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**Prasad M**
B.Tech. (Agril. Engg.) Scholars, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

**Raghu SN**
B.Tech. (Agril. Engg.) Scholars, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

**Raghunandan Reddy**
B.Tech. (Agril. Engg.) Scholars, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

**Mallikarjuna Muddappa**
Assistant Professor, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

**B Maheshwara Babu**
Professor, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

**U Satish Kumar**
Professor and Head, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

**Rajesh NL**
Assistant Professor, Department of Soil Science, College of Agriculture, UAS, Raichur, Karnataka, India

**Corresponding Author:**
**Prasad M**
B.Tech. (Agril. Engg.) Scholars, Department of Soil and Water Conservation Engineering, College of Agricultural Engineering, UAS, Raichur, Karnataka, India

# Assessment of soil loss by Rusle in Fatepur sub watershed, Raichur taluk, Raichur district, Karnataka using remote sensing and GIS

**Prasad M, Raghu SN, Raghunandan Reddy, Mallikarjuna Muddappa, B Maheshwara Babu, U Satish Kumar and Rajesh NL**

## Abstract

This research centres around assessing soil erosion within the Fatepur sub-watershed, an agricultural region situated in Raichur taluk, Raichur district, Karnataka, India. The detrimental effects of soil erosion on agriculture, water quality, and the overall health of the ecosystem are of focus. The main goal of this study is to gauge the extent of soil loss within the sub-watershed using the Revised Annual Soil Loss Equation (RUSLE) and to evaluate its applicability in this specific area. The RUSLE model invloves various factors such as rainfall erosivity, soil erodibility, slope length and gradient, crop management practices, and techniques for erosion control. This investigation amalgamates data from various sources like field surveys, laboratory analyses, and remote sensing to estimate these influencing factors. The outcomes divulge that the average annual soil loss stands at 24.87 tons per hectare per year, signifying a state of moderate erosion. Regions featuring steep terrain, sparse crop canopies, and poor residue management are particularly prone to erosion. Among the examined factors, rainfall erosivity and slope characteristics emerge as the most pivotal contributors to soil loss. On the other hand, the influence of crop management practices and erosion control methods is relatively marginal. In conclusion, the study underscores the necessity of implementing erosion control measures to uphold soil productivity within the sub-watershed. This imperative arises due to the fact that the observed soil loss surpasses the recommended tolerance threshold. The findings derived from this research provide valuable direction for local authorities and farmers in developing effective strategies for soil conservation and promoting sustainable land use practices in the area.

**Keywords:** Watershed, soil loss, rule, remote sensing, GIS

## Introduction

Soil erosion stands as a notable environmental concern, endangering agricultural productivity, land integrity, and water reservoirs. The depletion of valuable topsoil through erosion can result in diminished crop yields and escalated sediment accumulation in rivers and lakes, and the degradation of ecosystems. Estimating the extent of soil loss and understanding the factors influencing it. In this research, it is focused on the estimation of annual soil loss in the Fatepur sub-watershed located in Raichur Taluk. It is situated in Karnataka, India, is predominantly an agricultural region characterized by semi-arid climatic conditions. The Revised Universal Soil Loss Equation (RUSLE) is a widely used tool for assessing soil erosion. It takes into account multiple factors such as rainfall erosivity, soil erodibility, slope characteristics, crop cover management, and erosion control techniques. By applying the RUSLE model, this aims to estimate the annual soil loss in the Fatepur sub-watershed, providing valuable insights for land use planning, erosion control strategies, and sustainable agricultural practices.

Numerous scholars have employed the RUSLE model to evaluate soil erosion. For instance, Prasanna Kumar *et al*. (2011) [11] employed the RUSLE model to calculate soil loss in a compact hilly sub-watershed located in Kerala. Meanwhile, Ganasri *et al.* (2016) [4] utilized a GIS-based approach with the RUSLE methodology to pinpoint the spatial arrangement of regions susceptible to erosion across the Nethravathi basin. It's worth noting that the bulk of these research efforts have centred around specific watersheds and basins. The Fatepur sub-watershed boundary in Raichur taluk, Karnataka, India is chosen as the focal point for erosion assessment to enable state governments to enact mitigation measures and assess the effectiveness of conservation structures. To tackle these issues, this research aims to evaluate the spatial and temporal changes in soil erosion using the RUSLE model within a geospatial framework.

The main objective of this study is to assess soil erosion within the Fatepur sub-watershed by employing the RUSLE model, utilizing data encompassing rainfall patterns, slope characteristics, soil composition, land utilization, and conservation efforts. The outcomes of this research endeavour offer a foundational framework for crafting initiatives aimed at curtailing soil erosion and enhancing the long-term viability of agricultural output within the Fatepur sub-watershed. Additionally, the discoveries coming from this study will enrich our understanding of soil erosion dynamics in semi-arid regions, with a particular focus on Raichur Taluk. It will serve as a baseline for future monitoring and assessment studies, facilitating evidence-based decision-making for land management and conservation efforts. The results will also provide important information for policymakers, researchers, and local communities working towards sustainable land use practices and mitigating the impacts of soil erosion.

## Material and Methods

### Study Area

This research project was conducted within the Fatepur sub-watershed located in Raichur taluk, which is part of Raichur district in Karnataka (see Fig.1). Fatepur Sub-watershed has a geographical area of 2097 ha. It lies between 77°17'18"E to 77°17'41"E longitudes and 16°13'08"N to 16°17'44"N latitudes, and 356 m to 377 m altitude from mean sea level. The Fatepur sub watershed is divided into three micro watersheds. Namely Fatepur north west-1 micro watershed, Fatepur north west-2 micro watershed and Fatepur-2 micro watershed. Jowar, cotton, and pulses thrive in rainfed cultivation, while paddy, sugarcane, maize, chillies, cotton, and pulses are cultivated under irrigation in this region (Source: Anonymous). The Fatepur sub-watershed's topography is predominantly marked by rolling terrain featuring gentle slopes. The hydrology of the Fatepur sub-watershed is sustained by numerous small streams that eventually merge into the Krishna river. The hydrology of the watershed is influenced by the rainy season, which typically between June to September. Land use in the Fatepur sub watershed is predominantly agricultural, the majority land used for rainfed crops such as sorghum, groundnut, and pigeon pea. Some areas of the watershed are meant also for grazing.

GIS can be employed to depict the elements of the Revised Universal Soil Loss Equation (RUSLE) across both temporal and spatial dimensions. In the realm of GIS, the RUSLE model serves the purpose of furnishing a spatial representation of soil erosion patterns and categorizing regions that are particularly susceptible to erosion. For the study conducted, a dataset spanning 32 years (from 1990 to 2021) of rainfall data was sourced from the Main Agricultural Research Station at University of Agricultural Sciences in Raichur. Additionally, soil maps were obtained from the RS and GIS Lab within the framework of SUJALA III at the Agriculture College, UAS Raichur (as illustrated in Figure 2)

### Rainfall Map

Rainfall has two distinguishable impacts on soil erosion. The first arises from the kinetic energy of individual raindrops, which dislodges soil particles upon impact. The other is associated with rainfall intensity, quantified by the volume of rain received within a specific timeframe. The data collected from rain gauge stations were sourced from the Main Agricultural Research Station, UAS, Raichur, as illustrated in Figure 3.

### Geology and soil

In terms of its geomorphology, the Fatepur sub-watershed lies within the expansive Deccan traps, a vast volcanic region that spans across a significant portion of western and central India. The geological composition of this watershed is primarily characterized by basaltic rocks. Within the Fatepur sub-watershed, the prevalent soil type is a combination of red and black soil, a common occurrence in gently undulating plains. Red soil exhibits a coarse-grained texture and boasts superior drainage capabilities compared to black soil. Consequently, these soils demonstrate a heightened responsiveness to effective water management practices. Red soil is notably enriched with iron oxide, imparting its distinct hue, while black soil is rich in organic content. The soil mapping efforts within this region have been organized into three distinct micro-watersheds as depicted in Figures 4, 5, and 6. It is worth noting that both types of soil, red and black, are well-suited for agricultural activities within the Fatepur sub-watershed.

### Revised universal soil loss equation (Rusle)

RUSLE, an established erosion modeling system, is extensively employed for assessing the typical erosion potential of cultivated land. Regarded as a standard instrument for evaluating soil degradation, RUSLE's foundation rests upon erosion phase theory, incorporating insights gleaned from over 10,000 years of observations in natural precipitation settings as well as data gathered from numerous rainfall simulation experiments. Across agricultural and forested watersheds, RUSLE has found wide-ranging utility for simulating soil erosion and estimating sediment yield. The RUSLE methodology is formally articulated in the work of Renard *et al.* (1997) [13] as follows:

$$A = R \times K \times LS \times C \times P \qquad (1)$$

### Rainfall erosivity (R) factor

The rainfall erosivity factor of rainfall (R) is determined by the interaction between falling raindrops and the intensity of rainfall. It is calculated by multiplying the kinetic energy of raindrops with the maximum rainfall intensity observed over a 30-minute period, as explained by Pandey *et al*. in 2007 [9]. However, in India, comprehensive meteorological data is often limited. As a result, Singh's empirical equation from 1981 [15] has been adopted to estimate annual and seasonal R-factors specifically in the Indian context. The calculation of the annual erosion index proceeds as follows:

$$R_a = 79 + 0.363 \times P \qquad (2)$$

In this context, signifies the average annual Rainfall Erosivity Factor (expressed in Mt-ha/mm), while P denotes the rainfall amount in millimetres. The calculation of R involved the analysis of rainfall data collected from five rain gauge stations within the Fatepur sub-watershed and its adjacent regions. To determine the spatial distribution of R-factors throughout the study region, an Inverse Distance Weighting (IDW) interpolation technique was utilized, as shown in Figure 7. This IDW interpolation procedure considered 32 years of rainfall data, and the resulting estimated R-factors are detailed in Table 1.

## Soil erodibility (K) factor

This signifies a soil erodibility factor employed to evaluate the soil's vulnerability to erosion. as classified by Schwab *et al*. in 1981 [14], which takes into account the soil texture class and the organic matter content. This assessment is visualized in Figure 8. Under standard conditions, the unit plot measures 22.6 meters in length and a gradient of 9%. It is kept in a continuous fallow state and subjected to tillage both uphill and downhill, following the approach outlined by Kim in 2006 [7]. The "K" values in this context indicate the rate of soil loss per unit of the Rainfall-Runoff Erosivity (R) index.

## Slope length and steepness (LS) factor

### Slope length (L) factor

As per the findings by Soo in 2011 [16], the factors of slope (S) and slope-length (L) play a significant role in accounting for the impact of topography on soil erosion, as illustrated in Figure 9. These factors signify a proportion of soil depletion occurring in particular circumstances. It's worth noting that steeper slopes and longer cliffs are more susceptible to increased runoff and potential flooding events. According to the insights provided by Renard and Ferreira in 1993 [12], this factor can be assessed through on-site measurements or by utilizing a digital elevation model (DEM). Additionally, Wischmeier and Smith in 1978 [17] define the L-factor as the distance between the point where runoff originates and the point at where the slope becomes gradual enough to initiate sediment deposition.

### Slope (S) factor

The slope-gradient component, labelled as "S," functions as an indicator of how the gradient of the slope profile affects soil erosion. It is typically expressed as a percentage or in degrees, representing the change in elevation over a given horizontal distance, as explained by Zhang *et al*. in 2008 [18]. When the gradient increases, it corresponds to an increased susceptibility to soil erosion. Given the interplay between the angle and length of the slope in influencing erosion, these two factors are often considered together (Morgan and Davidson, 1991) [8]. The slope gradient (S) and slope length (L) can both be precisely measured and subsequently combined into a unified factor referred to as the topographic factor LS, particularly when using Digital Elevation Models (DEMs) in Geographic Information Systems (GIS). The formulas defining slope length (L) and slope gradient (S) are provided as equations (3) and (4), respectively.

$$L = 1.4\left(\frac{A_S}{222.13}\right)^{0\cdot 4} \qquad (3)$$

$$S = \left(\frac{\sin\alpha}{0.0896}\right)^{1\cdot 3} \qquad (4)$$

Incorporating the parameters, A (Specific contributing area in square meters) and α (Slope angle in degrees) obtained from a Digital Elevation Model (DEM), equations (3) and (4) can be merged (Morgan and Davidson, 1991) [8]. This integration is expressed as Eq. (5), which is defined as follows:

$$LS = \sqrt{\left(\frac{l}{22}\right)^m (0.065 + 0.045s + 0.0065s^2)} \qquad (5)$$

In this context, the variables are defined as follows: L represents the slope length measured in meters, and S signifies the percent slope.

## Crop management (C) factor

Considering that C-factor values generally remain low for most Indian crops, the C-factors introduced by Karaburun's in 2010 [5] were utilized to illustrate the impact of cropping and management practices on soil erosion rates in agricultural regions. It's important to emphasize that the influence of plant canopy and land cover on soil erosion in forested areas can vary seasonally and based on crop production methods, as highlighted by Renard *et al*. in 1997 [13]. The C-factor's seasonal fluctuations are influenced by various factors, including rainfall, agricultural practices, crop types, and more. To enable a straightforward comparison of the relative effects of different management choices, adjustments can be applied to the C-factor. Typically, this factor ranges from nearly zero for well-protected land cover to one for barren fields. Land classification categories encompass water bodies, vegetation areas, built-up lands, wastelands, and agricultural lands, as depicted in Figure 10.

The present study, as proposed by Kim *et al*. in 2005 [6], C-values were employed. The C-factor values for the Fatepur sub-watershed are presented in Table 3. To generate the C-factor map, the land use-land cover map was subjected to reclassification based on the C-factor, which is notably responsive to land use and signifies the proportion of soil loss in cultivated soil. The computation of the C-factor was executed in accordance with the methodology outlined by De Jong *et al*. in 1998 [4].

$$C = 0.431 - 0.805\ \text{NDVI} \qquad (6)$$

## Conservation practice (P) factor

The conservation practice factor (P) quantifies the degree to which a conservation practice reduces soil loss when compared to conventional straight-row cultivation up and down the slope. Its purpose is to recognize the beneficial effects of these conservation practices, as elucidated by Ganasri and Ramesh in 2016 [4]. The P-factor takes into consideration management activities that decrease the potential for runoff erosion. This is achieved by influencing factors such as drainage patterns, runoff concentration, runoff velocity, and the hydraulic forces exerted by runoff on the soil. The P-factor is assigned a value between 0 and 1, representing the effectiveness range in reducing soil erosion through these management practices.

## Estimation of soil erosion by Rusle

In the context of RUSLE modeling, we can regard rainfall erosivity, soil erodibility, and the topographic factor as inherent factors that influence erosion processes. Collectively, these factors are instrumental in calculating the erosion rate for the Fatepur sub-watershed.

$$\begin{aligned} A &= R \times K \times LS \times C \times P \\ &= 315.74 \times 0.18 \times 4.56 \times 0.24 \times 0.4 \\ &= 24.87\ \text{t/ha/yr.} \end{aligned}$$

Soil erosion rate is found to be 24.87 t/ha/yr.

## Results and Discussion

### Rainfall Data Analysis

This graph illustrates 32 years of annual rainfall data spanning from 1990 to 2021. Among these years, the highest recorded rainfall was 1228 mm in 2020, while the lowest was 81.6 mm in 1991. Based on an analysis of this annual rainfall data, the average annual rainfall over this period is calculated to be 702.1 mm. Figure 11 presents the annual rainfall data for 30 of these years.

### Rainfall Erosivity (R) Factor

Ganasri and Ramesh (2016) [4] observed that the soil erosion rate in the catchment area is more sensitive to rainfall. Consequently, to characterize the seasonal distribution of sediment yield, The measurement of daily rainfall stands out as a more dependable metric for gauging shifts in soil erosion rates. However, utilizing annual rainfall offers advantages such as simplicity in calculation and greater geographical precision of the exponent. Therefore, in the present analysis, the R-component is determined using the average annual rainfall, which is calculated by dividing the total gross rainfall by the number of rainy days. The average R-factor falls within the range of 306.43 to 333.22 Mt-ha/cm, with an average value of 315.74 Mt-ha/cm. Based on these findings, it can be concluded that the rainfall in the Fatepur sub-watershed, Raichur taluk, is at an average level.

### Soil Erodibility Factor (K)

In order to determine soil erodibility, K-factor values were assigned to the specific soil types listed in the soil table. A lower K-factor value is associated with soils characterized by traits such as low permeability and reduced antecedent moisture content. In this particular case, the assigned K-factor value is 0.18 t-ha-hr/MJ-mm-ha.

### Topographic Factor (LS)

The topographic component quantifies the impact of both slope length and slope steepness on the erosion process. Flow accumulation and slope percentage were employed as inputs to calculate the LS component. As per the study's findings, the value of the topographic component increases within the range of 0 to 4.56 in relation to variations in flow accumulation and slope gradient.

### Crop Management (C) Factor

Land use data offers valuable insights into diverse aspects of land utilization, including crop practices, fallow areas, woodlands, wastelands, and surface water sources. These insights play a pivotal role in facilitating informed decision-making within the domains of development planning and erosion studies.

### Conservation Practice (P) Factor

P represents the sustainability practice factor, mirroring the measures adopted in the study area to mitigate water runoff and subsequently reduce erosion. The assigned values for (P) are 0.75, 0.65, and 0.45, corresponding to agriculture, wasteland, and forest, respectively, based on the prevailing tillage practices within the sub-watershed.

### Average annual soil loss (A factor)

The mean annual soil erosion (A) was computed by combining the generated raster data for each factor in the USLE study. Figure 12 illustrates the projected annual soil loss for the Fatepur sub-watershed, revealing that the area under examination possesses a gradual slope, resulting in minimal and acceptable levels of erosion loss. Table 4 presents the anticipated average annual soil loss for the Fatepur sub-watershed, categorized into three classes of erosion intensity, aiding in the assessment of potential erosion severity.

In the northern interior of the arid region, soil loss has been documented as less than 117 t/yr. In contrast, the dense forest areas exhibit high to very high rates of soil erosion, ranging from 3864 to 7320 t/yr, attributed to moderate slope and significant factors related to slope length and steepness. Soil erosion is categorized into low, high, and very high, with values spanning from 117 to 7320 t/yr. The average soil loss within the Fatepur sub-watershed stands at 3767 t/yr. Although there has been a substantial decrease in regions experiencing extreme and extremely severe erosion, there is a notable increase in areas characterized by mild erosion. Furthermore, evidence suggests increased soil degradation in zones of minor erosion, which have witnessed a significant decline. Soil erosion-resistant areas were identified through a qualitative assessment involving a combination of weighted soil erosion variables. This approach, when applied with a more comprehensive and long-term study, can provide a detailed historical overview of the region's soil erosion patterns. Additionally, the report delves into the historical land-use patterns in the region and evaluates the degree of depletion in vegetation cover over this timeframe. It's worth emphasizing that although only a limited number of sampled areas presently display notably high erosion rates, there is a concern that these figures could escalate in the future owing to heightened construction activities and increased deforestation within the region.

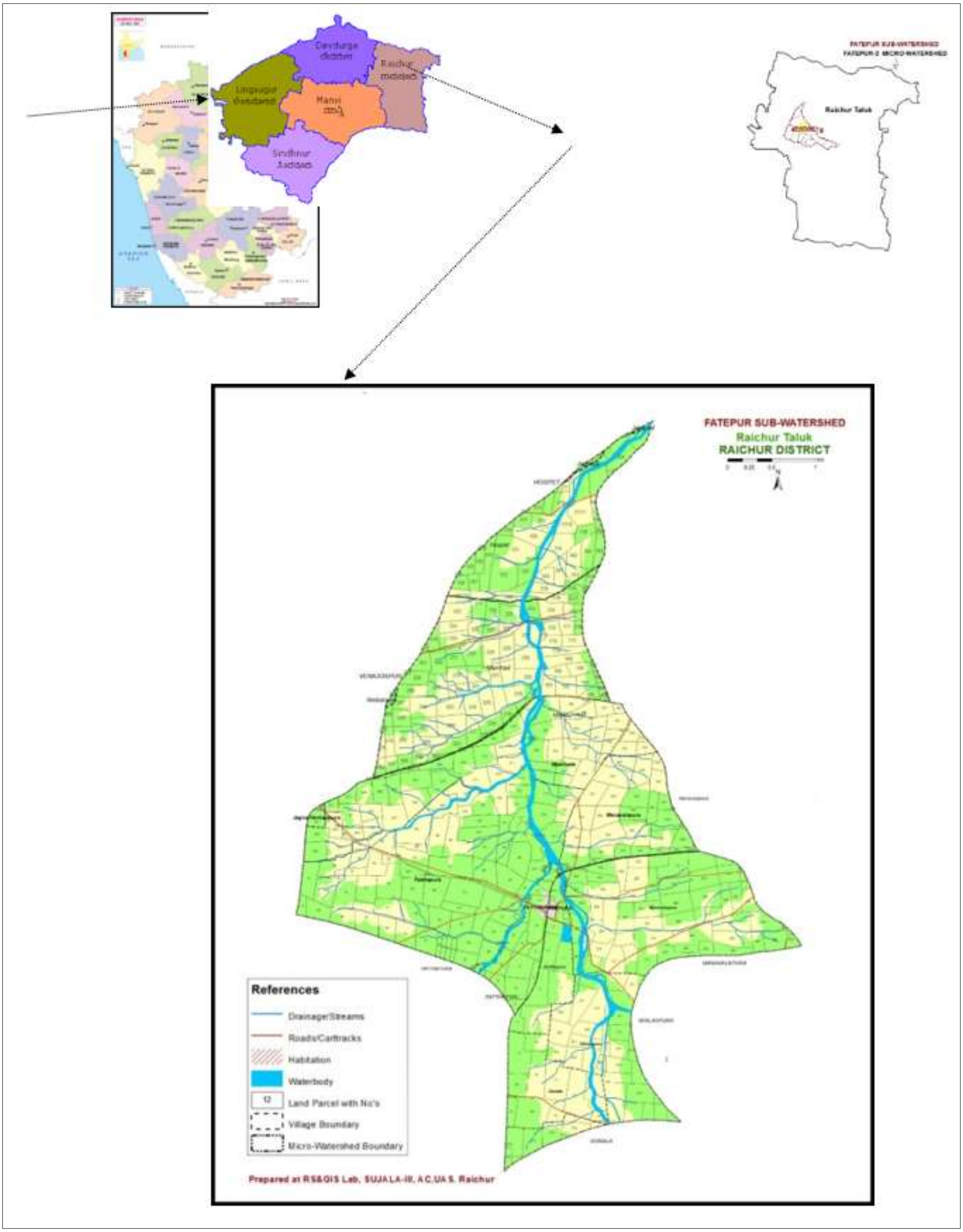

**Fig 1:** Location map of Fatepur sub watershed

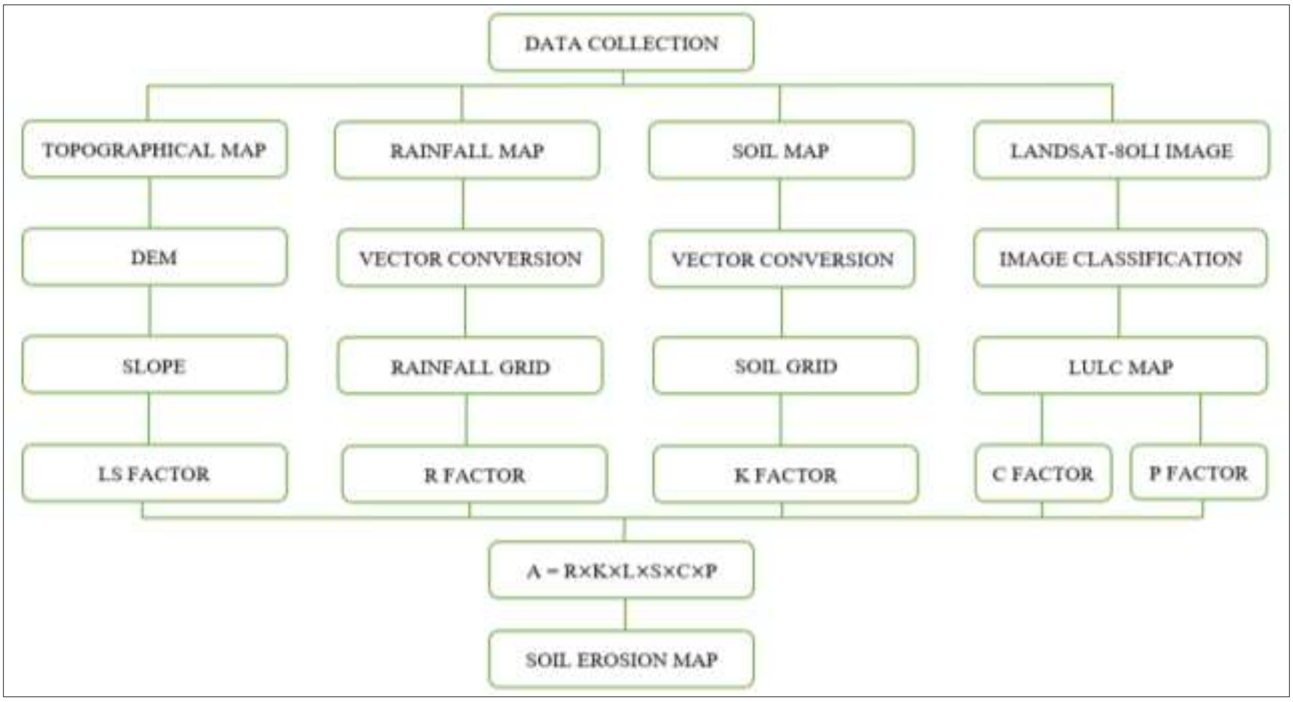

**Fig 2:** Flow chart of methodology to develop soil erosion map

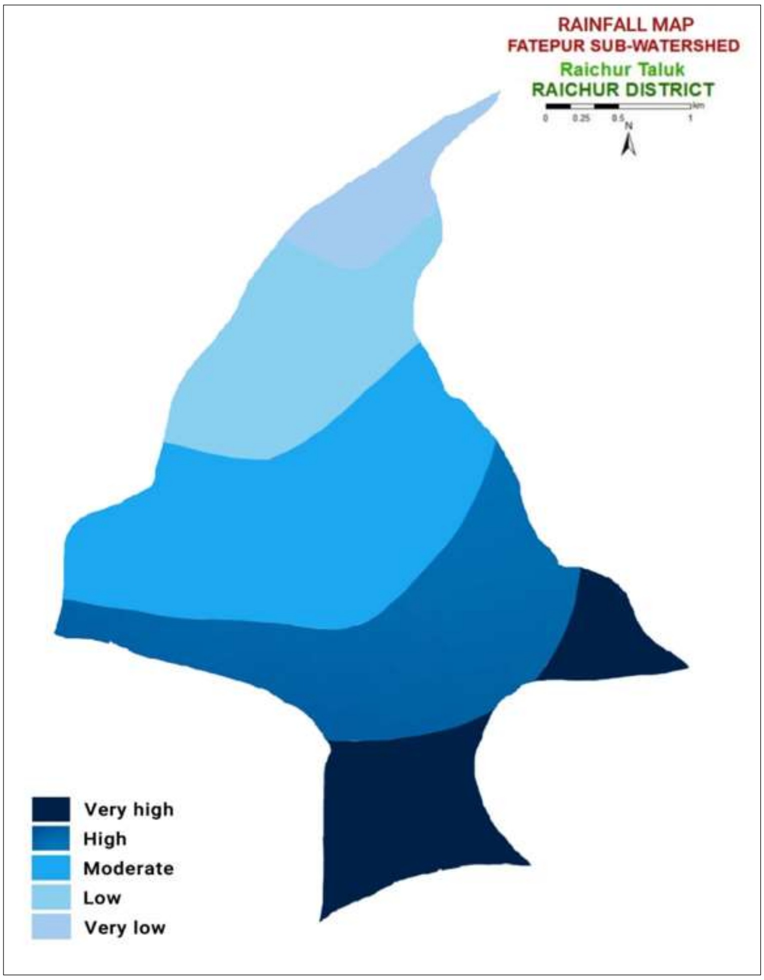

**Fig 3:** Rainfall map of Fatepur sub watershed

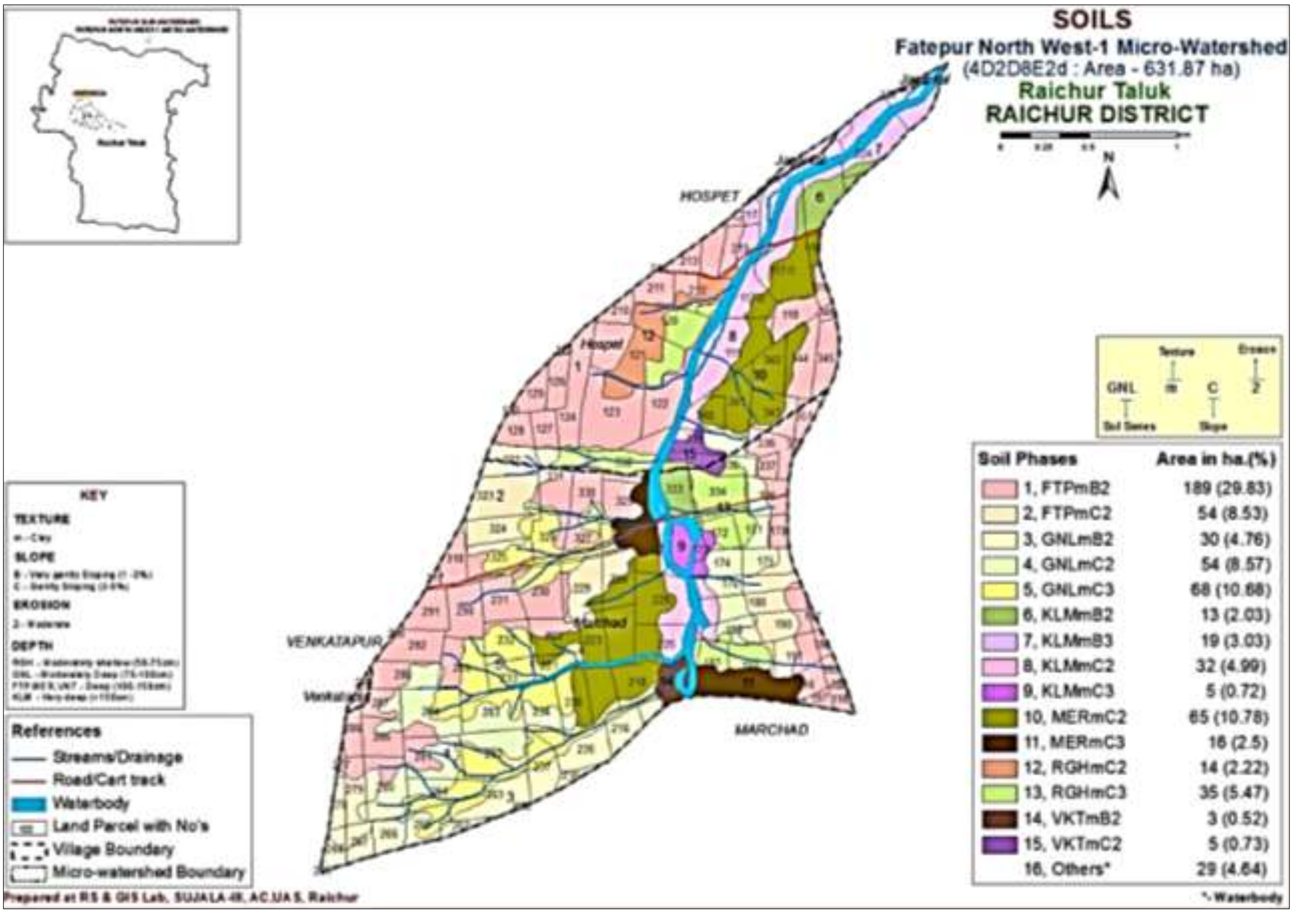

**Fig 4:** Soil map of Fatepur north west-1 micro watershed

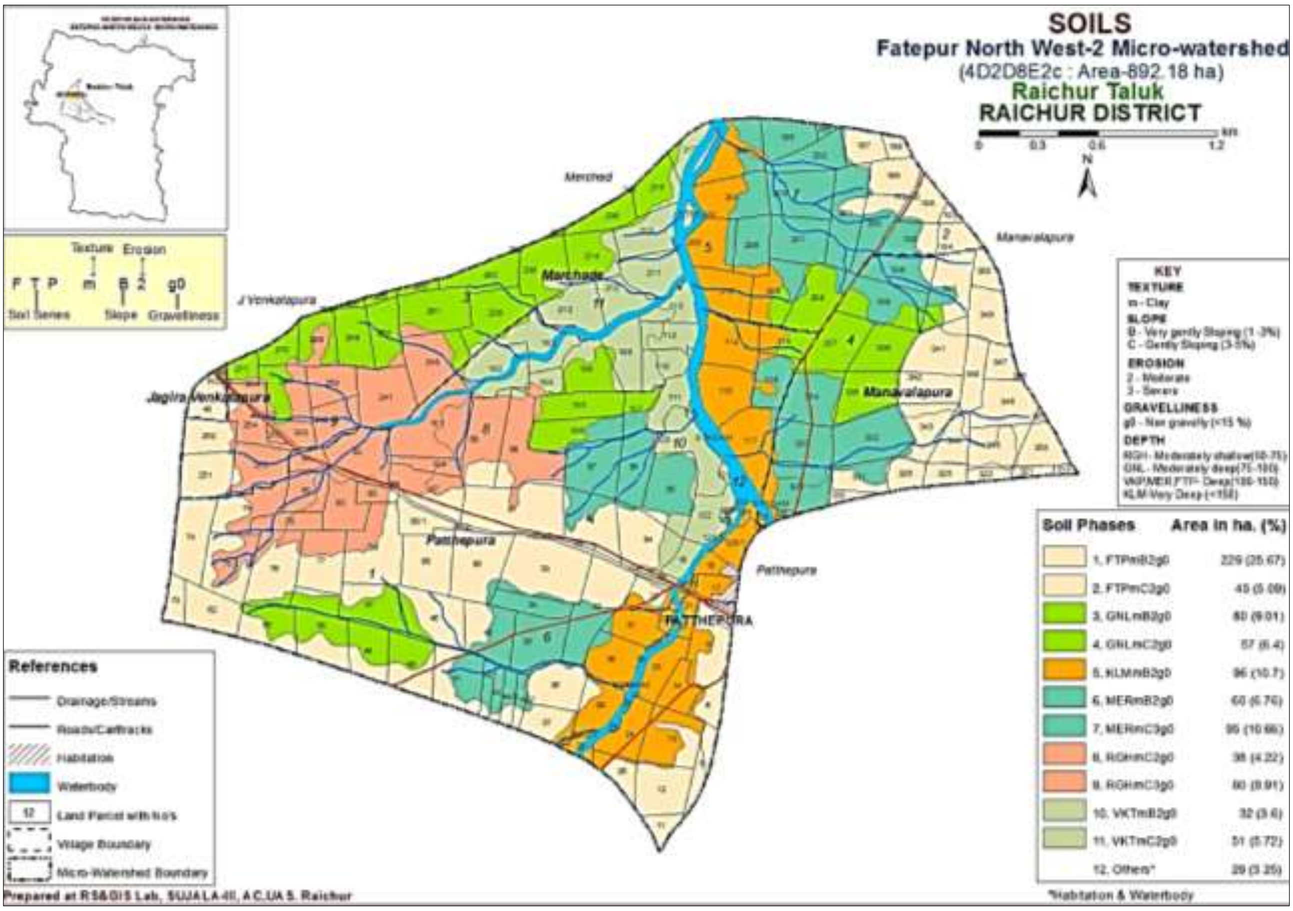

**Fig 5:** Soil map of Fatepur north west-2 micro watershed

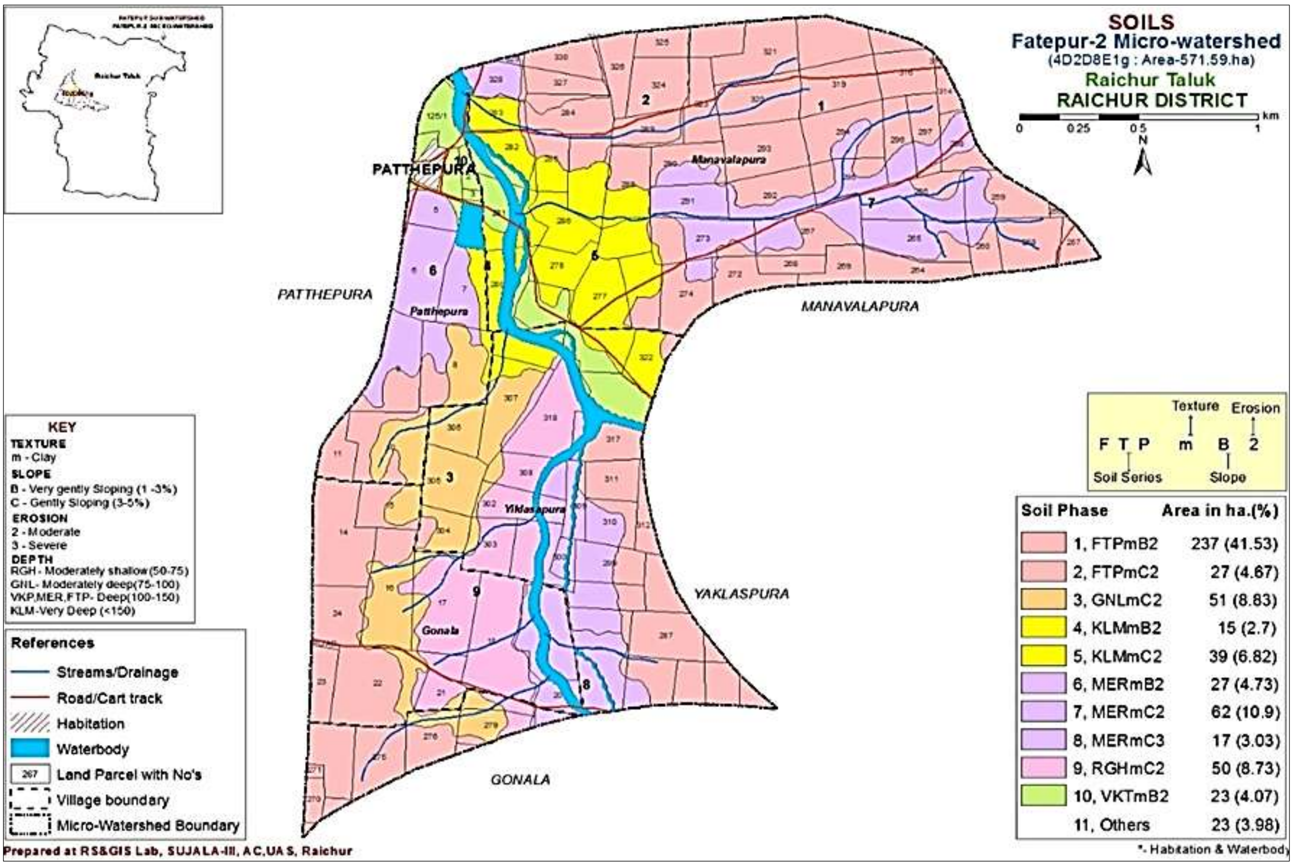

**Fig 6:** Soil map of Fatepur-2 micro watershed

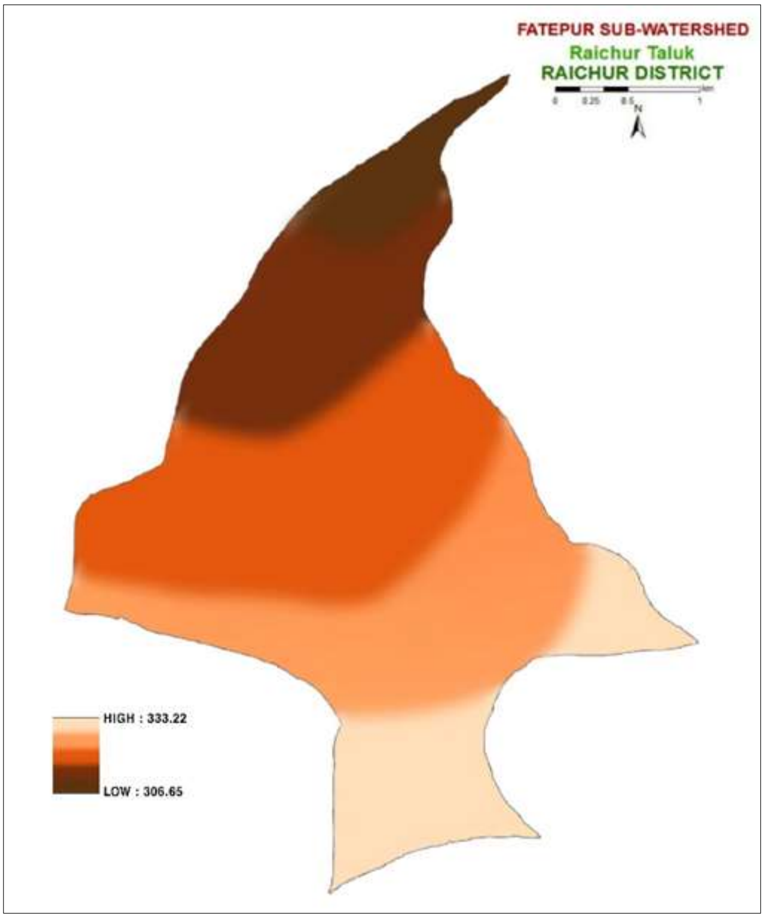

**Fig 7:** R-factor map of Fatepur sub watershed

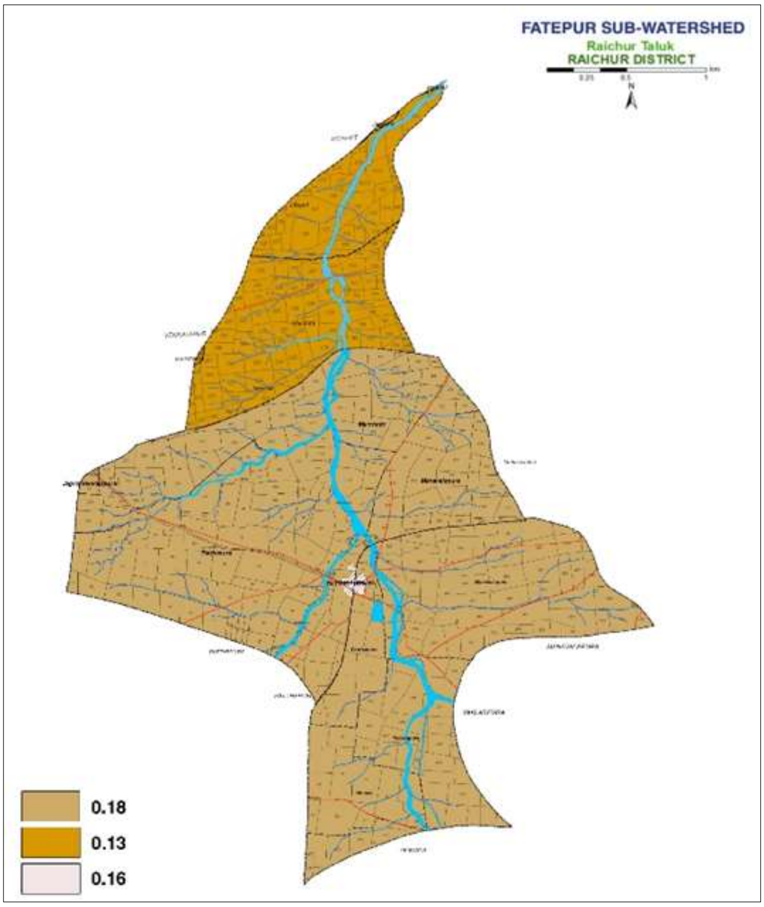

**Fig 8:** K-factor map of Fatepur sub watershed

**Fig 9:** LS-factor map of Fatepur sub watershed

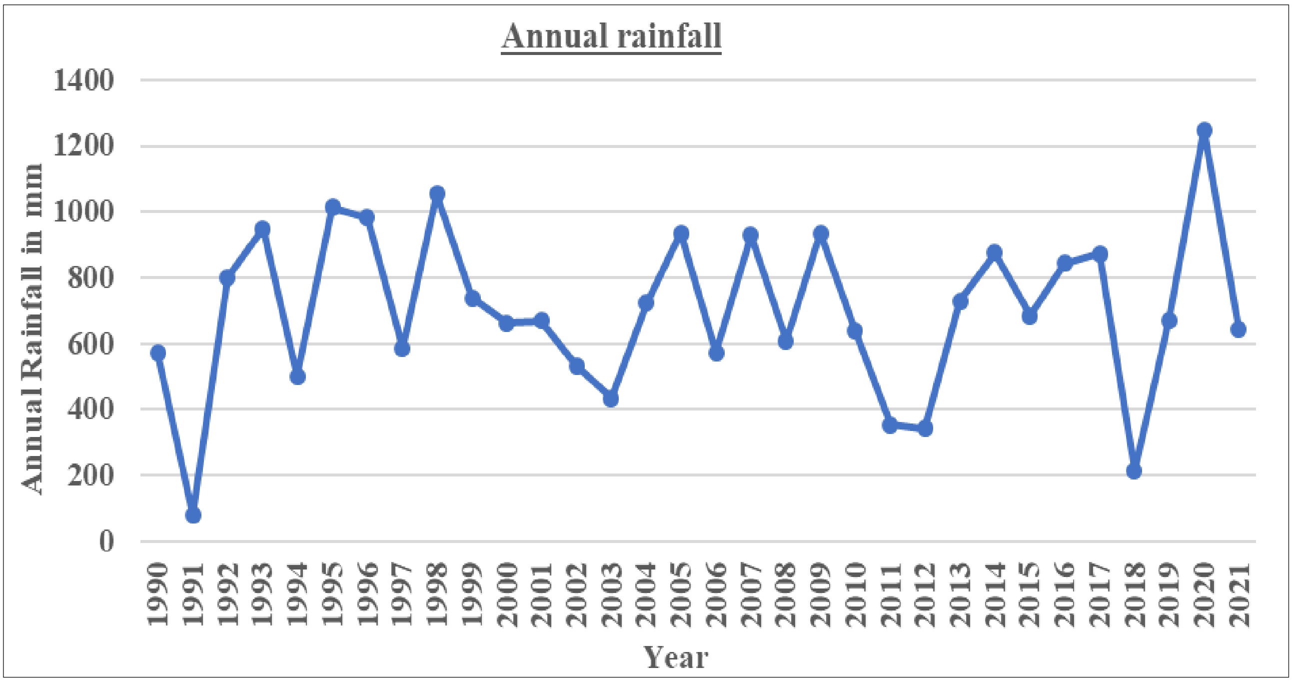

**Fig 11:** Annual rainfall of 32 years (1990 – 2021) of Fatepur sub watershed

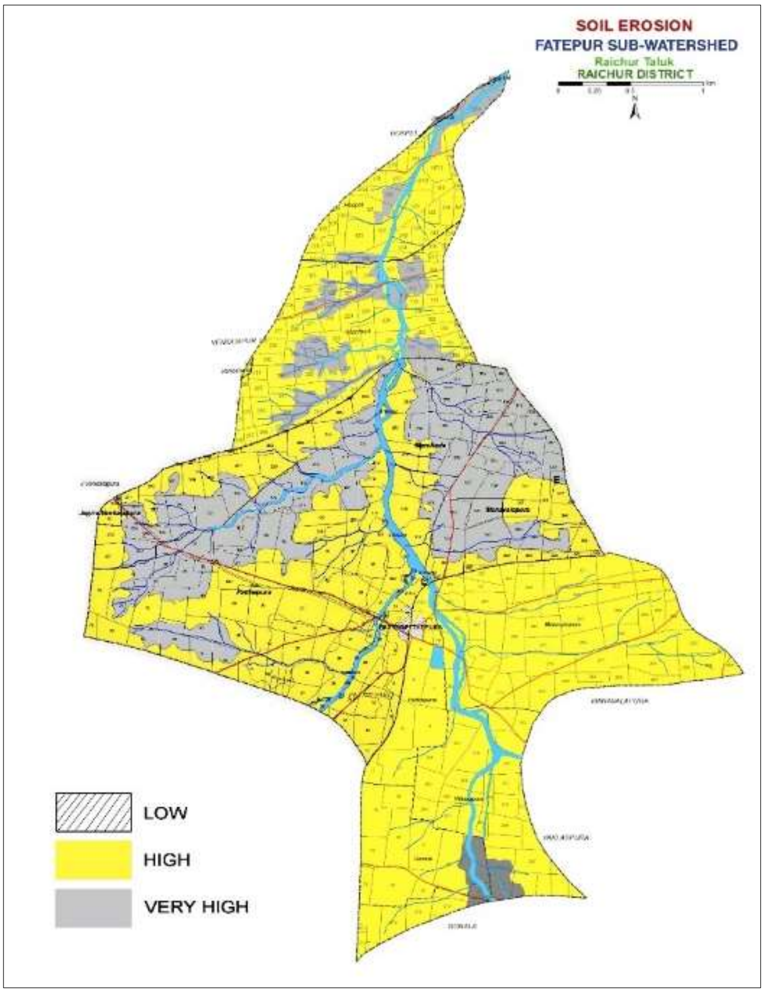

**Fig 12:** Soil erosion map of Fatepur sub watershed

**Table 1:** Rainfall erosivity (R) factor values

| Station name | Latitude | Longitude | Average annual rainfall (1990-2021) | |
|---|---|---|---|---|
| | | | Rainfall in mm | R-factor |
| UAS Raichur | 16°11’34.17’’ N | 77°19’01.24’’ E | 700.34 | 333.22 |
| Fatepur | 16°14’00.00’’ N | 77°17’14.00’’ E | 648.17 | 314.28 |
| Yaklaspura | 16°15’58.03’’ N | 77°17’10.83’’ E | 653.26 | 316.13 |
| Marched | 16°14’53.70’’ N | 77°15’47.15’’ E | 627.15 | 308.65 |
| Hospet | 16°16’38.57’’ N | 77°16’49.15’’ E | 632.05 | 306.43 |

**Table 2:** Soil Erodibility (K) factor values

| Soil texture | K-factor |
|---|---|
| Sandy clay | 0.13 |
| Clay | 0.18 |
| Loamy sand | 0.16 |

**Table 3:** C-factor values

| Sl. No. | Class name | C-factor |
|---|---|---|
| 1 | Thin vegetation | 0.18 |
| 2 | Agriculture | 0.24 |
| 3 | Water body | 0.59 |
| 4 | Livelihood | 0.36 |

**Table 4:** Soil erosion characteristics of the Fatepur sub-watershed

| Erosion categories | Soil loss Classes (t/yr) | Area (ha) | Area (%) | Avg. Soil loss (t/yr) |
|---|---|---|---|---|
| Low | 0-1000 | 98 | 4.79 | 117 |
| High | 1000-7000 | 1633 | 77.87 | 3864 |
| Very high | 7000-10000 | 366 | 17.34 | 7320 |
| Total | | 2097 | 100.00 | 11301 |

## Conclusions

This research paper set out to estimate the annual soil loss within the Fatepur sub-watershed of Raichur Taluk by applying the Revised Universal Soil Loss Equation (RUSLE). To calculate the potential for soil loss, the study incorporated multiple factors, including rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C), and conservation practice (P). These parameters were meticulously gathered and their values employed in the RUSLE formula. The results of this investigation disclosed a significant annual soil loss in the Fatepur sub-watershed, signalling a potential threat to its soil resources.

The study underscores the critical importance of adopting soil conservation measures and implementing effective land management practices within the Fatepur sub-watershed to mitigate soil erosion and safeguard the precious topsoil. By implementing such practices, it becomes feasible to minimize soil loss, protect the local ecosystem, and ensure the sustainability of agricultural production. However, it's important to recognize that the estimation of annual soil loss using the RUSLE relies on various assumptions and simplifications. Further research and on-site validation efforts are necessary to refine the precision of these findings. Moreover, it's essential to note that this study specifically concentrated on the Fatepur sub-watershed in Raichur Taluk, The findings may not be readily transferable to other regions without taking into account their unique characteristics.

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