Summer Fellowship Report

On

QGIS

Submitted by

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Under the guidance of

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Acknowledgement:

I sincerely express my gratitude to IIT-Bombay and FOSSEE for providing the platform to learn and explore open source software. The internship to work for FOSSEE project was a great opportunity to learn about the software and its widespread applications.

I am highly indebted to Dr. Kannan Moudgalya, Professor, Department of Chemical Engineering, IIT Bombay for initiating FOSSEE project which inspired students to learn about different open source software.

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With Regards,

Vaishnavi Uday Honap

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1 About QGIS

1.1 Introduction:

QGIS (previously known as **Quantum GIS**) is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data.

QGIS supports both raster and vector layers; vector data is stored as either point, line, or polygon features. Multiple formats of raster images are supported, and the software can geo-reference images.

Figure 1 QGIS Logo

1.2 Applications Of QGIS:

Since QGIS is free and open source software, it is very much useful in various applications some of the applications are as follows:

1. Forestry
2. Mining
3. Oil & Natural gas exploration.
4. Remote Sensing
5. Administration

1.3 Comparison Between QGIS and other Commercial Software:

For geo-processing and features ArcGIS needs separate license while QGIS is free software for all. QGIS uses the GDAL/OGR library to read and write GIS data formats. Over 70 vector formats are supported. While in ArcGIS it supports only limited number of formats. Various features are easily accessible in QGIS (i.e. more user friendly) than the ArcGIS.

1.4 Future Scope For QGIS:

QGIS allows user to write, modify source code. It makes the applications of QGIS in wide spread. QGIS integrates with other open-source GIS packages, including Post GIS, GRASS GIS, and Map Server. Plugins written in Python or C++ extend QGIS's capabilities.

1.5 QGIS features used for current Study:

Some of the QGIS features used for study are listed as below:

i. Vector Analysis
ii. Raster Analysis
iii. Map composer
iv. SAGA GIS

2 Estimation of soil erosion for Kerala floods 2018-2019.

2.1 Abstract

On 8 August 2018, severe floods affected the state of Kerala, due to unusually high rainfall during the monsoon season. In the aftermath of the flood, the water levels in rivers and wells of Kerala are depleting at an alarming rate.
In the present study, the sediment yield assessment by Universal soil loss equation (USLE) model is performed.
Kerala was chosen for testing USLE methodology using remote sensing and Geographic information system (GIS). To identify high potential soil loss areas during Kerala floods August 2018- which led to draught conditions.

Keyword: Sediment yield, remote sensing, Geographical information system.

2.2 Introduction - Study area:

Kerala state is in between northern latitudes 8°18' and 12°48' and eastern longitudes 74°52' and 77°22', divided into 14 districts and capital being Thiruvananthapuram, and a surface area of 38,863 km2. The state has a coast of 590 km. It experiences humid tropical rainforest climate.

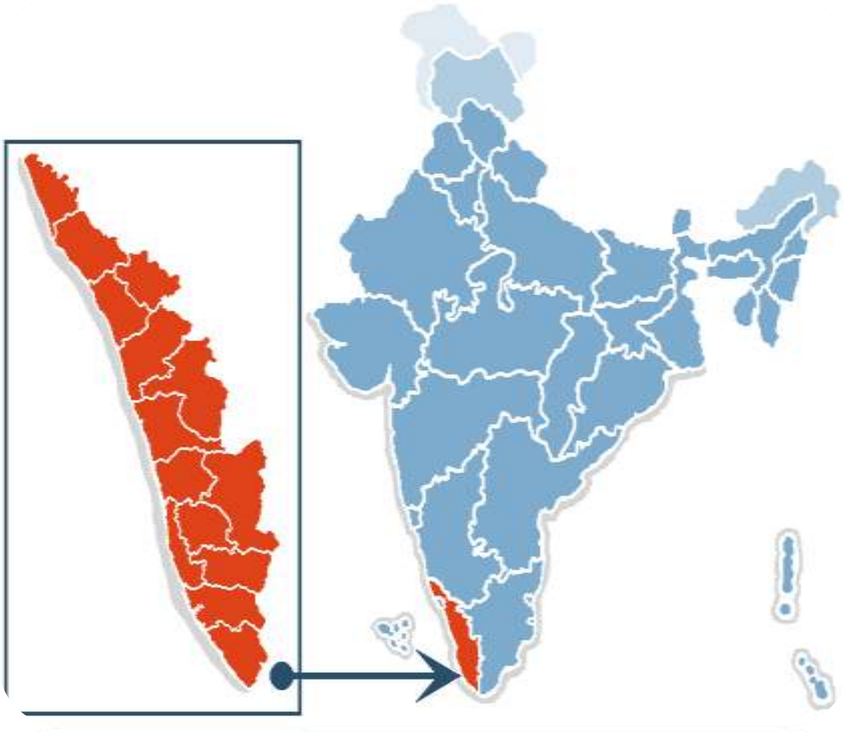


Figure 2 Location Of Kerala

2.3 Problem Statement:

On 8 August 2018 Kerala experienced an abnormally high rainfall from 1 June 2018 to 19 August 2018. This resulted in severe flooding in 13 out of 14 districts in the State.

A few days after receiving one of the highest rainfalls in a century, Kerala came under the threat of severe drought. Water level in wells, ponds and rivers has recorded lowest and some wells even collapsed.

The Centre for Water Resources Development and Management (CWRDM) attributes falling water levels to heavy leaching of top soil from the hills.

Therefore, there is a dramatic decrease in river flow and most of the lower order streams are also drying up alarmingly. A severe spell of rainfall resulted into heavy loss of top soil cover.

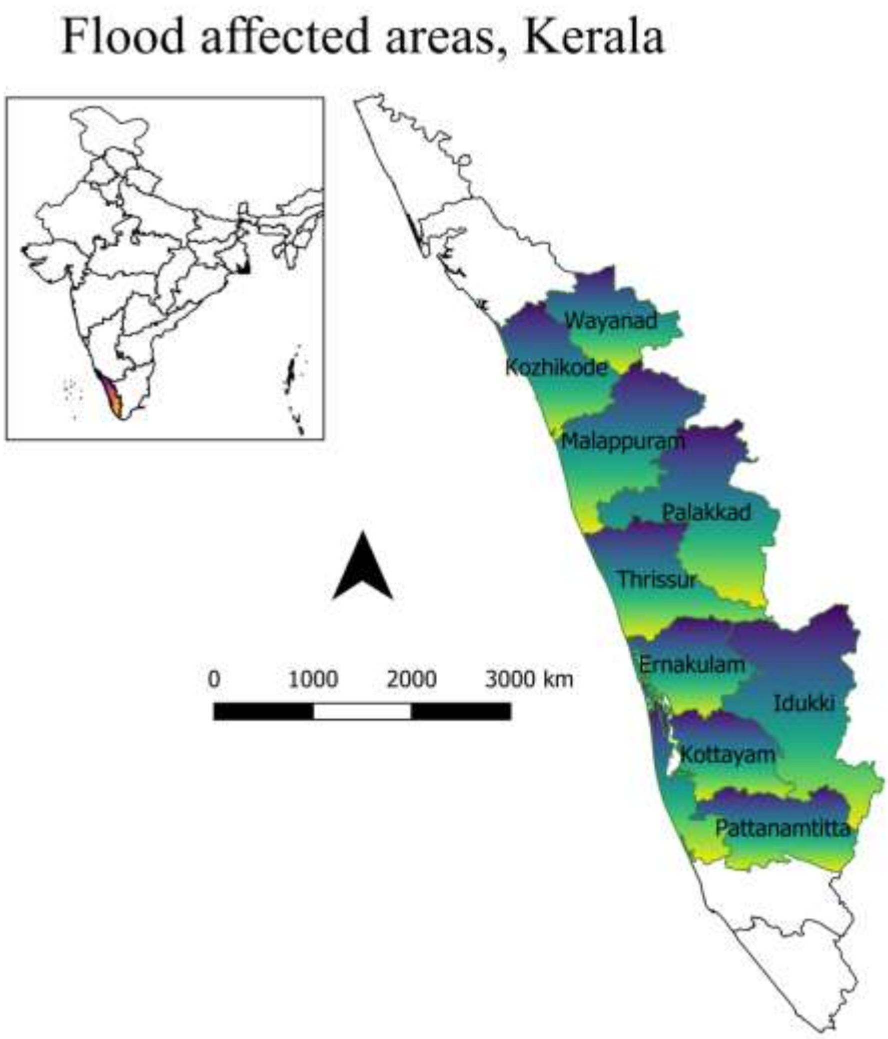


Figure 3 Flood affected areas, Kerala

Terminologies:

2.3.1 Soil Erosion

- Soil erosion is the process in which, the removal of the soil surface material is carried out by wind or water. (MISHRA)
- Water is the major factor for soil erosion where the process includes detachment, transportation and deposition of individual soil particles (sediment) by raindrop effect.

2.3.2 Sediment Yield

- Sediment yield can be defined as the amount of sediment reaching or passing a point of interest in a given period of time.
- The four natural factors having important impacts on sediment yield – vegetation, rainfall, soil, and topography – were selected for analysis.

2.4 Aim

Estimate amount of soil erosion, sediment load and sediment yield in Kerala 2018-19

2.5 Objectives:

- Estimate the soil erosion quantitatively for 2018-2019
- To detect vegetation cover change in Kerala.
- To estimate sediment load for 2018-2019 Kerala.

2.6 Data Used:

Data	Source
Landsat 8 satellite Images from 2018-2019 (30m resolution)	USGS – Earth Explorer
Rainfall data from 2014-2018 (5years data)	Indian metrological department
World soil map	Food and agriculture organization (FAO) of united nations.
SRTM DEM (90m resolution)	SRTM-CGIAR

Table 1 Data used

2.7 USLE Parameter Estimation

2.7.1 Soil erosion models:

The Universal Soil Loss Equation (USLE) model is one of the real advancements in soil and water protection in the 20th century. It was at first proposed by Wischmeier and Smith (1965)

The **USLE** is composed of six factors to predict the long-term average annual/seasonal soil loss (A). (G. R. Foster, 1981)

A = RKLSCP

Factor	Abbreviation	Unit
A	Average soil loss	tonnes/ha/yr
R	Rainfall erosivity	Metric tonnes ha^{-1} cm h^{-1} 100^{-1}
K	Soil erodibility	MJ cm ha−1 h−1 yr−1
LS	Topographic factor	-
C	Cover management	-
P	Conservation practice factor	-

Table 2 Soil erosion parameters

2.7.2 Sediment :

SY, a function of slope and gross erosion of a study area. (Kumar, Raghuwanshi, & Mishra, 2015), was calculated using following table: (Roy, p. 1 to 24)

	Equation	Units	Given by
SDR	0.627 (SLP)^0.403	Slope	William and Brendt
Sediment Yield	SDR *A		William and Brendt
Sediment Load	A* Area of district	Tonnes/yr	

Table 3 Sediment yield equation

SLP = Percentage slope of DEM of district
A = Total gross erosion computed from USLE

Equations:

$$A = RKLSCP$$

Factor		Equation	Given by
Rainfall Erosivity Factor	R	79+0.363Xa	Choudhary and Nayal 2003
Soil Erosivity Factor	K	f(Csand) * f(cl.si) * f(org) * f(hisand)	Williams Equation
Topographic Factor	LS	(f* Cell size/22.13)^m * (0.065+0.045s+0.0065s^2)	Rahaman, Aruchamy, Jegankumar, and Ajeez (2015)
Cover Management Factor	C	e^(-2*NDVI/1-NDVI)	Knjiffs equation 2012
Conservation Practice Factor	P	Landuse landcover classification	USDA handbook

2.8. Methodology

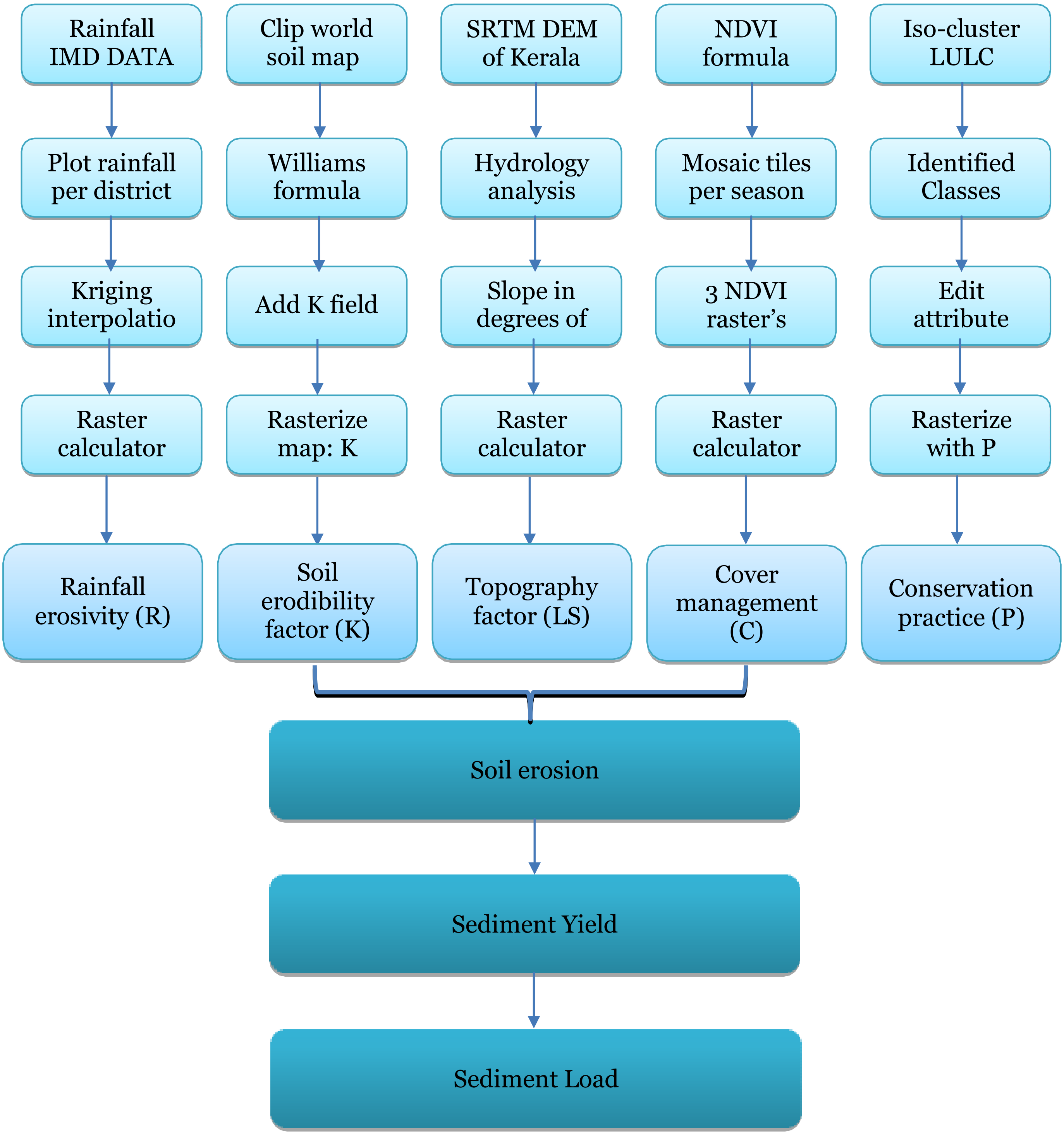


Figure 4 Detailed USLE methodology

2.9 Estimation of USLE input parameters:

2.9.1 Rainfall erosivity index (R)

In the USLE, the R factor quantitatively represents the impact of rainfall on the soil surface (M. Vinay, 2015)

1. District wise recent rainfall data from Indian metrological department is used.
2. Average rainfall was plotted for districts
3. Kriging interpolation is used to generate rainfall map.
4. Raster calculation is performed to get R map.

Due to heavy rainfall, districts like Alapuzha, Idukki, has high value of R factor ranging from 168 Metric tonnes ha^{-1} cm h^{-1} 100^{-1} and above.

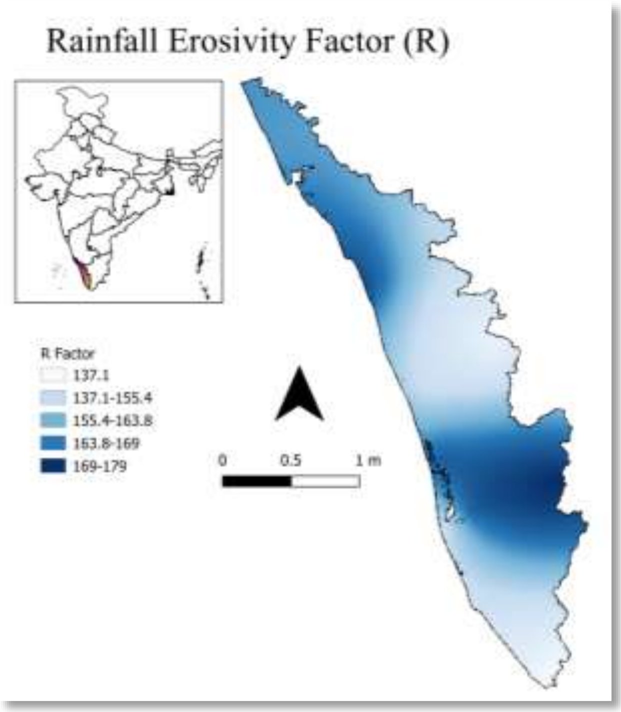


Figure 5 Rainfall Erosivity Factor

2.9.2 Soil erosivity factor (K):

In this study, K factor of the Kerala can be defined using the relationship between soil texture class and organic matter content.

1. The soil type's map was extracted from soil map of the world by food and agriculture organization of the United Nations.
2. Soil classification of the Kerala divided into 9 types of soil with varying soil characteristics.

Zero indicating soils with the least vulnerability to erosion and at the same time as 0.14 indicates soils which are highly vulnerable to soil erosion.

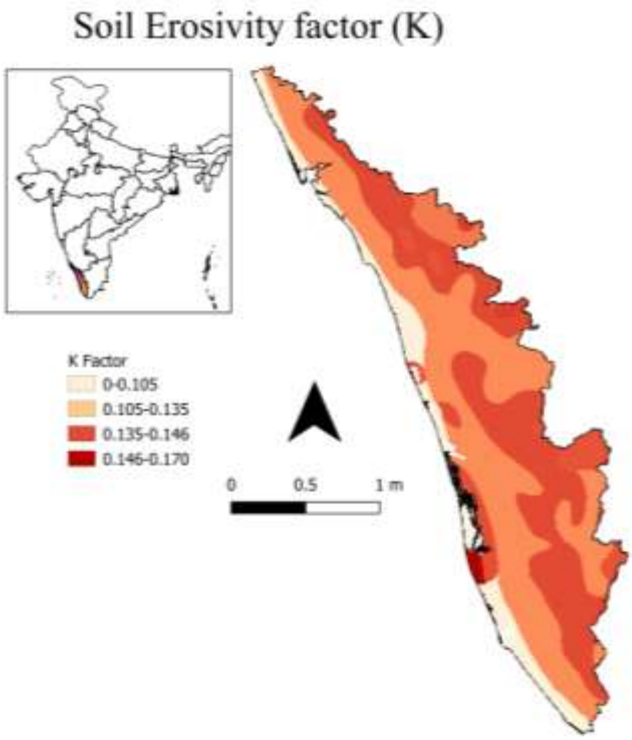


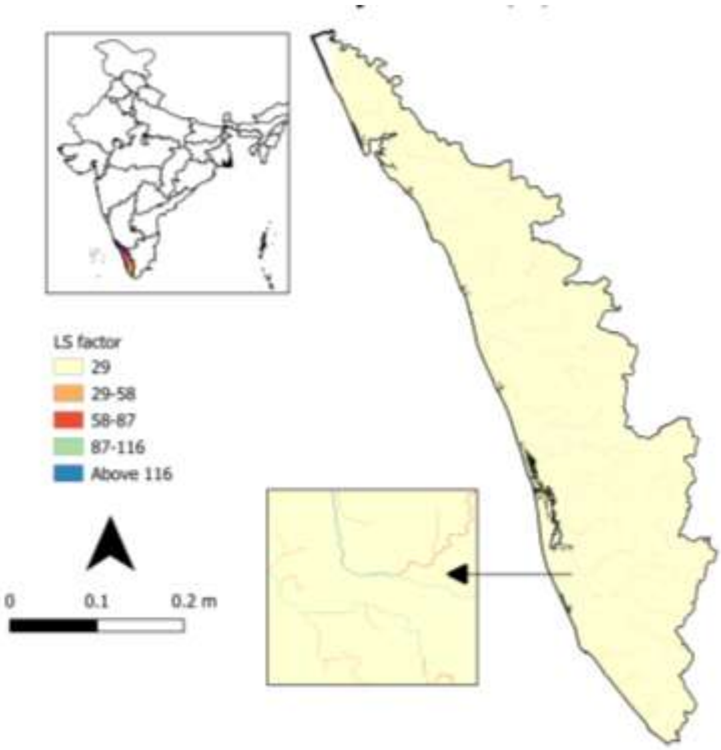
Figure 6 Soil erosivity map

Table shows value of k factor based on type of soil.

K- Value	Soil
0.05 to 0.15	Soil high in clay
0.05 to 0.2	Sandy soil
0.25 to 0.4	Slit loam soil
<0.4	High slit soil easily detached

Table 4 K factor values

2.9.3 Topography factor (LS):



Topological factor consisting of two sub-factors:
Slope gradient (**S**) and slope length factor (**L**);

Determined from Digital elevation model (DEM).

1. Elevation data was obtained from SRTM-CGIAR.
2. Using Slope of DEM and hydrology analysis of DEM (Flow fill, flow direction, flow accumulation)
3. LS factor was calculated in raster calculator.

Figure 7 Topography factor map

The value of 'LS' increases as hill slope length and steepness increase, under the assumption that runoff accumulates and accelerates in the down-slope direction

Following figures shows parameters required to estimate topography factor (LS): (MISHRA)

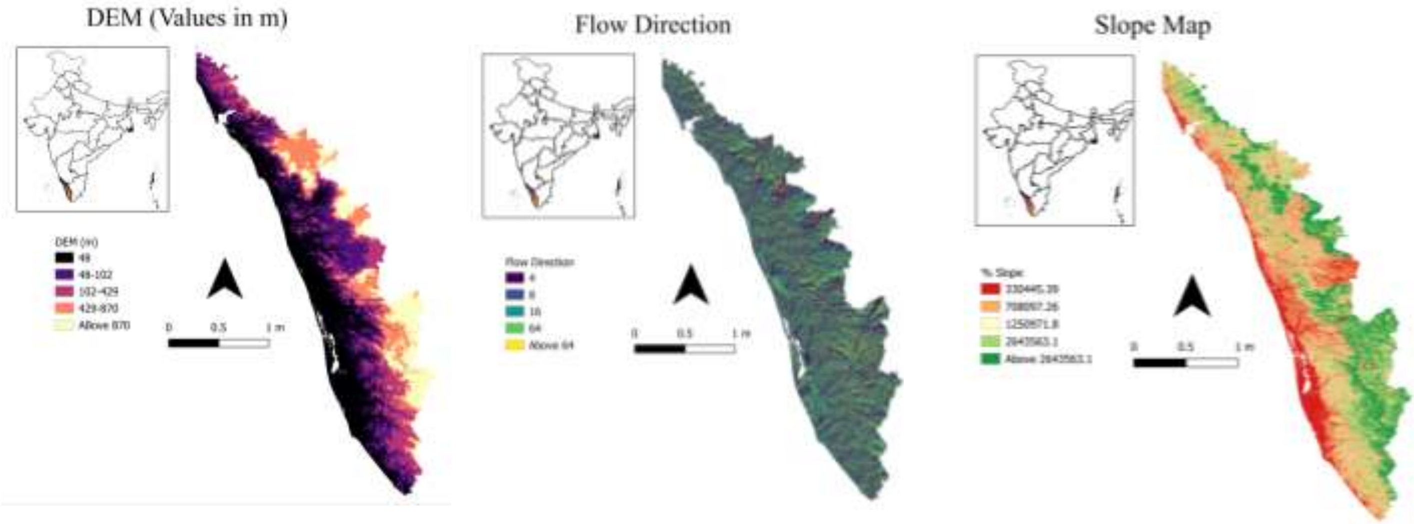


Figure 8 DEM, Flow direction, Slope

2.9.4 Cover management factor (C):

The Conservation practice factor (C) based on NDVI. Soil loss is very sensitive to vegetation cover. Vegetation cover protects the soil by dissipating the raindrop energy before reaching soil surface. (MISHRA)

1. Low C factor values were obtained for forest and plantation areas;
2. agricultural land showed moderate values.

C factor is observed 0.4 in January 2018, and in january2019. During the floods there is decrease in vegetation cover, C factor observed 0.7.

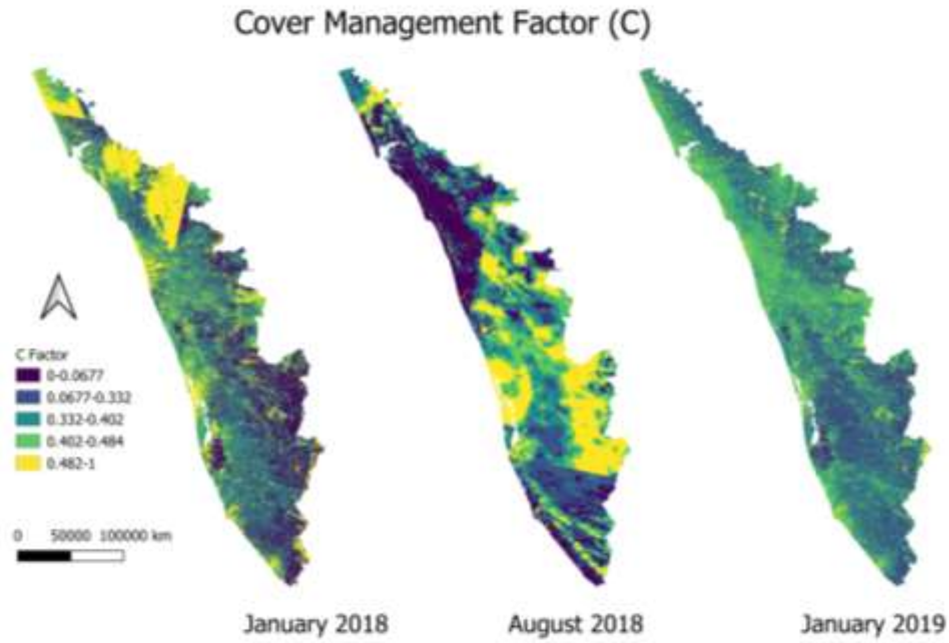


Figure 9 Cover management factor

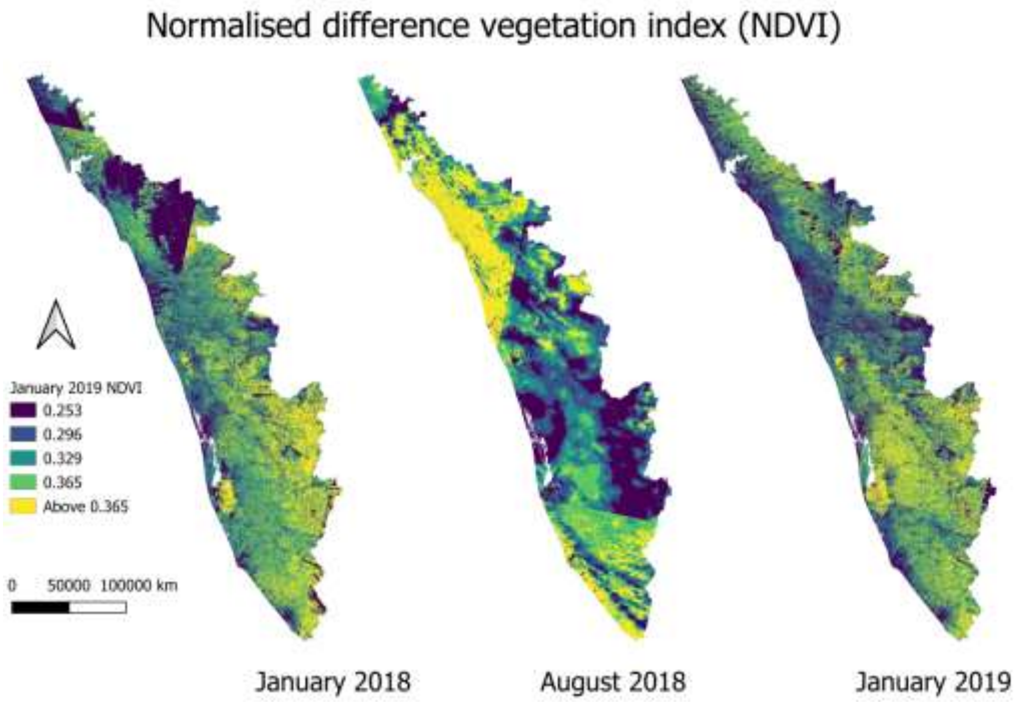


Figure 10 Normalised difference vegetation index

2.9.5 Conservation practice factor (P):

1. Lansat-8 (30m resolution) data downloaded from USGS earth explorer.
2. LULC generated using Iso-clustered unsupervised classification.

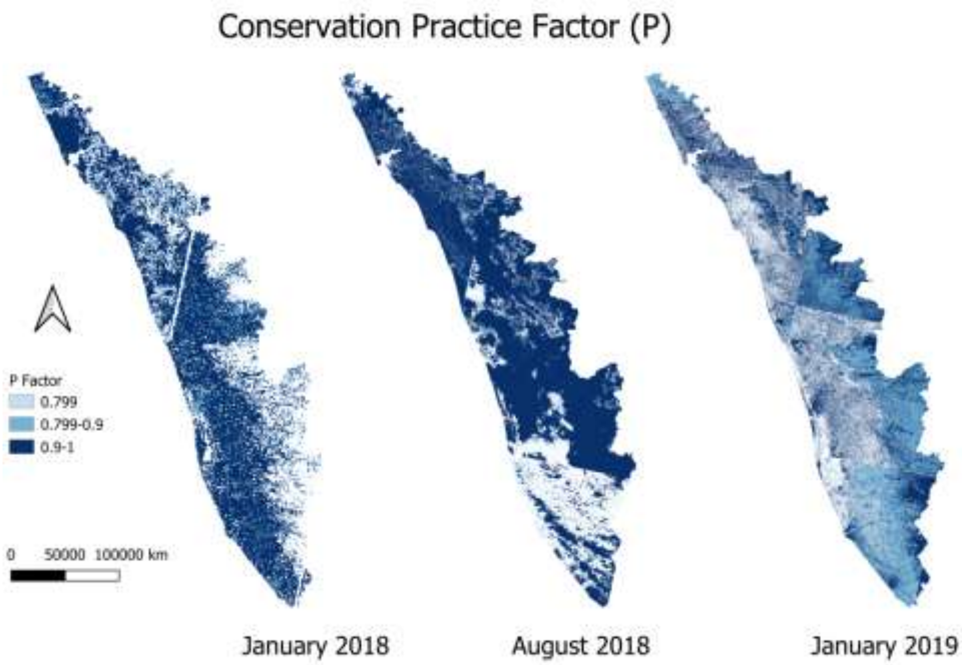


Figure 11 Conservation practice factor map

Before the floods value of P factor was between 0.8, and during the floods in august 2018 the value is increased to 0.89. After the floods the value again is observed between 0.8.

2.10 LULC classes and corresponding P factor values

The values of P factor in Table have been obtained from the original table provided by Wishmeier and Smith (1978)

Sr.no	Land use class	P values
1	Dense vegetation	1
2	Sparse vegetation	0.8
3	Built-up	1
4	Water bodies	1
5	Scrub land	1
6	Cropland	0.5
7	Fallow land	0.9
8	Barren land	1

Table 5 P factor values

2.10.1 Soil erosion:

USLE for Kerala floods found that erosion ranged from 55 and above metric tons/ha/yr for august 2018, with average value of 56.23 metric tons/ha/yr. These values are higher than average values in Jan 2018 (31.79), and Jan 2019 (30.01)

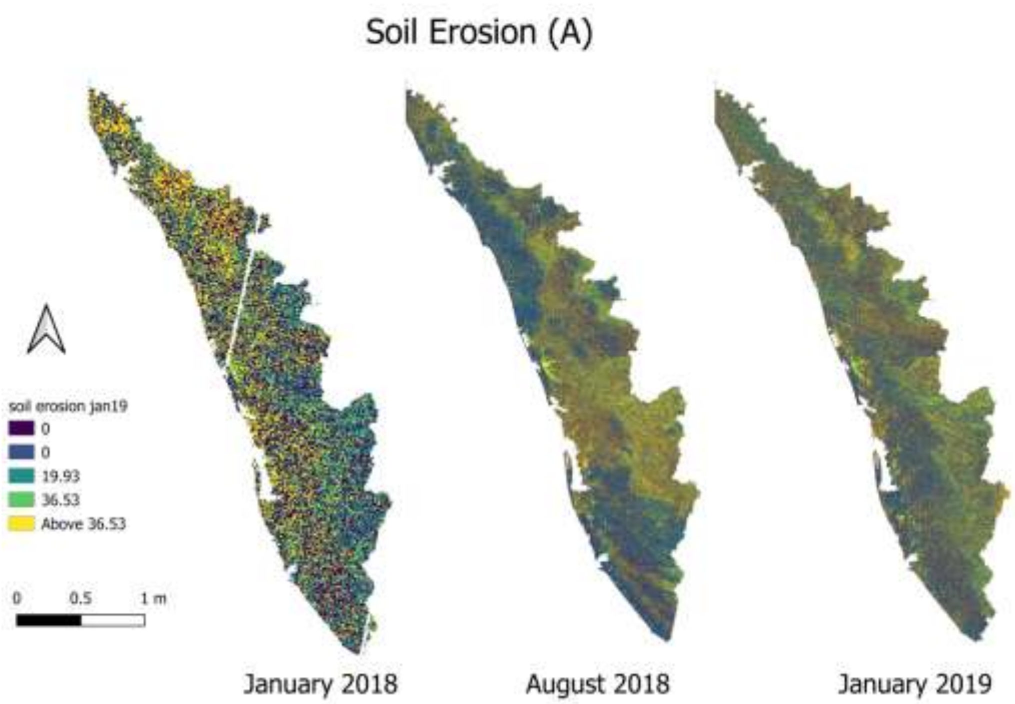


Figure 12 Soil erosion rates map

After completing data input procedure and preparation of R, K, C, P, and LS maps as data layers, they were multiplied in GIS environment to draw up the erosion risk map showing the spatial distribution of soil loss in the study area. (Goutam Kumar Das1, 2015)

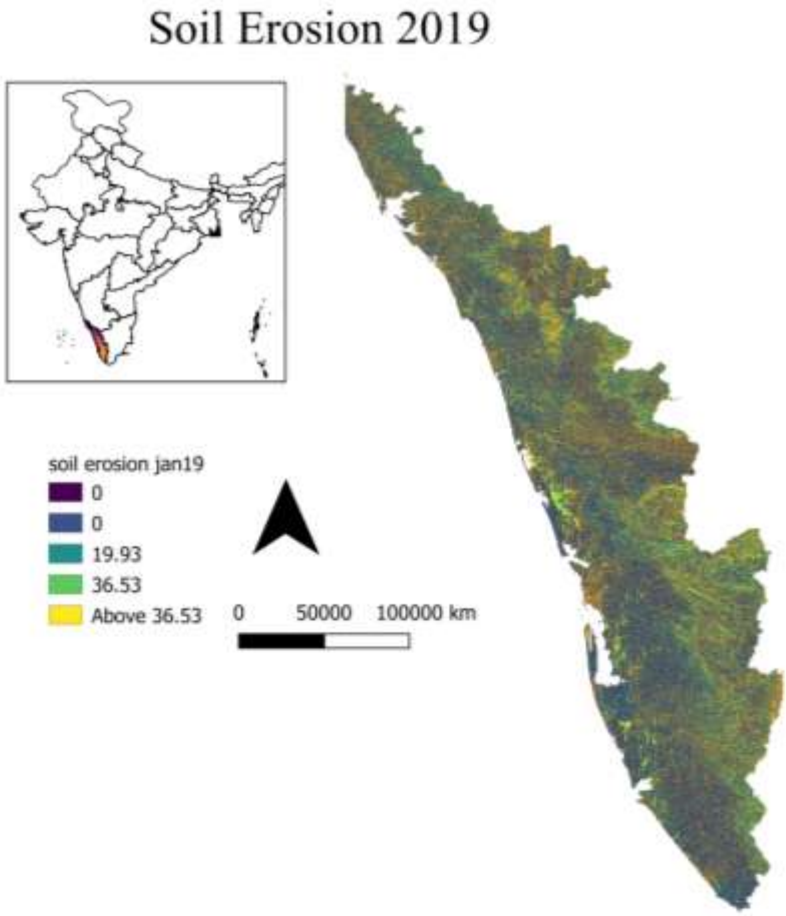
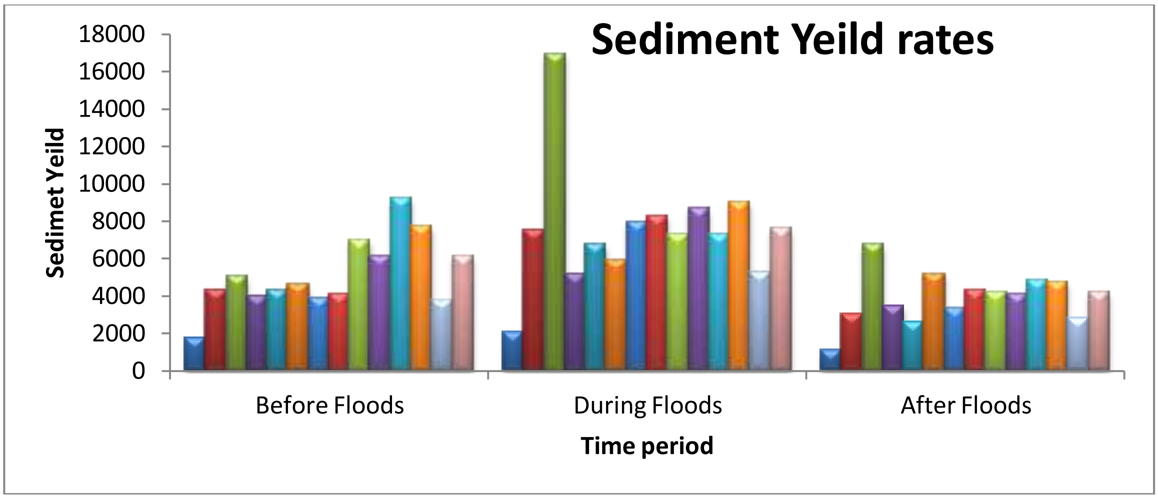
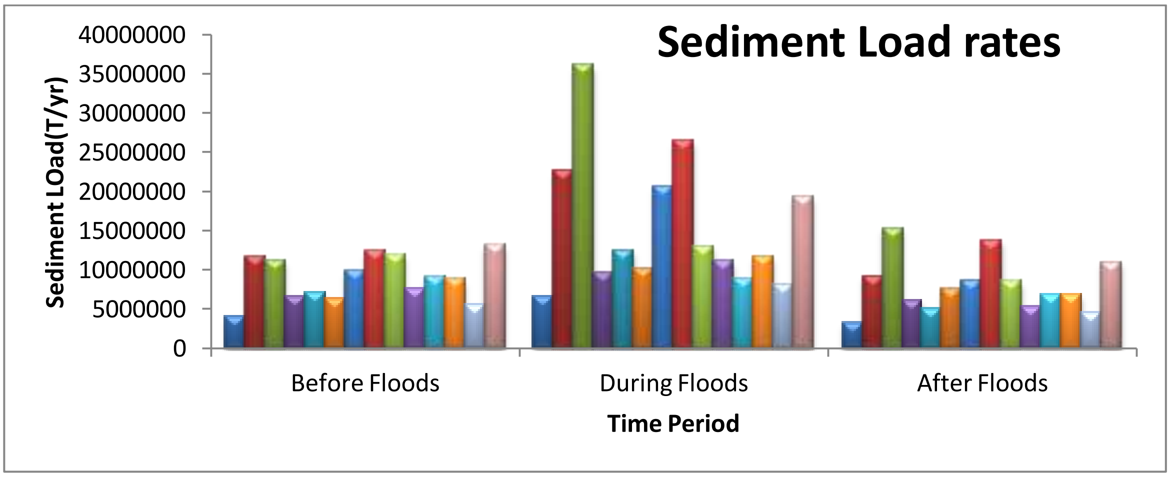


Figure 13 Soil erosion January 2019

2.11 Percentage change of USLE values





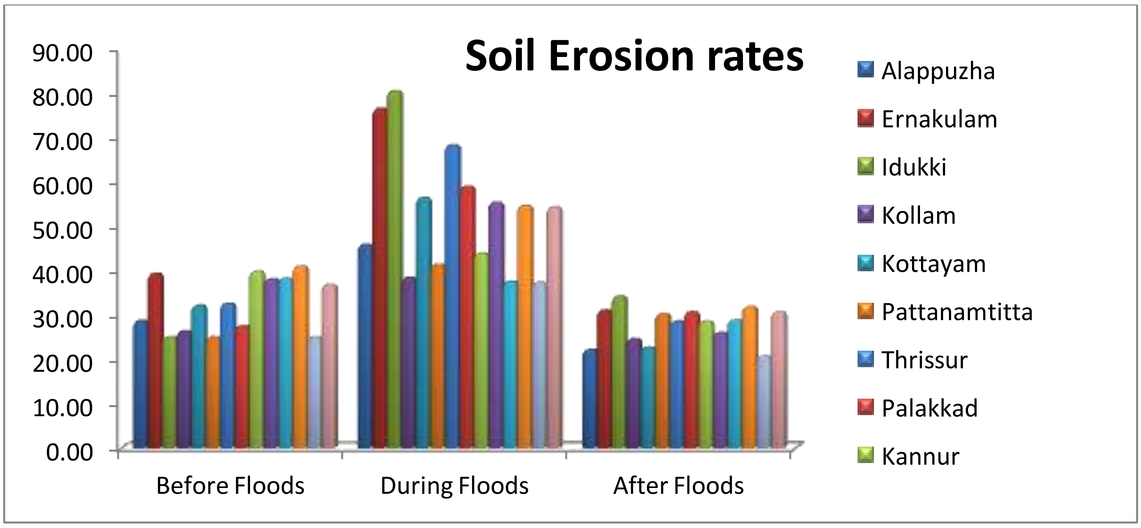


Figure 14 Analysis

2.12 Change in USLE parameters

District Name	% Change from Jan18-Aug18		% Change from Aug18-Jan19		% Change from Jan18-Jan19	
	Soil Erosion	Sediment Yield	Soil Erosion	Sediment Yield	Soil Erosion	Sediment Yield
Alappuzha	59.72	16.40	-51.71	-46.98	-22.87	-38.29
Ernakulam	94.76	74.17	-59.47	-60.42	-21.07	-31.06
Idukki	222.29	238.66	-57.53	-60.22	36.88	34.72
Kollam	45.58	31.16	-35.98	-32.88	-6.80	-11.96
Kottayam	75.29	58.19	-59.85	-61.26	-29.63	-38.72
Pattanamtitta	65.30	28.05	-27.01	-11.78	20.66	12.97
Thrissur	109.71	104.06	-58.19	-58.91	-12.32	-16.15
Palakkad	114.51	102.03	-47.99	-47.69	11.57	5.67
Kannur	10.14	4.90	-34.95	-42.75	-28.35	-39.94
Kasaragod	45.39	41.06	-53.11	-52.73	-31.83	-33.32
Kozhikode	-1.77	-21.28	-23.20	-33.97	-24.56	-48.02
Wayanad	33.28	16.39	-41.74	-47.28	-22.35	-38.64
Thiruvananthapuram	49.38	41.62	-44.46	-47.54	-17.04	-25.71
Malappuram	47.48	23.81	-43.54	-44.89	-16.73	-31.77
Average	69.4	54.2	-45.6	-46.4	-11.7	-21.4
Total	971.07	813.46	-638.73	-695.69	-164.43	-321.66

Table 6 Change in USLE parameters

2.13 Conclusion:

1. Rainfall, LULC (Land use land cover) change, and loss of vegetation cover are the main responsible factors for the soil loss in Kerala floods.
2. Unexpected high level of rainfall caused more soil is eroded during year 2018.
3. The estimated rainfall erosivity, range from 133.69 to 179.00 $MJ/mm \cdot ha^{-1} hr^{-1}$/year with average of 160.84 $MJ/mm \cdot ha^{-1} hr^{-1}$/year.
4. The estimated soil erosivity factor, range from 0.1045 to 0.1696 MJ cm ha−1 h−1 yr−1.
5. The estimated topography factor, range from 0 to 145.23 with average value 3.75.
6. The estimated cover management factor, range from 0 to 1 WIth average value of 0.75.
7. The estimated Conservation practice factor, range from 1 to 0.5.
8. January 2018 (before floods) had average USLE soil loss of 31.79 metric tons/ha/yr, or a total soil loss of 455.0944 metric tons/yr.
9. August 2018 (during floods) had average USLE soil loss of 56.23 metric tons/ ha/yr, or a total soil loss of 748.6 metric tons/yr. Thus, Soil erosion rate is significantly increased during flood period
10. January 2019 (after floods) had average USLE soil loss of 30.01 metric tons/ha/yr, or a total soil loss of 390.15 metric tons/yr.
11. Average sediment load for January 2018 is 88850, august 2018 is 154408.5, and for January 2019 is 79322.4 t/yr.

Floods due to heavy rainfall caused removal of top-soil cover during august 2018.

Floods resulted into removal of soil, caused water levels in ponds and wells decreased to a severe extent, which led to severe draught after the flood.

Amount of soil eroded and sediment yield increased during august 2018 significantly than January 2018.

3 Decadal change in Land use landcover classification of Western Ghats and associated soil erosion.

3.1 Problem statement:

The Western Ghats are internationally recognized as a region of immense global importance for the conservation of biological diversity supporting for development of sustainable agricultural growth, these areas has been recording low productivity which is proving to be a cause of concern.
The major reasons for this are the excessive surface runoff and soil erosion due to high intensity rainfall. This study uses remote sensing and GIS methodology to estimate Decadal change in Land use land cover, potential soil loss and sediments yield in western Ghats.

3.2 Introduction: Study area

The mountain range that runs along the west coast of peninsular India from Tamil Nadu through Kerala, Karnataka and Goa to Maharashtra is known as the Western Ghats. They are a mountain range that covers an area of 140,000 sqkm and is well known for its rich biodiversity. It is among the top eight biodiversity hotspots in the world.

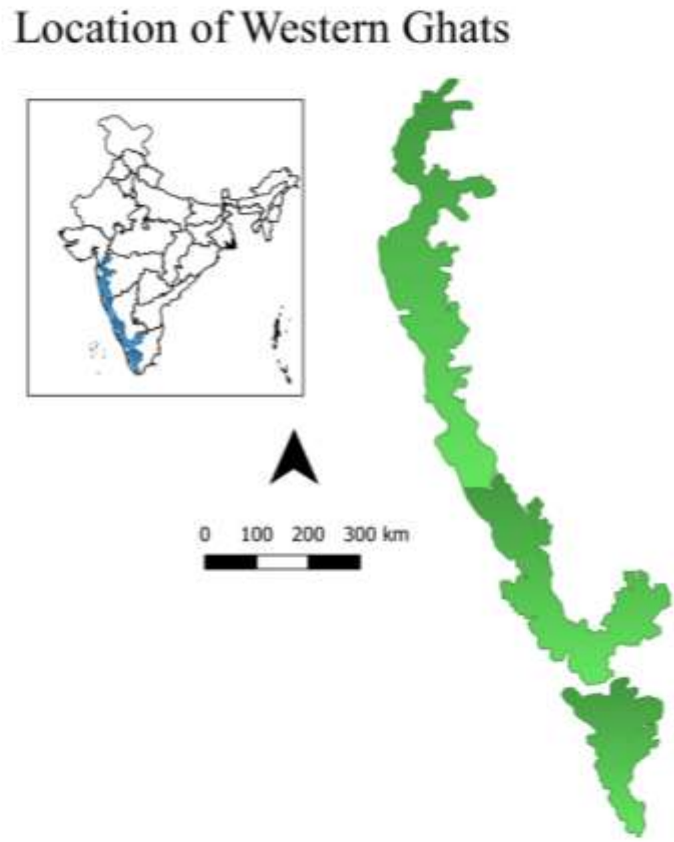


Figure 15 Location map

3.3 Aim

To find decadal Change in land use landcover (LULC) of Western Ghats and associated soil erosion.

3.4 Objectives:

- Estimate the decadal soil erosion quantitatively.
- To detect historic LULC change.
- To estimate sediment load for Western Ghats.

3.5 Data Used:

Data	Source
Landsat 8 satellite Images from 2018-2019 (30m resolution)	USGS – Earth Explorer
Rainfall data from 2014-2018 (5years data)	Indian metrological department
World soil map	Food and agriculture organization (FAO) of united nations.
SRTM DEM (90m resolution)	SRTM-CGIAR

Table 7 Data used

3.6 Soil erosion models: (Refer section 2.7)

3.7 Western Ghats Boundary:

Western Ghats are mountain ranges. The boundary of western ghats is digitized by Geo-referencing.

3.8 USLE parameter estimation

3.7.1 Rainfall Erosivity index (R):

R factor is one of the important factors influencing the rate of soil loss; it depends on the quantity and intensity of the rainfall. (M. Vinay, 2015)

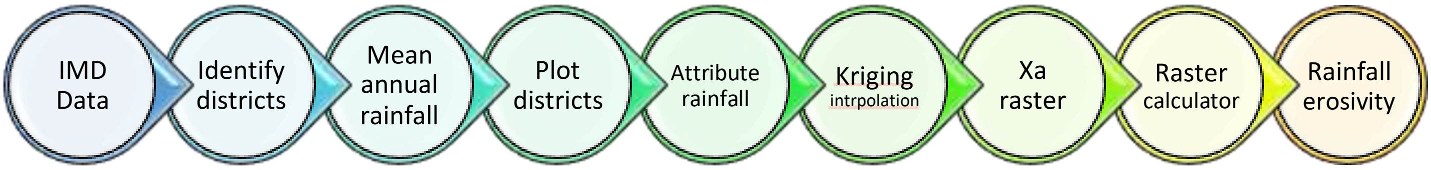


Figure 16 Methodology of R

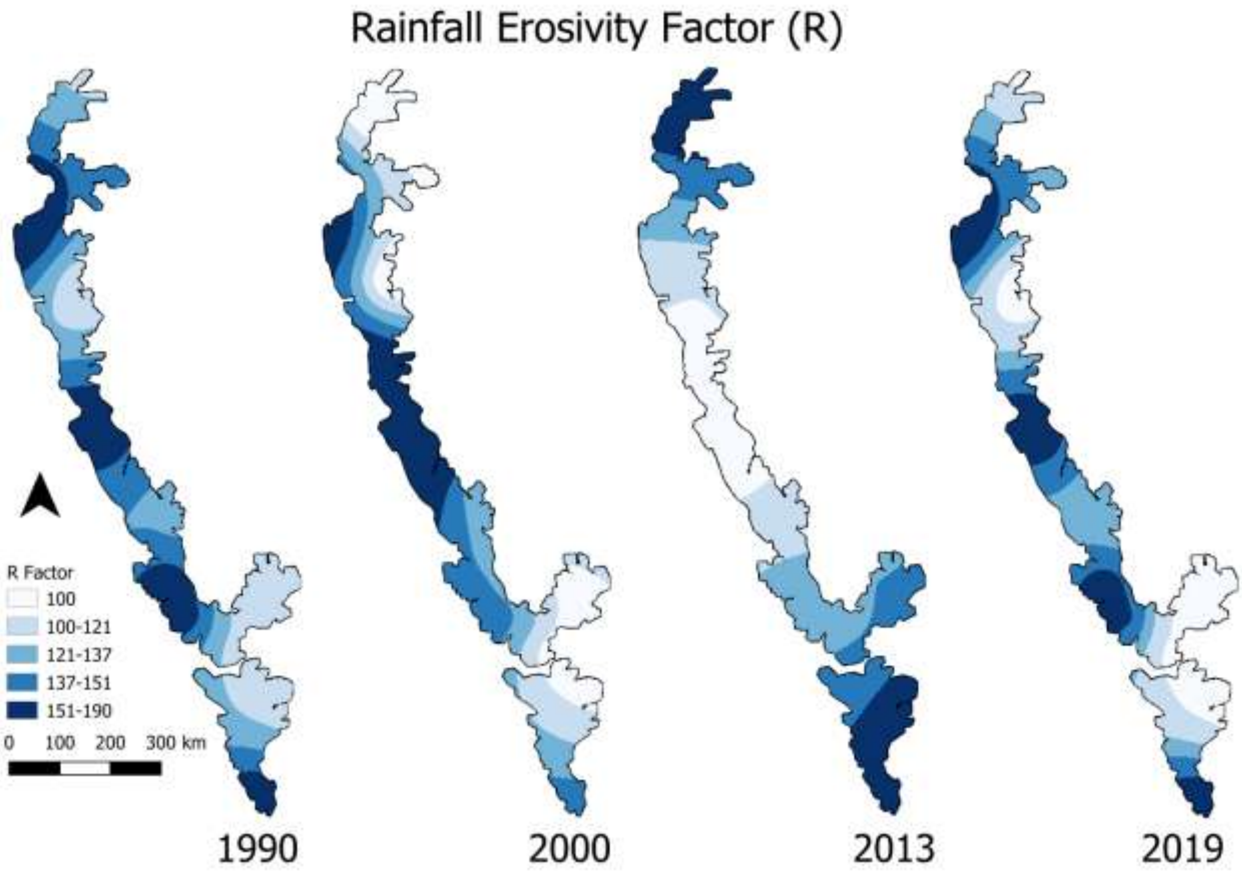


Figure 17 Rainfall erosivity index

Rainfall erosivity map shows the regions in Western Ghats with intensity of rainfall. This areas with high R value are potential areas for soil erosion due to heavy rainfall.

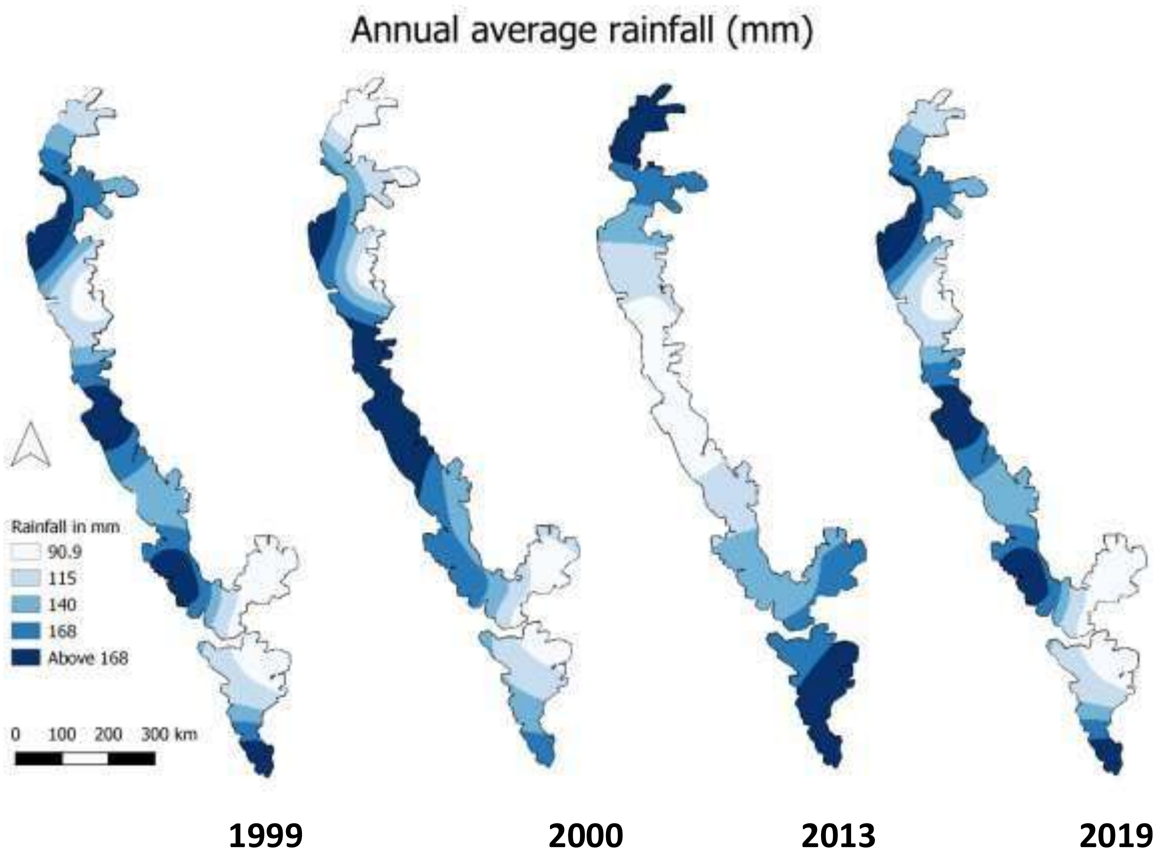


Figure 18 Average annual rainfall

Average annual rainfall data of 4 years have been used to calculate R factor.(Refer section 2.9.1)

3.7.2 Soil erosivity factor (K): (Refer section 2.9.2)

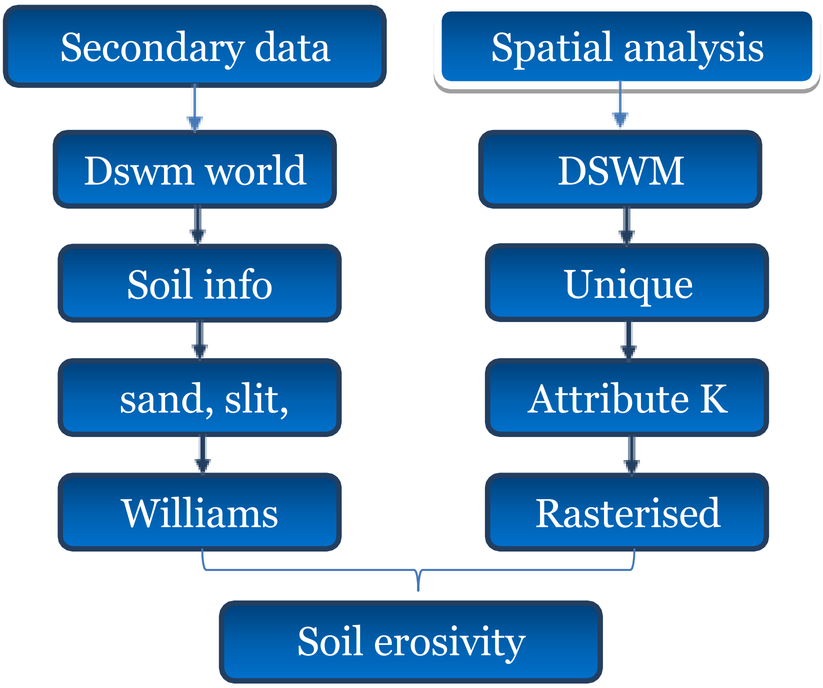


Figure 19 Methodology of K

Soil erosivity factor (K) represents susceptibility of soil to erosion. K factor is a function of particle size distribution, organic matter content, structure, and permeability
Soil classification of the Western Ghats is divided into 9 types of soil with varying soil characteristics.

K factor values ranges from 0 to 0.4. Zero indicating soils with the least vulnerability to erosion and at the same time as 0.4 indicates soils which are highly vulnerable to soil erosion by water.

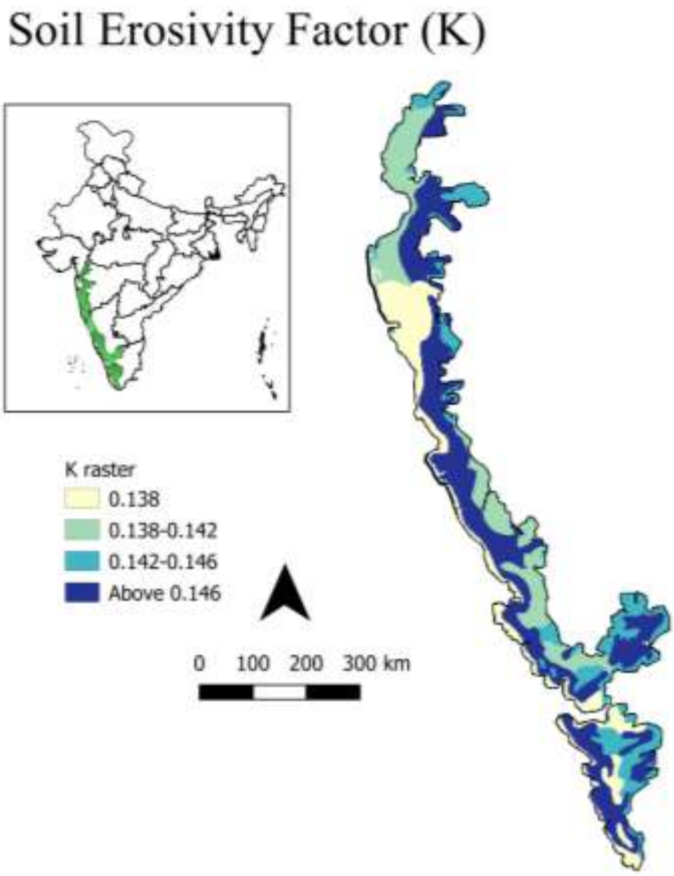


Figure 20 Soil erosivity factor

3.7.3 Topography Factor (LS):

Soil loss per unit area increases with increase in slope length and slope steepness. The L and S factor were computed together from the DEM. (Refer section 2.9.3)

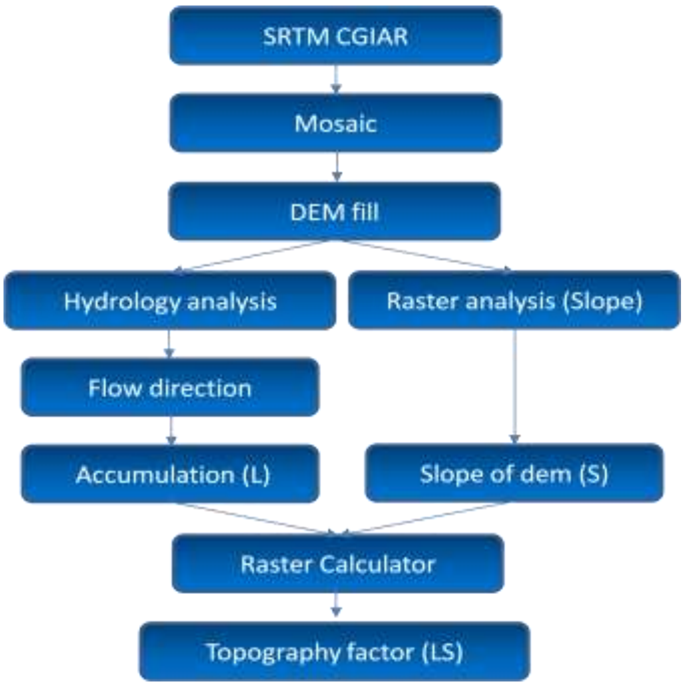


Figure 21Methodology of LS

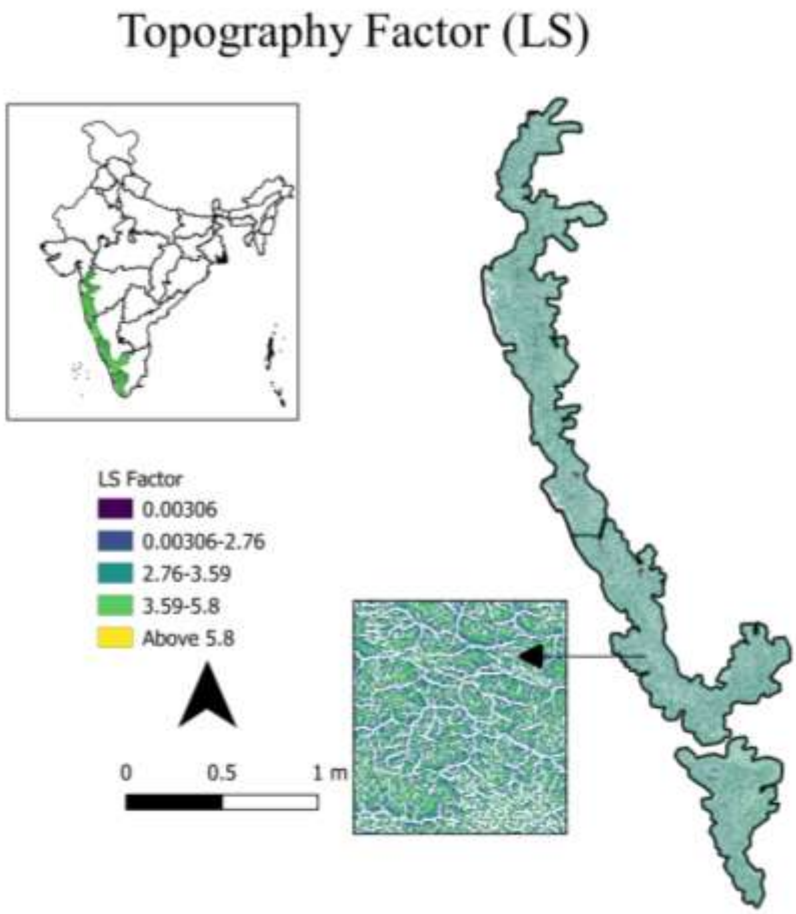


Figure 25 Topography Factor

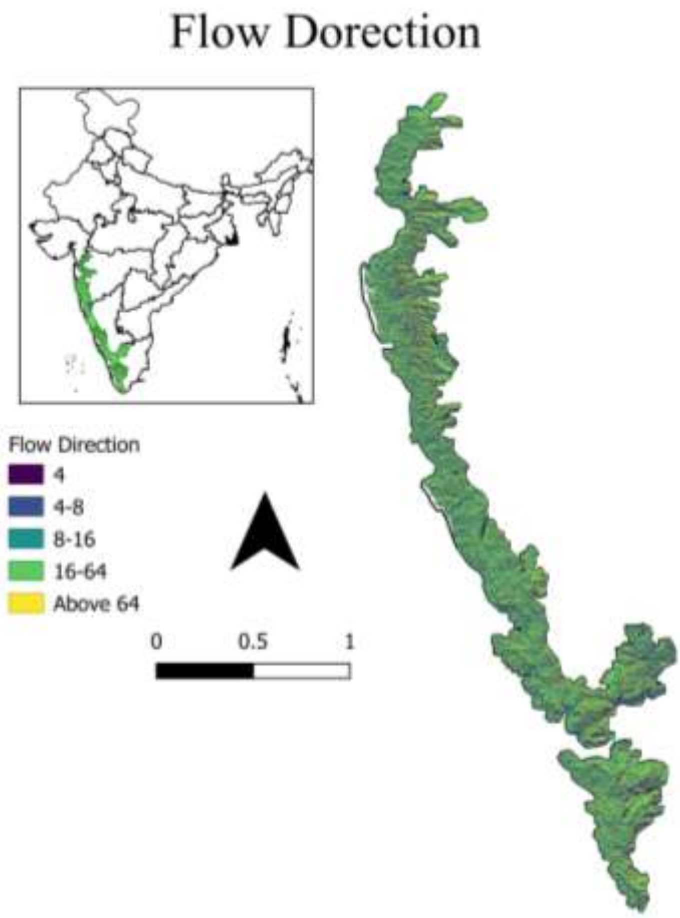


Figure 23 Flow direction

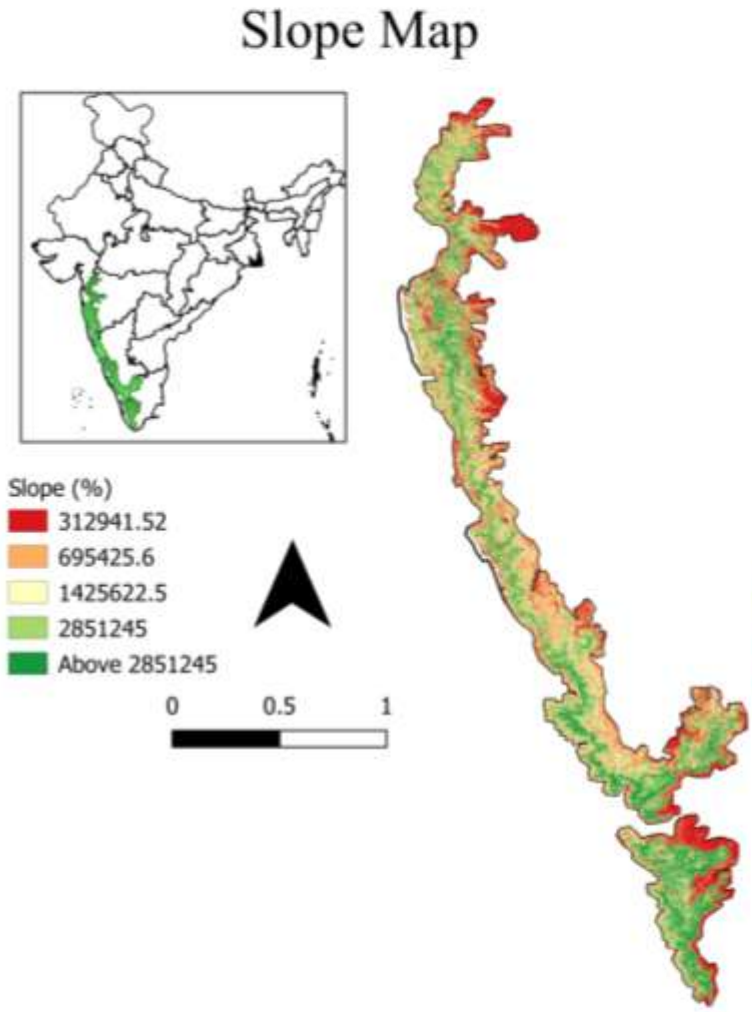


Figure 22 Slope

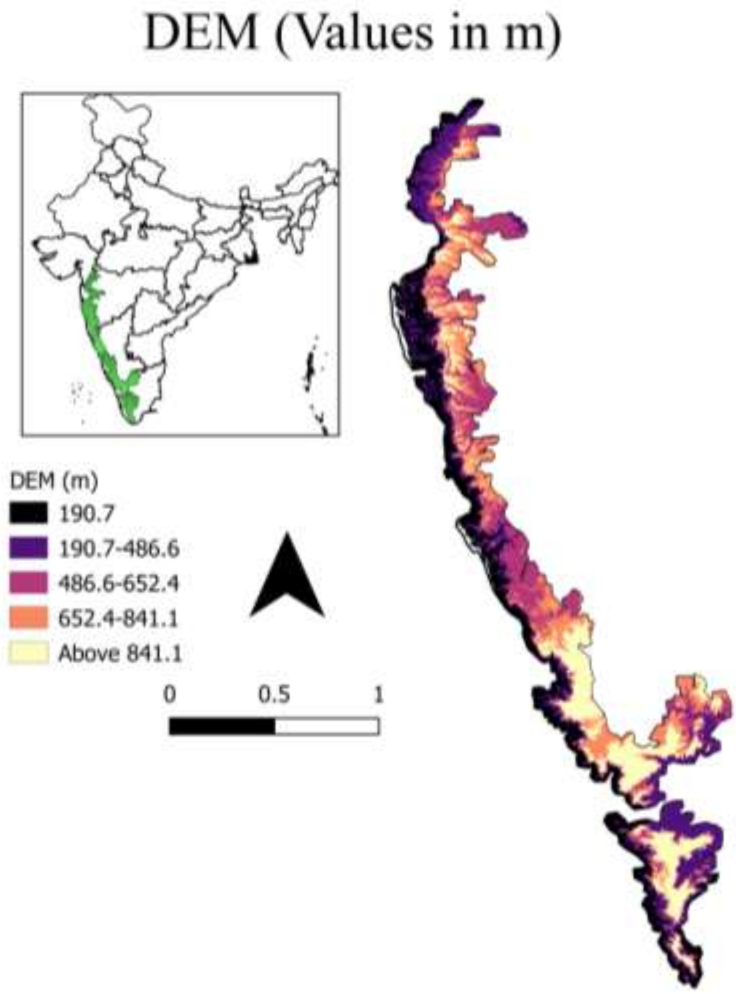


Figure 24 DEM

3.9 Cover management factor

The value of *C* decreases as surface cover and soil biomass increase, thus protecting the soil from rain splash and runoff. (Refer section 2.9.4)

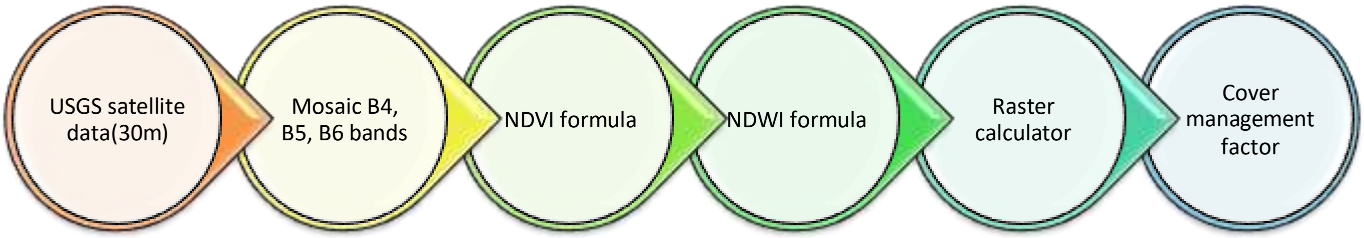


Figure 27 Cover management factor methodology

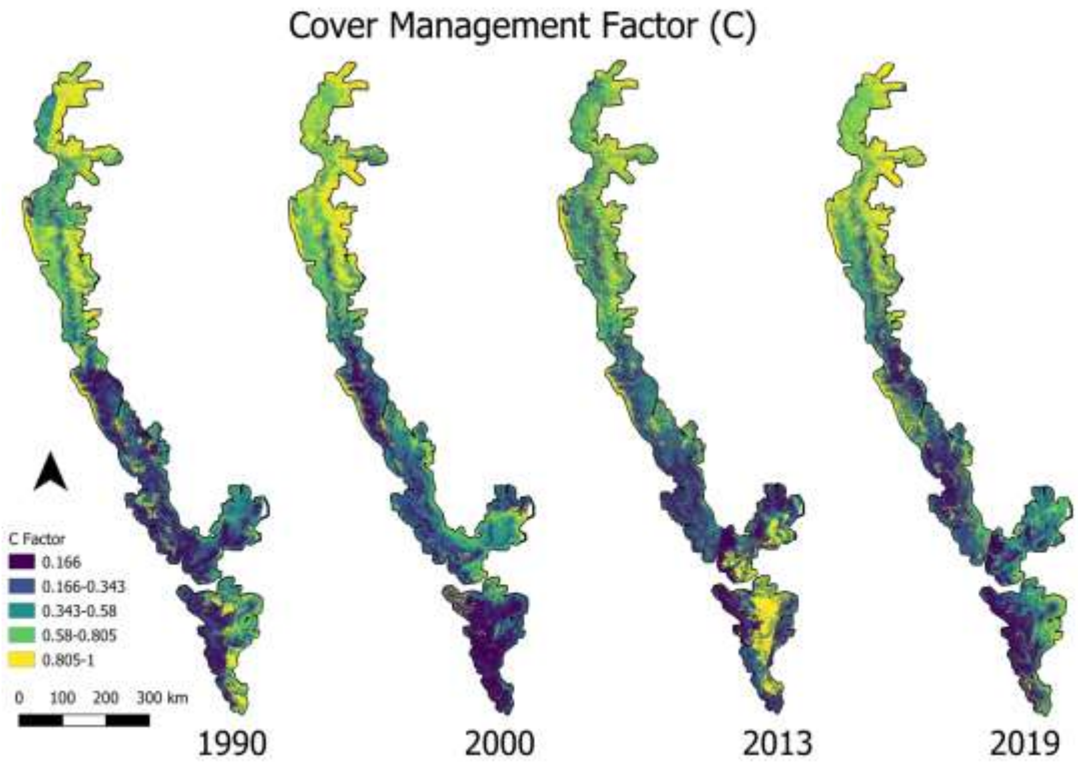


Figure 26 Cover management factor

With increase in vegetation cover value of C factor decreases and vice versa.

Normalised difference vegetation index (NDVI): It shows vegetation content of the area.

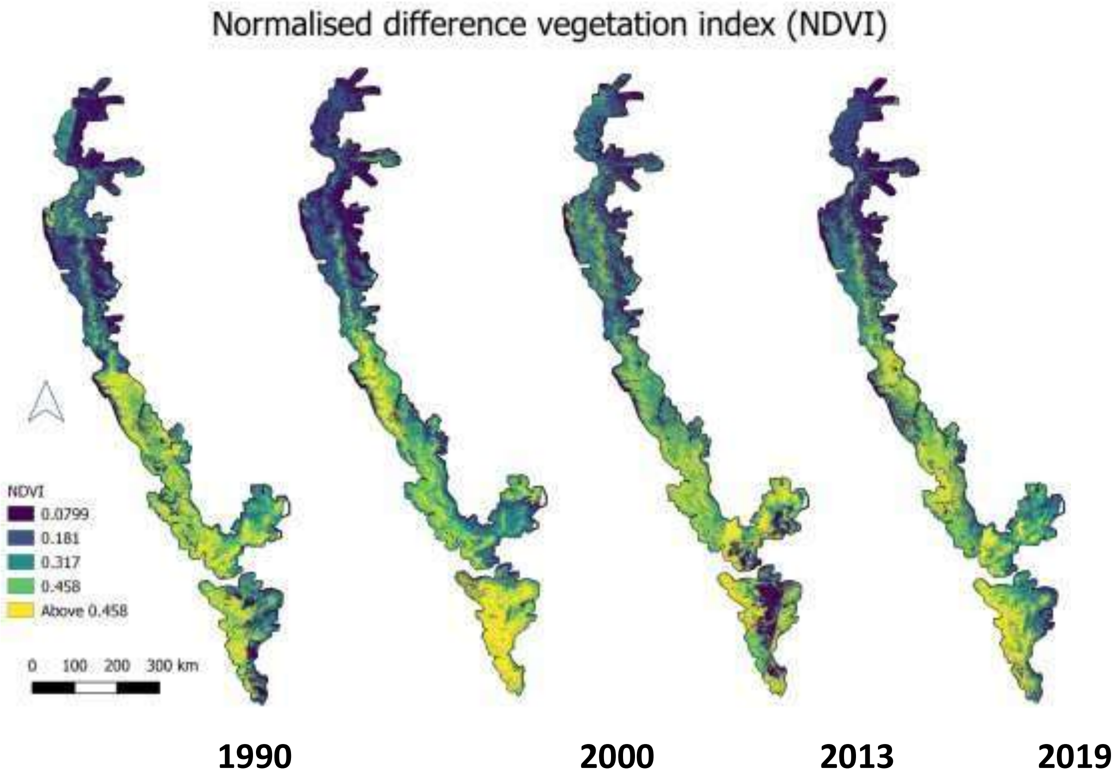


Figure 28 Normalised difference vegetation index

Normalised difference water index (NDWI): It shows water content from the vegetation in the area.

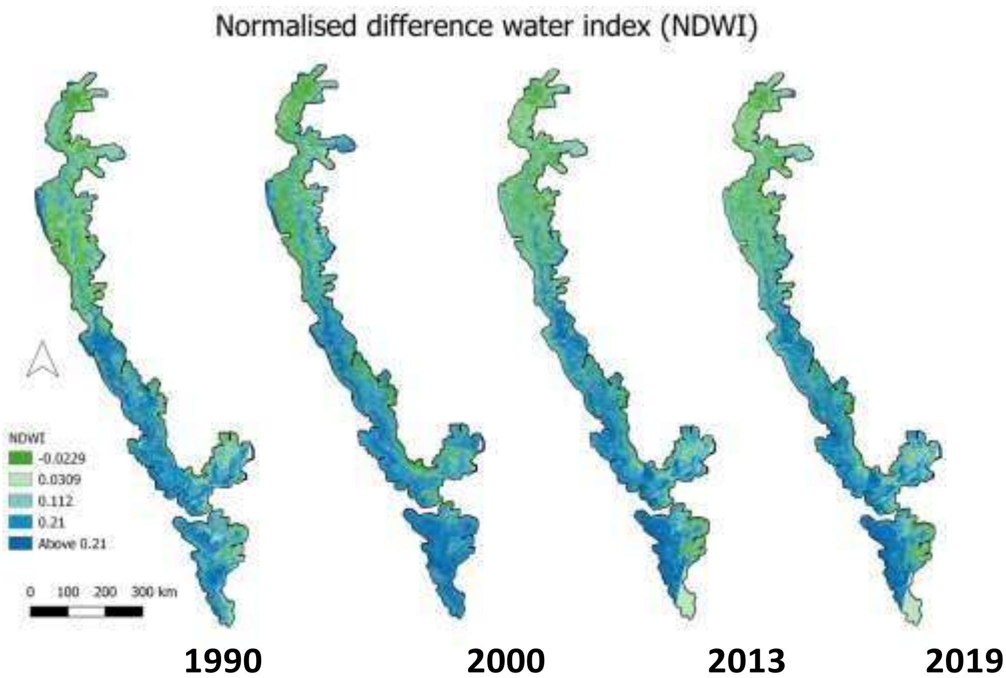


Figure 29 Normalised difference vegetation inde

Conservation practice factor (P):

This factor defines the ratio between soil loss from a field with the given conservation practice to that where no conservation is practiced. Decadal LULC with 8 classes is used to find value of P. (Refer section 2.9.5)

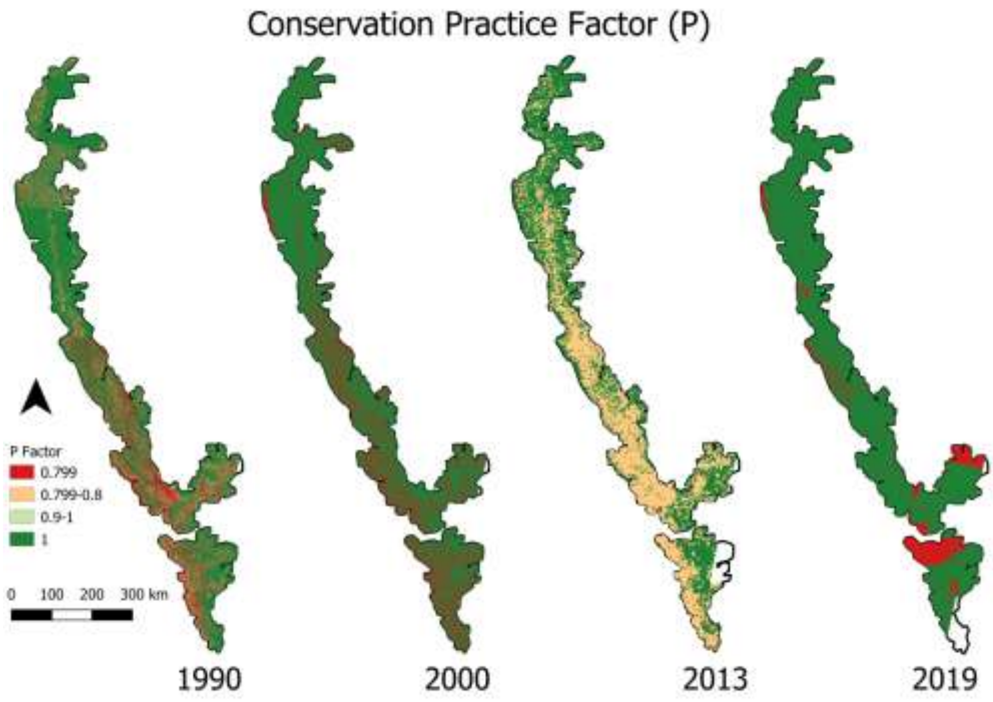
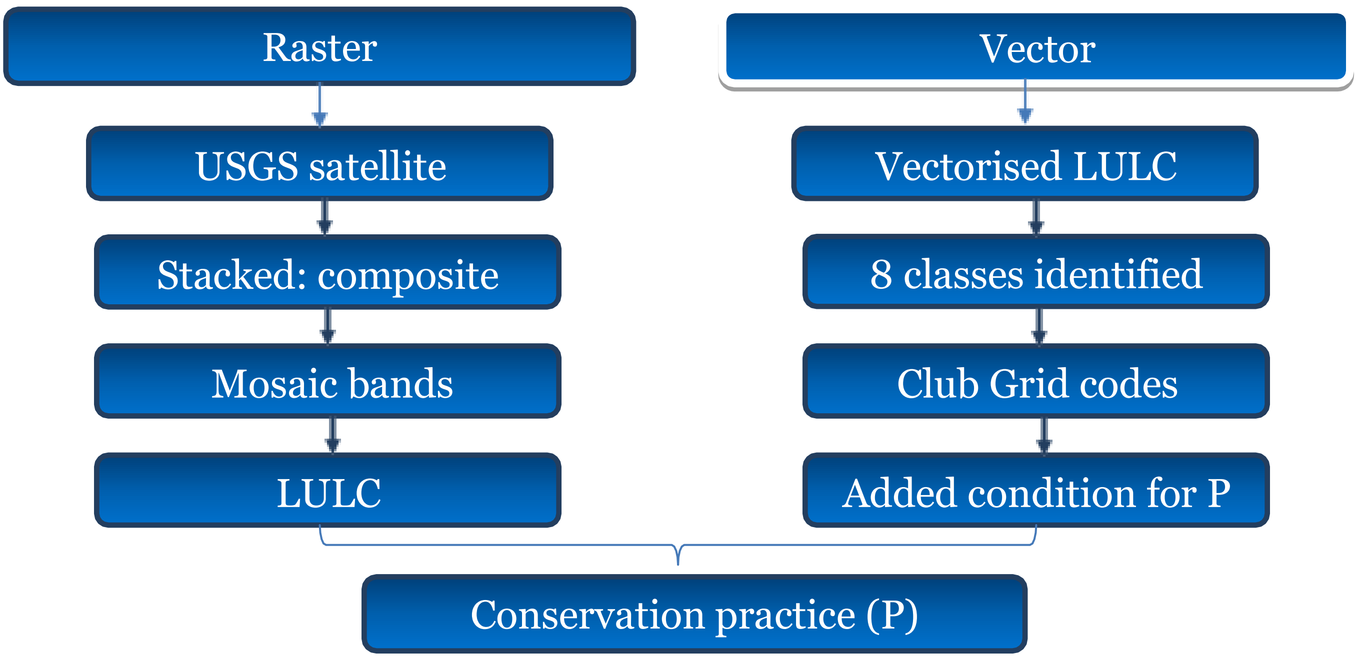


Figure 30 Conservation practice factor



Results:

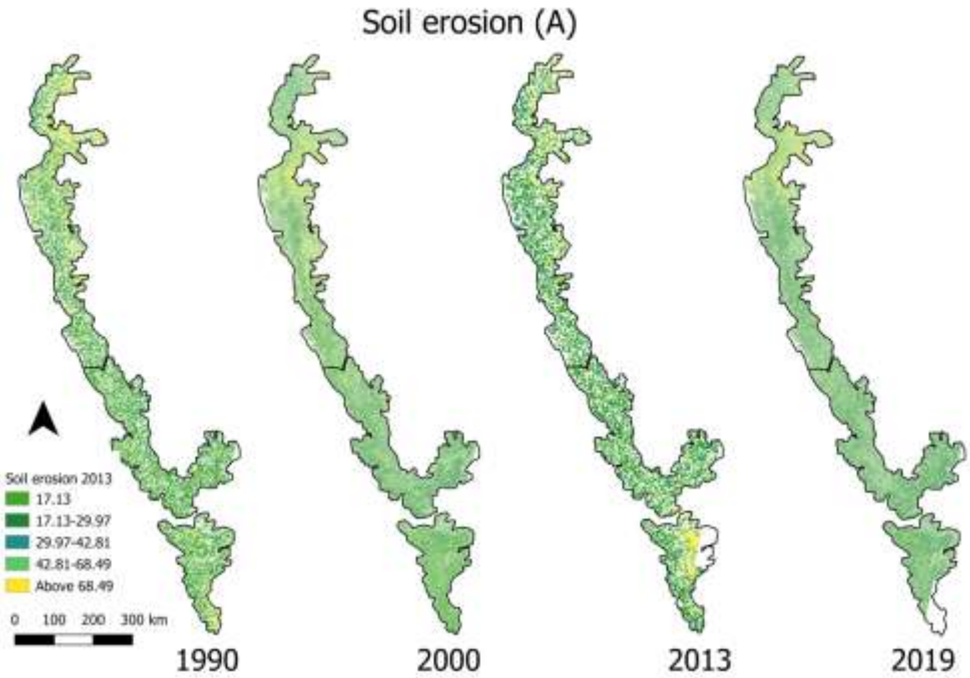


Figure 34 Soil erosion 2019

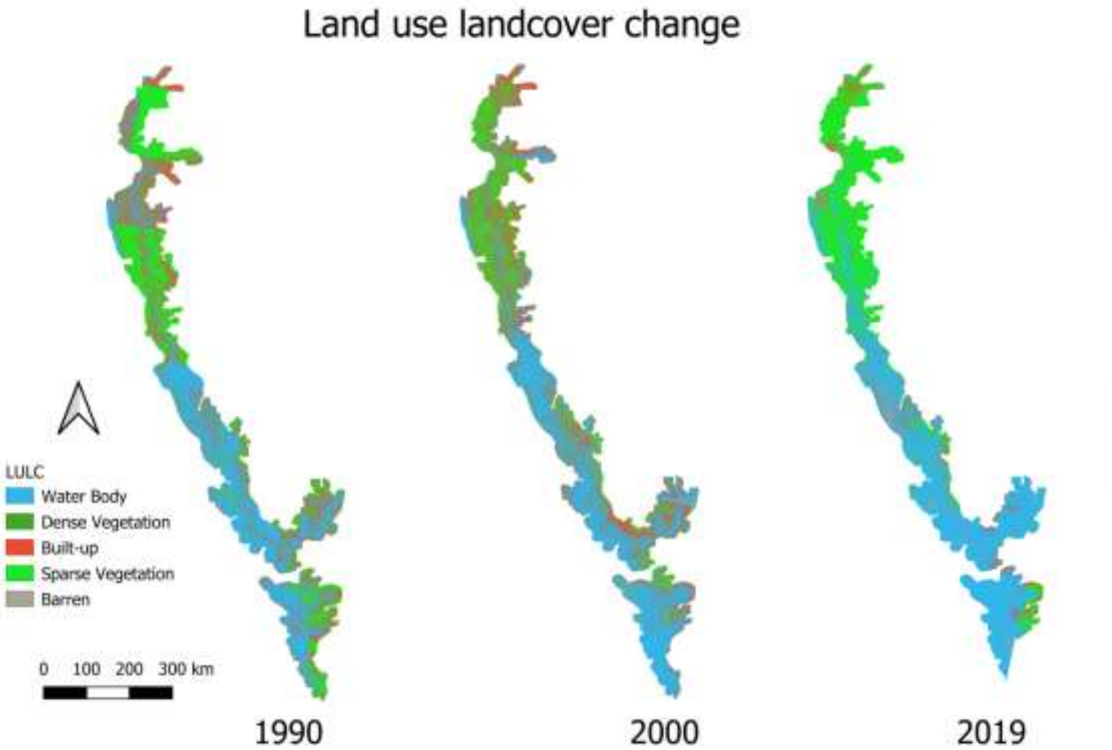


Figure 32 LULC change

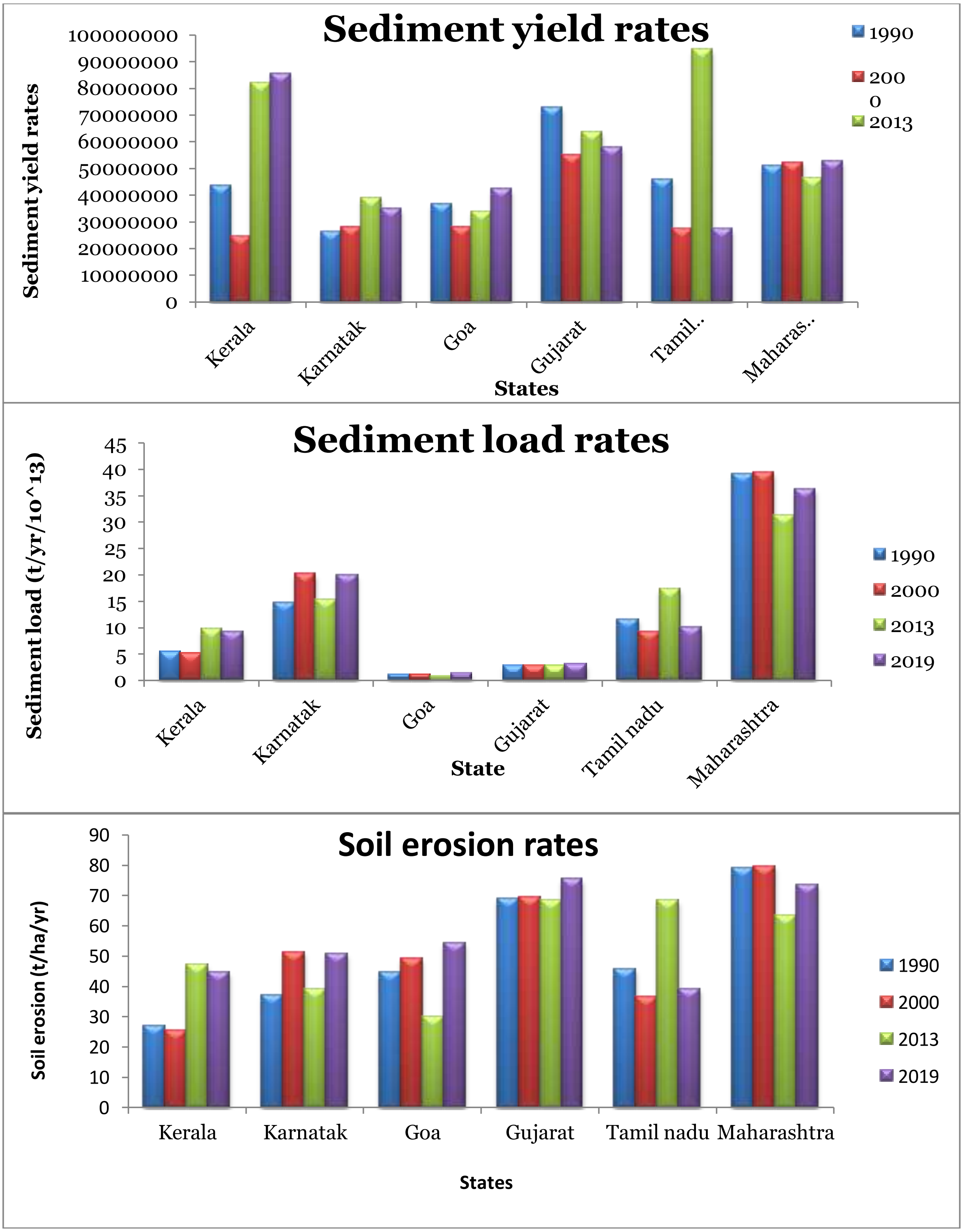


Figure 34 Analysis

3.10 Change in USLE parameters:

State name	% Change from 1990-2000		% Change from 2000-2013		% Change from 2013-2019		% Change from 1990-2019	
	Soil Erosion	Sediment Yield	Soil Erosion	Sediment Yield	Soil Erosion	Sediment Yield	Soil Erosion	Sediment Yield
Kerala	-5.81	-44.25	-44.25	-5.81	-5.21	4.27	66.05	95.20
Karnataka	38.35	7.78	7.78	38.35	30.38	-10.01	36.81	-32.86
Goa	10.62	-24.16	-24.16	10.62	80.37	24.28	22.16	8.39
Gujarat	0.16	-24.83	-24.83	0.16	10.00	-8.89	9.21	14.59
Tamil nadu	-20.07	-40.62	-40.62	-20.07	-42.68	-71.23	-14.43	-51.55
Maharashtra	0.85	2.71	2.71	0.85	15.59	13.07	-7.16	9.14
Average	4.02	-20.56	-20.56	4.02	14.74	-8.09	18.77	7.15
Total	24.10	-143.94	-123.37	28.12	88.45	-56.60	112.65	50.07

Table 8 Percentage changes in USLE parameters

3.11 Conclusion:

1) Rainfall, LULC (Land use land cover) change, and loss of vegetation cover are the main responsible factors for the soil erosion in Western Ghats.
2) The estimated rainfall erosivity, range from 118 to 154.00 $MJ/mm \cdot ha^{-1}hr^{-1}/year$ with average of 160.84 $MJ/mm \cdot ha^{-1}hr^{-1}/year$.
3) The estimated soil erosivity factor, range from 0.138 to 0.146 MJ cm ha^{-1} h^{-1} yr^{-1}.And an average value of 0.14341358469061 MJ cm ha^{-1} $h^{-1}$$yr^{-1}$
4) The estimated topography factor, range from 0.004 to 177.10 with average value 6.02.
5) The estimated cover management factor, range from 0 to 1.
6) The estimated Conservation practice factor, range from 1 to 0.5.
7) Year 1990 had average USLE soil loss of 53.22 metric tons/ha/yr, or a total soil loss of 302.27 metric tons/yr.
8) Year 2000 had average USLE soil loss of 55.11 metric tons/ ha/yr, or a total soil loss of 311.27 metric tons/yr.
9) Year 2013 had average USLE soil loss of 54.70 metric tons/ ha/yr, or a total soil loss of 316.47 metric tons/yr.
10) Year 2019 had average USLE soil loss of 57.28 metric tons/ ha/yr, or a total soil loss of 337.65 metric tons/yr.
11) Average sediment load for 1990 is 123888214816683.00t/yr
12) Average sediment load for 2000 is 453272312779987.00 t/yr
13) Average sediment load for 2013 is 128064776941637.00 t/yr
14) Average sediment load for 2019 is 462653402922269.00 t/yr

Rainfall is abundant; hence soil erosion rates are higher coupled with more sediment yield rates.
Amount of soil eroded and sediment yield increased during august 2019 than 1990.

4 Spoken tutorial Project

4.1 Introduction

This project is part of Free FOSSEE. The Spoken Tutorial project is the project started for making the spoken tutorial on Free and Open Source Software (FOSS) in various Indian languages for all the learners to learn in their vernacular language. (Spoken Tutorial Project, FOSSEE, 2019)

The Spoken Tutorial team prepares the lecture series videos in all Indian languages. The spoken tutorials are made by various experts/professionals of that field. The tutorials are made from various levels of expertise i.e. beginners' level, Intermediate level, Advanced level. (Spoken Tutorial Project, FOSSEE, 2019)

Figure 35 Spoken Tutorial project Logo

4.2 Project Description:

The project aims to involve various levels professionals, experts and learners. The project emphasizes on the Side by Side learning method. The project starts with writing the script for the tutorial, this scripts then goes through various quality check and then the final tutorial is recorded using the script. For writing the script, a writer has to give the checklist test which of 5 minutes consisting 10 questions in which various things are examined from the writer. (Spoken Tutorial Project, FOSSEE, 2019)

4.3 Contribution for the Spoken tutorial Project:

The tutorial creation procedure itself is so much innovative and informative. Working for the spoken tutorial project taught us more than anything. I had contributed few scripts for the Quantum GIS (QGIS) FOSS, some of them are as follows:

1. Using Plugins
2. DEM Analysis
3. Excel to point Google earth and shapefiles
4. Mask and Extract tools
5. Vector Analysis

5 References

G. R. Foster, D. K. (1981). Conversion of the universal soil loss equation to SI metric unit. *Journal of Soil and Water Conservatio* .

Goutam Kumar Das1, R. G. (2015). Modeling of Risk of Soil Erosion inKharkai Watershed using RUSLE and TRMM Data: A Geospatial Approach . *International Journal of Science and Research (IJSR)* , 1 to 10.

M. Vinay, R. a. (2015). QUANTIFICATION OF SOIL EROSION BY WATER USING GIS AND REMOTE SENSING TECHNIQUES: A STUDY OF PANDAVAPURA TALUK, MANDYA DISTRICT, KARNATAKA, INDIA . *ARPN Journal of Earth Sciences* , 103-110.

MISHRA, S. *APPLICATION OF UNIVERSAL SOIL LOSS EQUATION IN ESTIMATION OF SEDIMENT YIELD (Case study: Upper Mahanadi Catchment, India)*. ROURKELA : DEPARTMENT OF CIVIL ENGINEERING NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA .

Roy, P. (2018). Physical Geography. *Application of USLE in a GIS environment to estimate soil erosion in the Irga watershed, Jharkhand, India* , 24.

Spoken Tutorial Project, FOSSEE. (2019, June). Retrieved from Spoken Tutorial: https://spoken-tutorial.org/