A Project Report

On

ESTIMATION OF WATER BORNE SOIL LOSS USING RUSLE AND GEOGRAPHIC INFORMATION SYSTEM

-A CASE STUDY ON HUSSAIN SAGAR CATCHMENT

Submitted in partial fulfilment of the requirements for the award of degree of Bachelor of Engineering in Civil Engineering.

By

K. PRAGNA (1601-19-732-015)

K. RAJESH (1601-19-732-039)

Under the guidance of

Sri Ramanarayan Sankriti,

Assistant Professor, Department of Civil Engineering

DEPARTMENT OF CIVIL ENGINEERING

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY(Autonomous)

Affiliated to Osmania University, Gandipet, Hyderabad-500075

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DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

This is to certify that the project work entitled "**ESTIMATION OF WATER BORNE SOIL LOSS USING RUSLE AND GIS**" is a bonafide work carried out by

K. PRAGNA (1601-19-732-015)

K. RAJESH (1601-19-732-039)

In the partial fulfillment of the requirements for the award of degree of **BACHELOR OF ENGINEERING** in **CIVIL ENGINEERING** by the **OSMANIA UNIVERSITY** during 2022-2023 at **CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY(A)**. To the best of our knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

………………………….. ……………………………..

Sri Ramanarayan Sankriti Prof K. Jagannadha Rao

Assistant Professor and Guide **Head of the Department**

External Examiner

Date:

Place: Gandipet, Hyderabad.

DECLARATION

We, K. Pragna and K. Rajesh students of Bachelor of Engineering, final year, Civil Engineering department, Chaitanya Bharathi Institute of Technology(A), declare that the project entitled "ESTIMATION OF WATER BORNE SOIL LOSS USING RUSLE AND GIS" has been independently carried out under the esteemed guidance of Sri Ramanarayan Sankriti, Assistant Professor, Department of Civil Engineering, CBIT(A). This work has been submitted in partial fulfilment of the requirement for the award of Bachelor of Engineering in Civil Engineering by Osmania University, during the academic year 2022-2023.

Signature of Students

K. Pragna (1601-19-732-015)

K. Rajesh (1601-19-732-039)

ACKNOWLEDGEMENT

Firstly, we would like to express our immense gratitude and heartfelt thanks towards our institution Chaitanya Bharathi Institute of Technology, which created a great platform to attain profound technical skills in the field of Civil Engineering, thereby fulfilling our most cherished goal.

We extend our heartfelt thanks to our project guide, **Sri Ramanarayan Sankriti** (Assistant Professor) of Civil Engineering Department, for his excellent guidance, support and supervision. Without his supervision and many hours of devoted guidance this project would have never come out in this form.

We wish to thank **Asst. Prof. Sri Vasudev Rao**, Project coordinator for his help in completing the requirements for the project from beginning to end.

We would like to thank **Prof. K. Jagannadha Rao**, Head of the Department, Civil Engineering for providing such a great opportunity.

Our sincere thanks to **Prof. P. Ravinder Reddy**, Principal, CBIT for providing the necessary facilities to carry out this work.

Last but not the least, our appreciable obligation also goes to all the teaching and non-teaching staff members of Civil Engineering Department and earnest thanks to our dear parents for their moral support and heartfelt cooperation. We would also like to thank our friends, whose direct or indirect help enabled us to complete this project successfully.

ABSTRACT

Land degradation is a pervasive environmental and economic challenge of present time in the developing countries. Soil erosion caused by water is considered as one of the major type of land degradation. This study will include the estimation of the average annual soil loss of a part (almost 80%) of Hussain Sagar watershed and preparation of a spatially distributed soil loss map using a comprehensive methodology that integrates remote sensing and GIS technique with a well-known empirical method (Revised Universal Soil Loss Equation). GIS data layers including rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C) and conservation practice (P) factors were computed to estimate the average annual soil loss of the study area. The soil erosion rate was classified into four severity classes as slight, moderate, severe and extremely severe. The results indicate that more than 80% of the study area falls in very low erosion category, which may be due to level topography and regular vegetation cover and the high amount of soil loss (more than 100 t ha-1 year-1) is significantly low. The highest potential of estimated soil loss was 438.43 t/ha/yr. The results can certainly aid in implementation of soil management and conservation practices to reduce the soil erosion.

Key Words: Soil Loss, RUSLE, GIS, Catchment

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Nomenclature and Abbreviations

RUSLE- Revised Universal Soil Loss Equation

GIS-Geographic Information System

DEM- Digital Elevation Model

IDW- Inverse Distance Weighting

AAP- Annual Average Precipitation

CONTENTS

CHAPTER-1

INTRODUCTION

1.1 General

Degradation of agricultural land by soil erosion is a worldwide phenomenon leading to loss of nutrient rich surface soil, increased runoff from more impermeable subsoil and decreased water availability to plants. Thus, estimation of soil loss and identification of critical area for implementation of best management practice is central to success of a soil conservation program.

Waterborne soil erosion, also known as water erosion, is the process by which soil particles are removed from the surface of the land by the action of water. Water erosion is one of the most common and destructive types of soil erosion, and it is responsible for the loss of large amounts of fertile topsoil every year. Top soil is the upper fertile biologically active layer of soil which is rich in minerals, organic matter and micro-organisms. In this process, the soil particles are loosened or washed away in the valleys, oceans, rivers, streams or far away lands. This has been worsening due to human activities such as agriculture and deforestation.

Fig.1.1 soil erosion due to water

Source: https://www.erosioncontrolservices.net/wp-content/uploads/2021/01/soil-erosion-types-causes.jpg

Water erosion occurs when rainwater or runoff flows across the soil surface, carrying soil particles with it. The severity of water erosion depends on several factors, including the intensity and duration of rainfall, the slope gradient of the land, the type of soil, and the amount of vegetation cover. Water erosion can have significant impacts on agriculture, forestry and construction, as it can lead to loss of topsoil, reduced soil fertility and increased sedimentation in waterways. It can also result in increased runoff, which can lead to flooding and increased soil erosion downstream. Soil degradation in India is estimated to be occurring on 147 million hectares (M ha) of land, including 94 M ha from water erosion, 16 M ha from acidification, 14 M ha from flooding, 9 M ha from wind erosion, 6 M ha from salinity and 7 M ha from a combination of factors.

Preventing water erosion is important for maintaining soil health and productivity, as well as protecting natural resources and human communities. Techniques such as conservation tillage, cover cropping, contour ploughing and terracing can help to reduce water erosion and improve soil health. Other methods such as constructing sediment basins and sediment fences, can help to capture and contain eroded soil particles, preventing them from entering waterways.

In this study, soil erosion in the Hussain Sagar Catchment has been estimated with the help of RUSLE model integrated with GIS Software and to prepare the spatially distributed soil loss map.

1.2 Causes of Soil Erosion

Waterborne soil erosion is caused by a combination of natural and human factors that alter the flow of water and the stability of the soil. Here are some of the main causes of waterborne soil erosion:

1. **Steep slopes:** Slopes that are too steep can cause water to flow more rapidly and with greater force, leading to soil erosion.

2. **Heavy rainfall:** Heavy rainfall events can cause soil erosion by increasing the volume and velocity of water flowing over the land surface.

3. **Deforestation:** Removing trees and other vegetation from a landscape can increase the amount of runoff and decrease the stability of the soil, making it more prone to erosion.

4. **Agriculture:** Tillage, grazing, and irrigation practices can all increase the risk of soil erosion by disturbing the soil surface and reducing its ability to retain water.

5. **Urbanization:** The construction of buildings, roads, and other infrastructure can alter the natural drainage patterns of an area, leading to increased runoff and soil erosion.

6. **Mining:** Extractive activities such as mining can disrupt the natural landscape and lead to increased erosion by removing vegetation, altering soil structure and exposing bare ground.

7. **Climate change:** Climate change is causing more frequent and intense extreme weather events, such as floods and droughts, which can increase the risk of waterborne soil erosion.

1.3 Types of Soil Erosion

Waterborne soil erosion occurs when water flows over the surface of soil and carries away the soil particles. There are several types of waterborne soil erosion, including:

Sheet erosion: This occurs when water flows over a relatively flat surface and removes a thin layer of soil evenly across the surface. Sheet erosion can be difficult to detect as it does not create any distinct channels or rills.

Rill erosion: This occurs when water accumulates in small channels or rills and carries away soil particles. Rill erosion typically occurs on slopes and can create small gullies in the soil.

Gully erosion: This occurs when rills become larger and deeper, forming distinct channels or gullies. Gully erosion can cause significant damage to soil and can result in the loss of topsoil and vegetation.

Streambank erosion: This occurs when water flows along the banks of a stream or river, causing the banks to erode and collapse. Streambank erosion can lead to the loss of valuable land and habitat, as well as increased sediment and nutrient runoff into the waterway.

Coastal erosion: This occurs when waves and currents erode the shoreline and cause the land to recede. Coastal erosion can result in the loss of property, infrastructure, and habitats, as well as increased sediment and nutrient runoff into the ocean.

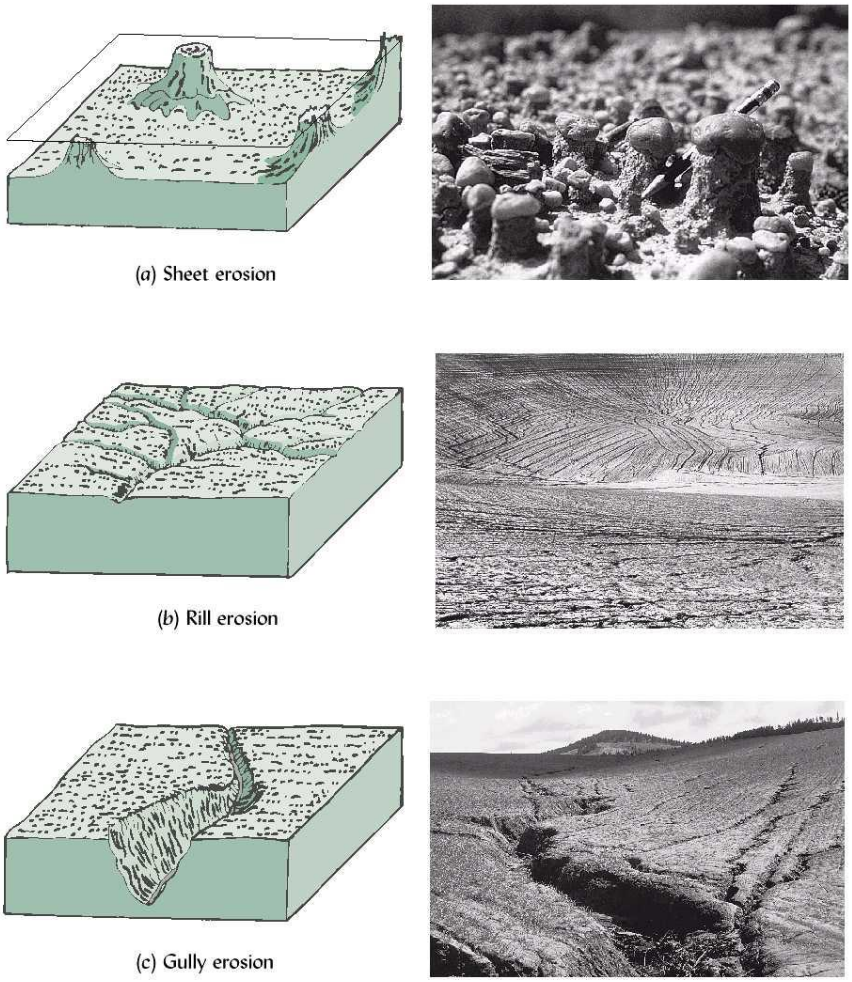

Fig.1.2 Types of soil erosion

Source: https://www.researchgate.net/profile/Safdar-Bashir/publication/320729156/figure/fig3/AS:555440053460992@1509438636094/Types-of-water-erosion -Modified-from.png

1.4 Effects of Soil Erosion

The major effects of soil erosion include:

Loss of Arable Land

Soil erosion removes the top fertile layer of the soil. This layer is rich in the essential nutrients required by the plants and the soil. The degraded soil does not support crop production and leads to low crop productivity.

Clogging of Waterways

The agricultural soil contains pesticides, insecticides, fertilizers and several other chemicals. This pollutes the water bodies where the soil flows.

The sediments accumulate in the water and raise the water levels resulting in flooding.

Air Pollution

The dust particles merge in the air, resulting in air pollution. Some of the toxic substances such as pesticides and petroleum can be extremely hazardous when inhaled. The dust plumes from the arid and semi-arid regions cause widespread pollution when the winds move.

Desertification

Soil erosion is a major factor for desertification. It transforms the habitable regions into deserts. Deforestation and destructive use of land worsens the situation. This also leads to loss of biodiversity, degradation of the soil and alteration in the ecosystem.

Destruction of Infrastructure

The accumulation of soil sediments in dams and along the banks can reduce their efficiency. Thus, it affects infrastructural projects such as dams, embankments and drainage.

1.5 RUSLE Equation

A quantitative and detail assessment is needed to know the extent and magnitude of soil erosion problems so that effective management strategies can be applied. And it is also very important to have a spatially distributed soil erosion map of a region or watershed. It helps in detecting soil erosion potential at different locations and thus helps in applying required safety measures to minimize it, in order to have a better agriculture and soil conservation planning.

The Revised Universal Soil Loss Equation (RUSLE) is an empirical model used to estimate soil erosion caused by rainfall and surface runoff. It was developed by the United States Department of Agriculture (USDA) to predict soil loss in agricultural lands, but it has since been widely used in other fields, including environmental management, land use planning and natural resource conservation. The RUSLE model estimates soil erosion by multiplying five factors: rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C), conservation and support practice (P).

The equation can be expressed as:

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

Where,

A is the estimated average annual soil loss (in tons per acre or tons per hectare).

R is the rainfall erosivity factor, which is a measure of the potential of rainfall to cause soil erosion.

K is the soil erodibility factor, which is a measure of the susceptibility of soil to erosion.

LS is the slope length and steepness factor, which accounts for the effect of slope on erosion.

C is the cover and management factor, which accounts for the protective cover provided by vegetation or crop residues.

P is the conservation practice factor, which reflects the effectiveness of soil conservation measures.

S is the support practice factor, which reflects the effectiveness of practices that support conservation measures.

The RUSLE model requires spatial data on the factors to estimate soil loss at a catchment or landscape level. This data can be obtained through remote sensing, field surveys, or Geographic Information Systems (GIS). The RUSLE model is a valuable tool for assessing soil erosion risk, designing erosion control measures, and evaluating the effectiveness of conservation practices.

1.6 Geographic Information System

Geographic Information Systems (GIS) is a computer-based system designed to capture, store, manipulate, analyse and present spatial or geographic data. GIS technology is used to manage, analyse and display data that has a location component or attribute. It is a computer-based tool that allows users to integrate various types of spatial data, such as maps, satellite imagery and aerial photographs, with attribute data, such as population, land use and infrastructure.

GIS technology enables users to visualize, analyse and understand spatial relationships, patterns, and trends in the data. It provides a powerful set of tools and techniques for spatial analysis, such as proximity analysis, surface analysis, and network analysis, which can be used to solve complex problems in various fields, such as environmental management, urban planning, natural resource management and emergency response. GIS is a valuable tool for soil erosion estimation as it provides a platform for integrating and analysing various spatial data layers related to soil erosion factors. This can help in identifying areas at risk of soil erosion, estimating soil loss, evaluating the effectiveness of erosion control measures, developing soil conservation plans and monitoring soil erosion over time.

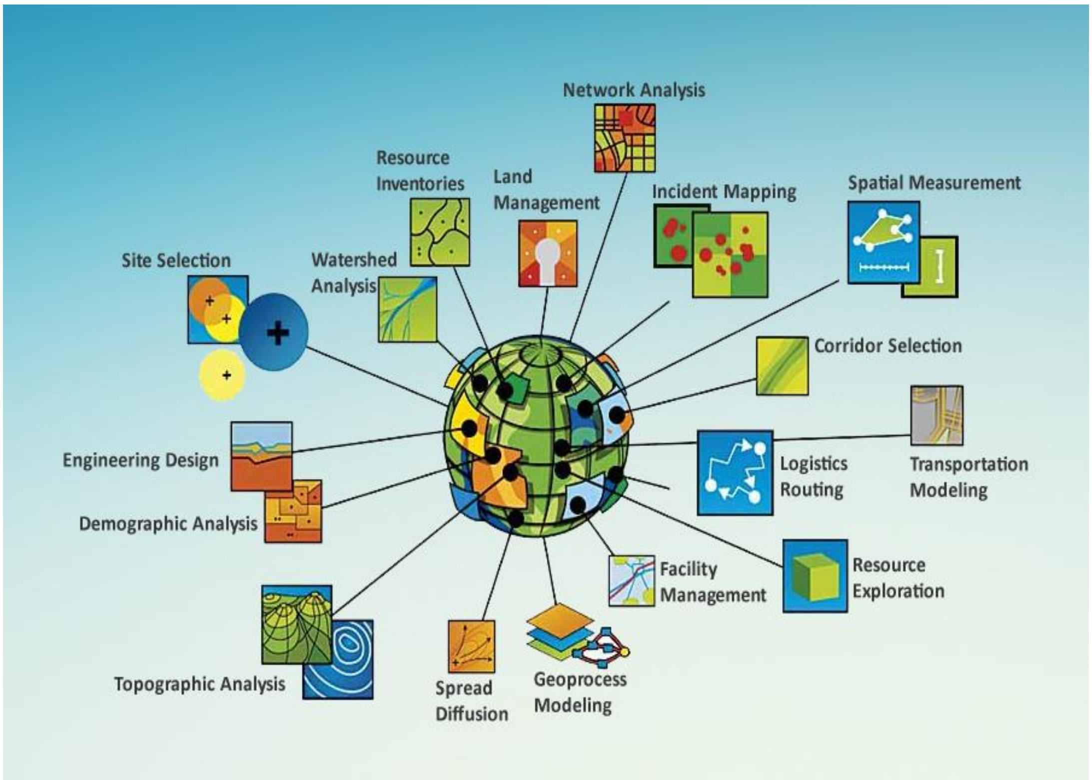

Fig.1.3 Uses of GIS in various sectors

Source: https://www.anantics.com/assets/images/gis3.png

Benefits of using GIS are

1. It eliminates all manual forms of geography-based analysis. There is no longer a need to print large maps on transparency sheets nor does one need a light table to get the effect of layering multiple printed sheets on top of one another.

2. The effects and problems of differently scaled maps can also be addressed as a GIS can convert and project all data on the same coordinate system and scale.

3. It centralizes and organizes the data for use in one comprehensive system. No longer will there be lost records and all of the data created and collected by the user can be stored and used again in the future with ease.

4. There is an infinite variety of maps that can be created with even just a few datasets.

1.7 Scope of Study

Soil erosion can cause severe damage to the environment by reducing soil fertility, causing landslides, and increasing sedimentation in water bodies like Hussain Sagar. This can affect the aquatic life and other ecological systems in the catchment. Soil erosion can cause siltation of the lake, reducing its storage capacity and affecting the quality of water. Studying soil erosion patterns can help identify areas that need immediate attention to protect the water quality and quantity. The catchment area is undergoing rapid urbanization, leading to increased land-use changes and human activities. Soil erosion can be exacerbated by these changes, causing more damage to the environment and threatening the sustainability of the region.

Studying soil erosion in the Hussain Sagar catchment is essential for understanding the environmental, social, and economic impacts of soil erosion and developing appropriate management strategies to protect the environment and improve the livelihoods of local communities.

1.8 Objectives

1. The objective of this study is to apply the RUSLE to the Hussain Sagar catchment,located at HYDERABAD, India, in order to estimate water-borne soil erosion and investigate its spatial distribution.
2. To prepare RUSLE factor maps for obtaining soil loss map.
3. To suggest conservation structures for the Hussain Sagar catchment.

CHAPTER-2

LITERATURE REVIEW

2.1 Review of Works

Sumantra Sarathi Biswas et al. (2015) estimated the amount of soil loss using RUSLE and GIS techniques of Barakar River basin, Jharkhand, India. The Barakar River is the principal tributary of the Damodar River in eastern India. The catchment area of the Barakar River is 6159 km^2. The soil in the Barakar river basin is mainly red soil and red loamy soil. The integration of Revised Universal Soil Loss Equation model and geographical Information technology has been used for soil loss estimation. Most of the areas (~80%) have suffered soil loss of less than 14 t ha^{-1} $year^{-1}$.High soil loss in upstream of the basin has a close relation to LS and K factor and drainage density. As a result of soil loss in the upper catchment areas, reservoir capacity has been depleted both in dead and live storage space. It is concluded the basin has faced moderate to high soil loss. It could be reduced through the proper land use and support practices.

Hamza Bougerra et al. (2021) estimated the amount of soil losses using RUSLE model and GIS tools: Case study of the Mellah catchment, Northeast of Algeria is studied. The Mellah catchment, which occupies an area of 551 km^2, is geographically located in the Seybouse basin, in the extreme northeast of Algeria. The studied area is subjected to Mediterranean climate.A comprehensive integration of Revised Universal Soil Loss Equation (RUSLE) model, remote sensing and GIS techniques is used to determine the catchment soil erosion vulnerability. The results concluded that the average soil loss is 10.21 t. ha-1.yr-1, with a total annual soil loss in the basin area of 5648.58 t. Around 90% of area was under very low erosion risk, and 5% of area was considered as moderate erosion risk while 3% of area was considered as high to very high erosion risk.

Surendra Kumar Singh et al. (2019) estimated the amount of soil loss by RUSLE Model using GIS Techniques: A Case study of Coastal Odisha, India". The study area Ganjam block belongs to Ganjam district of Odisha is a part of Indian peninsular subtropics, having tropical climate and sub-humid temperate region. The block covers an area of about 246 sq km. In this study, Revised Universal Soil Loss Equation (RUSLE) integrated with GIS has been used to estimate soil loss in the part of coastal Odisha system. They concluded that 90.9% (22330 ha) of the study area falls in very low erosion category. The other erosion classes such as moderate, high and very high erosion occurred in the range of 2.12%, 2.23% and 1.49 %, respectively.

Khalid Chadli's (2016) estimated soil loss using RUSLE model for Sebou watershed (Morocco). The Sebou watershed, located north west of Morocco between parallels 33°and 35°north latitude and 4°150 and 6°350west longitude, covers nearly 40,000 km.In the current study, the revised universal equation of soil losses (RUSLE) is implemented, to assess the risk of water erosion in the Sebou watershed. a geographic information system was also used.The results show that 78.83 % of the study area has a low risk of erosion, 17.36 % medium risk,3.04 % high risk and 0.77 % a very high risk.

K. Balasubramani et al. (2015) estimated soil loss in a semi-arid watershed of Tamil Nadu (India) using revised universal soil loss equation (rusle) model through GIS. Andipatti watershed is located in the Andipatti Taluk of Theni District in the state of Tamil Nadu. The watershed is with an areal extent of 250 sq.km. In this context, Revised Universal Soil Loss Equation (RUSLE) and GIS has been adopted to estimate soil erosion in the semi- arid Andipatti Watershed of Tamil Nadu, India. The soil loss values estimated for Andipatti watershed ranges from 0 to 95.54 ton/hec/yr with an average of 5.26 6 t/ha/yr.

Jeevan et al. (2016) estimated the soil erosion rate of Kulekhani Reservoir Catchment, Nepal (2016). Studywatershed is located southwest of capital city Kathmandu in the Mahabharat range of central Nepal. Kulekhani watershed occupies 124.75 km2 of areal area. In order to estimate soil erosion from watershed, RUSLE and GIS environments along with remote sensing data were used. The required factors were obtained from Digital Elevation Map (DEM), meteorological data, soil map, land use maps. Average soil erosion rate of watershed was found to be 195.11 Mg ha-1 year-1. It is concluded that soil erosion rate of comparatively 41% area was tolerable but has no distinct zone and approximately 58% area of catchment was on the verge of high to very severe intensity classes.

B.P. Ganasri et al. (2016) estimated the amount of soil erosion by RUSLE model using remote sensing and GIS of Nethravathi Basin. In this paper, the soil loss model, Revised Universal Soil Loss Equation (RUSLE) integrated with GIS has been used to estimate soil loss in the Nethravathi Basin located in the southwestern part of India. The results indicate that the estimated total annual potential soil loss of about 473,339 t/yr. The predicted soil erosion rate due to increase in agricultural area is about 14,673.5 t/yr. The probability zone map has been 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.

Vipin Joseph Markose et al. (2016) estimated soil loss and prioritized the sub-watersheds of Kali River basin using Revised Universal Soil Loss Equation (RUSLE) model. The catchment area of Kali River basin has undergone several developmental activities in the last two decades which increased soil erosion in the river basin The results show that ∼42 % of the study area falls under low erosion risk and only 6.97 % area suffer from very high erosion risk. Anthropogenic activities such as deforestation, construction of dams, and rapid urbanization are the main reasons for high rate of soil loss in the study area. They concluded that the use of GIS and RUSLE have to be an effective approach for estimating the magnitude and spatial distribution of erosion.

Avijit Mahala (2018) estimated soil loss using RUSLE and GIS techniques—a study of a plateau fringe region of tropical environment. The present study area reflects undulated plateau fringe landform with gently sloping dissected plateau topography. All factors have been multiplied in GIS environment to estimate soil loss. High-magnitude soil loss region (> 10 t ha−1 year−1) covers 4.88% of the total area and extends up to the upper reaches of the watershed. Topographic and soil factors best represent this loss. Low-magnitude soil loss region (< 2.5 t ha−1 year−1) in the lower reaches of the watershed is a result of successful land management activity. Soil erosion is dominated process of land degradation in the upper reaches of the watershed and estimation of soil loss is an important input for land-use land-cover management. The study also inferred that RUSLE soil erosion model could be effectively used in tropical plateau fringe environment.

Amit Kumar et al. (2014) estimated Soil Loss in Western Himalaya, India . The study revealed that forest cover, crop land and scrub/grass land constitute 87.4 % of soil erosion susceptible area. The rate of depletion of soil was estimated at 25.63 t/ha/yr. It was highest in stony/barren land (60.3 t/ha/yr) and lowest in case of tea garden (16.09 t/ha/yr). It was felt that there is a need of implementation of soil and water conservation measures in the region to curb the soil loss. The undulating nature of terrain was observed as the main contributing factor for soil erosion. It was concluded that RS and GIS based RUSLE model can be efficiently used in mountainous regions to determine the status and extent of soil erosion.

Anissa Mahleb et al. (2022) estimated soil loss over a Semiarid Watershed: Case Study of Meskiana Catchment, Algerian-Tunisian Border. The main purpose of the present study is to adapt the RUSLE model to map the spatial distribution of soil erosion susceptibility in dry climate watershed based on the geographic information system (GIS) and remote sensing (RS) technique. For data processing, slopes, precipitations, lithofacies, Normalized Difference Vegetation Index (NDVI), drainage density, and land use were integrated. The results showed that the annual soil loss is about 61 t/ha/year in the entire study area, and identified the most heavily eroded areas, requiring immediate action.

Ajaykumar et al. (2018) estimated soil loss vulnerability of an agriculture mountainous watershed in Maharashtra, India. a. The spatial variation in rate of annual soil loss was obtained by integrating raster derived parameter in GIS environment. The thematic layers such as TRMM [Tropical Rainfall Measuring Mission] derived rainfall erosivity (R), soil erodibility (K), GDEM based slope length and steepness (LS), land cover management (C) and factors of conservation practices (P) were calculated to identify their effects on average annual soil loss. They concluded that the highest potential of estimated soil loss was 688.397 t/ha/yr ,the mean annual soil loss is 1.26 t/ha/yr. In the western basin the soil is prone to erosion due high rainfall runoff ratio shows that parts with natural forest cover in the periphery regions have least rate of soil loss, whereas areas with human intrusion have high rate of soil erosion (> 5t/ha/yr). Topography changes along with high LS-factor and precipitation swift these parts to be more vulnerable to soil loss.

Jobin Thomas et al (2018) estimated computed the longtime average annual soil loss from a tropical mountainous river basin, viz., MRB, and identified critical erosion-/deposition-prone areas using RUSLE model and TLSD function in ArcGIS. Thematic layers representing different factors of RUSLE (R, K, LS, C and P) were used to generate spatially distributed gross soil erosion rates of the basin. Mean gross soil erosion in MRB I s 14.36 t/ha/yr, whereas mean net erosion is only 3.60 t/ha/yr. Majority of the basin area (86%) of MRB experiences only slight erosion and nearly 3% of the area traps most of the eroded sediments. Soil erosion in MRB is a result of the combined effect of steep and rugged topography and vegetation characteristics along with high quantum of annual rainfall. Mean gross erosion rates in natural vegetation belts are relatively higher, compared to agriculture, settlement/built-up areas and tea plantation. Finally they concluded that the RULSE model, coupled with TLSD function, helps mapping of vulnerable zones to soil erosion and deposition, which has crucial significance in the formulation of comprehensive land management strategies

2.2 Critical Appraisal

RUSLE and GIS have been shown to be effective tools for estimating soil loss, particularly when used together. However, the accuracy of soil loss estimates can be influenced by a variety of factors, and the selection of appropriate input parameters and data sources is critical for producing reliable results. It is also found that GIS decreases all manual forms of geography-based analysis.

CHAPTER-3

STUDY AREA

Hussain Sagar is a lake located in the heart of Hyderabad, Telangana, India. It is situated at a latitude of 17.4236° N and a longitude of 78.4734° E. The lake is surrounded by several important landmarks, such as the Necklace Road, NTR Gardens and the Secretariat. The catchment area of Hussain Sagar is approximately 24.32 square kilometers, with the Musi River being the main source of inflow into the lake. The lake's catchment area includes several urban areas, including parts of Hyderabad and Sundaraja, which contribute to the pollution and degradation of the lake's water quality. The lake has a maximum depth of 32 feet and a surface area of 5.7 square kilometers. It is a popular tourist destination, attracting visitors from across the country and around the world. The lake is also an important source of drinking water for Hyderabad and its surrounding areas.

The Hussain Sagar catchment area is located in the southern part of India and is part of the Musi River basin. The catchment receives rainfall mainly from the southwest monsoon, which occurs from June to September. The average annual rainfall in the catchment is around 800-900 mm, with the highest rainfall occurring during the monsoon season. The rainfall in the Hussain Sagar catchment is influenced by several factors, including the topography, land use, and regional climate patterns. The catchment is characterized by undulating terrain with elevations ranging from 400 to 800 meters above sea level. The land use in the catchment is dominated by agriculture, with some urban areas and forested areas. The monsoon rainfall is characterized by intense and heavy rain events, which can lead to soil erosion and flooding in the catchment.

The soil properties of the catchment area vary depending on the location and land use practices. The soil in the urbanized areas around the lake is typically compacted and heavily disturbed due to construction activities and other human interventions. In contrast, the soil in the more rural and forested areas is generally richer in organic matter and has better water-holding capacity. Soil erosion is a significant issue in the catchment area, particularly in the areas with steep slopes and poor vegetation cover. The erosion can result in the sedimentation of the lake, which can affect its water quality and ecological health.

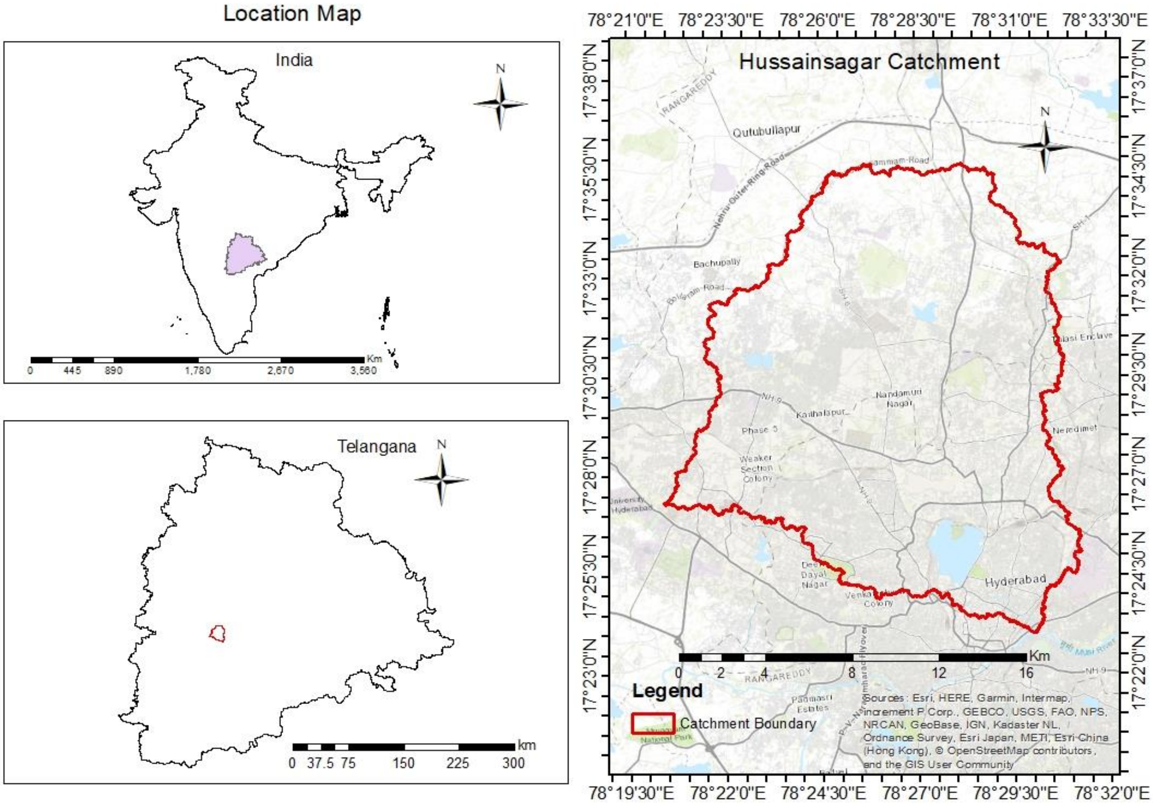

Fig.3.1 Location Map of Hussain Sagar Catchment

CHAPTER-4

METHODOLOGY

Soil erosion of a catchment area is estimated through several models. In this study, soil erosion has been estimated with the help of RUSLE model. The Revised Universal Soil Loss Equation (RUSLE) is a widely used method for predicting soil loss due to water erosion. When combined with Geographic Information System (GIS) technology, it becomes a powerful tool for soil conservation planning and management. A geographic information system (GIS) is a type of database containing geographic data combined with software tools for managing, analysing and visualizing those data. Five parameters are influencing the RUSLE equation. They are used in this study as raster formats such as rainfall erosivity (R), soil erodibility (K), steepness factor (LS), crop factor (C) and support practice factor (P).

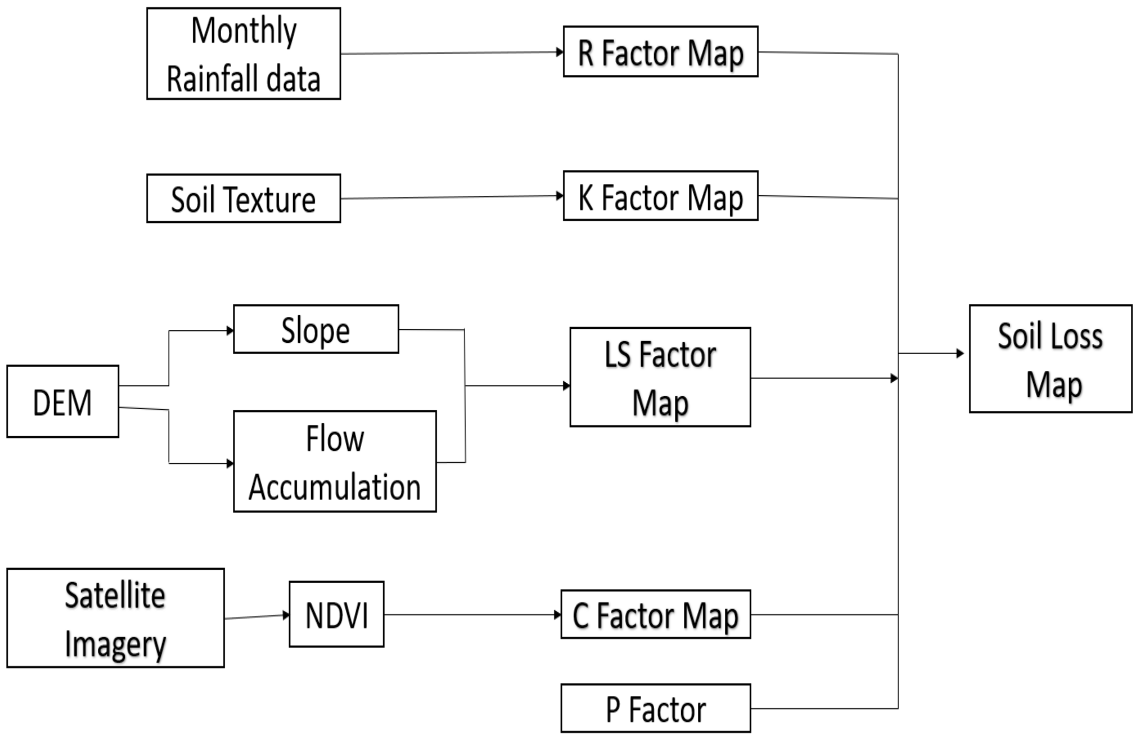

Fig.4.1 Flow Chart of Methodology

4.1 Preparation of Boundary

The digital elevation model (DEM) of the study area is downloaded from Earth Explorer Website (https://earthexplorer.usgs.gov/) by choosing our area of interest which is Hussain Sagar in our study. The SRTM DEM data was used to prepare sub-basin boundary, slope and LS factor layers. The next step is to process the DEM to create a suitable boundary. This can be done by applying filters, smoothing and resampling techniques to remove any noise or errors in the data. It is also essential to ensure that the DEM has consistent units, projections and coordinate system and threshold. In our study we used UTM 44N projection, cell size of 30m and threshold of 60. Once the criteria have been determined, the boundary can be created using GIS software or other specialized tools. This involves extracting the area that meets the defined criteria and converting it into a polygon feature. The resulting boundary can then be exported in a suitable format for further analysis or visualization. It is also essential to consider any other relevant factors such as land use, geology or hydrology.

Fig.4.2 DEM before pre-processing

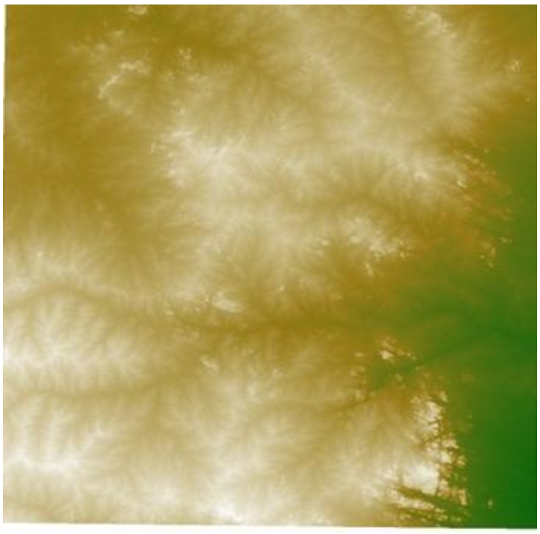

Fig.4.3 DEM after pre-processing

Fig.4.4 Hussain Sagar Boundary

Preparing a boundary is an essential step in soil loss estimation, as it helps define the area of interest and the spatial extent of the analysis. A well-defined boundary helps define the geographic extent of the study area, which is essential for selecting appropriate data sources, models and methods for soil loss estimation. It also helps ensure that the analysis focuses on the relevant factors that influence soil loss in the area. A boundary can help identify areas within the study area that are experiencing high levels of erosion or are at high risk of erosion. This information can help prioritize conservation efforts, such as the implementation of soil conservation practices, to reduce soil loss in these areas.

4.2 PREPARATION OF RUSLE FACTOR MAPS

4.2.1 Rainfall Erosivity Factor (R)

The rainfall erosivity is an important factor for determining the rate of soil erosion, particularly in terms of rainfall intensity and it is often used to reflect the impact of rainfall on soil erosion. The rainfall data collected from the Indian Meteorological Department (IMD), Hyderabad or from the online websites. The annual average rainfall for the period of 1981–2021 from nearby meteorological stations in the study area was used to compute Rainfall erosivity factor (R factor). The relation for finding R factor is given by the equation below:

$$R = 79 + 0.363 \times AAP \qquad (2)$$

Where AAP is the average annual precipitation.

4.2.2 Soil Erodibility Factor (K)

The soil erodibility factor (K) corresponds to the susceptibility of soil toward erosion by means of transportability of sediment through runoff events under standard conditions. This factor is an empirical measure of soil erodibility as affected by inherent soil properties. The soil texture plays an important role in determining the K factor along with soil structure, organic matter content and permeability. It is assumed that the established K value remains the same and treated as permanent in most of the cases. However, the only reliable way to establish the local K value is based on the runoff plots under standard conditions of bare fallow land. But, estimation of local K value for a large basin is often difficult due to complexity of landscape and its relief variation with heterogeneous soil cover. For the present study, the relevant soil data layers such as soil texture, organic carbon, silt content and clay content for the study area are downloaded from the Soil Grids website (https://soilgrids.org/). These layers and the Hussain Sagar boundary are imported into GIS and processed. K factor is found using those layers by creating a new raster layer using “Raster Calculator” and from the formula given below:

$$K = \left\{0.2 + 0.3exp\left[0.0256SAN\left(1 - \frac{SIL}{100}\right)\right]\right\} \times \left(\frac{SIL}{CLA+SIL}\right)^{0.3} \times \left[1.0 - \frac{0.25C}{C+exp(3.72-2.95C)}\right] \times \left[1 - \frac{0.7SN}{SN+exp(-5.51+2.95SN)}\right] \quad (3)$$

Where,

SAN is the subsoil sand fraction

SIL is the subsoil silt fraction

CLA is the subsoil clay fraction (in %)

C is the topsoil carbon content (in %)

SN=1-SAN/100

4.2.3 Slope Length and Steepness Factor (LS)

LS factor generally defines the effect of topography on soil erosion. It is a combination of two factors, namely slope length factor (L), slope steepness factor (S) and they are directly proportional to soil erosion and sediment yield due to progressive accumulation of runoff through the down slopes The slope length factor (L) and slope steepness (S) factor can be estimated through field measurement (for small area) or from a digital elevation model (for large area). It includes processing of the topographic data by Using the "Fill" tool in the "Terrain Analysis" menu to fill any sinks or depressions in the DEM and "Slope" tool in the "Terrain Analysis" menu to calculate the slope of the terrain. GIS tools, and its accuracy is determined by combining the L and S to form a topographic factor (LS). The quality of the LS factor depends on the resolution of the DEM data. The flow accumulation and slope raster were created using the SRTM DEM (30 m cell size) data in ArcGIS spatial analyst module. The LS factor was computed using the formula:

$$LS = (((a \times c) \div 22.13)^{0.4}) \times (\sin(slope) \div 0.0896)^{1.3}) \quad (4)$$

Where,

LS is slope length and steepness factor

a is flow accumulation

c is cell size which is the resolution of the DEM

sin slope is the slope degree values in sin

4.2.4 Cover Management Factor (C)

The C factor represents the second most critical factor after topography. It affects the soil erosion rate by various types of cropping pattern and vegetation cover over an area. The soil loss from a vegetation-rich field is relatively less than the rate of soil loss from a barren land. It depends on the combination of vegetation cover, cropping pattern and land management practices. The required land use data is collected from swat website.

4.2.5 Support Practice Factor (P)

The conservation practice factor (P) is an important and most uncertain parameter in RUSLE model. It depends on various soil conservation measures adapted in the field, such as terracing, contour tillage and permanent barriers or strips. These measures will reduce the runoff potential, which, in turn, reduces the amount of soil erosion. The support practice essentially affects soil erosion through altering the flow pattern, gradients or direction of surface runoff and by reducing the amount and rate of runoff. Generally, the conservation rating of an area ranges from 0.001 to 1, the low value indicating more effective conservation practice, while the high value showing poor conservation practice adopted in that place. The required land use data is collected from the swat website. The downloaded data is imported into the ArcGIS and by using some GIS tools such as reclassify, clip the final raster layer is created.

CHAPTER-5

RESULTS AND DISCUSSIONS

5.1 R-Factor

R factor is calculated based on rainfall data over a period of 40 years of study area from equation 2 and these values are interpolated spatially through GIS technique and R factor map is generated is shown in Figure 5.1. Many studies revealed that the soil erosion rate in the catchment is more sensitive to rainfall. The daily rainfall is a better indicator of variation in the rate of soil erosion. While the advantages of using annual rainfall include its ready availability, ease of computation and greater regional consistency of the exponent. Therefore, in the present analysis, average annual rainfall was used for R factor calculation. The annual average rainfall erosivity factor (R) was found to be in the range of 363.088 to 364.006 MJ ha/mm/hr/yr.

Table 5.1 Mean annual rainfall and R-factors of Hussain Sagar Catchment

Station	Latitude	Longitude	AAP	R
1	17.45	78.47	792.8422	366.8017
2	17.55	78.52	782.6137	363.0888
3	17.5	78.5	782.6137	363.0888
4	17.72	78.28	792.8422	366.8017
5	17.63	78.48	782.6137	363.0888
6	17.55	78.52	782.6137	363.0888
7	17.2	78.65	718.08	339.663
8	17.32	78.13	792.8422	366.8017
9	17.63	78.4	792.8422	366.8017

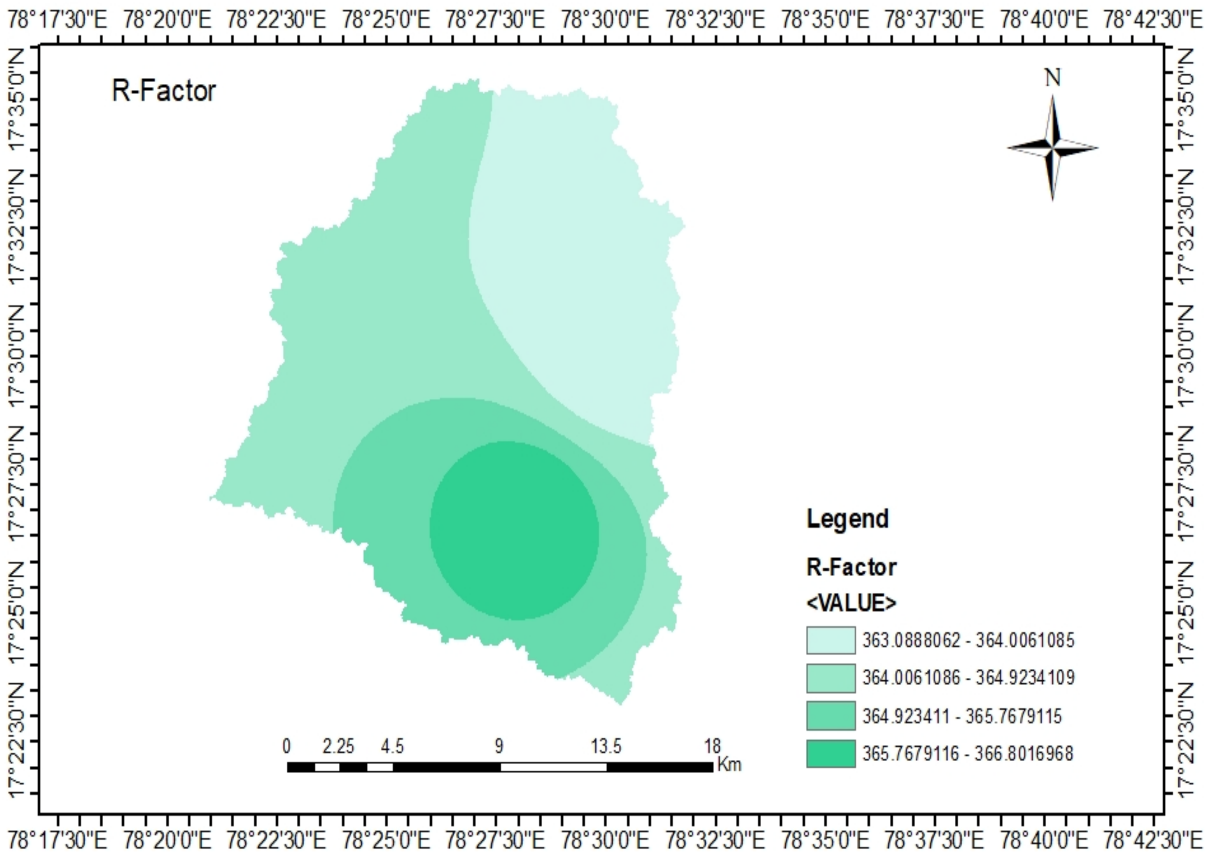

Fig.5.1 R-Factor Map

The interpolation technique used to estimate the R factor in RUSLE depends on various factors, such as the quality and distribution of rainfall data, the specific requirements of the study, and the availability of software and resources. The Thiessen polygon method and IDW interpolation are commonly used methods for estimating the R factor in RUSLE.The method used in this study is IDW method. This method assigns weights to neighboring meteorological stations based on their distance from the point of interest, and the estimated value at a specific location is based on the weighted average of the rainfall values at the neighboring stations.

5.2 K-Factor

The soil erodibility factor (K) represents the soil properties such as texture, profile and organic content toward soil loss. Soil erodibility (K) of the study area was calculated using equation 3. The K values of the study area range from 0.1 to 0.1417 t h MJ−1 mm−1, but majority of the area shows the value of 0.1 t h MJ−1 mm−1. The higher K factor values are found in areas, particularly located in the upper parts of the Hussain Sagar catchment.

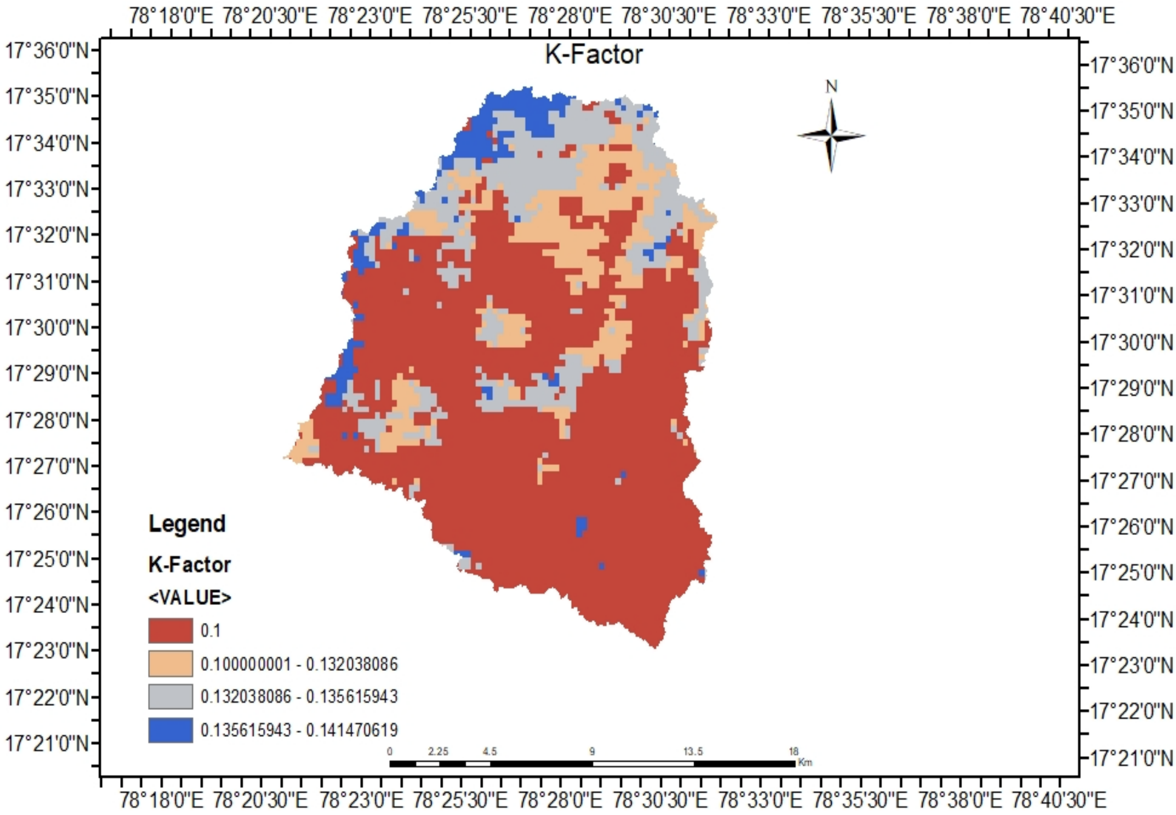

Fig.5.2 K-Factor Map

5.3 LS-Factor

Topographic factor represents the influence of slope length (L) and slope steepness (S) on erosion process. LS factor was calculated by considering the flow accumulation and slope in percentage as an input. From the analysis, it is observed that the value of topographic factor increases in a range of 0 to 176.72 as the flow accumulation and slope increases but majority of the area shows the value ranging between 0 to 4.158. SRTM DEM of 30 m resolution is used to calculate LS factor, steeper the slope more will be the loss. Highest values of LS factor are mainly distributed in lower part of the river where slope is very high and the lowest LS factor values are found in majority area of the Hussain Sagar catchment where the slope is generally low.

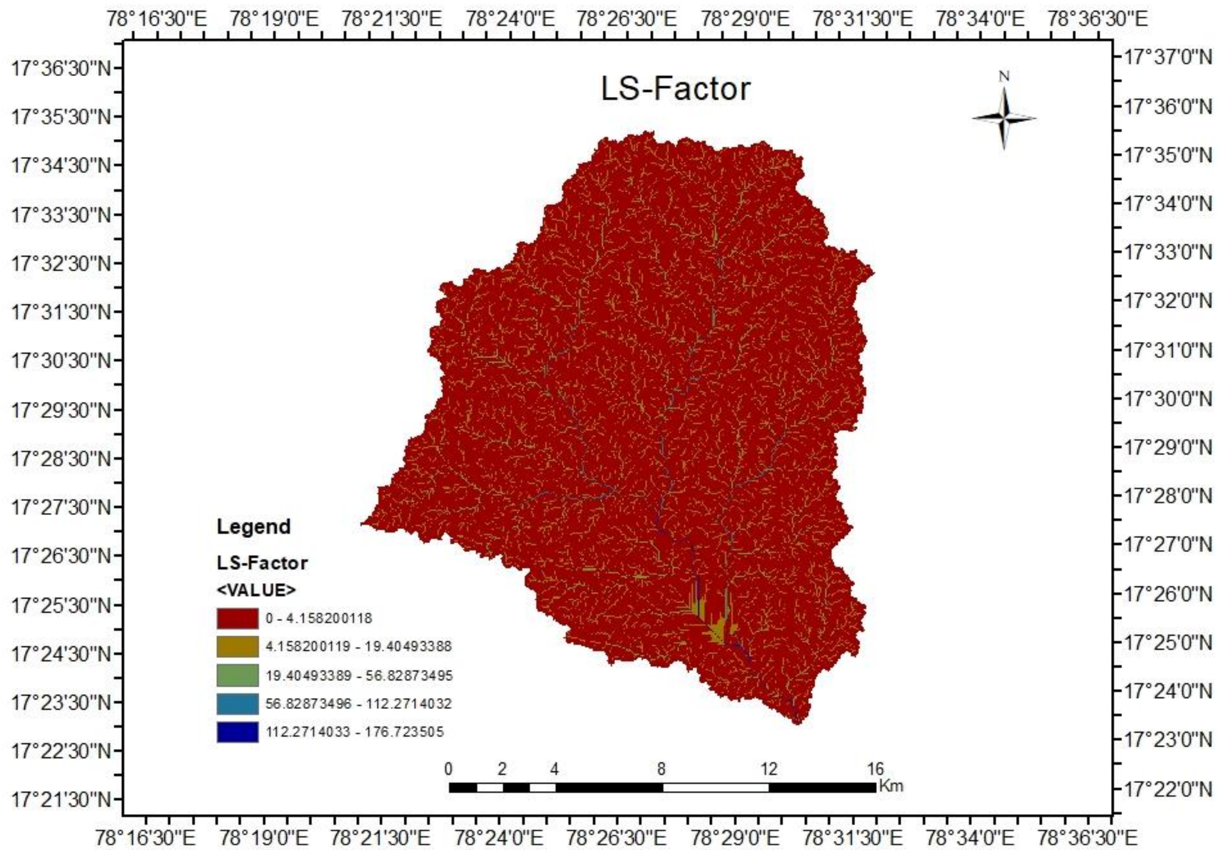

Fig.5.3 LS-Factor Map

5.4 C and P Factor

The cover management factor C depends on the land use and it is the ratio of soil loss from a cropped land in a particular condition to the soil loss in the continuous tilled fallow on the same soil and slope. The support practice factor (P) is the ratio of soil loss with a particular support practices to the corresponding loss of up and down slope cultivation. C factor and P factor are obtained from land use and land cover map of the study area. The different land use categories describe their ability to resist or aggravate the soil erosion of the study area. Lower values of C factor and P factor indicate the study area is not susceptible to soil erosion. Land use land cover map are obtained from supervised unsupervised classification of the Landsat satellite image or from swat.tamu.edu.

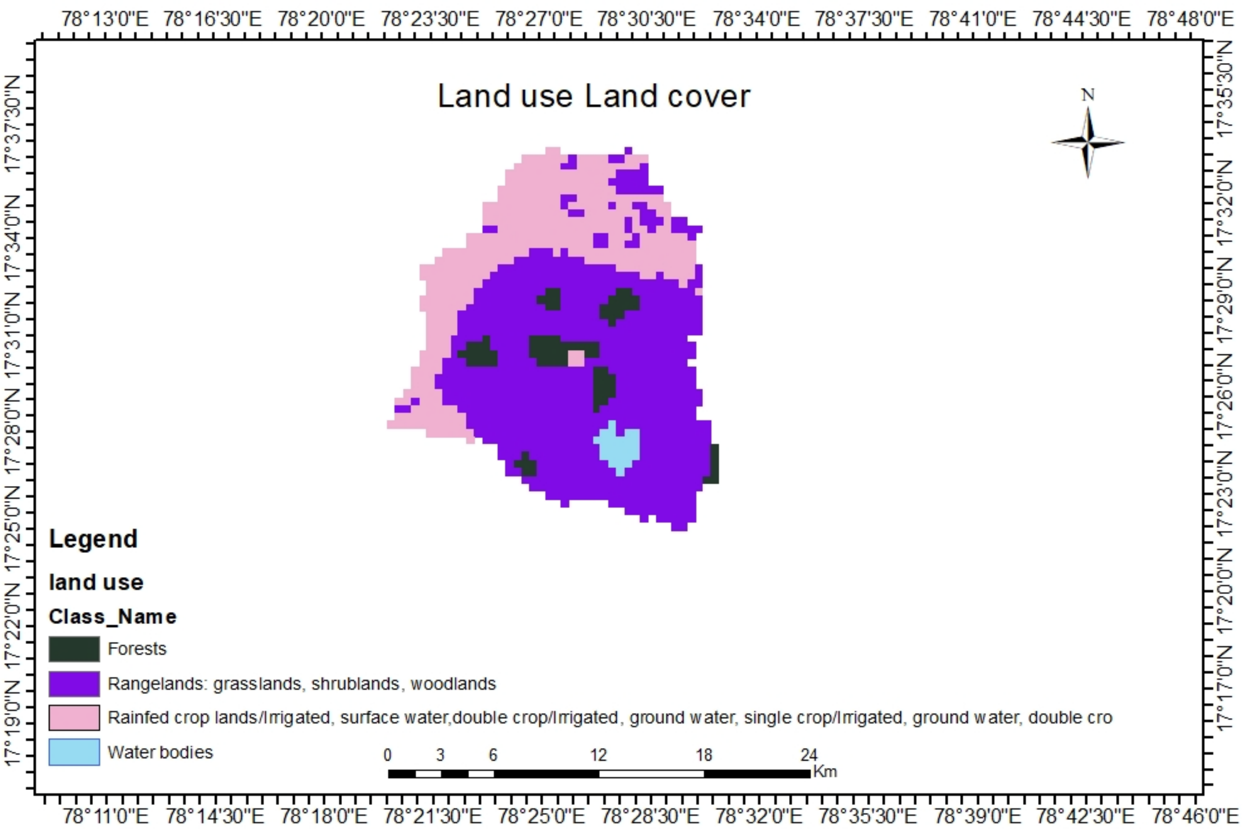

Fig.5.4 Land use Land cover

Table 5.2 Land use/land cover classes and their 'C' and 'P' values(Amit kumar et.al (2014))

Land use Land cover	P factor	C factor
Forests	0.1	0.003
Rangelands: grasslands, woodlands	0.8	0.02
Agricultural lands	0.4	0.25
Water bodies	0.5	1

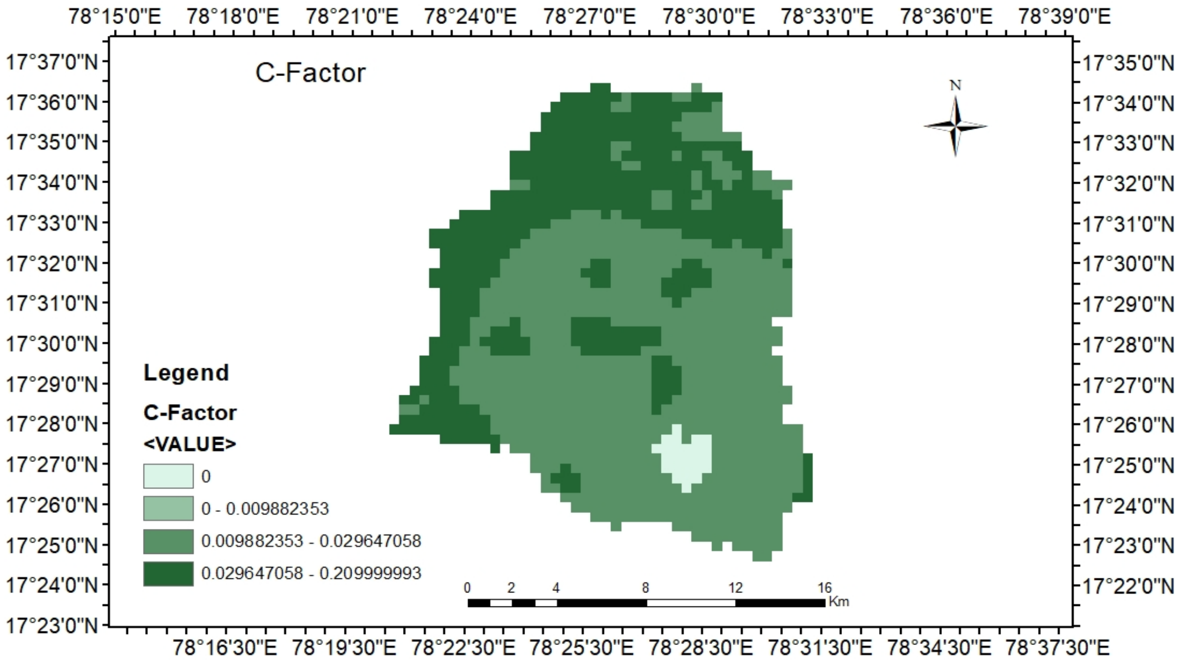

Fig.5.5 C-Factor Map

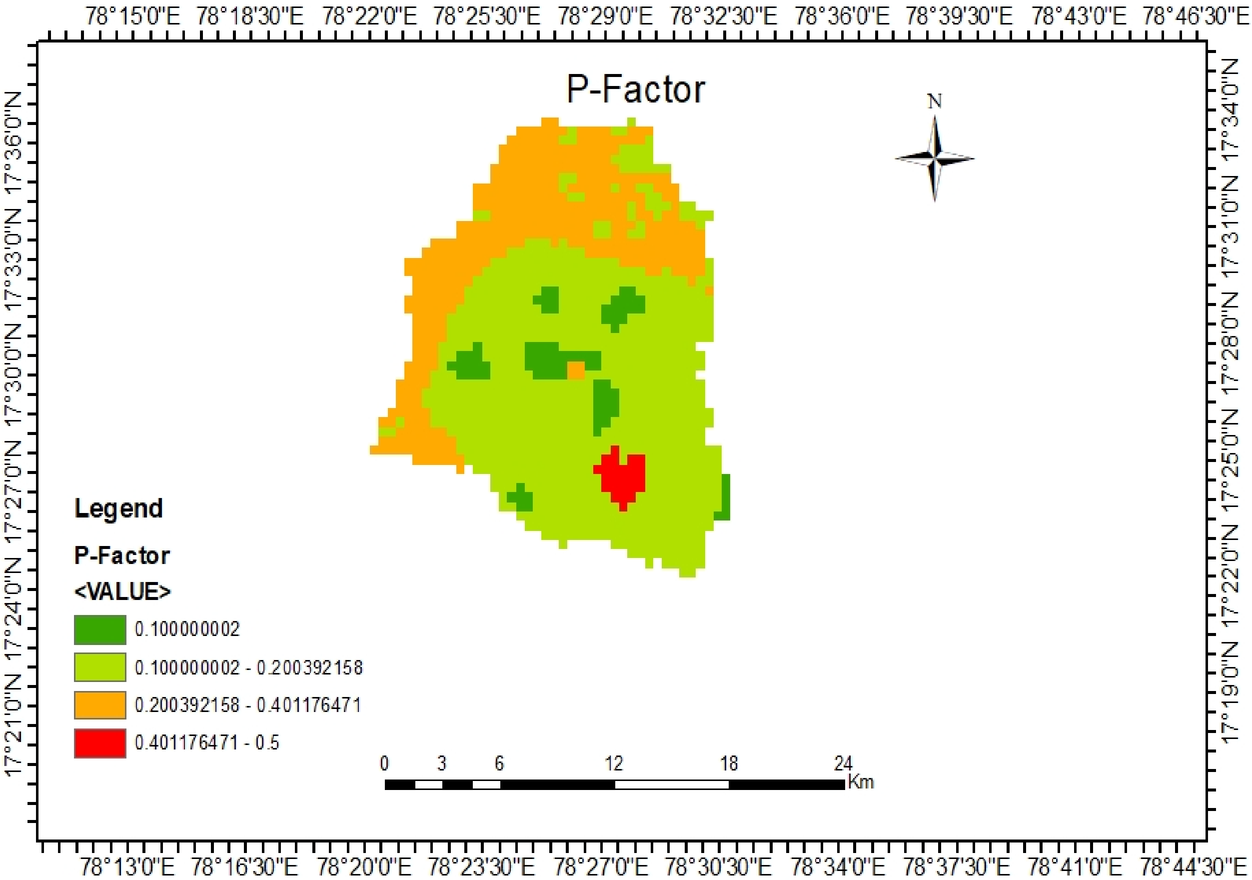

Fig.5.6 P-Factor Map

5.5 Annual Soil Loss Estimation

The average annual soil loss has been computed by multiplying the developed raster data from each factor of RUSLE analysis. The final soil erosion map displays the average annual soil loss of Hussain Sagar is shown in Figure 5.7. The GIS analysis has been carried out for RUSLE to estimate annual soil loss on a pixel-by-pixel basis and the spatial distribution of the soil erosion in the study area. The average annual soil loss of the study area Hussain Sagar ranges from 0 tons/ha/yr to 438.43 tons/ha/yr. Upper part of the catchment has the annual soil loss mostly ranging between 6 tons/ha/yr to 87 tons/ha/yr. It is observed that most part of the study area comes under low erosion category.

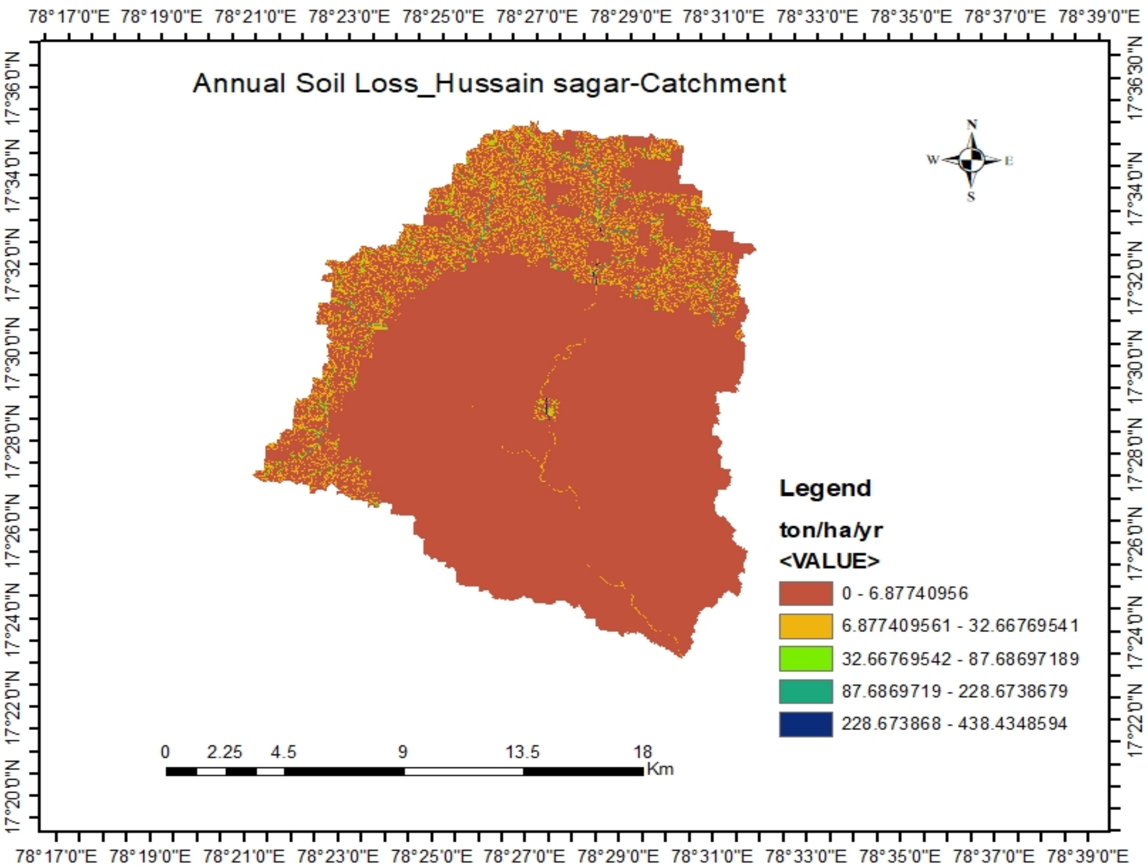

Fig.5.7 Annual Soil Loss Map

Table 5.3 Soil Loss Classes

Class	**Soil loss rating (t/ha/yr)**	**Hazard severity**
1	0-1	Very slight
2	1-10	Slight
3	10-20	Moderate
4	20-50	Severe
5	50-100	Very Severe
6	>100	Extremely Severe

Source:
https://www.researchgate.net/profile/Krishna_Bahadur_Kc/publication/257793080/figure/download/tbl2/AS:668504520945694@1536395306929/erosion-classes-rating-and-percentage-of-area-coverage-for-1990-and-2000-

CHAPTER-6

CONCLUSIONS

The RUSLE is a very effective technique to quantitatively assess average soil loss in a watershed. In order to spatially visualize the erosion prone areas, the RUSLE could be integrated in GIS platform. This allows us to assess quantitatively the soil erosion, identify the risk zones and draw appropriate planning measures for implementing optimal land use management practices. Most of the areas (~80%) have suffered soil loss of less than 10 t/ha/yr and is under low risk of soil erosion as shown in fig 5.7. The study reveals that the upper parts of the catchment is prone to high rates of erosion (> 10 t ha1 year). Topography changes along with high LS-factor and precipitation swift these parts to be more vulnerable to soil loss.

The average annual soil loss map is very useful to adopt soil conservation measures and protective method of agriculture practices for sustainable natural resource management. Soil loss estimation in the Hussain Sagar Catchment can help identify areas of high erosion risk, such as steep slopes and areas with intensive agricultural practices. Implementation of soil and water conservation measures such as contour farming, terrace farming, conservation tillage and construction of check dams can help reduce soil erosion, prevent sedimentation of the lake and improve the water quality.

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