VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

ASSESSMENT OF SOIL LOSS IN WET TROPICAL REGION:A

CASE STUDY IN KUMARADHARA BASIN

A project report submitted for the partial fulfilment of academic requirements for the award of Degree of Bachelor of Engineering in
Department of Civil Engineering
Submitted by

DHANUSH B M	**4NI18CV023**
MEGHANA C S	**4NI18CV053**
KESHAVRAO	**4NI18CV039**
HARSHITH A	**4NI18CV030**

Under the supervision of

Mrs. Roopa N

Assistant Professor

Department of Civil Engineering
The National Institute of Engineering
(An Autonomous Institute under Visvesvaraya Technological University, Belagavi)
Manandavadi Road, Mysuru – 570 008, Karnataka, INDIA

July 2022

The National Institute of Engineering

(An Autonomous Institute under Visvesvaraya Technological University, Belagavi)

Manandavadi Road, Mysuru – 570 008, Karnataka, INDIA

• Recognized by AICTE, New Delhi
• Accredited by National Board of Accreditation, New Delhi
• Grant-in-Aid by Government of Karnataka

Department of Civil Engineering

CERTIFICATE

Certified that the project work entitled **Assessment of Soil Loss in Wet Tropical Region: A Case Study in Kumaradhara Basin** carried out by **Dhanush B M (4NI18CV023), Meghana C S (4NI18CV053**), **Keshavrao (4NI18CV039),** and **Harshith A (4NI18CV030)** a bonafide student of Civil engineering (VIII Semester)is submitted in partial fulfillment for theaward of Bachelor of Engineering in **The National Institute of Engineering, Mysuru,** an autonomous institute under Visvesvaraya Technological University, Belagavi during the year2022. It is certified that all suggestions/ corrections suggested during Internal Assessment have been incorporated in the Report deposited in the departmental library.

The project report/ dissertation has been approved as it satisfies the academic requirements in respect of Project work prescribed for the award of the said Degree.

Name & Signature of the Guide	Name & Signature of the HoD	Signature of the Principal

External Viva

Sl. No.	Name of the examiners	Signature with date
1.		
2.		

DECLARATION

We, **Dhanush B M, Meghana C S, Keshavrao, Harshith A**, bearing USN **4NI18CV023, 4NI18CV053, 4NI18CV039, 4NI18CV030**, students of the eighth semester B.E., Civil Engineering, The National Institute of Engineering, Mysuru, hereby declare that the project titled "Assessment of soil loss in wet tropical region: A case study in kumaradhara basin" has been carried out by us and report is submitted in partial fulfillment of the course requirements for the award of degree in Bachelor of Engineering in Civil Engineering, during the academic year 2021- 2022. The matter embodied in this report has not been submitted to any other university or institution for the award of any other degree.

Place: Mysuru

Date:

Dhanush B M

Meghana C S

Keshavrao

Harshith A

ACKNOWLEDGEMENT

We convey our gratitude to all who have made a valuable contribution to the project throughout. We wish to express our profound thanks to all those who have encouraged us in doing this project.

We express our humble gratitude and special thanks to **Mrs. ROOPA N**, our esteemed guide for dedicating her precious time and rendering constant support throughout the dissertation work. Her knowledge, guidance, cooperation, and constructive criticism have given us a great opportunity for learning and the successful completion of our work.

We also express our heartfelt gratitude to our Head of the Department **Dr. K C Manjunath** for his wholehearted support and encouragement. We are also thankful to our principal **Dr. Rohini Nagapadma** for all the facilities provided in the college. We also thank all our teaching and non-teaching staff members of the Department for their kind co-operation.

DHANUSH B M
MEGHANA C S
KESHAVRAO
HARSHITH A

ABSTRACT

Agricultural augmentation, deterioration of land, and other ontogeny activities contribute to soil erosion, which is a severe concern. The Western Ghats of India is one of the 34 global biodiversity hotspots, and habitat degradation has been causing havoc in this area for decades (ENVIS technical Report, 2013). The Kumaradhara River is a dominant part of wet tropical forested land located on the western side of the Western Ghats. It is a major tributary of the Netravathi River, featuring numerous perennial streams and dense evergreen forests. Kumaradhara river has tributaries namely, Hongadahalla and Kadumanehalla rivers and sub-catchments covering the parts of the rivers are Beedahalli, Mookanamane, and Marenahalli, having catchment areas of 33.21km^2, 42.24km^2, and 64.19km^2 respectively. Though multiple studies have been undertaken in other parts of the country that assess the amount of soil erosion, only a handful was conducted in the Kumaradhara river basin. Soil erosion and degradation of land resources are serious problems that affect the productivity of the land. A quantitative assessment is frequently required to infer the extent and magnitude of soil erosion so that sound management strategies can be established on a regional basis with the help of field measurements. For assessing the soil erosion in the study area, the soil erosion model is used. Models can be viewed as a virtual laboratory that pulls together data, observations, and information from other disciplines to achieve long-term environmental sustainability. The main objectives of this study are to use RUSLE and GIS techniques to estimate annual soil erosion rates and develop a soil erosion map for the year 2021 and anticipate LULC change for the years 2010, 2015, and 2020 for the Kumaradhara catchment. The results of the study can be used to develop land-use planning and management strategies in environmentally sensitive mountainous areas.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF NOTATIONS/ABBREVATIONS

RUSLE : Revised Universal Soil Loss Equation

GIS : Geographic Information System

RS : Remote Sensing

LULC : Land Use and Land Cover

QGIS : Quantum GIS

ARCGIS : Aeronautical Reconnaissance Coverage GIS

AMSL : Above Mean Sea Level

DEM : Digital Elevation Model

LANDSAT : Land Remote Sensing Satellite

NBSS & LP : National Bureau of Soil Survey and land Planning

AWC : Available Water Holding Capacity

IDW : Inverse Distance Weighted

SCP : Semi-Automation Classification Plugin

R : Rainfall erosivity factor

K : Soil erodibility factor

L : Slope Length factor

S : Slope Steepness factor

LS : Topography factor

C : Crop management factor

P : Conservation support practice factor

A : Annual Average Soil Loss

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Soil erosion, which is influenced by climate and land-use changes, has been identified as one of the major threats to the world's soil resources, which in turn affects agricultural productivity. Soil erosion is increased by anthropogenic activities, with agriculture being the leading cause of soil degradation globally. In India, serious soil erosion through gorges and gully, shifting cultivation, cultivated wastelands, sandy areas, deserts, and water logging affect nearly 130 million hectares of land (Kothyari, 1996). Excessive soil erosion, with its associated high rate of sedimentation in reservoirs and decreased fertility, has become a serious environmental issue for the country, with disastrous economic consequences. The biophysical environment, which includes soil, climate, terrain, ground cover, and their interactions, influences the soil erosion process. The slope, length, aspect, and shape of the terrain all have an impact on the mechanism of soil erosion. The effects of slope and aspect would be significant in the runoff mechanism. The runoff generated by the slope will find a path nearby, resulting in soil erosion as the velocity of the runoff increases. The government has taken numerous steps to address the issue and prevent further degradation of the soil layer. With the help of field measurements, a quantitative assessment is required to infer the extent and magnitude of soil erosion problems so that sound management strategies can be developed on a regional scale. However, simulation models for soil erosion are one of the best options for accurately estimating the amount of soil erosion with the help of remote sensing and GIS. There are several soil erosion models with varying degrees of complexity. The Revised Universal Soil Loss Equation (RUSLE), developed by the USDA Soil and Water Conservation Service in 1993, is one of the most widely used empirical models for assessing sheet and rill erosion. The use of geographic information systems (GIS) to integrate existing soil erosion models, field data, and data provided by remote sensing technologies appears to be an asset for estimating soil erosion in risk areas. Controlling soil erosion is one option for increasing crop productivity while reducing river and lake sedimentation. Thus, assessing soil loss and specifying sensitive areas for best management practice implementation is very important forthe successful implementation of best soil conservation activities.

1.2 BACKGROUND

The conventional measurement techniques and models' limitations in providing information on the spatial and temporal patterns of soil and water degradation across catchments limit the ability to develop cost-effective land management strategies. However, the development of new erosion assessment techniques, as well as recent advances in the application of remote sensing and geographic information systems (GIS) to the study of erosion and sediment delivery, offer significant potential for meeting these requirements.

1.3 OBJECTIVES OF THE STUDY

The objectives of the present study are:

1. Estimation and mapping of soil erosion using Remote sensing (RS) and Geographic Information System (GIS) approaches.
2. Assessment of Land use and Land cover (LULC) changes for the study area.

CHAPTER 2

LITERATURE REVIEW

Ratul Das and Barnali Gogoi (2020) conducted the Assessment of Soil loss in Sadiya Region, Assam, India using remote sensing and GIS. This study focuses on identifying areas of intense soil erosion in Sadiya, a subdivision of the Tinsukia district of Assam in India to facilitate the appropriate implementation of soil management and conservation schemes in an administrative unit. The annual soil loss of the Sadiya region has been estimated for the year 2016, using RUSLE and it has been found that the region of about 443865 tons of soil loss per year, with an average annual soil loss in the region, was 5.45 t RSin areas of higher elevation with more gradient. The results of the study can help in formulating management strategies for sustainable land conservation practices.

Vimha Ritse et al (2020) monitored land use land cover changes in the Eastern Himalayan landscape of Nagaland, Northeast India. LULC changes that occur quickly in response to urban growth and human settlements without sufficient planning put pressure on other land classes, such as forest land, agricultural land, and water bodies, potentially disrupting the ecosystem. This study provides first-hand knowledge on monitoring LULC changes in Nagaland's two emerging districts, which will be useful to authorities and stakeholders during land-use planning and development project execution in the future. The goal of this study is to use RS and GIS approaches to detect LULC changes in the Kohima and Dimapur districts of Nagaland, Northeast India, between 1998 and 2018.

Asish Saha et al (2018) carried out GIS-Based Soil Erosion Estimation Using Rusle in Upper Kangsabati Watershed, West Bengal, India. In this study, the IRS LISS III image has been used for generating the C factor by using the Normalized Difference Vegetation Index (NDVI). The present study is an attempt to focus on the estimation of soil erosion in the upper Kangsabati watershed by the RUSLE model. The potential soil erosion of the upper Kangsabati watershed varies from 0.014 to 13.42 t ha^{-1} $year^{-1}$. it was found that nearly 45% area is under the very high and high erosion-prone zone. If soil erosion from the agricultural land continues to disintegrate at the same rate, then it may lead to soil degradation and ultimately cultivable land will become unfit for cultivation. The rate of erosion may increase in the future due to continuous forest degradation for the extension of agricultural land and to some extent overgrazing.

Jobin Thomas and Sabu Joseph (2018) carried out the Assessment of soil erosion in a monsoon-dominated mountain river basin in India using RUSLE-SDR and Analytic hierarchy process (AHP). The objective was to estimate long-term average annual soil loss (A) and sediment yield (SY) in a tropical monsoon-dominated river basin in southern Western Ghats, India. The annual soil loss varies up to 785 t ha^{-1} $year^{-1}$, with a mean of 14.36 t ha^{-1} $year^{-1}$. The quantitative results of the study are expected to be beneficial for framing better watershed management strategies in the tropical mountainous terrains of the southern Western Ghats. The study also demonstrates the applicability of remote sensing and GIS techniques for modeling soil erosion using various geo-environmental factors.

Jobin Thomas (2017) carried out the Assessment of soil erosion in a tropical mountain river basin of the southern Western Ghats, India using RUSLE and GIS. The goal of this work is to use the RUSLE model and the TLSD function in ArcGIS to estimate gross and net soil erosion rates and deposition in a tropical mountainous river basin in the southern Western Ghats. Results indicated that prioritizing sub-basins and the planning of conservation actions are heavily influenced by regionally changing data on soil erosion and sediment deposition. As a result, the quantitative findings on soil erosion and accompanying carbon movement are predicted to be useful in developing basin-wide land management policies. It was concluded that, RULSE model, in combination with the Transport layer Security (TLS) function, aids in the mapping of sensitive zones to soil erosion and deposition, which is critical in the development of comprehensive land management strategies.

Alka Sahu et al (2017) carried out Soil Erosion assessment using RUSLE and GIS on Dudhawa Catchment. In this study, the RUSLE model was used to estimate soil loss from the Dudhawa reservoir catchment in the Dhamtari district of Chhattisgarh. All factors map of the model is generated in a GIS environment. RUSLE model is to be integrated with GIS to determine all the parameters of the model. The quantity of actual soil erosion calculated by the RUSLE model came out to be 216189.16 tons/year. It was observed the hat 6374.28-hectare area is under slight class whereas only 168.49-hectare area is under very severe class. The model can be applied for more alternate management practices, such as the effect of soil stabilization, contour bounding etc.

J.S. Rawat and Manish Kumar (2015) monitored land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. The study used geospatial tools to map out the state of land use/cover in one of the development blocks of the Hawalbagh block to discover the land consumption rate and changes that have occurred over the last two decades. According to the findings, vegetation and built-up land grew by 3.51 percent and 3.55 percent, respectively, while agricultural, barren land, and water bodies dropped by 1.52 percent, 5.46 percent, and 0.08 percent. The current study shows that remote sensing and GIS are key tools for temporal analysis and quantification of spatial phenomena that would otherwise be impossible to achieve using traditional mapping approaches. These technologies enable change detection in less time, at a lower cost, and with more precision.

B.P. Ganasri, H. Ramesh (2015) have assessed soil erosion by the RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. The objective was to create an approach that combines remote sensing data and GIS with the Revised Universal Soil Loss Equation (RUSLE) to estimate the spatial distribution of soil erosion at a catchment scale. It was observed that soil of about 473,339t was estimated with the help RUSLE model. Through the mapping of soil erosion using the RUSLE model, it was found that the land use land cover map of 2003 almost matched with the estimated sediment load of 441,870t during 2002-2003. As the model output reasonably agreed with observed data, GIS is a valuable tool in assessing soil erosion and estimating erosion loss.

K. Balasubramani et al (2015) have estimated soil erosion in a semi-arid watershed of Tamil Nadu (India) using the revised universal soil loss equation (RUSLE) model through GIS. The objective of the study was to identify and evaluate the deciding parameters of the RUSLE and prepare the corresponding thematic layers and overlay them using GIS to estimate the average annual soil loss and to identify vulnerable land use classes of the study area. The soil loss values estimated for Andipatti watershed range with an average of 5.26 6 t/ha/yr. The estimated pixel-level soil loss value was grouped into six classes. The study illustrates annual average soil erosion is lower in dense forests as well as irrigated agricultural fields. Most of the plantation tracts and fallow lands on the sloping foothills require immediate attention to soil conservation practices.

S. Abdul Rahaman et al (2015) carried out an Estimation of annual average soil loss, based the on RUSLE model in Kallar watershed, Bhavani basin, Tamil Nadu, India. This study attempts to utilize the RUSLE, combined with GIS technologies to generate soil erosion loss, erosion severity, and erosion hazard maps and Identify areas of critical soil erosion. The potential annual soil loss of the kallar watershed ranges up to 398.58 t h^{-1} y^{-1}. The estimated pixel-level soil loss rate was classified into five classes and the spatial distribution of soil loss and found that the critical soil loss occupies 3.82 % of the total area. It was observed that functions of C and P factors can be controlled and thus can greatly reduce soil loss through the management and conservational measures.

Sumantra Sarathi Biswas and Padmini Pani (2015) have Estimated the soil erosion in the Barakar River basin, Jharkhand, India using RUSLE and GIS techniques. The objective was to estimate soil loss in a plateau and plateau fringe river basin where soil erosion is significant. The estimated soil erosion of the Barakar river basin is ranged up to 282 t ha^{-1} $year^{-1}$ and it is considered moderate to high soil loss for the study area. The reduction of forests leads to soil erosion and land degradation in the catchment areas. Thus, conservationists and planners should implement the management strategies more accurately for the catchment areas to sustain the environment and accelerate the longevity of the reservoirs.

Pravat Kumar Shit and Arup Sankar Nandi (2015) mapped soil erosion risk zones using the RUSLE model on the jhargram sub-division in West Bengal, India. The study demonstrates the prognostic modeling capabilities of geo-spatial technology based on the soil erosion potential model to assess the effects of implementing land-use changes within the sub-tropical region in India. The results showed that 74.77 % of the study area is marked as low potential erosion (<2.0 t h^{-1} y^{-1}); 14.41 % area manifested as moderate erosion (2.0–5.0 t h^{-1} y^{-1}) and the remaining part is considered as high (6.24 %, 5.0–10.0 t h^{-1} y^{-1}) to very high (5.58 %,>10 t h^{-1} y^{-1}) erosion risk. The present information may help recognize areas that are vulnerable to soil loss and the proposed method will be used for generalized planning and assessment purposes for supervision and preservation of the soil erosion.

J.S. Rawat et al (2013) investigated the changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital, Uttarakhand, India. The purpose of this research is to show how multi-temporal satellite imageries can be used to define land use/cover dynamics in a Himalayan town, specifically Ramnagar, which is located in Uttarakhand's foothill zone in the Central Himalayan region. The town has grown 6.96 km2 in the last two decades along National Highway 121 but has grown very little in the northeast due to the dominance of riverbed and rocky terrain, which hinder urban growth. The method used in this study convincingly established the utility of GIS and remote sensing tools in determining land use/cover change patterns in urban areas.

V. Prasannakumar et al (2011) carried out a Regional Scale Erosion Assessment of a Sub-tropical Highland Segment in the Western Ghats of Kerala, South India. The goal of this research is to analyze actual soil erosion at a regional scale (1:50,000) using the RUSLE model in conjunction with remote sensing and GIS approaches. In a GIS setting, the quantitative output of estimated soil erosion potential ranges up to 109.31 t h^{-1} y^{-1}. Severe to great soil erosion risk affects a large section of the land, while zones of tolerable soil erosion risk cover only 22.18 percent of the entire area. The study illustrates the severity of erosion in the Western Ghats' tropical highlands, demonstrating the use of RUSLE in identifying erosion hazards and pinpointing high-risk regions where soil conservation efforts are critical.

V. Prasannakumar et al (2011) estimated soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology. The goal of this work was to employ RUSLE and GIS techniques to estimate the yearly soil erosion rate and generate a soil erosion intensity map for a mountainous sub-watershed of the river Pamba, which can then be used as a scalable model for diverse watersheds in the Western Ghats. According to the spatial pattern of classified soil erosion risk zones, places with high and severe erosion risk are found in the study area's west, northwest, and southern regions, while areas with low erosion risk are found in the study area's eastern and central regions. The estimated amount of soil loss and its spatial distribution can serve as a foundation for comprehensive watershed management and sustainable land use. The implementation of control measures should be prioritized in areas with high and severe soil erosion.

Prakasam. C (2010) investigated land use and land cover change detection through a remote sensing approach: A case study of Kodaikanal taluk, Tamil Nadu. The paper's major goal is to examine the type and breadth of land use/land cover changes in Kodaikanal Taluk during the last 40 years, as well as the driving causes behind such changes. It has been estimated that about half of all forest lands have been converted to agricultural, harvested, or built-up land in the last 40 years. Empirical observation reveals that due to an increase in the cost of cultivation, problems due to shortage of labor, supply of low-quality adulterated fertilizers, and price fluctuation in the market the farmers prefer to sell their land. Hence there is a risk of a decline in the extent of land under agriculture in the study area. The increase in the area under built-up lands may lead to a lot of environmental and ecological problems. This paper helps in undertaking effective measures and proper land use planning to conserve natural resources.

Silva, Gordon and Heath (2009) used remote sensing to analyze and study land-use/land-cover use changes impact on the environment of Madison County Alabama. The monitoring of land/use land cover changes was essential in view point of the developers, planners, policy makers and government officials, public and private organizations. The sources like remote sensing images, land-use/land-cover use maps, GPS data, etc. are used in the study. Six classes or categories of land-use/land-cover were analyzed to determine changes and the relationship to suburban sprawl.

P. P. Dabral et al (2008) carried out a soil Erosion Assessment in a Hilly Catchment of North Eastern India Using USLE, GIS, and Remote Sensing. There is currently no gauging station in the Dikrong river basin to quantify soil loss. Traditional soil loss calculation methods are time-consuming, expensive, and biased, especially in Arunachal Pradesh's steep terrain. Hence, the USLE model is developed. The places with the highest LS factor and conservation factor suffer the most soil losses. The Dikrong River Basin's Spatial Distribution of Soil Loss shows that moderate erosion potential zones cover 25.61 percent of the land, while severe erosion potential zones cover 13.88 percent.

Karsidi (2004) works on land use/land cover change detection, identification, analysis and prediction using remote sensing and GIS techniques in the downstream of the Ci Tarum watershed and its surroundings in West Java, Indonesia. Supervised Maximum Likelihood classification and NDVI transformed images are used to classify and identify land use/land cover categories. A post-classification comparison approach was used to detect land use/land cover changes, and a Markov Cellular automata model is used to predict possible future land use/land cover patterns in the study area.

Mahoney et al (2003) observed that Land use/cover changes are mostly occurred due to human institutions, population size and distribution, economic development, technology and other factors. The study has proved that the effects of land-use and land-cover change depend on the understanding of past land-use practices, current land-use and land-cover patterns, and projections of the future. NASA’s Land-Cover/Land-Use Change Program (LCLUC) website is a rich resource on information about several international land cover and land use projects. Advancements in the quality and availability of many lands cover and land-use change products have enhanced the range and size of the user community. Long-Term Landsat temporal datasets become valuable sources for Land-Cover and Land-Use Change detection. Land products are increasingly used operationally for many applications including forecasting and change detection as well as policy and decision-making processes.

Sangavongse (1995) explained that generally, the land use land cover change studies involve more than one technique and each Researcher prefers a different technique by comparing the Results. The study has proved that the usage of Landsat TM for mapping the Land Use/Land Cover Change in the Chiang Mai area which is the second largest city in Thailand provided satisfactory results. However, the study emphasizes that research work on Land Use/Land Cover should be conducted on a regular basis so that the information becomes authentic and can be used in various areas. This Research also investigated the use of GIS data and sequential Air photos of test areas as another means of studying Land use/Land cover change.

Wischmeier and Smith (1978) carried out a prediction of rainfall Erosion Losses- A Guide to Conserving Planning. The objective of the research is to develop a research model that can be recommended for rill and inter-rill kinds of soil erosion for accurate mapping. Soil loss equations are much less accurate at predicting specific events than they are atpredicting long-term averages. The USLE is used to forecast long-term average soil lossesunder certain conditions. Runoff was estimated to be responsible for 90% of erosion on thesteeply rolling wheat land.

CHAPTER 3

METHODOLOGY

3.1 STUDY AREA

Kumaradhara river is a tributary of the Netravathi River, which originates in Western Ghats, Karnataka and flows for 126 km, and joins the Arabian Sea on the west. Kumaradhara catchment covers an area of 1776 sq. km which extends from 12°29’4” N to 12°58’33” N latitude and 75°95’8” E to 75°47’48” E longitude. Kumaradhara basin is rich in biodiversity and the freshwater ecosystems are extremely diverse, distinctive, and vital to livelihoods and economies. It spreads across three districts, Dakshina Kannada, Kodagu, and Hassan.

Kumaradhara river has tributaries namely, Hongadahalla and Kadumanehalla rivers and sub-catchments covering these parts of the rivers Mookanamane, Bidahalli, and Marenahalli are chosen for the present study. Mookanamane catchment covers an area of 41km^2 which extends from 12º45’0” to 12º49’30” N latitude and 75º43’30” to 75º46’30” E longitude with an elevation of 1179m Above Mean Sea Level (AMSL). Bidahalli catchment covers an area of 33 km^2 extending from 12º36’0” to 12º40’30” N latitude and 75º42’0” to 75º46’30” E longitude with an elevation of 1485m AMSL. Marenahalli catchment covers an area of 64 km^2 extending from 12º52’30” to 12º57’30” N latitude and 75º40’0” to 75º46’30” E longitude with an elevation of 1293m AMSL. Figure 3.1 indicates the study area.

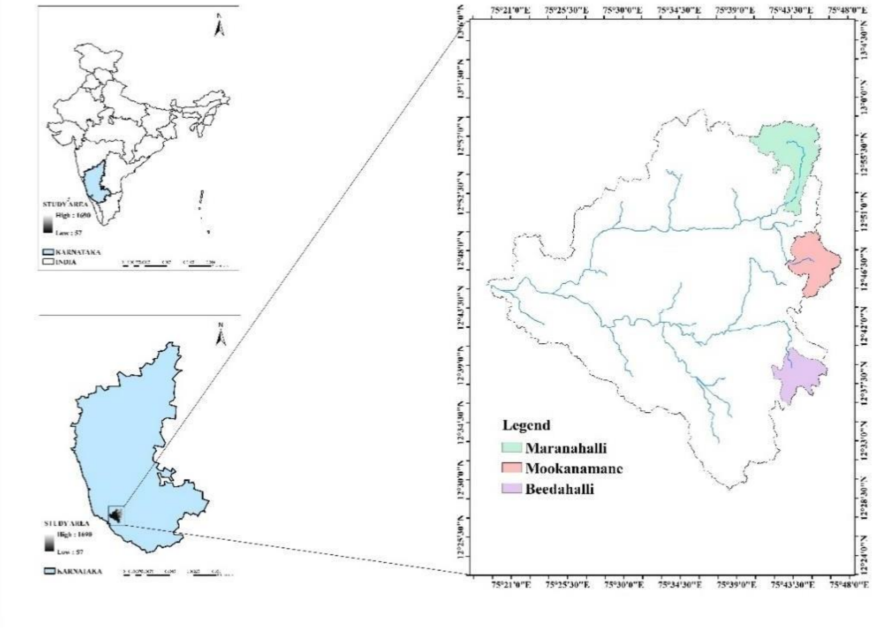
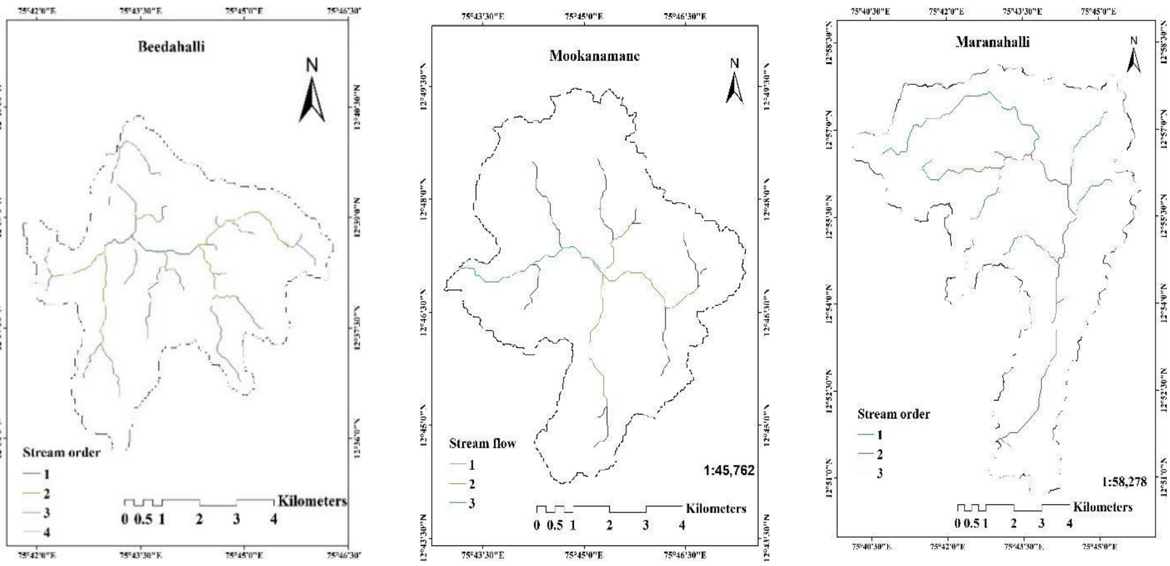


Figure 3.1: Study area



(i) **(ii)** **(iii)**

Figure 3.2: Catchment (i) Bidahalli (ii) Mookanamane (iii) Marenahalli

3.2 DATA USED

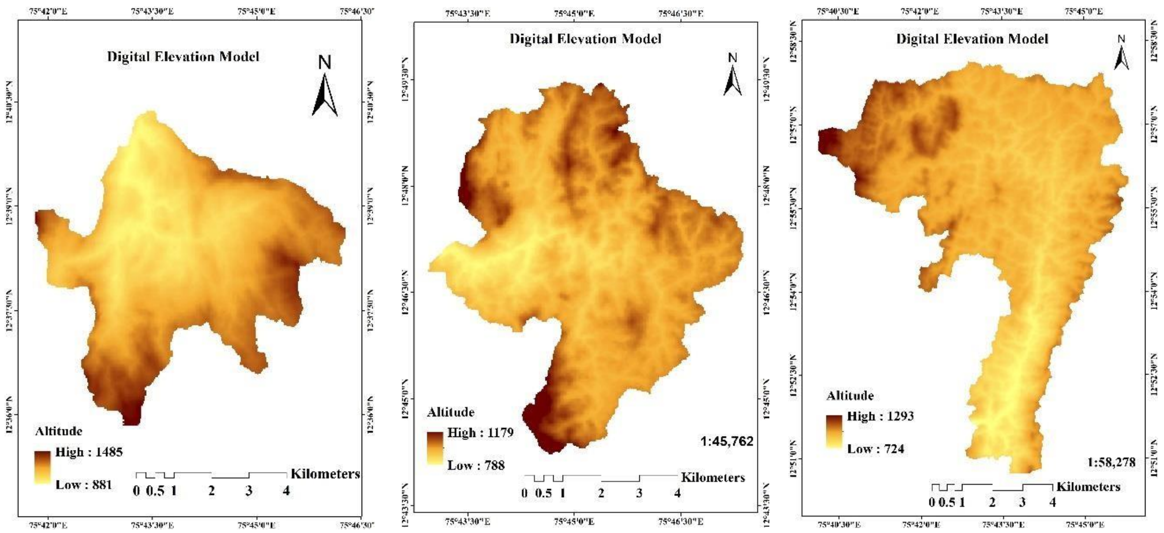
Data is the most basic unit of information from which research can be conducted. It could include values, images, statistics, and phrases. The use of data or datasets is essential for any analytical work. The quantitative assessment of soil erosion using the RUSLE model is entirely dependent on the data used. The data used for the study of the RUSLE model includes precipitation data, soil map, Land use and Land cover maps, Digital Elevation Model (DEM), and satellite images (LANDSAT images) for the catchment's Bidahalli, Marenahalli, and Mookanamane. LANDSAT-7, LANDSAT-7, and LANDSAT-8 images for the years 2010, 2015, and 2020 respectively were collected from https://earthexplorer.usgs.gov/. The details of the data used are shown in Table 3.1.

Table 3.1 Datasets used for the study

Sl No.	Data type	Source	Description
1	Digital elevation model	https://earthexplorer.usgs.gov/	DEM (30m resolution)
2	Satellite image	https://earthexplorer.usgs.gov/	LANDSAT-7 image (2010) LANDSAT-7 image (2015) LANDSAT-8 image (2020)
3	Soil data	The National Bureau of soil survey and land use planning. India.	Soil map for the year 2003.
4	Rainfall data	Indian meteorological department, India	Rainfall data for a period of 12 years (2010-2021) with 9 rain gauge stations.
5	Land use and land cover		Five LULC classes using LANDSAT-8 IMAGE (2021)

3.2.1 Digital Elevation Model (DEM)

Digital Elevation Model (DEM) is a digital file that contains ground altitudes for earth positions at regular horizontal intervals. In other words, DEM is a virtual representation of georeferenced information. The DEM data files with 30m resolution pertaining to the study areas were taken from the source https://earthexplorer.usgs.gov/. Figure 3.3 shows the DEM of catchments.



(i)(ii) (iii)Figure 3.3: DEM (i) Bidahalli (ii) Mookanamane (iii) Marenahalli

3.2.2 Soil map

The National Bureau of Soil Survey and Land Planning (NBSS & LP) in India provided a soil map for the catchments of Bidahalli, Marenahalli, and Mookanamane. The Bidahalli catchment has two types of soil, the Marenahalli watershed has five types of soil, and the Mookanamane catchment has five types of soil. The following five types of soil were commonly found in these catchments:

Very deep, clayey soil with medium Available Water Holding Capacity (AWC) on laterite plateaus.
Deep, well-drained, gravelly clay soils on slopes of steeply sloping hill ranges.
Very deep, well-drained, gravelly clay soils with low AWC on low hill ranges
Very deep, moderately drained, loamy over sandy soils of valleys, with a shallow water table.
Deep well-drained, clayey soils with medium AWC on laterite plateaus.

3.2.3 Precipitation data

The rainfall data for this project was collected in and around the study areas using nine rainfall gauge stations from the Indian Meteorological Department over 12 years (2010-2021). To improve accuracy, gauge stations not only in the catchment but also near catchments were considered. The gauge stations were set and clipped using Inverse Distance Weighted (IDW) interpolation in Quantum GIS (QGIS) 2.18, above which the basins were placed and clipped. The R-factor is mapped using rainfall data.

3.2.4 Satellite images

The images for the years 2010, 2015, and 2020 were collected from the source https://earthexplorer.usgs.gov/. LANDSAT-7 images were used for the years 2010 and 2015. Wherein, LANDSAT-8 images were used for the year 2020.

3.2.5 Land use and Land cover map

Land use and land cover play a huge influence in estimating soil erosion, especially when mapping the Crop management (C) and Conservation Support Practice (P) components for the RUSLE model. LANDSAT-8 pictures from 2021 were used to map land use and land cover in Bidahalli, Marenahalli, and Mookanamane. The Semi-Automatic Classification Plugin (SCP) Documentation was used to map the land use and land cover in QGIS 3.16.

3.3 RUSLE MODEL

This chapter covers the fundamental principles of the RUSLE model's technique and the methodology for estimating the model's six parameters. The six parameters of the RUSLE model will be estimated based on the rainfall, DEM, soil type map, and land cover map.

The degree of erosion, from watersheds, is all influenced by a complex interplay of terrain, geology, climate, soil, vegetation, land use, and man-made developments (Shen and Julien, 1993). The USLE is the most extensively used approach for predicting long-term rates of interill and rill erosion from field or farm size units subject to various management practices around the world. The USLE was developed by Wischmeier and Smith (1965) based on data collected over several years from around 10,000 small test plots across the United States. RUSLE was created to include new studies after its initial publication of the USLE in 1978. (Wischmeier and Smith, 1978). The RUSLE's core structure is similar to that of the USLE, but it additionally includes process-based auxiliary components for estimating time-variable soil erodibility, plant development, residue management, residue breakdown, and soil surface roughness as a function of physical and biological processes. RUSLE now includes updated erosivity (R) values, new topographical component (L and S factor) connections that incorporate rill and inter-rill erosion ratios, seasonality consideration for the K factor, and extra P factors for rangelands and subsurface drainage, among other enhancements. The RUSLE model is represented by equation 3.1

$$A = R \times K \times LS \times C \times P \qquad 3.1$$

Where,

A = Computed spatial average soil loss and temporal average soil loss per unit of area, expressed in the units selected for K and the period selected for R. In practice, these are usually selected so that A is expressed in $ton \times acre^{-1} \times yr^{-1}$, but other units can be selected (that is, $ton \times ha^{-1} \times yr^{-1}$);

R = Rainfall erosivity factor-the rainfall erosion index plus a factor for any significant runoff from snow melt expressed in $MJ\ mm\ ha^{-1}\ h^{-1}$ per year;

K = Soil erodibility factor – the soil-loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6-ft (22.1- m) length of uniform 9% slope in continuous clean-tilled fallow;

L = Slope length factor – the ratio of soil loss from the field slope length to soil loss from a 72.6-ft length under identical conditions;

S = Slope steepness factor – the ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions.

C = Crop management factor – the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow

P = Support practice factor – the ratio of soil loss with a support practice like contouring, strip-cropping, or terracing to soil loss with straight-row farming up and down the slope.

The dimensionless effects of slope length and steepness are represented by the L and S factors, while the dimensionless effects of cropping and management systems and erosion control measures are represented by the C and P factors. The methodology flowchart is shown in Figure 3.4.

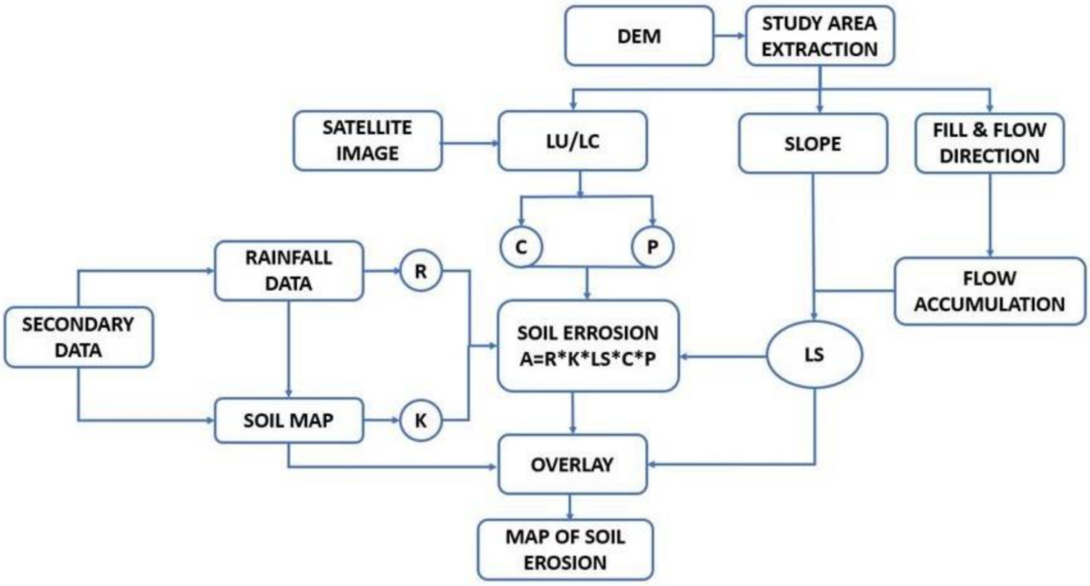


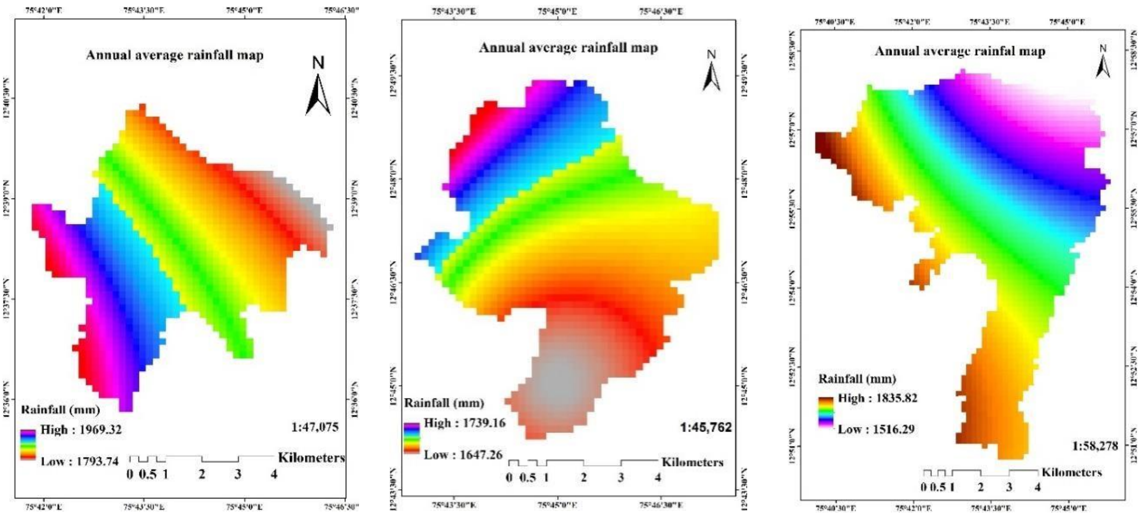
Figure 3.4: Flowchart of Methodology

3.3.1 Rainfall erosivity factor (R)

The rainfall and runoff erosivity factors were calculated by Wischmeier and Smith (1958) using research data from a variety of sources. The mean yearly sum of individual storm erosion index values, EI_{30}, is defined as the rainfall-runoff erosivity factor, where E is the total storm kinetic energy and I_{30} is the greatest rainfall intensity in 30 minutes. Continuous rainfall intensity measurements are required to calculate storm EI_{30}. As a result, rainfall data for all of the catchments were collected over 12 years.

According to Renard et al. (1997), the numerical value utilized for R in RUSLE must measure the effect of raindrop impact as well as indicate the volume and rate of runoff of soil predicted to occur as a result of the rain. Wischmeier's rainfall-runoff erosivity factor (R) appears to match these criteria better than any of the numerous other rainfall parameters.

Based on the smallest to largest precipitation in the 9-gauge stations, the average precipitation for each study area was computed. Rainfall maps are shown in Figure 3.5.



(i) (ii) (iii)

Figure 3.5: Rainfall map (i) Bidahalli (ii) Mookanamane (iii) Marenahalli

The Inverse Distance Weighing method of interpolation is used to estimate the spatial distribution of average annual precipitation (P) in the research area. Ten years of rainfall data from nine rain gauge stations in and around the study area were used in the interpolation method. The measured average rainfall levels ranged from 1793.74 to 1969.32, 1647.26 to 1739.16 mm, and 1516.29 to 1835.82mm in Bidahalli, Mookanaman,e and Marenahalli respectively. The rainfall erosivity factor is calculated by followinthe g equation cited by Singh et al 1981. Equation depicted in 3.2

$$R = 0.79 + 0.363P \qquad 3.2$$

Where,

R = Rainfall erosivity factor

P = Average Annual Precipitation

3.3.2 Topography factor (LS)

The topographic factor LS is the ratio of soil loss under specified conditions to soil loss at a site with a "standard" slope steepness of 9% and a slope length of 22.13 m. The slope length (L) and slope steepness (S) effects on soil erosion are accounted by the topographic erosivity factor LS. The effect of slope length on erosion is measured in slope length (L).

The slope length is the distance between the site of origin of overland flow and the point where deposition begins or runoff water enters a well-defined channel. As a result, as the slope length grows, the soil loss per unit area increases.

The effect of slope steepness on erosion is indicated by slope steepness (S). The influence of slope steepness on soil loss is greater than that of slope length. The higher the erosion, the steeper the slope. The most severe erosion occurs between a 10% and a 25% slope. As a result, the topographic factor is determined using equation 3.3.

$$LS = [Q_a M/22.13]^{y} \times (0.065+0.045\times S_g+0.0065\times S_g^2) \qquad 3.3$$

Where,

LS= Topographic factor

Q_a= Flow Accumulation grid

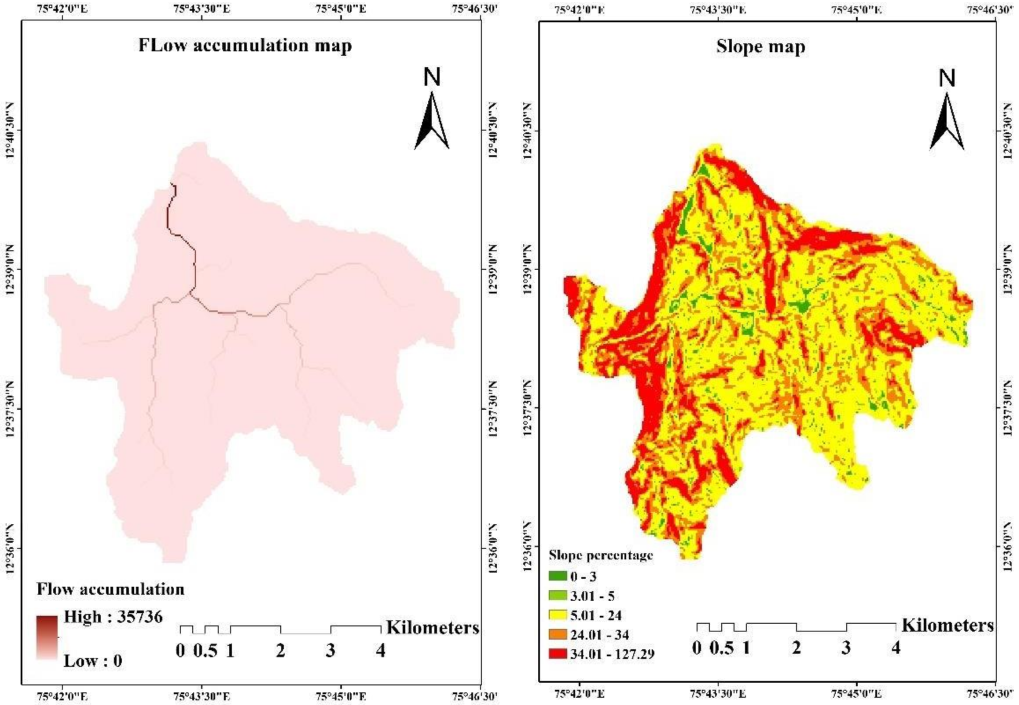
S_g= Grid slope in percentage

M= Grid size(X×Y)

y= dimensionless exponent that assumes the value of 0.2-0.5

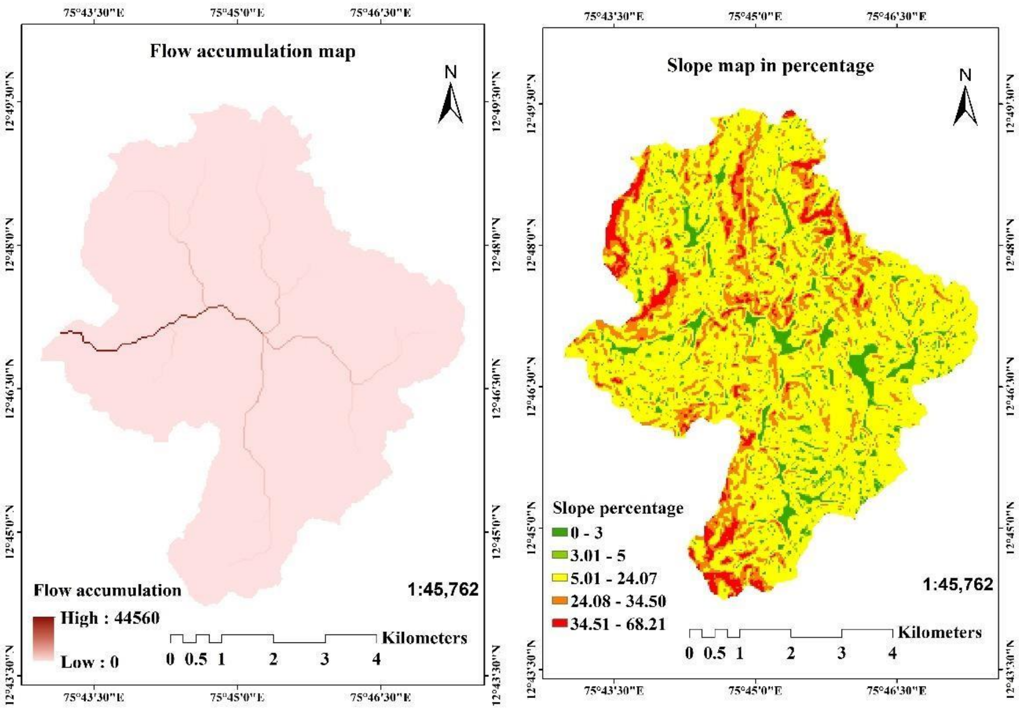
As indicated in the Table below, Wischmeier and Smith (1978) came up with variable values of exponent y for different slopes depending on slope steepness. The flow accumulation and slope maps for the study areas are shown in Figures 3.6, 3.7 and 3.8

Slope	<1%	1-3%	3-4.5%	>4.5%
Y	0.2	0.3	0.4	0.5



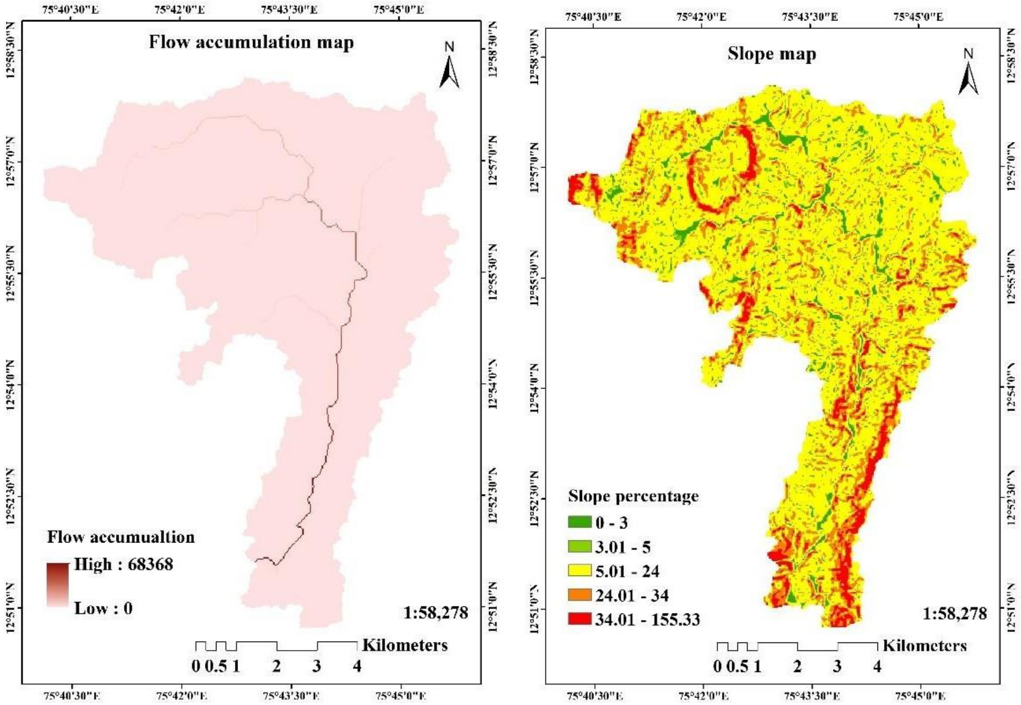
(i) (ii)

Figure 3.6: Bidahalli (i) Flow Accumulation (ii) Slope Map



(i) (ii)

Figure 3.7: Mookanamane (i) Flow Accumulation (ii) Slope Map



(i) **(ii)**

Figure 3.8: Marenahalli (i) Flow Accumulation (ii) Slope Map

3.3.3 Crop management factor(c)

For crop management, the C-factors are the most important values. Because C-factors are not readily available in most Indian crops. As a result, Karaburun (2010)'s C-factors were used to show the impact of cropping and management practices on soil erosion rates in agricultural land. The effect of vegetation canopy and ground covers on soil erosion reduction in forested areas varies depending on the season and crop production system. The seasonal variation of the C factor is influenced by a variety of factors, including rainfall, farming techniques, crop type, and so on. The crop management factor map was created using the study area's land use-land cover map. LANDSAT images have been used to classify the land use land cover of Bidahalli, Mookanamane, and Marenahalli into five land use-land cover classes: water bodies, forest, cultivated land, built-up land, and barren land.

3.3.4 Conservation support practice factor (P)

The P-factor shows the impact of various soil erosion-prevention measures in the area, such as contour farming, terracing, and strip cropping. It is the ratio of soil loss from land with conservation methods (such as contouring, strip cropping, terracing, and so on) to soil loss from a site with no soil erosion control measures. The P-factor has a range of 0 to 1. A value close to 0 denotes good conservation practice, whereas a value close to 1 denotes bad conservation practice. The P factor takes into account control measures that influence drainage patterns, runoff concentration, runoff velocity, and hydraulic forces applied by runoff on the soil to lower runoff's erosion potential. Because there is a lack of field data on conservation activities in the study areas, the P-factor value was obtained by citing V. Prasannakumar et al (2011).

The input variables of RUSLE were co-registered to a common reference to reduce geo-location mistakes and enhance horizontal accuracy. After projecting all of the data from the Geographic Coordinate System (WGS84 datum) to the Universal Transverse Mercator (zone 43 N) with a grid cell size of 30 m, the analysis was completed. After generating all of RUSLE's input elements, the quantitative output was calculated in ArcGIS on a pixel-by-pixel basis (using the raster calculator tool).

3.4 LAND USE LAND COVER METHODOLOGY

3.4.1 General

The methodology included in the report aims at providing the reader with information on the completion of the study. Such remarks help the reader to assess the credibility and reliability of the research techniques and their validity.

3.4.2 Details of Procedures involved in this Study

The LANDSAT images were acquired from the USGS Earth Explorer website to map changes in land use and land cover (LULC) in the catchment of Bidahalli, Marenahalli, and Mookanamane. Table 3.2 lists the details of the USGS pictures that were downloaded. The LANDSAT 7 image was used to map changes between 2010 and 2015(LULC), Whereas LANDSAT 8 images are utilized for mapping 2020 LULC changes. Enhanced Thematic Mapper plus has photos from 2010 and 2015 (ETM plus). Operational land imager (OLI) and Thermal infrared sensor images are available for 2020(TIRS). Because the cloud cover is limited between February and March, all of these photographs were downloaded during those months.

The satellite pictures were imported into QGIS 2.16.3 (GISPO Ltd, Finland, Northern Europe) and a False Color Composite (FCC) of the images was made using the Nearest Neighbor Algorithm using bands 4 (Near Infrared), 3 (Red), 2 (Green) for LANDSAT TM and bands 5

(Near Infrared), 4 (Red), 3 (Green) for LANDSAT OLI TIRS. Bands 1 (Coastal Aerosol), 6 (Shortwave Infrared (SWIR1)), and 7 (Shortwave Infrared (SWIR2)) were added to the Qgis software together with the previously stated bands. The photos were then clipped using the research area's boundary vector layers.

For LULC classification of pictures using QGIS Software, a supervised classification method was used. Supervised classification is a method in which the user performing the classification uses pixels termed training areas to construct sample sites for a data set. The final transformation was performed using the maximum likelihood approach, a prominent and commonly used algorithm (Vimha Ritse et al). This approach assigns the highest probability to the pixels, and the resulting spectral signatures are then employed by the computer system to classify the entire image. The methodology flowchart is shown in Figure 3.9.

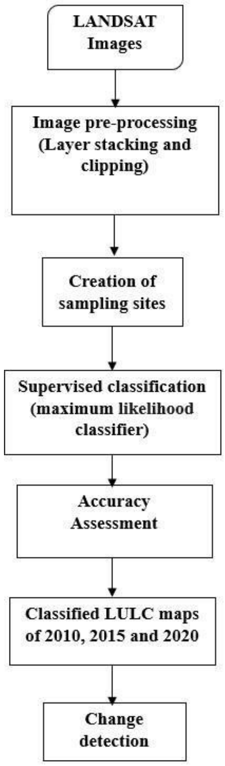


Figure 3.9: Flowchart of Methodology of LULC

Table 3.2 Details of Satellite images

Year	2010	2015	2020
Satellite ID	LANDSAT-7	LANDSAT-7	LANDSAT-8
Sensor	ETM Plus	Enhanced Thematic Mapper Plus	Operational land imager (OLI) & Thermal infrared sensor (TIRS)
Path/Row 145/051	18/02/2011	27/03/2016	09/03/2021

3.4.3 Classification and accuracy assessment

The LULC maps are classified into 5 different classes, Water Bodies, Forest, cultivated land, Built-up land, and Barren land, using the LANDSAT level 1 classification in the present study. A maximum-likelihood algorithm is used to determine the number of land cover types and the training pixels for each of the desired classes using land cover information. The description of the land use classes and land cover statistics are given in Table 3.3. The adopted equations for the calculation of user's accuracy, producer's accuracy, overall accuracy, and kappa coefficient are as follows,

$$\text{User's accuracy} = \left(\frac{xi}{xj}\right) * 100$$

Where,

xi = Number of correctly classified samples in each category

xj = Total number of reference samples in that category (Row Table)

$$\text{Producer's accuracy} = \left(\frac{xi}{xk}\right) * 100$$

Where,

xk = Column total of the reference samples

$$\text{Overall accuracy} = \left(\frac{xd}{xT}\right) * 100$$

Where,

xd = Diagonal total of correctly classified samples

xT = Total number of reference points

$$\text{Kappa coefficient} = \left(\frac{(xd * xT) - B}{(xT * xT) - B}\right)$$

Where,

B = Sum of products of row total and column total for each LULC type in the confusion matrix

In the present study, a confusion matrix was produced to calculate the overall accuracy and kappa coefficient for each land use land cover category.

Table 3.3: Land Use Land Cover categorization scheme for the study area

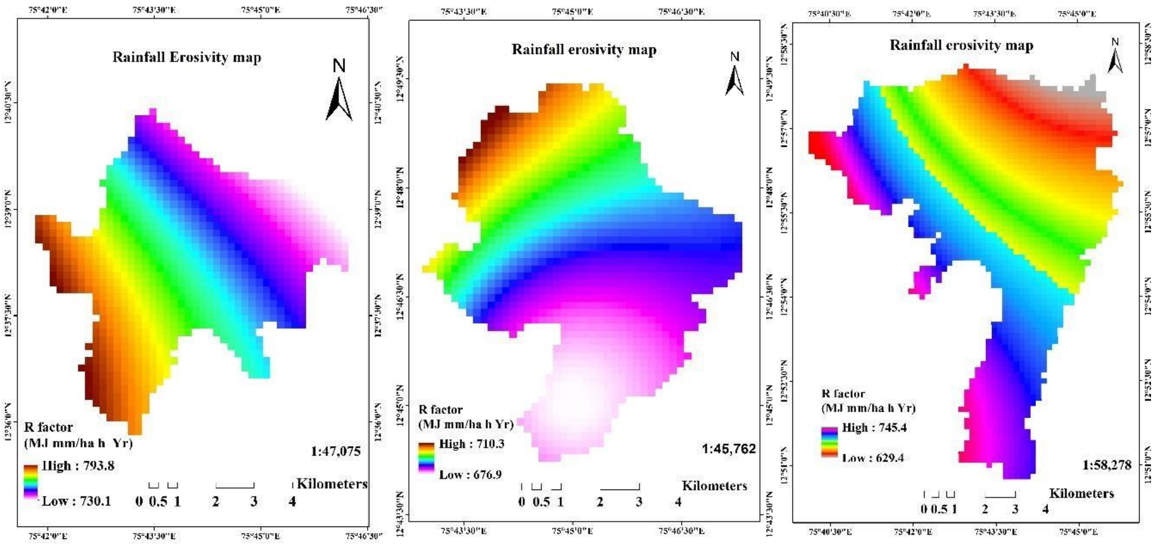
Sl.No	Class	Description
1	Water Bodies	Surface water that is retained as ponds, rivers, flowing as streams and other bodies of water
2	Forest	Land covering dense or evergreen forests, deciduous forests, tall grass and scrublands.
3	Cultivated land	A cycle of a cultivated area, involving a brief period of farming, harvest and then a return to bare soil
4	Built-up land	The land occupied by buildings and other man–made constructions and also settlements such as roads, industries etc.,
5	Barren land	Land having lack of water, soil management and sparsely vegetated terrain and Bare rock exhibits evidence of erosion, and ground deformation.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Rainfall erosivity factor (R)

The R-factor quantifies the effect of rainfall impact and also reflects the amount and rate of runoff likely to be associated with precipitation events and is considered to be the most highly correlated index to soil loss at many sites throughout the world. The greater the intensity and duration of the rain storm, the higher the erosion potential (V. Prasanna Kumar et al.2011). In this analysis, the R factor was calculated using the average annual rainfall (obtained by dividing the total precipitation by the total number of rainy days). The estimated R factor value ranges from 730.129 to 793.863 MJ mm/ha h Yr for Bidahalli, 676.954 to 710.315 MJ mm/ha h Yr for Mookanmane, and 629.416 to 745.404 MJ mm/ha h Yr for Marenahalli. It is observed that rainfall is high in the Bidahalli region as indicated by the results. Figure 4.1 displays maps of the R-factor.

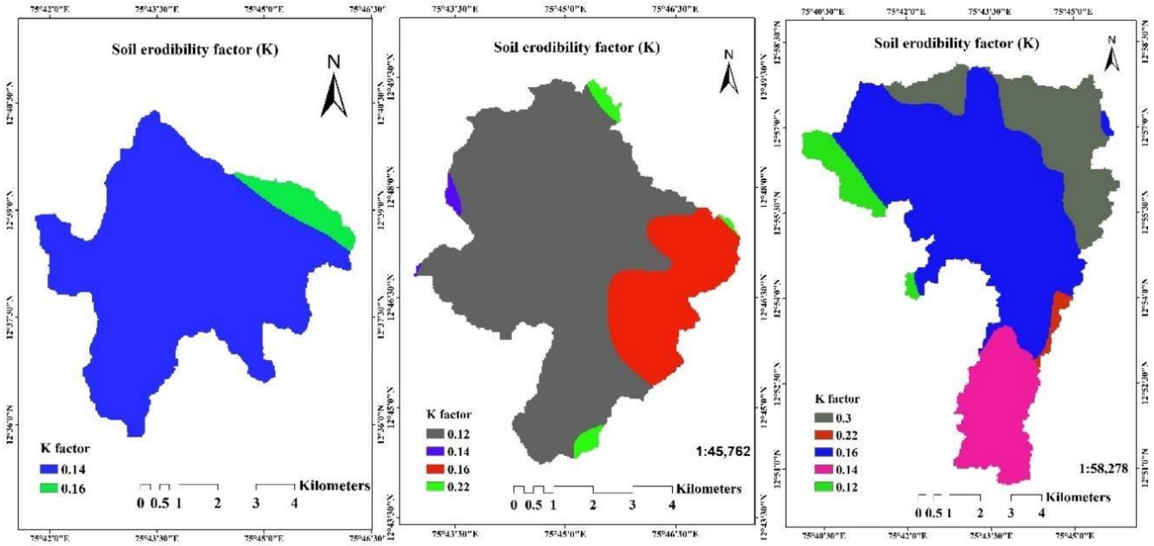


(i) **(ii)** **(iii)**

Figure 4.1: R factor (i) Bidahalli (ii) Mookanamane (iii)Marenahalli

4.2 Soil erodibility factor (K)

The K factor map was prepared from the soil texture map of the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Government of India. The K factor values are found to be ranging between 0.14 and 0.16 for Bidahalli, 0.12 and 0.30 for Marenahalli, and 0.12 and 0.22 for Mookanamane. Figure 4.2 displays maps of the K-factor.

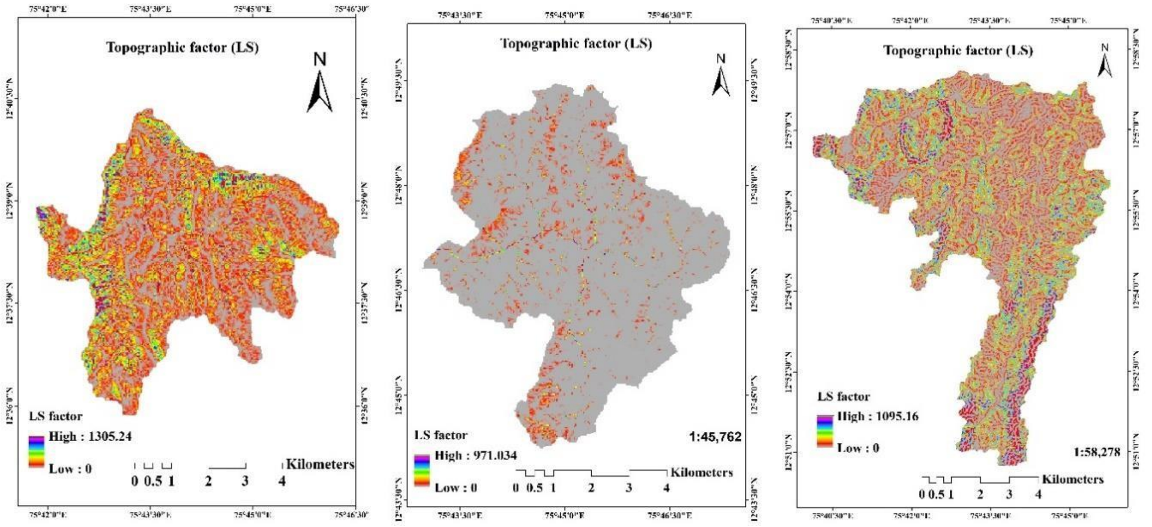


(i) (ii) (iii)

Figure 4.2: K factor (i) Bidahalli (ii) Mookanamane (iii) Marenahalli

4.3 Topographic factor (LS)

The topographic factor represents the influence of slope length and slope steepness on the erosion process. By using the flow accumulation and slope in percentage as inputs, the LS factor was determined. The LS factor values are found to be ranging between 0 to 1305.24 for Bidahalli, 0 to 1095.16 for Marenahalli, and 0 to 971.034 for Mookanamane. Figure 4.3 displays maps of LS-factor



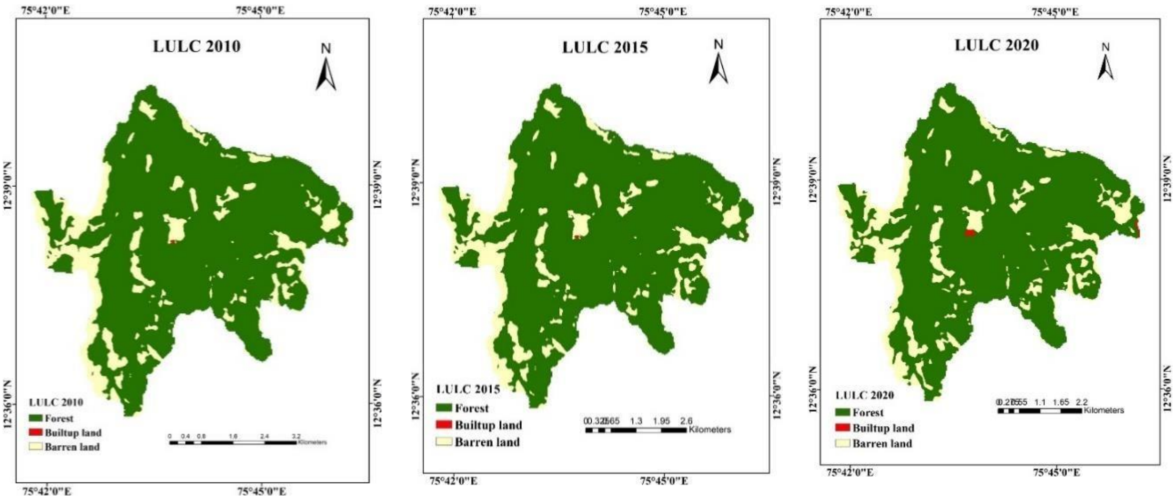
(i) **(ii)** **(iii)**

Figure 4.3: LS factor (i) Bidahalli (ii) Mookanamane (iii)Marenahalli

4.4 Land use and Land cover

4.4.1 Comparison of Landcover Datasets

The study area was classified according to the requirements of the research work and its applications. Bidahalli catchment spreads over 33.21 km^2 in which 83.01% (27.57 km^2) of the total area is covered by forest in the year 2010, and in 2015 and 2020 the area covered is 82.94 % (27.54 km^2), and 82.52 % (27.40 km^2). The classification maps for the years 2010, 2015, and 2020 are shown in Figure 4.4. Table 4.1, explains the percentage of area covered by each class in the Bidahalli catchment. Mookanamane catchment spreads over 42.24 km^2 in which 89.25 % (36.80 km^2) of the total area is covered by forest in the year 2010, and in 2015 and 2020 the area covered is 87.64 % (35.39 km^2), and 87.22 % (35.22km^2). The classification maps of Mookanamane are shown in Figure 4.5 and Table 4.2 explains the percentage of area covered by each class. Marenahalli catchment spreads over 64.19 km^2. The classification maps for the years 2010, 2015, and 2020 are shown in Figure 4.6. Table 4.3, explains the percentage of area covered by each class in the Marenahalli catchment. According to 2010 results, the maximum area of the catchment i.e., 93.79 % (60.18 km^2) of the area is covered by forest. In the year 2015 it covers 92.94 % (59.67 km^2) and in 2020 92.61 % (59.43 km^2). The forest covers in these three catchments are the lands with tree canopy, evergreen, and semi-evergreen vegetation types producing other forest products. Built-up land is the area developed due to non-agricultural uses and barren lands are the degraded lands devoid of vegetation.

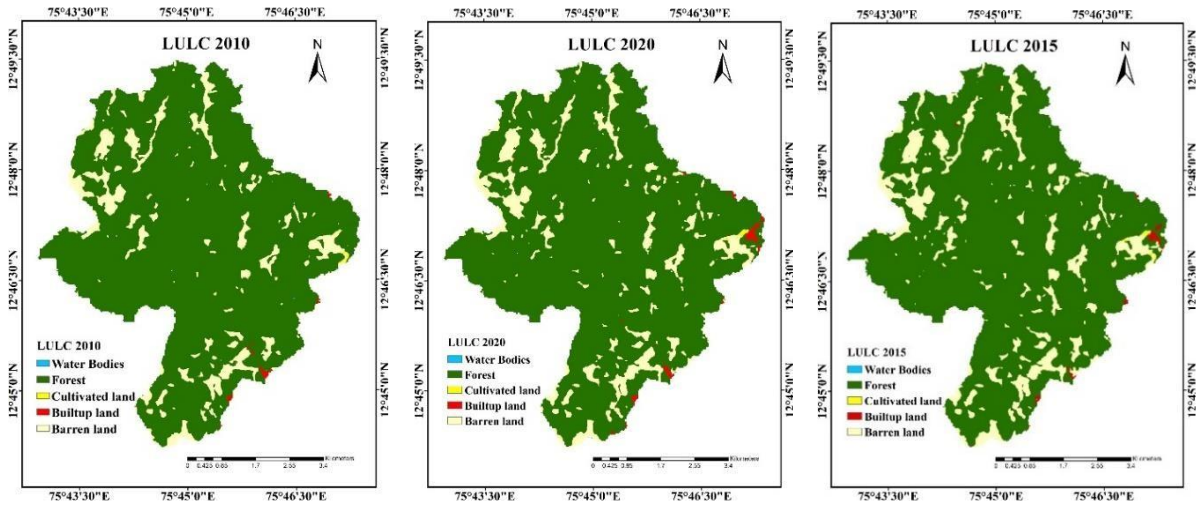


(i) **(ii)** **(iii)**

Figure 4.4: Bidahalli LULC (i) 2010 (ii) 2015 (iii) 2020

Table 4.1: LULC classification of Bidahalli

LULC class	2010		2015		2020	
	km^2	%	km^2	%	km^2	%
Forest	27.57	83.01	27.54	82.94	27.40	82.52
Built-up land	0.0117	0.03	0.035	0.106	0.054	0.165
Barren land	5.6284	16.947	5.6277	16.945	5.74	17.30

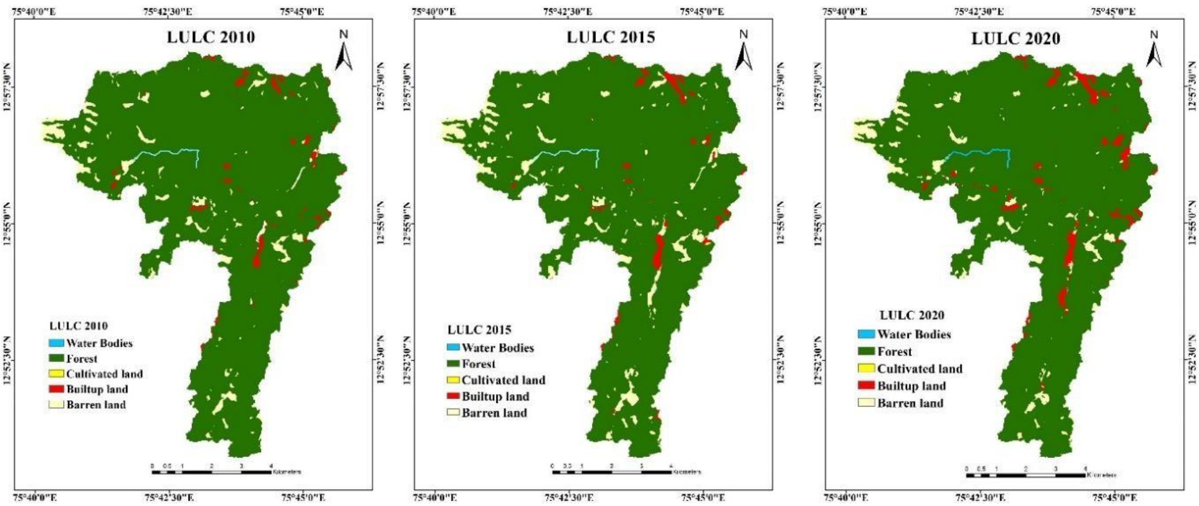


(i) (ii) (iii)

Figure 4.5: Mookanamane LULC (i) 2010 (ii) 2015 (iii) 2020

Table 4.2: LULC classification of Mookanamane

LULC class	2010		2015		2020	
	km^2	%	km^2	%	km^2	%
Water Bodies	0.015	0.036	0.012	0.020	0.008	0.010
Forest	36.808	89.251	35.396	87.640	35.277	87.220
Cultivated land	0.034	0.083	0.053	0.129	0.039	0.100
Built-up land	0.086	0.210	0.136	0.322	0.197	0.480
Barren land	4.296	10.418	5.246	11.870	5.627	12.190



(i) **(ii)** **(iii)**

Figure 4.6: Marenahalli LULC (i) 2010 (ii) 2015 (iii) 2020

Table 4.3: LULC classification of Marenahalli

LULC class	2010		2015		2020	
	km^2	%	km^2	%	km^2	%
Water Bodies	0.019	0.030	0.027	0.042	0.015	0.030
Forest	60.185	93.779	59.672	92.940	59.43	92.57
Cultivated land	0.006	0.009	0.012	0.018	0.019	0.030
Built-up land	0.931	1.451	1.208	1.780	1.469	2.290
Barren land	3.035	4.730	3.257	5.207	3.235	5.090

4.4.2 Accuracy assessment and change analysis of classified images

Accuracy assessment and change detection of land use land cover is very important for understanding the interaction and relationship between humans and nature (Chughtai, Hassan, & Abbasi, 2021). The accuracy of LULC is calculated using various measures such as overall accuracy, user's accuracy, producer's accuracy, and Cohen's kappa coefficient (Congalton, 2019). In this study, a confusion matrix was produced to calculate the overall accuracy and kappa coefficient for each land use and land cover category. The value of overall accuracy and kappa coefficient is given in Table 4.4. According to (R & G.G, 1977), Cohen's kappa shows substantial and perfect agreement if the values fall between 0.6 to 1.

In the present study the kappa coefficients of both the catchments lie in the above range and hence it is considered as substantial agreement.

Table 4.4: Accuracy Table

Catchment	Year	Overall Accuracy	Kappa coefficient
Bidahalli	2010	92.85	0.75
	2015	93	0.77
	2020	91.05	0.74
Mookanamane	2010	91.02	0.88
	2015	88.05	0.85
	2020	89.00	0.86
Marenahalli	2010	91.00	0.88
	2015	91.00	0.90
	2020	89.04	0.86

4.4.3 LULC change detection

The LULC classes and the changes in Marenahalli catchment in the year 2010-2015, and 2015-2020 are shown in Table 4.5. Water Bodies and Barren land exhibited both negative and positive changes whereas the cultivated land, and built-up land showed positive changes, but it is observed that forest area is decreasing with negative changes. Minimal changes were observed in all other classes and built-up land is having the most substantial changes. The forest covers the maximum area of the catchment and it showed a decreasing trend. The decrease in forests is attributed to the conversion of forest lands into developed areas being used for various types of developmental works. The area under built-up land increased due to gradual increase in demand for shelter by inhabitants in and around Marenahalli. The area of Barren land is rising due to farmer's disregard of agricultural operations and clearing of land, which suggests a clear plan for new structures and communities.

The changes in LULC classes for the years 2010-2015, and 2015-2020 are presented in Table 4.6 for Mookanamane catchment Built-up land, barren land, and cultivated land shows an increasing trend. Similar to Marenahalli the forest area is decreasing. Built-up land shows an increasing trend due to a gradual increase in communities of people. It has been recognized as a tourist spot due to which there is an increase in buildings, roads, and hotels. Forest areas are reduced due to human intrusion into forest areas and othersettlement activities.

The changes in LULC classes for the year 2010-2015, and 2015-2020 are presented in Table 4.7 for Bidahalli catchment Built-up land and barren land shows an increasing trend. Similar to Marenahalli the forest area is decreasing. Built-up land shows an increasing trend due to a gradual increase in communities of people. Forest areas are reduced due to human intrusion into forest areas and other settlement activities.

Table 4.5: Change analysis in Marenahalli

Year	2010-2015			2015-2020		
	Area in km^2		Changes in km^2	Area in km^2		Changes in km^2
	2010	2015		2015	2020	
Water Bodies	0.019	0.027	+0.008	0.027	0.015	-0.012
Forest	60.185	59.672	-0.513	59.672	59.43	-0.242
Cultivated land	0.006	0.012	+0.006	0.012	0.019	+0.007
Built-up land	0.931	1.208	+0.277	1.208	1.469	+0.261
Barren land	3.035	3.257	+0.222	3.257	3.235	-0.022

Table 4.6: Change analysis in Mookanamane

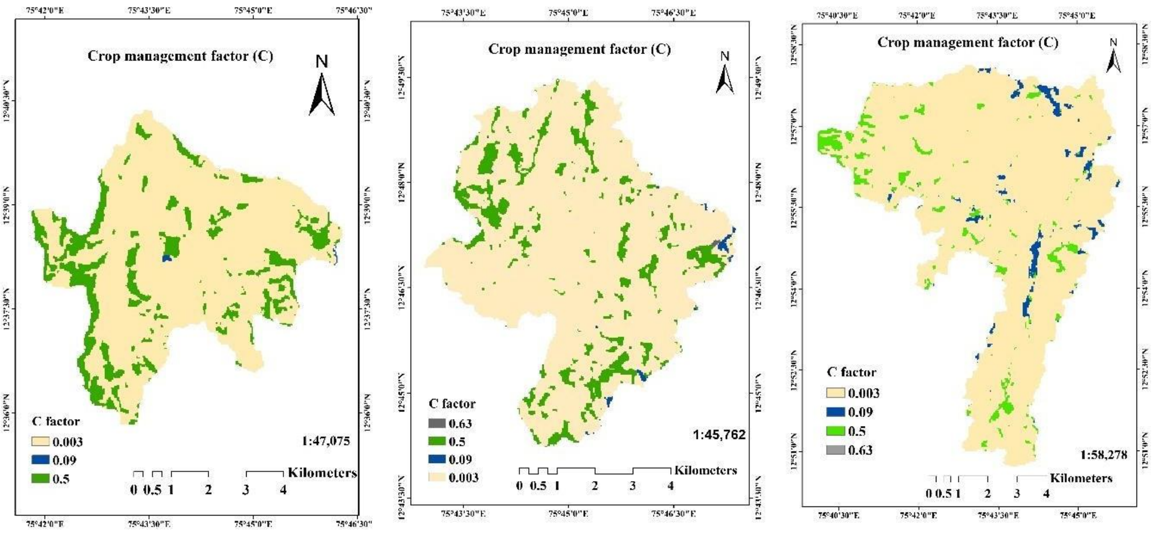
Year	2010-2015			2015-2020		
	Area in km^2		Changes in km^2	Area in km^2		Changes in km^2
	2010	2015		2015	2020	
Water Bodies	0.015	0.012	-0.003	0.012	0.008	-0.004
Forest	36.808	35.396	-1.412	35.396	35.277	-0.119
Cultivated land	0.034	0.053	+0.019	0.053	0.039	-0.014
Built-up land	0.086	0.136	+0.050	0.136	0.197	+0.061
Barren land	4.296	5.246	+0.950	5.246	5.627	+0.381

Table 4.7: Change analysis in Bidahalli

Year	2010-2015			2015-2020		
	Area in km^2		Changes in km^2	Area in km^2		Changes in km^2
	2010	2015		2015	2020	
Forest	27.57	27.54	-0.03	27.54	27.40	-0.14
Built-up land	0.011	0.035	+0.024	0.035	0.054	+0.019
Barren land	5.6284	5.6277	-0.0007	5.6277	5.7487	+0.121

4.5 Crop management factor (C)

One of the most important factors controlling the risk of soil erosion is crop management. It measures the amount of vegetation that protects the soil surface from raindrop impact at a certain height above the soil surface, as well as the additional protection provided by the cover that is in direct contact with the soil surface, or surface cover. Five land use types have been established for the study area: water bodies, forests, cultivated land, built-up land, and barren land. Table 3 was used to give the crop management factor for various land-use patterns (B.P. Ganasri, H. Ramesh). Figure 4.7 depicts the magnitude and spatial distribution of the crop management factor. The crop management factor was found to be between 0.03 to 0.63.

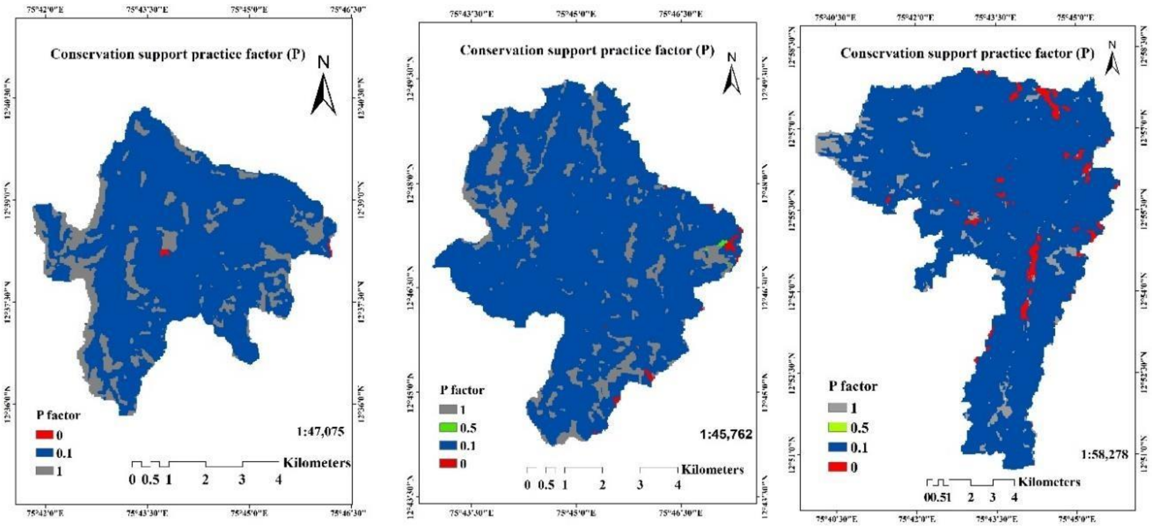


(i) (ii) (iii)

Figure 4.7: C factor (i) Bidahalli (ii) Mookanamane (iii)Marenahalli

4.6 Conservation Support Practice Factor (P)

In the present study, the P factor values were calculated by assessing land use/land cover patterns and associated support behavior. From V. Prasannakumar 2011 et al., the P-factor related to the type of land use and land cover was taken. The estimated P-factor values range from 0 to 1, with the maximum value allocated to natural areas (forest, grassland, etc.) and the lowest value assigned to terraced land and cultivated land with strip and contour cropping. The lower the P-value, the more effective the conservation practice is deemed to be at reducing soil erosion. Figure 4.8 depicts the magnitude and spatial distribution of the conservation Support Practice factor.

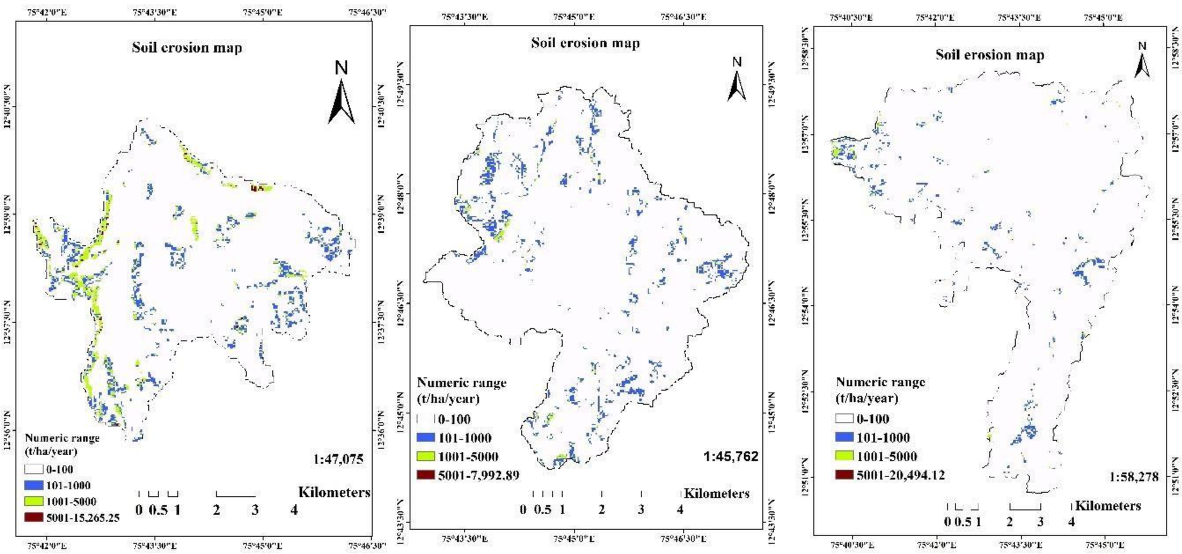


(i) (ii) (iii)

Figure 4.8: P factor (i) Bidahalli (ii) Mookanamane (iii)Marenahalli

4.7 Estimated soil loss

Qualitative and quantitative analysis of soil loss of Kumaradhara Basin is attempted based on the RUSLE model considering soil, terrain, rainfall, and data from distant sensing. The study location has an irregular geography made up of hills with a high elevation, and the majority of the territory is covered with forest. Quantitative analysis and results of soil erosion determined using the RUSLE model varied from 0 to 7992.89 t ha^{-1} $year^{-1}$ for Mookanamane, 0 to 20494.12 t ha^{-1} $year^{-1}$ for Marenahalli, and 0 to 15265.25 t ha^{-1} $year^{-1}$ for Bidahalli. Also, it has been found that topography, LULC have the biggest implications on erosion rate variations. A remarkable part of the land (5.1% of total area) falls under moderate (101-1000 t ha-1 year-1) to very high (5001-20494.13 t ha^{-1} year^{-1}) soil erosion risk, while the areas with an acceptable risk of soil loss 94.5% of the total area in Maranhalli. In the case of Mookanamane, 7.37% of the total area is characterized by Moderate (101-1000 t ha^{-1} year^{-1}) to very high (5001-7992.89 t ha^{-1} year^{-1}) soil erosion risk, whereas the zones of manageable soil erosion risk occupy 92.61% of the total area. But, as of Bidahalli, a portion of the area (12.9% of the complete area) is characterized by Moderate (101-1000 t ha^{-1} year-1) to very high (5001-15265.26 t ha-1 year^{-1}) soil erosion risk, whereas the region of manageable soil erosion risk occupies 87.1% of the total area. The details of the categories of soil loss, area, and the amount of soil loss area are shown in Table 4.8. According to estimates, the soil erosion risk regions in the sub-catchments of the Kumaradhara basin only make up around 15% of the overall site, making the rate of erosion there acceptable. Due to the larger area of deep evergreen forest, there is little risk of soil erosion in the study area. It has been noted that the risk of soil erosion in forests is minimal and a moderate risk of soil erosion on barren land. The soil erosion risk in mountainous areas is high on steep slopes and high on steep slopes with bare terrain. The study area does not have a very high risk of soil erosion because there is a limited amount of steeply barren ground. Soil erosion maps are represented in Figure 4.9.



(i) (ii) (iii)

Figure 4.9: Soil erosion map (i) Bidahalli (ii) Mookanamane (iii)Marenahalli

Table 4.8: Categories of soil erosion, area, and the amount of soil loss

	Mookanamane			Bidahalli			Marenahalli		
Erosion categories	Interval in t ha^{-1} $year^{-1}$	Area in km^2	Area in %	Interval in t ha^{-1} $year^{-1}$	Area in km^2	Area in %	Interval in t ha^{-1} $year^{-1}$	Area in km^2	Area in %
Low	0-100	37.9	92.61	0-100	28.7	87.1	0-100	60.7	94.5
Moderate	101-1000	2.1	5.34	101-1000	2.2	6.9	101-1000	1.8	2.9
High	1001-5000	0.4	1.16	1001-5000	1.5	4.9	1001-5000	0.8	1.3
Very high	5001-7992.89	0.3	0.87	5001-15265.26	0.3	1.1	5001-20494.13	0.5	0.9
Total	-	41	100	-	33	100	-	64	100

CHAPTER 5

CONCLUSION

Even for a small watershed, using conventional approaches to identify erosional risk zones would need a significant volume of data and computational effort. RUSLE model is a highly efficient method for calculating the average soil loss in a catchment. The GIS platform integrated with the RUSLE to spatially depict the erosion-prone areas. This enables us to create appropriate planning measures for applying the best land-use management methods, identify the risk zones, and quantitatively quantify soil erosion. In the present study, a higher percentage of vegetation that covers the higher gradient has a reduced risk of soil erosion than a gradient with no vegetation. The anticipated rate of soil loss and its geographical transmission can serve as a foundation for the watershed's sustainable land use and comprehensive management. Implementing control measures should be emphasized in areas with high soil loss. While the current analytical approach aids in mapping susceptibility zones, precipitation intensity data, soil nature, and field measurements can improve remote sensing and GIS-based analysis's ability to anticipate the future and its accuracy. The results support the creation of the best land cover planning and management techniques for farmers and policymakers' long-term expansion of natural resources.

REFERENCES

- *Ahmet Karaburun., 2010. Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed. Ozean Journal of Applied Sciences 3(1), 2010 ISSN 1943-2429 and Ozean Publication.*
- *B.P. Ganasri., H. Ramesh., 2015. Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin. China University of Geosciences (Beijing) and Peking University. Production and hosting by Elsevier B.V 1674-9871/.*
- *Félicien Majoro., Umaru Garba Wali., Omar Munyaneza., François-Xavier Naramabuye., Philibert Nsengiyumva., Concilie Mukamwambali., 2020. Soil Erosion Modelling for Sustainable Environmental Management in Sebeya Catchment, Rwanda. Journal of Water Resource and Protection, 2020, 12, 1034-1052.*
- *G. Sreenivasulu., N. Jayaraju., M. Pramod Kumar., T. Lakshmi Prasad., 2013. An Analysis on Land Use/Land Cover Using Remote Sensing and GIS – A Case Study In and Around Vempalli, Kadapa District, Andhra Pradesh, India. International Journal of Scientific and Research Publications, Volume 3, Issue 2013, ISSN 2250-3153.*
- *J.S. Rawat., Manish Kumar., 2015. Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. National Authority for Remote Sensing and Space Sciences. Production and hosting by Elsevier B.V 1110-9823/.*
- *J.S. Rawat., Vivekanand Biswas., Manish Kumar., 2013. Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Sciences 16, 111–117.*
- *Jobin Thomas., Sabu Joseph b., K.P. Thrivikramji., 2017. Assessment of soil erosion in a tropical mountain river basin of the southern Western Ghats, India using RUSLE and GIS. China University of Geosciences (Beijing) and Peking University. Production and hosting by Elsevier B.V 1674-9871/.*
- *K.G. Renard., G.R. Foster., G.A. Weesies., D.K. McCool., D.C. Yoder., 1997. Predicting soil erosion by water: A Guide to Conservation Planning with Revised Universal Soil Loss Equation (RUSLE). United states department of agriculture.*
- *P. P. Dabral., Neelakshi Baithuri., Ashish Pandey., 2008. Soil Erosion Assessment in a Hilly Catchment of North Eastern India Using USLE, GIS, and Remote Sensing. Water Resour Manage (2008) 22:1783–1798.*
- *Prakasam.C., 2010. Land use and land cover change detection through remote sensing approach:A case study of Kodaikanal taluk, Tamil Nadu. International journal of geomatics and geosciences Volume 1, No 2, 2010 0976 – 4380*
- *Praveen Kumar Mallupattu., Jayarama Reddy Sreenivasula Reddy., 2013 Analysis of Land Use/Land Cover Changes Using Remote Sensing Data and GIS at an Urban Area, Tirupati, India. Hindawi Publishing Corporation and The Scientific World Journal Volume 2013, Article ID 268623, 6 pages.*

- *S. Dutta., 2016. Soil erosion, sediment yield, and sedimentation of reservoir: a review. Model. Earth Syst. Environ. (2016) 2:123 and Springer International Publishing Switzerland.*
- *Umesh C. Kothyari., 1996. Erosion and sedimentation problems in India. Global and Regional Perspectives (Proceedings of the Exeter Symposium, July 1996). IAHS Publ. no. 236.*
- *V. Prasannakumar., H., Vijith., N. Geetha., R. Shiny., 2011. Estimation of soil erosion risk within a small mountainous sub-watershed in Kerala, India, using Revised Universal Soil Loss Equation (RUSLE) and geo-information technology. Water Resource Manage. Springer Science + Business Media B.V.25:3715–3727.*
- *V. Prasannakumar., H., Vijith., N. Geetha., R. Shiny., 2011. Regional Scale Erosion Assessment of a Sub-tropical Highland Segment in the Western Ghats of Kerala, South India. Water Resource Manage. Springer Science + Business Media B.V.25:3715–3727.*
- *Vimha Ritse., Himolin Basumatary., Amenuo Susan Kulnu., Gitamani Dutta., Mayur Mausoom Phukan., Nabajit Hazarika., 2020. Monitoring land use land cover changes in the Eastern Himalayan landscape of Nagaland, Northeast India. Environ Monit Assess 192:711 and Springer Nature Switzerland AG.*
- *Wischmeier, W. H., and Smith, D.D. 1978. Predicting rainfall erosion losses—a guide to conservation planning. U.S. Department of Agriculture, Agriculture Handbook No. 537.*