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Watershed management of dal lake catchment (J&K) based on erosion intensity hazard using geospatial technique

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ABSTRACT

Watershed management is the optimal use of soil and water resources within a given geographical area so as to enable sustainable production.Watershed prioritization has gained importance in natural resources management, especially in the context of watershed management. Erosion intensity analysis has been commonly applied to prioritization of watersheds. The investigation of basins for planning soil conservation requires a selective approach to identify smaller hydrological units, which would be suitable for more efficient and targeted conservation management programme. One criterion, generally used to determine the vulnerability of catchments to erosion, is the erosion intensity mapping. The quantitative analysis of erosion intensity is an important aspect of characterization of watersheds. Using micro-watershed as a basic unit in erosion intensity analysis is the most logical choice because all hydrologic and geomorphic processes occur within the watershed. The present study makes an attempt to prioritize twenty five micro-watersheds of Dal lake catchment of Srinagar district, Jammu and Kashmir, based on erosion intensity analysis, using remote sensing and Geographical Information System. Accordingly twenty five micro-watersheds have been classified into four categories based on very severe erosion intensity unit as very high, high, medium and low in terms of priority for conservation and management. The result of the erosion intensity analysis has revealed that micro-watersheds DMW1, DMW5, DMW7, DMW9 and DMW23 fall under very severe erosion class and are more susceptible to soil erosion and hence technical measures has been suggested for the very high priority micro-watershed.

Introduction

The transport of detached sediment from the watershed areas through the drainage network, gives rise to appreciable loss of soil fertility, rapid sedimentation of the reservoirs and decrease in available water for irrigation in command areas. Many human activities affect the characteristics and conditions of watersheds and therefore, affect the quality and quantity of water to reduce soil erosion, planning, conservation and management of the watershed is vital. Watershed management is an integrated method of management of water, land and environment within a topographic boundary. Conservation of soil and water plays an important role in a watershed management.

Proper planning at smaller hydrologic units like milli and micro watershed level is a prerequisite for development of the drainage channels. Therefore it is recognized that a watershed based approach to restoration is necessary for healthy and productive watersheds. It also recognizes that we will not be able to restore all degraded areas at once even with the most aggressive proposed management. The sensible approach is to undertake an inventory of the land and water resources available and then use a systematic planning method to make the best use of resources. An attempt to assess the erosion intensity hazard and prioritization of watersheds for treatment would aid for better planning in combating this menace. Therefore, there is a need to assign relative priorities to different regions within a catchment (Jain and Goel, 2002). The prioritization process identifies the highest priority watershed(s) or erosion susceptibility zone in which to conduct management. Watershed prioritization is the ranking of different micro-watersheds of a catchment according to the order in which they have to be taken for treatment and soil conservation measures. Once the micro-watersheds were prioritized, quantitative assessment of erosion intensity of micro-watersheds serve as basic information for adopting suitable soil and water conservation measures in a micro-watershed.

The rapid evolution in satellite remote sensing and Geographical Information System (GIS) has made possible the development of new techniques for facilitating the mapping of degraded / eroded lands (Skidmore et al. 1997). Remote sensing data provides accurate timely and real time information on various aspects such as size and shape of the watershed, land use/land cover, physiography, soil distribution, drainage characteristics etc. During the last few decades remote sensing and Geographical Information System (GIS) approaches has gained importance in soil loss estimation, generating overlays and making site-specific decisions (Irvem et al. 2007; Wu and Wang 2007 ; Sekhar and Rao 2002; Hazarika and Honda 1999). Multi-spectral remotely sensed satellite data plays a vital role in the generation of the overlays (Shibani 2007). Remote sensing data is being extensively used in watershed studies especially for making site specific decisions.

In the present study an attempt has been made to quantify erosion intensity of micro-watersheds of Dal lake catchment and

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prioritize micro-watersheds based on erosion intensity in which to conduct management. The present study involves the use of remote sensing and Geographic Information System (GIS) analysis techniques to evaluate erosion intensity of twenty five (25)micro-watersheds of Dal lake catchment. For Erosion intensity mapping, land use/land cover map of the micro-watersheds was carried out using multi-temporal data of IRS-1C LISS III of 2006. The slope map for the study area was generated from the contours of Survey of India (SOI) toposheets at 1:50,000 scale following a 40 m contour interval, whereas Soil map was generated using secondary data obtained from Division of the Soil Sciences Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST). A composite erosion intensity unit map on 1:50,000 scale was prepared using the thematic maps of slope, land use, soil class, soil depth. This composite map was then superimposed on the drainage map with micro-watershed boundaries in order to obtain micro-watershed wise composite erosion intensity unit map.Based on composite erosion intensity unit map, the micro-watersheds having the high value for very severe erosion intensity unit was assigned highest priority, next lower value was assigned second priority and so on. The micro-watershed which had the lowest value of very severe erosion intensity unit was assigned last priority. Thus an index of very high, high, medium and low priority was produced and hence technical measures have been suggested for the very high priority micro-watershed.

Study Area

The study area is situated between the geographical coordinates of 34°02´ - 34°13´ N latitude and 74°50´ - 75°09´ E longitude. The catchment has an area of approx. 328 km², nearlyhalf of which comprises the Dachigam National Park. The Dal lake catchment is a fan shaped and broadens in the westward direction. The climate of the study area is sub-humid temperate with an average annual rainfall of about 951.53 mm. The maximum temperature rises up to 37°C in June, while minimum temperature can be as low as -14°C in January. The catchment is surrounded by Sindh basin in the north and Jehlum basin in the south directions. Marsaris a glacial oligotrophic alpine lake and is major feeding source to the famous Dal Lake.

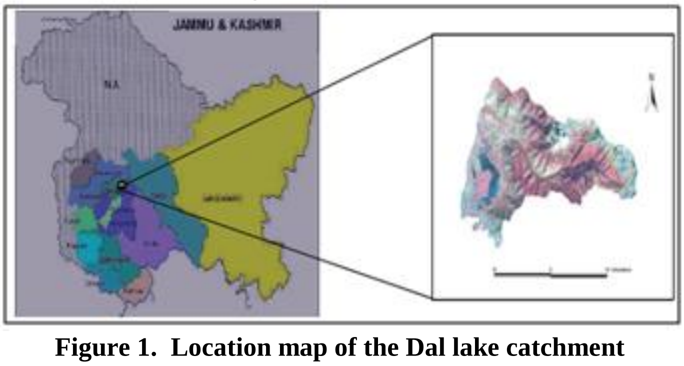

Figure 1. Location map of the Dal lake catchment

Database and Methodology

The data used for the study includes satellite image IRS-1C LISS-III data (acquired on october,2006) and Survey of India (SOI) Toposheets, 1961 on a scale of 1:50,000. Soil map was gathered from Division of the Soil Sciences Sheri-e-Kashmir University of Agricultural Sciences and Technology (SKUAST).

All the layers were geo-referenced and brought to a common scale (real coordinates), so that overlay could be performed. A computer based software programme (Arcview version: 3.2a &ERDAS imagine version: 8.7) was used to estimate the erosion intensity of the study area.The study was carried out on micro-watershed level utilizing survey of India (SOI) toposheets, for the demarcation of micro-watersheds. Accordingly catchment area has been delineated into 25 micro-watersheds. Further, these micro-watersheds have been assigned code, namely DMW1 upto DMW 25 as shown in figure 2.For the generation of drainage map of the study area all steams were digitized from Survey of India (SOI) Toposheets, 1961 on a scale of 1:50,000. The digitization was done in GIS system (Arcview version: 3.2a). Land use/land cover mapping was carried out using standard method of analysis of remotely sensed data followed by the ground truth collection and interpretation of satellite data. For this purpose digital data IRS-1C LISS III of 2006 image was used and the analysis of interpreted maps and image processing of the satellite data was carried out using EDRAS imagine version: 8.7. The visual interpretation of the IRS data led to the identification and delineation of land use/land cover categories such as, agriculture, bare rock, barren, water body, fallow land, forest, meadows, orchards, pastures, plantation, settlement, sparse forest, wet plantation etc.The slope map for the study area was generated from the contours of Survey of India (SOI) toposheets at 1:50,000 scale following a 40 m contour interval, whereas Soil map was generated using secondary data source.

Determination of erosion intensity unit is primarily based upon the integrated information on soil characteristics, slope and land use/land cover. The composite map for delineating different erosion intensity units was prepared through superimposition of the maps showing soil unit, soil depth, slope and landuse/ land cover. This thematic mapping of erosion intensity for entire catchment was done using the overlay and union techniques. Based on ground truth conducted during fieldwork and published data, weightage was assigned to each erosion intensity unit (Table 1). The final integration of erosion intensity mapping units has been done based on the total sum of weightages of landuse/land cover, soil depth & soil unit and slope. If the summation is between 12 to 14, the unit is considered as Very Severe erosion intensity class, while sum of 9 to 11 gives Severe erosion intensity class, sum of 6 to 8 gives Moderate to slight erosion class class, sum of 5 to 7 gives Slight to negligible erosion intensity class. Adopting this classification, composite erosion intensity map was generated as given in Fig. 6.

Figure 2. Codification of micro-watershed of Dal lake catchment

Based on the Composite Erosion Intensity Unit mapping micro-watersheds that require treatment measures were prioritized using simple rule that the micro-watersheds with higher value of very Serve erosion will be rated as rank 1, next highest value will be assigned rank 2 and so on. The final priority/ranking was given by classifying the highest and lowest range of very severe erosion class into four classes as very high

(9.49-2), high (1.99-1.40), Medium (1.39-0.96) and low (0.95-0).

Result and Discussion

The analysis has shown that about 36.79% of the total free draining area falls under Gently sloping category. Its followed by Moderately steep, which is spread on 29.57% of the free draining area. Strongly sloping is spread on an area of 24.14% of the total free draining area (Table 2). Higher slope classes such as Moderately Steep is prevalently spread in the micro-watershed of DMW1, DMW5, DMW7 and DMW9 with an area coverage of 18.24 sq.km, 7.62 sq.km, 9.32 sq.km and 11.8 sq.km respectively. Steep slope is prevalent in the micro-watersheds of DMW1, DMW7 and DMW9 with an areal coverage of 4.14 sq.km, 3.7 sq.km and4.53 sq.km. Slope map for Dal lake catchment is given in figure3.

The visual interpretation of the IRS data led to the identification and delineation of land use/land cover categories such as agriculture, bare rock, barren, water body, fallow land, forest, meadows, orchards, pastures, plantation, settlement, sparse forest, wet plantation etc. The colour-coded map (Figure 4) represents different land use/land cover classes, free drainage area is majorly covered with forests with area coverage of 27.24% followed by sparse forest and Bare rock with an area coverage of 13.62% and 13.61%. Plantation, Settlement and barren also form prominent land cover in the free drainage area with an areal coverage of 8.35%, 6.02% and 8.38% respectively. The area coverage with different land use/land cover categories is given in table 3.

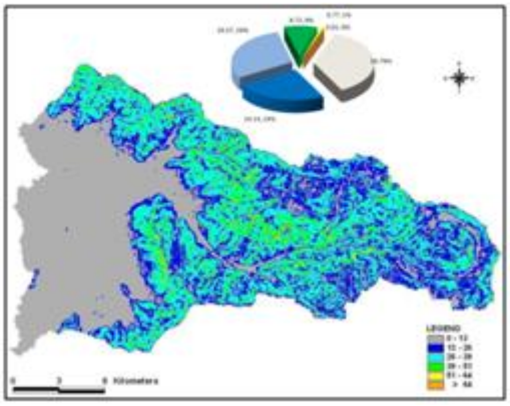

Figure 3. Slope map of free draining area of Dal lake catchment

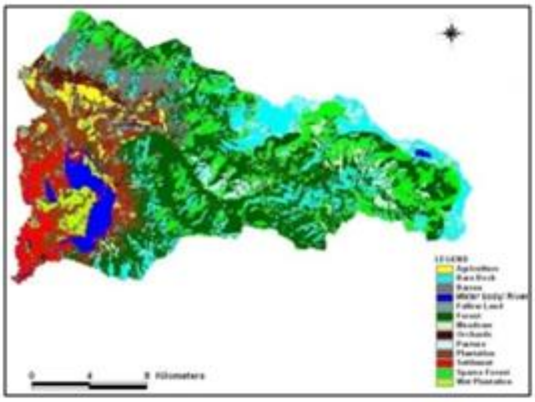

Figure 4. Land use/ Land cover map of Dal lake catchment

The soil class in free draining area of Dal lake catchment is comprised of six soil units (Figure 5). Forest soils are largely spread in the free drainage with an areal coverage of 43.08% followed by Mountain soils and midland soils with an area coverage of 16.11% and 15.90%. Lower belt soils and narrow valley soilsalso form prominent soil cover in the free drainage area with an areal coverage of 7.86% and 8.88%.Area (Sq. km) under different soil categories of the free drainage area of Dal lake catchment is given in table 4.

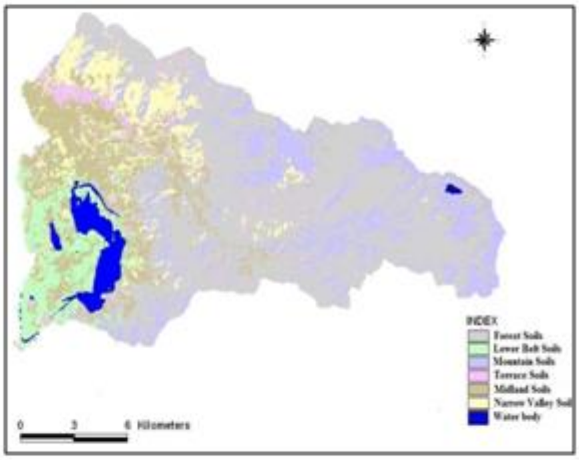

Figure 5. Soil map of free draining area of Dal lake catchment

A composite erosion intensity unit map on 1:50,000 scale was prepared using the thematic maps of slope, drainage, land use/land cover, soil class, soil depth. This composite map was then superimposed on the drainage map with micro-watershed boundaries in order to obtain micro-watershed- wise composite erosion intensity unit map. As shown in the figure 6moderate to slight erosion is predominantly spread in the lower part of the free draining area, covering an area of 49.69% of the total free draining area. The area under different erosion intensity categories is given in table 5. Serve erosion is spread in an area of 29.64% of the total free draining area, where as very serve is spread in the free drainage area with an area coverage of 13.75%. Area under different erosion intensity categories of micro-watersheds of the free drainage area of Dal lake catchment is given in table 6.

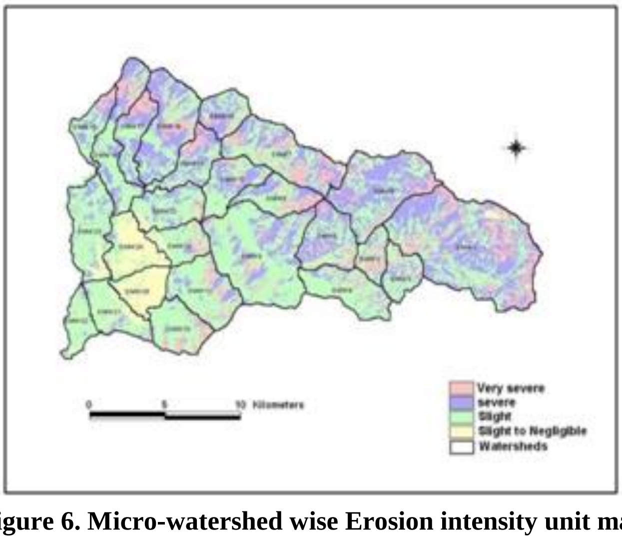

Figure 6. Micro-watershed wise Erosion intensity unit map of the free draining area of Dal lake catchment

Based on the Composite erosion intensity Unit mapping micro-watersheds that require treatment measures were prioritized using simple rule that the micro-watersheds with higher value of very Serve erosion will be rated as rank 1, next highest value will be assigned rank 2 and so on. The final priority/ranking was given by classifying the highest and lowest range of very severe erosion class into four classes as very high (9.49-2), high (1.99-1.40), Medium (1.39-0.96) and low (0.95-0). Micro-watersheds DMW1, DMW5, DMW7, DMW11, DMW23, DMW9 and DMW16 fall under very high priority (Table 7).

Table 1: Legends used for evaluation of composite erosion intensity mapping

Erosion intensity class	Slope % / Weightage	Land use/Land cover / Weightage	Soil unit / Soil Depth / Weightage	Total sum of Weightages
(a) Very severe	Very very steep > 64% / (4)	Bare rock, Agriculture / (4)	Mountain soils/ Shallow / (4)	12
(b) Severe	Steep to very steep 40-64% / (3)	Barren, Orchards, Fallow land / (3)	Midland Soils /Moderately Shallow / (3)	9
(c) Moderate to Slight	Strongly sloping to moderately steep 20-40% / (2)	Sparse Forest, Meadows, Pastures / (2)	Lower belt soils, Terrace Soils, Lower Belt Soils / Moderately Deep / (2)	6
(d) Slight to Negligible	Gently sloping to strongly sloping 0-20% / (1)	Dense forest, Plantation / (1)	Forest soils/Deep / (1)	3

Table 2: Area under different slope classes of Dal lake catchment

Slope class	Area (sq. km)	Area (%)	Description
0 – 13	120.68	36.79	Gently sloping
13 – 26	79.18	24.14	Strongly sloping
26 – 39	97.00	29.57	Moderately sloping
39 – 51	28.60	8.94	Steep
51 – 64	2.51	0.73	Very steep
64-77	0.03	0.01	Escarpments

Table 3: Area (Sq. km) under different land use/land cover categories in free drainage catchment area of Dal lake catchment

LU/LC Categories	Area (sq.km)	Area (%)
Agriculture	13.47	4.10%
water Body/River	15.83	4.82%
Orchards	8.17	2.48%
Plantation	27.43	8.35%
Settlement	19.77	6.02%
Meadows	8.67	2.64%
Sparse Forest	45.38	13.82%
Barren	27.52	8.38%
Pasture	15.48	4.71%
Bare Rock	44.67	13.61%
Wet Plantation	8.58	2.61%
Forest	89.4	27.24%
Fallow Land	3.82	1.16%

Table 4: Area (Sq. km) under different soil categories of the free drainage area of Dal lake catchment

Soil units	Area (sq.km)	Area (%)
Forest Soils	141.32	43.08%
Lower Belt Soils	25.79	7.86%
Mountain Soils	52.84	16.11%
Terrace Soils	10.95	3.34%
Midland Soils	52.16	15.90%
Narrow Valley Soil	29.13	8.88%
Water Body	15.83	4.83%

Table 5: Area (Sq. km) under different Erosion categories of the free drainage area of Dal lake Catchment.

Erosion intensity class	Area (sq.km)	Area (%)
Very Severe	45.15	13.75%
Severe	97.28	29.64%
Moderate to Slight	163.09	49.69%
Slight to Negligible	22.69	6.91%

Table 6: Area (Sq. km) under different Erosion intensity categories of micro-watersheds of the free drainage area of Dal lake catchment

Micro-Watersheds	Very Severe	Severe	Moderate to Slight	Slight to Negligible
DMW1	9.49	19.57	15.94	1.62
DMW2	0.94	1.62	4.26	0
DMW3	1.49	1.13	2.76	0
DMW4	1.15	1.74	9.32	0
DMW5	2.94	10.22	7.54	0.67
DMW6	1.97	5.14	5.41	0
DMW7	5.04	6.83	8.03	0.15
DMW8	1.74	2.93	4.32	0.07
DMW9	2.45	7.81	18.18	0
DMW10	1.8	0.84	7.58	0.05
DMW11	2.18	2.29	9.93	0
DMW12	0.6	2.35	7.32	0.71
DMW13	0.95	3.31	5.59	0
DMW14	1.2	3.92	4.03	0.2
DMW15	1.15	2.98	3.13	0
DMW16	2.37	9.05	7.31	0.02
DMW17	1.39	3.82	3.23	0.01
DMW18	1.49	5.07	7.75	0.12
DMW19	0.8	2.16	3.41	0
DMW20	0	0.27	3.13	6.39
DMW21	0.2	0.8	6.84	1.67
DMW22	0.2	0.8	3.12	1.67
DMW23	2.55	0	8.34	2.12
DMW24	1.06	0.63	5.21	0.73
DMW25	0	0	1.37	6.51

Table 7: Prioritization of micro-watershed based on Erosion intensity

Micro-Watersheds	Very Severe	Severe	Moderate to Slight	Slight to Negligible	Prioritization	Priority Ranking
DMW1	9.49	19.57	15.94	1.62	1	Very high
DMW2	0.94	1.62	4.26	0	16	Low
DMW3	1.49	1.13	2.76	0	9	High
DMW4	1.15	1.74	9.32	0	13	Medium
DMW5	2.94	10.22	7.54	0.67	3	very high
DMW6	1.97	5.14	5.41	0	8	High
DMW7	5.04	6.83	8.03	0.15	2	very high
DMW8	1.74	2.93	4.32	0.07	10	High
DMW9	2.45	7.81	18.18	0	5	very high
DMW10	1.8	0.84	7.58	0.05	9	High
DMW11	2.18	2.29	9.93	0	7	very high
DMW12	0.6	2.35	7.32	0.71	18	Low
DMW13	0.95	3.31	5.59	0	15	Low
DMW14	1.2	3.92	4.03	0.2	12	Medium
DMW15	1.15	2.98	3.13	0	13	Medium
DMW16	2.37	9.05	7.31	0.02	6	very high
DMW17	1.39	3.82	3.23	0.01	11	Medium
DMW18	1.49	5.07	7.75	0.12	9	High
DMW19	0.8	2.16	3.41	0	17	Low
DMW20	0	0.27	3.13	6.39	20	Low
DMW21	0.2	0.8	6.84	1.67	19	Low
DMW22	0.2	0.8	3.12	1.67	19	Low
DMW23	2.55	0	8.34	2.12	4	very high
DMW24	1.06	0.63	5.21	0.73	14	Medium
DMW25	0	0	1.37	6.51	20	Low

As depicted in figure 7, Micro-watersheds DMW3, DMW6, DMW8, DMW10, DMW18 and DMW4, DMW14, DMW15, DMW17 and DMW24 fall under high priority and medium priority respectively. Micro-watershed DMW2, DMW12, DMW13, DMW19, DMW20, DMW21 and DMW22 fall under low priority. Below shows priority in which the Micro-watersheds have to be taken up for conservation measure.

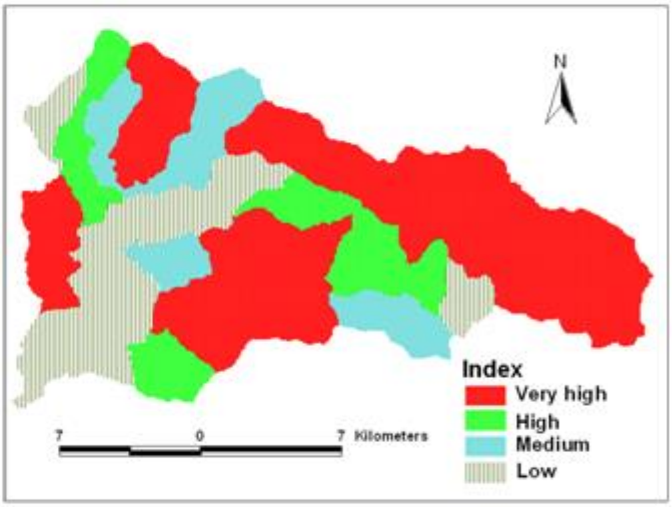

Figure 7. Prioritization of micro-watershed based on Erosion intensity

Watershed management of very high priority micro-watersheds

Activities to be undertaken

For undertaking soil conservation measures in the Dal lake catchment area various indirect or preventive measures like direct or remedial measures like engineering measures have been discussed in the following paragraphs. Even as suggestions have been made regarding certain specific treatment measures to be undertaken in a particular micro-watershed, these measures, however, may require further micro-planning during the implementation stage.

Preventive Measures

It is always better to undertake preventive measures than to mitigate the factors that ultimately lead to soil erosion. Such preventive measures will indirectly help to conserve soil in the long run, keeping in view the importance of integrating eco-restoration strategy with socioeconomic needs of the local community wherein both ecology and economics are developed. The preventive measures that are suggested for the study area have been discussed below.

Afforestation / Vegetative cover

The forests in the micro-watershed under study have been observed to occupy higher sloppy ground and bears highly erodible soils which gets easily transported down the slopes. As such various vegetative measures have been proposed which are as follows:-

Afforestation:-The study of the area has shown that the micro-watershed has a considerable degraded forest area and accordingly afforestation programme has been suggested in such area which will help to intercept rainfall and prevent the soil erosion due to improved binding of soil with the roots as well as by reducing splash erosion.

Silvipasture:- Silvipasture has also been proposed on the degraded forest areas. The presence of silvipasture dissipates the impact force of rain drops on the soil surface and protects the soil from splash erosion by modifying the volume, drop size and impact velocity of rainfall.

Pasture development:- Development of the pasture land has also been suggested in Bhaks, which are used by the Bakerwals, Nomads etc in the forests for growing of live stock.

Crate Wire Structures:- The micro-watershed under study being hilly often produce flash floods which erode the lands located along the banks of drainage lines. Such a bank erosion problem is accentuated in the lower reaches of the micro-watershed. The micro-watershed being sensitive to the problem needs protection by crate wire structures. Further it is suggested that willow tree should be planted on both sides of crates to provide additional support to banks.

Check Dams:- A series of Rubble dry stone Masonry Check dams (RDSM) are recommended to be created on the drainage lines to prevent them from erosion and in case of vegetative check dams it is proposed that further protection by lines of Mawa Check dams (Willow) above and below the degraded drainage lines may be provided. This will help in sediment control and more and more vegetation would come on the deposited slit and will further start arresting slit.

Conclusion

Watershed management is an effective tool of management of soil, water and environment. Management of resources at watershed level will reduce the complexity of the problem. Watershed prioritization is one of the most important aspects of planning for implementation of its development and management programmes. Delineating catchment into zones of soil degradation helps in prioritizing the areas where soil erosion measures should be applied depending upon the severity of erosion. This only not helps in saving the precious time but also the money to be spent in the treatment of watershed. Remote Sensing and G1S techniques have emerged as powerful tools for watershed management programmes. The present study demonstrate the utility of remote sensing and GIS techniques in prioritizing micro-watersheds based on erosion intensity. The erosion susceptibility zone map will be helpful in identification of priority zones for the evaluation and suggestion of soil conservation measures based on the existing terrain conditions. GIS and remote sensing approach in prioritization of micro-watersheds is found to be more appropriate and useful. This approach will certainly help planners and decision makers in judicious allocation and utilization of available resources for treatment of small hydrologic units and effective checking of soil erosion.

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