

**SOIL EROSION PREDICTION USING REVISED UNIVERSAL SOIL LOSS
EQUATION (RUSLE) IN GOOGLE EARTH ENGINE (GEE)**

by

Mr. Tarange Prashant Madhukar

(Reg. No. 2020/09)



DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING

**DR. ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL
ENGINEERING AND TECHNOLOGY**

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI- 413722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA**

2022

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A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA**

In partial fulfillment of the requirements for the degree

of

MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)

in

SOIL AND WATER CONSERVATION ENGINEERING



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APPROVED BY

Dr. S. B. Nandgude

(Chairman and Research Guide)

Dr. A. A. Atre

(Committee Member)

Dr. B. K. Gavit

(Committee Member)

Dr. S. B. Gadge

(Committee Member)

**DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING
DR. ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL
ENGINEERING AND TECHNOLOGY
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST- AHMEDNAGAR,
MAHARASHTRA STATE (INDIA)**

2022

Dedication

*Affectionately dedicated to
Farmers, Teachers, Parents
and Well Wishers*

..... Mr. Tarange Prashant Madhukar

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
thereof has not been submitted
by me or any other person to any
other University or Institute
for a Degree or
Diploma.

Place: M. P. K. V., Rahuri

(Tarange Prashant Madhukar)

Date: / /2022

Dr. S. B. Nandgude

Research Guide and Head,

Department of Soil and Water Conservation Engineering,

Dr. Annasaheb Shinde College of Agricultural Engineering, Mahatma

Phule Krishi Vidyapeeth, Rahuri – 413 722,

Dist. Ahmednagar, Maharashtra State (India).

CERTIFICATE

This is to certify that the thesis entitled “**SOIL EROSION PREDICTION USING REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) IN GOOGLE EARTH ENGINE (GEE)**” submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in the partial fulfillment of the requirement for the award of the degree of **MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)** in **SOIL AND WATER CONSERVATION ENGINEERING**, embodies the results of a piece of bonafide research work carried out by **MR. TARANGE PRASHANT MADHUKAR** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Place: M. P. K. V., Rahuri

Date: / /2022

(S. B. Nandgude)

Research Guide

Dr. S. B. Nandgude

Professor and Head,
Department of Soil and Water Conservation Engineering,
Dr. A.S. College of Agricultural Engineering and Technology,
Mahatma Phule Krishi Vidyapeeth, Rahuri – 413 722,
Dist. Ahmednagar, Maharashtra State (India).

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Place: M. P. K. V., Rahuri

(**S. B. Nandgude**)

Date: / /2022

Dr. D. D. Pawar
Dean,
Faculty of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth, Rahuri – 413 722,
Dist. Ahmednagar, Maharashtra State (India).

CERTIFICATE

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Place: M. P. K. V., Rahuri

(D. D. Pawar)

Date: / /2022

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*Place: MPKV, Rahuri
Date: / / 2022*

(Tarange Prashant Madhukar)

TABLE OF CONTENTS

Chapter No.	Title	Page No.
	CANDIDATE'S DECLARATION	I
	CERTIFICATE OF RESEARCH GUIDE	II
	CERTIFICATE OF HEAD OF THE DEPARTMENT	III
	CERTIFICATE OF DEAN	IV
	ACKNOWLEDGEMENT	V
	TABLE OF CONTENTS	VII
	LIST OF TABLES	IX
	LIST OF FIGURES	X
	LIST OF ABBREVIATION	XII
	LIST OF SYMBOLS	XIV
	ABSTRACT	XV
1.	INTRODUCTION	1
2.	REVIEW OF LITERATURE	5
	2.1 Soil Erosion Employing Revised Universal Soil Loss Equation (RUSLE).	5
	2.2 Soil Erosion Employing Revised Universal Soil Loss Equation (RUSLE) By Using Google Earth Engine (GEE).	11
	2.3 Estimation of Temporal Change in Soil Erosion	13
3.	MATERIALS AND METHODS	21
	3.1 Location of Study Area	21
	3.2 Datasets Used for Soil Loss Estimation	21
	3.2.1 Software and System Used	22
	3.2.1.1 GOOGLE EARTH ENGINE (GEE)	22
	3.2.1.2 Key Features of GEE	23
	3.2.1.2.1 Components of the Earth Engine Code Editor	23
	3.2.2 Thematic Map	26
	3.2.3 Revised Universal Soil Loss Equation (RUSLE) Model	27
	3.3.1.1 Rainfall Erosivity Factor (R):	27
	3.3.1.2 Soil Erodibility Factor (K):	30
	3.3.1.3 Topographic Factor (LS):	32
	3.3.1.4 Vegetative Cover Factor (C):	34
	3.3.1.5 Conservation Measure Factor (P):	36
	3.3.2 Working in Google Earth Engine	36
	3.3.3 Determination of temporal change of soil loss in the Mula river basin	36

4.	RESULTS AND DISCUSSION	39
	4.1 Soil Loss Estimation Using RUSLE equation in Google Earth Engine (GEE)	39
	4.1.1 Rainfall Erosivity Factor (R)	39
	4.1.1.1 Spatial distribution of average rainfall erosivity	43
	4.1.2 Soil erodibility factor (K)	50
	4.1.3 Topographic Factor (LS)	51
	4.1.4 Vegetative Cover Factor (C)	53
	4.1.5 Conservation Practice Factor (P)	58
	4.1.6 Average Soil Loss using Revised Universal Soil Loss Equation (A)	58
5.	SUMMARY AND CONCLUSIONS	69
	5.1 Summary	69
	5.2 Conclusions	70
6.	LITERATURE CITED	71
7.	APPENDICES	77
	APPENDIX-I	77
	APPENDIX-II	90
	APPENDIX-III	91
8.	VITAE	95

LIST OF TABLES

Table No.	Description	Page No.
4.1	Rainfall Erosivity Factor (R)	39
4.2	Area under different Rainfall erosivity classes for Mula river basin for year 1996-2000.	43
4.3	Area under different Rainfall erosivity classes for Mula river basin for year 2001-05.	44
4.4	Area under different Rainfall erosivity classes for Mula river basin for year 2006-10.	46
4.5	Area under different Rainfall erosivity classes for Mula river basin for year 2011-15	47
4.6	Area under different Rainfall erosivity classes for Mula river basin for year 2016-20	49
4.7	Spatial coverage of topographic factor (LS)	52
4.8	Vegetative Cover Factor (C) of Mula River Basin for Pentad study	54
4.9	Area under different soil erosion classes in the Mula River Basin in km ²	59
4.10	Area under different classes of annual soil erosion of Mula River Basin year for 1996-2000	60
4.11	Area under different classes of annual soil erosion for Mula River Basin for year 2001-2005	62
4.12	Area under different classes of annual soil erosion for Mula River Basin for year 2006-10.	63
4.13	Area under different classes of annual soil erosion for Mula River Basin for year 2011-15	65
4.14	Area under different classes of annual soil erosion for Mula River Basin for year 2016-20	66

LIST OF FIGURES

Figure No.	Description	Page No.
3.1	Study area of Mula River basin	22
3.2	Components of the Earth Engine Code Editor	23
3.3	The Script Manager	24
3.4	The Assets Manager	24
3.5	The Get Link button	24
3.6	The layer visualization tool	24
3.7	The Inspector Panel	25
3.8	The code editor	26
3.9	Flow chart of estimation of R factor in GE	29
3.10	Working screenshot of estimation of R factor in GEE	29
3.11	Flow chart of estimation of K factor in GEE	31
3.12	Working screenshot of estimation of K factor in GEE	31
3.13	Flow chart of procedure of LS Factor in GEE	33
3.14	Working screenshot of estimation of LS factor in GEE	33
3.15	Flow chart of procedure of C Factor in GEE	35
3.16	Working screenshot of estimation of C factor in GEE	35
3.17	Flow chart of methodology in GEE	36
4.1	Average rainfall erosivity (R) values of Akole tehsil	40
4.2	Average rainfall erosivity (R) of Sangamner tehsil	40
4.3	Average rainfall erosivity (R) of Parner tehsil	41
4.4	Average rainfall erosivity (R) of Ahmednagar tehsil	42
4.5	Average rainfall erosivity (R) of Rahuri tehsil	42
4.6	Area distribution under Rainfall erosivity for mula river basin for year 1996-2000	43
4.7	Average Rainfall Erosivity Map for Mula River Basin for year 1996-2000	44
4.8	Area distribution under Rainfall erosivity for mula river basin for year 2001- 05	45
4.9	Rainfall Erosivity Map for Mula River Basin for year 2001-05	45

4.10	Area distribution under Rainfall erosivity for mula river basin for 2006-10	46
4.11	Rainfall Erosivity Map for Mula River Basin for year 2006-10	47
4.12	Area distribution under Rainfall erosivity for mula river basin for 2011-15	48
4.13	Rainfall Erosivity Map for Mula River Basin for year 2011-15	48
4.14	Area distribution under Rainfall erosivity for mula river basin for 2016-20	49
4.15	Rainfall Erosivity Map for Mula River Basin for year 2016-20	50
4.16	Soil Erodibility Factor Map for Mula river basin (k)	51
4.17	Area distribution for Topographic factor (LS) for mula river basin	52
4.18	Slope Map of Mula river basin	52
4.19	Topographic Factor (LS) of Mula river basin	53
4.20	Average Vegetative Cover Factor (C) of Mula River Basin for year 1996-2000	54
4.21	Average Vegetative Cover Factor (C) of Mula River Basin for year 2001-05	55
4.22	Average Vegetative Cover Factor (C) of Mula River Basin for year 2006-10	56
4.23	Average Vegetative Cover Factor (C) of Mula River Basin for year 2011-15	57
4.24	Average Vegetative Cover Factor (C) of Mula River Basin for year 2016-20	57
4.25	Conservation Practice Factor for Mula River Basin (P)	58
4.26	Average Soil Loss (tonnes/ha-yr) for pentad study (2000-20)	59
4.27	Areas of different soil erosion intensity grades in the Mula River Basin	60
4.28	Area distribution under Soil Erosion of mula river basin for year 1996-2000	61
4.29	Soil Erosion Map of Mula River Basin for year 1996-2000	61
4.30	Area distribution under Soil Erosion for mula river basin for year 2001-05	62
4.31	Soil Erosion Map of Mula River Basin for year 2001-05	63
4.32	Area distribution under Soil Erosion of mula river basin for year 2006- 10	64
4.33	Soil Erosion Map of Mula River Basin for year 2006-10	64
4.34	Area distribution under Soil Erosion of mula river basin for year 2011- 15	65
4.35	Soil Erosion Map of Mula River Basin for year 2011-15	66
4.36	Area distribution under Soil Erosion for mula river basin for year 2016- 20	67
4.37	Soil Erosion Map of Mula River Basin for year 2016-20	67

LIST OF ABBREVIATIONS

Abbreviation	Description
A	Average annual soil loss (tonnes/ha/yr)
Agril.	Agricultural
B. Tech	Bachelor of Technology
C factor	Cover management factor
GEE	Google Earth Engine
DEM	Digital Elevation Model
DIST.	District
Dept.	Department
e. g.	For example,
Engg.	Engineering
RS	Remote Sensing
GIS	Geographic Information System
et al.,	Others
Fig.	Figure
Ha	Hectare
Km	Kilometer
km ⁻²	Per square kilometer
K	Soil Erodibility
R	Rainfall erosivity
C	Vegetative Cover Factor
LS	Topographic Factor
P	Conservation Measure Factor
GPS	Global Positioning System
M	Meter

MPKV	Mahatma Phule Krishi Vidyapeeth
Hrs.	Hours
mm	Millimeter
t	Tonnes
USLE	Universal Soil Loss Equation
RUSLE	Revised Universal Soil Loss Equation
MUSLE	Modified Universal Soil Loss Equation
EUROSEM	European Soil Erosion Model
Sr.	Serial
No.	Number
RS	Remote Sensing
Sq.km	square kilometer
LS factor	Slope length and steepness factor
M.P.K.V.	Mahatma Phule Krishi Vidyapeeth
t/ha/yr.	Tonnes per hectare per year
Yr.	Year
Pub.	Published
Viz	Namely

LIST OF SYMBOLS

Symbol	Parameter
t	Time
%	Percentage
&	And

ABSTRACT

**Soil Erosion Prediction Using Revised Universal Soil Loss Equation (RUSLE) in
Google Earth Engine (GEE)**

by

Mr. Prashant Madhukar Tarange**Masters of Technology****(Agricultural Engineering)**

in

Soil and Water Conservation Engineering**Mahatma Phule Krishi Vidyapeeth, Rahuri,****District - Ahmednagar (Maharashtra)****2022**

Name of the Guide : Dr. S. B. Nandgude**Department : Soil and Water Conservation Engineering**

Soil erosion is serious issue in India which reduces the productivity of agricultural land and availability of water. Soil erosion is defined as detachment, transportation and deposition of soil particles from one place to another under influence of wind, water or gravity forces. So, the present study was taken up for estimation of soil loss and temporal changes in soil erosion of Mula river basin using Google Earth Engine (GEE). The selected watershed for this study was Mula river basin which is situated in Ahmednagar district. The latitude and longitude of Mula river basin at starting point and outlet point are 19° 48' N, 74° 01' E and 19° 52' N, 74° 83' E having a geographical area of 2570 km². Watershed characteristics such as flow direction, flow accumulation, slope, soil erodibility, rainfall erosivity, and soil loss were determined using the Google Earth engine and ArcGIS.

Revised universal soil loss equation (RUSLE) was used to estimate soil loss from study area. Temporal variation in soil erosion was estimated for every five-year interval from 1996-2000 to 2016-20. The erosivity factor (R factor) estimated using monthly and annual rainfall data. Sand, silt, clay and organic matter of soil were used to determine the soil erodibility factor (K factor). Flow Accumulation and Digital Elevation Model (DEM) were used to calculate topographic factor (LS factor). The vegetation cover factor (C factor) was derived from Normalized Difference Vegetation Index (NDVI).

The highest and lowest estimated rainfall erosivity factor (R) were found in year 2016-20 (1151.18 MJ-mm/ha-hr-yr) and 2011-15 (300.41 MJ-mm/ha-hr-yr), respectively. The erodibility (K) was found in the range of 0.0251 to 0.0388 (tonnes-ha-hr/ha-MJ-mm). The topographic factor (LS) was found in the range of 0- 9.9524. Vegetative cover factor (C) values for every five-year interval were ranged from 0.0104 to 0.2894, 0.0037 to 0.2735, 0.0092 to 0.2933, 0.0097 to 0.2796, and 0.0167 to 0.2832.

Average annual soil loss for 5-year interval starting from 2000 to 2020 was found 10.0691 tonnes/ha/yr, 9.5124 tonnes/ha/yr, 11.8232 tonnes/ha/yr, 8.6023 tonnes/ha/yr, and 11.2180 tonnes/ha/yr respectively during the 20-year period. Maximum variation in soil loss was found in year 2011-15 and 2001-05 respectively. This variation is attributed to rainfall erosivity factor (R) which is influence by rainfall distribution and rainfall amount. So, it is inferred that rainfall characteristics are playing vital role in soil erosion of Mula basin. It is therefore essential to have proper soil cover during rainy season to reduce the impact of rainfall. Estimated net soil erosion for every pentad study shows area under high erosion class (10 – 20 tonnes/ha/yr), very high erosion class (20 – 40 tonnes/ha/yr) and severe erosion class (40 – 80 tonnes/ha/yr) in the range of 5% - 20%. This area demands immediate adaptation of conservation practices to be adopted on priority basin for protection from loss of natural resources.

Combine use of Revised universal soil loss equation (RUSLE) and Google Earth Engine (GEE) cloud platform gives faster and real time information for analysis of various parameter required for soil loss and other studies in natural resource management. So, these model and tool can be used very effectively and efficiently for larger basins in study of various parameters and planning of natural resources in watershed.

1. INTRODUCTION

Soil erosion is most dangerous environmental issue that threatens the world food production (Dudal 1981). Soil erosion is known as detachment, transportation and deposition of soil particles from one position to another while being influenced by gravity, wind, water forces. One of the types of soil degradation it causes is the deterioration of the soil's physical, chemical, and biophysical properties (FAO 1978). The FAO-led Global soil partnership estimates that 75 billion tonnes of soil globally are eroded every year from arable lands worldwide. The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) estimate that soil erosion in India is increased up to 119 million ha land. About 773.5 million tonnes of soil erode each year in Maharashtra (Durgude, 2015). Soil erosion create direct impact on soil fertility which reduces production of food. So, soil erosion control is needed for conservation of natural resources in agricultural and urban areas.

Climate change has accelerated a soil erosion in many locations worldwide (Nearing et al., 2004) and it direct affects ecosystem services and human well-being. Despite several case studies, there is a dearth of understanding of the global disparities in the effects of climate change on soil erosion. Climate change is producing changes in rainfall behaviour, which is a primary element driving soil loss. Soil sequesters greenhouse gases in a year equal to 5 % of all human-made greenhouse gas emissions annually. But, due to soil erosion, this greenhouse gas is released into the atmosphere. So, planning for soil erosion control measure demands proper understanding and study of soil erosion in quantifiable manner.

Soil loss can be quantified in a variety of ways, including the standard soil erosion field method, although these are both costly and time consuming (Castillo et al., 2012). So, many scientists turn to use of satellite image data to estimate soil erosion. Now, there are number of models developed to estimate and monitor soil erosion. The Universal Soil Loss Equation (USLE, Wischmeier and Smith, 1978), the Modified Universal Soil Loss Equation (MUSLE, Williams and Berndt, 1977), the European Soil Erosion Model (EUROSEM, Morgan et al., 1998), and the Revised Universal Soil Loss Equation are some significant examples (RUSLE). USLE is the most well-known and widely used empirical soil loss model in the world (Wischmeier and Smith, 1978). The model was updated to the revised universal soil loss equation (RUSLE) in 1980 by the Agriculture Department of the United States and Agricultural Research Service (USDA - ARS), which was an enhanced version of the USLE. According to the Global Applications of Soil Erosion Modelling Tracker (GASEMT), USLE and RUSLE are two of the top 25 soil erosion models in the world (Borrelli et al., 2021).

RUSLE is more efficient than the USLE because it is adjusted to measure seasonal changes in some of the important parameters such as soil moisture and soil stability. The impact of configuration is calculated using the volume of runoff flowing in a dense line instead of the amount of silt reaching the line. Application and use of RUSLE has increased over the last few decades, mostly due to the growth of applications for remotely sensed (RS) and geographical information

systems (GIS). The data processing and modeling of soil erosion on a large scale is time demanding and costly. As a result, RS and GIS softwares are now widely used for estimating soil loss. The RUSLE model has the advantages of having a simple formula, fewer parameter requirements and higher measurement accuracy as compared to the other erosion models. It has become a widely used quantitative measurement model for global erosion. Remote sensing and GIS facilitate the process of the RUSLE model local scale (Haregeweyn et al., 2017; Yesuph and Dagne, 2019), region scale (Fenta et al., 2020a; Tamene and Le, 2015), continental scale (Bosco et al., 2015), and global scales (Borrelli et al., 2017; Wuepper et al., 2020).

There are many traditional image processing tools available in market for data processing. But, new platform of Google Earth Engine (GEE) has a large data stored functions, which can quickly retrieve and process remote sensor data as compared to traditional image processing tools (Gorelick et al., 2017). It has become the forum for the world's most advanced cloud information processing technology. The data is readily available and free to worldwide in GEE cloud platform. GEE database easily provides a variety of sources, including satellite imagery, location data sets, weather data, land cover / land use maps and social and economic data (Gorelick et al. 2017). It is capable of performing cloud computing and earth data detection over a large distance and long-term measurement in the short time (Gorelick, N. 2017).

So, combine use of RUSLE model with geospatial tool like GEE can make planning of natural resources in watershed faster, more accurate and real time. These kinds of studies are very few at international and national level. Large river basin requires lot of data and its processing. So, RUSLE and GEE will make analysis more informative and location specific. Mula river basin of Ahmednagar district is having limited data where use of this kind of model and Geospatial techniques will help us in better planning of natural resources. There is no such kind of study in past on Mula river basin has been conducted.

Therefore, in this context the present study was undertaken to develop a model on GEE platform to estimate soil loss in large river basin using RUSLE. For this purpose, Mula river basin is selected as a study area situated in the Ahmednagar district. The river has her origin near Harishchandra gad. The latitude and longitude of Mula river basin at starting point and outlet point are $19^{\circ} 48' N$, $74^{\circ} 01' E$ and $19^{\circ} 52' N$, $74^{\circ} 83' E$. The river basin covers a total area of 2570 km^2 . Ahmednagar district has a hot and dry climate. Ahmednagar district falls in the rain fed region as the entire winds are blocked in the Sahyadri range and rest of the dry winds move to the other areas. It has a warm summer and is generally dry throughout the year except during the south-west monsoon season. So, Ahmednagar district has an uneven rainfall. Ahmednagar's average rainfall is 566 mm (Patil, 2020). The most of the land in the study region is agricultural land, and farming is the primary source of income for the majority of the population. The availability of soil erosion information in the study area is required to plan soil conservation strategy and increase food

production through proper land resource management. It is also necessary to generate information on soil loss in order to maintain and improve natural resources. Therefore, research was conducted to estimate soil erosion using RUSLE for Mula river basin in Google Earth Engine with following specific objectives:

- To develop a model in Google Earth Engine (GEE) for Estimation of Soil Erosion Employing Revised Universal Soil Loss Equation (RUSLE).
- To estimate Temporal Change in Soil Erosion in Mula River Basin by using developed Model.

2. REVIEW OF LITERATURE

In this chapter, reviews of past research work done by researchers around the world are elaborated. The main purpose of this chapter is to present a gist of conceptual framework relating to a study carried out by various investigators on soil erosion prediction using revised universal soil loss equation (RUSLE). There are some researches into the soil loss estimation of watershed by using USLE and RUSLE in google earth engine and remote sensing. Keeping in view the objectives of the study, review of literature related to the study are presented under the following sub-headings:

2.1 To estimating soil erosion employing revised universal soil loss equation (RUSLE).

Jabbar (2003) studied application of GIS to estimate soil erosion using RUSLE. The study was carried out at the northern part of Shaanxi province. The total area of watershed is 13746 km². This study indicated that multi-temporal and multi-spectral remote sensing data provide valuable and very important factors like cover management and conservation practice factor for this study. Since the crop cover is a powerful weapon to reduce the direct impact of rainfall on soil particles. It can be recommended that all barren lands in Shaanxi should be converted to agricultural land or forest plantations through proper land reclamation measures. GIS has given a very useful environment to undertake the task of data compilation and analysis within a short period at very high resolution. GPS data can be used for updating the aged survey of local area topographic map, which is the prime source of data for the DEM and geo-coding of image.

Kouli et al. (2007) studied Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS framework, Chania, North-western Crete, Greece. Crete is considered a semi-arid region. The average annual precipitation is estimated to be 900 mm. Soil loss values range between 0 and 1982 tonnes/ha/yr for the Magagistra watershed, with a mean value of 85,513 tonnes/ha/yr, between 0 and 3975 tonnes/ha/yr with a mean value of 107.625 tonnes/ha/yr for the Kastelli watershed, between 0 and 1,150 tonnes/ha/yr. Milias basin with a mean value of 77.174 tonnes/ha/yr, between 0 and 3901 tonnes/ha/yr for the Tiflos basin (mean value equal to 82.666 tonnes/ha/yr), between 0 and 2366 tonnes/ha/yr for the Arapi watershed (mean value equal to 83.725 tonnes/ha/yr), between 0 and 3733 tonnes/ha/yr for the Tavronitis basin with a mean value of 125.69 tonnes/ha/yr, between 0 and 4254 tonnes/ha/yr for the Keritis watershed (mean value equal to 193.527 tonnes/ha/yr) and between 0 and 4156 tonnes/ha/yr for the Kalami watershed with a mean value of 205.467 tonnes/ha/yr.

Bizuwerk et al. (2008) used GIS technology for modelling soil loss rate in a wash river basin, Ethiopia. Based on the analysis, the amount of soil loss in a basin was about 37684000 tonnes/yr from 11.2 million hectare. The amount of soil loss of each parcel of land in the basin was ranged from 0 to 30.4145 tonnes/ha/yr. The mean annual soil loss of a basin was 28.84 tonnes/ha/yr. The result of study falls were the ranges of the findings of FAO (1984). According to the estimate of FAO (1984), the annual soil loss of the highlands of Ethiopia ranged from 1248

– 23400 million ton per year from 78 million of hectare of pasture, ranges and cultivated fields throughout Ethiopia.

Ettazarini et al. (2017) studied assessment of soil loss risk using integrated remote sensing and geographic information system (GIS) techniques in the Argana basin, Morocco. The study area is about 1305 km² and is located in the western part of high Atlas. The weather of study area is varied from arid to semi-arid. The model used in this study was the Revised Universal Soil Loss Equation. The result shows that the annual mean of soil loss ranges from 0.036 to 270.572 (tonnes/ha/yr). Lands representing 17.23% of global surface showed low to moderate risk, while high to very high risk and severe to very severe risk were revealed in surfaces corresponding to 55.78% and 26.99% respectively. In this research it is demonstrated that the soil loss risk is real threatening thus soils as well as the Argan trees as principal natural resources necessary for the socio-economic development durability in the region.

Bonilla et al. (2010) predicted water erosion using the Revised Universal Soil Loss Equation (RUSLE) in a GIS in central Chile. In this study, RUSLE was integrated into a Geographic Information System (GIS), and used to evaluate the effects of different combinations of vegetative cover on soil erosion rates for Santo Domingo County in Central Chile. Soil losses were estimated for the current and for three alternate scenarios of vegetative cover. Under current conditions, 39.7% of the country is predicted to have low erosion rates (< 0.1 tonnes/ha/yr), 39.8% has intermediate rates (0.1-1.0 tonnes/ha/yr), and 10.4% has high erosion rates (> 1.1 tonnes/ha/yr). The remainder of the surface (10.2 %) was not subjected to erosion. Under the recommended alternate scenario, 89.3% of the country was predicted to have low erosion rate and no areas affected by high soil loss.

Kumar et al. (2014) studied the Revised Universal Soil Loss Equation within a Geographic Information System (GIS) environment to investigate the spatial distribution of annual soil loss potential in the Kothagiri Taluka, Nilgiri district of Tamilnadu (India). The study area receives rainfall both in southwest and northeast monsoons. The study area receives an annual average rainfall of 3046 mm and exhibits a wet climatic condition with a mean minimum and maximum temperature of 20.5 °C and 30.7 °C, respectively. The climate of the Kothagiri area is temperate and salubrious throughout the year. The average annual R factor values were ranged from 150 mm/ha-h-year to 450 mm/ha-h-year. The R factor values for the Kothagiri, Ooty and Mettupalayam were ranging from 52 to 316, 30 to 280 and 30 to 550 mm/ha-h-yr. respectively. The value of LS factor was 0.00 in the flat areas in the western part of the taluka and 24.01 in the high-lands in the northern, north eastern and southern parts of the study area. The soil loss in Kothagiri Taluka was ranging from 0.54 to 27.11 tonnes/ha/yr. The average annual soil loss value of the Kothagiri Taluk was 15.74 tonnes/ha/yr. The erosion map produced was then categorized into five different erosion risk classes. According to this model, approximately in 70 % of the

taluka area has very low erosion risk to low erosion risk and 17% moderate erosion risk. But erosion risk is high and very high on 8.28 % and 3.54% area of taluka respectively.

Thapa (2014) studied spatial estimation of soil erosion using RUSLE Modelling: A case study of Dolakha District, Nepal. The severity assessment of soil erosion GIS-based RUSLE equation considering rainfall, soil, DEM, land use, and land cover. The soil erosion rate categorized into six classes based on its severity, and 5.01% of the regions found under extreme risk (> 80 Mg/ha/yr) and 70% of areas remained in a low-risk zone. This area shows that high elevation along with prompt rainfall susceptible to soil erosion. Result suggests the area of north eastern part suffers from high soil erosion risk due to steep slope. The predicted severity can provide a basis for conservation and planning processes at the decision-makers. The regions with high to very severe soil erosion warrant needs a special priority and control measures. While this model forms a basis on mapping and prediction using remote sensing and GIS-based analysis for vulnerability zones, such studies suggested for conservation and refining the model in the future.

Ganasri and Ramesh (2015) studied assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi basin. The weather of watershed in southwest monsoon period (June to sept) is the coolest part of the year with the mean daily temperature below 25°C . The mean daily temperature during March to May is 35°C and whether is highly humid all through the year. This study indicates that the Nethravathi Basin was a tropical coastal humid area having a drainage area of 3128 km^2 up to the gauging station. The parameters of RUSLE model were estimated using remote sensing data and the erosion probability zones were determined using GIS. The results indicate that the estimated total annual potential soil loss of about 473,339 tonnes/yr was comparable with the measured sediment of 441,870 tonnes/yr during the water year 2002 and 2003. The predicted soil erosion rate due to increase in agricultural area is about 14,673.5 tonnes/yr. The probability zone map was derived by the weighted overlay index method indicate that the major portion of the study area comes under low probability zone and only a small portion comes under high and very high probability zone. The results can certainly aid in implementation of soil management and conservation practices to reduce the soil erosion in the Nethravathi Basin.

Rahaman et al. (2015) studied estimation of annual average soil loss, based on RUSLE model in Kallar watershed, Bhavani basin, Tamil Nadu, India. The study area is Kallar watershed situated in Eastern part of Western Ghats stretching from West to the East. It is part of Bhavani River basin, which is the main in Moyar and Bhavani River. The climate of this area is temperate and salubrious for more than half of the year. The average day temperature of the sub watershed is 20.15°C to 30°C and the average rainfall is about > 1400 mm. The result shows that the average annual soil erosion was 398.58 tonnes/ha/yr. Based on the result soil erosion was classified into soil erosion severity map with five classes, very low, low, moderate, high and critical

respectively. The classified soil loss map shows that 8.68% of the total area falls under the Nil with tolerable rate of <10 tonnes /ha /yr followed by 41.93% of the total area comes under low soil loss with rate of soil erosion 10 - 50 tonnes/ha/yr. The critical soil loss occupies 3.82 % of the total area, losing more than 300 tonnes/ha/yr. Other soil loss categories, like moderate and high covers 33.95% and 11.59 % of the total area with average annual soil loss < 50 and < 300 tonnes/ha/yr respectively.

Gaubi et al. (2016) studied a GIS based soil erosion prediction using the revised universal soil loss equation (RUSLE) Lebna watershed, Cap Bo, Tunisia. The river Lebna watershed is in the northeast of Tunisia in the Cap Bon region covers an area of approximately 2840 km². The average annual rainfall at Lebna river is about 450 mm. The empirical model RUSLE for assessing soil erosion is used to evaluate soil erosion potentials in this area and to detect the sensitive zones presenting a priority of protection. The spatial distribution of annual average rate of soil loss resulting of this methodology shows an average of 24 ton/ha/year. Lebna watershed belongs to a zone of rather a steep erosive potential knowing that the maximum acceptable limit value of the erosive potential estimated is 12 ton/ha/year.

Saha et al. (2018) studied on GIS based soil erosion estimation using RUSLE model: A Case Study of Upper Kangsabati Watershed, West Bengal, India. The study was carried out in the upper Kangsabati watershed of Puruliya district, West Bengal with an area of 276.19 km². The average annual rainfall in this watershed is 1393 mm and the annual mean temperature is 25.6°C with mean summer and mean winter temperature are 29.0 °C and 21.3 °C respectively. Average annual soil erosion was estimated based on the five parameters defined in the Revised Universal Soil Loss Equation (RUSLE) and with the help of Geographical Information technology. Overlay of five parameters, viz., rainfall–runoff erosivity factor (R), soil erodibility factor (K), slope length and steepness factor (LS), cover and management factor (C) and support and conservations practices factor (P) was done in GIS platform. The potential soil erosion of the upper Kangsabati watershed varies from < 0.014 to 13.42 tonnes/ha/yr. It is classified into four soil erosion zones. These zones are low (< 0.014 tonnes/ha/yr), moderate (0.014 – 1.0 tonnes/ha/yr), high (1.0 - 5.0 tonnes/ha/yr) and very high prone zone (5.0 – 13.42.0 tonnes/ha/yr). In the whole watershed it is found that nearly 45% area is under very high and high erosion prone zone.

Koirala et al. (2019) studied estimation of soil erosion in Nepal using a RUSLE modelling and Geospatial Tool. Rapid changes in altitude and aspect along the latitude have created a wide range of climatic condition in Nepal. As consequences, within span of 200 km Nepal encounters almost all type of climate from subtropical to alpine. The temperature in Nepal varies mainly with topographic variation along north-south direction. The importance of the study is to produce the spatial distribution of soil erosion of Nepal, which can be used the conservation and management planning processes, at the policy level, by land use planners and policy-makers. The output is

based on the model RUSLE processed in ArcGIS. The five factors that influence the soil erosion by water include rainfall erosivity, soil erodibility, topography, cover and support practices. The mean potential soil erosion rate for Nepal is estimated to be 25 tonnes/ha/yr, with an annual loss of 369 MT. It has been found that the erosion rate of Nepal varies from as low as 0 t to 273 tonnes/ha/yr. By physiographic region, it has been found that the Middle Mountains have the maximum mean annual erosion with 38.39 tonnes/ha/yr followed by the high mountains (32.46 tonnes/ha/yr) with Terai having the lowest erosion potential (0.06 tonnes/ha/yr).

Panditharathne et al. (2019) studied application of revised universal soil loss equation (RUSLE) model to assess soil erosion in Kalu Ganga River Basin in Sri Lanka. The annual rainfall average is about 4,000 mm. The maximum rainfall value of 4,466 mm was recorded in Kudawa and the lowest average annual rainfall value of 2,613 mm was recorded in Kaluthara rain gauge station. The entire basin has a low soil erosion severity and the mean annual soil erosion rate of the basin is low which is 0.63 tonnes/ha/yr. Area under moderate to high risk with 5 to over 12 tonnes/ha/yr erosion severity is about 1.89% of the entire basin. The mean sediment yield value for the Kalu Ganga main stream was 0.29 tonnes/ha/yr. Based on erosion estimates, the basin landscape was divided into four different erosion severity classes: very low, low, moderate, and high. About 1.68% of the areas (4714 ha) in the river basin were identified with moderate to high erosion severity (>5 tonnes/ha/yr) class which urgently need measures to control soil erosion.

Barman et al. (2020) studied soil erosion assessment using revised universal soil loss equation model and geo-spatial technology: A case study of upper Tuirial river basin, Mizoram, India. The geographical area of Tuirial river basin is 53,393.09 ha. The state reposes under direct influence of southwest monsoon with an annual average precipitation of about 2500 mm. Rainfall and temperature data collected for a period of 2007 to 2016 at the study area gives the average annual rainfall of 2732 mm, average monthly temperature of 21.24 °C with maximum and minimum temperature of 15.39 °C and 27.19 °C respectively. The objective of the study was to estimate annual soil loss in the upper Tuirial river basin by using RUSLE where various parameters such as rainfall erosivity factor (R), soil erodibility factor (K), slope length (L), slope steepness factor (S), crop management factor (C) and practice management factor (P) were taken into consideration. Land use land cover (LULC) derived from Satellite data of Sentinel 2A Digital Elevation Model (DEM) were integrated into the model. The results revealed that the river basin has an average annual soil loss of 115.4 Mg/ha/yr, and annual sediments loss to the tune of 6.161 million Mg/yr, from the basin. About one-fourth (24.78%) of the total basin could be classed as very high to very severe soil erosion prone area that need immediate conservation measures.

Boufala et al. (2020) studied assessment of the risk of soil erosion using RUSLE method and SWAT model at the M'dez watershed, Middle Atlas, Morocco. Geographically the M'dez watershed with a total area of 3350 km² and perimeter of about 378 km is a part of extensive basin

sebou located in northern Morocco, entirely in the middle Atlas Mountain. This study indicates that the soil erosion risk assessment of the M'dez basin was carried out by two methods: the RUSLE method and the SWAT hydro-agricultural model. The results obtained during this work led to the production of two erosion maps for the basin in study area. For the swat model, the specific degradation of the watershed is estimated at 3.95 tonnes/ha/yr. Also, for RUSLE model, the average loss of the basin is estimated at 2.694 tonnes/ha/yr. Comparison of the two methods showed that a large area of the basin is exposed to a low to moderate risk of erosion, with about 98.66% of the basin area by the RUSLE empirical model, and 84.47% by the Swat model. Indeed, these two methods have given very interesting results in terms of a quantitative description of the M'dez basin. Thus, the established maps allowed a classification to quantify the losses in soils and its spatial distribution. However, the Swat model is an interesting and complete approach. It takes into consideration transport and sedimentation and thus quantifies sediment production and nutrients at the watershed level. Currently, it is recommended to use the performance of the Swat model in sustainable environmental and agricultural policies to assess sedimentation and pollution generated by agricultural activities and transport downstream.

Dahal (2020) studied soil erosion estimation using RUSLE modelling and Geospatial tool on case study of Kathmandu District, Nepal. Kathmandu is the largest city in Nepal which is very densely populated. The average temperature varies from 28 to 30 °C and in winter average temperature is 10.1 °C. Average annual rainfall is recorded about 1400 mm. The estimation of potential soil erosion in the Kathmandu district, the RUSLE model was used, in which five factors were determined with the help of GIS and various factors like mean annual rainfall of 10 years data, soil data, DEM, land use of specific location were used. The soil erosion rates of Kathmandu district were classified into six various classes based on rate of erosion that is found in specific location in which 2.18% of the land fall under extreme risk, 70.14% of the land area was in the low-risk zone, about 10.53%, 8.73%, 5.56% and 2.85% of land fall under moderate, high, very high and severe zone. In Dakshinkali, Nagarjuna and Budanilkantha areas, there was high erosion. The results showed that the areas with steep slope, high intensity of rainfall, bare land was most prone to erosion. The projected risk zone can guide for the conservation and proper utilization of land. Regions which was very prone to soil erosion demand high attention to apply appropriate measure to control it.

Pal and Samanta (2021) studied Estimation of Soil Loss Using Remote Sensing and Geographic Information System Techniques - case study, Kaliaghai River Basin, Purba & Paschim Medinipur district, West Bengal, India. In this study RUSLE (Revised Universal Soil Loss Equation) model was used for soil loss estimation. Different parameters, namely the rainfall and runoff factor (R), soil erodibility factor (K), slope length and steepness factor (LS), crop management factor (C) and conservation practice factor (P), that are the mandatory inputs to

RUSLE, have been either derived from remote sensing data or through conventional data collection systems. These parameters are obtained from monthly and annual rainfall data, soil map of the region, Digital Elevation Model (DEM), RS techniques (with use of Normalized Difference Vegetation Index) and land use/land cover map, respectively. This experiential study was carried out on the Kaliaghai river basin under Purbo and Paschim Medinipur district of West Bengal. Soil loss was very high in the river basin area, calculated as 1927779 tonnes/yr using RUSLE model.

Galdies et al., (2022) studied estimates of soil erosion rates in a principal watershed in Gozo, Malta under current and future climatic conditions. The study area which is home to more than 31,000 people living in an area of 68 km². Land use changes in the area have affected a large part of the valley that is tightly linked to agricultural activities which have modified the landscape into terraced fields. The site clearly shows the presence of natural hydraulic features such as gullies, slope wash, rills, tributaries and the main watercourse. The aim of the study was to estimate the current and future annual soil erosion rate in the Ramla watershed situated in Gozo, Malta. For this study the RUSLE model was used, assisted by remote sensing and GIS techniques. The inclusion of the highest possible DEM data as well as reflecting climatic changes to the R factor based on the latest climate projections for Gozo derived from a total of eight CMIP6 climate change models. The estimated annual soil loss, as a percentage of the total area of study varies from low (85.1%), to moderate (13.3%) and high (1.6%). Within a climate change context, a reduction in the annual soil erosion rate has been estimated for the period 2080–2100, ranging from 5 tonnes/ha/yr under SSP126 to 6 tonnes/ha/yr under SSP585.

Marcinkowski et al. (2022) studied assessment of soil erosion under long-term projections of climate change in Poland. Poland ranks among Europe's largest countries with a surface area of 312,683 km². It is located in Central and Eastern Europe, between the Baltic Sea and the Carpathian Mountains. Poland has highly variable soils characterised by low content of colloids, clay minerals, and humic substances. The study describes historical and future projected soil loss rates in Poland using the latest high-resolution datasets and the RUSLE model. Total annual soil loss for Poland is estimated at 14 Mt. The highest soil loss rate is observed in the south of Poland with mean annual erosion rate of 1.7 tonnes/ha/yr. Although it occupies only 16% of the territory of Poland, its share in total soil loss in the country is 62%. The results of this study are valuable for the development of the national soil conservation policy. The study fills the spatial gap in modelling of changes in soil erosion caused by climate in the Northern and Eastern part of Europe.

2.2 To estimating soil erosion employing revised universal soil loss equation (RUSLE) by using Google earth engine (GEE).

Papaiordanidis et al. (2019) studied erosion prediction using revised universal soil loss equation (RUSLE) in Google Earth Engine (GEE) cloud-based platform. The study area is located at the centremost part of Greece, along the mountain range of Pindus. The geographical area of

watershed is 12,431.25 km². The average annual rainfall is from 1100 mm to 1800 mm. The mean monthly temperature ranging from 0.9 °C to 21.4 °C. This study was to predict soil erosion in the mountain range of Pindos during a full seasonal cycle. Resources from GEE and ESDAC were used to produce the predicted soil erosion maps by calculating RUSLE for January, April, July, and October 2018. After comparing the different results both by their sum and mean erosion per hectare per month, the seasonal factors of RUSLE were investigated. It was found that months with the highest erosion predictions are October and January with corresponding mean erosions 3.25 and 2.88 tonnes/ha/month and total erosion of the study area 162,027 and 143,010 tonnes/ha/month.

Wang and Zhao (2020) studied on dynamic changes of soil erosion in the Taohe river basin using the RUSLE model and Google Earth Engine. The Taohe river basin was the largest tributary and an important water conservation area in the upper reaches of the yellow river. The geographical area of watershed is 2,5500 km². The Taohe River Basin is located in the hinterland of the mainland. It has obvious plateau continental climate characteristics. In this study, several parameters of the revised universal soil loss equation (RUSLE) model were extracted by using Google Earth Engine. The soil erosion modulus of the Taohe river basin was calculated based on multi-source data, and the spatio-temporal variation characteristics of the soil erosion intensity were analysed. The results showed the average soil erosion modulus of the Taohe river basin in 2000, 2005, 2010, 2015 and 2018 were 1424, 1195, 1129, 1099 and 1124 tonnes/ha/yr, respectively, and the overall downward trend was obvious. The ranges of soil erosion in the Taohe river basin in 2000, 2005, 2010, 2015 and 2018 was basically the same mainly with slight erosion and the soil erosion in the middle and lower reaches was more serious. During dealing with the vegetation cover factor and conservation practice factor in the RUSLE model, Google Earth Engine provided a new approach for soil erosion investigation and monitoring over a large area.

Elnashar et al. (2021) studied soil erosion assessment in the Blue Nile River basin driven by a novel RUSLE-GEE framework. The Blue Nile River basin covers an area 308,474 km². The Blue Nile River basin has been characterised by two distinct climatic zone the humid Ethiopian Highlands and semiarid south east Sudan. The average annual rainfall of watershed is 5.11 to 251.67 mm in January to September. This study indicates that they attempted to assess soil erosion by water by utilizing the RUSLE model in the GEE environment in the Blue Nile River basin. Our RUSLE-GEE model estimates showed that the entire Blue Nile River Basin produces an average soil loss rate of 39.73 tonnes/ha/yr, of which 57.98 and 6.40 tonnes/ha/yr were the portion mean soil loss rate in the Upper and Lower Blue Nile sub-basins, respectively. Approximately 27% of the total area was placed under urgent soil conservation measures, covering 32.48% and 0.12% of the croplands in the upper and lower Blue Nile sub-basins, respectively.

Kumar et al. (2021) studied RUSLE model-based assessment of soil erosion in Parbati river basin, central India using Google Earth Engine and GIS. This study focuses on Parbati river basin, a major north flowing cratonic river and a tributary of river Chambal to identify erosion prone areas using RUSLE model. This study indicates that gullied areas were contributing most to the high soil erosion rate in the basin. The rate of soil erosion in gullied areas was much higher than the permissible value of 4.5 tonnes/ha/yr recognised for India. The result reveals that annual rate of soil loss for Parbati river basin was 319 tonnes/ha/yr. Lowest soil loss rate was 36 tonnes/ha/yr observed in open forest area and highest amount of soil loss was 316 tonnes/ha/yr observed in gullied area class. Also, this study helps in understating special pattern of soil loss in the river basin and also useful for the identifying and prioritising of erosion prone areas so as to plan for their conservation.

2.3 To Estimate Temporal Change in Soil Erosion.

Bhattarai and Dutta (2007) studied estimation of soil erosion and sediment yield using GIS at catchment scale. The study area is the M91 sub-watershed of the Mun River. It is the largest right bank tributary of the Mekong River, situated in the north-eastern part of Thailand. The total draining area of Mun basin is approximately 69,000 km². The average annual rainfall in the basin is 1,200 mm which varies from 1,600 mm in the east and 1,000 mm in the west part of the basin. The average annual soil loss was found 150.54 tonnes/km² at 1990 and 322.46 tonnes/km² at 2000. The computed and observed values were observed to have some discrepancy for both annual and monthly sediment yield. better estimates of sediment yield were obtained using 30 m DEM than 90 m because of the effect of DEM resolution on different USLE parameters like l, s factors and sediment delivery ratio (SDR).

Beskow et al. (2009) studied Soil erosion prediction in the Grande River Basin, Brazil using distributed modelling. The study area is located in southern Minas Gerais State covering area about 6273 km². The temporal distribution of precipitation has two different seasons a hot and rainy summer (85% of precipitation) and dry and cold winter with the overall basin receiving the influence of cold fronts and frost formation. Average annual precipitation ranges from 1600 mm to over 2300 mm near Mantiqueira mountain. Mean SDR value for the Grande River Basin was 0.016, meaning that we estimated that 1.62% of the soil loss generated in the basin was transported to the outlet. For the studied period, average sediment transport was equal to 0.813 tonnes/ha/yr, however, values ranged between 0.34 and 1.39 tonnes/ha/yr. The major area of the basin (about 53%) had an average annual soil loss of less than 5 tonnes/ha/yr. The results obtained to conclude that 49% of the overall basin presently has soil loss greater than the tolerable rate. This is indicating that there are zones where the erosion process is critical, meaning that both management and land-use have not been used appropriately in these areas of the basin.

Meusburger et al. (2011) studied spatial and temporal variability of rainfall erosivity factor for Switzerland. The precipitation regime of Switzerland is characterised by a distinct seasonality with lowest precipitation in winter and highest in summer. The rainfall distribution in winter is characterised by westerly winds causing high precipitation in the north-western part and low precipitation in central and eastern parts of Switzerland. The mean value of long-term rainfall erosivity is 1323 MJ-mm/ha-hr-yr with a range of lowest values of 124 MJ-mm/ha-hr-yr at an elevated station in Grisons to highest values of 5611 MJ-mm/ha-hr-yr 15 in Ticino. All stations have highest erosivity values from July to August and lowest values in the winter month. The increasing trends of erosivity in May, September and October when vegetation cover is susceptible are likely to enhance soil erosion risk for certain agricultural crops and alpine grasslands in Switzerland.

Alkharabsheh et al. (2013) studied impact of land cover change on soil erosion hazard in Northern Jordan using remote sensing and GIS. The study area is located in the northern part of Jordan, over an area of 1400 km². This study assessed the impact of land cover on the erosion in agricultural areas in northern part of Jordan in 1992 and 2009. The RUSLE model was successfully applied resulting mean erosion loss of 9.53 and 8.97 tonnes/ha/yr for 1992 and 2009 respectively. This was subsequently reclassified to erosion risk levels. By comparing the change of the erosion risk levels with the land cover change map of the study area using geographic overlay analysis. It was evident that the main reason for soil erosion change was the abandonment of rainfed crops and their conversion to rangelands.

Bhadra et al. (2018) studied temporal variation in water induced soil erosion by RUSLE model using RS and GIS. Mago basin lies in the upstream of the Tawang river basin. The total area of the basin is 839 km². The annual rainfall in the basin averages 1,139 mm. The temporal variation in the area under slight soil erosion showed a decreasing trend. Increasing trends were observed over the years in areas under moderate to very severe soil erosion classes. The average soil loss by water for each year crossed permissible soil loss limit of 12 tonnes/ha/yr except for the year 2006. The average annual soil loss map was prepared and it was found that 56.65, 10.83, 10.36, 10.15, 7.31, 4.70 percent areas of the snow/glacier free area of the Mago basin fell under slight, moderate, high, very high, severe, and very severe erosion classes, respectively.

Katara (2013) studied estimation of runoff and soil loss using remote sensing and GIS. In the present study, Ahar River catchment is selected as a study area located in Udaipur district, Rajasthan (India). The study area is part of Girwa and Badgaon blocks of Udaipur district covering an area of about 348.23 km². The Ahar River catchment is characterized by subtropical and sub-humid to semi-arid climatic conditions. The average annual rainfall of the basin is 620.89 mm. Annual runoff in the study area ranged from 29.34 mm in year 2002 to 315.28 mm in year 2006. Rainfall erosive factor for 10-year period varied from 1522.93 to 10225.88 MJ-mm/ ha-hr-yr with

an average value of 3264.84 MJ-mm/ ha-hr-yr. About 35% of the total study area is under high (20 tonnes/ha/yr) to very severe (>80 tonnes/ha/yr) soil erosion, which requires urgent attention to plan and manage soil resources by implementing soil conservation measures.

Mondal et al. (2016) studied Change in rainfall erosivity in the past and future due to climate change in the central part of India. The study area is a part of the Narmada River basin, covering Burhanpur, Sehore, Barwani, Harda, Dewas, Indore, Khandwa and Khargone districts of Madhya Pradesh state in India. The climate of watershed experiences hot and dry summer with cool winter. During the monsoon season (June to September), maximum rainfall (above 90% of annual) occurs in this region where the average annual rainfall is 1370 mm and the distribution of rainfall declines from east to west. Nine rainfall locations were selected that distributed throughout the study area and surrounding. The results indicate gradually increasing projected rainfall while the past rainfall has shown a declined pattern by Mann–Kendall test with statistical 95% confidence level. Rainfall erosivity has increased due to the projected increase in the future rainfall (2080 s) in comparison to the past. Rainfall erosivity varies from -32.91 % to 24.12 % in the 2020s, -18.82 to 75.48 % in 2050 s and 20.95–202.40 % in 2080s. The outputs of this research can be helpful for the decision makers to manage the soil water conservation in this study area.

Uddin et al. (2016) studied estimation of soil erosion dynamics in the Koshi basin using GIS and remote sensing to assess priority areas for conservation. The Koshi river basin with a total area of 88,518 km². The maximum average annual precipitation in the basin is 3078 mm and the minimum 207 mm. This study used remote sensing data and a geographic information system (GIS) to estimate the spatial distribution of soil erosion across the entire Koshi basin, to identify changes between 1990 and 2010. The estimated annual erosion from the basin was around 40 million tonnes (40 million tonnes in 1990 and 42 million tonnes in 2010). Erosion risk was divided into eight classes from very low to extremely high and mapped to show the spatial pattern of soil erosion risk in the basin in 1990 and 2010. The erosion risk class remained unchanged between 1990 and 2010 in close to 87% of the study area, but increased over 9.0% of the area and decreased over 3.8%, indicating an overall worsening of the situation. The study provides the first assessment of erosion dynamics at the basin level and provides a basis for identifying conservation priorities across the Koshi basin.

Chen et al. (2019) studied assessment of soil loss from land use/land cover change and disasters in the Longmen Shan Mountains, China. The study area covering an area of 55213 km². The mountainous areas with an elevation of 1000–2000 m belong to the humid climate zone, while the polar regions with an elevation of 2000–5000 m belong to the cold alpine climate zone. The results showed that from 2005 to 2017, the highest rate of ecosystem change was in the other ecosystems category, with an increase in mean soil loss to 4.06 tonnes/ha/yr. The mean soil loss in Yingjing was relatively small, as the estimates for 2005 and 2017 were 0.08 tonnes/ha/yr and

0.09 tonnes/ha/yr, respectively. The areas with severe soil loss are along rivers, mainly distributed along the Minjiang and Tuojiang River basins and their tributaries. The findings of this study will be helpful for identifying high-risk zones, and developing policies to minimize human, environmental and economic losses in any disastrous event.

Paul et al. (2019) studied Assessing land use–land cover change and soil erosion potential using a combined approach through remote sensing, RUSLE and random forest algorithm. The study presented on a geospatial analysis to detect LULC changes (1984–2010) in a Canadian watershed by using object-based classification of Landsat satellite images. The detected LULC changes were implemented into the Revised Universal Soil Loss Equation (RUSLE) to examine the soil erosion potential. The soil erosion risk is divided into five classes ranging from very low (<6 tonnes/ha/yr) to severe (33 tonnes/ha/yr) levels. The random forest algorithm was then implemented and detected that the topography and LULC conditions of 1999 and 2010 had the most influence on the erosion in 2010. The findings of this study will support efficient LULC management to reduce soil erosion and the consequent degradation of water quality.

Zhang et al. (2019) studied dynamic changes of soil erosion in the north and south mountains of Lanzhou. This study takes the north and south mountains of Lanzhou as the study area. The total area of watershed is 1940.08 km². Among them green parts account for 844.66 km² and non-green region accounts for 1147.4 km². The climate type belongs to temperate semi-arid continental monsoon climate, with an annual average temperature of 9.1 °C and yearly average rainfall of 327.7 mm, mostly concentrated from July to September. In this study the soil erosion modulus of the north and south mountains of Lanzhou based on the five major soil erosion factors in the RUSLE model was calculated. The analysis of temporal and spatial variation of soil erosion shows the average soil erosion modulus of north and south mountains fluctuates and decreases from 1995 to 2018. The result shows that the erosion intensity of the north and south mountains of Lanzhou is mainly micro erosion in 1995, 2000, 2005, 2010, 2015 and 2018.

Huang et al. (2020) studied assessment of the soil erosion response to land use and slope in the Loess Plateau - A Case Study of Jiuyuangou (JYG). The Jiuyuangou (JYG) watershed located in the left bank of Wuding river basin, northern Shaanxi of China. The climate is semi-humid, with an average annual temperature of 8°C and the average annual evaporation is 1519 mm. The average precipitation is 475.1 mm and there is a high-intensive precipitation from June to September indicating significant inter-annual variability, the precipitation in 1964 was more than 735.3 mm are three times than that in 1956. The results show that the quantities of soil erosion decreased clearly from 1977 to 2015 in the study area, which from 2011 tonnes/km² area in 1977 to 164 tonnes/km² area in 2004 and increased slowly to 320 tonnes/km² area in 2015. No significant soil erosion (<300 tonnes/km² area) changed in JYG watershed, which increased dramatically from 8.93% to 69.34% during 1977–2015. The area of farmland in this study area

has been reduced drastically. The annual average soil erosion modulus of grassland was also showing a dropped trend from 1977 to 2015.

Fu et al. (2021) studied Estimating the Impact of Land Cover Change on Soil Erosion Using Remote Sensing and GIS Data by USLE Model and Scenario Design. The study area of watershed Liangcheng County. It is located in southern Ulanqab, in the inner Mongolia Autonomous Region, North China. The area of watershed is 3456.12 km². (e mountainous area covers 47.83% of the study area, comprised an approximately equal proportion (25%) of hills and basins. The area belongs to the semi-arid temperate continental monsoon climate. The average temperature is 6.1°C, and the average annual rainfall (1989–2018) is 409.6 mm. The average annual soil loss of watershed is estimated for 2001 and 2010. The USLE model was applied to assess the soil erosion before and after the implementation of ecological projects in this study. The statistical results show that the erosivity value in 2010 is generally higher than that in 2001. The average erosivity value in 2010 is 113.53 MJ-mm/ ha-hr-yr, compared with 98.62 MJ-mm/ ha-hr-yr in 2001. The average annual soil loss was found 14190 tonnes/ (km² area) in 2001 and 14012 tonnes/ (km² area) in 2010.

Jiang (2013) studied GIS-based time series study of soil erosion risk using the Revised Universal Soil Loss Equation (RUSLE) model in a micro-catchment on Mount Elgon, Uganda. The study area is located on the Ugandan territory of Mount Elgon. Mount Elgon is a transboundary mountain which lies on the border of western Kenya and eastern Ugandan. The mean annual air temperature is about 23°C. Moreover, average minimum and maximum temperature is 15 °C and 28 °C, respectively. The mean annual precipitation is generally high around 1500 mm. For the year 2000 the soil loss estimated by flow length method in this year varies between 0 and 4995 tonnes/ha/yr, with the average value 364 tonnes/ha/yr. For the year 2006, the estimated annual soil loss varies between 0 and 4698 tonnes/ha/yr, which is similar to the result of year 2000. The result for 2012 showed that the estimated soil loss values vary between 0 and 6053 tonnes/ha/yr. The mean soil loss value is 362 tonnes/ha/yr, which close to the one for year 2000.

Yang et al. (2021) studied Spatial–temporal evolution patterns of soil erosion in the Yellow River Basin from 1990 to 2015: impacts of natural factors and land use change. The Yellow River Basin covers four geomorphic units from west to east, namely, the Qinghai–Tibet Plateau. The climates in different sub-regions of the basin differ significantly with great annual and seasonal variations. The precipitation in most areas of the basin ranges from 200 to 650 mm, whereas that in the middle and upper reaches is more than 650 mm. The temperature of the northern part is between 31 and 37 °C, while that of the southern part ranges from 21 to 31 °C. The results showed that the loss of N, P, K and organic matter decreased from 1990 to 2015, but an interval maximum was observed in 2005. The loss of N, P, K and organic matter was the largest

in 1990 with 419.25×10^4 tonnes, 228×10^4 tonnes, 4941×10^4 tonnes and 7935.75×10^4 tonnes, respectively. From 1990 to 2000, the loss of N, P, K and organic matter firstly showed a decreasing trend and then increased sharply due to the increase of total soil erosion amount from 2000 to 2005, with increments of 70.5×10^4 tonnes, 25.5×10^4 tonnes, 543.75×10^4 tonnes and 1417.5×10^4 tonnes, respectively. From 2005 to 2015, the loss of N, P, K and organic matter decreased with the decrease in total soil erosion amount and reached the smallest value with 143.25×10^4 tonnes, 89.25×10^4 tonnes, 2064×10^4 tonnes and 2563.5×10^4 tonnes, respectively.

Gong et al. (2022) studied estimating the soil erosion response to land-use land-cover change using GIS-based RUSLE and remote sensing: a case study of Miyun Reservoir, North China. Miyun County which includes 17 towns, is situated in the mountainous region of Beijing and has an area of approximately 2230 km². The climate of the region is warm and semi-humid continental monsoon, with an annual rainfall ranging between 407 mm in the northwest zones to 797 mm in the south-east. Between 2003 and 2013, light soil erosion increased by 587.46 km² and extremely severe soil erosion increased by 9.57 km². The extents of slight, moderate, severe, and very severe soil erosion, however, decreased by 8.02, 445.21, 142.69, and 1.11 km², respectively. A total of 57.5% of land with moderate soil erosion has been converted to light soil erosion, which could be highly beneficial for the improvement of vegetation control of soil and water losses. The results generated from this study may be useful for planners and land-use managers to make appropriate decisions for soil conservation.

Critique of Reviews

From above reviews it is clear that estimating soil loss is urgently needed as it poses a direct threat to global food security and the environmental ecosystem. Soil erosion has been found to have widespread consequences, including increased runoff from more impermeable sub-surfaces, loss of nutrient-rich topsoil, soil productivity, biodiversity, and indirect environmental damage. As a result, researchers have emphasised the significance of estimating soil loss, its spatial distribution, and the extent of soil erosion risk within the catchment. The estimates will provide a thorough understanding of the processes and factors that contribute to soil erosion, as well as potential soil losses due to land-use change and landscape position.

Various soil loss estimation models have been developed and used by scientists all over the world. Each model is distinct in its own right, in terms of capability and suitability. The RUSLE model has been found to be more accurate in estimating soil loss over large areas than other models used around the world. The RUSLE model is used by various researchers in conjunction with geospatial technologies such as Geographical Information System (GIS) and Remote Sensing (RS) to estimate soil loss in watersheds and large river basins. The RUSLE model has the advantage of being compatible with any GIS software and requiring intermediate data.

There are numerous free GIS software's available that can estimate soil loss. The main benefit of using GIS software is that it covers a large area in a short amount of time. Previous studies have found that GIS software can operate on large areas with greater accuracy. However, very few studies in the world, including India, have used the Google Earth Engine (GEE) platform to estimate soil loss. GEE benefits from cloud storage and computing facilities. The primary advantage of GEE is the availability of its own data on cloud storage. GEE cloud storage houses a massive amount of earth observation data. Using those datasets, estimating soil loss over a large basin has become very simple and time consuming.

Previous researchers have highlighted the importance of temporal soil loss estimation to understand the trend of erosion in a specific area over time. The temporal soil loss data will help us better understand the factors responsible for soil erosion. The role of climate change in soil erosion can be comprehended. It will aid in the development of comprehensive mitigation strategies to combat climate change.

3. MATERIAL AND METHODS

The aim of this research work is to study the soil loss estimation using revised universal soil loss equation in google earth engine. This chapter deals with description of study area, collection and processing of data. Furthermore, this chapter also explains the details methodology adopted in this research work. This project was carried during the academic year 2021-22. The location details of study area are explained below.

3.1 Location of study area

3.1.1 Study area

The watershed selected for the study area is Mula River basin. The Mula river has its origin near Harishchandra gad in Ahmednagar district of Maharashtra. The area of Mula river basin cover five tehsils. These are Akole, Sangamner, Parner, Ahmednagar and Rahuri which are located in Ahmednagar district as shown in fig. 3.1. The latitude and longitude of Mula river basin at starting point is 19° 48' N and 74° 01' E. The latitude and longitude of Mula river basin at outlet point is 19° 52' N and 74° 83' E. The total area covered under this watershed is 2570 km². Ahmednagar district is mainly a drought prone area. The average annual rainfall in the Ahmednagar district is 566 mm (Patil, 2020). Average rainfall in the western part of Akole tehsil is higher than other tehsils of study area. Climate of Ahmednagar district is generally hot and dry. The soil type found in study area is broadly divided into four categories namely coarse shallow soil, medium black soil, deep black soil and reddish soil. In Ahmednagar, the wet season is windy and overcast. The dry season is mostly clear and it is hot year-round. Over the course of the year, the temperature typically varies from 12 °C to 37 °C and is rarely below 9 °C or above 40 °C.

3.2 Datasets used for soil loss estimation

Sr. No.	Name of data	Source of data
1.	Rainfall data	www. maharain.com
2.	Sand Data	Open land Map sand content
3.	Silt Data	Open land Map silt content
4.	Clay Data	Open land Map clay content
5.	Organic carbon content	Open land Map soil organic carbon content
6.	Digital elevation model	Hydro-SHEDS DEM
7.	Flow Accumulation	Hydro-SHEDS Flow Accumulation
8.	NDVI	MODIS

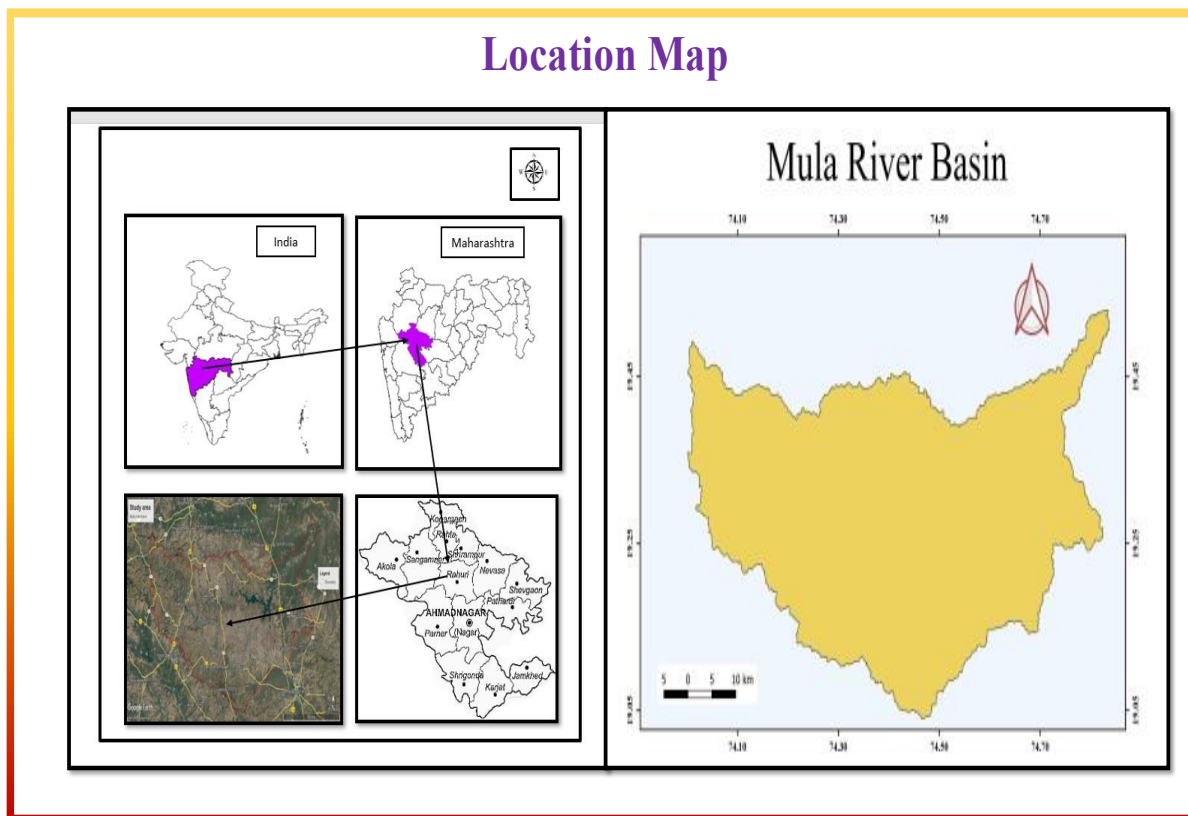


Fig. 3.1 Study area of Mula River basin

3.2.1 Software and System

Arc-GIS, GEE, Google Earth software were used for processing of images obtained by Satellite. Google Earth Engine software was used for estimation of different parameter of RUSLE model and soil loss of study area.

3.2.1.1 GOOGLE EARTH ENGINE (GEE)

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities. Scientists, researchers, and developers use earth engine to detect changes, map trends and quantify differences on the Earth's surface. Earth engine is available for commercial use and remains free for academic and research use. Earth Engine Explorer (EE Explorer) is a lightweight geospatial image data viewer with access to a large set of global and regional datasets available in the earth engine data catalog. It allows for quick viewing of data with the ability to zoom and pan anywhere on earth, adjust visualization settings and layer data to inspect change over time.

- How to find data in the data catalog.
- Adding data to the workspace.
- Explanation of interface features.

3.2.1.2 Key Features of GEE

Earth engine public data catalog

Earth Engine's public data catalog provides more than 40 years of historical imagery and scientific datasets, including satellite data like Landsat, Sentinel-2, and MODIS, as well as geophysical, weather, climate, and demographic data.

Cloud platform integration

Earth Engine is integrated with google cloud, enabling provisioning and permissions to be configured and monitored like other google cloud services.

Compute

Leverage google cloud to process petabytes of data with zero configuration or server management.

API

Full-featured JavaScript, Python, and REST APIs.

Code Editor

Web-based IDE for writing and running scripts. Ideal for prototyping and iteration.

3.2.1.2.1 Components of the Earth Engine Code Editor:

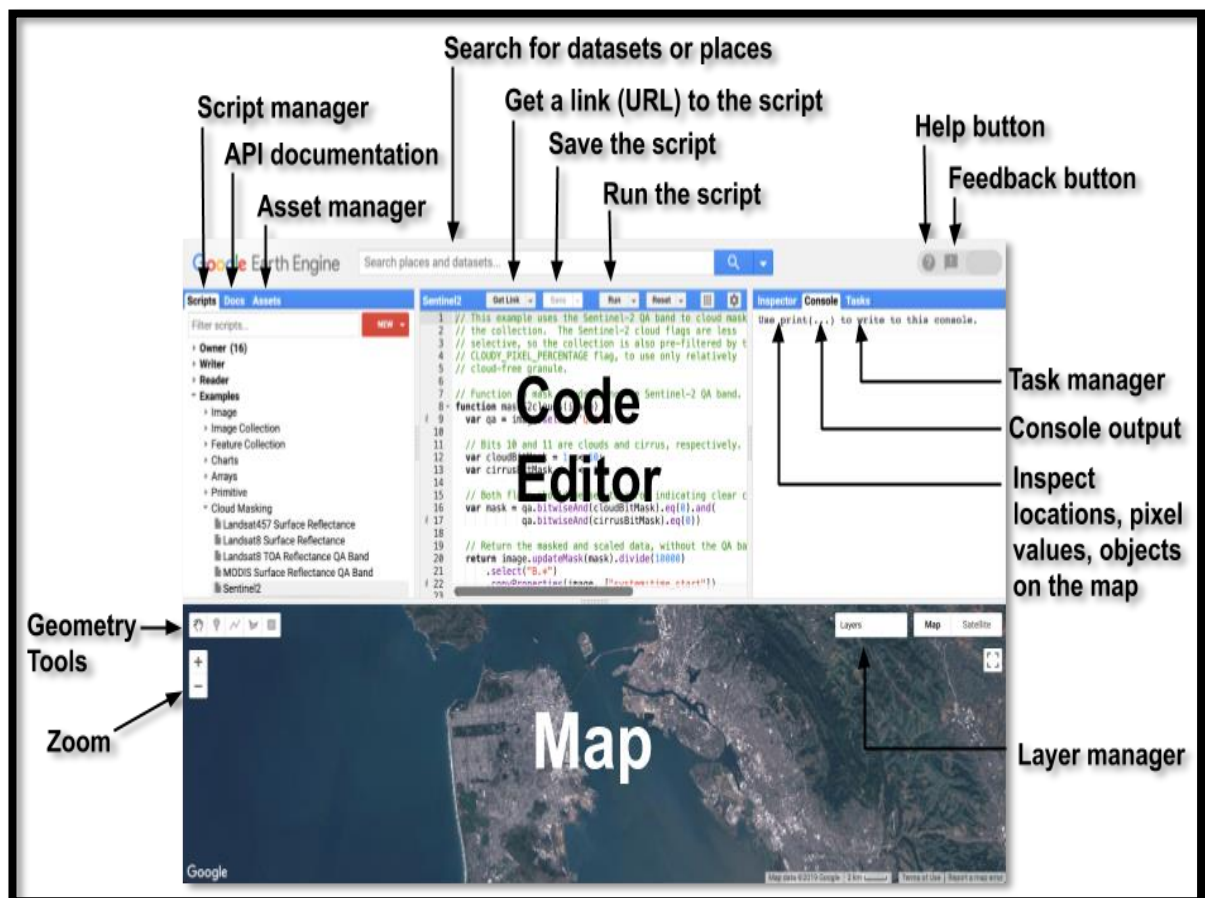


Fig. 3.2 Components of the Earth Engine Code Editor

The Script Manager:

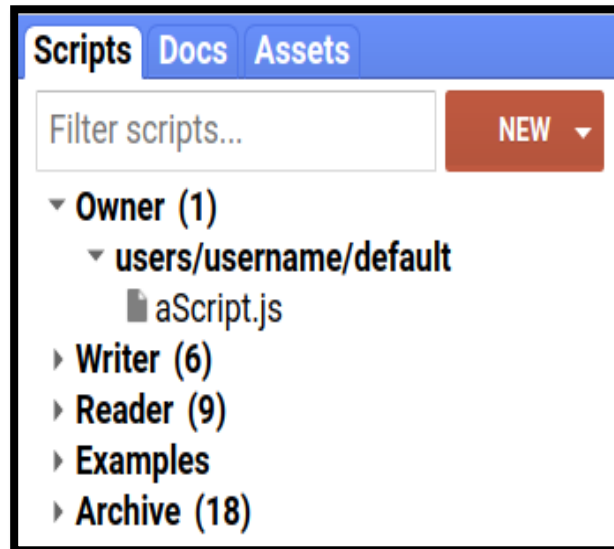


Fig. 3.3 The Script Manager

The Assets Manager:

The **Scripts** tab is next to the API docs in the left panel of the code editor. The script manager stores private, shared and example scripts in git repositories hosted by google. The repositories are arranged by access level, with private scripts stored in a repository own in the **owner** folder: `users/username/default`. Only admin have access to the repositories in the **owner** folder unless you share them with someone else.

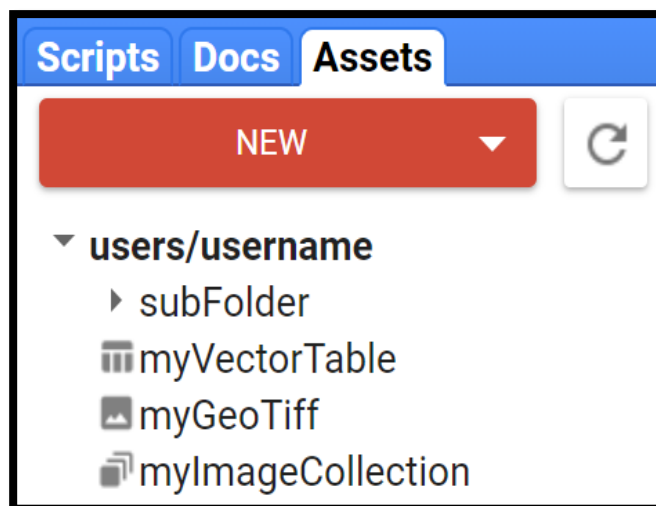


Fig. 3.4 The Assets Manager

The Get Link button:

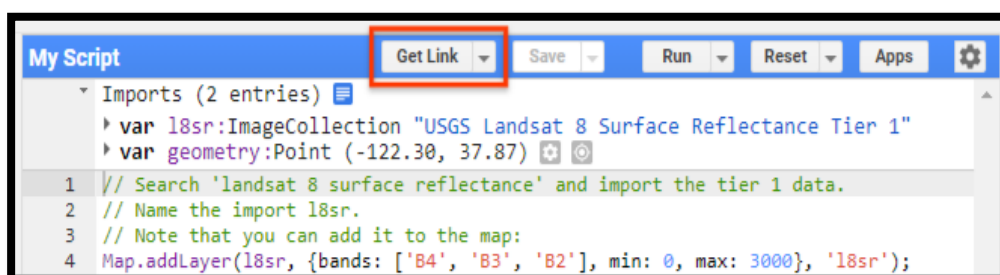


Fig. 3.5 The Get Link button

The Get Link button at the top of the code editor provides an interface for generating script URLs and setting script behaviour options.

The layer visualization tool:

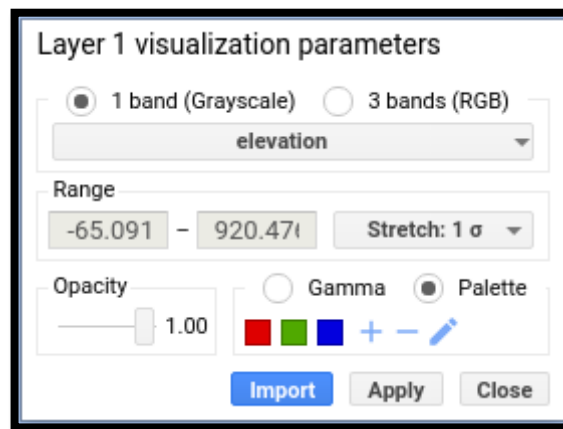


Fig. 3.6 The layer visualization tool

Use the Layer Manager in the upper right corner of the map to adjust the display of layers you added to the map. Specifically, you can toggle the visibility of a layer or adjust its transparency with the slider.

The Inspector Panel:

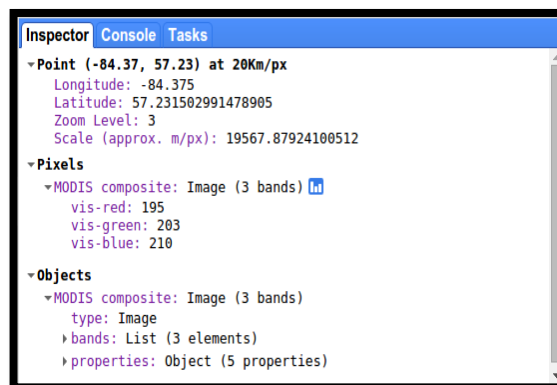
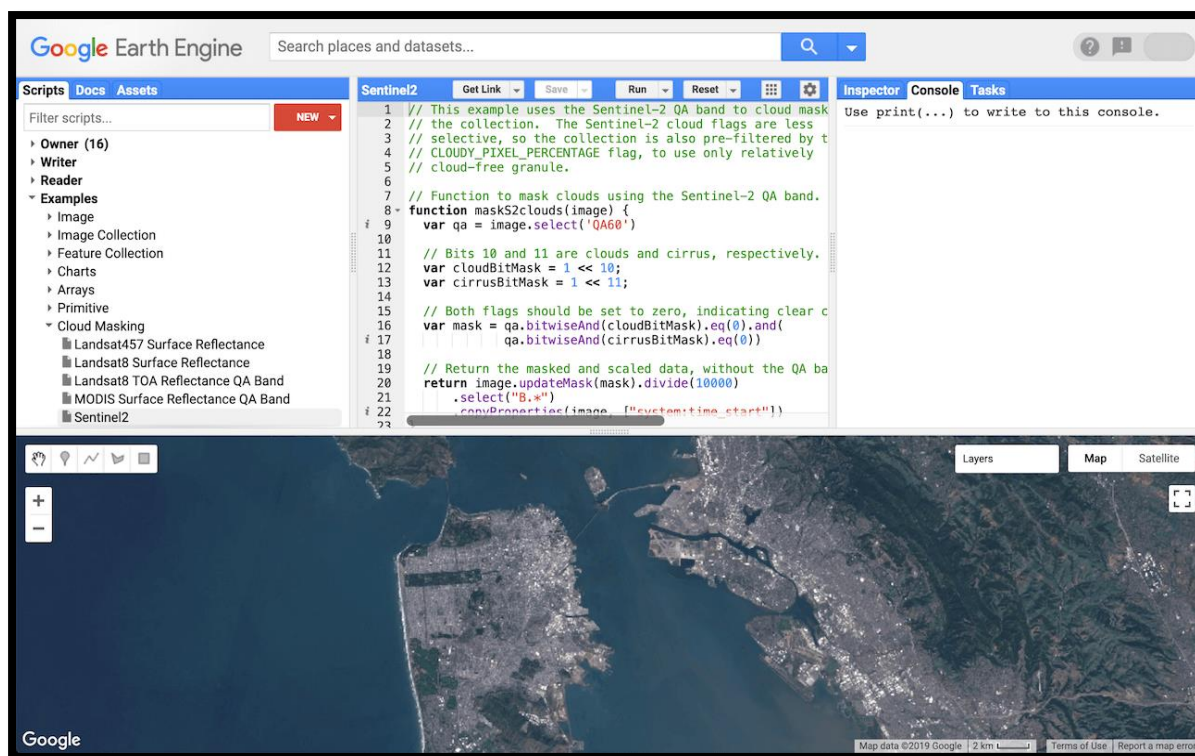


Fig 3.7 The Inspector Panel

The inspector panel used for querying the map, an output console, and a manager for long-running tasks.

The code editor:

The Code Editor is an interactive environment for developing earth engine applications as shown in fig. 3.5. The centre panel provides a java-script code editor. Above this editor, there is save, run and reset options are available to save the current script, run it, and clear the map. The help button in the upper right contains links to this Guide and other resources for getting help.



Opening and running code in the Code Editor:

The steps below demonstrate how to open earth engine and execute a custom script that displays an image.

1. Open the earth engine code editor here: code.earthengine.google.com. Admin will need to enable access by logging in using a registered Google account.
2. Navigate to the scripts tab located on the far left of the code editor. There you will find a collection of example scripts that access, display, and analyse Earth Engine data.

Earth Engine data structures:

The two most fundamental geographic data structures in earth engine are `image` and `feature` corresponding to raster and vector data types, respectively. Images are composed of bands and a dictionary of properties. Features are composed of a `geometry` and a dictionary of properties. A stack of images is handled by an `image-collection`. A collection of features is handled by a `feature-collection`.

3.2.2 Thematic Maps

Thematic maps such as soil erodibility factor, vegetative cover factor, topographic factor and meteorological data-based rainfall maps are the main inputs required for soil erosion estimation and analysis of temporal changes.

- Rainfall erosivity map was prepared using rainfall data for year 1996-2000, 2001-05, 2006-10, 2011-15 and 2016-20.
- Soil erodibility map was prepared using sand, silt, clay and organic matter content of soil

in GEE by using java script.

- Topographic factor map was prepared by using flow accumulation and DEM in GEE by using java script.
- Cover management factor map was prepared by using MODIS data source available on GEE for year 1996-2000, 2001-05, 2006-10, 2011-15 and 2016-20.
- Soil loss map was prepared in GEE for year 1996-2000, 2001-05, 2006-10, 2011-15 and 2016-20 by using GEE.

Following methodology was adopted to prepare thematic maps which include rainfall erosivity map (R), soil erodibility map (K), topographic map (LS), cover management factor map (C), conservation practice factor (P) and soil loss map (A).

3.2.3 Revised Universal Soil Loss Equation (RUSLE) Model

The RUSLE model estimates the long-term mean annual soil loss rate due to water erosion based on major soil erosion factors: pedological (soil erodibility: K-factor), climatological (rainfall erosivity: R-factor), topographic (slope length and steepness: LS-factor), and anthropogenic (cover management: C-factor; support practice: P-factor). The RUSLE model was used to estimate soil erosion. The Revised Universal Soil Loss Equation (RUSLE) has improved the effects of soil roughness and the effects of local weather on the prediction of soil loss. RUSLE is scientific based tool, which has the same formula as USLE, but has several improvements in determining factors. These include some new and revised iso- erodent maps; a time-varying approach for soil erodibility factor; a sub factor approach for evaluating the cover-management factor; a new equation to reflect slope length and steepness; and new conservation-practice values (Renard, *et al.* 1997). The following equation (1) was (Kenneth et. Al. 1991) used for estimation of soil loss.

$$A = R \cdot K \cdot LS \cdot C \cdot P \quad (1)$$

Where,

A refers to the amount of soil loss (tonnes/ha/yr),

R refers to the rainfall erosivity factor (MJ-mm/ha-hr-yr.),

K refers to the soil erodibility factor, (tonnes-ha-hr/ha-MJ-mm),

LS is the topographic factor (dimensionless) which includes slope length (L) multiplied with slope steepness (S),

C refers to the vegetative cover factor (C) (dimensionless)

P refers to the conservation practice factor, (dimensionless).

3.3.1.1 Rainfall Erosivity Factor (R):

Precipitation is one of the important external forces that causes soil erosion. It is affected by volume, intensity, duration, pattern of rainfall and rate of resulting overland flow. Rainfall erosivity is ability of the rain to cause erosion, measured in MJ-mm/ha-h-yr. Rainfall erosivity is of high importance as precipitation is the driving force of erosion and has a direct impact on the

detachment of soil particles, the breakdown of aggregates and the transport of eroded particles. It is an important parameter for soil erosion risk assessment under future land use and climate change. The use of erosivity dataset can be widely extended to other applications landslide risk assessment, flood risk forecasting, Hydrology, post-fire conservation measures, agricultural management and design of crop rotation scenarios. It can be calculated based on the rainfall kinetic energy (E) and the maximum 30-minute rainfall intensity (I30) (Wischmeier and Smith, 1978). This method requires data over more than 20 years (Renard et al., 1997). Furthermore, it cannot reflect continuous records of rainfall (Wang et al., 2016). Alternatively, several studies have established a relationship between rainfall erosivity with more readily available rainfall data: For instance, using monthly rainfall data (Karydas et al., 2020) or annual rainfall data (Parveen and Kumar, 2012). The rainfall data from five tehsils (Akole, Ahmednagar, Sangamner, Rahuri and Parner) of Ahmednagar district were used in this study to calculate rainfall erosivity factor (R-value). Equation no. (2) used for estimating rainfall erosivity factor which was proposed by Ketkar P. et. al (2014),

$$y = 0.0022x^2 - 0.7526x + 152.35 \quad (2)$$

Where,

y is the annual rainfall erosivity factor (MJ-mm/ha-hr-yr.),

x is annual rainfall (mm).

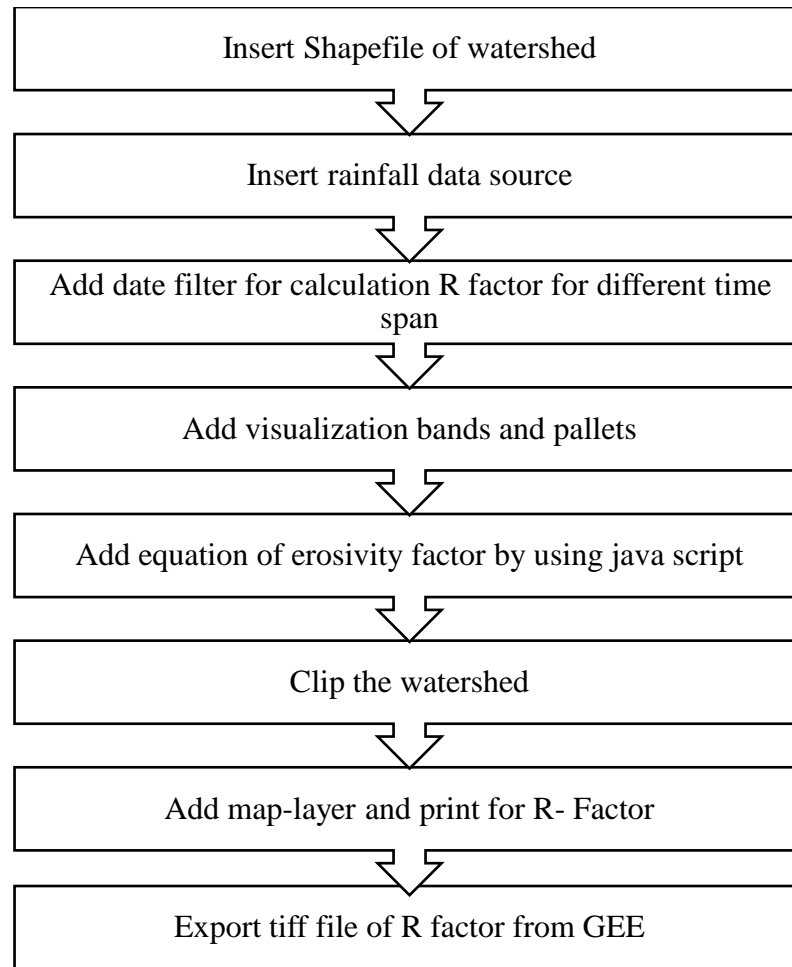


Fig. 3.9 Flow chart of estimation of R factor in GEE

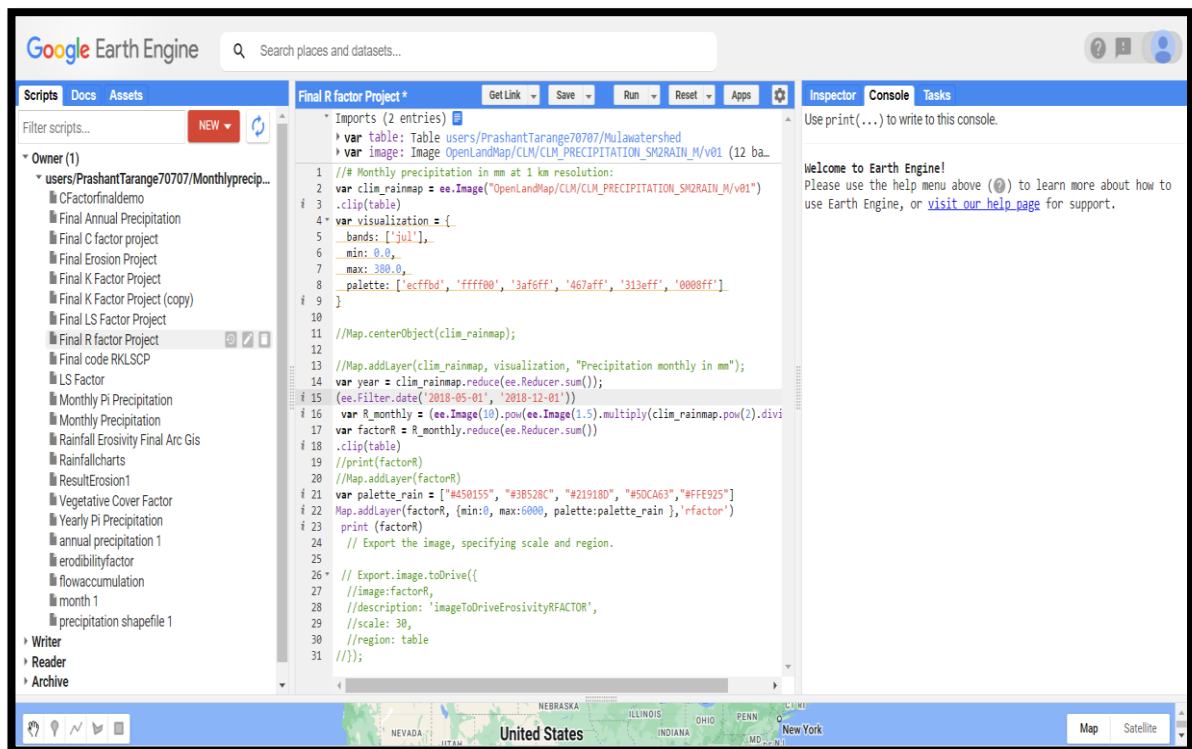


Fig. 3.10 Working screenshot of estimation of R factor in GEE

3.3.1.2 Soil Erodibility Factor (K):

3.3.1.2.1 Concept of soil erodibility

Soil erodibility is the soil's inherent resistance to water erosion and is controlled by the physio-chemical properties of the soil. Soil erodibility is a function of the complex interaction between the sand, silt, and clay fractions of the soil and other factors such as organic matter, soil texture, and profile permeability class. Soil erodibility is defined as the susceptibility of soil particles to detachment and transport by raindrop impact and runoff (Renard, et al., 1997). These processes are influenced by soil properties such as particle size distribution, structural stability, organic matter, soil chemistry and water transfer properties (Lal, 1994). The soil erodibility factor is defined as the average rate of soil loss per unit of rainfall erosivity index from a unit plot (Zhang, et al., 2004). A unit plot is defined as ploughed contiguous fallow land with a uniform slope of 9% and a length of 22.1 m. Soil erodibility is a function of soil physical properties and organic matter. Knowledge of soil erodibility is a basic requirement for erosion prediction, conservation planning and sediment assessment related to watershed environmental parameters. The soil erodibility factor (K) is a measure of the overall effect of a particular combination of soil properties. Some of these properties affect the soil's ability to infiltrate and therefore help determine the amount of runoff.

3.3.1.2.2 Computation of soil erodibility

The soil erodibility equation is statistically accurate and technically valid, but it has proven too complex as an operational tool for an engineer to solve. So, an equation no. (3) is used for estimating Soil Erodibility Factor proposed by Williams J.R and Renard K.G (1983).

$$K = \{0.2 + 0.3 \exp[-0.0256 * Sand \left(1 - \frac{silt}{100}\right)]\} * \left[\frac{silt}{clay+silt}\right]^{0.3} * \left[1 - \frac{0.25C}{C + \exp(3.72 - 2.95C)}\right] * \left[1 - \frac{0.7S_{n1}}{S_{n1} + \exp(-5.51 + 22.9S_{n1})}\right]$$

(3)

Where,

K = Soil Erodibility factor (tonnes-ha-hr/ha-MJ-mm)

Sand, Silt and Clay represent the sand, silt and clay content in the soil percentage (%),

C is the organic carbon content in soil (%),

$$S_{n1} = 1 - Sand/100.$$

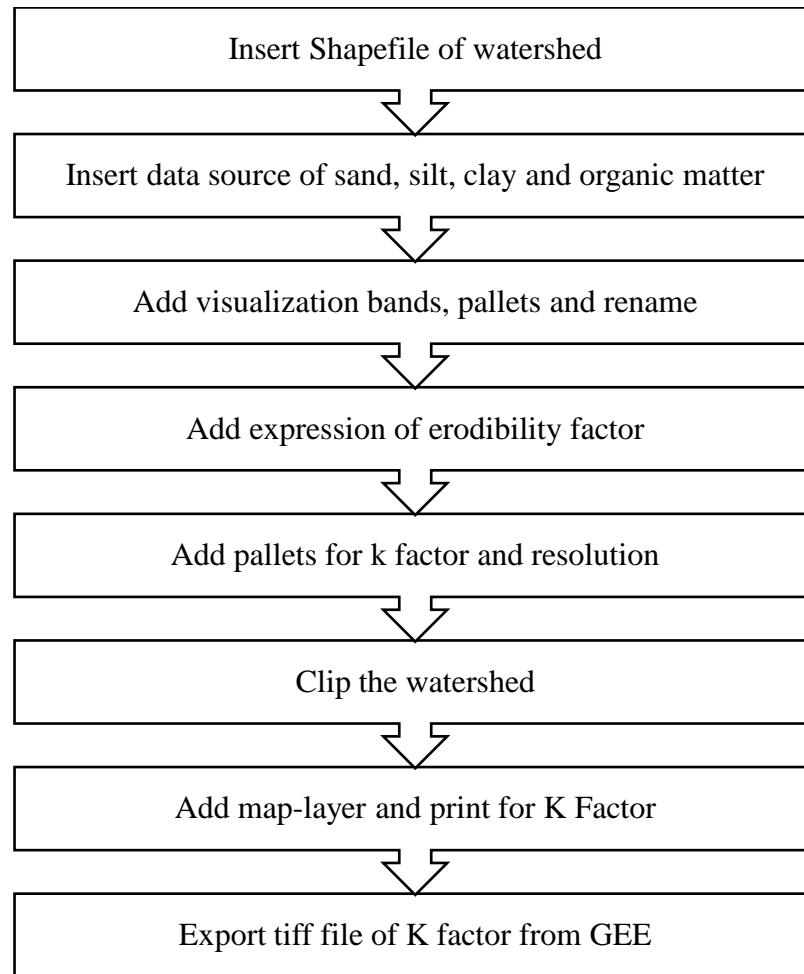


Fig. 3.11 Flow chart of estimation of K factor in GEE

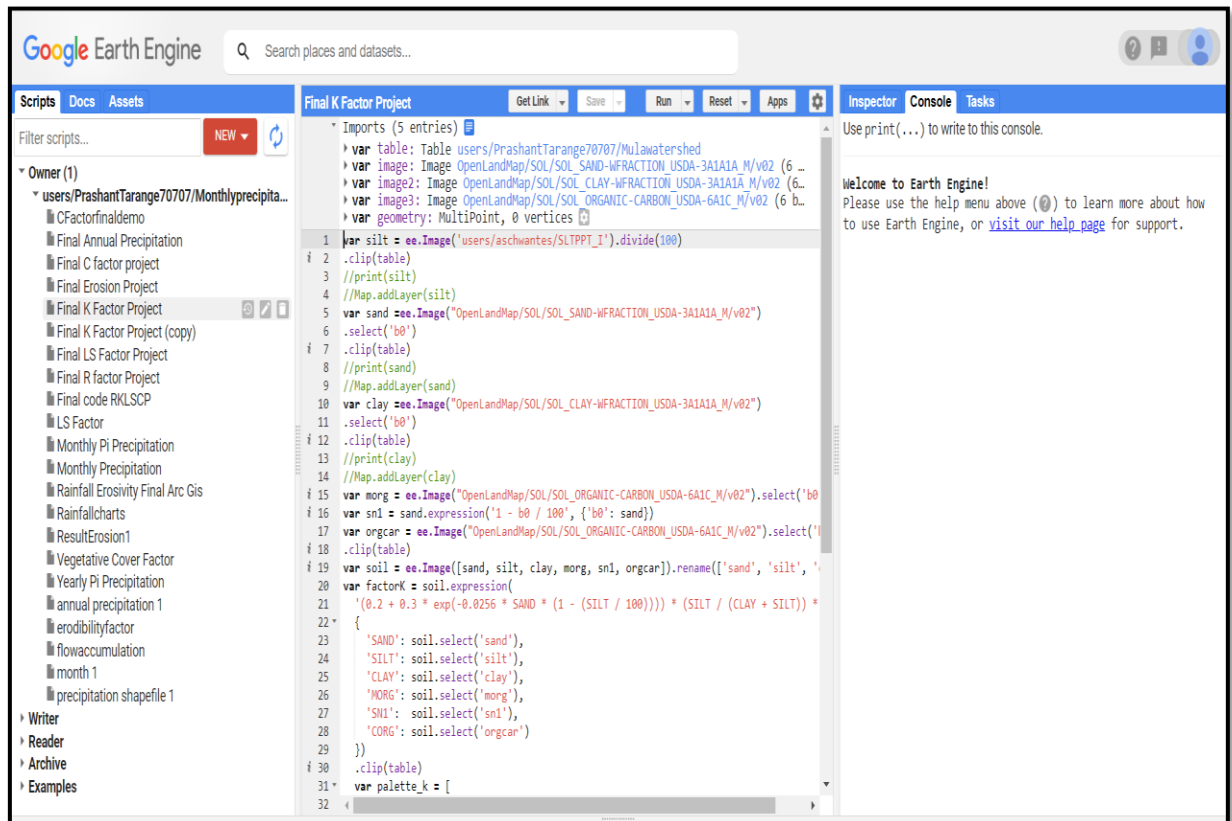


Fig. 3.12 Working screenshot of estimation of K factor in GEE

In present study, the K factor was estimated for the study area with the help of soil data available on Google Earth Engine (GEE) such as sand, silt, clay and organic matter. The sand (%), silt (%), clay (%) and organic carbon content (%) data was obtained from Open Land Data Source which is available for world.

3.3.1.3 Topographic Factor (LS):

3.3.1.3.1 Concept of Topographic factor (LS)

The topographic factor (LS) is the ratio of soil loss per unit area from a field to the loss from a field of 22.13 m length and a uniform slope of 9%, other things being constant (Wischmeier and Smith, 1965). Water erosion of soil is a function of Slope steepness (fall) and slope length, which modify the energy of hydrologic inputs. The intensity with which a given rain is caught on the ground depends on the angle of its incidence. The angle of incidence depends on the position (i.e., both aspect and slope) of the ground relative to the direction from which the rain falls. Thus, for a given direction of rain, the proportion of rain actually caught on the ground will vary with slope or inclination. It is generally accepted that erosion increases with increasing slope length because greater accumulation of runoff on longer slopes increases its separation and transport capacities. The runoff velocity and effective depth of interaction between surface soil and runoff increases with increasing slope. The slope (S) and length (L) factors are combined into a topographic factor (LS) in estimating soil erosion.

3.3.1.3.2 Computation of Topographic factor (LS)

The computation of topographic factor at a small scale, the slope length factor is generally measured by field data, but at a large scale, it is mainly obtained by DEM data. Topographic factor (LS-factor) includes Flow Accumulation (FA) and slope (S) and their overall contribution to the soil erosion. In this study LS factor was determined by using Hydro-SHEDS Flow Accumulation and Hydro-SHEDS Hydrologically Conditioned DEM. Slope map of study area in percentage was created by using DEM. An equation no (4) used for estimating Topographic Factor (LS) proposed by Moore and Burch (1985

$$T = [(FA * Resolution) / 22.1]^2 * [\sin(S * 0.01745) / 0.09]^{1.4} \quad (4)$$

Where,

FA is the flow accumulation,

S is the Slope,

Resolution = 30 m.

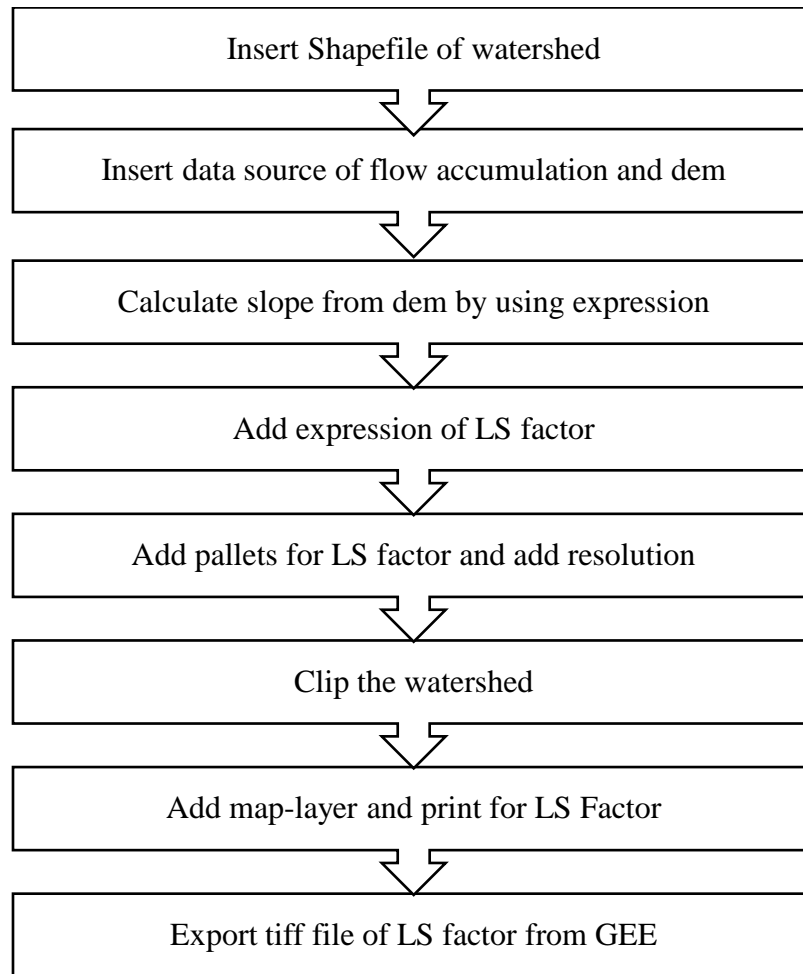


Fig. 3.13 Flow chart of procedure of LS Factor in GEE

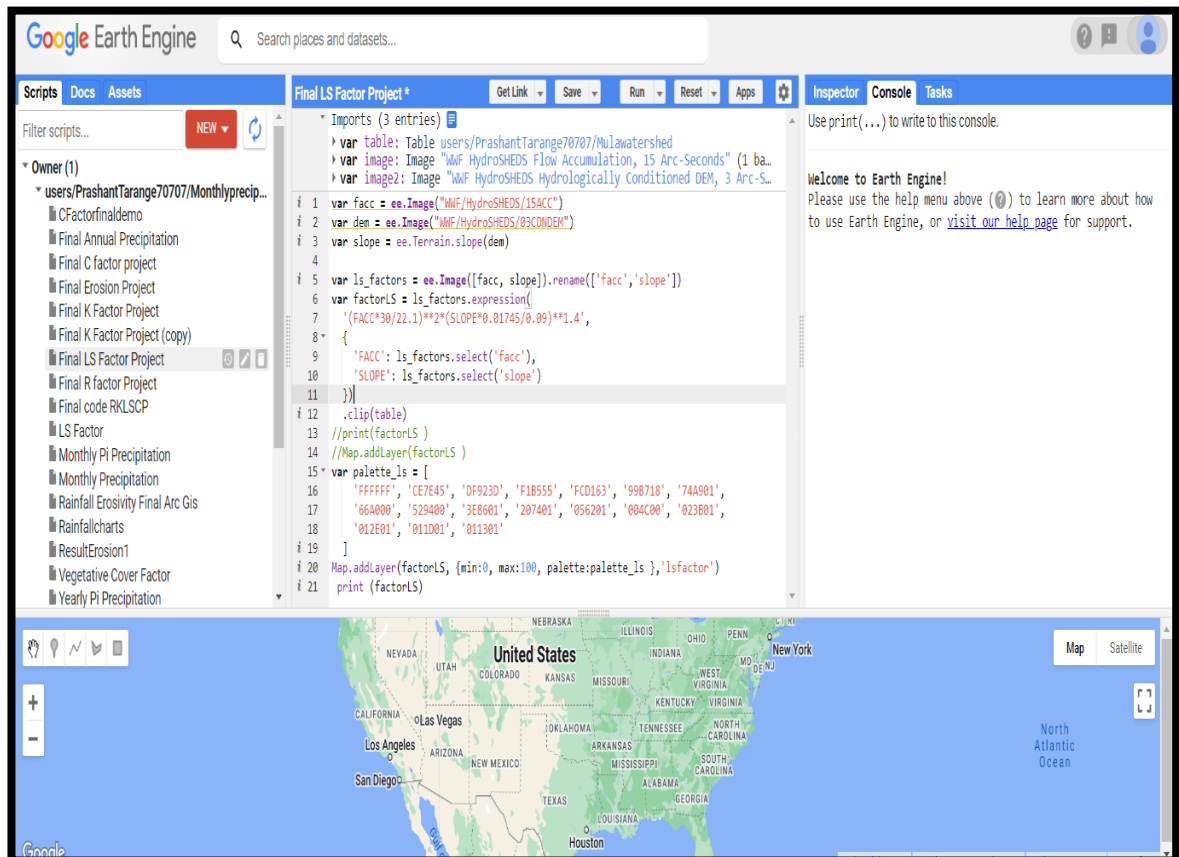


Fig. 3.14 Working screenshot of estimation of LS factor in GEE

3.3.1.4 Vegetative Cover Factor (C):

3.3.1.4.1 Concept of Vegetative Cover Factor (C)

Vegetation can protect the surface soil and slow down the rate of soil erosion. The crop management factor is the ratio of soil loss from cultivated land under certain conditions to soil loss from pure fallow on the same soil and slope under the same rainfall conditions. The cover management factor represents the effect of plants, crop sequence, crop geometry and other cover surface on soil erosion. Cover includes plant canopies, mulches, plant debris or densely growing plants in direct contact with the soil surface. The canopy captures raindrops and if close to the ground, the water running off the leaves has much less energy than raindrops (Wischmeier and Smith, 1978). It also depends on the specific phase of growth and development of the vegetation cover at the time of erosive rains. In addition to these natural causes, other anthropogenic factors leading to soil erosion are overgrazing, deforestation and improper land management.

3.3.1.4.2 Computation of Vegetative Cover Factor (C)

The normalized difference vegetation index (NDVI) is the most commonly used data source for calculation of vegetation cover factor. So, the vegetation cover factor for the study area was calculated by NDVI data. It is often used worldwide to monitor drought and predict agricultural production, assist in predicting hazardous fire zones, and map desert encroachment. NDVI is preferred for global vegetation monitoring because it helps to compensate for changing illumination conditions, surface slope, aspect, and other extraneous factors (Lillesand *et al.* 2004). The equation (5) used for C-factor map was proposed by (Tamene and Le, 2015; Van der Knijff *et al.*, 2000)

$$C = \exp \left[-2.5 \frac{NDVI}{1-NDVI} \right] \quad (5)$$

Where,

C is the cover management factor (dimensionless),

NDVI is the Normalized Difference Vegetation Index (dimensionless).

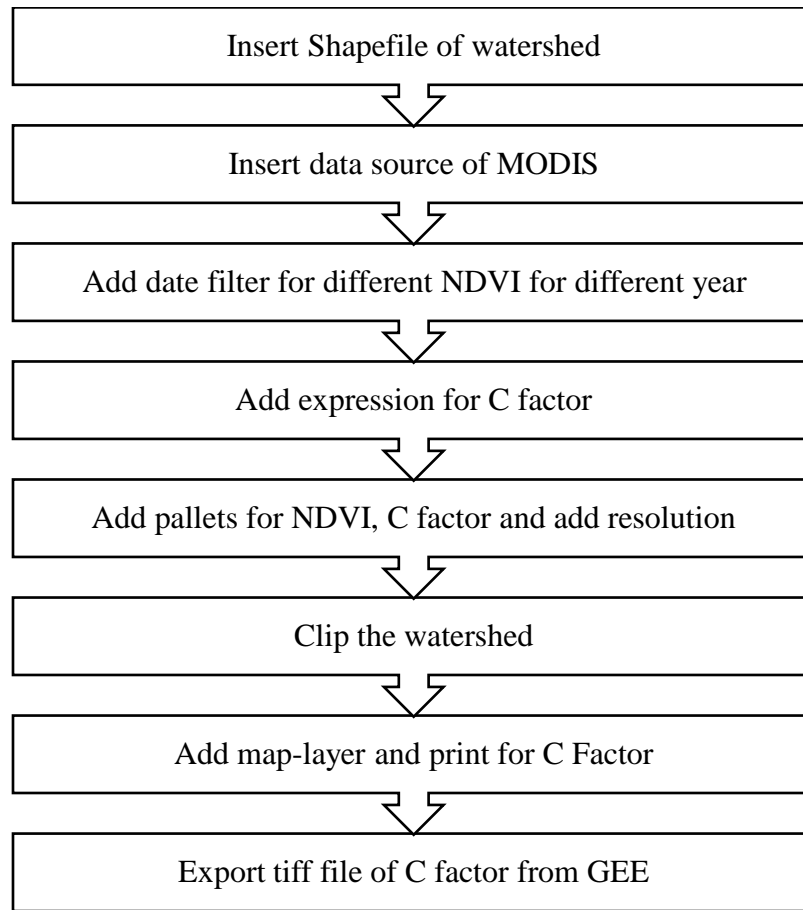


Fig. 3.15 Flow chart of procedure of C Factor in GEE

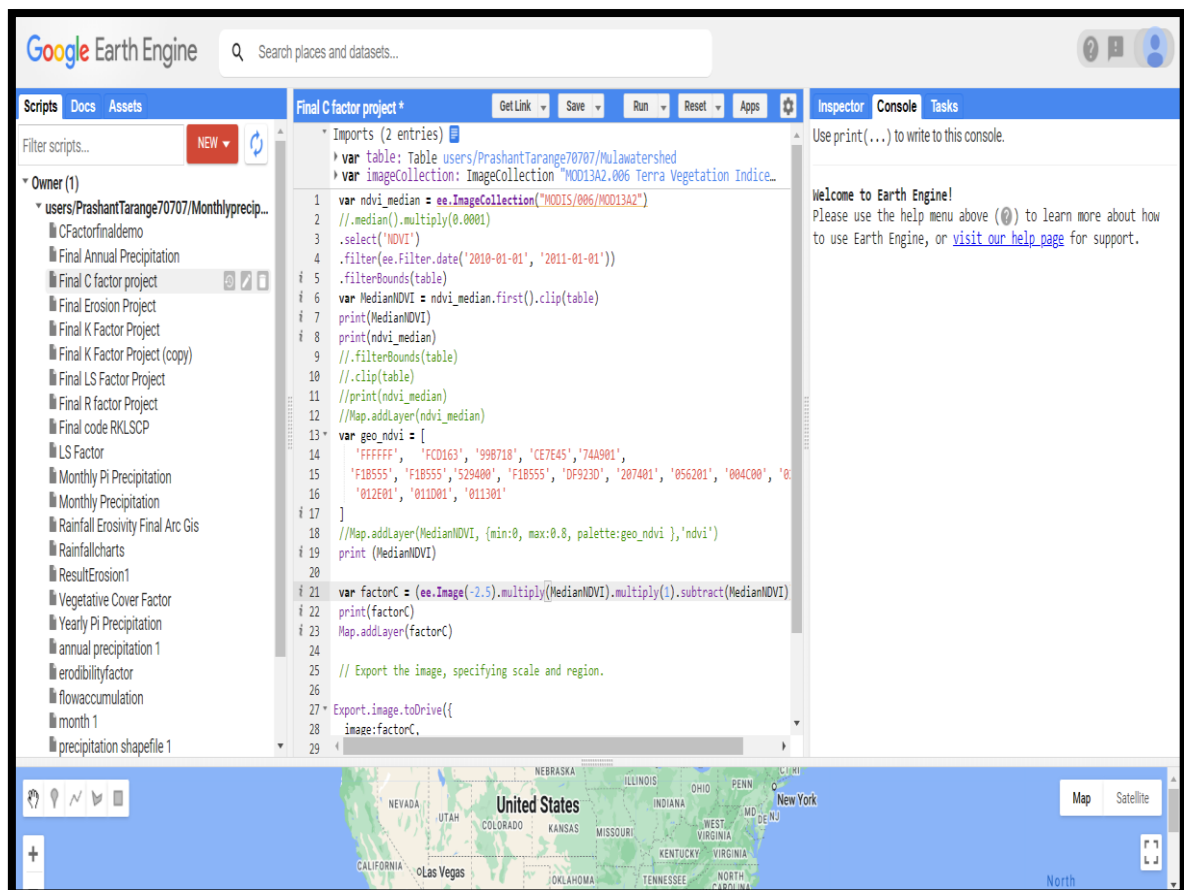


Fig. 3.16 Working screenshot of estimation of C factor in GEE

3.3.1.5 Conservation Measure Factor (P):

The conservation practice factor refers to the percentage of soil loss to planting down the slope before adopting soil and water conservation measures. The p value is ranging between 0 - 1. The highest value represents to areas with no conservation practices (forest/natural vegetation) and decreasing values represents to crop land with conservation measures.

3.3.2 Working in Google Earth Engine

The shapefile of study area was uploaded as assets in Google earth engine (GEE). Also, the map representing the R factors was uploaded as assets in GEE which was calculated by using rainfall data. The remaining factors such as K, LS and C was calculated in GEE by using different data sources available in cloud data source of GEE in java script programming language. The Sentinel-2 collection was filtered using GEE's Integrated Development Environment (IDE) in JavaScript programming language, in order to acquire the least cloudy image. So, the mean value of different input data (e.g., NDVI, elevation, slope, slope length, slope steepness) and erosion parameter (e.g., R, K, LS, C, and P factor) were resulting soil loss rate (A) in the GEE.

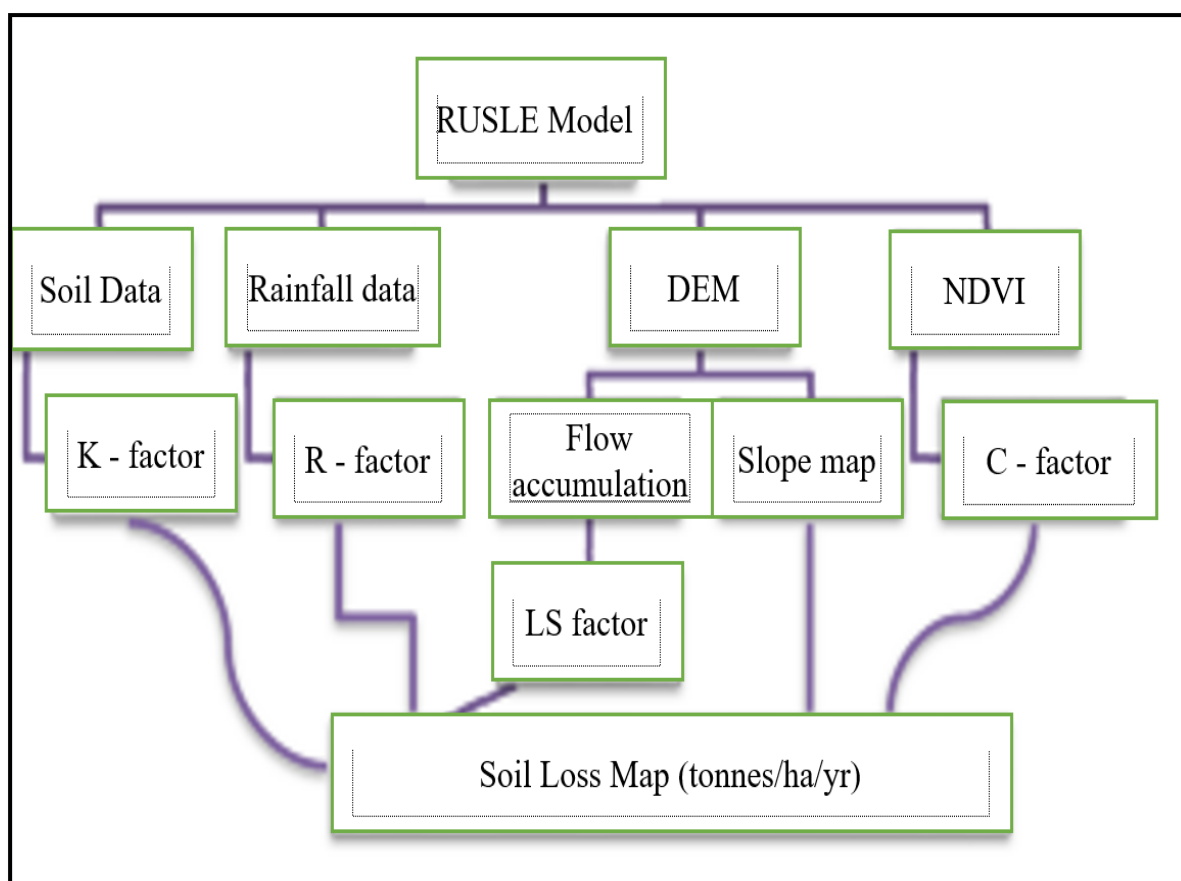


Fig.3.17 Flow chart of methodology in GEE

3.3.3 Determination of temporal change of soil loss in the Mula river basin

The different parameters of RUSLE were calculated in developed model in GEE for determination of soil loss for pentad study. The temporal change in soil loss of study area from 2000 to 2020 was estimated by the developed model in GEE. The temporal change of soil loss was

studied for year 1996-2000, 2001-05, 2006-10, 2011-15 and 2016-20 respectively for Mula river basin.

4.RESULTS AND DISCUSSION

This chapter includes the results of different parameters such as rainfall erosivity factor (R), crop management factor (C) for pentad study (2000 to 2020), soil erodibility factor (K), topographic factor (LS), support conservation practices factor (P) and soil loss using RUSLE for pentad study of Mula river Basin in Google Earth Engine (GEE).

4.1 Soil Erosion Estimation Using RUSLE equation in Google Earth Engine (GEE)

4.1.1 Rainfall Erosivity Factor (R)

The value of rainfall erosivity factor (R) calculated for 1996-2000, 2001-05, 2006-10, 2011-15 and 2016-20 is shown in following table.

Table 4.1 Rainfall Erosivity Factor (R)

Sr. No.	Year	Rainfall erosivity factor (MJ-mm/ha-hr-yr)
1.	1996-2000	448.32 – 737.81
2.	2001-05	310.63 – 1003.78
3.	2006-10	406.48 – 1142.33
4.	2011-15	300.41 – 843.49
5.	2016-20	368.35 – 1151.18

Annual Precipitation data of five tehsils namely Akole, Sangamner, Parner, Ahmednagar and Rahuri were used to generate Rainfall erosivity map. The average pentad erosivity values ranges from 448.32 – 737.81 MJ-mm / ha-hr- yr for year 1996-2000, 310.63 – 1003.78 MJ-mm / ha-hr- yr for year 2001-05, 406.48 – 1142.33 MJ-mm / ha-hr- yr for year 2006-10, 300.41 – 843.49 MJ-mm / ha-hr- yr for year 2011-15, 368.35 – 1151.18 MJ-mm / ha-hr- yr for year 2016-20. The highest and lowest average rainfall erosivity factor was found in Akole tehsil in 2016-20 and Sangamner in 2011-15 because of high intense storms in Akole and low precipitation in Sangamner.

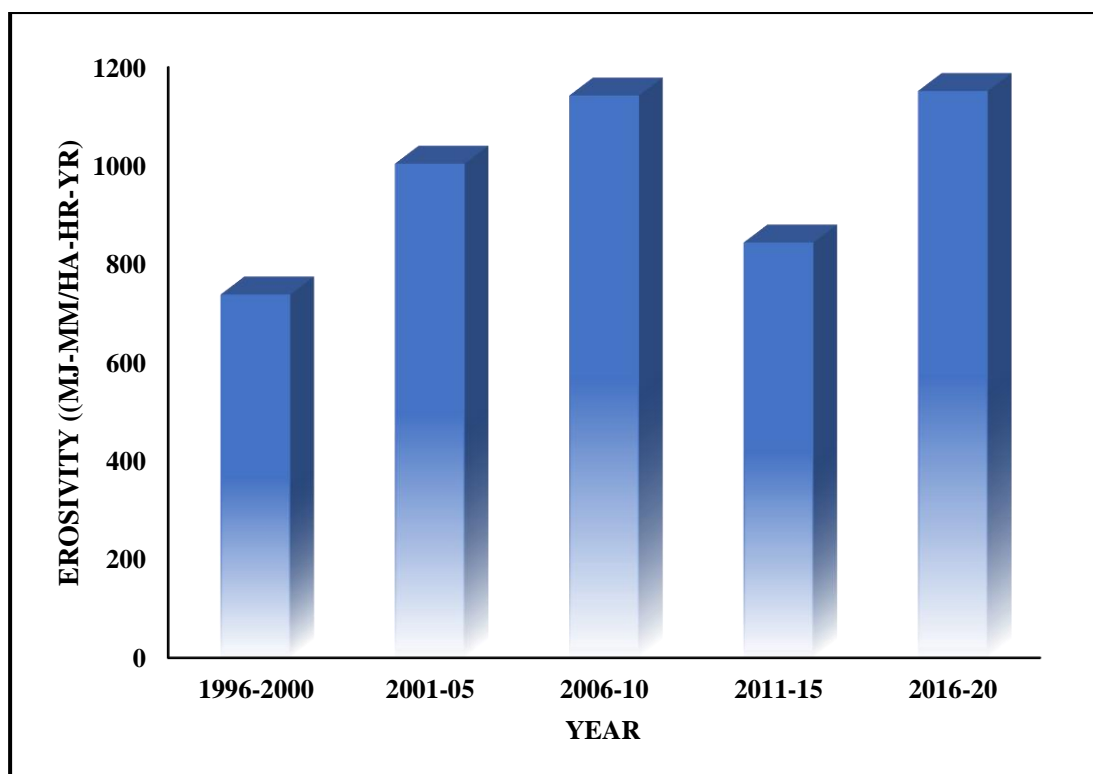


Fig. 4.1 Average rainfall erosivity (R) values of Akole tehsil

Figure 4.1 shows the erosivity of Akole tehsil for pentad research. The average annual rainfall of Akole tehsil is 881.92 mm with average erosivity 975.78 MJ-mm/ha-hr-yr. The highest and lowest average rainfall erosivity were found in year 2016-20 (1151.18 MJ-mm / ha-hr- yr) and 1996-2000 (737.81 MJ-mm / ha-hr- yr) respectively.

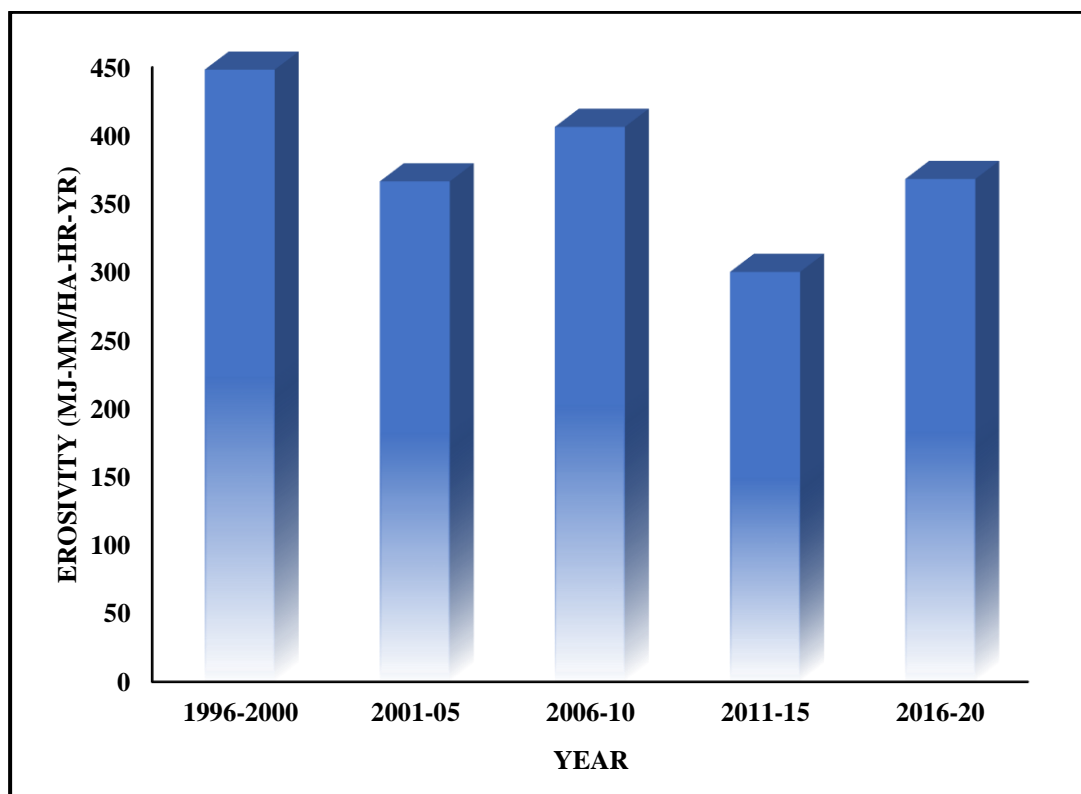


Fig. 4.2 Average rainfall erosivity (R) of Sangamner tehsil

The estimated average erosivity of Sangamner tehsil for pentad study is shown in fig. 4.2. The average rainfall of Sangamner tehsil is 501.30 mm with average rainfall erosivity is 378.03. The highest and lowest erosivity were found in year 1996-2000 (448.32 MJ-mm / ha-hr- yr) and 2011-15 (300.41 MJ-mm / ha-hr- yr) respectively.

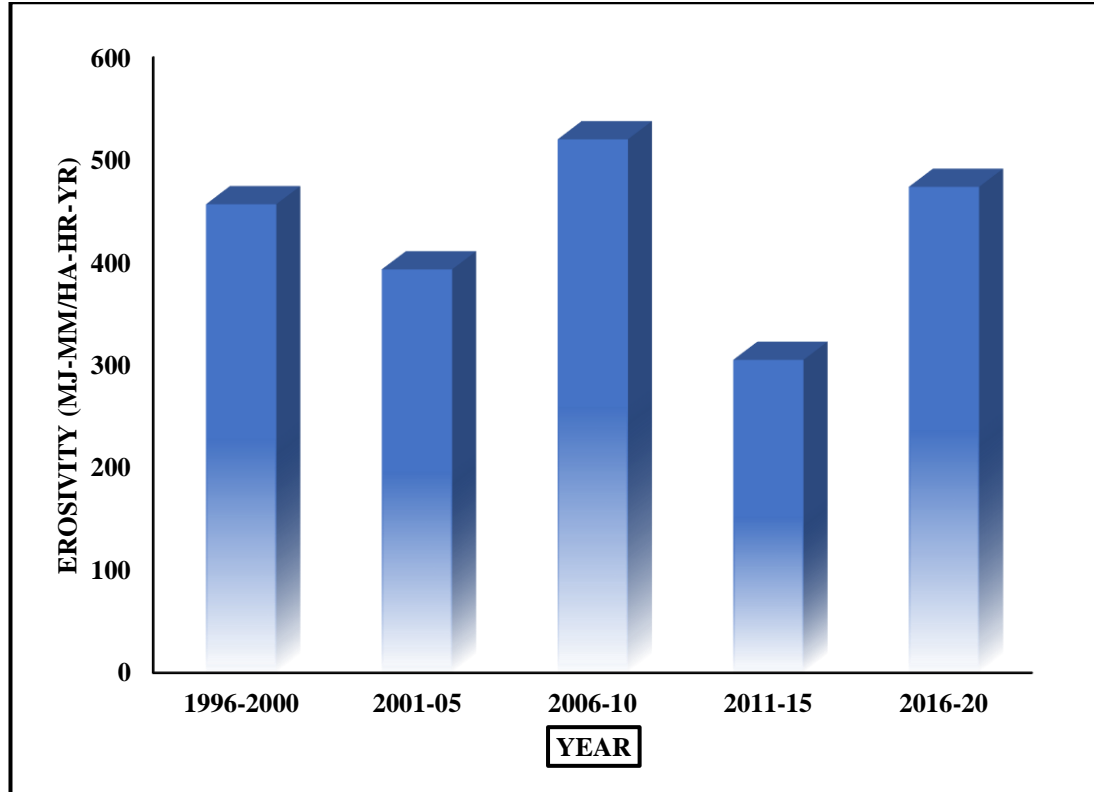


Fig. 4.3 Average rainfall erosivity (R) of Parner tehsil

The average rainfall erosivity of Parner tehsil is not changed by any specific trend as shown in fig.4.3 because low variation in precipitation of Parner thesil. The average rainfall of Parner tehsil is 503.71 mm with average rainfall erosivity 429.83 MJ-mm/ha-hr-yr. The highest and lowest average erosivity were found in year 2006-10 and 2011-15 respectively.

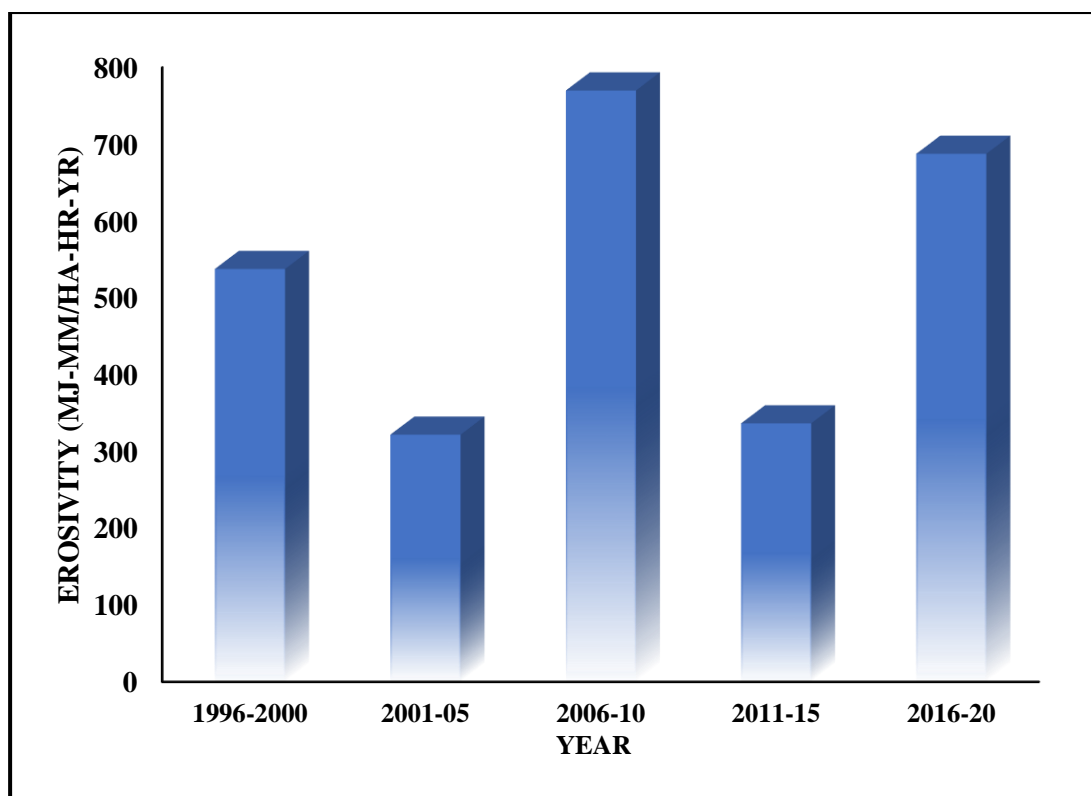


Fig. 4.4 Average rainfall erosivity (R) of Ahmednagar tehsil

There is no specific trend found in rainfall erosivity of Ahmednagar as shown in fig.4.4. The average annual rainfall of tehsil is 555.98 mm with an average annual erosivity 530.81 MJ-mm/ha-hr-yr. The highest and lowest average rainfall erosivity were found in year 2006-10 and 2001-05 respectively.

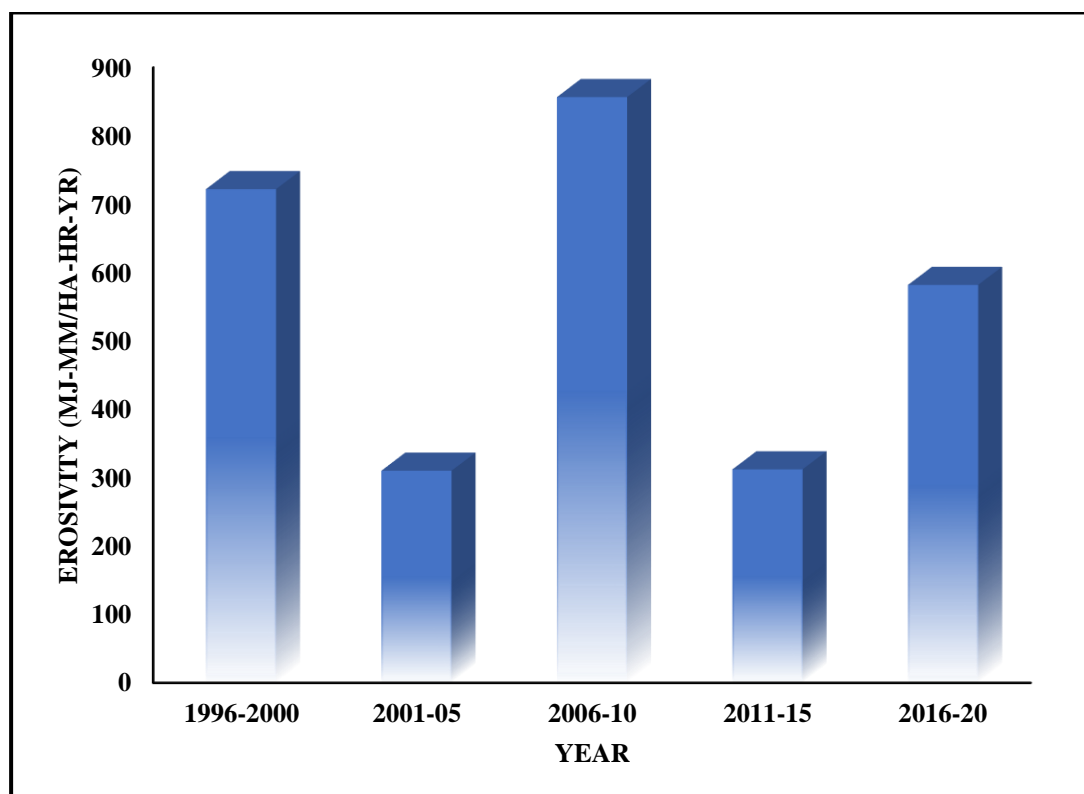


Fig. 4.5 Average rainfall erosivity (R) of Rahuri tehsil

The average rainfall erosivity of Rahuri tehsil has found very less in 2001-05 than 1996-2000 due to very low precipitation as compare to precipitation of 1996-2000 as shown in fig.4.5. The average rainfall of tehsil is 586.37 mm with an erosivity 556.86 MJ-mm/ha-hr-yr. The highest and lowest average erosivity were found in year 1996-2000 and 2001-05 respectively.

4.1.1.1 Spatial distribution of average rainfall erosivity:

Table 4.2 Area under different Rainfall erosivity classes for Mula river basin for year 1996-2000.

Sr. No.	Rainfall erosivity class MJ-mm/ha-hr-yr	Area (Km ²)	Area (%)
1.	300.01-450	16.74	0.65
2.	450.01-600	1848.40	71.92
3.	600.01-750	704.86	27.43
4.	750.01-900	0	0.00
5.	900.01-1050	0	0.00
6.	1050.01-1200	0	0.00

In Figure 4.6, the distribution of calculated rainfall erosivity for the years 1996-2000 is shown. The rainfall erosivity ranges from 448.32 to 737.81 MJ-mm/ha-hr-yr, with an average value of 553.17 MJ-mm/ha-hr-yr. The area under rainfall erosivity classes 300.01-450 MJ-mm/ha-hr-yr, 450.01-600 MJ-mm/ha-hr-yr and 600.01-750 MJ-mm/ha-hr-yr have been found 16.74 km² (0.65%), 1848.40 km² (71.92.96%) and 704.86 km² (27.43%).

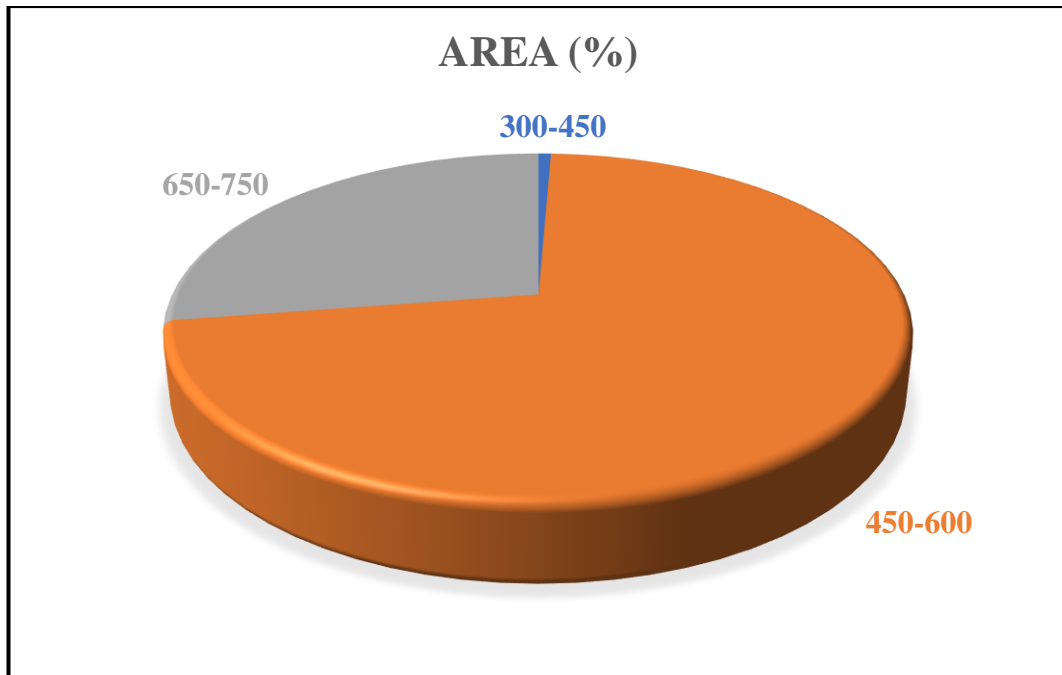


Fig. 4.6 Area distribution under Rainfall erosivity for mula river basin for year 96-2000

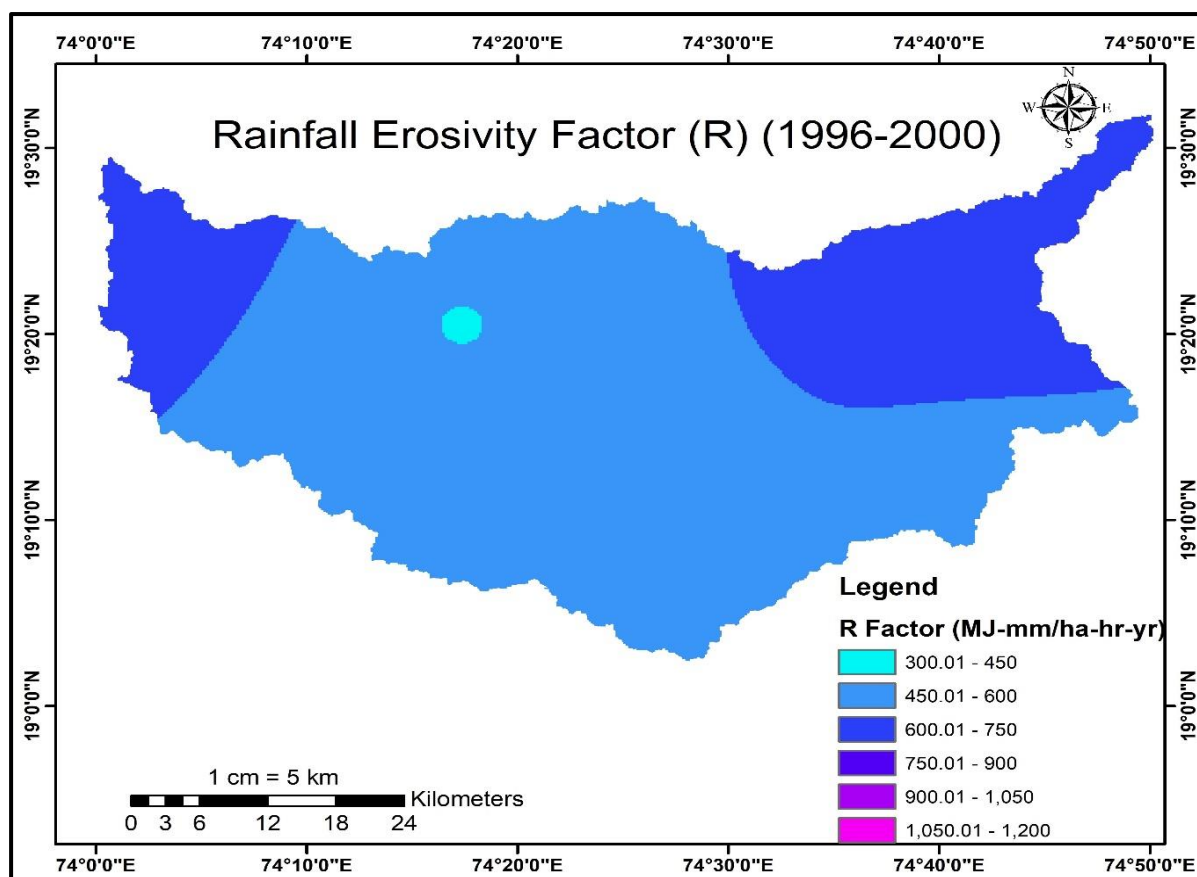


Fig. 4.7 Average Rainfall Erosivity Map for Mula River Basin for year 1996-2000

Table 4.3 Area under different Rainfall erosivity classes for Mula river basin for year 2001-05.

Sr. No.	Rainfall erosivity class	Area (Km ²)	Area (%)
1.	300.01-450	1847.72	71.90
2.	450.01-600	332.44	12.94
3.	600.01-750	209.22	8.14
4.	750.01-900	132.39	5.15
5.	900.01-1050	48.23	1.88
6.	1050.01-1200	0	0.00

In Figure 4.8, the distribution of the computed average rainfall erosivity for the year 2001-05 is given. The rainfall erosivity ranges from 310.63 to 1003.78 MJ-mm/ha-hr-yr with an average rainfall erosivity value 428.50 MJ-mm/ha-hr-yr. The area under rainfall erosivity class 300.01-450 MJ-mm/ha-hr-yr was found 1847.72 km² (71.90 %) which is increased by 1830.98 km² from an area of year 1996-2000. For class 450.01-600 MJ-mm/ha-hr-yr area was found 332.44 km² (12.94 %) decreased by 1515.96 km² area of year 1996-2000 under this class. The area under 600.01-750 MJ-mm/ha-hr-yr class was found 209.22 km² (8.14%) decreased by 495.64 km², for 750.01-900 MJ-mm/ha-hr-yr 132.39 km² (5.15%) and 900.01-1050 MJ-mm/ha-hr-yr 48.23 (1.88 %).

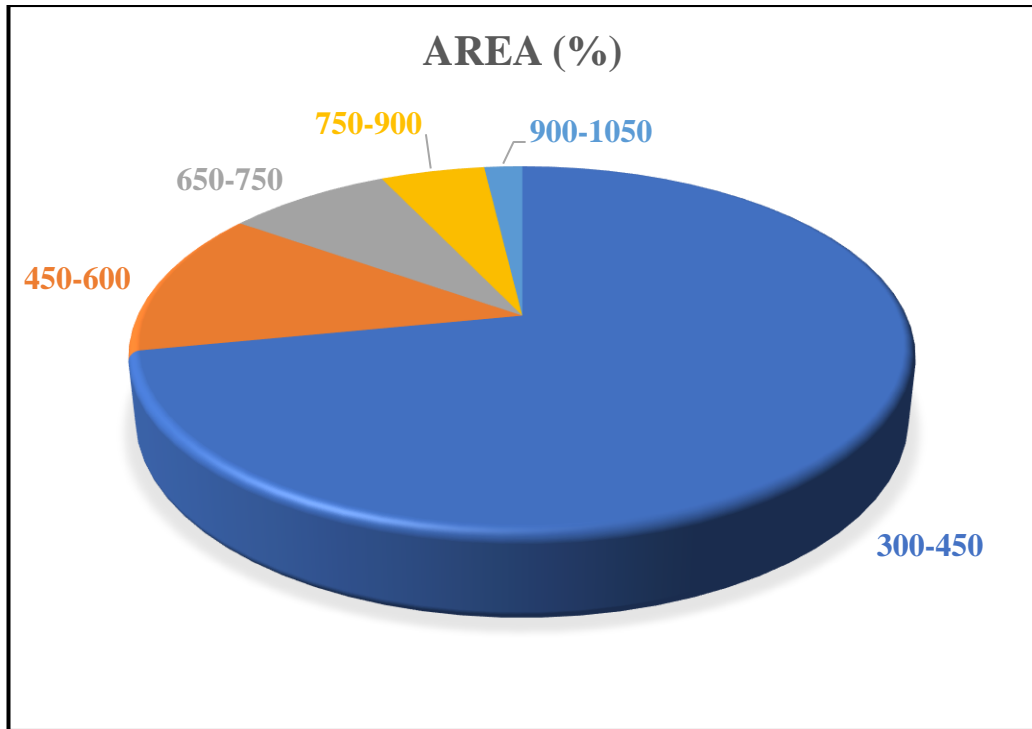


Fig. 4.8 Area distribution under Rainfall erosivity for mula river basin for year 2001- 05

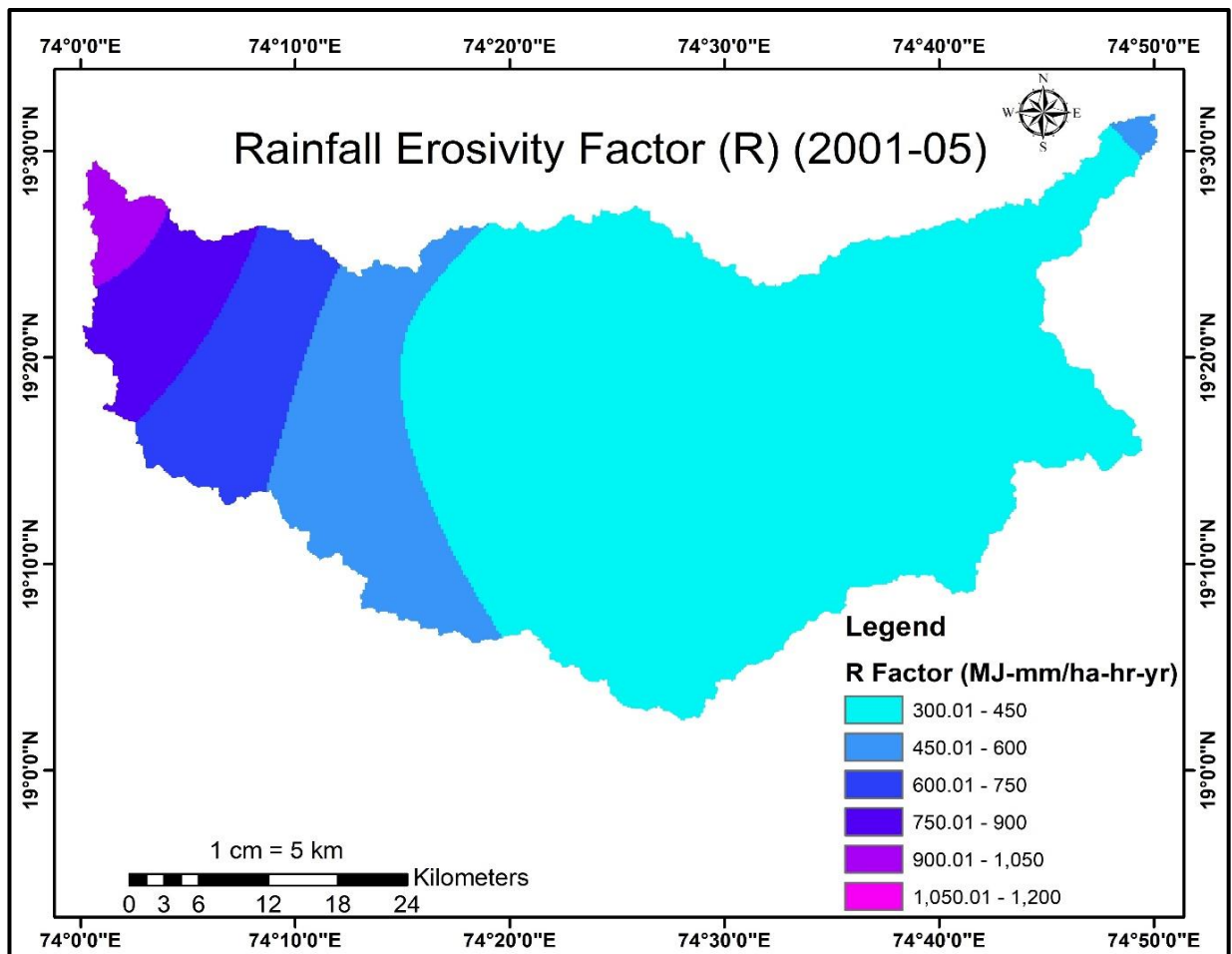


Fig. 4.9 Rainfall Erosivity Map for Mula River Basin for year 2001-05

Table 4.4 Area under different Rainfall erosivity classes for Mula river basin for year 2006-10.

Sr. No.	Rainfall erosivity class	Area (Km ²)	Area (%)
1.	300.01-450	1013.04	39.42
2.	450.01-600	669.09	26.03
3.	600.01-750	727.42	28.30
4.	750.01-900	104.56	4.07
5.	900.01-1050	36.02	1.40
6.	1050.01-1200	19.87	0.77

In Figure 4.10, geographical distribution of the computed average rainfall erosivity for the year 2006-10 is given. The rainfall erosivity ranges from 406.48 to 1142.33 MJ-mm/ha-hr-yr with the average rainfall erosivity value 671.53 MJ-mm/ha-hr-yr. The area under rainfall erosivity class 300.01-450 MJ-mm/ha-hr-yr was found 1013.04 km² (39.42%) which is decreased by 834.68 km² from an area of year 2001-05. For class 450.01-600 MJ-mm/ha-hr-yr class area was found 669.09 km² (26.03%) increased by 336.65 km² as compare to year 2001-05 under this class. The area under 600.01-750 MJ-mm/ha-hr-yr class was found 727.42 km² (28.30 %) increased by 518.20 km², 750.01-900 MJ-mm/ha-hr-yr 104.56 km² (4.07%) decreased by 27.83 km², 900-1050 MJ-mm/ha-hr-yr class 36.02 km² (1.40%) and 1050-1200 MJ-mm/ha-hr-yr 19.87 km² (0.77%).

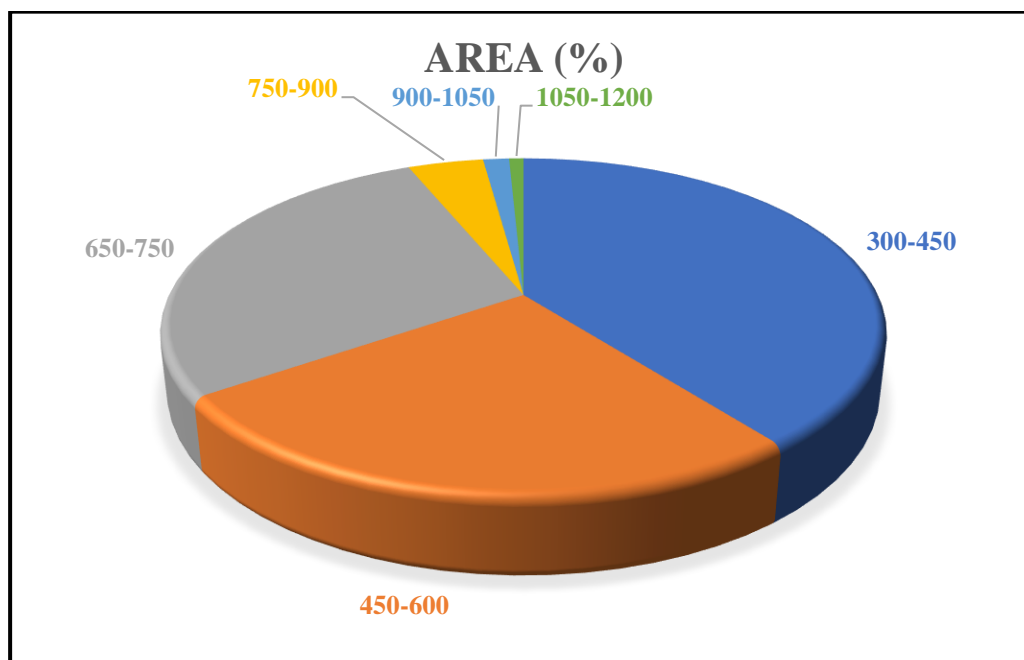


Fig. 4.10 Area distribution under Rainfall erosivity for mula river basin for 2006- 10

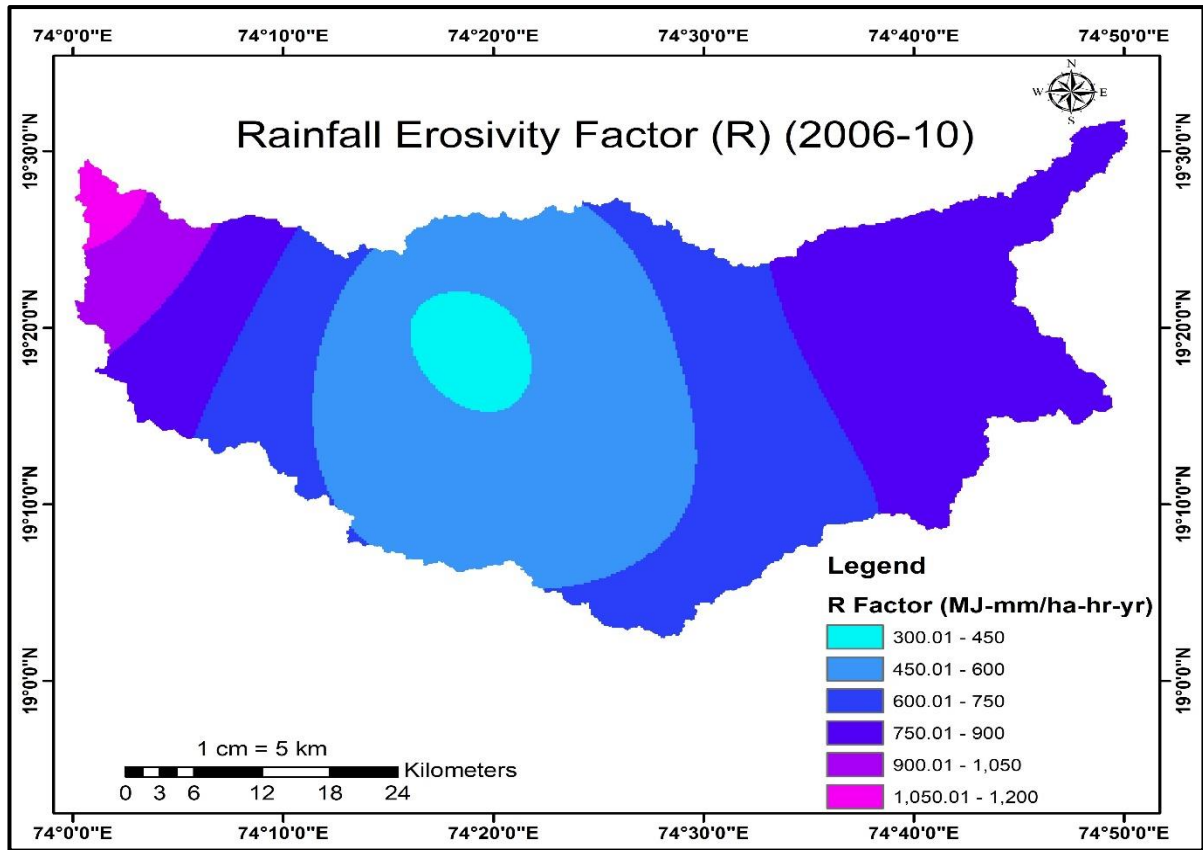


Fig. 4.11 Rainfall Erosivity Map for Mula River Basin for year 2006-10

Table 4.5 Area under different Rainfall erosivity classes for Mula river basin for year 2011-15.

Sr. No.	Rainfall erosivity class	Area (Km ²)	Area (%)
1.	300.01-450	1573.26	61.22
2.	450.01-600	645.13	25.10
3.	600.01-750	223.35	8.69
4.	750.01-900	128.26	4.99
5.	900.01-1050	0	0.00
6.	1050.01-1200	0	0.00

In figure 4.12, the distribution of the computed average rainfall erosivity for the year 2011-15 is given. The range of the average rainfall erosivity varies from 300.41 to 843.49 MJ-mm/ha-hr-yr with the average rainfall erosivity value 389.29 MJ-mm/ha-hr-yr. The area under rainfall erosivity class 300.01-450 MJ-mm/ha-hr-yr was found 1573.26 km² (61.22%) which is increased by 560.22 km² from year 2011-15. For erosivity class 450.01-600 MJ-mm/ha-hr-yr area was found 645.13 km² (25.10%) decreased by 23.96 km² than year 2006-10. The area under 600.01-750 MJ-mm/ha-hr-yr class is 223.35 km² (8.69%) decreased by 504.07 km², 750.01-900 MJ-mm/ha-hr-yr 128.26 km² (4.99%) decreased by 23.60 km² than year 2006-10.

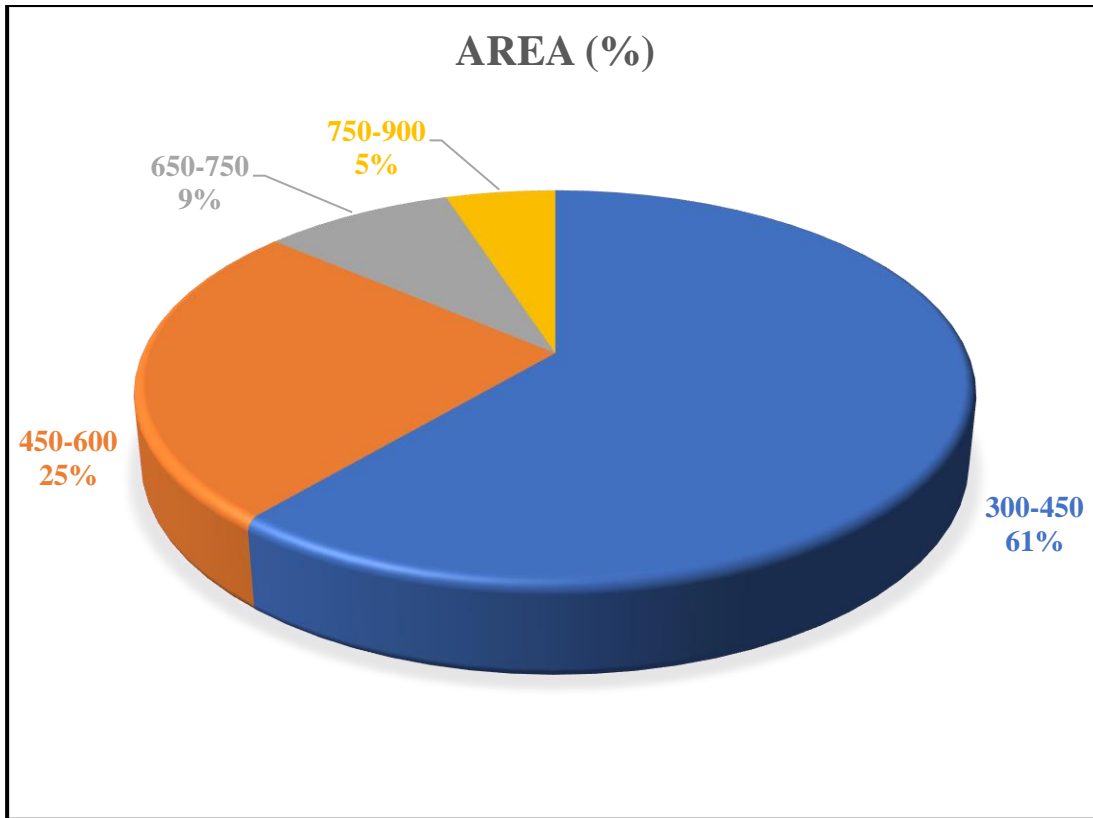


Fig. 4.12 Area distribution under Rainfall erosivity for mula river basin for 2011- 15

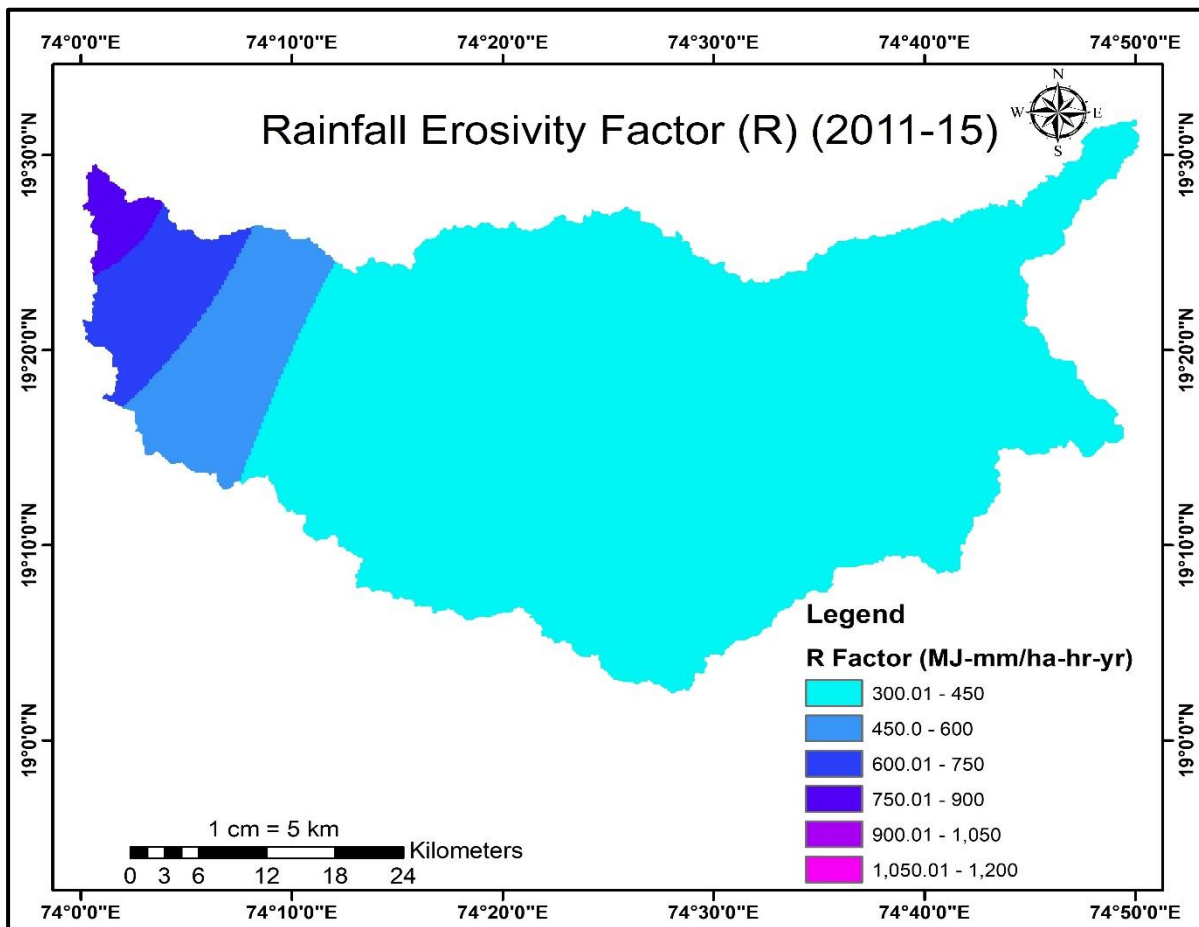


Fig. 4.13 Rainfall Erosivity Map for Mula River Basin for year 2011-15

Table 4.6 Area under different Rainfall erosivity classes for Mula river basin for year 2016-20.

Sr. No.	Rainfall erosivity class	Area (Km ²)	Area (%)
1.	300.01-450	1439.89	56.03
2.	450.01-600	726.18	28.26
3.	600.01-750	163.11	6.35
4.	750.01-900	123.56	4.81
5.	900.01-1050	79.08	3.08
6.	1050.01-1200	38.18	1.49

In figure 4.14, the distribution of the computed average rainfall erosivity for the year 2016-20 is given. The range of the average rainfall erosivity varies from 368.35 to 1151.18 MJ-mm/ha-hr-yr with the average rainfall erosivity value 582.82 MJ-mm/ha-hr-yr. The area under rainfall erosivity class 300.01-450 MJ-mm/ha-hr-yr was found 1439.89 km² (56.03%) decreased by 133.37 km² as compare to year 2011-15. For class 450.01-600 MJ-mm/ha-hr-yr area found 726.18 km² (28.26%) increased by 81.05 km², 600.01-750 MJ-mm/ha-hr-yr class has 163.11 km² (6.35%) decreased by 60.24 km², 750.01-900 MJ-mm/ha-hr-yr 123.56 km² (4.81%) decreased by 4.7 km², 900-1050 MJ-mm/ha-hr-yr class 79.09 km² (3.08%) and 1050-1200 MJ-mm/ha-hr-yr class was found 35.18 km² (1.49%).

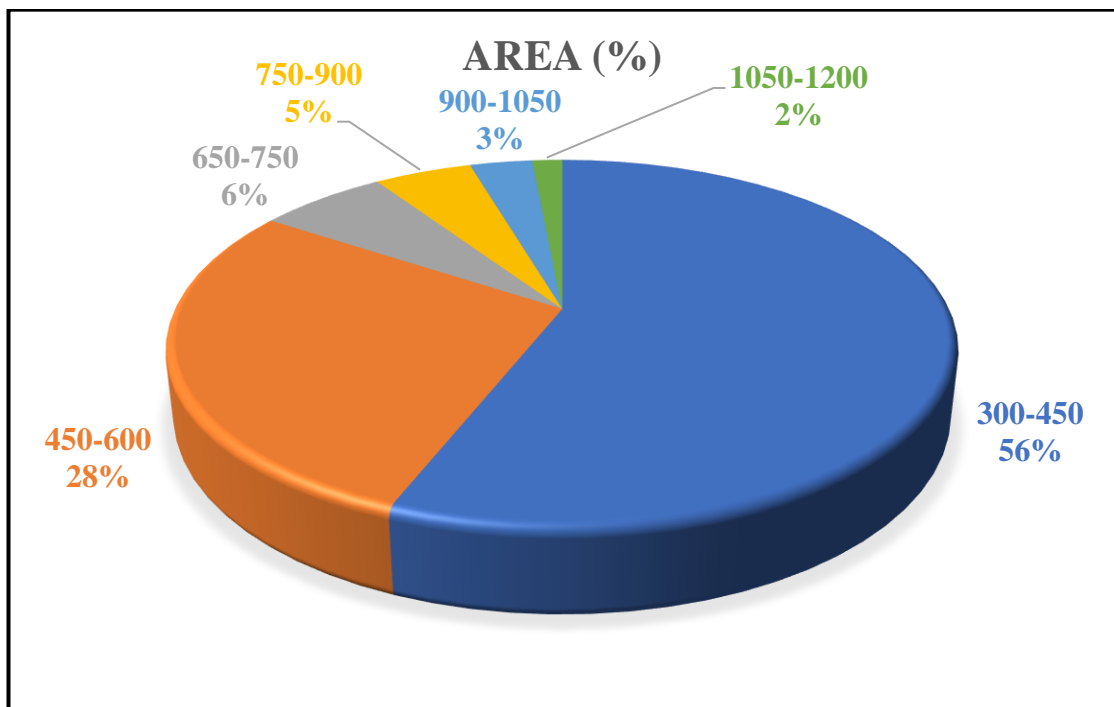


Fig. 4.14 Area distribution under Rainfall erosivity for mula river basin for 2016-20

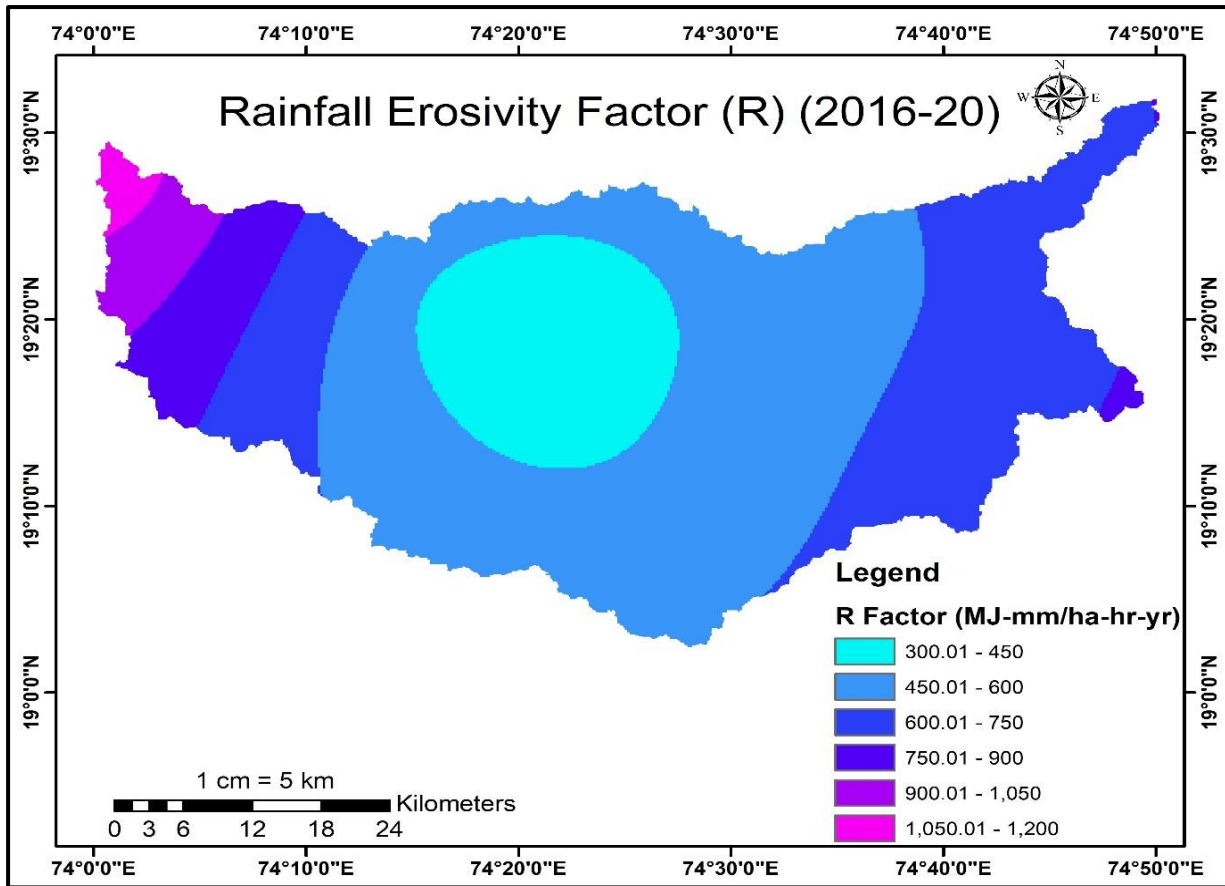


Fig. 4.15 Rainfall Erosivity Map for Mula River Basin for year 2016-20

4.1.2 Soil erodibility factor (K)

Sand, silt, clay, and organic matter content data were used to evaluate the Mula river basin's soil erodibility factor (K) map. The value of soil erodibility factor was computed for Mula river basin by using google earth engine (GEE). The weighted soil erodibility factor value for study area ranging between 0.0251 to 0.0388 tonnes-ha-hr/ha-MJ-mm. The average value of soil erodibility factor was 0.0311 tonnes-ha-hr/ha-MJ-mm. The soil types found in Mula river basin are sandy clay loam and clay loam by using open land data source (according to USDA soil texture triangle).

Soil erodibility factor (K) map for Mula river basin is shown in Fig. 4.16.

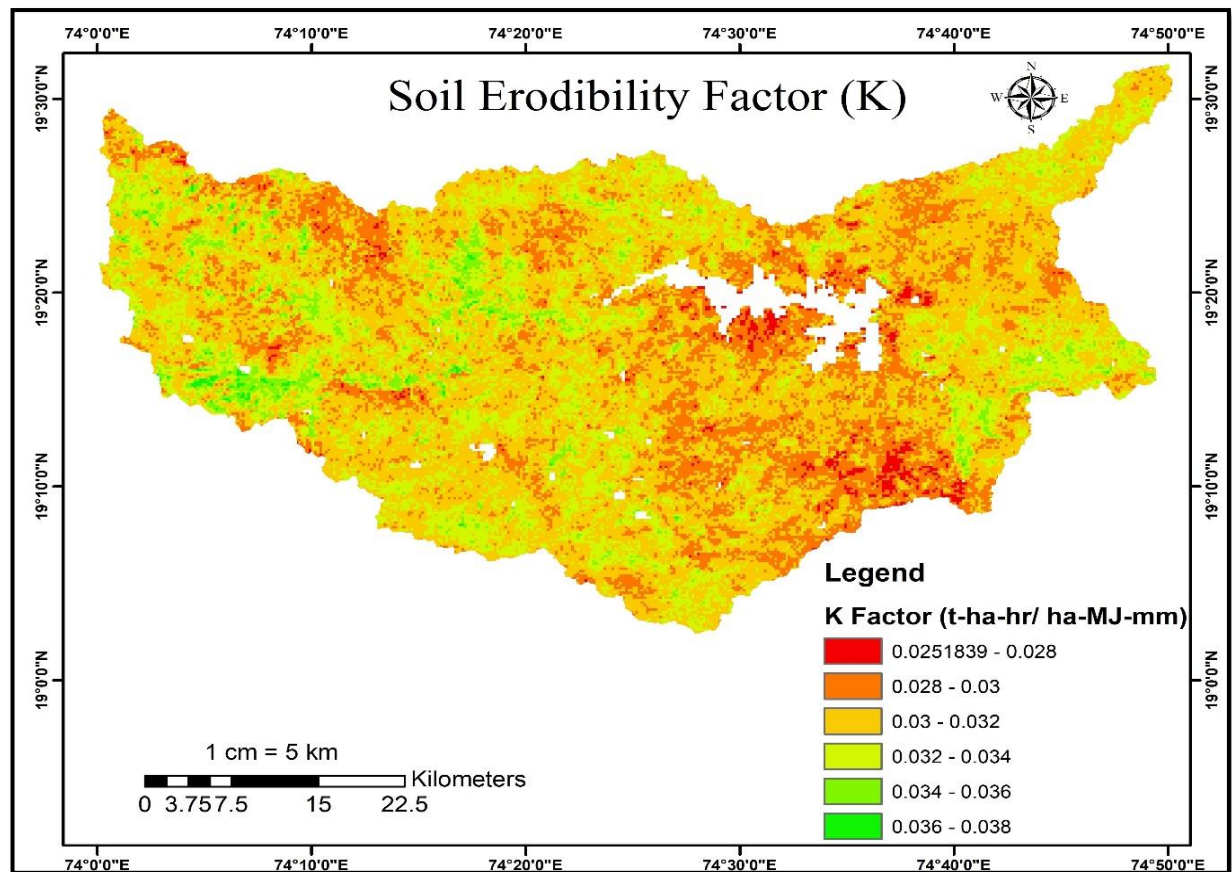


Fig. 4.16 Soil Erodibility Factor Map for Mula river basin (k)

4.1.3 Topographic Factor (LS)

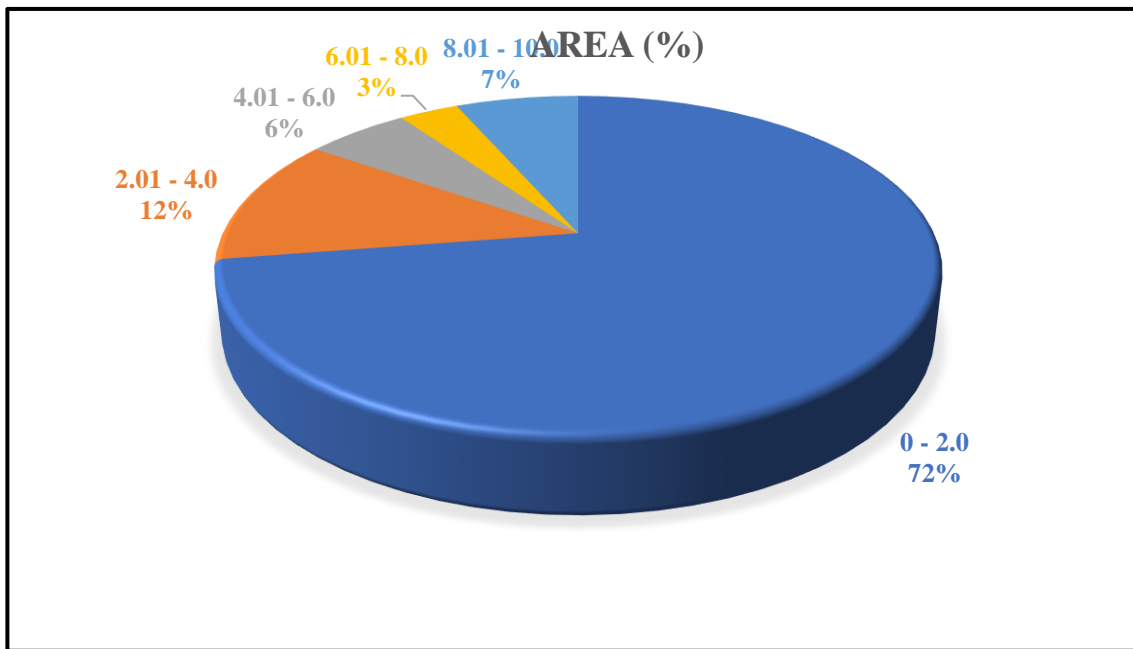
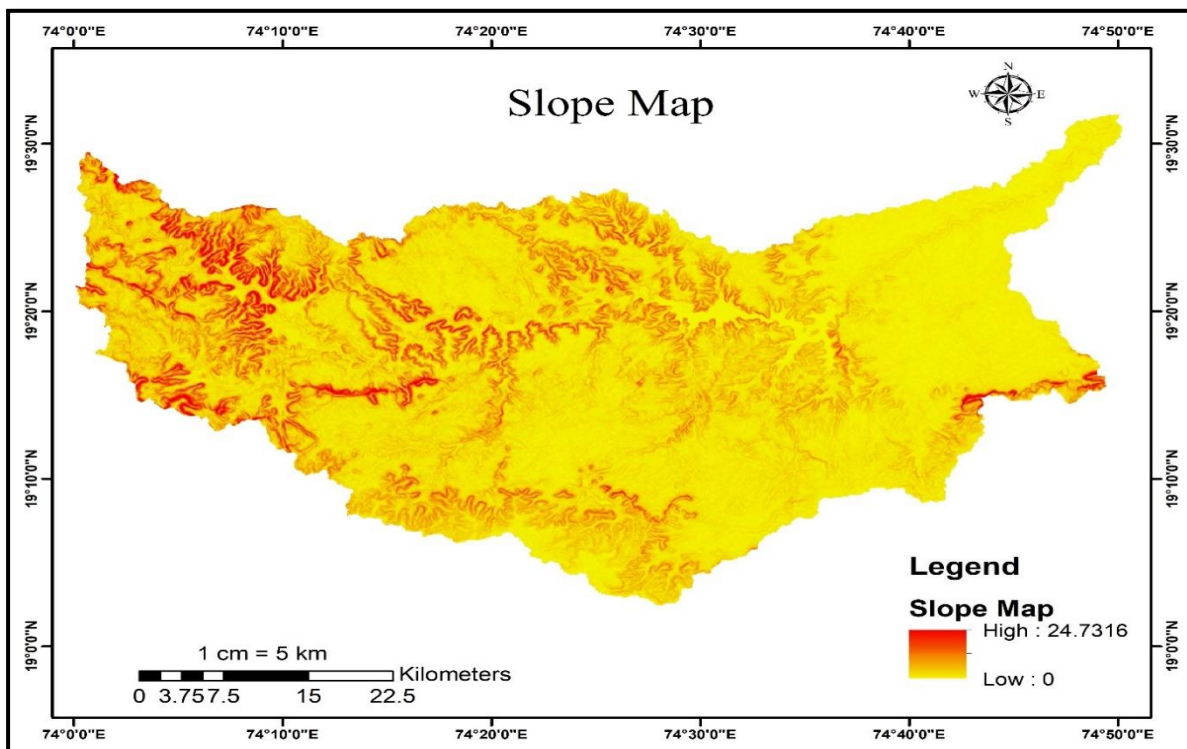
Hydro-SHED DEM of the mula river basin was used to create a slope map and Hydro-SHEDS Accumulation is used for flow accumulation map in google earth engine. A topographic factors (LS) map is created by combining a slope map and a flow accumulation map. While deriving topographic factors, GEE techniques predict very high slope at starting point of study area due to hilly region. The slope of the Mula river basin ranges from 0 to 24.7316, as illustrated in fig. 4.18. The majority part of the Mula river basin's downstream slope is mild. So, the LS factor values in the Mula river basin were not very high. The lowest LS values were found near the watershed's centre, which correlates to low elevation areas and the stream bed. Thus, the basin is subject to a high risk of erosion at upstream side and low risk of erosion at downstream side.

The study area was classified in six slope classes 1) nearly level (0 – 3%), 2) gentle (3-5%), 3) modarately gentle (5-10%), 4) steep (10-15%) 5) modarately steep (15-20%) and 6) very steep (>20%).

The coverage of the topographic factor is shown in the table.4.7. The topographic factor (LS) values for the watershed ranges from 0 to 9.9524 shown in the fig. 4.19. The larger area of the Mula basin is covered by the LS factor which was ranges from 0 to 2 (72.53%), 2.01 to 4 (12.13%), 4.01 to 6 (5.55%), 6.01 to 8 (3.18%) and 8.01 to 10 (6.58%). The lowest part of the mula river basin found covered by the topographic factor in the range of 6.01 and 8 (3.18%).

Table 4.7 Spatial coverage of topographic factor (LS)

Sr. No	Class	Area (km ²)	Area (%)
1.	0 – 2.0	1864.49	72.53
2.	2.01-4.0	312.00	12.13
3.	4.01-6.0	142.85	5.55
4.	6.01-8.0	81.88	3.18
5.	8.01-10.0	169.32	6.58

**Fig. 4.17 Area distribution for Topographic factor (LS) for mula river basin****Fig. 4.18 Slope Map of Mula river basin**

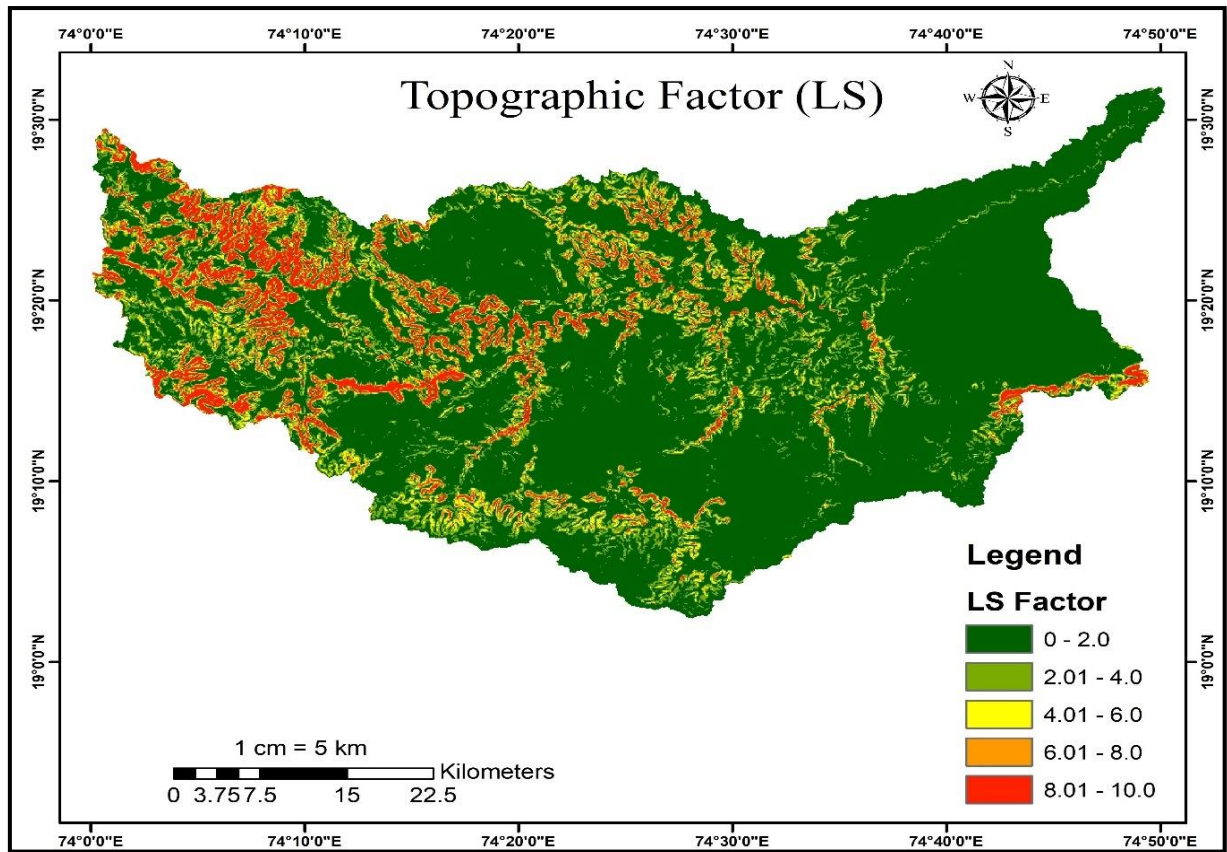


Fig. 4.19 Topographic Factor (LS) of Mula river basin

4.1.4 Vegetative Cover Factor (C)

The spatial distribution of vegetative cover factor (C) of Mula river basin is generated from the Normalized Difference Vegetation Index (NDVI) map, under Google Earth Engine software. The NDVI map of Mula basin is created using MOD13A2.006 Terra Vegetation Index's 16-day global 1 km data source available on GEE. Average vegetative cover factor values in the Mula basin ranges from 0.0104 – 0.2894 for year 1996-2000, 0.0037 – 0.2735 for year 2001-05, 0.0092 – 0.2933 for year 2006-10, 0.0097 – 0.2796 for year 2011-15, 0.0167 – 0.2832 for year 2016-20. The average values of vegetative cover factor (C) for pentad study are 0.1667, 0.1315, 0.1525, 0.1474 and 0.1531 respectively. The average value of vegetative cover factor is changed slightly in pentad study from 2000-2020 due to low conservation practices adopted in Mula river basin.

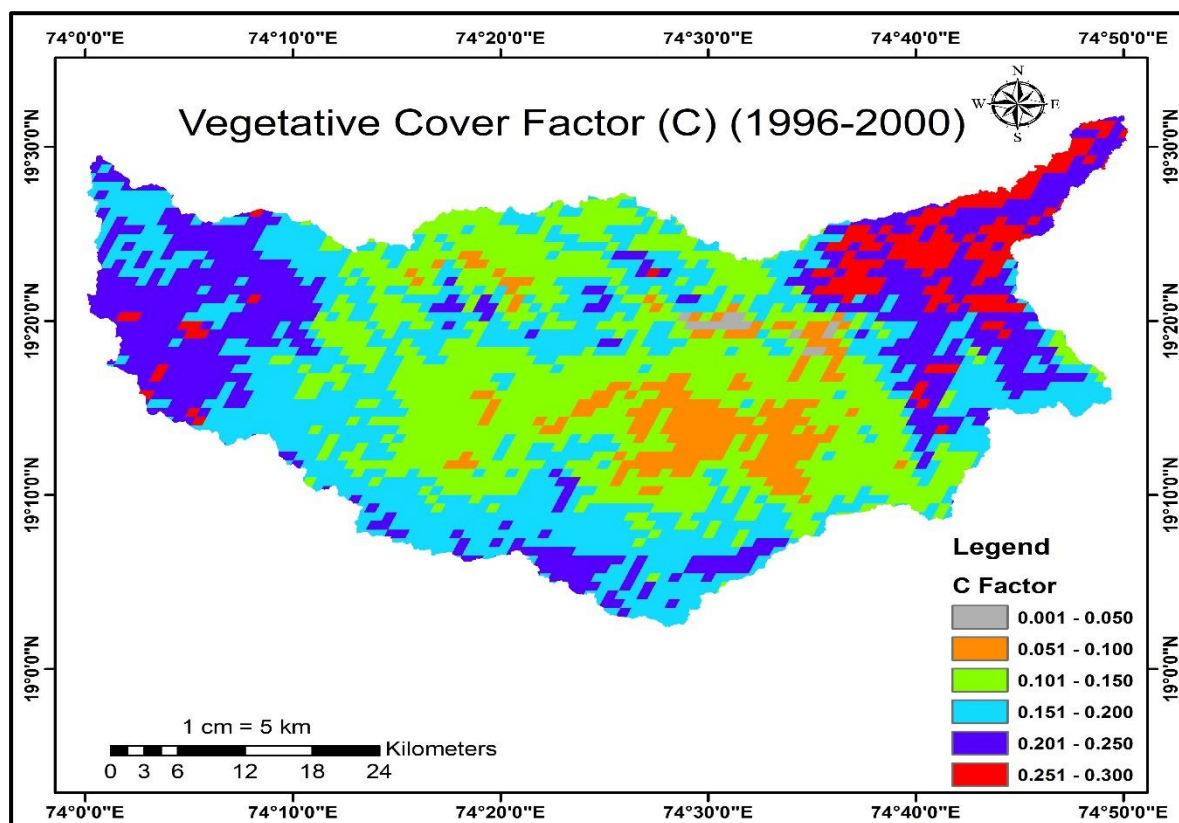
Crop management factor values were greater on the watershed's downstream side. This is because of larger amount of watershed is covered by agriculture sector on downstream side of Mula basin. Crop management factor values are low on the upstream and middle of the watershed, where there is hilly terrain and permanent pastures.

Table 4.8 Vegetative Cover Factor (C) of Mula River Basin for Pentad study.

Sr. No.	Year	Cover Management Factor (C)
1.	1996-2000	0.0104 – 0.2894
2.	2001-05	0.0037 – 0.2735
3.	2006-10	0.0092 – 0.2933
4.	2011-15	0.0097 – 0.2796
5.	2016-20	0.0167 – 0.2832

Average Vegetative Cover Factor (C) Map of Mula River Basin for year 1996-2000:

The average highest and lowest values of cover management factor are found in east side and middle side of study area in year 1996-2000 as illustrated in figure. 4.20. The highest and lowest values of vegetative cover factor (C) of Mula river basin are 0.2894 and 0.0104. The average value of vegetative cover factor (C) factor is 0.1667.

**Fig. 4.20 Average Vegetative Cover Factor (C) of Mula River Basin for year 1996-2000**

Average Vegetative Cover Factor (C) Map of Mula River Basin for year 2001-05:

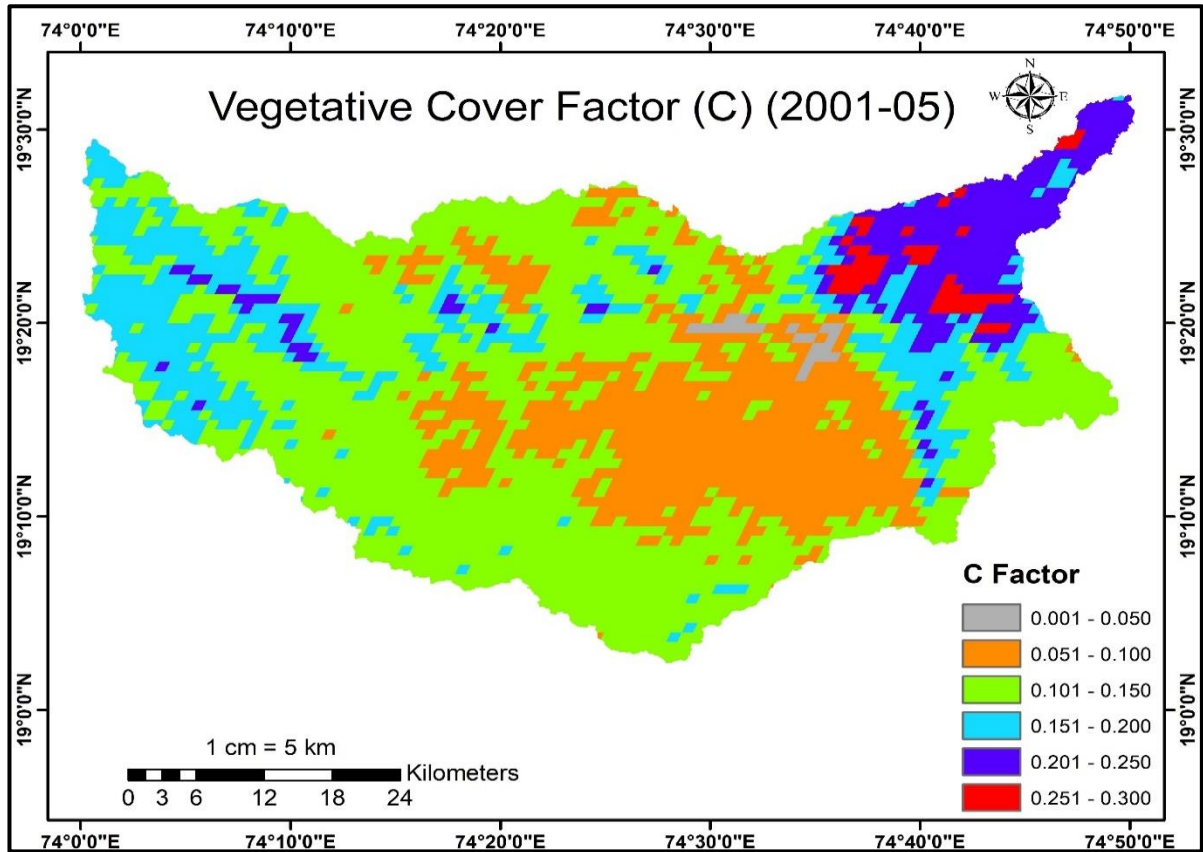


Fig. 4.21 Average Vegetative Cover Factor (C) of Mula River Basin for year 2001-05

The highest and lowest value of cover management factor is found in east side and middle side of study area in 2001-05 as illustrated in figure. 4.21. The average highest and lowest values of vegetative cover factor (C) of Mula river basin are 0.2735 and 0.0037. The average value of vegetative cover factor (C) is 0.1315.

Average Vegetative Cover Factor (C) Map of Mula River Basin for year 2006-10:

The average estimated value of vegetative cover factor (C) for year 2006-10 is 0.1525. The average highest and lowest values are 0.2933 and 0.0092. The highest value has been found in north-east side of basin as illustrated in fig. 4.22.

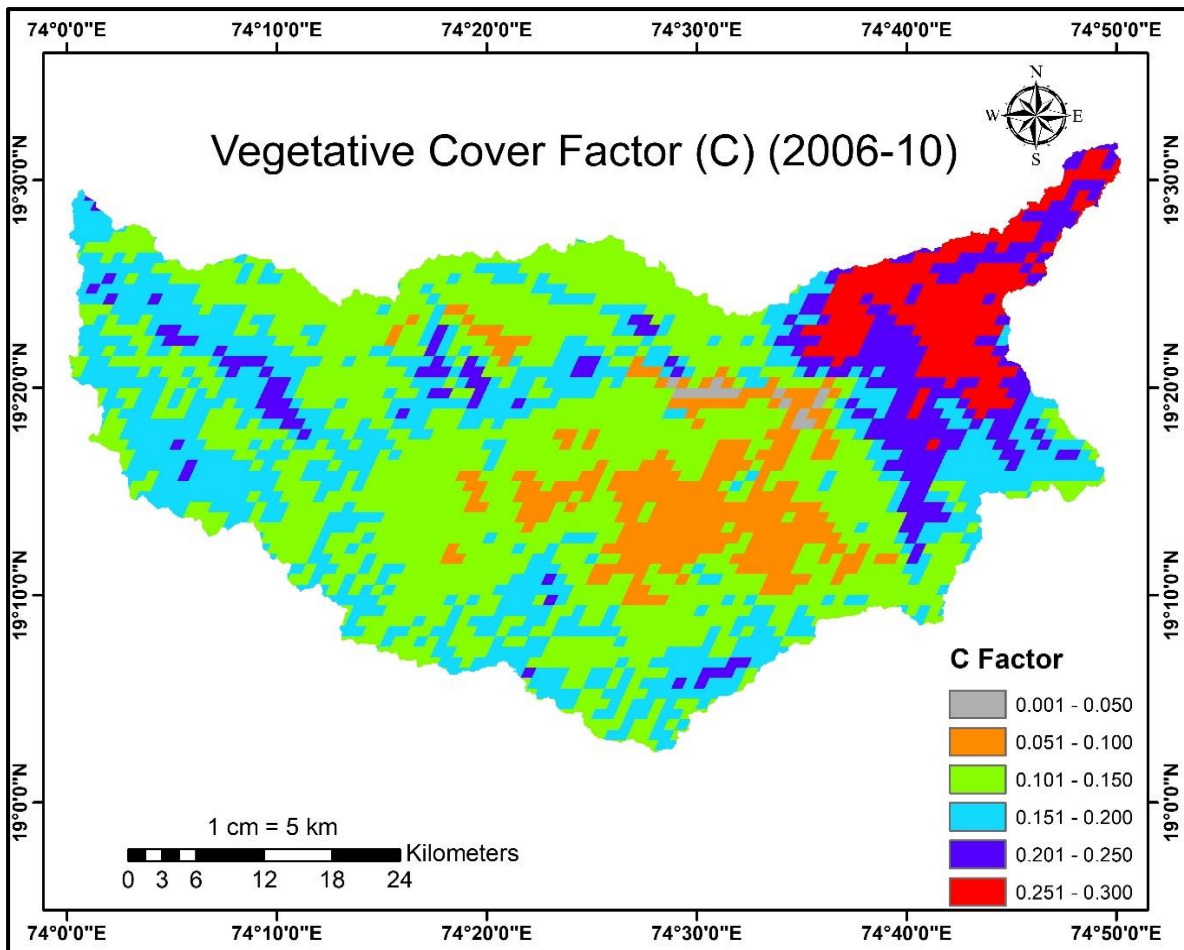


Fig. 4.22 Average Vegetative Cover Factor (C) of Mula River Basin for year 2006-10

Average Vegetative Cover Factor (C) Map of Mula River Basin for year 2011-15:

The average value of vegetative cover factor (C) for year 2011-15 estimated is 0.1474. The average highest and lowest values are 0.2796 and 0.0097. The highest and lowest value are found in east side and middle of watershed shown in figure. 4.23.

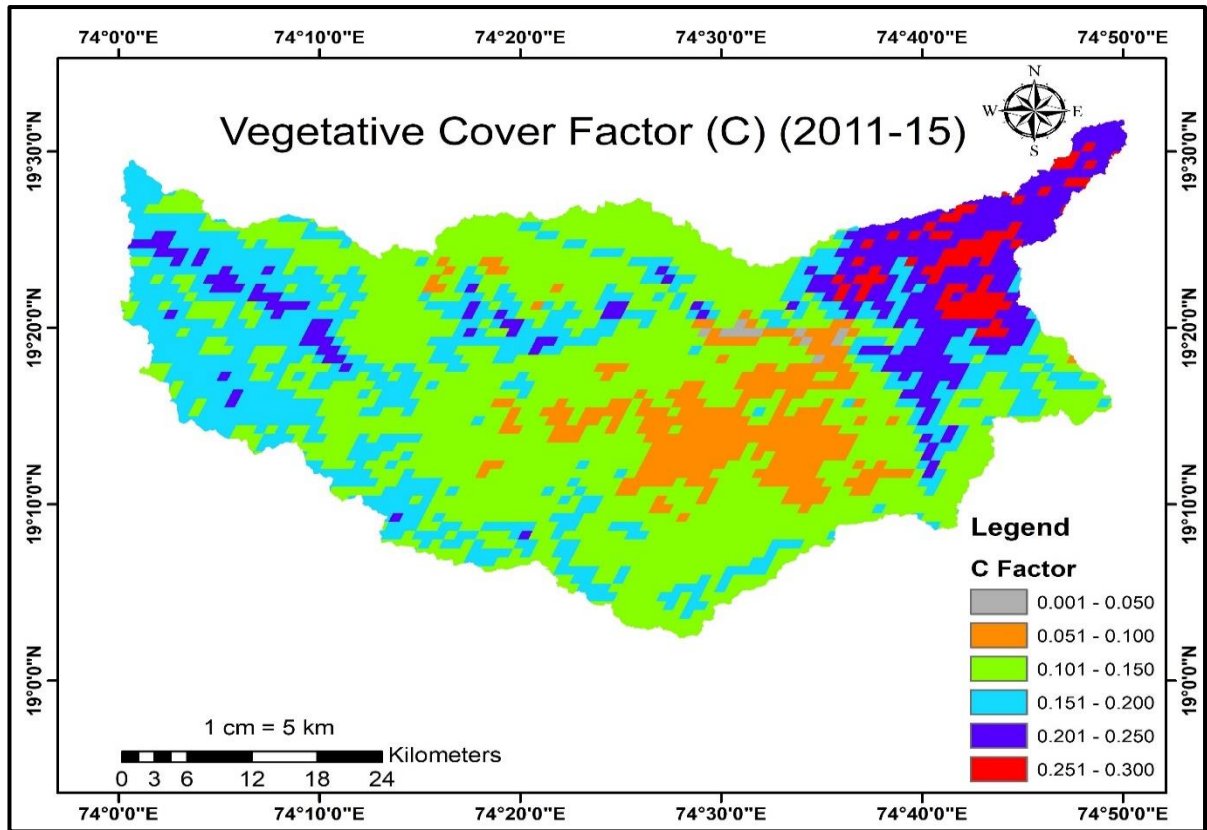


Fig. 4.23 Average Vegetative Cover Factor (C) of Mula River Basin for year 2011-15

Average Vegetative Cover Factor (C) Map of Mula River Basin for year 2020-21:

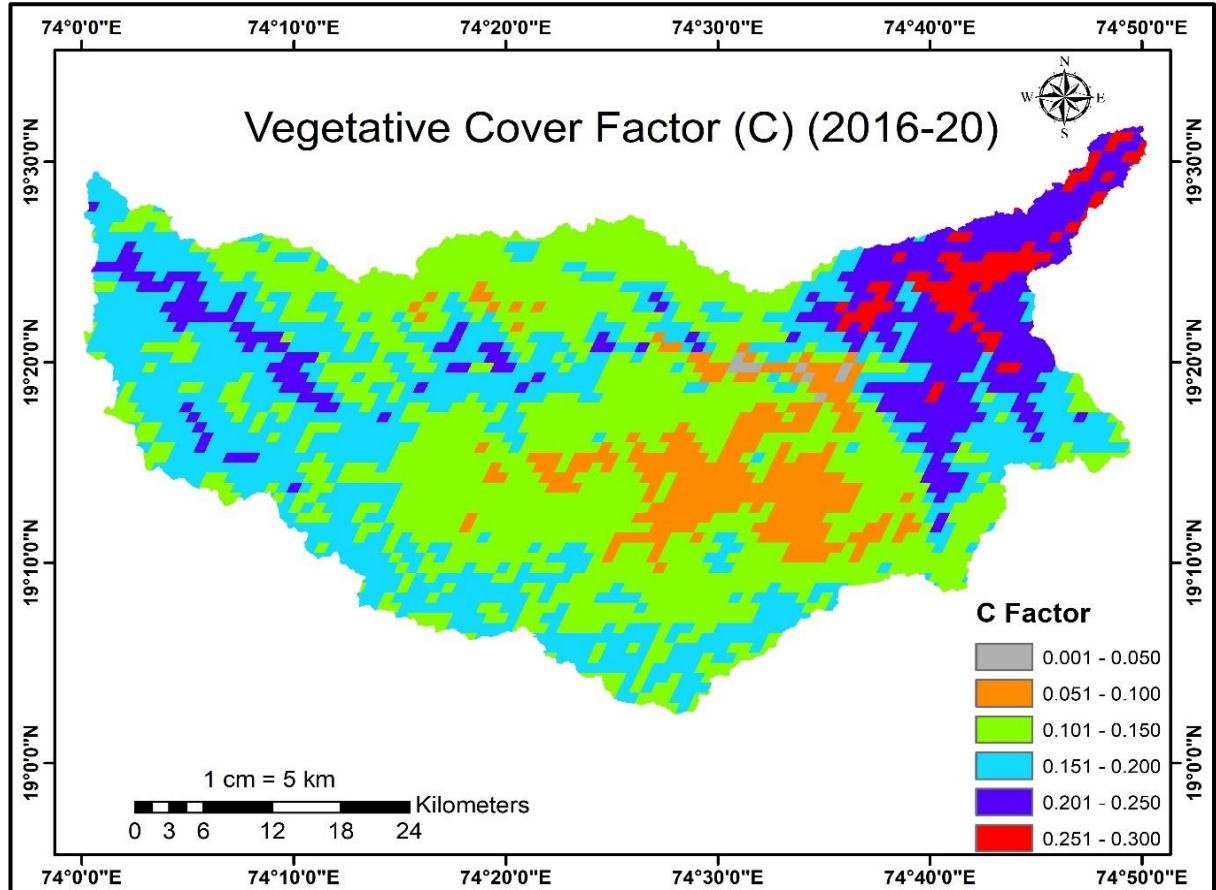


Fig. 4.24 Average Vegetative Cover Factor (C) of Mula River Basin for year 2016-20

The highest value of cover management factor is found in east side of study area in 2016-20 as shown in fig. 4.24. The average highest and lowest values of C factor of Mula river basin are 0.2832 and 0.0167. The average value of C factor is 0.1531.

4.1.5 Conservation Practice Factor (P)

The Mula river basin is completely untreated in terms of soil and water conservation structures. It is critical to develop and recommend various soil conservation methods based on land capability in diverse areas. As a result, the conservation practice factor (P) for the Mula river basin is set to 1 in the determination of soil loss in GEE, assuming the study area is untreated. Figure 4.25 shows the conservation practice factor (P).

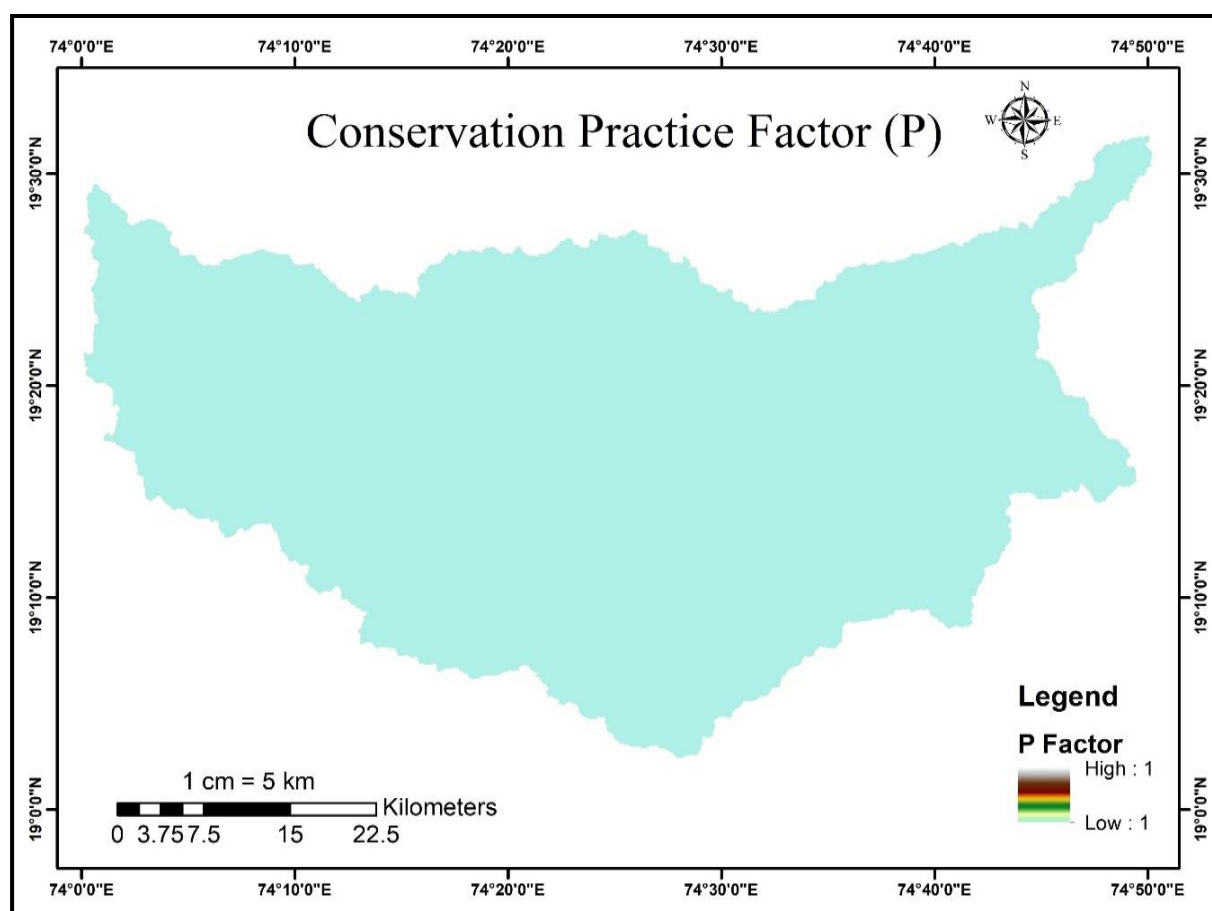


Fig.4.25 Conservation Practice Factor for Mula River Basin (P)

4.1.6 Average Soil Erosion using Revised Universal Soil Loss Equation (A)

The average annual rainfall erosivity factor (R) and soil erodibility factor (K), topographic factor (LS), vegetation cover factor (C), and conservation practice factor (P) are used to compute the average soil loss (tonnes/ha/yr) of Mula river basin for the year 1996-2000, 2001-05, 2006-10, 2011-15, and 2016-20. All the factors layer viz. rainfall erosivity factor (R) and soil erodibility factor (K), topographic factor (LS), vegetation cover factor (C), and conservation practice factor (P) are generated in Google Earth Engine (GEE) and overlaid to obtain the soil Erosion of Mula river basin by using JavaScript programming language. The net soil erosion estimated in the pentad study area is grouped into the following scales of priority: Slight (0 to 5 tonnes/ha/yr),

Moderate (5 to 10 tonnes/ha/yr), High (10 to 20 tonnes/ha/yr), Very High (20 to 40 tonnes/ha/yr), Severe (40 to 80 tonnes/ha/yr) & Very Severe (> 80 tonnes/ha/yr) erosion classes as per the guidelines suggested by Singh *et al.* (1992) for Indian conditions.

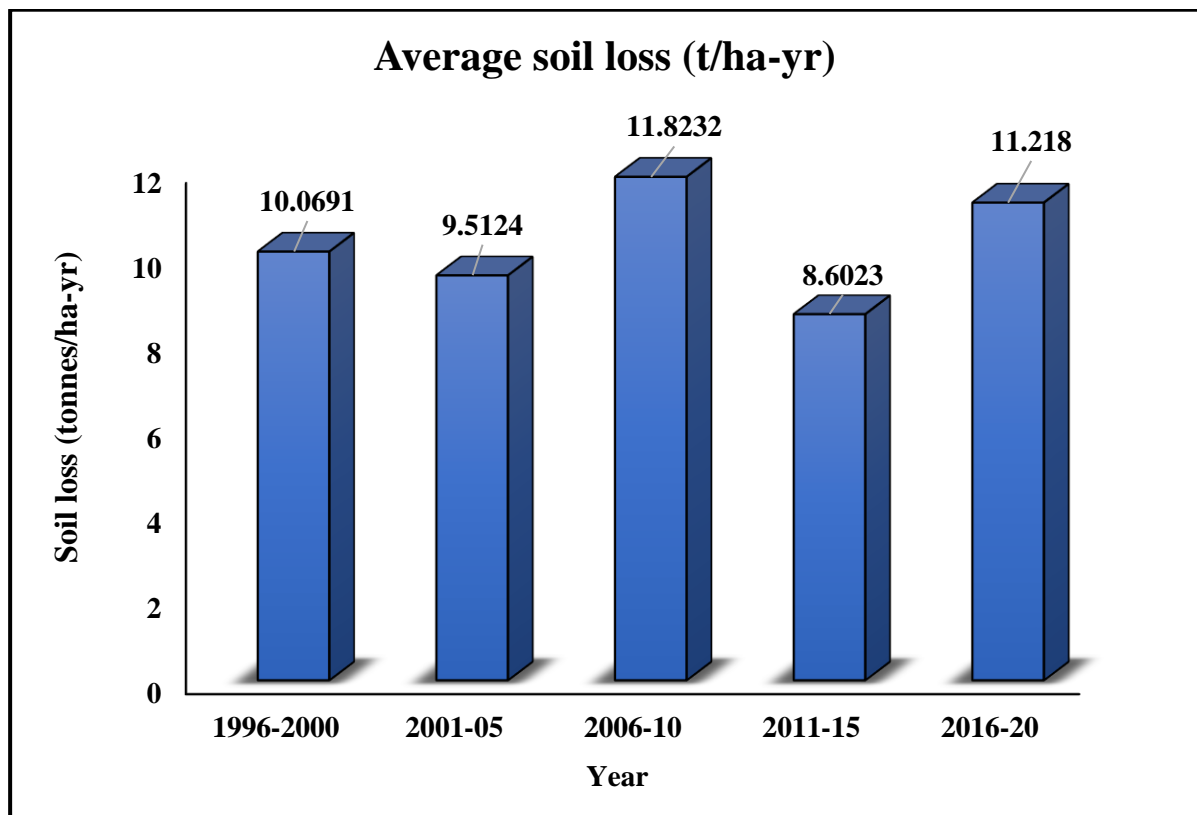


Fig. 4.26 Average Soil Loss (tonnes/ha-yr) for pentad study (2000-20)

The average soil loss of Mula river basin is found 10.0691 tonnes/ha-yr in year 1996-2000, 9.5124 tonnes/ha-yr in year 2001-05, 11.8232 tonnes/ha-yr in year 2006-10, 8.6023 tonnes/ha-yr in year 2011-15 and 11.2180 tonnes/ha-yr in year 2016-20. The highest average soil loss is found in year 2006-2010 due to high precipitation in those years in Ahmednagar district and lowest is found in year 2011-15 due to low rainfall in those years.

4.1.6.1 Spatial distribution of Average Soil Erosion

Table 4.9 Area under different soil erosion classes in the Mula River Basin in km².

Year	Slight	Moderate	High	Very High	Severe
96-2000	1897.23	285.49	205.49	114.32	67.63
2001-05	1914.63	324.78	164.75	95.67	70.17
2006-10	1763.65	326.33	239.17	141.79	99.06
2011-15	1993.23	306.81	135.69	78.89	55.38
2016-20	1749.06	305.73	225.37	129.02	160.82

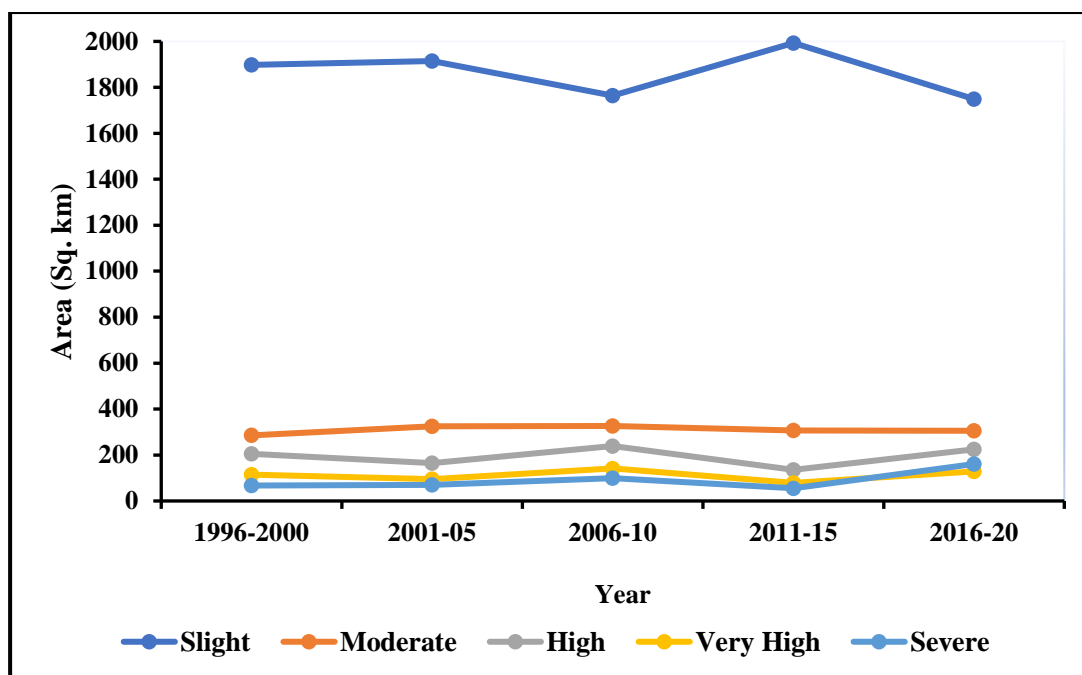


Fig. 4.27 Areas of different soil erosion intensity grades in the Mula River Basin

The area under slight erosion is increased from 2006-10 to 2011-15. But after that it decreases slowly for year 2016-20 due to low and high precipitation in year 2011-15 and 2016-20 as illustrated in fig. 4.27. Also, area under moderate and high erosion is slightly changed and area under severe and very high erosion class is approximately same for each interval.

Table 4.10 Area under different classes of annual soil erosion of Mula River Basin year for 1996-2000.

Sr. No.	Soil erosion class	Area (Km ²)	Area (%)
1.	Slight Erosion	1897.23	73.82
2.	Moderate Erosion	285.49	11.11
3.	High Erosion	205.33	7.99
4.	Very High Erosion	114.32	4.45
5.	Severe Erosion	67.63	2.63

The area under slight erosion class was found 1897.23 km², moderate erosion class 285.49 km², high erosion class 205.33 km², very high erosion class 114.32 km² and severe erosion class 67.63 km² as shown in fig 4.28. The highest percentage of area is found in the slight soil erosion class (73.82%), followed by moderate (11.11%), high (7.99%), very high (4.45%) and severe erosion (2.63%). About 85% of the area was found in the slight to moderate erosion class. Also, it shows that a very small area was subject to severe erosion.

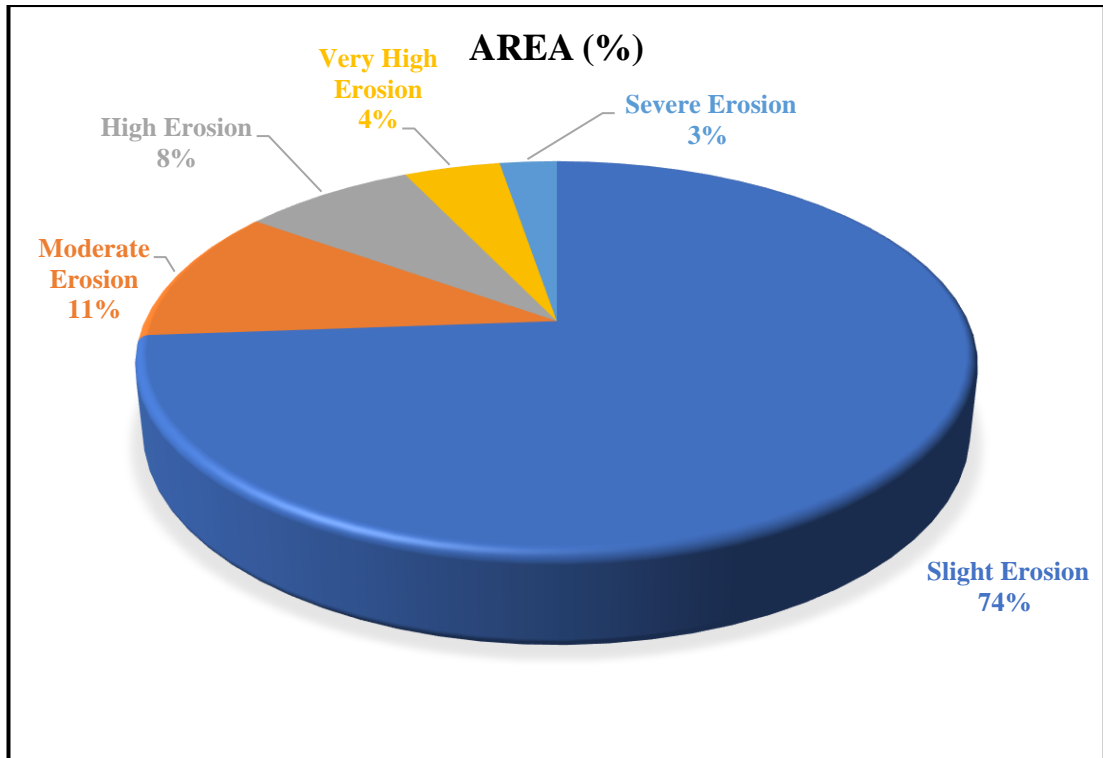


Fig. 4.28 Area distribution under Soil Erosion of mula river basin for year 1996-2000

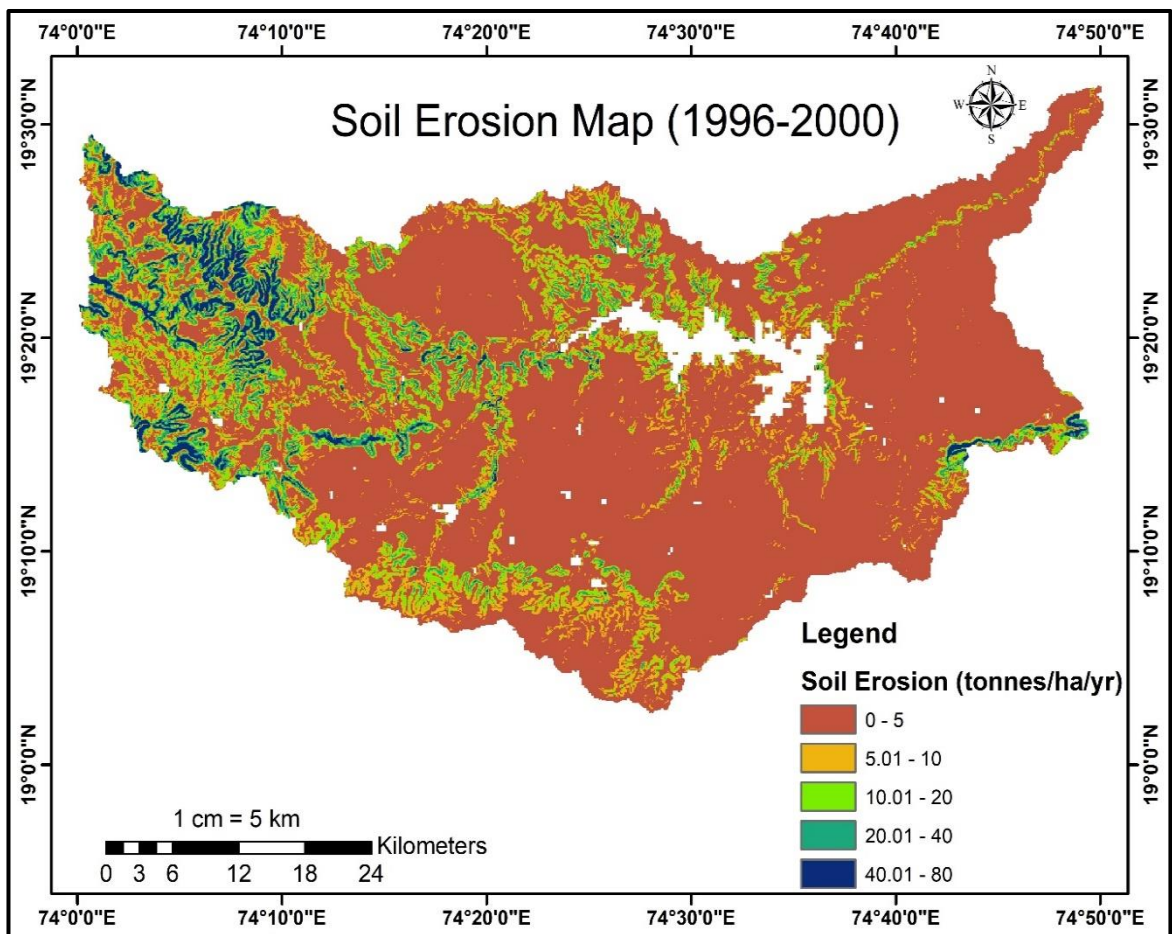


Fig. 4.29 Soil Erosion Map of Mula River Basin for year 1996-2000

Table 4.11 Area under different classes of annual soil erosion for Mula River Basin for year 2001-2005.

Sr. No.	Soil erosion class	Area (Km ²)	Area (%)
1.	Slight Erosion	1914.63	74.50
2.	Moderate Erosion	324.78	12.64
3.	High Erosion	164.75	6.41
4.	Very High Erosion	95.67	3.72
5.	Severe Erosion	70.17	2.73

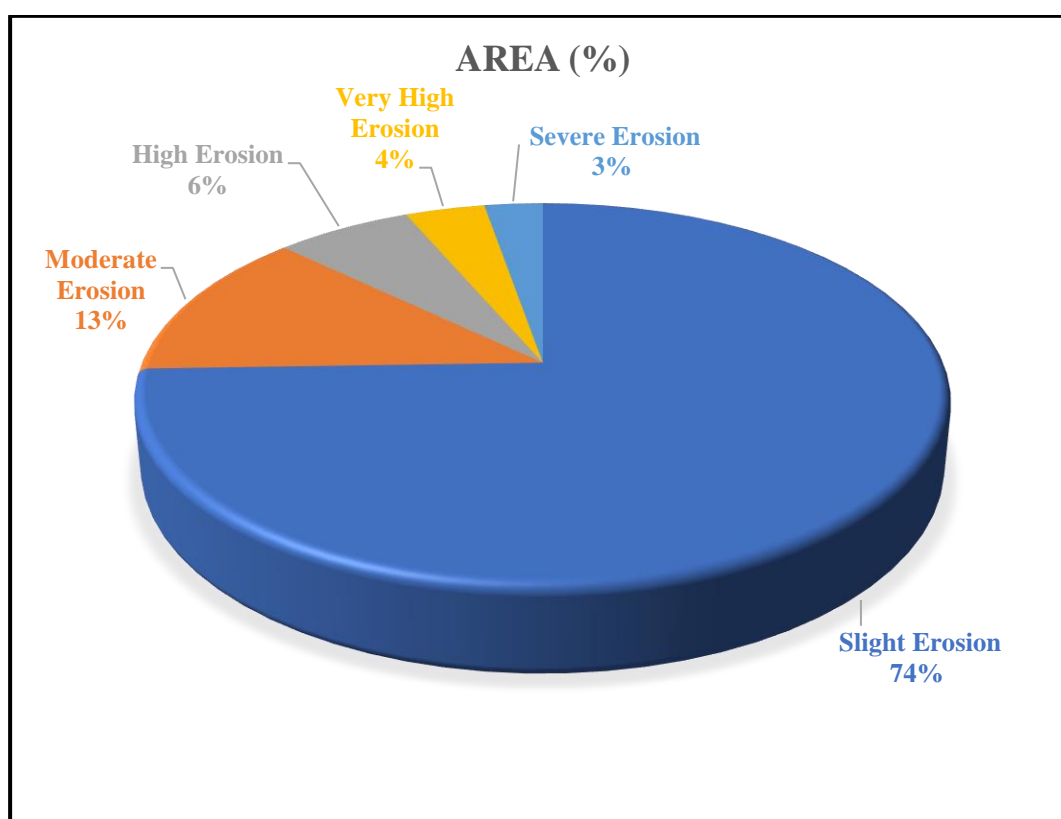


Fig. 4.30 Area distribution under Soil Erosion for mula river basin for year 2001-05

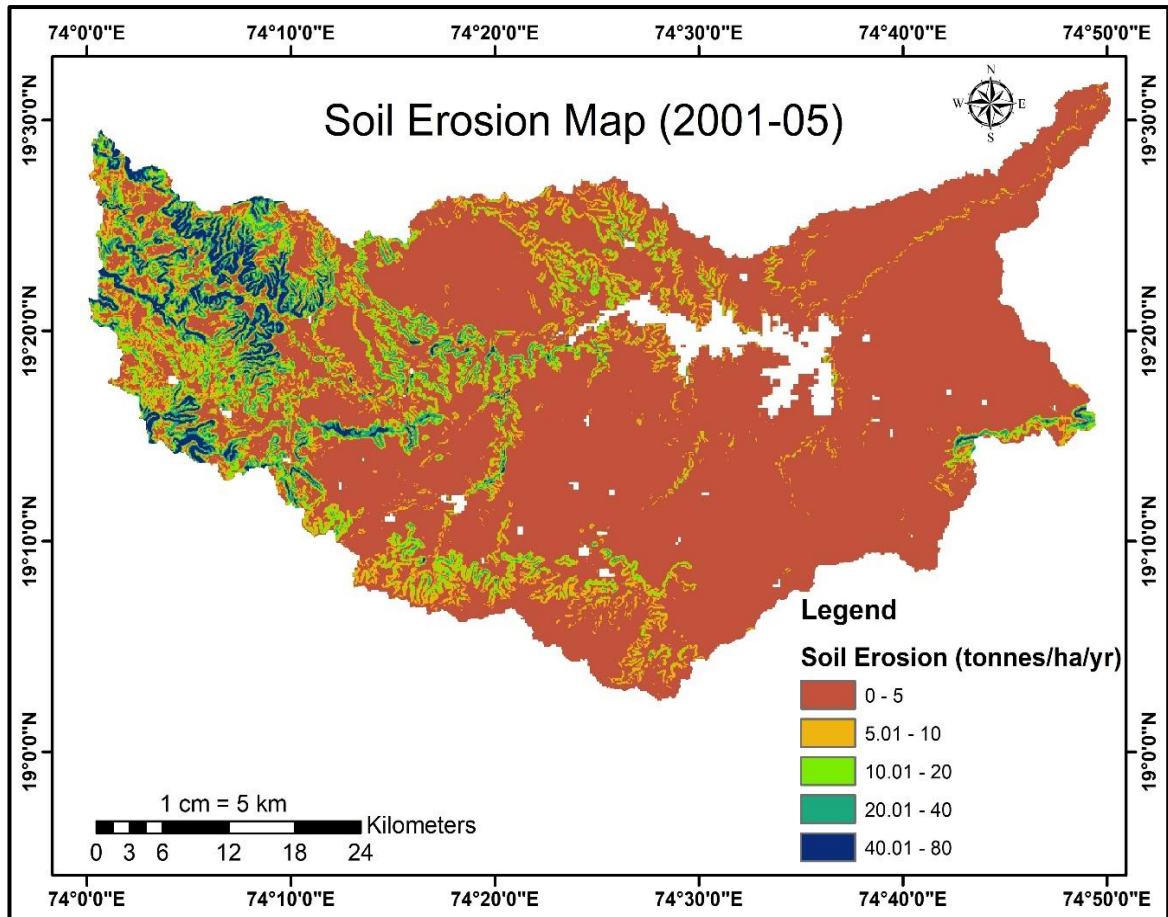


Fig. 4.31 Soil Erosion Map of Mula River Basin for year 2001-05

The area under slight erosion class was found 1914.63 km², moderate erosion class 324.78 km², high erosion class 164.75 km², very high erosion class 95.67 km² and severe erosion class 70.17 km² as illustrated in fig 4.30. The highest percentage of area is found in the slight soil erosion class (74.50 %), followed by moderate (12.64 %), high (6.41 %), very high (3.72 %) and severe erosion (2.73 %). More than 70 % of the area was found in the slight erosion class. It shows that a very small area was subject to severe erosion. About 2 % area is increased under slight erosion class and area under moderate erosion class in year 2001-05 as compared to year 1996-2000.

Table 4.12 Area under different classes of annual soil erosion for Mula River Basin for year 2006-10.

Sr. No.	Soil erosion class	Area (Km ²)	Area (%)
1.	Slight Erosion	1763.65	68.62
2.	Moderate Erosion	326.33	12.70
3.	High Erosion	239.17	9.31
4.	Very High Erosion	141.79	5.52
5.	Severe Erosion	99.06	3.85

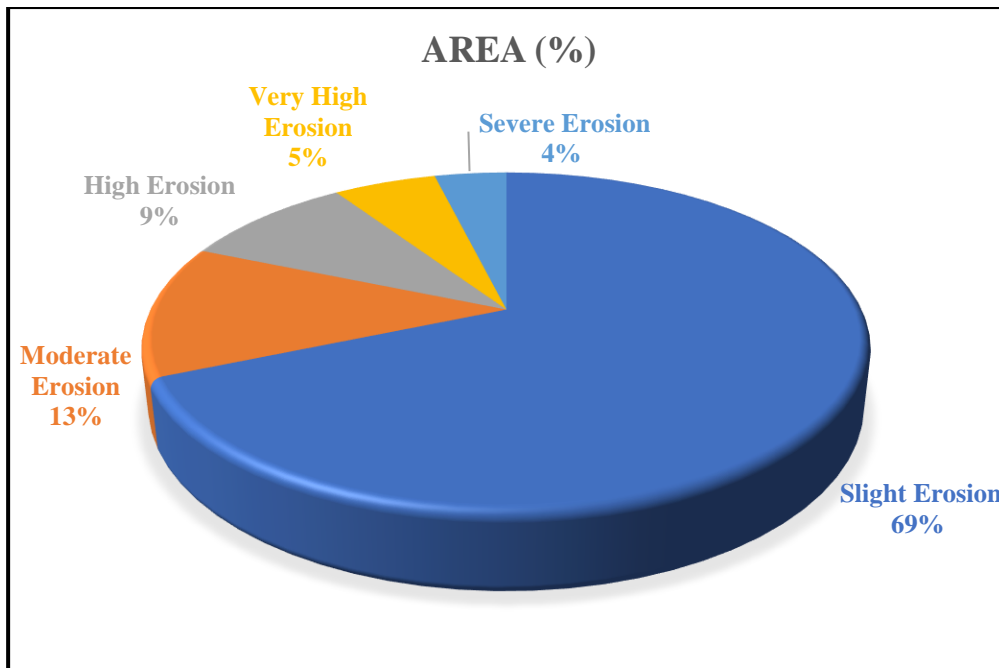


Fig. 4.32 Area distribution under Soil Erosion of mula river basin for year 2006- 10

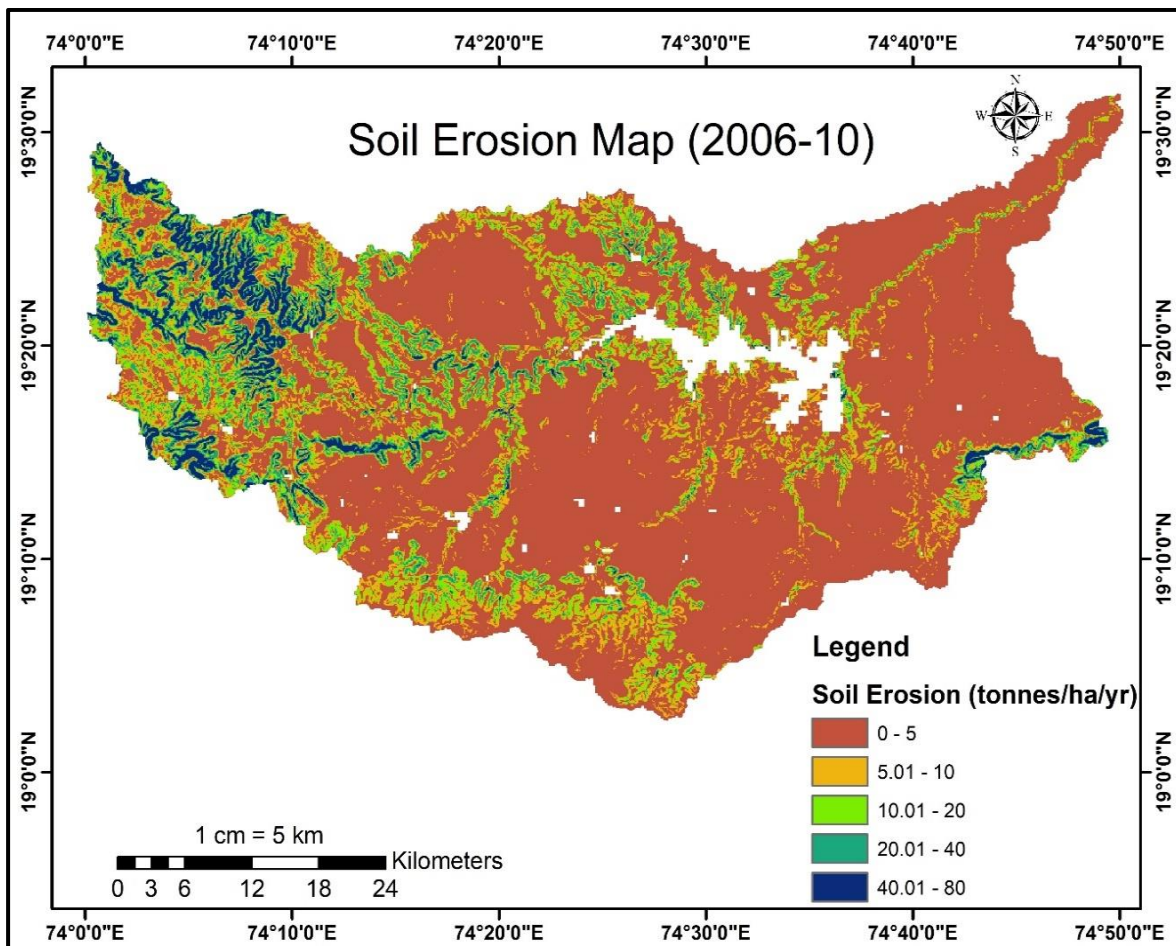


Fig. 4.33 Soil Erosion Map of Mula River Basin for year 2006-10

The area under slight erosion class was found 1763.65 km², moderate erosion class 326.33 km², high erosion class 239.17 km², very high erosion class 141.79 km² and severe erosion class 99.06 km² as illustrated in fig 4.32. The highest percentage of area was found in the slight soil erosion class (68.62 %), followed by moderate (12.70 %), high (9.31 %), very high (5.52 %) and severe erosion (3.85 %). More than 65 % of the area was found in the slight erosion class. It was

found that area under sever erosion class is increased due to high rainfall in year 2006-10 which causes more severe erosion than year 1996-2000 and 2001-05.

Table 4.13 Area under different classes of annual soil erosion for Mula River Basin for year 2011-15.

Sr. No.	Soil erosion class	Area (Km ²)	Area (%)
1.	Slight Erosion	1993.23	77.56
2.	Moderate Erosion	306.81	11.94
3.	High Erosion	135.69	5.28
4.	Very High Erosion	78.89	3.07
5.	Severe Erosion	55.38	2.15

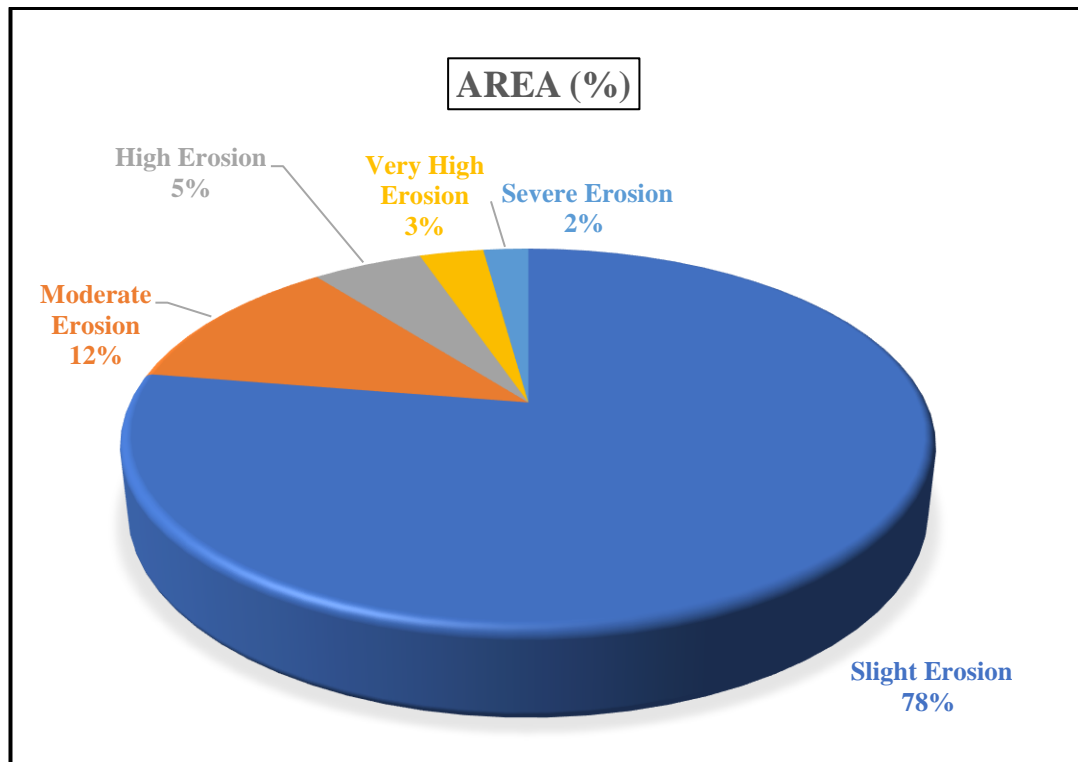


Fig. 4.34 Area distribution under Soil Erosion of mula river basin for year 2011- 15

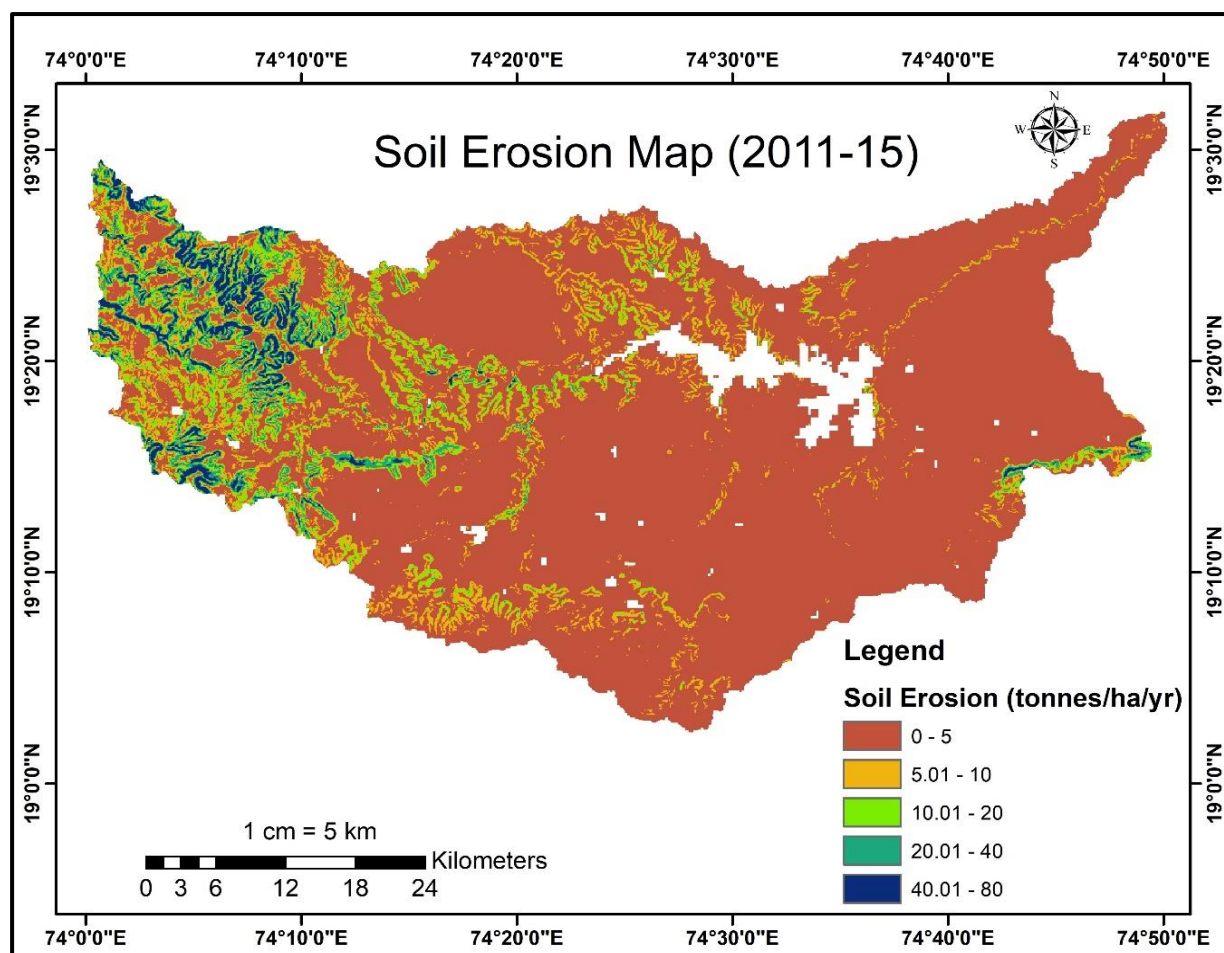


Fig. 4.35 Soil Erosion Map of Mula River Basin for year 2011-15

The area under slight erosion class was found 1993.23 km², moderate erosion class 306.81 km², high erosion class 135.69 km², very high erosion class 78.89 km² and severe erosion class 55.38 km² as illustrated in fig 4.34. The highest percentage of area was found in the slight soil erosion class (77.56 %), followed by moderate (11.94 %), high (5.28 %), very high (3.07 %) and severe erosion (2.15 %). More than 85 % of the area was found in the slight erosion class to moderate erosion class which was very high as compare to other three classes which is less than 10 t/ha-yr.

Table 4.14 Area under different classes of annual soil erosion for Mula River Basin for year 2016-20.

Sr. No.	Soil erosion class	Area (Km ²)	Area (%)
1.	Slight Erosion	1749.06	68.06
2.	Moderate Erosion	305.73	11.90
3.	High Erosion	225.37	8.77
4.	Very High Erosion	129.02	5.02
5.	Severe Erosion	160.82	6.26

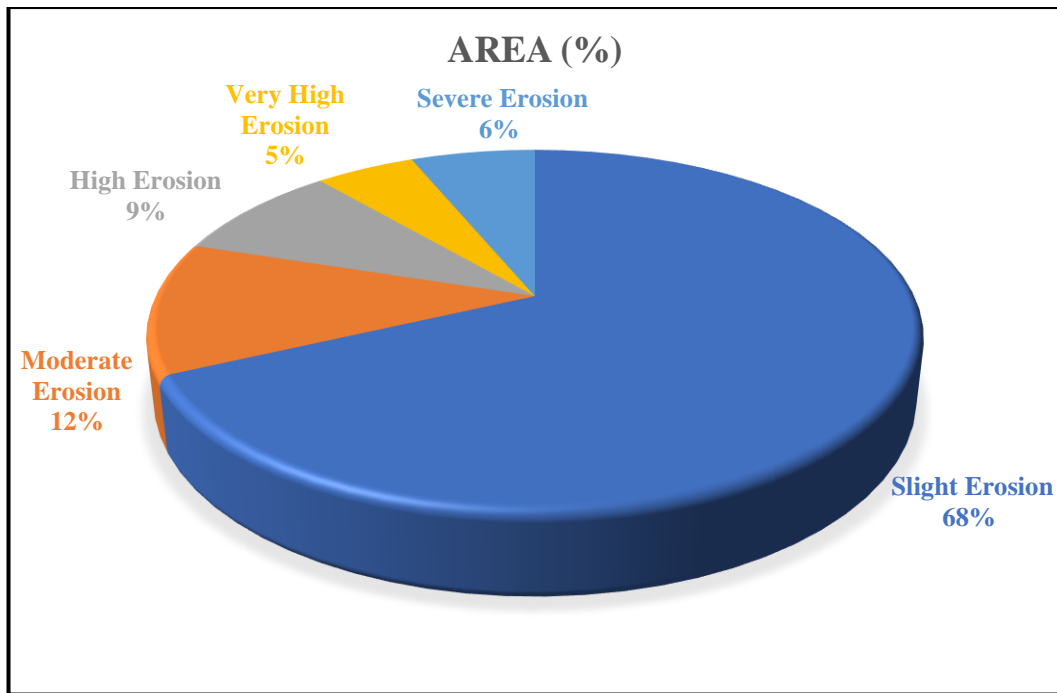


Fig. 4.36 Area distribution under Soil Erosion for mula river basin for year 2016- 20

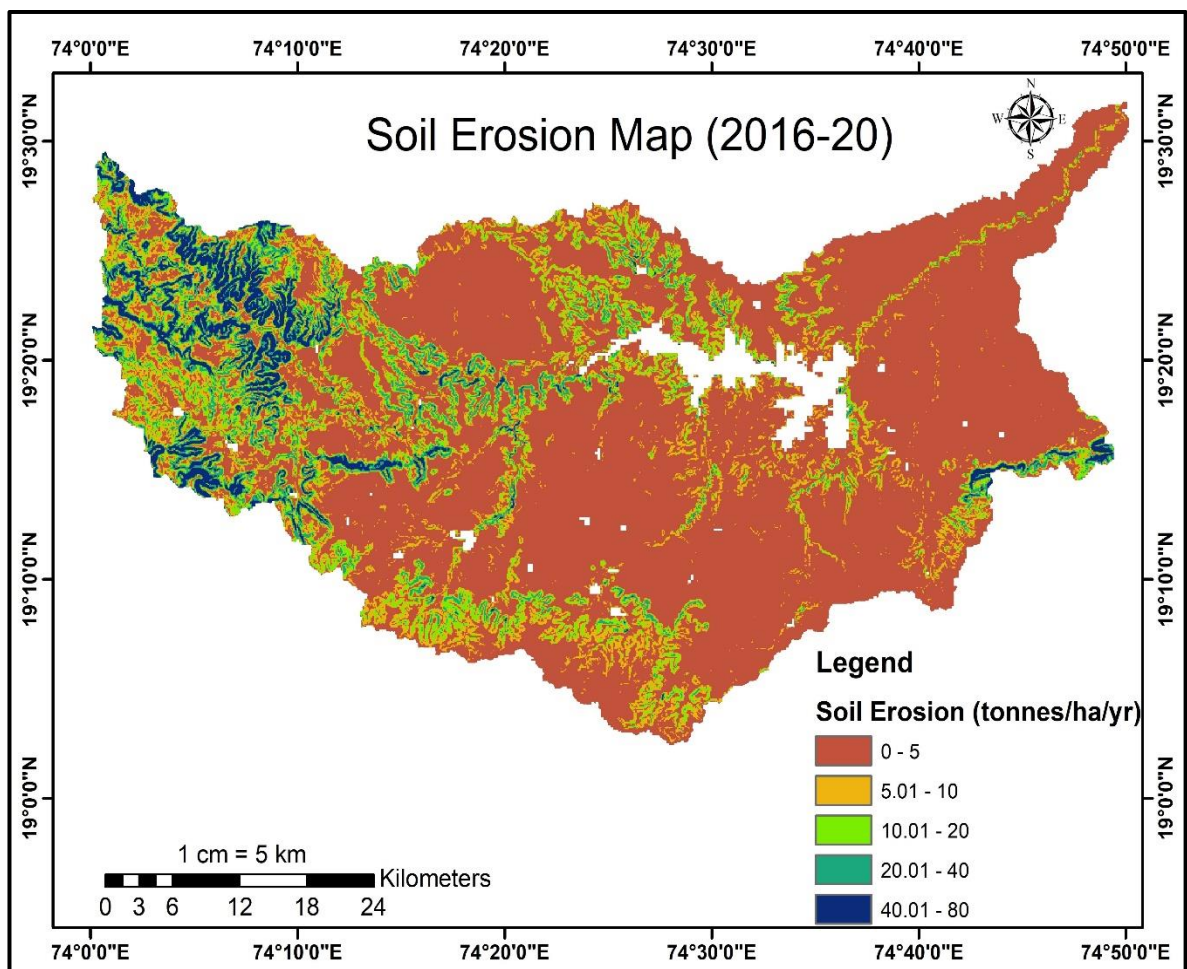


Fig. 4.37 Soil Erosion Map of Mula River Basin for year 2016-20

The area under slight erosion class 1749.06 km², moderate erosion class 305.73 km², high erosion class 225.37 km², very high erosion class 129.02 km² and severe erosion class 160.82 km² as shown in fig 4.36. The highest percentage of area was in the slight soil erosion class (68.06 %),

which is followed by moderate (11.90 %), high (8.77 %), very high (5.02 %) and severe erosion (6.26 %). Area under severe erosion was found high as compare to all other years which cause high impact on degradation of soil due to high intense precipitation in this year and up to 79 % area comes under slight to moderate erosion.

5. SUMMARY AND CONCLUSIONS

This section presents the summary of the introduction, methodology used, results and conclusions derived from this investigation.

5.1 Summary

Soil erosion is known as detachment, transportation and deposition of soil particles from one place to another while being influenced by gravity, wind, water forces. The most severe type of land degradation occurs due to soil erosion, particularly in developing nations like India, Uganda, and China as well as certain established nations like Spain (Brunner et al., 2004; Nekhay et al., 2009; Zhang et al., 2010). Soil erosion is serious issue in India which reduces the productivity of agricultural land and availability of water. Climate change has accelerated a soil erosion in many locations worldwide and it directly affects ecosystem services and human well-being.

Soil loss measured by different models but revised universal soil loss equation (RUSLE) is more efficient than the other soil loss estimation models. The Google earth engine (GEE) is newly launched platform has a large data storage function, which can quickly retrieve and process remote sensor data as compared to traditional image processing tools. So, combine use of RUSLE model with geospatial tool like GEE can make planning of natural resources in watershed faster, more accurate and real time. These kinds of studies are very few at international and national level.

The area selected for the study is Mula river basin. The Mula river has its origin near Harishchandra gad in Ahmednagar district of Maharashtra. The Mula river basin spread in five tehsils. These are Akole, Sangamner, Parner, Ahmednagar and Rahuri. The total area covered under this watershed is 2570 km². Mula river basin of Ahmednagar district is having limited data where use of this kind of model and Geospatial techniques will help us in better planning of natural resources. There is no such kind of study in past on Mula river basin has been conducted.

The Revised universal soil loss equation (RUSLE) is used to estimate soil Erosion from study area. Temporal variation in soil erosion is estimated for pentad study (1996-2000 to 2015-20). The rainfall erosivity factor (R) estimated using monthly and annual rainfall data. For the study, meteorological data has gathered for the years 1996-2000, 2001-05, 2006-10, 2011-15, and 2016-20. Sand, silt, and clay and organic matter of soil data has used to determine the soil erodibility factor (K). DEM and flow accumulation was used to calculate topographic factor (LS). The vegetation cover factor (C) is derived from NDVI. By combining all these factors in GEE soil loss estimated for Mula river.

Following are the results from the study:

Precipitation data of rainfall erosivity factor for different five tehsils namely Akole, Sangamner, Parner, Ahmednagar and Rahuri of Mula river basin has collected from maharain data portal. The erosivity factor for the Mula river basin estimated for pentad study were 448.32 – 737.81 MJ-mm/ha-hr-yr, 310.63 – 1003.78 MJ-mm/ha-hr-yr, 406.48 – 1142.33 MJ-mm/ha-hr-

yr, 300.41 – 843.49 MJ-mm/ha-hr-yr and 368.35 – 1151.18 MJ-mm/ha-hr-yr. The estimated highest rainfall erosivity has found in Akole tehsil and lowest value has found in Sangamner tehsil.

The soil erodibility factor of Mula basin ranges from 0.0251 to 0.0388 tonnes-ha-hr/ha-MJ-mm and average of soil erodibility factor is 0.0311 tonnes-ha-hr/ha-MJ-mm. The highest value of erodibility has found in upstream side of Mula basin. The major soil type found in watershed is clay loam and lowest is sandy clay loam.

The Slope of Mula river basin ranges from 0 – 24.7316. The topographic factor of Mula river basin has found in the range of 0 to 9.9524 and its average value is 2.1903. The maximum area under topographic factor of Mula river basin has in the range of 0 to 2 (72.53 %) and lowest area has in the range of 6.01 to 8 (3.18 %).

The vegetative cover factor has estimated for pentad study ranges from 0.0104 to 0.2894, 0.0037 to 0.2735, 0.0092 to 0.2933, 0.0097 to 0.2796 and 0.0167 to 0.2862. The average value of vegetative cover factor for pentad study are 0.1667, 0.1315, 0.1525, 0.1474 and 0.1531 respectively. The average value of C factor for pentad study was slightly changed due to change in land under agriculture sector.

The estimated average annual soil loss for Mula river basin for pentad study are 10.0691 tonnes/ha-yr, 9.5124 tonnes/ha-yr, 11.8232 tonnes/ha-yr, 8.6023 tonnes/ha-yr and 11.2180 tonnes/ha-yr. The highest and lowest area comes under slight erosion (70 % - 80 %) and severe erosion (2 % - 6 %) for pentad study respectively. The highest average annual soil Erosion has found in year 2006-10 (11.8232 tonnes/ha/yr) and 2011-15 (8.6023 tonnes/ha/yr).

5.2 Conclusions

Based on the results of the study following conclusions are drawn.

- The erosivity factor for the Mula river basin for pentad study were ranging between 448.32 – 737.81 MJ-mm/ha-hr-yr, 310.63 – 1003.78 MJ-mm/ha-hr-yr, 406.48 – 1142.33 MJ-mm/ha-hr-yr, 300.41 – 843.49 MJ-mm/ha-hr-yr and 368.35 – 1151.18 MJ-mm/ha-hr-yr.
- The soil erodibility factor of Mula river basin is ranging between 0.0251 to 0.0388 tonnes-ha-hr/ha-MJ-mm.
- The highest and lowest estimated soil loss found in the year of 2006-10 (11.8232 tonnes/ha/yr) and 2011-15 (8.6023 tonnes/ha/yr).
- There is no specific trend observed in soil loss for pentad study.
- The RUSLE model using Google Earth Engine (GEE) platform provide easy and reliable technique for estimation of soil Erosion for large area in short time.
- The different parameters data required for RUSLE such as rainfall, soil properties, topography and vegetation cover can be obtained from GEE cloud platform and easily utilise for soil loss estimation.

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APPENDICES

APPENDIX- I

• **Monthly Rainfall (mm) Data for year 1996-97**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	55	0	0	0	0
4	Apr	0	0	0	22	0
5	May	6	0	14	0	0
6	Jun	55	82	87	67	87
7	July	15	154	147	71	112
8	Aug	127	114	142	112	125
9	Sep	187	197	147	135	201
10	Oct	178	24	101	75	108
11	Nov	0	24	43	50	74
12	Dec	0	0	0	0	0

• **Monthly Rainfall (mm) Data for year 1997-98**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	41	0	0
6	Jun	664	99	49	121	118
7	July	517	239	654	47.4	150.5
8	Aug	415	13	11	11	27
9	Sep	412	241	477	127	214
10	Oct	772	161	164	147	177
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

• **Monthly Rainfall (mm) Data for year 1998-99**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	22	0
5	May	6	0	14	0	0
6	Jun	117	82	101	67	87
7	July	211	102	98	71	178
8	Aug	147	119	122	118	215
9	Sep	121	97	168	158	213
10	Oct	133	207	101	75	138
11	Nov	0	46	33	64	49
12	Dec	0	0	0	0	0

• **Monthly Rainfall (mm) Data for year 1999-2000**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	41	0	0
6	Jun	664	99	49	121	118
7	July	517	39	98	47	150.5
8	Aug	45	13	11	11	27
9	Sep	1912	104	425	146	98
10	Oct	722	61	106	147	117
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2000-01**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	50.1	7	4.1	67.5	74
6	Jun	227	200	227	225	181
7	July	101	36	92	74	148
8	Aug	179	170	216	121	108.5
9	Sep	35	50	46	103	27
10	Oct	75	76	27.4	68	150.5
11	Nov	0	0	0	0	0
12	Dec	3	0	3	0	0

- **Monthly Rainfall (mm) Data for year 2001-02**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	2	2	1	1	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	5	0	0	0	0
5	May	0	2	0	0	0
6	Jun	105	57	39	63	111
7	July	9	48	0	16	67.1
8	Aug	169	155	148	66	81.1
9	Sep	90	94	145	175.6	161.2
10	Oct	100	127	246	117	143.2
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

• **Monthly Rainfall (mm) Data for year 2002-03**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	16	
2	Feb	0	0	0	0	
3	Mar	0	0	0	0	
4	Apr	0	0	0	16	74
5	May	0	0	0	0	0
6	Jun	162	235	197	219	221
7	July	12	14.2	10	20	18
8	Aug	131	114	96	84	119.3
9	Sep	62	105	22	60	44
10	Oct	33	33	0	54	0
11	Nov	0	16	0	23	0
12	Dec	0	0	0	0	0

• **Monthly Rainfall (mm) Data for year 2003-04**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	3	0
5	May	14	0	14	89	14
6	Jun	26	13	10	95	165
7	July	37	35	85	127	214
8	Aug	54	78	79	22	15
9	Sep	62	39	74	133	92
10	Oct	21	25	51	17	2
11	Nov	0	0	0	3	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2004-05**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	23	56	55	56	250
6	Jun	115	46	113	134	190
7	July	104	181	64	50	45
8	Aug	27	85	21	134	423
9	Sep	233	286	223	198	269
10	Oct	39	97	88	53	167
11	Nov	15	8	11	25	10
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2005-06**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0		11	4
2	Feb	0	7	0	0	0
3	Mar	9	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	0	0	0
6	Jun	27	48	10	143	336
7	July	108	131	155	84	174
8	Aug	35	89	35	67	163
9	Sep	223	232	239	201	253
10	Oct	98	98	26	23	154
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2006-07**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	11	0	0	0	9
4	Apr	0	0	0	0	31
5	May	0	9	23	13	270
6	Jun	193	250	104	125	104
7	July	51	110	100	113	100
8	Aug	140	184	124	116	124
9	Sep	342	251	379	186	379
10	Oct	72	48	66	36	66
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2007-08**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	5	4.5	23.5	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	12	7.4	0	6.7	0
5	May	0	0	0	0	0
6	Jun	189	190	318	236	267
7	July	85	65	77	56	253
8	Aug	179	70	143	47	120
9	Sep	178	53	184	140	231
10	Oct	0	0	0	0	0
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2008-09**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	45	1	20	0	0
4	Apr	0	0	0	0	0
5	May	0	0	0	0	0
6	Jun	29	15	17	25	91
7	July	31	18	93	64	153
8	Aug	105	68	80	86	218
9	Sep	354	208	397	304	459
10	Oct	129	79	64	8	85
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2009-10**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	0	0	0
6	Jun	76	144	103	13	3
7	July	59	101	94	85	281
8	Aug	188	104	203	79	55
9	Sep	173	99	55	106	187
10	Oct	70	16	95	18	20
11	Nov	59	117	136	151	284
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2010-11**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	0	0	0
6	Jun	165	121	155	92	198
7	July	140	78	147	135	165
8	Aug	255	145	183	162	242
9	Sep	222	167	299	124	71
10	Oct	9	88	29	43	122
11	Nov	39	77	73	136	243
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2011-12**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	0	0	0
6	Jun	30	39	94	22	106
7	July	124	114	151	59	171
8	Aug	107	98	157	62	112
9	Sep	92	77	119	68	81
10	Oct	21	40	68	29	30
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2012-13**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	0	0	0
6	Jun	7.2	23	44.5	33	27
7	July	89.1	48.5	131.5	118.8	179
8	Aug	37.3	43	64.8	123	104
9	Sep	40.4	42	148	120.4	133
10	Oct	51.1	92	124.2	101	205
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2013-14**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	19	0	0
5	May	0	0	0	15	0
6	Jun	142.6	165	137.1	88.3	171.8
7	July	117.7	97.7	90.5	84.2	337.8
8	Aug	41.2	29.3	35	40.9	169.2
9	Sep	132.9	206.7	146.8	136.9	164
10	Oct	116.3	40.8	73.5	82.6	32.6
11	Nov	0	0	0.3	0	0
12	Dec	0	0	0	20	0

• **Monthly Rainfall (mm) Data for year 2014-15**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	5	43	0	2
4	Apr	0	0	19	0	0
5	May	0	0	0	0	0
6	Jun	53.6	17.9	28.5	14.6	17.8
7	July	75.8	34.7	62.9	81.3	313.3
8	Aug	202.1	114.1	195.7	216.6	331.9
9	Sep	45.6	44.3	29.6	35.5	100.1
10	Oct	22.9	27.1	6.6	17.7	34.4
11	Nov	71.4	48	59.8	42.4	20.1
12	Dec	0	8.1	0	3.5	5.3

• **Monthly Rainfall (mm) Data for year 2015-16**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0.8	0	0	0.6
2	Feb	0	0	0	0	0
3	Mar	29.1	41.4	57	78.9	72.1
4	Apr	6.7	2	13.2	10.6	21.1
5	May	2.3	7.7	5.1	6	17.5
6	Jun	114.4	93.9	69.4	55.2	213.7
7	July	1	9.9	18.9	30.6	243.8
8	Aug	14.3	11.4	23.8	7	40.8
9	Sep	171.7	180.4	136.6	133	160.5
10	Oct	35	52.3	46.2	36	33
11	Nov	41	34.4	10.8	28.2	44.5
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2016-17**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0.6	0	1.5	0
3	Mar	5.4	0	2.1	0	9.4
4	Apr	0	0	0	0	0
5	May	0.6	12	12.8	0	42.3
6	Jun	119.3	55.5	103.2	40.6	35.7
7	July	127.7	70.1	108.2	123	372.1
8	Aug	77	42	47.7	116.5	364.5
9	Sep	154.1	159.8	196.1	187.4	169.4
10	Oct	91.5	97	70.4	26.5	
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	0

- **Monthly Rainfall (mm) Data for year 2017-18**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	2.3	0	2.4	1.6
6	Jun	194.7	127.1	125.6	113.4	205.1
7	July	15.8	40.4	43.2	97.8	529.4
8	Aug	259.7	155	224.4	134	214.7
9	Sep	198.8	153.7	166.3	115.4	195.3
10	Oct	57.7	111	62	117.3	115.8
11	Nov	0	0	0	0	0
12	Dec	0	0	0	0	3.1

• **Monthly Rainfall (mm) Data for year 2018-19**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0.6
4	Apr	0	0.8	0	2.5	1.7
5	May	0.2	0.3	0.2	0.6	0.1
6	Jun	100.6	100.3	79	129.7	166.9
7	July	47.8	34.1	54.9	41.6	398.4
8	Aug	71.4	50.6	76.7	59.2	267.7
9	Sep	34.6	30.4	27.7	22.8	58.9
10	Oct	3.6	13.3	0	6.2	12.6
11	Nov	3.5	5.4	1	40.1	55.6
12	Dec	0	0	0	0	0

• **Monthly Rainfall (mm) Data for year 2019-20**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0	0	0	0	0
2	Feb	0	0	0	0	0
3	Mar	0	0	0	0	0
4	Apr	0	0	0	0	0
5	May	0	0	0	0	0
6	Jun	94	104.3	78.7	80.9	109.6
7	July	143.3	88.3	89.6	156.4	449.6
8	Aug	71.7	41.5	80.7	89	376.9
9	Sep	163.3	158.7	156.9	119.4	194.1
10	Oct	183.4	166.6	163.8	180.3	124.1
11	Nov	18.7	25.1	15.4	62.5	10
12	Dec	1.1	0.8	3.5	1.1	0.3

- **Monthly Rainfall (mm) Data for year 2020-21**

Sr. No.	Month	Nagar	Parner	Rahuri	Sangamner	Akole
1	January	0.2	0	0	0	0
2	Feb	0	0.3	0.6	0	0
3	Mar	3.1	0.1	0.4	6	0.2
4	Apr	0	0	0.2	0.9	0
5	May	6.7	15.8	0.9	2	7.3
6	Jun	296	222.6	261.8	198.4	139.6
7	July	213.2	166.4	223.5	264.3	136.2
8	Aug	80.8	63.7	107.2	100.5	322.5
9	Sep	237.4	239.8	257.6	326.5	196.9
10	Oct	124.8	133.5	92	315.5	139.2
11	Nov	0.5	2.9	4	9	3.9
12	Dec	0.5	0.7	0.3	0.8	1.6

APPENDIX- II

1. Rainfall Erosivity Factor (R) (MJ-MM/Ha-Hr-Yr)

Sr. No.	Year	Nagar	Parner	Rahuri	Sangamner	Akole
1.	1996	467.17	324.11	504.77	471.21	784.75
2.	1997	485.24	415.12	247.21	347.21	795.98
3.	1998	787.68	833.06	565.64	446.98	1193.74
4.	1999	189.64	151.53	1078.38	287.25	341.49
5.	2000	635.91	385.84	522.57	610.73	678.19
6.	2001	397.89	304.83	454.12	245.47	427.00
7.	2002	205.64	351.60	156.12	314.61	292.98
8.	2003	178.19	88.78	148.16	310.39	328.95
9.	2004	479.36	848.50	480.78	592.66	2048.30
10.	2005	349.16	373.03	313.96	369.87	1921.65
11.	2006	983.35	1108.12	947.24	472.29	1416.03
12.	2007	588.45	193.36	813.98	305.80	1166.00
13.	2008	687.35	192.49	637.89	307.61	676.78
14.	2009	541.35	457.72	671.38	261.64	741.69
15.	2010	1049.08	648.94	1212.54	685.05	1711.15
16.	2011	178.60	173.33	472.29	179.82	326.05
17.	2012	94.41	101.18	345.24	420.89	588.45
18.	2013	405.09	386.65	329.24	296.38	1179.44
19.	2014	286.45	124.12	231.10	315.79	1028.54
20.	2015	219.45	240.34	184.96	289.17	1094.98
21.	2016	448.05	243.60	388.28	319.58	851.09
22.	2017	767.24	473.21	535.58	456.46	1003.11
23.	2018	106.07	97.04	98.29	126.12	527.48
24.	2019	647.83	465.52	471.56	679.56	1662.39
25.	2020	1468.51	1089.63	1417.74	260.04	1673.58

APENDIX- III

- **Code for Rainfall Erosivity Factor (R)**

```

var clim_rainmap =
ee.Image("OpenLandMap/CLM/CLM_PRECIPITATION_SM2RAIN_M/v01")

.clip(table)

var visualization =
{
bands: ['jul'],

min: 0.0,

max: 380.0,

palette: ['ecffbd', 'ffff00', '3af6ff', '467aff', '313eff', '0008ff']
}

var year = clim_rainmap.reduce(ee.Reducer.sum())

var R_monthly = (ee.Image(10).pow(ee.Image(1.5) log10()).multiply(clim_rainmap.pow(2)
.divide(year).subtract(0.8188))))).multiply(1.735)          ..... Ref.( Wischmeier and
Smith 1978)

var factorR = R_monthly.reduce(ee.Reducer.sum())

.clip(table)

//print(factorR)

//Map.addLayer(factorR)

var palette_rain = ["#450155", "#3B528C", "#21918D", "#5DCA63", "#FFE925"]

Map.addLayer(factorR, {min:0, max:6000, palette:palette_rain },'rfactor')

print (factorR)

```

- **Code for Soil Erodibility Factor (K)**

```

var silt = ee.Image('users/aschwantes/SLTPPT_I')

.clip(table)

var sand = ee.Image("OpenLandMap/SOL/SOL_SAND-WFRACTION_USDA-
3A1A1A_M/v02")

var clay = ee.Image("OpenLandMap/SOL/SOL_CLAY-WFRACTION_USDA-
3A1A1A_M/v02")

var morg = ee.Image("OpenLandMap/SOL/SOL_ORGANIC-CARBON_USDA-
6A1C_M/v02").select('b0').multiply (0.58)

var sn1 = sand.expression('1 - b0 / 100', {'b0': sand})

var orgcar = ee.Image("OpenLandMap/SOL/SOL_ORGANIC-CARBON_USDA-
6A1C_M/v02").select('b0')

var soil = ee.Image([sand, silt, clay, morg, sn1, orgcar]).rename(['sand', 'silt', 'clay',
'morg', 'sn1', 'orgcar'] )

var factorK = soil.expression(
  '(0.2 + 0.3 * exp(-0.0256 * SAND * (1 - (SILT / 100)))) * (SILT / (CLAY +
SILT)) ** 0.3 * (1 - (0.25 * CLAY / (CLAY + exp(3.72 - 2.95 * CLAY)))) * (1 -
(0.7 * SN1 / (SN1 + exp(-5.51 + 22.9 * SN1))))',
  ...Ref- (Williams J.R and Renard K.G 1983)
  {'SAND': soil.select('sand'),
  'SILT': soil.select('silt'),
  'CLAY': soil.select('clay'),
  'MORG': soil.select('morg'),
  'SN1': soil.select('sn1'),

```

```
'CORG': soil.select('orgcar'}})

Map.addLayer(factorK, {min:0, max:0.5, palette:palette_k },'kfactor')

print(factorK)
```

- **Code for Topographic Factor (LS)**

```
var facc = ee.Image("WWF/HydroSHEDS/15ACC")

var dem = ee.Image("WWF/HydroSHEDS/03CONDEM")

var slope = ee.Terrain.slope(dem)

var ls_factors = ee.Image([facc, slope]).rename(['facc','slope'])

var factorLS = ls_factors.expression(

'(FACC*Cell size/22.1)**0.4*(SLOPE*0.01745/0.09*1.4)**1.4',

{

'FACC': ls_factors.select('facc'),

'SLOPE': ls_factors.select('slope')

})

.clip(table)

var palette_ls = [

'FFFFFF', 'CE7E45', 'DF923D', 'F1B555', 'FCD163', '99B718', '74A901',

'66A000', '529400', '3E8601', '207401', '056201', '004C00', '023B01',

'012E01', '011D01', '011301'

]

Map.addLayer(factorLS, {min:0, max:100, palette:palette_ls },'lsfactor')

print (factorLS)
```

- **Code for Vegetative Cover Factor (C)**

```

var ndvi_median = ee.ImageCollection("MODIS/006/MOD13A2")

var geo_ndvi = [
  'FFFFFF', 'CE7E45', 'DF923D', 'F1B555', 'FCD163', '99B718', '74A901',
  '66A000', '529400', '3E8601', '207401', '056201', '004C00', '023B01',
  '012E01', '011D01', '011301'
]

Map.addLayer(ndvi_median, {min:0, max:0.8, palette:geo_ndvi },'ndvi')

print (ndvi_median)

var factorC = expression(ee.Image(-2.5).multiply(ndvi_median)
.multiply(ee.Image(1).subtract(ndvi_median))    ref. (Tamene and Le, 2015; Van der
Knijff et al., 2000)

print(factorC)

Map.addLayer(factorC)

```

Code for Soil Loss Estimation

```

var erosion = expression (factorR).multiply(factorK).multiply(factorLS))

```

8. VITAE

PRASHANT MADHUKAR TARANGE
MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING)
in
SOIL AND WATER CONSERVATION ENGINEERING
2022

Title of Thesis		:	“Soil Erosion Prediction Using Revised Universal Soil Loss Equation (RUSLE) in Google Earth Engine (GEE)”
Major field		:	Soil and Water Conservation Engineering
Biographical information		:	
Personal	Date of Birth	:	14 th July, 1998.
	Place of Birth	:	At-Tarangfal, Tal-Malshiras, Dist.-Solapur.
	Father’s Name	:	Mr. Tarange Madhukar Aagatrao.
	Mother’s Name	:	Mrs. Tarange Sunanda Madhukar.
Education	S.S.C obtained (2014)		Passed SSC from Gopalrao Dev Prashala, Malshiras.
	H.S.C obtained (2016)		Passed HSC from Sadashivrao Mane Vidyalaya, Akluj.
	Bachelor Degree obtained (2020)	:	Bachelor of Technology Degree from Shriram College of Agricultural Engg. and Tech., Paniv with CGPA-8.78.
	Name of University	:	Mahatma Phule Krishi Vidyapeeth, Rahuri
Address		:	At-Tarangfal, Tal-Malshiras, Dist.-Solapur. Pin Code-413107.
	Email-id	:	prashantmtarange@gmail.com
	Contact Number	:	8208244082