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ENVIRONMENTAL ASSESSMENT OF SOIL EROSION ON LAKNAVARAM LAKE BASIN

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ABSTRACT

The aim of this work is to estimate soil erosion on Laknavaram lake basin, JayashankarBhupalpally district, Telangana. Soils play a major role in production of food, storage of water, nutrients and organic matter. Loss of soils effects its ability to perform these functions. Soil loss reduces its potential in crop production, damages drainage network, decreases the capacity of hydraulic structures. Estimation of soil erosion in this study has been done using USLE model. The USLE was developed from soil erosion plot and rainfall simulator experiments. The USLE is composed of six factors to estimate the average annual soil loss (A). The equation includes rainfall erosivity factor(R), soil erodibility factor (K), the topographic factors (L and S), cover management(C), practice management (P).The equation takes the simple product form: A=R.K.LS.C.P (Where LS is calculated together as a single factor).

Keywords: *xArcGIS, DEM (Digital Elevation Model), USLE and LANDSAT, LISS-3.*

I. INTRODUCTION

Recent observations in India have brought in to light the alarming fact that reservoir sedimentation, resulting from degradation of the watersheds is on high 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 and man.

Scientific management of soil, water and vegetation resources on watershed basis is very important to arrest erosion and rapid siltation in rivers, lakes and estuaries. Because land management practices create a variety of conditions that influence the magnitude of surface erosion, land managers frequently want to predict the amount of soil loss by surface erosion. Several models are available for predicting erosion. USLE model and GIS has been used for determining the quantity of soil erosion. The past data on land use/land cover was interpreted from LISS-3 digital data of the catchment area.

II. STUDY AREA

The Laknavaram Lake is in the limits of Laknavaram village in Govindaraopet Mandal, Jay Shankarbupalpally

District. It is located at a distance of 80km (approximately) from Warangal. The location of the Laknavaram Lake is 18° 9′ 1.58″ N, 80° 4′ 10.56″ E. The catchment area map of the Laknavaram basin is shown in fig.1.

The annual average rainfall of this catchment is 95.5mm. The total surface area is 40.46 sq.km. The total area under irrigation is 3500 acres.

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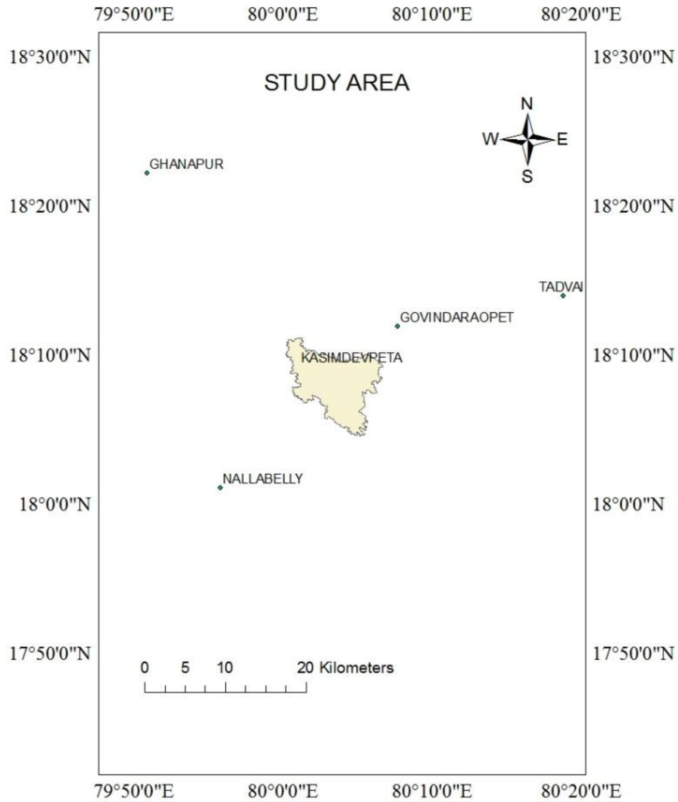

Fig.1. Study Area

III. DATA USED

To develop the soil erosion riskmap data from various sources is required. The GIS software provides the platform for integrating all the data and obtaining the final risk map. For the calculation of each factor in the USLE model different data is required. The data used from different sources is tabulated in the following table

Table I Data Used

S.NO	Data Type	Source	Description
01	Rainfall data	Town planning office,Warangal	Past 15yrs data of 6 raingauge stations
02	Soil Data	http://www.fao.org/geonetwork	Soil map of the year 2007
03	DEM	www.usgs.gov	ASTER DEM(27.8m resolution)

04	Satellite image	www.bhuvannrsc.gov.in	LISS-3 Image(2011-2012,with resolution 22.5m,RGB bands,3210)

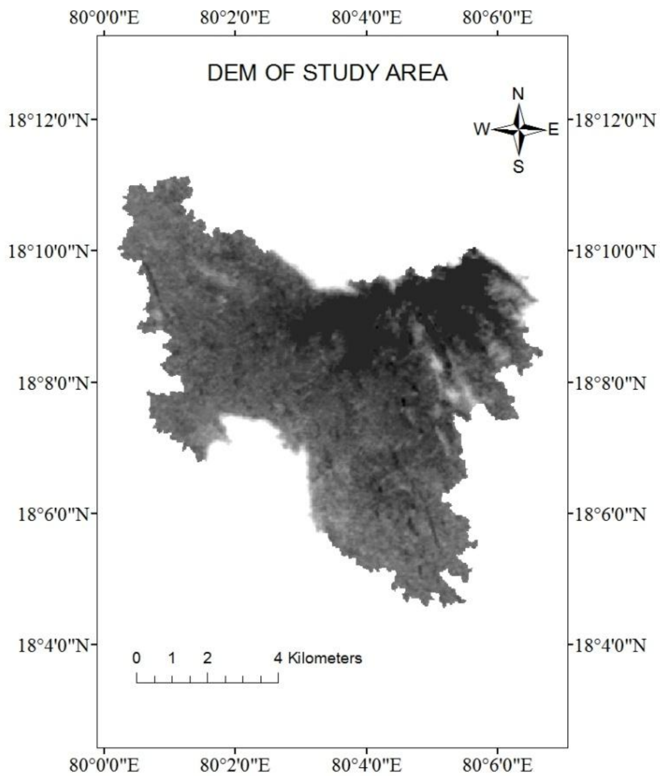

Fig.2. Dem of catchment area

A digital elevation model (DEM) is a satellite image that gives the information about elevation of the particular area. Technique used for generating digital elevation model is interferometric synthetic aperture radar. Some of the basic uses of DEMs are: extracting parameters for geomorphology, modelling of water flow, creation of relief maps etc.

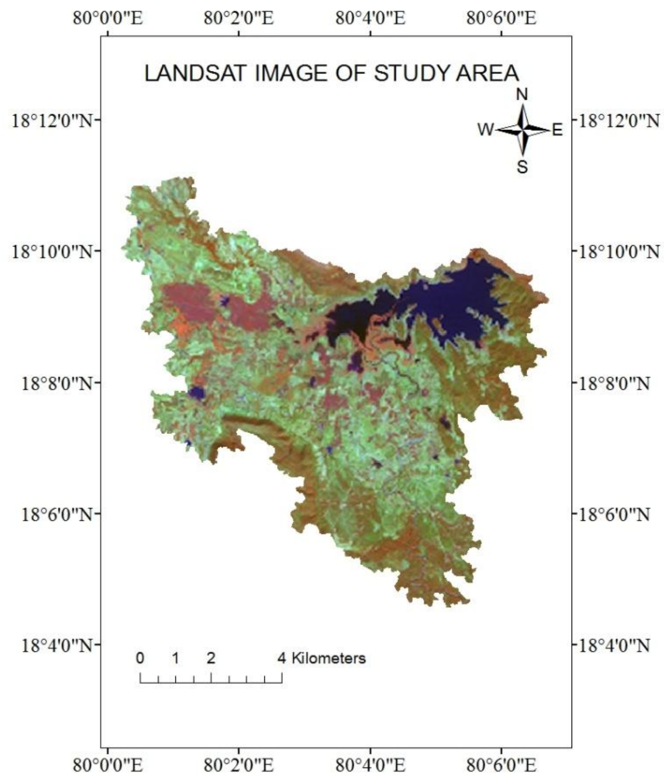

Fig.3. Landsat image of catchment area

LANDSAT image gives the details about land cover and the data are a valuable resource for global change research and applications in agriculture, forestry,etc.

IV. METHODOLOGY

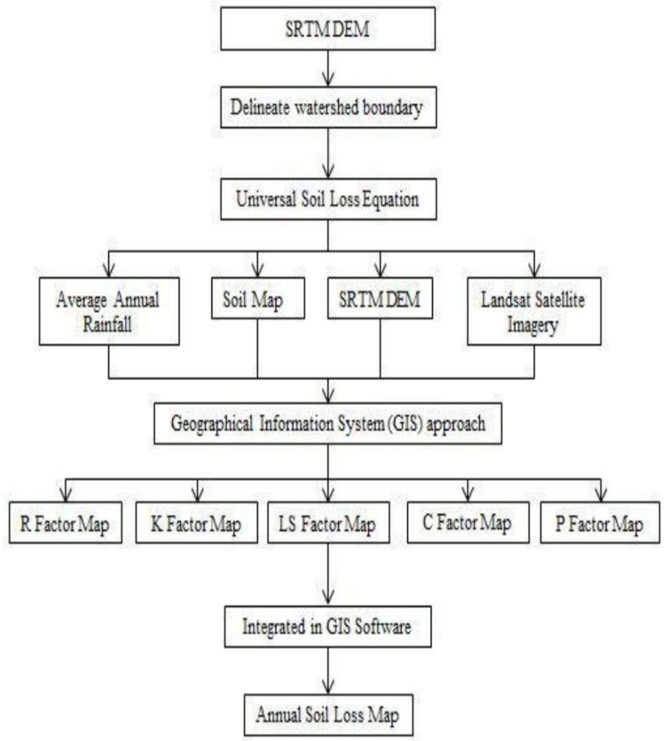

Fig.4. Flow chart showing the methodology of entire work

The USLE, developed by scientists W. Wischmeier and D. Smith, has been the most widely accepted and utilized soil loss equation for over 30 years. It is designed as a method to predict average annual soil loss caused by sheet and rill erosion. While it can estimate long - term annual soil loss and guide conservationists on proper cropping, management, and conservation practices.

The USLE for estimating average annual soil erosion is:
A=R*K*LS*C*P
A= average annual soil loss (t ha^{-1} yr^{-1})
R= rainfall erosivity index (MJ mm ha^{-1} h^{-1} yr^{-1})
K= soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1})
LS= topographic factor; L is slope length and S is slope
C= crop management factor
P= practice management factor

Rainfall erosivity factor (R): Erosivity factor is determined by both rainfall and the energy imparted to the land surface by the rain drop impact.

Soil erodibility factor (K): K is expressed as soil loss per unit area for unit plot.

Slope length (L):and Steepness (S) factor: Slope length factor is the ratio of soil loss from field slope length to that from 27.8m length plot under identical conditions. The slope steepness factor is the ratio of soil loss from the field slope gradient to that from 9 % slope under otherwise identical conditions.

Cover and management factor (C)**:** The crop management factor 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.

Support practice factor (P): The P factor 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

V. MODELLING AND RESULT

Development of Soil Erosion Factors

Rainfall erosivity (Rfactor): In this study, GIS plays a major rolein preparing thematic layers and estimating soil erosion. The rainfall data of 15 years (1998-2012), obtained from the Town Planning Office, Warangal was used to estimate the mean annual rainfall and to prepare R factor.

The rainfall erosivity R factor map can be developed by using Kurtz-Coopers equation.

Kurtz-Cooper Equation:

$$R=1.24P^{1.36}$$

R= rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1})

P= mean annual average rainfall (mm)

The rainfall distribution map is created using the annual rainfall data in ArcGIS and it is substituted in the above equation in Raster Calculator, thus R factor map is derived. The rainfall distribution map and Rfactor map are shown in the figures below:

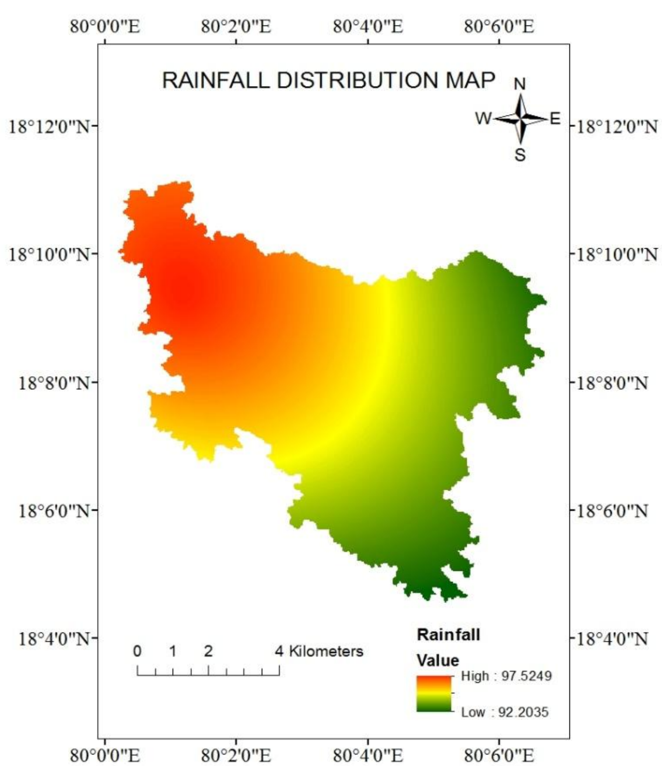

Fig.5. Rainfall distribution map

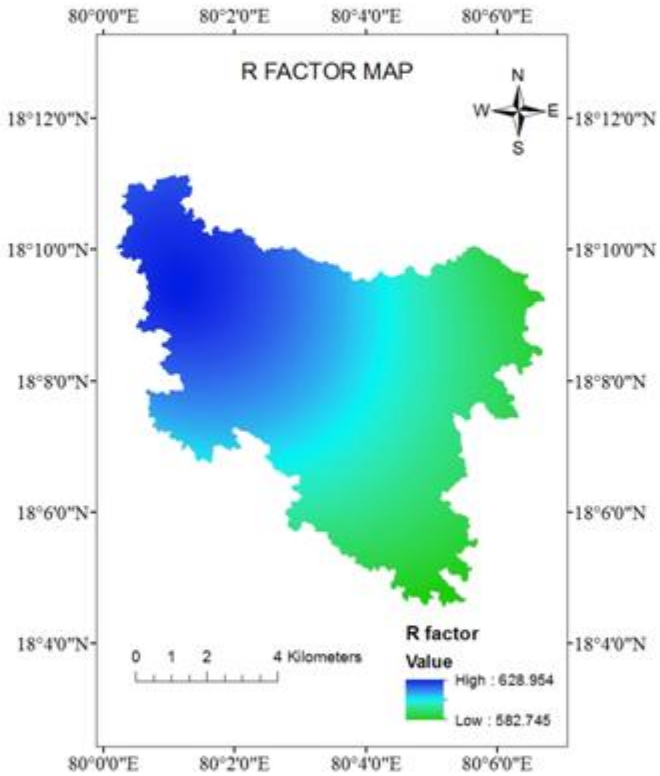

Fig.6. R factor map

The map gives the average annual rainfall distribution in cm over the study area.The maximum average annual rainfall in the study area is found to be 97.52cm.

High value of R factor indicates high erosion due to high impact of rain drops. Higher the intensity of rainfall higher will be the Rfactor values

Soil Erodibility Factor(K Factor):

The k-factor depends on the following soil parameters in combination:

- Percentage of silt, very fine sand, clay and organic matter
- Structure
- Drainage

The k-factor is derived from the soil map for the study area, following the steps are included in developing the k factor map:

- Conversion of the soil map from vector to raster format; this is a common GIS function.
- Determination of the soil texture class for each type of parent material of the geological map.
- Reclassification of the raster soil texture map into k values according to the specific soil parameters using William's Equation.

The type of top soil available in the study area is lithosol.Its composition is found to be the following:

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Table II Soil Composition

Soil Sample	% of sand(m_s)	% of silt(m_{silt})	% of clay(m_c)	% of organic carbon(OrgC)
Lithosol	58.9	16.2	24.9	0.97

The k factor is calculated using William's equation:

$$f_{csand}=(0.2+0.3.\exp[-0.256.m_s.(1-\frac{m_{silt}}{100})])$$

$$f_{cl\text{-}si}=(\frac{m_{silt}}{m_c+m_{silt}})^{0.3}$$

$$f_{orgc}=(1-\frac{0.25.orgC}{orgC+\exp[3.72-2.95.orgC]})$$

$$f_{hisand}=(1-\frac{0.7\left(1-\frac{m_s}{100}\right)}{\left(1-\frac{m_s}{100}\right)+\exp[-5.51+22.9.\left(1-\frac{m_s}{100}\right)]})$$

$$K_{usle}=f_{csand}*f_{cl\text{-}si}*f_{orgc}*f_{hisand}$$

$$K=0.1317*K_{usle}$$

f_{csand} is a factor, that lowers the K indicator in soils with high coarse-sand content and higher for soils with little sand,

$f_{cl\text{-}si}$ gives low soil erodibility factors for soils with high clay-to-silt ratios,
f_{orgc} reduces K values in soils with high organic carbon content,
f_{hisand} lowers K values for soils with extremely high sand content.
Therefore the K Factor map of the catchment area is shown in figure below:

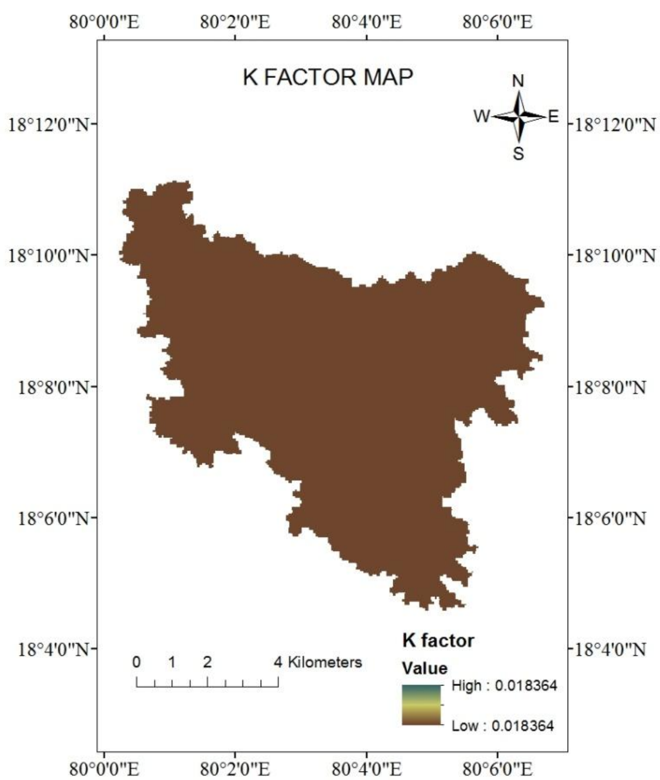

Fig.7. K factor map

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K factor depends on type of soil .The higher the vegetal cover lower will be the k value.

*Topographic Factor(LS Factor):*The overall topography contributes two factors to soil erosion in the USLE, namely the length factor (L) and the steepness factor (S) .The LS factor is calculated by multiplying the L and S factors together. The LS factor map have been prepared from the slope and aspect map derived from the DEM.

The formula used in the Raster Calculator to calculate LS factor is
Power (“flowaccumulation”*[cellresolution]/22.1,0.4)*Power (Sin (“slope”*0.01745))/0.09, 1.4)*1.4
Where cell resolution is the resolution of DEM used (i.e., 27.8m), and slope is also a raster data that is obtained from DEM.

***Flow accumulation*:** The result of flow accumulation is a raster of accumulated flow to each cell, as determined by accumulating the weight for all the cells that flow into each down slope cell. This obtained by first determining the raster of flow direction.

***Flow direction*:**It shows the direction of flow in the particular area using the elevation and the slope of that area. Therefore the LS Factor map of the catchment area is shown in figure below:

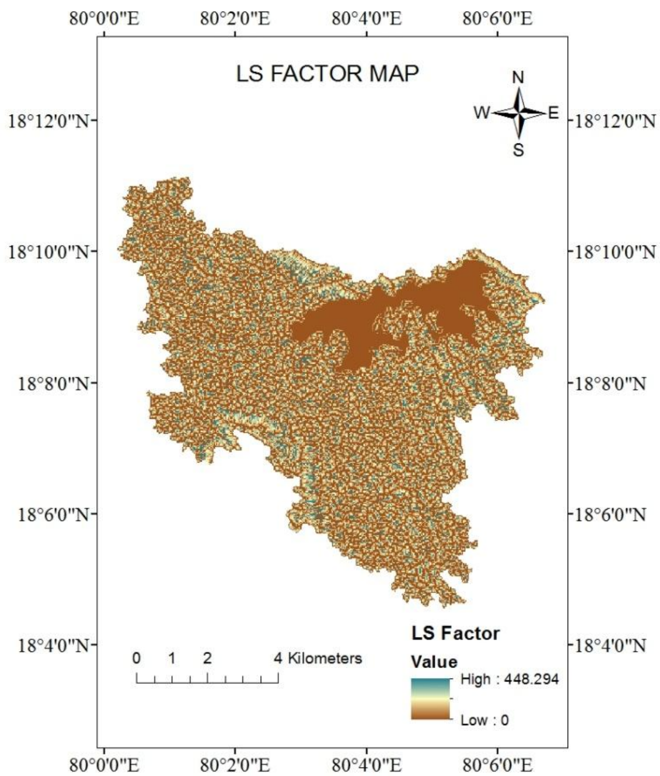

Fig.8. LS factor map

LS Factor map indicates about the slope of the area.

Crop Management Factor(C Factor):The C-factor represents how management affects soil loss. It is mainly related to the vegetation cover percentage and it is defined as the ratio of soil loss from specific crops to the equivalent loss from tilled, bare test-plots. The value of C depends on vegetation type, stage of growth and cover percentage.

Table III C Factor Values For Different Types Of Land Cover

S.N.O	Land Use Class	C Facor
1	Agriculture	0.28
2	Barren Land	0.75
3	Forest	0.05
4	Builtup area	0.028
5	Waterbody	0.00

The land cover of the catchment area and the C factor map of the catchment area are shown below
Landuse map has been developed from the LANDSAT image.

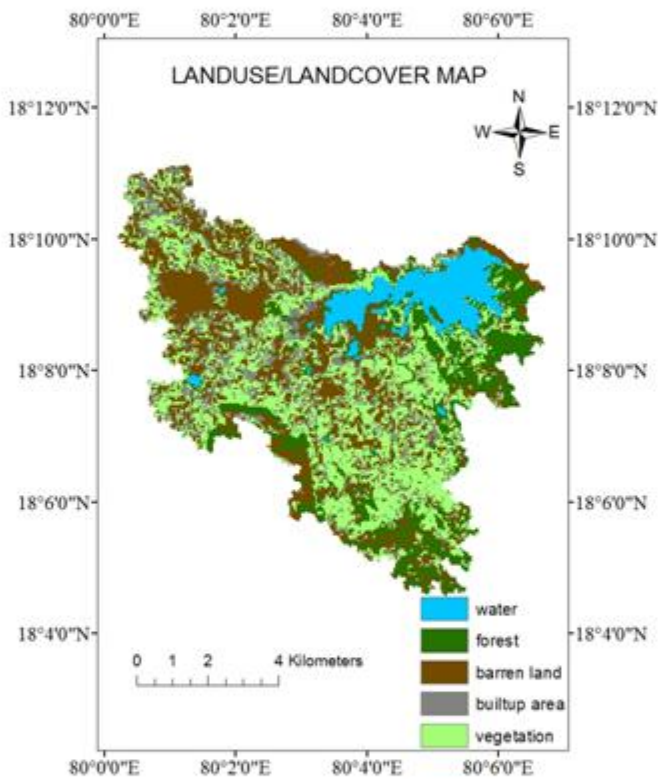

Fig.9. Landuse/landcover map

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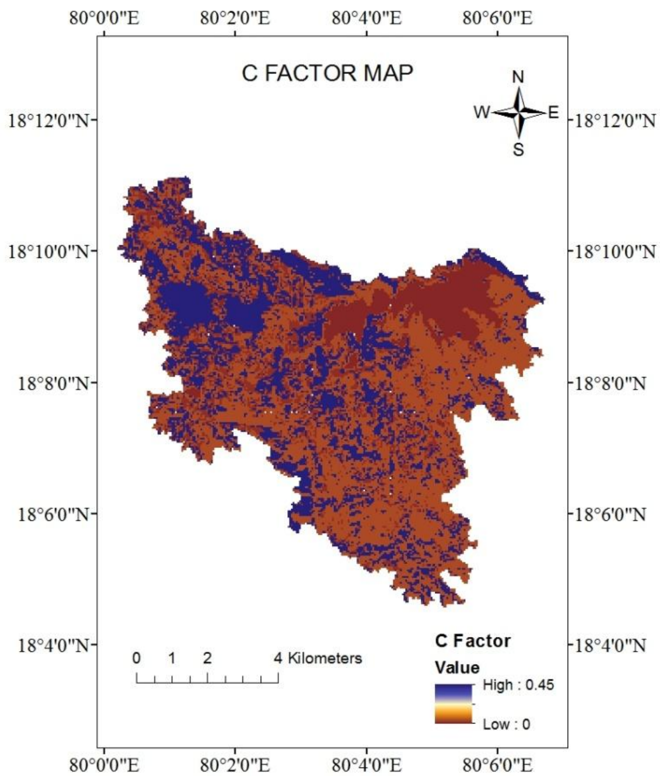

Fig.10. C factor map

Practice Management Factor(P Factor):The support practice factor P represents the effects of those practices that helps to prevent soil from eroding by reducing the rate of water runoff. The values of P are calculated as rates of soil loss caused by a specific support practice divided by the soil loss caused by row farming up and down the slope. The P Factor map of th catchment is shown in the figure below

Table IV P Factor Values

Slope%	P Factor
0.0-7.0	0.55
7.0-11.3	0.60
11.3-17.6	0.80
17.6-26.8	0.90
>26.8	1.00

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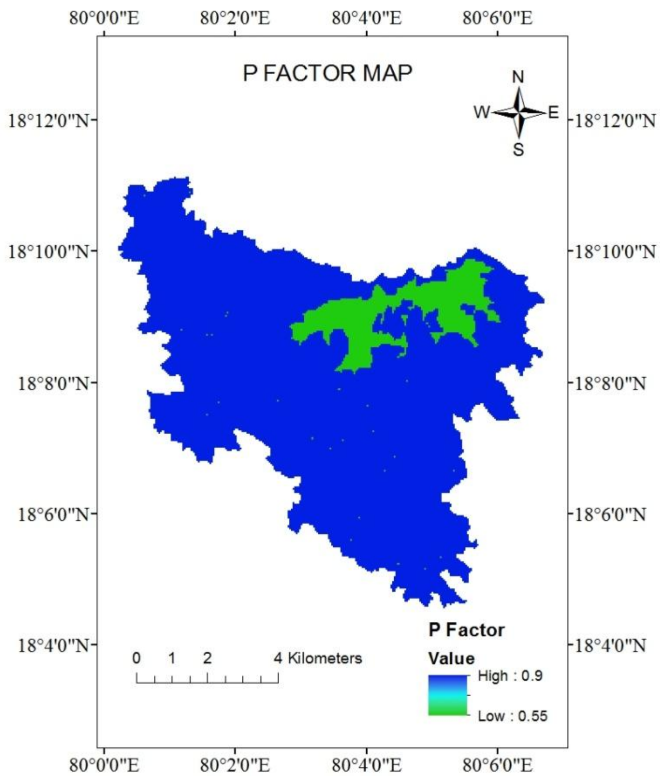

Fig.11. P factor map

P factor map is developed from dem.It depends upon the support practices in that area.

Preparation of soil erosion map:All the thematic maps of all factors generated are integrated in the raster calculator in ArcGIS software to obtain final soil erosion map. The soil erosionmap is shown in the figure below:

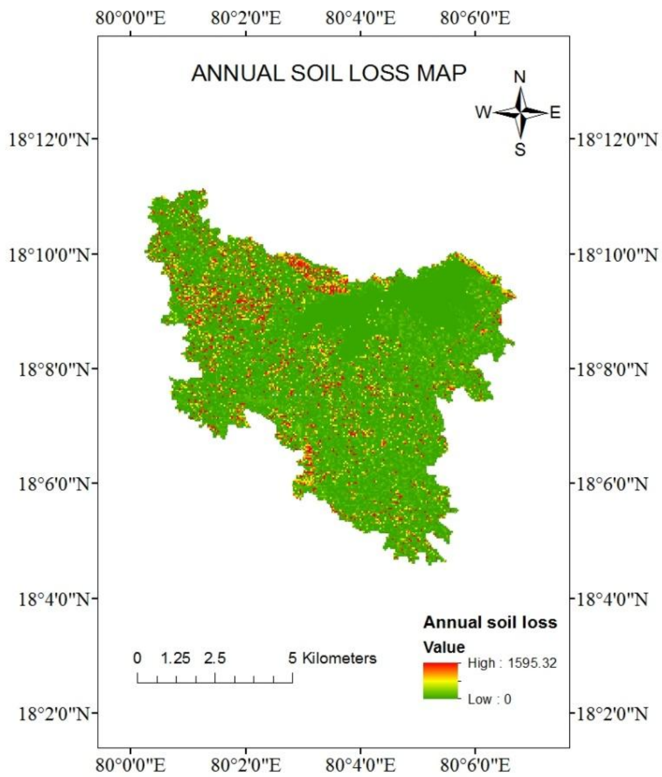

Fig.12. Annual soil loss map

VI. CONCLUSION

The average annual soil loss on Laknavaram lake basin using USLE model is found to be 1595.32 tons/hectare/year.

- This data can be used in predicting the capacity of the reservoir and to which extent scouring due to erosion of catchment area can be occurred.
- This model can be used in predicting the land use/land cover of the catchment.
- The areas where maximum erosion occurs can be identified and preventive measures can be taken.
- The suitable measures can be suggested in agricultural areas for effective farming.

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