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# Assessment of Soil Erosion using GIS for Cheyyeru Sub Basin, Chittoor.

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**Abstract:**

Watersheds, and their management, have become a major focus of resource management in countries around the world. Much of this interest is the result of land-use practice that has led to increased soil erosion. Recently there has been increase in number of reports warning of high levels of soil erosion and detoriation of major watersheds. Sediment is building up in reservoirs and stream beds resulting in reduced irrigation and power production while increasing the incidents and severity of flooding. These watershed problems are especially acute in developing countries where growing populations are exerting intense pressure on increasingly scarce land and water resources. Most of the people in these areas live and work on the land. So, as rural populations increase, land formerly formed extensively are now being formed more intensively, while formerly follow lands, usually more susceptible to erosion, are being cultivated. This, in combination with similarly motivated overuse of grazing lands of upland areas, a result of more intensive shift in agriculture and excessive timer extraction, has also accelerated soil erosion on downstream damages.

**Key words**: Erosion risk assessment, Land degradation, Geographical information systems (GIS), Remote sensing (RS).

## Introduction

Watersheds, and their management, have become a major focus of resource management in countries around the world. Much of this interest is the result of land-use practice that has led to increased soil erosion. Recently there has been increase in number of reports warning of high levels of soil erosion and detoriation of major watersheds. Sediment is building up in reservoirs and stream beds resulting in reduced irrigation and power production while increasing the incidents and severity of flooding. For example, Bowonder et al., report a 60 percent loss in the storage capacity of nizamsagar reservoir in telangana due to severe soil erosion in the upper small watershed (Bowonder et al, 1985). The actual rate of sedimentation was 25 times the original assumed rate the impact of such soil erosion is felt by rural people throughout the watershed to reduce incomes as well as inadequate supplies of wood and clean water, has dramatically increased the potential for erosion and downstream damages. These watershed problems are especially acute in developing countries where growing populations are exerting intense pressure on increasingly scarce land and water resources. Most of the people in these areas live and work on the land. So, as rural populations increase, land formerly formed extensively are now being formed more intensively, while formerly follow lands, usually more susceptible to erosion, are being cultivated. This, in combination with similarly motivated overuse of grazing lands of upland areas, a result of more intensive shift in agriculture and excessive timber extraction, has also accelerated soil erosion on downstream damages.

The immediate case of concern- increased soil erosion and associated downstream problems is a physical factor, these watershed problems result from a mixture of bio physical, economic, social, political and institutional factors. Some consequences of these factors are reduction in the productivity of forests, fisheries, agricultural and grazing lands; decreased returns from investments in hydro electric power generation and irrigation projects; and losses of property and impairment of human health.

The practices required to reduce these losses by protecting small watersheds from degradation are well recognized. However, the management of watersheds have been largely unsuccessful, partly because the concentration has been almost exclusively on biophysical aspects such as slope, soil texture, and vegetative cover, without proper regard for socioeconomic aspects. For successful project implementation, economic, social, political and institutional considerations are paramount.

The level of concern about watershed management is evident from the wide variety of programmes and institutions actively involved in the study and management of watersheds. In Asia, for example, the recently established International Centre for Integrated Mountain Development (ICIMOD) located in Kathmandu., Nepal, has a primary focus on the management of intensively used upland watersheds. The U.S. Agency for International Development (USAID) has funded many watershed projects in the Thailand, Indonesia, and the Philippines, as well as provided funding for Association of Southeast Asian Nations (ASEAN) Watershed Project. The Food and Agriculture Organization of the United Nations (FAO) has funded watershed management activities in many Asian countries including Afghanistan, Pakistan, India, Nepal, Burma, Thailand, Indonesia and the Philippines (William Eastern et al., 1986). Integrated watershed management programme (IWMP) has been established by department of land resources in India.

The main goal of this study was to determine and evaluate the soil erosion and groundwater potential zones in Cheyyeru sub basin with qualitative approach using GIS techniques and to give some suggestions to take some measurements against to soil erosion and to make sustainable use of land resources.

***Description of the study area:***

Cheyyeru sub basin is located in parts of Pileru, kalikiri and sodam mandals and occupying an area of 487.87 Sq km of Gundloor, Doddipalle and Thatiguntapalevillages in Chittoor District and is situated between the stretches from 13°38’20”North Latitudes and 78°48’14”East Longitudes and covers an area of 48788.81hactares(487.97 sq kilometres), with respect to the survey of India Toposheet number 57K/10, 57K/13, 57K/14 NE on a scale of 1:50,000 scale. The location map of the Cheyyeru sub basin is as shown in the figure 4.1.

The area experience humid tropical climate and the summer months are very hot and the mercury level rises to +42°Celsius. Winter months are pleasant. Winter months are ideal for agricultural field work. Rainfall is generally scanty. The average rainfall per annum is 753.55 mm.

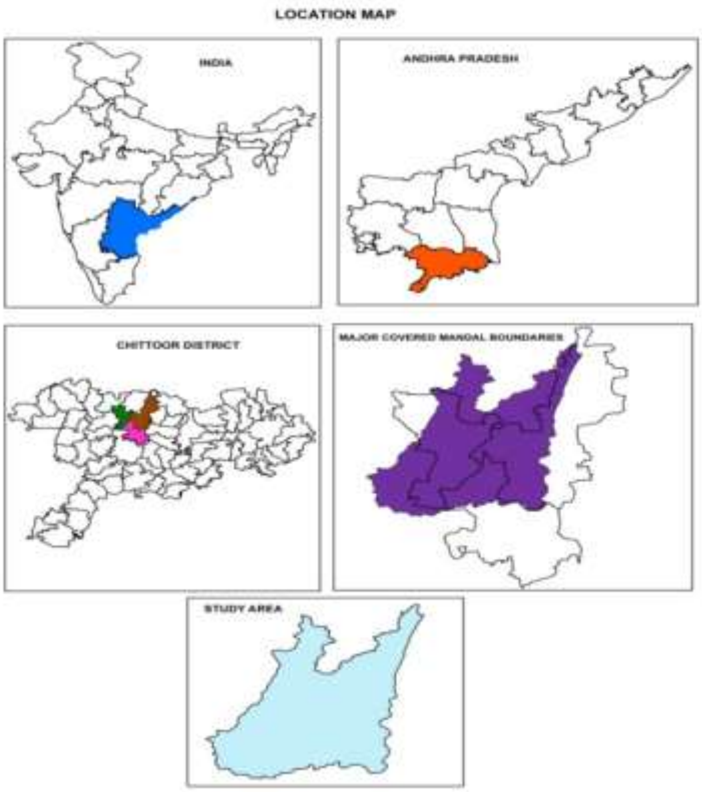



Fig. 1: Location map of the Cheyyeru Sub basin GIS techniques for assessing the erosion risk in CHEYERU sub basin.

## Methodology

***Steps involved in the determination of soil erosion:***

STEP 1: Delineation of study area from the toposheet and satellite imagery.

STEP 2: Computation of rainfall erosivity factor, soil erodability factor, topographic factor, cover management factor and conservation support practice factor of USLE model from precipitation data, soil survey, Digital Elevation Model (DEM) and land use/ land cover maps for the estimation of actual soil erosion.

**Step 1: Delineation of basin from the toposheet and satellite imagery:** The base map (Figure 4.1) of the study area is delineated from Survey of India (SOI) toposheet of 1:50000 scale using ArcGIS 10.2.2 software. Influencing rain gauge stations located in and around the catchment are identified and marked on the map. The prepared base map is used for the extraction of study area from satellite image (LISS-3) and Carto DEM.

**Step 2: Actual annual soil erosion estimation using USLE model:** In this study USLE an empirical model has been used for the assessment of annual soil loss. The USLE is applied to the CHEYERU sub basin by representing the basin as a grid of square cells and calculating soil erosion for each cell. The USLE can be expressed as (Renard et al., 1997) $A=R \times K \times LS \times C \times P$

Where A is the average soil loss caused by erosion (t/ ha/ year), R is the rainfall erosivity factor (MJ mm/ ha/ h/ year), K is the soil erodability factor (t ha h /MJ/ ha/ mm), LS is the topographic factor, C is the crop management factor or cover management factor, and P is the conservation support practice factor. The LS, C, and P factors are dimensionless.

***a) RAINFALL EROSIVITY FACTOR (R)***

The rainfall erosivity factor (R) reflects the effect of rainfall intensity on soil erosion, and requires detailed, continuous precipitation data for its calculation (Wischmeier and Smith, 1978). R is an indication of the two most important characteristics of a storm determining its erosivity:

- Amount of rainfall
- Peak intensity sustained over an extended period

Previous studies indicate that soil loss from cultivated fields is directly related to the energy and intensity of each rainfall. The value of R used in RUSLE must quantify the effect of raindrop impact and must also reflect the amount and rate of runoff likely to be associated with the rainfall. As there is a lack of rainfall intensity data in the study area, rainfall erosivity is calculated on an annual precipitation basis. R factor is calculated using the following equation in Raster calculator tool of ArcGIS software.

R= 0.5*P*1.73

Where P = average annual rainfall

Spatial distribution of average annual precipitation (P) in the study area is estimated. In the process of interpolation, 10 years rainfall data for specified basins were collected and calculated.

***b) SOIL ERODIBILITY FACTOR (K)***

Soil Erodibility (K) represents the susceptibility of soil or surface material to erosion, transportability of the sediment, and the amount and rate of runoff given a particular rainfall input, as measured under a standard condition. The standard condition is the unit plot, 72.6ft long with a 9 percent gradient, maintained in continuous fallow, tilled up and down the hill slope (HyeonSik Kim, 2006). Texture is the principal factor affecting erodibility, however; structure, organic matter, and permeability also contribute. Soil structures affect both susceptibility to detachment and infiltration. Permeability of the soil profile affects erodibility because it affects runoff. K values reflect the rate of soil loss per rainfall-runoff erosivity (R) index. Soil erodibility factors (K) are best obtained from direct measurements on natural runoff plots. Normally nomograph is used to determine the K factor for a soil, based on its texture; % silt plus very fine sand, % sand, % organic matter, soil structure, and permeability (Wischmier and Smith, 1978). The Cheyyeru sub basin consists of 9 different soil types with varying soil characteristics. In this study, Soil erodability value is assigned to different soil types based on soil texture, permeability and antecedent moisture content of the soil. The soil map is reclassified with assigned K-Factor value. The K factor is a numerical value from 0 to 1 in which soil erodability values closer to 0 are less prone to soil erosion.

***c) Topographic Factor (LS)***

The Topographic factor represents a ratio of soil loss under given conditions to that at a site with the "standard" slope steepness of 9% and slope length of 72.6 feet. The two constituents of this factor are slope length (L) and slope steepness (S). Slope length (L) is the effect of slope length on erosion. The slope length is defined as the distance from the point of origin of overland flow to the point where either the slope decreases to the extent that deposition begins, or runoff water enters a well-defined channel. The topographic factor is calculated using the following equation

LS = (FlowAcc grid * cell size / 22.13)m* (0.065 + 0.045 (Slope grid)+ 0.006 * (slope grid)2)

Where slope is in percentage The Raster Calculator in the Spatial Analyst extension of ArcMap is used to calculate the LS grid. The Raster Calculator expression of the equation above is: LS = Pow ([Flow Accumulation grid] * cell size / 22.13, 0.4) * (0.065 + 0.045 * [slope grid]+0.0065*pow ([slope grid], 2)) .To calculate LS factor, Flow Accumulation grid is derived from DEM after conducting fill and flow direction processes in ArcGIS. The slope grid is also derived from DEM.

***d) Crop Management Factor (C):***

The C-factor is used to reflect the effect of cropping and management practices on soil erosion rates in agricultural lands and the effects of vegetation canopy and ground covers on reducing soil erosion in forested regions (Renard et al., 1997), which varies with season and crop production system. The relative impacts of management options can easily be compared by making changes in the C-factor which varies from near zero for well-protected land cover to 1 for barren areas. The Cover management factor map is prepared on the basis of LU/LC map of the study area. The area associated with each land use/ land cover classes have been calculated. The C values are assumed as proposed by Kim et al., (2005). The land use/ land cover map is reclassified based on assumed C factor value for the generation of C factor map.

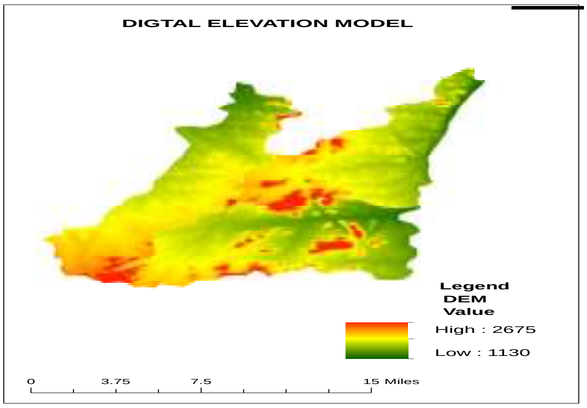
***e) Conservation Support Practice (P)***

The conservation practice factor (P) factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope and is used to account for the positive impacts of those support practices. The P factor accounts for control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, runoff velocity, and hydraulic forces exerted by runoff on soil. The supporting mechanical practices include tillage (furrowing, soil replacement, seeding, etc.), strips of close-growing vegetation, deep ripping, terraces, diversions, and other soil- management practices orientated on or near the contour that result in the collection and storage of moisture and reduction of runoff. The value of P- factor ranges from 0-1. The P-factor values are taken from the slope values of the study area and the values are as shown in the table 5.5.

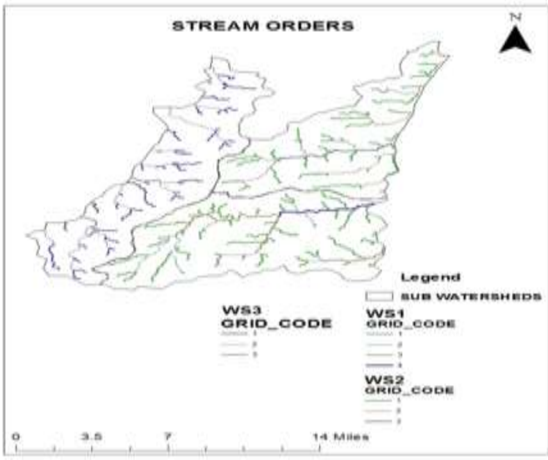
**Table 5.4: Details of Slope and Respective P-Factor Vales**

| Slope (%) | P-factor |
|---|---|
| 1-2 | 0.6 |
| 3-8 | 0.5 |
| 9-12 | 0.69 |
| 13-16 | 0.8 |
| 17-20 | 0.89 |
| 21-25 | 1 |

The DEM of the study area is as shown in figure




The stream order map of study area is as shown in figure




## SOIL EROSION ANAYSIS

### *Rainfall erosivity index (R):*

The soil erosion rate in the catchment is more sensitive to rainfall. The daily rainfall is better indicator of variation in rate of soil erosion with the added advantage that it can be used to characterize the seasonal distribution of sediment yield.The advantages of using annual rainfall include its ready availability, ease of computation and greater regional consistency of the exponent. Therefore in the present analysis annual average rainfall is used for R factor calculation.

### *Soil erodability factor (k):*

The factors like texture, structure, organic matter content and permeability are very significant in determining soil erodability. K factor values are assigned to respective soil types in soil map to generate soil erodability map.The factors like texture, structure, organic matter content and permeability are very significant in determining soil erodability. K factor values are assigned to respective soil types in soil map to generate soil erodability map.

***LS factor (LS):***

Topographic factor represents the influence of slope length and slope steepness on erosion process. LS factor is calculated by considering flow accumulation and slope grid as input.

***Crop management factor (C):***

Information on land use permits a better understanding of the land utilization aspects on cropping pattern, fallow land, forest and wasteland and surface water bodies, which are vital for development planning/erosion studies. Remote sensing and GIS technique has a potential to generate a thematic layer LU/LC of a region`. Crop management factor is assigned to different land use patterns. Using LU/LC map and C factor value, C factor map is prepared in ArcGIS.

The C-factor values which are derived from land use land cover are shown in the table

| **S.No** | **Class name** | **Area km$^2$** | **Percentage of area** | **C-factor** |
|---|---|---|---|---|
| 1 | Agricultural land | 280.8 | 63.7 | 0.33 |
| 2 | Built up | 1.134 | 0.25 | 0.3 |
| 3 | Forest area | 104.845 | 23.8 | 0.9 |
| 4 | Waste land | 50.78 | 11.52 | 0.5 |
| 5 | Water body | 3.21 | 0.73 | 0 |

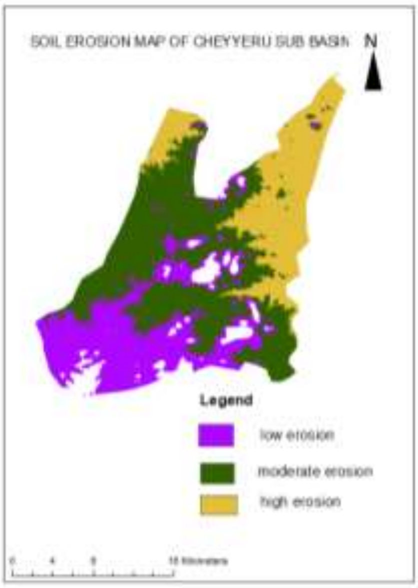
***Conservation practice factor (P):***

The conservation practice factor was taken from the table 5.5 it ranges from 0.5-1.0.

The categories of soil erosion and the area and amount of soil loss of Cheyyeru sub basin are shown in the table

| **Erosion Categories** | **Numeric range (t/ha/year)** | **Area (ha)** | **Area (%)** | **Soil loss (t/year)** |
|---|---|---|---|---|
| Low | <5 | 23648.25 | 53.8 | 1.8 |
| Moderate | 5-10 | 10461.49 | 23.8 | 5.6 |
| High | 10-15 | 6791.18 | 15.45 | 3.2 |
| Total | | 40900.92 | 100 | 10.6 |

From the table it was observed that most part of the study area comes under low erosion category, high erosion occurred only in few portion of the study area. Average annual soil loss is 259.16 t/ha/year. The soil erosion map prepared was as shown in the figure .




The observations are as follows:

1.Based on the slope map the slopes of the study area are divided into seven classes 1,2,3,4,5,6,7. These are nearly level, very gentle slope, gentle, moderately slope, moderately steep slope, steep slope, and very steep slope.

1.Four soil mapping units were identified in this watershed.

2.By using morphometric analysis groundwater potential zones have been identified and it was known that sodam has very good GW potential, Pileru has moderate GW potential, and kalikiri has poor GW potential.

3.The rate of soil erosion for Cheyyeru sub basin was obtained as 259.16 t/year.

***Recommendations:***

1. Based on the technical study various soil conservation and drought proofing works and soil erosion control measures such as contour bunding, strip contouring and water harvesting structures like check dam, farm ponds are suggested.
2. Ground water development with conservation measures and horticulture nurseries are suggested in the cultivated areas associated with lineaments. Irrigation is also suggested for major vegetable crops. Drip irrigation for horticulture plantations is suggested.
3. Fodder/fuel wood/silvipasture development is suggested in marginal lands with 0-5% slope. Shelter belt/strip plantation is also suggested in the roads.
4. These areas need to be provided with mini farm ponds for improving soil moisture regime. In the higher slopes brushwood, rubble and masonry check dams can be constructed.
5. For horticulture plantation like Mango and Un irrigated crops, Contour cultivation, Contour bunding, Gully plugging, Brush wood dams, rubble dams etc, are suggested to facilitate the arrest of soil erosion and improve soil moisture regime.

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