The Andhra Agric. J 66 (4): 650-653, 2019

Remote Sensing and GIS Based Modeling of Crop/Cover Management Factor (C) of USLE in Guravajipetta Watershed

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ABSTRACT

Soil erosion is one of the major environmental problems in terms of degradation. Soil loss due to erosion can be determined using Universal Soil Loss Equation (USLE). The key aspects influencing the quantity of soil erosion mainly rely on the vegetation cover, topography, soil type, and climate. One of the most influencing parameters used in USLE model is C factor that represents effects of vegetation and other ground covers. Estimating ground cover by analysis of Remote Sensing imagery involves Normalized Difference Vegetation Index (NDVI), an indicator that shows vigor of vegetation. Guravajipeta watershed lies in Guravajipeta Gram panchayat of Kanigiri Mandal in Prakasam district of Andhra Pradesh. The main objective of this study was to estimate crop/cover management factor (C) values for the study area with help of NDVI of the area. The NDVI map of the study area was derived from 8th December 2015 LANDSAT- 8 ETM+ imagery. The NDVI map of the area was prepared by using ERDAS IMAGINE 2011 software. The final crop/ cover management factor (C) map was generated using the regression equation in Spatial Analyst tool of ArcGIS 10.3 software. It was found that C factor value of the study area varied between 0 and 1.

Keywords: *Erosion, USLE, C factor, LANDSAT- 8, ETM+, NDVI*

Soil erosion is one of the major environmental problems in terms of soil degradation. Soil erosion leads to significant on- and off-site impacts such as significant decrease in the productive capacity of the land and sedimentation. The key aspects influencing the quantity of soil erosion mainly rely on the vegetation cover, topography, soil type, and climate.Evaluating soil erosion risks is a difficult task due to several concurrent processes, which affects individually other multifaceted interactions and continues at amounts that vary in both time and space(Bahrawi et al, 2016). Several developed and examined models for calculating soil loss from erosion by water from a hill slope, or a minor catchment are available. With the availability of GIS competencies, the efforts are directed to be based on spatially distributed models, simulating erosion dynamics and surface runoff of more complex and larger catchments.

For quantification of soil loss, several models developed and used for either research or operational purposes are USLE (Universal Soil Loss Equation, 1965), EPIC (Erosion/Productivity Impact, 1984), EUROSEM (European Soil Erosion Model, 1993), RUSLE (Revised Universal Soil Loss Equation, 1997), Rill Grow (a model for rill initiation and development, 1998), SEMMED (Soil Erosion Model for Mediterranean Regions, 1999), EGEM (Ephemeral Gully Erosion Model, 1999), PESERA (Pan-European Soil Erosion Risk Assessment, 2003), and so forth.

The USLE model was developed based on 40 years experimental ûeld observations of Agricultural Research Service of the United States Department of Agriculture and presently, it is the most-widely used soil erosion assessment model. The USLE model is considered as an index method associating factors that represent how climate, soil, topography and land use affect soil erosion caused by raindrop impact and surface runoff. The USLE model determines the soil loss for a given area as a product of six key factors whose values at a particular location can be expressed numerically (Machiwal et.al, 2015). The soil loss can be computed by using the following USLE model expressed as

$$A = R \times K \times LS \times C \times P \quad .... (1)$$

Where,

‘A’ is the average annual potential soil loss in tons/ha/year
‘R’ is the rainfall erosivity factorin MJ mm ha^{-1} h^{-1} $year^{-1}$
‘K’ is the soil erodibility factor in t ha h MJ^{-1} mm^{-1}
‘LS’ is the slope length and steepness factor
‘C’ is the land-cover management factor
‘P’ is the conservation practice factor

R factor expresses the erosivity occurring from rainfall at a particular location. An increase in the intensity and amount of rainfall results in an increase in the value of R. The K factor expresses inherent erodibility of the soil or surface material. The value of K is defined as a function of the particle-size distribution, organic-matter content, structure, and permeability of the soil or surface material. The LS factor expresses the effect of topography, specifically hill-slope length and steepness, on soil erosion. An increase in hillslope length and steepness results in an increase in the LS factor. The C, crop/cover management factor is used to express the effect of plants and soil cover. Plants can reduce the runoff velocity and protect surface pores. The C factor measures the combined effect of all interrelated cover and management variables and it is the factor that most readily changed by human activities. The P factor is the conservation/support practice factor. It expresses the effects of supporting conservation practices, such as contouring, buffer strips of close-growing vegetation and terracing on soil loss at a particular site. A good conservation practice will result in reduced runoff volume, velocity and less soil erosion. The USLE concept has more recently been modified and adapted by a large number of researchers by including additional data and incorporating research results.

One of the most important parameters in USLE is the crop/cover management factor (C) that represents effects of vegetation and other land covers. The C factor reflects the effect of cropping and management practices on the soil erosion rate(Patil and Sharma, 2013). The C factor indicates how conservation plans will affect the average annual soil loss and how that soil loss potential will be distributed in time during construction activities, crop rotations or other management schemes. Vegetation cover protects the soil by dissipating the raindrop energy before reaching the soil surface. As such, soil erosion can be effectively limited with proper management of vegetation, plant residue and tillage (Lee, 2004). In USLE the C factor is generally computed using empirical equations that contain field measurements of ground cover. Since the satellite image data provide up to date information on land cover, the use of satellite images in the preparation of land cover maps is widely applied in natural resource surveys (Deng et al., 2008).

The traditional method for spatial estimation of C factor is assigning values to land use/cover classes using classified remotely sensed images of study areas. At the end of supervised or unsupervised classification, land use/land cover classes are derived from image of study area and then C factors that are obtained from USLE guide tables or computed using field observation for each land use/land cover classes assigned to each pixel in respective land use/land cover class (Karaburun, 2009). Since all pixels in a vegetation class have the same C factor value, those pixels can't represent variation of this vegetation class over the study area. Researchers developed many methods to estimate C factor using NDVI for soil loss assessment with USLE. These methods employ regression model to make correlation analysis between C factor values measured in field or obtained from guide tables and NDVI values derived from remotely sensed images. The unknown C factor values of land cover classes can be estimated using equation obtained from linear regression analysis. The aim of this study is to estimate C factor values of land cover classes using NDVI values by regression analysis for erosion modeling in Guravajipetta watershed.

MATERIAL AND METHODS

About study area

The study area selected for this study is Guravajipeta watershed, which lies in Guravajipeta Gram panchayat of Kanigiri Mandal in Prakasam districts of Andhra Pradesh. The watershed is located between latitudes $15^{0}12'37''$N and longitude $79^{0}23'53''$E at ridge point and latitude $15^{0}15'18''$N and longitude $79^{0}24'24''$E at valley point. The total geographical area of the watershed is 5775 hectares.About 724 mm of precipitation falls annually.The temperatures in the area are in the range between 42 ^{0}C during summer and 35 ^{0}C during winter. There are 7 number of habitations in the watershed. The village there is a population of 3045 with various communities. The location map of the study area is shown in the Fig. 3.1.

Normalized Difference Vegetation Index (NDVI)

Remote Sensing techniques are employed for monitoring and mapping the condition of ecosystems of any part of earth. Vegetation cover is the one of most important biophysical indicators to assess soil erosion. Vegetation cover can be estimated using vegetation indices derived from satellite images. Vegetation indices allow us to delineate the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. The Normalized Difference Vegetation Index (NDVI), one of the vegetation indices, measures the amount of green vegetation. The spectral reflectance difference between Near Infrared (NIR) and red is used to calculate NDVI. The formula of NDVI can be expressed as [7]:

$$NDVI = (NIR - red) / (NIR + red) \quad .... (2)$$

The NDVI is used widely in remote sensing studies since its development. NDVI values range from -1.0 to 1.0, where higher values are for green vegetation and low values for other common surface materials. Bare soil is represented with NDVI values

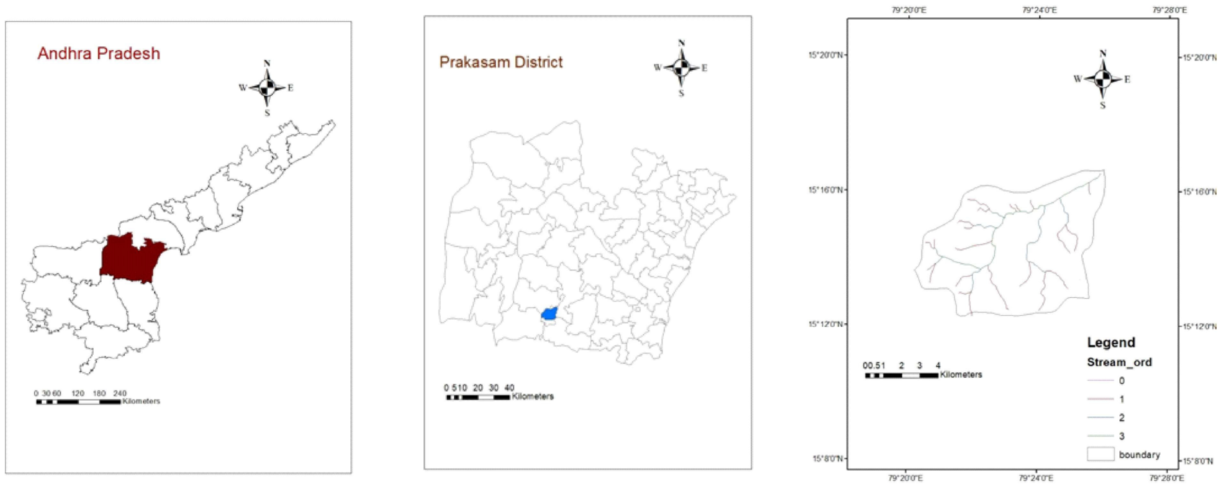

Fig 1. Location map of the study area.

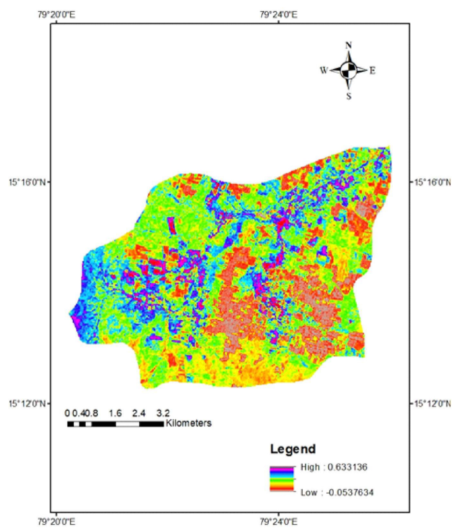

Fig 2. NDVI map of the study area.

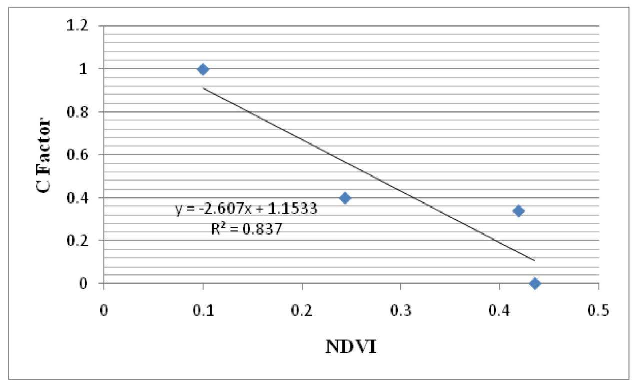

Fig 3. Relation between NDVI and USLE C-factor

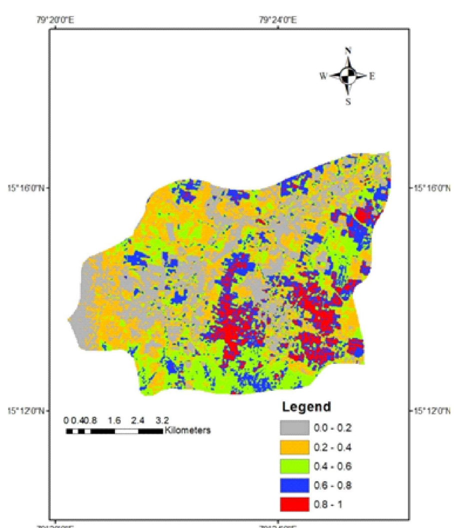

Fig 4. C factor map of study area.

which are closest to 0 and water bodies are represented with negative NDVI values. More than 20 vegetation indices have been proposed and used at present by various researches. Since NDVI provides useful information for detecting and interpreting vegetation and land cover, it has been widely used in Remote Sensing studies.

Crop/Cover management factor (C)

Estimation of soil loss is very much sensitive to vegetation cover with slope steepness and length of slope factor. Vegetation coverprotects the soil by dissipating the raindrop energy before reaching soil surface. The value of C depends on vegetation type, stage of growth and cover percentage. The C factor values vary between 0 and 1 based on types of land covers. Since NDVI values have correlation with C factor, many researchers are using regression analysis to estimate C factor values for land use/land cover classes in erosion assessment (Lin et al., 2006). The goal of regression analysis is to estimate the unknown values of dependent variable based upon values of an independent variable using a mathematical model. The linear or non-linear regression equations are developed using correlation analysis between NDVI values obtained from remotely sensed image and corresponding C factor values obtained from USLE guide tables.

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 (Vicente et al., 2007), the C factor values for bare soil and forest land cover were set to 1 and 0, respectively in the regression analysis. The line obtained after analysis is the regression line that describes relationship between C and NDVI values and R shows the correlation coefficient of regression analysis shown in Fig 3. The regression equation was found as:

$$\text{C factor} = 1.1533 - 2.607 \times \text{NDVI} \quad \text{..........} \ (3)$$

The NDVI map of the study area was derived from 8th December 2015 LANDSAT-8 ETM+ imagery using ERDAS IMAGINE 2011 software. Then final C factor map was generated using NDVI map and the regression equation in Spatial Analyst toolbox of ArcGIS 10.3 software.

RESULTS AND DISCUSSION

The NDVI map of the study area obtained by using ERDAS 2011, well-known image processing software is presented in Fig 2. The imagine NDVI values of the Guravajipeta watershed are found to vary between from -0.053 to 0.633. After ground verification, it was observed that area showing value of NDVI was densely covered forest and green vegetation and area with lower value of NDVI was nearly barren/open land. Using NDVI map, the C factor map of the area was prepared in ArcGIS 10.3 software. The spatial distribution of crop/cover management factor (C) in the study area is shown in Fig 4. The C factor value of study area is found to vary between0 to 1.On this map, lower value of C factor indicates that the area possesses good vegetative cover and higher value indicates barren/open land.

CONCLUSION

An attempt was made to estimate C factor of land cover classes using NDVI values for modeling soil erosion using ArcGIS 10.3 software in Guravajipeta watershed. A regression analysis was performed between NDVI and C factor using linear relationship assumption. C factor values were assigned to pixels of NDVI image through regression equation. Based on an assumption, the C factor map of Guravajipeta watershed was produced to use in USLE soil erosion model based on assumption that NDVI and C factor values are correlated with each other. It should be noted that C factor values can be precisely estimated using empirical equations that contain field measurements of land cover classes. In this particular study, Remote Sensing and GIS techniques are used as it offers an optimal method to estimate Crop management factor (C) values of land cover classes of large areas in a short time.

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Received on 25.06.2019 and revised on 07.08.2019