Final Report

Assessment of water availability and sediment yield in the upper Yerrakalva Basin

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Abstract

The objectives of the study were the assessment of water availability and soil erosion in sub basin and estimation of sediment rate into Yerrakalva reservoirThe assessment of water balance was taken up using semi distributed model (SWAT). Soil erosion from sub basins and rate of sedimentation in Yerrakalva reservoir has been estimated by RUSLE and remote sensing techniques respectively.

The total catchment area of Yerrakalva reservoir is 1662.45 sq km. Total 19 watersheds, having area of 0.36 to 214.15 sq km, were demarcated In each sub basin the monthly water availability have been computed from SWAT model during the years 2004 to 2012. The monthly water availability trends in each sub basin were studied and found that there was no significant trend in the water availability. The sediment rate into reservoir has been estimated by remote sensing techniques and it is found to be 39.33 ton/sq.km/year. The revised area capacity curve prepared from Remote Sensing techniques is validated with hydrographic survey data of reservoir. The average annual soil loss and sediment rate was estimated using RUSLE in Yerrakalva reservoir catchment area are 0.49 ton/acre/year and 31.80 ton/sq.km/year respectively. These scientific assessments are very useful for management of reservoir water allocation for drinking, irrigation and industrial purposes especially during non monsoon period. These hydrological assessments are to be a part of IWRM plans in the basin to match with the future demands.

CHAPTER I

INTRODUCTION

1.1 GENERAL

The knowledge of water availability or yield in a river catchment is an indispensable prerequisite in the sustainable management of water resources at watershed and basin wide levels. Stehr et al. (2008) reported that the study of water resources at river catchment level has been widely adopted as a better way of managing and assessing these important natural resources. At the decision making stage, models are usually employed for the purpose of selecting an optimal courses of action. Such models are often constructed to enable reasoning within an idealized logical framework about the processes. Due to the complexity in the representation of these natural processes and conditions, models are usually calibrated prior to the application of the models to obtain a realistic description of the processes match with the reality.

Various physically based hydrological models have been identified and used to simulate hydrological processes in a river catchment. One of the promising candidates of the models is SWAT. SWAT has been adjudged by researches as computationally efficient in its prediction . Against this background, the main objective of this study is to identify challenges and prospects of using SWAT in the prediction of water yield within a river catchment. The specific objective of the study was to model the hydrology and predict the water yield and balance of a selected catchment in Nigeria using SWAT. Through the application of SWAT for hydrological modeling and prediction of water yield and balance, some challenges and prospects of applying SWAT to predict basin water characteristics within a river catchment could be identified.

Sedimentation is a natural process that can impact the reservoir management. The periodic deposition of these sediments reduces the storage capacity of the reservoir.Recent observations in India have brought in to light the alarming fact that reservoir sedimentation, resulting from degradation of the watersheds is on manifold rise compared to the rate that was assumed at the time the projects were designed. This leads to watershed deterioration which renders fertile lands barren, reduction in storage capacity of the dams and hence reduction in their operational life. The main factors causing soil erosion are climate, soil, vegetation, topography. The reservoir sedimentation survey can be carried out using a conventional method which combines a hydrographic and topographic survey. The surveys conducted by this method are accepted as being time consuming, laborious and costly. At present, remote sensing data has been widely used for water body detection and mapping with high resolution and wide area coverage. The use of remote sensing data evolved as a result of the negative aspects of conventional method.

1.2 NEED FOR THE PROJECT

Water and wind are the main agents responsible for soil erosion. Sedimentation and soil erosion includes the processes of detachment, transportation and deposition of solid particles also known as sediments. The forms of water responsible for soil erosion are raindrop impact, runoff and flowing water. Erosion from mountainous areas and agricultural lands are the major source of sediment transported by streams and deposited in reservoirs, flood plains and deltas. Sediment load is also generated by erosion of beds and banks of streams, by the mass movements of sediment such as landslides, rockslides and mud flows, and by construction activity of roads, buildings and dams. Sheet erosion happens when raindrop impact transports particles and becomes runoff traveling over the surface of the ground. Rill erosion occurs when water from sheet erosion combines to form small concentrated channels. For Realistic and effective planning of available water storage one must know the net storage available in the reservoir excluding the silt volume. To ascertain the net available storage, regular periodic sedimentation surveys of these lakes and reservoirs must be conducted. The satellite remote sensing is very useful, economical and reliable tool for conducting such surveys and monitoring sedimentation in reservoirs.

1.3 SOIL EROSION

Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind. The soil erosion that is caused due to water potential is generally referred as water erosion. The greater the intensity and duration of rainstorm, the higher the erosion potential. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter are easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts are required to move larger sand and gravel particles.

1.4 FORMS OF WATER EROSION

1.4.1 Sheet Erosion

Sheet erosion is the movement of soil from raindrop splash and runoff water. It typically occurs evenly over a uniform slope and goes unnoticed until most of the productive topsoil has been lost. Deposition of the eroded soil occurs at the bottom of the slope in low areas. Lighter-coloured soils on knolls, changes in soil horizon thickness and low crop yields on shoulder slopes and knolls are other indicators.

1.4.2 Rill Erosion

Rill erosion results when surface water runoff concentrates, forming small yet well-defined channels. These distinct channels where the soil has been washed away are called rills when they are small enough to not interfere with field machinery operations.

1.4.3 Gully Erosion

Gully erosion is an advanced stage of rill erosion where surface channels are eroded to the point where they become a nuisance factor in normal tillage operations. Surface water runoff, causing gully formation or the enlarging of existing gullies, is usually the result of improper outlet design for local surface and subsurface drainage systems.

1.4.4 Bank Erosion

Natural streams and constructed drainage channels act as outlets for surface water runoff and subsurface drainage systems. Bank erosion is the progressive undercutting, scouring and slumping of these drainage ways. Poor construction practices, inadequate maintenance, uncontrolled livestock access and cropping too close can all lead to bank erosion problems.

1.5 RESERVOIR SEDIMENTATION

Dams are constructed for many reasons such as flood attenuation, hydropower generation, storage for irrigation, navigation, etc. Reservoir sedimentation is filling of the reservoir behind a dam with sediment carried into the reservoir by streams. The flow of water from the catchment upstream of a reservoir is capable of eroding the catchment area and of depositing material either upstream of the reservoir, or in the still water of the reservoir. The nature of the material in the catchment area and the slope of the catchment area and the inlet streams are a factor, as is the nature of the ground cover. When a reservoir is relatively small in relation to the mean annual runoff and the sediment yield is relatively high, there is a high risk that it would silt up in a short period of time. Reservoir sedimentation occurs worldwide at a rate of about 0.8 percent per year, but the sedimentation rate in many regions such as Asia is much higher.

1.6 OBJECTIVES

- Estimate the water availability in the baisn
- To Estimate of soil erosion from the catchment area of the reservoir using Universal Soil Loss Equation (USLE) in GIS Environment.
- To compute of sedimentation rate into the reservoir from its catchment area.
- To determine spatial vulnerability of high soil erosion rates in the reservoir catchment area.
- Validation of estimated reservoir sedimentation rate with hydrographic survey data of reservoir or estimated rate of sedimentation into reservoir by remote sensing technique.

CHAPTER 2

LITERATURE REVIEW

The following literature surveys related to the report have been made. The pervious works carried out by the various authors related to this study are discussed in this Chapter.

2.1 LITERATURE SURVEY

B.Y. Liu et al., (2001) evaluated the relationship between soil loss and slope length for steep slopes (upto 60%). Soil loss data from natural runoff plots at three locations on the loess plateau in China were used. In the USLE, the m value was recommended as 0.2,0.3,0.4 and 0.5 for slope gradients less than 1%,1-3%,3.5-4.5 % and 5% or greater, respectively. However in RUSLE, m (slope length exponent) continues to increase with slope steepness. This study recommends to use slope length exponent of 0.5 for the gradient greater than 30% and upto 60%. Though RUSLE is improved technology, the soil loss is best approximated with ‖Slope length exponent‖ from USLE than RUSLE.

Okan Fistikoglu et al., (2002) A Geographic Information System (GIS) has been integrated with the USLE (Universal Soil Loss Equation) model in identification of rainfall-based erosion and the transport of nonpoint source pollution loads to the Gediz River, which discharges into the Aegean Sea along the western coast of Turkey. The purpose of the study is to identify the gross erosion, sediment loads, and organic N loads within a small region of the Gediz River basin. Similar studies are available in literature, ranging from those that use a simple model such as USLE to others of a more sophisticated nature. The study presented here reflects the difficulties in applying the methodology when the required data on soil properties, land use and vegetation are deficient in both quantity and quality, as the case is with most developing countries.

Dilip Durbude et al., (2005) The study area of this paper is Linganmakki Reservoir, Karnataka. The water pixel area are calculated from the satellite imageries and elevation of water level is collected. The various operations like band slicing, band rationing and Normalised difference water index were performed to identify the water pixels.The volume of water is computed using prismoidal formulae
given in equation 2.1.

$$V = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 * A_2}\right) \quad (2.1)$$

Where, *h* is the Elevation difference, *A1* and *A2* are the Water spread Area at different Elevations.

The difference between the previous and revised cumulative capacity represents the loss of capacity due to sedimentation in the zone under study. Limitation of the remote sensing technique is that the revised capacity in the portion below the lowest observed level and above the highest observed level can't be determined. This limitation is not significant since the zone of interest, from the point of view of operation, is the live storage zone only.

Reetesh Katiyar et al., (2006) Study Area for this project is Ramganga reservoir and the data used is IRS-1C LISS III. In this study, the catchment for the Ramganga reservoir has been divided into nine sub-watersheds to determine the sub-watershed most prone to soil erosion. Also, temporal IRS-1B LISS-III images between years 2000-2001 are used on ILWIS image processing and GIS software for the assessment of reservoir sedimentation in Ramganga catchment. The LISS III images at a resolution of 23.50 m are used to compute the water index, while the GIS system is used to analyse the topography. The integrated effect of all the parameters is evaluated to find sedimentation rate in the reservoir. For the quantification of volume of sediments deposited in the reservoir, the basic information extracted from the satellite images is the water spread area. The elevations of the water level of reservoir at the time of satellite passes are obtained. It is therefore concluded that the sedimentation in reservoir may be estimated with reasonably accuracy using remote sensing data. This methodology is adopted for validating the sediment rate calculated using RUSLE method.

Ram Singh et al., (2006) This study is in the catchment area of Jamni River, a tributary of the Betwa, is spread over parts of Lalitpur district, Uttar Pradesh (UP), and Tikamgarh and Sagar districts, Madhya Pradesh (MP) in Bundelkhand region.The Rainfall Erosivity Factor(R-Factor) is calculated using equation 2.2

$$R = 0.1059abc + 52 \qquad 2.2$$

where a is the average annual rainfall (mm), b the maximum 24 h rainfall (mm/24 h), c the maximum 1 h rainfall.

Ashish Pandey et al., (2007) In this study, Karso watershed of Hazaribagh, Jharkhand State, was divided into 200 × 200 grid cells and average annual sediment yields were estimated for each grid cell of the watershed to identify the critical erosion prone areas of watershed for prioritization purpose. *R* was computed by analyzing the available rainfall charts of different years available from automatic rain gauge station located in the watershed. As the area of the selected region for this study is small (27.93 km2), the spatial distribution of R was assumed to be uniform. The land use/land cover map was derived from the satellite images and served as a guiding tool in the allocation of C and P factors for different land use classes. The C factor values were the representative values for allocating the USLE land cover and management factors corresponding to each crop/vegetation condition as given by USDA. For estimation of soil erodibility factor, representative soil samples from nine locations in the watershed were collected and analyzed for determination of textural classes. Based on the relative proportion of sand, silt, clay and organic carbon, soil erodibility factor was estimated.

Kamuju Narasayya et al., (2007) The water spread areas of the reservoir at different levels between Full Reservoir Level (FRL) and Minimum Draw Down Level (MDDL) in different months of the year could be computed from satellite imageries. Knowing the reservoir levels (as ground truth) on date of pass of the satellite, Elevation-Capacity curves could be established and compared with that at the time of impoundment of reservoir. Shift in the capacity curve will indicate extent of loss of reservoir capacity .The reservoir capacity between two elevations of Srisailam Reservoir was computed by following Prismoidal Formula using water spread areas at corresponding elevations

NDWI = (DNG - DNNIR)/(DNG + DNNIR) (2.3)

“If NDWI is positive and if the DN value of NIR band is less than the DN value of Red band and the Green band (NIR<RED< GREEN), only then the pixel must be classified as water‖.

Nuket Benzer (2010) The study area, Goynuk, covers 1,437 square kilometers and is located in the southeastern part of Bolu, Turkey. A land use map of the study area was generated from Landsat TM 2000 satellite imagery. A digital elevation model (DEM) interpolated from elevation contours was used to generate the slope and LS-factor.

RUSLE has the same formula as USLE, but with several improvements in determining factors. These include some new and revised isoerodent maps; a time-varying approach for soil erodibility factor; a sub factor approach for evaluating the cover-management factor; a new equation to reflect slope length and steepness; and new conservation-practice values. Spatial vegetative cover, extracted from Landsat TM imagery, was used to determine the spatial C-factor and P-factor. The study indicated that highly eroded areas are bare lands and steep conditions, whereas less eroded areas are low slope classes. Kulhan watershed is delineated from SRTM DEM 90m resolution raster data and the drainage for Kulhan watershed were developed using toposheets. For my study

Drainage pattern is also developed from DEM using GIS Modules. By the standard soil class as suggested by USDA in soil survey manual and standard texture class through laboratory experiments it was found that study area have five major types of soil namely clay loam, gravelly sandy clay loam, sandy clay loam and sandy loam. According to soil survey manual soil erodibility factor represents both susceptibility of soil to erosion and rate of runoff, as measured under the standard unit plot condition.

Ahmet Karaburun et al., (2010) The aim of this study is estimate C factor values for Buyukcekmece watershed using NDVI derived from 2007 Landsat 5 TM Image. The final C factor map was generated using the regression equation in Spatial Analyst tool of ArcGIS 9.3 software. A time-series of NDVI were derived from Landsat 5 TM images acquired on April, May, June and August 2007. An average NDVI of watershed area was calculated using those NDVI images. The study assumes that there exists a linear correlation between NDVI and C factor and uses bare soil and forest NDVI values as reference values. Sample NDVI values were collected for bare soil and forest land cover classes from average NDVI image. Since C factor values range from 0 for well-protected soil to 1 for bare soil) the C factor values for bare soil and forest land cover were set to 1 and 0, respectively in the regression analysis. The regression equation was found is given in equation 2.4,

C factor = 1.02 – 1.21 * NDVI (2.4)

The final C factor map was generated using the regression equation in Spatial Analyst tool of ArcGIS 9.3 software. This technique for generating C factor map is used in my study.

Arun Babu Elangovan et al., (2011) The paper contributes to the quantitative assessment of Revised Universal Soil Loss Equation's Rainfall Erosivity (R) from daily rainfall depth in a data scarce watershed region. Rainfall depth for every 15 minutes from self recording rainguages was measured at four locations in the watershed and a simple model was established between rainfall erosivity and depth of rainfall. 163 events that contribute to soil erosion were identified and regression analysis was carried out using linear, logarithmic, exponential, power, polynomial and quadratic methods. It was found that a power function gave the highest coefficient of determination when compared with five other simple regression analysis of the Rainfall erosivity (MJ-mm/ha-event) versus the depth of rainfall. The simple power function developed to estimate the R factor from the depth of rainfall is given as R = 0.193 P 1.895 where R is the rainfall erosivity factor and P is the depth of rainfall.

Reshma parveen et al., (2012) In this study, Soil erodibility (*K*) of the study area can be defined using the relationship between soil texture class and organic matter content .Here in this study 30 m ASTER DEM has been used for calculating LS Factor. Raster calculator was used to derive *LS* map based on flow accumulation and slope steepness . The support practice factor *P* represents the effects of those practices such as contouring, strip cropping, terracing, etc. that help prevent soil from eroding by reducing the rate of water runoff. The *P* value range 0 to 1 where 0 represents very good manmade erosion resistance facility and 1 represents no manmade erosion resistance facility .The study revealed that area covered un-der slight, moderate, high, very high, severe, very severe soil loss potential zones are 64.70%, 17.10%, 10.05%, 4.65%, 1.60%, 1.90% respectively.

Ishtiyaq Ahmad et al., (2013) stated that a number of parametric models have been 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. *Data source:* Toposheets with 1:50000, IRS 1C LISS-III satellite data, DEM. The Soil Erodability factor quantifies the cohesive character of a soil type and its resistance to dislodging and transport (particle size and density dependent) due to raindrop impact and overland flow sheer forces. All the factors required for soil erosion estimation were calculated using ILWIS 3.0 GIS software and stored as thematic maps in raster format. These maps were then multiplied together to generate the soil erosion map using Map Calculation operation. Contour lines and spot heights given in the Survey of India topographic maps are used to create DEM and Slope maps in GIS software. The digital image processing of LISS-III data of the year 2001-02 was carried out to prepare the land use map of the Tandula catchment. The estimated soil erosion from Tandula catchment estimated using USLE has been compared with two empirical formulae, namely Sediment yield of Tandula Reservoir and Khosla_s Method and also with the Sedimentation analysis using Remote Sensing data.

Rohit Goyal et al., (2013) The Study area of this study is Bisalpur reservoir, Rajasthan. The Methodology used for soil erosion modeling is RUSLE- Revised Universal Soil Loss Equation. Data used for this study are DEM – ASTER, NDVI – MODIS, Landuse and

Landcover-MODIS, Rainfall data, Soil Map. In the original USLE equation, R measures the kinetic energy of the rain and requires measurements of rainfall intensity with autographic recorders, which is not commonly available in data scarce developing and remote regions.

For this, in Revised USLE, the monthly precipitation surface is interpolated to determine value of each cell based on the values of nearby cells. A regression equation between annual precipitation and the R factor has been used as the records of rainfall intensity is not available in that region. Renard and Freimund (1994) developed a regression equation between annual precipitation and the R factor is given in 2.5 and 2.6

$$R = 0.0483 \times P1.61 \text{ for } P < 850 \text{ mm} \qquad (2.5)$$

$$R = 587.8 - 1.219 \times P + 0.004105 \times P \text{ for } P > 850 \text{ mm} \qquad (2.6)$$

Where, R factor is in [MJ mm ha-1h-1yr-1] and Pa is annual precipitation in [mm].The C factor and P Factor for this study has been directly assigned to Landuse and Landcover of MODIS data. For my study the Landuse and Landcover map is generated from the LANDSAT data and the P Factor are assigned to them in GIS.

Anamika Shalini Tirkey et al., (2013) This study demonstrated the utility of high resolution LISS IV satellite data with 5 m spatial resolution in multispectral for accurate mapping of landuse landcover which forms an important component while computing the land cover and management factor and erosion control practice factor for soil loss estimation using RUSLE model. The CARTOSAT-I DEM was used for computing the flow accumulation and the slope length (LS) factor with adequate precision. In this study because of the presence of a single rain gauge station in the watershed, the value of R-factor was calculated using equation 4.7

$$R = 81.5 + 0.375 * r \qquad (4.7)$$

Where, r = Mean annual rainfall in mm. The area is relatively small it can be assumed that the rainfall characteristics are nearly uniform for the watershed. The errors in the DEM represented as sinks were rectified using the fill tool in the GIS software. The corrected DEM was utilized to deduce the flow direction to prepare the flow accumulation map. The LS factor map was then prepared using the slope and flow accumulation map in raster calculator in ArcGIS.LS Factor map is generated for my study as per the methodology in this paper. R factor map is generated for my study as per this paper if there is no sufficient rainfall data to calculate the R factor as per the formula given in RUSLE equation.

Kelvin K. K. Kuok et al., (2013) USLE consists of five major factors namely R, K, LS, C and P for calculating the soil loss. In recent years, the parameters of K, R, and LS are extensively studied. How- ever, parameters of C and P are not fully studied yet. In this study, the impact of *C* and P factors are investigated using Buffer Zone Calculator. Buffer Zone Calculator as a tool to determine the sediment removal efficiency for different C and P factors .The selected study areas are Santubong River, Kuching, Sarawak. Results show that the outfall TSS is increasing with the increase of C values. The most effective and efficient land use for reducing TSS among 17 land uses investigated is found to be forest with undergrowth, followed by mixed forest, forest with no undergrowth, cultivated grass, logging 30, logging 10^6, wet rice, new shifting agriculture, oil palm, rubber, cocoa, coffee, tea and lastly settlement/cleared land. Results also indicate that the % reduction of TSS is increasing with the decrease of P factor. The most effective support practice to reduce the outfall TSS is found to be terracing, followed by contour-strip cropping, contouring and lastly not implementing any soil conservation practice.

Yahya Farhan et al., (2013) calculated Erosivity factor (R) and soil erodibility factor (K) using both USLE and RUSLE models, then an estimate of soil loss in three north Jordan locations was obtained using the RUSLE model. This study attempts to employ the revised version of the Universal Soil Loss Equation (RUSLE), combined with RS and GIS technologies to:

- estimate the potential soil loss from areas within the Wadi Kufranja catchment
- produce soil erosion risk and soil erosion severity maps,
- identify areas of critical soil erosion conditions which require urgent need for appropriate conservation measures and land management

Soils are of low erodibility if the silt content is low, regardless of corresponding high content in the sand and clay fractions. Then 115 soil samples were collected from the field representing the different soil types over the water- shed. Location of these samples was controlled by GPS to generate digital maps of soil properties for GIS layer. The maps were generated using the inverse distance weighted (IDW) interpolation method on point data (vector layers) for the soil samples analyzed.

Berhanu F. Alemaw et al., (2013) aimed at the analysis of prevailing sedimentation processes in the nearby dozens of dams found in the Lotsane catchment located within the Limpopo Basin of Botswana, and focuses on assessment of annual sedimentation rate. A spatial analysis and model- ling study was conducted based on the Revised Universal Soil Loss Equation and GIS to determine sediment yield and degree of impact of each reservoir for a given landscape, rainfall and catchment heterogeneity.

Rasool Imani et al., (2014) Among Universal Soil Erosion Equation (USLE) factors (R, K, L, S and P), Soil Erodibility Factor (K) is one of the most important and key factors which determines soil particles resistance to be detachment by water erosion (rainfall and/or runoff) forces. K factor is the rate of soil loss per rainfall erosion index unit and affected by 6 parameters including soil primary particles (silt, sand and clay), organic matter content ,permeability and structure of soil. In this study, 38 samples of surface soil (0 - 15 cm) were collected from Yamchi watershed and the percentage of silt, sand, clay and organic matter content were determined in soil laboratory. Using USLE nomograph equation, K factor was calculated for each soil sample and based on Kriging interpolation method, Soil Erodibility factor (K) map was constructed for entire study area.

C.P. Devatha et al., (2015) The objective of the present study is to estimate the annual soil loss using USLE model for Kulhan watershed of Shivnath basin, sub-basin of Mahanadi basin, Chhattisgarh using RS and GIS techniques. Land useland cover and topographical data for the study area was derived using GIS and carried out geographical data analysis. Data collection includes for the study were annual rainfall data, digital elevation model (DEM) from Shuttle

Radar Topographic Mission (SRTM), land-use classification map and soil series maps were obtained from Chhattisgarh Council of Science and Technology (CCOST), Raipur, Chhattisgarh.

The five major input parameters used in the study are rainfall erosivity factor (R), Length slope factor (LS), soil erodability factor (K), vegetation cover factor (C) and erosion control factor (P). The rainfall erosivity factor had been determined from annual rainfall data of study area. The soil survey data was used to develop the soil erodability factor and DEM of study area was used to generate topographic factor (LS).The value of cover management factor and support practice factor were obtained from land use land cover map. After generation of input parameters, analysis was performed for estimation of soil erosion using USLE model by spatial information analysis approach. The quantitative soil loss (t/ha/year) ranges were estimated and classified the watershed into different levels of soil erosion severity and also soil erosion index map was developed. The watershed is classified according to Indian condition as suggested by Singh et, al into different erosion classes such as (>5) slight, (5-10) moderate, (10-20) high, (20-40) very high, (40-80) sever, (>80) very severe.

Hakan tanyas et al., (2015) The original method of the RUSLE and according to this method, a factor called soil loss ratio (SLR) for given conditions is calculated by using 5 different sub factors by the equation 4.8

$$SLR = PLU.\ CC\ .\ SC\ .\ SR\ .SM \tag{4.9}$$

where PLU is prior-land-use, CC is canopy cover, SC is surface-cover, SR is surface roughness, and SM is soil-moisture. Surface-Cover (SC) can be calculated from NDVI whereas CC cannot. Thus Vegetation Density (VD) is used to calculate SC and CC. VD is calculated from Advanced Vegetation Index (AVI) and Soil Index (SI).Soil Moisture factor can be estimated from Moisture Index from Topographic wetness Index. Prior Land Use is the effects of previous crop and tillage practices on Soil Erosion. Soil Consolidation factor can be linked directly to PLU. Terrain Ruggedness Index is used to calculate the Surface Roughness (SR) value. It is the difference between the value of a cell and the mean of 8 surrounding cells.

CHAPTER 3

STUDY AREA

3.1 GENERAL

West Godavari District is one of the 13 districts, in the Coastal Andhra region of Andhra Pradesh, India.The district is in the delta region of the Krishna and Godavaririvers. Khammam district lies to the north, East Godavari district to the east, the Bay of Bengal to the south, and Krishna district to the west.YerraKaluva dam has been situated across the Yerrakaluva river in Jangareddigudem mandal of West Godavari district.

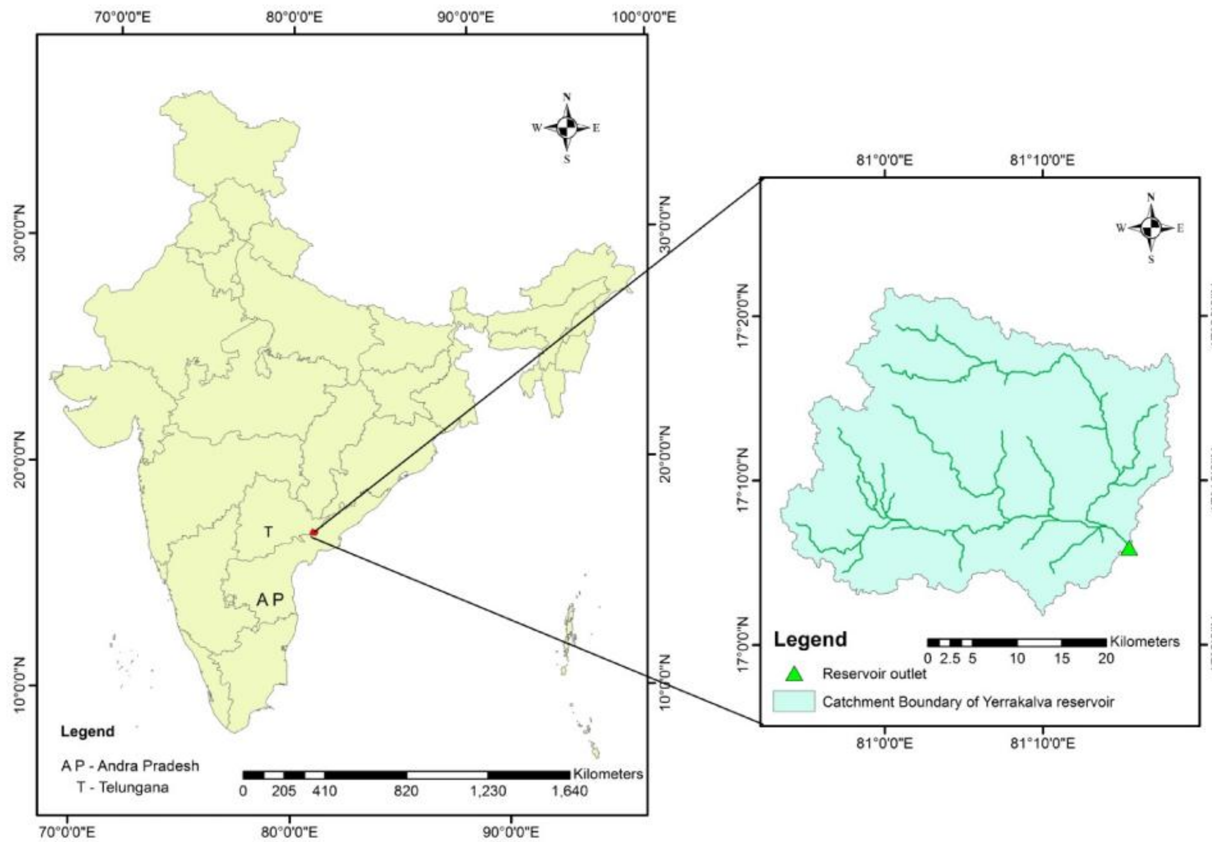

Figure 3.1 Location of Study Area

3.2 LOCATION

YerraKaluva basin situates at Konguvarigudem of Jangareddigudemmandal in West Godavari District, Andra Pradesh.The geographic location of the basin is 81° 15' 22" E Longitude and 17° 5' 44" N Latitude. The catchment area of this basin is about 1085 sq.km.

3.3 CLIMATE

The region has a tropical climate similar to the rest of the Coastal Andhra Pradesh region. The summers (March–June) are very hot and dry while the winters are fairly pleasant. The temperatures in the summers often rise over 50 degrees during the day.The rainy season (July–December) is often the best time for tourist visits, as fields are brilliantly green with paddy crops, rivers flowing with monsoon water, and a relatively cool climate.

3.4 AGRICULTURE AND IRRIGATION

The standard of living and the per capita income of the district is one of the highest in the State. The district is overwhelmingly rural with nearly 80 per cent of the population living in the rural areas.Of the geographical area of 7,79,535 hectares the net cultivated area constitutes 58.1 per cent.The chief source of irrigation for the district are canals from the Godavari and the Krishna rivers and open head channels from minor rivers like Tammileru, YeraKaluva, Juleru, Bynere, Tamileru and Gunderu besides a good number of tanks and wells.

3.5 DEMOGRAPHICS

According to the 2011 census West Godavari district has a population of 3,934,782.The district has a population density of 508 inhabitants per square kilometer.West Godavari has a sex ratio of 1004 females for every 1000 males, and a literacy rate of 74.32%.

CHAPTER 4

MATERIALS AND METHODOLOGY

Estimation of water availability or yield and water balance in a river catchment is critical to the sustainable management of water resources at watershed level in any country. Therefore, in the present study, Soil and Water Assessment Tool (SWAT) interfaced with Geographical Information System (GIS) was applied as a tool to predict water balance and water yield of a catchment area

SWAT was originally developed by the United States Department of Agriculture (USDA) to predict the impact of land management practices on water, sediment and agricultural chemical yields in large un-gauged basins [6]. The SWAT model is a catchment-scale continuous time model that operates on a daily time step with up to monthly or annual output frequency. The model operates by dividing a catchment into sub-catchments and each sub-catchment is connected through a stream channel' and further divided into a Hydrological Response Unit (HRU). The HRU is a unique combination of a soil and vegetation types within the subcatchment. The model calculation was performed on a HRU basis and flow and water quality variables were routed from HRU to sub-basin and subsequently to the catchment outlet. The simulation of hydrological cycle by SWAT is based on the water balance as in (4.1)

$$SW_t = SW_o + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right)_t \qquad (4.1)$$

where SW_t is the final soil water content (mm water);SW_o is the initial soil water content in day i(mm water); t is the time (days); R_{day} is the amount of precipitation in day i (mm water); Q_{surf} is the amount of surface run-off in day i (mm water); E_a is the amount of evapo-transpiration in day i (mm water); W_{seep} is the amount of water entering the vadose zone from the soil profile in day i (mm water); and Q_{gw} is the amount of return flow in day i (mm water).

Water availability or yield is the total amount of water leaving the HRU and entering main channel during the time step. It is one of the important parameters that need to be estimated for sustainable management of water resources of the study area. Water yield of a river catchment is estimated by the model using equation (4.2):

$$WYLKD=SURQ+LATQ+GWQ+TLOSS \qquad (4.2)$$

where *WYLD* is the amount of water yield (mm H2O), *SURQ* is the surface runoff (mm H2O), *LATQ* is the lateral flow contribution to stream flow (mm H2O), *GWQ* is the groundwater contribution to stream flow (mm H2O) and *TLOSS* is the transmission losses (mm H2O) from tributary channels in the HRU via transmission through the bed.

4.1 RUSLE

Research on soil erosion and its effect on agricultural productivity started in 1930s. During 1940 and 1956, research scientists began to develop a quantitative procedure for estimating soil loss in the Corn Belt in the United States. Several factors were introduced to an early soil loss equation, in which slope and practice were primarily considered. It was recognized that a soil loss equation could have a great value for farm planning and the Corn Belt equation could be adapted for other regions. In 1946, a group of erosion specialists held a workshop in Ohio to reappraise the factors previously used and added a rainfall factor. U.S. Department of Agriculture, Agricultural Research Service (ARS) established the National Runoff and Soil Loss Data Center at Purdue University in 1954 to locate, assemble, and consolidate all available data throughout the United States.Based on the data assembled at the Data Center and previous studies, Wischmeier, Smith, and others developed the Universal Soil Loss Equation (USLE). An Agriculture Handbook (No. 537) describing USLE was published in 1965 and revised in 1978. With a widespread acceptance, USLE has become the major conservation planning tool which is used in the United States and other countries in the world.

With additional research, experiments, data, and resources become available, research scientists continue to improve USLE, which led to the development of Revised Universal Soil Loss Equation (RUSLE). RUSLE has the same formula as USLE, but has several improvements in determining factors. These include some new and revised isoerodent maps; a time-varying approach for soil erodibility factor; a sub factor approach for evaluating the cover-management factor; a new equation to reflect slope length and steepness; and new conservation-practice values and methodology as shown in figure 4.1.

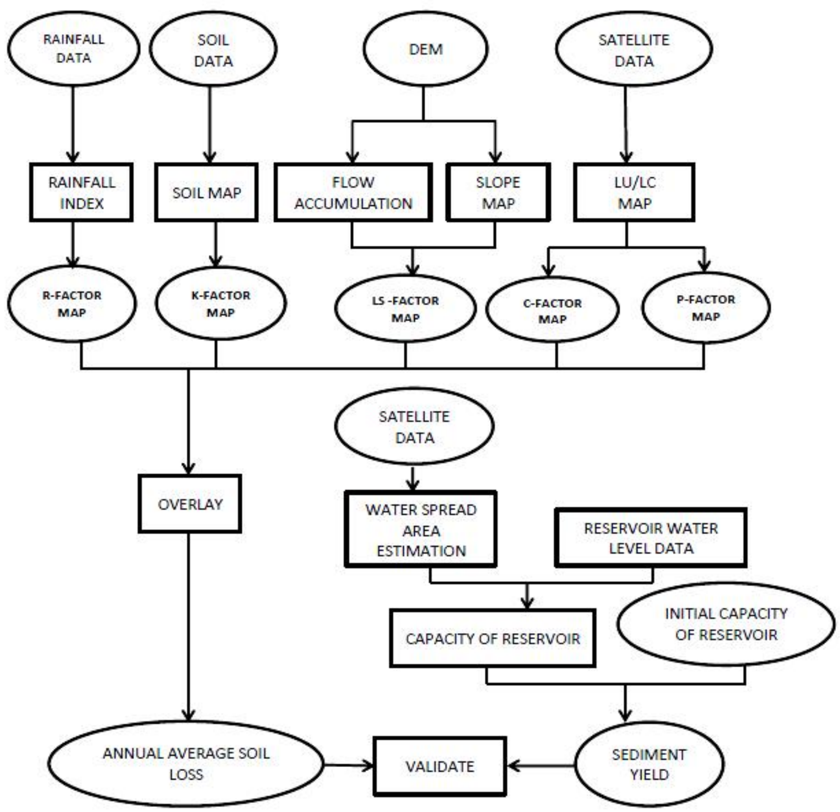

Figure 4.1 Methodology for RUSLE and its Validation

The underlying assumption in the RUSLE is that detachment and deposition are controlled by the sediment content of the flow. The erosion material is not source limited, but the erosion is limited by the carrying capacity of the flow. When the sediment load reaches the carrying capacity of the flow, detachment can no longer occur. Sedimentation must also occur during the receding portion of the hydrograph as the flow rate decreases. The basic form of the RUSLE equation has remained the same, but modifications in several of the factors have changed. Both USLE and RUSLE compute the average annual erosion expected on field slopes are given by

$$A=R*K*L*S*C*P \qquad (4.3)$$

Where,

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

R = **rainfall-runoff erosivity factor**—the rainfall erosion index plus a factor for any significant runoff from snowmelt (100ft×tonf×acre-1×yr-1);

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

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

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

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

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

4.2 RESERVOIR SEDIMENTATION USING SATELLITE IMAGERIES

The Satellite Remote Sensing (SRS) method for assessment of reservoir sedimentation uses the fact, that the water spread area of reservoir at various elevations keeps on decreasing due to sedimentation. Remote Sensing technique gives us directly the water spread area of the reservoir at a particular elevation on the date of pass of the satellite. Water spread area can be calculated by various techniques from the satellite imageries. In this study, water spread area is calculated by Normalized Differential Water Index (NDWI). NDWI is used to classify the water pixels from the satellite imageries and the classified image is converted to shapefile and water spread area of reservoir is calculated. Reservoir Level data for each day was collected from the reservoir authority which is noted at reservoir daily. From the water spread area and reservoir level, the volume of the reservoir is calculated using Trapezoidal formula. Cumulative volumes area calculated for different levels of reservoir as possible.

Stage-Capacity curve for the corresponding year is generated using the volume and its respective reservoir level. The original Stage-Capacity curve that is prepared initially at the time of reservoir construction is compared with the current Stage-Capacity curve and the difference in volume is calculated from it. The capacity difference is due to the sedimentation that is deposited into the reservoir over the period of time. Thus the sedimentation rate is estimated from the difference in capacity and the age of reservoir.

4.3 DATA USED

4.3.1 Satellite Imagery

LANDSAT 8 (OLI) satellite data has been used for Landuse and Land Cover Classification. The Specification of Landsat 8 data is given in the Table 4.1. The Satellite data for the study are in Standard FCC is shown in the Figure 4.2

Table 4.1 Specification of LANDSAT 8 Imageries

<table>
<tr><td rowspan="12">Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013</td><th>Bands</th><th>Wavelength (micrometers)</th><th>Resolution (meters)</th></tr>
<tr><td>Band 1 - Coastal aerosol</td><td>0.43 - 0.45</td><td>30</td></tr>
<tr><td>Band 2 – Blue</td><td>0.45 - 0.51</td><td>30</td></tr>
<tr><td>Band 3 – Green</td><td>0.53 - 0.59</td><td>30</td></tr>
<tr><td>Band 4 – Red</td><td>0.64 - 0.67</td><td>30</td></tr>
<tr><td>Band 5 - Near Infrared (NIR)</td><td>0.85 - 0.88</td><td>30</td></tr>
<tr><td>Band 6 - SWIR 1</td><td>1.57 - 1.65</td><td>30</td></tr>
<tr><td>Band 7 - SWIR 2</td><td>2.11 - 2.29</td><td>30</td></tr>
<tr><td>Band 8 - Panchromatic</td><td>0.50 - 0.68</td><td>15</td></tr>
<tr><td>Band 9 – Cirrus</td><td>1.36 - 1.38</td><td>30</td></tr>
<tr><td>Band 10 - Thermal Infrared (TIRS) 1</td><td>10.60 - 11.19</td><td>100 * (30)</td></tr>
<tr><td>Band 11 - Thermal Infrared (TIRS) 2</td><td>11.50 - 12.51</td><td>100 * (30)</td></tr>
</table>

* Resampled to 30 meters

4.3.2 DEM

ASTERDEM Data of 30 meters spatial resolution has been used to prepare Slope Map and Flow accumulation Map from which LS Factor map can be prepared. It s also used to delineate the Watershed boundary for the Study Area.

4.3.3 Soil Map

Soil map from NBSS has been used to prepare the thematic layer for the Study area. The Soil Erodability map is derived from soil map.

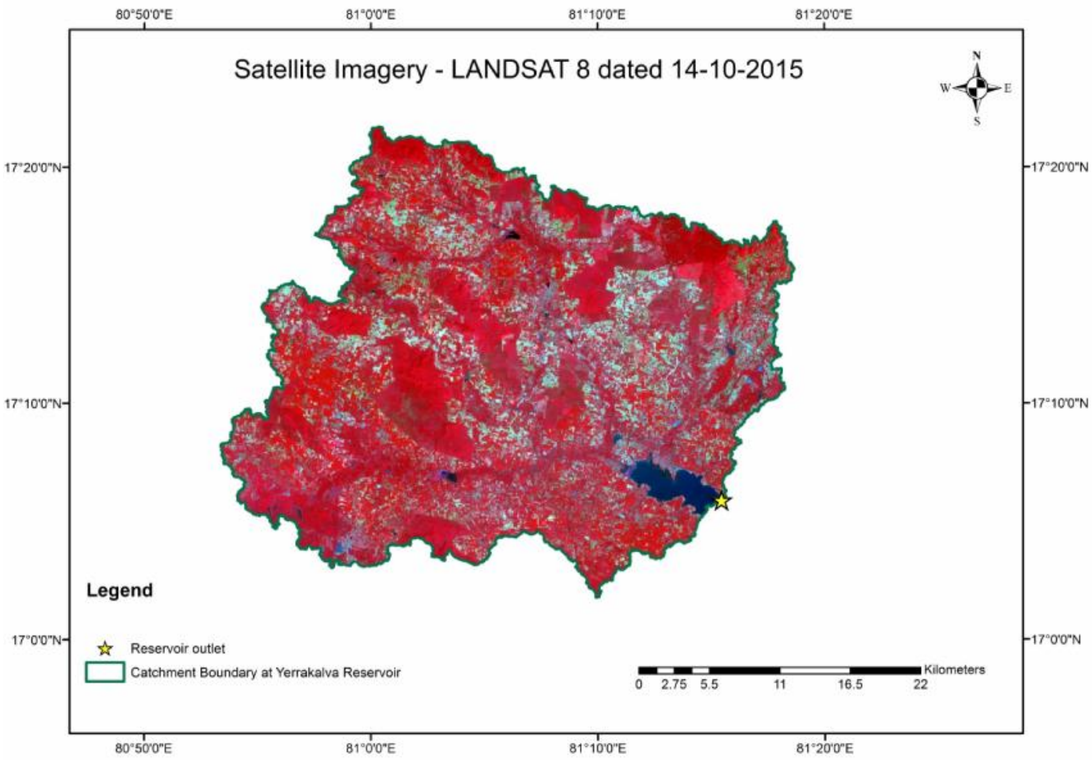

Figure 4.2 Standard FCC of Landsat 8 Satellite Imagery

4.4 SOFTWARES USED

4.4.1 ARC GIS 10.2

ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database.

4.4.2 ERDAS IMAGINE 9.1

ERDAS IMAGINE is a remote sensing application with raster graphics editor abilities designed by ERDAS for geospatial applications.

4.5 WATERSHED DELINEATION

Watershed of the reservoir is delineated using SWAT model in ArcGIS Software. ASTERDEM is used to delineate the watershed for the reservoir. The DEM is filled for the sinks in it. The Flow Accumulation and Flow Direction map is prepared from DEM. The streamlines are created from the Flow Accumulation and Flow Direction Raster maps. The watershed is delineated by selecting the outlet of reservoir along the streamline. The catchment area and the drainage pattern for Yerra kaluva Reservoir is shown in Figure 4.3.

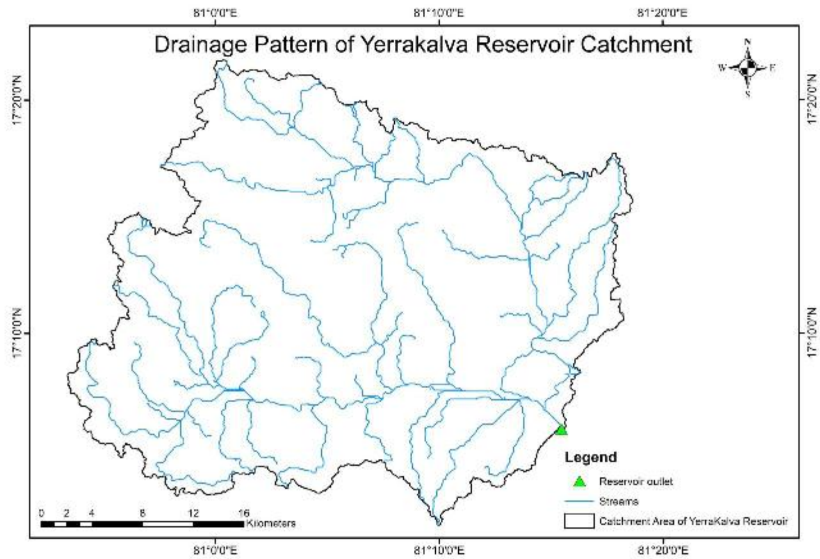

Figure 4.3 Catchment area and Drainage pattern of Yerrakaluva Reservoir

4.6 BASE MAP PREPARATION

The required base maps for the study such as Landuse and Landcover map, Slope Map, DEM, Soil Maps are prepared.

4.6.1 Land use and Land cover

The land use map is required for preparing the cover management factor of the RUSLE. Land use/Land cover classification was carried out by Supervised Classification method with six landuse classes viz, Forest, Crop land, Plantation, Barren Land, Settlement and water body. Different classes were identified in the basin and the sample pixels are selected with the reference base maps such as Toposheet mosaic, ArcGIS maps. Land use/Land cover map is prepared by the supervised classification in ERDAS Imagine with the spectral signatures of different classes. The Landuse and Land cover map for the Yerra kaluva catchment is shown in the Figure 4.4.

4.6.2 Soil Map

Soil maps at the scale of 1:500,000 prepared by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur have been used. It is georeferenced and digitized for the catchment of Yerra Kaluva Reservoir. The Soil Map for the Study area is shown in the Figure 4.5. The description of codes of soils presented in the soil map is given in the Table 4.2

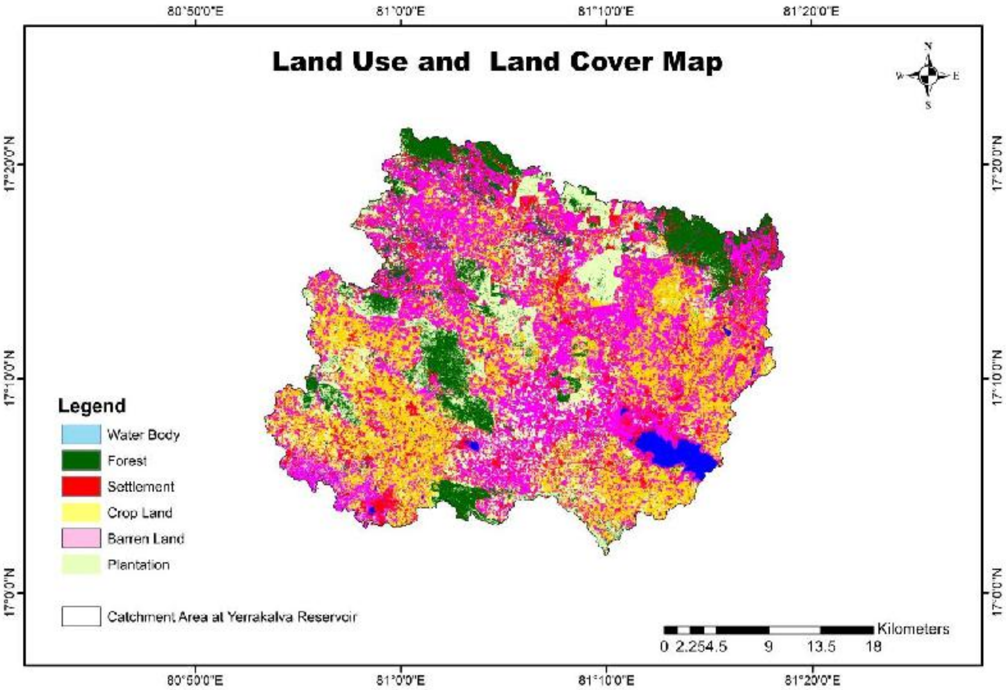

Figure 4.4 Land use and Land cover Map

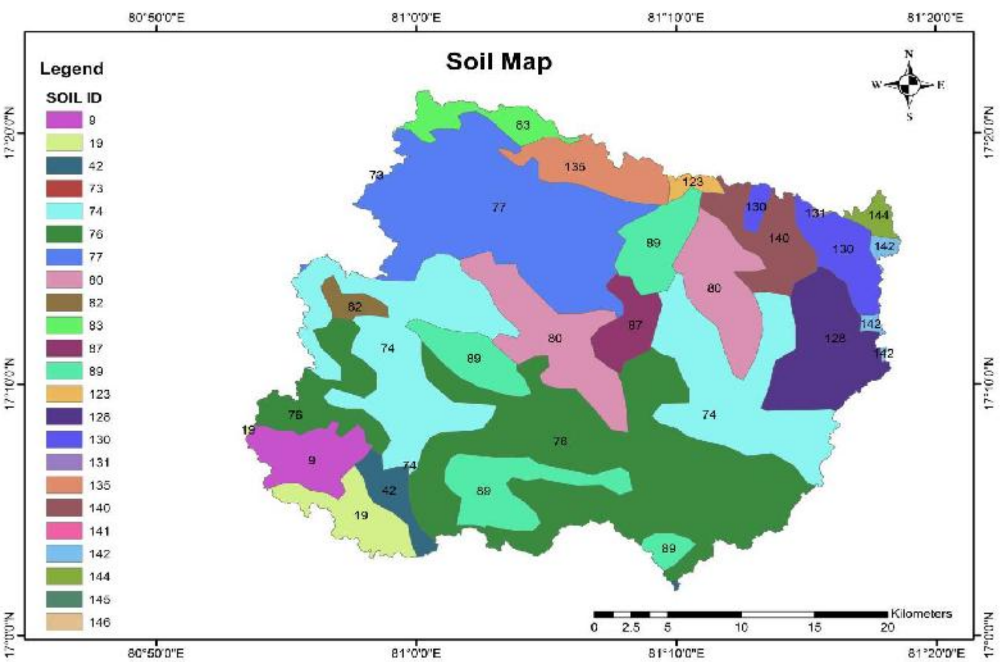

Figure 4.5 Soil map

Table 4.2 Description of Soil types in the study area (NBBSS & LUP)

Mapping Unit	Description	Soil Taxonomy
9	Moderately deep, well drained, gravelly clay soil with low AWC, on rolling lands, moderately eroded; associated with: Moderately deep, well drained clay soils.	Clayey-Skeletal, mixed, TypicRhodustalfs
19	Moderately deep, well drained, clayey soils with high AWC on gently sloping lands, moderately eroded; associate with: Deep, well drained, loamy soils with very high AWC	Fine , mixed Typic Haplustalfs Fine loamy, mixed, TypicUstropepts
42	Very deep, moderately well drained, cracking clay, calcareous soils with very high AWC, on nearly level valleys, salinity in patched; associated with: Deep, well drained, loamy over sandy, calcareous, stratified soils	Fine, montmorillonitic, (calcareous), VerticUstropepts Loamy over sandy, mixed (calcareous), Typic Ustifluvents
73	Deep, well drained, loamy soils with high AWC, on very gently sloping inter hill basins, moderately eroded; associated with: Deep, well drained, loamy soils	Fine Loamy, mixed, TypicPaleustalfs. Coarse loamy,mixed, RhodicPaleustalfs.
74	Very deep, well drained, loamy soils with high AWC, on very gently sloping plains, moderately eroded: associated with : very deep, well drained, clayey soils.	Fine Loamy, mixed, TypicPaleustalfs. Fine, mixed, TypicHaplustalfs.
76	Very deep, well drained, clayey soils with high AWC, on gently sloping lands, moderately eroded; associated with Moderately shallow, well drained, clayey soils	Fine mixed, RhodicPaleustalfs Fine, mixed,TypicUstorthents
77	Very deep, well drained, clayey soils with high AWC, on gently sloping lands, moderately eroded; associated with : very deep, well drained, loamy soils.	Fine, mixed, Rhodic Paleustalfs. Fine loamy,mixed, TypicUstropepts.
80	Deep, moderately well drained, loamy soils with high AWC, on gently sloping lands, moderately eroded; associated with : moderately deep, well drained, clayey soils.	Fine loamy, mixed Typic Haplustalfs. Fine, mixed, TypicUstropepts
82	Shallow, somewhat excessively drained gravelly loam soils with very low AWC, on hills and ridges, severely eroded; associated with: Moderately shallow, somewhat excessively drained, gravelly clay soils.	Loamy- skeletal, mixed, Lithic Ustorthents Clayey – skeletal, mixed, TypicUstorthents.

83	Very shallow, somewhat excessively drained, loamy soils with very low AWC, on hills and ridges, very severely eroded: associated with: moderately deep, somewhat excessively drained, clayey soils with high AWC.	Loamy, mixed, Lithic Ustorthents. Fine, mixed, TypicRhodustalfs.
87	Very deep, moderately well drained, cracking clay soils with very high AWC, on very gently sloping valleys, slightly eroded.	Fine, montmorillonitic, VerticUstropepts.
89	Rock outcrops on hills and ridges: associated with:Very shallow, somewhat excessively drained,gravelly loam soils with very low AWC, severely eroded.	Rock Lands Loamyskeletal, mixed, Lithic Ustorthents
123	Deep, well drained,loamy soils with high AWC, on very gently sloping interhill valley, moderately eroded; associated with: Deep, well drained, loamy soils.	Fine loamy, mixed,TypicPaleustalfs Fine, loamy,mixedTypicHaplustalfs.
128	Deep, well drained, loamy soils with surface crusting and medium AWC, on undulating lands, moderately eroded; associated with: Deep, well drained, clayey soils.	Fine loamy, mixed, TypicHaplustalfs Fine , mixed, RhodicPaleustalfs
130	Deep, well drained, clayey soils with surfacecrusting and high AWC, on rolling lands, moderately eroded: associated with : Deep, well drained, clayey soils	Fine, mixed, TypicHaplustalfs
131	Shallow, somewhat excessively drained, gravellyclay soils with very low AWC, on steeply sloping hill ranges, severely eroded : Rock outcrops.	Clayey-skeletal, mixed, (paralithic) Haplustalfs. Rock Lands.
135	Moderately deep, somewhat excessively drained,clayey soils with medium AWC, on steeply sloping hill ranges, severelyeroded : associated with: Rock outcrops	Fine, mixed, TypicUstropepts. Rock Lands
140	Moderately shallow, somewhat excessivelydrained, gravelly clay soils with very low AWC, on steeply sloping hill ranges, very severely eroded :associated with : Rock outcrops.	Clayey-skeletal, mixed, TypicArgiustolls.
141	Very deep, well drained, clayey soils with low AWC, on gently sloping lands, moderately eroded; associated with: Deep, well drained, clayey soils.	Fine, mixed, RhodicPaleustalfs Fine , mixed, TypicUstropepts
142	Deep, well drained, clayey soils with medium AWC, on very gently sloping plains, moderately eroded; associated with: Deep, well drained clayey soils.	Fine., mixed, ultic, Paleustalfs Fine , mixed, TypicUstropepts

144	Very deep, well drained, clayey soils with high AWC, on rolling lands, severely eroded; associated with: Very deep, well drained, clayey soils.	Fine , mixed, TypicUstropepts Fine , mixed, TypicHaplustalfs
145	Very deep, well drained, clayey soils with high AWC on very gently sloping valleys, slightly eroded; associated with: Very deep, moderately well drained, cracking clay, calcareous soils.	Fine , mixed, TypicUstropepts Fine montmorillonitic (Calcareous), VerticUstropepts
146	Very deep, moderately well drained, cracking clay soils with very high AWC, on very gently sloping plains, moderately eroded; assocaiated with: Very deep, moderately well drained, cracking clay soils	Fine montmorillonitic, TypicHaplusterts Fine, montmorillonitic, Vertic, Ustropepts

4.6.3 DEM and Slope map

DEM is required for computing the slope length and slope steepness factor (LS Factor) of the RUSLE. The DEM of the study area was generated using ASTERDEM data is shown in Figure 4.6. It is found that Northwest direction of the study area has high elevation and hilly region and the reservoir is at low elevation region situated in Southeast direction. DEM is used to delineate watershed and sub basin boundaries of the reservoir. It is also used to create drainage network to the reservoir. The DEM was then used to create the slope map for the study area using GIS software is shown in the Figure 4.7. The lower the slope value, the flatter the terrain and the higher the slope value, the steeper the terrain. It is found that the terrain of the study area is mostly flatter.

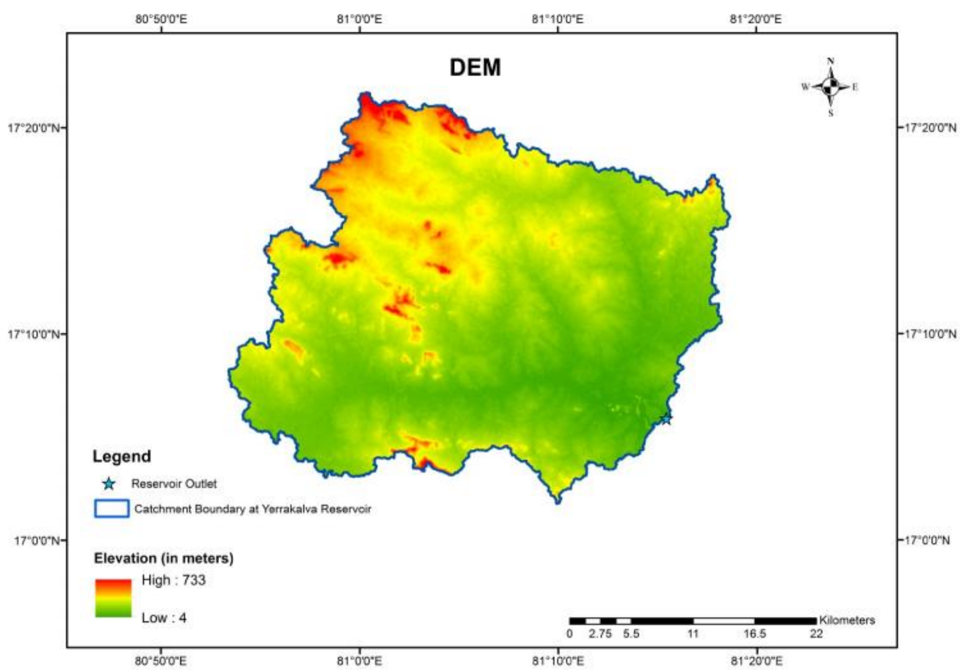

Figure 4.6 DEM of Yerrakalva watershed

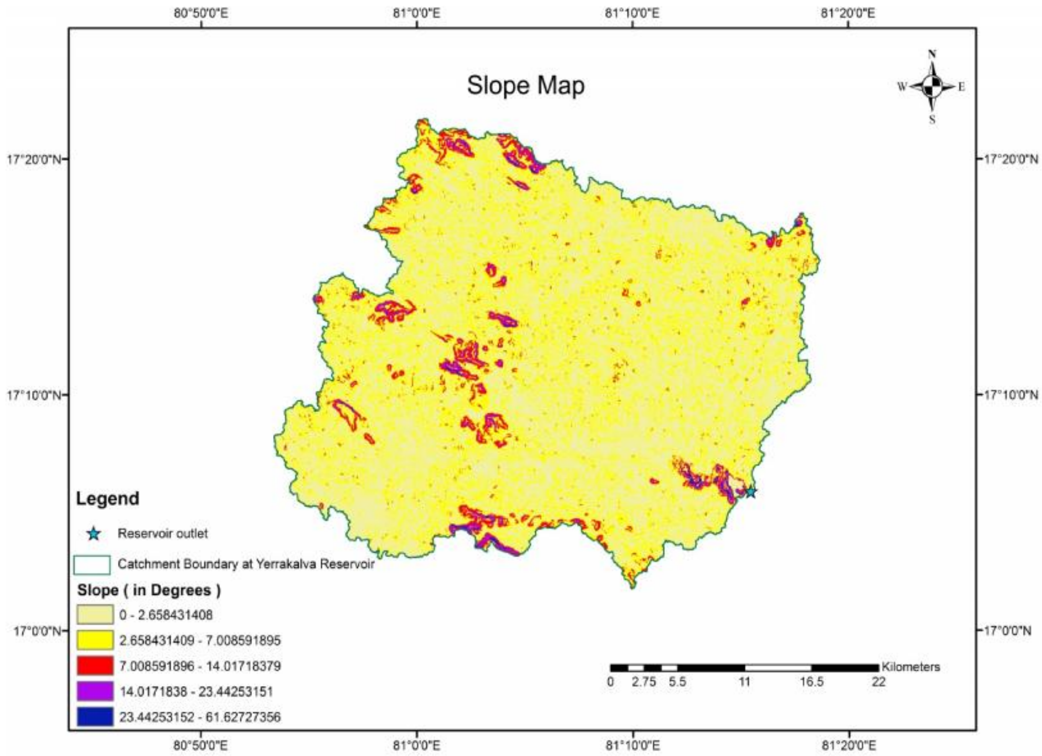

Figure 4.7 Slope Map of Yerrakalva watershed

4.6.4 Toposheet Mosaic

The Survey of India Toposheets are mosaicked for the study area and used as reference for Base maps that are prepared. The Toposheet Numbers that are used for the study area are. The mosaicked toposheet is shown is Figure 4.8

4.7 RAINFALL – RUNOFF EROSIVITY FACTOR

It is a measure of the erosive force and intensity of rain in a normal year.R factor is calculated from Annual Average rainfall from Raingauge station.In India, simple relationship between Erosivity index (R) and annual rainfall (X) has been developed by Singh et al, 1981 after analyzing the data collected from 45 stations distributed in different rainfall zones throughout the country. The relationship between R factor and average annual rainfall is given by a linear equation 4.4

$$R= 79 + 0.363* X \quad (4.4)$$

Where, R – Rainfall Erosivity Factor and X - Average annual Rainfall.

The Thessien polygon has been prepared with average annual rainfall for the study area and R factor values has been substituted. The Location, Average Annual Rainfall and R factor values of rain gauge stations around the reservoir are given in the Table 4.2. The Annual rainfall is calculated from 10 years daily rainfall data.The R factor values are assigned to respective polygons and R factor Map is prepared. The R factor map of the YerraKaluva catchment area is shown in Figure 4.9

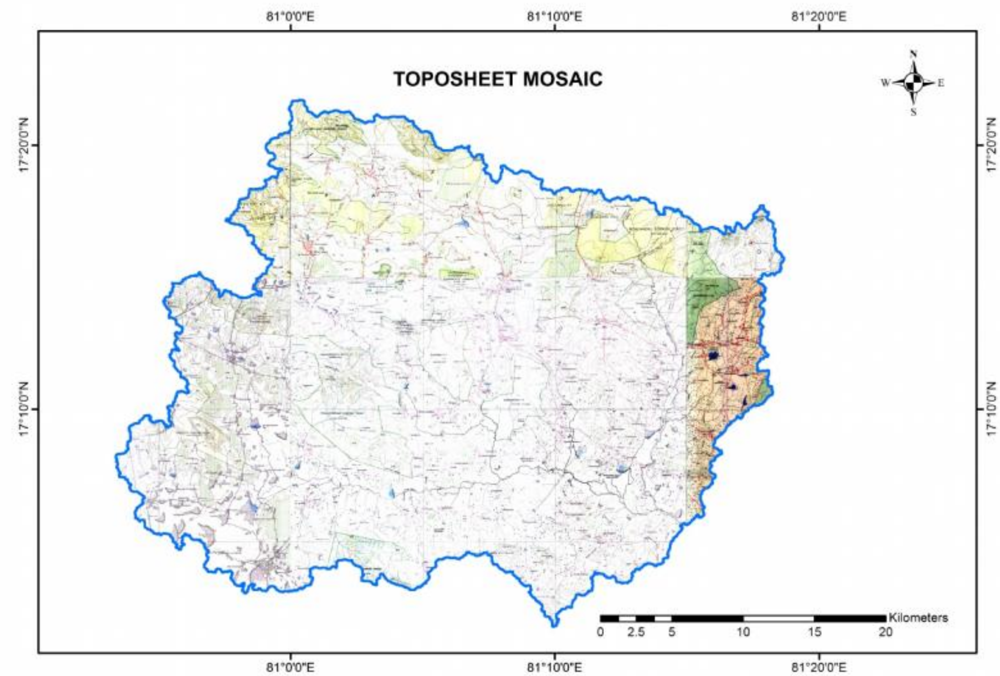

Figure 4.8 Toposheet mosaic of the study area

Table 4.3 Rainfall station and R factor values

S.No	**Rainfallgauge Location**	**Latitude (Decimal Degree)**	**Longitude (Decimal Degree)**	**Average Annual Rainfall in mm**	**R - Factor**
1	Aswaraopeta	17.2526	81.1380	1162.7	501.06
2	Dammapeta	17.2700	81.0119	1213.8	519.61
3	Jeelugumili	17.2113	81.1342	1148	495.72
4	Buttayagudem	17.2034	81.3214	1178	506
5	Jangareddigudem	17.1208	81.2966	1306.8	553.37
6	T Narasapuram	17.1032	81.0803	1342	566.23

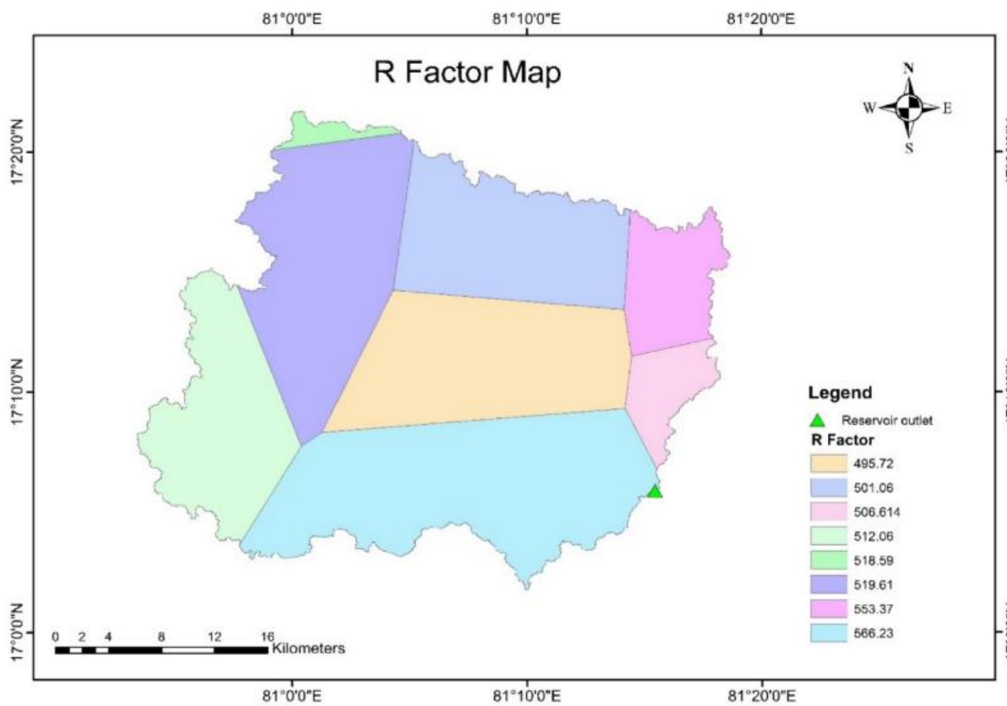

Figure 4.9 R Factor Map of Yerrakalva Catchment area

4.8 SOIL ERODIBILITY FACTOR (K - FACTOR)

It is the measure of the susceptibility of soil particles to detach and get transported by rainfall and runoff. Soil map for the study area has been prepared from the NBSS and LUP soil map by Georeferencing and digitization. Soil textural class has been identified using Nomograph. Soil Taxonomy and its textual class are given in the Table 4.4 and respective K factor is given in Table 4.5. The soil Taxonomy map is prepared by combining similar soil groups from NBSS soil classification. Soil Taxonomy map is shown in the Figure 4.10.

Table 4.4 Textural Class Classification

S.No	Soil Taxonamy	Silt	Sand	Clay	Organic matter	Textural Class
1	RhodicPaleustalfs	15.1	42.8	42.2	0.45	Clay
2	TypicPaleustalfs	13.8	44.2	42.1	0.36	Clay
3	LiticUstrothents	25.1	40	34.9	0.42	Clayey Loam
4	TypicUstopepts	21.6	47.4	31.1	0.49	Sandy Clay Loam
5	TypicHaplustalfs	30.7	35.9	33.4	0.52	Clayey Loam
6	TypicRhodustalfs	15.3	56.4	28.4	0.45	Sandy Clay Loam
7	UlticPaleustalfs	10.3	67.7	22.1	0.32	Sandy Clay Loam
8	TypicArgiustolfs	57	10	33	<0.5	Sandy Clay Loam

Table 4.5 K Factor values for different textual classes of soil

S.No	Soil Taxonamy	Textural Class	K- Factor
1	RhodicPaleustalfs	Clay	0.22
2	TypicPaleustalfs	Clay	0.22
3	LiticUstrothents	Clayey Loam	0.3
4	TypicUstopepts	Sandy Clay Loam	0.2
5	TypicHaplustalfs	Clayey Loam	0.3
6	TypicRhodustalfs	Sandy Clay Loam	0.2
7	UlticPaleustalfs	Sandy Clay Loam	0.2
8	TypicArgiustolfs	Sandy Clay Loam	0.2

Soil Textural class is identified from the percentage of silt, sand and clay content in different soil groups using Nomograph and Soil Texture map is prepared. Soil Texture map for the study area is shown in Figure 4.11.

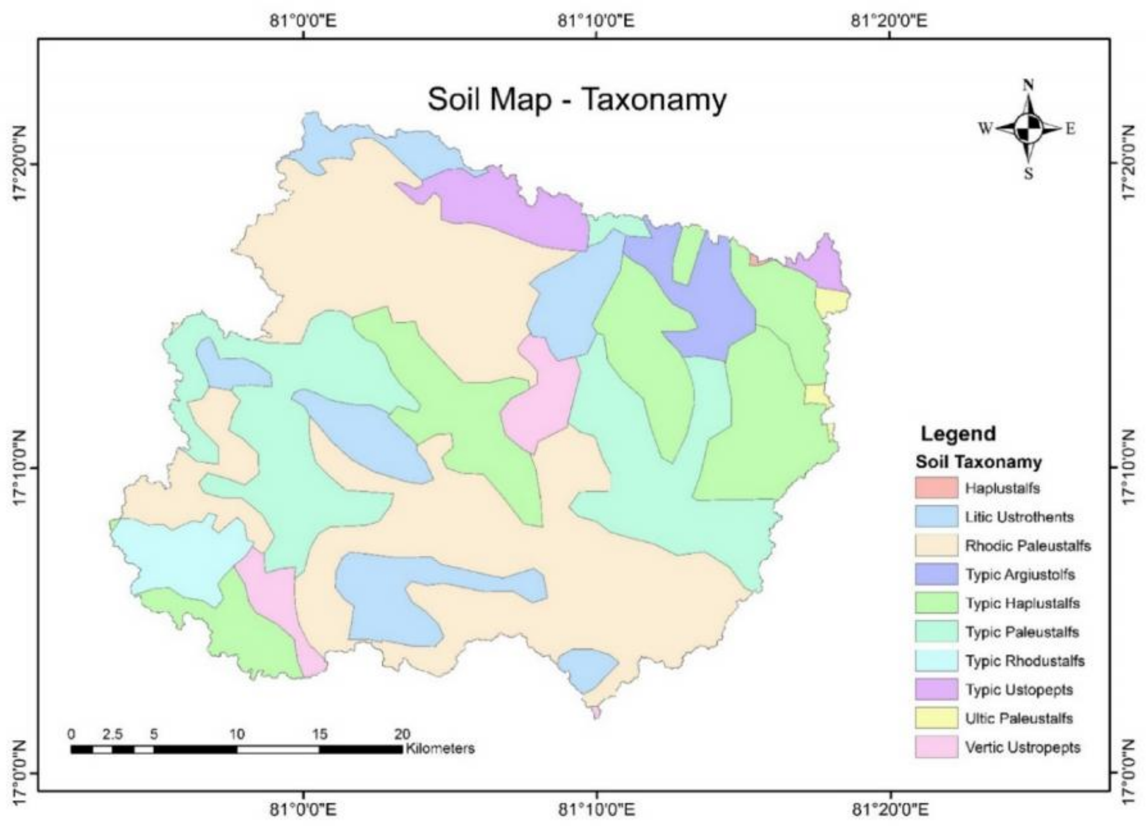

Figure 4.10 Soil Taxonomy Map

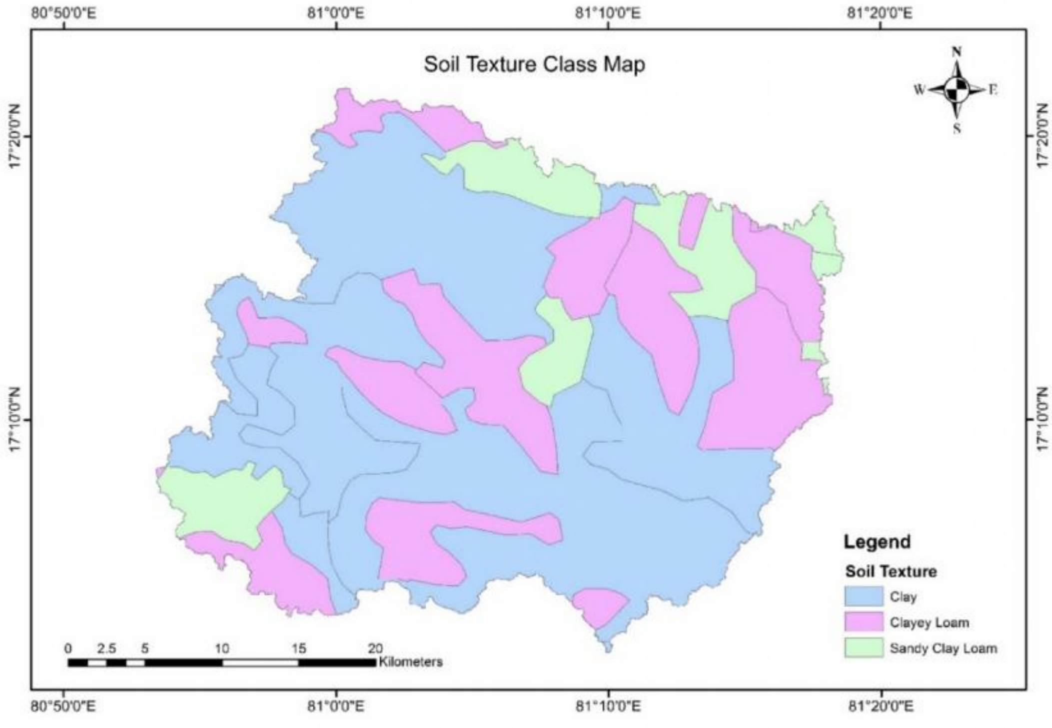

Figure 4.11 Soil Texture Map

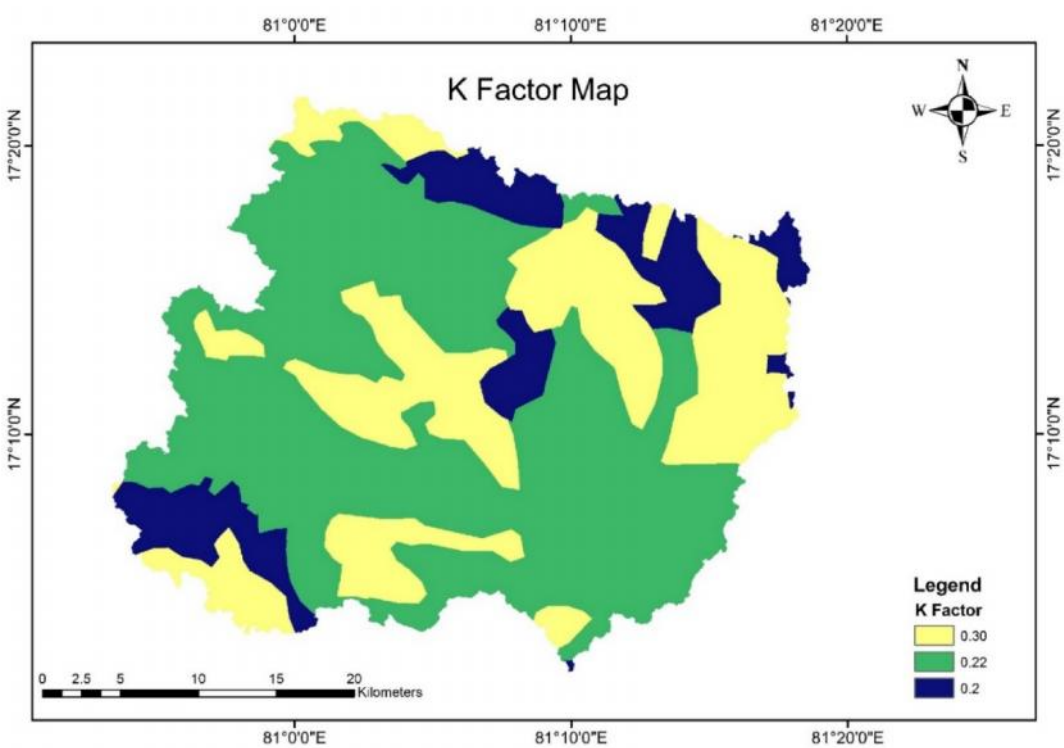

Figure 4.12 K Factor Map

K factor Values are assigned for different textural classes of soil and the vector data is converted into raster data of grid size 30 m × 30 m and K factor map is prepared and shown in the Figure 4.12.

4.9 SLOPE LENGTH AND SLOPE STEEPNESS FACTORS (LS- FACTOR)

Slope Length is the ratio of soil loss from the field slope length to that from a 72.6 foot (22.1meter) length on the same soil type and gradient.Slope Steepness is the ratio of soil loss from the field gradient to that from a 9 percent slope under identical conditions. This factor is calculated using ASTERDEM in ARCGIS 10.2.

L factor is calculated using equation 4.5,

$$L = \left(\frac{\lambda}{22.1}\right)^{m} \tag{4.5}$$

Where, L is the slope length factor, λ is the horizontal plot length in metre , m is a variable exponent calculated from the ratio of rill-to-interrill erosion.

S factor is calculated using, equation 4.6,

$$S = \left(\frac{\sin(0.01745 \times \theta_{deg})}{0.09}\right)^{n} \tag{4.6}$$

Where, θ is the slope in degrees, 0.09 is the slope gradient constant, n is an adjustable value depending on the soil's susceptibility to erosion. Flow Accumulation and Slopes in Degree are created using DEM of the study area. The LS factor is computed using equation 4.7 in Raster Calculator.

LS = Power("FA"*[R]/22.1,0.4)*Power(Sin("S"*0.01745))/0.09,1.4)*1.4 (4.7)

Where,

FA – Flow Accumulation Raster
S - Slope in degree
R - Cell Size
m = 0.4
n = 1.4

LS Factor map of Yerrakaluva catchment area is shown in Figure 4.13

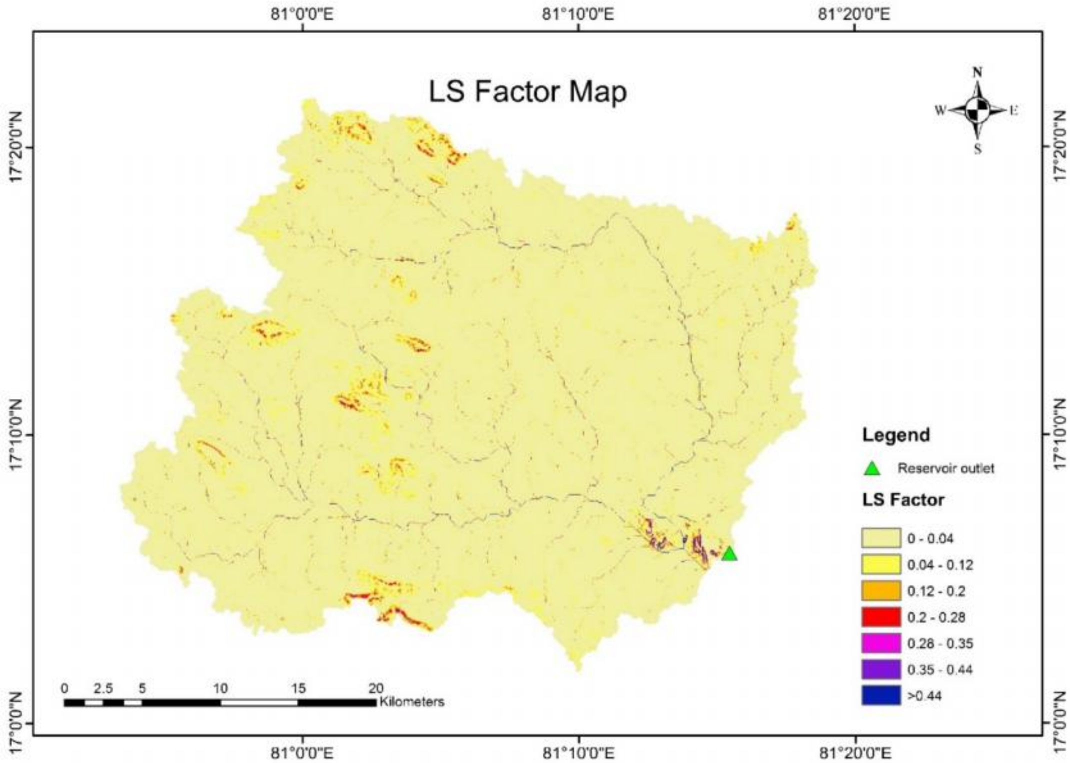

Figure 4.13 LS Factor Map

4.10 COVER MANAGEMENT FACTOR (C - FACTOR)

It is the ratio of soil loss from land under specified crop or conditions to the corresponding soil loss from tilled, bare soil. It is affected by

- crop canopy (leaves and branches of the crop, which intercept the raindrops and dissipate some of their erosive force),
- surface cover (crop residues and live vegetation on the soil surface),
- soil biomass (all vegetative matter within the soil; residue helps to improve the flow of water into the soil and the soil water-holding capacity),
- tillage (type, timing and frequency of tillage operations; has an effect on soil porosity, surface roughness and compaction),
- previous year's crop,
- Distribution of erosive rainfall over the growing season.

C – Factor map is prepared by assigning C factors to respective land use and land cover. C Factor values for different land use and land cover for this study are shown in Table 4.6

Table 4.6 C Factor values for different Land use and Land cover

S.No	Land cover and Land use	Area (in percentage)	C- Factor
1	Waterbody	1.15	0
2	Forest	11.95	0.04
3	Settlement	10.58	0.2
4	Cropland	24.1	0.34
5	Barren Land	32.12	1
6	Plantation	20.1	0.28

The Landuse/Land cover map is converted to polygons and grouped the polygons for each Landuse and Landcover classification. C factor values for different Landuse/Landcover given in the Table 4.6 are assigned for respective polygons. The polygons are then converted to raster grid of 30 m × 30 m cell size. The C factor map that is derived from Landuse/Landcover map is shown in Figure 4.14.

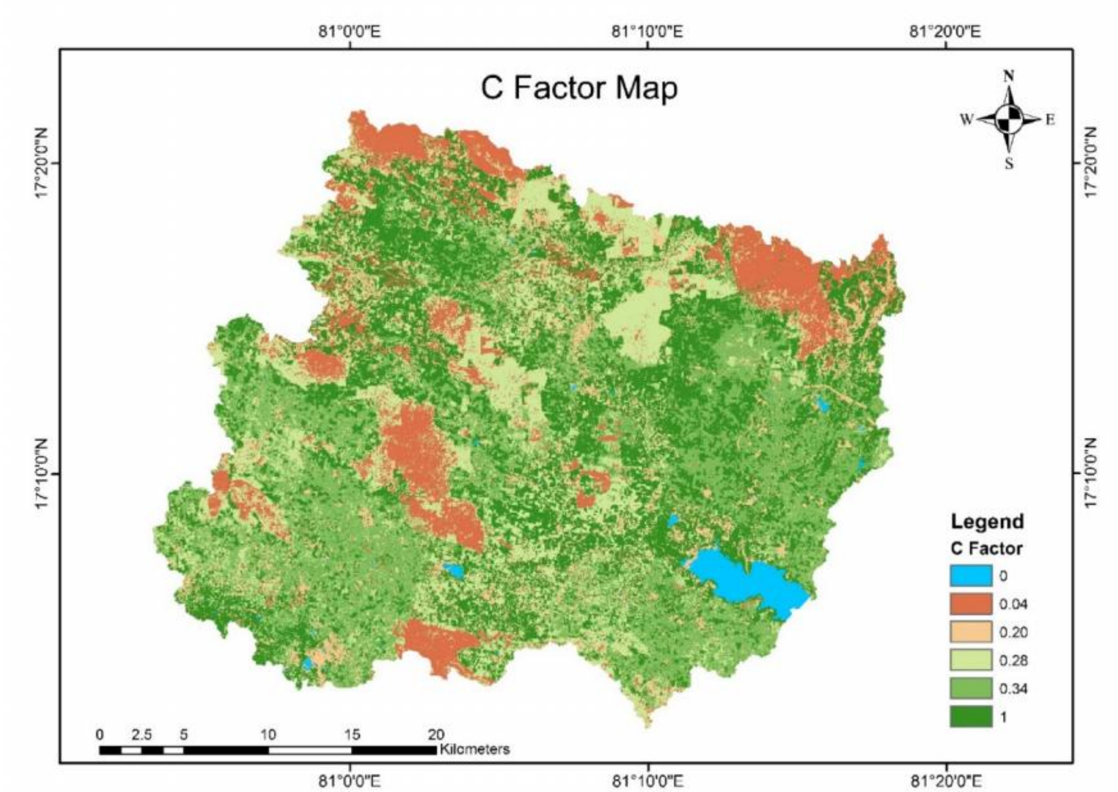

Figure 4.14 C Factor Map

4.11 SUPPORT PRACTICE FACTOR (P FACTOR)

It is the ratio of soil loss with a given surface condition to soil loss with up-and-down hill plowing. P factor map is prepared from the slope map according to Shin et al, 1999. P Factor values for different Slope range according to Shin, 1999 is shown in Table 4.7. P Factor map for the study area is shown in Figure 4.15

Table 4.7 P Factor values for different Slopes

S.No	Slope (%)	P- Factor
1	< 7	0.55
2	7.0-11.3	0.6
3	11.3 – 17.6	0.8
4	17.6- 26.8	0.9
5	>26.8	1

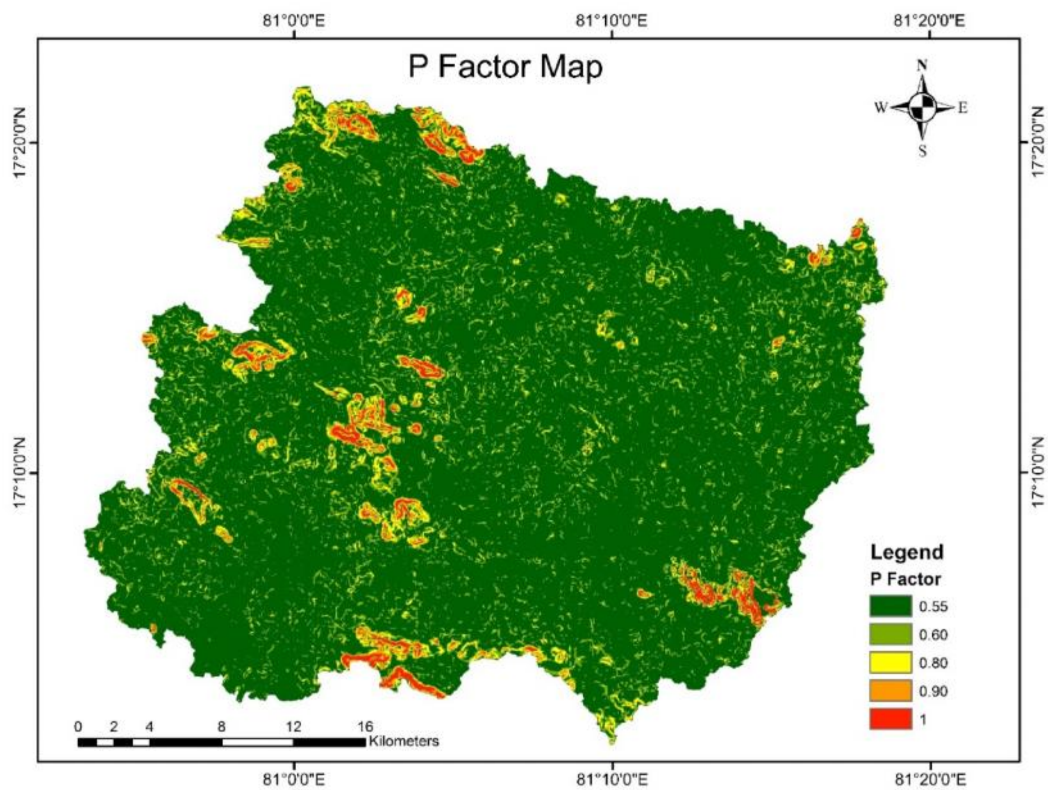

Figure 4.15 P Factor Map

CHAPTER 5

RESULTS AND DISCUSSION

5.1. WATER AVAILABILITY

The SWAT model was setup and calibrated for daily observed river discharges of 2009-2012 at Ananathapalli G-D site (1662 km^2) which is located downstream of Yerrakalva reservoir. Since discharges at G-D site are regulated by the reservoir, the reservoir is also incorporated in the model to take into account the effect of reservoir regulation on flows at G-D site. The discharge data of four years from 2005 to 2008 were used for validation of the model. The results exhibited fairly good agreement between observed and simulated daily values, with coefficient of determination (R^2) of 0.65 and Nash–Sutcliffe simulation efficiency (E_{NS}) of 0.64 for calibration and 0.62 and 0.62 respectively for validation. The monthly values, aggregated from daily values, however, indicated a very high performance with R^2 and E_{NS} of 0.98 and 0.95 for calibration and 0.87 and 0.87 respectively for validation. The model also computed various water balance components and it was found that surface runoff amounted to 16.6%, lateral flow 3.1%, base flow 22.4% and ET 55.7% of average annual rainfall during calibration and 16.2%, 2.8%, 19.5% and 56.9% respectively during validation. The annual water yield was computed as 580 mm (41.8%) and 536 mm (38.3%) during calibration and validation respectively. Overall, the model demonstrated good performance in capturing the patterns and trend of the observed flow series, which confirmed the appropriateness of the model for future scenario simulation.

In SWAT modeling, water availability or yield can be defined as the total amount of water leaving the HRU and entering main channel during the time step. It is one of the important parameters to be estimated for efficient water management and planning of the case study area. The contributions of each sub-basins in the watershed area to water yield during the period of simulation period was examined using the calibrated SWAT model. The detailed water availability as given in the table 5.1

5.2. ANNUAL AVERAGE SOIL LOSS

Annual Average soil erosion is estimated from five Factor maps in Raster form with uniform cell size. Average soil loss map is created using raster calculator by multiplying five Factor maps. The Map showing Annual Average Soil loss is shown in Figure 5.1. The Average Annual soilloss of Yerrakalva Reservoir Catchment area is 0.49 tonnes/acre/yror 121 tonnes/sq km/yror 0.864 ha-m /100sq km /yror 0.000782 TMC/yr.

5.3 ANNUAL AVERAGE SOIL LOSS – SUB BASIN WISE

Soil loss is estimated for each sub basins to identify the spatial variability of soil loss in the catchment area. The annual average soil loss maps for each sub basins are shown in Figure 5.2 to 5.8

Table 5.1 water availability in the sub basins

Average monthly water availability(mm)	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	SC-7	SC-8	SC-9	SC-10	SC-11	SC-12	SC-13	SC-14	SC-15	SC-16	SC-17	SC-18	SC-19
Jan	16.22	13.91	8.58	4.56	5.12	4.47	41.44	4.34	2.57	2.89	4.70	4.38	5.19	2.74	1.08	1.77	2.54	2.29	1.86
Feb	6.57	5.54	3.91	2.04	2.26	2.23	41.69	2.09	1.19	1.46	2.48	2.21	2.39	1.15	0.38	0.68	0.90	1.07	0.74
Mar	7.87	5.98	2.88	0.99	1.45	1.28	30.94	1.41	0.79	0.76	1.64	1.63	1.60	0.68	0.33	0.38	0.56	0.68	0.43
Apr	2.34	1.50	1.47	0.34	0.59	0.73	14.64	1.12	0.50	0.31	1.19	1.63	0.67	0.25	0.16	0.14	0.25	0.41	0.18
May	3.00	1.43	3.98	0.88	2.27	1.91	6.51	2.82	1.49	0.73	2.99	3.58	2.66	1.01	0.65	0.21	0.58	1.10	0.32
Jun	24.81	16.57	9.18	1.09	3.88	3.46	2.55	5.65	2.58	2.07	6.31	7.53	4.61	1.44	1.26	0.35	1.02	1.88	0.50
Jul	63.62	48.66	45.89	15.61	42.64	5.74	1.46	10.56	4.34	5.44	11.68	13.32	46.53	20.06	5.38	3.31	5.66	3.50	4.13
Aug	129.07	107.00	88.55	45.96	94.45	41.85	9.90	45.57	27.91	28.56	53.57	42.91	100.82	46.90	18.36	9.94	17.20	22.28	12.90
Sep	150.02	128.10	90.22	50.64	84.82	35.03	13.79	38.19	24.24	19.94	41.18	36.59	88.88	43.51	27.13	14.12	28.01	19.27	18.49
Oct	101.81	87.69	65.73	38.22	52.09	33.25	13.18	32.75	20.68	18.71	36.60	31.67	54.32	26.65	11.70	9.51	16.77	17.27	11.56
Nov	66.91	57.26	53.98	32.04	42.52	38.62	8.45	38.18	26.24	22.01	41.28	34.65	43.56	22.90	11.77	8.40	15.33	20.51	10.21
Dec	36.48	31.42	23.73	13.30	15.42	12.84	24.32	11.83	7.31	7.35	12.97	11.70	15.77	8.09	3.86	3.97	6.47	6.25	4.55

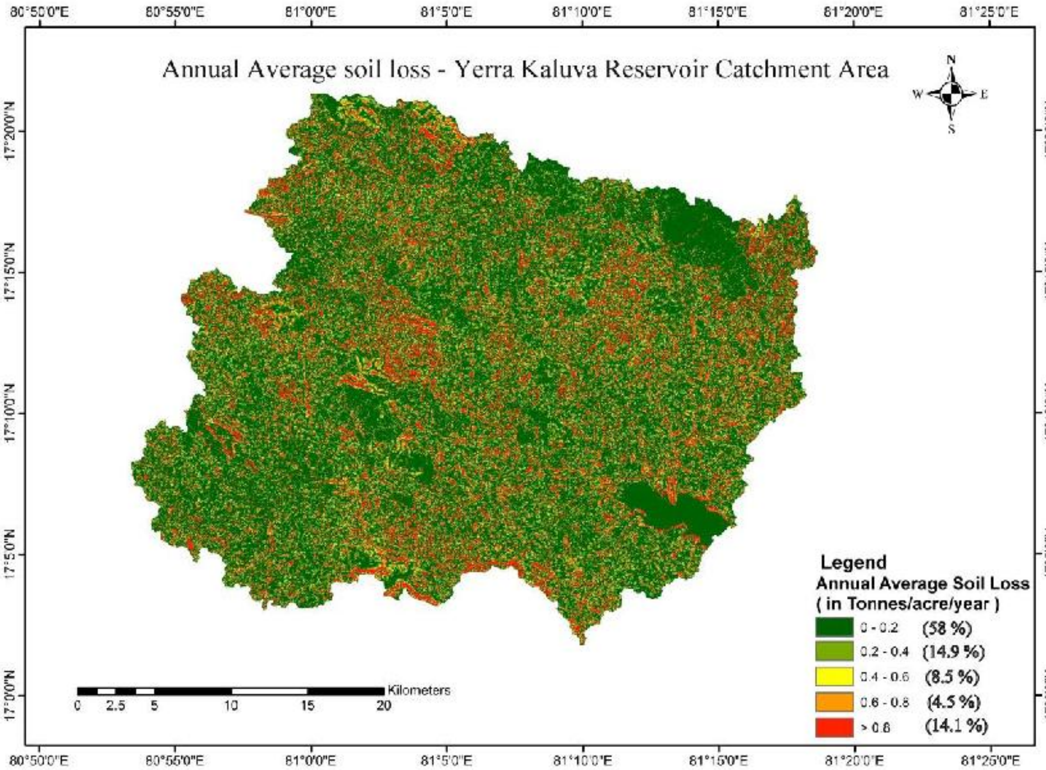

Figure 5.1 Average Annual Soil Loss Map

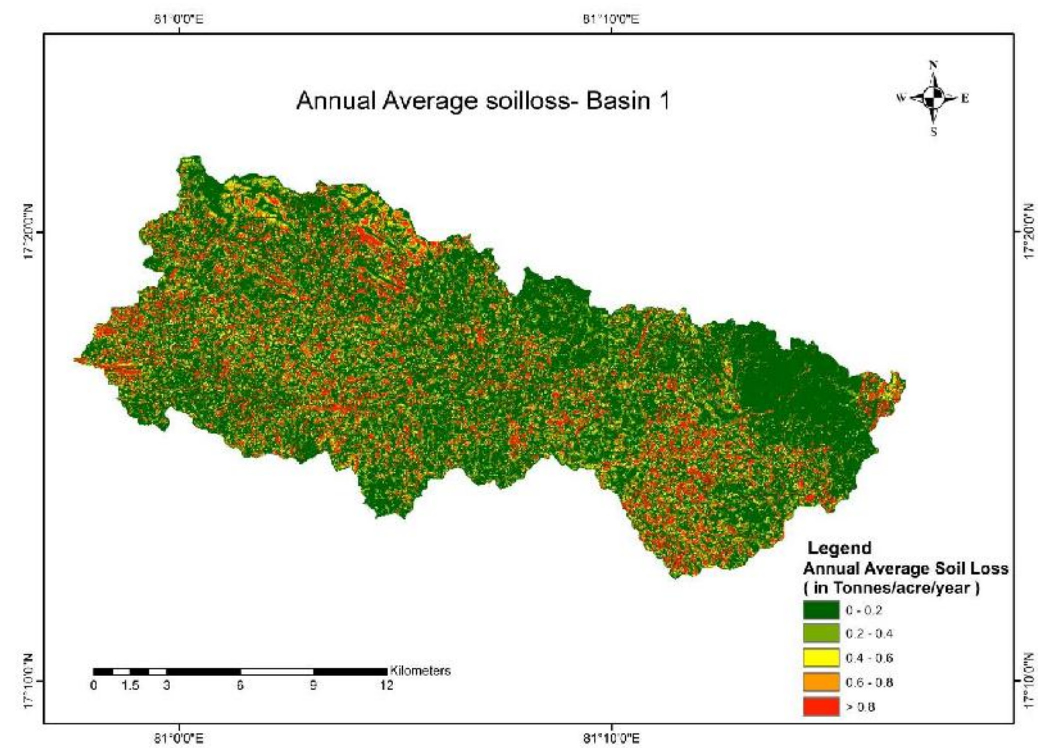

Figure 5.2 Annual average soil loss for sub basin 1 in Yerrakaluva reservoir catchment

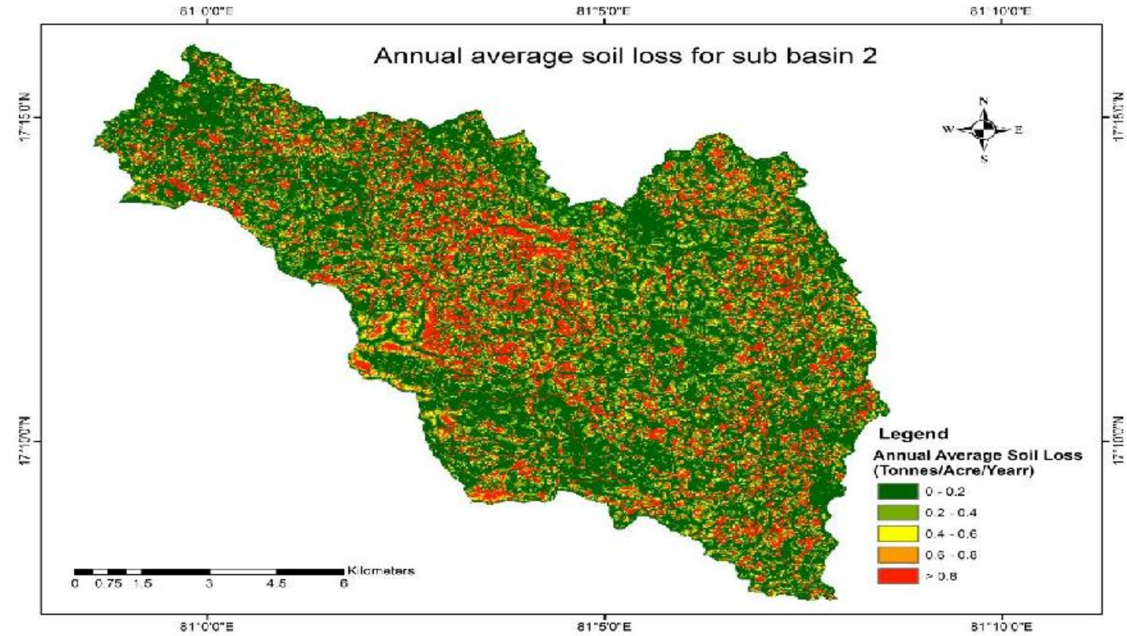

Figure 5.3 Annual average soil loss for sub basin 2 in Yerrakaluva reservoir catchment

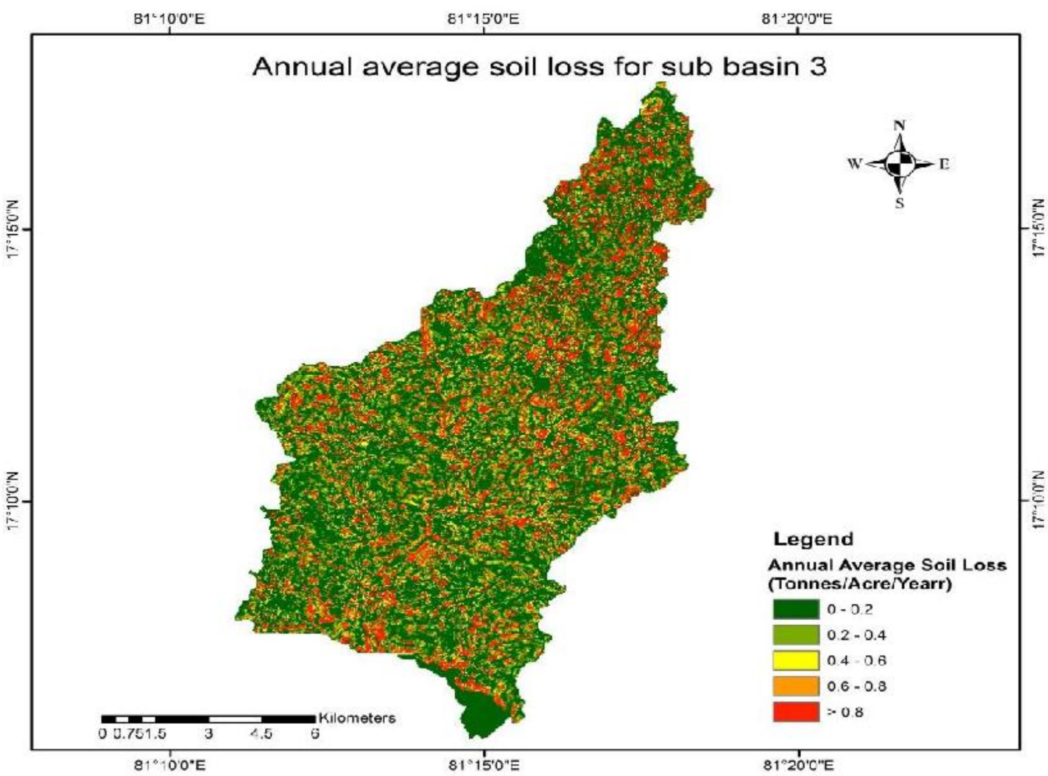

Figure 5.4 Annual average soil loss for sub basin 3 in Yerrakaluva reservoir catchment

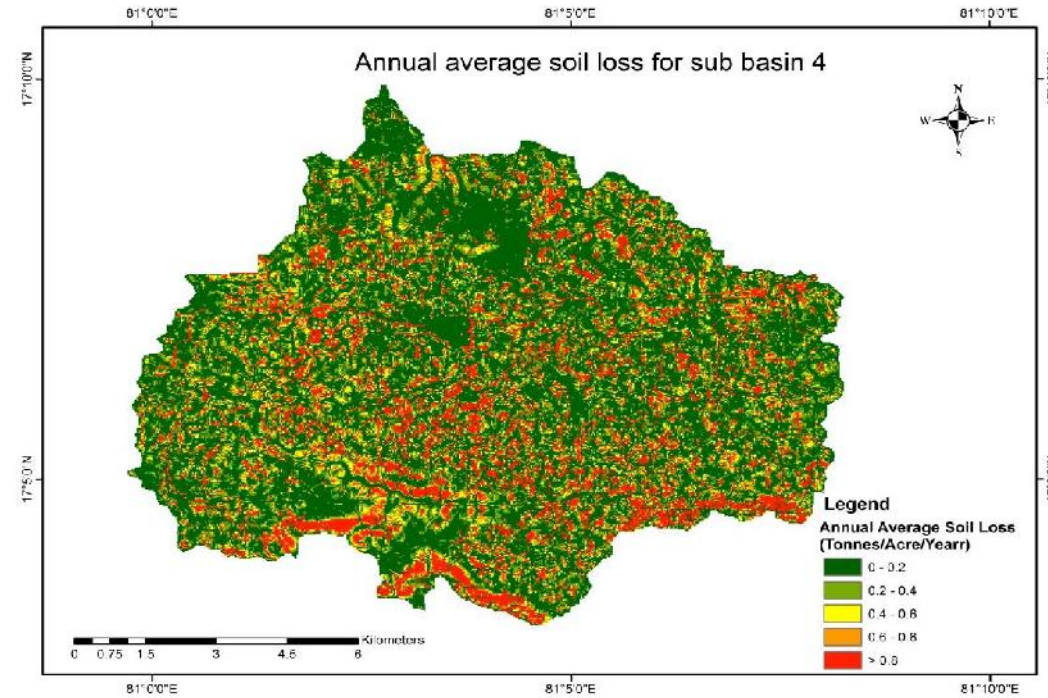

Figure 5.5 Annual average soil loss for sub basin 4 in Yerrakaluva reservoir catchment

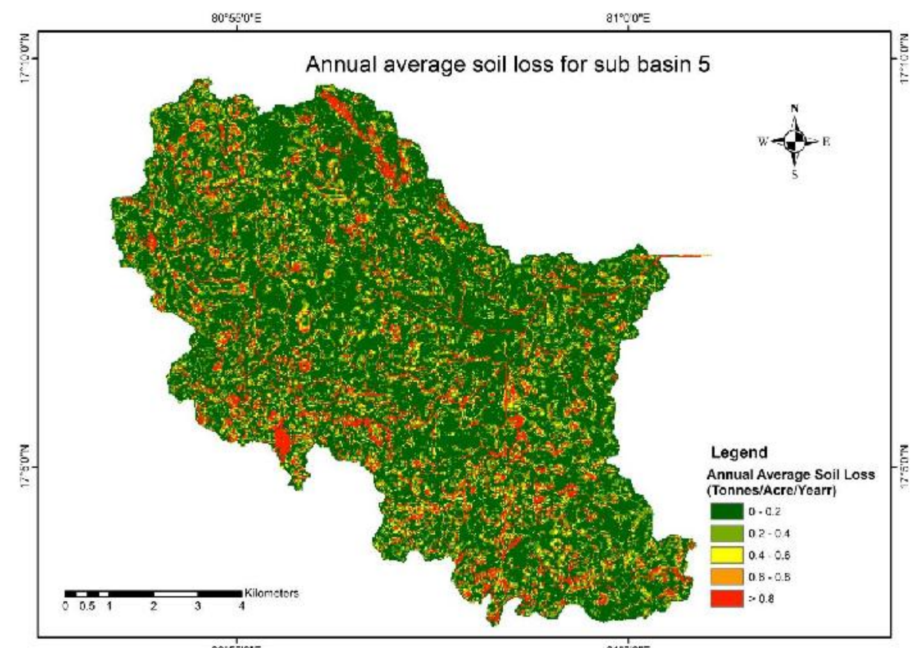

Figure 5.6 Annual average soil loss for sub basin 5 in Yerrakaluva reservoir catchment

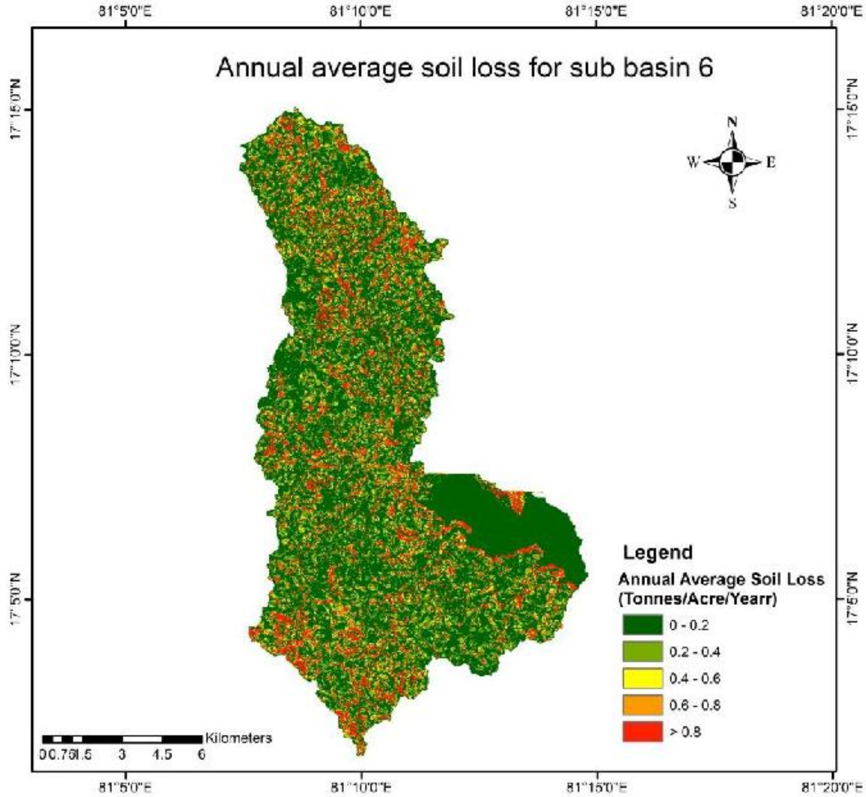

Figure 5.7 Annual average soil loss for sub basin 6 in Yerrakaluva reservoir catchment

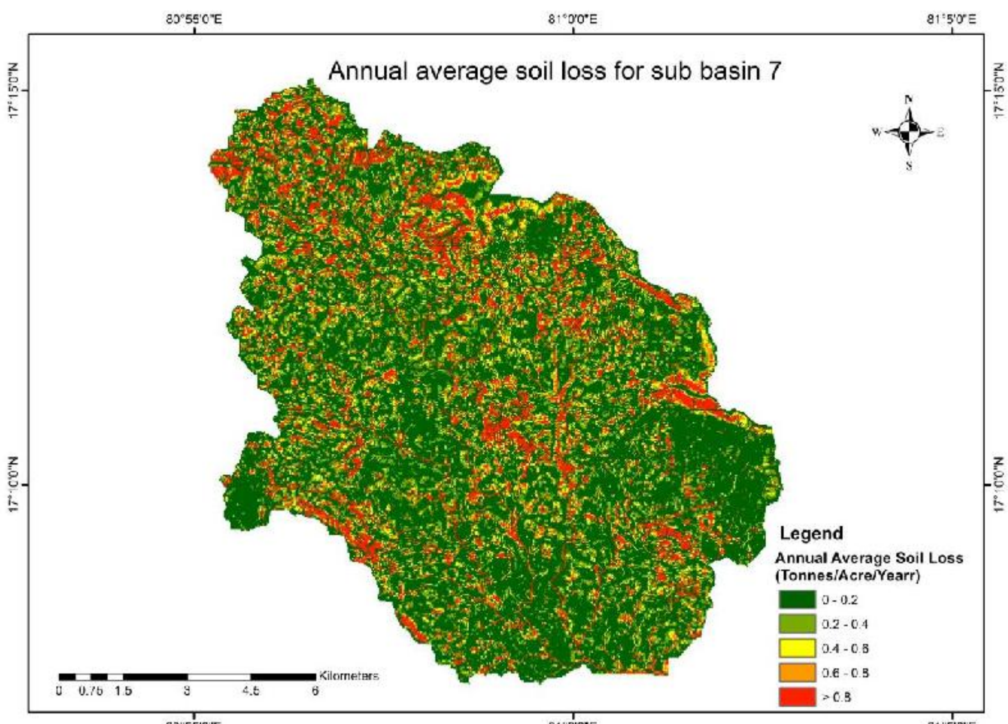

Figure 5.8 Annual average soil loss for sub basin 7 in Yerrakaluva reservoir catchment

The annual average soil loss of each sub basin is calculated and prioritization was done is shown in the Figure 5.9. It is found that sub basin 3 is more vulnerable to soil erosion as it has fallow lands and hilly regions with the estimate of 0.62 Tonnes/acre/year. Sub basin 5 is found to be less vulnerable with average annual soil loss of 0.39 Tonnes/acre/year as the slope is uniform in this sub basin.

5.4 SEDIMENT DELIVERY RATIO (SDR)

Sediment delivery ratio (SDR) is defined as the sediment yield from an area divided by the gross erosion of that same area. SDR is expressed as a percent and represents the efficiency of the watershed in moving soil particles from areas of erosion to the point where sediment yield is measured. 50

According to USDA SCS (1979), SDR is calculated using,

$$SDR = 0.51\ A^{-0.11} \qquad (5.1)$$

where A = drainage area in square miles.

5.5 SEDIMENT YIELD BY RUSLE

SDR for Yerra Kaluva catchment is 0.263 for the catchment area of 1085 sq kms. The Gross erosion of Yerra kaluva reservoir catchment area is is 131285 tonnes/yr. The estimated sediment rate at Yerrakaluva reservoir is 34527 tonnes/yr. The sediment yield at Yerrakaluva reservoir is 31.82 Tonnes/km2/yr The estimated sediment rate at Yerrakaluva reservoir is 34527 tonnes/yr. The sediment yield at Yerrakaluva reservoir is 31.82 Tonnes/km2/yr and sub-basin wise given in table 5.2.

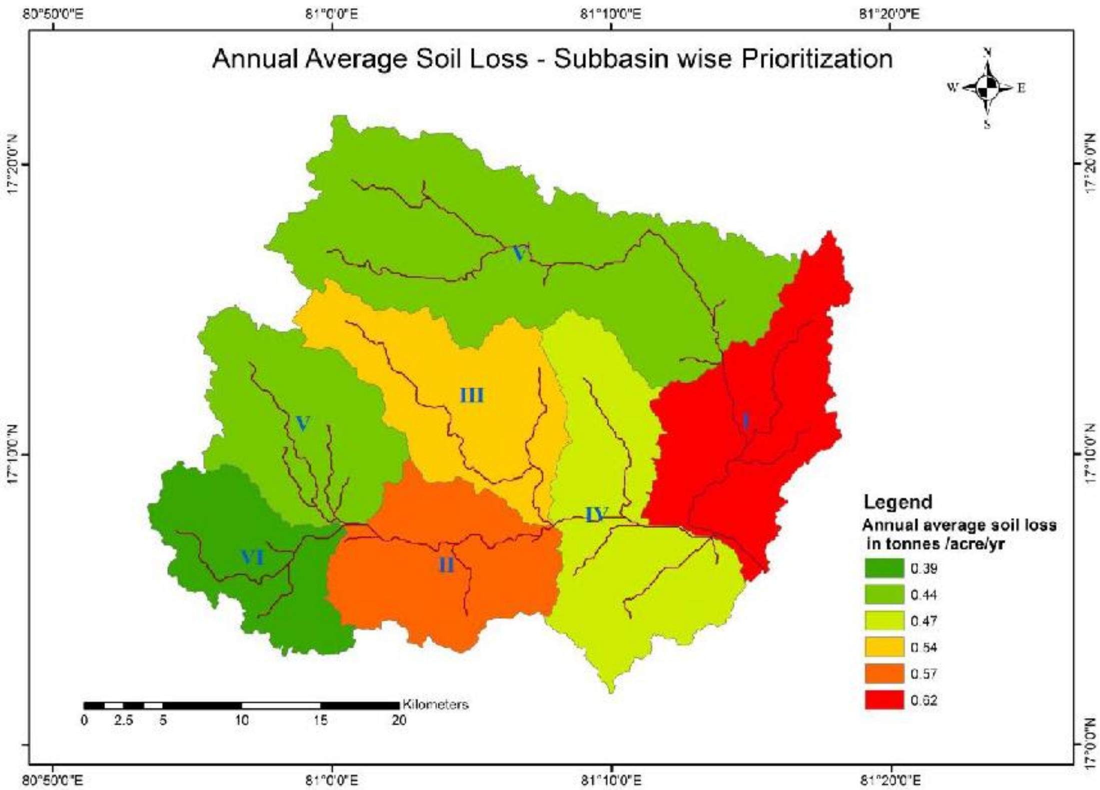

Figure 5.9 Annual average soil loss in Yerrakaluva reservoir catchment – Sub basin wise

Table 5.2 Annual average soil loss and sediment yield for sub basins

Sub Basin	Catchment Area (Km2)	Annual Average Soil Loss (T/acre/yr)	Sediment Yield (T/Km2/yr)
1	294.49	0.44	28.59
2	138.97	0.54	35.1
3	143.80	0.62	40.29
4	121.27	0.57	31.99
5	95.65	0.39	25.35
6	164.61	0.47	30.35
7	125.8	0.44	28.59
Whole Basin	1085	0.49	31.82

5.6 NDWI

NDWI defined by McFeeters (1996), in which Green and NIR bands are used to monitor changes related to water content in water bodies. NDWI is designed to 51 maximize the reflectance of a water body by using green wavelength, minimize the low reflectance in Near-IR, and take advantage of the high reflectance in Near-IR of vegetable and soil features. NDWI is used to delineate the water spread area in Landsat 7 imageries. The equation to calculate NDWI is given below.

$$NDWI = \frac{GREEN-NIR}{GREEN+NIR} \qquad (5.2)$$

Table 5.3 LANDSAT 7 sensor specification

	Landsat 7 bands	**Wavelength (micrometers)**	**Resolution (meters)**
Enhanced Thematic Mapper Plus (ETM+)	Band 1	0.45-0.52	30
	Band 2	0.52-0.60	30
	Band 3	0.63-0.69	30
	Band 4	0.77-0.90	30
	Band 5	1.55-1.75	30
	Band 6	10.40-12.50	60*(30)
	Band 7	2.09-2.35	30
	Band 8	0.52-0.90	15

5.7 WATER SPREAD AREA

Water spread area for different levels of reservoir is calculated from satellite imageries of different dates using NDWI classification. The classified image is converted into polygons using ArcGIS 10.2 and the water spread area is extracted from those polygons. The water spread for each dates are given in the Figure 5.10 to Figure 5.16.

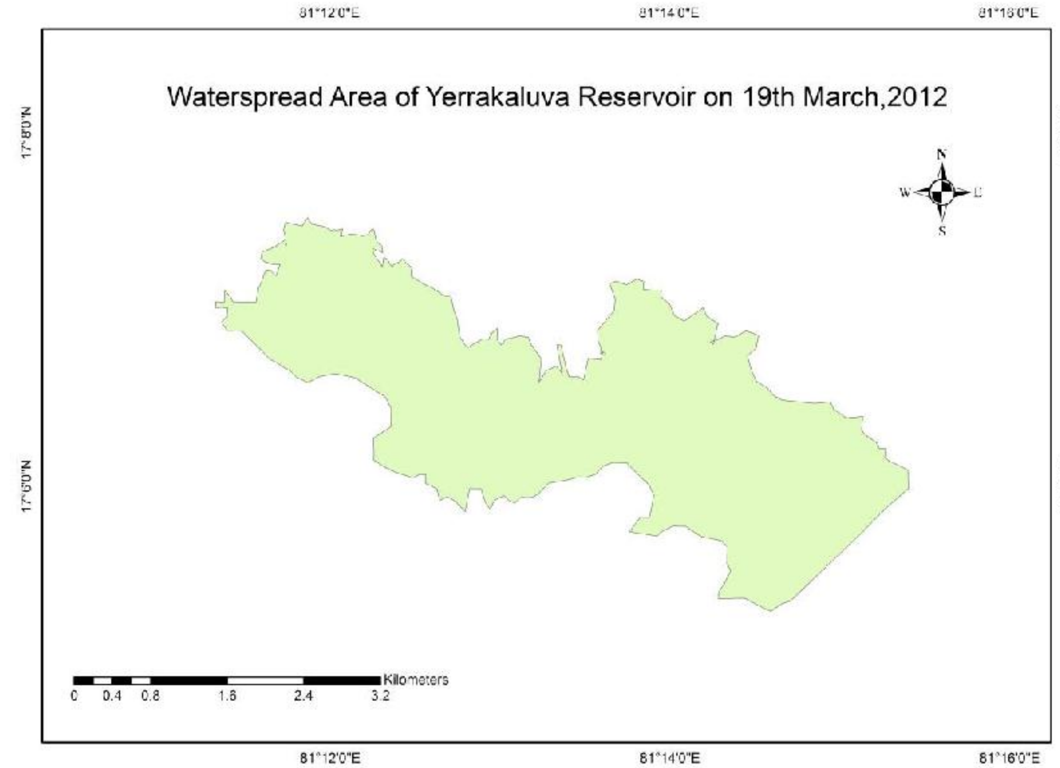

Figure 5.10 Water spread area for YerraKaluva Reservoir – March 19th, 2012

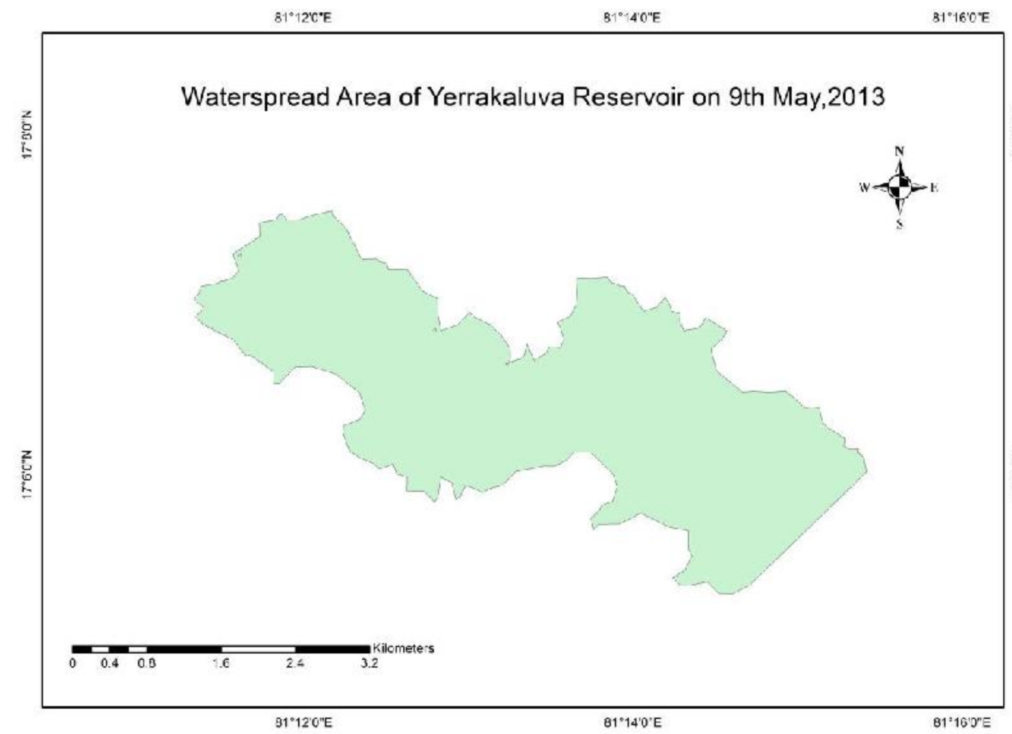

Figure 5.11 Water spread area for YerraKaluva Reservoir – May 9th,2013

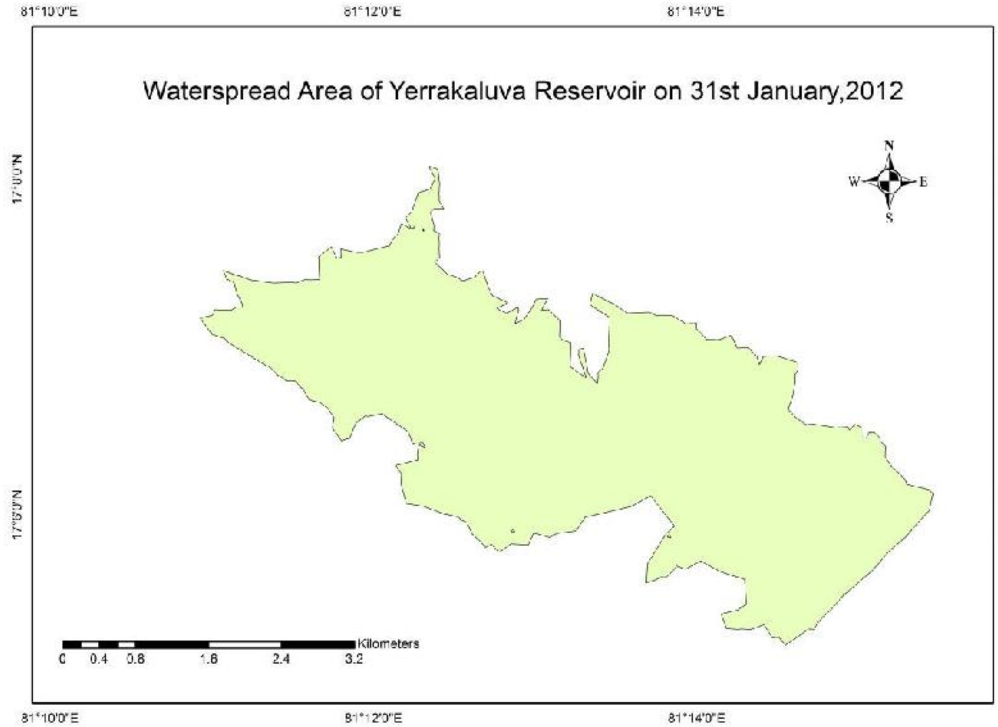

Figure 5.12 Water spread area for YerraKaluva Reservoir – January 31st ,2012

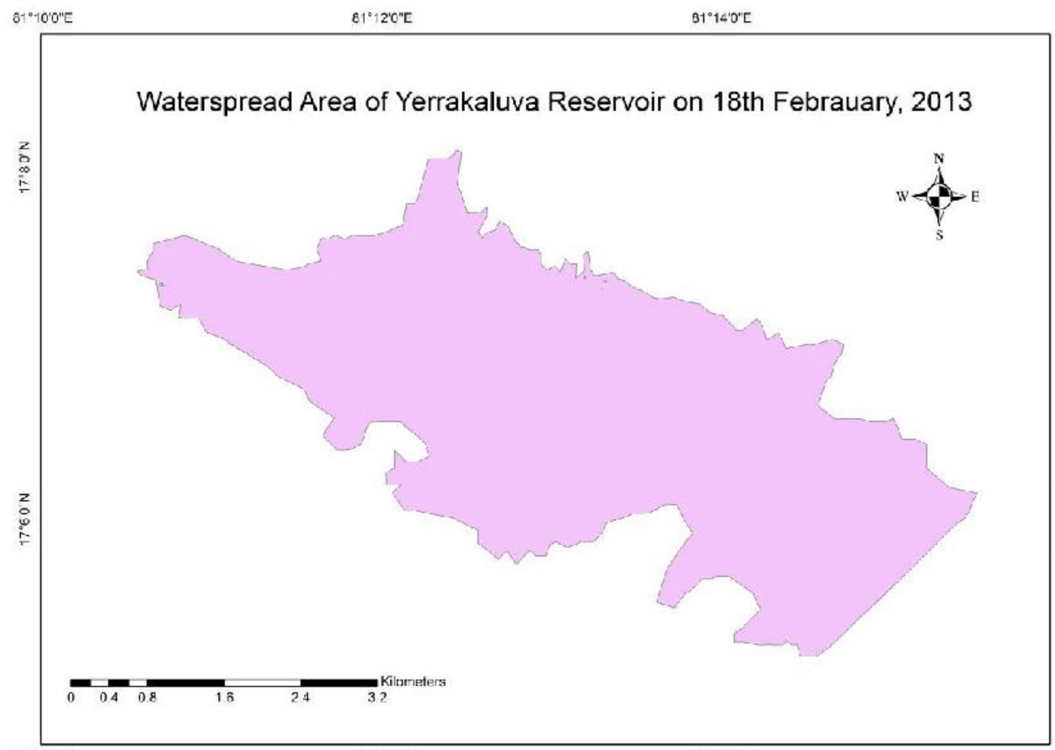

Figure 5.13 Water spread area for YerraKaluva Reservoir-February 18th , 2012

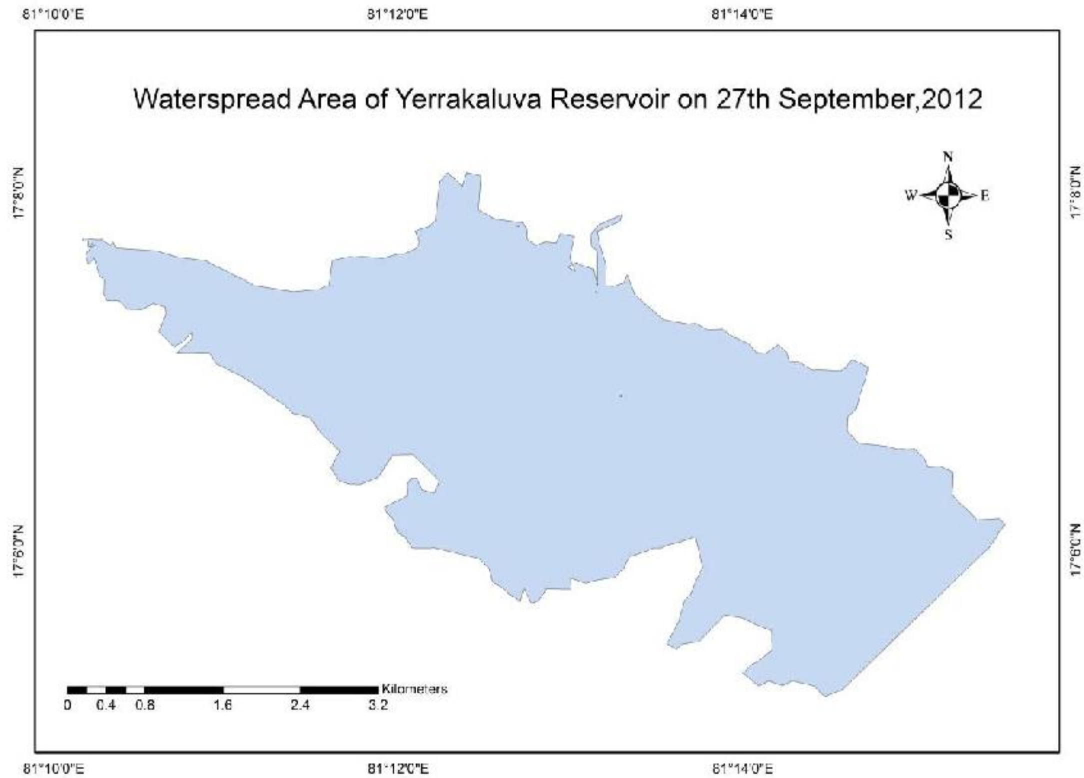

Figure 5.14 Water spread area for YerraKaluva Reservoir – September 27th,2012

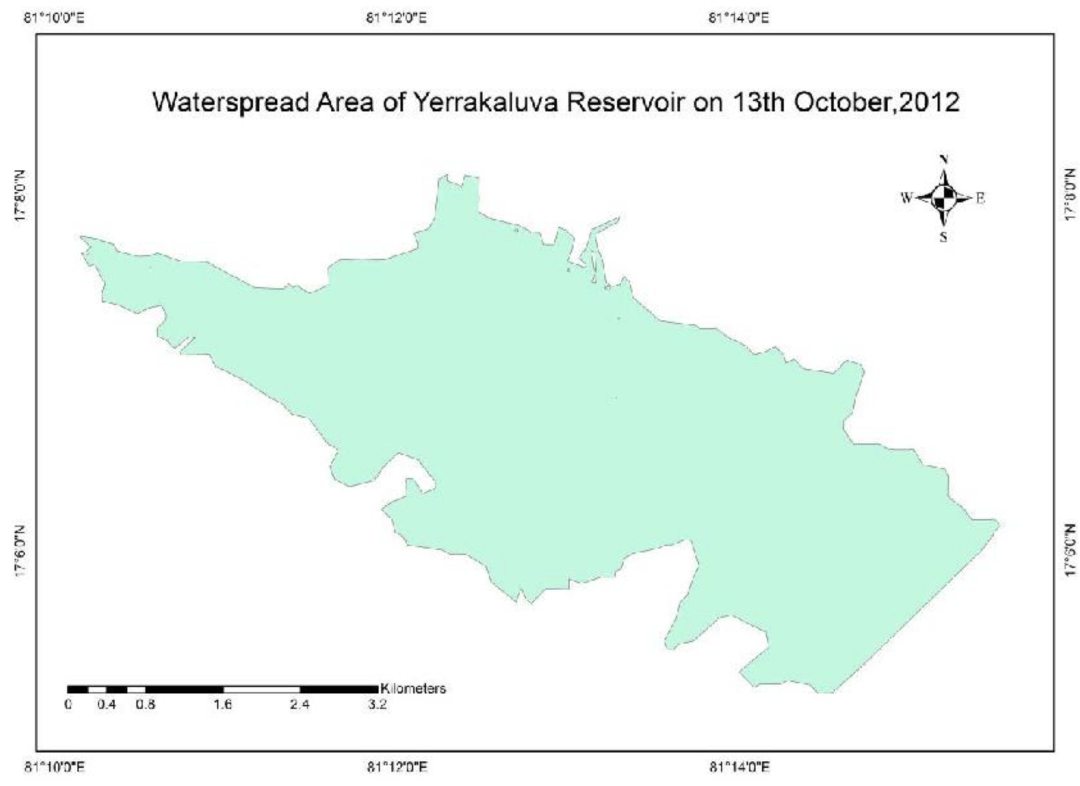

Figure 5.15 Water spread area for YerraKaluva Reservoir – October 13th,2012

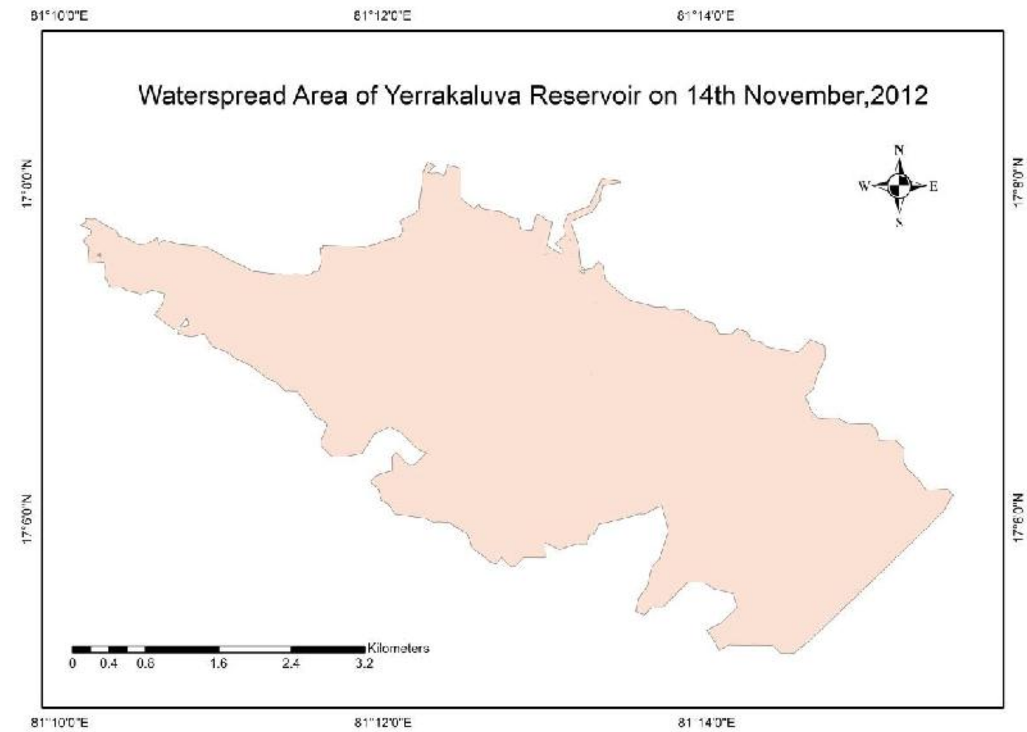

Figure 5.16 Water spread area for Yerrakaluva Reservoir – November14th, 2012.

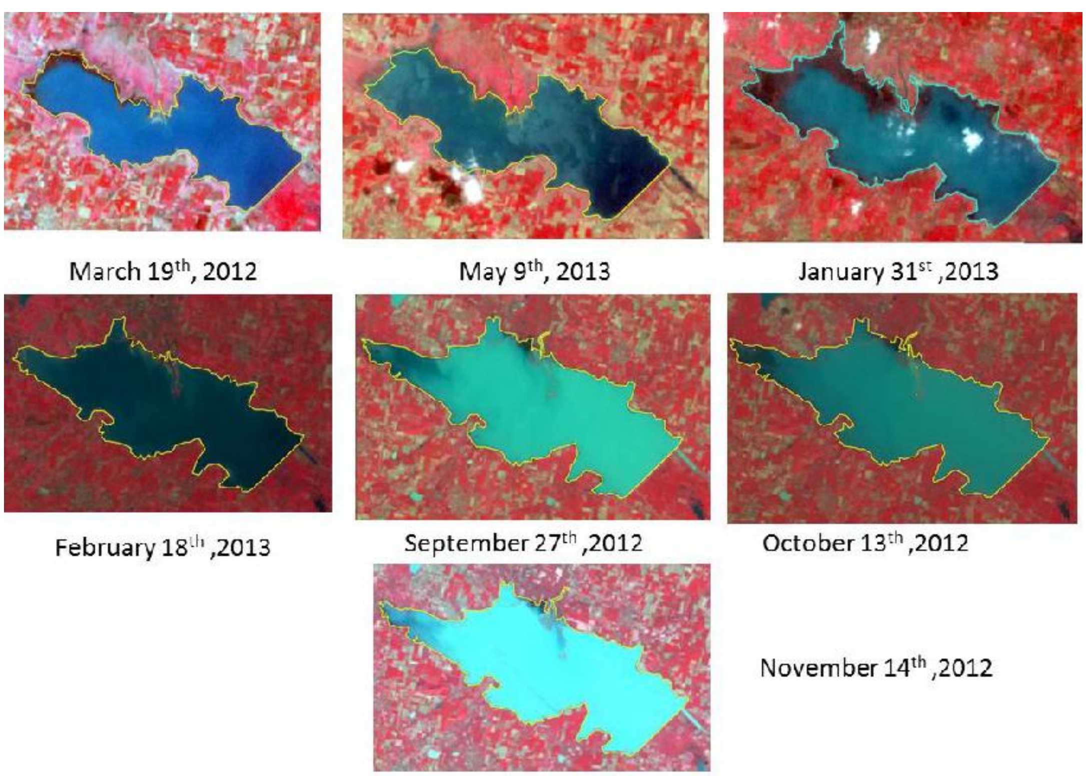

Figure 5.17 Standard FCC with water spread area

The water spread area for different reservoir level of Yerrakaluva is given in the Table 5.4

Table 5.4 Water spread area of Yerrakaluva Reservoir for different levels

Date of satellite passing	**Reservoir level (m)**	**Water Spread Area (m^2)**
19-Mar-12	78.5	11780833
9-May-13	78.7	12566538
31-Jan13	80.11	16209200
18-Feb-13	81.11	19232198
27-Sep-12	82.35	21968915
13-Oct-12	82.63	22264645
14-Nov-12	82.85	22595691

5.8 CAPACITY OF RESERVOIR

Volume of reservoir at different level difference is calculated using trapezoidal formulae with waterspread areas of different stages on different dates. Cumulative volume of the reservoir is calculated and shown in Table 5.5. It is found that volume of reservoir at +82.82 is 107746553.2 cubic meter.

Table 5.5 Cumulative volume of reservoir

Date of satellite passing	**Reservoir level (m)**	**Water Spread Area (m^2)**	**Cumulative volume (m^3)**
19-Mar-12	78.5	11780833	32918334.6
9-May-13	78.7	12566538	33161756
31-Jan-13	80.11	16209200	53394251.21
18-Feb-13	81.11	19232198	71093423.6
27-Sep-12	82.35	21968915	96619308.76
13-Oct-12	82.63	22264645	102811961.03
14-Nov-12	82.85	22595691	107746553.2

The stage capacity curve for Yerra Kaluva Reservoir using Satellite imageries for 2013-2013 is given in the Figure 5.16 and the original Stage-capacity curve that is drawn at the time of reservoir construction is given in Figure 5.17

5.9 SEDIMENT YIELD FROM STAGE CAPACITY CURVES

The Stage Capacity curve for 2012 and 1980 are shown in the Figure 5.18. The capacity of reservoir at +82.85 in 2012 that is calculated from water spread areas from remote sensing imageries is 3.805 TMC. The capacity of reservoir at +82.85 in 1980 is 3.8491 TMC. The capacity difference at reservoir level +82.85 is 0.0441 TMC for 32 years. Thus, the sediment yield into the reservoir is estimated as 39.33 Tonnes/sq Km /Year.

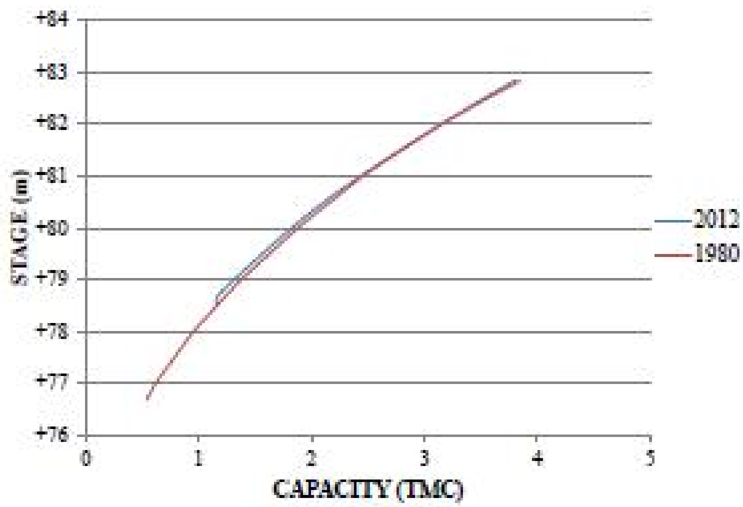

Figure 5.18 Stage Capacity curves for Yerrakalava reservoir.

CHAPTER 6

CONCLUSION

This study focused on the estimation of water availability or yield with the use of SWAT 2009, a physically based semi-distributed hydrological model interfaced with Arc GIS software. The preparation of thematic maps and database necessary for the successful running of the model was done using the GIS components. The model was simulated daily for a period of 26 years (2005-2012) and the performance evaluation of the model was carried out using Nasch Suclitiffe Efficiency (NSE) and Coefficient of Determination (R2). The Nash and Sutcliffe Efficiency (NSE) and Coefficient. The results exhibited fairly good agreement between observed and simulated daily values and water availability estimated in micro level of sub-basins

Sedimentation assessment and mapping of erosion prone areas are very essential in soil conservation and watershed management. The annual average soil loss in the catchment area of Yerra kaluva is calculated using RUSLE model. This model helps us to understand the spatial distribution of soil erosion in the reservoir catchment area using GIS and satellite remote sensing derived paramenters. Annual average soil loss map is prepared by multiplying five Factor map namely R Factor map, K Factor map, LS Factor map, C Factor map and P Factor map in GIS in Raster format. The average annual soil loss of Yerra kalva reservoir catchment area is 0.49 Tonnes/acre/yr or 121 Tonnes/sq km/yr or 0.864 ha-m /100sq km /yr or 0.000782 TMC/yr. Sediment Delivery Ratio is calculated for the catchment area using USDA formulae. Sediment Delivery Ratio for the catchment area of 1085 square Kilometer 0.263. Sediment rate from the catchment area of the reservoir is calculated from Average annual soil loss and SDR is 34527 Tonnes/yr. Sediment yield at the Resevoir by RUSLE model is 31.8 Tonnes/sq. Km/year. It is found that sub basin 3 is more vulnerable to soil erosion as it has more fallow lands and hilly regions with the estimate of 0.62 tonnes/acre/year.

Water spread area of Yerra kaluva reservoir is estimated from Satellite imageries for different dates and volume is computed with Water spread area and the reservoir level of same date using trapezoidal formulae. The capacity of reservoir in 2012 is compared with the capacity in 1980 and the capacity loss is estimated as 0.0441 TMC. The sediment yield into the reservoir using Remote Sensing imageries is estimated as 39.33 Tonnes/sq Km /Year.

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Evaluation of urban storm water network in Hyderabad city using SWMM

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