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Estimating Soil Erosion and the Effect of Changing Land Use and Land Cover in the Bringi Catchment's Devalgam Watershed Using RS and GIS

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Abstract: One of the main factors contributing to soil degradation worldwide is soil erosion. The geographical variability of erosion at the Devalgam watershed was evaluated using the Revised Universal Soil Loss Equation (RUSLE) model in a GIS environment. DEM ASTER (30 m × 30 m). The model was fed with annual rainfall data from 1990, 2000, 2010, and 2020 as well as soil and LULC maps. In the Devalgam watershed, the mean annual soil loss ranged from 0 to 127.32, 140.34, 146.49, and 187.23 t/ha/yr for the years 1990, 2000, 2010, and 2020. The mean annual sol loss was calculated to be 16.6, 18.3,19.1, and 22.08 t/ha/yr. According to a zonal statistical analysis of soil erosion for various types of land cover, open forests and barren areas were more likely to experience erosion with the least susceptible to erosion were vegetation, built-up areas, orchards, and agriculture, with estimates of 85.12 and 52.35 t/ha/yr, respectively. According to the current study, managing natural resources is increasingly dependent on the LULC change in the Devalgam Watershed. GIS and remote sensing technologies have shown to be useful tools for analyzing LU/LC changes on a watershed-by-watershed basis. Six LU/LC classes were used to categorize the study area: built-up, barren terrain, vegetation, farmland, woodland, and orchards. and it was discovered that, out of the total area, or 2058.618 hectares, the least area was covered by orchards (0.5%), while the highest area was covered by forest (30.5%), followed by barren ground (25.7%). The examination of the overlay of analysis of the changes from 1990 to 2020 was conducted using LANDSAT-5 1990 over LANDSAT-8 OLI 2020. The findings also indicate that whereas the area under agricultural, built-up areas, barren land, and orchards expanded by 123%, 36.5%, 0.5%, and 36.4%, respectively, the area under forests and vegetation dropped by 17.3% and 48%. With a kappa coefficient of 0.84, 0.71, 0.75, and 0.87, respectively, the overall accuracy for the categorized imageries LANDSAT-5 (1990), LANDSAT-7 (2000), LANDSAT-7 TM (2010), and LANDSAT-8 OLI (2020) was determined to be 86.6%, 76.6%, 80%, and 90%.respectively
Keywords: Soil erosion, Land use and land cover, Visual image interpretation, Devalgam watershed, Remote sensing, GIS.

I. INTRODUCTION

The foundation of production in forestry and agriculture, the source of human nutrition, and an essential part of the environment for humans is soil. Less than 0.3% of human food comes from sources other than the land, accounting for 99.7% of the total. Soil erosion causes the loss of roughly 10 million hectares of agricultural year, which lowers the amount of cropland that can be used to produce food (Pimentel 2006 and Zachar 2011). Thus, the task is to maintain and protect the soil resource bases for future generations in addition to increasing output on a sustainable basis. The soil, climate, and landform conditions, which are further characterized by intrinsic qualities such as agro-ecological contexts, use, and management, determine the boundaries of the land's production capacity. Thus, a thorough analysis of our land resource is required to determine its potential and identify the challenges in maximizing land use in a sustainable manner.

A complicated and natural phenomena known as "soil erosion" happens when fertile surface soil is broken away by wind and water, exposing beneath soil and resulting in sedimentation in reservoirs. Many elements affect it, such as the location of the topographic slope, vegetation, and soil composition, all of which have a big impact on the soil's erosional activity (Mohamadi and Kavain 2015). Globally, soil erosion is a serious issue. Human activity has caused 1,964.4 million hectares (Mha) of land degradation worldwide (Das, 2014). Of this, 548.3 Mha are prone to wind erosion and 1,903 Mha to water erosion. Water erosion has been identified as the primary driver of land degradation caused by anthropogenic activities across 1094 Mha of land worldwide, or 56% of the total.(1991, Oldman et al.)

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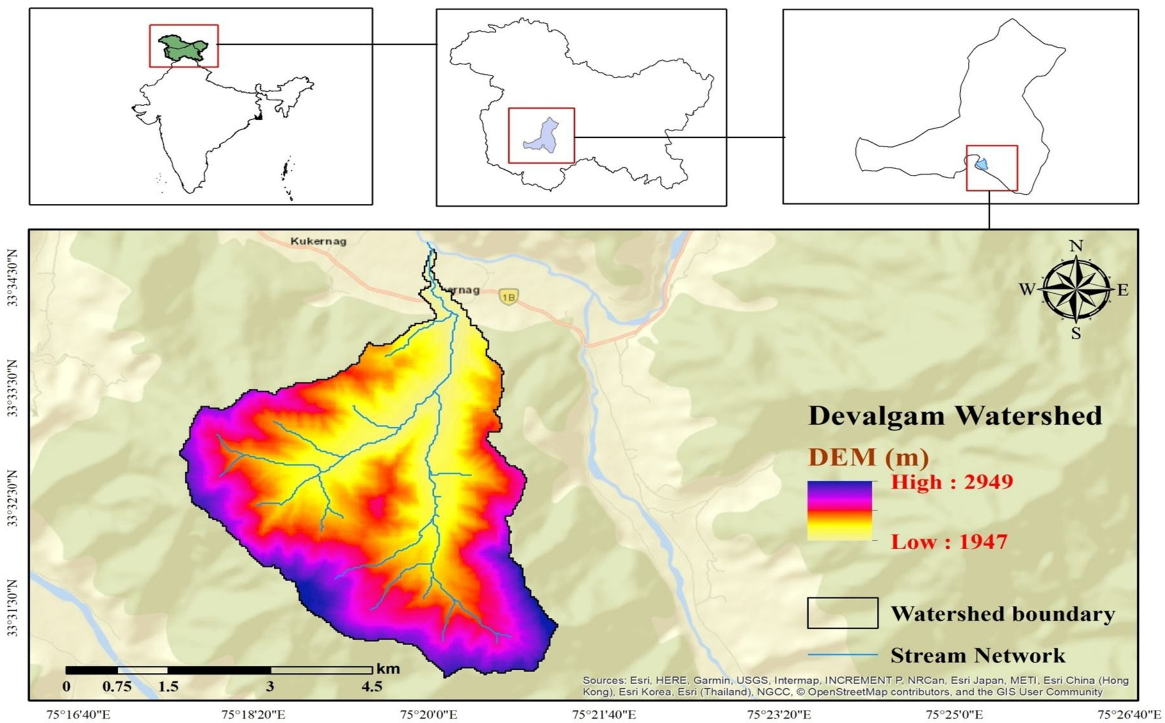
India loses over 5334 million tonnes of soil annually for a variety of causes.(Pandey and colleagues, 2007; Dhruvanarayan and Babu, 1983)Jammu and Kashmir has 35.86% of its total land degraded, compared to 29% across the nation (ISRO, 2016).Twenty tonnes are lost in the J&K and Ladakh UTs.

II. MATERIALS AND METHODS

A. Study Area

The study area is located in the Anantnag district's southern portion of the Kashmir Valley. The watershed's geographical size is 2058.618 hectares (20.58 Km2). 33◦31′ to 33◦34′ North latitude and 75◦160′ to 75◦26′ East longitude correspond to the study area's locations. The Devalgam watershed is situated at a height of 1430-2202 meters (amsl). Forest vegetation dominates the watershed. The location map of area is shown in figure below



B. Land cover and use (LULC)

The main land uses in this watershed were classified as horticulture, agriculture, forests, barren land, and vegetation. The majority of the watershed was made up of forest, then barren ground, and agriculture, with maize and paddy being the main crops farmed from June to August. Peas and mustard were among the crops cultivated from September to November. The two main horticultural products farmed in the region are walnut and apple.

C. Soil Characteristics

The paedogenic processes and parent material differ greatly since the Deval Gam watershed is located in the southern portion of the Kashmir valley, which has a very diverse topography. The district's soils have a wide range of edaphic, morphological, physical-chemical, and mineralogical characteristics. The district's soils range widely in origin from lacustrine to alluvial. Mountain, alluvial, karewa, and peaty soils are the primary soil types found in the district.

D. Climate

Devalgam (District Anantnag) experiences a temperate climate, with summers being fairly hot and winters being extremely cold. Snowfall is the main source of precipitation in the area during winter. From November through January, below-freezing temperatures are recorded.

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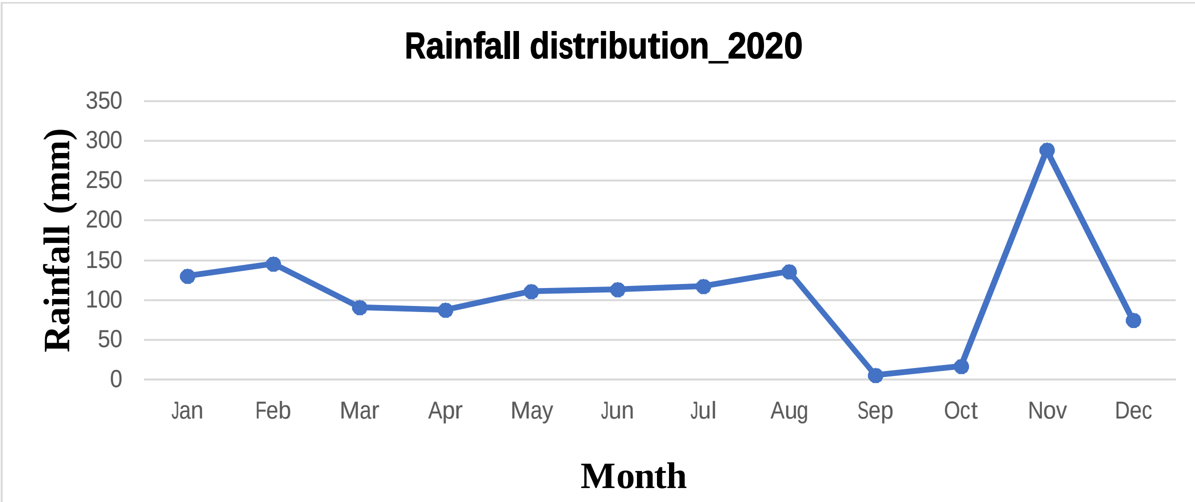
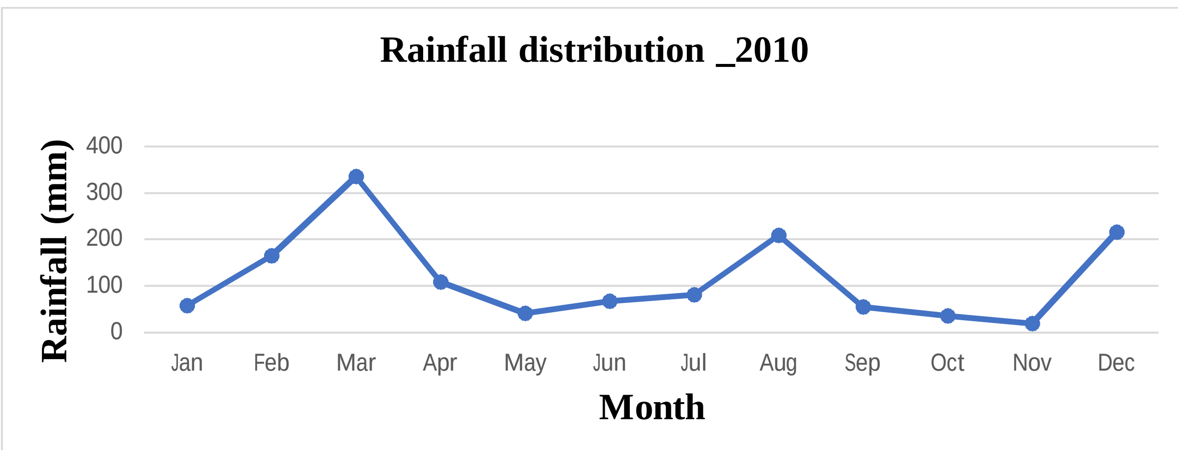
E. Rainfall

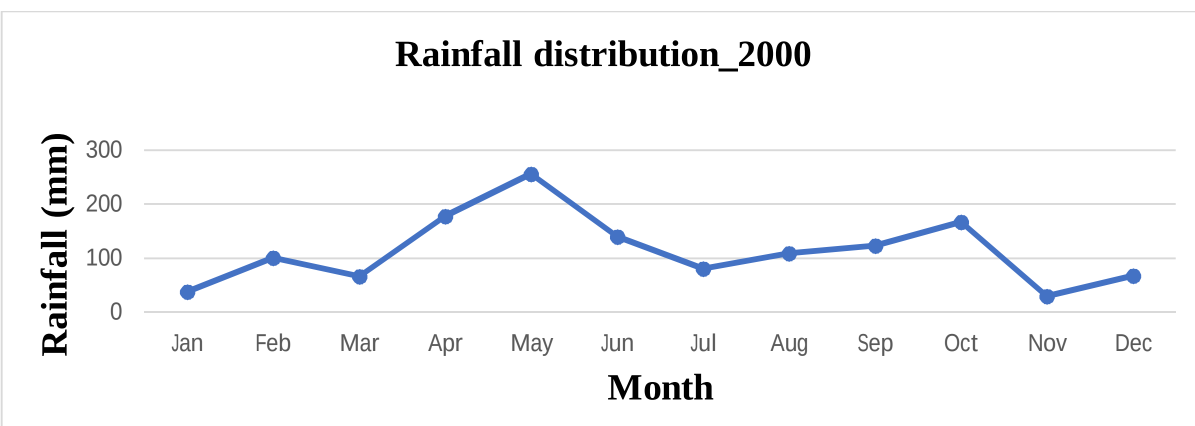
The rainfall data of the year 2020 shows that total annual rainfall was 1318 mm The rainfall data was provided by the department of Meteorology station kokernag (Anantnag). The rainfall generally breaks in the middle of March through May. April and May month's account for the major share of rainfall. The rainfall distribution of the study area for year 1990, 2000, 2010 and 2020 is as shown in figure below.



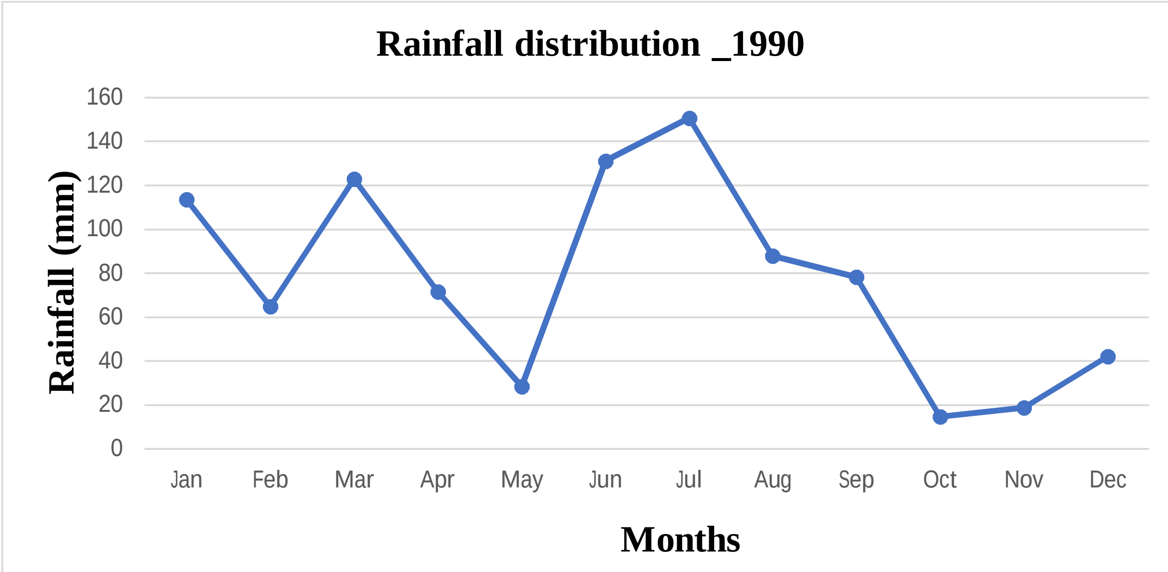
Monthly Rainfall distribution in (mm) of Devalgam watershed in year 2020, district Anantnag, Jammu and Kashmir.



Monthly Rainfall distribution in (mm) of Devalgam watershed in year 2010, district Anantnag, Jammu and Kashmir.



Monthly Rainfall distribution in (mm) of Devalgam watershed in year 2000, district Anantnag, Jammu and Kashmir.



Monthly Rainfall distribution in (mm)of Devalgam watershed in year 1990, district Anantnag, Jammu and Kashmir.

F. Temperature

Summer is extremely hot, with July and August being the hottest months, and winter is extremely cold, with sub-zero temperatures reported from November to January, according to comparison of temperature data during the time period considered in this study, i.e., between -6.8^{0}C and 34^{0}C. The mean maximum temperature reaches 24.5^{o}C in month of July, while the mean minimum temperature reaches minus 2.0^{o}C in month of January.

Data	Description	Source of data
Meteorological data	Rainfall data (1990,2000,2010,2020)	Meteorological Station (Kokernag) Anantnag
Remote sensing data	ASTER Digital Elevation Model (DEM) LANDSAT-8 LANDSAT7 LANDSAT-5	www.earthexplorer.usgs.gov

G. Remote Sensing data used

The satellite imagery has a lower resolution but has multispectral capabilities and is ideal or studying large areas than aerial photography. Remote sensing data in the form of satellite imageries in digital format is available from National Remote Sensing Agency (NRSA), Remote sensing data used in our study involves:

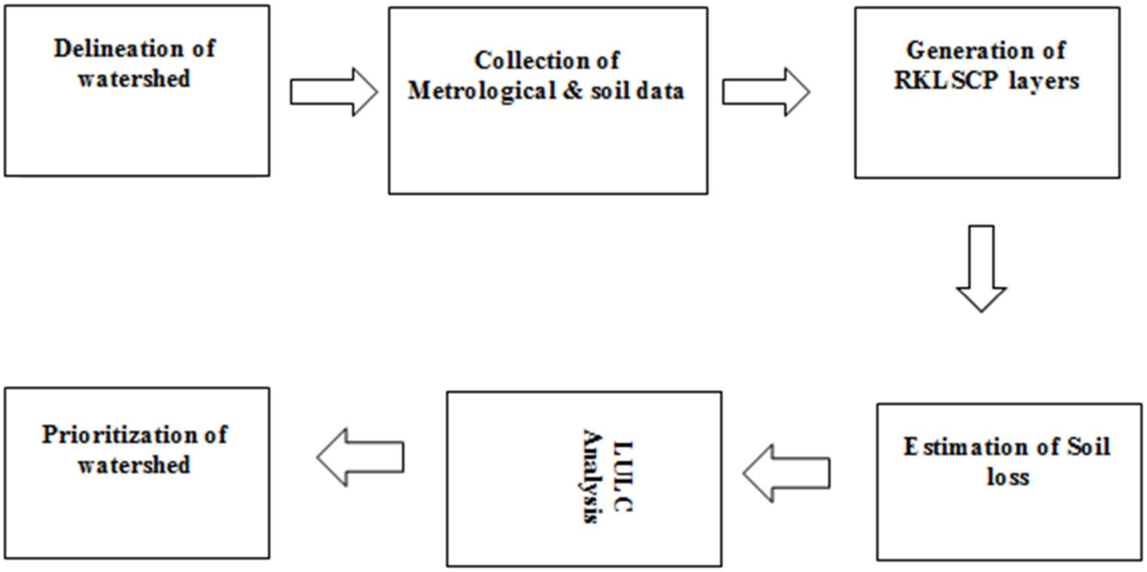
1) *Digital Elevation Model (DEM):* ASTER DEM with the resolution of 30 m was downloaded from www.earthexplorer.usgs.gov for the study area. was obtained from Department of Remote sensing, Ecology and Environment, J&K.
2) *LANDSAT imagery:* The processed imagery of Landsat TM for the year 1990, 2000 and Landsat 8- OLI imagery (5.8 m resolution) for the year 2010 and 2020 was obtained from Climate Change Lab at Centre for Climate Change and Mountain Agriculture, Division of Environmental science, SKUAST-Kashmir.

H. Software used

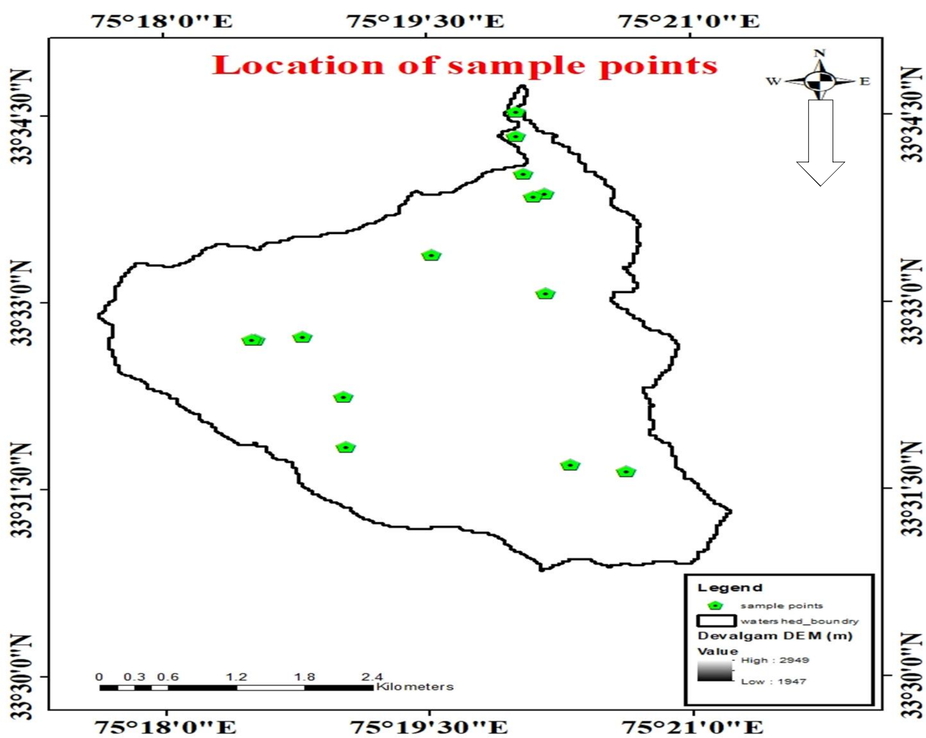
Software's used for the research:
Image and Geospatial analysis
Arc GIS 10.4.1
Others
Microsoft Excel and Word

III. METHODOLOGY

The methodology adopted to accomplish the different objectives of the study is given as follows.



After estimating all input factor of RUSLE independently, average annual soil loss was calculated by multiplying RKLSCP layers in the raster calculator of Arc tool box



1) Estimation of LULC Parameters and Assess their Effect on Soil Erosion

The ASTER DEM , LANDSAT -5 (TM) LANDSAT-7 and LANDSAT-8 (OLI) remotely sensed images of the study area for the years 1990, 2000,2010 and 2020, respectively were used together in Arc GIS with ground measurements to analyze the change in land use/land cover.

2) Estimation of Soil Loss using RUSLE Model

RUSLE is an erosion model developed to forecast long term mean annual soil loss due to excess runoff from field slopes, both from rangelands and from specified cropping and management systems. For this reason, widespread usage has proved the utility and acceptability of RUSLE. It is not only applicable to agricultural conditions but to others as well as construction sites. The flow chart of Rusle model is shown in fig 3.7 the RUSLE method given by Renard *et al*., 1996 and is expressed as:

$$A = R \times K \times L \times S \times C \times P \qquad (1)$$

Where,

- A = Average soil loss per unit area by erosion (t/ha/yr),
- R = Rainfall erosivity factor (MJ mm/ha/h/yr),
- K = Soil erodibility factor (t h/MJ/mm),
- L = Slope length factor,
- S = Slope steepness factor,
- C = Plant cover and management practice factor,
- P = Conservation support practice factor.

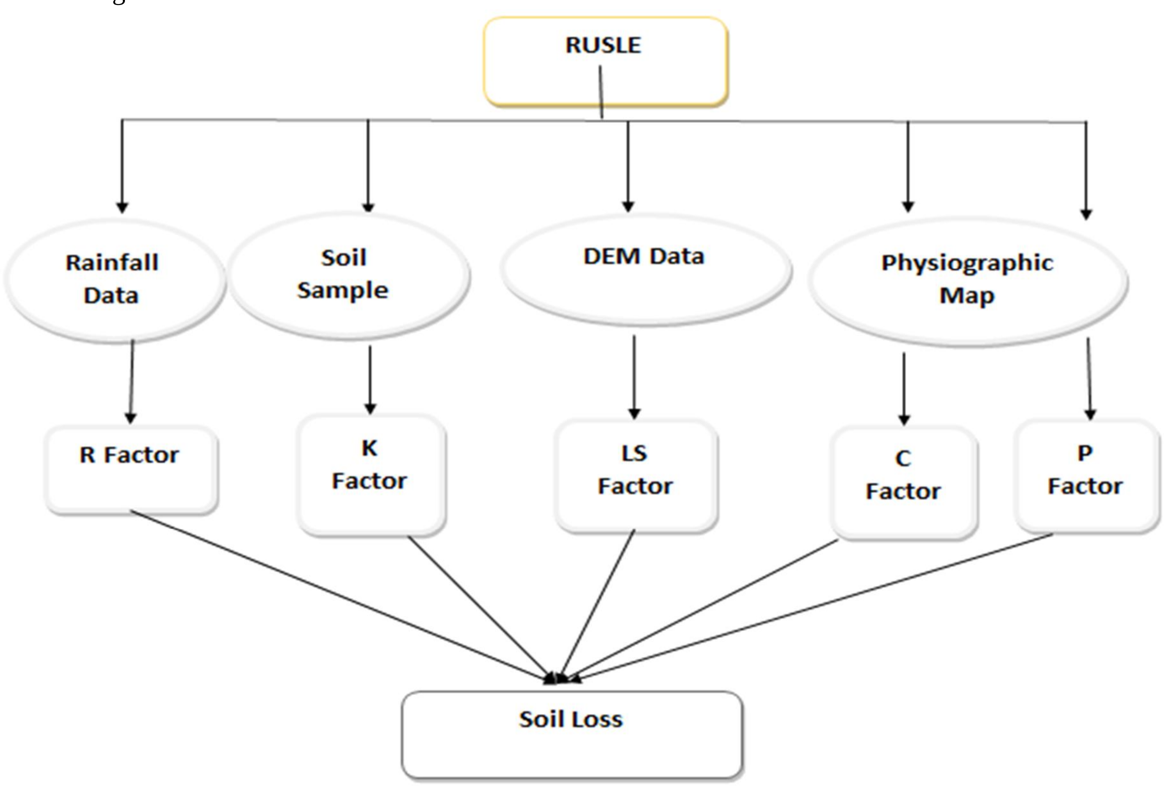
3) Rainfall erosivity factor (R)

The Rainfall erosivity Factor is a climate factor that determines the ability of rain to cause soil erosion. Since the rain play an important role in the detachment of soil therefore, R-factor is one of the key factor for determining the soil erosion. The monthly rainfall distribution of Devalgam watershed for year 1990,2000,2010 and02020 is shown in fig 3.2, 3.3 3.4 and 3.5. The following expression given by sing *at al*., 1981 was employed to calculate the Rainfall Erosivity Factor.

$$R = 81.5 + 0.375 \times P \qquad (2)$$

$$P = AR + 0.329 \times DEM \qquad (3)$$

R = Rainfall erosivity factor (MJ mm/ha/h/yr),
P = Rainfall raster;
AR = Annual Rainfall (mm); and
DEM = Digital Elevation Model



Flow chart of RUSLE MODEL

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4) Soil Erodibility Factor (K)

The soil erodibility factor (K) is the soil loss rate per index of rainfall erosion. K factor usually varies between 0 to 1. Potential as well as the rate and volume of runoff. The texture, organic matter, structure, and permeability of a soil decide its erodibility (Efe and Ciirebal, 2008). The K-factor indicates how quickly the soil is detached by splash during rainfall and/or surface flow, and thus shows the change in the soil per unit of applied external force of energy (Dumas and Printemps, 2010).

Renard 1997, used Wischmeier and Smith's 1978 equation to calculate the K-factor. It goes like this:

$$K = \frac{(2.1\times10^{-4}) \times (12\text{-}OM) \times M^{1.14} + 3.25(S-2) + 2.5 \times (P-3)}{100} \qquad (4)$$

Were,

OM = Percent of organic matter,

S = Soil structure class (1-4),

P = Soil permeability class (1-6),

M = (% silt + % very fine sand) × (100- % clay)

The texture of the soil affects the structure and permeability of the soil. Texture determination has already been debated. The USDA-proposed codes were used to assess the soil structure (1972).

5) Calculations

- The calculations was done to acquire the results of soil texture analyis as given below.
- Let the weight of soil = a gm
- Hydrometer reading at 40 sec = b
- Temperature for 40 sec observstion = c
- Corrected hydrometer reading at 40 sec = d

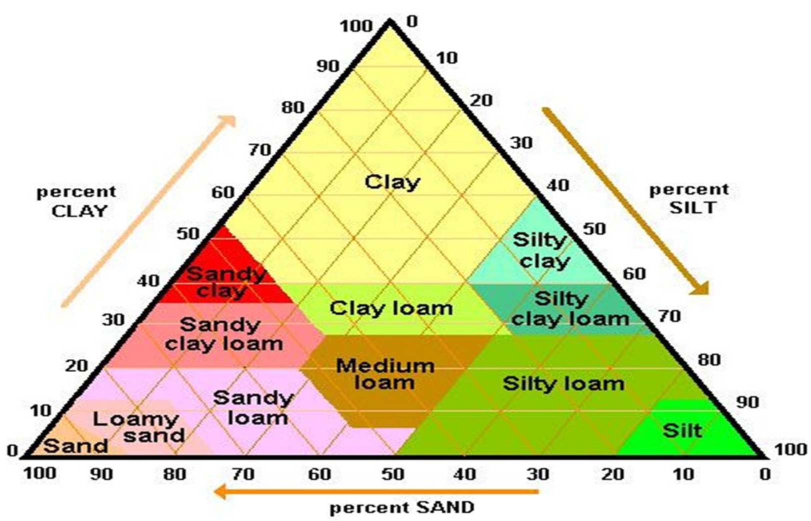
  Where, $d = b + (c - 20) \times 0.36$ (5)
- Hydrometer reading at 7 hours = e
- Temperature for 7 hours observation = f
- Corrected hydrometer reading at 7 hours = g
- Quantity of silt + clay = d
- Quantity of clay = g
- Therefore, the amount of clay = (d – g)

$$\% \text{ clay} = g / a \times 100 \qquad (6)$$

$$\% \text{ silt} = d - g / a \times 100 \qquad (7)$$

$$\% \text{ sand} = \{100 - (\% \text{ silt} + \% \text{ clay})\} \qquad (8)$$

Soil texture class was determined using the ISSS triangular texture diagram shown in figure below.



Soil texture triangle

6) LS factor

a) Slope Length & Gradient factor (LS)

The L and S factor in RUSLE shows the impact of topography on soil loss. DEM of devalgam watershed was used to estimation of both length and slope (LS) factor. First the slope map and flow accumulation map of study area were prepared, then same were used for the preparation of L and S maps.

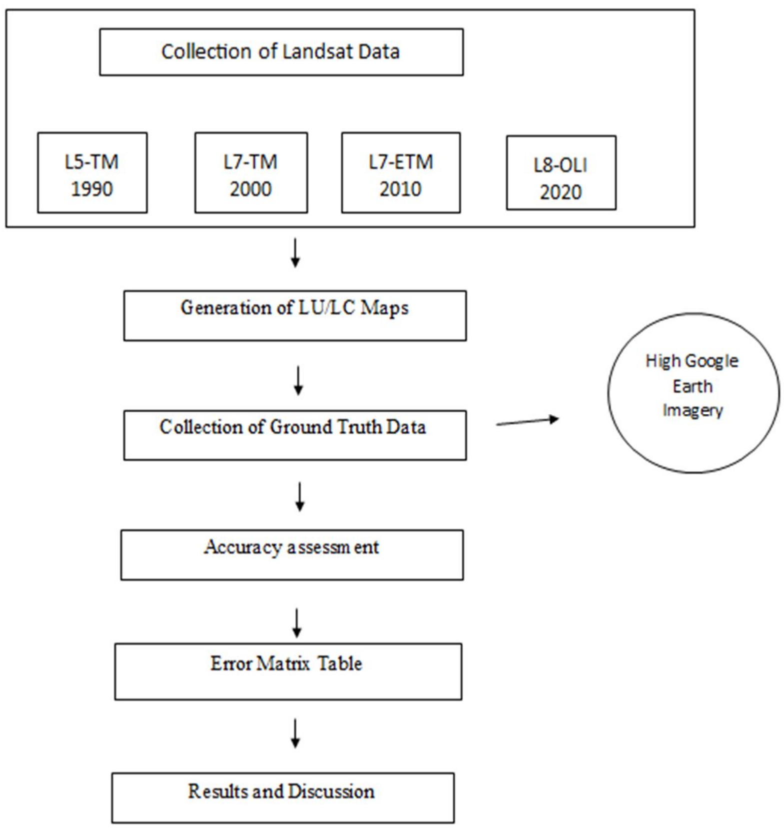
LS factor calculated by using following formula given by Moore *et al.,* (1992)

$$\text{LS factor} = \left(\frac{As}{22.13}\right)^{n}\left(\frac{\text{Sin}\beta}{0.0896}\right)^{m} \qquad (12)$$

Were,
A_s = The specific area, = flow accumulation x resolution of imagery
β = Slope gradient (radian),
n = 0.4 and m = 1.3

7) Land use/land cover change detection

The land use/land cover change in Devalgam watershed was investigated using remote sensing and GIS, which are powerful tools to derive accurate and timely information on the spatial distribution of land use/land cover changes over large areas. The aim of change detection process is to recognize land use/land cover on digital images that change features of interest between two or more dates (Muttitanon and Tripathi, 2005). LANDSAT -5 (TM) LANDSAT-7(TM) and LANDSAT-8 (OLI) remotely sensed images of the study area for the years 1990, 2000,2010 and 2020, respectively were used together with ground measurements to analyze the change in land use/land cover. The flow diagram indicating the methodology for land use/cover change detection is given in figure below



8) Kappa- Coefficient: Kappa coefficient measures the difference between how much agreements are actually present ("observed" agreement) compared to how much agreement would be expected to be present by chance alone ("expected" agreement).

Kappa = (observed accuracy - expected accuracy)/ (1 - expected accuracy)

$$\mathbf{k} = \frac{po-pe}{1-pe}$$

Overall Accuracy = $\frac{\text{Total Number of Correctly classified Pixels (Diagnol)}}{\text{Total Number of Reference Pixels}} \times 100$ .. (3.13)

(Rwanga and Ndambuki 2017)

Kappa Coefficient (T) = $\frac{(TS \times TCS) - \Sigma(\text{Column total} \times \text{Row Total})}{TS^2 - \Sigma\,(\text{Column Total} - \text{Row Total})} \times 100$ …. (3.14)

9) Change Detection

The magnitude of change (MC), the percentage of change (PC) and the annual rate of change (ARC) for each land use/land cover class during each period of time were computed based on the following equations:

$$MC\ (ha) = A_i - A_f \quad (13)$$

$$PC\ (\%) = \frac{Ai - Af}{Ai} \times 100 \quad (14)$$

$$ARC\ (ha.\ per\ year) = \left(\frac{Ai - Af}{n}\right) \quad (15)$$

$$ARC\ (\%) = \left(\frac{Ai - Af}{Ai \times n}\right) \times 100 \quad (16)$$

Were

A_i = is the class area (ha)at the initial time.

A_f =is the class area(ha)at the final time.

(n) = is the number of years of the time period.

IV. RESULTS AND DISCUSSION

Remote sensing and GIS are tools which play an important role in evaluation of watershed development program .This chapter includes the results of LULC categories and percent change of each LULC category, LULC maps, slope map, R factor map, K factor map, LS factor map, P factor map, C factor maps for four years (1990-91, 2000-01, 2010-11 and 2020-21), soil loss using RUSLE equation for (1990-91, 2000-01, 2010-11 and 2020-21), and comparison of soil erosion for different land use and land cover.

A. Estimation of Soil Loss

Delineation of watershed

Delineation of the Deval gam watershed and preparation of drainage map was developed on ArcGIS 10.4.2 software with the help of ASTER DEM. The digital elevation model was downloaded from www.earthexplorer.usgs.com which was in tagged information file format (TIFF) with a 30- meter resolution. The digital elevation model is shown of study area is shown in fig 4.1.

B. Development of a Database for RUSLE

1) Rainfall erosivity factor (R)

The rainfall erosivity factor (R) values for the study area for the year 1990, 2000, 2010 and 2020 were calculated using equations 3.2 and 3.3. Rainfall data were used generated in ArcMap using the raster calculator tool. These are shown in fig 4.3,4.4,4.5 and fig. 4.6 respectively. It can be observed from fig 4.3,4.4, 4.5 and 4.6 that the value of R-Factor calculated for different years are shown in table below (MJ mm/ha/h/yr).

2) Rainfall Erosivity Factor

S.no	Year	Rainfall Erosivity Factor (MJ mm/ha/h/yr) [Low]	Rainfall Erosivity Factor (MJ mm/ha/h/yr) [High]
1	1990	668.62	792.242
2	2000	831.13	951.79
3	2010	841.69	965.312
4	2020	822.08	969.374

3) Soil Erodibility Factor (K)

Soil erodibility factor (K) values for the study area were calculated using Equation 3.4 and 3.5 soil texture data was used to obtain K-Factor, soil erodibility factor map was generated in ArcMap using IDW technique of the interpolation tool. K-Map is shown in fig. 4.7. location and K values of different samples points are shown in Table 4.2.

4) Slope length and gradient factor (LS)

The l and S factor in RUSLE reflects the effect of topography on erosion. Slope length and gradient factor (LS) values for the study area were calculated using equation 3.12. LS Map is shown in fig 4.8. as observed from the map LS factor ranges from 0.04 To 8.12

5) Cover management factor (C) and support practice factor (P)

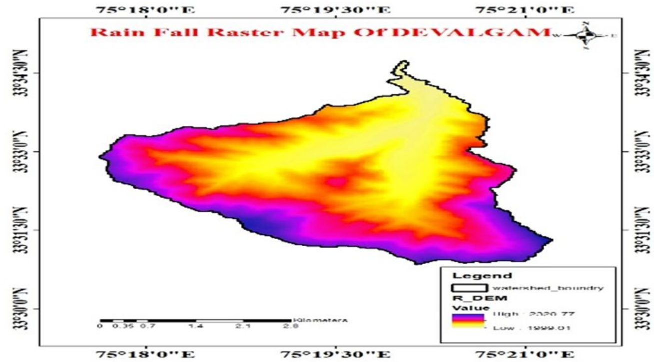
C- Factor represents the effect of cropping and management practices in agricultural management, and the effect of ground, tree, and grass covers on reducing soil loss in the non- agricultural situation. P- factor is the ratio of soil loss for given conservation practices to the soil loss, obtained from up and down the slope. Both C and P factor values of the study area were obtained from Tabulated values given by Singh *et.al* (1992) for Indian conditions shown in table 3.6 and 3.7 C -Factor and P Factor maps were prepared using the land use land cover Map which is shown in Fig. 4.9. C factor and P Factor maps are shown in fig. 4.10,4.11,4.12 ,4.13 and fig. 4.14 respectively. As observed from the map, C-Factor ranges from 0 to 0.6 while P-Factor ranges from 0.55 to 1.

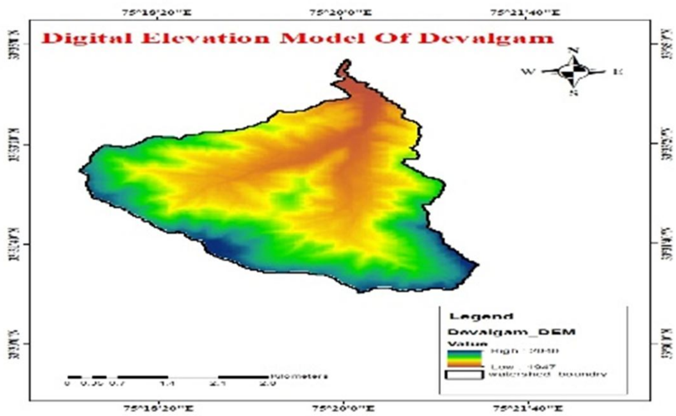
6) Estimation of annual soil loss (A)

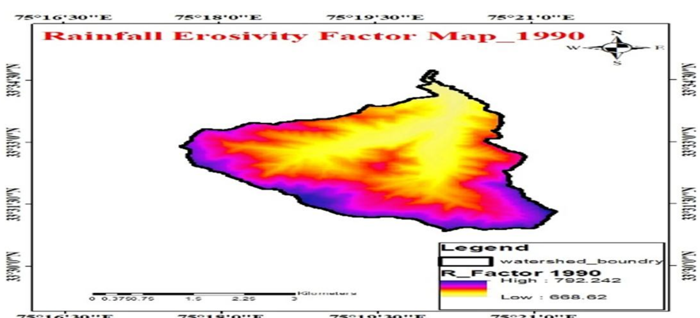
The annual soil loss of Deval gam watershed is calculated by using the RUSLE Equation (Equation 3.1) the soil loss(A) map was prepared by multiplying RKLSC and P layers in ArcGIS by using raster calculator tool of Arc tool box as shown in fig 4.15. soil loss values are shown in table 4.3 Also, the zonal statistical values of the soil erosion for different LULC's in the table below

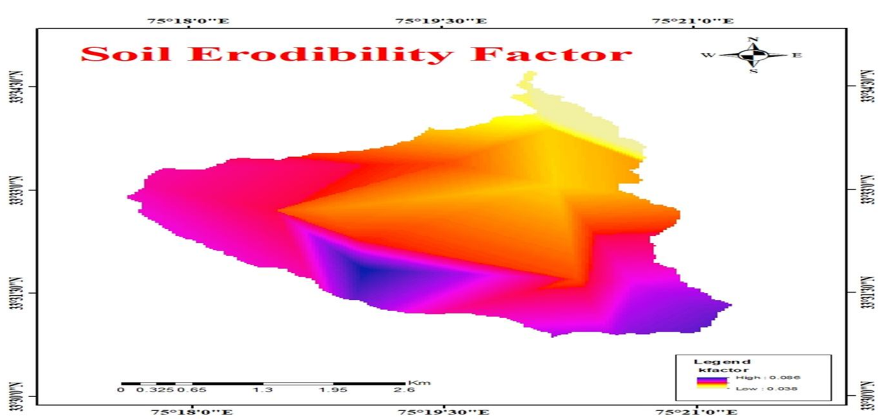
Place	Land use	Latitude (DD)	Longitude (DD)	Sand	Silt	Clay	Soil Class	OC_%	OM_%	K (MJ mm/ha/h/yr)
Goi-Hard Devalgam	Rice	75.343	33.695	2.27	51.5	46.23	Silt clay loam	1.86	3.20	0.038
Soyan Devalgam	Barren land	75.33611	33.57917	46.76	24.28	28.96	sandy-clay-loam	1.80	3.10	0.044
Devalgam	Agri. Land	75.33611	33.56444	45.7	24.5	29.8	Sandy clay loam	1.78	3.06	0.042
Upper- Sunbrari	Forest	75.31694	33.53722	41.52	49.08	9.4	Silt loam	1.04	1.79	0.086
Dawood pora	Agri. Land	75.33528	33.56389	35.11	36.86	28.03	loam	1.21	2.08	0.069
Upper-Sunbrari	Barren land	75.31694	33.53111	32.29	54.11	13.6	Silt loam	1.12	1.93	0.080
Nala Sunbrari	Grass land	75.32556	33.55639	34.18	50.92	14.9	Silt clay loam	1.15	1.98	0.073
Sunbrari	Shrub land	75.33861	33.52833	33.25	40.2	26.55	Loam	1.13	1.94	0.077
Bun - devalgam	Shrub land	75.33306	33.57556	17.52	34.04	48.44	clay	1.80	3.10	0.044
Bun devalgam	Orchard	75.33333	33.57222	30.64	36.56	32.8	clay loam	1.77	3.05	0.043
Chari Tanzil	Grass land	75.34389	33.5275	31.08	40.2	28.72	clay loam	1.82	3.13	0.047
Magam	Maize	75.31333	33.54556	20.54	44.16	35.03	silt clay loam	1.31	2.25	0.062
Devalgam	Grass land	75.33389	33.56972	31.04	34.36	34.8	clay loam	1.76	3.03	0.042

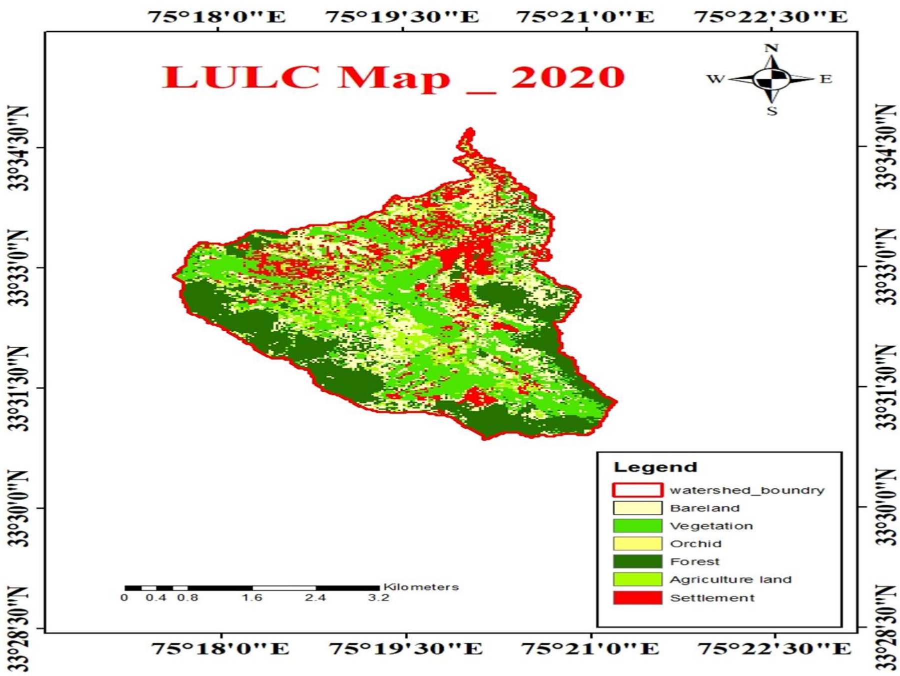
Takia magam	Maize	75.31306	33.54528	10.6	48.3	41.08	silt loam	1.67	2.87	0.056











7) Soil loss

Minimum (t/ha/yr.)	Maximum (t/ha/yr.)	Mean (t/ha/yr.)
0	187.23	22.08

Zonal statistical analysis of soil erosion for various LULC's

LULC	Area (ha)	Min. (t/ha/yr)	Max. (t/ha/yr)	Mean (t/ha/yr)
Agricultural land	306.006	0	75.22	9.1
Barren land	528.383	0	187.23	85.12
Forest	628.875	5.3	98.23	52.35
Settlements	306.007	2.18	14.02	4.56
Vegetation	280.167	6.1	31.25	15.88
Orchards	9.903	0	14.55	5.66

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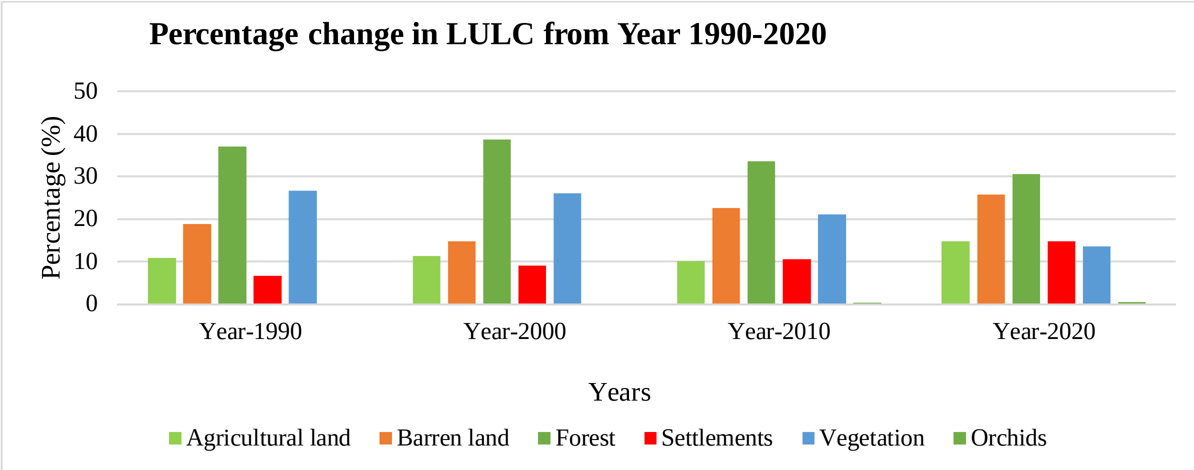

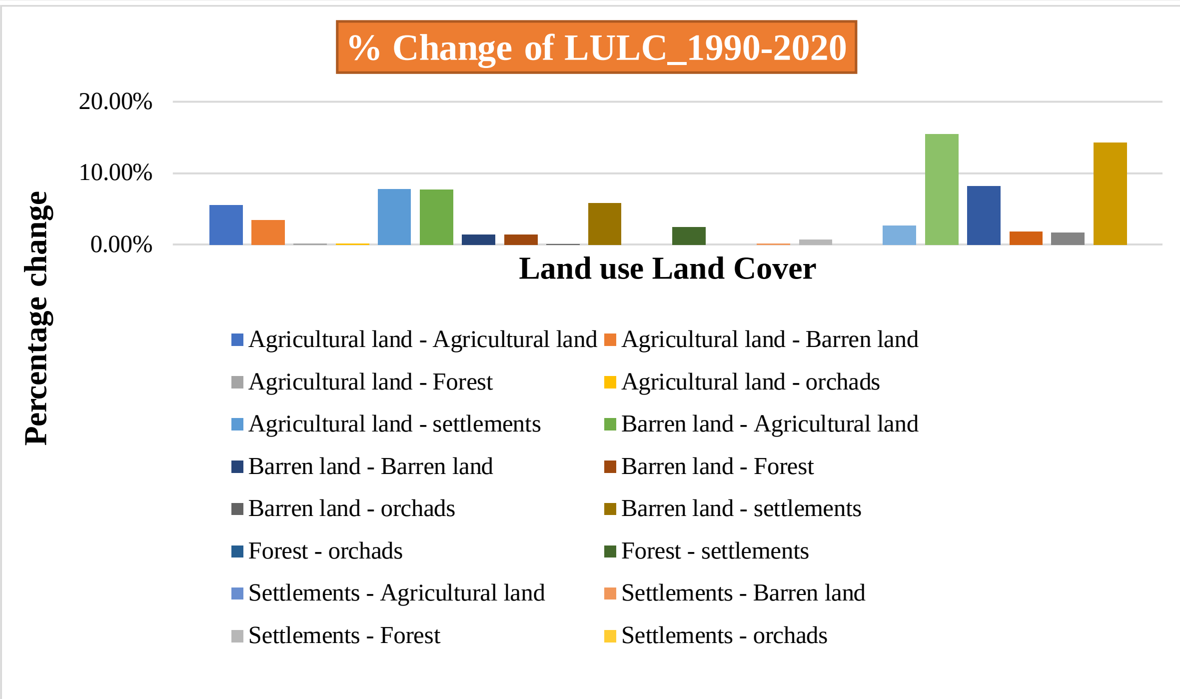

V. CONCLUSION

1) The results of this study reveal that rainfall intensity and slope are the most dynamic and most important factors affecting surface runoff.
2) The severe and very severe erosion was found to be distributed mainly with in the areas of high slope gradient and also sections of moderate forest (barren lands) LULC class.
3) The Among different LULC, the maximum mean soil loss was found in Barren lands (85.12t/ha/yr), followed by Forest areas (52.35 t/ha/yr), vegetation (15.88 t/ha/yr), agricultural land (9.1 t/ha/yr), orchards (5.66 t/ha/yr), settlements (4.56 t/ha/yr).
4) Upper Sunbrari and Nala Sunbrari areas of watershed were found to be more prone to soil erosion hence; needed an immediate conservation plan.
5) The soil loss estimation for Devalgam watershed was found in increasing order for the year 1990-91(0 -16.6t/ha/yr), 2000-01 (0 -18.3 t/ha/yr), 2010, (0 -19.1t/ha/yr), and 2020(0 -22.08t/ha/yr).
6) With increasing rainfall intensity, in particular, produced the most runoff, soil erosion. Rainfall is thought to be the most significant cause of erosion.

7) The Rainfall erosivity factor also shows an increasing order from year 1990 to 2020, which is the most dynamic cause of soil loss.
8) The conservation strategies recommended include i) contour farming ii) conservation tillage iii) conservation of wastelands to agriculture iv) afforestation under social forestry program and v) putting stop to overgrazing of the pastures.
9) From the results, it is observed that location upper Sunbrari which has the highest K value (0.086); has a low clay content and low organic matter. Location Goi-hard Soyan with the lowest K value (0.038); has a high clay content and high organic matter. Soils with higher K values should have lower clay content and are more prone to erosion.

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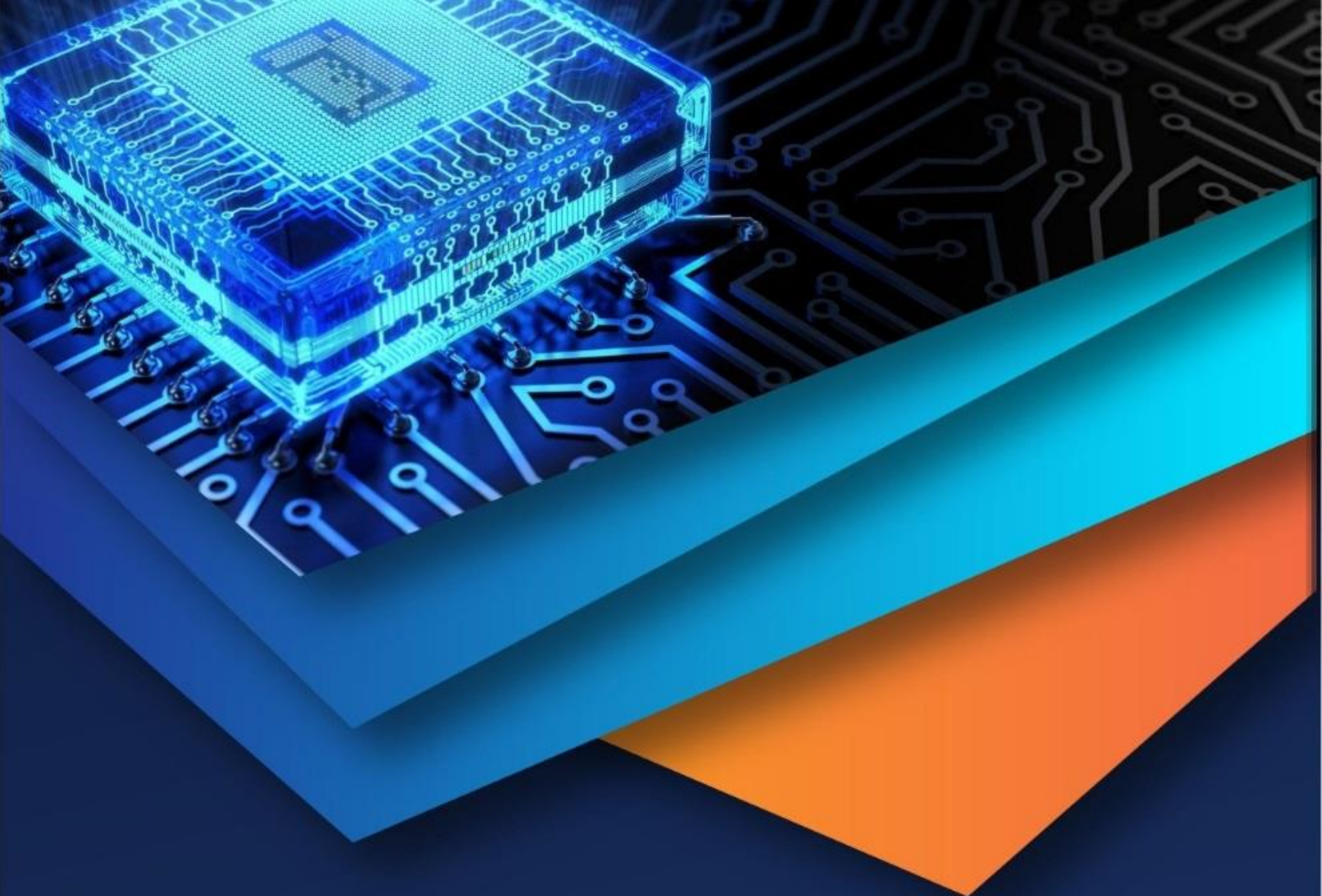

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