Watershed characterization and soil resource mapping for land use planning of Moolbari Watershed, Shimla District, Himachal Pradesh in Lesser Himalayas

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Precise characterization and inventorization of soil resource of Moolbari watershed was undertaken using satellite imagery and Survey of India toposheets to generate several layers of maps such as watershed boundary, drainage, soils, land use and land cover, physiography, slope and soil erosion using Geographic Information System technique.

The watershed has been broadly divided into six physiographic units. Drainage pattern is dominantly rectangular and trellis and drainage density is 18 per sq. km. About 45% of the total area is under forests. The cultivated land is estimated to be 20% of the total area and the rest is mostly under grazing and scrub land. Soil–physiography relationship was established during detailed soil resource mapping. The texture of soils is dominantly loam/silt loam to clay loam with varying proportions of gravel. The soils are rich in organic matter. They are slightly to strongly acidic in reaction. The distribution of soils in the watershed is related to physiography, land use/land cover, slope and aspect.

Keywords: Geographic Information System, land capability, land-use plan, satellite imagery, soil characteristics.

Introduction

OVER the past few decades there have been rising concerns from planners and researchers about the Himalayan ecosystem which is facing a serious problem of land degradation owing to the susceptible geology (sedimentary origin), steep topography and adverse climatic conditions, and increased anthropogenic influence on land resources. The severity of this problem is evident from the continued decline in the productivity of land and increased rates of sedimentation of rivers. The degradation of land resource base at such an alarming rate in the Himalayan region may jeopardize the food/feed security besides posing a major threat to the existence of fragile ecosystems over a period of time. The situation necessitates development of watersheds on sustainable basis for optimal use of natural resources[1]. With the general acceptance of watershed as the principal unit of planning of all development activities based on sustainable utilization of locally available natural resources, hence, the watershed requires the detailed characterization and inventorization of soil resources[2]. The soil information of Himachal Pradesh is available on 1 : 1 m, 1,250,000 or 1 : 50,000 scale which do not seem to be effective for devising suitable land-use plan as micro-level variations are high and critical for the utilization of land for agricultural purposes and the information on detailed scale (1 : 12,500) is almost non-existent. Hence, the present study was undertaken to characterize the Moolbari watershed, Shimla district, Himachal Pradesh in Lesser Himalayas with respect to drainage, land use, physiography, slope, etc. to prepare detailed soil resource inventory and to assess their problems and potentials for land use.

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Materials and methods

Study area

The Moolbari watershed is located between lat. 31°7′38″–31°10′45″N and long. 77°4′39″–77°12′E covering about 1285.4 ha. This watershed comes under Mashobra block of district Shimla and is situated 18 km away from Shimla on Shimla–Bilaspur Highway (Figure 1). The Ghanahatti town is located on the southern boundary of watershed from where most of the villages are approachable within 0–8 km. The watershed includes eight revenue villages namely Nehra, Dochi, Kiuru, Jubbar, Tikkari, Moolbari, Neog and Shanol. The climate is humid, sub-temperate with mean annual rainfall of 1076 mm and mean annual temperature (MAT) of 15°C. The mean maximum and mean minimum temperatures are 18.9°C and 11.0°C respectively. The mean maximum and mean minimum summer temperatures are 23.8°C and 16.3°C respectively.

The mean maximum and mean minimum winter temperatures are 12.7°C and 4.3°C respectively. June is the hottest month with mean maximum temperature of 24.7°C and January is the coldest month with mean minimum temperature of 3.5°C and, therefore, snowfall usually occurs in this month. The area, therefore, qualifies for 'thermic' temperature regime as the MAT is 15°C and the difference between mean summer months temperature and mean winter months temperature is more than 5°C. Rains start in June and continue up to September; more than 75% of the rainfall is received during these months. However, there are light showers occurring during all the months so the soil profile is never dry for 45 days. The area, therefore, qualifies for 'Udic' moisture regime. The climatic water balance is shown in Figure 2. The length of growing period in the area exceeds 300 days.

Methodology

Soil resource mapping: Detailed soil survey of the watershed was carried out adopting the latest available procedures[3,4]. An innovative three-tier approach, viz. image interpretation, field surveys and laboratory investigations, and cartography and Geographic Information System (GIS) was adopted. PAN data on 1 : 12500 scale (Scene GEO-PO95/R049-PN-AN-10 November 2001) obtained from NRSA, Hyderabad was visually interpreted based on textural and tonal variations. Toposheets and existing information were also used for delineating the landform units and land use together with physical verification in the field. The information thus generated was transferred on the topobase, 1 : 12,500 prepared from the Survey of India topographical sheets (1 : 15,000 scale), which were used as base maps for undertaking field surveys. In field surveys, a three-tier approach was adopted which comprises:

- Detailed study of soils, covering all physiographic units to develop soil physiographic relationship and mapping legend. Representative pedons were studied to a depth of 150 cm. Morphological features were studied and horizon-wise soil samples were collected for laboratory characterization.
- Checking of soils in different physiographic units at interval of 50–200 m depending upon the heterogeneity of terrain. Soil boundaries were delineated on map while actual traversing.

During field survey, field reviews were conducted to correlate and classify the soils up to phases of soils series[5]. Soil samples of representative pedons were analysed for particle size distribution, pH and organic carbon following the procedure outlined by Sharma *et al.*[6]. On the basis of landform analysis, field surveys and laboratory studies, the soil resource map of Moolbari watershed was prepared on 1 : 12,500 scale. The soil and climatic data was assessed to work out the suitability of soils for dominant crops grown in the area following a parametric

Figure 1. Location map of Moolbari watershed, Shimla, Himachal Pradesh.

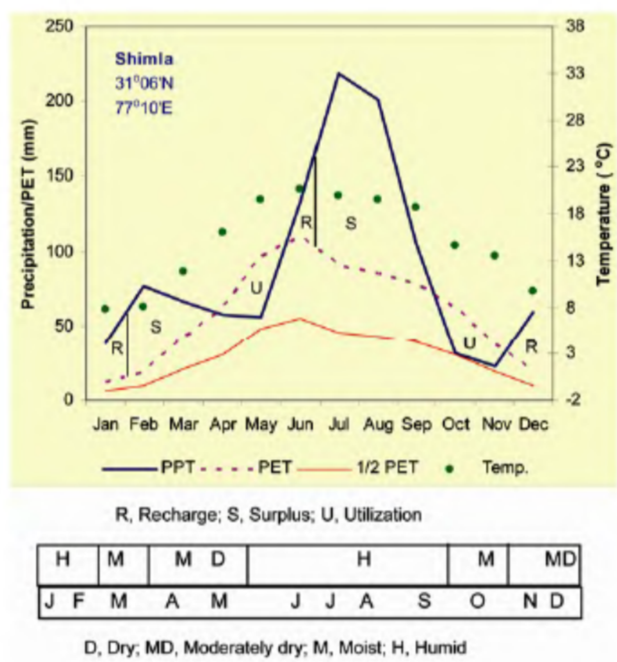

Figure 2. Water balance diagram.

approach[7], and land capability grouping of soils was done according to the standard procedure[3]. The soil and other maps thus prepared were digitized using the software Arc map. Each mapping unit has been evaluated and interpreted for land capability and its suitability for land use and maps were generated under GIS environment.

Results

Watershed characteristics

The Moolbari watershed is oval in shape with perimeter and area of 15.5 km and 1285.4 ha respectively. It has a maximum length of 5–6 km north-south and maximum breadth 3.25 km south-west to south-east. The area is drained by perennial stream Bari-ka-khad which finally merges with Sutlej River. The drainage pattern is dominantly rectangular in south-west and trellis in north-west depending upon slope, land use and geology. The drainage density is 18 per sq. km. The general slope is south-west to north-east. More than 70% area of the watershed has 25–50% or more slope and these lands are severely eroded with scanty vegetation or lying barren. About 10% of the area has slopes less than 15% and is mostly under cultivation.

Land use/land cover

Major land use identified after interpretation of RS data coupled with field checks is given in Figure 3. About 30% of the area is occupied by dense forest. The forest species consists of *Quercus leucotrichophora*, *Pinus roxburghii*, *Grewia optiva*, *Rhododendron arboretum*, *Toona ciliata* and *Celtis australis*. Cultivated land constitutes about 19% of the land followed by grazing land (13%). More than 4% of the area is occupied by rock outcrops, some of which are active quarries.

Physiography and relief

The entire watershed is extremely hilly of complex topography with an elevation ranging from 1200 to 2000 m. The general slope is south-west to north-east. The major physiographic units delineated were steep to very steep hill slopes, moderately steep to very steep hill slopes, hill terraces, hill slopes with pasture, hill slopes with forest cover and lower hill terraces/piedmont slopes (Figure 4). The relief is excessive and the watershed is drained by perennial stream Bari-Ka-Khad, which merges finally into Sutlej River. Geologically, the area is composed

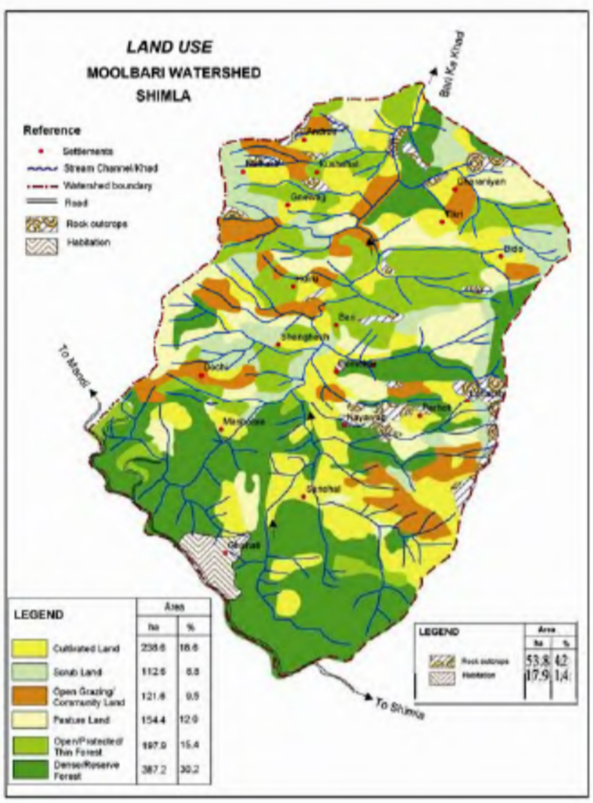

Figure 3. Land use in Moolbari watershed.

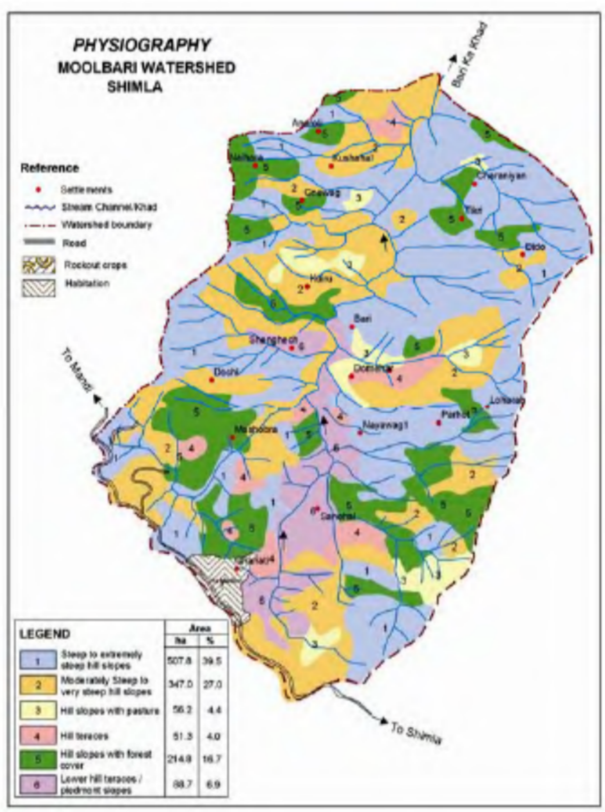

Figure 4. Physiography of Moolbari watershed.

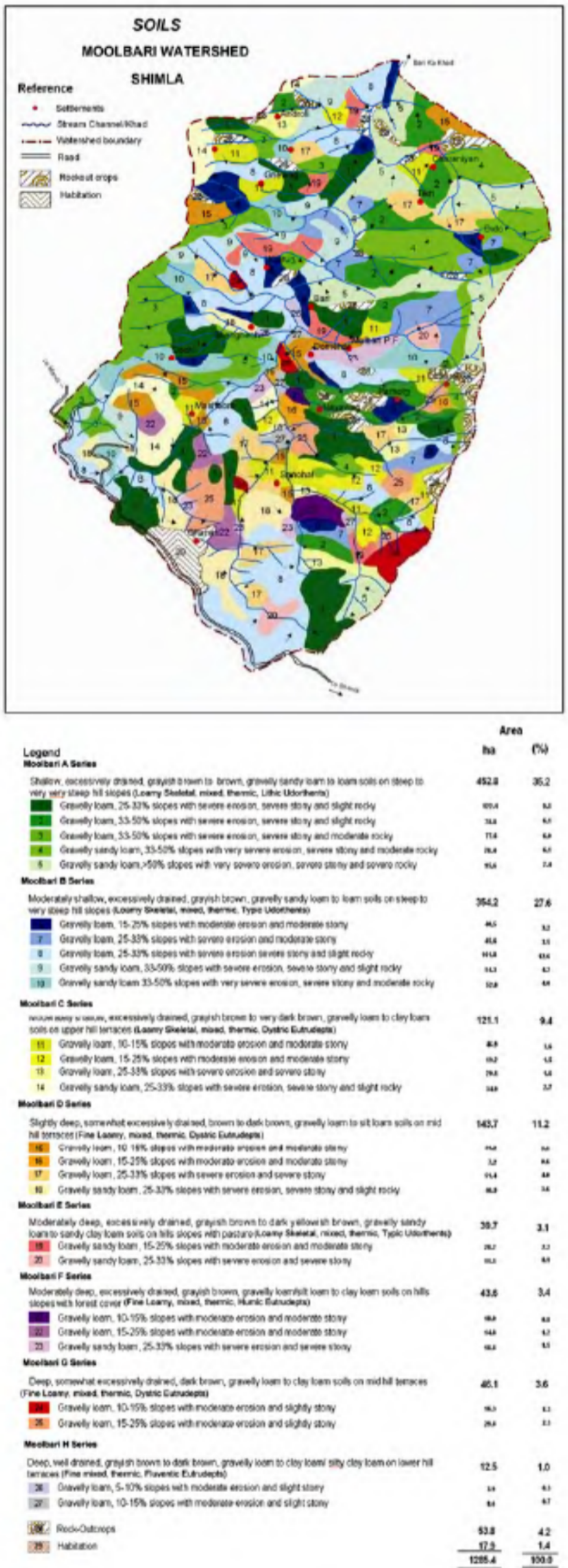

Figure 5. Soil map of Moolbari watershed.

mainly of phyllites with patches of schist and quartzite which are massive and folded. The lower hill slopes are derived from colluvial and alluvial deposits. The aspect of watershed is dominantly south-east and north-west.

Soil resources

Detailed soil resource inventory of watershed was carried out and a total of eight soil series were identified and mapped into 27 phases (Figure 5). Shallow (25–50 cm) to moderately shallow (50–75 cm), sandy loam to loam soils occurring on very steep hill slopes are classified as Lithic/Typic Udorthents. Upper hill terraces are occupied by moderately shallow, gravelly loam to clay loam soils while moderately deep (75–100 cm) loam to silt loam occur on mid-hill terraces classified as Dystric Eutrudepts. Moderately deep, sandy loam to sandy clay loam soils occur on hill slope with pasture. However, moderately deep loam to gravelly clay loam soils rich in organic matter found on hill slopes with forests. The former are classified as Typic Udorthents while the latter one placed under Humic Eutrudepts. Deep, gravelly loam to clay loam soils occur on mid hill terraces while clay loam to silty clay loam soils occur on lower hill terraces. These soils are classified as Dystric Eutrudepts Fluventic and Eutrudepts respectively. The pedogenic evolution of these soils varies from young soils (AC) to moderately developed (ABC) soils; these soils, therefore, are placed under Entisols and Inceptisols. The distribution of soils in the watershed is related to physiography, land use/land cover, slopes and aspect. The clay content of soil varies from 20% to 40% (Table 1) and its distribution with depth does not show any pattern. The pH of surface soil varies from 5.6% to 6.5% and decreases with the depth. Soils are rich in organic carbon and their content varies from 1.4% to 4.5% depending upon the land use, aspect and erosion.

Soil degradation

The soil resource data indicated that about 18% area of the watershed is affected by severe erosion, and immediate attention for soil and water conservation measures such as bunding, gully plugging, vegetative barriers and permanent vegetative cover is needed to check further expansion of gullies. More than 56% of the area is affected by severe soil erosion requiring measures such as check dams, bench terracing, grass cover, etc. Similarly, soil and water conservation modules were designed based on soil and watershed characteristics[8] for watershed soil-based resource management and planning. These lands also suffer from stoniness and restrict their use for cultivation. Soil erosion status is depicted in Figure 6.

Table 1. Physico-chemical properties of soils

Depth (cm)	Particle size distribution (%) Sand (0.05–2.0 mm)	Silt (0.002–0.05 mm)	Clay <0.002 mm	Coarse fragments (%) >2.0 mm	Text. class	pH (1 : 2.5) H_2O	Org. C (%)	CEC cmol (p^+) kg^{-1}	B.S. (%)
Moolbari A series – Lithic Udorthents									
0–12	41.8	37.2	21.0	40–50	gl	5.9	4.14	11.6	59
Moolbari B series – Typic Udorthents									
0–19	30.3	48.7	21.0	30–40	gl	6.0	4.48	13.8	60
19–42	28.7	46.3	25.0	45–55	gl	6.0	3.50	11.9	69
Moolbari C series – Dystric Eutrudepts									
0–11	29.8	43.2	27.0	25–30	gl	6.3	3.14	9.4	67
11–40	26.3	44.7	29.0	30–35	gcl	5.7	2.10	9.1	69
Moolbari D series – Dystric Eutrudepts									
0–16	43.5	42.5	14.0	20–25	gl	5.6	2.17	9.1	69
16–39	31.9	42.1	26.0	15–20	l	5.5	1.60	9.0	71
39–55	37.9	39.1	23.0	15–20	l	5.5	1.52	9.3	72
55–70	32.0	48.0	20.0	25–30	gl	5.5	1.03	9.0	60
Moolbari E series – Typic Udorthents									
0–18	51.5	28.5	20.0	25–30	gsl	6.3	2.34	9.2	66
18–39	53.1	21.9	25.0	30–40	gsl	6.2	1.17	9.1	70
39–61	53.1	22.9	24.0	40–45	gscl	6.1	0.31	9.2	66
61–82	55.1	21.9	23.0	45–50	gscl	6.3	0.27	9.2	70
82–97	55.9	19.1	25.0	60	gscl	6.2	0.16	9.0	71
Moolbari F series – Humic Eutrudepts									
0–11	31.8	44.6	23.6	40–45	gl	6.5	3.38	23.4	68
11–40	27.7	38.6	33.7	25–30	gcl	6.4	3.08	23.5	68
40–65	27.2	41.7	31.1	8–10	gcl	6.5	2.01	23.7	68
65–80	35.1	47.9	17.0	40–45	gl	6.6	1.63	10.3	67
Moolbari G series – Dystric Eutrudepts									
0–15	36.9	36.6	26.5	20–25	gl	5.5	1.4	20.2	68
15–38	19.5	44.3	36.2	15–20	Cl	4.2	1.37	16.4	62
38–61	22.6	45.1	32.3	20–25	Cl	4.6	1.29	17.0	59
61–88	28.8	38.4	32.8	15–20	Cl	4.5	1.16	18.1	57
88–116	27.9	37.8	34.3	20–25	Cl	4.7	0.38	18.2	60
116–150	29.5	34.2	36.3	30–35	gcl	4.7	0.30	18.0	65
Moolbari H series – Fluventic Eutrudepts									
0–15	30.5	48.2	21.3	30–35	gl	6.3	3.07	21.0	68
15–38	26.3	43.5	30.2	10–15	cl	6.3	2.16	22.7	67
38–69	18.1	42.1	39.8	5–10	sicl	6.2	1.14	26.2	65
69–100	14.8	46.6	38.6	10–15	sicl	6.2	0.57	16.4	74
100–125	17.4	43.4	39.2	15–20	sicl	6.1	0.42	24.7	62

B.S.: Base saturation.

Land capability classification

The soil resource data have been interpreted for land capability classes for land-use planning. It can also be used for other allied activities like forestry, social forestry, silvipasture, agri-horticulture, grassland development, etc.

The land capability classification is an interpretative grouping of different soils mainly on the basis of inherent soil characteristics, external land features and environmental factors. It serves as an important tool in land-use planning to show the relative suitability of soils for cultivation of crops, pastures, forestry in addition to focusing the problems which need preventive measures. This provides clues to the management and improvement of different soils for increasing production.

According to the USDA land capability classification (LCC)[9], land is divided into eight classes from I to VIII, however, the criterion laid down in USDA classification was modified slightly keeping in view the local conditions[10]. The first four classes, i.e. I–IV are suitable for cultivation. Classes V–VII are suitable for grazing

Table 2. Land capability classification

Land capability sub class	Description	Map unit	Area (ha)	Area (%)
IIe	Good cultivable land with deep fine loamy soils on moderate slopes with moderate erosion. Suitable for all crops with certain management practices.	26	3.9	0.3
IIIes	Moderately good cultivable terraced land with moderately deep to deep fine loamy soils on moderately steep slopes with moderate erosion and surface stoniness. Need careful management like contour terracing, strip cropping, etc.	19, 21, 22, 24, 25, 27	107.7	8.4
IVes	Fairly good terraced cultivable land with slightly deep soils on moderately steep to steep slopes with moderate erosion and stoniness suitable for limited cultivation. Need intensive conservation measures, well suited to agro-forestry and agro-horticulture.	6, 11, 12, 15, 16	152	11.8
Vse	Lands presently not suitable for arable farming due to severe problem of stoniness besides erosion. Suitable for forestry and silvi-pastural farming.	17, 18, 20, 23	128.6	10.0
VIes	Non-arable land with moderate restrictions of steep slopes, surfaces stoniness severe erosion and shallow soils. Best suited to grazing, forestry and silvi-pasture, medicinal and aromatic plants.	7, 8, 9, 13	281.8	21.9
VIIes	Fairly well suited to grazing or forestry with very severe problems of erosion, slopes and soil depth, stoniness and droughtiness. Development of these lands for permanent pastures *ghasnis* or medicinal and aromatic plants is desirable. Plantation of drought-resistant tree species is also possible.	1, 2, 3, 4, 14	392.1	30.5
VIIIes	Rock outcrops with little or no soil suited to wildlife and recreation.	5, 10, 28	201.4	15.7
	Habitation		17.9	1.4

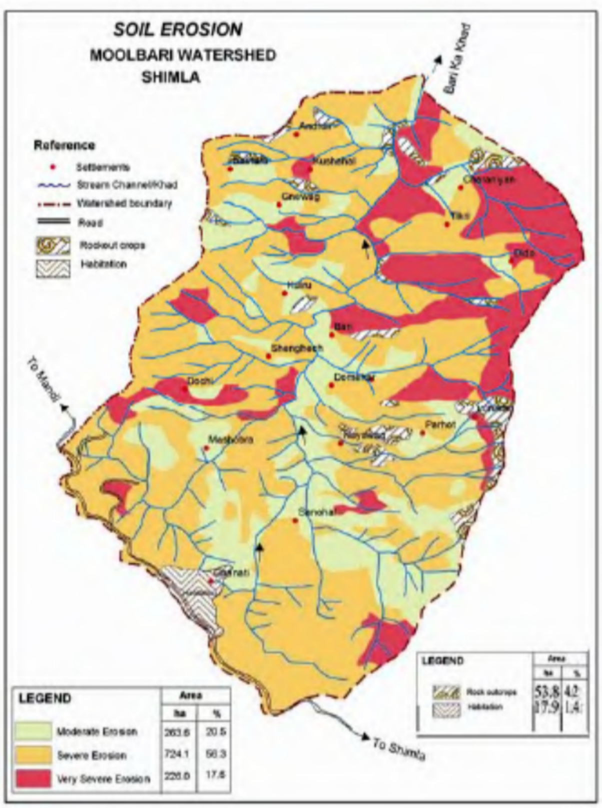

Figure 6. Soil erosion of Moolbari watershed.

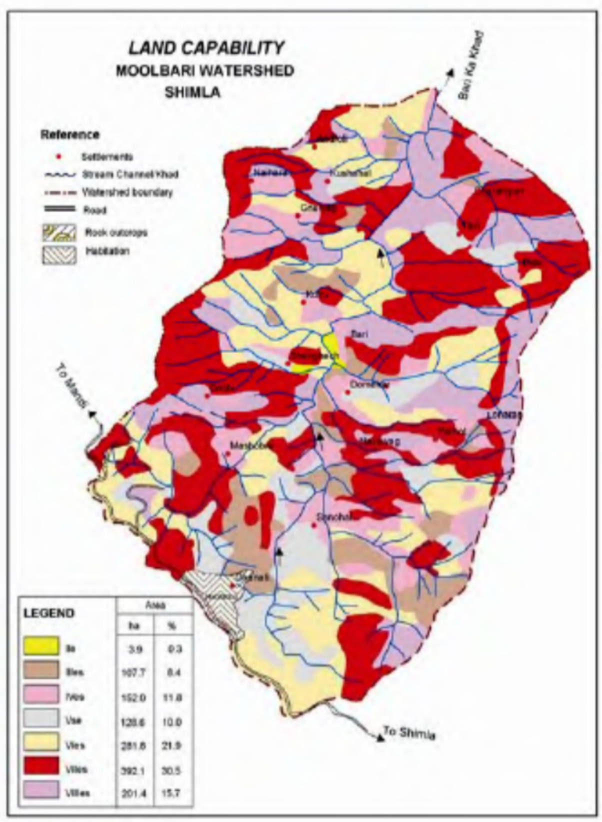

Figure 7. Land capability of Moolbari watershed.

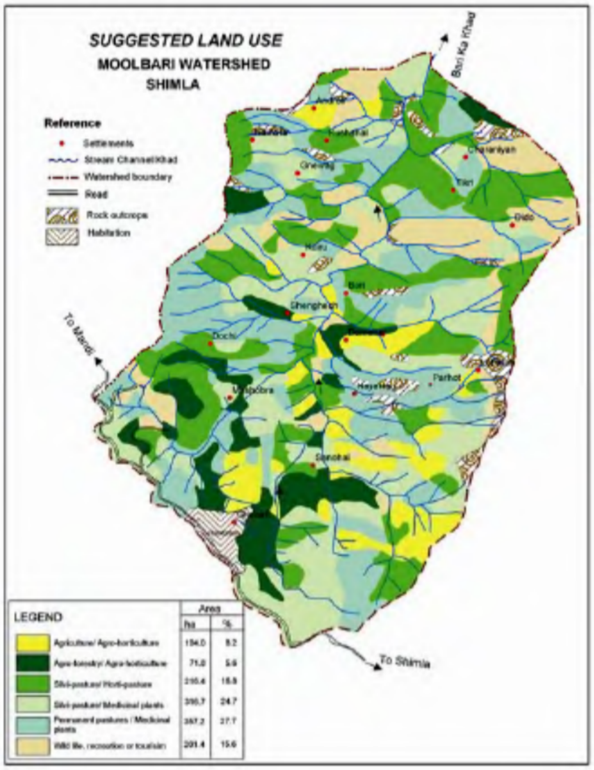

Figure 8. Suggested land use of Moolbari watershed.

and forestry. Class VIII is suitable for wildlife and recreation purposes. These classes may further be divided into subclasses depending on the number and severity of limitations. These limitations include erosion (*e*), wetness (*w*), soil root zone (*s*) and climate (*c*).

The land capability grouping, their description and extent of occurrence are presented in Table 2 and Figure 7. About 0.3% of the land is grouped into class II, 8% as class III nearly 12% into class IV and 10% into class V. The rest of the area is placed under VI to VII classes. Most land of the watershed has the risk of both soil and erosion limitations.

Land suitability analysis revealed that about 14% of the area is suitable for agriculture/agroforestry/agro-horticulture[11]; about 42% of the watershed area having moderate soil depth is suitable for silvi-pasture/horti-pasture so the existing forest cover has to be strengthened with grasses as undergrowth to protect the area against erosion. However, where the forest cover is thin, there is a scope to develop horti-pasture system with soil conservation measures. About 28% of the area which is mostly degraded is fit for pasture and medicinal plants. Soil site suitability evaluation suggested that only 5–6% of the area is suitable for vegetable crops while 1% of the area is suitable for horticultural crops. About 15% of the area comprising rock outcrops and shallow soils with severe surface rockiness can be used for wildlife, recreation and watershed protection. Figure 8 shows suggested land use based on watershed characteristics and soil resource data.

Different components of watershed such as drainage, physiography, soils, land use, etc. through remote sensing data in combination with Survey of India toposheet helped to make an inventory of soil resources and assess their potential for land use. The database thus generated can be digitized, stored and processed for generation of thematic and interpretative maps for watershed development plan using GIS.

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ACKNOWLEDGEMENT. We thank DST, New Delhi for funding project under co-ordinated programme on Bio-Geo data base for ecological modelling in Himalayas.