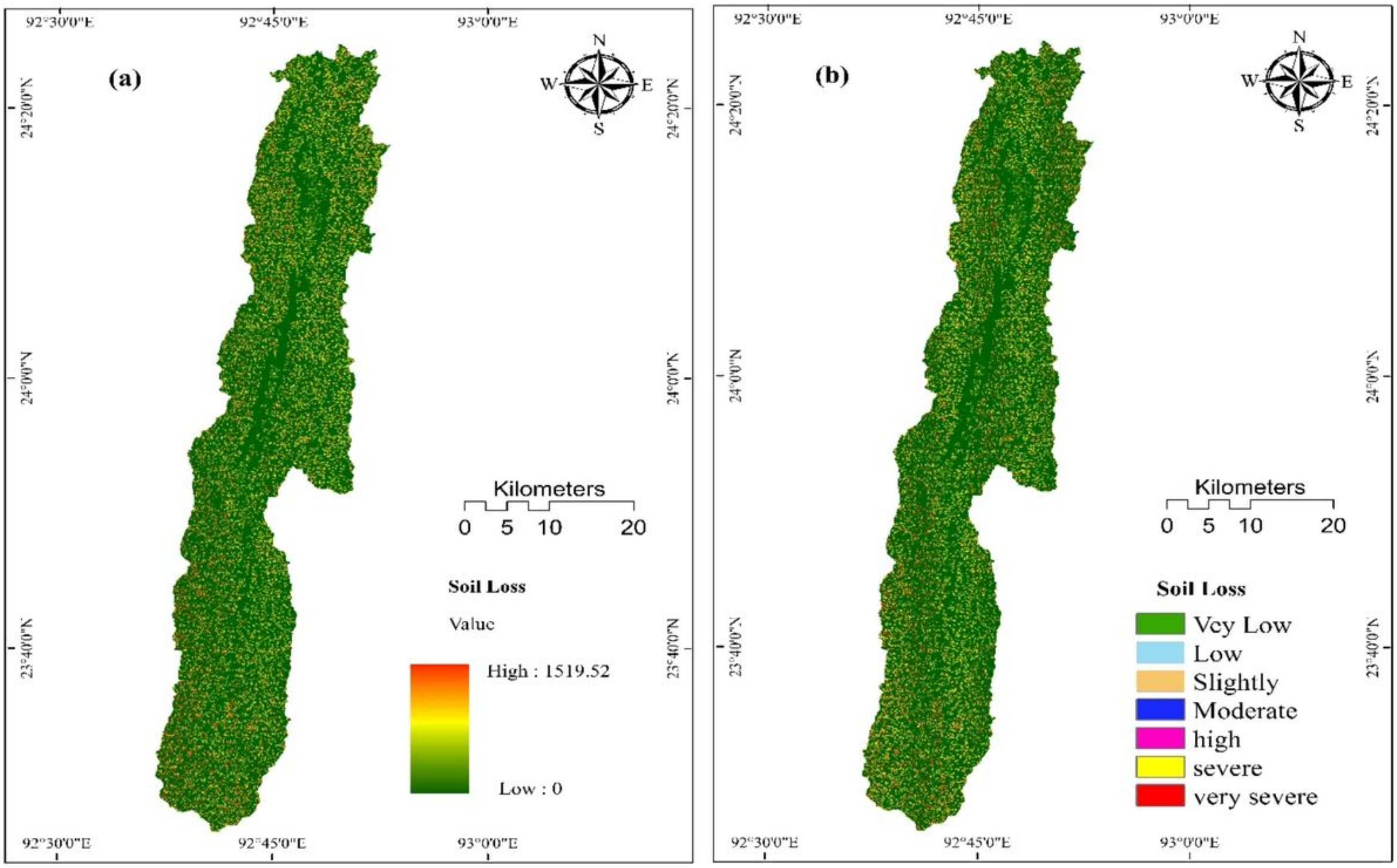

Figure 17

a. Average annual soil loss of Tuirial basin in thousand t $ha^{-1}yr^{-1}$, **b.** Zone wise average annual soil loss of Tuirial basin in thousand t $ha^{-1}yr^{-1}$

Figure 18

Highly sediment transport through Tuirial river

Figure 19

Highly erodible bare ground due to shifting cultivation on the hill slope of Tuirial basin