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Watershed Development Prioritization by Applying WERM Model and GIS Techniques in Takoli Watershed of District Tehri (Uttarakhand)

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Abstract— Conservation of soil and land in hilly region is an expensive and critical process. This conservation measures need various steps starting from the identification of most vulnerable and erosion prone region. The identification and appropriate treatment measure will also help in formulation of integrated water resource management programme for sustainable development. Uttarakhand State is one of the important area where such information can be utilized. Takoli watershed is one of the important watershed of Tehri district Uttarakhand. The main objective of the present study is to determine the vulnerability of catchment to erosion for further prioritization of Takoli watershed. For the present study IRS P6 Satellite images of LISS III sensors is used to assess land use/land cover and vegetation indices by applying NDVI technique, while a GIS system is used to evaluate the topographical condition. For assessing the relative vulnerability of different watershed to soil erosion the factors responsible for soil erosion were considered using the Watershed Erosion Response Model (WERM). This is an index-based approach, based on the surface factors mainly responsible for soil erosion. The integrated effect of all the parameters is evaluated by applying weighted overlay technique of GIS to find different areas vulnerable to soil erosion. The analysis reveals that about 11.48 % area is most susceptible to soil erosion. Based on the integrated index, a priority rating of the watersheds for soil conservation planning is recommended for watershed development and management.

Keywords— Watershed, WERM, Soil Erosion, Weighted Overlay, NDVI.

I. INTRODUCTION

Uttarakhand is a hilly area where water and soil resources have got immense importance. However, continuous failure of monsoon, increasing demand and over exploitation of these resources leads to water and soil degradation. This problem could be sorted out to certain extent by constructing water and soil conservation structures. The development of land and water resources on a sustainable basis without deterioration and with a constant increase in productivity is the mainstay of mankind. Soil erosion is a complex dynamic process of land denudation by which productive surface soils are detached, transported and accumulated at a distant place. The detachment of soil particles occurs either by hydrological (fluvial) processes of sheet, rill or gully erosion, or through the action of wind. Soil erosion results in loss of precious soil resources for cultivation and causes siltation of reservoirs and natural streams. The problems of land degradation are prevalent in many forms throughout the state. In absence of comprehensive and periodic scientific surveys, estimates have been made on the basis of localized surveys and studies.

Numerous treatment technologies in the form of engineering measures and agronomic practices are available. But all these measures are costly and cumbersome. Hence, identification of most vulnerable areas to apply suitable technologies as per the site conditions and their application in correct way is most important to achieve the desired results. These technologies when adopted within the boundary of watershed, facilitates favorable interaction among various watershed factors such as physiographic, land slope, soil characteristics, land use, hydrological behavior etc. Drainage basins, catchments and sub-catchments are the fundamental units for the management of land and water resources. Catchments and watersheds have been identified as planning units for administrative purpose to conserve these precious resources.

One criterion, generally used to determine the vulnerability of catchments to erosion, is the sediment yield of a basin. In India, sediment yield data are generally not collected for smaller sub-catchments and it becomes difficult to identify the most vulnerable areas for erosion that can be treated on a priority basis. The All India Soil and Land Use Survey (AISLUS), established in 1988, have been assigned the task of

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priority delineation. Initially, the AISLUS conducted soil surveys in the upper parts of catchments using Survey of India (SOI) topographic maps and village cadastral maps. Erosion control treatments were started in the upper parts of the catchments with a view that treatments taken up in the downstream catchments at later stages would not be adversely affected by unprotected upper reaches. The present investigation aims to put forward a scientific approach to handle the integrated watershed management strategy through a case study implemented to demonstrate the watershed prioritization exercise.

II. Study Region

The region selected for the present study is Takoli gad watershed which is located in Devaprayag block of Tehri district .It lies between 78°37'46.541"E & 30°19'42.129"N and occupy the area of 27.8762 sq.km. The region is diversified by physiographic condition which consists of dense forest, open forest, wasteland and agriculture land. The region receives rainfall between 97-100cm annually.

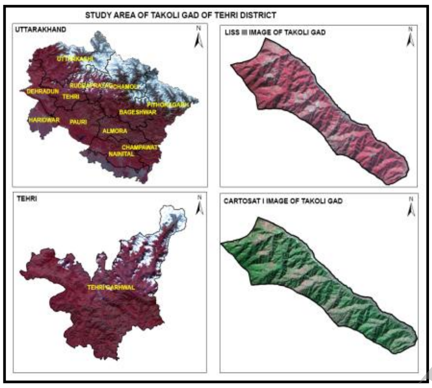

Figure-1

Geological And Geomorphological map of Tehri Garhwal

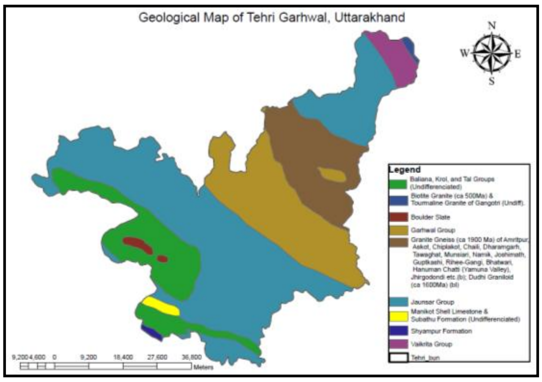

Figure-2

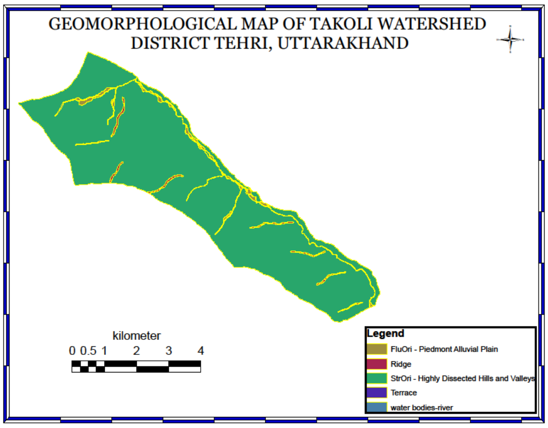

Figure-3

III. Methodology

Satellite remote sensing provides reliable and accurate information on natural resources, which is pre-requisite for planned and balanced development at watershed level. Integration of Remote sensing and GIS techniques provides reliable, accurate and update database for watershed management.

In assessing the relative vulnerability of different watersheds to soil erosion, the major factors responsible for soil erosion were considered using the Watershed Erosion Response Model (WERM). It is one of the most commonly used models for qualitative prioritization of watershed. The major factors responsible for soil erosion includes rainfall, soil type, vegetation, topographic and morphological characteristics of the basin. In assessing the relative vulnerability of different watersheds to soil erosion, the major factors responsible for soil erosion were considered using the Watershed Erosion Response Model (WERM).

It is one of the most commonly used models for qualitative prioritization of watershed. The major factors responsible for soil erosion includes rainfall, soil type, vegetation, topographic and morphological characteristics of the basin.

For land use and land cover mapping, images of IRS P6 satellites of LISS III sensor are used. Remotely sensed data usually contains both systematic and unsystematic errors, which are being removed through rectification. Image was registered geometrically using topographic maps. The common uniformly distributed Ground Control Points (GCPs) were marked with root mean square error less than 0.002-0.008 and the images were resample by using cubic convolution method. As the image covers adjacent areas, a subset image has been taken out for further analysis. Six classes are identified by applying supervised classification technique. To assess the biomass conditions NDVI approach is used by applying following formula:

NDVI=NIR-VIS/NIR+VIS ……. (1)

Where NIR = Near Infrared

VIS = Visible Red

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Aster DEM of Takoli gad watershed was used for the estimation of slope factor. Knowledge based weight assignment was carried out for each thematic layer and they were integrated and analyzed by using the weighted overlay technique (ESRI, 1988). Weighted overlay only accepts integer raster's as input so continuous (floating point) raster's have been reclassified as integer before they can be used.

SOFTWARE USED
I. Erdas Imagine
II. 10Arc GIS 10.1

IV. WATERSHED PRIORTIZATION BY APPLYING WATERSHED EROSION RESPONSE MODEL (WERM)

In assessing the relative vulnerability of different watershed to soil erosion, the factors responsible for soil erosion were considered using the watershed erosion response model (WERM) is a process based on prediction technology built on the fundamentals of hydrology, plant science, and hydraulics and erosion mechanism.

V. PARAMETERS FOR WERM MODEL

Parameters used for WERM are slope, vegetation density, land use / land cover condition and rainfall .the suitable weight were assigned to each thematic layer after considering their influence upon soil erosion

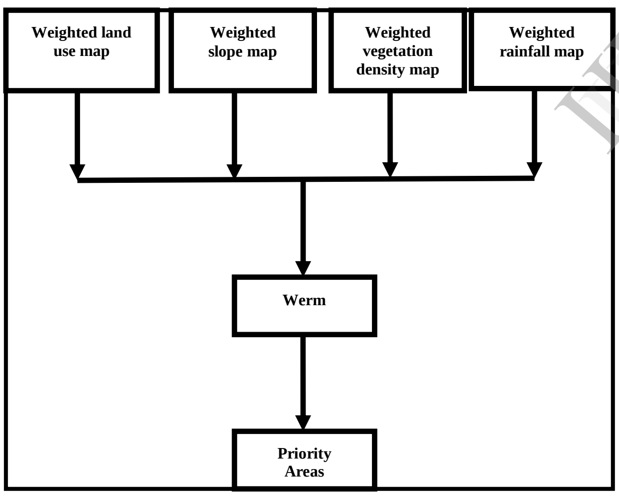

Figure-4, METHODOLOGY TO DERIVE PRIORITY AREAS

VI. RAINFALL

The amount and intensity of rainfall affect the sediment yield from a basin. The high rainfall areas are highly vulnerable to soil erosion as compare to low rainfall areas. In the study region, rainfall decreases from west to east. By assessing the rainfall conditions, three rainfall classes have been identified and appropriate weight age is assigned.

Table-1 Weight Assigned For Rainfall Classes

Rainfall class	Rainfall	Assigned weight
High	>500	3
Medium	250-500	2
Low	<250	1

VII. VEGETATION

Vegetation reduces the raindrop capability to detach soil particle and significantly affects the erosion process the effectiveness of vegetation depends on the height and continuity of canopy, density of ground cover and the root density .generally forest are most effective in reducing erosion because of their large canopies. A numbers of methods have been used to identify different phonological stages of vegetation, including the application of the normalized difference vegetation index (NDVI), which is used as an indicator of vegetation condition. The NDVI index is calculated and classified in to the five classes with suitable weights.

Table-2 Weight Assigned For Vegetation.

Vegetation class	Assigned weight
Very dense vegetation	1
Dense vegetation	2
Medium vegetation	3
Poor vegetation	4
No vegetation	5

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VIII. SLOPE

The topographic feature that mostly influences the erosion process is the degree of slope, a higher slopes resulting in higher erosion .with the advent of GIS technique, it is now possible to prepare the digital elevation model (DEM) of an area.

Table -3 Weight Assigned For Slope Classes.

Slope class	Percentage slope	Assigned weight
Nearly level	0-1%	1
Very level	1-3%	2
Gentle	3-5%	3
Moderate	5-10%	4
Strong	10-15%	5
Steep	15-35%	5
Very steep	>35%	5

IX. LAND USE/ LAND COVER

Land use land cover plays a very crucial role in soil vulnerability analysis. The land under vegetation cover is less vulnerable as compare to follow and barren land. The thick forest and grassland prevents soil erosion. Land should be used properly by considering its capability and limitations otherwise it would cause severe soil erosion. Supervised classification technique is used to classify IRS P6 data set and six classes are identified and appropriate weight has been given accordingly.

Table-4 Weight Assigned For Land Use /Land Cover Classes

Land use land cover	Assigned weight
Water Body	Restricted
Forest	1
Grassland	2
Agriculture Land	3
Fallow Land	4
Barren Land	5

The integrated effect of all four parameters considered in this study, the individual weights of all the parameters were added together. This sum was further sub divided in to four different categories for the purpose of assessing the relative vulnerability ,and codes were assigned to each category Areas with higher final weight were considered to be most vulnerable to soil erosion Thus an area with code of above 14 is highly vulnerable to soil erosion and must be given the highest priority for the purpose of sustainable development by adopting suitable water and soil conservation measure .The range of accumulated weight and the corresponding priority code is given in Table -5

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Table -5 Ranges Of The Accumulation Weight And Corresponding Priority Areas.

Range Of Accumulate Weight	Vulnerability	Code
>14	Very High	1
11-14	High	2
8-11	Medium	3
<8	Low	4

X. PRIORITIZATION OF WATERSHED

Weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis .by applying this technique four priority areas have been suggested by considering slope, rainfall, vegetation and land use land cover condition .For the analysis purpose water body is considered as a restricted category.

S.No	Prioritization	Area(Sq.Km)	%
1	Very High	3.2029	11.48%
2	High	10.38035	37.2456%
3	Moderate	10.1789	36.5230%
4	Low	3.9361	14.1233%
Total		27.87	100

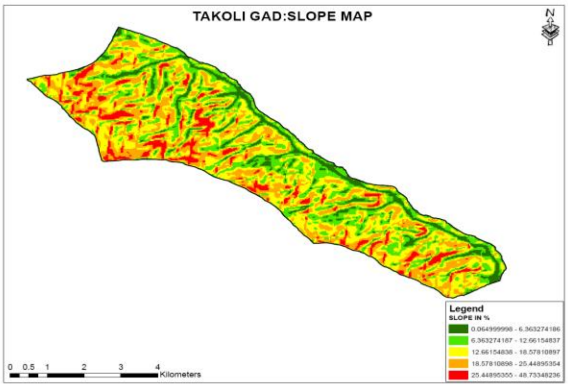


Figure-5

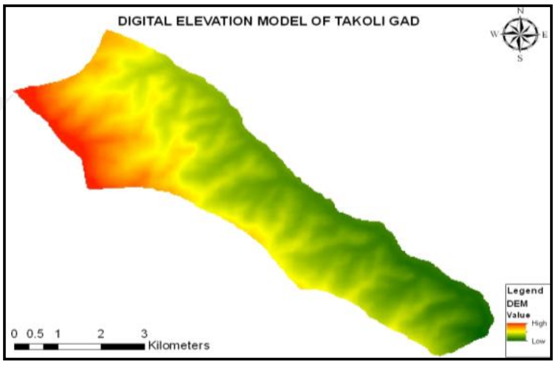


Figure-6

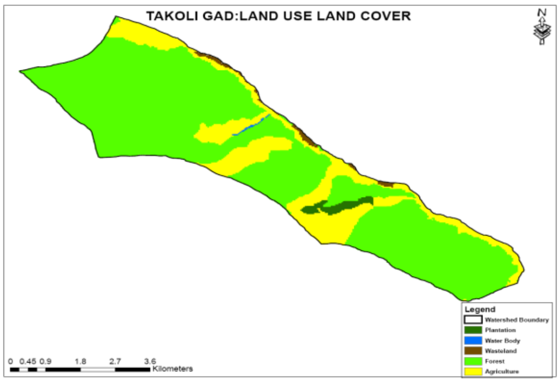
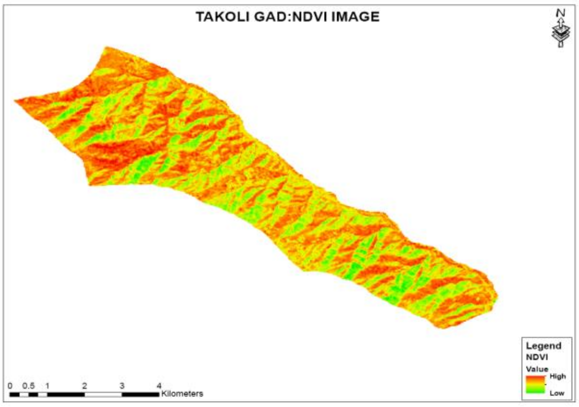


Figure-7



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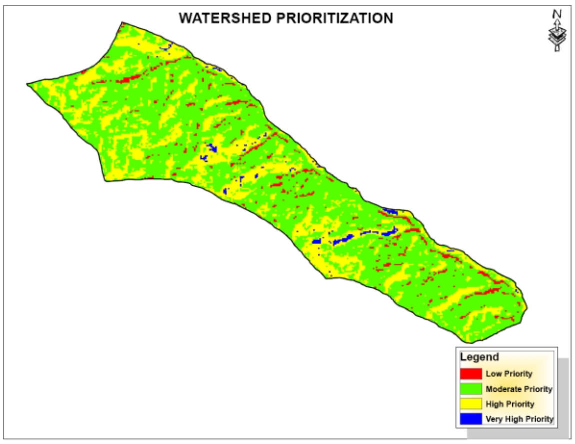

Figure-9

The soil analysis reveals that the very high vulnerable area is sandy skeletal with steep slopes and have severe erosion landform .This category accounts for 3.2029 sq. km (11.48 %).The major factor that contribute to soil erosion potential in this area were assessed, in this area mainly steep slopes, lack of vegetation and barren land are the dominant factors for soil erosion .This area must be brought under vegetations through proper afforestation. High priority areas are situated adjacent to very high priority areas. The total area which comes under this class is about 10.38 sq km (37.245%), Barren land, hilly areas and rainfall are the responsible factors for soil erosion in this region.

XI. Conclusion

The analysis reveals that its significant topographical and land use variation offers a suitable site for watershed prioritization study .Areas within watershed with different soil erosion potentials have been assessed with a view for adopting soil conservation measures. The very high priority areas have higher erosivity values due to their location in the hilly terrain with undulating topography. Because of the slope condition, and the rocky surface the soil erosivity values range from moderate to high. The low priority areas are mostly cropped lands with gentle slope and thick forest areas. These areas have good vegetations cover and therefore do not need immediate attention.

This application is useful to help the watershed managers in objectively prioritizing the watershed with respect to the stipulated norms. The application can also be used for monitoring and evaluation of the watershed programme which is an important component, but is in variably missing.

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