ESTIMATION OF SOIL EROSION USING RUSLE AND ArcGIS IN DHOLPUR DISTRICT

Submitted in partial fulfillment of the requirements for the award of degree of

Master of Technology

In

WATER RESOURCE ENGINEERING

CIVIL ENGINEERING

Submitted by

UMESH KUMAR

(2014PCW5203)

Supervised by

Prof. Gunwant Sharma

DEPARTMENT OF CIVIL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

JUNE 2016

A

DISSERTATION REPORT

ON

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JAIPUR 302017

DECLARATION

I hereby certify that the work which is being presented in the dessertation report entitled **"ESTIMATION OF SOIL EROSION USING RUSLE AND ArcGIS IN DHOLPUR DISTRICT"**, in partial fulfillment of the requirements for the award of the Degree of Master of Technology and submitted in the Department of Civil Engineering of the Malaviya National Institute of Technology Jaipur is an authentic record of my own work carried out during a period from July 2014 to June 2016 under the supervision of Prof. Gunwant Sharma, Professor, Department of Civil Engineering, Malaviya National Institute of Technology Jaipur, India.

The matter presented in the report has not been submitted by me for the award of any degree of this or any other Institute.

(**UMESH KUMAR**)
Student ID: **2014PCW5203**

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date:
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ACKNOWLEDGEMENT

I owe great thanks to many people who helped and supported me during the project.

I would like to express gratitude and deep regards to my mentor Prof. Gunwant Sharma, Department of Civil Engineering, MNIT Jaipur for their exemplary guidance, monitoring and constant encouragement throughout the project. His supervision and willingness to share his vast knowledge have helped me to complete the assigned task.

I would also like to thanks Prof. A. K. Vyas, DPGC Convener, and Dr. Mahesh K. Jat , associate professor, Department of Civil Engineering, MNIT Jaipur for extending every possible help and encouragement.

(Umesh Kumar)

ABSTRACT

This study applies Geographical Information System (GIS) and the Revised Universal Soil Loss Equation (RUSLE) to predict the annual average soil loss rate in the Dholpur District (Rajasthan). To achieve the objectives of the thesis, the RUSLE Parameters were calculated using the remote sensing data, rainfall data, and soil texture data which were collected from U.S. Geological Survey, WRD department and soil conservation department of Rajasthan. The soil texture, permeability and structure property of soil data were used to create the soil erodibility factor (K), and a digital elevation model of the basin t was applied to generate the topographic factor (LS). The cover-management factor(C) was calculated from making NDVI map from Landsat data for 2008 and 2013 years. The support practice (P) factor was created by giving the value to LULC maps which were made by supervised classification of a satellite image of 2008 and 2013 years. Usually C and P factors determine from land cover and land use classes respectively. The rainfall–runoff erosivity (R) was resulted from yearly rainfall data. It is also important to note that the steepest slopes show a high risk of soil erosion, it is consequently recommended that further study is commenced to inaugurate the suitable soil and water conservation measures that should be implemented in these areas as well as the whole catchment. This thesis shows the comparative study of estimation of soil erosion between 2008 and 2013 years.

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Chapter 1

INTORODUCTION

1.1 SOIL EROSION:

The term soil has devised from the Latin word solum. Soil can be defined as a loose inorganic particulate material formed from the mechanical and chemical disintegration and decomposition of rocks and minerals on the earth`s crust through the actions of natural or mechanical or chemical agent; with or without organic matter content that supports plant life. Soil formed from the weathering of rocks if remain at the place of origin by various agencies like wind, water, ice, gravity are called Transported Soils also referred as Sedimentary soils. Soil erosion is a process that transforms soil into the sediment. Sediment consists of transported and deposited particles or aggregates derived from rock, soil, or biological material.

Erosion is a natural geological phenomenon occurring continually over the earth`s surface resulting from the removal of soil particles by rainwater or wind, transporting them to another place. Some human activities can significantly increase erosion rates leading to loss of soil cover where erosion has taken place and typically problems due to deposition of sediment elsewhere (like silting of the reservoir). Soil loss by water is one of the highest important lands degradation problems and a critical environment hazard of modern times worldwide. Accelerated erosion due to human- induce environmental alteration at a global scale is causing an extravagant intensification of geomorphic process activity and sediment fluxes in many parts of the world. It largely depends on topography, vegetation, soil and climatic variables and, therefore, exhibits pronounced spatial variability due to catchment heterogeneity and climatic variation.

Manchanda et al. (2002) stated that soil systems like most natural systems, are in dynamic equilibrium. Most variations are slow and imperceptible particularly when viewed in the time frame of the human lifespan. However, catastrophic events such as high intensity storms can accelerate erosion processes resulting in measureable changes. The variations are mainly in the structure and arrangement of the material and such changes are referred to as ‘structural changes’. Changes are assessable directly or indirectly or may be inferred from the behavior of the system. Many of the changes are associated to uses of the soil where there arises the need of information of the spatial distribution of soil kinds for developing rational land use planning.

Soil erosion is one of a most serious environmental problem as it removes soil rich in material and increases natural level of sedimentation in the rivers and reservoirs reducing their capacity as well as life span. It has been estimated that in India near about 5334 m- tons of soil is being detached yearly due to various reasons and about 113.3 m ha of land is subjected to soil erosion due to water (Narayan and Babu, 1983, Jain et al., 2010).

The land degradation stems from a combination of changes in land use, agricultural intensification and intense thunderstorms. Erosion may also be exacerbated in the future in many portions of worlds because of climatic changes towards a more vigorous hydrologic cycles (Amore et al., 2004).

Thus information on soil resources and its management is an important endeavor to all as everyone`s livelihood depends directly or indirectly on these natural resources. In recent years with the rate of knots of developments, we have faced the rapid deterioration of soil resources. It is quite evident from data that all the Greener Earth abundant with all natural resources that we inherited from our fore-fathers, has been significantly eroded and stolen from the future generation. It is a matter of great anxiety that above 57% of the total geographic area of the country is suffering from various forms of degradation such as water erosion, wind erosion, chemical and physical deterioration, where much of the land is suffering from water logging and soil salinity due to rapid industrialization and urbanization. In this era, where our country`s population has crossed the one billion mark, constraints arise to use these resources to meet the increasing need for food, fodder and fiber. Much of the fertile land is degraded due to over and improper use of the increased productivity pressure. Thus soil and water conservation practices are now required to be implemented.

Soil erosion over earth thus being a quite –frequent and well distributed problem, mapping the level of risk of areas exposed to rain and wind erosion is therefore all important issue. Many Models of soil erosion estimation highlight the importance of soil coverage by active green vegetation and residue. There is a need for modeling and quantitative estimation of erosion on these landscapes for both on-site and off-site assessment of its impact. These models have been developed for fine study scale (field or catchment scale) along with the help of Remote Sensing (RS) and Geographical Information system (GIS) techniques in combinations. The low data demanding models make soil erosion estimation and its spatial distribution feasible with reasonable costs and better accuracy in larger scales.

Malchanda et al. (2002) state that an intimate knowledge of the soil kinds and their spatial distribution is a essential in developing rational land use plan for agriculture , forestry, irrigation, drainage etc. Soil resource inventory provides an insight into the potentialities and limitation of soil for its effective exploitation. Soil survey affords an accurate and scientific inventory of different soils, their kind and nature, and size of distribution so that one can make a prediction about their characters and potentialities. It also provides adequate information in terms of land form, terraces, vegetation, as well as characteristics of soils (viz., texture, penetration, structure, stoniness, drainage, bitterness, salinity, and so on) which can be used for planning and development.

For the conservation of land from soil erosion, it is imperative to locate and measure the type, degree and severity of soil erosion for proper planning to conserve or to opt for alternative uses. Government organization like National Bureau of Soil Survey Land Use Planning, Central Soil and Water Conservation Research and Training Institute, Indian Council of Agriculture Research etc. are working with objectives to prepare soil resource map at state and district level and to provide research inputs in soil resource mapping, land evaluation, land use planning, land resource management on different kinds of soils in the country. They carry out agro-ecological and soil degradation mapping for qualitative assessment and monitoring the soil health towards viable land use planning and identification of soil potential and problems.

Here, a study has been done to identify soil-erosion prone areas over Dholpur district watershed, using Soil Erosion Model ‘RUSLE’ integrated with satellite RS-GIS as a useful tool. Yearly precipitation data, Soil map, a Digital elevation Model, Land- cover and land use types and slope steepness are used to determine the RUSLE values. Within a raster –based GIS, the RUSLE model can predict erosion potential on a cell-by-cell basis. This has distinct advantages for identifying the spatial patterns of soil loss present within a large region. GIS can be used to isolate and query these locations to yield vital information about the role of individual available in contributing to the observed erosion potential values.

1.2 The Objectives of this project are:

- To estimate of soil erosion using ArcGIS and RUSLE in Dholpur district.
- To prepare six factor`s layers of RUSLE in ArcGIS
- To prepare of LULC maps of the study area to identify changes detection.
- Study the effects of various parameters on soil erosion.

1.3 Thesis Outline

The thesis outline can be divided into seven chapters. The *chapter 1* primarily gives the objective of the present research work. The rest of the thesis is arranged as follows: *Chapter 2* is for the literature review which includes the related research work that has been completed by other people and has been discussed thoroughly. This chapter shows how the application of GIS and RS assists in estimation of soil erosion with RUSLE. Erdase Imagine is utilized for the LULC change detection study and give knowledge about existing classes in that area. *Chapter 3* is allocated for the description of the study area and data used for the complete work. *Chapter 4* illustrates the methodologies used for estimation of soil erosion using RUSLE in ArcGIS. In this chapter flowchart also demonstrates the methodologies and techniques of supervised classification and NDVI map making also described. Then the techniques and equations used for the calculation of RUSLE factors also discussed. Results and discussions have been collectively put in *Chapter 5* along with detailed analysis and output results of LULC change and soil erosion maps. In this chapter also show variations between results of 2008 and 2013 in respect to soil erosion quantity and area of soil erosion classes. The discussion is provided in detail in relation to the objectives. *Chapter 6* concludes the research work and recommends the future work. *Chapter 7* contains references from which we acquired a lot of knowledge for this project work.

CHAPTER 2

LITRATURE REVIEW

2.1 INTRODUCTION

Soil erosion is the wearing away of the land surface by physical forces such as rainfall, flowing water, the wind or anthropogenic agents that abrade, detach and remove soil or geological material from one point on the earth`s surface to be deposited elsewhere. The soil is basic to all life forms and is the primary means of food production, it is an essential element of terrestrial ecosystems, sustaining their primary producers (micro-organism, herbivores, omnivores) while providing major sinks for heat energy, nutrients, water and air as stated by Breetzke(2004).

2.2 LITERATURE REVIEW

Pandey et al. (2007) describe Soil erosion as one of the most serious environmental problems as it removes soil rich in nutrients and increases natural level of sedimentation in the streams, rivers and reservoirs dropping their storage capacity as well as life span. The land degradation stems from a combination of changes in land use, agricultural intensification and intense rainstorms. For preserving and improving soil productivity, high priority should be given for preservation of soil resources by promoting optimum land use. To renovate the productivity of the soil and to prevent further damage from taking place, planning, conservation and controlling of the watersheds are vital. Therefore, an attempt to assess the erosion hazard and prioritization of watersheds for treatment would aid in better planning to combat this menace.

Yue-qing.,et al.(2009) describe that due to the presence of fragile karst geo-ecological environments, such as environments with tremendously poor soil cover, low soil-forming velocity, and fragmentized terrain and physiography, as well as unsuitable and intensive land use, soil erosion is a serious problem in Guizhou Province, which is situated in the center of the karst areas of southwestern China; assessment of soil loss rate and spatial distribution for conservation planning is immediately needed.

Bhattarai and Dutta (2006) Mention that Soil erosion has been accepted as a severe problem arising from agricultural intensification, land deprivation and possibly due to global climatic change. Sediment deposition into a reservoir reduces the reservoir capacity and widening of flood plains during floods on the river bed and banks. Soil erosion is the most significant contributor of offsite ground water pollution on a global scale with furthermost of the pollutants originating within an agricultural setting.

Generally, repeatedly cultivated soils, fallow soils or soils that are bare through overgrazing by stock or pest animals are particularly vulnerable. The problem is common such areas where cropping soils have slopes of 0-5 %.

Process of Soil erosion:

There are three steps of accelerated Soil erosion by water:

Detachment: This is loosening of soil particles caused by flowing water, freezing and thawing of top soil or the impact of flowing raindrops.

Transportation: This is the transfer or removal of the soil particles by rolling, floating, or splashing.

Deposition: the particles get deposited at some other place lower in elevation.

This process is described in given Figure 2.1 below

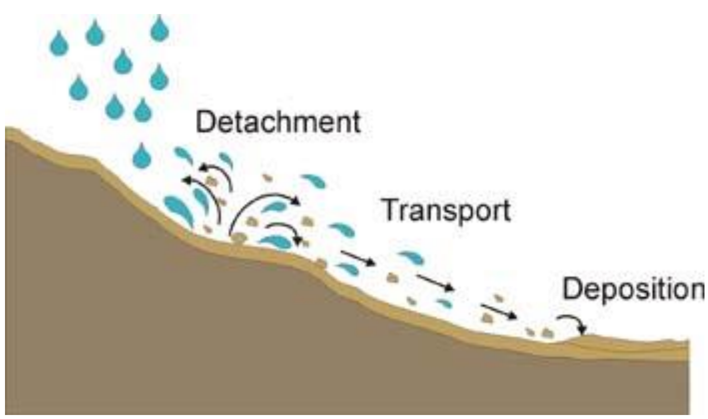


Figure 2.1 Soil Erosion Process (Source: www.wiki.ubc.ca)

Saha (2005) studied soil erosion and described the processes. He explained that soil erosion is a three stage process which involves detachment, transport and subsequent deposition. Different energy source agents decide different types of erosion. There are four principal sources of energy: physical, such as wind and water, gravity, chemical reactions and anthropogenic, such as tillage. Soil erosion begins with detachment from the soil surface, which is caused by break down of aggregates by raindrop impact and shearing and drags force of flowing water and the wind. Detached particles transported by flowing water (over-land flow and inter-flow) and the wind, and dumped when the velocity of water or else wind decreases by the influence of slope or ground cover.

Jain et al. (2010) also illustrated that the detached sediment is transported down slope primarily by flowing water, although there is a small amount of downslope transport by raindrop splash also. Once runoff starts over the surface areas and in the streams, the quantity and size of material transported increases with the velocity of overflow water. Howeve, if transport capacity is lower than the amount of eroded soil material available, then the amount of sediment exceeding the transport capacity gets deposited. The amount of sediment load passing the outlet of a catchment is known as the sediment yield.

Types of Soil Erosion:

Lal (1990) classifies soil erosion mainly as Geological and Accelerated Soil Erosion. Geological soil erosion is the one that occurs naturally due to physical factor likes Wind, water, ice, etc. while the accelerated soil erosion is one of that is caused due to anthropogenic activities and often cannot be compensated by new soil formation.

- **Geological Erosion:** Under natural undisturbed conditions equilibrium is established between the climate of a place and the vegetative cover that protects the soil layer. Vegetative covers like trees and forests retard the transportation of soil material and act as a check against excessive erosion. A certain amount of erosion, however, does take place even under the natural cover. This erosion, called geologic erosion, is a slow process and is compensated by the formation of soil under the natural weathering process. Its effect is not of much consequence so far as agricultural lands are concerned.

- **Accelerated Erosion:** When land is put under cultivation, the natural balance existing between the soil, its vegetation cover and climate is disturbed. Under such condition, the removal of surface soil due to natural agencies takes places at a faster rate than it can be built by the soil formation process. Erosion occurring under these conditions is referred to as accelerated erosion. Its rates are higher than geological erosion. Accelerated erosion depletes soil fertility in agricultural land.

According to Erosion Agents:

Soil erosion is broadly categorized into different types depending on the agent which trigger the erosion activity. Revealed below are the four main types of soil erosion:

- **Water Erosion:** Water erosion is seen in many portions of the world. Basically, running water is the most common agent of soil erosion. This includes rivers which erode the river basin, rainwater which erodes various landforms, and the sea waves which erode the coastal areas. Water erodes and transports soil particles from a higher altitude and deposits them in low lying areas. Water erosion may further be classified, based on different actions of water responsible for erosion, as : (i) raindrop erosion, (ii) sheet erosion, (iii) rill erosion, (iv) gully erosion, (v) stream bank erosion, and (vi) slip erosion.
- **Wind Erosion:** Wind erosion is most often observed in arid zones where in strong winds brush against different landforms, cutting through them and loosening the soil particles, which are lifted and transported towards the direction in which the wind blows. The best example of wind erosion is sand dunes and mushroom rocks structures, typically found in deserts.
- **Glacial Erosion:** Glacial erosion, also denoted to as ice erosion. It is mutual in cold areas at high altitudes. When soil comes in contact with bulky moving glaciers, it attach to the base of those glaciers. This is eventually carried with the glaciers, and as they start melting it is deposited in the course of the moving lumps of ice.
- **Gravitational Erosion:** Although gravitational erosion is not as mutual a phenomenon as water erosion, it can cause huge loss to natural, as well as artificial buildings. It is basically the mass movement of soil due to gravitational force. The best patterns of this

are landslides and slumps. While landslides and slumps happen within seconds, phenomena such as soil creep take a longer period for the occurrence.

Water Erosion:

The soil erosion initiated by water as an agent is called water erosion. In water erosion, the water acts as an agent to dislodge and transport the eroded soil particle from one place to another.

Types of Water Erosion: The different kinds of water erosion are defined in the following section according to Das, G. (2000)

Splash Erosion: It ia a type of soil erosion is caused by the stroke of a raindrop. The kinetic energy of dropping raindrop dislodges the soil particle and the resultant runoff transports soil particles. Splash erosion is the first stage of soil erosion by water. It occurs when raindrops hit the bare soil. The explosive influence breakdowns soil aggregates so that distinct soil particles are ‘splashed’ onto the soil surface. The splashed particles can rise as high 0.60 meters above the ground and move up to 1.5 meters from the point of impact. The particles block the spaces between soil aggregates, so that the soil forms a crust that reduces infiltration and increases runoff.

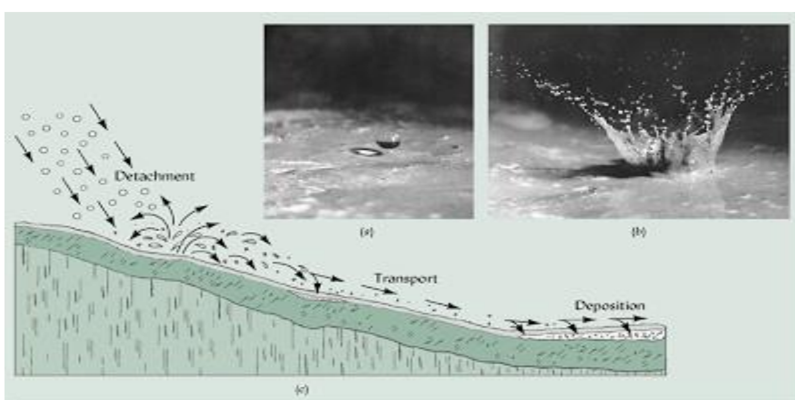


Figure 2.2 Splash erosion

(Source: http://restoringutopia.blogspot.in/2010/07/like-hollow-point-bullets-from-sky.html)

Sheet Erosion: Sheet erosion is the elimination of topsoil in thin layers by raindrop impact and shallow surface flow. This action termed skimming and is prevalent in the cropland. It results in damage of the finest soil particles that have most of the existing nutrients and organic matter in the soil. Soil loss is so slow that the erosion usually goes unobserved, but the cumulative impact accounts for great soil losses. This type of soil erosion is mostly responsible for the loss of soil productivities. Soils most susceptible to sheet erosion are overgrazed and cultivated soils where is little vegetation cover to protect and retain the soil. Early signs of sheet erosion include bare areas, water mooching as soon as rain falls, visible grass roots, exposed tree roots, and exposed subsoil and stony soils. Soil deposits on the high side of obstructions such as fences may indicate active sheet erosion. Vegetation cover is vital to inhibit sheet erosion because it defends the soil, impedes water flow and encourages water to permeate into the soil. The surface water flows that cause sheet erosion rarely flows for more than a few meters before concentrating into rills.

Figure 2.3 Sheet Erosion (Source: https://www.qld.gov.au)

Rill Erosion: Rill's formation is the intermittent process of transforming to gully erosion. The advance form of the rill is the initial stage of gully creation. The rills are shallow drainage lines smaller than 30cm deep and 50 cm wide. They develop when surface water concentrates in depressions or low points through paddocks and erodes the soil. Rill erosion is common in the bare agricultural land, particularly overgrazed land, and in the recently tilled soil where the soil structure has been loosened. The rills can generally be removed with farm machinery. Rill erosion is mostly occurring in alluvial soil and is quite frequent in Chambal river valley in India.

Rills in a recently cultivated paddock.

Figure 2.4 Rill Erosion (Source: https://www.qlv.au)

Gully Erosion: The advance phase of rills is transformed into the initial stage of the gully. Gully formation are originated when the depth and width of the rill are more than 40 cm. Gullies are deeper channels that cannot be removed by ordinary cultivation. Hillsides are more susceptible to to gullying when they removed vegetation, through deforestation, over-grazing or by other ways. The eroded soil is easily transported by the flowing water after being removed from the ground, typically when rainfall falls during short, intense storms. Gullies diminish the productivity of farmland where they incise into the land, and produce sediment that may clog downstream water bodies. Because of this, much effort is required to spent into the study of gullies within the scope of geomorphology, in the inhibition of gully erosion, and in the restoration of gullied landscapes. The total soil loss from gully development and subsequent downstream river sedimentation can be sizable.

Figure 2.5 Gully Erosion

(Source: http://passel.unl.edu/Image/siteImages/GullyErosionPasture-NRCS-LG.jpg)

Tunnel Erosion: Tunnel erosion take place when surface water moves into and through dispersive subsoils. Dispersive soil is poorly structured so they erode simply when wet. The tunnel starts when surface water moves into the soil alongside cracks or channels or through rabbit warrens and old tree root cavities. Dispersive clays are the first to be removed by the water flow. As space enlarges, additional water can pour in and further erode the soil. As the tunnel enlarges, parts of the tunnel roof collapse leading to ruts and gullies. Symptoms of tunnel erosion include water seepage at the foot of a slope and fine sediment fans downward of a tunnel outlet. This type of erosion is more frequent in foothills where elevation is between 550-750 meter.

Figure 2.6 Tunnel Erosion

(Source: http://www.ccma.vic.gov.au/soilhealth/photos.htm)

Stream Bank Erosion: Stream bank erosion occurs where streams begin cutting deeper and wider channels as a concern of an augmented peak flows or the elimination of local protective vegetation. Stream bank erosion is common along rivers, watercourses and drainage system where banks have been eroded, sloughed or undercut. This is quite predominant in alluvial river and streams. Generally, stream bank erosion becomes a problem where development has inadequate the meandering nature of streams, where streams have been channelized, or where stream bank structures (like bridges, culverts, etc.) are situated in places where they can really cause damage to downstream areas. Stabilizing these parts can help safeguard watercourses from continued sedimentation, loss to adjacent land uses, control undesirable meander, and improvement of habitat for fish and wildlife.

Figure 2.7 Stream Bank Erosion (Source: http://www.dep.wv.gov)

Factors Affecting Soil Erosion: (Suresh R. 2000)

Soil erosion comprises the processes of detachment of soil particles from the soil mass and subsequent transport and deposition of those soil/sediment particles. The main factors responsible for soil erosion, in India, are excessive deforestation, overgrazing and faulty agricultural practices. Soil erosion is a very complicated problem as many complex factors affect the rate of erosion and therefore it is difficult to solve. These factors include:

- **Climatic Factor:** The climatic factors that influence erosion are rainfall amount, intensity, and frequency. During the periods of frequent or continuous rainfall, high soil moisture or saturated field conditions are developed, a greater percentage of the rainfall is converted into a runoff. This in turn results in soil detachment and transport causing erosion at a high rate.
- **Temperature:** While frozen soil is highly resistant to erosion, rapid thawing of the soil surface brought about by warm rains can lead to serious erosion. Temperature also influences the type of precipitation. Although falling snow does not cause erosion, heavy snow melts in spring can cause considerable runoff damage. Temperature also influences the amount of organic matters that gets collected on the ground surface and gets incorporated into the topsoil layer. Areas with warmer climates have a thinner organic cover on the soil. Organic matter cover on the surface protects the soil by shielding it from the impact of falling rain and helping in the infiltration of rainfall that would

otherwise cause more runoff. Organic matter inside the soil increases the permeability of the soil to cause more percolation and reduce runoff.

- **Topographical Factors:** Among the topographical factors, slope length, steepness and roughness affect erodibility. Generally, the longer slope increases the potential for erosion. The extreme erosion potential is at the base of the slope, where runoff velocity is the greatest and runoff concentrates. Slope steepness, along with surface bumpiness, and the quantity and intensity of precipitation control the speed at which runoff flows down a slope. The steeper the slope, more rapidly the water will flow. The faster it flows, the more likely it will cause erosion and increase sedimentation. Slope quickens erosion as it increases the velocity of flowing water. Small differences in slope make a big difference in damage. According to the laws of hydraulics, four times increase in slope doubles the velocity of flowing water. This doubled velocity can intensify the erosive power four times and the carrying (sediment) capacity by 32 times.

- **Soil:** Physical characteristics of soil have a bearing on erodibility. Soil properties convincing erodibility comprise texture, structure and cohesion. Texture denote the size or arrangement of sizes of the individual soil particles. Three comprehensive size classifications, ranging from small to large are clay, silt, and sand. Soil having a huge amount of silt-sized particles is most susceptible to erosion from both wind and water. Soil with clay or sand-sized particles is less prone to erosion. Structure remarks the degree to which soil particles are clumped together, forming more clumps and pore spaces. Structure influences both the capability of the soil to absorb water and its physical resistance to erosion. Another property is the cohesion which refers to the binding force between the soils particles and it impacts the structure. When moist, the individual soil particles in a cohesive soil adhere together to form a doughy stability. Clay soils are very cohesive, and sand soils are the least cohesive.
- **Vegetation:** Vegetation is probably the most key physical factor influencing soil erosion. A good cover of vegetation protects the soil from the impact of raindrops. It also binds the soil together, making it more resistant to runoff. A vegetative cover provides organic matter, slows down runoff, and filters sediment. On a graded slope, the condition of

vegetative cover will decide whether erosion will be stopped or only a little halted. A thick, robust cover of vegetation is one of the best protections against soil erosion.

Mechanics of Soil Erosion:

Soil erosion is initiated by a detachment of soil particles due to the action of rain. The detached particles are transported by erosion agents from one place to another and finally get settled at some place leading to soil erosion process. Different soil erosion processes are shown in

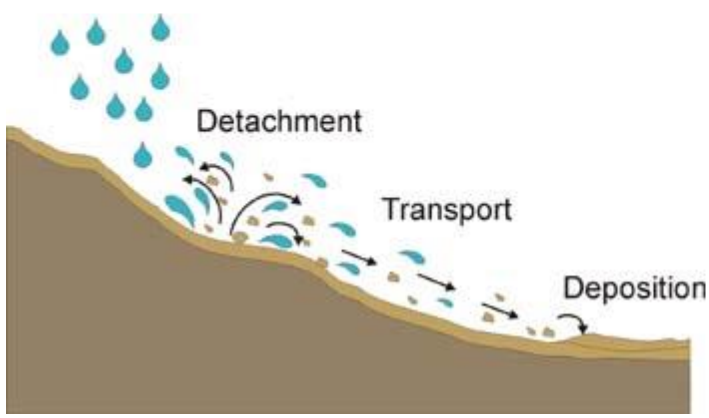


Figure 2.8 Process of water erosion by the impact of raindrops

(Source: www.landfood.ubc.ca)

Mechanics of soil erosion due to water and the wind is discussed below.

Mechanics of Water Erosion: There are three steps for accelerated erosion by water:

- Detachment or loosening of soil particles caused by flowing water, freezing and thawing of the top soil, and/or the impact of falling raindrops,
- Transportation of soil particles by floating, rolling, dragging, and/or splashing and
- Deposition of transported particles at places of lower elevation.

Rain enhances the translocation of soil through the process of splashing as shown in. Individual raindrops detach soil aggregates and redeposit them as particles. The dispersed particles may then plug soil pores, reducing water intake (infiltration). Once the soil dries, these particles develop into a crust at the soil surface and runoff is further increased.

Mechanics of Wind Erosion:

Wind erosion occurs where the soil is exposed to the dislodging force of the wind. The intensity of wind erosion varies with surface roughness, slope and types of cover on the soil surface and wind velocity, duration and angle of incidence. Fine soil particles can be carried to a great height and for (may be) hundreds of kilometers. The whole occurrence of wind erosion could be defined in three different phases. These are the initiation of movement, transportation and deposition.

Effects of Soil Erosion:

According to literature reports, these effects of soil erosion may be categorised into several chief groups: alterations in mechanical and mineral structures of soil, changes and conversions of ground surface morphology, amendments in water balance of eroded catchments and reduction of soils' fertility (Valentin et al., 2005; Widomski et al. 2010)

The testified changes in mechanical and mineral compositions of soils are replicated by decreased content of organic matter and notified content of all soil fractions (i.e. removal of clay segments and growth of coarse ones), which in turn may be reflected in reduced water permeability and water capacity of eroded slope and enlarged volume of generated surface runoff. The volume of infiltration rate of surface water into deeper stratums in the eroded profile may be decreased. Thus, the water balance of eroded catchment may be significantly altered, generally shortened - the subsequent water balance of eroded catchment usually presents reduced inflow of water into the underground aquifer, thus limiting water availability for floras (Valentin et al., 2005; Widomski et al., 2010). Increased run-off may also effect in increased removal of nutrients form the top layer of soil, diminishing and even, partial or complete, removal of the top soil layer. The noticeable site effects of soil erosion such as rills and erosional gullies organized with changes in soils fertility and water storage capacity may drastically reduce its agricultural or forestry productivity. It destroys the surface soil structure by separation of clay and silt texture fractions (sheet erosion). Erosion destroys the relief of the soil surface (gully erosion) and increase siltation of water streams and reservoirs.

The soil erosion badly affects the livelihood of the people in one way or other. The major losses and problem occur due to the soil erosion from various agents are listed below.

1. Siltation of rivers.
2. Siltation of irrigation channels and reservoirs.
3. Problems in crop irrigation and the consequent need for conserving the water.
4. Damage to the sea coast and formation of sand dunes.
5. Disease and public health hazards.

Soils eroded by water get dumped on river beds, thus growing their level and triggering floods. These floods sometime have various great effects, such as killing human and animals and damaging various buildings.

Soil erosion decreases the water supply by soil to the vegetation for their growth. It also disturbs the activity of soil micro-organisms and decrease the crop yield.

The top stratum of soil contains most of the organic matter and nutrients, loss of this soil reducing soil fertility and disturbing its structure badly.

Use of Satellite Remote Sensing and GIS in Soil Erosion Modelling:

Soil erosion over the earth is a quite-frequent and well distributed problem. Mapping the level of risk of areas subjected to rain and water erosion is therefore all vital problem. Models of soil erosion focus the importance of soil coverage by active green vegetation and residue. There is a need for modelling and quantitative estimation of erosion processes on these landscapes for both on-site and off-site assessment of its impact. These models have been developed only for fine study scale (field or catchment scale) along with the assistance of Remote Sensing(RS) and Geographical Information System(GIS) techniques in combination with less data demanding model makes soil erosion estimation and its spatial distribution feasible with reasonable costs and better accuracy in larger scales.

Breetzke (2004) defines GIS as an arrangement of computer hardware, software, and geographic data that persons interact with to integrate, analyze, and visualize data; identify relationships, patters, and trends; and find solutions to problems. According to Borrrough (1986) a GIS is : 'a system capturing, storing, checking. Integrating, manipulating, analyzing and displaying data which are spatially referenced to the Earth.' The components that make up a GIS include that of computer systems and software, spatial data, data management and analysis procedures and geographically referenced data.

Saha et al., (2005) describe that Satellite data can be used for studying erosional features, such as gullies, rainfall interception by vegetation and vegetation cover factor. DEM (Digital Elevation Model) is the vital inputs required for soil erosion modeling can be made by examination of stereoscopic optical and microwave (SAR) remote sensing data. Geographic Information System (GIS) has emerged as a strong tool for handling spatial and non-spatial geo-referenced data for preparation and visualization of input and output, and for interaction with models. There is considerable potential for the use of GIS technology as an aid to the soil erosion inventory with reference to soil erosion modeling and erosion risk assessment.

Dimitrios et al. (2013) The study indicated that using RS and GIS technologies simultaneously with precipitation data resulted in an effective and accurate assessment of soil erosion in considerable short time and low cost for large watersheds. In addition, the implementation of both methodologies resulted in an effective and accurate assessment of soil erosion rate within short amount of time and with low cost for a large scale watershed such as this of Yialias River

Saini et al. (2015) the main objective of the study is to assess the sites vulnerable to soil erosion based on the multi-criteria evaluation (MCE) in the upper catchment of Markanda River. The scope of the current study is constrained to identification of soil erosion sensitive sites. GIS is used for derivation, integration, and spatial analysis of geographic layers of each theme. Analytical Hierarchy Process (AHP used for analysis of the weights of soil erosion influencing factors like as rainfall, vegetation, slope, soils and land use and land covers.

The modeled result based on multi-criteria assessment in GIS proves that identification of sites vulnerable to soil erosion is pre-requisite. Such models based integrated maps can help us better understand the causes, make predictions, and plan how to implement preventative and restorative strategies and to prioritize the area according to the severity of erosion.

Kim et al., (2014) in this study the RUSLE model united with GIS is effective to estimate the potential of soil erosion for the targeted watershed. From basic overlays of the 5 variables and the raster calculator, the model was accurately depicted. Although this RUSLE model combined with GIS is effective tool for the estimation of soil loss, carefulness is needed when interpreting the results considering the assumptions made to create each variable and mistakes of an empirical equation for the RUSLE model

Li et al. (2004) applied the Revised Universal Soil Loss Equation (RUSLE), remote sensing, and geographical information system (GIS) to the mapping of soil erosion hazard in Brazilian Amazonia. Soil map and soil inspection data were used to create the soil erodibility factor (K), and a digital elevation model image was applied to generate the topographic factor (LS). The cover management factor (C) was developed based on vegetation, water, and soil element images derived from spectral mixture analysis of a Landsat Enhanced Thematic Mapper Plus image. A soil erosion risk map with five classes (very low, low, medium, medium-high, and high) was produced created on the simplified RUSLE within the GIS environment. The results indicate that most successional and developed forests are in very low and low erosion risk areas, while agroforestry and pasture are commonly associated with medium to high risk areas.

Basayigit and Dinc (2010) in their study of Soil loss prediction Ggirdir Lake in Turkey discussed methodology of GIS describing three main steps:

1) Digitizing and creating a database,
2) Data derivation for the soil loss model, and
3) Estimation of equations.

They illustrated that the GIS model needs the input of spatially distributed data of the Eğirdir lake watershed. A database was made by digitizing the analogue map information using ARCGIS software (ESRI 1994). The meteorological information collected by 8 stations in the study area was analyzed to compute the mean annual rainfall using Kriging (exponential) model and number of rainy days in a year. The soil map was digitized, and a database for the soil-mapping units in the soil map was created. The database specified each soil property (soil texture, depth and stones) required. They obtained parent material from digitized physical maps. The data of mean rainfall per rain day, yearly rainfall and rainfall intensity were calculated from daily rainfall data.

They determine Slope gradients using contour lines achieved by digitizing topographical maps which were used to generate a digital elevation model (DEM). The vegetation variables such as land cover type and interception were derived from the Landsat-7 ETM+ images. The land cover classification and vegetation intensity were evaluated by using a supervised classification method, and normalized vegetation index (NDVI). The bands of red (band 3; 0.63-0.69 µm), near infrared (band 4; 0.75-0.90 µm) and infrared (band 7; 2.09-2.35 µm) were implemented for classification. They used REDAS software for image processing. The final land use classes are: woods, irrigated agricultural area, non-irrigated agricultural area, bushes, and barren soil.The final vegetation intensity classes are: dense, moderate, few-moderate and few.

There are some advantages of linking soil erosion models with a GIS such as the following:

The opportunity of rapidly producing input data to simulate different sceneries.

GIS provides an important spatial/analytical function performing the time-consuming georeferencing and spatial overlays to develop the model input data at numerous spatial scales.

Visualization can use to display and animate sequences of model output images across time and space. Therefore, visualization enables objects to be viewed from all external perspectives, and to invoke insight into data through manipulable visual representations.

The potential efficacy of remotely sensed data in the form of aerial photographs and satellite sensors data has been well accepted in mapping and assessing landscape attributes controlling soil erosion such as physiographic, soils, land use/land cover, relief, soil erosion pattern (Pande et al., 1992)

Remote sensing can facilitate studying the factors enhancing the process, such as soil types, slope gradient, drainage, geology and land cover. Multispectral satellite images provide valuable information related to seasonal land use dynamics. Satellite data can be used for studying erosion features, such as rainfall interpolation, vegetation and vegetation cover factor.

Models for Soil Erosion Estimation:

A proper assessment of erosion problem is greatly dependent on its spatial, economic, environmental and cultural context. The information of soil erosion sources of catchment area can be useful for determining the rate of soil erosion. In order to demarcate such soil erosion prone zones where conservation measures are highly required to be effective, there has increased demands for watershed and sub-watersheds or regional scale soil erosion models development. These soil loss rate predictions at sub-watershed or regional scale are calculated through simple empirical models even with the development of a range of physically based soil erosion and sediment transport equations.

The actual amount of soil erosion depends on different factors such as rainfall, vegetation cover, and soil erodibility and topography. Assessment of soil erosion as to how first soil is being eroded is helpful in planning conservation practice work.

Modelling can provide a quantitative and sound approach to estimate soil erosion and sediment yield under a wide range of conditions. Models available in the literature foe soil erosion estimate can be grouped into two categories;

- Physically-based models
- Empirical models

Physically based models are intended to represent essential mechanism controlling erosion process by solving corresponding equations. These models are the synthesis of the individual component that affects the erosion process and it is argued that they are highly capable of assessing both the spatial and temporal variability of the natural erosion process.

The physically-based models include ANSWERS, WEPP, KINEROS and EUROSEM.

Empirical models are generally the simplest form of model types. They are statistical in nature and based primarily on the analysis of observations and seek to characterize response from these data (Wheater et al., 1993). The data requirements for such models are usually less as compared to conceptual and physical based models.

The empirical models are USLE, MUSLE and RUSLE and MMF.

Most of these models need information related to soil type, land use, landform, climate and topography to estimate soil loss. They are designed for a specific set of conditions of the particular area. The Universal Soil Loss Equation (USLE) (Wischmer and Smith, 1965) was designed to predict soil loss from sheet and rill erosion in specific conditions from agriculture fields. Modified universal soil loss equation (MUSLE) (Williams& Berndt; Meyer, 1975) a modified version of USLE is applicable to other conditions by introducing hydrological runoff factor for sediment yield estimation. Water erosion prediction project (WEPP) (Lane and Nearing, 1989) is process based, continuous simulation model, developed to replace USLE (Okoth, 2003). Areal non-point source watershed environment response simulation (ANSWERS) (Beasley etal, 1980) designed to compute soil erosion within a watershed. The European Soil Erosion Model (EUROSEM) (Morgan *et al.*, 1991, 1992) is a single process–based model for assessing and risk prediction of soil erosion from fields and small catchments. Morgan, Morgan and Finney (MMF) model is an empirical model developed for mean annual soil loss estimation from field-sized areas on hill slopes (Morgan *et al.,* 1984) having a strong physical base.

Due to the complexity of variables involved in soil erosion it becomes difficulties to measure or predict the erosion the erosion in a precise manner. The latest advances in remote sensing technology have provided very useful methods of surveying, identifying, classifying and monitoring several forms of earth resources. .Remote sensing data provide accurate, timely and real time information on various aspects of watershed such as land use/ land cover, physiographic, soil distribution, drainage characteristics etc. It also assists in the identification of the existing or potential erosion prone areas and provides data inputs to many of the soil erosion and runoff models. For assessing soil erosion from watersheds, several empirical models based on the geomorphological parameters were

developed in the past to qualify the sediment yield (Misra et al., 1984; Jose and Das, 1982)

Chapter 3

STUDY AREA AND DATA ACQUISITION

3.1 GENERAL

This chapter describes the area under study and the data obtained/used for the study. At first, precise details about the study area is given to demonstrate the features of the area in terms of geography, land use / land cover and general narrative. Then, it explains the technical details of the different kinds of data used for the study.

3.2 STUDY AREA: DHOLPUR DISTRICT

Dholpur district with an area of 3034 sq. km is located in easternmost extremity of the state of Rajasthan and is situated with in latitude 26°21’19” and 26°57’33” North and longitude 77°13’06” and 78°16’45” East. It is bounded by Bharatpur district in North West of Swaimadhopur and Karauli district in south west and rest of the boundaries are bordered by Agra district of Uttar Pradesh and Bhind – Morena district of Madhya Pradesh.The population of the district as per 2011 census is 1206516 persons including 653747 males and 552869 females. The rural and urban population is 959066 and 247450 respectively.

3.3 GEOGRAPHICAL AND PHYSICAL FEATURES:

The geographical coordinates of Dholpur (Dhaulpur) district are 26° 42' 0" North, 77° 54' 0" East. The Chambal River makes the southern boundary of the district, crossways which lies the state of Madhya Pradesh. Along the bank of the Chambal River the district is deeply intersected by ravines; low ranges of hills in the western part of the district supply quarries of fine-grained and easily worked red sandstone. The range of sand stone hills runs from Dholpur town in a south western direction attaining at one place on the attitude of 356.91 Meters above sea level. The land in Dholpur region is fertile and rises from alluvial plain near the level. Hills and broken grounds characterize almost the whole region; along the valley of the Chambal as uneven and lofty wall of rocks separate the land on the river from the uplands.

3.3.1 CLIMATE:

Dholpur experiences quite variations in its seasons. It is quite hot in summers while cold in winters. Dholpur recorded highest temperature at 48 °C on June 3, 1995. The hot months are May and June. They mark the cruel summer season. Temperatures in summers are generally higher than 40 °C. Coldest months are December and January where temperatures occasionally reach near-zero and subzero levels. The lowest recorded temperature is -2.3 °C on January 29, 1990

DHOLPUR DISTRICT BASE MAP

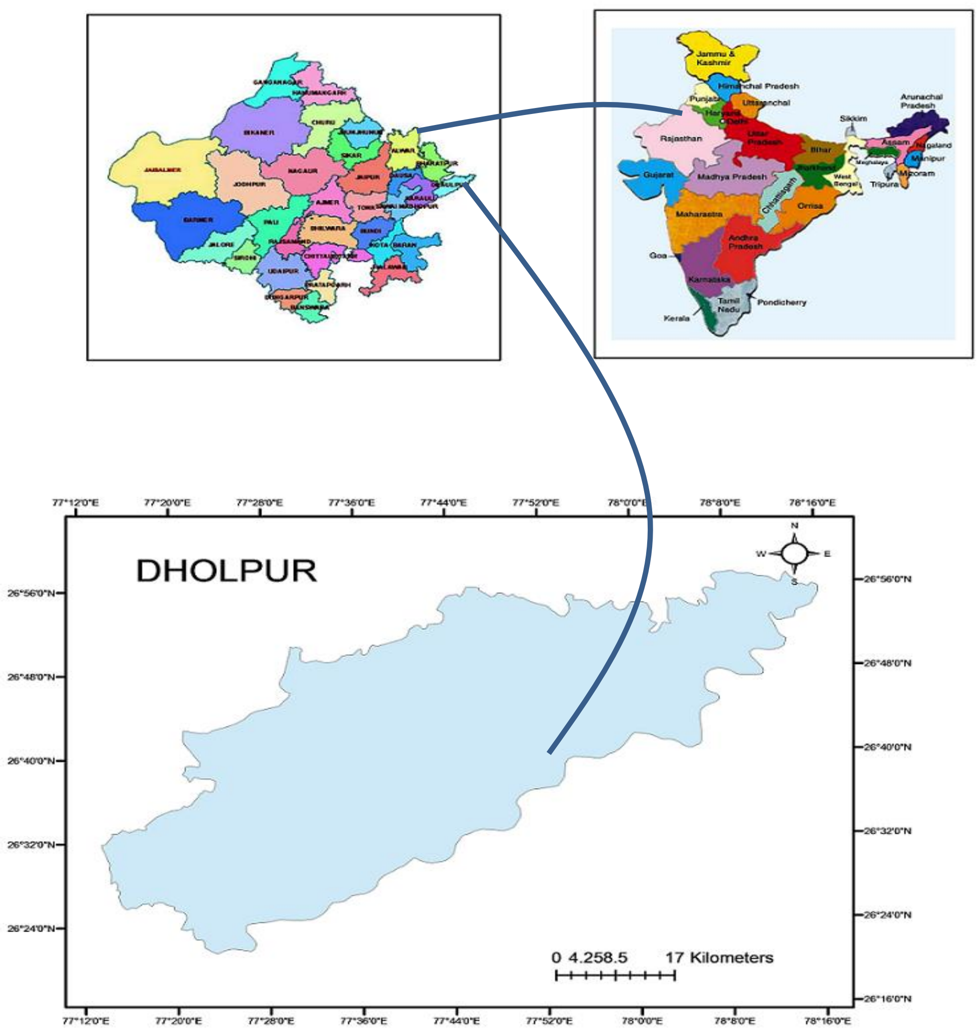


Figure 3.1 Dholpur District Base Maps

3.4 DATA:

There are several types of data that have been utilized for this research work which are listed in the table. The data generally used for such research work can be divided into two types' i.e. remote sensing data and ancillary data. In this study both remote sensing and ancillary data has been used. The satellite images have been used for classification by using remote sensing application to obtain the desired results. Apart from this, some vector data have also been used from different sources.

a) Satellite data:

Table 3.1-Record of Satellite data acquired.

RS Data	Year of Acquisition	Band/Color	Resolution	Source
Landsat TM	2008	Multi-spectral	30 m	U.S. Geological Survey
Landsat OLI/TIRS	2013	Multi-spectral & Panchromatic	30 m (MS) 15 m(Pan)	U.S. Geological Survey
DEM (SRTM)	2014		1-ARC (30m)	U.S. Geological Survey

b) Ancillary Data:

Table 3.2-Record of Ancillary data

Ancillary Data	Year	Source
Rainfall	2008, 2013	WRD Rajasthan (http://waterresources.rajasthan.gov.in/)
Soil Map	2008	Soil Conservation Department Rajasthan

Rainfall Data:

Table 3.3-Rainfall data

Sr. No.	Rain Gauge Station	2008	2013
1	Dholpur	1319.6	1145
2	Saipau	804.0	882
3	Rajakhera	1080.0	996
4	Bari	1044.0	1115
5	Baseri	1093.0	1176
6	Sarmathura	900.1	1092
Average	1041.1		1067.7

Chapter 4

METHODOLOGY

4.1 GENARAL

Problems related to soil erosion, movement and deposition of sediment in rivers, lakes and river mouth persist through the geologic ages in nearly all parts of the earth. Nevertheless, the situation is aggravated in recent times with man's increasing interferences with the environment. Thus, a reasonable course of action is to develop and use empirical models. The lack of availability of data such as sediment deposition data, rainfall intensity at smaller intervals (less than 30 min) in the study area, has limited the options for selection of data intensive models such as WEPP and USPED, , soil erosion module in SWAT (soil and water assessment tool) models. Therefore, RUSLE model was designated and applied in study area as it requires a land use land cover map that can be created by remote sensing images, management practices, soil types (texture etc.) and properties. The other advantage of a selection of RUSLE is that the factors of this model can be easily integrated with GIS for better analysis. The main goal of present study is to integrate RUSLE model with remote sensing and GIS techniques for evaluating the erosion risk in Dholpur district. This methodology describes the basic concepts, the procedure of the RUSLE model to estimate parameters and parameter calculation of RUSLE model. The parameters of RUSLE model have been assessed based on the rainfall events, DEM, soil type, and land cover. The whole methodology used in the current study is schematically represented in flow chart in figure 4.1-.

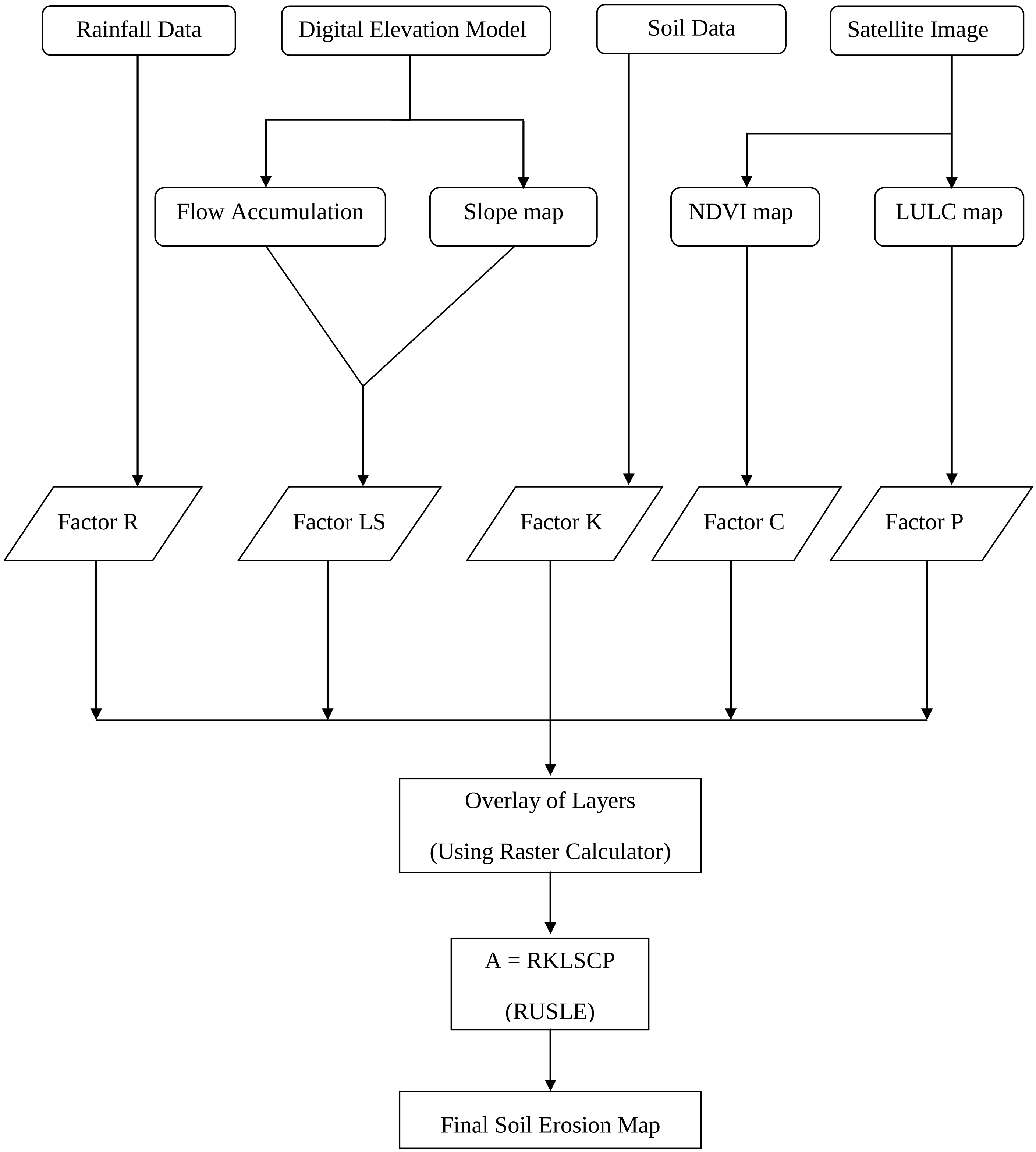


Figure 4.1 Flow chart of Methodology

4.2 Revised Universal Soil Loss Equation (RUSLE):

The Revised Universal Soil Loss Equation (Renard, 1997) is improved from of USLE (Wischmeier and Smith 1965, 1978), used to estimate average annual soil erosion potential,

$$\mathbf{A = R \times K \times L \times S \times C \times P}$$

Where,

A= computed average annual soil loss (ton/ha/year)

R= rainfall erosivity factor (MJ -mm /ha-hr-yr),

K = soil erodibility factor (t-ha- hr/ ha-MJ- mm),

L = slope length factor (dimensionless),

S= slope steepness / gradient factor,

C = cover management factor (dimensionless) and

P = conservation practice factor.

4.3 PARAMETERS:

a) Rainfall-Runoff Erosivity Factor R:

The rainfall erosivity factor(R) replicates the effect of rainfall intensity on soil destruction, and requires detailed, continuous rainfall data for its calculation (Wischmeier and Smith, 1978). The assessment of rainfall erosivity factor used in RUSLE must quantify the effect of raindrop impact and must also reflect the amount and rate of runoff likely to be related to the rainfall.

The R-factor was calculated by using the formula by Ram Babu et.al(2004)

Annual Relationship:

$$\mathbf{R_a = 81.5 + 0.380\ P_a}$$

Seasonal Relationship:

$$R_s = 71.9 + 0.361\ P_s$$

Where,

R = Average Erosion Index, P = Average annual rainfall (mm), Subscript a and s stands for annual and seasonal.

b) **Soil Erodibility Factor K:**

Soil Erodibility factor (K) characterizes the susceptibility of soil or surface material to erosion, transportability of the sediment, and the quantity and rate of runoff given a specific rainfall input as measured under a standard circumstance**.** The standard situation is the unit plot, 22.6 m long with a 9% slope, maintained in continuous fallow, tilled up and downcast the hill slope (Kim, 2006). The soil erodibility factor K was estimated on the basis of soil textures.

In RUSLE, K is assumed to be constant throughout the year. Tables of K values are available in Soil Conservation Service Offices for most of the soils in the U.S. In the absence of published data, a widely used relationship foe predicting erodibility is a nomograph by Wischmeir et al. (1971). Soil erodibility in the nomograph is predicted as a function of the soil and soil profile parameters:

Percent silt (MS; 0.002-0.05 mm).

Percent very fine san (VFS; 0.05-0.1 mm).

Percent sand (SA; 0.1-2 mm).

Percent organic matter (OM).

Soil structure code (s).

Soil permeability code (p).

The analytical relationship for the nomograph by Wischmeier et al. (1971) is given by following regression equation,

$$\mathbf{K = (2.1 \times 10^{-4} (12-OM) M^{1.14} + 3.25 (s-2) + 2.5 (p-3)) / 759.4}$$

Where,

K = soil erodibility (tons-yr/ MJ-mm), OM = percentage organic matter, p = soil permeability code, s = soil structure code, M = a function of the primary particle size fraction given by;

$$\mathbf{M = (\%\ silt + \%\ sand) \times (100- \%\ clay)}$$

Table 4.1- Attributes of Soil map used in RUSLE

Sr. No.	Class Name	% Sand	% Silt	% Clay	M	Soil structure code (s)	Permeability Code (p)	Soil organic matter % (OM)
1	Silty Loam	20	65	15	7225	2	3	1
2	Loam	41	41	18	6724	2	3	1.5
3	Sandy Clay Loam	60	13	27	5329	3	4	2
4	Clay	20	20	80	1600	1	6	0.6

Source: Soil Conservation Service National Soils Handbook (SCS, 1983)

Soil structure code (s):

1 - Very five granular

2 - Fine granular

3 - Medium or coarse granular

4 – Blocky, platy, prism like

Soil permeability code (p):

1 – Rapid (>150 mm/hr.)

2 – Moderate to rapid (50-150 mm/hr.)

3 – Moderate (15-50 mm/hr.)

4 – Slow to moderate (5-15 mm/hr.)

5 – Slow (1-5 mm/hr.)

6 – Very slow (< 1 mm/hr.)

c) Slope Length and Slope Steepness Factor LS:

The Topographic factor represents a ratio of soil loss under given condition to that at a place with the "standard" slope steepness of 9% and slope length of 22.6 m. Topographical factor constitutes two factors which are sloped length (L) and slope steepness (S).

Slope length (L) is the effect of slope length on erosion. The slope length is defined as the distance from the point of origin of overland flow to the point where either the slope decreases to the extent that deposition begins, or runoff water enters a well-defined channel. Thus, the soil loss per unit area increases as the slope length increases. Slope steepness (S) signifies the effect of slope steepness on erosion. The effects of slope steepness have a greater impact on soil loss than slope length. Steeper the slope, the greater is the erosion.

The influence of topography on erosion in RUSLE is accounted for by the LS factor. The slope length factor (L) is calculated using following equation,

$$L = (\lambda / 22.13)^{m}$$

Where,

22.13 = the RUSLE unit plot length and m = a variable slope-length exponent.

Slope length λ is well-defined as the horizontal distance from the origin of overland flow to the point where either (1) the slope gradient decreases enough that deposition begins or (2) the runoff becomes concentrated in a defined channel.

The slope-length exponent m is calculated as,

$$m = \beta / (1+\beta)$$

$$\beta = (\sin\theta / 0.0896) / [3.0 (\sin\theta)^{0.8} + 0.56)$$

Where**,**

θ= slope angle.

The slope steepness factor is evaluated from (McCool et al., 1987, 1993)

$$S = 10.8\sin\theta + 0.03 \qquad S < 9\% \text{ (i.e. } \tan\theta < 0.09)$$

$$S = (\sin\theta / \sin 5.413)^{0.6} \qquad S \geq 9\% \text{ (i.e. } \tan\theta \geq 0.09)$$

d) Cover-Management Factor C:

The cover-management factor is the ratio of soil loss from an area with specified cover and management to that of an identical area in tilled continuous fallow. De Jong (1994) in his PhD thesis described the use of vegetation indices in order to extract vegetation parameters for erosion models. Based on his work following statements can be assumed to be valid in general:

NDVI and RUSLE C-factor are correlating; 2) there is a linear relation between NDVI and RUSLE C- factor.

Based on these assumptions the NDVI map can be analyzed to formulate the linear equation between NDVI and C factor. The NDVI values less than Zero (0) indicate the water body and snow, so the negative values should not be considered in preparing the C factor equation. With these boundary conditions the regression equation for C factor can be developed.

$$C_i = 0 \qquad \text{if NDVI} \leq 0$$

$$C_i = [-(1/NDVI_{max})(NDVI)_i + 1] \qquad \text{if NDVI} > 0$$

e) Conservation Practice Factor P:

The conservation practices factor (P) is the soil-loss ratio with a specific support practice to the corresponding soil loss with upslope and downslope tillage (Renard et al. 1997). The P factor interprets for control practices that decrease the erosion potential of the runoff by their impact on drainage patterns, runoff concentration, runoff velocity, and hydraulic forces applied by runoff on the soil. The value of P factor ranges from 0 to 1, the value imminent to 0 indicates good conservation practice and the value approaching 1 describes poor conservation practice.

The values of conservation practice factor, P for different management practices are tabulated in Haan et al. (1994).

Table 4.2- Codes as per the Land Cover Classes in India which used in our study

Sr. No.	Class name	Conservation practice (P)
1	Tropical Dry Deciduous	1
2	Scrubland	0.9
3	Irrigated Agriculture	0.35
4	Water bodies	0
5	Barren land	1
6	Bare rocks	0
7	Settlement/built up	0
8	Fallow land	0.8

4.4 Land Use / Land Cover (LULC):

The land cover indicates the vegetation (natural and planted), water, bare rock, bare soil and similar surface and also man-made constructions occur on the earth's surface. While land use indicates a series of operations on land which are carried out by humans, with the objective to manufacture products and/or to benefit from using land resources including soil resources and vegetation resources which are part of the land cover (DeBie *et al*. 1996). The LULC changes are generally caused by the inappropriate management of agricultural, urban, range and forest lands which result in severe environmental problems such as landslides, flood, soil erosion etc.

4.4.1 Image Classification to obtain Land use / Land cover

Image classification is a kind of technique which is the used in many remote sensing applications for the extraction of thematic information of the study area. In the present study, the land use / land cover (LULC) is the main ‘subject ‘that has to be extracted using a suitable classification method for LULC change detection. Basically, the classification of an image consists of a mapping process to accumulate the image pixels into significant groups each denoting different class for different land category (Jensen, 1995). The classification process requires a classification system which is a specifically designed algorithm for the application purpose because it mainly varies upon the objective and type of the work.

The most common method used for RS image classification is a pixel based method which includes the process in which the classifier examine different pixel values and group them into different classes which are completely based on their spectral properties. This practice is based on statistical techniques such as supervised and unsupervised classification where the classes are supervised by the analyst and non-supervised (i.e. fully automatic based on spectral values) respectively. The benefit of the traditional pixel based image classification proves very efficient especially in the case of the satellite images of low resolution.

In this study, the classification method used is Supervised Classification method. As discussed above, in this method the analyst groups different pixels in different classes accordingly.

4.4.2 Supervised Classification Method

In the supervised classification method, identification of the Information classes (i.e., land cover type) of interest in the image is done. These are known as Training Sites. The image processing software, ERDAS used in this study is then used to develop a statistical characterization of the reflectance values for each information class. This stage is often called signature analysis/signature editor and may involve developing a characterization which is as simple as the mean or the rage in which the reflectance values lies on each band, or as composite as detailed analysis of the mean, variance and covariance over all bands. Once the statistical characterization has been achieved for each class, the image is then classified by inspecting the reflectance for each pixel and making a decision about which of the signatures it resembles the most. (Eastman, 1995).

Supervised Classification Steps**:**

- Select training areas
- Generate signature file
- Classify

4.4.3 Accuracy Assessment

The accuracy assessment of the classified images has been achieved with the help of a tool called accuracy assessment tool in the ERDAS Imagine software. Since the data used in this study belongs to the past, hence ground truth cannot be obtained so as to obtain referral points. In this study Google Earth has been used as a referral platform by comparing the random points taken on the classified image with the Google Earth image of that period. The points get equally and randomly distributed on the classified image. The viewer in ERDAS can be linked with the Google Earth and the reference class can be assigned the same class if it shows the same feature when scrolled on Google Earth. The overall accuracy in our classified image is 73%.

4.5 Normalized Deference Vegetation Index (NDVI):

NDVI: The Normalized Difference Vegetation Index (NDVI) is a identical index allowing you to create an image displaying greenness (relative biomass). This index takes advantage of the contrast of the characteristics of two bands from a multispectral raster dataset—the chlorophyll color absorptions in the red band and the high reflectivity of plant materials in the near-infrared (NIR) band. An NDVI is a lot used in worldwide to monitor drought, monitor and forecast agricultural production, support in predicting dangerous fire regions, and map desert encroachment. The NDVI is chosen for global vegetation monitoring because it helps reimburse for changing illumination conditions, surface slope, aspect, and other unnecessary factors.

The different reflection in the red and infrared (IR) bands assists us to regulate density and intensity of green vegetation growth using the spectral reflectivity of solar radiation. Green leaves normally show better reflection in the near-infrared wavelength range than in visible wavelength ranges. When leaves are water strained, sickly, or dead, they become more yellow and reflect significantly less in the near-infrared range. Clouds, water, and snow show better reflection in the visible range comparison in the near-infrared range, while the change is almost zero for rock and bare soil.

NDVI FORMULA:

$$NDVI = (NIR - RED) / (NIR + RED)$$

For Landsat 8 data NDVI formula:

$$NDVI = (Band5 – Band4)/ (Band5 + Band4)$$

For Landsat 5 data NDVI formula:

$$NDVI = (Band4 – Band3)/ (Band4 + Band3)$$

To making NDVI map in ArcGIS 10.3 first of all we add band4 and band5 in ArcMap10.3 for Landsat8 data. Then we Enable the Image Analysis Toolbar (Windows > Image Analysis). The image analysis window will be displayed in ArcMap. Under image analysis options in NDVI select band4 as a red band and band5 as an infrared band. Now tick scientific output and click on ok. After that under properties select NDVI icon which looks like a leaf. Then this will be created NDVI layer(or map) which range will be from -1 to +1.

A similar procedure should be followed for Landsat 5 TM data taking band3 as a red band and band 4 as an infrared band.

In our output of NDVI for Landsat8 data (Nov 2013) value of NDVI vary from -0.12 to +0.45 and the mean value is 0.079. For Landsat5 data (Nov 2008) value of NDVI vary from -0.23 to +0.398 and mean value is 0.028.

4.6 SOIL EROSION ESTIMATION USING RUSLE IN ARCGIS:

ESTIMATION OF RUSLE PARAMETERS:

Every parameter was calculated in GIS platform (ESRI ArcGIS 10.3). The following sections define the computation rationales of the six factors from rainfall data, soil surveys, a digital elevation model (DEM) and land use/land cover maps. The spatial resolution of the data was set at 30 m.

IN PUT DATA:

Digital Elevation Model – raster

Station Location Annual Rainfall Map –location.shp

Land Cove Map (LULC) – lulc

Soil Map – soil

NDVI Map

All above data available in D drive in INPUT FOLDER.

Now add above mentioned data in the ArcMap.

SOFTWARE REQUIRED: ARC-GIS (10.3)

First of all we should set the processing extent, raster resolution (cell size) and other standard environmental parameters in the beginning of project work to avoid repeated definition of these limits while using any tool in tool box.

First of all open ArcMap and go to Geoprocessing and click on Environments tool as shown below.

First of all define the current work place and select the given input data folder and then click ok. Also select the output _default.gdb folder in Scratch workspace.

First of all we can define output coordinate system so that all the layers produced should be in same coordinate and projection system. Select output coordinates and then either select from already defined with some existing dataset or choose as specified below. If this option is selected then click on right tab and either import or select the required coordinate and projection system.

For our project we are using WGS coordinate system and UTM project system. Then select projected coordinate system, then select UTM then select WGS 1984 then select northern hemisphere and then select Zone 43 and click ok. We have defined the output coordinate and project systems.

Now we need to defining processing extent. In the present case processing extent is boundary of dholpur district which is available in supplied data with name of dholpur.shp in dholpur boundary folder. Now go to processing extent in Environments and select the file dholpur.shp file from the input data folder.

Now we define the Cell size of all raster maps by clicking on Raster Analysis then select as specified below from dropdown menu and the write the required pixel size. Here we take cell size 30 meters.

Here we can also define processing mask to confine our operations with in defined area. For our project work we will use dholpur.shp which boundary of study area as mask layer. Click ok.

i. **Calculation of R factor:**

Go to the Spatial Analyst >> Interpolation>>Spline

Input point feature – Location_r.shp from (RAIN LOCATION_2013 FOLDER in INPUT DATA folder).

Z value field – select RAINFALL from dropdown menu.

Output – Factor_R

Make sure the Rain map (Factor_R) is added in the viewer, go to Spatial Analyst>> Raster Calculator. The Raster Calculator window will open.

To calculate the R factor map use rain map (Factor_R) as an input map and Equation which is written as follow in raster calculator,

Factor_R_N	81.5 + 0.380 * “Factor_R”

Give the output name to the raster as Factor_R_N and store it in the same folder from where the output has been used. Similar procedure should be follow for 2008 rainfall data to create Factor_R_N.

ii. Calculation of K Factor:

Make sure that the soil map is added in the viewer, if not add soil map from input data folder. Uncheck all other maps, so that only soil map is visible in the viewer. We can see that in the study area only four types of soil exists.

Open attribute table of the soil map, read the entire attribute column in the table, refer to the equation, all the required parameters for these equations are available in the attribute table.

To calculate K, open attribute table click table option << add field << name = k, type = float. Right click on the k, select field calculator type the below equation.

k = (((((2.1)*(10^(-4)))* (12-[OM]) *([M_value_1]^1.14))+(3.25*([s]-2)) +(2.5*([p]-3))) / 759.4

Now to generate K factor

Then go to Arc tool box >> conversion tool >> to raster >> polygon to raster

Input – soil.shp, value field – k, output – Factor_K

iii. Calculation of P Factor:

Add Lulc.shp (of 2013)

Open Attributes Table >>Create an Add field give name Con_P

To generate P factor map , we can refer to the values of conservation practice for each land cover from literature. Then go to toolbox >> conversion tool >> to raster >> polygon to raster

Input – lulc.shp, value field – Con_P, output – Factor_P. Similar procedure should be follow for 2008 data.

iv. Calculation of C factor: =

Add NDVI map in the viewer. Note down the range of NDVI in the map ($NDVI_{min}$ = Low: -0.129912 and $NDVI_{max}$ = High: 0.451011).

Prepare the linear equation for C Factor calculation, as follow:

$C = 0 \qquad NDVI \leq 0$

$C_i = [-(1/NDVI_{max})(NDVI)_i + 1] \qquad \text{if } NDVI > 0$

Now use conditional function in Raster Calculator to generate the C Factor map using NDVI and linear equation developed above;

Use following conditional expression in Raster Calculator to compute Factor C.

Factor_C	Con("NDVI2013" <=0,0,((-1 ((1/0.451011) * ("NDVI2013")))+ 1))

Now C Factor map will appear in the viewer. Similar procedure should be followed 2008 data.

v. Calculation of LS Factor:

LS factor is a topographic factor, to calculate LS factor, we need DEM, Flow Accumulation and slope in degree map. As the first step, the elevation value was modified by filling the sinks in the grid. This is done to avoid the problem of discontinuous flow when water is trapped in a cell, which is surrounded by cells with higher elevation. This was done by using the Fill tool under Hydrology section found under Spatial Analyst Tool Function in ArcGIS.

Then, Flow direction was generated from the Fill grid. The Flow direction tool takes a terrain surface and identifies the down-slope direction for to each cell. This grid shows the on surface water flow direction from one cell to one of the eight neighboring cells. This was done by using the Flow direction tool under Hydrology section found in Spatial Analyst Tool Function in ArcGIS.

On the basis of the Flow direction, Flow accumulation is calculated. Flow accumulation tool identifies how much surface flow accumulates in each cell; cells with high accumulation values are commonly stream or river channels. It also identifies local topographic highs (zones of zero flow accumulation) such as mountain peaks and ridgelines. That was done by using the Flow accumulation tool under Hydrology section found under Spatial Analyst Tool Function in ArcGIS.

Derive the slope map using Slope Function In Spatial Analyst tools or 3D Analyst tool in the Arc Toolbox. Now g to 3D Analyst Tools >> Raster Surface >>Slope give input as DEM and output as Slope_Dhop and output measurement in degree.

Now calculating the L Factor map, using Factor_M and type equation as described above in raster calculator. And calculate the S Factor map, using Slope in degree map and type equation as below-

Factor_F	((Sin(“Slope”*0.01745)/0.0896)/(3*Power(Sin(“Slope”*0.01745),0.8)+0.56))
Factor_M	“Factor_F”/(1 + “Factor_F”)
Factor_L	Power(((“Flow_Accumulation” * 30) / 22.13), “Factor_M”)
Factor_S	Con((Tan(“Slope” *0.01745) < 0.09),(10.08* Sin(“Slope”* 0.01745) + 0.03), (16.8* Sin(“Slope*0.01745) – 0.05))
Factor_LS	Factor_L*Factor_S

vi. Soil Erosion Calculation:

Add all the RUSLE parameters maps in the viewer (i.e. R Factor map, K Factor map, C Factor map, LS Factor map, S Factor map)

Multiply all the maps in raster calculator, the final soil erosion map will appear in the viewer, make it permanent.

RUSLE = Factor_R_N*Factor_K*Factor_LS*Factor_C*Factor_P

Chapter 5:

RESULT AND DISCUSSION (SOIL EROSION ESTIMATION)

5.1 Land Use /Land Cover (LULC) Results:

Image classification is defines as the process of creating thematic maps from the satellite imagery of an area. A thematic map is a representation of the various features of an image that shows the spatial distribution of a particular theme. Here LULC maps of study area are prepared by supervised classification. In this study 9 classes of land cover and land uses are taken which is built up, forest, scrubland, ravines, pasture/barren, cropland, rocks, fallow land and waterbody.

LULC Map of 2008 year is given figure 5.1

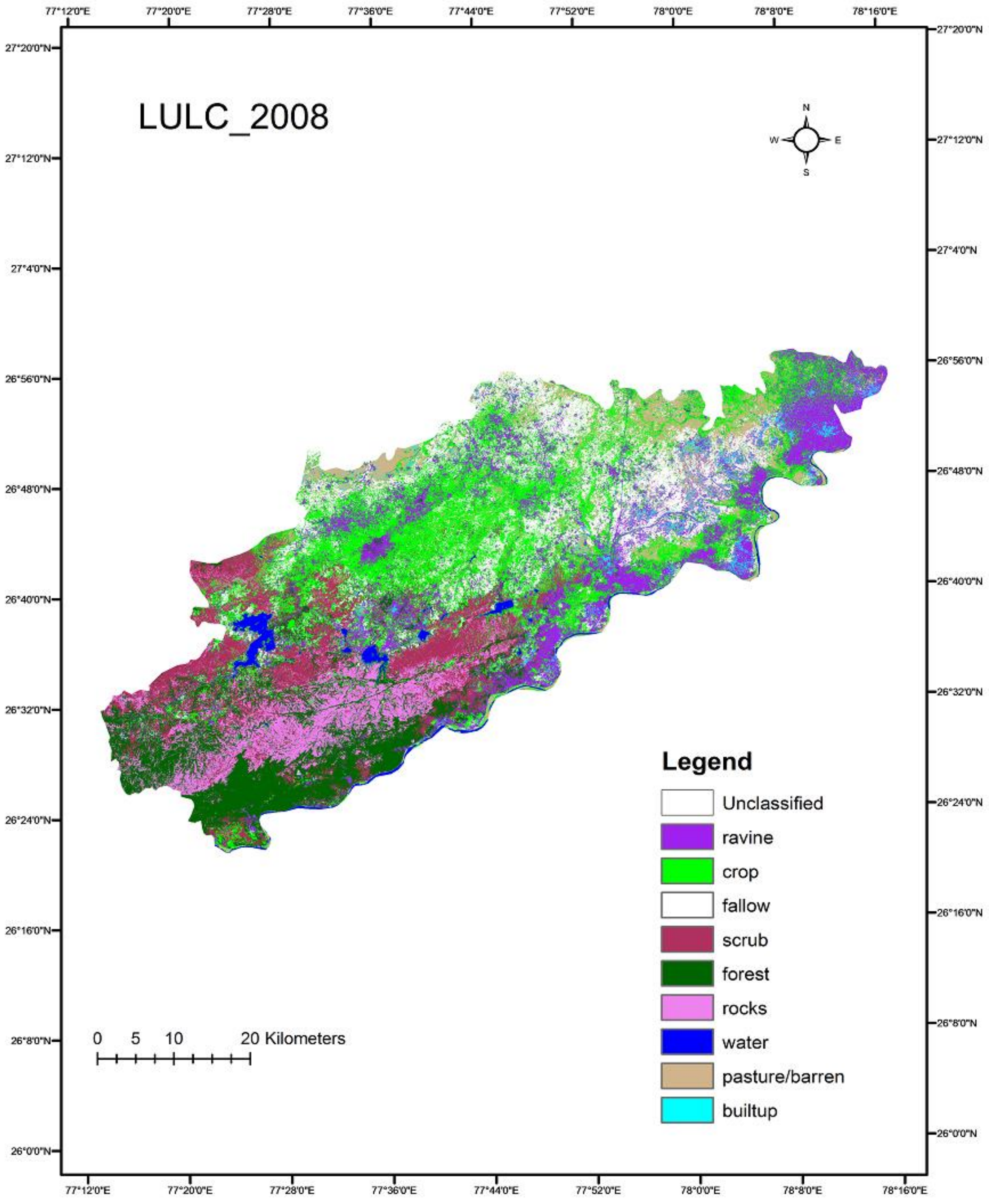


Figure 5.1 LULC Map (2008)

LULC Map of2013

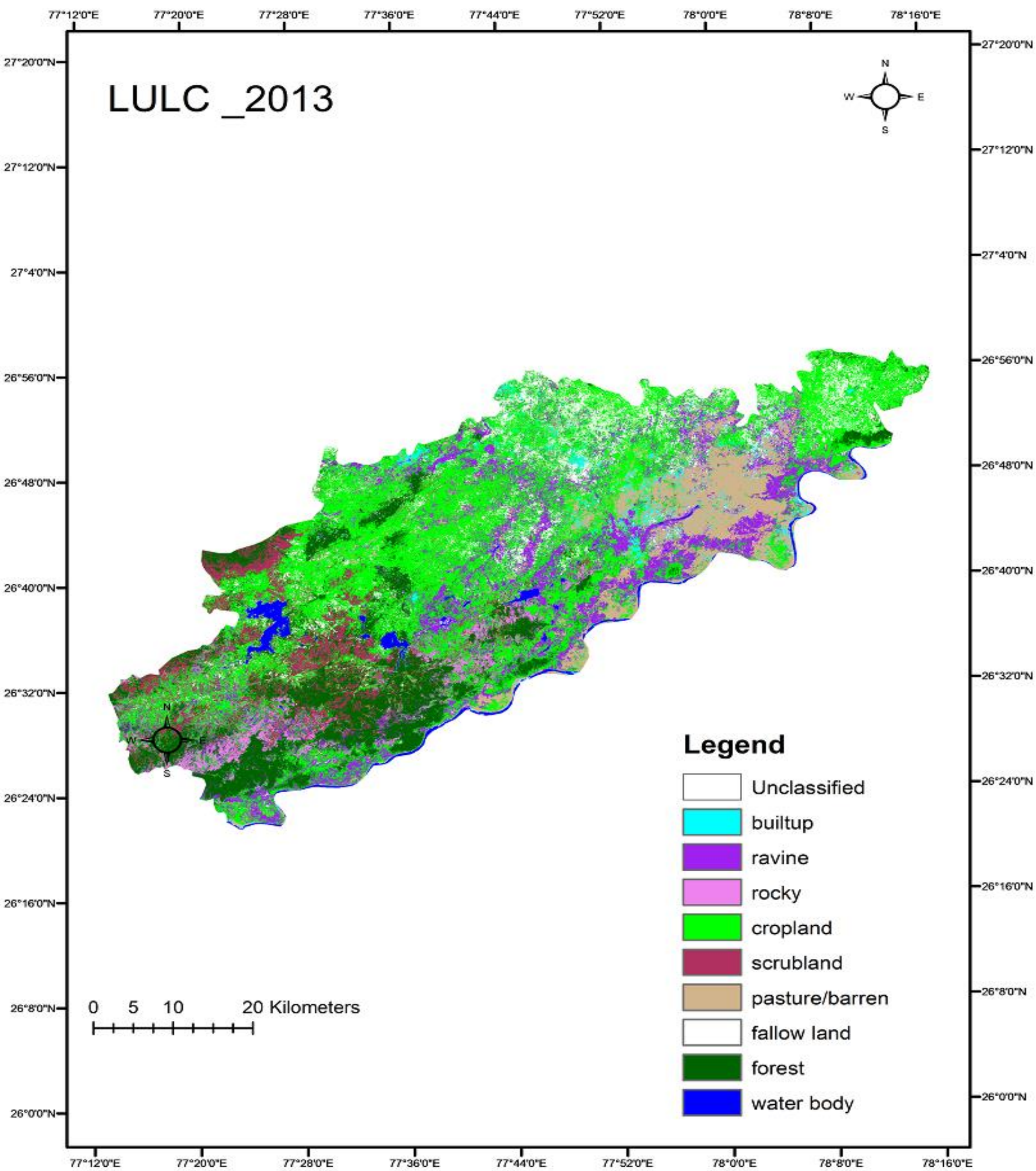


Figure 5.2 LULC Map (2013)

5.1.1Variation of LULC classes in 2008 and 2013 Years:

YEAR	2008
CLASS	AREA(ha)
Builtup	4872.24
Ravine	48442.5
Rocky	24948.9
Cropland	81752.9
Scrubland	34472.8
pasture/barren	24341.5
fallow land	40887
Forest	38991.7
water body	4857.75
TOTAL AREA	303400

YEAR	2013
CLASS	AREA(ha)
Builtup	5679.27
Ravine	40268.1
Rocky	9742.5
Cropland	121711
Scrubland	21435.7
pasture/barren	29014.2
fallow land	25878.8
Forest	43717.4
water body	6120.36
TOTAL AREA	303400

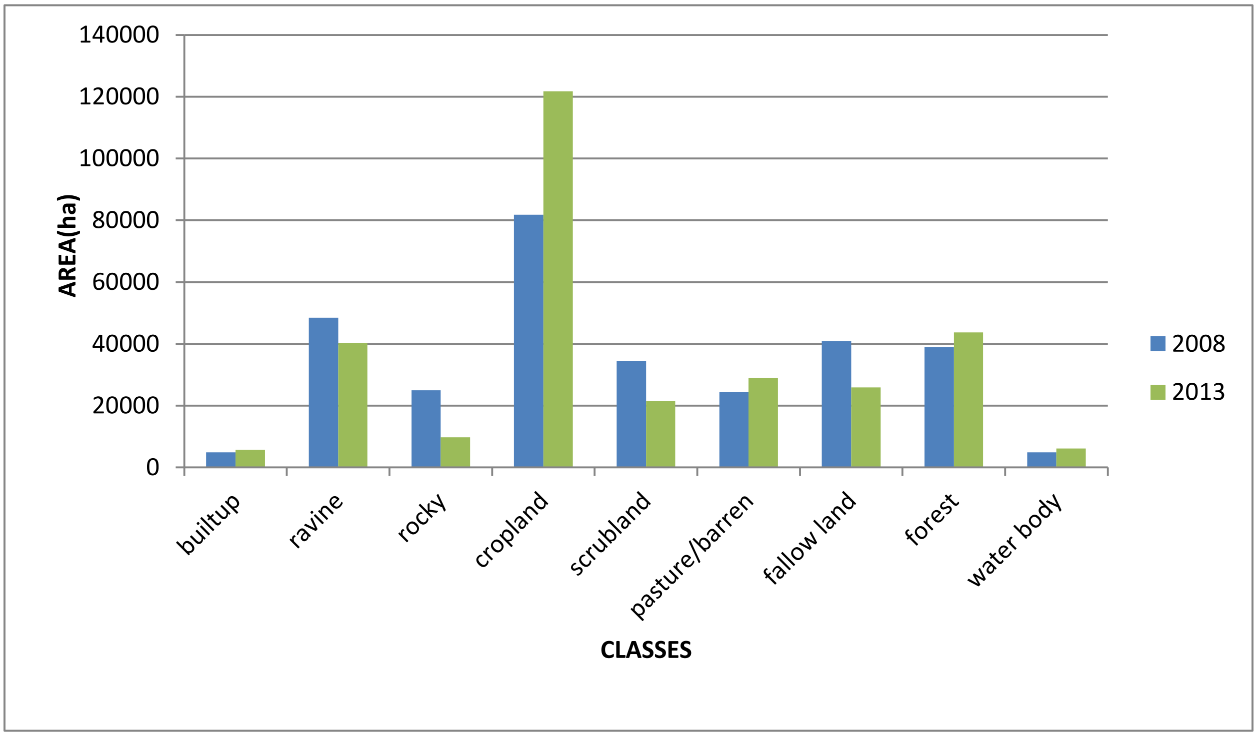


Figure 5.3 Variation of LULC classes in 2008 and 2013 Years

From above figure 5.3 (chart and tables) is clear that cropland, barren and builtup are increased in 2013 year with respect to 2008 year which leads to increase in soil erosion in 2013. Rocky area is decrease due to mining. Ravine land is decrease in 2013 due to some part of that is converted in cropland in 2013 year.

5.2 NDVI Maps of 2008 and 2013:

The Normalized Difference Vegetation Index (NDVI) is a identical index allowing you to create an image displaying greenness (relative biomass).

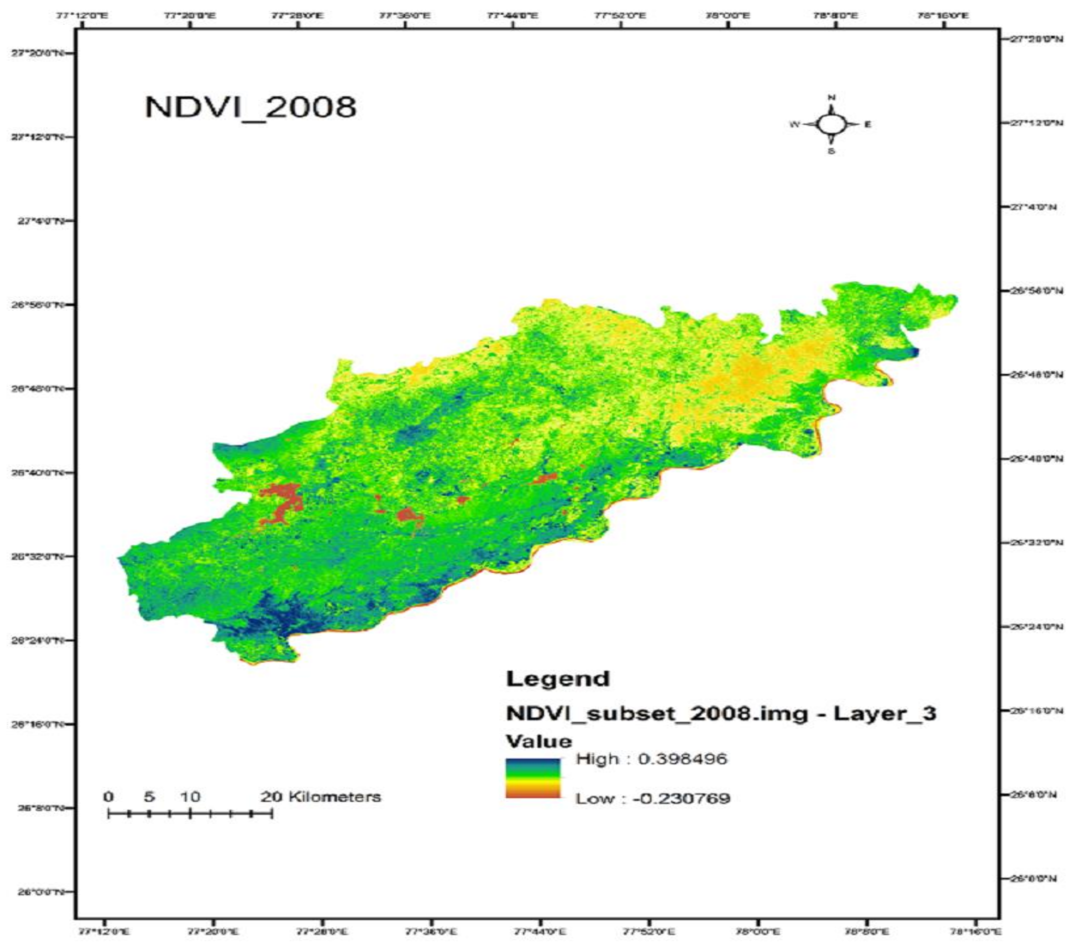


Figure 5.4 NDVI Map (2008)

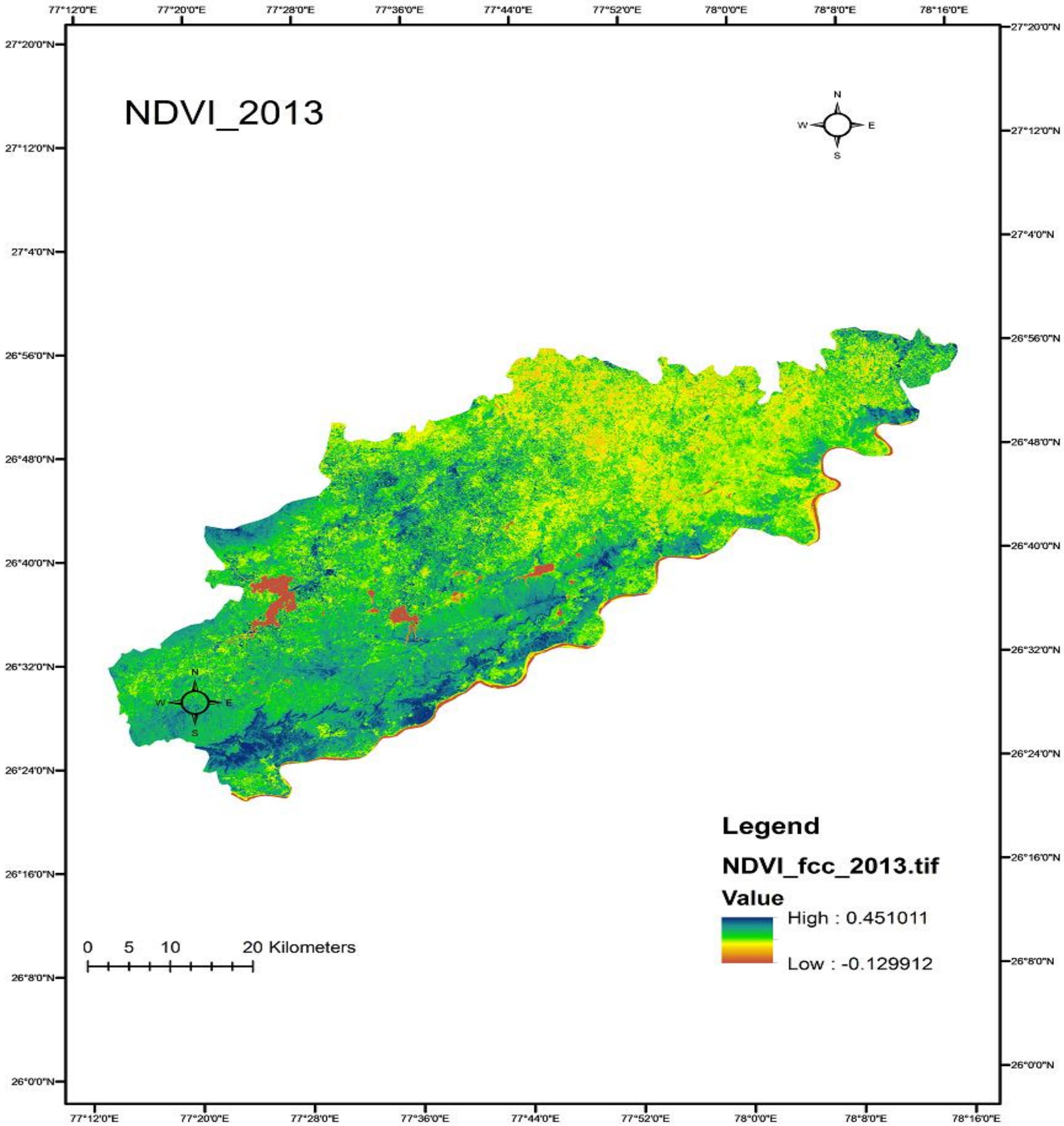


Figure 5.5 NDVI Map (2013)

Value of NDVI is varying from -1 to +1. Higher value of NDVI is represents healthy vegetation and lower or negative show for water, rocks and bare land etc. In our NDVI maps the value of NDVI varies from -0.1299 to +0.4510 in 2013 year and from -0.2307 to +0.3984. This variation is due to increase in cropland and forest in 2013 with respect to 2008 year.

5.3 Rainfall-Runoff Erosivity Factor (R):

The soil loss is closely related to rainfall partly through the detaching power of raindrop striking the soil surface and partially through the contribution of rain to runoff. Rainfall erosivity factor is one of the main contributors to soil erosion. In estimation of rainfall erosivity factor (R) we use annual rainfall data. The value of R Factor vary for year 2008 from 314.723 to 705.857 and for 2013 from 416.662 to 528.337 which depend on station`s rainfall. The mean value for 2008 year is 478.759 and for 2018 year are 488.671. R factor maps are shown in figures 5.6 and 5.7

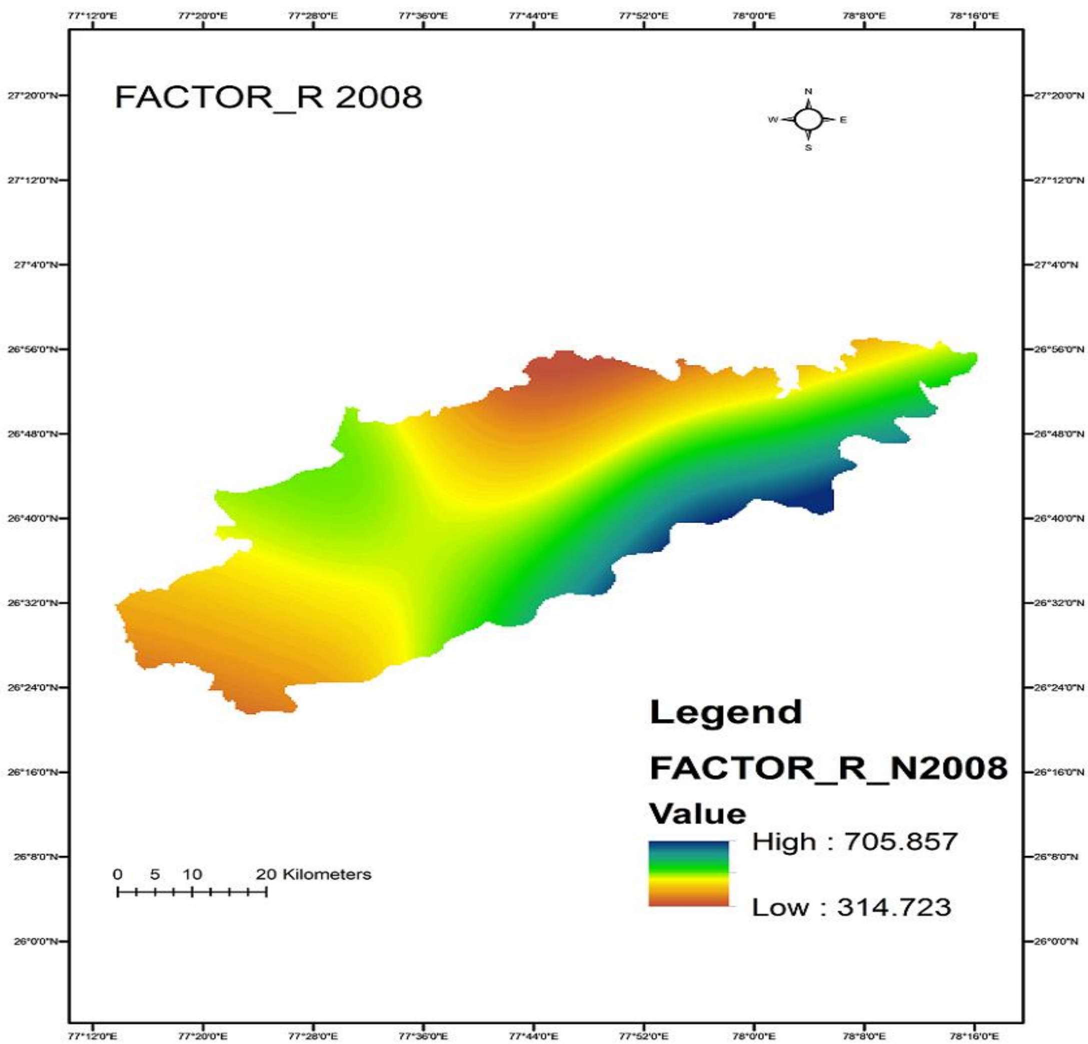


Figure 5.6 R-Factor Maps (2008)

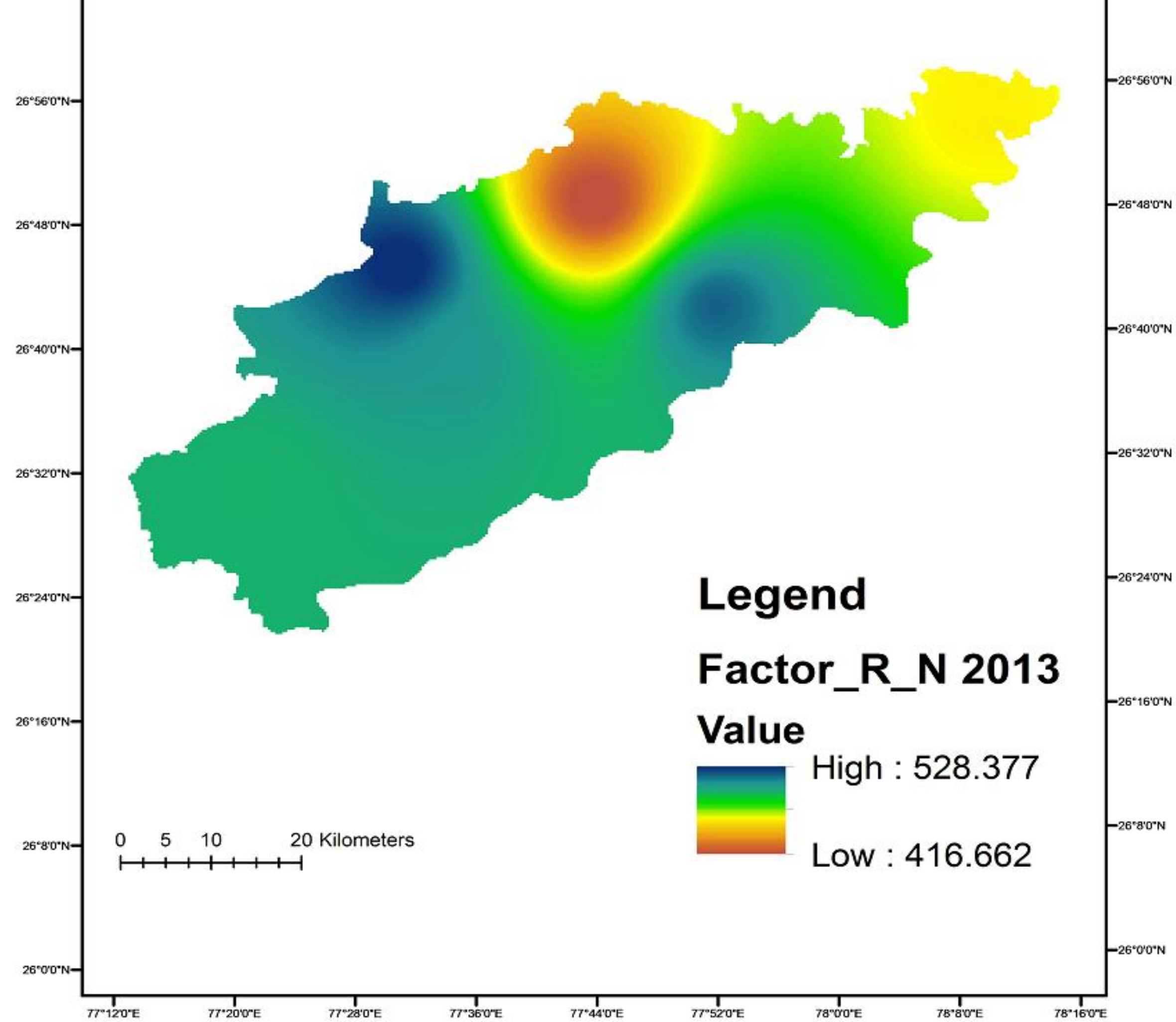


Figure 5.7 R-Factor Maps (2013)

5.4 Soil Erodibility Factor (K):

This factor computes the cohesive character of a soil type and its resistance to dislocate and transport due to raindrop impact and overland flow shear forces. The K-factor is determined for a particular soil type and reflects the physical and chemical properties of the soil, contributing to its erodibility potential. In this study four types of soil texture is exist which are loam, silty loam, sandy clay loam and clay. In which loam type soil more susceptible to soil erosion and cover maximum area of dholpur district. In this work for both of year (2008 & 2013) the soil map are taken similar. The value of k factor varies from 0.0197659 to 0.0762459. Most of study area has higher value because of mostly area has loam type soil texture property. The mean value is 0.067662. K factor map has shown in figure 5.8

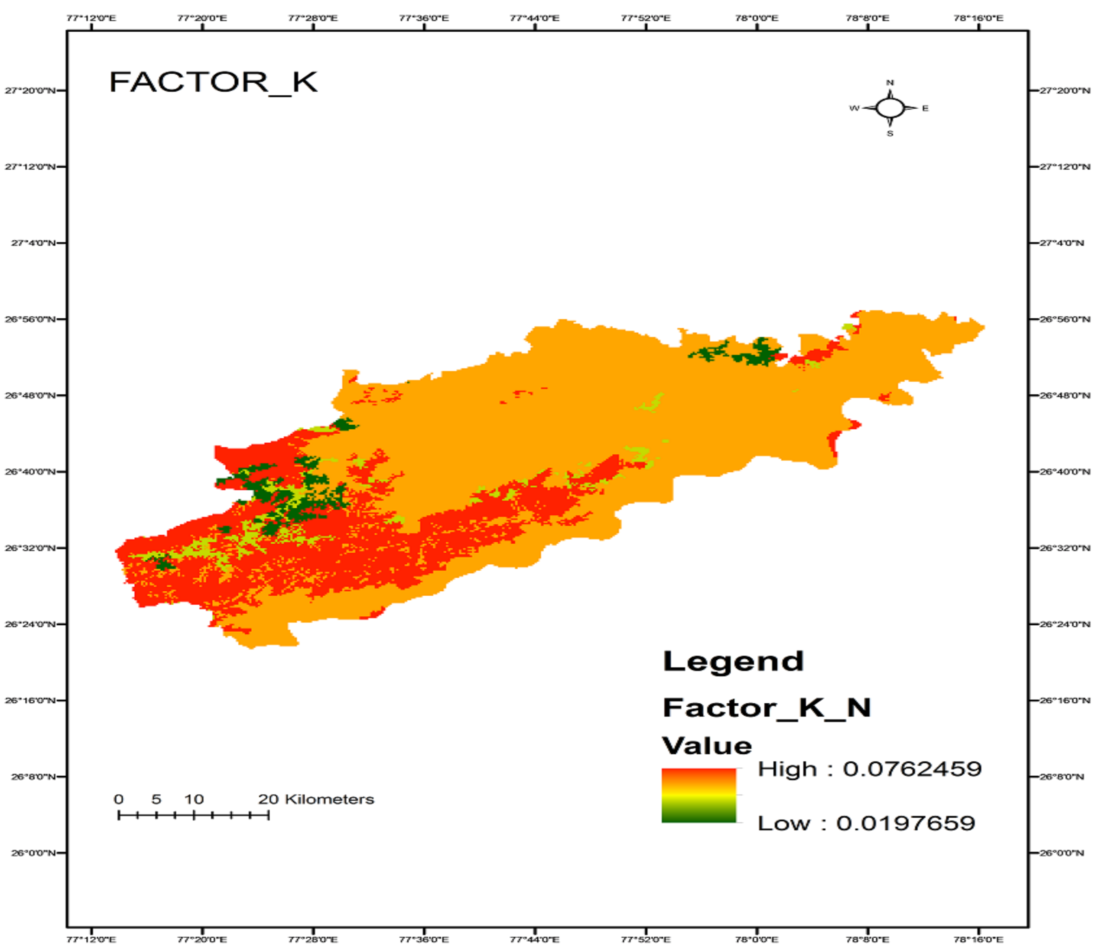


Figure 5.8 K-Factor Map

5.5 Length-Slope Factor (LS):

The topographic factor is a very important parameter in soil erosion, since the gravity force is playing an important role in surface runoff. Thus, the LS factor for RUSLE is computed using the raster calculator in Arc Map to build an expression for estimating slope length factor, based on flow accumulation and slope steepness which is also used in this study. With the help of Digital Elevation Models (DEM) into GIS, the slope gradient (S) and slope length (L) may be determined accurately and in RUSLE both the factors L and S are combined to give the topographic factor LS. In the present study Factor LS has taken similar for both years (2008 & 2013). The values of LS factor vary from 0 to 416.021 and mean value is 0.475220 and standard deviation is 2.968447. The LS factor map of study area shown in below figure 5.9

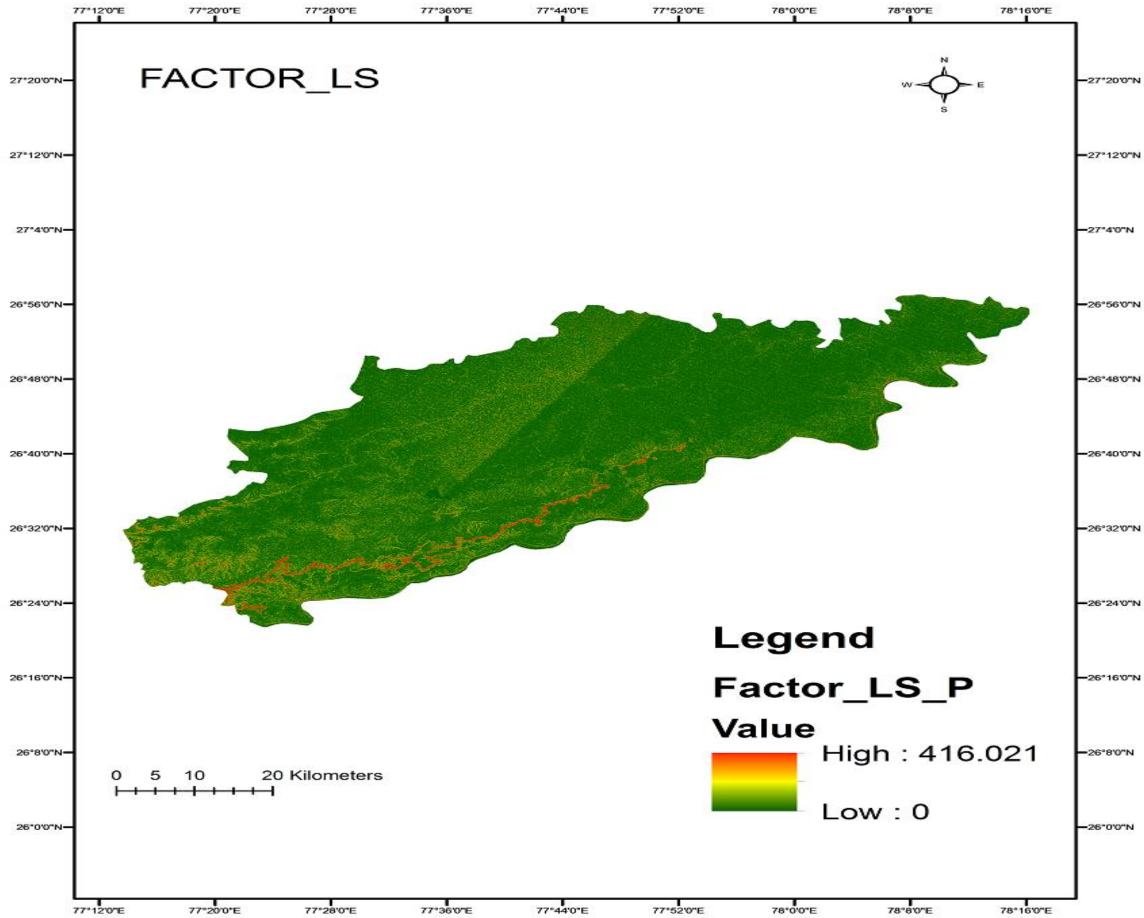


Figure 5.9 LS-Factor Map

5.6 Cover-Management Factor (C):

The land cover and management factor represent the effects of vegetation, soil erosion control practices and management and its value of which ranges from 0 in water bodies to 1 in barren lands. The NDVI maps can be analyzed to formulate the linear equation between NDVI and RUSLE C-factor. Here negative values should not be considered in preparing the C factor equation. The value of C factor varies from 0 to 0.463768 in 2008 and for 2013 varies from 0 to 0.999888. This difference in values of year 2008 and 2013 is because of vegetation cover is more and barren land is less in 2008 compare to 2013 so in the 2013 value of factor C is high. The mean value of C factor in 2008 is 0.13262 and in 2013 is 0.25054**.**

Factor C maps shown in below figures 5.10 and 5.11

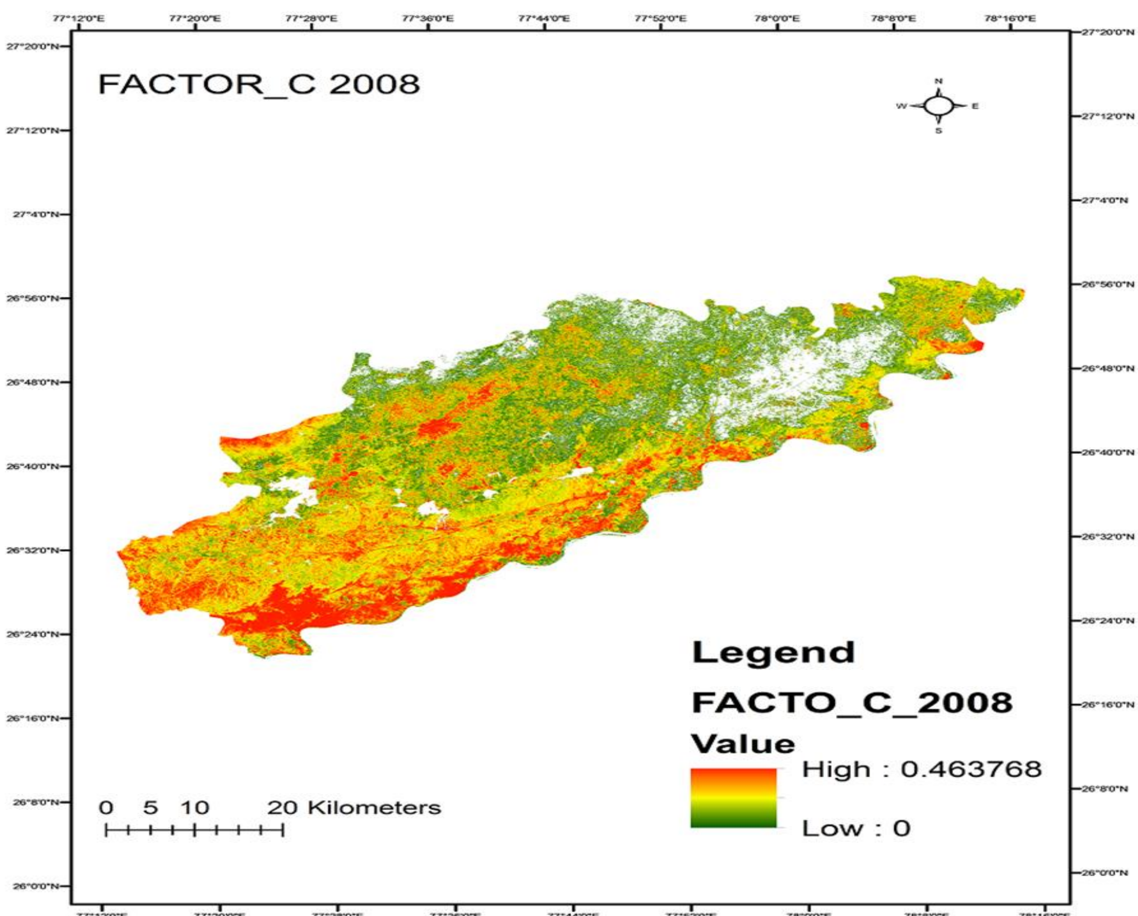


Figure 5.10 C-Factor Map (2008)

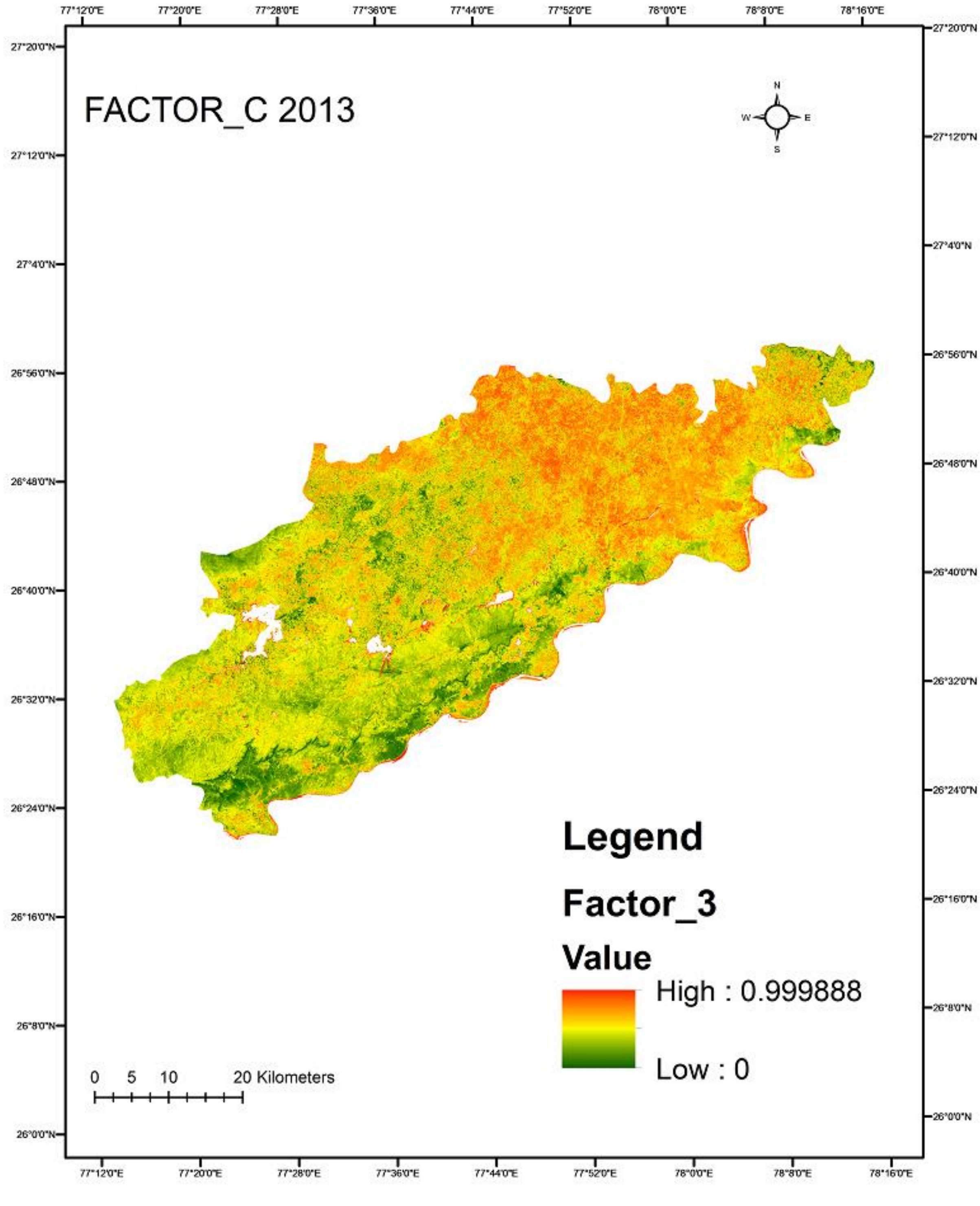


Figure 5.11 C-Factor Map (2013)

5.7 Conservation Practice Factor (P):

P is the factor that reflects the impact of support practices and considers any practice applied by humans to reduce erosion and the average annual erosion rate. P factor map was prepared from Land use/land cover map and is used for understanding the conservation practices in the study area. The value of factor P varies from 0 to 1 for both years. Value 0 to use for waterbody, built up and rocks because in that areas no soil erosion generally. And value 1 used for barren and ravine (pasture) land where no conservation practices and higher soil erosion. The mean value of P factor for 2013 is 0.281320 and for 2008 is 0.214537. These differences are due to higher cropland and barren area in 2013 with respect to 2008 year.

The P factor maps for 2008 and 2013 years have shown in below figures 5.12 and 5.13.

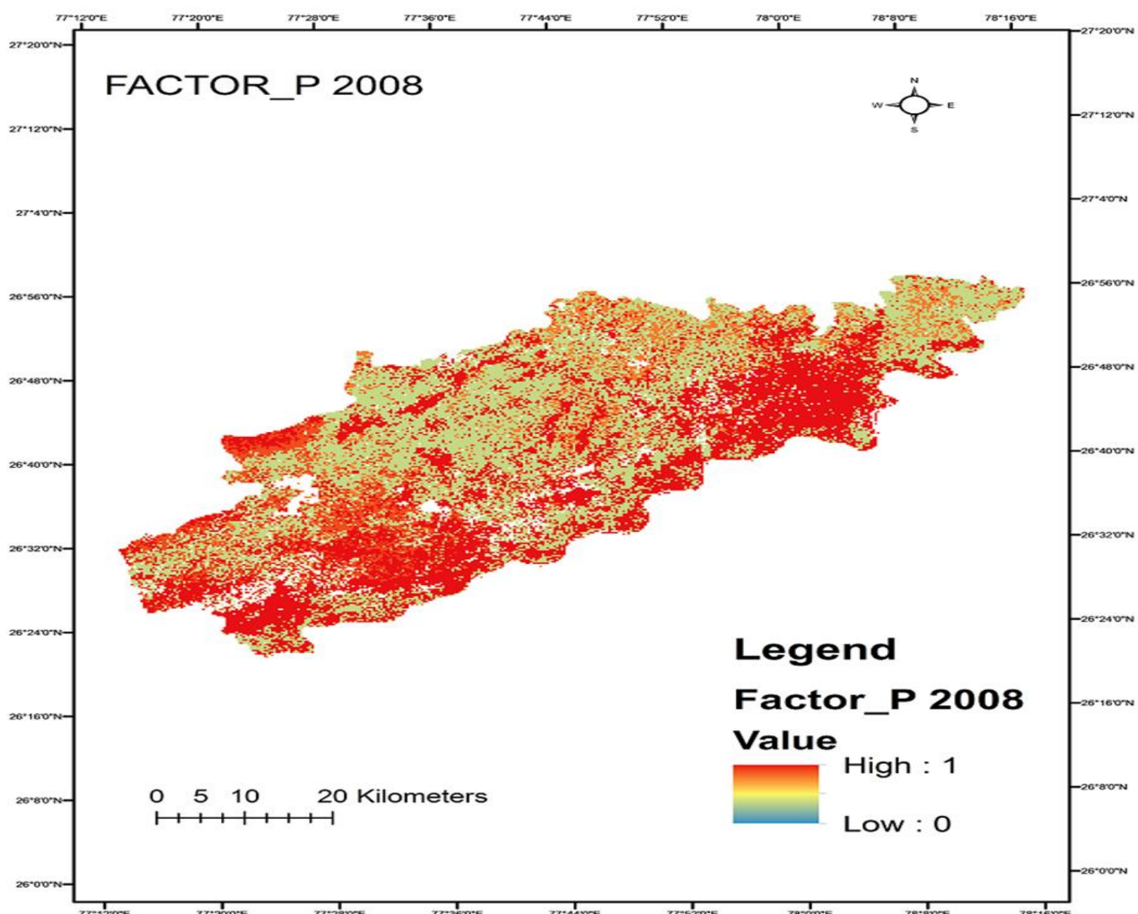


Figure 5.12 P-Factor Map (2008**)**

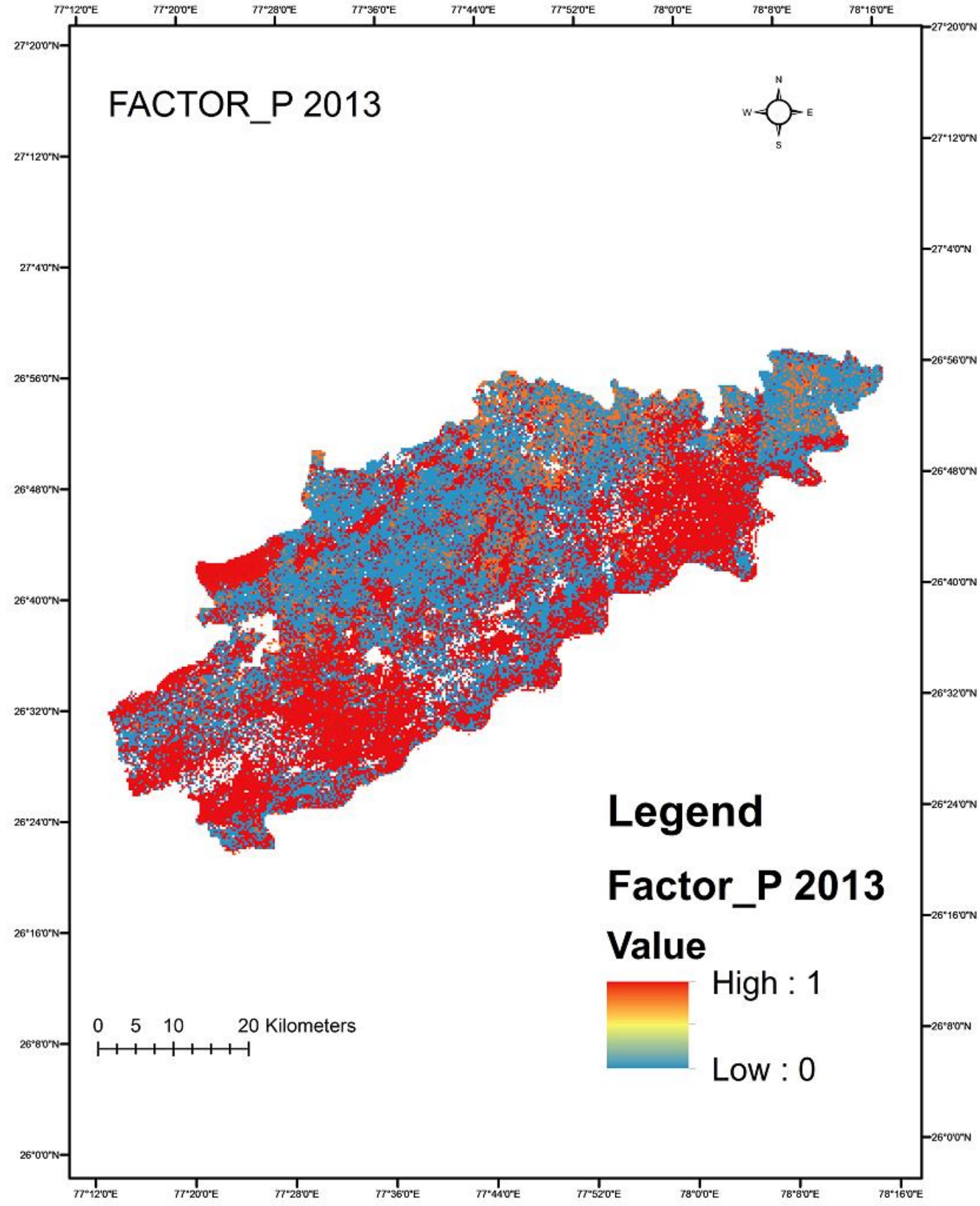


Figure 5.13 P-Factor Map (2013)

5.8 Soil Erosion Estimation (RUSLE RESULTS):

After preparing all the RUSLE parameters, R, K, LS, C, P, the respective maps were in raster format keeping the cell size (30 meter) and projection uniform. These factor maps were then superimposed in raster calculator using the RUSLE Equation and soil erosion estimated (calculated) or soil erosion risk map generated.

Soil Erosion in 2008:

After overlaying all RUSLE factors of 2008 in raster calculator in ArcGIS (Spatial Analyst Tool) soil erosion map generated. In 2008 year total soil erosion was 304506.31 ton and mean value of soil erosion was 7.56 t/ha/year. In 2008 min value of soil erosion vary from 0 to 1300 t/ha/year. In 2008 soil erosion is divided in 7 classes which area and range is given in table 5.1-

Table 5.1- Areas of Soil erosion classes in (2008)

CLASS	RANGE OF SOIL EROSION(t/ha/year)	AREA(KM^2)	%AREA
VERY SLIGHT	**< 1**	**765**	**25.18**
SLIGHT	**1−5**	**390**	**12.83**
MODERATE	**5−10**	**309.75**	**10.19**
MODERATELY SEVERE	**10−40**	**1017**	**33.47**
SEVERE	**40−80**	**478**	**15.74**
VERY SEVERE	**80−500**	**78**	**2.56**
EXTERMLY SEVERE	**>500**	**0.25**	**0.08**
TOTAL		**3034**	**100**

From table 5.1 we see that 49 % area of dholpur district is in moderately to severe condition of soil erosion. So we first of all in that area conservation practices should be implemented.

Soil Erosion map of Dholpur district in 2008 year shown in below figure

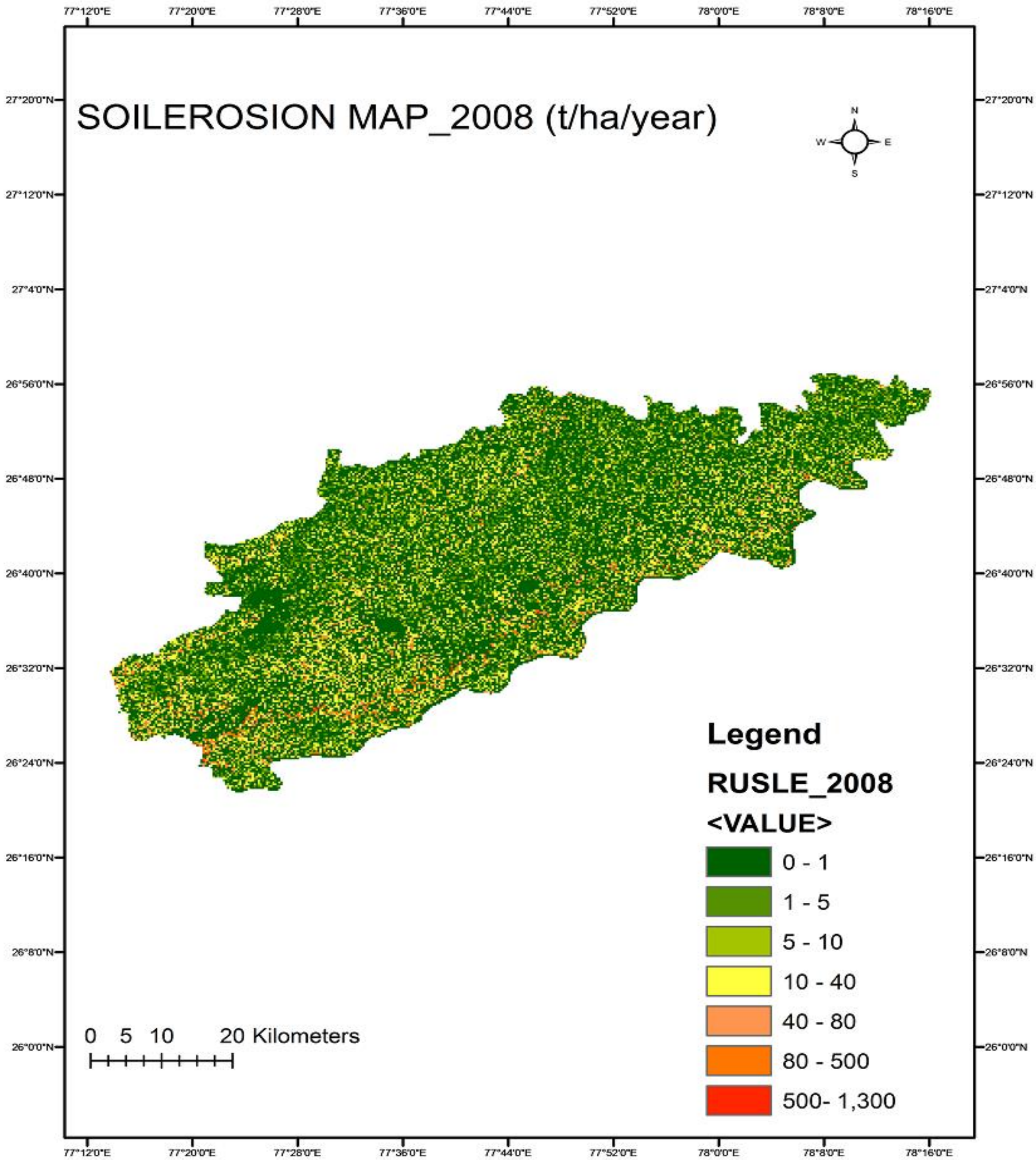


Figure 5.14 Soil Erosion Map (2008)

Soil Erosion in 2013:

After overlaying all RUSLE factors of 2013 in raster calculator in ArcGIS (Spatial Analyst Tool) soil erosion map generated. In 2013 year total soil erosion is 321239.68 ton and mean value of soil erosion was 7.86 t/ha/year. In 2008 min value of soil erosion vary from 0 to 1600 t/ha/year. In 2008 soil erosion is divided in 7 classes which area and range is given in table 5.2-

Table 5.2- Areas of Soil erosion classes in (2013)

CLASS	RANGE OF SOIL EROSION(t/ha/year)	AREA(KM^2)	%AREA
VERY SLIGHT	< 1	522	17.18
SLIGHT	1−5	375	12.34
MODERATE	5−10	215	7.07
MODERATELY SEVERE	10−40	1293	42.56
SEVERE	40−80	513	16.88
VERY SEVERE	80−500	116	3.81
EXTERMLY SEVERE	>500	4	0.13
TOTAL		3034	100

From table we show that near about 56% area of Dholpur district is in moderately to severe condition of soil erosion. So we should have first in this area conservation practices should be implement.

The area of special class can be calculated by exporting that data in tiff format and can be open erdas imagine to calculated. Or by classifying pixels in classify tools of 3D analyst tool we can calculate by counting no of that class pixel and multiplying by cell resolution**.**

Soil Erosion map of Dholpur district in 2013 year shown in below figure-

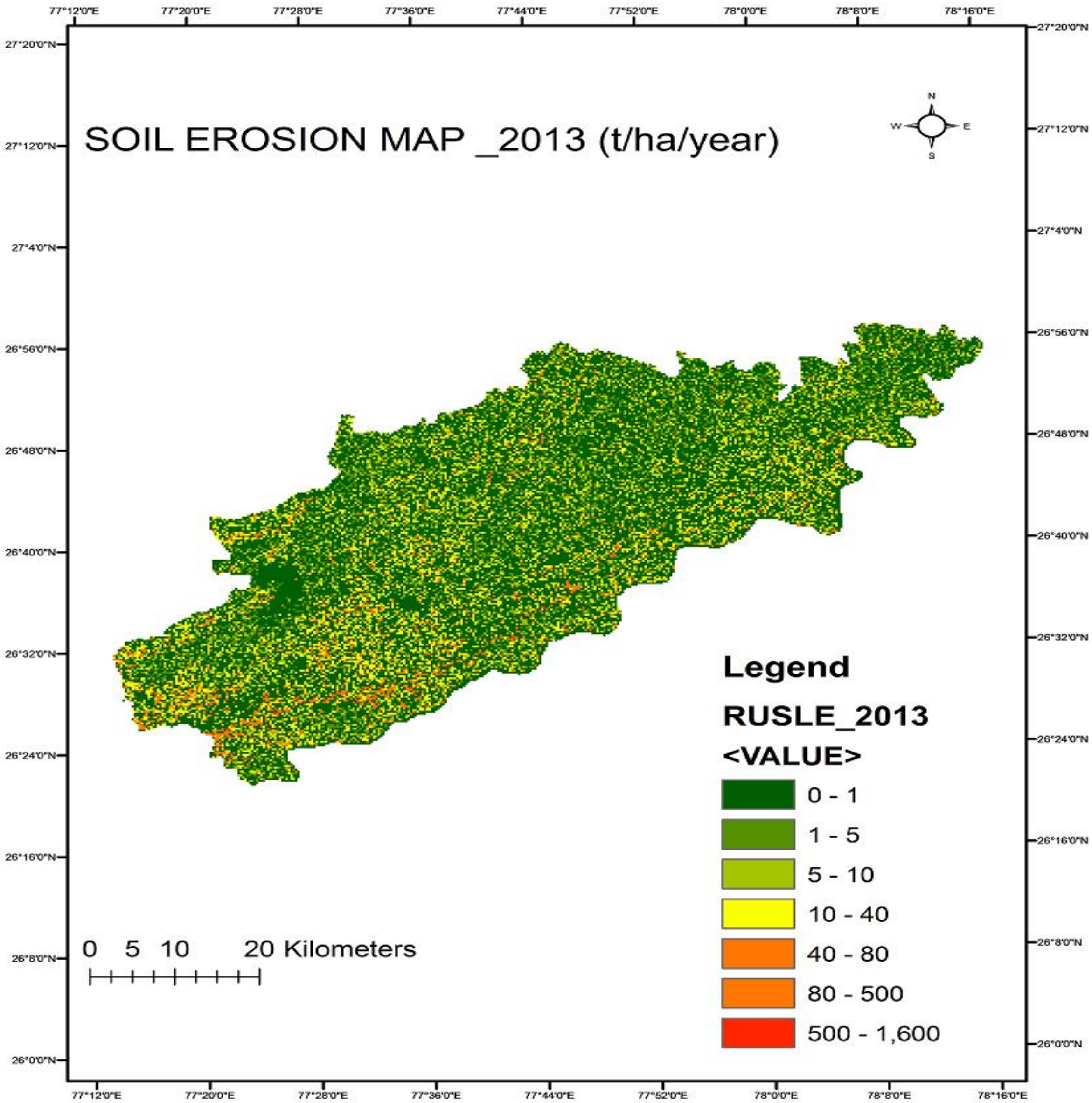
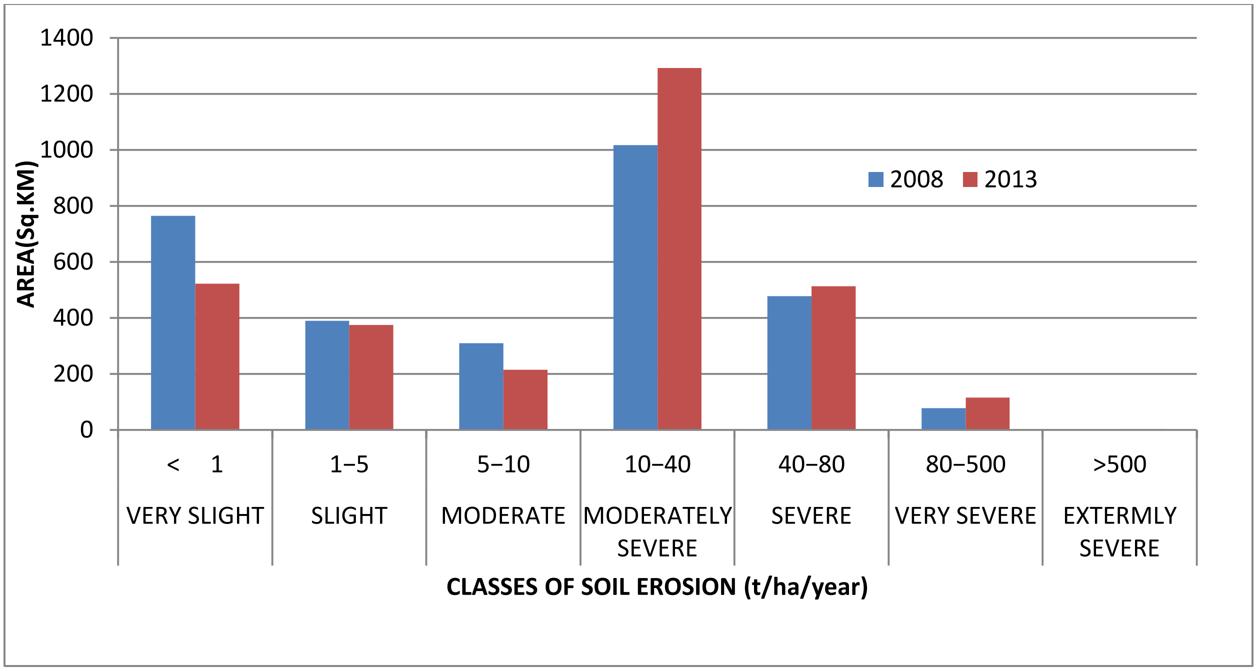


Figure 5.15 Soil Erosion Map (2015)

5.9 Comparison bet ween 2008 and 2013 Soil Erosion Results:

YEAR	2008		
CLASS	RANGE OF SOIL EROSION(t/ha/year)	AREA(KM^2)	%AREA
VERY SLIGHT	< 1	765	25.18
SLIGHT	1−5	390	12.83
MODERATE	5−10	309.75	10.19
MODERATELY			
SEVERE	10−40	1017	33.47
SEVERE	40−80	474	15.74
VERY SEVERE	80−500	78	2.56
EXTERMLY SEVERE	>500	0.25	0.08
TOTAL		3034	100

YEAR	2013		
CLASS	RANGE OF SOIL EROSION(t/ha/year)	AREA(KM^2)	%AREA
VERY SLIGHT	< 1	522	17.18
SLIGHT	1−5	375	12.34
MODERATE	5−10	215	7.07
MODERATELY			
SEVERE	10−40	1293	42.56
SEVERE	40−80	509	16.88
VERY SEVERE	80−500	116	3.81
EXTERMLY SEVERE	>500	4	0.13
TOTAL		3034	100



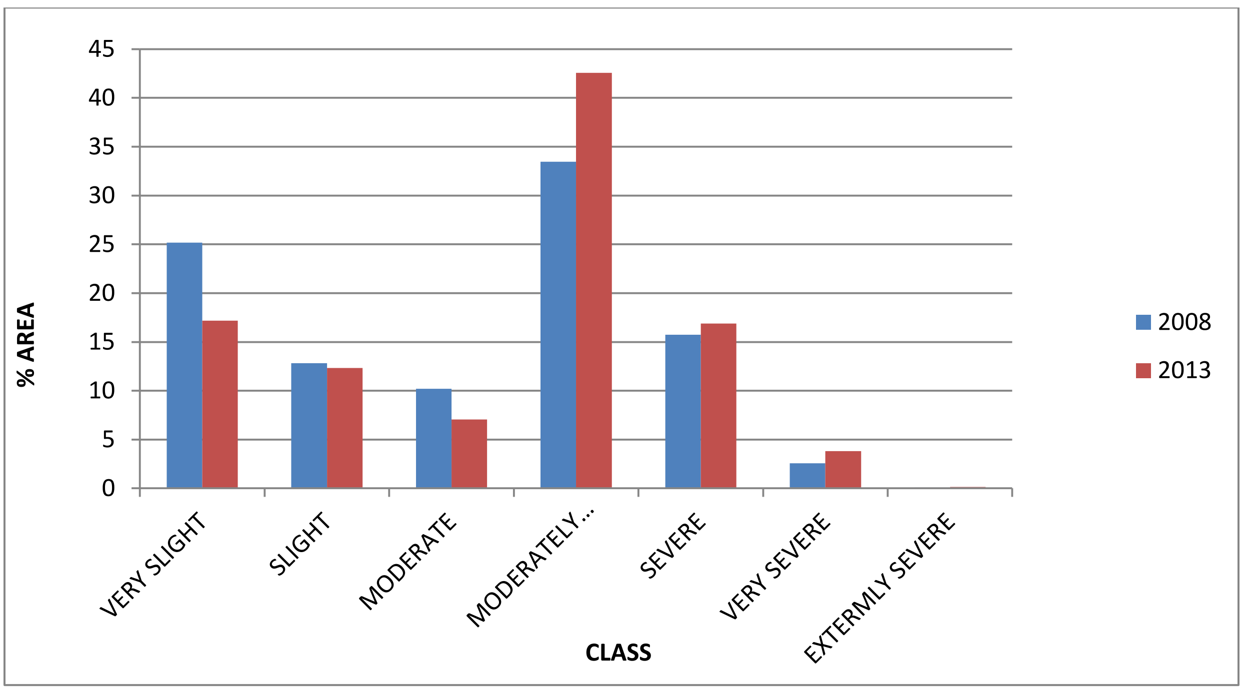


Figure 5.16 Comparison bet ween 2008 and 2013 Soil Erosion Results

From above Figure 5.16 (column chart) is clear that in 2013 year condition of soil erosion of moderately severe is increased in 9.09% area and condition of severe erosion increased in 1.15 % area with respect to 2008 year. This is due to increase in cropland and barren/pasture land in 2013 year comparison to 2008 year according to LULC classification of 2008 and 2013 years.

Chapter 6

CONCLUSION AND RECOMMENDATIONS

This study reveals that GIS is a valuable tool in assessing and assisting the estimation of soil erosion at the watershed scale. Thus Remote Sensing and GIS here has been productively used for Soil Erosion study of Dholpur District.

In this study quantitative assessment is effectively accomplished by calculating rates of soil loss and developing a soil intensity map of the study area using Soil Loss Equation RUSLE. Soil Erosion Model RUSLE too has shown significant results identifying spatial pattern of soil loss within Dholpur district by predicting erosion potential on a cell-by-cell basis.

The result and discussion indicate that in 2013 total soil erosion is 321239.68 ton and in 2008 was 304506.31. This increase in soil erosion quantity is due to in 2013 intensive cropland and barren land increase comparison to 2008 years which is identify by preparing the LULC map of that's years. In 2013 years area of moderately severe and severe conditions also increased by 9.09 % and 1.15% respectively comparison to 2008 year.

This study recommends that soil conservation practice first of all should be implemented in areas of moderately severe to severe condition of soil erosion.

REFERENCES

Saha, S.K., 2003. Water and Wind Induced Soil Erosion Assessment and Monitoring Using Remote Sensing and GIS. In: Satellite Remote Sensing and GIS Applications in Agricultural Meteorology, pp. 315e330.

Renard, K., Foster, G., Weesies, G., McCool, D., Yoder, D., 1997. Predicting Soil Erosion by Water: a Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). US Government Printing Office, Washington, DC.

Jain, S.K., Kumar, S., Varghese, J., 2001. Estimation of soil erosion for a Himalayan watershed using GIS technique. Water Resources Management 15 (1), 41-54.

Kim, H.S., 2006. Soil Erosion Modeling Using RUSLE and GIS on the IMHA Watershed, South Korea. Doctoral dissertation. Colorado State University, USA.

Karaburun, Ahmet, 2010. Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed. Ocean Journal of Applied Sciences 3 (1), 77-85

Shinde, Vipul, Tiwari, K.N., Singh, Manjushree, 2010. Prioritization of micro watersheds on the basis of soil erosion hazard using remote sensing and geographic information system. International Journal of Water Resources and Environmental Engineering 2 (3), 130-136.

Wischmeier, W.H., Smith, D.D., 1978. Predicting Rainfall Erosion Losses: a Guide to Conservation Planning. Agriculture Handbook 282. USDA-ARS, USA.

Xu, Y.Q., Shao, X.M., Peng, J., 2009. Assessment of soil erosion using RUSLE and GIS: a case study of the Maotiao River watershed, Guizhou Province, China. Environmental Geology 56, 1643-1652.

Remortel Van, R., Hamilton, M., Hickey, R., 2001. Estimating the LS factor for RUSLE through iterative slope length processing of digital elevation data. Cartography 30 (1), 27-35.

Suresh R. 2000. Soil and Water Conservation Engineering. Standard Publishing Distributors. India: New Delhi.

Pandey, Ashish, Chowdary, V. M.., Mal, B. C. (2007). "Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing" Water Resource Manage. 21:729–746

Manchand M.L. , M.Kudrat., Tiwari A.K. (2002). "Soil survey and mapping using remote sensing" International Society for Tropical Ecology Tropical Ecology 43(1): 61-74, 2002 .

Ganasri, B.P., Ramesh, H., Assessment of soil erosion by RUSLE model using remote sensing and GIS - A case study of Nethravathi Basin, Geoscience Frontiers (2015), http://dx.doi.org/10.1016/j.gsf.2015.10.007

Dimitrios. Alexakis ., Diofantos G. Hadjimitsis., Athos Agapiou (2013) "Integrated use of remote sensing, GIS and precipitation data for the assessment of soil erosion rate in the catchment area of "Yialias" in Cyprus" Atmospheric Research 131 (2013) 108–124.

Rick D. Van Remortel., Matthew E. Hamilton., Robert J. Hickey. (2011) "Estimating the LS factor for RUSLE through iterative Slope length processing of Digital Elevation Data within Arc Info Grid." Cartography, 30:1, 27-35, DOI: