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Sediment Yield Estimation for Watershed Management in Lolab Watershed of Jammu & Kashmir State Using Geospatial Tools

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Abstract Sediment Yield estimation on the basis of texture, slope, land use and soil erosion has become inevitable component for effective watershed management in terms of conserving soil and water resources. To assess the sediment yield, it is necessary to prepare a land use / land cover map, to characterize the erosion processes and estimate the total yield on the basis of above mentioned defined parameters. This paper aims to prioritize the micro-watersheds by estimating Sediment Yield Index (SYI) for identification of the critical areas which need immediate remedial measures in Lolab watershed of Jammu and Kashmir State. In the present study, the satellite data from IRS P6 (Resourcesat-1) LISS III sensor with spatial resolution of 23.5 meters, Arc GIS 9.3 and Erdas Imagine 9.2 GIS software were used. Land use/ Land cover map with a total of seven categories was prepared. Agriculture was the major class with 38.98 percent followed by sparse forests with 31.85 percent area. Besides this, Slope, Soil texture and Soil erosion maps were also prepared. The soil erosion map revealed that about 30 percent of the total area was in the moderate to severe class of erosion while as about 49 percent area was in the slight to moderate erosion class. Sediment Yield Index (SYI) was estimated for forty three micro-watersheds individually with the help of delivery ratio and weightage value using an empirical formula. The prioritization of micro-watersheds was done on the basis of the estimated SYI value and conservation measures were suggested accordingly.
Keywords *Remote Sensing; Micro-Watershed; Sediment Yield Index; Prioritization; Conservation*

1. Introduction

Land and water are two basic natural resources for the survival of living systems. These two resources have been interacting with each other in various phases of their respective cycles. The future of the nation depends largely on the effective utilization, management and development of resources in an integrated and comprehensive manner. Watersheds have long been identified as planning units for conservation of these precious resources [3]; and the basic objectives of any conservation and management strategy are to find out the problems and accordingly adopt a judicious approach for optimum utilization of all natural resources. The total amount of erosional debris exported from a watershed is its Sediment Yield. The sediment yield process can be divided into upland and lowland phases. The sediment detachment process predominates in the upland phase whereas sediment transport and deposition are the main processes in the low land phase [1]. During recent times, Sediment Yield modeling approach is being used to estimate sediment yield from different hydrological units. The specific needs of sediment yield modeling are varied and no single model can meet the requirements fully. Sediment prediction requirements for each of the available models are determined largely by the duration of the event to be simulated; size, shape, the morphometry of the area and the sources of the sediment. The major factors influencing the sediment yield are the land use, soil texture, soil erosion, and slope [6]. Eroded soil in the form of sediment gets deposited in the reservoirs, eventually reducing designed storage capacity [11]. The information on sources of sediment yield within a watershed can be used as perspective on the rate of soil erosion, occurring within that watershed [5]. As such, a holistic approach for land and water management in a watershed is an ideal strategy for effective conservation of the resources. The identification and demarcation of watersheds that are prone to yielding higher sediment yield should be the primary task for soil resource management [7]. In order to opt for such measures, the proper approach is to identify the problematic areas at the micro level and then initiate soil and water conservation measures. So, prioritization at the micro-watershed level assumes much significance as the areas with higher priority are taken first for conservation measures and areas with lower priority are taken subsequently. This helps in conserving the less priority areas and at the same time proves beneficial for the areas where the problem is more severe.

It is in this context, the present study was carried out in order to analyse the land use/ land cover pattern of the Lolab watershed, to estimate the Sediment Yield Index (SYI) for each individual micro-watershed and to prioritize the micro-watersheds for soil conservation measures.

1.1. Study Area

The Lolab Watershed of the Kashmir valley with an area of about 28,162 hectares has been taken up as the study area. The watershed lies between 34^{0} 41’ to 34^{0} 24’ N Latitude and 74^{0} 09’ to 74^{0} 23’ E Longitude. It has been divided into forty three micro-watersheds in accordance to the guidelines of the Watershed Atlas of India (WAI).

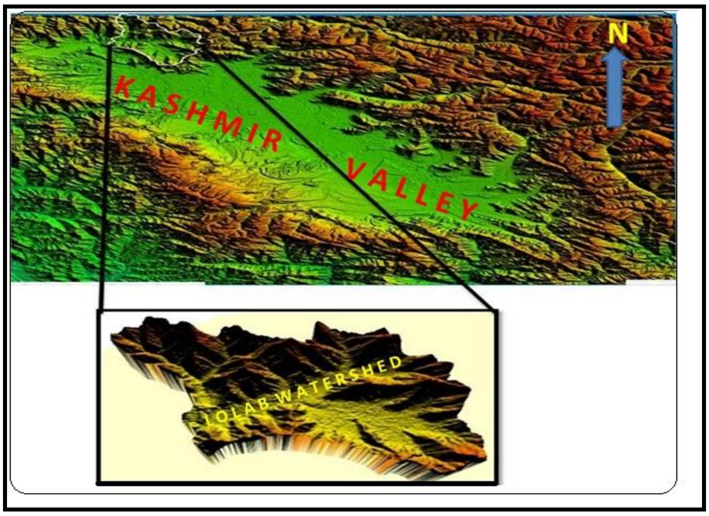

Figure 1: *Location Map of the Study Area*

The watershed can be divided into three distinct physiographic units i.e. the Mountains, the Karewas and the Flood plains. The Lolab Valley is the most fascinating and picturesque of the Himalayan Valleys in Kashmir. The Lolab kol has its source in the Nandmarg, the Kimsar and the Bagalsar heights, north of the Wular Lake. The main stream of the Lolab has a length of about 30 kilometers and flows in a westerly direction. One of its lateral tributaries is the Kalaruch nala which originates below the peak of Nalgat 3645 meters and joins the Lolab below Khumarial. A little before its junction with the Kahmil, the Lolab kol receives the Haheom kol which flows from the north.

2. Materials and Methods

The satellite data of Indian Remote Sensing Satellite IRS-P6 (Resourcesat-1) FCC with a resolution of 23.5 meters of June, 2011, Arc GIS 9.3 and Erdas Imagine 9.2 GIS software were used for this study. The methodology for this study included supervised classification approach. A tentative legend with Erosion Intensity Mapping Units was prepared with the help of scheme devised by All India Soil & Landuse Survey (Ministry of Agriculture). The Erosion Intensity Mapping Units (EIMU) implies a set of relevant parameters which are responsible for the detachment of soil (soil erosion) and also exert combined and reciprocal influence on soil detachment. The factors considered include physiography and slope, which control amount and velocity of runoff; soil characteristics, that decide potentiality for erosion; vegetation cover conditions that afford protection to soil; land use that indicates interference by human and biotic factors; present erosion status and existing soil conservation measures that modify the influence of other factors. This was followed by selection of sample strips with observation points for ground truthing exercise. While selecting the observation points, all the EIMUs were given due representation. After the field visit, the legend was finalized and accuracy estimation procedure was performed.

Land use/Land cover map, Slope map, Soil Texture map, and Soil Erosion map were prepared. The Weightage value and Delivery ratio for each mapping unit was included which had been estimated by AIS & LUS using their INGRESS customized software. These Weightage values and Delivery ratios were actually estimated by considering the EIMU parameters and their relevant values. Different mapping units had different Weightage values and Delivery ratios. Besides these two, the area of the each Individual Erosion Intensity Mapping Unit and area of each micro watershed were together used in an empirical formula to estimate the Sediment Yield Index [4]. These SYI values for each micro watershed were then categorized into three priority categories, High, Medium and Low depending upon the intensity of the problem. The individual ranking was also given to all the micro-watersheds and a prioritization map was prepared. Accordingly, conservation measures for each micro-watershed were then suggested.

3. Results and Discussion

3.1. Land use / Land cover of Lolab watershed (2011)

Agriculture was the dominant land use category (Figure 2) in the Lolab watershed in 2011 with 38.98 percent followed by the sparse forest cover with 31.85 percent. The percentage distribution under different land use / land cover categories is given in Figure 3.

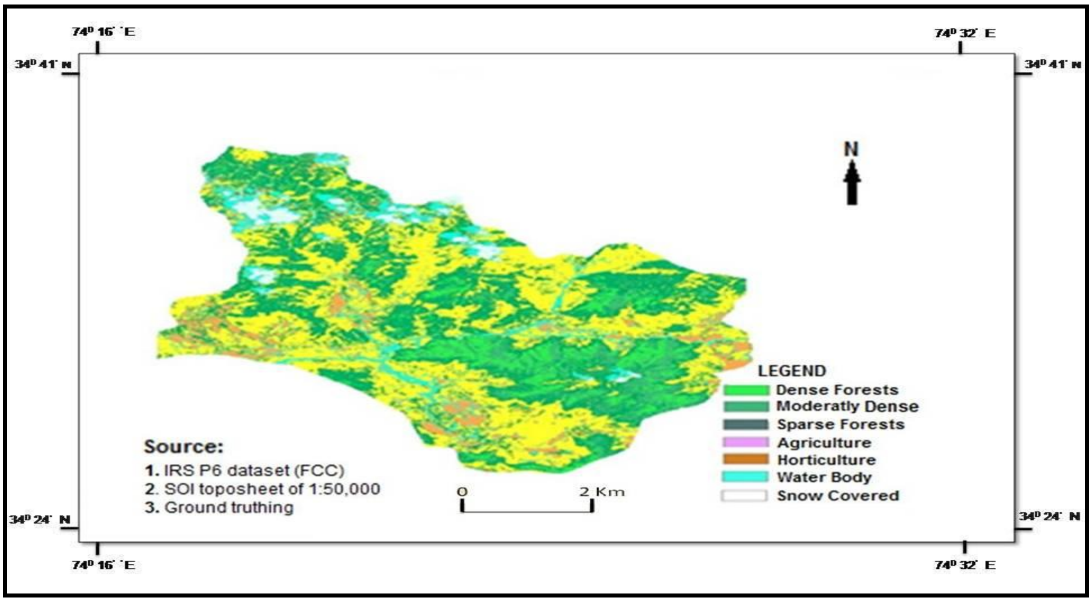

Figure 2: *Land Use / Land Cover Map (2011) of Lolab Watershed*

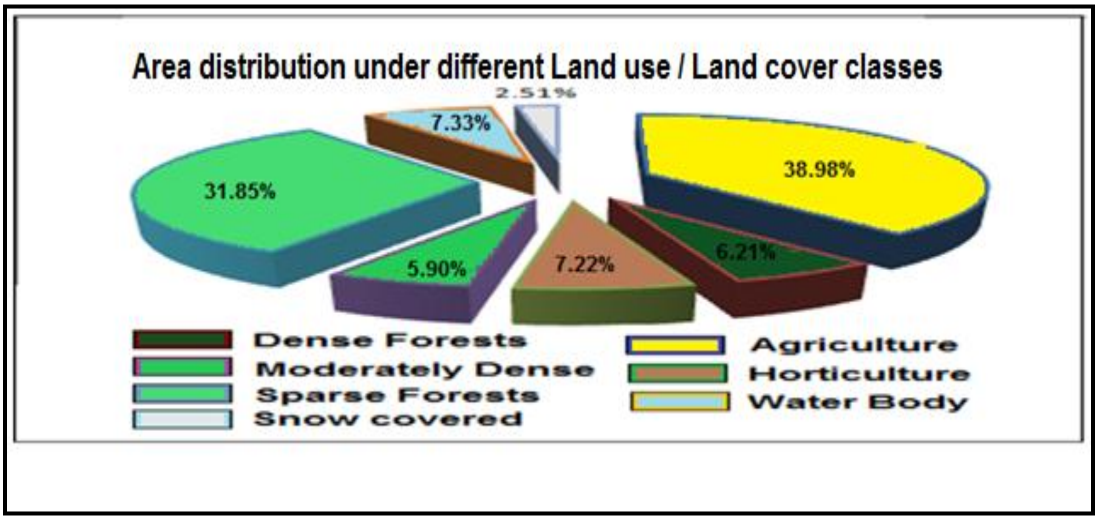

Figure 3: *Area Distribution Under Different Land Use / Land Cover Classes*

3.2. Slope

Importance of slope factor in prioritization of watersheds has been recognised at various levels by different researchers [2, 8, 9, 10]. Thus, a slope map (Figure 4) was prepared which is one of the important parameters for estimating Sediment Yield Index. The various categories of slope were, very gentle to gentle, gently to moderately sloping, moderately to steep and steep to very steep. Being a mountainous area, the major slope category was steep to very steep sloping land.

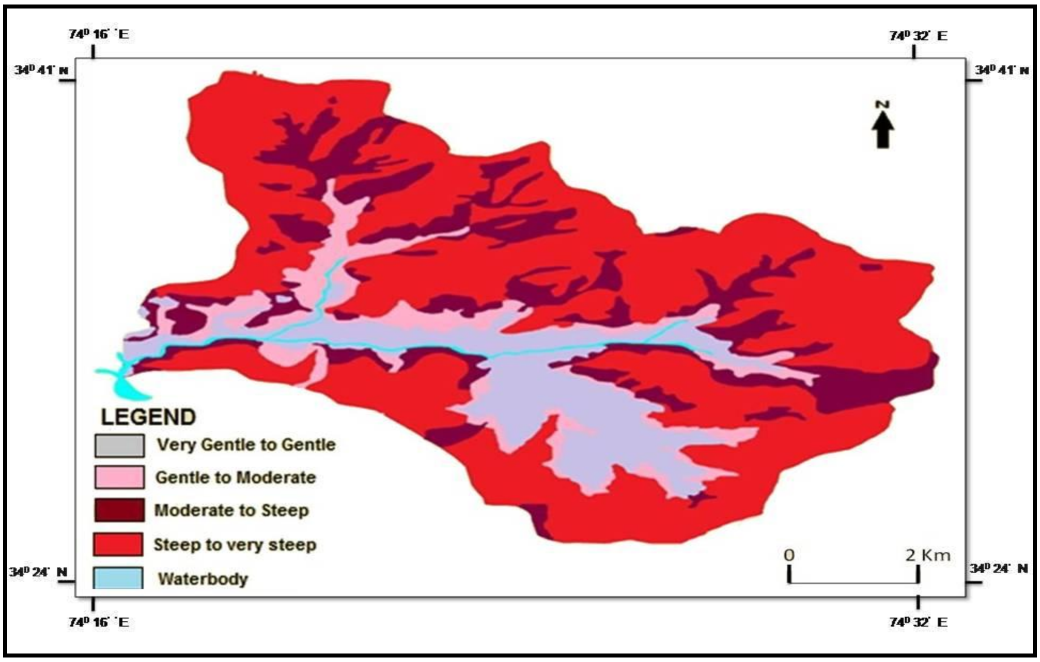

Figure 4: *Slope Map of the Lolab Watershed*

3.3. Soil Texture

Soil texture map was prepared to comprehend erodibility characteristics of the soil in the study area, which plays a significant role in influencing the Sediment Yield for a particular mapping unit. A total of three soil texture classes were delineated, out of which the fine loamy soil was the major class which accounted for 79.58 percent of the total area of the watershed and was followed by fine silty soil with 16.53 percent of the total area. The percentage wise description is shown in Table 1.

Table 1: *Soil Texture Classes and Their Percentage*

S. No.	Classes	Percentage
1	Fine Loamy soils	79.58
2	Fine Silty Soils	16.53
3	Fine Silty to Fine Soils	3.89

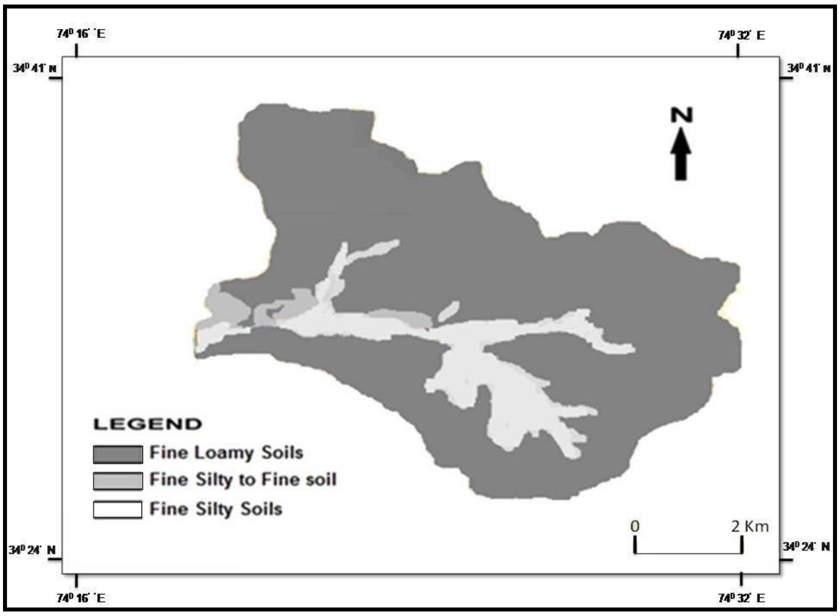

Figure 5: *Soil Texture Map of the Study Area*

3.4. Soil Erosion Status

Degradation of agricultural land by soil erosion is worldwide phenomenon leading to loss of nutrient rich surface soil, increased runoff from more impermeable sub soil and decreased water availability to plants. Thus, estimation of soil loss and identification of critical areas for implementation of best management practice is central to the success of all soil conservation programmes. A soil erosion map (Figure 6) was prepared with four soil erosion classes. The major class of erosion was Slight to Moderate erosion with 49 percent followed by Moderate to Severe class with 30 percent area. The percentage wise break up of erosion classes is given in Table 2.

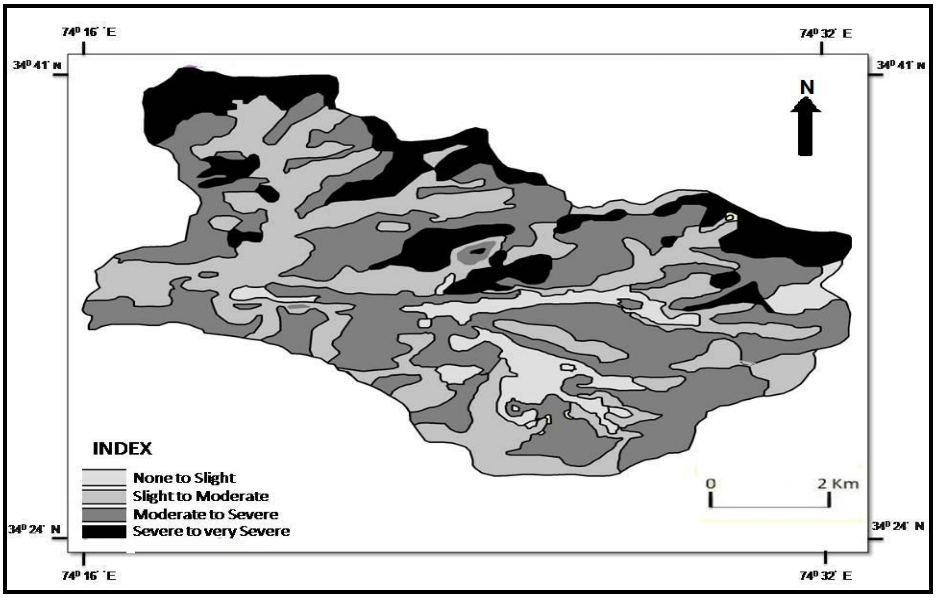

Figure 6: *Soil Erosion Map of the Study Area*

Table 2: *Soil Erosion Classes and their Percentage*

S. No.	Soil Erosion classes	Percentage
1	None to Slight	7
2	Slight to Moderate	49
3	Moderate to Severe	30
4	Severe to very Severe	14

3.5. Prioritization of Micro-Watersheds in Lolab Watershed

Considering the massive investment in the watershed development programmes, it is important to plan the activities on priority basis for achieving fruitful results, which also facilitates, in addressing the problematic areas to arrive at suitable solutions. The resource based approach is found to be realistic for watershed prioritization since it involves an integrated approach. Sediment Yield Index model (SYI) has been used in the present study area to prioritize the micro-watershed of Lolab Watershed. The Erosion Intensity Mapping Units (EIMU) were assigned with their respective weightage values and delivery ratios on the basis of methodology devised by AIS & LUS which takes into account the different characteristics of each mapping unit such as physiography, slope, soil texture, erosion class, management status, soil colour, surface condition, land use / land cover etc.

The Sediment Yield Index was calculated by using the empirical formula:

$$SYI = \frac{\sum_{i=1}^{i=n} (Ae1 \text{ x } We1 \text{ x } De1) \text{ x}100}{AMW}$$

Where,
SYI= Sediment Yield Index
Ae1= Area (ha) of ith Erosion Intensity Mapping Units
We1= Weight age value of the Erosion Intensity Mapping Unit
De1= Delivery Ratio of ith Erosion Intensity Mapping Unit
AMW= Total area of the micro-watershed

The Sediment Yield Index of forty three micro watersheds along with their relative priority is given in the Table 3.

Table 3: *Sediment Yield Index (SYI) of Micro-Watersheds in Lolab Watershed*

S. No.	Hydrologic unit	Area in ha.	Sediment Yield Index (SYI)	Relative Priority
1.	1EIB6m1	1474	4397.78	1
2	1EIB6m2	1660	1471.27	3
3	1EIB6m3	1548	1163.06	16
4	1EIB6n1	676	2090.442	2
5	1EIB6n2	1115	1129.63	20
6	1EIB6n3	865	1296.34	6
7	1EIB6n4	1081	1190.10	14
8	1EIB6n5	1105	1242.61	9
9	1EIB6n6	824	1240.83	11
10	1EIB6n7	1406	1254.66	7
11	1EIB6p1	904	857.04	40
12	1EIB6p2	1331	884.28	39
13	1EIB6p3	979	977.591	34
14	1EIB6q1	1441	985.15	33
15	1EIB6q2	950	1123.90	21

16	1EIB6q3	1429	1438.62	4
17	1EIB6r1	665	1170.23	15
18	1EIB6r2	678	805.46	41
19	1EIB6r3	579	1137.24	18
20	1EIB6s1	1507	1146.365	17
21	1EIB6s2	644	1086.56	25
22	1EIB6s3	1038	1230.06	12
23	1EIB6s4	4032	268.49	43
24	1EIB6t1	908	1133.65	19
25	1EIB6t2	1015	1048.67	28
26	1EIB6t3	892	1102.20	23
27	1EIB6t4	675	1223.41	13
28	1EIB6t5	710	957.08	35
29	1EIB6t6	1270	1319.60	5
30	1EIB6u1	1153	913.85	36
31	1EIB6u2	1415	891.50	38
32	1EIB6u3	1083	1057.98	27
33	1EIB6u4	801	1242.21	10
34	1EIB6u5	1042	896.84	37
35	1EIB6v1	781	770.89	42
36	1EIB6v2	1547	1021.43	29
37	1EIB6v3	939	1245.62	8
38	1EIB6v4	1374	1021.23	30
39	1EIB6v5	1543	1098.96	24
40	1EIB6k1	726	1016.46	31
41	1EIB6k2	932	1081.82	26
42	1EIB6k3	1157	1112.06	22
43	1EIB6k4	660	986.01	32

The Sediment Yield Index (SYI) pertaining to all 43 micro-watersheds of Lolab watershed were estimated. The micro-watersheds were arranged with respect to the decreasing order of their SYI and graded into three categories as high, medium and low on the basis of SYI range as given in Table 4.

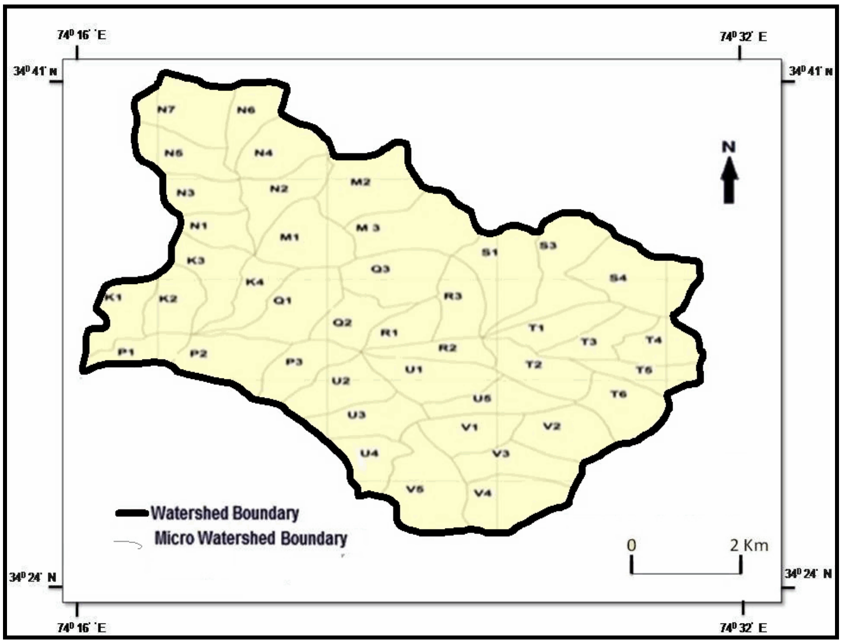

***Figure 7**: Micro-Watershed Index Map of the Study Area*

***Table 4**: Weightage Values and Delivery Ratios of Erosion Intensity Mapping Units (EIMU) considered for calculating Sediment Yield Index (SYI) of Lolab Micro-watersheds*

S. No.	Erosion Intensity Mapping Unit	Weightage Value	Delivery Ratio
1	A1	12	0.56
2	A2	14	0.60
3	A3	15	0.63
4	A4	12	0.57
5	A5	17	0.70
6	K2	18	0.70
7	K3	15	0.64
8	K4	19	0.77
9	K5	13	0.60
10	M1	20	0.85
11	M2	13	0.67
12	M3	17	0.69
13	M4	20	0.81
14	M5	14	0.70
15	M6	18	0.82
16	M7	17	0.74
17	M8	13	0.64
18	M9	19	0.78
19	M10	13	0.60
20	River		

Source: AIS & LUS; 2002

S. No.	Priority Category	No. of Watersheds
1.	High	13
2.	Medium	18
3.	Low	12
Total No. of Watersheds		43

***Table 5**: Micro-Watersheds under Different Priority Categories with their SYI*

High(1200 & above)	Medium(1000 to 1199)	Low(<1000)
M1(4397.78)	M3(1163.06)	P1(857.04)
M2(1471.27)	N2(1129.63)	P2(884.28)
N1(2090.44)	N4(1190.10)	P3(977.59)
N3(1296.34)	Q2(1133.90)	Q1(985.15)
N5(1242.61)	R1(1170.23)	R2(805.46)
N6(1240.83)	R3(1137.24)	S4(268.49)
N7(1254.66)	S1(1146.36)	T5(957.08)
Q3(1438.62)	S2(1086.56)	U1(913.85)
S3(1230.06)	T1(1133.65)	U2(891.50)
T4(1223.41)	T2(1046.67)	U5(896.84)
T6(1319.60)	T3(1102.20)	V1(770.89)
U4(1242.21)	U3(1057.98)	K4(986.01)
V3(1245.62)	V2(1021.43)	
	V4(1021.23)	
	V5(1098.96)	
	K1(1016.46)	
	K2(1081.82)	
	K3(1112.06)	

Sediment Yield Index calculated reveals the state of erosion problems in the, Lolab watershed. Out of the total 43 micro-watersheds in the watershed, 13 are placed in the high priority category, 18 in medium category and 12 micro-watersheds are placed in the low category (Figure 8).

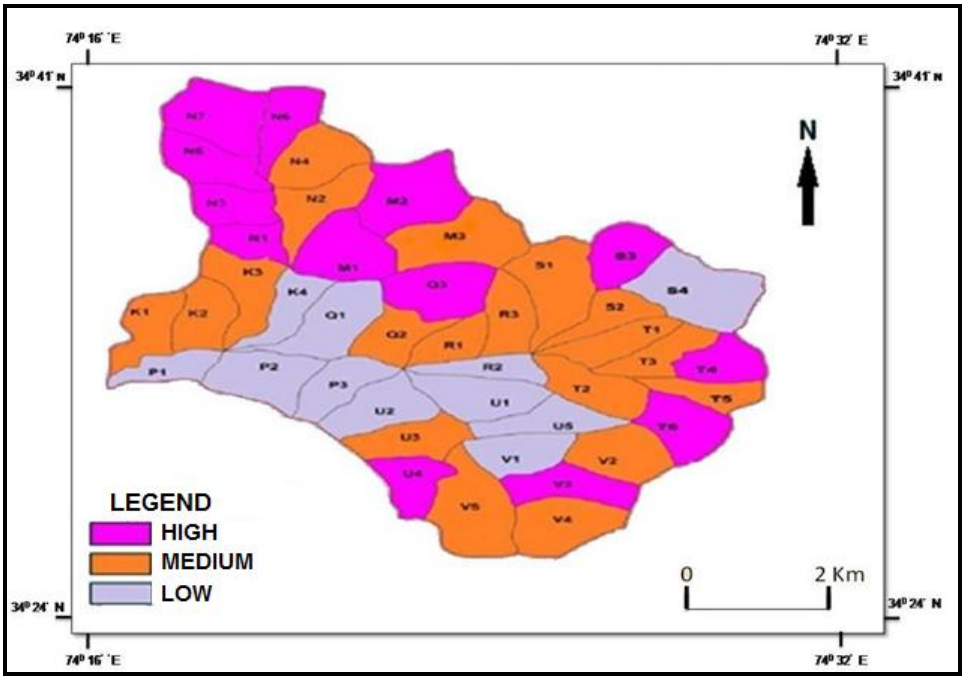

Figure 8: *Micro-Watershed Prioritization Map of the Study Area*

4. Conclusion

Watershed prioritization plays a key role in planning and management for sustainable development programmes. The Lolab watershed of Kashmir valley comprising of fourty three micro-watersheds is facing severe soil erosion problems. In some of the micro-watersheds, the severity of the problem is more while as in some, moderate and slight but overall the situation is alarming. The micro-watersheds i.e. M1, M2, N1, N3, N5, N6, N7, Q3, S3, T4, T6, U4, and V3 fall in the high category where the slope is very steep of southern aspects, forests moderately dense and poorly managed, and the micro-watersheds i.e. M3, N2, N4, Q2, R1, R3, S1, S2, T1, T2, T3, T5, U3, V2, V4, V5, K1, K2, K3 fall in the medium priority categories, where slope is very steep of southern aspects, forests moderately dense, slight to moderate erosion, poorly managed, whereas, the P1, P2, P3, Q1, R2, S4, U1, U2, U5, V1 and K4 micro watersheds fall under the category of low priority where the slope is very gently to gently sloping flood plains, slight erosion and comparatively well managed. The prioritization of micro-watersheds for soil and water conservation measures would prove to be a very fruitful exercise for initiating remedial measures in accordance to the intensity and magnitude of the problem. It is one of the basic approaches for effective management of natural resources at the watershed level.

This priority determines the type of measures to be adopted for better management of natural resources. Both Engineering and Biological measures should be adopted to arrest this soil erosion within the watershed. In terms of engineering measures, Crate Wire Mashes should be resorted in nallas having wide cross section up to an extent of 8 meters, stream bank protection by constructing wire crates opposite to direction of flow and strike against stream banks. Besides these measures, construction of Landslide/slip control, Gunny bag check dams, Bench terracing, Silt traps, construction of Bypass Channels and Settling basins should also be initiated depending upon the intensity of erosion. In biological measures, conservation measures like Direct Sowing, Afforestation, Patch

Sowing, Rotational Grazing, and Vegetative Barriers in contour furrows etc. should be initiated in accordance to the severity of the problem.

References

[1] Anonymous. *Report on Demarcation of Priority Watersheds in Pohru River Valley Project Catchment 2002*. AIS & LUS. Ministry of Agriculture, Report No. 1249. 5-6.

[2] Bayramin, I., Dengiz, O., Baskan, O., and Parlak, M. *Soil Erosion Risk Assessment with ICONA Model: Case Study Beypazari Area*. 2003. http://journals.tubitak.gov.tr/Agriculture/issues/tar-03-27- 2/tar-27-2-7-0211-3.pdf.

[3] Food and Agriculture Organization (FAO). *Soil and Water Conservation in Semi-Arid Areas*. 1987.

[4] Gupta, P., and Uniyal, S. *Watershed Prioritization of Himalayan Terrain, Using SYI Model*. International Journal of Advancement in Remote Sensing, GIS and Geography. 2013. 1 (1) 42-48.

[5] Jain Manoj, K., Mishra Surendra, K., and Shah, R.B. *Estimation of Sediment Yield and Areas Vulnerable to Soil Erosion and Deposition in Himalayan Watershed using GIS*. Current Science. 2010. 98 (2) 25.

[6] Khan, M.A., Gupta, V.P., and Moharana, P.C. *Watershed Prioritization using Remote Sensing and Geographical Information System: A Case Study from Guhiya*. Ind.J.Ari. Environ. 2001. (49) 456-475.

[7] Kothyari, U.C., and Jain Sanjay, A.J. *Sediment Yield Estimation using GIS.* Hydro. Sci. J. Sci. Hydrologique. 1997. 42 (6) 833-844.

[8] Lufafa, A., Tenywa, M.M., and Isabirye, M. *Prediction of Soil Erosion in a Lake Victoria basin Catchment using a GIS-based Universal Soil Loss model*. Agric Syst. 2003. 76; 883-894.

[9] Suresh, M., Sudhakar, S., Tiwari, K.N., and Chowdhary, V.M. *Prioritisation of Watersheds using Morphometric Parameters and Assessment of Surface Water Potential using Remote Sensing*. Journal of Indian Society of Remote Sensing. 2004. 31 (1) 25-35.

[10] Singh, R.K, Saha, S.K and Kumar, S. *Soil Conservation Prioritization of Watershed based on Erosional Soil Loss and Morphometric Analysis using Satellite Remote Sensing & GIS-A Case Study*. Indian Institute of Remote Sensing (NRSA), Dehradun: Map India, 2005.

[11] Vito A.V. *ASCE-Manuals and Reports on Engineering Practice*. 54. Sedimentation Engineering. 1975. 745.