iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: XI Month of publication: November 2023

DOI: https://doi.org/10.22214/ijraset.2023.57009

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue XI Nov 2023- Available at www.ijraset.com

RUSLE and GIS Based Soil Erosion Modelling in a Micro-Watershed (1E1C4a2) in the Budgam district of Jammu and Kashmir

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Abstract: A comprehensive methodology that integrates Revised Universal Soil Loss Equation (RUSLE) model and Geographic Information System (GIS) techniques was adopted to determine that soil erosion vulnerability of micro-watershed in J&K India. The spatial pattern of annual soil erosion rate was obtained by integrating geo-environmental variables in a raster based GIS method. GIS data layers including, rainfall erosivity (R). Soil erodibility (K), slope length and steepness (LS), cover management (C) and conservation Practice (P) factors were computed to determine their effect on average annual soil loss in the area. The resultant map of annual soil erosion shows maximum soil loss of 2.9246 t h Y with a close relation to grass land area, agricultural lands and orchards (with low LS) . The spatial erosion maps generated with RUSLE method and GIS can serve as effective inputs in deriving strategies for land planning management in the environmentally sensitive agricultural areas.
Keywords: Soil Erosion, Revised Universal Soil Loss Equation (RUSLE), GIS, Maps, Micro-watershed

I. INTRODUCTION

According to recent assessments over 80% of the world's agricultural land suffers from moderate to sever erosion which included loss of productivity. Because of this and population growth, the global per capita food supply is currently declining. In many areas of the world., on site impacts of increased soil loss are frequently couped with serious off site impacts related to the increased mobilization of sediments and its delivery to rivers. These off site impacts include water pollution, reservoir sedimentation, the degradation of aquatic habitats and the increased cost of water treatment. The limitations of current measurement techniques and models to provide information on the spatial and temporal patterns of soil and water degradation across catchments restrict ability to develop cost effective land management strategies. However, the advent of new techniques of erosion assessment and recent developments in the application of remote sensing and geographic information system (GIS) to the study of erosion and sediment delivery offer considerable potential for meeting these requirements. Since disturbed lands in watersheds are significant source of sediment, a systematic rating of their potential for erosion would be useful in soil conservation planning. Most importantly mapping and assessment of erosion prone areas enhance soil conservation and watershed management. Maps showing the spatial distribution of natural and management plans, allowing identification of preferential areas where action against soil erosion is more urgent or where the remediation effort will have highest revenue. The site is situated at latitude (33.9770-34.0256N) and longitude of (74.6962-74.7246E) which located in the province of Kashmir and covers an area of 4197.80 ha. The region is highly undulating and exhibits a uniform topography, with a mean elevation of 5770 m above msl and general northwest terrain slope. The study area receives an annual average rainfall of 690 mm and exhibits a dry climatic condition. Almost 80% of the area is occupied by agricultural lands and orchids, followed by grasslands, forest plantation. Gynomorphically, the micro watershed is characterized by steep structural hills, denudation hills, grasslands and agricultural lands with thin vegetation. The soil texture is clay followed by clayey with silt.

II. METHODOLOGY

Determining the intensity, amount and distribution of erosion has a big important environmental management specialists to make an informed decision on the suitable soil and water conservation measures that should be installed in a given area. The Universal Soil Loss Equation (Wischmeier, 1997) or Revised Soil Loss Equation (Renald et al., 1997) is of ten used to predict rainfall erosion in landscape/ watersheds using GIS

A. Topography and Climate

The general topography of the area is both mountainous and plan. While the southern and south-western parts are mostly hilly and the eastern and northern parts are relatively plain. The average height of the mountains is 1.610 meters. The climate of district Budgam is of temperate type

B. Land use land cover

The land cover is mostly agricultural and horticultural in the watershed. The soil is mostly clayey with good amounts of silt and sand.

C. Agricultural System

The weather conditions in the valley as well as the district being temperate multiple cropping has not been successful. Paddy and maize are the main crops while as pulses and vegetables are also grown in different pockets of the district

D. Data Source

The quantitative evaluation of the soil erosion loss by RUSLE is based on its component factor; such as: rainfall data, digital elevation model (DEM), soil type map, land cover map and satellite map. The use of GIS provides the tools to manage and analyze these data. However, the evaluation of these data is necessary before they are used. The uncertainties regarding data sources may introduce larger uncertainties in soil erosion estimates. Such as data interpolation, conversion, and registration

E. The Digital Elevation Model (DEM)

Digital elevation model (DEM) is digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. In other word, digital elevation model (DEM) data are digital representations of cartographic information. The DEM data files of the study area are available from Environmental Science Division. The DEM data was added to ArcGIS 10.2 to calculate the flow length and slope steepness.

F. Soil Data

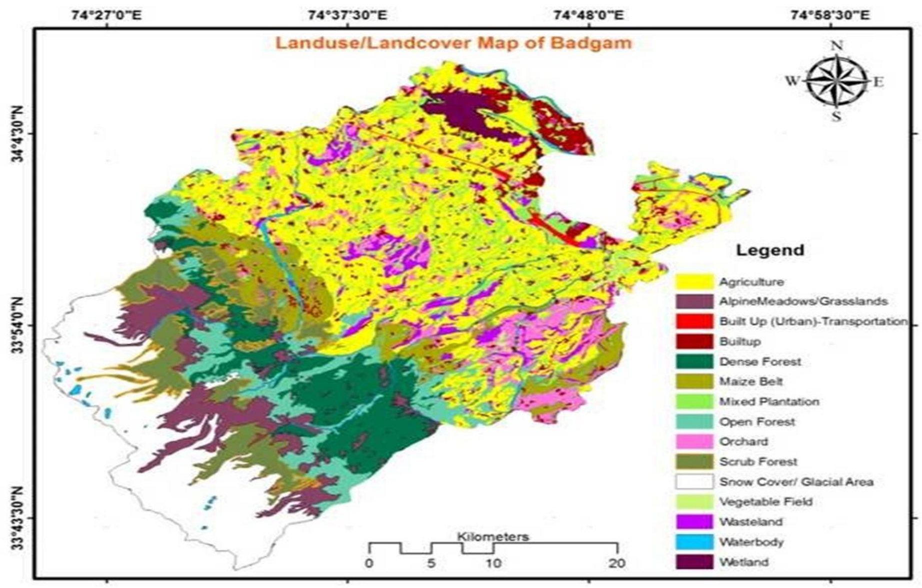
The soil data for this study was obtained from the Division of Soil Science. The soil type of the area is mostly clayey.

G. Precipitation Data

The rainfall data used in this study is from the rainfall station at Meteorological Department. In order to increase the accuracy of the result additional rainfall data from different areas, which are not located in the study area but are close enough it, were used.

H. Land use Land Cover.

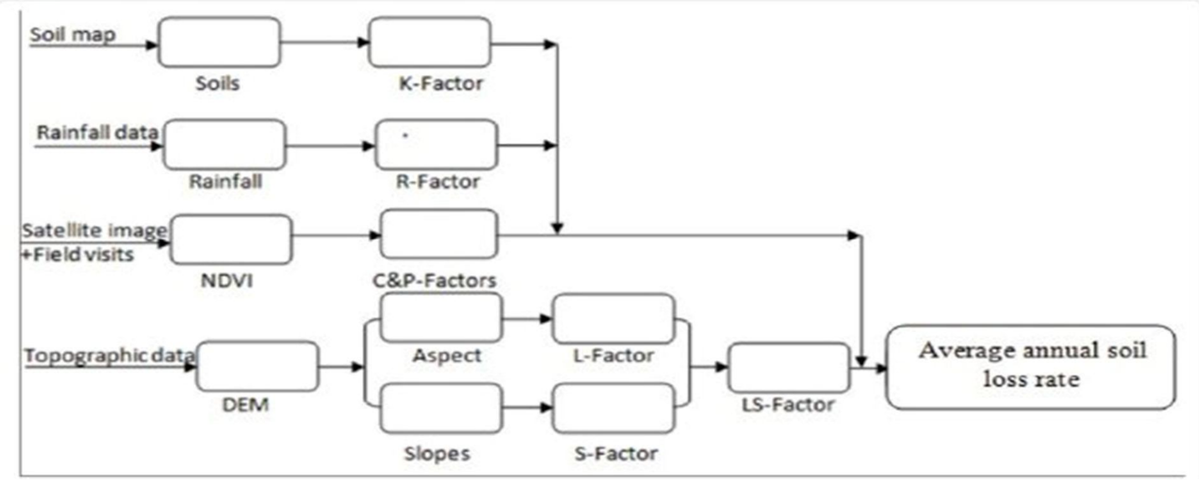
The role of land use land cover category has been immense particularly in estimating C and P factors of the RUSLE model. Tus their influence on soil loos would be to some Extent decisive, however, slope length and slope gradient have put strong reflection of their pattern at final result of RUSLE model. Usually C and P factors are determined from satellite map. And other necessary information, the value of C and P factors were obtained from the Environmental Science s Division of Skuast-K



III. LAND USE LAND COVER OF BUDGAM DISTRICT

A. Data Analysis

Data analysis was undertaken using RUSLE model, ArcGIS 10.2, Microsoft office Excel 2013 and different equations proposed by many authors. The slope length and steepness (LS factor) is derived from DEM by application of ARCGIS. The following figure shows overall methodology for generating RUSLE factors



Overall Methodology for generating RUSLE factors.

B. Calculation of RUSLE Factors

1) Rainfall Erosivity Factor (R factor)

The rainfall factor, is a measure of the erosive force of a specific rainfall. This is determined as a function of the volume, intensity and duration of rainfall and can be computed from a single storm, or a series of storms to include cumulative erosivity from any time period. Sheet and rill erosion is the dominant type of erosion in barren soil surfaces. For the present analysis, R factor for the Micro-Watershed (1E1C4a2) was computed from available rain gauge data, using the following equation , because the watershed has no record of daily rainfall intensity

Rfactor=79+0.363 (MAR)

= 330.824 MJ.mm$(\text{ha.h.yr})^{-1}$

Where; MAR= 693.73 mm (mean annual rainfall)

The rainfall erosivity factor (R) was found to be in the range of 330.824 MJ. Mm.. (ha.h.yr)

2) Soil Erodibility factor (K Factor)

The soil erodibility factor (K) represents the susceptibility of a soil type to erosion. K factor reflects the ease with which the soil is detached by splash during rainfall and /or by surface flow and therefore shows the change in the soil per unit of applied external force of energy. This factor is related to integrated effect of rainfall, runoff, and infiltration and accounts for the influence of soil properties on soil loss during storm events on sloping areas. This factor is obtained inherent soil properties. The sampling sites are chosen randomly so that each land cover or land use area is included. The equation reads as shown below:

$$K = 2.1 \times 10^{-6} \times M\,(12-OM)^{1.14} + 0.025\,(S-3) + 0.0325\,(P-2)$$

Where;

K= soil erodibility factor in t.ha/MJ.mm

M = (Percentage of very fine sand + Percentage silt) x (100-Percentage clay)

OM= Percentage of organic matter

S= Code according to soil structure (very fine granular + 1. Fine granular =2, coarse granular +3, lattice or massive + 4) and

P= Code according to the permeability /drainage class (fast-1, fast to moderately fast = 2, moderately fast =3, moderately fast to sow =4, slow =5, very slow =6

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To apply equation soil textural classes were estimated using the textural triangle for the purpose of determining S and P values According to textural classification system, the percentage of sand (size 0.05 to 2.0 mm), silt (0.005 to 0.05mm), and clay (size less than 0.005 mm) are plotted along three sides of an equilateral triangle. The equilateral triangle is divided into 10 zones and each zone indicates a type of soil. The soil can be classified by determining the zone in which it lies.

3) The topographic (LS) factor , takes rill erosion into account. Ther topographic factor consists of two sub-factor: a slope gradient factor and a slope length factor: The L factor
4) Is defined as the distance from the source of runoff to the point where either deposition begins or runoff enters a well defined channel that may be part of a drainage network. S factor reflets the slope steepness on erosion. The longer the slope length the grater is the amount of cumulative runoff.

Bothe the sub factors of topographic factor are determined from digital Elevation Model
(DEM) . Flow direction map was first generated from DEM. From flow direction map flow accumulation map was created. This was done in GIS environment. The LS factor was calculated from the following formula

$$LS=\left(\frac{\text{Flow accumulation x Cell size}}{22.13}\right)^{0.4} \text{ x } \left(\sin\frac{(\infty^{x3.14})}{(180\_\_\_\_)^{1.3}}\right)$$

0.0896

After calculating the value of LS and LS map was prepared in GIS environment. LS factor in Arc Map is calculated using Unit Stream Power Erosion Deposition (USPED)

5) Cover factor

The C -factor measures the effect of all interrelated cover and management variables. C factor is measured as the ratio of soil loss from land cropped under specific conditions to the corresponding loss from tilled land under continuous flow conditions.

In our study LULC (Land use land cover) map was used to estimate C- Factor distribution based on land cover classification results. Depending upon the vegetation cover obtained from imagery (LISS 2005), The value of C-factor was estimated from the table (Source: Soil and Water Conservation Society, 2003) shown below

Vegetation Classification	C-Factor
Natural Vegetation/ Forest	0.001
Agriculture/Crop	0.128
Grass/Scrub	0.003
Urban	0.03
Average	0.31

6) Support Practice (P) Factor

Usually, the P factor is determined from experimental data like satellite images aerial photos and some field observations The P factor is the ratio of soi loss with specific support practice to the corresponding loss with up and down slope tillage. The p factor was determined from experimental data like Satellite Images (LISS 20005) and some field observations. The below table represents the value of support practice factor according to the vegetation classification (Source: Soil and Water Conservation Society, 2003).

Vegetation Classification	P-Factor
Natural Vegetation/ Forest	1
Agriculture/Crop	0.92
Grass/Scrub	1
Urban	1
Average	0.96

IV. RESULTS AND DISCUSSION

Basically the erosion values obtained can through RUSLE depend upon the above six parameters of RUSLE and their values vary considerably due to varying weather conditions. The result of RUSLE parameters and average annual soil loss are presented as follow

Average rainfall of last 14 years (R) = 693.2 mm

R factor was then determined by subsisting the value of average annual rainfall in eqn[3.2]

R factor = 79+0.363R

$\boxed{\text{R factor} = 330.82}$

A. *Soil erodibility K factor*

The soil erodibility factor is obtained from the soil samples which were dried and and their texture was determined.

Sample No.	Clay%	Silt%	Coarse sand%	Fine Sand	Organic Corbon	Organic Matter
1	53.97	22	1.65	18.21	2.42	4.17
2	46.76	19	1.71	25.34	4.17	7.19
3	33.33	28	1.64	31.11	3.43	5.92
4	28.91	34	3.57	27.54	3.47	5.98
5	53.3	6	1.92	31.65	4.13	7.13
6	44.84	20	2.06	30.07	1.75	3.03
7	36.55	26	1.12	29.88	3.74	6.45
8	30.65	30	1.44	33.81	2.38	4.1
9	44.43	26	2.33	22.13	2.96	5.11
10	48.53	22	1.46	24.65	1.95	3.36
11	54.95	20	1.34	21.76	1.13	1.95
12	35.92	30	2.18	26.66	3.04	5.24
13	51.07	20	1.38	24.66	1.68	2.89
14	35.58	34	2.78	21.99	3.28	5.65
15	53.65	8	3.57	31.22	2.07	3.56
16	53.29	8	2.32	33.57	1.63	2.82
Average	44.11	22.06	2.03	27.14	2.70	4.66

Soil Texture analysis

After determining the texture and organic matter of soil samples and substituting the value of structural and permeability code(proposed by USDA) in the equation the erodibility value for each soil texture was estimated

M	S	P	100K	K
1850.8663	4	2	8.657	0.087
2360.6616	5	2	7.976	0.080
3940.8367	5	2	19.140	0.191
4374.8786	2	3	20.841	0.208
1758.255	4	2	5.233	0.052
2761.8612	1	4	16.211	0.162
3545.586	1	4	14.218	0.142
4425.2235	1	4	27.792	0.278
2674.5841	1	4	11.878	0.119
2401.0755	5	2	12.815	0.128
1881.288	5	2	11.631	0..116
3630.7728	5	2	18.982	0.190
2185.2138	5	2	12.889	0.129
3606.8758	5	2	17.733	0.177
1817.847	5	2	9.500	0..95
1941.7347	5	2	11.148	0.111

K value of samples

After determining the K values the K map can be prepared in Arc GIS software. This can be done by Kriging or IDW (Inverse Distance Weight) interpolation method.

Slope Length and Steepness LS Factor

The slope map can be prepared from the DEM of the area. A flow direction map can be prepared from the slope map and FD map can be used as input for the creation of flow accumulation map. These two raster's can be used along with the cell size of "30" The resulting raster is LS map of RUSLE eqn..

B. Annual Average Soil Loss

Rainfall erosivity , soil erodibility, slope length and steepness, cover management, and support practice factors are calculated. The RUSLE calculated the annual average soil loss (for the watershed) from the Eq. using the six factors and it is estimated as A=2.9246 Mg per ha per yr (2.9246 mega gram per ha per yr) which is equal to 2.9246 tonnes per ha per yr. The final of this study was compared to results from different watersheds in the area and concluded that overall result of this study is in an acceptable range.

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