ESTIMATION OF SOIL EROSION AND SEDIMENT YIELD ON ONG CATCHMENT, ODISHA, INDIA

A

DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE

DEGREE OF

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BY

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CERTIFICATE

*This is to certify that the Dissertation entitled "***ESTIMATION* **OF SOIL EROSION AND SEDIMENT YIELD ON ONG CATCHMENT, ODISHA, INDIA***" submitted by* ***SANJAY KUMAR BEHERA*** *to the* **National Institute of Technology, Rourkela***, in partial fulfillment of the requirements for the award of Master of Technology in Civil Engineering with specialization in Water Resources Engineering is a record of bona fide research work carried out by him under my supervision and guidance during the academic session 2014-15. To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.*

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Date-

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List of Abbreviations

USLE	Universal Soil Loss Equation
DEM	Digital Elevation Model
R	Rainfall erosibility factor
K	Soil erodibility factor
C	Cover management factor
P	Support practice factor
A	Average annual soil loss rate
GIS	Geographical Information System

Abstract

Soil erosion problem is one of the major problems in India. It is very difficult to estimate precise soil erosion for a particular period of time. Many experimental and theoretical methods have been derived for estimation of soil erosion on watershed basin. These methods involve Geographical Information System (GIS) which is used for the computation of sediment yield of Ong river basin Odisha, India. In this method spatial data of Ong catchment is disintegrated into homogenous grid cells to capture the catchment heterogeneity. The gross soil erosion in each cell was calculated using Universal Soil Loss Equation (USLE) by determining its various parameters. Here for the study of soil erosion, the Ong catchment at lower Mahanadi region is chosen as availability of gauged data at multiple locations within watershed area. The Ong catchment is having an area of 5128 km2 at the lower Mahanadi region in India. Using these maps, the gross soil erosion was routed to the watershed outlet using hydrological drainage paths, for derivation of transport capacity limited sediment outflow maps. These maps depict the amount of sediment rate from a particular grid in spatial domain and the pixel value of the outlet grid indicates the sediment yield at the outlet of the watershed. By analysis of field data of ONG catchment with USLE method, the annual sediment yield of ONG catchment show good agreement with less than ±42% error. The highest sediment yield obtained at Salebhata gauging station which is equal to 24.3 ton/hect/year.

Keywords: DEM (Digital Elevation Model), GIS (Geographical Information System), Soil Erosion Sediment yield, USLE (Universal Soil loss Equation), ONG catchment, lower Mahanadi region.

CHAPTER 1
INTRODUCTION

1.1 General

Soil erosion is the process in which it includes detachment, transport and subsequent deposition. By the impact of raindrop and the shear force of flowing water, the sediment is detached from soil surface. Primarily by the flow of water the removed sediment is transported to down slope, although there is a small amount of sediment transfer occurs toward downslope by raindrop splash. Consideration of soil erosion is essential for the planning of watershed or catchment improvement works. Due to sediment erosion, it has been accepted that some critical problems raised in the field of agriculture and land degradation which may causes climatic change. Soil erosion decreases not only the storage capacity of the downstream basins but also deteriorates the efficiency of the watershed. Generally exact estimation of sediment-transport amounts depend on estimation of overland flows .Sediment yield is defined as the amount of sediment load passing through the outlet of a watershed. Therefore, any mistakes in the estimation of overland flows would be magnified fully over inaccurate estimation of soil erosion. Worldwide, more than 50% of pasturelands and about 80% of farming lands suffer from soil erosion (Pimentel et al. 1995).It is informed that, universal, about 6,000,000 ha of fertile land is being lost every year due to just soil erosion and related factors (Dudal 1981). It is estimated that near about 1,964.4 MH of total land area have been now degraded (UNEP 1997). From which, about 1,903 MH and 548.3 MH land area are affected soil erosion problems due to water and wind respectively. In India, Land degradation by soil erosion is a serious issue. Water and soil losses are the main causes for sediment inflowing the basin which causes the decrease of water quality. Soil erosion strongly effects the health of living beings. Hence, it more essential to calculate the soil erosion. By seeing the importance of estimation of soil erosion many researchers work in this field. The information on sources of sediment yield within a watershed can be used as perspective on the amount of soil erosion occurring at that watershed. Despite the improvement of a range of physically based soil erosion and sediment transport equations, sediment yield estimates at a watershed or regional scale are achieved mainly through simple experimental models as the detailed data required for application of physically based models. To estimate soil erosion and sediment yield some simple empirical models are widely used for their simplicity, which makes them applicable even if only a limited amount of input data is available. Universal Soil Loss Equation (USLE) proposed by Wischmeier and Smith (1978), Modified Universal Soil Loss Equation (MUSLE) proposed by Williams (1975) or Revised Universal Soil Loss Equation (RUSLE) by Renard et al. (1991) are quite regularly used for estimation of gross amount of surface erosion and sediment yield at various watershed areas (e.g. Williams and Berndt 1972; Griffin et al. 1988; Ferro et al. 1998; Jain and Kothari 2000; Kothyari et al. 2002; Ferro and Minacapilli, 1995; Ferro 1997; Kothyari and Jain 1997). There are some of the examples commonly used watershed models based on USLE methodology to compute soil erosion such as Erosion Productivity Impact Calculator (EPIC) (Williams et al., 1984) and Agricultural Non-Point Source Pollution Model (AGNPS) (Young et al., 1987). While USLE/RUSLE may not copy the real picture of erosion process as they are based on factors computed or calibrated on the basis of observations, it has been widely applied all over the world mainly due to the easiness in the model formulation and easily available data-set (Bartsch et al., 2002; Jain and Kothyari, 2001; Jain et al., 2001). Wischmeier and Smith, 1978 shows that USLE model gives better results for estimating soil erosion at plot scale. In case of catchment, part of eroded soil is deposited inside catchment before it spreads the catchment outlet. Nevertheless, soil erosion calculated by USLE can be directed to catchment outlet using the theory of sediment delivery ratio by applying suitable technique .In rainfall and catchment heterogeneity, both soil erosion and sediment transport processes are spatially varied due to the spatial variation. Such inconsistency has stimulated the use of data intensive distributed method for the estimation of catchment erosion and sediment yield by discretizing a catchment into sub-areas each having around homogeneous characteristics and constant rainfall distribution (Young et al., 1987; Beven, 1989). To summarize the spatial difference of the parameters like topography, soil and land use in a watershed, the use of Geographical Information System (GIS) method is well suitable. GIS techniques work by discretizing the catchment into small grid cells which are used for the computation of such physical characteristics of these cells i.e. slope, land use and soil type. By knowing these physical characteristics of grid shell, soil erosion and deposition in the different sub-areas of the catchment can be studied. A number of different models (both experimental and process-based) have been established to interpret soil loss data based on GIS. Many researchers also used empirical relationship between Delivery Ratio (DR) and catchment area in order to compute sediment load. Jain et al. (2003) made a calculation of sediment yield for the HAHARO catchment in upper Damodar valley. The sediment–discharge relationship was developed using daily data. For estimation of the sediment yield using the experimental relationship, various topographical parameters such as land use and topography were generated using Geographic Information System (GIS) technique. He also utilized experimental equation to estimate sediment delivery ratio in order to calculate sediment yield at catchment outlet. By using GIS, Remote Sensing (RS) with Universal Soil Loss Equation (USLE) to detect the critical erosion prone areas of watershed for ranking purpose. Here in this thesis, estimation of soil yield by using the USLE parameter to estimate the rainfall based erosion on ONG catchment at Salabhata gauging station.

1.2 Soil Erosion

By the cause of water and air flow, erode of soil surface occurs is called as soil erosion. From which flow of water is more responsible for erosion where the process includes detachment, transportation and deposition of individual sediment particles by effect of raindrop and flowing water (Foster and Meyer 1977; Wischmeier and Smith 1978; Julien 2002). Erosion is one of the main problems in agriculture and natural resources management. It causes the decrease of soil productivity, pollutes the streams and fills the reservoirs (Fangmeier et al. 2006). Human activity such as construction of roads, highways, and dams, control works on streams and rivers, mining, and urbanization usually accelerate the process of erosion, transport, and sedimentation (Julien 2010).

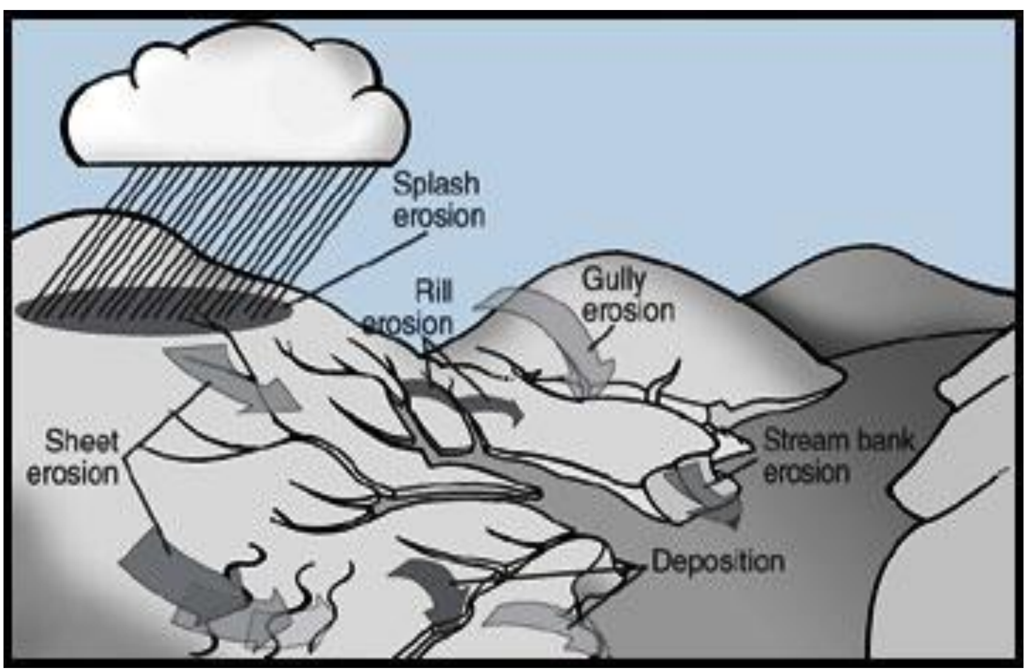

Figure 1.1 - Soil Erosion Processes

Here figure 1.1 shows the process of soil erosion and sedimentation. When rain drop falls on the ground, the process of soil erosion occurs which causes removal of soil particles by splash. It causes a thin overland flow named as sheet erosion or interrill erosion where removed particles are laterally transported to the rills (Foster and Meyer 1977). Through flow in rills most of the downslope sediment transport occurs. Rill erosion occurs when water from sheet erosion combines to form concentrated small channels which is the prevalent form of surface erosion.

In this figure it clearly shows that, rills gradually join to form larger channels and results to gully erosion which is similar as rill erosion but larger in scale. Stream channel erosion results from concentrated water which forms from rills and gullies, and causes removal of sediment from streambed and stream banks. When the amount of detached soil is more than the transport capacity of soil, only the transportable amount will be carried to downslope and the rest will be deposited on the segment.

1.3 Soil Erosion Models

The Universal Soil Loss Equation (USLE) model is one of the major developments in soil and water conservation in the 20th century. This empirical model has been applied around the world to estimate soil erosion by raindrop impact and surface runoff. USLE model is the resultant of decades of soil erosion experimentation conducted by university faculties and federal scientists across the U.S. It was initially proposed by Wischmeier and Smith (1965) based on the concept of detachment and transportation of particles from rainfall in order to estimate soil erosion rates in agriculture areas.

1.4 Geographic Information System (GIS)

Geographic Information System (GIS) is a computerized database management system which enables the user to capture, store, retrieve, analyze, manage and visualize the spatial data that are linked to the real-world coordinates (ESRI 2005). GIS is improved with a set of geospatial tools that can perform statistical analysis, identify relationships and determine patterns and trends. However, in general, information of GIS is hugely applied in the field of environment particularly in hydrologic and hydraulic modeling, flood mapping and watershed management etc.

1.5 Objectives of the study

The overall objective is to determine the soil erosion rates using the USLE model and ArcGIS 10.2 at the Ong River Basin. Some specific objectives are:

1. To study on different mathematical models used for sediment yield estimation.
2. To calculate the annual average soil loss rate at ONG catchment by using the rainfall data, Digital Elevation Model (DEM), Soil Type Map, and Land Cover Map data.
3. To identify of erosion prone area in the river basin using Remote Sensing and GIS.

1.6 Thesis outline

Chapter 1 introduces the work of estimating the annual soil erosion using USLE parameter on different river basin.

Chapter 2 focuses about the previous research works related to Soil erosion using USLE parameters in deferent river basin.

Chapter 3 describes about the geographical location of the study area, its characteristics and available hydrological data.

Chapter 4 covers the use of remote sensing and GIS as a tool to delineate different maps, and briefly describe about the procedure the find out input parameters for USLE.

Chapter 5 incorporates the results obtained from the USLE model and the analysis of Sediment Yield.

Chapter 6 provides the summary and conclusions estimating the annual soil erosion on Ong river basin.

CHAPTER 02
REVIEW OF LITERATURE

2.1 INTROUCTION

In accordance to the objectives mentioned for the calculation of sediment yield, the complete work has been done using remote sensing GIS method. This method was used for calculation of all parameters of Universal Soil Loss Equation.

2.2 GEOGRAPHIC INFORMATION SYSTEM SOIL EROSION MODELLING

Many scientists have come out with procedure and methods of generating the sediment loss zone maps by identifying remote sensing based spatial layers of sediment yield controlling parameters using GIS.

Narayana and Babu *et al.,* (1983) carried out work on Soil erosion problem of India. In the absence of accurate estimates of total erosion in the country, this paper presents a process to arrive at a first estimate of soil erosion, sediment loads of rivers and sedimentation in reservoirs. In this analysis, existing annual soil loss data for 20 different land resource regions of the country sediment loads of some rivers, and rainfall erosivity for 36 river basins and 17 catchments of major reservoirs were utilized and statistical regression equations are developed for forecasting sediment yield. Using these terminologies and corresponding values of area, rainfall, rainfall erosivity and surface runoff, annual values of total sediment loads of streams, sediment deposition in reservoirs, and sediment lost permanently into the sea are estimated. According to this estimate, which is treated as a first approximation, soil erosion is taking place at the rate of 16.35 ton/ha/annum which is more than the permissible value of 4.5-11.2 ton/ha. About 29% of the total eroded soil is lost permanently to the sea. Ten percent of it is deposited in reservoirs. The remaining 61% is dislocated from one place to the other.

Kothiyari *et al.,* (1996) carried out work on the problem of soil erosion which is predominant over about 53 % of the total land area of India. The regions of high erosion include the severely eroded gullied land along the banks of the rivers Yamuna, Chambal and Mahi and other west flowing rivers in western Indian states. In addition the Himalayan and lower Himalayan regions have been greatly affected by soil erosion due to concentrated deforestation, large scale road construction, mining and cultivation on steep slopes. Surveys of existing large and medium-sized Indian reservoirs have indicated that at least six large reservoirs (storage > 100 Mm^3) and three medium-sized reservoirs (storage 20-100 Mm^3) have already lost more than 25% of their capacities. In the present paper many data related to erosion and sedimentation problems in India were presented. Qualitative analysis of these data is also undertaken to identify the possible causes of intensive erosion and sedimentation. Some of the potential remedial measures are briefly discussed.

Subramanian *et al.,* (1996) carried out work on information collected on sediment transport in Indian rivers. It shows the major contribution which Indian rivers make to the total amount of sediment delivered to the ocean at a global scale, but also highlights the large temporal and spatial variability of riverine sediment transport in the Indian sub-continent. This variability is evident not only in the quantity of the sediment transported but also in the size and mineralogical features of the sediment loads.

Adinarayana *et al.*, (1996) carried out work on a new way of introducing "Integrated Resources Units" (IRUs) to the Sediment Yield Index (SYI) model of the All India Soil and Land Use Survey, in order to identify acute hydrological units over a large basin, which was tested in a drainage basin of the Western Ghats mountainous zone which receives heavy rainfall. The IRUs, amassed from integrated analysis, include the multiple basin resources of soils, slopes, drainage and the dynamic land-use pattern. The IRU has been used as the strategic unit for assigning the erosivity and transportability values of the detached material in the SYI model for deriving priority classes for sub-basins. The significant variation in SYI values calls for conservation planning in cases of high and very high priority sub-basins. A treatment-oriented land-use planning scheme, using Geographical Information Systems, was also formulated for sustainable development of the basin. If the suggested biological engineering practices were used on the priority sub-basins, there would be less erosion and consequently massive investments to control erosion, or worse, to rehabilitate the affected lands, could be reduced. The IRU approach is also helpful in monitoring the dynamic aspects of the basin and for redefining the management strategies accordingly.

Kothyari and Jain *et al.*, (1997) carried out work on method which was developed in the present study for the determination of the sediment yield from a catchment using a GIS. The method involves spatial disaggregation of the catchment into cells having uniform soil erosion features. The surface erosion from each of the discretized cells is routed to the catchment outlet using the concept of sediment delivery ratio, which is defined as a function of the area of a cell covered by forest. The sediment yield of the catchment was defined as the sum of the sediments delivered by each of the cells. The spatial discretization of the catchment and the derivation of the physical parameters related to erosion in the cells are performed through a GIS method using the Integrated Land and Water Information Systems (ILWIS) package.

Wayne, Mahmoudzadeh and Myers *et al.*, (2002) carried out work on Sedimentation surveys of dams in small sandstone drainage basins near Sydney, Australia, exhibit that land use is the leading factor for determining sediment yields and soil loss rates. Cultivated basins yield an average sediment yield of 7.1 t/ha/year whereas grazed pasture and forest/woodland basins transfer averages of only 3.3 and 3.1 t/ha/year, respectively. Yet, these yields are high by Australian standards. Sediment transfers from grazed pasture and forest/ woodland basins are similar because the forest/woodland basins are also grazed. Dam sediments are enhanced in clay and organic matter in comparison to topsoil's. Gullies and bank erosion are not active geomorphic processes in the drainage basins investigated so that the measured sediment yields could be validly associated to soil loss rates determined by empirical soil loss equations, Modified Universal Soil Loss Equation (MUSLE), Soil loss and Revised Universal Soil Loss Equation (RUSLE), which do not account for gully and channel erosion. These equations precisely predicted the measured sediment yields, with MUSLE being the most precise. Although Soil loss is the only empirical equation to use Australian data, MUSLE achieved slightly better, despite being a basic version of the Universal Soil Loss Equation (USLE) that is used for teaching. RUSLE predictions of soil loss rates were also closely correlated with measured sediment yields.

Jain and Kumar and Varghese et al., (2001) carried out work on the fragile ecosystem of the Himalayas has been an increasing cause of worry to ecologists and water resources designers. The steep slopes in the Himalayas along with exhausted forest cover, as well as high seismicity have been main factors in soil erosion and sedimentation in river reaches. Estimation of soil erosion is a must if adequate provision is to be made in the design for conservation of structures to offset the ill effects of sedimentation during their generation. In the present study, two diverse soil erosion models, i.e. the Morgan model and Universal Soil Loss Equation (USLE) model, have been used to estimate soil erosion from a Himalayan watershed. Parameters essential for both models were generated using remote sensing and subsidiary data in GIS mode. The soil erosion assessed by Morgan model is in the order of 2200 t km−2 yr−1 and is within the limits reported for this region. The soil erosion assessed by USLE gives a higher rate. Therefore, for the current study the Morgan model stretches, for area located in hilly terrain, fairly good results.

Singh *et al.,* (2002) carried out work on Mathematical modeling of watershed hydrology, which was employed to address a wide spectrum of environmental and water resources problems. A historical viewpoint of hydrologic modeling is provided, and new growths and challenges in watershed models were discussed. Model building, standardization, and data processing have received a great deal of consideration, while model validation, error proliferation, and analyses of ambiguity, risk, and reliability have not been treated as thoroughly. Finally, some remarks are made concerning the future outlook for watershed hydrology modeling.

Dutta and Bhattarai *et al.*, (2006) carried out work on a GIS-based method, which was applied for the determination of soil erosion and sediment yield in a small watershed in Mun River basin, Thailand. These technique involves spatial breakdown of the catchment into homogenous grid cells to capture the catchment heterogeneity. The net soil erosion in each cell was designed using Universal Soil Loss Equation (USLE) by carefully determining its various parameters. The idea of sediment delivery ratio was used to route surface erosion from each of the discretized cells to the catchment outlet. The sequence of sediment delivery from grid cells to the catchment outlet is signified by the topographical characteristics of the cells. The result of DEM resolution on sediment yield was examined using two different resolutions of DEM. The spatial discretization of the catchment and derivation of the physical parameters related to erosion in the cell are accomplished through GIS techniques.

Pandey, Chowdary *and* Mal et al., (2006) carried out work on Karso watershed of Hazaribagh, Jharkhand State, India was categorized into 200 × 200 grid cells and average annual sediment yields were measured for each grid cell of the watershed to identify the critical erosion prone areas of watershed for ranking purpose. Average annual sediment yield data on grid basis was proposed using Universal Soil Loss Equation (USLE). In general, a major restriction in the use of hydrological models has been their inability to handle the large amounts of input data that describe the heterogeneity of the natural system. Remote sensing (RS) technology provides the vital spatial and temporal information on some of these parameters. A recent and developing technology represented by Geographic Information System (GIS) was used as the tool to generate, manipulate and spatially organize disparate data for sediment yield modeling. Thus, the Arc Info 7.2 GIS software and RS (ERDAS IMAGINE 8.4 image processing software) provided spatial input data to the erosion model, while the USLE was used to predict the spatial distribution of the sediment yield on grid basis. The deviation of assessed sediment yield from the observed values in the range of 1.37 to 13.85 percent specifies accurate estimation of sediment yield from the watershed.

Gebhardt and Jackson *et al.*, (2007) carried out work on the Modified Universal Soil Loss Equation (MUSLE), which was related to average annual sediment yield on 14 small rangeland drainage basins by substituting average annual runoff and a calibrated design discharge for the runoff and peak flow terms respectively in MUSLE. The objective was to determine if a design discharge could be prescribed which would enable MUSLE, in this form, to be used for annual sediment yield estimates on small rangeland drainage basins.

Carolina,Joris de Vente and Castillo et al., (2008) carried out work on Extensive land use changes that had occurred in many areas of SE Spain as a result of reforestation and the abandonment of agricultural activities. Similar to this the Spanish Administration spends large funds on hydrological control works to reduce erosion and sediment transport. Though, it remains untested how these large land use variation affect the erosion processes at the catchment scale and if the hydrological control works efficiently reduce sediment export. A mixture of field work, mapping and modelling was used to test the impact of land use scenarios with and without sediment control structures (check-dams) on sediment yield at the catchment scale. The study catchment is located in SE Spain and suffered important land use changes, increasing the forest cover 3-fold and decreasing the agricultural land 2D5-fold from 1956 to 1997. In addition 58 check-dams were built in the catchment in the 1970s accompanying reforestation works. The erosion model WATEM-SEDEM was applied using six land use scenarios: land use in 1956, 1981 and 1997, each with and without check-dams. Adjustment of the model provided a model efficiency of 0D84 for absolute sediment yield. Model use showed that in a scenario without check dams, the land use changes between 1956 and 1997 caused a progressive decrease in sediment yield of 54%. In a scenario without land use changes but with check-dams, about 77% of the sediment yield was reserved behind the dams. Check-dams can be effective sediment control measures, but with a short-lived result. They have significant side-effects, such as encouraging channel erosion downstream. While also having side-effects, land use changes can have important long-term effects on sediment yield. The application of either land use changes (i.e. reforestation) or check-dams to control sediment yield depends on the basis of the management and the specific environmental conditions of each area.

Pandey and dabral *et al.*, (2008) carried out work on soil erosion valuation of Dikrong river basin of Arunachal Pradesh (India). The river basin was separated into 200×200 m grid cells. The Arc Info 7.2 GIS software and RS (ERDAS IMAGINE 8.4 image processing software) provided spatial input data and the USLE was used to forecast the spatial distribution of the average annual soil loss on grid basis. The average rainfall erosivity factor (R) for Dikrong river basin was found to be 1,894.6 MJ mm ha−1 h−1 year−1. The soil erodibility factor (K) with a scale of 0.055 t ha h ha−1 MJ−1 mm−1 is the highest, with 0.039 t ha h ha−1 MJ−1 mm−1 is the least for the watershed. The highest and lowest value of slope length factor (LS) is 53.5 and 5.39 respectively for the watershed. The highest and lowest values of crop management factor (C) were found out to be 0.004 and 1.0 respectively for the watershed. The highest and lowest value of conservation factor (P) were found to be 1 and 0.28 respectively for the watershed. The average annual soil loss of the Dikrong river basin is 51 t ha−1 year−1. About 25.61% of the watershed area is found out to be under slight erosion class. Areas covered by moderate, high, very high, severe and very severe erosion potential zones are 26.51%, 17.87%, 13.74%, 2.39% and 13.88% respectively. Therefore, these areas need immediate attention from soil conservation point of view.

. Arekhi and Shabani *et al.,* (2010) carried out work on Modified Universal Soil Loss Equation (MUSLE) application study in order to estimate the sediment yield of the Kengir watershed in Iyvan City, Ilam Province, Iran. The runoff factor of MUSLE was computed using the measured values of runoff and peak rate of runoff at outlet of the watershed. Topographic factor (LS) and crop management factor(C) are determined using geographic information system (GIS) and field-based survey of land use/land cover. The conservation practice factor (P) was obtained from the literature. Sediment yield at the outlet of the study watershed is simulated for six storm events spread over the year 2000 and validated with the measured values. The high coefficient was used for determination value (0.99), which indicates that MUSLE model sediment yield predictions are satisfactory for practical purposes.

Arekhi and Rostamizad *et al.,* (2011) carried out work on accurate estimation of water and soil losses from agro-ecologically diverse areas was extremely important for designing appropriate resource management or soil/ water preservation measures. The advanced KW-GIUH-MUSLE (Kinematic wave- Geomorphological Instantaneous Unit Hydrograph-Modified universal Soil loss equation) model is tested for its sediment yield estimation potential on three agro-ecologically diverse micro-watersheds in Almora district of Uttaranchal. It was observed that estimates are associated with about 49% mean relative errors and mean DV value of about 0.51 in Salla Rautella and Naula micro-watersheds. This presented that point forecasts of annual sediment yields are of moderate quality. However, root mean square error assessments and comparison of mean and standard deviation values for the observed and simulated sediment yields showed that long term sediment yields could be estimated quite realistically. The analysis thus clearly showed that the developed KW-GIUH-MUSLE model could indeed be utilized for obtaining reasonable sediment yield estimates for un-gauged/ inadequately gauged micro-watersheds.

Corina and Viorel et al., (2011) carried out work on a quantitative estimate of the current annual rate of soil surface erosion in the Codrului Ridge and Piedmont (due to the pluvial denudation and sheet erosion) and a spatial representation of the results by implementing GIS techniques. The database used for the application of the ROMSEM model (Romanian Soil Erosion Model) consist of Digital Elevation Model (DEM) with a resolution of 10 m, for computing the topographic factor (LS), soil map (with information about the type, texture, structure and degree of soil erosion), land use map, based on Corine Land Cover 2000 and corrected according to ortophotos dating from 2005, with a 0.5 m resolution, and the rainfall erosivity index map in Romania. The assessment of the surface erosion in the Codrului and Piedmont Ridge was achieved in two stages: first was assessed the potential erosion (the peak value of the erosion in an area devoid of vegetation) based on the climatic, topographic and soil factors. The actual surface erosion map was obtained in the second stage of the mathematical modeling erosion, by mixing the effect of natural or crop vegetation.

Parveen and Kumar *et al.,* (2012) carried out work on Soil erosion which is problem for the areas of agricultural activity where soil erosion not only leads to decreased agricultural productivity but also reduces water availability. Universal Soil Loss Equation (USLE) is the most popular empirically based model used globally for erosion prediction and control. Remote sensing and GIS techniques have become valuable tools specially when assessing erosion at larger scales due to the amount of data needed and the greater area coverage. The present study presents a part of Chotanagpur plateau with rolling topography, with a very high risk of soil erosion. In the present study an effort has been made to assess the annual soil loss in Upper South Koel basin using Universal Soil Loss Equation (USLE) in GIS framework. Such information can be of huge help in identifying priority areas for implementation of erosion control measures. The soil erosion rate was determined as a function of land topography, soil texture, land use/land cover, rainfall erosivity, and crop management and practice in the watershed using the Universal Soil Loss Equation (for Indian conditions), remote sensing imagery, and GIS techniques.

Ahmad and verma *et al.,* (2013) carried out work on Assessment of soil erosion. A number of parametric models was developed to forecast soil erosion at drainage basins, yet Universal Soil Loss Equation, popularly known as USLE model is most widely used empirical formula for estimating annual soil loss from agricultural basins. With the advance of Remote Sensing technique it becomes possible to measure hydrologic parameters on spatial scales while Geographic Information System integrates the spatial analytical functionality for spatially distributed data. In the present paper the application of USLE model and GIS, for soil loss estimation has been presented for the Tandula reservoir catchment area on Tanudula River at Balod Tehsil of Durg district of Chhattisgarh State, India. The result obtained from USLE model has been compared with existing model, Nayak and Khoslas method, it is observed that USLE with GIS give better result as compared to other two methods.

CHAPTER 3

THE STUDY AREA AND DATA COLLECTION

Introduction

In this chapter covers a brief description of the Ong River Basin at Salebhata gauging station along with the data set required to study erosion and sedimentation in the basin. Application of soil erosion modeling, topography, rainfall, soil type and land use are also discussed briefly in this chapter.

3.1The study area

The study area covers Salebhata gauging station of the Ong catchment in Odisha. It covers four districts in Odisha namely Balangir, Bargarh, Nuapada and Sonpur. The Ong river basin lies between latitude 20˚44ˈ20.56ˈˈN and20˚52ˈ28.21ˈˈN and longitude 82˚34ˈ23.71ˈˈE and 83˚49ˈ10.11ˈˈ E. It is the right bank tributary of the Mahanadi river basin which is situated in the Balangir District of Odisha, India. The total Catchment area of Ong catchment is approximately 5128 sq.km. It flows all across Odisha and joins Mahanadi in Sambalpur 11 km upstream of Sonpur where Tel river is merge. The normal yearly rainfall in the basin is 1,300 mm which varies from 1,600 mm in the east and 900 mm in the west part of the basin. Around 75% of annual rainfall is focused in the four monsoon months of June, July, August and September.

Figure 3.1 shows the location of Ong catchment in Mahanadi basin at Orissa and Chhattisgarh.

Figure 2.2 shows the superposition of Ong catchment on Orissa. The gauging stations are represented in their respective area

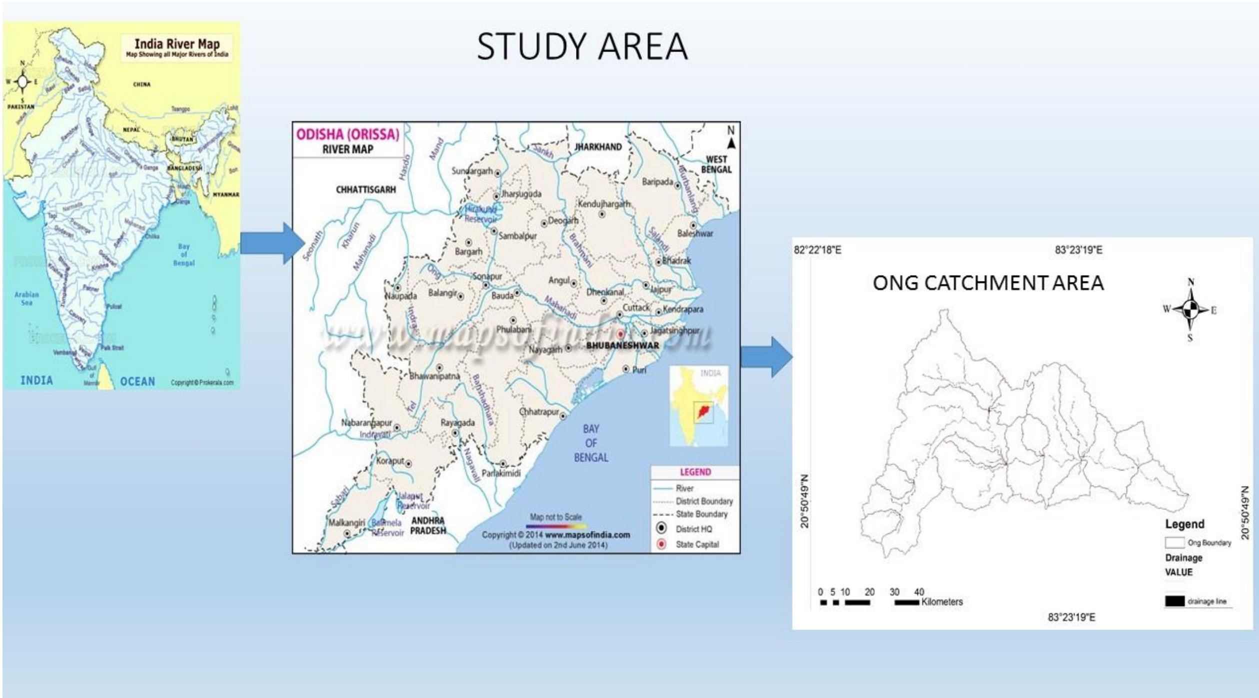

Figure 3.1 present the Location of Study Area

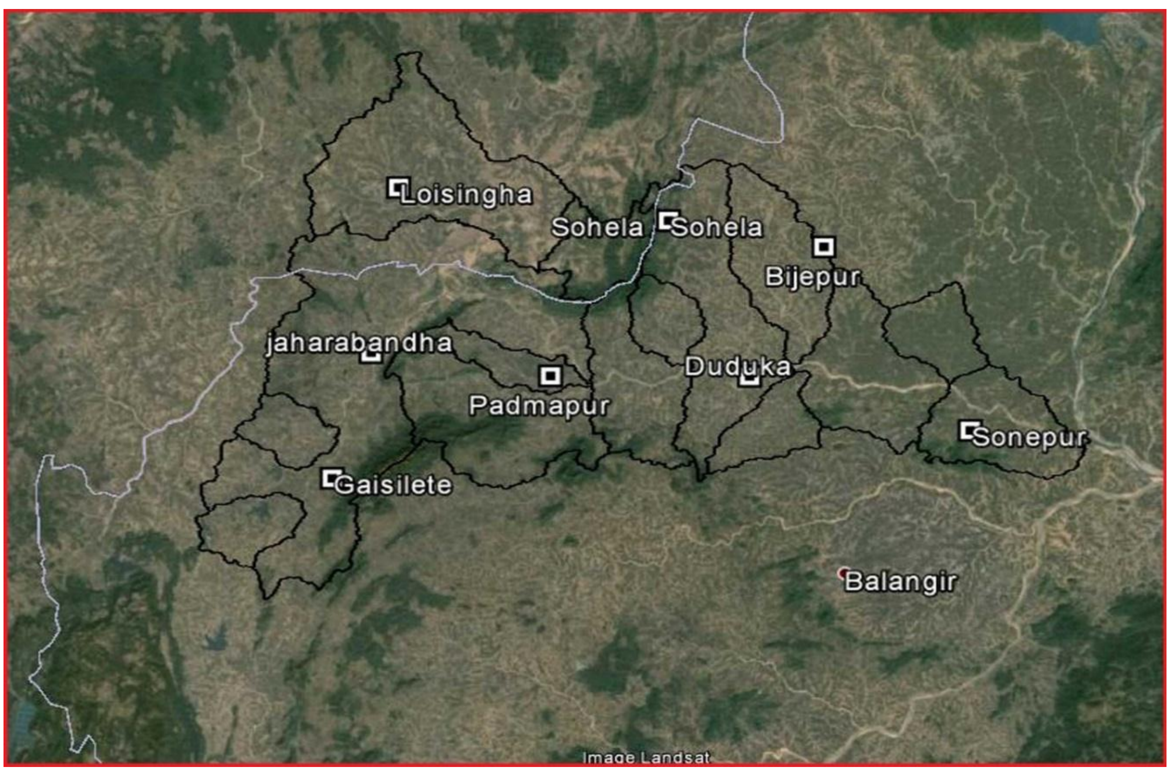

Figure 3.2. Synoptic view of the study area (Source: Google Map)

3.1.1. Topography

The area of the catchment has a mountainous topography. The elevation ranges from 103m to 1005m from mean sea level. So the slope in the area is high. Entire area is covered by undulating hilly tracts. The basin is surrounded by hills from the eastern side.

3.1.2. Land use/land cover

In the catchment area is cover by mostly forested land. About 25.38% of the total geographical area of the district is covered with dense forest. The major forest products of the district are Wood, firewood and sal leaves. While adequate growth is mainly located in the river valleys. Unproductive lands are present in patches. Currently the forest cover is regularly decreasing due to quick extension of mine areas around the basin. The soil in this catchment is mix red soil and black soil.

3.1.3. Agriculture

In this catchment area rice is mainly agricultural crop, in this area adverse climate land used pattern, and variable rainfall and light texture soil, the cropping pattern of the district mainly depend on rainfall.

3.1.4. Soil.

Figure3.4 present the catchment area of the soil can be classified into two groups based on the soil formation namely residual and transported soil. The upper Basin of river is grouped under red gravel, red earth. The central region of river basin goes under mixed red and black loams, whereas the lower basin grouped under red loam lateritic and lateritic soils. The delta region of the catchment is under clay soil. The soil map of India showing the study area is shown in Figure 3.3. Figure 3.3 shows the soil types of different parts India.

Figure 3.4 shows the soil map of Ong catchment derived from the India map by ARC GIS.

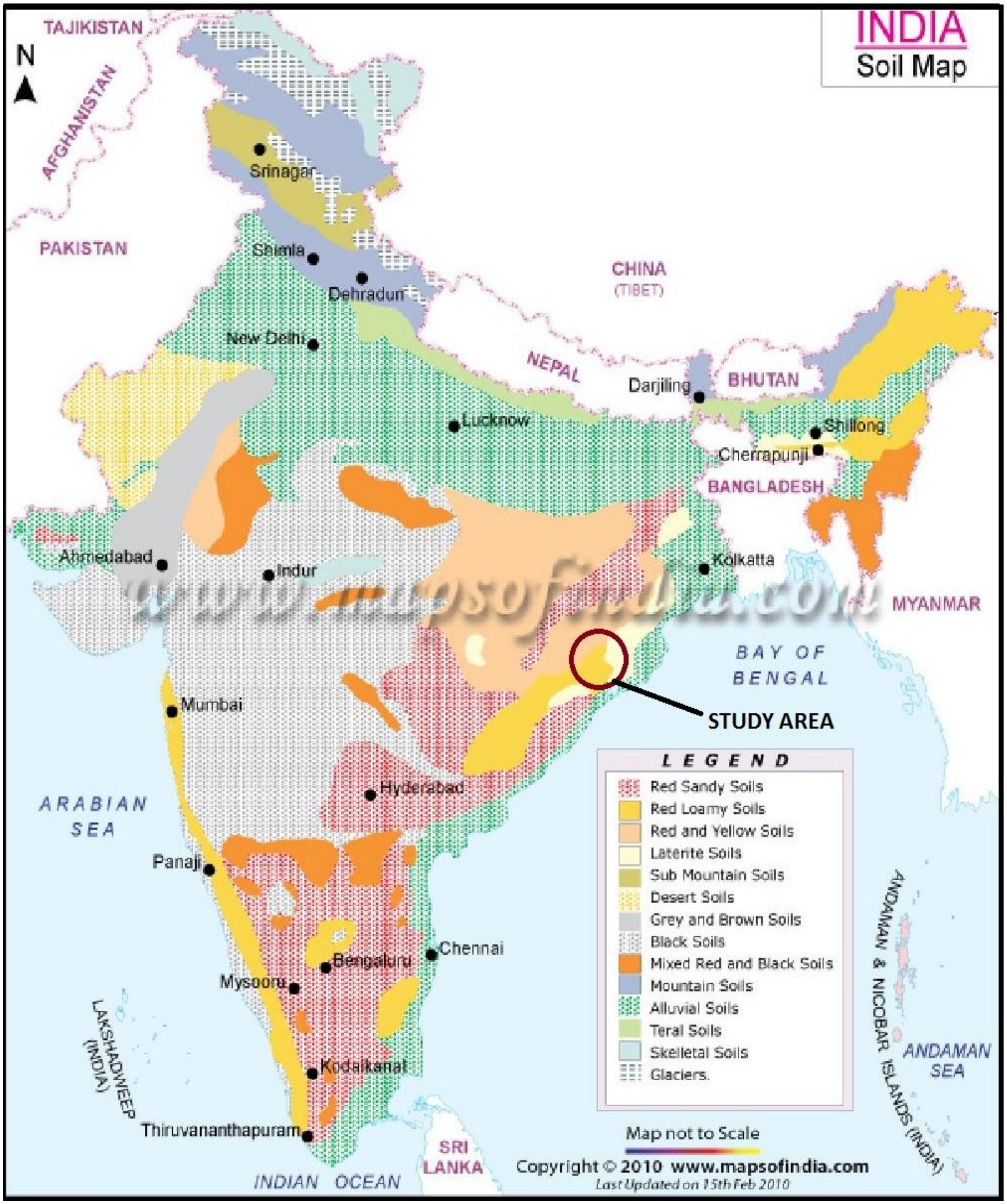

Figure 3.3. Shows Soil map of the study area (Source: www.mapsofindia.com)

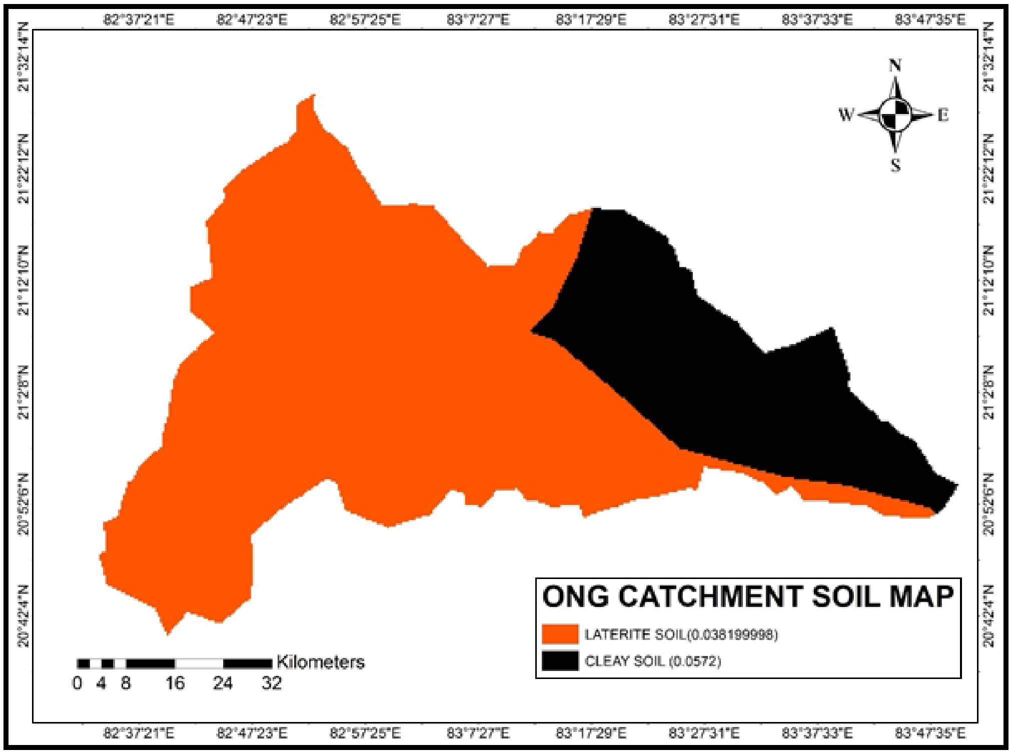

Figure 3.4. Shows Soil map of the Ong catchment area

3.1.5. Industry

In catchment area consisting in four district such as Balangir, Bargarh, Sonepur and Nuapada among which is two districts occupies in an important location in the mineral map of the state. The available minerals are Bauxite, Lime Stone, Manganese, Graphite, Quartz, Galena, Gem Stone dolomite, mica, lead copper, and zinc. Mainly Iron-ore and manganese-ore deposits are available around the study area. Based on these minerals many small and medium industries are established around the study area.

3.1.6. Temperature

The temperature which overcomes in and everywhere the catchment area is tropical. The climate of the area is categorized by tyrannically warm summer with maximum humidity. Temperature begins to increasing quickly achieving the maximum during the month of May. During the summer high temperature up to 42°C. The climate becomes more pleasurable with the advent of the monsoon in June and remains as such up to the end of October. The temperature in the month of December is lowest i.e. around 12°C. Occasionally it even drops down to 6°C.

3.2 Data collection & analysis

3.2.1. Rainfall Data

Monsoon season starts from June to September in Odisha. Average annual rainfall In Catchment area is about 1400mm.Around 80% of the annual rainfall occurs during Monsoon Season. During this season the intensity of rainfall is high. For the present study Daily rainfall data were collected from eight rain gauge stations nearer to the study area which. The eight stations are at Sohela, Bijepur, Gaisilite, Jaharabandha, Padmapur, Duduka, Losingha and Sonepur. Available rainfall data were from June 2000 to September 2010 (Source: Odisha rainfall monitoring system). Figure 3.12 and 3.13 show the daily rainfall of the. From the observed data it is clear that rainfall during January to May is almost zero. During monsoon months the intensity is such high that June of 2010 the rainfall meas. Average rainfall was calculated thiessen-mean or Isohyetal method can be applied over the catchment as not a single rain gauge station present inside the catchment. Table 3.1 presents the location and the available rainfall recorded in years of the rainfall gauge stations in the Ong Catchment, and figure 3.5 shows the rain average rain fall in year of 2000-2010 in different gauging station in the catchment area.

Table 3.1 - Rainfall data in different Gauging Stations in the Ong catchment (source Orissa monitoring system)

STATION	DISTRICTS	Longitude	Latitude	Begin Date	End Date	Country/State	Precipitation mm/ year
Sohela	Bargarh	83.398	21.189	1/1/2000	1/1/2010	India(Odisha)	1400
Bijepur	Bargarh	83.072	21.187	1/1/2000	1/1/2010	India(Odisha)	1500
Gaisilite	Bargarh	83.804	20.189	1/1/2000	1/1/2010	India(Odisha)	1300
Jaharabandh	Bargarh	82.813	21.036	1/1/2000	1/1/2010	India(Odisha)	1500
Padamur	Bargarh	83.071	21.12	1/1/2000	1/1/2010	India(Odisha)	1300
Duduka	Balangir	83.48	20.991	1/1/2000	1/1/2010	India(Odisha)	1400
Losinga	Balangir	83.508	20.877	1/1/2000	1/1/2010	India(Odisha)	1400
Sonepur	Sonepur	83.804	20.933	1/1/2000	1/1/2010	India(Odisha)	1500

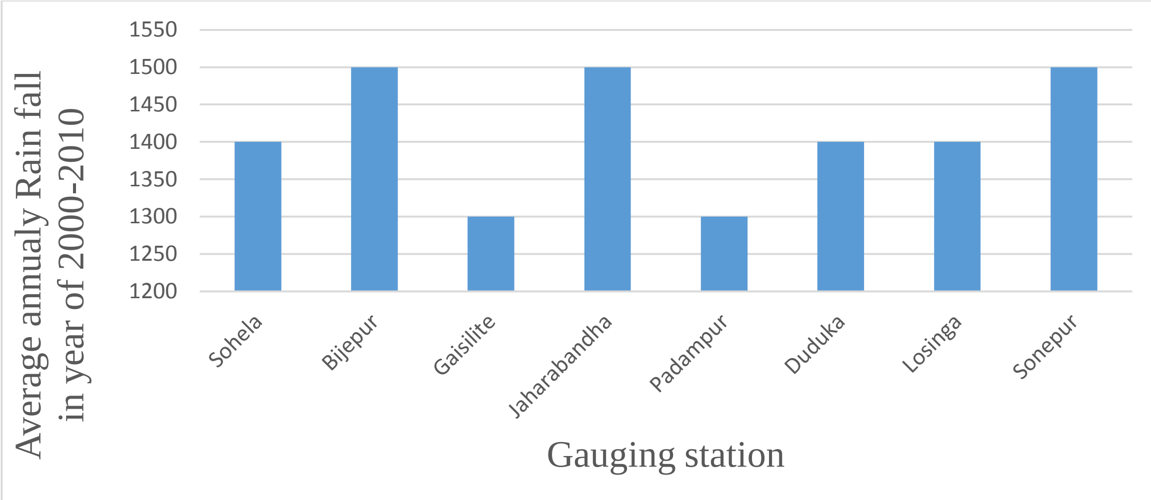

Figure 3.5 shows the Average annual Rain fall in year of 2000-2010

3.2.2. Flow data

Average monthly flow data is collected from INDIA-WRIS version 4.0 on Ong catchment at Salebhata gauging station. From the June to October (2004-2010). Table 3.2 show the monthly discharge data on Salebhata gauging station respectively. From the observed data it is clear that the discharge during August of 2006 .is maximum and January of 2000 is minimum. It is represented in table 3.2 given below

Table 3.2. Average Monthly discharge data

Year/Month	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
2004	88.314	130.32	312.201	42.15	41.46
2005	67.707	120.93	135.02	99.829	27.24
2006	45.55	204.85	1002.25	121.68	12.33
2007	160.69	173.68	97.93	221.056	63.304
2008	150.14	28.18	266.84	422.88	14.11
2009	140.31	575.78	165.11	71.63	26.02
2010	150.04	96.16	106.77	135.9	21.88

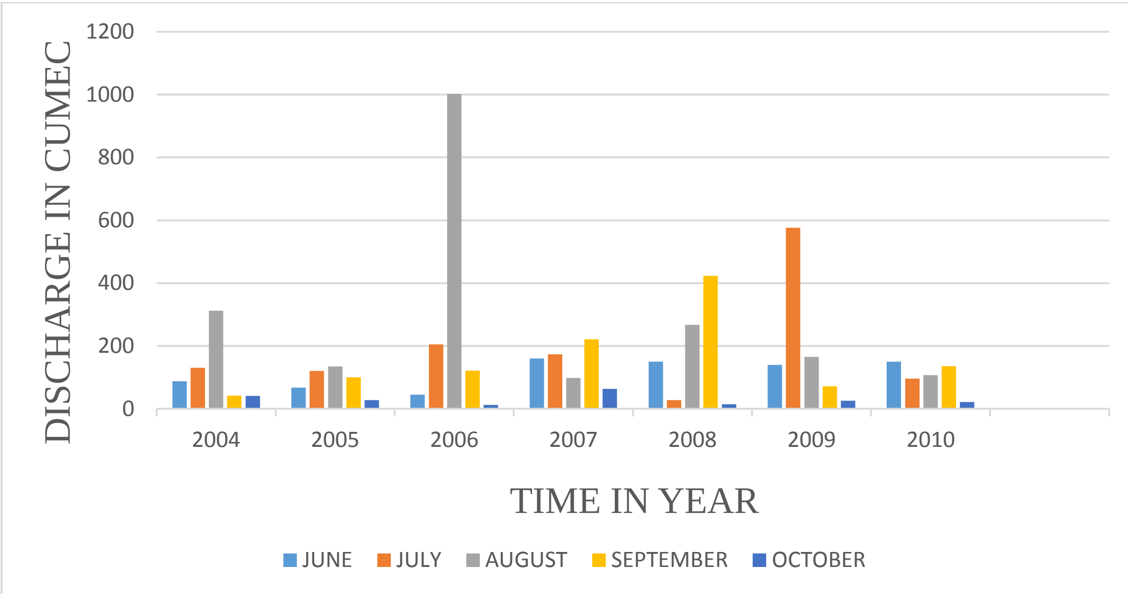

Figure 3.6 shows a graph between discharge and time in year

3.2.3. Sediment Yield Data

The sediment yield data is most important study in Ong catchment .This data is collected from INDIA-WRIS This study estimated sediment yields at proposed gauging station on the Ong catchment. The study was based on annually sediment yield estimated at the salebhata gauging station on Ong catchment. The observed sediment yield data is collected from India-wris during the period 2004 to 2010. Table 3.3 presents sediment yield for the stations located in the Ong catchment. The unit for sediment yield for the catchment is given in ton of sediments per square kilometer of the watershed area per year

Table 3.1 gives sediment yield in tons per year. This value is computed from suspended sediment and discharge observed at the salebhata gauging station

Table 3.3. The sediment yield data at the Salebhata gauging station of the Ong Catchment

YEAR	**SEDIMENT YIELD (ton/year)**
2004	6283.2
2005	6554.32
2006	7344.82
2007	6554.23
2008	5468.58
2009	4828.96
2010	4629.29

The following dataset are used to calculate soil erosion in the Ong catchment:

1. Digital Elevation Model (DEM) (Data source: BHUVAN, cell size: 30 by 30m)
2. Average Annual precipitation data (Data Source: India-wris)
3. Average Annual discharge data (Data Source: india-wris)
4. Land cover types map (Data source: AWIFS)
5. Soil types map (Data source: FAO, vectorized map)
6. Sediment yield reports in the Ong River Basin (Data source: india-wris)

3.2.4. Digital Elevation Model (DEM)

A DEM can be used to classify different basin characteristics such as: drainage area, elevation, slope steepness, slope length, and streams relief ratio. DEM of the Ong catchment produced by the BHUVAN is presented in Figure 3.7, (BHUVAN 2009). The purpose of this data set was to provide a single consistent elevation model to be used for national scale mapping, GIS, remote sensing applications, and natural resources assessment of Ong river basin Odisha.

As seen in the Figure 3.7, topography of the Ong River Basin ranges from 103m to 1005m with an average elevation of 457m. This DEM will be used to compute the slope length and slope steepness factors in USLE model for the purpose of this study.

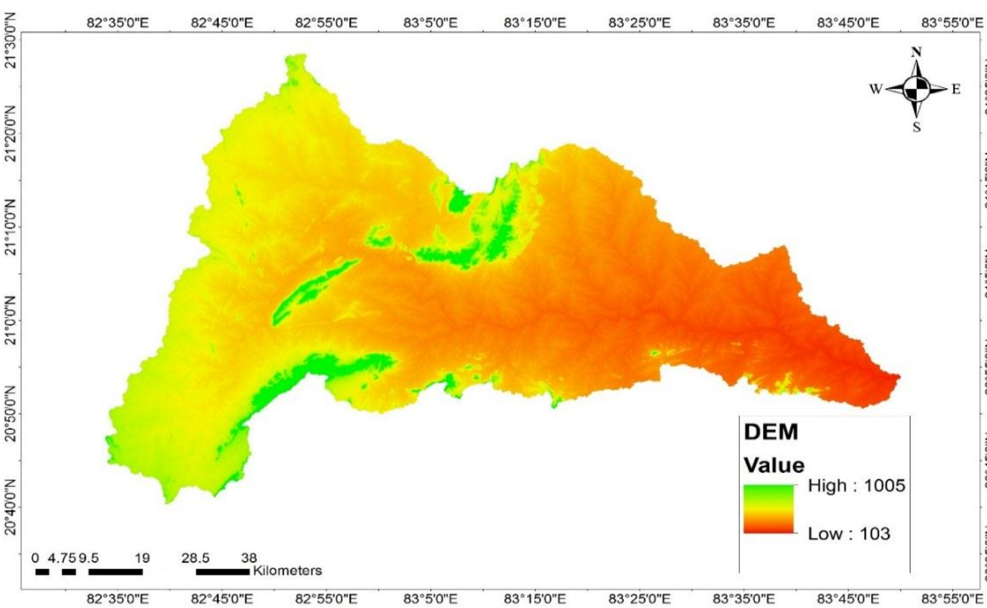

Figure 3.7 the digital elevation model of Ong catchment

3.2.5. Land Cover Map

In this study the land cover map is collected from AWiFs (Advanced wide field sensor) satellite sensor. About 10 to 12 images with 30 m spatial resolution were used for the purpose of classification that included 11 to 12 main land classes with a number of mixed classes and are as follows:

1. Urban Areas
2. Orchards/Fruit Trees,
3. Irrigated Agricultural land,
4. Rain Fed Agricultural Lands,
5. Pistachio Forests
6. Natural Forests,
7. Rangeland, with
8. Barren lands,
9. Marsh/Swamp Areas,
10. Water Bodies
11. Permanent Snow

The developed map by AWiFs is used for the determination of this study. Figure 3.8 represents land cover classification map of the Ong catchment. In this study Land cover valuation and detecting are essential for sustainability of natural resources.

Figure 3.8 shows the land classification of Ong catchment derived by supervised image classification. The areas having all the parameters are classified on the basis of color as presented by NRS (national remote sensing institute)

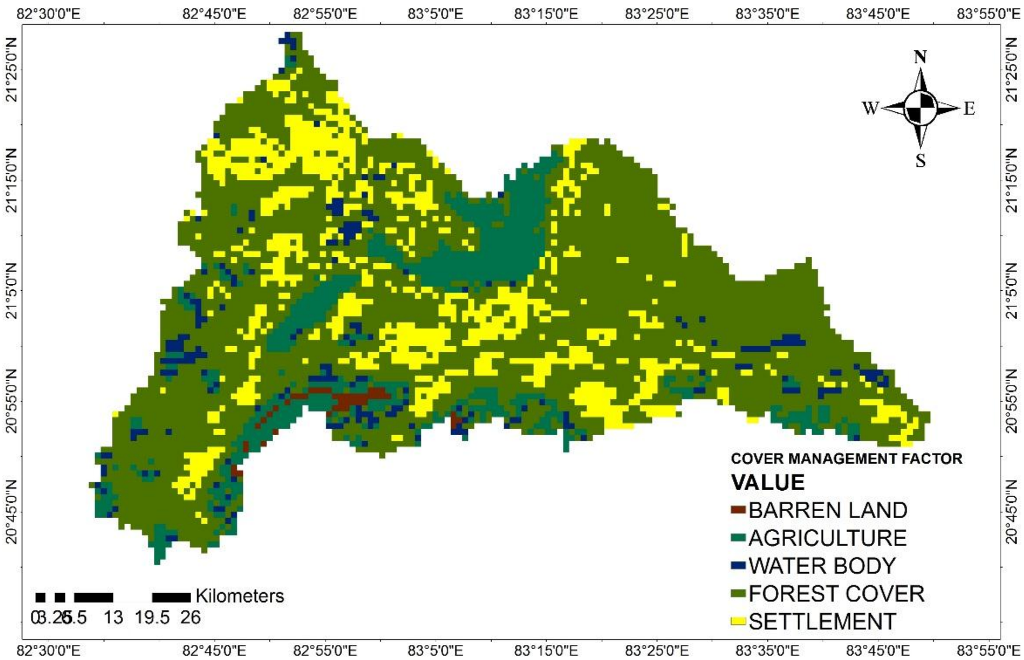

Figure 3.8. Land cover classification map of the Ong catchment

3.3. Summary:

Chapter 3 presents the site description and data sets with topography, average annual rainfall, soil types, land use cover, and sediment yield survey data of the Ong catchment. These data are required to analyze and estimate the Universal Soil Loss Equation- USLE- technique erosion factors. Chapter 4 will present the use of these data. Topography data DEM is used to estimate the slope length (L) and slope steepness (S) factors. Average annual precipitation is used to compute the rainfall-runoff erosivity factors (R). Vectorized soil type map is transformed into raster data with 30m grid cell size to calculate the soil erodibility factor (K). The land cover map, extracted from Landsat Thematic Mapper, is used to predict the cover management factor (C).

CHAPTER 04
METHODOLOGY

Introduction:

This chapter describes the procedure to estimate the annual average soil loss rate using the USLE model. Section 4.1 presents the basic concepts of USLE parameter estimation; Section 4.1.1 through Section 4.1.6 covers the estimation and reasonability analysis of the five parameters used in USLE model. A summary and discussion on the results of the parameters used in soil erosion estimation is shown in section 4.2.

4.1 USLE Parameters:

Initially the USLE (Universal Soil Loss Equation) was developed for soil erosion estimation in croplands on sloping topography (Wischmeier and Smith 1978). Researchers have been involved in soil erosion examination for a long time and many models for soil erosion loss estimation have been developed (Wischmeier and Smith 1978; Nearing et al. 1989; Veihe et al. 2001; Shen et al. 2003). However in practice, the Universal Soil Loss Equation (USLE), Modified Universal Soil Loss equation (MUSLE) later the Revised Universal Soil Loss Equation (RUSLE) are the most common model used for predicting soil erosion loss at different situations including forest, rangeland and disturbed areas (Renard et al. 1997).

Exact amount of soil loss is not possible for each variable under field conditions. Hence soil-loss equations were developed to allow conservation planners, environmental researchers and others concerned with soil erosion to extrapolate the limited erosion data to many localities and conditions that have not been directly represented in the research (Morgan 2011).

Soil erosion caused by impact of raindrop and surface runoff (Renard et al. 1997). It has been widely used to estimate soil erosion loss, assess soil erosion risk, guide development and conservation plans in order to control erosion under different land-cover conditions (Millward and Mersey1999; Boggs et al. 2001; Mati and Veihe 2001; Angima et al. 2003). The underlying assumption in the USLE is that detachment and deposition are controlled by the sediment content of the flow. The erosion process is not cause limited; however, it is limited by the transport capacity of the flow. When the sediment load reaches the transport capacity of the flow, detachment can no longer happen. Both USLE, MUSLE and RUSLE estimate the average annual erosion .But here the USLE equation is used as shown in equation 4.1.

$$A= R * K *L *S *C * P \quad \text{(Eq-1)}$$

Where

A = calculated average annual soil loss predicted and temporal average soil loss per unit of area. A is expressed in unit tons/ (acre× yr.), but other units can be selected (that is, tons / (ha× yr.))

R= Rainfall-runoff erosivity factor (MJ mm ha^{-1} hr^{-1});

Erosivity factor is determined by both rainfall and the energy imparted to the land surface by the rain drop effect.

K = Soil erodibility factor: It is defined as soil loss per unit of area for unit plot.

L = Slope length factor: It is the ratio of soil loss from field slope length to that from 22.13 m length plot under identical conditions.

S = Slope steepness factor: It is the ratio of soil loss from the field slope gradient to that from 9 % slope under otherwise identical conditions

C = Cover management factor : It is the expected ratio of soil loss from land cropped under specified conditions to soil loss from clean, tilled fallow or identical soil and slope and under the same rainfall.

P = Support practice factor: It is expressed as a ratio, which compares the soil loss from investigated plot cultivated up and down the slope. P ranges from 1.0 for up and down cultivation to 0.25 for contour strip cropping of gentle slope.

L and S factors are dimensionless parameters which represent the impact of topographic effects on soil erosion rates. C and P factors stand for dimensionless impacts of cropping and management systems on soil erosion control practices.

4.1.1 Rainfall-Runoff Erosivity Factor (R)

Rainfall erosivity is a statistical description of the possible of rainfall to erode soil (Wischmeier 1960) and is one of the key input parameters for USLE modeling. Rainfall erosivity (R factor) is defined as the long-term average product of the total rainfall energy (E30) and the maximum 30 min rainfall intensity for storm events (Wischmeier and Smith 1978; Renard et al., 1997). Generally we used monthly, seasonal and annual rainfall data to estimate the R_factor. Rainfall erosivity estimation using rainfall data for different rain gauge station in Ong river basin such as Padmapur, Jharabandha, Bijepur, Duduka, Loishinga, Sonepur, Gaisilete, Sohela. We using the rainfall data for from different rain gauge stations located in different zones, Using this data to established linear relationships between average annual rainfall and computed EI30 values for different zones of India and iso-erodent maps were drawn for annual and seasonal EI30 values (Ram Babu et al. 2004). Following equation was developed for Damodar valley area, in Jharkhand, India by Ram Babu et al. (Jain et al 2004).But the lower Mahanadi river basin, Odisha is near to damodar valley so that in generally to use in this equation in this present study

$R = 81.5 + 0.38R_N\ (340 \leq R_N \leq 3500\ \text{mm})$ …. …………………………. (Eq-2)

Where R_N is the average annual rainfall in mm. For the present study, Eq. 2 is used to calculate annual values of R-factor by replacing R_N with actual observed annual rainfall in a year. Renard and Freimund (1994) estimated (R) factor were used as a data point in the basin. To each data point needs spatial interpolation along the basin to make the same grid cell size as the other thematic maps like DEM, Soil type map, Land use map and Topographic map. Hence, the average annual precipitation and R factor for each data point were inserted into ArcGIS and spatially interpolated using the Ordinary Kriging method found in the ArcGIS Spatial Analyst toolbox. Kriging is a common technique used by students in many studies around the world to interpolate between the available data points. The technique is based on numerical models that include autocorrelation- that is, numerical relationships between the measured data points. As a result, geostatistical techniques are not only capable of producing an estimate surface but they also provide some measure of the certainty or accuracy of the predictions. Figure 4.1 present thiessen polygon maps of the Ong Catchment. The catchment boundaries and rain gauge station are shown with the help of boundary lines and points.

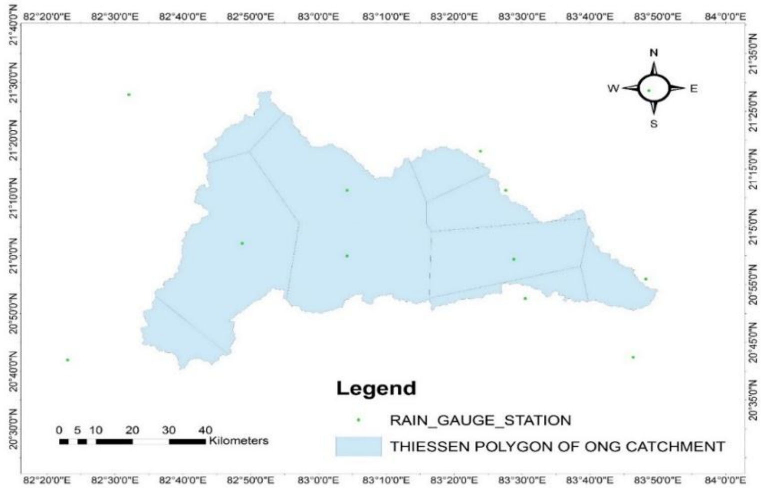

Figure 4.1 – Rainfall (Thiessen polygon) map of the Ong Catchment

4.1.2 Soil Erodibility Factor (K):

Soil erodibility factor (K) is associated to the combined effect of rainfall, runoff, and infiltration on soil loss. This factor accounts for the effects of soil properties on soil loss during storm events on upland areas (Renard et al. 1997). In practical sense, K is a lumped parameter representing an integrated relationship between annual average erosion, profile reaction to erosion, and hydrological processes. For a particular soil, the soil erodibility factor is the rate of erosion per unit erosion index obtained from a unit plot and is small enough to be removed by normal tillage operation.

These are the following method to find out the soil erodibility factor (K):

At first soil map of world was downloaded from the digital soil map of the world food and agriculture organization (FAO) of the United Nations Version 3.6, completed January 2003. The soil map of the world is in polygon shape and has all the soil data in its attributes table. By using shape file of the catchment of Ong basin attributes from the world map was extracted by using clipping tool of ARC GIS. Using the FAO soil data value was assigned for the respective soil. Based on that value the polygon file of Ong catchment is converted into raster image.

The soil erodibility factor (K) ranges in value from 0.02 to 0.69 (Goldman, Jackson, and Bursztynsky 1986). Soils with high clay content have low K values, about 0.05 to 0.15, which is mainly due to their resistance to detachment. Texture is the main factor affecting the K values. Courser texture soils, such as sandy soils, have low K values that range from 0.05 to 0.2. It is due to low surface runoff caused by excessive infiltration even though these soils are easily detached.

In case of slit loam soil such as medium texture soils, have moderate K values which typically range from 0.25 to 0.4. It is due to their moderate susceptibility to detachment and moderate runoff. In this study Soils having maximum silt content are most erodible of all soils. They are easily separate, tend to crust and produce high rates of runoff. K values for these type of soils tend to be greater than 0.4. Organic matter content decreases erodibility, reduce susceptibility of the soil to detachment, and increases infiltration rates, which in turn decreases runoff and erosion. Figure 4.2 represents the nomograph used to determine K factors based on the soil texture, percentage of silt plus very fine sand (0.002-0.1mm), percentage of sand (0.1-2mm), percentage organic matter, soil structure and permeability.

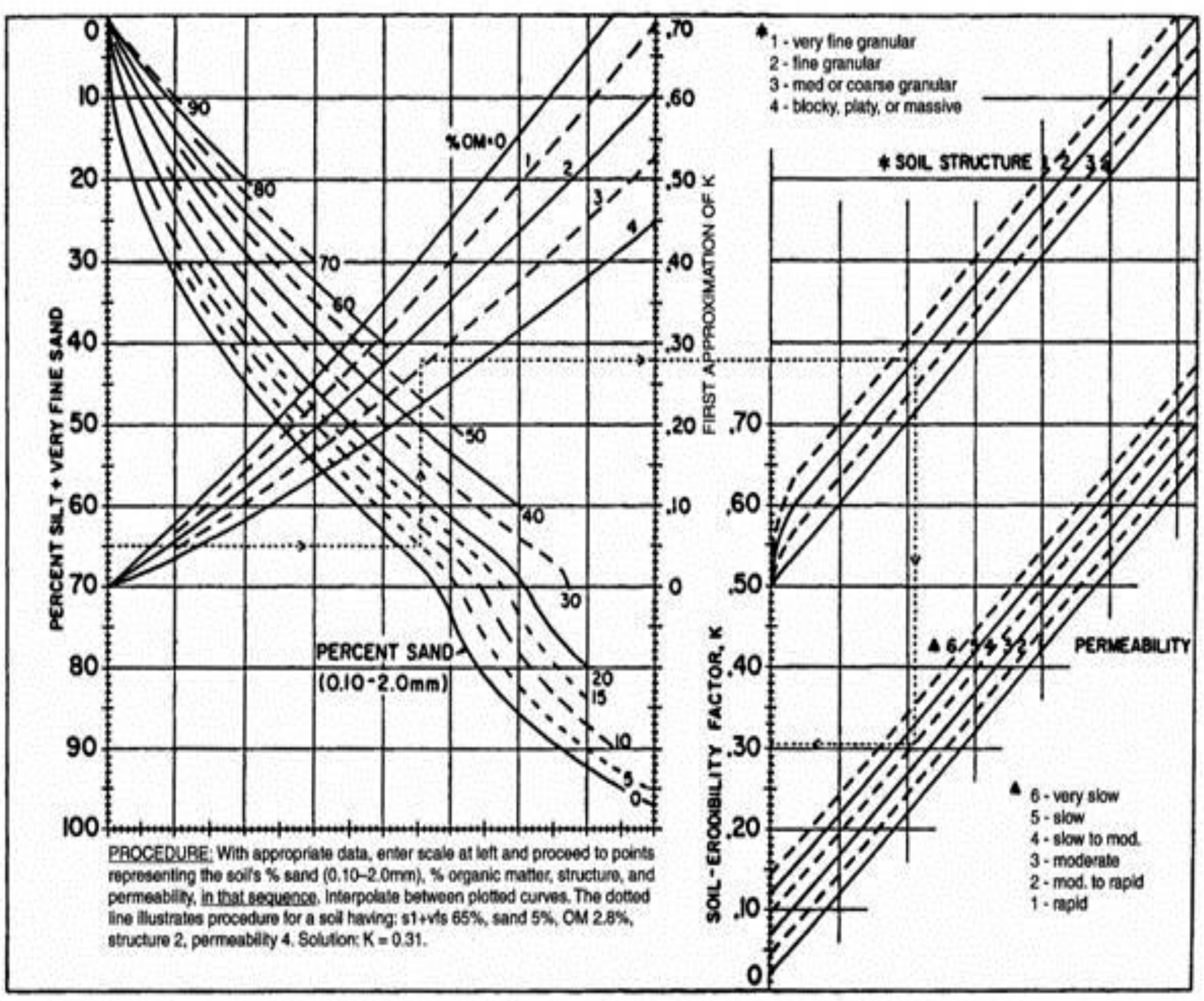

Figure 4.2 – Soil Erodibility Nomograph (after Wischmeier and Smith 1978).

4.1.3 Slope Length and Slope Steepness Factor (LS)

The result of topography on soil erosion is accounted for by the LS factor in USLE, which combines the effects of a slope length factor (L) and a slope steepness factor (S). It is know that an increase in the slope length (L) will results in increase in soil erosion per unit area due to the increasing in accumulation of surface runoff on downslope direction. As the slope steepness (S) increases, the velocity and soil erosion of surface runoff also increases.

Slope length (L) is defined as the horizontal distance from the origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff becomes concentrated in a defined channel (Wischmeier and Smith 1978). Slope length (L) is also quantified as the ratio of soil loss from the field slope length to soil loss from a 22.3m long plot under identical conditions.

These are the following procedure to calculate the LS factor:

At first the Dem of the catchment area was downloaded from catrosat1 section in Bhuvan store. Then exact catchment area was extracted from the data by using Ong shape file. Then degree slope was calculated using surface tool in spatial analysis. Flow direction and flow accumulation was found out form the DEM by using hydrology tool box under spatial analyst section. Then final LS value was obtained by using this expression [LS= power (“flow accu”* cell size/22.1, 0.4) *power (sin (“slope_deg”*0.01745)/0.09, 1.4)*1.4] in raster calculator under map algebra in spatial analyst tool box. The final LS value is obtained by dividing old LS value by 100. The range should be within 0 to 90. Figure 4.3 gives a brief idea about procedure for computing LS factor in ARC GIS.

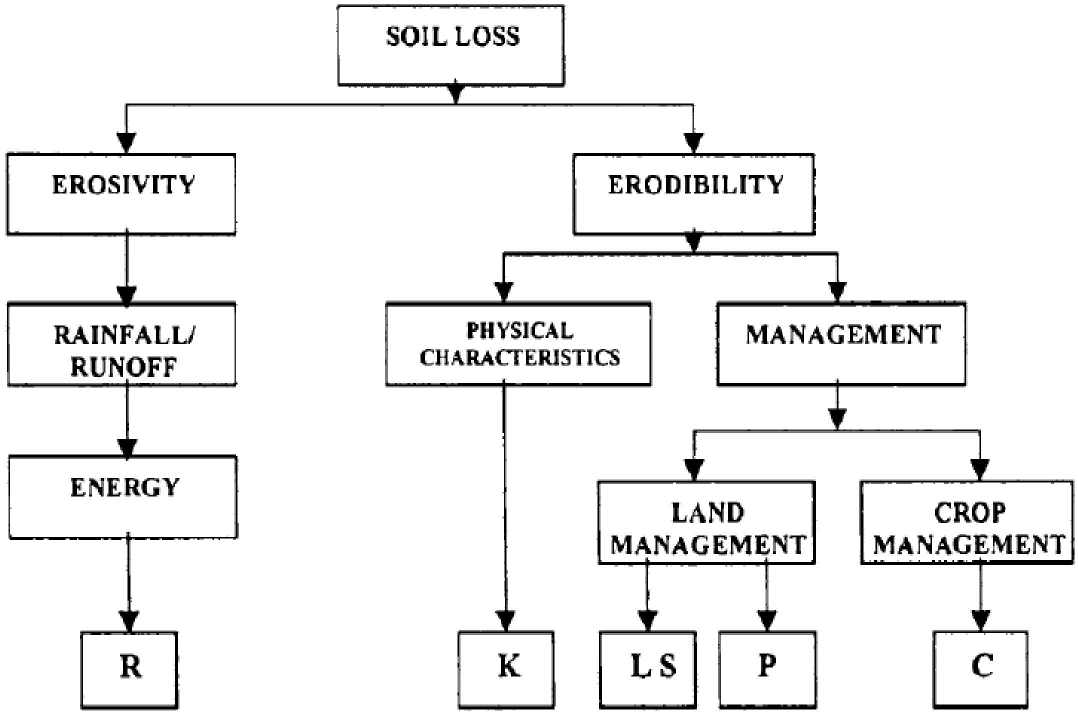

Figure 4.3 shows the schematic representation of USLE components

4.1.4 Cover Management Factor (C)

The Cover Management Factor (C) shows the effect of vegetation cover, cropping and management practices on soil erosion rates. It is defined as the ratio of soil loss from a particular site with a specified cover and management to soil loss from the standard unit plot mentioned in early chapters

Cover management factor (C) factor estimates for different vegetation types and soil prevention methods are significant because they can be used to estimate the extent of soil loss that can be decreases by proper management practices and all possible mitigation measures and the estimated costs of implementation can be considered without actually carrying out the action.

The quantity of protective cover of crops or vegetation for the land surface influences the soil erosion rates. The cover management factor (C) value is 1 when the land has continuous bare fallow with no vegetation coverage (standard plot condition) and it is lower when there is more vegetation or crop cover resulting in lower amount of soil erosion. For dense and mature forests, where the trees cover and undergrowth vegetation covers between 75 to 100% of the surface area, the C value is almost 0.001 and there is no necessity for soil conservationists to take any erosion prevention actions.

These are the following procedure to calculate the cover management factor (C).

At first the 3 bands from AWiFs Advanced wide field sensor (collected from Bhuvan) was converted into composite band using image analysis tool. The raster image was extracted by mask from the composite image. Then sample color for each file was obtained by using image classification tool. Similar color sample file was merged and names were assigned to different sample file and a signature file was made. Supervised image classification was carried out using maximum likelihood classification in image classification tool. Then the classified raster image was converted into polygon file. Then the attributes having same grid code was merged using editor tool. After merging all the polygons having same grid code values were assigned to these grid codes. Area and perimeter were calculated for these polygons. Based on these assigned values the polygon file was again converted into raster image. The value of c factor must varies from -1 to 1

4.1.5 Support Practice Factor (p)

Support Practice Factor (P) in USLE model is account for the ratio of soil loss with a specific support practice to corresponding soil loss with upslope and downslope tillage. These practices essentially effect erosion by adjusting the flow pattern, steepness, or direction of surface runoff and by decreasing the amount and rate of runoff. The support practice factor (p) for the cultivable lands are: contouring, strip-cropping, terracing, and subsurface drainage. Whereas for dry land or rangeland area, the support practice factors are soil disturbing practices to result storage of moisture and reduction of runoff.

Support Practice Factor (P) is ranged from 0 to 1. It is equivalent to 1 when the land is directly cultivated on the slope and less than 1 when the adopted conservation practice reduces soil erosion. Terracing and contouring are common and effective support practices on the field level. The effects of terracing are reflected in the hill slope length and gradient, because it reduces the length of the hill slope. Contouring changes the flow direction and cause runoff to flow around the hill slope rather than directly downslope.

These are the following procedure to calculate the (P) factor:

At first the Dem of the catchment area was downloaded from catrosat1 section in Bhuvan store. Then exact catchment area was extracted from the DEM by using Ong shape file. Then percentage slope was calculated using surface tool in spatial analysis. Then again reclassification of that slope map was done basis of contouring or strip cropping and interval value was assigned according to shin (1999). Then after reclassification of the raster image, it was converted into polygon file. In the attribute table of the shape file the polygon having same grid code are merged. After merging all the polygon having same grid code values were assigned depending upon the interval taken. Based on these values the polygon file was converted into raster image

Table 4.1 diagram present how to applying the USLE factors within ArcGIS software. The table indicates which data were used to create the USLE parameters and how the annual average soil loss map was generated.

4.2 Summary

Chapter 4 presents the methodology used to estimate the USLE parameters. USLE has six parameters, which are rainfall-runoff erosivity (R), soil erodibility (K), slope length and slope steepness (LS), cover management (C), and support practice factor (P). All the parameters are computed in raster image having identical pixel size, linear and angular units. Then those images are multiplied in raster calculator for obtaining annual sediment yield in tons per pixel.

CHAPTER 05

RESULTS & DISCUSSION

Introduction

In this chapter**,** annual average soil loss rate distribution of the Ong catchment is found out. The erosion prone area of the catchment due to deforestation and irregular rainfall distribution is discussed in this section 5.1.The basic concept of the sediment yield with its comparative analysis will be covered in this Section.

5.1 USLE Parameters Estimation

These are the following parameters of USLE such as

1. Rainfall-runoff erosivity factor(R):
2. Soil Erodibility Factor (K):
3. Slope Length and Slope Steepness Factor (LS):
4. Cover Management Factor (C):
5. Support practice factor (P)

5.1.1 Rainfall-runoff erosivity factor(R)

Rainfall erosivity (R factor) is defined as the long-term average product of the total rainfall energy (E30) and the maximum 30 min rainfall intensity (I) for storm events (Wischmeier and Smith 1978; Renard et al., 1997. Following equation was developed Damodar valley area in Jharkhand India by Ram Babu et al. (Jain et al 2004) and in this equation is used in the present study due to the lower Mahanadi river basin, Odisha, India is nearer to Jharkhand

$R = 81.5 + 0.38R_N\ (340 \leq R_N \leq 3500\ \text{mm})$ …. ……………………………………. (Eq-2)

Where R_N is the average annual rainfall in mm. For the present study, Eq. 2 is used to compute annual values of R-factor by replacing R_N with actual observed annual rainfall in a year.

To calculate the R factor using Arc GIS, the area of the catchment is divided into eight region on the basis of thiessen polygon. Then for those eight gauging station present on these region annual rain fall summation value is computed. Then rain fall erosivity factor is calculated by using the above equation in field calculator present in the attribute table of the polygon file in arc GIS.

In the table 5.1.1 rain fall erosivity factor is represented for eight gauging station. These factor is computed from different rainfall data for these eight gauging station. It is observed that rainfall erosivity factor is maximum in sohela of balangir district and lowest in sonepur.
Figure 5.1.1 Represent rainfall erosivity factor calculated for Ong catchment area using ARC GIS. The color code ranges from grey (low rainfall erosivity factor) to light brown (high erosivity factor). The region having same color has same erosivity factor. In this figure Padamapur, duduka, Jharbandha have same erosivity factor.

Table 5.1.1 – Rainfall-runoff erosivity factor (2004)

SLNO-	STATION NAME	DISTRICT	R_FACTOR (MJ mm ha^{-1} hr^{-1})
1	Jharbandha	Baragarh	551.94
2	Sonepur	Sonepur	418.72
3	Sohela	Balangir	643.406
4	Padamapur	Baragarh	551.94
5	Bijepur	Baragarh	605.23
6	Gaisilite	Baragarh	580.35
7	Loisingha	Balangir	449.72
8	Duduka	Balangir	551.94

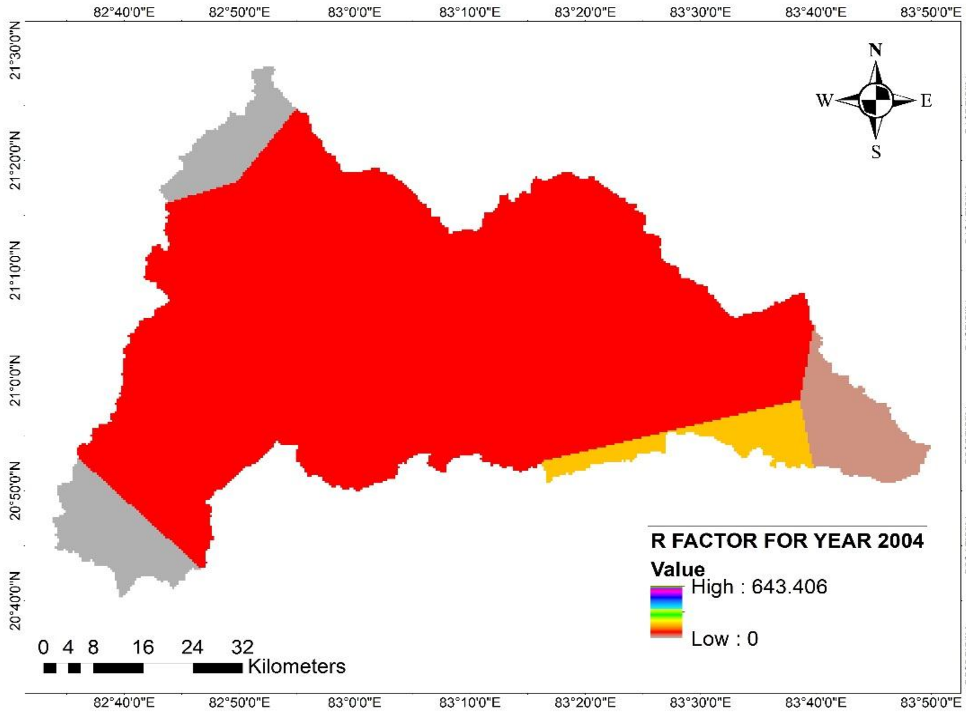

Fig 5.1.1 Rainfall-runoff erosivity factor (R) for 2004

In the table 5.1.2 rain fall erosivity factor is represented for eight gauging station. These factor is computed from different rainfall data for these eight gauging station. It is observed that rainfall erosivity factor is maximum in Bijepur of Bargarh district and lowest in duduka in balangir district.

Figure 5.1.2 Represent rainfall erosivity factor calculated for Ong catchment area using ARC GIS. The color code ranges from grey (low rainfall erosivity factor) to light brown (high erosivity factor). The region having same color has same erosivity factor. In this figure duduka and sonepur have same erosivity factor.

Table 5.1.2 – Rainfall-runoff erosivity factor (2005)

SLNO-	STATION NAME	DISTRICT	R_FACTOR
1	Jharbandha	Baragarh	643.406
2	Sonepur	Sonepur	380.94
3	Sohela	Balangir	643.406
4	Padamapur	Baragarh	705.15
5	Bijepur	Baragarh	698.23
6	Gaisilite	Baragarh	657.23
7	Loisingha	Balangir	420.09
8	Duduka	Balangir	380.94

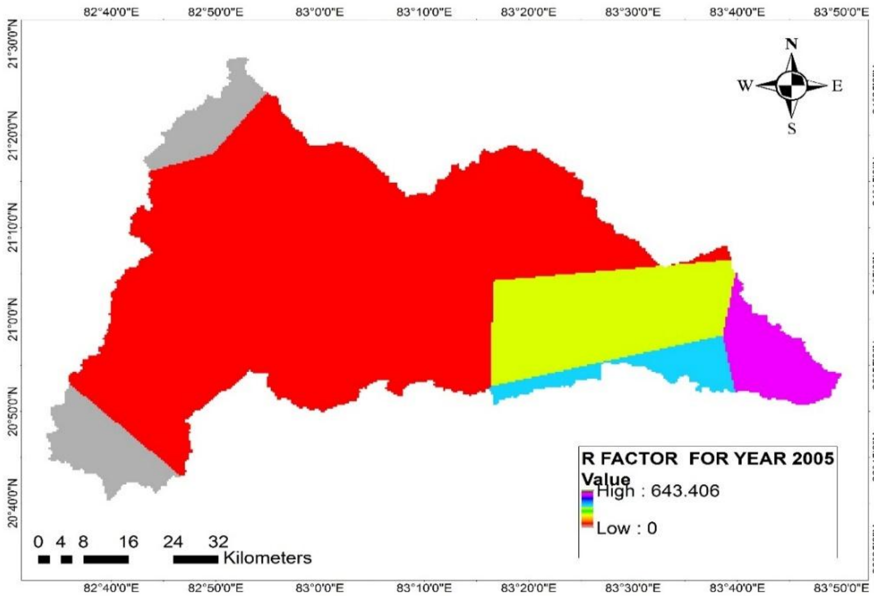

Fig 5.1.2 Rainfall-runoff erosivity factor (R) for 2005

In the table 5.1.3 rain fall erosivity factor is represented for eight gauging station. These factor is computed from different rainfall data for these eight gauging station. It is observed that rainfall erosivity factor is maximum in sonepur district and lowest in duduka in balangir district.

Figure 5.1.3 Represent rainfall erosivity factor calculated for Ong catchment area using ARC GIS. The color code ranges from grey (low rainfall erosivity factor) to light brown (high erosivity factor). The region having same color has same erosivity factor. In this figure sohela and Padmapur have same erosivity factor.

Table 5.1.3 – Rainfall-runoff erosivity factor (2006)

SLNO-	STATION NAME	DISTRICT	R_FACTOR
1	Jharbandha	Baragarh	728.078
2	Sonepur	Sonepur	889.266
3	Sohela	Balangir	721.078
4	Padamapur	Baragarh	721.078
5	Bijepur	Baragarh	808.201
6	Gaisilite	Baragarh	709.25
7	Loisingha	Balangir	420.09
8	Duduka	Balangir	740.34

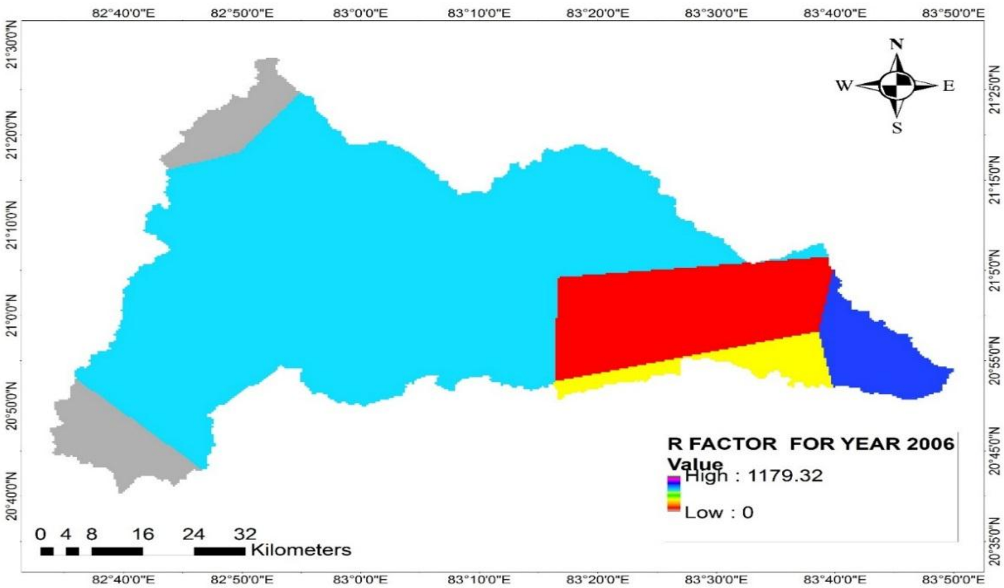

Fig 5.1.3 Rainfall-runoff erosivity factor (R) for 2006

In the table 5.1.4 rainfall erosivity factor is represented for eight gauging station. These factor is computed from different rainfall data for these eight gauging station. It is observed that rainfall erosivity factor is maximum in duduka and lowest in Jharbandha.

Figure 5.1.4Represent rainfall erosivity factor calculated for Ong catchment area using ARC GIS. The color code ranges from grey (low rainfall erosivity factor) to light brown (high erosivity factor). The region having same color has same erosivity factor. In this figure sohela and sonepur have same erosivity factor.

Table 5.1.4 – Rainfall-runoff erosivity factor (2007)

SLNO-	STATION NAME	DISTRICT	R_FACTOR
1	Jharbandha	Baragarh	608.56
2	Sonepur	Sonepur	650.56
3	Sohela	Balangir	650.56
4	Padamapur	Baragarh	708.56
5	Bijepur	Baragarh	730.56
6	Gaisilite	Baragarh	858.22
7	Loisingha	Balangir	732.18
8	Duduka	Balangir	915.22

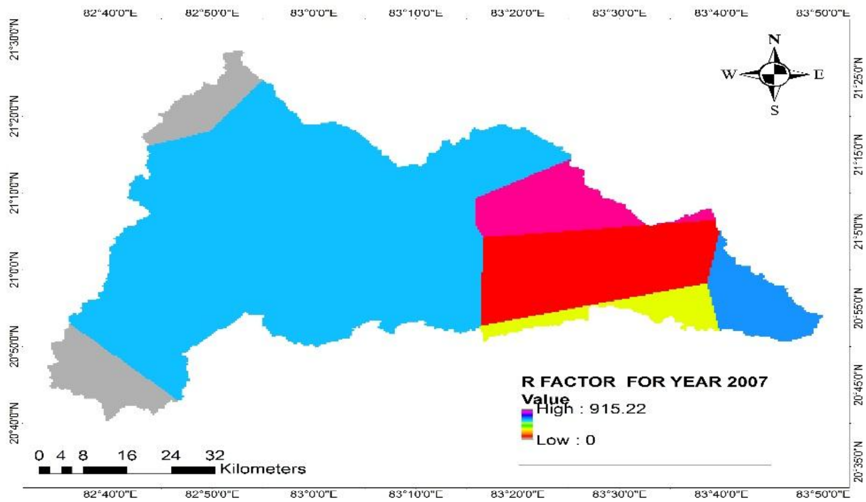

Fig 5.1.4 Rainfall-runoff erosivity factor (R) map for 2007

In the table 5.1.5 rainfall erosivity factor is represented for eight gauging station. These factor is computed from different rainfall data for these eight gauging station. It is observed that rainfall erosivity factor is maximum in duduka and lowest in Jharbandha.

Figure 5.1.5 Represent rainfall erosivity factor calculated for Ong catchment area using ARC GIS. The color code ranges from grey (low rainfall erosivity factor) to light brown (high erosivity factor). The region having same color has same erosivity factor. Here all the regions have different erosivity factor

Table 5.1.5 – Rainfall-runoff erosivity factor (2008)

SLNO-	STATION NAME	DISTRICT	R_FACTOR
1	Jharbandha	Baragarh	496.84
2	Sonepur	Sonepur	524.58
3	Sohela	Balangir	724.08
4	Padamapur	Baragarh	557.64
5	Bijepur	Baragarh	604.76
6	Gaisilite	Baragarh	858.22
7	Loisingha	Balangir	677.22
8	Duduka	Balangir	940.3

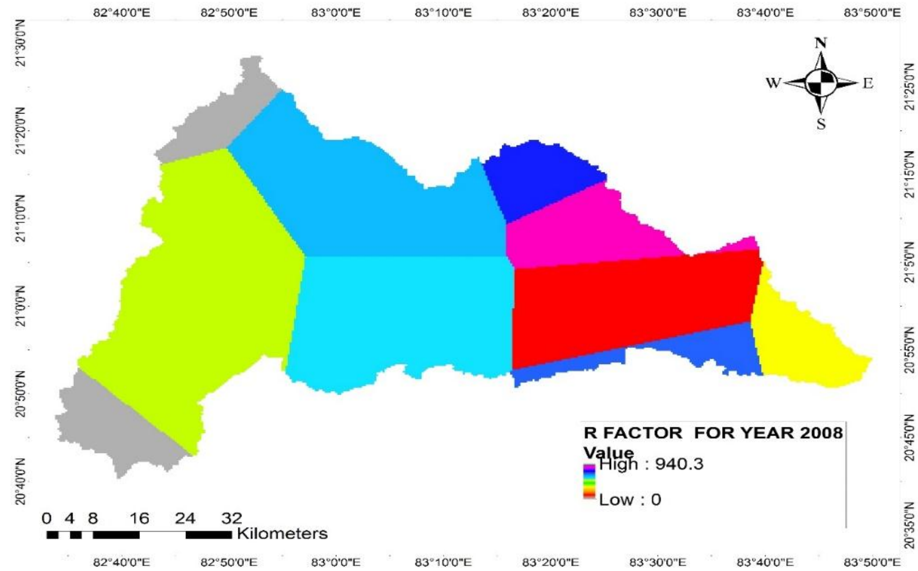

Fig 5.1.5 Rainfall-runoff erosivity factor (R) map for 2008

In the table 5.1.6 rain fall erosivity factor is represented for eight gauging station. These factor is computed from different rainfall data for these eight gauging station. It is observed that rainfall erosivity factor is maximum in duduka and lowest in Loisingha.

Figure 5.1.6 Represent rainfall erosivity factor calculated for Ong catchment area using ARC GIS. The color code ranges from grey (low rainfall erosivity factor) to light brown (high erosivity factor). The region having same color has same erosivity factor. Here all the regions have different erosivity factor

Table 5.1.6 – Rainfall-runoff erosivity factor (2009)

SLNO-	STATION NAME	DISTRICT	R_FACTOR
1	Jharbandha	Baragarh	504.82
2	Sonepur	Sonepur	638.58
3	Sohela	Balangir	601.72
4	Padamapur	Baragarh	615.78
5	Bijepur	Baragarh	514.32
6	Gaisilite	Baragarh	592.98
7	Loisingha	Balangir	497.6
8	Duduka	Balangir	852.52

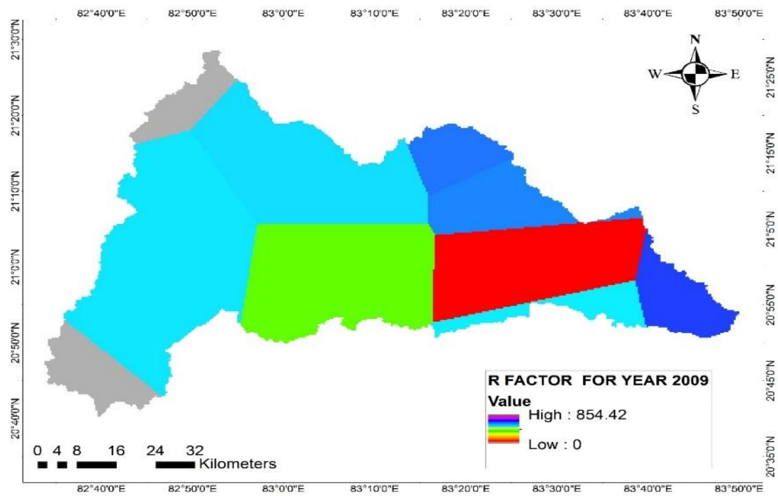

Fig 5.1.6 Rainfall-runoff erosivity factor (R) map for 2009

In the table 5.1.7 rain fall erosivity factor is represented for eight gauging station. These factor is computed from different rainfall data for these eight gauging station. It is observed that rainfall erosivity factor is maximum in Padmapur and lowest in Loisingha.

Figure 5.1.7 Represent rainfall erosivity factor calculated for Ong catchment area using ARC GIS. The color code ranges from grey (low rainfall erosivity factor) to light brown (high erosivity factor). The region having same color has same erosivity factor. Here all the regions have different erosivity factor

Table 5.1.7 – Rainfall-runoff erosivity factor (2010)

SLNO-	STATION NAME	DISTRICT	R_FACTOR
1	Jharbandha	Baragarh	354.43
2	Sonepur	Sonepur	491.14
3	Sohela	Balangir	475.32
4	Padamapur	Baragarh	518.88
5	Bijepur	Baragarh	505.96
6	Gaisilite	Baragarh	479.36
7	Loisingha	Balangir	321.66
8	Duduka	Balangir	470.734

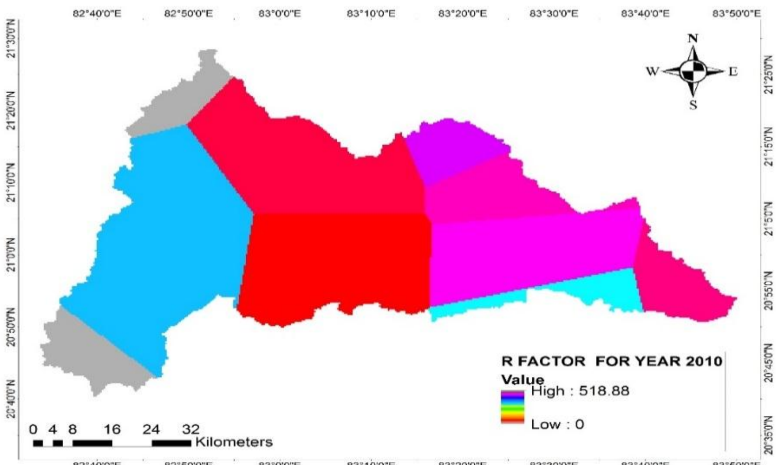

Fig 5.1.7 Rainfall-runoff erosivity factor (R) map for 2010

5.2 Soil Erodibility Factor (K):

Soil erodibility factor (K) is associated to the combined effect of rainfall, runoff, and infiltration on soil loss. This factor accounts for the effects of soil properties on soil loss during storm events on upland areas (Renard et al. 1997).

Fig- 5.2. presents the results of K values in the Ong River Basin. These values range from 0.038 for the red or laterite soil land to 0.057 gives the clay soil for the catchment area (Jain et al.2009)

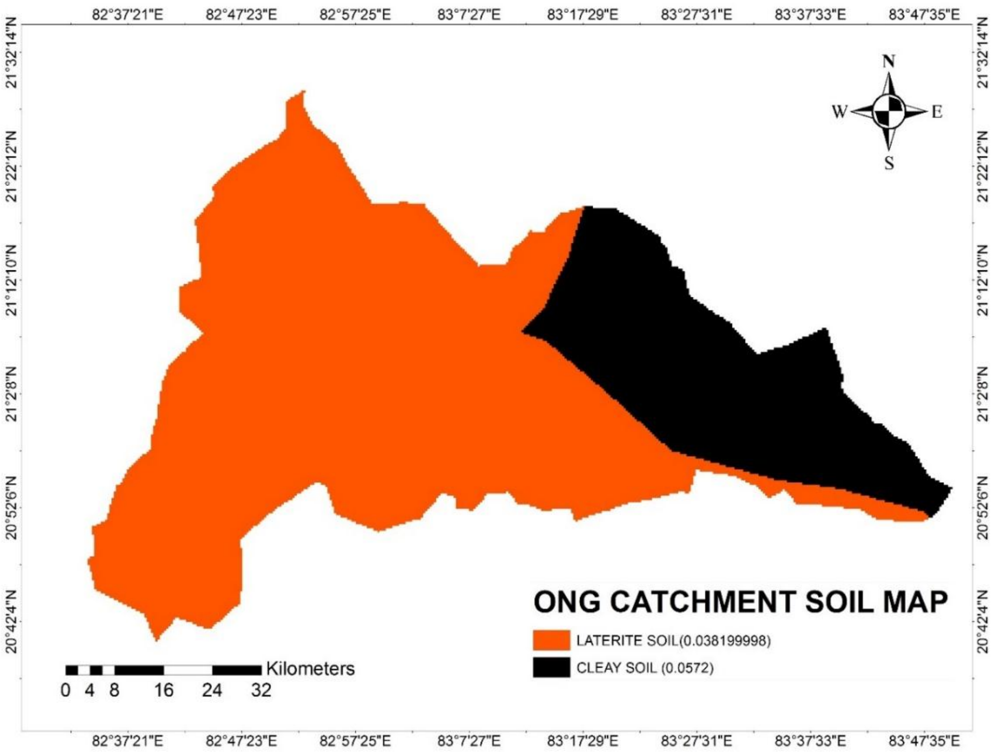

Figure 5.2. – Soil erodibility (K) map of the Ong catchment

5.3 Cover Management Factor (C)

The Cover management "C" factor is dimensionless, which is the ratio of soil loss occurring on field plots with the variables in place over field plots without vegetation cover. The estimation of C factor for various vegetation types and soil prevention techniques are important as they can be used to predict the extent of soil loss. It can be reduced by proper management practices and all possible mitigation measures and the estimated costs of implementation can be considered without actually carrying out the action. USLE uses soil loss ratio (SLR) to present cover management factor (C). SLR is an estimate of the ratio of soil loss at any given time under actual conditions to losses experienced under the referenced conditions. Figure 5.3. present the land cover map of Ong catchment of Mahanadi basin. Supervised classification was carried out for identifying the areas having vegetation, forest, urban settlement, water body and barren land. The value is taken from (Jain et. al.2009) and is described in table 5.3.

Table 5.3.: Cover management factor values used for Ong catchment

Type of land cover	Cover management factor values
Barren land	0.65
Agriculture	0.40
Water body	1
Forest cover	0.03
Settlement	0.80

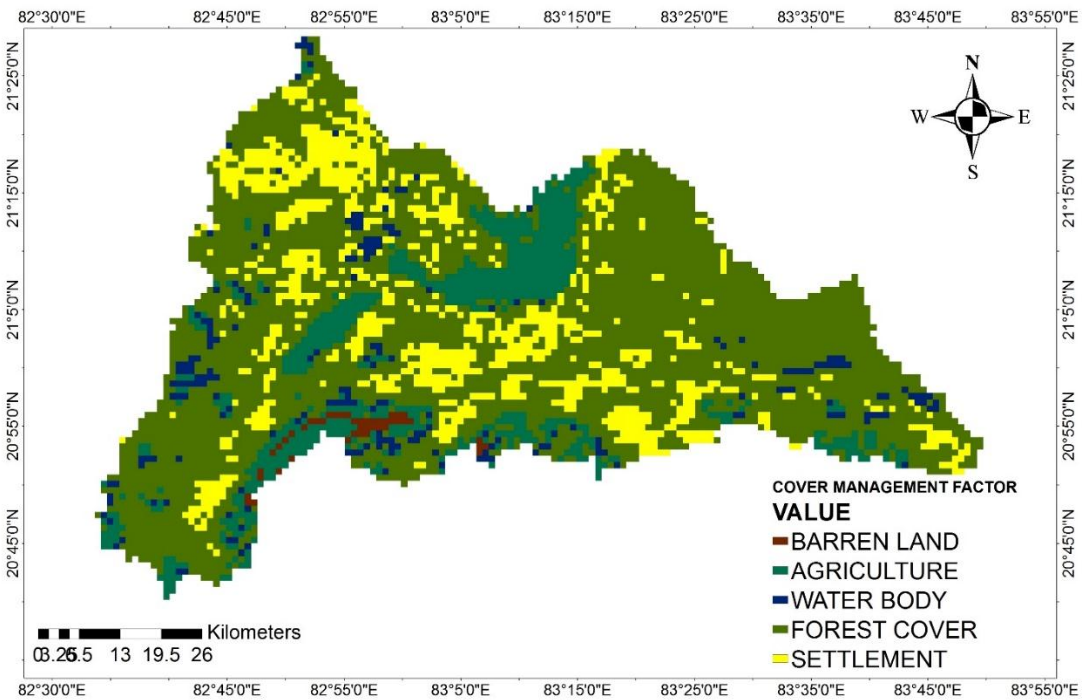

Figure 5.3. – Cover management factor map of the Ong catchment

5.4-Slope Length and Slope Steepness Factor (LS)

The effect of topography on soil erosion is accounted for by the LS factor in USLE, which combines the effects of a slope length factor (L) and a slope steepness factor (S). It is know that an increase in the slope length (L) will results in increase in soil erosion per unit area due to the progressive accumulation of surface runoff on downslope direction. As the slope steepness (S) increases, the velocity and soil erosion of surface runoff also increases

Figure 5.4.1 Represent slope based on percentage rise. Surface tool of ARC GIS was used for calculation of slope from DEM of Ong catchment

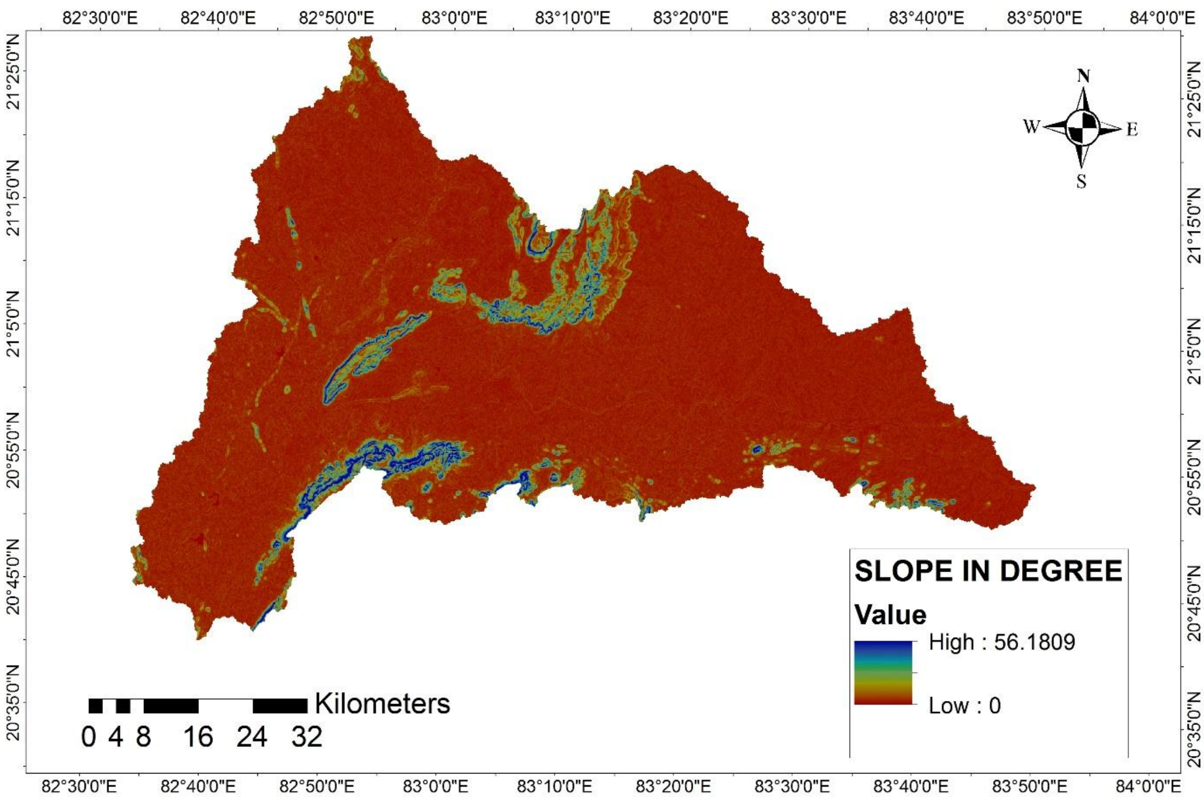

Figure 5.4.1– Slope based on degree rise

Figure 5.4.2 Represent flow accumulation of Ong catchment. It was computed from flow direction raster image by using flow direction tool bar in hydrology under spatial analyst tool box. The black color in the image shows no flow accumulation and the white part shows high flow accumulation.

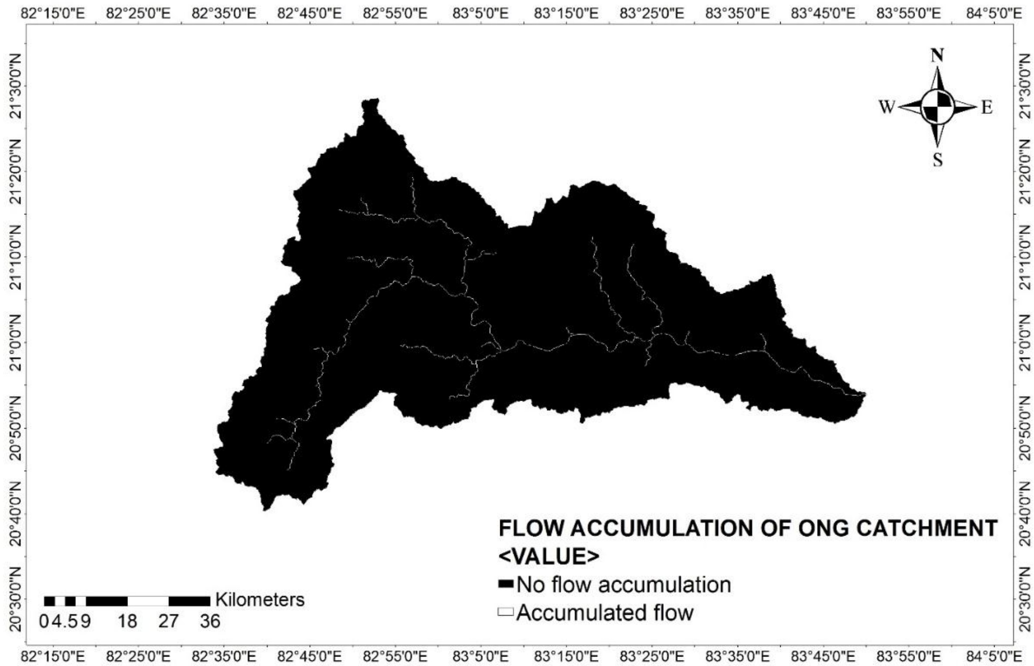

Figure 5.4.2 shows flow accumulation diagram of Ong catchment

Table 5.4.3 presents the results of LS values in the Ong catchment. These values range from minimum value of 0 and maximum value of 60.4708 for the catchment area.

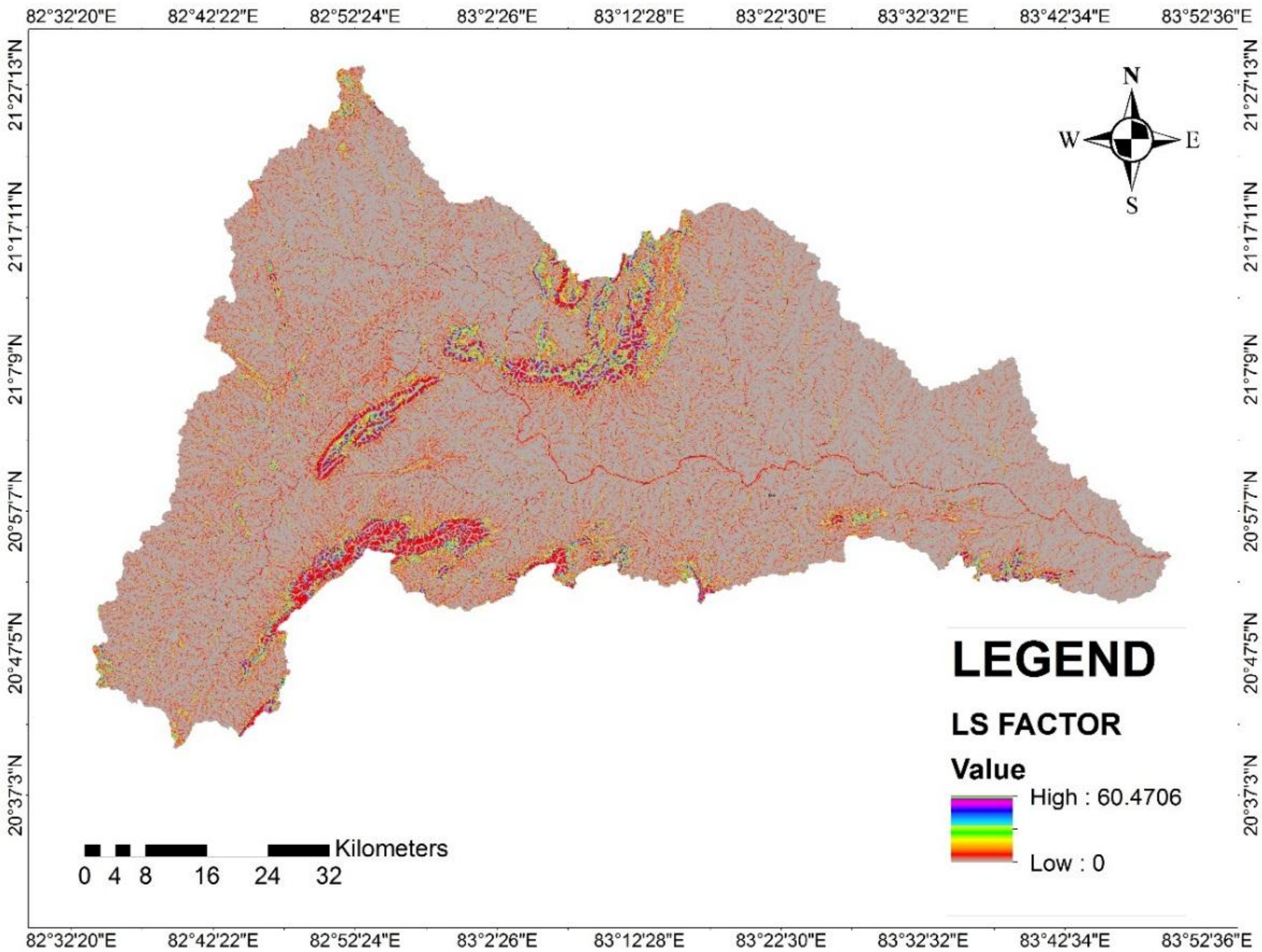

Figure 5.4.c – LS factor map of the Ong catchment

5.5 Support Practice Factor

Support Practice Factor (P) in USLE model is account for the ratio of soil loss with a specific support practice to corresponding soil loss with upslope and downslope tillage. Support Practice Factor (P) is ranged from 0 to 1. It is equal to 1 when the land is directly cultivated on the slope and less than 1 when the adopted conservation practice reduces soil erosion.

Currently there are no support practices in place within the study site. The common practice is to assign a value of 1 for the P factor. For future use, after calculating the estimated soil loss by USLE, the P factor values can be adjusted for prediction of various prevention measures

5.6.1 Estimation of Annual Average Soil Loss Rate (A) (2004)

For estimating annual soil loss rate in 2004 using five parameters such as

1) Rainfall runoff erosivity factor (R): 418.72 ~ 643.406mm
2) Soil erodibility factor (K): 0.037 ~ 0.054
3) Slope length factor & slope steepness factor (LS): 0 ~ 60.470
4) Cover management factor (C): 0 ~ 1
5) Support practice factor (P) 1.0

Figure 5.6.1.a Represents multiplication of all four parameters. These raster images were multiplied using raster calculator of ARC GIS. The images were multiplied pixel wise and final value is obtained on the basis of pixel. The maximum value obtained is 23.329 per hector per year.

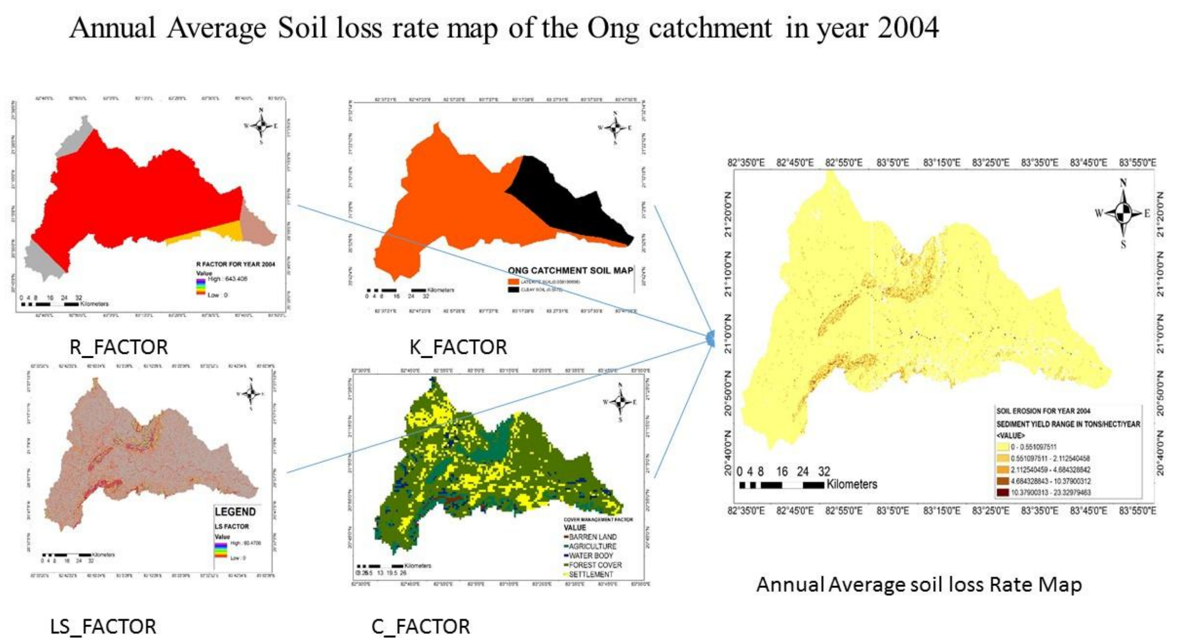

Figure 5.6.1.a. sediment yield in tons per hector per year of year 2004

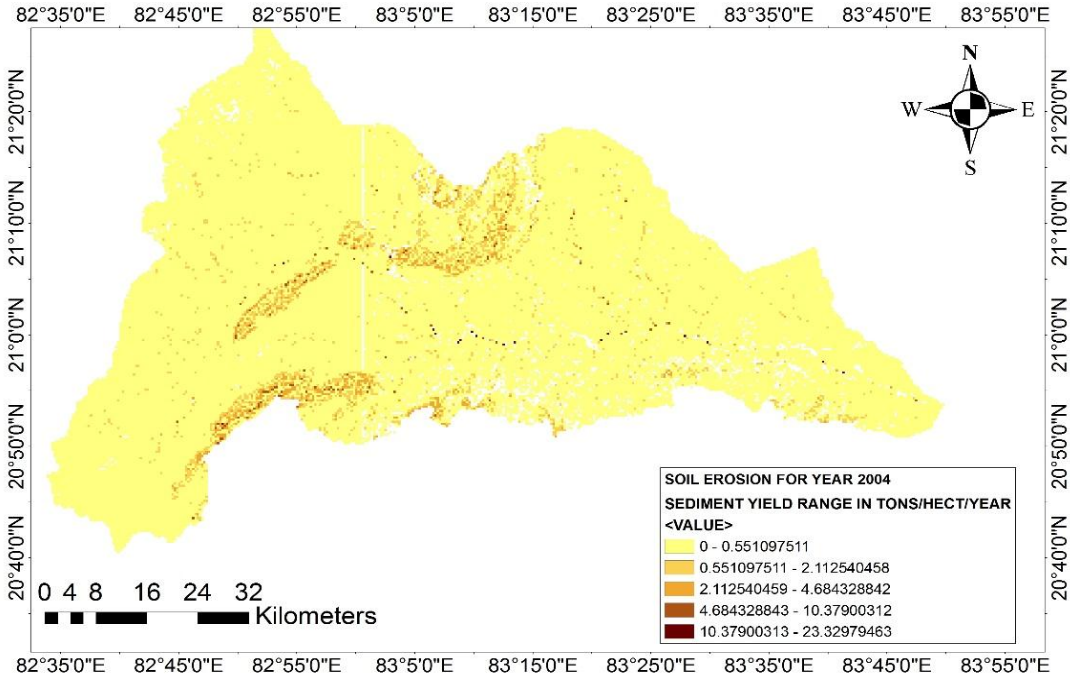

Figure 5.6.1.b. Annual Average Soil loss rate map of the Ong catchment in year 2004

5.6.1.b The above figure is product of all four parameters on pixel basis . The highest value of theoretical sediment yield in tons per hector per year is 23.329. After adding all the pixel values the net sediment yield in tons per year is 7392.28. Observed sediment yield at the gauging station computed from daily data of discharge and suspended sediment obtained from India Wris is 6238.24 in tons per year. The error obtained is 17.29%.

Table 5.6.1.a is a tabular representation of the coordinates obtained by estimation for highest erosion in the year 2004. These coordinates are obtained by using identification tools of ARC GIS on the annual average soil loss rate map. Then these coordinates were used in lat long.net website to find out name and district of the area.

Table 5.6.1.a. shows the maximum erosion prone area in the catchment in the year 2004 (source field study)

Latitude	longitude	Erosion prone area	Districts
20.903069	83.791720	Mayurudan	Sonepur
21.0232	82.756654	Baripali	Bargarh
21.107107	82.96183	Jhar	Bargarh
21.174327	83.204588	Sargue	Surbarnapur
20.998248	83.482390	Burda	Balangir

5.6.2 Estimation of Annual Average Soil Loss Rate (A) (2005)

To estimating annual soil loss rate in 2005 using five parameters such as\

1) Rainfall runoff erosivity factor (R): 380.94 ~ 705.15mm

2) Soil erodibility factor (K): 0.037 ~ 0.054

3) Slope length factor & slope steepness factor (LS): 0 ~ 60.470

4) Cover management factor (C): 0 ~ 1

5) Support practice factor (P) 1.0

Figure 5.6.2.a Represents multiplication of all four parameters. These raster images were multiplied using raster calculator of ARC GIS. The images were multiplied pixel wise and final value is obtained on the basis of pixel. The maximum value obtained is 27.195 per hector per year.

Annual Average Soil loss rate map of the Ong catchment in year 2005

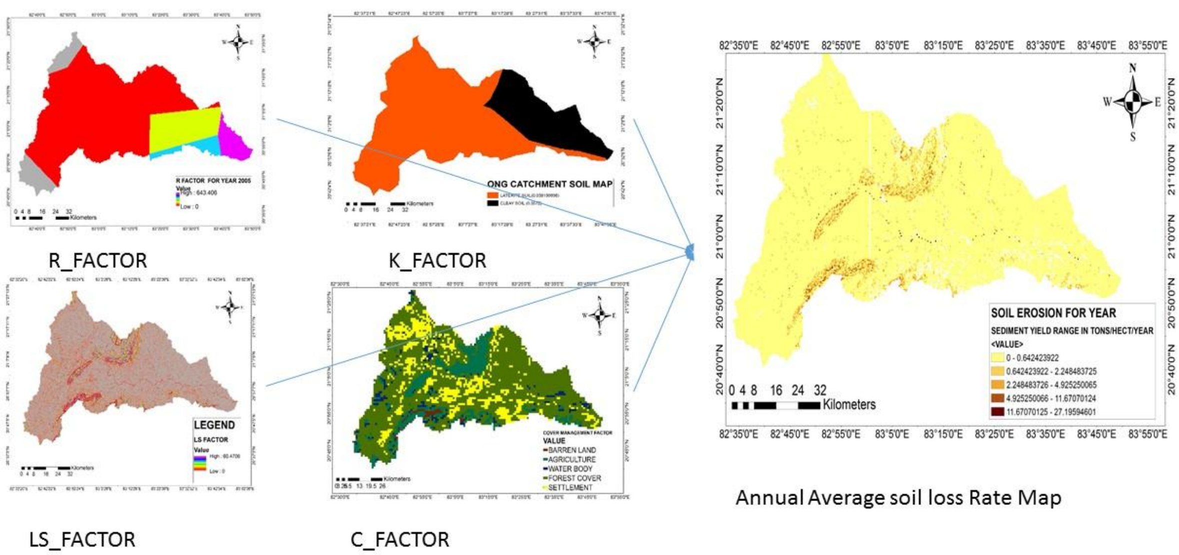

Figure 5.6.2.a Annual Average Soil loss rate map of the Ong catchment in year 2005

5.6.2.a The above figure is product of all four parameters on pixel basis . The highest value of theoretical sediment yield in tons per hector per year is 27.195. After adding all the pixel values the net sediment yield in tons per year is 6554.32. Observed sediment yield at the gauging station computed from daily data of discharge and suspended sediment obtained from India Wris is 5636.715 in tons per year. The error obtained is 16.27%.

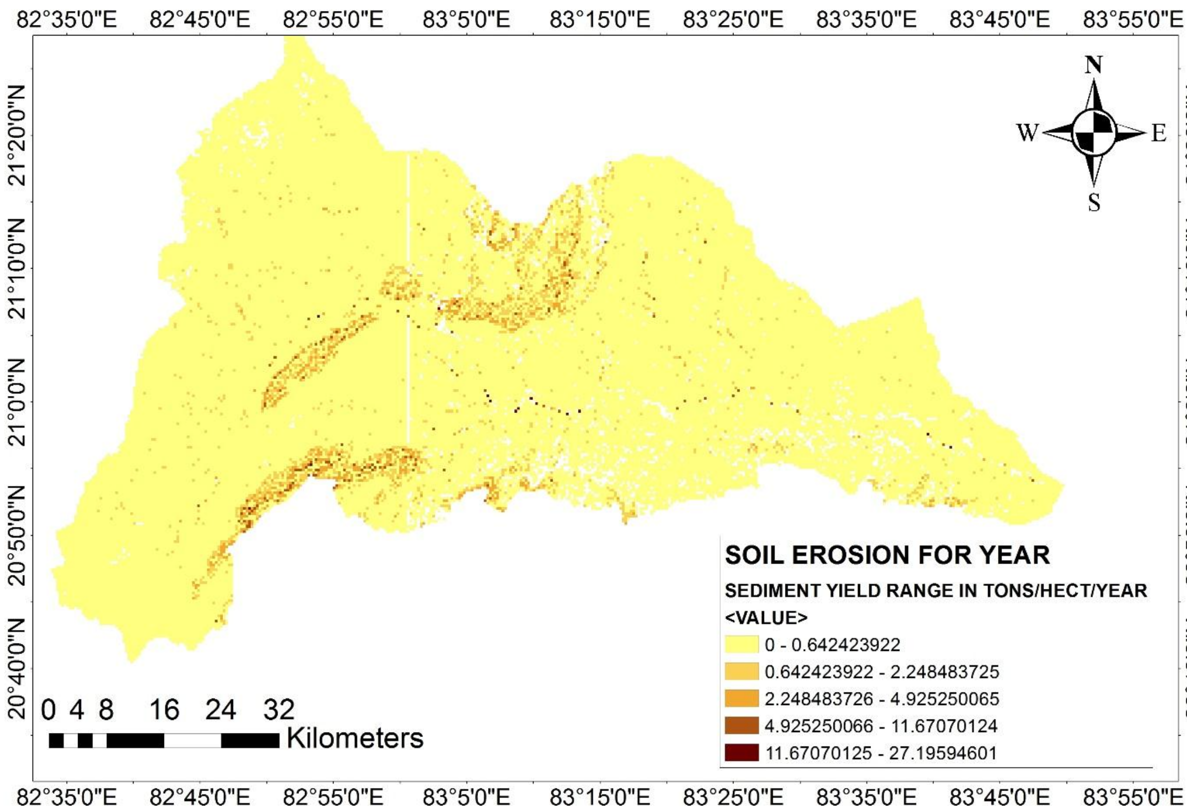

Figure 5.6.2.b sediment yield in tons per hect per year 2005

Table 5.6.2.a is a tabular representation of the coordinates obtained by estimation for highest erosion in the year 2005. These coordinates are obtained by using identification tools of ARC GIS on the annual average soil loss rate map. Then these coordinates were used in lat long.net website to find out name and district of the area.

Table 5.6.2.a shows the maximum erosion prone area in the catchment area in the year 2005 (source field study)

Latitude	longitude	Erosion prone area	Districts
20.903069	83.791720	Mayurudan	Sonepur
21.0232	82.756654	Baraipali	Bargarh
21.107107	82.96183	Jhar	Bargarh
21.174327	83.204588	Sargue	Surbarnapur
20.998248	83.482390	Burda	Balangir

5.6.3 Estimation of Annual Average Soil Loss Rate (A) (2006)

To estimating annual soil loss rate in 2006 using five parameters such as

1) Rainfall runoff erosivity factor (R): 420.99 ~ 1179.32mm

2) Soil erodibility factor (K): 0.037 ~ 0.054

3) Slope length factor & slope steepness factor (LS): 0 ~ 60.470

4) Cover management factor (C): 0 ~ 1

5) Support practice factor (P) 1.0

Figure 5.6.3.a Represents multiplication of all four parameters. These raster images were multiplied using raster calculator of ARC GIS. The images were multiplied pixel wise and final value is obtained on the basis of pixel. The maximum value obtained is 32.80 per hector per year.

Annual Average Soil loss rate map of the Ong catchment in year 2006

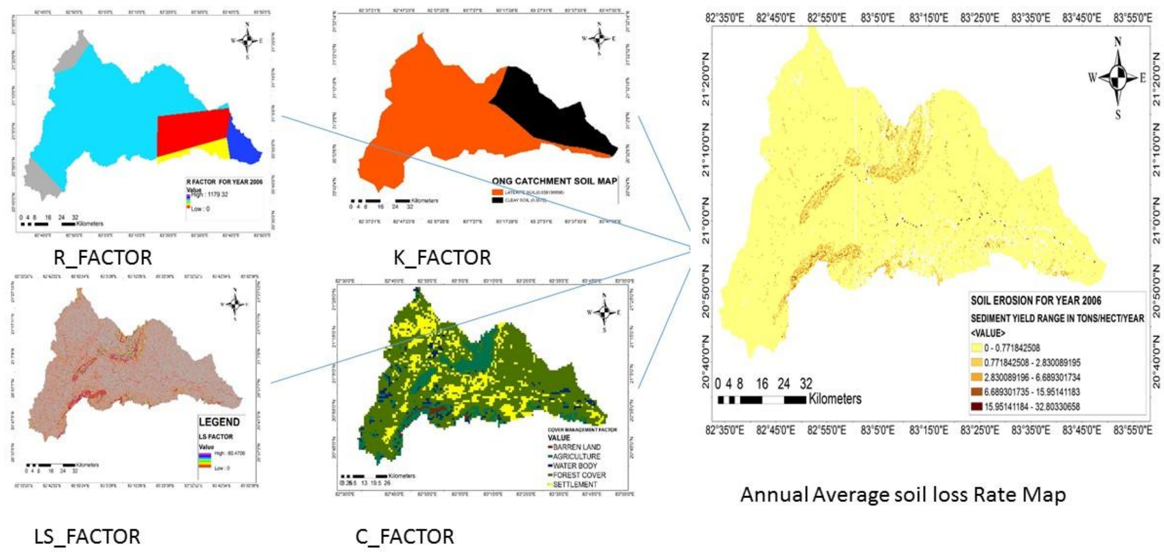

Figure 5.6.3.a Annual Average Soil loss rate map of the Ong catchment in year 2006

5.6.3.b The above figure is product of all four parameters on pixel basis . The highest value of theoretical sediment yield in tons per hector per year is 32.80. After adding all the pixel values the net sediment yield in tons per year is 9067.69. Observed sediment yield at the gauging station computed from daily data of discharge and suspended sediment obtained from India Wris is 7344.82 in tons per year. The error obtained is 23.45%.

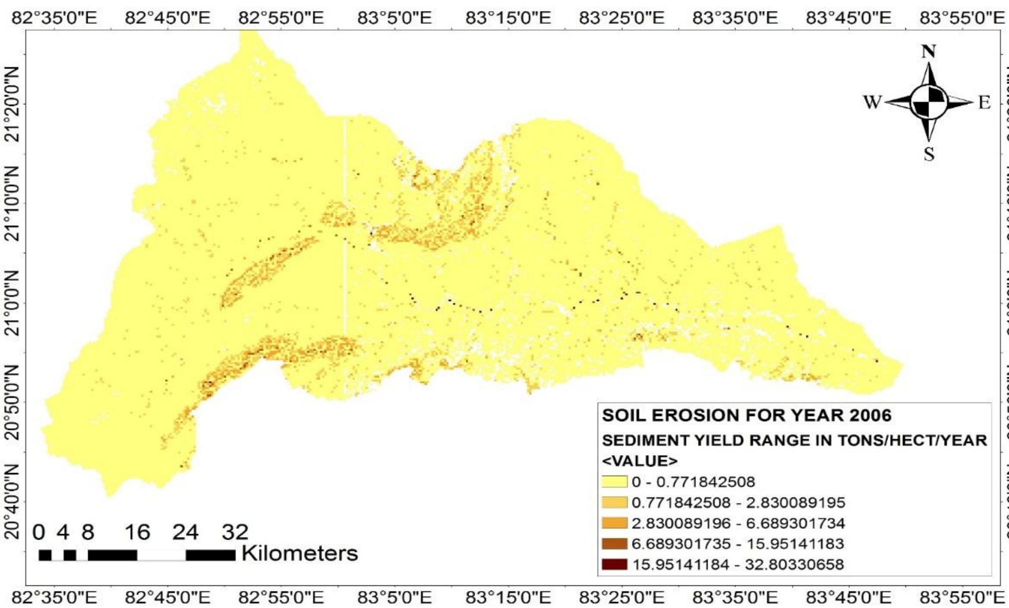

Figure 5.6.3.b sediment yield in tons per hect per year in 2006

Table 5.6.3.a is a tabular representation of the coordinates obtained by estimation for highest erosion in the year 2006. These coordinates are obtained by using identification tools of ARC GIS on the annual average soil loss rate map. Then these coordinates were used in lat long.net website to find out name and district of the area.

Table 5.6.3.a shows the maximum erosion prone area at the catchment area in the year 2006 (source field study)

Latitude	Longitude	Erosion prone Aera	Districts
20.902474	83.789935	Mayurudan	Sonepur
20.907233	83.658470	Loisinga	Balangir
21.244521	82.946416	Mundpadar	Sonepur
21.057734	82.763198	Jharbandha	Bargarh
20.85290	82.74326	Cherangaihain	Bargarh

5.6.4-Estimation of Annual Average Soil Loss Rate (2007)

To estimating annual soil loss rate in 2007 using five parameters such as

1) Rainfall runoff erosivity factor (R): 532.18 ~ 915.22mm

2) Soil erodibility factor (K): 0.037 ~ 0.054

3) Slope length factor & slope steepness factor (LS): 0 ~ 60.470

4) Cover management factor (C): 0 ~ 1

5) Support practice factor (P) 1.0

Figure 5.6.4.a Represents multiplication of all four parameters. These raster images were multiplied using raster calculator of ARC GIS. The images were multiplied pixel wise and final value is obtained on the basis of pixel. The maximum value obtained is 25.82 per hector per year.

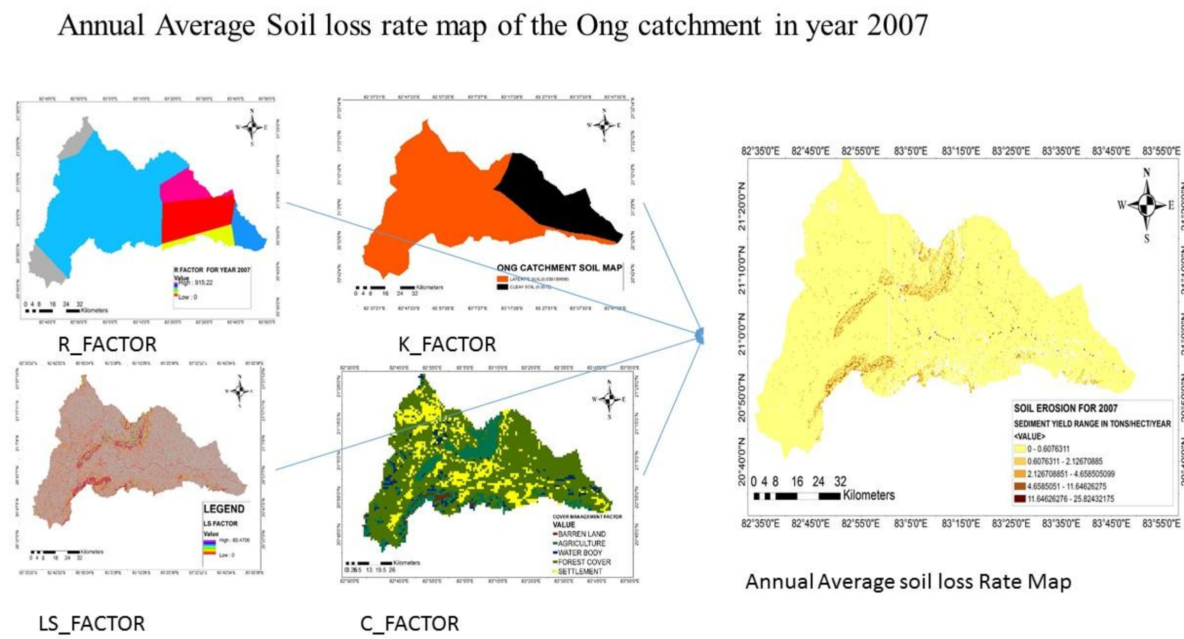

Figure 5.6.4.a Annual Average Soil loss rate map of the Ong catchment in year 2007

5.6.4.b The above figure is product of all four parameters on pixel basis . The highest value of theoretical sediment yield in tons per hector per year is 25.82. After adding all the pixel values the net sediment yield in tons per year is 7710.86. Observed sediment yield at the gauging station computed from daily data of discharge and suspended sediment obtained from India Wris is 6554.23 in tons per year. The error obtained is 17.6%.

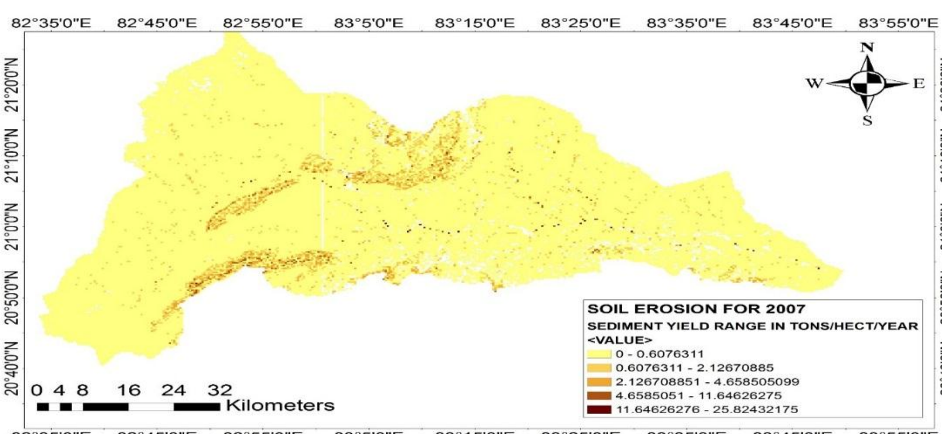

Figure 5.6.4.b sediment yield in tons per hector per year for 200

Table 5.6.4.a is a tabular representation of the coordinates obtained by estimation for highest erosion in the year 2007. These coordinates are obtained by using identification tools of ARC GIS on the annual average soil loss rate map. Then these coordinates were used in lat long.net website to find out name and district of the area.

Table 5.4.a shows the maximum erosion prone area at the catchment in the year 2007 (source field study)

Latitude	Longitude	Erosion prone Aera	Districts
20.902930	83.789876	Mayurudan	Sonepur
21.08165	83.414873	Balangir	Balangir
20.865334	82.816676	Chhetgaon	Bargarh
20.728501	82.768611	Baddakala	Balangir

5.6.5-Estimation of Annual Average Soil Loss Rate (2008)

To estimating annual soil loss rate in 2008 using five parameters such as

1) Rainfall runoff erosivity factor (R): 496.84 ~ 940.3mm

2) Soil erodibility factor (K): 0.037 ~ 0.054

3) Slope length factor & slope steepness factor (LS): 0 ~ 60.470

4) Cover management factor (C): 0 ~ 1

5) Support practice factor (P) 1.0

Figure 5.6.5.a Represents multiplication of all four parameters. These raster images were multiplied using raster calculator of ARC GIS. The images were multiplied pixel wise and final value is obtained on the basis of pixel. The maximum value obtained is 26.15 per hector per year.

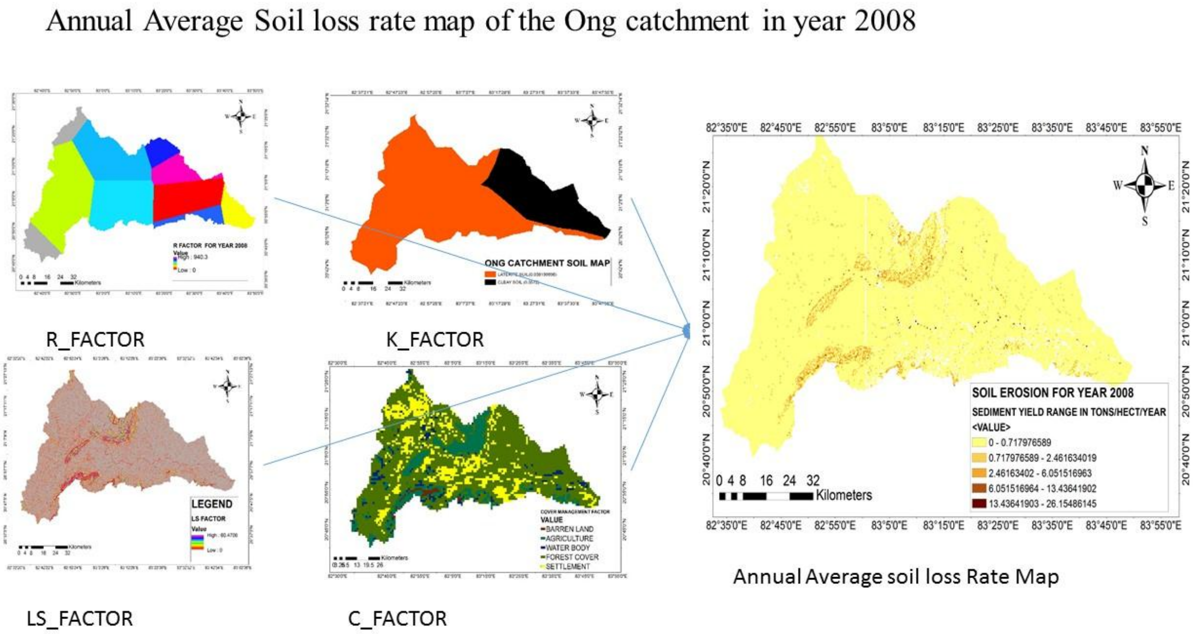

Figure 5.6.5.a. Annual Average Soil loss rate map of the Ong catchment in year 2008

5.6.5.b The above figure is product of all four parameters on pixel basis . The highest value of theoretical sediment yield in tons per hector per year is 26.15. After adding all the pixel values the net sediment yield in tons per year is 7291.44. Observed sediment yield at the gauging station computed from daily data of discharge and suspended sediment obtained from India Wris is 5468.58 in tons per year. The error obtained is 33.3%.

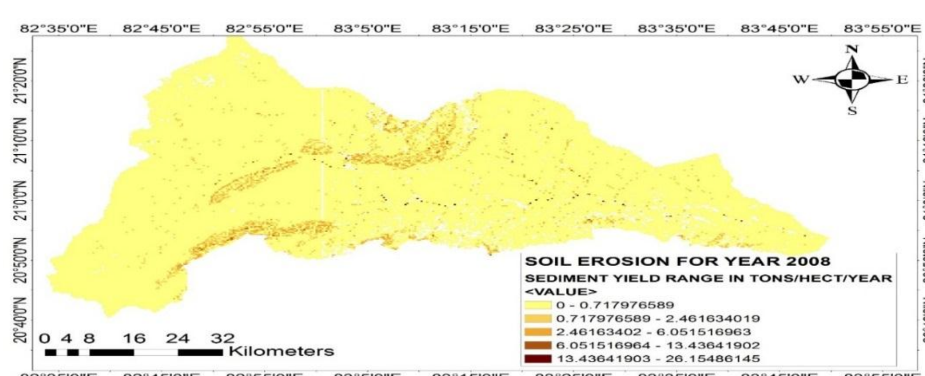

Figure 5.6.5.b Sediment yield in tons per hector per year for 2008

Table 5.6.5.a is a tabular representation of the coordinates obtained by estimation for highest erosion in the year 2008. These coordinates are obtained by using identification tools of ARC GIS on the annual average soil loss rate map. Then these coordinates were used in lat long.net website to find out name and district of the area.

Table 5.3 shows the maximum erosion prone area at the catchment in the year 2008 (source field study)

Latitude	Longitude	Erosion prone Aera	Districts
21.047125	82.835712	Turla	Bargarh
20.988591	83.143614	Kansar	Bargarh
21.103281	83.153608	Gyan	Bargarh
21.279837	83.257825	Jhar	Bargarh
20.874376	83.662337	Badimunda	Balangir

5.6.6-Estimation of Annual Average Soil Loss Rate (2009)

To estimating annual soil loss rate in 2009 using five parameters such as

1) Rainfall runoff erosivity factor (R): 496.84 ~ 940.3mm

2) Soil erodibility factor (K): 0.037 ~ 0.054

3) Slope length factor & slope steepness factor (LS): 0 ~ 60.470

4) Cover management factor (C): 0 ~ 1

5) Support practice factor (P) 1.0

Figure 5.6.6.a Represents multiplication of all four parameters. These raster images were multiplied using raster calculator of ARC GIS. The images were multiplied pixel wise and final value is obtained on the basis of pixel. The maximum value obtained is 23.67 per hector per year.

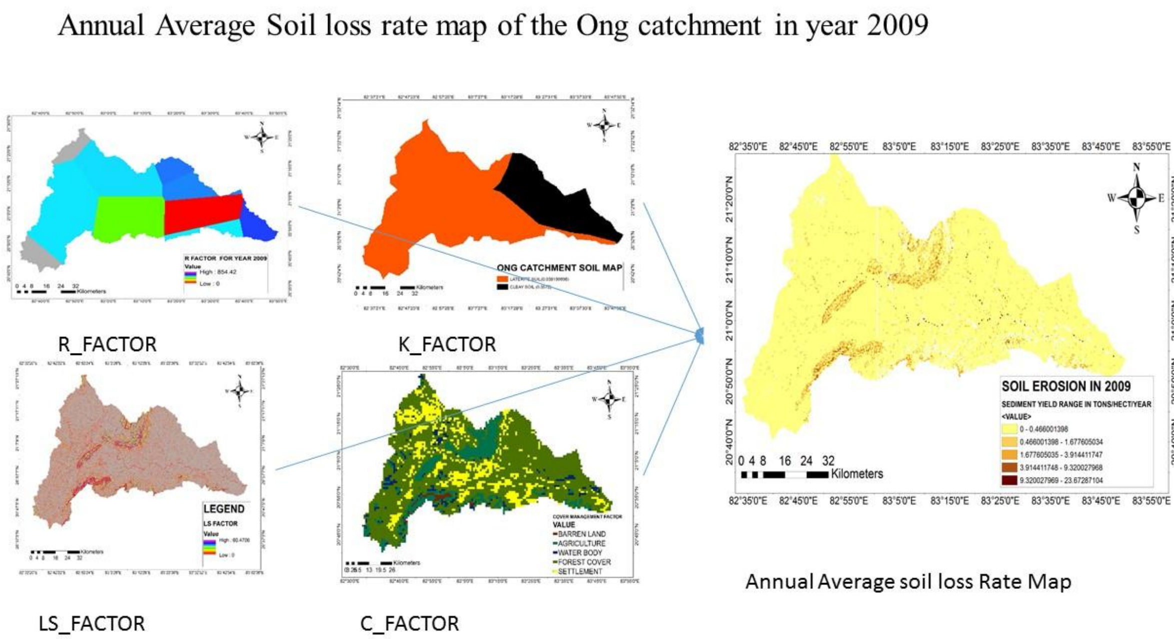

Figure 5.6.6.b Annual Average Soil loss rate map of the Ong Catchment in year 2009

5.6.6.b The above figure is product of all four parameters on pixel basis . The highest value of theoretical sediment yield in tons per hector per year is 26.67. After adding all the pixel values the net sediment yield in tons per year is 6382.75. Observed sediment yield at the gauging station computed from daily data of discharge and suspended sediment obtained from India Wris is 4828.96in tons per year. The error obtained is 26.97%.

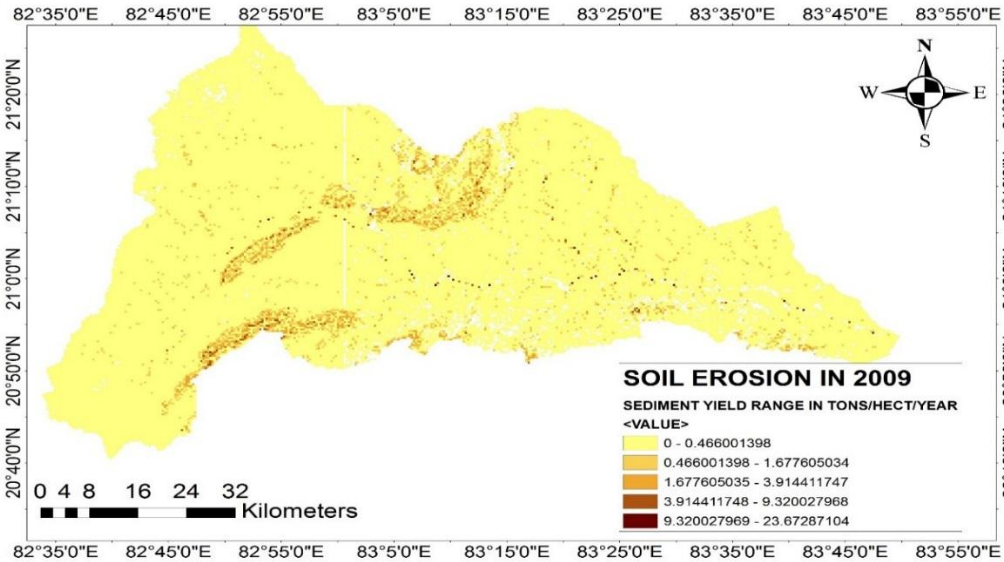

Figure 5.6.5.b Sediment yield in tons per hector per year for 2009

Table 5.6.6.a is a tabular representation of the coordinates obtained by estimation for highest erosion in the year 2009. These coordinates are obtained by using identification tools of ARC GIS on the annual average soil loss rate map. Then these coordinates were used in lat long.net website to find out name and district of the area.

Table 5.6.6.a shows the maximum erosion prone area at the catchment in the year 2009 (source field study)

Latitude	Longitude	Erosion prone area	Districts
20.812250	82.714974	Makhanamunda	Bargarh
20.771086	82.746589	Temrimal	Bargarh
21.108896	82.959349	Padamapur	Bargarh
20.923393	83.754184	Kudopali	Bargarh
21.236054	83.118392	Beheramala	Sonepur

5.6.7-Estimation of Annual Average Soil Loss Rate (2010)

To estimating annual soil loss rate in 2010 using five parameters such as

1) Rainfall runoff erosivity factor (R): 321.66 ~ 518mm

2) Soil erodibility factor (K): 0.037 ~ 0.054.88

3) Slope length factor & slope steepness factor (LS): 0 ~ 60.470

4) Cover management factor (C): 0 ~ 1

5) Support practice factor (P) 1.0

Figure 5.6.7.a Represents multiplication of all four parameters. These raster images were multiplied using raster calculator of ARC GIS. The images were multiplied pixel wise and final value is obtained on the basis of pixel. The maximum value obtained is 21.93 per hector per year.

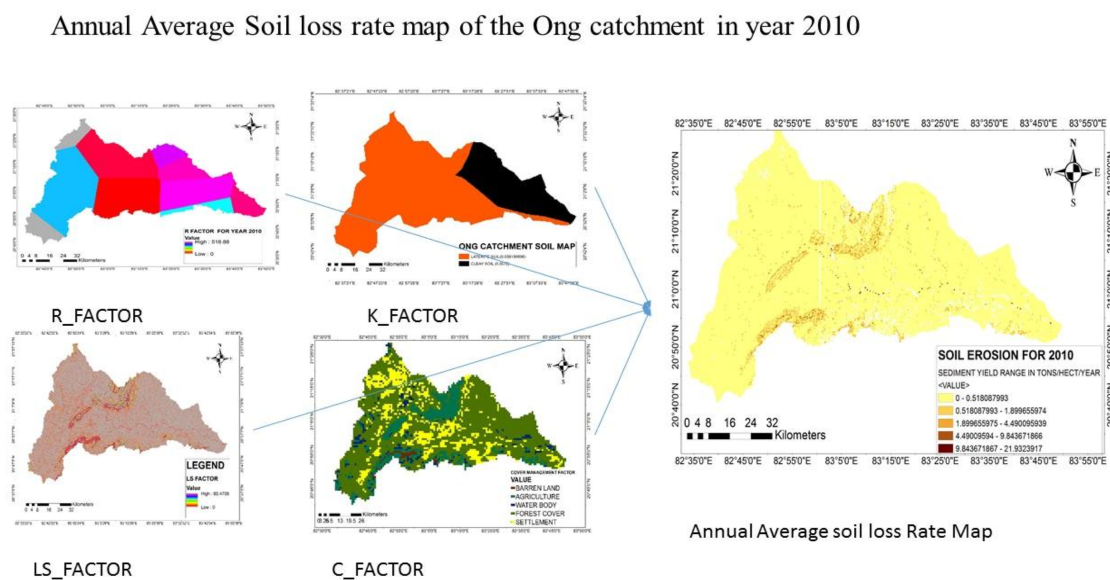

Figure 5.6.6.b Annual Average Soil loss rate map of the Ong Catchment in year 2010

5.6.7.b The above figure is product of all four parameters on pixel basis . The highest value of theoretical sediment yield in tons per hector per year is 21.93. After adding all the pixel values the net sediment yield in tons per year is 5510.30. Observed sediment yield at the gauging station computed from daily data of discharge and suspended sediment obtained from India Wris is 4629.29 in tons per year. The error obtained is 19.02%.

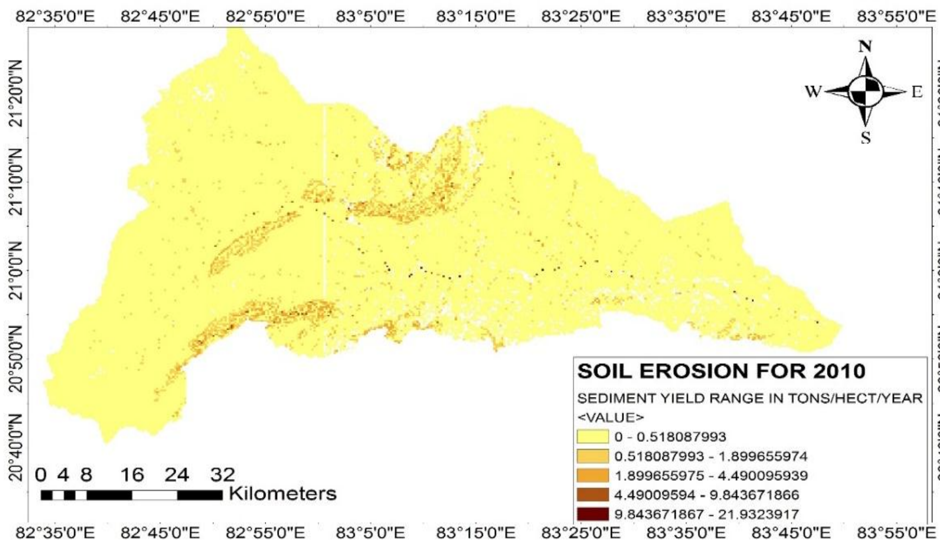

Figure 5.6.7.b sediment yield in tons per hector per year for 2010

Table 5.6.7.a is a tabular representation of the coordinates obtained by estimation for highest erosion in the year 2010. These coordinates are obtained by using identification tools of ARC GIS on the annual average soil loss rate map. Then these coordinates were used in lat long.net website to find out name and district of the area .

Table 5.6.7.a shows the maximum erosion prone area at the catchment in the year 2010 (source field study)

Latitude	Longitude	Erosion prone area	Districts
21.11403	83.071406	Saraikela	Bargarh
21.03384	83.071406	Binka	Subarnapur
20.961398	83.188970	Semelunda	Bargarh
21.21431	83.111910	Sonepur	sonepur

5.7 Final result validation of computed and observed sediment yield

This table 5.7.1 presents us the simulation, carried out for a DEM resolutions of 30 m. The computed and observed value of sediment yield for year 2004 to 2010 and average annual for 7 years at the catchment outlet is presented in Table 5.7.1 . This table shows a comparison between computed sediment yield and observed sediment yield. The error obtained is within 33.3%.

Table: 5.7.1 Comparison between observed and computed values of sediment yield (source field study)

Year	Gauging station	Observed sediment yield in tons/year	Computed sediment yield in tons/year	Percentage of error
2004	Salebhata	6283.2	7392.28	17.25
2005	Salebhata	5636.715	6554.32	16.27
2006	Salebhata	7344.82	9067.69	23.45
2007	Salebhata	6554.23	7710.86	17.64
2008	Salebhata	5468.58	7291.44	33.3
2009	Salebhata	4828.96	6382.75	26.97
2010	Salebhata	4629.29	5510.25	19.02

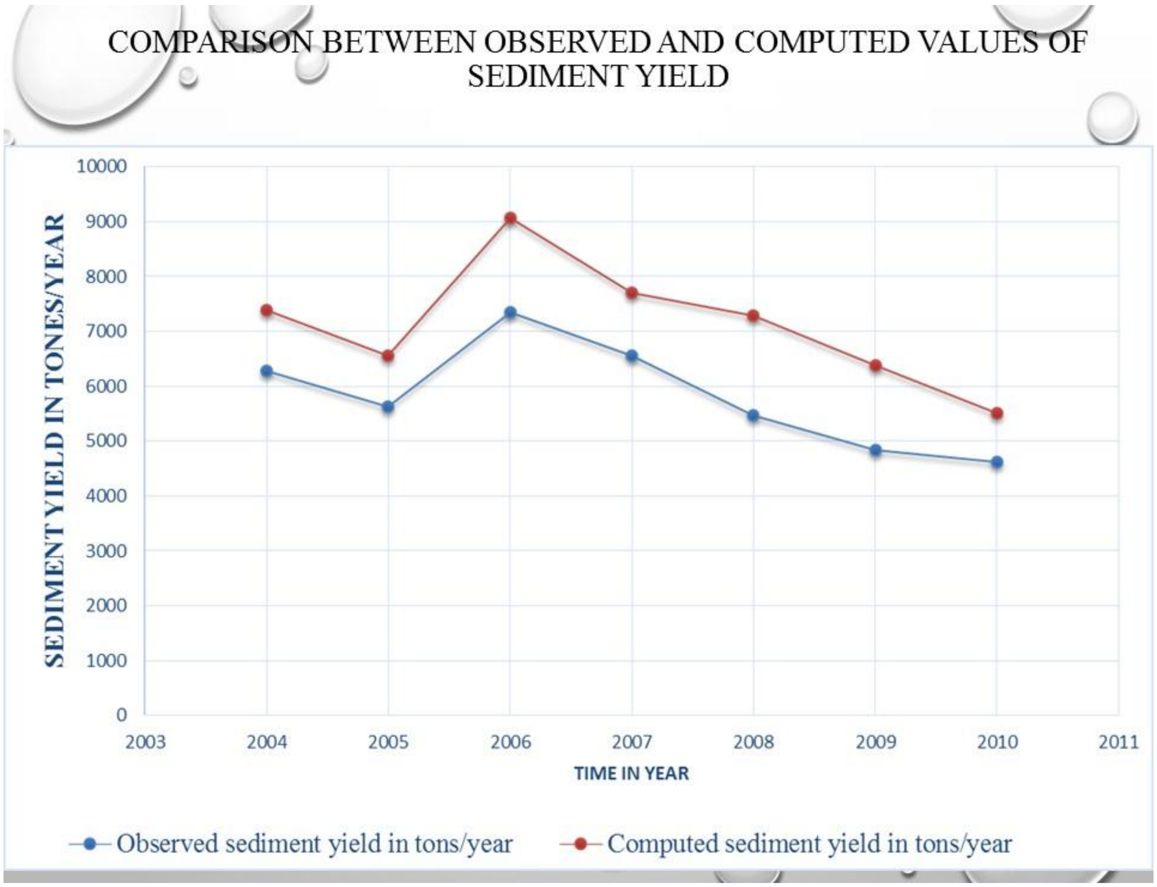

Figure 5.7 shows the graphical representation of observed sediment yield and computed sediment yield

This figure shows the graphical representation of observed sediment yield and computed sediment yield. In this figure shown in the maximum sediment yield deposited in the year of 2006 and minimum sediment yield deposited in the year of 2010.

CHAPTER 06

SUMMARY AND CONCLUSIONS

6.1 Summary and Conclusions

Soil erosion by water continues to be a serious global issue, particularly in Odisha where climatic and topographic conditions accelerate the process of erosion and sedimentation. The primary objective of this study was to generate mapping for use in prediction of soil erosion rates in the Ong catchment. A comprehensive approach was used to combine ArcGIS v.10.2 with USLE model to estimate the gross erosion rates and to evaluate the spatial distribution of soil loss rates under different land uses at the catchment. And also to locate the maximum erosion prone area.

6.2 Specific conclusions related to the results of the USLE model application at the Ong catchment are summarized below.

1. The annual average soil loss rate of the Ong catchment were estimated to be 8318.22 tons/year of 2006 to 2010.
2. In case of the spatial distribution of erosion rates at the Ong Catchment, the relationship between probability and annual average soil loss rates is analyzed. The analysis indicated that up to seventy percent of the mean annual soil loss rates are in the range of tolerable soil loss rate (0 – 5 tons/acre/year). Moreover, western part of the basin is prone to extensive erosion than the eastern part.
3. Sediment yield of all seven years are compared and maximum erosion obtained is below 34%. Erosion prone areas are located in the catchment.
4. Type of soil found out is laterite soil and clayey soil. Slope stiffness factor obtained is less than 60.

Scope

- The simulation of USLE gives good agreement i.e. more study should be done to find out actual location of erosion prone areas and to follow different types of cultivation or forestation in order to prevent soil erosion.
- This study helps to calculate the change of cross section of the river basin due to sediment deposited.
- This study helps to predict suspended load concentration at the gauging site.
- This study helps to perform various hydrological operations like flood routing, determination of capacity and water spread corresponding to each elevation.
- This study helps in identifying the erosion prone areas of the river basin.
- This helps for taking measures for conservation of soil that can be implemented on those areas for checking of siltation of soil.

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