Universal Journal of Environmental Research and Technology
eISSN 2249 0256
Available Online at: **www.environmentaljournal.org**
2016 Volume 6, Issue 1: 27-35

Open Access **Research Article**

Application of Watershed Erosion Response Model in Planning Resource Conservation of Dehrang Catchment, District Raigad

Deshpande Yogesh*[1], Shindikar Mahesh[1], Jaybhaye Ravindra[2], Patil Sanjay[3]

[1] Applied Science Research Laboratory, College of Engineering, Pune (Autonomous)
[2] Department of Geography, S.P. Pune University
[3] Maharashtra Remote Sensing Applications Centre, Pune

***Corresponding Author: deshpandeys13.appsci@coep.ac.in**

Abstract:

Dehrang dam located in Panvel tahsil of Raigad district is the main source of water supply to the city of Panvel in district Raigad. However, the storage capacity of the reservoir is decreasing thus causing the water scarcity. The sediments accumulated as a result of erosion at the bottom of the reservoir is affecting the storage capacity of the reservoir ultimately leading to water scarcity and thus affecting the increasing population of Panvel city. The resource conservation of the catchment area is useful to reduce the sedimentation of the reservoir for which the priority areas should be decided to implement the conservation measures. Watershed Erosion Response Model has the ability to decide the priority areas for the conservation. Prioritization for the conservation of Dehrang catchment has been carried out by applying 'Watershed Erosion Response Model' in the present study. The remote sensing data and GIS techniques have also been found useful to apply this model. This model can be effectively applied to plan the resource conservation in the catchments of other reservoirs to mitigate the problem of sedimentation followed by water scarcity.

Keywords: Conservation, GIS, Panvel, Prioritization, WERM

1.0 Introduction:

Erosion is a major threat to land and water resources. The steep slopes, high rate of deforestation, poor irrigation practices and overgrazing are the main causes of soil degradation in many developing countries (Sreenivasulu and Udaybhaskar, 2010). The environmental degradation of a watershed due to natural or anthropogenic causes is threat to a reliable and acceptable water supply (Sinha and Punia 2000). Such degradation is reflected through the sedimentation that affects the quantity and quality of water. This has been evident by the environmental status report of the Panvel Municipal Council which stated the TSS of 35 Mg/l and turbidity of 40 NTU for Dehrang reservoir water. The natural process of soil erosion is responsible for the environmental problems like sedimentation of reservoir which decreases the water storage capacity eventually leading to the water scarcity. The loss of storage capacity of reservoirs due to siltation highlighted the need of watershed management in India. The sustainable development of water resources has become the key issue especially in densely populated urban areas. Soil erosion is a complex dynamic process of land denudation either by hydrological or by Aeolian processes (Jain and Goel, 2002), which results in siltation of reservoirs and natural streams (Biswas *et al*. 1999).

The entire catchment does not degrade uniformly and so its vulnerable parts need more attention than the other. Prioritization of watershed means the location and determination of vulnerable watershed which is in state of environmental degradation (Sinha and Punia, 2000). The selection of vulnerable watersheds on priority basis rather than treating the entire catchment is suitable in developing countries due to limitations of funds. The significant financial and manpower requirements need to be engaged in managing watersheds and so it becomes vital to select the proper smaller areas for better targeting of resource conservation programmes. The study of erosion and priority classification for conservation purpose is crucial for the proper watershed management strategies and can assist in implementation of soil conservation measures on a priority basis (Sreenivasulu and Udaybhaskar, 2010). Thus, it is essential to assign relative priorities to various parts of the catchment (Jain and Goel, 2002). The prioritization of catchment becomes significant as it lessens the expenditure and time in the management activities.

Watershed Erosion Response Model (WERM) can be applied to demarcate erosion susceptibility zones of the catchment (Sreenivasulu and Udaybhaskar, 2010; Jain and Goel, 2002). Jain and Goel (2002) applied WERM using Remote Sensing data and GIS techniques. They have divided the study area into different watersheds and found out the watersheds with maximum susceptibility to erosion. This model integrates the environmental factors to give the priority areas for the resource conservation within catchment areas. Geographical Information System provides reliable platform for the integration of these environmental factors. The main objective of the present investigation is to apply the 'watershed erosion response model' (WERM) to carry out the prioritization of Dehrang catchment for the resource conservation.

1.1 Study Area:

Dehrang catchment is located in Panvel and Karjat tahsils of Raigad district, Maharashtra (Fig.1). The catchment lies between 18°59'24" N to 19°3'59" N latitudes and 73°14'14" E to 73°17'14" E longitudes covering an area of 28.92 km^2. The catchment is mostly covered by protected forest area with some agricultural patches and few settlements. The catchment generally slopes from east to west and varies in altitude from85 m to 802 m. It exhibits mostly undulating topography and relatively gently sloping land near the reservoir.

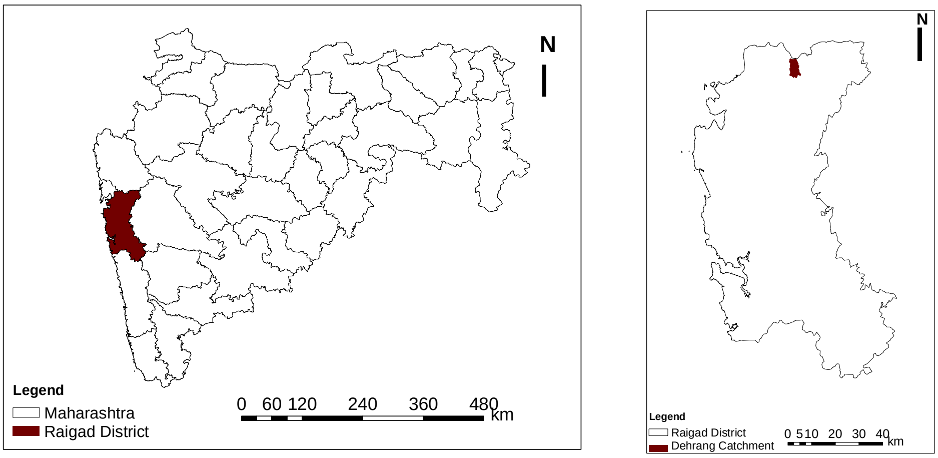

Fig. a: Location of Study Area

2.0 Materials and Methods:

The present study is based on topographical map and remote sensing data. The Survey of India Toposheet has been processed in GIS environment and the drainage network (Fig. 2) has been obtained from it. The Shuttle Radar Topography Mission (SRTM) data has been processed to get digital elevation model (DEM) and the contours (Fig. 2) have been generated. Dehrang catchment and its watersheds (Fig. 3)have been demarcated.The slope map has been prepared from DEM. The LISS IV data dated 21st December 2011 procured fromNational Remote Sensing Centre (NRSC) has been processed in ERDAS Imagine and vegetation cover map has been prepared.

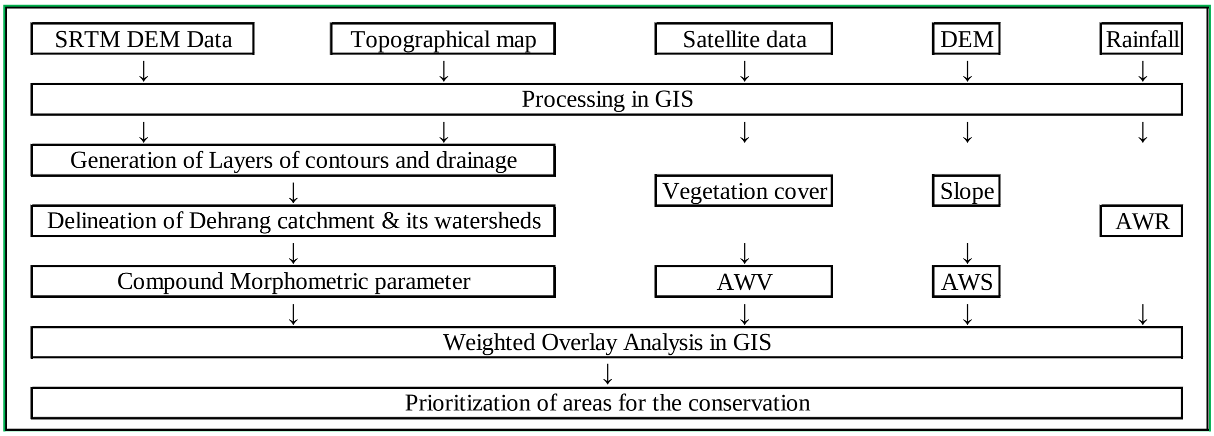

Table 1: Formulae for Estimation of Morphometric Parameters

Morphometric Parameter	Formula	References
Drainage density (Dd)	Lμ/ A	(Reddy, 2008)
Stream frequency (Fs)	Nμ / A	(Reddy, 2008)
Bifurcation ratio (Rb)	$N\mu / N\mu_{+1}$	(Singh, 2000)
Form factor (Rf)	A/Lb^2	(Singh, 2000)
Circularity Index (Rc)	$4\prod A/Pr^2$	(Singh, 2000)
Relief Ratio (Rh)	H/Lb	(Hajam *et al.*, 2013)

Table 2: Slope Range and the Weights Assigned

Slope (%)	0 to 1	1 to 3	3 to 5	5 to 10	> 10
Land	Level Land	Very Gently Sloping	Gently Sloping	Moderate Sloping	Steep sloping
Weight	1	2	3	4	5

2.1 WERM:

To carry out an assessment of the environmental factors responsible for soil erosion, Watershed Erosion Response Model (WERM) has been used in the present study. The WERM is based on prediction technology based on the principles of hydrology, plant science, hydraulics and erosion mechanics (Laflen, 1991). The environmental factors namely rainfall, slope, vegetation density and morphometric parameters are used in this model. These parameters are assigned with appropriate weights by taking into account their impact on soil erosion.

2.2 Morphometric Parameters:

These are termed as erosion risk assessment parameters. For the estimation of morphometric parameters of the demarcated watersheds initially, the stream ordering has been carried out by using Strahler's method and further stream number (Nμ), stream length (Lμ), area (A) and perimeter (Pr) of watershed have been obtained in GIS environment. Watershed length (Lb) has been obtained by the formula $Lb = 1.312\ A^{0.568}$ (Hajam *et al.*, 2013). The maximum and minimum elevations of each watershed have been obtained from DEM in GIS environment and the difference between them i.e. watershed relief (H) has been calculated.

Drainage density indicates the closeness of the spacing of the stream channels (Reddy, 2008) and the higher the drainage density more is the possibility of erosion(Sreenivasulu and Udaybhaskar, 2010). Higher drainage density is observed where soils are easily eroded or relatively impermeable (Nag, 1998, Reddy, 2008).Higher the value of stream frequency, higher is the runoff (Chandniha and Kansal, 2014). The relatively high bifurcation ratio indicates early hydrograph peak with a potential for flash flooding during the storm events while its lower value suggests higher permeability (Hajam*et al.*, 2013). Thus, the higher values of drainage density, stream frequency and bifurcation ratio have been assigned with maximum weight and lowest values with the minimum weight.

Form factor and circularity index indicating the shape of the watershed vary from 0 (highly elongated shape) to 1 (perfect circular shape)

(Singh, 2000). The higher the value of the form factor and circularity index, the more circular is the shape of the watershed (Singh, 2000) and watershed with the circular shape is the most hazardous since it produces the peak flow within shortest time of concentration (Ratnam *et al.*, 2005, Javed *et al.*, 2009). Shape of watershed is also responsible for movement of silt (Sreenivasulu and Udaybhaskar, 2010). The more elongated the shape of watershed, the lower the possibility of silt load reaching to its outlet (Sreenivasulu and Udaybhaskar, 2010).Thus, the highest values of the form factor and circularity index have been assigned with maximum weight and lowest values with the minimum weight.

Relief ratio indicates the intensity of erosional process acting on the ground slope (Hajam*et al.*, 2013). Thus, the highest value of relief ratio has been assigned with the maximum weight and lowest value with the minimum weight. After assigning the weights to the watersheds for each morphometric parameter, the compound morphometric parameter value for each watershed has been obtained.

2.3 Slope:

The process of erosion is mostly influenced by the steepness of slope. Slope also affects the soil stability (Sreenivasulu and Udaybhaskar, 2010). More the slope more is the carrying capacity of the channels and more the chances of soil detachment. The areas with steep slope are more susceptible to soil erosion as compared to areas with gentle slope. Accordingly, the catchment has been divided into five slope classes and the weights have been assigned to them. Very low rainfall has been assigned with minimum weight '1', low rainfall with '2', moderate rainfall with '3', high rainfall with '4' and very high rainfall with '5'.

Area weighted Slope (AWS) has been calculated for each watershed by using the following formula.

$$AWS = \left(\sum_{i=1}^{5}(Ai \times wSi)\right) \div \sum_{i=1}^{5} Ai$$

where Ai is the area under i^{th} slope class and wSi is the weight for i^{th} slope class.

2.4 Vegetation:

Vegetation of a catchment is the other main factor which governs the soil erosion process in the catchment (Sreenivasulu and Udaybhaskar, 2010). The areas with poor vegetation are more susceptible to soil erosion as compared to areas with densevegetation. Accordingly, the catchment has been divided into five classes and the weights have been assigned to them. Very dense vegetation has been assigned with minimum weight '1', dense vegetation with '2', moderate vegetation with '3', poorvegetation with'4' and extremely poor vegetation with '5'.Area weighted Vegetation (AWV) value has been calculated for each watershed by using the following formula.

$$AWV = \left(\sum_{i=1}^{5} Ai \times wVi\right) \div \sum_{i=1}^{5} Ai$$

where Ai is the area under i^{th} vegetation class and wVi is the weight for i^{th} vegetation class.

2.5 Rainfall:

The areas with high rainfall are more susceptible to soil erosion as compared to areas with low rainfall. Accordingly, the catchment has been divided into five classes and the weights have been assigned to them. Very low rainfall has been assigned with minimum weight '1', low rainfall with '2', moderate rainfall with '3', high rainfall with'4' and very high rainfall with '5'.Area weighted Rainfall (AWR)value has been calculated for each watershed by using the following formula.

$$AWR = \left(\sum_{i=1}^{5} Ai \times wRi\right) \div \sum_{i=1}^{5} Ai$$

where Ai is the area under i^{th} rainfall class and wRi is the weight for i^{th} rainfall class.

2.6 Prioritization for Conservation:

The weighted overlay analysis has been carried out in GIS environment. This technique is used for integrated analysis by applying a common measurement scale to varied input parameters. The present study uses common measurement scale of '1 to 8' for different environmental parameters. The highest compound parameter value has been assigned with weight '8' while the lowest compound parameter value with weight '1'.Similarly the highest AWS value has been assigned with weight '8' while the lowest AWS value with weight '1' whereas the lowest AWV value has been assigned with weight '8' and the highest AWV value with weight '1'. The reasoning for this is the watershed with higher slope causes higher erosion and watershed with higher vegetation amount causes the lesser erosion (Sreenivasulu and Udaybhaskar, 2010). Finally, the weighted overlay analysis has been carried out and priority areas for the conservation within Dehrang catchment have been found out.

3.0 Results and Discussion:

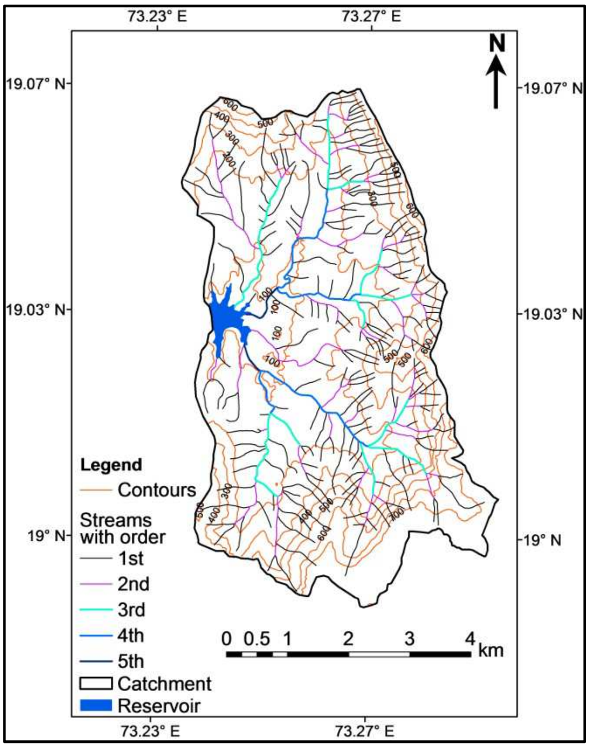

Fig. b Contour and Drainage Map

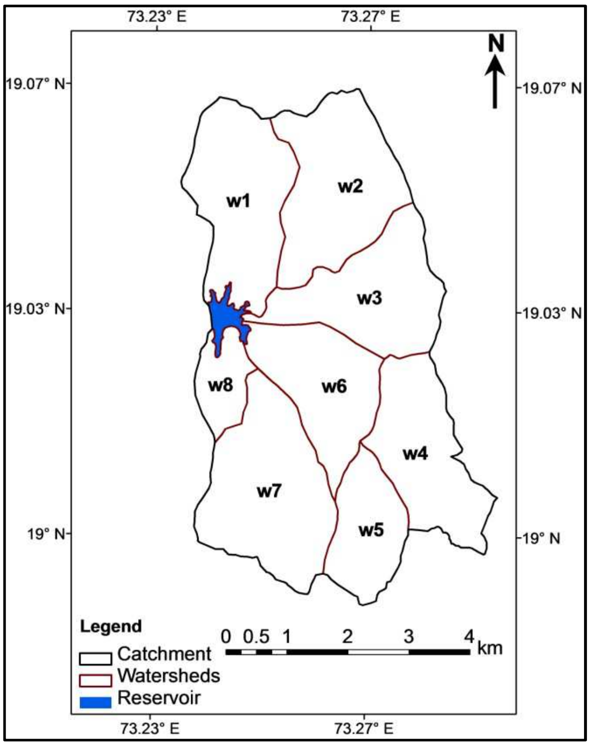

Fig. c Delineation of Watersheds

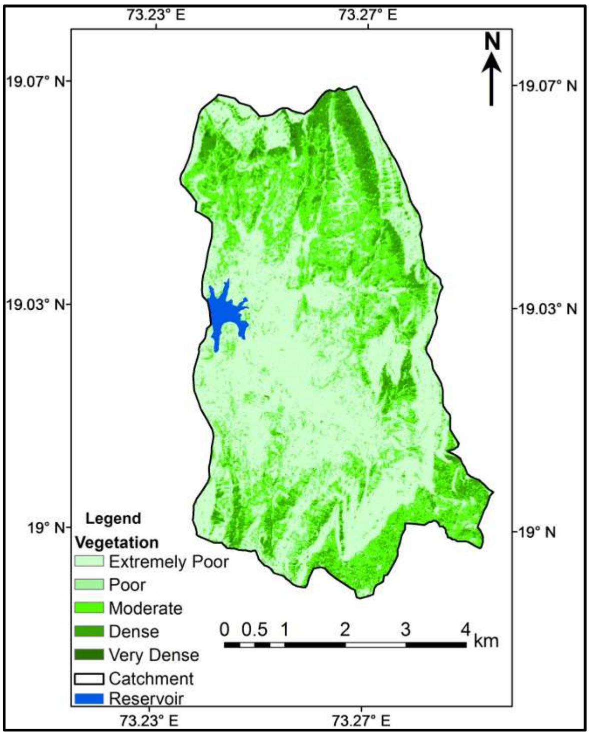

Fig. d: Vegetation Cover Map of Dehrang Catchment

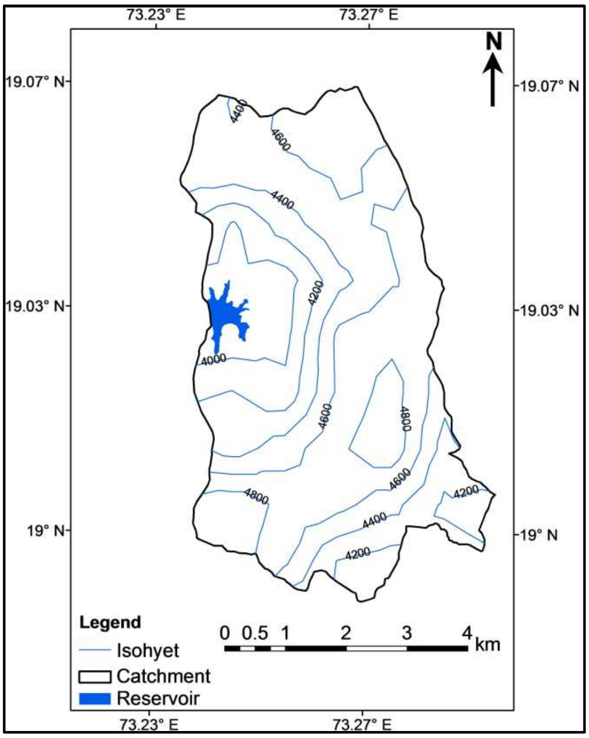

Fig. e: Rainfall Map of Dehrang Catchment

Table 3: Morphometric Measurements of Watersheds of Dehrang Catchment

Watershed	N_1	N_2	N_3	N_4	Nµ	A	P	Lb	Lµ	Z	z	H
w1	23	3	1	-	27	4.40	11.18	3.05	17.40	699	85	614
w2	41	12	2	1	56	4.67	9.81	3.15	26.61	658	90	568
w3	40	11	3	1	55	3.97	10.00	2.87	22.86	660	85	575
w4	23	8	2	1	34	2.34	6.50	2.12	14.36	785	146	639
w5	13	3	1	-	17	1.19	5.71	1.45	7.07	802	151	651
w6	21	5	-	-	26	3.77	9.53	2.79	16.43	539	85	454
w7	29	6	2	1	38	5.18	9.72	3.34	20.68	778	94	684
w8	5	2	-	-	7	3.41	8.74	2.63	4.18	299	85	214

Nµ: Stream Number, Lµ: Stream Length, A: Area of watershed, P: Perimeter of watershed, Lb: Length of Watershed, Z: Maximum elevation of watershed, z: Minimum elevation of watershed, H: Relief of watershed

Table 4: Morphometric Parameters of Watersheds of Dehrang Catchment

Watershed	Dd	Fs	Rb	Rf	Rc	Rh
w1	3.95	6.13	5.33	0.47	0.44	0.20
w2	5.7	12	3.81	0.47	0.61	0.18
w3	5.75	13.84	3.43	0.48	0.5	0.20
w4	6.14	14.55	2.96	0.52	0.7	0.30
w5	5.96	14.33	3.67	0.57	0.46	0.45
w6	4.36	6.89	4.2	0.48	0.52	0.16
w7	4	7.34	3.28	0.46	0.69	0.20
w8	1.23	2.05	2.5	0.49	0.56	0.08
Average	4.64	9.64	3.65	0.49	0.56	0.22

Dd: Drainage density, Fs: Stream frequency, Rb: Bifurcation ratio, Ff: Form factor,
Rc: Circularity Index, Rh: Relief Ratio

The watersheds 'w2', 'w3', 'w4' and 'w5' lie in the eastern part of the catchment which is highly undulating area show the higher values of drainage density and stream frequency. The watershed 'w4' with highest drainage density (6.14) and highest stream frequency (14.55) has been assigned highest weight and the watershed 'w8' with lowest drainage density (1.23) and lowest stream frequency (2.05) has been assigned lowest weight. Highest bifurcation ratio (5.33) is observed for watershed 'w1' and has been assigned highest weight while lowest value (2.5) is observed for watershed 'w8' which has been assigned the lowest weight.

The highest values of form factor (0.57 for watershed 'w5') and circularity ratio (0.7 for watershed 'w4') have been assigned with highest weight while the lowest values of form factor (0.46 for watershed 'w7') and circularity ratio (0.44 for watershed 'w1') have been assigned with lowest weight. The watershed 'w5' shows highest relief ratio (0.45) and has been assigned with highest weight while the watershed 'w8' having lowest relief ratio (0.08) has been assigned with lowest weight. The watersheds 'w4' and 'w5' lying in the eastern part show relief ratio values very high than the average value.

Further, the compound morphometric parameter values for all watersheds of Dehrang catchment have been obtained (Table 5) and the largest value has been assigned with highest weight and smallest value with lowest weight.

Table 5: Compound Morphometric Parameter (CMP) of the watersheds

Watershed	Weights Assigned						CMP
	Dd	Fs	Rb	Rf	Rc	Rh	
w1	2	2	8	3	1	5	3.50
w2	5	5	6	2	6	3	4.50
w3	6	6	4	4	3	4	4.50
w4	8	8	2	7	8	7	6.67
w5	7	7	5	8	2	8	6.17
w6	4	3	7	5	4	2	4.17
w7	3	4	3	1	7	6	4.00
w8	1	1	1	6	5	1	2.50

The values of area weighted slope (AWS), area weighted vegetation (AWV) and area weighted rainfall (AWR) have been obtained (table 6)

Table 6: Parameter Values for 'WERM'

Watershed	w1	w2	w3	w4	w5	w6	w7	w8
CMP	3.50	4.50	4.50	6.67	6.17	4.17	4.00	2.50
AWS	4.64	4.78	4.71	4.91	4.70	4.45	4.82	4.57
AWV	3.92	3.52	4.11	4.04	4.04	4.85	4.31	4.69
AWR	2.05	3.19	3.04	3.24	2.67	2.98	3.48	1.69

Thus, AWS value is highest for watershed 'w4' attracting higher weight and lowest for watershed 'w6' attracting lower weight. The AWV value is highest for watershed 'w6' attracting lower weight and lowest for watershed 'w2' attracting highest weight. The AWR value is highest for watershed 'w7' attracting higher weight and lowest for watershed 'w8'attracting lower weight.

3.1 Prioritization for Conservation:

The weighted overlay analysis (Table 7) performed in the GIS environment. The higher the susceptibility to erosion the higher should be the priority for the conservation. Weighted overlay analysis has been performed in GIS environment and the result has divided the area into the five priority classes for the conservation as shown in the figure f.

Table 7: Parameters of 'WERM' and the Weights Assigned

Watershed	w1	w2	w3	w4	w5	w6	w7	w8
CMP	2	6	5	8	7	4	3	1
AWS	7	3	4	1	2	5	6	8
AWV	7	8	4	5	6	1	3	2
AWR	2	6	5	7	3	4	8	1

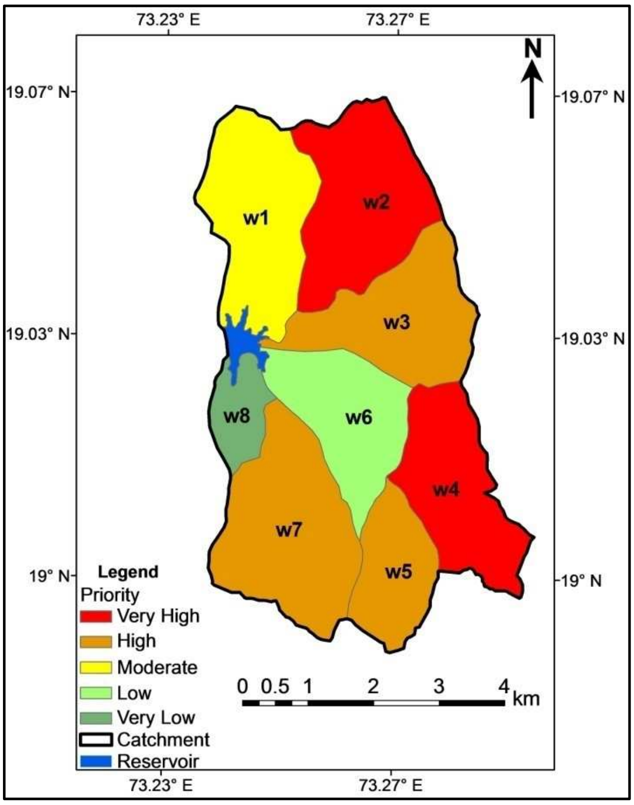

Fig. f: Prioritization for Conservation of Dehrang Catchment

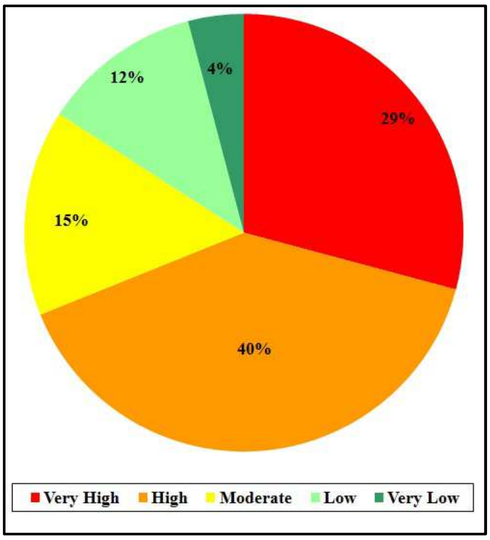

Fig. g: Area under Priority Classes

The watersheds 'w2' and 'w4' show the highest priority followed by the watersheds 'w3', 'w5' and 'w7'. The watershed 'w1' shows the moderate priority while the watersheds 'w6' low and 'w8' very low priority for the conservation.

4.0 Conclusion:

The resource conservation measures should be implemented first to the watersheds 'w2' and 'w4' and then to the watersheds 'w3', 'w5' and 'w7'. The watersheds 'w1' shows low priority for conservation while the watersheds 'w6' and 'w8' should be considered at last for the purpose of conservation. The results of prioritization have shown that about 16 % area of the catchment is least important for the conservation that lies in the central part which is relatively gentle area of the catchment. About 40 % area needs high priority for the conservation. About 29 % area that lies in the eastern part of the catchment which is mostly undulating found most susceptible to erosion and must be immediately undertaken for the implementation of resource conservation measures that will control the erosion and further sedimentation in the Dehrang Lake. The Watershed Erosion Response Model (WERM) integrates various environmental parameters such as ground slope, vegetation, rainfall and morphometric parameters and can be effectively used to get the erosion susceptibility zones of the catchment. Thus, WERM has found to be useful for the delineation of priority areas for the resource conservation of Dehrang catchment. The remote sensing data made it easy to apply the model. The GIS techniques also play a vital role in applying WERM.

5.0 Acknowledgement:

Survey of India for topographical map, National Remote Sensing Centre, ISRO for LISS IV data and United States Geological Survey for SRTM data.

References:

1) Biswas, S. Sudhakar, S. & Desaiand V.R. (1999) Prioritisation of Sub-Watersheds Based on Morphometric Analysis of Drainage Basin: A Remote Sensing and GIS Approach. *J. Indian Society Of Remote Sensing,* 27(3): 155-166
2) Chandniha, S. K. And Kansal, M. L. (2014): Prioritization of Sub-Watersheds Based on Morphometric Analysis Using Geospatial Technique in Piperiya Watershed, *India. Appl. Water Sci.,* 1–10.
3) Hajam, R., Hamid, A. And Bhat, S. (2013): Application of Morphometric Analysis for Geo-Hydrological Studies Using Geo-Spatial

Technology- A Case Study of Vishav Drainage Basin. *Hydrol Current Res*, 4: 157.
4) Jain, S. K. and Goel, M. K. (2002): Assessing the Vulnerability to Soil Erosion of the Ukai Dam Catchments Using Remote Sensing and GIS. *Hydrological Sciences*, 47(1): 31-40.
5) Javed, A., Khanday, M. Y. and Ahmed, R. (2009): Prioritization of Subwatersheds Based on Morphometric and Land Use Analysis Using Remote Sensing and GIS Techniques. *J. Indian Society of Remote Sensing*, 37: 261-274.
6) Laflen, J. M. (1991): WERM- A Next Generation of Erosion Prediction Technology. J. *Soil Water Cons*. 46: 34-38.
7) Nag, S. K. (1998): Morphometric Analysis Using Remote Sensing Techniques in the Chaka Sub-Basin, Purulia District, West Bengal. *Journal of the Indian Society of Remote Sensing*, 26:69-76.
8) Panvel Municipal Council (2015): Environmental Status Report, 32-33.
9) Ratnam, K. N., Srivastava, Y., Rao, V. V., Amminedu, E. and Murthy, K. (2005): Check Dam Positioning By Prioritization of Micro-Watersheds Using SYI Model and Morphometric Analysis – Remote Sensing and GIS Perspective. *J. Indian Society of Remote Sensing,* 33: 25-38.
10) Reddy, P. (2008): A Textbook of Hydrology, University Science Press, New Delhi, 91-93.
11) Singh, S. (2000): Geomorphology, Prayag Pustak Bhawan, Allahabad, 361-362, 368-369.
12) Sinha, A. K. and Punia, M. (2000): Watershed Erosion Response Model (WERM) for Prioritization and Management of Multifunctional Watershed: Experience from Western India in Brandt, J., B. Tress, and G. Tress (Editors): Multifunctional Landscapes: Interdisciplinary Approaches to Landscape Research and Management. Conference Material for the Conference on 'Multifunctional Landscapes', Centre For Landscape Research, Roskilde, October 18-21, 2000, 226.
13) Sreenivasulu, Vemu and P. Udaybhaskar (2010): An Integrated Approach for Prioritization of Reservoir Catchment Using Remote Sensing and Geographic Information System Techniques. *Geocarto International,* 25:2, 149-168.