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EROSION POTENTIAL ASSESSMENT USING RUSLE EQUATION IN JAYAPURA WATERSHED OF CHIKKAMAGALURU DISTRICT USING RS AND GIS TECHNIQUES

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ABSTRACT

A study was carried out to assess soil erosion potential of Jayapura watershed using in Karnataka State using Indian Remote Sensing Linear Imaging Self-Scanning System (LISS III) data sets in the GIS environment. Results revealed that, calculated rainfall erosivity (R) factor of the study area (by using 29 years of rainfall) was 32309.24MJ mm/ha/h/year, soil erodability (K) factor values varying from 0.22 to 0.3, Slope length and steepness (LS) factor ranges from 0 to 400.5, crop cover (C) factor varies from 0.214 to 3.433 and conservation practice (P) factor has yielded 0 to 134.99. Integration of these factors using spatial tool in Arc Map software, soil erosion of the watershed ranges from 0 to 8,47k t/ha/year. Spatial analysis indicates that soils are prone to high erosion rate, especially in upper reaches of the watershed.

KEY WORDS
RUSLE
Watershed
RS&GIS, Erosion

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INTRODUCTION

Soil is an important non-renewable natural resource, supports life on earth. Now a days soil degradation has serious impacts on land including components like landscape, vegetation cover, hydrologic systems inturn declining land productivity and loss of biodiversity (Singh *et al.,* 2008). Soil is a heterogeneous mass consisting of different components such as mineral salts, water, air, organic matter and living organisms (Chinmayee *et al.,* 2013).The adverse influences of widespread soil erosion are on soil degradation, decline in agricultural production, water quality and increasing the sedimentation of reservoirs. Economically, the decreasing of arable land and its quality is due to loss of top fertile soil on account of soil erosion affecting its productivity. Additionally, a decrease in surface water storage capacity of lakes and reservoirs by sedimentation and a decrease in water quality by suspended soil particles, toxic materials and pesticides are caused by soil erosion (Pal and Samanta, 2011).

Nearly about 1.1 billion hectares of world's soils are affected by water erosion, 0.55 billion hectares by wind erosion. In India about 130 million hectare of land (45% of total geographical area) is affected by serious soil erosion through ravine and gully, shifting cultivation, cultivated wastelands, sandy areas, deserts and water logging (Govt. of India, 1989). According to Ministry of Agriculture (Government of India, 1980), Nearly 175 M ha constituting 53 per cent of India's geographical area is subject to environmental degradation.

In the recent past, concept of watershed based holistic development i.e., protection and rehabilitation of land and associated aquatic and terrestrial resources, while recognizing the benefits of socio-economic growth and development (Thorns, 1990). The RUSLE (Revised Universal Soil Loss Equation) were the most widely used empirical erosion models to asess soil erosion potential for croplands (Wischmeier and Smith 1978, Renard *et al.*, 1997 and USDAARS-NSL 2003).

Keeping these points, a study was undertaken to assess soil erosion potential using RUSLE equation in Jayapura watershed of Chikkamagaluru district using RS and GIS techniques.

MATERIALS AND METHODS

Study was carried out in Jayapura Village in Koppa Taluk of Chikkamagaluru District, Karnataka State, India. A watershed flowing through Jayapura village is known by that watershed is located in the Western Ghats Fig.1. It is located between 13º15³ to 13º30³ N latitude and 75º15³ to 75º30ºE longitude with an elevation of 570m MSL and covers an area of about 163.27km².

A detailed study was carried out using the survey of India (SOI) Toposheets number 48 0/7 of scale 1:50,000 scale, IRS LISS-III satellite Imagery with 6m resolution is used to generate various thematic maps of the study area. The Toposheets are rectified using geometric correction using ERDAS IMAGINE. Latitude and longitude values of Toposheets are entered to the intersection grids in the Toposheets and thus Toposheets is rectified. The AOI layer is overlaid on the rectified Toposheets to extract the study area and preparation of thematic maps. The detailed methodology as depicted below.

The average annual soil loss by introducing improved means of computing the soil erosion factors. These factors vary over space and time and depend on other input variables. Therefore, soil erosion within each pixel was estimated with the RUSLE.

A = R*K*L*S*C*P

Where, A is the computed spatial average of soil loss over a period selected for R, usually a yearly basis (t/h/ year);

R is the rainfall-runoff Erosivity factor [MJ mm/ ha/ h/ year)];

K is the soil erodability factor [t ha h ha/MJ/ mm)];

L is the slope length factor;

S is the slope steepness factor;

C is the cover and management factor and

P is the conservation support-practices factor.

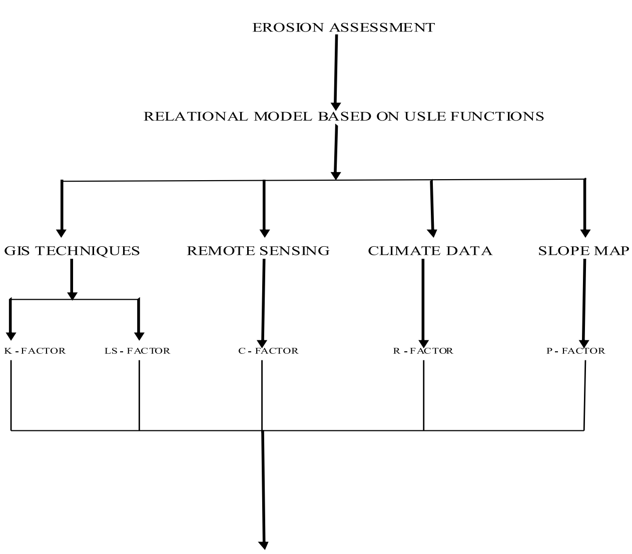
Rainfall Erosivity (R)

The R factor quantifies the effect of rainfall impact and also reflects the amount and rate of runoff likely to be associated with precipitation events. Monthly Rainfall data of 30 years for three stations namely Jayapura, Balehonnur and Koppa are analyzed to prepare R factor map. The R factor is the sum of the erosion index values for all rainstorms in a single year. In an N-year period, the R factor is calculated as:

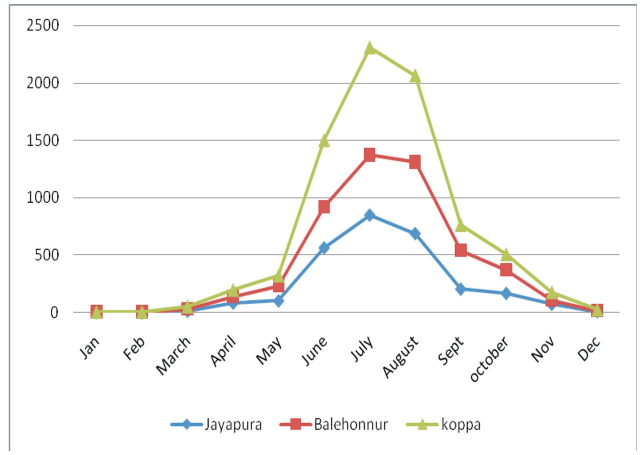
$$R = \sum_{i=1}^{j}(EI_{30})_i / N$$

Where (EI30) is the erosion index EI30 (MJ/mm/ha/h) for storm i, and j is the number of storms in the N-year period.

E (MJ/ha/mm) is the total storm kinetic energy and I30 (mm/h)



Flow Chart 1: Soil Erosion Assessment



Graph 2: Annual Average monthly Rainfall data of Jayapura, Balehonnur, Koppa X axis indicate month and Y axis indicate Rainfall data

is the maximum 30-min rainfall intensity. A direct computation of R requires continuous rainfall intensity data at a time interval equal to or 30 min. since, there are no recorded long-term data for rainfall amounts and intensities, R must be derived from the precipitation data according to the modified Fournier's index (MFI). The MFI represents a widely used parameter for rainfall Erosivity and is determined by the ratio between monthly and annual precipitation which is shown below.

$$MFI = \sum_{i=1}^{12}(P_i^2 / P)$$

Where, Pi (mm) is the average monthly precipitation and P (mm) the average annual precipitation.

$$R = (4.17 * MFI) - 152$$

The rainfall and runoff Erosivity index (R) factor represents the Erosivity occurring from rainfall and runoff at a particular location. An increase in the intensity and amount of rainfall results in an increase in the value of R. The average value of R factor is estimated from long-term annual rainfall records and expressed in MJ mm/ha/h/year.

Soil erodability (K)

It represents the susceptibility of soil or surface material to erosion, transportability of the Environmental sediment, and the amount and rate of runoff for a given rainfall input, as measured under a standard condition. The K factor is an empirical measure of soil erodability as affected by intrinsic soil properties. Though texture is the principal factor affecting K, structure, organic matter content and permeability are also contributing factors. In the present study several soil samples were collected and the textural analysis was carried out to identify the major soil types present in the area. Soils in the study area were classified into 3 textural types and the corresponding K values were identified from the table proposed by Morgan, (1995).

Slope length and steepness factor (LS)

The effect of topography on soil erosion is accounted for by the LS factor in RUSLE, which combines the effects of a slope length factor, (L), and a slope steepness factor, (S).

In general, as L-factor increases, total soil erosion and soil erosion per unit area increase due to the progressive

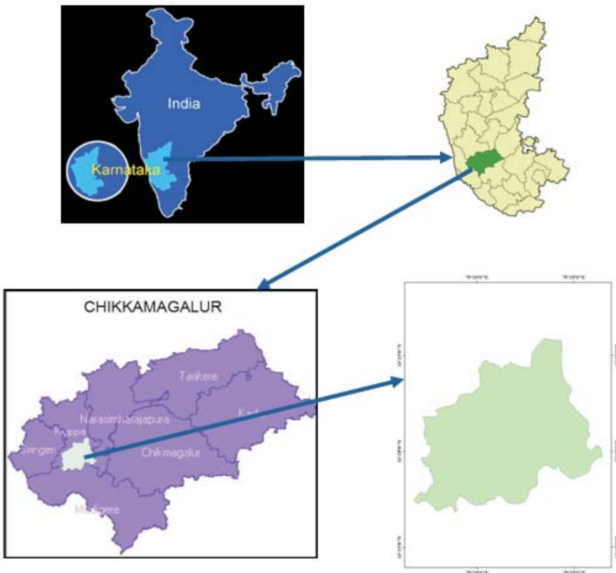


Figure 1: Location of the study area

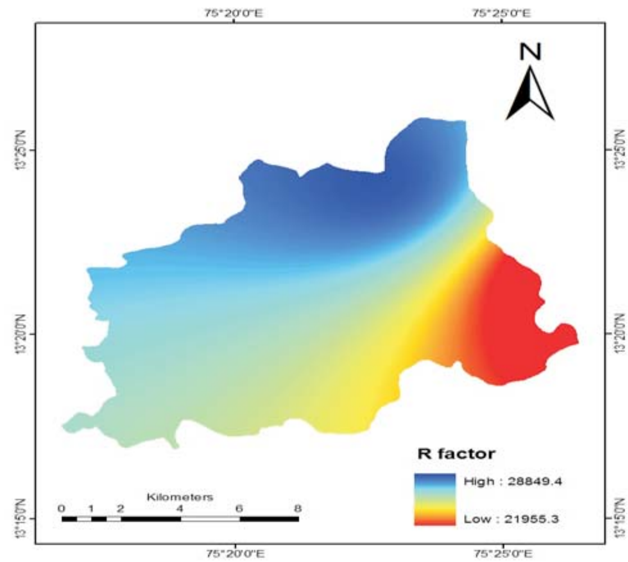


Figure 2: Spatial distribution map of Rainfall Erosivity (R) Factor of Jayapura watershed

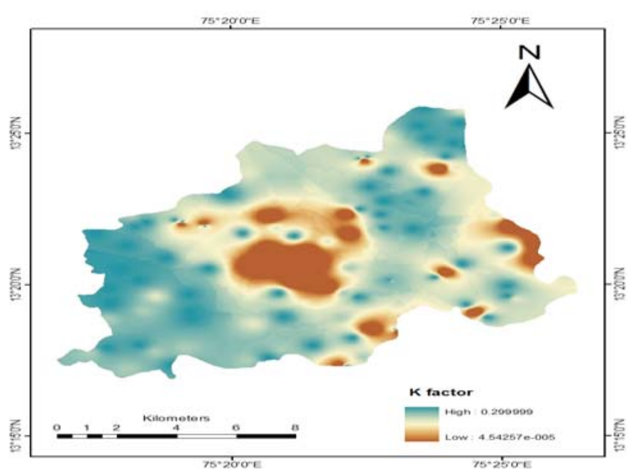


Figure 3: Spatial distribution map of soil erodability (K) factor of Jayapura watershed

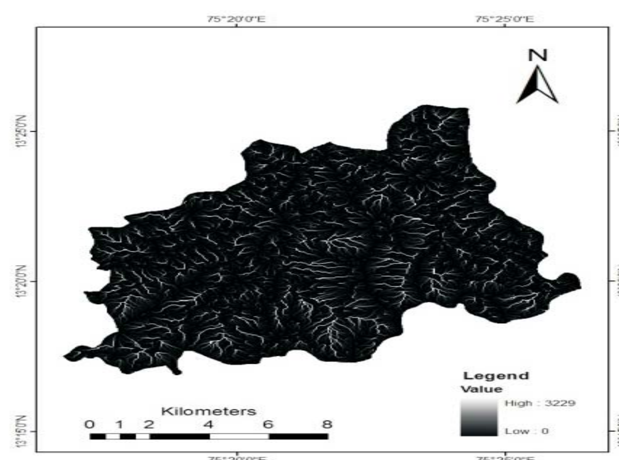


Figure 4: Flow accumulation Map of Jayapura watershed, Chikmagalur District

accumulation of runoff in the down slope direction. As the S-factor increases, the velocity and Erosivity of runoff increase. The combined LS factor was computed for the watershed by means of ArcGIS spatial analyst extension using the DEM using the equation

LS = POW ([flowacc] *cell size / 22.1, 0.4) *POW (Sin ([slope] * 0.01745) / 0.0896, 1.3)

Where flow accumulation denotes the accumulated upslope contributing area for a given cell,

LS = combined slope length and slope steepness factor, cell size = size of grid cell (for this study 10 m) and sin slope = slope degree value in sin.

Cover management factor (C)

The C factor is defined as the ratio of soil loss from land cropped under specific conditions to the corresponding loss from clean-tilled, continuous fallow (Wischmeier and Smith 1978). It is the second most important factor (after topography), reflects the effects of cropping and management practices on soil erosion rates as the soil loss decreases when the vegetation cover increases (Lee, 2004).

Using DEM data, in ERDAS IMAGINE 9.2 mapping had been done for normalized difference vegetation index (NDVI) values. NDVI is an indicator of the vegetation vigor and health are used along with the following formula to generate the C factor value image for the Jayapura study area.

C = exp [-á * NDVI / (â – NDVI)]

Where á and â are unit less parameters that determine the shape of the curve relating to NDVI and the C factor.

Conservation practice factor (P)

The support practice factor (P-factor) reflects the effects of practices that will reduce the amount and rate of water runoff, which in turn, reduces the amount of erosion (Aladdin Yuksel *et al.*, 2008).

The P factor values were estimated by assessing the slope map derived from Cart sat DEM. The lower the P value, the more effective the conservation practice is deemed to be at reducing soil erosion. These values were added to inverse distance weighted (IDW) technique was used for the generation of spatial surface of the P factor.

The RUSLE equation composed of six factors R, K, LS, C and P were integrated within the raster calculator option of the ArcGIS spatial analyst to assess and quantify annual soil erosion rate (A) using RUSLE equation. The estimated soil loss of the Jayapura watershed is in tons/hectare/year.

RESULTS AND DISCUSSION

Rainfall Erosivity analysis

The R factor quantifies the effect of rainfall impact and also reflects the amount and rate of runoff likely to be associated with precipitation events. Monthly average rain fall data of 29 years (1973-2002) collected from three stations namely Jayapura, Balehonnur and Koppa are analyzed to prepare R factor map (Fig. 2 and Table 1).

The calculated R factor ranges from 21249.76031 to 32309.23539 which was calculated from 1973 to 2002. In Jayapura watershed for 3 stations namely Jayapura, Koppa, Balehonnur has yielded R factor of 28849.44899, 32309.23539, 21249.76031 respectively. Whereas, the highest R factor was noticed in Koppa station which is used for the study (Fig. 3). These results were in accordance with Dabral *et al.* (2007) assessed soil erosion of Dikrong river basin of Arunachal Pradesh (R factor 1,894.6 MJ mm ha^{-1} h^{-1} $year^{-1}$).

Soil erodibility Factor (K)

The susceptibility of soil or surface material to erosion by the action of wind and water is known as soil erodibility. The amount and rate of runoff for a given rainfall input, as measured under a standard condition. The K factor is an empirical measure of soil erodability as affected by intrinsic soil properties (texture, structure, organic matter and permeability). In the present study several soil samples were collected and the textural analysis was carried out to identify the major soil types present in the area.

The estimated K values for the mapped soil units of the study area are listed in Table 2. The textural class of the study area varies from fine to loamy skeletal and fine loamy with K factor 0.22, 0.25 and 0.30. Similarly, Vipul *et al.* (2010) estimated soil erodibility factor (K) varied from 0.325 - 0.476. Computed K factor for each soil sample unit were added into GIS environment and a continuous surface representing the spatial distribution of K factor values for entire study area has been made (Fig 4) using the inverse distance weighted (IDW) interpolation method. The generated K factor map shows a maximum and minimum value. These results were in accordance with Reshma and Uday (2012) in soil erodibility K-factor varied from 0.23-0.37 in Upper South Koel Basin, Jharkhand.

Table 1: R factor using MFI values of three stations

Stations	Easting	Northing	MFI	R factor
Jayapura	75.36	13.4	6954.78393	28849.44899
Koppa Balgadi	75.35	13.5	7784.46892	32309.23539
Balehonnur	75.45	13.3	5095.86578	21249.76031

Table 2: Soil erodability index

Texture Class	K Factor
Fine	0.22
Loamy skeletal	0.25
Fine Loamy	0.3

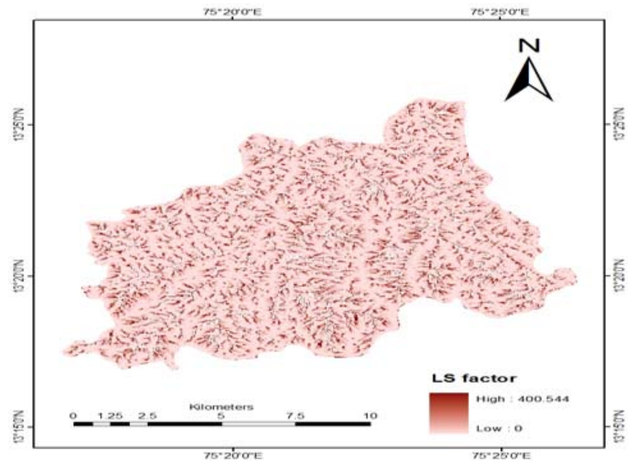


Figure 5: Spatial distribution map of (LS) Factor of Jayapura watershed

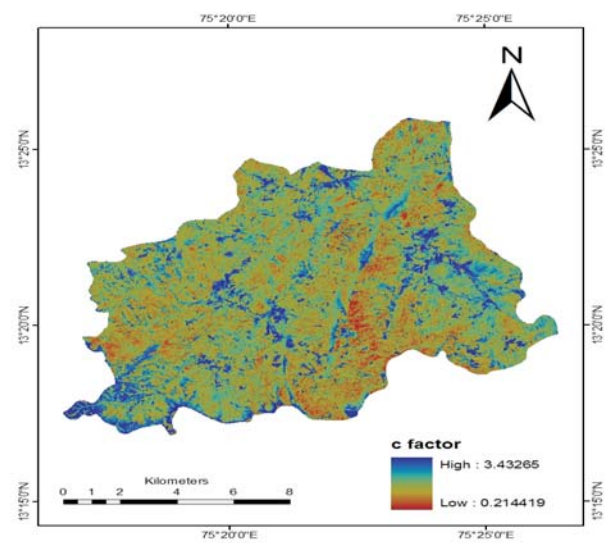


Figure 6: Spatial distribution map of crop management (C) Factor of Jayapura watershed

Slope length (LS)

The topographic factor includes the length (L) and degree (gradient) of slope (S) which affects soil erosion by water in a landscape. It can be estimated depends on the resolution of the digital elevation model (DEM). The combined topographic (LS) factor was computed rather than considering the individual slope length and slope angle; because soil erosion is much

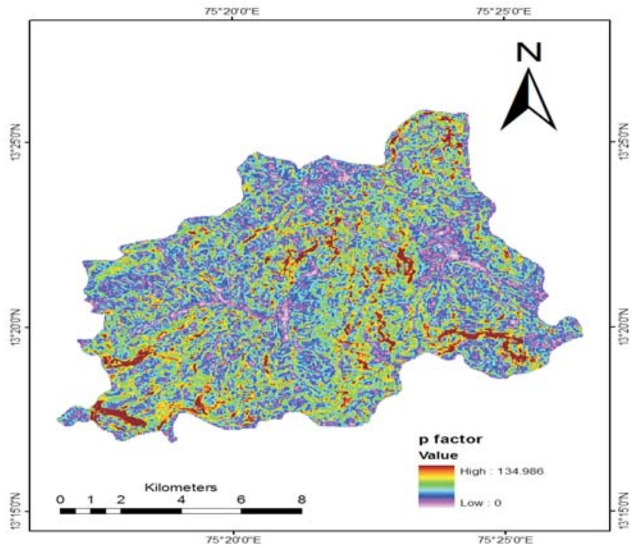


Figure 7: Spatial distribution map of conservation practice (P) Factor of Jayapura watershed

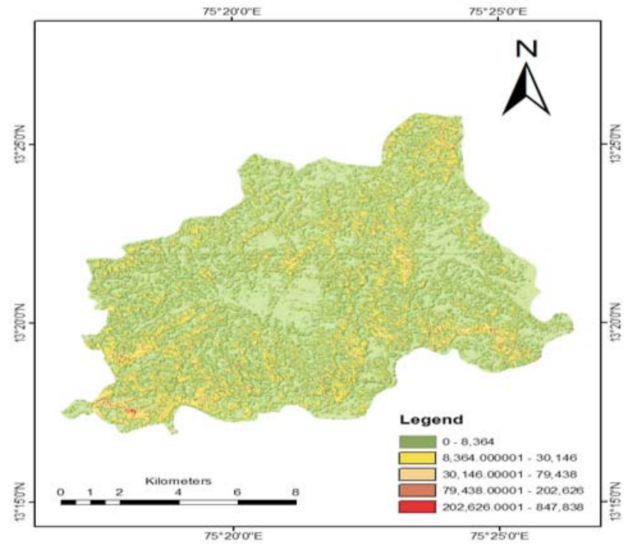


Figure 8: Soil erosion estimation map of Jayapura watershed

influenced by the upstream contributing area rather than individual slope lengths. The LS combined factor was calculated from the table prepared by Renard *et al.* (1997). The flow accumulation and slope steepness were computed from the DEM using ArcGIS spatial analyst tool (Fig. 4).

The combined LS factor for the watershed was calculated and its spatial distribution in different spatial gradients of the watershed is presented in Fig 5. The LS factor value in the study area varies from 0 to 400.5. Physiographical division of Jayapura watershed belong to hilly zone with an altitude drops from 1300m to 570m. The study area experiences a tropical climate marked by heavy rainfall. The data further indicated that lands with steep slopes had higher LS values while lower alluvial plains had lowest LS value Potdar *et al.* (2003).

Cover management factor (C)

Information on land cover management (C) and conservation practices (P) factors were collected through field survey. The IRS P6 LISS-IV satellite image was used to interpret the land cover classes based on field knowledge of the study area. The normalized difference vegetation index (NDVI), an indicator of the vegetation vigor and health are used along with the following formula to generate the C factor value image for the study area. The C factor ranges between 0.2144 and 3.432 (Prasannakumar *et al.*, 2011). Crop management (C) factor are presented in Fig 6.

Conservation practice factor (P)

The support practice factor (P-factor) reflects the effects of practices that will reduce the amount and rate of water runoff, which in turn, reduces the amount of erosion. The P-factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. P factor is as shown in the Fig. 7. After estimating different RUSLE factors (R, K, LS, C and P), the total soil loss (A) was estimated by multiplying all the factors. Integration of RUSLE parameters using spatial analyst tool in Arc Map software to get soil loss estimation final output as shown in the Fig 8.

The R factor has been calculated has yielded 28849.44899, 32309.23539 and 21249.76031 respectively. The Soil erodibility Factor (K) interpolated has values varying from 0.22 to 0.3 for different types of soils present in the watershed. The Erosive Slope length Factor (LS) computed from cart sat DEM has yielded a values varying from 0 to 400.5. The Cover management factor (C) computed from Land sat image varies from 0.2144 to 3.4326. Conservation practice factor (P) has yielded a value varies from 0 to 134.986. Finally, integration of these factors has yielded soil erosion in the watershed it varies from 0 to 8, 47,838 t/ha/year.

Revised Universal Soil Loss Equation (RUSLE) which is used in the present study to estimate soil erosion in Jayapura watershed of Chikmagalur district has indicated that soil erosion is high in the upper reaches than lower reaches of the watershed.

The following Mitigative measures are Construction of boulder checks dams in high erosion areas is very helpful to control soil erosion. In piedmont regions, *i.e.* in moderate erosion areas, contour bunding, contour trenching, will helps to control soil erosion and conservation. Construction of artificial ponds and tanks in the forest area will control runoff and in-turn soil erosion.

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