A Case Study Of Ramgad Watershed, Nainital For Soil Erosion Risk Assessment Using CORINE Methodology

Peeyush Gupta and Swati Uniyal

Uttarakhand Space Application Centre, Dehradun, Uttarakhand, India

Abstract

Soil erosion is the major threat, among others, to the conservation of the soil and water resources. Even though soil erosion can be caused by geomorphological processes, anthropological or accelerated erosion, which is mainly favoured by human activities, is the major trigger factor for the loss of soil and water resources. Soil erosion has accelerated on most of the world, especially in developing countries, due to different socio-economic, demographic factors and limited resources (Ni and Li, 2003).

There are various factors which play important role for the erosion of soil and important among them are vegetation cover, topography, soil and climate. Therefore, there is a need to accurately assess soil erosion and thereby determine the specific control measures adaptable to these conditions and Remote Sensing (RS) and Geographic Information System (GIS)-based soil erosion risk assessment models continue to play an important role for soil conservation planning. There are various models and processes involved in GIS for soil erosion and coordination of information on the environment (CORINE) is one useful model among them and has great potential for producing accurate erosion risk maps.

In the present study soil erosion risk of Ramgad watershed, Nainital was evaluated based on topographic, land use, climatic parameters and vegetation characteristics with regard to general erosion risk in the watershed area which basically includes the simulating erosion potential in the watershed area and CORINE methodology was used here in integration with GIS. The results of study indicate that in Ramgad Watershed 24.9%, 52.2% and 22.76% of area are under low, moderate and high actual erosion risk respectively.

Keyword: *CORINE, RS, GIS, Erosion, Watershed.*

1. Introduction

Soil to mankind is a basic natural resource. Man depends on plants, and plants grow on soil. Soil indeed occupies an important role in the biosphere. But at present time Soil erosion is one of the most important ecological problems which is threatening our soil resources day by day. Soil erosion is one form of soil degradation along with soil compaction, low organic matter, and loss of soil structure, poor internal drainage, salinization, and soil acidity problems. These other forms of soil degradation, serious in themselves, usually contribute to accelerated soil erosion. Problems associated with land resources are increasing at a tremendous rate. Good quality land is scare, and often negatively affected by inadequate use. Soil erosion is one of the most difficult problems facing the world, particularly in country as ours and this problem is important for us because India is a primarily agricultural country where land is by far the most valuable asset we have. Beside this India's physiography, topography, climate, monsoon everything is different and unpredictable.

Problems associated with soil erosion, movement and deposition of sediment in rivers, lakes and estuaries persist through the geologic ages in almost all parts of the earth. But the situation is aggravated in recent times with man's increasing interventions with the environment. Rapid population increase, technological development, decreasing forest land to gain more agricultural land, deteoriation of forest areas caused by fires and overexploitation, uncontrolled use of agricultural lands and pastures without any prevention cause to increase of erosion and soil losses. Besides these facts, some natural hazards also increase the soil erosion.

Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks. Soil losses and erosion is one of main causes of fertility decreasing, sedimentation in canals and irrigation canals and rivers, decreasing of storage capacity in dams, increasing of floods frequency, environmental pollution and it prevents from stable development.

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils. Erodibility is majorly influenced by texture, organic matter, stoniness and structure in perception of both water storage and resistance to sediment detachment and transport (Kirkby et al. 2000).

Factors contributing to erosion are

1.1. Land use Humans play a major role in soil erosion through their use and abuse of natural resources for example deforestation, grazing, arable land use, faulty farming systems, high crop intensity, housing construction, and mining etc.

1.2. Climate The two most important climatic factors having a direct effect on erosion are precipitation and wind velocity. Other climatic factors have an indirect effect on soil erosion, such as water balance, evapotranspiration, temperature and relative humidity. Indirect factors affect the erosivity of rainfall by altering the soil moisture regime and the proportion of rainfall that may become surface runoff. For erosion control it is necessary to investigate physical characteristics of rainfall, including the amount, distribution, intensity, energy load, seasonality and variability of rainfall and the formation and course of surface runoff.

1.3. Soil The susceptibility of a soil to erosion is influenced by its physical, hydrological, chemical and mineralogical properties as well as its soil profile characteristics. Important soil physical and hydrological properties that affect the resistance of a soil to erosion include texture, structure, and water retention and transmission properties.

1.4. Hydrology Infiltration, surface detention, overland flow velocity, and subsurface water flow are important soil erosion components of the hydrological cycle. The different types of flow and their velocities may be turbulent or laminar, steady or unsteady, uniform or non-uniform and influence the extent of erosion.

1.5. Landforms Slope gradient; slope length and shape of slope are the important variables of landform that affect erosion processes for all types of soil erosion, e.g., splash, sheet, rill, and gully erosion.

1.6. Vegetation cover The amount of soil erosion is also affected by vegetation cover as Soil erosion potential is increased if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of surface runoff and allows excess surface water to infiltrate.

Assessing the soil erosion rate is essential for the development of adequate erosion prevention measures for sustainable management of land and water resources. Geographic Information System (GIS) technologies are valuable tools in developing environmental models through their advance features of data storage, management, analysis, and display (Burrough, P.A; McDonnell, 1998). RS and GIS integrated erosion prediction models do not only estimate soil loss but also provide the spatial distributions of the erosion. Especially generating accurate erosion risk maps in GIS environment is very important to locate the areas with high erosion risks and to develop adequate erosion prevention techniques.

In this study for the sake of soil erosion risk mapping or can say for the qualitative evaluation of the potential erosion areas, Remote sensing and GIS technology has been used in the framework of CORINE (Coordination of information on the Environment) for Ramgad watershed, Nainital. CORINE METHODOLOGY is a standard method to determine erosion risks and qualities of the lands and in the present study prove to be an important tool to assess potential erosion risk areas along with actual erosion risk areas in the form of spatially distributed maps.

2. Study area

This study is the assessment of soil erosion risk area of Ramgad watershed. Ramgad watershed located on $29^{0}27''$ N and $79^{0}37''$ E Nainital is a lake city and famous tourist destination of Uttarakhand.

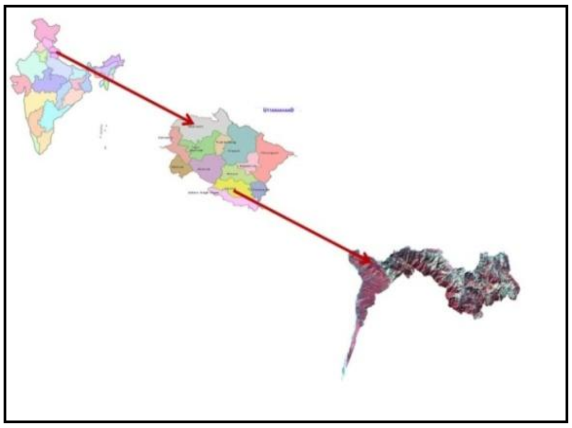


Fig.1:-Study area

2.1. Soil
The area having different types of soil as Alluvial sandy loam sandy, fertile, clay soil, brown forest soil, red black, clay soil.

2.2 Climate
The monthly maximum and minimum temperatures in the town range between 280C and 70C. The rainy season arrives earlier than in the plains and continues up to the end of September. The heaviest rainfall is observed on the outer slopes of the hills. Average annual rainfall in Nainital is 2583.3 mm. Maximum rainfall occurs normally in the months of July and August which accounts for nearly 50% of the total of annual rainfall. During winter, very low temperatures are encountered because of rainfall.

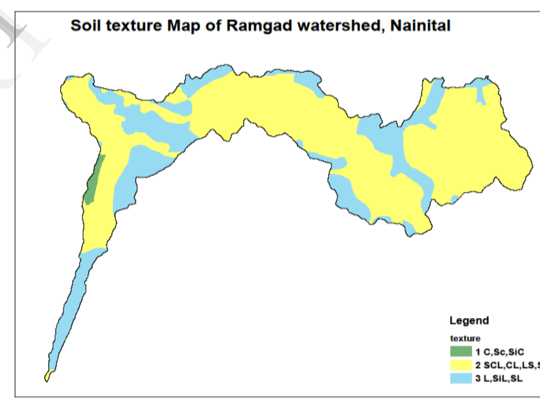
2.3 Vegetation type
Rich in flora (typical temperate climate plants).The hilly region is covered with Sal, Pine, Oak, Buruns, and Kafal and other trees growing unto6000 ft. along with Deodar, Surai at higher altitudes. There are small tracts of cultivated lands and fruit orchards in between the forests in this region. The Bhabhar region has Babul, Kikar in abundance besides Sal, Khair, and Shisham as big trees and Bhabhar grass and lantana form the undergrowth. These are considered to be the vegetation of dry and arid zones. Haldu is also common in Bhabhar region. The aquatic flora comprises of *Potamogeton pectinatus*, *Potamogeton crispus*, *Polygonum glabrum*, *Polygonum amphibian*, *Polygonum hydropiper* (Water pepper) and *Hydrilla verticellata*. Several species of medicinal flora and horticulture plants have also been reported. Forest types are moist, temperate, subtropical, pine, subalpine.

3. Materials and Methodology
The methodology requires the preparation of erodibility map, erosivity, Slope, and land surface information as an essential database for generation of potential soil erosion risk map and actual soil erosion risk map. For preparation of erodibility map database of soil texture, soil depth and stoniness is required, studies were carried out over study area and digital soil map was prepared in figure 2.

Information on the surface stoniness and texture classes of each map unit was added to the soil database. Distribution of different texture, stoniness and depth classes according to their area in per hectare in watershed and their percentage is shown in table 1.

Soil texture, depth and stoniness map then prepared and according to CORINE methodology all three were regrouped in figure (2,3,4) and then crossed in GIS environment and the erodibility map prepared by this and again reclassified into low, medium and high erodibility classes in figure 7.

Fig.2:-Soil texture map



Texture			
S.No	**Class**	**Area (ha)**	**%**
1	C, SC, Si C	526.5	0.92
2	SCL,CL,LS,C	40542.75	70.63
3	L, Si L, SL	16335	28.46
Depth			
S.No.	**Class**	**Area (ha)**	**%**
1	> 75	15030	26.18
2	25-75	35088.75	61.13
3	< 25	7285.5	12.69
Stoniness			
S. No.	**Class**	**Area (ha)**	**%**
1	> 10%	23312.25	40.61
2	< 10%	34092	59.39
3	-	-	-

Tab.1 Spatial distribution of soil texture, depth and stoniness in hectare and percentage of the whole area

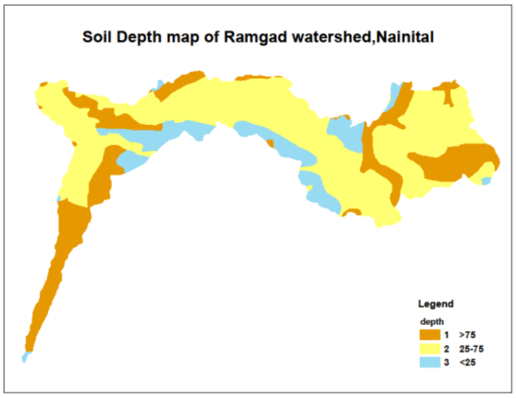


Fig.3:-Soil Depth map

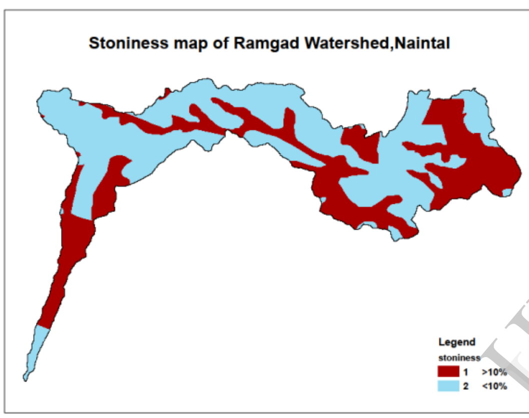


Fig.4:-Stoniness map

3.1 Soil erosivity

Soil erosive factors are both precipitation and temperature and play an efficient role for soil physical and chemical properties. So, here both are investigated simultaneously. For CORINE methodology Fournier index (FI) as precipitation index and Bagnouls–Gaussen aridity index (BGI) as drought index are incorporated to the calculation.

FI is calculated by the formula given below

$$FI = \sum_{i=1}^{12} Pi^2/P$$

Where Pi is the total precipitation fall in (i) month (mm) and P, the annual average amount of precipitation (mm).For calculation of this index for study area monthly precipitation data had been taken from the website of India water portal for the years 1990-2011and feed in the above equation and similarly FI index has been calculated for the study area.

BGI is calculated by the formula given below

$$BGI = \sum_{i=1}^{12} (2ti - Pi)Ki$$

Where ti is the monthly average temperature value in the month (i) (_C), Pi the total precipitation fall in (i) month (mm), and ki the evaluation of the month when (2ti - Pi>0).

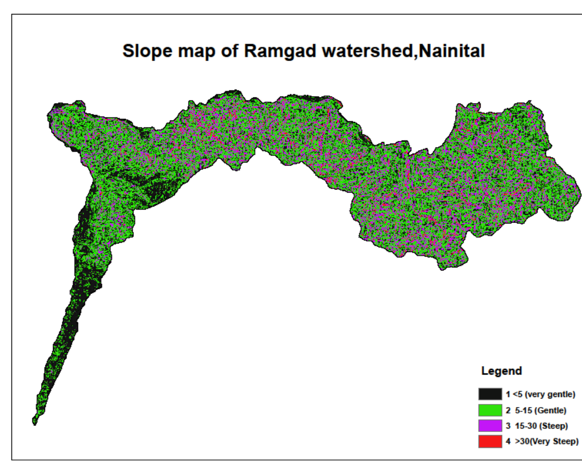
For this index calculation large time period temperature data has been taken and index has been calculated. After calculation of both the indexes Soil erosivity has been calculated by multiplying both and according to CORINE index classes it fall under 3 index classes.

3.2 Potential soil erosion and actual soil erosion

After calculating soil erosivity index, in GIS environment soil erodibility, slope map prepared from aster DEM (figure 5) and erosivity have been crossed and potential soil erosion risk map produced which was reclassified according to low, medium and high classes figure 8. The all three classes of potential erosion map along with their area in hectares and their percentage are shown in table 4.

Actual soil erosion risk map has been obtained by overlaying both potential risk map and land use land cover map prepared by visual interpretation technique in which all the forest area, grasslands has been put in productive class and the area left behind put under non-productive class shown in figure 6. Table 5 is showing the comparison of area and their respective percentage in different classes of both potential and actual erosion risk map.

Fig.5 Slope map



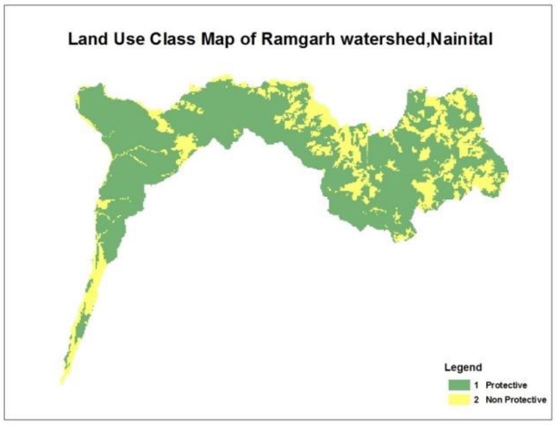


Fig.6:-Land Use/Land cover map

Slope			
S.No.	**Class**	**Area (ha)**	**Percentage**
1	< 5	14163.05	24.71
2	5-15	29022.01	50.62
3	15-30	12271.22	21.41
4	> 30	1872.165	3.27

Land use class			
S.No.	**Class**	**Areas**	**Percentage**
1	Productive	42716.25	74.44
2	Non-Productive	14667.75	25.56

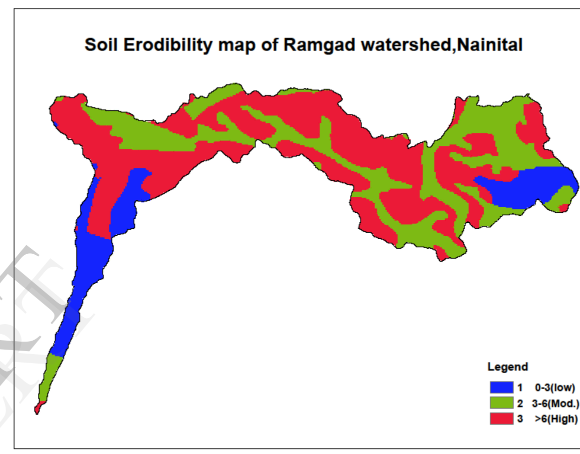
Tab.2: Spatial distribution of Slope and Land Use category in the study area in ha and %

4. Result and Discussion

The results indicate that in the study area for soil texture class 0.92% of total area is under clayey soil, while 70.63% of area is under loamy sandy category and 28.46% of area is under loamy texture class. So, soil of the study area is more susceptible to erosion because maximum percentage of soil in the study area is of loamy category which has maximum potential for soil erosion. Similarly depth of the soil in the watershed area fall in the category of very deep (26.18%), moderately deep (61.13%) and low deep (12.69%) so according to this area is susceptible to erosion and regarding stoniness part 40.61% of area has >10% stoniness and 59.39% area has <10% stone cover which is also an indicator of high erosion because more will be the stones over the area less will be the soil able to erode and vice versa. Then the erodibility map was prepared which clearly indicate that 14.85 % of the study area is under low erodible Soil, 33.07% of the study area is under moderate erodible and 52.08% of the study area is under highly erodible Soil.

Soil Erodibility			
S. No	**Class**	**Area (ha)**	**Percentage**
1	Low	8525.25	14.85
2	Moderate	18983.25	33.07
3	High	29895.75	52.08

Tab.3 Spatial Distribution of Soil erodibility in the study area in ha and %
Fig.7 Soil erodibility map



The erosivity index which is obtained by multiplying FI and BGI index is found for the study area under class 3 that is highly erodible class. The slope map which is obtained from Carto DEM indicate that 24.71% of the study area has slope less than 5%, 50.62% of the area has slope in the category of 5-15%, 21.41% of the area has slope in the category of 15-30% and 3.27 of the area has >30% category which clearly indicates that study area has more percentage of steep slope compare to gentle so area more susceptible to erosion.
Potential Soil erosion risk map has been prepared by overlaying slope, erosivity and erodibility map. This clearly indicate that the area is how much susceptible for erosion results shown in the table 4 indicating that 6.53% of the area is under low category,26.02% of the area under medium and 67.45% of the area is highly erodible.

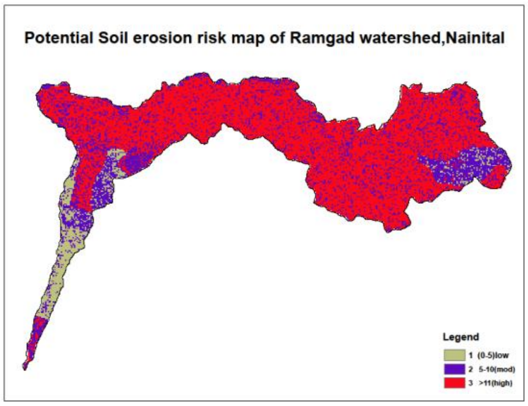


Fig.8 Soil erodibility map

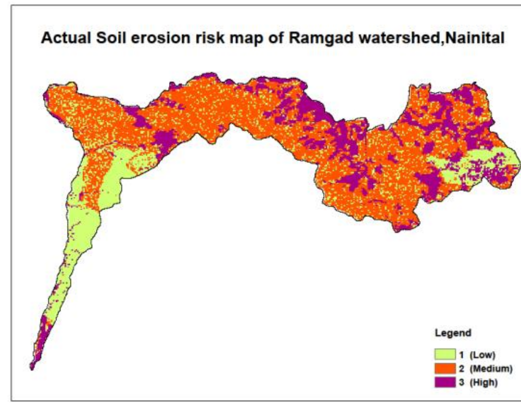


Fig.9 Actual Soil erosion risk map

The land use land cover map for the study area has been classified into two broad classes protective which includes all the forest area and other class is non-protective which includes area which is not under forest because forest area binds the soil and decreases the probability of erosion in comparison of open or agricultural area. By overlaying potential soil erosion risk map and vegetation map actual soil erosion risk map has been prepared.

Potential Soil erosion Risk			
S. No	Class	Area (ha)	Percentage
1	Low	3696.75	6.53
2	Medium	14730.75	26.02
3	High	38191.5	67.45

Tab.4 Spatial Distribution of Potential Soil Erosion risk map of the study area in ha and percentage

Potential Soil erosion Risk			
S.No	Class	Area (ha)	Percentage
1	Low	3696.75	6.53
2	Moderate	14730.75	26.02
3	High	38191.5	67.45
Actual Soil Erosion Risk			
S.No	Class	Area (ha)	Percentage
1	Low	14076	24.95
2	Moderate	29499.75	52.29
3	High	12843	22.76

Tab.5 Comparison between potential and Actual soil erosion spatial distribution in the study area in ha and %

This map indicates that 24.95% of the area is under low erosion category, 52.29% is under medium and 22.76% of the area is under highly erodible class.

On comparing both potential and high erodible class it has been found that vegetative cover has reduced the probability of highly erodible area as reduction in percentage of high erodible class has been noticed for the area and increase in percentage of both low and moderate class has been noticed in actual erosion risk map compared to potential erosion risk maps.

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