Impact Factor (QJIF): 8.47 E-ISSN: 2583-1615, P-ISSN: 3049-3498

International Journal of Research in Academic World

Received: 13/March/2026 **IJRAW:** 2026; 5(5):195-207 **Accepted:** 24/April/2026

Assessment of Morphology and Soil Erosion Risk in Arain Macro - Watershed of Ajmer District (Raj.) Using RUSLE and Morphometric Parameters

[*1]Dr. Shilpi Yadav, [2]Narendra Kumar and [3]Sabir Khan

[*1]Assistant Professor, Department of Geography, Sophia College (Autonomous), Ajmer, Rajasthan, India.

[2]Lecturer, Department of Physics, Tak Shiksha Niketan T.T. College, Ajmer, Rajasthan, India.

[3]GIS Expert, Department of Forest, Working Plan Office, Betul, Madhya Pradesh, India.

Abstract

The identification of priority areas for the establishment of control measures is one of the first objectives of conservation plans. The Watershed area of Arain Watershed is 1189 sq kms and located between 25055” N to 26030’ N latitude and 74050’’ E to 75015’ E longitudes. In this study, prioritization of sub-watersheds of the Arain Sub - Watershed has been done based on soil erosion risk. A methodology, based on Revised Universal Soil Loss Equation (RUSLE), has been applied using remotely sensed data, together with other ancillary data in a GIS environment. Based on the RUSLE model, the potential average annual soil loss of each parcel of land in the watershed’s ranges from 0 to 8437.21 t/ha/year. The result showed that moderate soil loss is observed in Six macro - watershed and rest of the macro watersheds fell under low soil erosion classes. About 15 – 20% of the macro- watershed fall in below the annual average soil loss of the entire watershed. On the other hand, Ground Truth has been also done for verifying this study and satisfactory results are achieved related to this study. Whereas, the quantitative analysis of morphometric parameters is found to be of immense utility in Sub-watershed prioritization for soil and water conservation and natural resources management at micro level. The present work is an attempt to carry out a detailed study of linear and shape morphometric parameters in 19 Macro Watershed of Arain Watershed and their prioritization for soil and water resource management. Topographic maps of 1972 on 1:50000 scale was utilized to delineate the drainage system, thus to identify precisely water divides using Geographic Information System (GIS). Following Strahler’s stream ordering scheme, it has been found that in Arain Watershed the total number of streams is 1711 belonging to different stream orders with the highest order of 7. The study has shown that the Arain Watershed is in conformity with the Horton’s law of stream numbers and stream lengths. The prioritization was carried out by assigning ranks to the individual indicators and a compound value (Cp) was calculated. Watersheds with highest Cp were of low priority while those with lowest Cp were of high priority. Thus, an index of high, medium and low priority was produced. The highest priority zone consists of 9 macro watersheds, medium of 8 and low of 02 Sub-Watershed. High priority indicates that these macro-watersheds are susceptible to greater degree of erosion and application of soil conservation measures becomes inevitable to preserve the land from further erosion and to alleviate natural hazards.

Keywords: Soil Erosion, Arain Sub - Watershed, RUSLE, Morphometric Analysis, Prioritization, Remote Sensing and GIS.

Introduction

Land degradation, a decline in land quality, is a serious threat to the prosperity of rural population in the world (Eswaran, *et al.*, 2001). It has negative effects on the standard of living of the inhabitants, especially in developing countries like Ethiopia, where agriculture is considered as the main source of peoples’ income and food (Hurni, 1993).

Soil erosion by water occurs throughout the world, especially more in the humid/sub-humid mountainous region. It is the process of detachment or entrainment, transportation of surface soil particles from original location and accumulation of it to new depositional area. Various human activities disturb the land surface of the earth, and thereby induce the significant alteration of natural erosion rates. Soil erosion by running water has been recognized as the most severe hazard threatening the protection of soil as it reduces soil productivity by removing the most fertile topsoil.

Estimation of sediment deposition in a reservoir using conventional techniques like hydrographic survey is a cumbersome procedure. It involves huge time, manpower and even it is not cost effective. The technology of Remote Sensing and Geographical Information Systems (GIS) is gaining importance as a powerful tool in the management of information in agriculture, natural resources assessment, environmental protection, and conservation (Javed *et al.* 2009; Mani and Chakravorty 2007). There is considerable potential for the use of GIS technology as an aid to soil erosion inventory with reference to soil erosion modeling and

***Corresponding Author:** Dr. Shilpi Yadav

erosion hazard assessment.

For assessing soil erosion from the watershed, several empirical models based on the geomorphological parameters were developed in the past to quantify the sediment yield (Pandey *et al.* 2006; Misra *et al.* 1984). Several other methods such as Sediment Yield Index method proposed by Bali and Karale (1977) and Universal Soil Loss Equation (USLE) given by Wischmeier and Smith (1978) are extensively used for prioritization of the watersheds. The USLE has been widely applied at a watershed scale based on lumped approach (Griffin *et al.* 1988; Dickinson and Collins 1998) to catchment scale (Jain *et al.* 2001; Jain and Kothari 2000) used USLE and RUSLE to predict the magnitude and spatial distribution of erosion within a GIS (Geographical Information System) environment using ILWIS and Arc GIS software.

The present study is an attempt at comprehensive investigation of environmental aspects of the watershed management in real-time perspective using remote sensing and GIS techniques. The main objective of this study is prioritization of Sub-watersheds based on soil erosion risk. The analysis used the climatological (rainfall erosivity), pedological (soil erodibility), topographic (slope length and steepness), anthropogenic (cover management and supporting conservation practices) approaches which are further supported by land cover data. This study has provided a package of scientific knowledge that can be used effectively to transfer technology from the researcher to the user.

Materials and Method

To meet the objectives for the study area, data from the both primary and secondary sources have been used. They include the following:

i). Landsat 8 images, band 3, 4, 5; Resolution - 30 meter a Kharif – 18 October 2023
ii). ASTER DEM, Resolution – 30 meters.
iii). Survey of India Toposheet on the scale of 1:50,000 (No.45j/6,/7,/8,/9,/10,/11,/12,/15,/16)
iv). Rainfall data of 12 years (2011-2023).
v). Primary data has land cover/land use, drainage, and slope.
vi). Secondary data, which are, Geomorphology, Lithology and Soil.

The data so obtained were digitized and converted into digital format in ArcGIS 10.5 for the spatial analysis. RUSLE Model was applied on the selected criteria. All the layers were then converted into raster format and spatial analyst tool was applied for finding out the suitable location for the Conservation of the Soil Erosion in the Pisangan Watershed.

Description of the Study Area

The Watershed area of Arain Watershed is 1189 sq kms and located between $25^{0}55''$ N to $26^{0}30'$ N latitude and $74^{0}50''$ E to $75^{0}15'$ E longitudes. The climate of the study area is semi-arid and very hot in sum1mer and extremely cold in winter. The monsoon is of very short duration. The Aravali Mountain range (one of the oldest in the world) in western India runs approximately 482 km from northeast to southwest across the State of Rajasthan. The study area has an average elevation of 312 mtr. Arain Watershed is the part of Ajmer District and covers Ajmer City. Ajmer district is spread over an area of 8,481 sq. kms and it is bounded by Nagaur district to the north, Jaipur and Tonk to the east and Bhilwara district to the south and Pali district to the east. The Population of Ajmer District 2011 census is approximately 2, 58,491. The watershed is well connected by National Highway No-8 and State highways making all the important places of the district easily accessible.

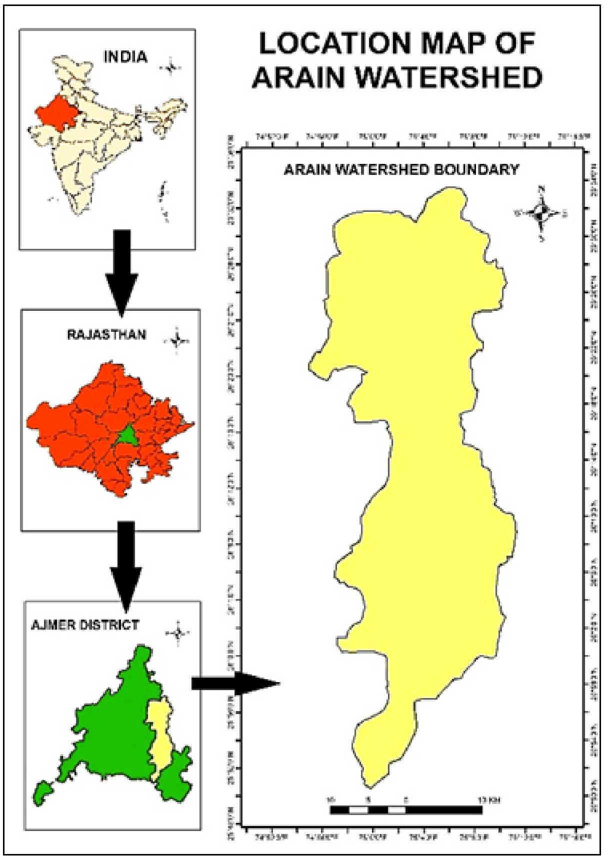

Fig 1: Study Area Map

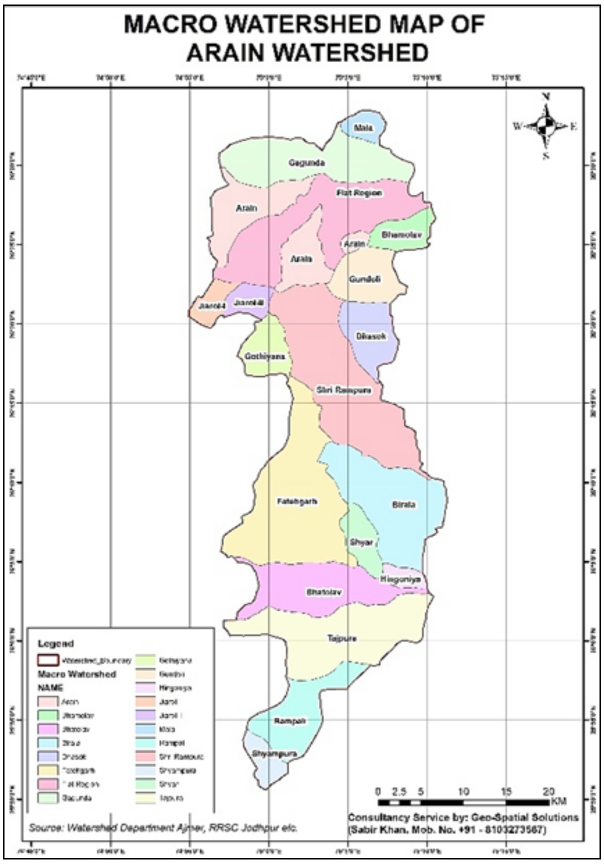

Fig 2: Macro Watershed Map of Arain Watershed

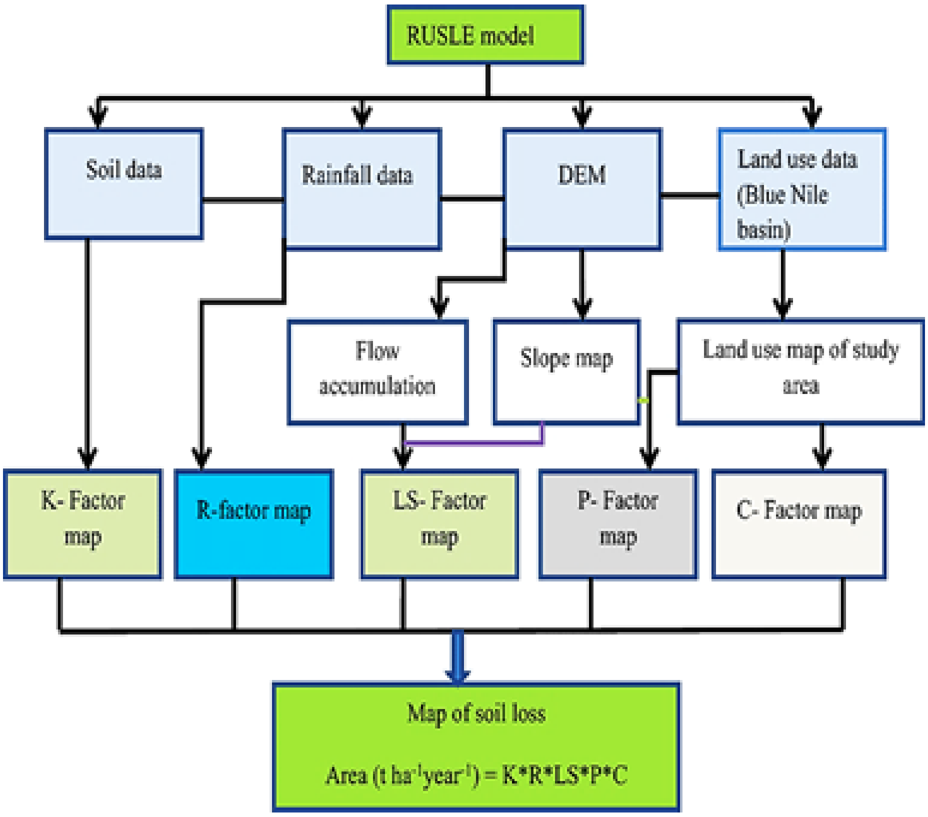

Fig 3: Conceptual Methodology

Preparation of thematic maps was a necessity for the study region, where digitization was used with the help of "ArcGIS" software and ERDAS is used for image processing. Interpolation of rainfall is done using ArcGIS spatial analyst tool. Referring to previous studies, different criteria were chosen for estimation of soil erosion.

Drainage

Drainage network helps in delineation of watersheds and for suggesting various soil conservation measures. Drainage pattern is defined as the plan, which the individual stream courses collectively form. It refers to both spatial relations of individual streams and the overall pattern made by the individual drainage lines. The drainage pattern of Arain Sub - Watershed is formed by various tributaries and sub-tributaries of Banas River.

The Dendritic drainage pattern of Arain Watershed can be observed due many contributing streams. They develop where the channel follows the slope of the terrain. After drainage identification, orders are assigned to each tributary and sub-tributary respectively.

Table 1: Stream Order of Arain Watershed

Stream Order	Number of Streams	Length(kms)
1	878	859.63
2	429	412.63
3	217	204.45
4	101	72.78
5	27	23.27
6	40	28.58
7	19	16.14
Total	1711	1617.48

Stream Order of Arain Watershed

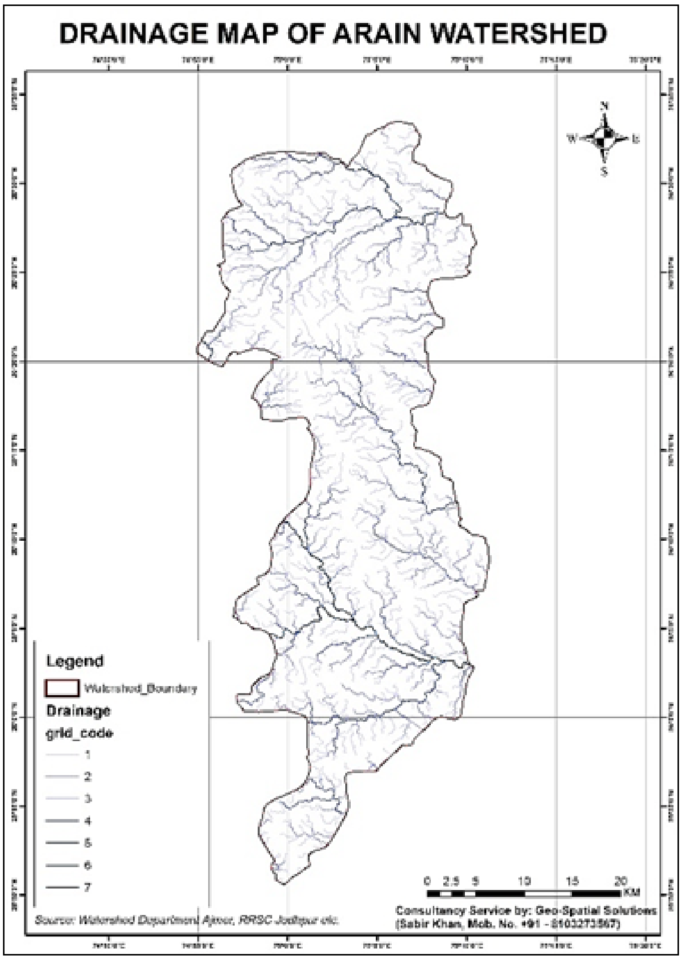

Fig 4: Drainage and Waterbody Map

DEM and Slope

Digital Elevation Model is derived from ASTER Data. The Digital Elevation Model of Arain Sub - Watershed shows the areas elevation (height) at a class of 352-428 m, 428-475 m, 475-545m, 545-657m and 657-888 respectively.

Watershed average slope offers information about the watershed topography. It is considered an independent variable. The average slope of a watershed influences radically the value of the time of concentration and, directly, the runoff generated by a rainfall.

Slope Map, is created with the help of Digital Elevation Model using ArcGIS -10.5 software. DEM is the basic input for generation of Slope map.

Soil

One of the most important features of soil, from the standpoint of its water holding capacity is variation in porosity with depth. Porosity is a measure of the open space within some soil or rock and it is function of the sizes of particles and the way they are arranged. Texture indicates the relative content of particles of various sizes, such as sand, silt and clay in the soil. Soil texture is an important soil characteristic to estimating Soil Erosion and Conservation. The study area has been having different types of soil texture as loamy, sandy loamy, loamy sand, clay loam, sand and rock outcrops.

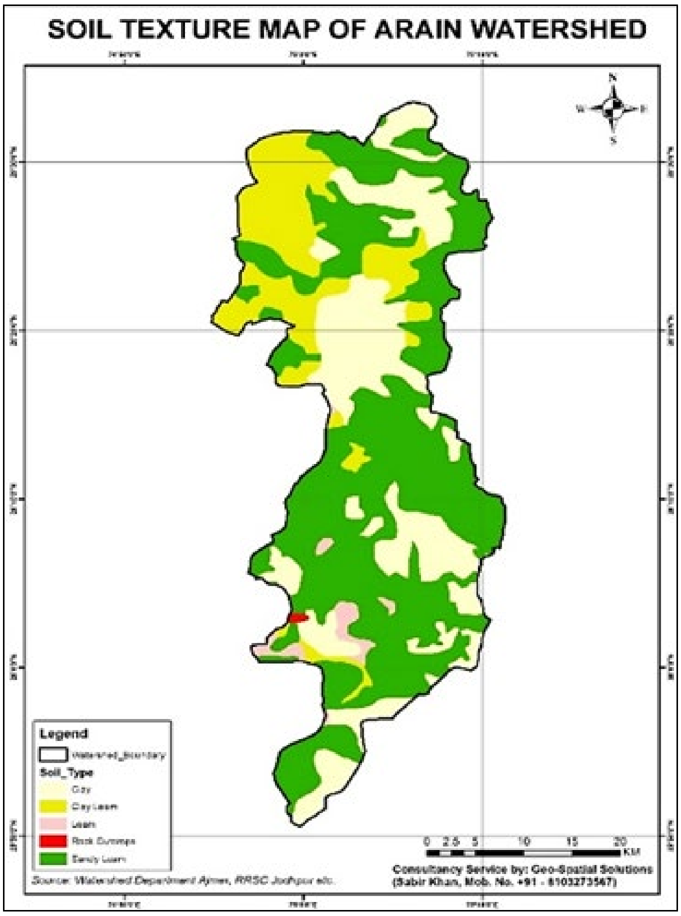

Fig 5: Soil Texture Map of Arain Watershed

Revised Soil Erosion Model — RUSLE

The Universal Soil Loss Equation was used to determine the average annual soil loss and its spatial distribution on the watershed. The RUSLE predicts soil loss for a given site as a product of six major erosion factors Eq. 1, whose values at a particular location can be expressed numerically. The limitation of this model is that it does not estimate deposition, sediment yield, channel erosion, or gulley erosion. Thus, the RUSLE is suitable for predicting long-term averages, and the soil erosion is estimated as follows:

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

Where:

A = Estimated Average annual soil loss (tons per acre per year),
R = Rain Erosivity Factor,
K = Soil Erodibility Factor,
LS= Topographic Factor,
C= Land Cover and Management Factor,
P= Conservation and Support Practice Factor.

Development of Model Database for RUSLE

The step wise methodology to apply USLE model for soil erosion assessment is listed as below: -

- For the estimation of soil erosion, the rainfall data of 12 years (2012-2023) were procured from the Indian Meteorological Department (I.M.D) from which the rainfall runoff erosivity factor (R-factor) was estimated.
- The soil map was procured from the National Bureau of Soil Survey & Land Use Planning, and it was digitized and converted to digital format on 1:50,000 scale. The soil erodibility factor (K-factor) map was then digitized and prepared in ArcGIS using the soil map procured from NBSS&LUP and the values of K-factor were assigned to the different soil types in the region according to the U.S. customary units.
- The Aster DEM with 30m spatial resolution was used to prepare the slope map and the flow accumulation map of the study area, which were then used for preparing the LS factor map in ArcGIS. The errors in the DEM represented as sinks were rectified using the fill tool in the GIS software. The corrected DEM was utilized to deduce the flow direction to prepare the flow accumulation map. The LS factor map was then prepared using the slope and flow accumulation map in raster calculator in ArcGIS. The drainage of the study area was delineated from the Survey of India topographical map in 1:50,000 scale.
- The land use/landcover (LU/LC) map was prepared from the Landsat 8 satellite data with the help of supervised classification in which provided accurate mapping of different LU/LC categories due to its high spatial resolution, and therefore helped in mapping up to the first level of LU/LC classification given by NRSC. LU/LC map was used for preparing the land cover and management factor (C-factor) map. The values of C-factor were assigned to the different land use/landcover classes in the study area keeping reference of the earlier studies.
- The P-factor map was also prepared using the land use/landcover map of the watershed and the values of P-factor were assigned to the different features based on the soil conservation practices taken up in the study area referring to previous studies
- All the five parameter maps (having the same coordinate system) were converted to grid with 30m x 30m cell size (to maintain uniform cell size at par with spatial resolution of ASTER DEM). The layers were then overlaid and multiplied pixel by pixel, using Equation 1, to estimate the soil erosion and the spatial distribution of different soil erosion zones in the Arain watershed.
- Raster Calculator was used to build the expression: R * [K] * [C] * [P] * [LS] which, when applied to all cells in a raster coverage of the watershed, produced a map of

average annual soil erosion.

Results and Discussion

R-Factor (Rainfall Erosivity Factor)

Soil erosion occurs when raindrops act upon the soil particles. Potential ability of rain to cause erosion is known as erosivity (R – factor) which is a function of the physical characteristics of rainfall. It is defined as the product of kinetic energy and the maximum 30-minute intensity and shows the erosivity of rainfall events (Wischmeier and Smith, 1978).

Due to rainfall characteristics and absence of automatic hourly rain intensity records in many rainfall stations in Arain, it is difficult to apply erosivity equation proposed by Renard *et al.*, (1997) for Arain, condition. Therefore, the erosivity factor R was calculated according the equation given by Hurni (1985), derived from a spatial regression analysis for Arain, conditions based on the easily available mean annual rainfall (P). The R-factor is given by a regression equation as:

$$R = -8.12 + 0.562P$$

Where, P is the Mean Annual Rainfall in mm.

To determine the value of the R-factor is vary from 93.422 to 1401.48 in this study, the average of annual historic rainfall event (12-years) was collected from 24 meteorological stations located within and near the study area. Using spatial analyst extension in ArcGIS 10.5, IDW interpolation was done to generate an estimated surface from these scattered set of point data.

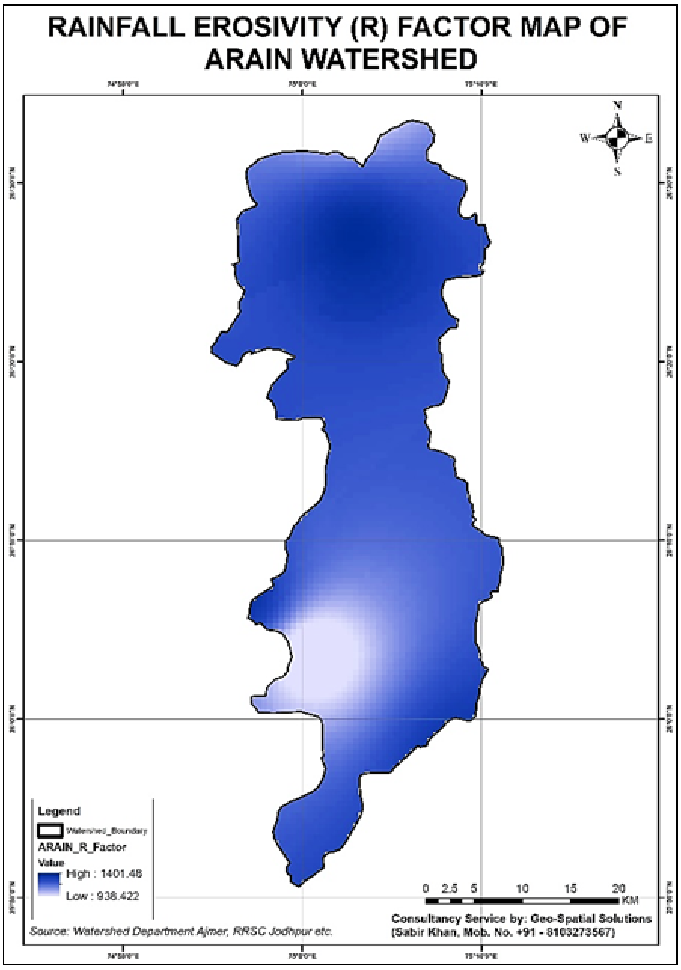

Fig 6: Rainfall Erosivity (R) Factor Map

K-Factor (Soil Erodibility Factor)

This factor quantifies the cohesive character of a soil type and its resistance to dislodging and transport due to raindrop impact and overland flow shear forces. The K-factor is empirically determined for a particular soil type and reflects the physical and chemical properties of the soil, which contribute to its erodibility potential. The K value of soils in the study area was however determined from the previous studies and was found in the range 0 to 0.76. The watershed under study has 6 types of soil viz., Sand, Clay Loam, Loam, Sandy Loam, Loamy sand, Rock Outcrops. The values were assigned to the K factor for these soil types are shown in Table given below:

Table 2: K Factor Values of Soil Texture based on Organic matter contain in %

Soil Texture	K Factor value
Sand	0.07
Clay	0.22
Clay Loam	0.3
Loam	0.19
Sandy Loam	0.13
Loamy sand	0.04
Rock Outcrops	0

K Factor Values of Soil Texture based on Organic matter contain in % (Source: W. H. Wischmeier and D. D. Smith, 1978)

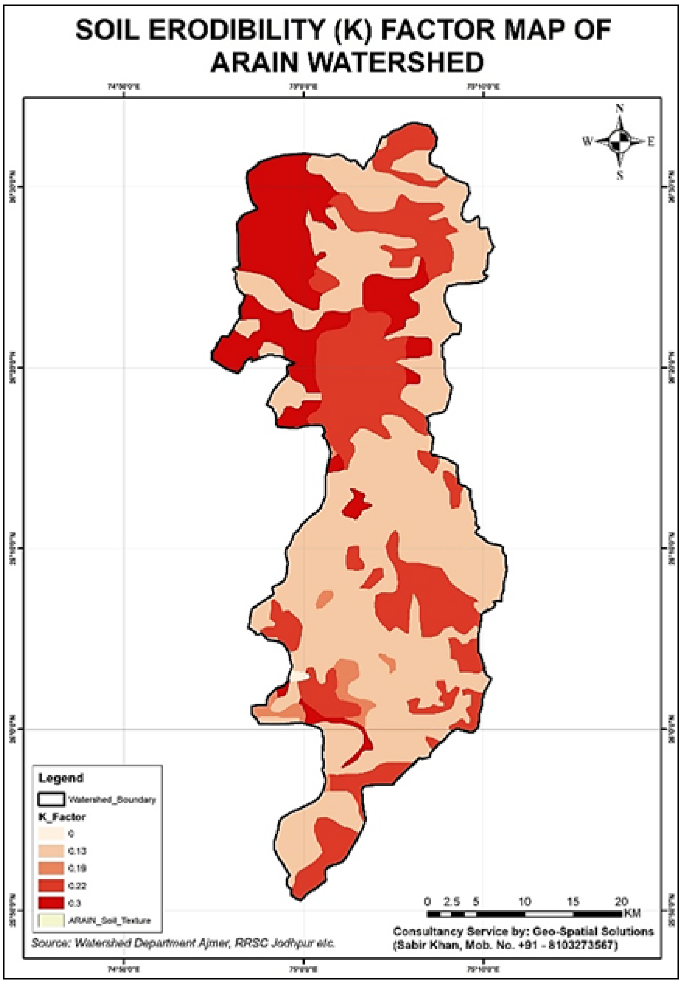

Fig 7: Soil Erodibility (K) Factor Map

LS Factor (Slope Length/Topographic Factor)

The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by (Wischmeier and Smith 1978).

$$LS = (X/22.1)\ m(0.065 + 0.045\ S + 0.0065\ S2) \quad (1)$$

Where

X = slope length (m) and S = slope gradient (%)

Slope percentage layer was derived from digital elevation model (DEM) of the study area and slope length was assumed to be fixed as 30 m for each pixel. The values of X and S were derived from DEM. To calculate the X value, Flow Accumulation was derived from the DEM after conducting FILL and Flow Direction processes in Arc Hydro tool.

$$X = (\text{Flow accumulation} * \text{Cell value}) \quad (2)$$

By substituting X value, LS equation will be:

$$\mathbf{LS = (Flow\ accumulation * Cell\ value/22.1)\ m(0.065 + 0.045\ S + 0.0065\ S2)} \quad (7)$$

Moreover slope (%) also directly derived from the DEM using ArcGIS.

LS value varies from 0 to 5.413. which shows soil erosion occurs in waste Land area.

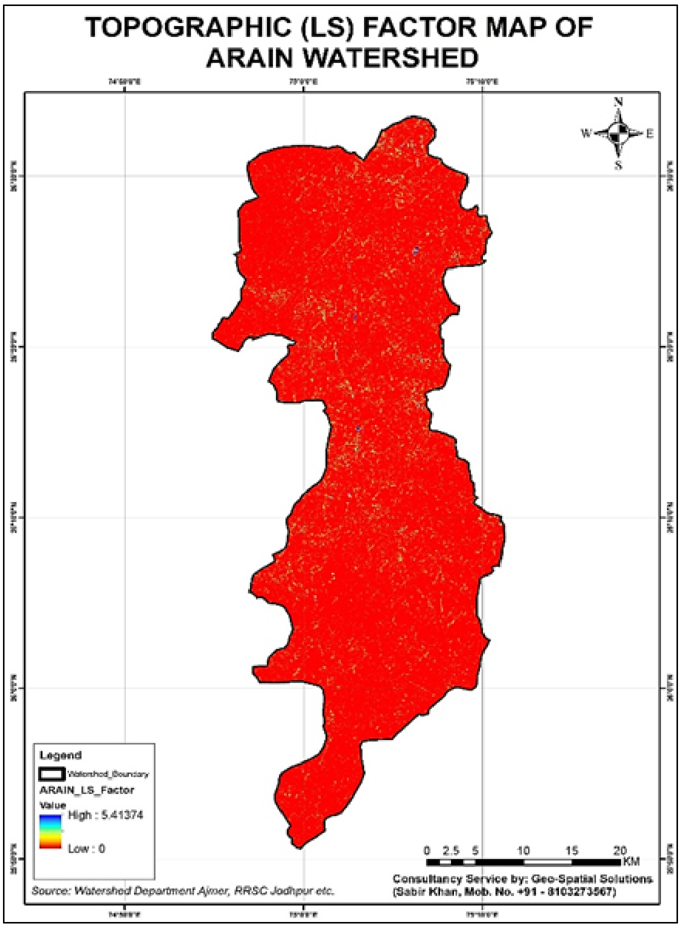

Fig 8: Topographic (LS) Factor Map

C- Factor (Land Cover and Management Factor)

The land cover and management factor represent the effects of vegetation, management and erosion control practices on soil loss, the value of which ranges from 0 in water bodies to slightly greater than 0.63 in barren land where there is no vegetation, root biomass, or other surface cover to resist erosive forces. Thus, the plant cover factor C, expresses the relation between erosion on bare soil and erosion under cultivation and is based on plant cover, production level and cropping techniques. The C-factor value and the spatial distribution of crop management factor are shown in Table 2 and Fig. 4 respectively.

Table 3: Crop Management Factor for Different Land Use/Land Cover Classes (Source: USDA (1972), Rao (1981)).

S. No.	Land Use Class	C – Factor
1.	Settlement	0.09
2.	Cultivated Land	0.63
3.	Fallow land	0.5
4.	Waste Land	0.5
5.	Forest	0.003
6.	Water body	0

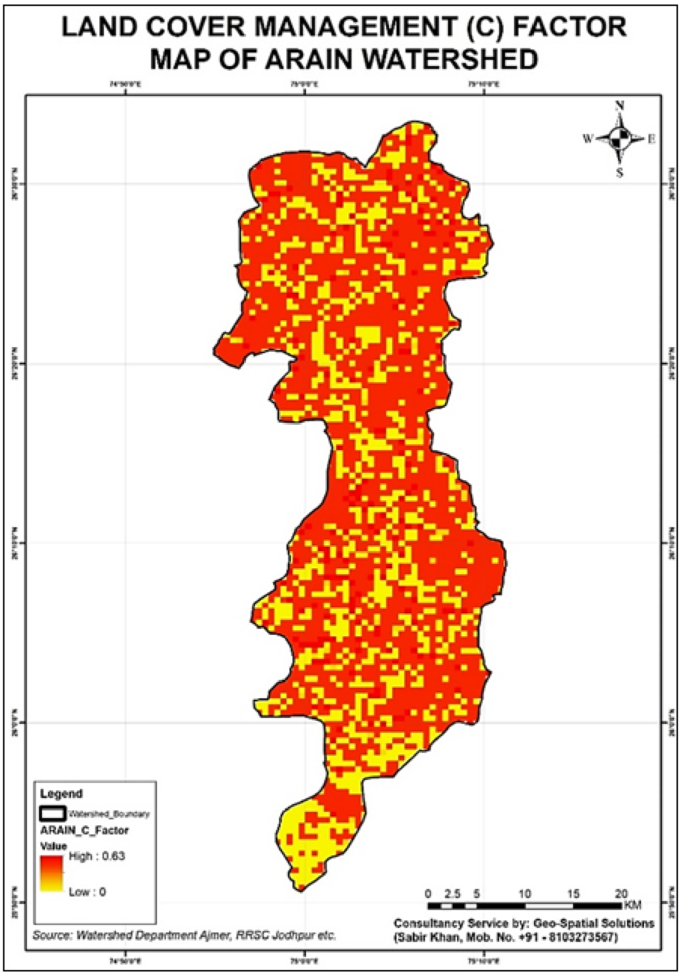

Fig 9: Land Cover and Management (C) Factor Map

P-Factor (Erosion Control Practice Factor)

Erosion control practice factor (P-factor) is the ratio of soil loss with a specific support practice to the corresponding loss with up slope and down slope cultivation. The P-factor map generated is used for understanding the conservation practices being taken up in the study area. The erosion control practice factor accounts for the control practices that reduce the erosion potential due to runoff by their influence on drainage patterns, runoff concentration, runoff velocity, and hydraulic forces exerted by runoff on soil. The supporting mechanical practices include the effects of contouring, strip cropping, or terracing. In the present study, however, no major conservation practices are followed except bunded agricultural lands which are limited to paddy growing areas only. The values 0.28 and 1 as used in earlier studies were assigned to bunded fields and non-paddy fields respectively to the P-factor map which was prepared with the help of the land use landcover map of the study area. The P-factor value and the spatial distribution of P – factor.

Table 4: Erosion Control Practice Factor (P) For Different Land Use/Land Cover Classes (Source: USDA (1972), Rao (1981)).

S. No.	Land Use Class	P – Factor
1.	Settlement	1
2.	Cultivated Land	0.5
3.	Fallow land	0.9
4.	Waste Land	1
5.	Forest	0.8
6.	Water body	1

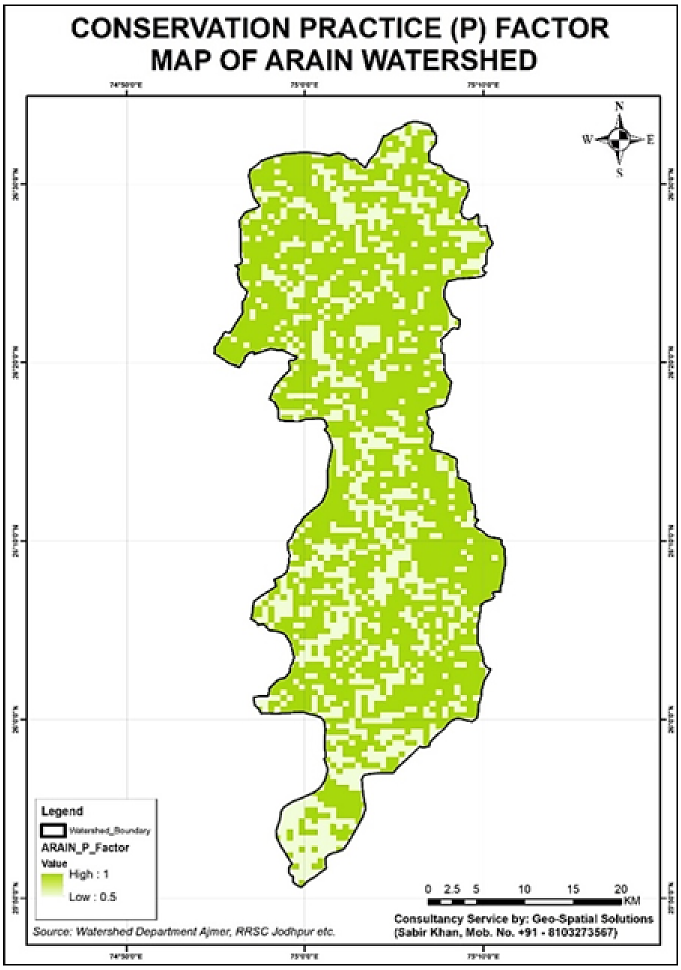

Fig 10: Conservation Practice (P) Factor Map

Average Annual Soil Loss Using RUSLE

Annual soil loss based on 11-year average rainfall erosivity factor is termed as average annual soil loss. The annual soil loss for sub-watersheds was calculated by annual average R (based on annual average rainfall data of 2012-2023) and K, LS, C and P factors. The soil erosion rate (t/ha/yr) was estimated as total soil loss of sub-watershed 1(t/yr) divided by total geographical area of Sub-Watershed (ha) in the number sub- watershed. The classification of erosion rate has been given 3 categories of soil loss. All the layers viz. R, K, LS, C and P were generated in GIS and were overlayed to obtained the product, which gives annual soil loss (A) for the Arain Sub - Watershed. These values gave annual soil loss per hectare per year at pixel level. These values are converted to the loss per pixel in m2 (i.e. 30×30 m) and all values are added in GIS domain to obtain total annual soil loss per hectare for the Arain Sub - Watershed. A surface of annual soil loss was overlayed with the sub-watershed map of Arain Sub - Watershed which contains 19 sub-watersheds to get sub-watershed wise soil loss. All values for each sub-watershed were summed using 'summarized zone' option in ArcView GIS 10.5 to obtain soil loss in each sub-watershed. The total loss thus obtained per sub-watershed is then converted to the soil loss/ha/year for whole study area. sub-watersheds are then classified in different soil loss classes.

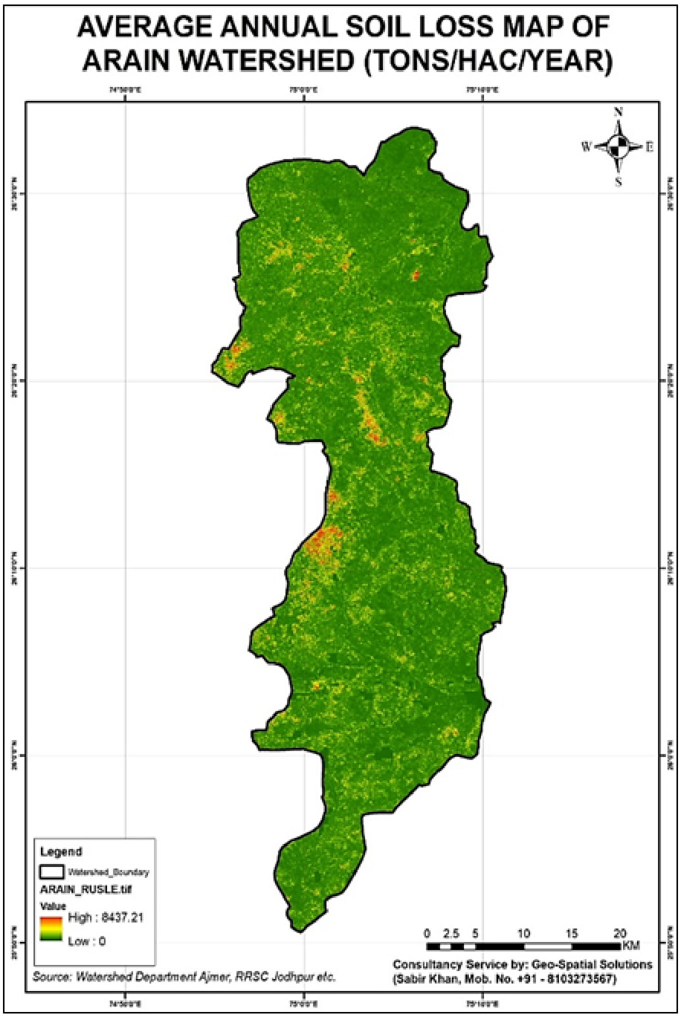

Fig 11: Average Annual Soil Loss Map (A) Factor Map

Prioritization

Watershed management has assumed importance in India in view of the reported loss of storage capacity of several major reservoirs due to increasing siltation. In addition, there is a need to preserve the soil-water-vegetation ecosystem in river valleys in harmony with resource exploitation and development programmes. The large financial and manpower commitments involved in treating watersheds require a selective approach. Identification of smaller hydrological units is needed for more efficient and better targeted resource management programmes. This has created renewed interest in erosion surveys and sediment yield prediction studies to identify problem area with relatively high sediment yield potential to take up conservation measures on priority basis.

Priority fixation has been done based on average annual soil loss of Arain Sub - Watershed. Highest priority for soil conservation treatments is given to sub-watershed having highest soil loss and accordingly priority has been assigned up to sub-watershed having lowest soil loss. Priority map of Arain Sub - watershed. All India Soil and Land Use Survey (AISLUS) and National Bureau of Soil Survey and Land Use Planning (NBSS-LUP) have suggested priority class for every individual macro-watershed of Arain Watershed which is based on observed sediment yield data. According to AISLUS, sub-watersheds are classified into five priority classes such as low, very low, medium, high, and very high based on sediment yield value. For validation purpose, AISLUS priority map was reclassified into three classes wherein the AISLUS suggested high and very high classes are merged in high, medium is kept as it is and low and very low classes are merged in low class. The priority map developed using RUSLE in this study was validated using AISLUS suggested priority map. It is found that, out of 19 sub-watersheds of Arain, 12 macro-watersheds agree with AISLUS and NBBS-LUP suggested priority, 5 macro-watersheds under predict and 2 macro - watersheds over predict the priority suggested by AISLUS. This shows that there is 73% agreement between RUSLE calculated priorities. AISLUS and NBSS-LUP suggested priority for sub-watersheds of Arain Sub - Watershed.

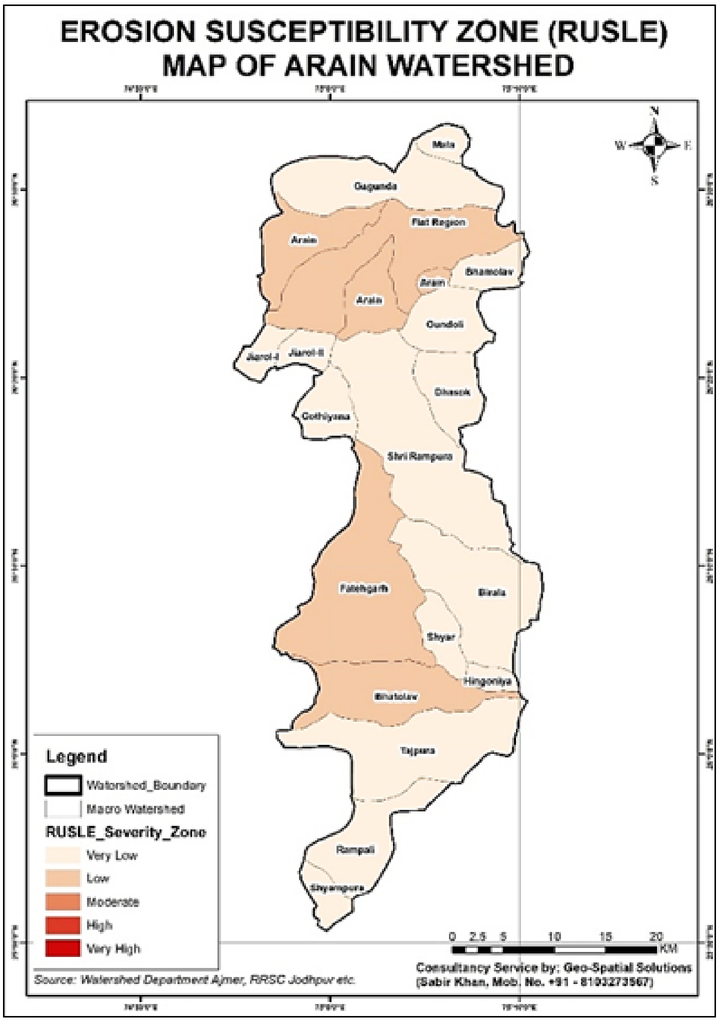

Fig 12: Severity Map of Soil Erosion Using RUSLE Model

The Study was carried out on watershed level utilizing SOI toposheets, (1972). All the streams were digitized from Survey of India Toposheets, 1961 on 1:50,000 scale. The study was carried out in GIS environment utilizing ArcGis 10.5 for digitization and Erdas Imagine 9.2 Software. Strahler's system of stream analysis is probably the simplest, most used system and same has been adopted for this study.

Table 5: Sources of Data Required

S. No.	Type of Data	Sources of Data	Utility
1	Remote sensing data	Landsat 8 and Aster Dem (Advanced Space borne Thermal Emission and Reflection Radiometer) Satellite Images	Thematic mapping, vegetative cover factor for sediment yield estimation Erosion -intensity zoning, slope map, Digital elevation map of the study area.
2	Topographical data	Survey of India Toposheet on the scale of 1:50,000 (No., 45i/6,/7,/10,/11,/15,/16)	Base map, contour map, drainage map.
3.	Socio Economic Data	Ground Truth Survey	For Soil and Water resource Conservation
4.	Secondary Data	Soil and Watershed Department of Ajmer.	Watershed Map

Table 6: Morphometric Parameters

S No.	Morphometric Parameters	Formulas	Reference
1	Stream Order	Hierarchical rank	Strahler (1964)
2	Stream Length (Lu)	Length of the Stream	Horton (1945)
3	Mean Stream Length (Lsm)	Lsm=Lu/Nu Where, Lu=Total stream length of order 'u' Nu=Total number of stream segments of order 'u'	Strahler (1964)
4	Stream Length Ratio (RL)	RL=Lu/lu-1 Where, Lu= Total stream length of order 'u' Lu-1= Total stream length of its next lower order	Horton (1945)
5	Bifurcation Ratio (Rb)	Rb=Nu/Nu+1 Where, Nu=Total number of stream segments of order 'u' Nu+1= Total stream length of its next higher order	Schumn (1956)
6	Mean Bifurcation Ratio (Rbm)	Rbm=Average of bifurcation ratios of all orders	Strahler (1957)
7	Drainage Density (D)	D=Lu/A Where, Lu= Total stream length of all orders A=Area of the basin(km2)	Schumn (1956)
8	Basin Length (Lb)	Lb=1.312*A0.568 Where, Lb=Length of the basin(km) A=Area of the basin(km2)	Horton (1932)
9	Stream Frequency (Fs)	Fs=Nu/A Where, Nu=Total number of stream segments of all orders A=Area of the basin(km2)	Horton (1932)
10	Texture Ratio (Rt)	Rt=Nu/P Where, Nu=Total number of stream segments of all orders P=Perimeter of the basin(km)	Horton (1932)
11	Form Factor (Rf)	Rf=A/Lb2) Where, A=Area of the basin(km2) Lb2 =Sq of basin length	Horton (1932)
12	Circularity Ratio (Rc)	Rc=4*Pi*A/P^2 Where, Pi='Pi' value i.e., 3.14 A=Area of the basin(km2) P2 = Sq of the perimeter(km)	Miller (1953)
13	Elongation Ratio (Re)	Re=(2/Lb)*(A/Pi)^0.5 Where, Lb=Basin length(km), A=Area of the basin(km2)	Schumn (1956)
14	Compactness Ratio (Cc)	Cc=0.2821*P/A^2 Where, P=Perimeter of the basin(km) A=Area of the basin(km2)	Horton (1945)

Watershed Characteristics

The arrangement of streams in a drainage system constitutes the drainage pattern, which in turn reflects mainly Geomorphology, structural/or lithologic controls of the underlying rocks. The drainage network shows dendritic to sub-dendritic pattern, Parallel & Sequent streams system.

- Drainage ordering represent the number of streams presents in each order defined i.e. 1, 2, 3, 4, 5, 6 and 7 stream orders.
- **Stream Order (Su):** For every watershed, stream ordering is the first and foremost analysis. The observation illustrates the maximum frequency is in the first order it has been also notified that, as the stream order increases there is decrease in stream frequency.
- **Stream Number (Nu):** The total number of streams carried out in an order is known as Stream order.
- **Stream Length (Lu):** The total stream length of various orders has been computed with the help of ArcGIS-10.5 software.

Table 7: Stream Order of Arain Watershed

S. No.	Stream Order	Number of Streams	Length(kms)
1	1	878	859.63
2	2	429	412.63
3	3	217	204.45
4	4	101	72.78
5	5	27	23.27
6	6	40	28.58
7	7	19	16.14
	Total	1711	1617.48

Generation of Thematic Maps

- To prepare thematic map first base map has been generated. A base map is a map shows only essential geographic references (such as rail, road, main drainage (double line) on which additional information is plotted; e.g., a topographic map on which geologic information is recorded. A map designed for the presentation and analysis of data; it usually includes only the coordinate, geographical and major political outlines. To prepare base map identify permanent features from georeferenced FCC images and rectify all features from SOI toposheet with scale of 1:50000. After rectification digitization of permanent features (metaled road, rail line, canal, political boundaries and forest boundary) has been done.
- To generate various theme maps of study area information has been extracted from Kharif season satellite images taken by LANDSAT 8 2023. These Satellite imageries had been georeferenced and merged using image processing software ERDAS IMAGINE 9.2. These remotely sensed data were geometrically rectified with respect to survey of India toposheets on 1:50,000 scale. These merged data were used in the present study. Image enhancement techniques were applied for better interpretation of the study area. In this way different layers like, drainage, soil, land use/landcover have been generated for corresponding theme maps. To compare and interpret all these theme maps overlay analysis has been done. The entire procedure of theme map generation from georeferenced data have been done in ArcGIS 10.3 environment. After completion of map generation field verification or ground truth survey has been done for area estimation. After that final theme maps have been

prepared of the present study.

- Drainage has been digitized as separate segments for every stream order.
- Delineation of watershed, and macro watershed have been done.
- Digital Elevation Model is derived from Aster Data from the USGS website. The Digital Elevation Model of Arain Watershed shows the areas elevation (height) at a class of
- Slope map is created with the help of Digital Elevation Model (Aster Data) using ArcGIS-10.5 software. DEM is the basic input for generation of slope map. Slope map is created in spatial analysis tool.
- A land use/land cover map has been prepared with the help of Remote Sensing Data i.e. LANDSAT 8 Satellite imagery, shows the comprehensive information on the spatial distribution of land use/land cover categories and the pattern of their change is a prerequisite for management and utilization of the land resources of the study area.

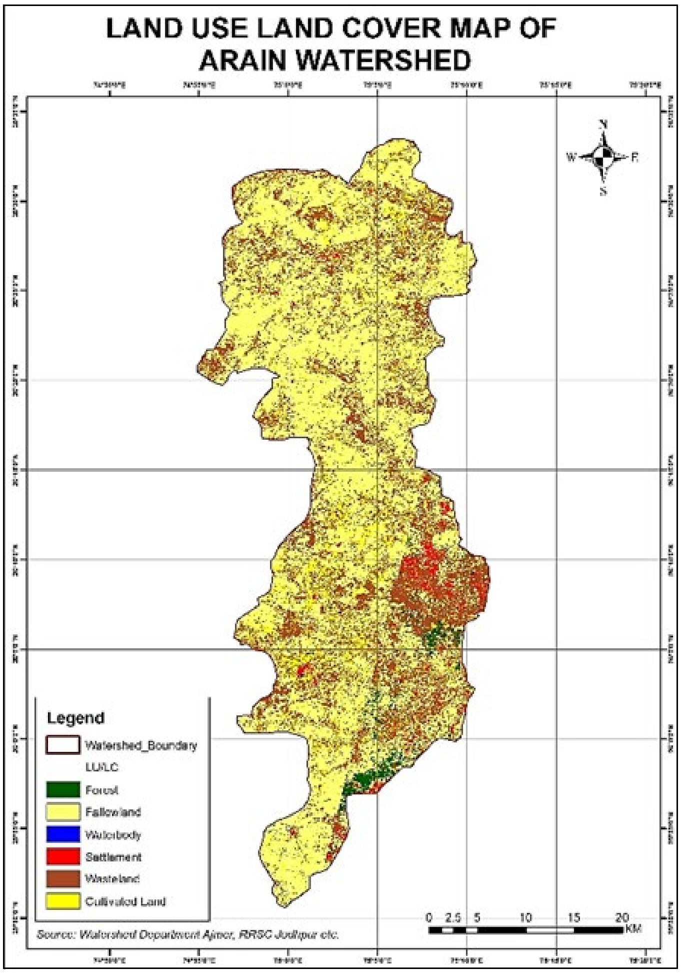

Fig 13: LULC Map of Arain Watershed

Results and Discussion

Stream Number and Order: The first and most important parameter in the drainage basin analysis is ordering, whereby the hierarchal position of the streams is designated. Following Strahler's scheme, it has been found that in Arain watershed the total number of streams is 1711, out of which 878 belong to 1st order, 429 are of 2nd order, 217 are of 3rd order, 101 are of 4th order, 27 of 5th, 40are of 6th order, and 19 is of 7th order. The Watershed wise number and order is given in the table 3 and depicted in fig. 3. It reveals that the highest number of streams is found in Fatehgarh (232), followed by Shri Rampura (209) and Tajpura (190), where as the smallest number of streams is found in Mala (17) followed by Jiarol-II (19) and Hingonia (25). It is also revealed that the first order streams are highest in number in all watersheds which decreases as the order increases and the highest order has the lowest no of streams. It is revealed that the drainage network of the Arain Watershed is characterized by total length of (1617.48 km). The watershed wise drainage length given in the table reveals that Fatehgarh constitutes the highest proportion of drainage length of (215.98 km), followed by Shri Rampura which is (205.37 km), while the lowest contributors are Mala contributing 13.07 km. Hingonia (15.29 km) and Jiarol-II (16.76 km).

Linear Parameters: The Linear Parameters include Drainage Density (Dd), Stream Frequency (Fs), Bifurcation Ratio (Rb), Drainage Texture (Rt), Length of overland flow (Lg).

Drainage Density: The drainage density in the Arain Watershed exhibits a wide range in its values from Mala 0.98 (lowest) in Nand to 1.70 (highest). The high value of drainage density (1.70) indicates that the region is composed of impermeable sub-surface materials, sparse vegetation and high mountainous relief.

Stream Frequency: In Arain Watershed the lowest stream frequency is in Bhamolav (1.10), followed by Gundoli (1.11) and Dhasok (1.14). The highest stream frequency is found in Hingonia (2.50). High stream frequency is indicative of high relief and low infiltration capacity of the bedrock pointing towards the increase in stream population with respect to increase in drainage density. The watersheds having large area under dense forest have low drainage frequency and the area having more agricultural land have high drainage frequency. High value of drainage frequency produces more runoff in comparison to others.

Mean Bifurcation Ratio: The mean bifurcation ratio of the Arain Watershed is 3.10. The lowest Rbm is found in Jiarol - I (1.72) whereas highest Rbm of 8.13 is in Arain. Low Rbm value indicates less structural disturbance and the drainage patterns have not been distorted whereas high Rbm value indicates high structural complexity and low permeability of terrain.

Drainage Texture: The lowest Drainage Texture of 1.14 is in Jiarol-II, while as the highest is in Fatehgarh (3.44). The Drainage Texture of the sub-watersheds in Arain Watershed ranges from very course to course.

Length of Overland Flow: The Length of overland flow of Pisangan Watershed is 1.57. It is highest in Mala (2.05), while as lowest is found in Jiarol - I (1.17). Higher value of Lg is indicative of low relief and whereas low value of Lg is an indicative of high relief.

Shape Parameters: The shape parameters include Form Factor (Rf), Shape Factor (Bs), Circulatory Ratio (Rc), Elongation Ratio (Re) and Compactness Coefficient (Cc).

Form Factor: Form Factor is highest in Hingonia (0.18), and lowest in Fatehgarh and Shri Rampura (0.01), indicating them to be elongated in shape and suggesting flatter peak flow for longer duration.

Shape Factor: Shape Factor is lowest in Hingonia (5.54), while as it is highest in Shri Rampura (85.99). Pisangan Watershed has a Shape Factor of 34.97. Hingonia has the lowest Circulatory Ratio of 4.68, and it is highest in Fatehgarh (14.38) indicating that all the watersheds represent an elongated shape. Hingonia has the highest Elongation Ratio of 0.48 and the lowest of 0.12 is found in Shri Rampura and Fatehgarh. Arain Watershed has an Elongation Ratio of 0.25 which indicates moderate relief and gentle ground slope.

Prioritization Analysis

The Watersheds have been broadly classified into three priority zones according to their compound value (Cp): -, High (5.30-7.30), Moderate (7.31 – 8.30), and Low (8.31-12.30).

The watershed wise prioritization ranks are given in this table and the final prioritized map of the study area.

Prioritization Analysis of Morphometric Parameter

High Priority: The watersheds which fall in high priority category are Bhatolav, Birala, Fatehgarh, Flat Region, Gagunda, Hingoniya, Rampali, Shri Rampura and Tajpura. These watersheds generally consist of steep slopes, high drainage density, high stream frequency, low form factor and low elongation ratio. These can be classified under very severe erosion susceptibility zone Thus need immediate attention to take up mechanical soil conservation measures gully control structures and grass waterways to protect the topsoil loss.

Moderate Priority: There are five watersheds falling in moderate priority. These include Bhamolav, Dhasok, Gothiyana, Gundoli, Jiarol-I, Jiarol-II, Shyampura and Shyar. These watersheds consist of moderate slopes, moderate values of drainage density, stream frequency, drainage texture and moderate to high form factor, circulatory ratio, and elongation ratio.

Low Priority: This category has been attained by Arain and Mala. These watersheds consist of lower slopes, very low drainage density, stream frequency, texture ratio, high form factor, circulatory ratio and elongation ratio. These watersheds can be categorized under very slight erosion susceptibility zone and may need agronomical measures to protect the sheet and rill erosion.

Table 8: Macro -watershed wise Erosion Susceptibility Zone of the Morphometric Analysis

S. No.	Macro - Watershed	Compound Value	Erosion Susceptibility Zone
1.	Arain	12.8	Low
2.	Bhamolav	8.8	Moderate
3.	Bhatolav	5.9	Severe
4.	Birala	6.8	Severe
5.	Dhasok	7.5	Moderate
6.	Fatehgarh	5.3	Severe
7.	Flat Region	7	Severe
8.	Gagunda	7.3	Severe
9.	Gothiyana	7.7	Moderate
10.	Gundoli	8.6	Moderate
11.	Hingoniya	5.8	Severe
12.	Jiarol-I	8.1	Moderate
13.	Jiarol-II	8.6	Moderate
14.	Mala	9.4	Low
15.	Rampali	6.6	Severe
16.	Shri Rampura	6.8	Severe
17.	Shyampura	8.3	Moderate
18.	Shyar	8.6	Moderate
19.	Tajpura	6.3	Severe

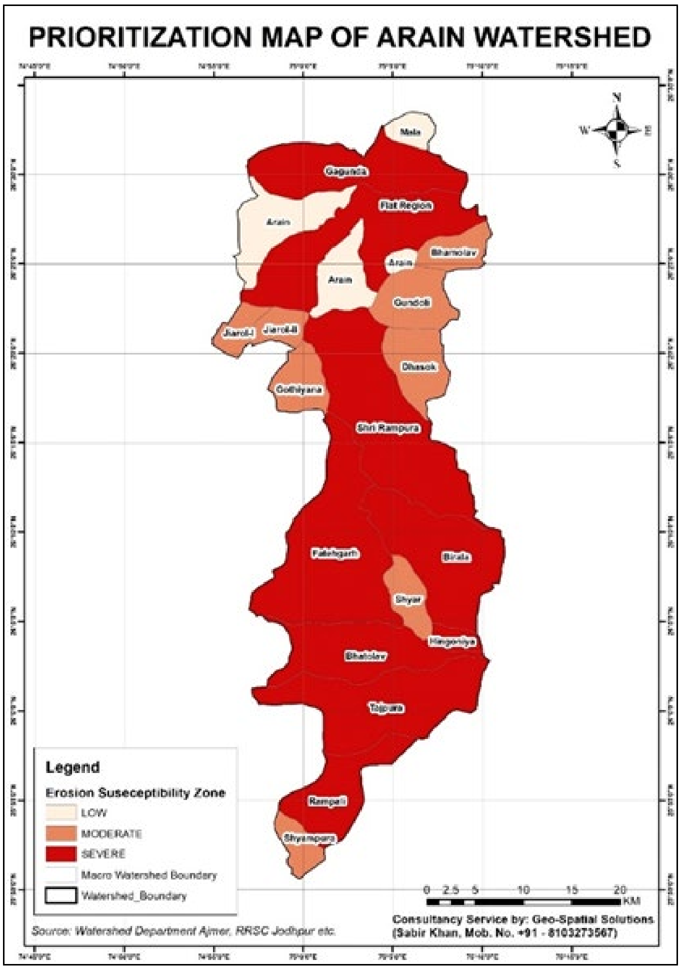

Fig 14: Prioritization map of Morphometric Analysis the study of Arian Watershed

Validation by Ground Truthing

The action or process of confirming or validating by direct observation on the ground.

The outcome of the combined soil loss assessment map was validated by ground truthing. Their location in the field was identified using a Global Positioning System. Maximum erosion are found in prioritized areas that shows results are matched. So various conservation measures to be taken in high priority zone (Hotspot) for sustainable development in the study area.

Fig 15: Ground Truth of the Higher Priority Zone of the Arain Sub - Watershed.

Conclusion

A quantitative assessment of average annual soil loss in sub-watersheds of Arain Sub -Watershed was made using the well-known RUSLE with a view to know the spatial distribution in the study watershed. The use of GIS and remote sensing data enabled the determination of the spatial distribution of the RUSLE parameters. The total amount of average annual potential soil loss in the Arain Sub- Watershed is about 68.8551 t/ha/year in 1201.86 sq/km. The result showed that very high soil loss (0 to 8437.21/ha/yr) is observed in the valley as well as in the ridges of the Arain watershed. The result showed that out of 19 macro watershed, moderate soil loss is observed in Six macro - watershed and rest of the macro watersheds fell under low soil erosion classes This may be due to the low average surface slope of less than 5% with plain topography. About 15-20% of the macro-watersheds fall in below the annual average soil loss of the entire watersheds.

Watershed prioritization is one of the most crucial parts of planning for the execution of its development and management programs, according to the morphometric approach. The current study shows how effective GIS is for morphometric analysis and Arain Watershed macro-watershed prioritizing. The morphometric features of various watersheds demonstrate their respective traits about the watershed's hydrologic response. According to the study, the Arain Watershed complies with Horton's legislation about the quantity and length of streams. Due to the region's impermeable subsurface materials, scant vegetation, and high mountainous relief, which increase surface runoff and degree of dissection, the drainage density value of 1.70 shows that the area is highly mountainous. The watersheds that fall into the high-priority category are Bhatolav, Birala, Fatehgarh, Flat Region, Gagunda, Hingoniya, Rampali, Shri Rampura, and Tajpura. These watersheds are mostly composed of steep slopes, high drainage density, high stream frequency, low form factor, and low elongation ratio. High priority indicates the greater degree of erosion in the watersheds and it becomes a potential candidate for applying soil conservation measures. As a result, immediate attention to soil conservation measures is required in these watersheds

Recommendation

We should be taken some measures and conservation steps likes Contour bunding, crop rotation, Waterways, Strip Cropping, Afforestation, Proper use of fertilizers and ploughing system, etc. to control soil erosion for development of the study area.

Acknowledgement

Authors are thankful to State Remote Sensing Application Centre (Jodhpur) in Collaboration with the Department of Watershed Development & Soil Conservation (Govt. Of Rajasthan, Jaipur), Indian Meteorological Department (IMD), National Bureau of Soil Survey and Land Use Planning (NBSS-LUP) from where I received all kinds of resource support.

References

1. Agarwal CS. Study of drainage pattern through aerial data in Nahagarh area of Varansi district, U.P. *J. Indian Soc. remote sensing*. 1998;26(4):169-175.
2. Biswas S, Sudhakar S, Desai VR. Prioritisation of subwatersheds based on morphometric analysis of drainage basin: A remote sensing and GIS approach.

Journal of Indian society of remote sensing. 1999;27(3):155-166.
3. Chopra R, Dhiman R, Sharma PK. Morphometric analysis of subwatersheds in Gurdaspur district, Punjab using remote sensing and GIS techniques. *Journal of Indian society of remote sensing*. 2005;33(4):531-539.
4. Chorley RJ, Donald Malm EG, Pogorzelski HA. A new standard for estimating drainage basin shape. *Amer. Jour. Sci.* 1957;255:138-141.
5. Clarke JI. Morphometry from Maps. *essays in geomorphology*. New York: Elsevier Publ. Co.; 1966. p. 235-274.
6. Das AK, Mukherjee S. Drainage morphometry using satellite data and GIS in Raigad district, Maharashtra. *Jour. Geol. Soc. India*. 2005;65:577-586.
7. Gangalakunta P, Amal K, Kothiram S. Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India – a remote sensing and GIS approach. *Inter. Jour. Appl. Earth and Geoinformation*. 2004;6:1-16.
8. Pareta K, Pareta U. Quantitative morphometric analysis of a watershed of yamuna basin, India using ASTER (DEM) data and GIS. *International journal of Geomatics and Geosciences*. 2011;2(1):248-269.
9. Krishnamurthy J, Srinivas G, Jayaram V, Chandrasekhar MG. Influence of rock types and structures in the development of drainage networks in typical hardrock terrain. *ITC J.* 1996;3-4:252-259.
10. Morisawa ME. Relation of morphometric properties to runoff in the Little Mill creek, Ohio, drainge basin. Tech. rep. 17. New York: Columbia University, Department of geology, ONR; 1959.
11. Nag SK. Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. *J. Indian Soc. remote sensing*. 1998;26(1&2):69-76.
12. Pandey V, Chowdary M, Mal BC. Morphological analysis and watershed management using GIS. *Journal of Hydrology (India)*. 2004;27(3-4):71-84.
13. Mishra S, Nagarajan R. Morphometric analysis and prioritization of sub-watersheds using GIS and Remote Sensing techniques: a case study of Odisha, India. *international journal of geomatics and geosciences*. 2010;1(3):501-510.
14. Schmid BH. Critical rainfall duration for overland flow an infiltrating plane surface. *Journal of hydrology*. 1997;193:45-60.
15. Schumm SA. The relation of drainage basin relief to sediment loss. *Internat. Assoc. Sci.Hyd. Pub.* 1954;36:216-219.
16. Schumm SA. Evolution of drainage system and slope in badlands of Perth Amboy, New Jersey. *Bull.Geol.Soc.Am.* 1956;67:597-46.
17. Schumm SA. Sinuosity of alluvial rivers on the great plains. *Geol. Soc. Amer. Bull.* 1963;74:1089-1100.
18. Strahler AN. Quantitative analysis of watershed geomorphology. *Trans. Am. Geophys. Union*. 1957;38:913-920.
19. Strahler AN. Quantitative geomorphology of drainage basin and channel network. In: Chow VT, editor. *Handbook of applied hydrology*. New York: McGraw Hill; 1964. sec-4-II.
20. Kanth TA, Hassan ZU. Morphometric Analysis And Prioritization Of Watersheds For Soil And Water Resource Management In Wular Catchment Using Geo-Spatial Tools. 2012:30-41.
21. Tirkey AS, Pandey AC, Nathawat MS. Use of Satellite Data, GIS, and RUSLE for Estimation of Average Annual Soil Loss in Dalton Ganj Watershed of Jharkhand (India). *Journal of Remote Sensing Technology*. 2013;1(1):20-30.
22. Dickinson, Collins R. Predicting erosion and sediment yield at the catchment scale, soil erosion at multiple scales. *CAB International*. 1998:317–342.
23. Eswaran H, Lal R, Reich PF. Land degradation: an overview. In: Bridges EM, Hannam ID, Oldeman LR, Pening de Vries FWT, Scherr SJ, Sompatpanit S, editors. *Responses to Land Degradation*. International Conference on Land Degradation and Desertification. New Delhi, India; 2001.
24. Hurni H. Land Degradation, famine, and resource scenarios in Ethiopia. In: Pimentel D, editor. *World Soil Erosion and Conservation*. Cambridge: Cambridge University press; 1993.
25. *IWMP Report of Ajmer District*. Soil and Water conservation Department; 2009.
26. Jain MK, Kothyari UC. Estimation of soil erosion and sediment yield using GIS. *Hydrological Sciences Journal*. 2000;45(5):771–786.
27. Griffin ML, Beasley DB, Fletcher JJ, Foster GR. Estimating soil loss on topographically non-uniform field and farm units. *J Soil Water Conserve*. 1988;43(4):326–331.
28. Misra N, Satyanarayana T, Mukherjee RK. Effect of topo elements on the sediment production rate from sub-watershed in Upper Damodar Valley. *J Agril Engg (ISAE)*. 1984;21(3):65–70.
29. National Remote Sensing Centre (NRSC). *Manual of National Land Use Land Cover Mapping Using Multi-Temporal Satellite Data*. Hyderabad: Department of Space; 2006.
30. Pandey V, Chowdary M, Mal BC. Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS and remote sensing. *Water Resour Manage*. 2007;21:729–746.
31. Renard KG, *et al.* Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). In: Renard KG, Foster GR, Weesies GA, Mc Cool DK, Yoder DC, editors. *Agricultural Handbook*. Vol. 703. Washington, DC: US Department of Agriculture; 1997. p. 21–64.
32. *Soils of Ajmer district for optimizing land use*. (NBSS Publ. 99). Nagpur: National Bureau of Soil Survey & Land Use Planning (Indian Council of Agricultural Research); Maharashtra, India.
33. Wischmeier WH, Smith DD. Predicting rainfall erosion losses- A guide to conservation planning. *USDA Agricultural Research Services Handbook 537*. Washington, D.C: USDA; 1978. p. 57.
34. Bali YP, Karale RL. A sediment yield index as a criterion for choosing priority basins. *IAHS-AISH Publ*. 1977;222:180-188.
35. Rao YP. Evaluation of cropping management factor in universal soil loss equation under natural rainfall condition of Kharagpur, India. In: *proceedings of Southeast Asian regional symposium on problems of soil erosion and sedimentation*. Bangkok: Asian Institute of Technology; 1981. p. 241-254.