MODELLING FOR EVALUATING OF ANNUAL SOIL EROSION (A) IN THE MICROWATERSHED USING RUSLE.

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ABSTRACT

Background:- One of the leading causes of land deterioration is soil erosion caused by water. Erosion has a role in the sedimentation of dams and the temporary or permanent reduction of agricultural land's productivity.

Objectives:-This study aimed to map and estimates the mean annual soil loss in the Gurrampalem watershed, Gurrampalem village, Pendurthi Mandal, Andhra Pradesh, India, using GIS and remote sensing techniques.

Methods: - The data was assessed using Remote Sensing (RS) and Geographic Information Systems (GIS) techniques. The erosion risk by water was calculated using the Revised Universal Soil Loss Equation (RUSLE). Five inputs, such as rainfall erosivity (R-factor), soil erodibility (K-factor), slope and length of slope (LS-factor), plant cover (c-factor), and anti-erosion practices (P-factor), are used in the model to calculate the erosion loss rates.

Findings: - The average annual soil loss from the Gurrampalem reservoir's catchment area is 4 t ha^{-1} yr^{-1}. Very low-class soil erosion accounts for the largest portion, covering an annual loss of 43.6%. Moderate class, Low class, moderately severe class and severe class, accounted for 24.5%, 18.4%, 8.2%, and 5.3%, respectively The mean yearly SY of the study reservoir has a range of values from 2.12 t yr^{-1} to 50.2 t yr^{-1}. Designing the proper land management to reduce soil erosion in the basin can be aided by utilizing the information on erosion factors in conjunction with the GIS/RUSLE application.

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1. INTRODUCTION

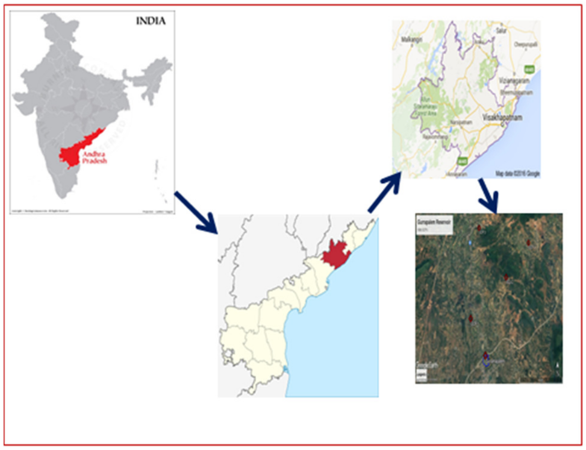
Soil and water are both essential elements. In arid locations, water erosion seriously affects both quantity and quality; it causes the pedological surface layers to deteriorate and the ingredients within them to shift (1). Nonetheless, several research works indicate that the Mediterranean area is susceptible to climate change, with increasing aridity hastening water-induced erosion (2)(3). Nonetheless, soil is a non-renewable resource that offers a wide range of goods and advantages for the ecosystem (4) (5). But soil loss is the most common type of land damage, and management practices and land use worldwide affect how severe it is (6) (7). As a result, soil erosion degrades water quality and hurts natural resources by lowering agricultural productivity (8).

2. Study area:-

Gurrampalem Reservoir is a Minor Irrigation tank, Ayacut 133.9 Acres.

Project Details:	
Longitude	: 83°10' 42''
Latitude	: 17°52' 02''
Hydrology:	
Catchment Area	: 15.65Sq Mts
Maximum Flood Discharge	: 19.74 Cusecs
Length of Bund	: 420M
Length of Surplus Weir	: 19.30M
Capacity of Tank	: 5.63Mcft
Ayacutdars	: 239Nos
Ayacut	: 133.9Acres
Mandals Benefited	: Pendurthi and 4 others
Water Utilization	: Irrigation Purpose
Cropping Pattern	: Paddy and Other

Figure 1. Location map of Gurrampalem Reservoir



3. Materials and Methods:-

The soil erosion modelling by RUSLE (Revised Universal Soil Loss Equation) is a modified form of the USLE (9). RUSLE is expressed as

$$A = R * K * LS * C * P \quad \_\_\_ \text{ (Eq.1)}$$

Where, A is the annual rate of soil loss (t ha^{-1} yr^{-1}), R is the rainfall erosivity (MJ mm ha^{-1} h^{-1} yr^{-1}), K is the soil erodibility (t ha h ha^{-1} MJ^{-1} mm^{-1}), LS is the topographic factor stated as slope length and steepness, C is the factor for crop management and P stands for conservation supporting practice.

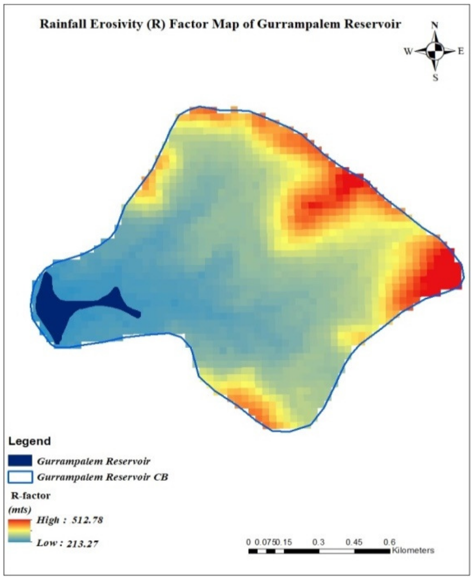
A. Rainfall Erosivity:

Rainfall erosivity is one of the critical elements in RUSLE because it directly affects the disintegration of aggregates, the detachment of soil particles, and the transport of eroded particles through runoff. Erosion is primarily caused by rainfall. The average yearly sum of the individual storm erosion index values (EI_{30}), where E is the total storm kinetic energy, and I_{30} is the most incredible rainfall intensity in 30 minutes, is the rainfall erosivity. Wischmeier and Smith (10) advised the need for at least 20 years of continuous rainfall data in order to compute storm EI_{30}. Babu et al., (11) developed an empirical method for India that calculates the rainfall erosivity factor using readily available rainfall data. The formula is:

$$R = 81.5 + 0.38 * P \quad \_\_\_\_ \text{ (}\textit{Eq.2}\text{)}$$

Where, P is the annual precipitation for areas where annual precipitation ranges between 240 mm and 3500 mm. The mean annual precipitation over the most recent 30 years ranges from approximately 346.65 mm to 1135.21 mm around the study area. The rainfall erosivity factor was calculated by using Equation (2). A spatially distributed R-factor map of the study area (Figure 2) was derived by ordinary Kriging spatial interpolation that was performed in ArcGIS 10.1. The Rainfall erosivity factor (R) during the year 1992-2022 ranges from 213.27 MJ mm ha^{-1} h^{-1} yr^{-1} to 512.78 MJ mm ha^{-1} h^{-1} yr^{-1}. In the study area, the mean R-value is 365.03 MJ mm ha^{-1} h^{-1} yr^{-1}.

Figure 2: Rainfall Erosivity Map of Gurrampalem Reservoir



B. Soil Erodibility Factor (K):

The inherent susceptibility of the soil to erosion depending on the soil profile characteristics is represented by the soil erodibility factor (K). In this study, the soil type map was extracted from the digital soil map of the world (DSMW) published by the Food and Agriculture Organization (FAO) of the UNESCO and the K factor is estimated using the equation of Williams [12]. The K factor of soil can be ascertained using a nomograph to evaluate the texture (silt%, sand%, clay%, permeability%, soil structure%, organic matter %), permeability, and soil structure [13].

$$K=27.66 * m1.14*10-8* (12-a) + 0.0043 *(b-2) + 0.0033*(c-3) \quad \_\_ \; \textit{Eq. 3}$$

Where, K= soil erodibility, m = silt (%) + very fine sand (%) × (100-clay (%)), a = organic matter (%), b = structure code: *where,* 1 is very structured or particulate, 2 is fairly structured, 3 are slightly structured and 4 is solid; c = profile permeability code: *where,* 1 is rapid, 2 is moderate to rapid, 3 is moderate, 4 is moderate to slow, 5 is slow and 6 very slow. However, using Equation 4 to get the K-value requires determining a number of parameters, some of which are not easily accessible for the given location. Therefore, using published research (Table 2) that was easily accessible, soil erodibility values for different soil texture classes in the study area were determined [14].

Table 2: Soil types with their Texture (silt%, sand%, clay%, permeability%, soil structure%, organic matter %)

S. No	Soil type	% Sand	% Slit	% Clay	m	b	c	a (%)
1	Barren Land	60	13	27	5329	3	4	2
2	Built Up area	62	12	26	5338	3	4	2
3	Clayey soils	20	20	60	1600	1	6	0.6
4	Fine loamy soils	25	65	10	7235	4	5	1
5	Fine loamy to loamy skeletal soils	22	66	12	7249	4	5	1
6	Fine soils	20	65	15	7225	4	5	1
7	Loamy skeletal soils	41	41	18	6724	2	3	1.5
8	Waterbody	60	13	27	5329	3	4	2

The zones with low K values (0.10-0.25) were huge, including the total catchment area of 72.78 hectares. In contrast, areas with a moderate K-factor (0.25-0.35) accounted for 50.81 ha that spread from the northern to the southern regions. The lowest K (<0.10) and highest K (0.35-0.45) factors correlate with the 3.02 ha and 20.14 ha of total catchment area (TCA), as depicted in Figure 4 and Table 3.

Figure 3: K-factor Map of Gurrampalem Reservoir

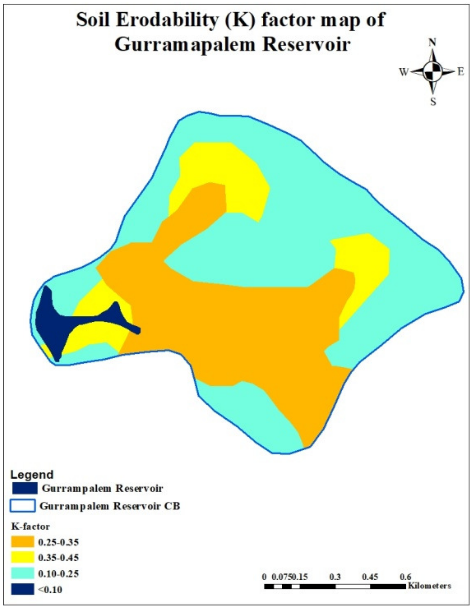


Table 3: K-factor values of Gurrampalem Reservoir

S.No	K factor	Area in ha
1	<0.10	3.02
2	0.10-0.25	72.78
3	0.25-0.35	50.81
4	0.35-0.45	20.14

C. Slope length and Steepness Factor (LS):

The slope length and steepness factor accounts for the effect of topography on erosion. Many workers have used the L and S factors as a combined LS-factor. The LS factor has been computed by an empirical formula as suggested by Moore and Wilson (12):

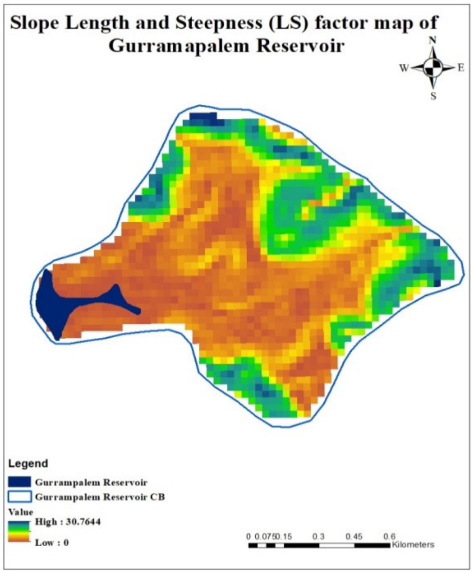
$$LS = 1.4\ (Flow\ accumulation * Cell\ size / 22.1322.13.)\ 0.4 * (Sin\ slope * 0.0896) 1.3 \quad \_\_Eq.4$$

Where, LS = combined slope length and slope steepness factor; Flow accumulation = accumulated upslope contributing area for a given cell; Cell size = size of grid cell (for this study cell size is 30 m) and Sin slope = slope degree value in sin. In the study, reservoir topography is primarily composed of low slope class, comprising 51.28 ha; near slope, which covers 30.72 ha; moderate slope, which consists of 38.25 ha; steep slope, which encompasses 19.19 ha; and very steep slope, which includes 4.28 ha, tabulated in Table 4 and Figure 4.

Table 4: LS-factor values of Gurrampalem Reservoir

S.No	Values of LS factor	LS class	Area in ha
1	<5	Low slope	51.28
2	05 to 10	Near slope	30.72
3	10 to 20	Moderate slope	38.25
4	20-40	Steep slope	19.19
5	>40	Very steep slope	4.28

Figure 4: LS-factor Map of Gurrampalem Reservoir



D. Cover Management Factor (C):

The cover management factor explains how vegetation cover affects soil erosion. Cover management factor (C) is the soil loss ratio from an area with specific cover and management methods to the same amount of soil loss from continuously fallow, clean-tilled land. The kind, growth stage, and plant cover percentage all affect the value of C. The Normalized Difference Vegetation Index (NDVI) was used to calculate the C-factor, which was then created using Sulistyo's (15), equation:

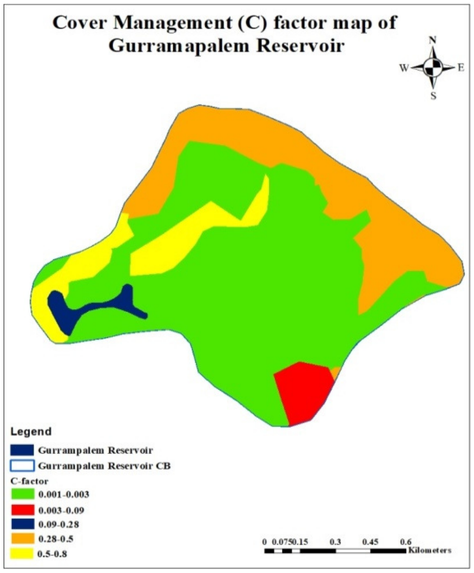
$$C = 0.6 - 0.77\ NDVI \qquad \_\_\_\ (Eq.\ 5)$$

The majority of the reservoir catchment area is covered by the 0.001-0.003 class, encompassing 98.62 ha. The remaining are 0.003-0.09 class (16.25 ha), 0.09-0.28 class (5.17 ha), 0.28-0.5 class (13.47 ha), and 0.5-0.8 class (10.21 ha) respectively, illuminated in Table 5 and Figure 5.

Table 5: C-factor values of Gurrampalem Reservoir

S.No	C factor	Area in ha
1	0.001-0.003	98.62
2	0.003-0.09	16.25
3	0.09-0.28	5.17
4	0.28-0.5	13.47
5	0.5-0.8	10.21

Figure 5: C-factor Map of Gurrampalem Reservoir



E. Conservation practice factor (P):-

To mitigate the adverse effects of precipitation, techniques such as contouring, terracing, and strip cutting provide the necessary support [(16)]. Land uses, including agriculture, were categorized into general groups based on factor P by Ghosh et al. [(17)]. Since different management techniques are more effective on different slopes, the farmland was divided into six slopes and assigned a probability value to each. Accordingly, this inquiry used a technique considering the average slope and parcel shape. P-values were assigned to various combinations of slope and LULC category (Table 6) after the slope thematic map and LULC categories were converted to vector format.

Table 6: Values of the support practices (P) factor for various LULC classes

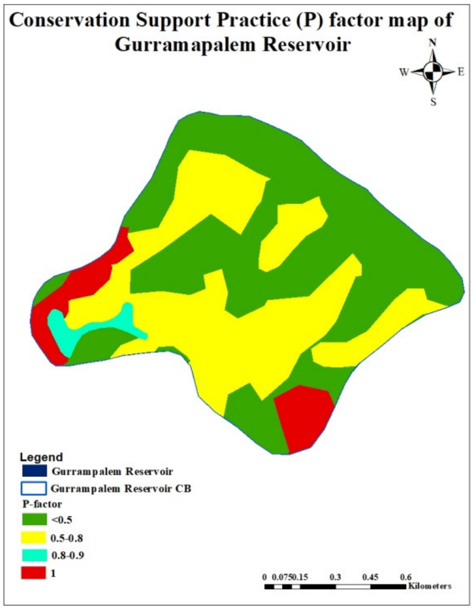
S.No	LULC Category	P-Factor
1	Agriculture Crop Land	0.5
2	Agriculture Fallow	0.9
3	Degraded Forest	1
4	Dense forest	0.8
5	Built up area	1
6	Wastelands	1
7	Waterbodies	1

The Gurrampalem reservoir catchment area is mostly dominated by a P-factor of <0.5 class with 81.60 ha followed by 0.5-0.8 class accounts for 52.42 ha, 0.9-1 class with 6.45 ha and 0.8-0.9 class covers 3.25 ha tabulated in Table 7 and Figure 7.

Table 7: P-factor values of Gurrampalem Reservoir

S.No	P factor	Area in ha
1	<0.5	81.60
2	0.5-0.8	52.42
3	0.8-0.9	3.25
4	0.9-1	6.45

Figure 6: P-factor Map of Gurrampalem Reservoir



4. Results and Discussion:-

Following the preparation of all RUSLE parameters (R, K, LS, C, and P), the corresponding raster maps were maintained with a uniform projection and cell size of 30 meters. The RUSLE Equation was then used to superimpose these factor maps in a raster calculator, generating a soil erosion risk map or estimated soil erosion. Based on the rate of erosion, the study area's soil erosion is divided into six classes: very low-soil erosion (0–1 t ha^{-1} yr^{-1}), low soil erosion (1–5 t ha^{-1} yr^{-1}), moderate soil erosion (5–10 t ha^{-1} yr^{-1}), moderately severe soil erosion (10–20 t ha^{-1} yr^{-1}), severe soil erosion (20–40 t ha^{-1} yr^{-1}), and extreme soil erosion (>40 t ha^{-1} yr^{-1}), as indicated in the Table 8.

Table 8: Soil Erosion Zones Classification

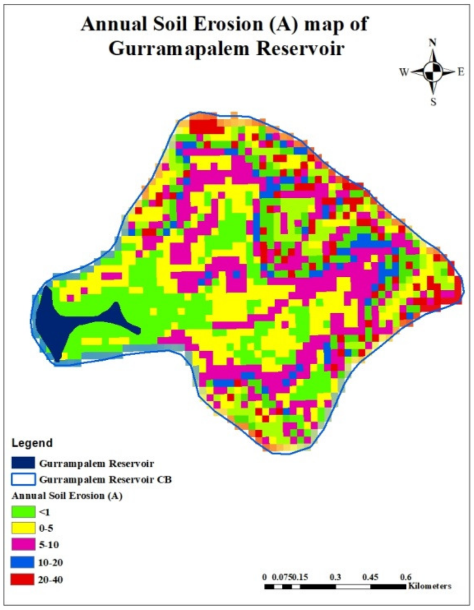
Class	Soil Loss Zones (t ha^{-1} yr^{-1})	Indicator
1	0 to 1	Very Low
2	1 to 5	Low
3	5 to 10	Moderate
4	10 to 20	Moderately severe
5	20-40	Severe
6	> 40	Extreme

Most of the catchment area of Gurrampalem reservoir (62.6 ha) has been dominated by very low-class soil erosion. Followed by moderate-class soil erosion (35.2 ha), low class soil erosion (26.5 ha), moderately severe class soil erosion (11.8 ha) and severe class soil erosion (7.6 ha), as illustrated in the Figure 7 and Table 9.

Table 9: Annual Soil Erosion Zones of Gurrampalem Reservoir

Class	Rate of erosion (t ha^{-1} yr^{-1})	Area (ha)	Area (%)	Average soil loss (t.ha^{-1} yr^{-1})	Total soil loss (t yr^{-1})
1	0 to 1	62.6	43.6	0.25	15.7
2	1 to 5	26.5	18.4	1.52	40.3
3	5 to 10	35.2	24.5	6.12	215.4
4	10 to 20	11.8	8.2	11.25	132.8
5	20-40	7.6	5.3	22.56	171.5

Figure 7: Annual Soil Loss (A) Map of Konam Reservoir



5. Conclusion:-

Prioritization of various micro-watersheds on the basis of morphometric analysis and soil erosion risk maps is necessary to plan soil and water conservation measures at watershed scale in order to conserve the natural resources. Remote sensing and GIS techniques have been effectively used in recent times as tools to carry out the morphometric analysis. The incorporation of empirical hydrological models like RUSLE with remote sensing and GIS techniques has increased the applicability of these models to identify the erosion prone area in the watersheds and to evaluate the best management practices to reduce the soil erosion from the prioritized areas.

The average annual soil loss from the Gurrampalem reservoir's catchment area is 4.05 t ha^{-1} yr^{-1}. Very low-class soil erosion accounts for the largest portion, covering an annual loss of 43.6%. Moderate class, Low class, moderately severe class and severe class, accounted for 24.5%, 18.4%, 8.2%, and 5.3%, respectively.

6. Data availability Statement:-

The authors confirm the data supporting the findings of this study are available with the article and its Supplementary material. Raw data that support the findings of the study are available from the corresponding author, upon reasonable request.

7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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