Remote Sensing and GIS based modeling of crop/cover management factor (C) of USLE in Shakker river watershed

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Abstract— To take measures in controlling soil erosion it is required to estimate soil loss occurring in the area. Soil loss due to erosion can be determined using predictive models such as Universal Soil Loss Equation (USLE). The accuracy of prediction by this model merely depends on parameters used in this model. One of the most influencing parameters used in this 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. Shakker river watershed lying in Narmada Basin situated in Narsinghpur and Chhindwara districts of Madhya Pradesh, India was selected for this study. The main objective of this study was to estimate crop/cover management factor (C) values for study area with help of NDVI of the area. The NDVI map of the study area was derived from IRS P6 LISS III imagery. The NDVI 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 9.3 software. It was found that C factor value of the study area varies between 0.18 and 1.

Keywords— Erosion, USLE, C factor, LISS III, NDVI

I. INTRODUCTION

Soil erosion assessment studies play key role for various soil and water conservation planning processes including reservoir sedimentation analysis, studies on river morphology changes and river bed siltation and agricultural project planning. Erosion process result in soil loss from a watershed and it is difficult to estimate soil loss as it arises from a complex interaction of various hydro-geological processes [16]. Estimating the soil loss risk and its spatial distribution is one of the key factors for successful erosion assessment. Thus it can be possible to develop and implement policies to reduce the effect of soil loss under varied geographical conditions [4]. The accuracy of estimating soil erosion risk depends on prediction model and its factors. Researchers have developed many predictive models that estimate soil loss and identify areas where conservation measures will have the greatest impact on reducing soil loss for soil erosion assessments [2].

Universal Soil Loss Equation (USLE), such a predictive model at root level, was designed to predict longtime average soil losses of runoff plots from specific field areas in specified cropping and management systems. The USLE [21] estimates the average annual rate of soil loss can be expressed as:

$$A = R.K.L.S.C.P$$

Where, $A$ is the estimated rate soil loss per year, $R$ is the rainfall erosivity factor, $K$ is the soil erodibility factor, $LS$ is the slope length and steepness factor (also known as topographic factor), $C$ is the crop/cover and management factor and $P$ is the conservation/support practice factor [21]. The 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 hill-slope 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

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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. 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 [18]. 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 [10]. In USLE the C factor is computed using empirical equations that contain field measurements of ground cover [22, 15]. 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 [5].

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 are assigned to each pixel in respective land use/land cover class [9]. 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 [20]. Researchers developed many methods to estimate C factor using NDVI for soil loss assessment with USLE [12]. 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 Shakker river watershed. In present study the cell size of 30 m × 30 m has been used for all the raster computations and for preparation of C factor map of the study area.

II. MATERIAL AND METHODS

A. About Study Area

The Shakkar River rises in the Satpura range, east of the Chhindi village, Chhindwara district, Madhya Pradesh, India. The watershed area lies between 22°20'N to 23°00'N latitudes and 78°40'E to 79°20'E longitudes with elevation range from 314 to 1154 m above MSL (mean sea level). The watershed covers 2223 km² of total geographical area up to the gauging point. The climate of the basin is generally dry except the southwest monsoon season. May is the driest month of the year. The normal maximum temperature during the month of May is 42.5°C and minimum during the month of January is 8.2°C. Soils are mainly clayey to loamy in texture with calcareous concretions invariably present. The study area generally receives rainfall by south west monsoon. The average annual rainfall of the area is 1245 mm whereas normal annual rainfall of the area is 1192.1 mm. The location of study area is shown in Fig.1.

![Fig. 1 Location map of the study area.](image)

B. Normalized Difference Vegetation Index (NDVI)

Remote Sensing techniques are employed for monitoring and mapping condition of ecosystems of any part of earth. Vegetation cover is one of the most important biophysical indicators to 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 [1]. 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 can be expressed as [7]:

\[
NDVI = \frac{(NIR - red)}{(NIR + red)}
\]

(2)

The NDVI has been used widely in remote sensing studies since its development [8]. 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 which are closest to 0 and water bodies are represented with negative NDVI values [11]. More than 20 vegetation indices have been proposed and used at present. Since NDVI provides useful information for detecting and interpreting vegetation and land cover, it has been widely used in Remote Sensing studies.

C. Crop/Cover Management Factor (C) Estimation

Soil loss is very sensitive to vegetation cover with slope steepness and length of slope factor [3]. Vegetation cover
protects 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 [6]. The C factor values vary between 0 and 1 based on types of land covers. Since NDVI values have correlation with C factor [17], many researchers are using regression analysis to estimate C factor values for land use/land cover classes in erosion assessment [13]. 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 constructed 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 [19], 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.

The regression equation was found as:

\[ C = 1.02 - 1.21 \times \text{NDVI} \]  

(3)

The NDVI map of the study area was derived from 8\(^{th}\) January 2011 IRS P6 LISS III 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 9.3 software.

III. RESULTS AND DISCUSSION

The NDVI map of the study area obtained by using ERDAS 2011, well-known image processing software and IRS P6 LISS III satellite imagery is presented in Fig. 2. The NDVI values of the Shakker river watershed found to vary between from -0.34 and 0.62.

After ground verification it was observed area having higher value of NDVI have densely covered forest and green vegetation and area with lower value of NDVI is nearly barren/open land.

Using NDVI map, the C factor map of the area was prepared in ArcGIS 9.3 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 between 0.18 and 1. On this map, lower value of C factor indicates the area possesses good vegetative cover and higher value indicates barren/open land.
The areal distribution and the respective C factor values as obtained from the above analysis in the study area are presented in following Table I. These C factor values are based on the values suggested by [14] for different land use/land cover classes.

### Table I
**SHOWING AREAL DISTRIBUTION WITH RESPECTIVE C FACTOR VALUES IN THE STUDY AREA.**

<table>
<thead>
<tr>
<th>C Factor</th>
<th>Area (km²)</th>
<th>Percent of total watershed area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.18</td>
<td>1444.60</td>
<td>64.98</td>
</tr>
<tr>
<td>0.28</td>
<td>734.04</td>
<td>33.02</td>
</tr>
<tr>
<td>1.00</td>
<td>44.36</td>
<td>2.00</td>
</tr>
<tr>
<td>Total area (km²)</td>
<td>2223</td>
<td></td>
</tr>
</tbody>
</table>

### IV. CONCLUSION

An attempt has been made to estimate C factor values of land cover classes using NDVI values for modeling soil erosion using ArcGIS 9.3 software. A regression analysis was performed between NDVI and C factor using an assumption. C factor values were assigned to pixels of NDVI image through regression equation. Based on an assumption, the C factor map of Shakker river watershed was produced to use in soil erosion methods such as USLE based on an 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.

### REFERENCES


