Morphometric Analysis for Soil Erosion Susceptibility Mapping in Upper Mutha Valley Catchment Using GIS-based Model; Pune, Western Maharashtra

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Abstract

Morphometric investigation of a drainage basin is very important for qualitative as well as quantitative description and explanation of the drainage basin. Various drainage basin characteristics particularly geomorphological are being used for developing the various hydrological models and to solve problems associated with hydrological and natural resource degradation. Therefore, in the present research, to identify the sub-watersheds which are most vulnerable to soil erosion, quantitative analysis of different Morphometric parameters were carried out and according to those intensity wise priorities were assigned to 29 sub-watersheds of Upper Mutha River catchment using GIS- based model of multicriteria analysis.. Mutha River is a one of the major tributary of the Bhima River. Mutha River is one of the prime river basin in Pune district and acts as a major source of fresh water. The morphometric parameters like Drainage network, Basin Geometry, Drainage texture, Relief properties are considered for analysis. Soil loss prioritization showing three sub watersheds coded as are subjected to severe and very high conditions of erosion and needs some watershed treatment to control the high rate of erosion. Eight sub watersheds are subjected to high conditions of erosion. Four sub watersheds are subjected to moderate and eleven sub watersheds are experiencing low or slight erosion. The model based outputs validate by using multivariate analysis and test the hypothesis by Students-'t' test.

Keywords *Morphometric analysis, Soil erosion, Prioritization, Conservation.*

Introduction:-

Soil erosion due to water is a environmental problem in number of heavy rainfall areas. Its damage has harmful impacts not only on agriculture but also on economy of countries like India. In the world, 75 billion tons soil is eroded by different agents of soil erosion (D. Pimentel et.al, 2013). Water is the major agent of soil erosion. Soil conservation can be carry out using different qualitative and numerical analyses of morphometric parameters.

Drainage systems are best studied using Morphometric parameters are help to recognize different land facets, land-forms, soil-formation and development processes. It can be seen that Geospatial analytical techniques and models are also useful to statistical investigation of streams and their networks.

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Study Area for Investigation:-

The administrative setting of the study area is in the Mulshi and Haveli Tahsil of Pune district, which is 45 km from Puny city. The area exhibits rugged topography in the upper reaches and varies in altitude from 640m in the river valley to 1160 m on the ridges of the catchment boundary mostly at the north-west water divide.

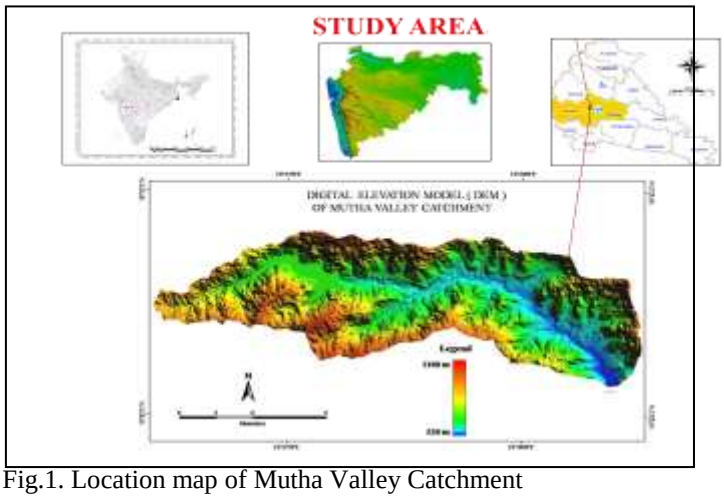


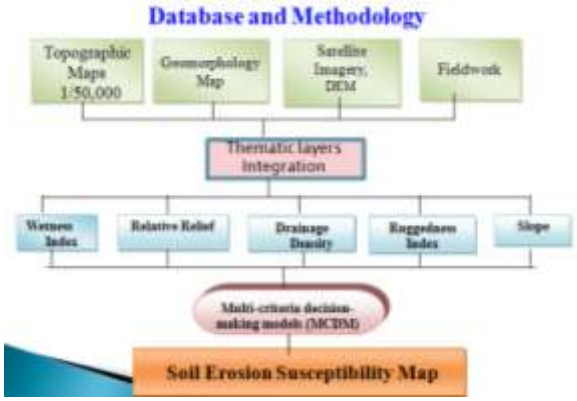
Fig.1. Location map of Mutha Valley Catchment

Major aim and Objective:-

1. To understand the susceptibility of soil erosion and prioritize the sub watersheds, GIS- based Multi-criteria analysis has used for different Morphometric parameter.
2. To validate output Multivariate Analysis has been performed.

Data and Methodology:-

Multi- Criteria Analysis is geospatial technique as a tool recommended for natural resource appraisal and management (Chowdary et al. 2003, 2008). These types of the models are required different geo-data-layers to execute outputs. In this study, to evaluate susceptibility areas of soil erosion different morphometric parameters i.e., relative relief, slope, drainage density, ruggedness index, and slope data layers are used . In this method the various layers are overlapped, considering different weight factors. Several thematic maps are generated in GIS environment to achieve combined framework of the study area and the soil erosion susceptibility areas.



Analysis, Result and Discussion:-

There are six steps to involved in analysis, these includes: (1) determination of the boundaries of 29 sub-watersheds using SOI toposheets on 1:50,000 scale (47 F/7 and 47 F/15) and ASTER DEM (30 m resolution); (2) To compute different Morphometric Parameters of Mutha valley catchment divided in to four classes of investigation and analysis i.e. Stream network analysis, Mutha Drainage Basin Geometry study, textural study of basin and Relief and landform properties like, density of Drainage (D), Stream frequency (Fs), ruggedness or dissection index (Rn), Average slope (S) in percentage, wetness index (wi) etc. (3) application of the MCA model used for some selective and important morphometric parameters to understand Soil Erosion Susceptibility areas in catchment. (4) Calculation the relative weight of each factor (29 sub-basins) and their prioritization using the composite grid-wise values of raster data; (5) Preparation of map of soil erosion susceptibility using the MCA model; and (6) validation of the final results by the multivariate PCA(Principal Component analysis) method and test the hypothesis using parametric Student's 't' test.

GIS based MCA (Multi-Criteria Analysis technique has been used to rate and weight the performance criteria guiding Soil erosion susceptibility mapping. The diverse factors used to find the Soil erosion susceptibility areas, are grouped mainly in three basic categories: lithological factors, drainage description, and morphometric parameters.

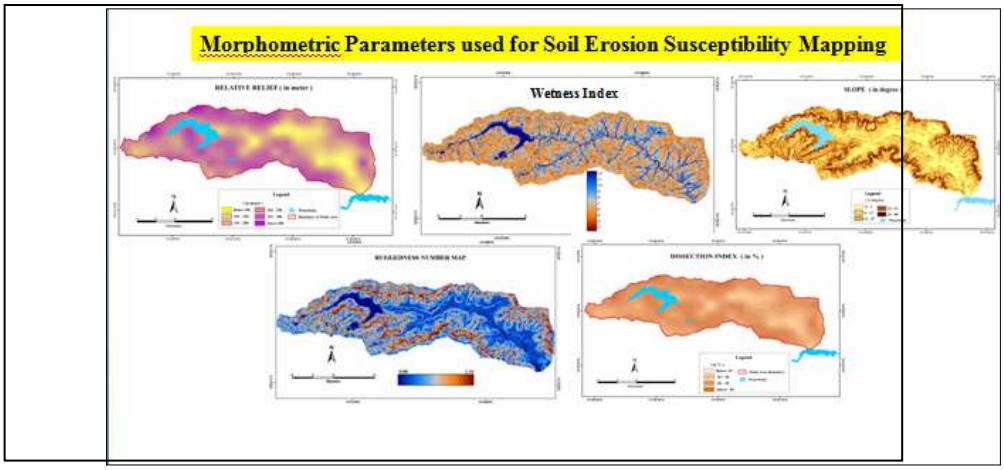


Fig.2.Different factors involved in analysis of Soil Erosion Susceptibility areas.

To calculate the Soil erosion susceptibility, spatial analysis tools of ArcGIS 10.0 software has been used. Each vector based thematic map layer has converted in raster layer using software function, the grid data structure of each raster was used and then assigned its specific weight and precise count in Multi-criteria function of software. Table-1 explain the different morphometric factors and assigned weight, fig. 2 depict the different factors involved in analysis of Soil erosion Susceptibility areas and fig.3 represent the composite prioritize map of Soil Erosion Susceptibility areas in Mutha Valley Catchment, which ranges from Very Low, Low, Medium, and high levels of priority.

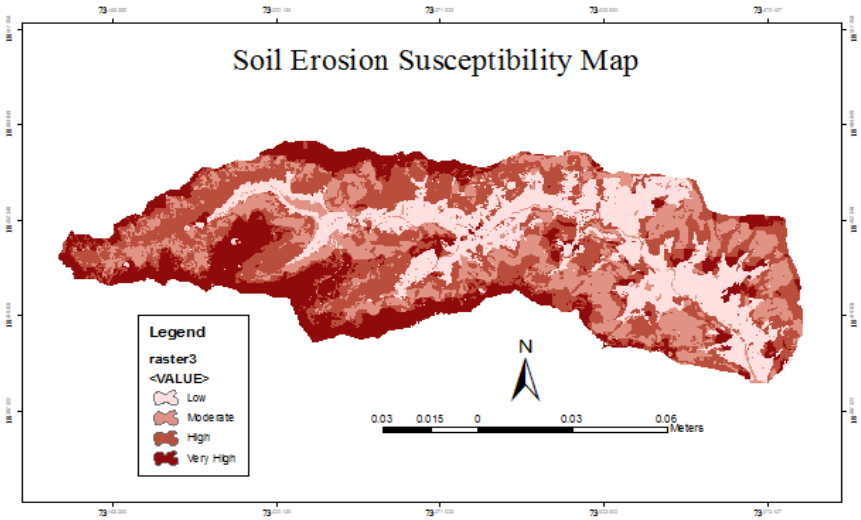


Fig.3. Priority levels of Soil Erosion Susceptibility areas in Mutha Valley Catchment

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Table-1; Weights assign to the affecting Morphometric Parameters

Morphometric Parameters		Score Values	Soil Erosion Category
Wetness Index	Very low Wetness Index	4	Very Low Soil Erosion
	Low Wetness Index	3	Low Soil Erosion
	Medium Wetness Index	2	Medium Soil Erosion
	High Wetness Index	1	High Soil Erosion
Relative Relief	Very low Relative Relief (< 10%)	4	Very Low Soil Erosion
	Low Dissection Index (10 – 20 %)	3	Low Soil Erosion
	Medium Dissection Index (20 – 30 %)	2	Medium Soil Erosion
	High Dissection Index (> 30%)	1	High Soil Erosion

Ruggedness Index	Very low Ruggedness Index	4	Very Low Soil Erosion
	Low Ruggedness Index	3	Low Soil Erosion
	Medium Ruggedness Index	2	Medium Soil Erosion
	High Ruggedness Index	1	High Soil Erosion
Dissection Index (%)	Very low Dissection Index (< 10%)	4	Very Low Soil Erosion
	Low Dissection Index (10 – 20 %)	3	Low Soil Erosion
	Medium Dissection Index (20 – 30 %)	2	Medium Soil Erosion
	High Dissection Index (> 30%)	1	High Soil Erosion
Drainage Density	Very low Drainage density (< 12/km^2)	4	Very Low Soil Erosion
	Low Drainage density (12 – 26/ km^2)	3	Low Soil Erosion
	Medium Drainage density (26 – 42/ km^2)	2	Medium Soil Erosion
	High Drainage density (42 – 90/ km^2)	1	High Soil Erosion
Slope in (%)	Very low slope values (0% – 7%)	4	Very Low Soil Erosion
	Low slope values (7% - 14%)	3	Low Soil Erosion
	Medium slope values (14% - 21%)	2	Medium Soil Erosion
	High slope values (21% - 29%)	1	High Soil Erosion

After grid wise calculation of the Morphometric parameters to find soil erosion susceptibility for the all 29 sub watersheds, (Fig.4.)it is observed that three sub watersheds are exposed to severe and very high soil erosion susceptibility areas require proper conservation planning to control soil erosion and conserve the resources. The Multi-criteria analysis showing Eight sub watersheds are subjected to high conditions of erosion. Four sub watersheds are subjected to moderate and eleven sub watersheds are experiencing low or slight erosion.

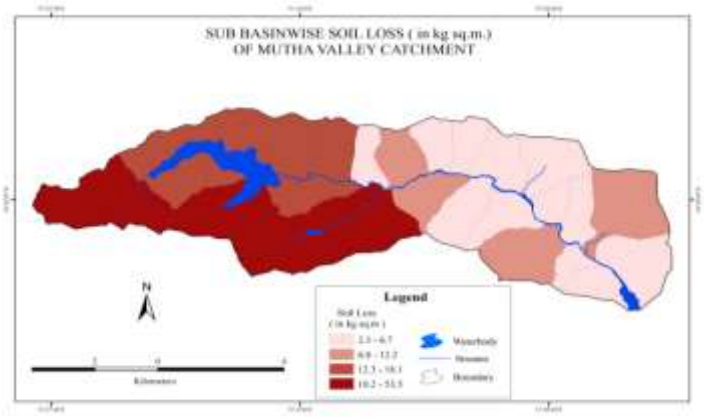

Fig.4. Sub- basin wise soil erosion susceptibility

Validation of Results using Multivariate analysis of different Morphometric parameters

The main aim of Multivariate analysis is to determinate the principal morphometric variables which are responsible for soil erosion in drainage basin. A multivariate analysis seems to be quite necessary to find out the relative importance of each variable/ parameters. The Principal component analysis is the suitable method to find principal morphometric parameters which are responsible for soil erosion in Mutha valley catchment.

Principal Component Analysis (PCA)

Table-2. Correlation matrix

Correlation Matrix	**WI**	**RR**	**DI**	**AS**	**RI**	**DD**	**SF**
AR	**1.00**	**0.85**	**0.63**	**0.32**	**0.58**	**0.17**	**-0.11**
RR		**1.00**	**0.97**	**0.39**	**0.75**	**0.09**	**-0.07**
DI			**1.00**	**0.25**	**0. 65**	**0.04**	**-0.01**
AS				**1.00**	**0.24**	**0.16**	**-0.08**
RI					**1.00**	**0.78**	**0.16**
DD						**1.00**	**0.28**
SF							**1.00**

Table.3. Computation for Prime or Principal Components.

Morphometric Parameters	Wetness Index	Relative Relief	Avg. Slope	Dissection Index	Ruggedness or Dissected Index	Drainage Density	Stream Frequency
P.C. 1 (58%)	0.76	0.82	0.49	0.77	**0.89**	0.55	0.26
P.C. 2 (13%)	0.01	0.32	0.39	0.41	-0.16	0.35	0.40

58% explained variance of first or Prime parameter that is ruggedness of dissected index, that showing main Morphometric parameter of Mutha river catchment and in 2nd principal component analysis ruggedness index showing negative influence in drainage basin dynamics. Without prime parameter other parameters are also important.

Test of significance of Morphometric Parameters

Table. 4. Assessment of different morphometric variables using Student's 't' Test

A	B	Correlation Coefficient value (r)	Calculated values of 't'	Table value of 't' on 0.01 level of significance and degrees of freedom is **141**
Ruggedness Index	Wetness Index	0.59	8.67	2.33
	Relative Relief	0.65	10.15	
	Dissection Index	0.60	8.30	
	Average Slope	0.42	6.84	
	Stream Frequency	0.52	7.12	
	Drainage Density	0.78	10.80	

Conclusion:-

Degradation of land in terms of soil erosion and soil erosion susceptibility mapping has been paid due attention in the present study so as to delineate the priority levels for conservation planning. The Multi-Criteria Analysis GIS based model is one of the best methods used for mapping of Soil Erosion Susceptibility and its mapping in study area. Morphometric parameter plays a very crucial role in mapping of Soil Erosion Susceptibility and help to conserve soil the important natural resource.

In the present study main or principal component showing as independent parameter that is Ruggedness or dissection factor and others are dependant factors. In the present situation negative or null hypothesis is rejected because all calculated values of different morphometric parameter are greater than tabulated value on the 0.01 level of significance. So, All the morphometric parameters are helpful for regionalization and representation of soil erosion susceptibility.

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