Spatial Analysis of Soil Loss Estimation in the Raichur District is part of Krishna River, Peninsular India using Geospatial Technology

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Abstract

A spatial technique is essential for proper utilization and soil preservation management often requires estimates of soil loss at a provincial scale. With the advent of powerful and high-speed personal computers, efficient techniques for soil loss estimation have evolved, of which geoinformatics technology are of great significance. A geospatial analysis was carried out to know the soil loss calculations in the Krishna River in part of Raichur district, Karnataka. An analytical representation such as Universal Soil Loss Equation (USLE) and its following Revised Universal Soil Loss Equation (RUSLE) are useful tools to produce the quantitative calculate about the essential for controlling management approach. Spatial data layers including, rainfall erosivity (R), soil erodability (K), slope length and steepness (LS), cover management (C) and conservation practice (P) factors were computed to estimate the average annual soil loss of the study area. The average estimated soil loss rate for the study area was found as 18.61 $t.ha^{-1}.yr^{-1}$. Further, the estimation of soil erosion rate was classified into four severity classes are namely as slight, moderate, severe and extremely severe. About, 70% (5870.20 km^2) and 14.33% (1201.71 km^2) of the study area falls under slight and moderate respectively potential soil loss in the study area. Approximately 983.68 km^2 area accounting for 11.73% of the study area falls under severe and extremely severe potential soil loss region cover an area of 330.41 km^2 accounting for 3.94% of the total study area. The based on outcome of the results, finally it is concluded that the spatial technology are very efficient and useful for the soil loss estimation.

Keywords: *Erosion; Geology; Geospatial; Slope; Soil;*

1. Introduction

Geospatial techniques are advent of powerful and high-speed personal computers, efficient techniques for revised universal soil loss equation have evolved in computation method of which geoinformatics technology are of great significance (Biswas & Pani, 2015; Arekhi et al., 2012; Nontananandh & Changnoi, 2012; Prasannakumar et al., 2012; Jain & Kothyari, 2000). This may be used for site assessment and development purposes and to aid in the decision support system of selecting erosion control factors. It suggests an estimate of the severity of erosion. It also give current information to validate the benefits of considered erosion control factors, such as the improvement of addition a diversion channel or stream network (Kaisara & Satish, 2022; Baigorria & Romero, 2007; Ekanayake & Dayawansa, 2003). For example, an interruption may shorten the length of slope used in calculating a LS factor. Also, the application of drainage networks will break raindrop impact and reduce runoff (Jain et al., 2007; Meyer & Wischmeier, 1969).

The revised universal soil loss equation has enhanced the outcome of soil parameters roughness and the results of local climate conditions on the prediction of soil loss and residual deposit discharge. The importance of estimating soil erosion and sediment discharge has long been documented to reduce the pollution by sediments as well as the chemicals carried with soil constituents (Amore et al., 2014; Morgan & Nearing, 2011; Sharma et al., 2002). The visual effects of soil erosion include in a small streams and drainages and sediment obstacle found in culverts or drainage networks. A well planned and designed for erosion control and/or water management plan will improve many concerns about construction site erosion and possible contamination. The USLE was developed by Weischmeier & Smith in 1958 and 1978 is the most widely used for soil erosion prediction technique.

Soil erosion is a natural geological occurrence consequential from the cutting of soil constituents by water or wind, transporting them elsewhere, whereas some human activities can drastically increase the soil erosion rates (Kinnell, 2010; Sidorchuk, 2009; Terranova, 2009; Bhattarai & Dutta, 2007; Nearing, 2004; Lin et al., 2002). In practical almost globally experimental models for evaluate the sheet and rill erosion is the universal soil loss equation (USLE).

2. Location of the study area

In peninsular India, Krishna River is one of the most important agricultural areas in the north Karnataka. The study area Raichur district is the part of Krishna River and the study area is situated in lower part of Krishna River, in north-eastern part of Karnataka state in India. It falls in the northern upland region, between 15º32' to 16º35 ' North latitudes and 76º13' to 77º37' East longitudes and also between the two major rivers namely the Krishna and the Tungabhadra. The district is bounded on the north by Yadgir on the south by Ballari district, on west by the Bagalkot and Koppal districts and east by the Mahabub Nagar district of Telangana. Administrative location of the district is shown in *Figure 1*.

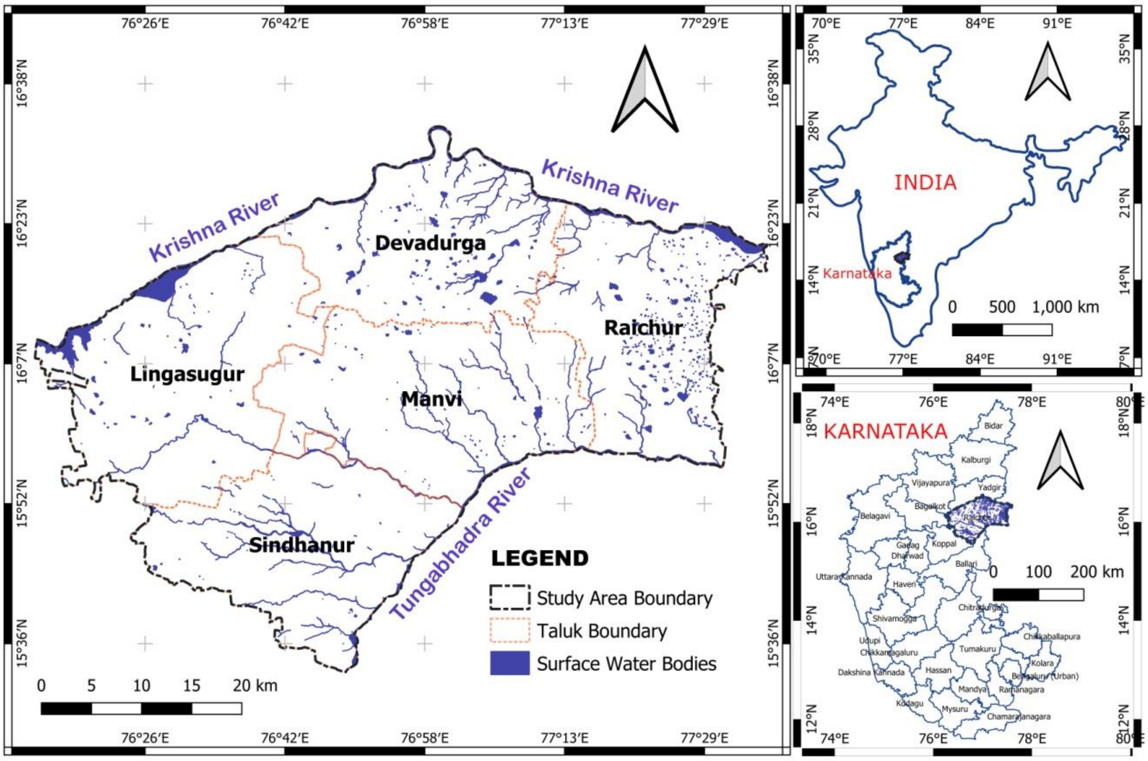

Figure 1. Location map of the study area

The district has a total geographical area of 8386 km^2. The district has been divided into five taluk; Raichur, Lingasgur, Manvi, Sindhanur and Deodurga, recently Sirwar and Maski are added as a new taluk in the District for administrative convenience. The population density of the district as per the 2011 Census is 230 per km2. The district forms part of Krishna catchment in northern part, while southern part forms the lower Thungabhardra catchment area and are perennial in nature. Approximately sixty percent of the geographical area in the district is under irrigation. Canals, tanks, wells, bore wells; lift irrigation and others are the important sources for irrigation.

3. Methodology

3.1. Materials

Basavaraj and Ibomcha, 2022; Basavaraj and Sharath 2019; Basavaraj and Nijagunappa 2011; 2012; 2015; Mitasova, 1996; are acknowledged using geoinformatics technology is spatial analysis for preparation of various thematic maps are the most fundamental prerequisite in any soil studies. The study area is about 8386 km^2. An efficient spatial analysis of study area maps like, stream network, geology, land use & land cover, slope aspect, soil map, etc., has been carried out using geoinformatics tools such as open source QGIS, MapInfo Pro version, AutoCAD-MAP, Garmin GPS and Bhuvan portal - ISRO satellite images and total 22 Survey of India (SOI) toposheets used from the Nakshe poratl as shown in *Table 1*. In additional to this, from the Earth explorer portal of SRTM satellite image data is also used to delineate the regional lithology and lineaments of the study area. During geology and soil mapping, a large number of fresh outcrop samples, soils were identified and collected from the in situ outcrops and prepared thematic maps for geology and soil classification study as shown in *Figure 7* and *Figure 2* are respectively.

Table 1. Material and data sources

Material Data	Data Source	Utilization for
56D/7, 56D/8, 56D/11, 56D/12, 56D/14, 56D/16, 56H/2, 56H/3, 56H/4, 56H/7, 56H/8, 56H/12, 57A/5, 57A/6, 57A/9, 57A/10, 57A/13, 57A/14, 57E/1, 57E/2, 57E/5, 57E/9	Nakshe portal, SOI toposheets	Settlement, Forest, Stream Network, Contour
Geology map	NRDMS Center, Raichur, GSI-Bangalore	Lithology, Soil
Satellite Images	Bhuvan portal -ISRO	Drainage network, DEM, Slope, Contours, Slope aspect, Hill shade

3.2. Soil type of the area

Study area can be broadly classified into three major zones. Zone one is the northern rugged plateau, zone two is the southern lower plains with inselbergs and isolated hillocks and zone third is valley fills. As the catchment area is an undulating terrain, it is quite likely that the land is subjected to different degrees of erosion resulting in varied depth of soils, making them fit for growing only a few set of crops. Soil type will help decide how much water reaches the river. Since the study area is covered predominantly by black cotton soils, which inhibit percolation and circulation of water, there are pockets of poor quality ground water in the area (Basavaraj Hatti and Laishram Ibomcha Singh, 2022, Sarangi et al. 2000). However, soils containing clay can be almost impermeable and therefore rainfall on clay soils will run off and contribute to flood volumes. After prolonged rainfall even free draining soils can become saturated, meaning that any further rainfall will reach the river rather than being absorbed by the ground. Keeping these factors in mind the study has been undertaken to analysis, classifies and prepared the thematic map of the soil types of study area as shown in *Figure 2.*

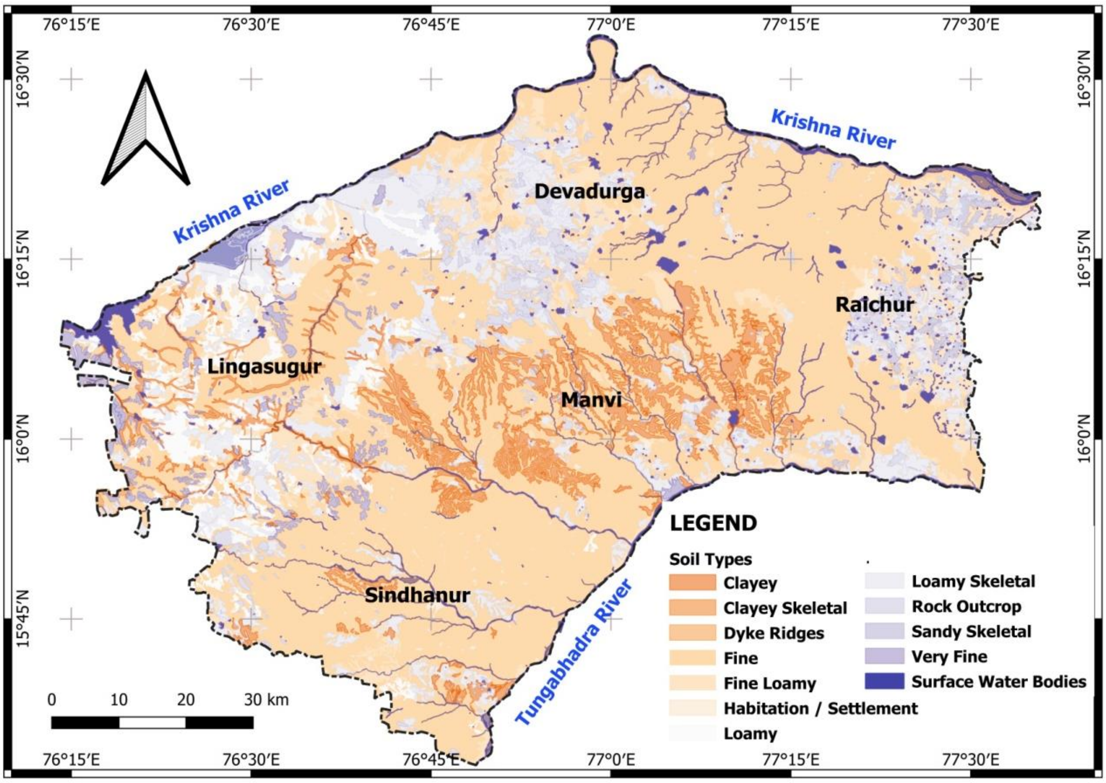

Figure 2. Soil types map of the study area

3.3. Climate and rainfall

The study area is located in the northern maidan region of Karnataka state, which is drought prone and falls in the arid region of the country. The climate of the study area can be appearance as mild to severe, with mild winters and hot summers. December is the coldest month with mean daily minimum of 17ºC, while May is the hottest month with mean daily maximum temperature of 42ºC. The day temperature in May often touches 45ºC. The South-West monsoon season generally commences during second week of June and lasts till the end of September. The average annual rainfall is around 675 mm, the bulk of which is received between the months of July and September.

3.4. Drainage

The Krishna river originates from Mahadev range of the western ghats near Mahabaleshwar at an altitude of about 1337m above mean sea level. It is observed that the less resistant rocks confined in the western part of the catchment has higher values of drainage density than that of the flat areas in the central part. The study area drainage pattern in dendrite drainage pattern, here sub stream meet with mainstream at right angle (*Figure 3*). There are very few natural lakes but many tanks have been constructed for the purpose of irrigation and domestic water supply.

3.5. Slope Aspect

The Slope aspect map (*Figure 4*) of the study area is prepared from the QGIS software using open source satellite images are downloaded from the Indian Space Research Organization (ISRO), Bhuvan portal. The study area aspect maps are make possible to quickly assess the slope and aspect of the topography for investigative the steepness and /or direction of slope (*Figure 5*) and to estimate the erosion, rainfall run-off and direction.

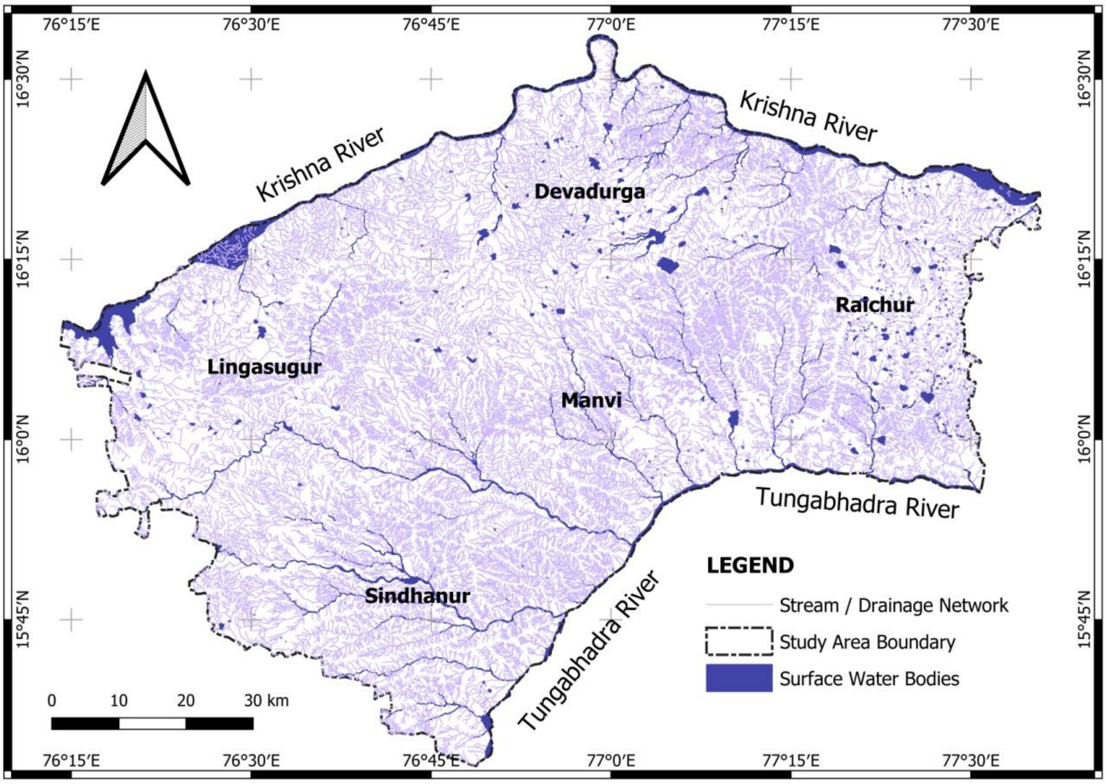

Figure 3. Stream network / drainage density map of the study area

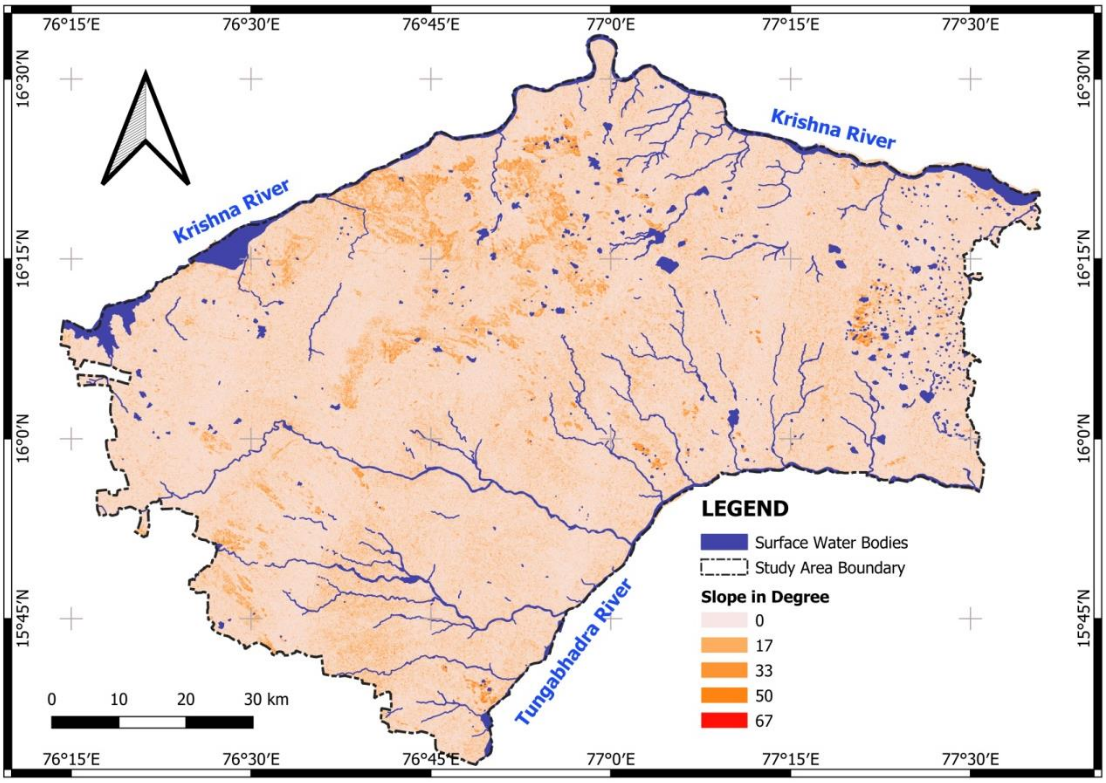

Figure 4. Slope map of the study area

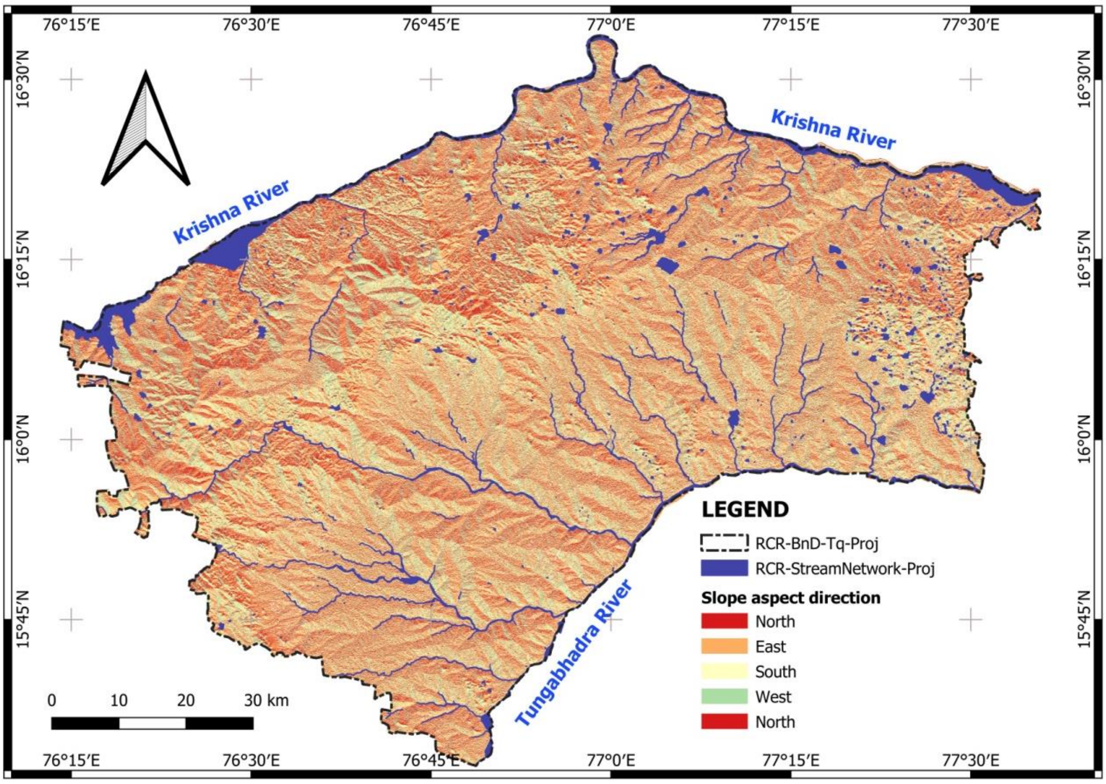

Figure 5. Slope aspect direction map of the study area

3.6. Land use and Land cover

Land use is the surface utilization of all the improvement and vacant land on a particular point, at a given time and space (Lal, 2001). This leads on back to the village from and the farmer to the field gardens, pastures fallow and forest and to the isolated

farmstead. Land use is the use actually made of any parcel of land, house, apartments, industrial locations are land use categories. Whereas the term residential, industrial and agricultural refers to a system of land utilization implying roads, neighbourhood retail and service activities as well as location of industry and carrying of agricultural explore.
The most part of land use and land cover map is shown in *Figure 6* for the agricultural fallow land; here one time of year cultivation is occurred. Here also shows existing agriculture, open fallow land, covered wetland, irrigation land portion of the study area. Here partial amount stream erosion is present. South central railway passes through the eastern part. Here different types of metal & un-metal roads are present.

3.7. Geology

The foremost geological formation of the study area involve the Dharwarian rocks of granites, gneisses and Dharwar schist's, are the main rock formations in the Raichur district. These formations are grouped under hard rock, as they do not have any primary porosity. However, less important porosity is developed due to faults, fractures, joints, and due to weathering, which improved permeability and water yielding capacity of these rocks. The study area is covered predominantly by black cotton soils, which inhibit percolation and circulation of water; there are pockets of poor quality sub-surface water in the study area. The geology of the study area is shown in the *Figure 7*.

4. Results and Discussions

Soil erosion calculations using Universal Soil Loss Equation (USLE) in combination of geoinformatics technology platform is considering rainfall, soil, topographic and open

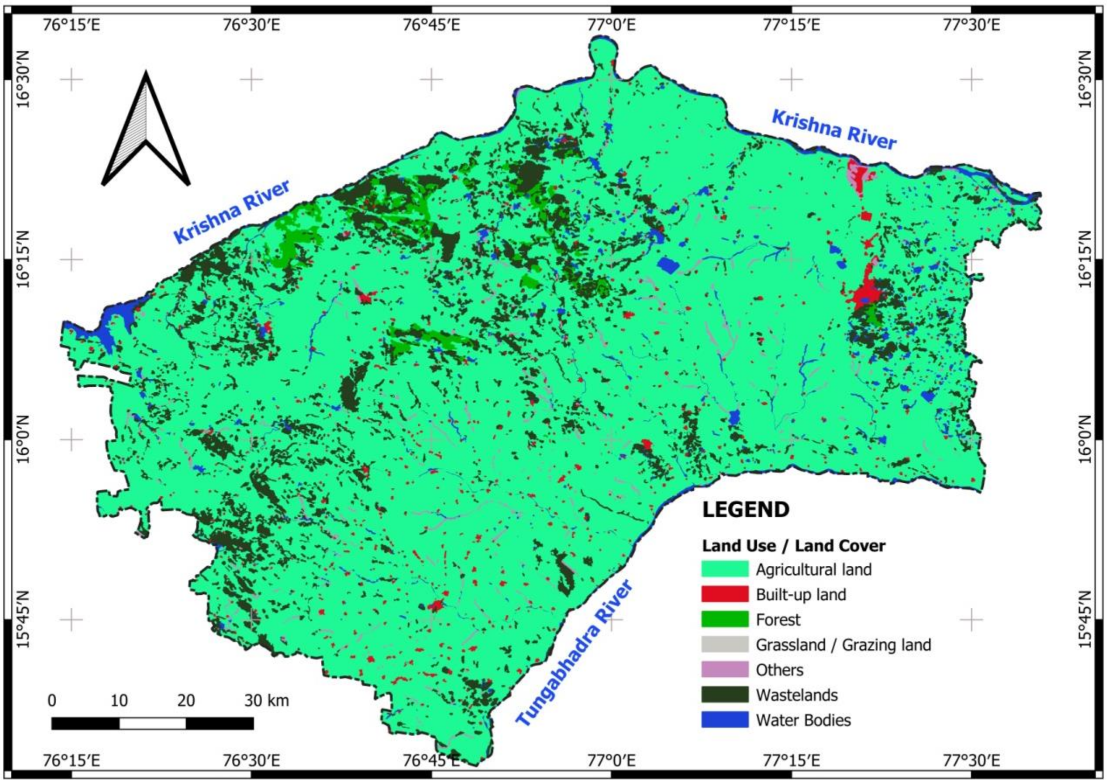

Figure 6. Land use and land cover map of the study area

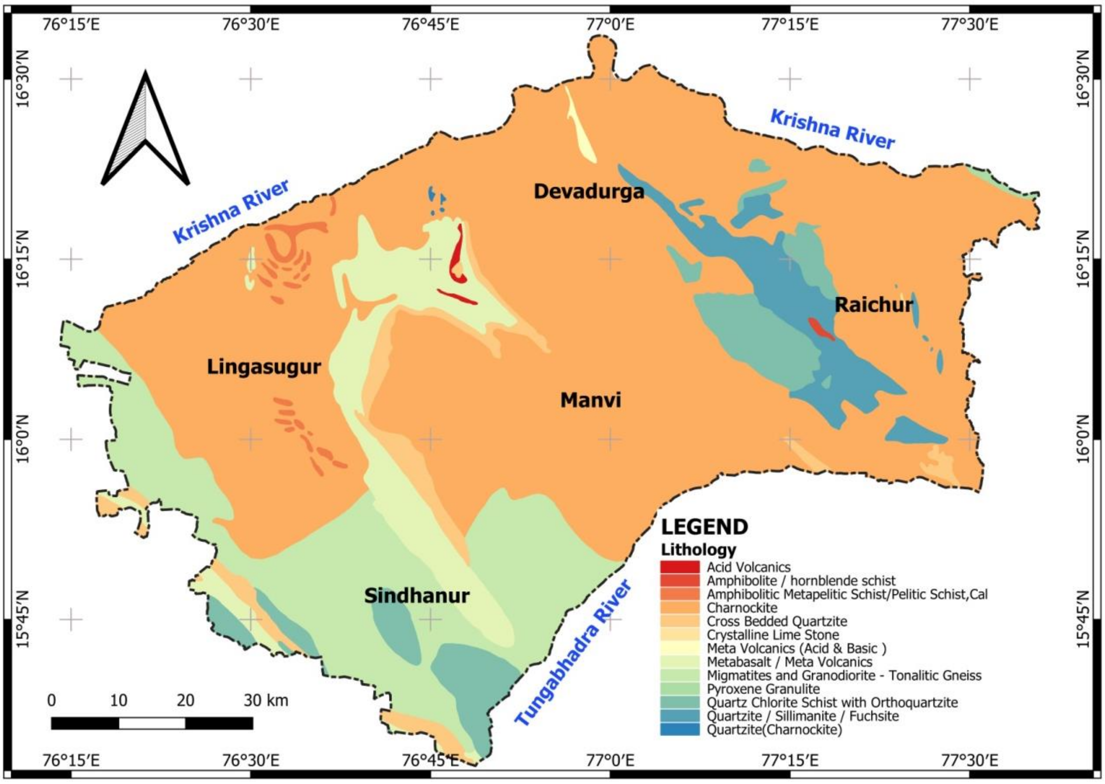

Figure 7. Geology map of the study area

Sources satellite imagery datasets from the line department. Geoinformatics was successfully used to calculate all the factors and prepare a spatially distributed raster map for each factor (i.e. R, K, LS and C). The spatially distributed map of annual average soil loss estimation was prepared by multiplying the raster maps of each factor using raster calculator in geoinformatics technology.

$$A = R \times K \times LS \times C \times P$$

It indicates the possible long term average annual soil loss in tons per acre per year. This is the amount, which is compared to the "average soil loss estimation" limits. R is the rainfall and runoff factor by geographic location as given in *Table 2*, R factor Data. The greater the intensity and duration of the rain storm, the higher the erosion potential (Tiwari et al., 2016; Louriero, 2000; Lal 1977). Select the R factor from *Table-2* based on the taluk and corresponding station where the calculation is to be made.

Table 2. R factor data

Taluk Name	Area in km^2	Annual rain fall in mm	R Factor
Devadurga	1509	682	394.2
Lingasgur	1949	614	377.1
Manvi	1794	709	489.6
Raichur	1535	643	409.7
Sindhanur	1599	669	433.8

K is the soil erosivity facto is show in the *Table 3.* It is the average soil loss in tons per hector per unit area for a particular soil in develop, continuous fallow with an indiscriminately selected slope length of 72.6 feet, and slope steepness of 9%. K is a evaluating of the vulnerability of soil particles to disconnection and carrying by rainfall and runoff. Texture is the principal factor affecting K, but structure, organic matter and permeability also contribute.

LS are the slope length gradient factor. The LS factor correspond to a ratio of soil loss under given circumstances to that at a site with the standard slope steepness of 9% and slope length of 72.6 feet. The steeper and longer the slope, the higher is the risk for erosion. In *Table 4,* LS Factor Calculation or the estimate the LS included in this information to obtain LS.

C is the crop / vegetation and management factor. It is used to determine the relative efficiency of soil and crop management classifications in terms of avoid soil loss. The C factor is ratios evaluates the soil loss from land under a detailed crop and management system to the consequent loss from constantly fallow and cultivate land. The C Factor can be determined by choose the crop type method (*Table 5*) that communicate to the field and then develop these factors together. The C factor resulting from this calculation is a universal C factor value for a particular crop that does not account for crop alternation or climate and annual rainfall distribution for the different agricultural regions of the country. This universal C factor, however, provides relative numbers for the different cropping; thereby helping you weigh the qualities of each classification.

The major crops observed in the study area are jowar, bajra, cotton, sorghum, sesamum, sunflower, redgram and vegetables like onion and chilli. Out of these, Bajra and sesamum are grown in a larger area compared to other crops.

P is the sustain practice factor. It replicates the effects of study that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. Data P factor was taken concerning land use and land cover map (*Figure 7*) in that the wide area of land was identified to be under agriculture, wasteland and social forest land uses hence the selection of (P) under these cover handle were calculated. The value of (P) in use is 0.75, 0.65, and 0.45 for agriculture, wasteland, and forest separately based on prevalent tillage practices followed in the watershed.

Table 3. K factor data

Soil Texture	Clay %	Silt %	Sand %	Organic matter content		
				Less than 2%	More than 2%	Average
Sandy Clay Loam	25	15	60	0.15	0.17	0.16
Loamy Sand	5	15	80	0.15	0.15	0.15
Sandy Loam	10	30	60	0.20	0.24	0.22
Sandy Loam	10	30	60	0.21	0.22	0.22
Sandy Clay Loam	10	30	60	0.22	0.23	0.22
Sandy Clay Loam	70	15	15	0.15	0.17	0.16
Sandy Clay	15	15	70	0.13	0.13	0.13
Clay	10	10	80	0.19	0.18	0.19
Loamy Sand	5	15	80	0.14	0.16	0.15
Sandy Loam	10	30	60	0.17	0.15	0.16
Sandy Loam	10	30	60	0.15	0.15	0.15
Sandy Clay Loam	25	15	60	0.16	0.16	0.16
Loamy Sand	5	15	80	0.14	0.13	0.14
Sandy Loam	10	30	60	0.17	0.19	0.18
Sandy Loam	10	30	60	0.17	0.15	0.16
Sandy Clay Loam	25	15	60	0.18	0.18	0.18
Sandy Clay Loam	25	15	60	0.18	0.18	0.18

Table 4. LS factor data

Slope Gradient	< 1	1 = < 3	3 = < 5	> 5
LS Weight assigned	0.2	0.3	0.4	0.5

Table 5. C factor data

Crop type	Factor
Bajra	0.40
Jowar	0.36
Cotton	0.32
Sorghum	0.35
Sesamum	0.27
Sunflower	0.26
redgram	0.21

The parameters (R, K, LS, C and P) are calculated for quantity of soil loss erosion in per hector per year (Lu et al. 2004). The R factor for a field cannot be changed. The K Factor for a field cannot be changed. LS factor Terracing need added investment and will cause some complication in cultivation. Study other soil preservation practices first. C factor, Consider cropping systems that will provide highest protection for the soil. Use least tillage systems where possible. P factor, Use support practices such as cross slope cultivation that will cause deposition of sediment to occur close to the source (Van der Knijff et al. 1999; Renard et al., 1997; Wischmeier and Smith, 1978)
Study area Raichur Districts Potential Soil loss estimation is calculated using Universal Soil Loss Equation (USLE) formula

$$A = R \times K \times LS \times C \times P$$

Where:
Rainfall and Runoff Factor (R); Therefore the R factor is obtained in *Table 2*. R factor is 420.88. Soil Erodibility Factor (K); The sample field consists of silt, clay and loam soil with average organic matter content. The K factor is obtained from *Table 3*. K Factor is 0.18. Slope Length-Gradient Factor (LS); The LS factor calculated using slope aspect value in *Table 4*. LS factor is 1.4. Crop or Vegetation and Management Factor (C); the C Factor is obtained from the crop type factor *Table 5*. C Factor is 0.27. Support Practice Factor (P); Flat slope farming is used on this sample field. The P factor was obtained from *Figure 7*. The P factor is 0.65.

Therefore,

$$A = R \times K \times LS \times C \times P$$
$$= 420.88 \ \text{x} \ 0.18 \ \text{x} \ 1.4 \ \text{x} \ 0.27 \ \text{x} \ 0.65$$
$$= 18.61 \text{ tons per acre per year}$$

The average soil loss rate was estimated at 18.61 $t.ha^{-1}.yr^{-1}$.

The average annual soil losses of the study area were then grouped into different severity classes based on the criteria of soil erosion risk classification suggested by FAO (2006). The details of severity classes and the spatial distribution of the same in the study area are shown in *Table 6* and *Figure 8*, respectively. Nearly 70.00% of the study area is falls under slight class. Approximately 4.00% areas come under extremely severe soil loss class. The areas with extreme severe soil loss should give more importance in terms of erosion control. Comparing Figure 8 and Figure 4 it can be easily observed that extremely severe erosion occurs mostly in areas with high slope values. While slight erosion is mostly observed in areas with low slope values. This may be due to the high/low LS factor values in the respective regions as LS factor calculation is highly dependent on slope value.

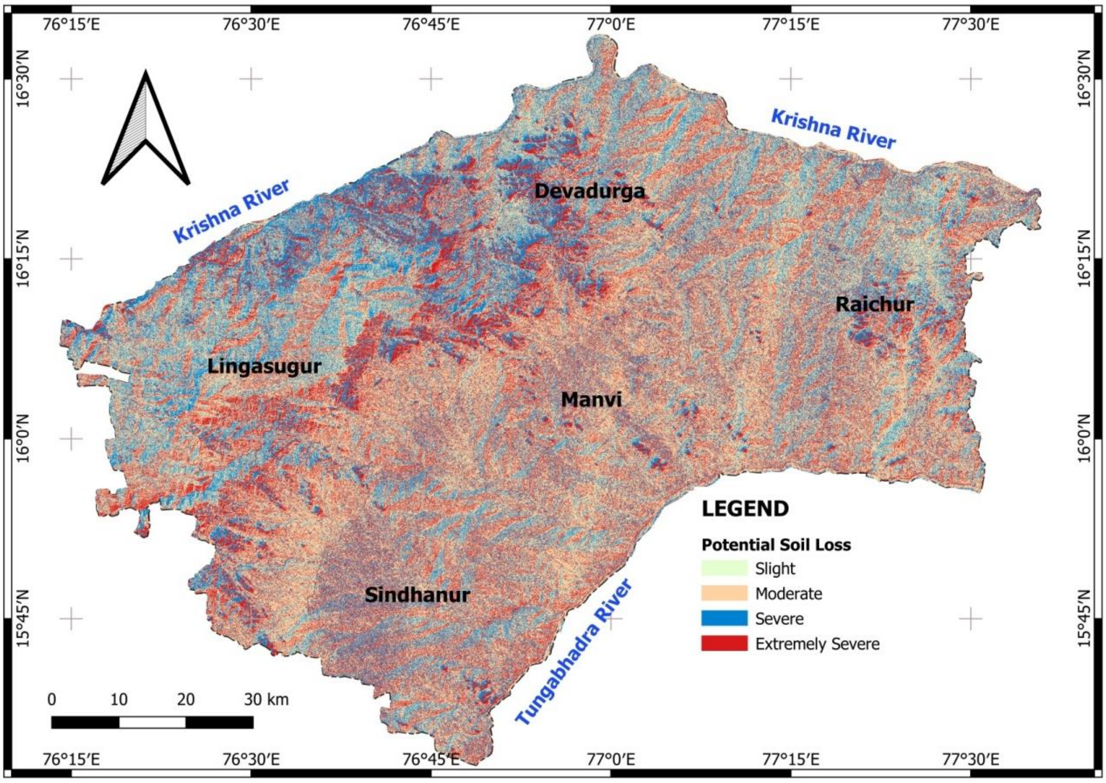

Figure 8. Soil loss severity classes map of the study area

5. Conclusion

In this research work, combined application of spatial techniques and geoinformatics technology are found an efficient tool in the estimation of soil loss calculations in the study area Raichur District is part of Krishna River in peninsular India with respect to efficiency, manpower, time and costs involved in study. About, 70% (5870.20 km^2) and 14.33% (1201.71 km^2) of the study area falls under *slight* and *moderate* respectively potential soil loss in the study area. Approximately 983.68 km^2 area accounting for 11.73% of the study area falls under *severe* and *extremely severe* potential soil loss region is cover an area of 330.41 km^2 accounting for 3.94% of the total study area. The outcomes of the research will be helpful as first hand information for local formers, agricultural planners and local authorities for land assessment, planning, management, administration, sustainable utilization and natural resources in the study area in future perspectives.

Table 6. Soil loss severity classes with loss rate and area covered

Severity Class	Soil Loss ($t.ha^{-1}.yr^{-1}$)	Area in km^2	Area in %
Slight	< 25	5870.20	70.00
Moderate	25 - 50	1201.71	14.33
Severe	50 - 100	983.68	11.73
Extremely Severe	> 100	330.41	03.94

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