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Land capability assessment for land use planning using remote sensing and GIS

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Abstract

A study was undertaken in a part of Solani watershed of Haridwar and Saharanpur districts in Uttaranchal and Uttar Pradesh, respectively for assessing the land capability, to adopt suitable soil conservation measures and suggest appropriate land use through remote sensing and GIS approaches. Thematic information on soils, slope and land use was generated from remotely sensed data, Survey of India toposheet and field survey. These spatial information were integrated using GIS techniques for generating basic resource maps such as composite land use and land capability. Present composite land use (*kharif* + *rabi*) and land capability maps were integrated and suitable criteria were framed to prepare land use adjustment plan for appropriate soil conservation needs and proper land utilization in parts of Solani watershed.

Additional keywords : Watershed, Shiwalik hills, land use/ land cover

Introduction

The problems of ever-increasing population and increased competition for a variety of demands have induced tremendous pressure on shrinking land resources. It is, therefore, essential to assess the potential of available land in terms of its capability for proper land use planning (Kharche and Gaikawad 1993). Timely and reliable information on land use/ land cover and its integration with soil, terrain characteristics and climate are necessary for land use planning. Several researchers have attempted the assessment and management of soil and land resources using satellite data and ancillary information integrated through Geographical Information System (Reddy *et al.* 1990; Saha *et al.* 1992; Khan *et al.* 1994). In view of this, an attempt has been made to assess land capability for land use adjustment according to FAO (1990), as well as suggesting soil conservation measures in parts of Solani watershed for efficient land utilization.

Materials and methods

Study area : The study area is part of 'Solani watershed' falling in the administrative districts of Saharanpur (U.P.) and Haridwar (U.A.). It lies between 29° 58' to 30° 17' N latitudes and 77° 45' to 78° 0' E longtitudes and occupies an area of about 397 sq. km. The area is characterized by '*Udic*' and '*Hyperthermic*' soil moisture and temperature regimes, respectively. The area receives an annual rainfall of nearly 1044 mm and has a mean annual temperature of about 24.3° C.

False colour composites of IRS-1C and LISS III (October, 1997 for *kharif* and March, 1998 for *rabi* seasons) were visually interpreted and various land use/land cover classes for both the seasons were delineated on a base map prepared from Survey of India Toposheets of 1:50,000 scale. The image characteristics viz., size, shape, texture, pattern and various associated features were considered for the interpretation. Contour information obtained from Survey of India toposheets (1:50,000 scale) was used to derive slope information based on Digital Elevation Model (DEM). The physiographic-soil map was prepared through visual interpretation supplemented with systematic soil morphological observations and analysis of soil samples.

GIS analysis : All maps comprising base map, existing soil-physiographic map, contour and visually interpreted land use/land cover maps were scanned and georeferenced to same UTM projection using Tie point and then resampled to the base map in ILWIS 2.1 (Integrated Land and Water Information System). A composite land use/land cover map was prepared by integrating *kharif* and *rabi* seasons land use/land cover maps through crossing operation in GIS. The thematic information on soils such as soil depth, texture, erosion, drainage and slope were integrated through GIS overlay operation for generating land capability classes and sub-classes based on their limitations and potentials. The spatial themes on composite land use/land cover and land capabilities were then overlaid and suitable criteria was framed according to FAO (1990), to generate land use adjustment map depicting different categories like 'Used Within Capability (W), 'Used Within Capability but needs conservation measures' (W+); 'Under used land potential' (U); and 'Over-used land' (O). Based on this, soil conservation measues have been suggested for better utilization of land.

Results and discussion

Land use/land cover mapping : The land use/land cover information for both *kharif* and *rabi* seasons were integrated on pixel by pixel basis to generate composite land use in GIS environment. The area statistics for different land use/land cover classes are presented in table 1. It was observed that a major part of the watershed is occupied by forest (46.85%). Different forest categories identified were dense forest (>40% canopy cover), moderately dense forest (20–40% canopy cover), open forest (<20% canopy cover) and forest plantation. The agricultural land accounts for 35.61 per cent of the study area. It was also noticed that agricultural land cultivated during *kharif* was higher than *rabi* season. This shows lack of irrigation facilities in the study area which hinders the cultivation of double crops. As a result, only half of the total agricultural land was cultivated during *kharif*+*rabi* seasons (54.5%). The major crops grown in the area during *kharif* season are paddy and

maize. Wheat is a dominant crop in *rabi* season. However, sugarcane occupies land during both *kharif* and *rabi* season in the study area.

Table 1. Area statistics for different land use/land cover categories

Land use/land cover	Area (hectares)	Area (%)
Agricultural land	**14165**	**35.61**
Kharif	2916	
Rabi	1772	
Kharif+Rabi	7728	
Plantation	437	
Fallow	1312	
Forest Land	**18648**	**46.85**
Dense forest	5335	
Moderately dense forest	9172	
Open forest	3880	
Forest plantation	261	
Waste land/Scrub land	**2284**	**5.74**
Habitation	**839**	**2.11**
Water bodies	**3843**	**9.66**

Physiographic-soil relationship: Physiographically, the area has been divided into four broad physiographic untis viz., Shiwalik hills, piedmont plains, uplifted terrace and alluvial plains. These physiographic units were further subdivided based on slope, land use and drainage condition. Based on intensive field work, physiographic - soil relationship was developed (Table 2).

Shiwalik hill (s): This unit comprises moderately steep to steep slope of southern Shiwalik hills and are either barren or covered by forests of different densities. Various forest cover types identified were *Shorea robusta* (Sal), *Pinus roxburghii* (Pine), *Tectona grandis* (Teak) and *Dalbergia sissoo* (Sisham). This unit is further divided into S_1 (Top of Shiwalik hills), S_2 (Upper side slope of Shiwalik hills) and S_3 (Lower side slope of Shiwalik hills). The soils of Shiwalik hills are very deep, well drained, light textured having moderate soil erosion with more than 50% coarse fragments. The dominant soils in this unit are loamy-skeletal Typic Haplustepts. This unit supports scrubs and moderately dense to dense forest.

Piedmont plains (P): This unit comprises 1 to 5 per cent slope and subdivided into upper piedmont (P_1, 3 to 5% slope) and lower piedmont (P_2, 1 to 3% slope). Further

subdivisions were made on the basis of landuse into P_{11} (forested), P_{12} (cultivated), P_{13} (barren/scrub), P_{21} (cultivated) and P_{22} (barren/scrub). The soil in these units are deep, well drained with texture ranging from loamy sand to sandy loam. There are 30 to 80% coarse fragments in subsurface of upper piedmont plain whereas in lower piedmont plains it ranges from 10 to 30%. The dominant soils in the piedmont plain are Typic Udorthents and Typic Eutrudepts.

Table 2. Soil and land characteristics of the mapping units

Map unit	Texture		Drainage	Soil depth (cm)	Slope (%)	Erosion	Coarse fragments		Area (ha)
	Surface	sub-surface					Surface (%)	Sub sur-face (%)	
A_1	sl,l	l,sicl	Well	130	1–2	el	-	–	2832.0
A_{21}	l,sl	sl,scl	Poor	150	0–1	el		–	695.7
A_{22}	sl,l	sl,cl	Mod.well	150	0–1	el	–	–	4062.5
A_{31}	sl	sl,sil	Well	160	2–3	el	–	–	3599.3
A_{32}	sl	sl,sil	Well	140	5–7	e3	–	–	354.2
A_4	ls,sl	ls,sl	Well	170	1–2	el	–	–	585.9
P_{11}	ls,cosl	sl,fsl	Well	110	2–3	e2	20–30	30–80	3731.0
P_{12}	ls,cols	ls,sl	Well	120	2–3	el	5–10	30–60	1124.9
P_{13}	cols	cosl,cols	Well	115	2–3	e2	5–10	10–40	464.7
P_{21}	sl	sl,l	Well	130	1–2	el	–	10–30	1528.9
P_{22}	ls	ls,sl	Well	140	1–2	e2	–	>35	501.2
R_1	ls,sl	ls,sil	Well	125	7–10	e3	5–10	–	3390.0
R_2	ls,sl	ls,l	Well	120	2–5	e2	–	–	22.4
R_3	ls	ls,sil	Well	125	7–10	e3	–	–	92.8
S_1	l,sl	grcl,grsl	Well	95	10–25	e2	20–40	40–80	1103.6
S_2	sl	grsl	Well	100	25–35	e3	5–15	30–60	2695.2
S_3	sl	grsl	Excessive	115	35–60	e3	5–10	20–30	916.0
River	–	-	–	–	–	–	–	–	3843.7

gr–gravelly, co–coarse, f–fine, sl–sandy loam, ls –loamy sand, cl–clay loam, l–loam, si–silt

Alluvial Plains (A) : These are formed by alluvial deposits carried by Solani river and its tributaries. It comprises of alluvial plain upland (A_1); alluvial plain low land (A_2); dissected alluvial plain (A_3); and flood plain (A_4). These sub units are further divided into A_{21} (poorly drained), A_{22} (moderately well drained to imperfectly drained), A_{31} (cultivated) and A_{32} (scrub) on the basis of land use and existing drainage conditions. The upland soils (A_1) are

characterised by well drained coarse-loamy Typic Udorthents, whereas, the soils of low land (A_2) were characterised by imperfectly drained coarse-loamy Aquic Eutrudepts and fine-loamy Typic Eutrudepts. The dissected alluvial plains (A_3) were characterised by light texture and moderate to severe erosion with 2 to 5% slope. The flood plain (A_4) is characterised by sand to clay loam texture. The dominant soils in this unit are coarse-loamy Typic Udifluvents and coarse-loamy Aquic Udifluvents.

Uplifted Terrace (R): This unit has characteristically undulating features and further subdivided into R_1 (forest), R_2 (cultivated) and R_3 (barren) based on land utilization types. The cultivated crops in R_2 were beans, maize and wheat. These units are characterised by loamy sand to coarse sandy loam soil texture, moderately gentle to moderately steep slope with moderate to severe erosion. The dominant soils found in these uplifted terraces are coarse-loamy Typic Udorthents and Typic Udipsamments.

Land capability: Soils have been classified into different land capability classes and subclasses based on their limitations and potentials (Fig 1a). Soils of Shiwalik hills (H) are rated as sub-classes IVt, VIt and VIIt lands which are suitable for forest and occupy an area of 1103, 2695 and 9149 hectares, respectively. The soils of upper piedmont plains both P_{11} (forested) and P_{13} (barren/scrub) though qualify for class III, they are allocated to forest on account of reserved forest. The soils of P_{12} and P_{21} qualify for sub-class IIt and have good potential to support wide range of crops with minimal management whereas, the soils of P_{22} classified as IIIe lands could be used for cultivation by adopting soil conservation measures and raising cover crops such as groundnut and peas. The soils of alluvial plains especially A_{21} and A_{22} are classified as IIw lands. Though having good potentiality, it may not be advisable to put these soils under the cultivation of crops other than paddy during *kharif* season due to limitations of poor drainage conditions. Alluvial plain upland (A_1) has very good capability (class I) to support double crops as well as long duration crops. In general, climate of study area is favourable to double cropping system, if soil and topography are not limiting. Soil-physiographic untis A_{31} and A_4 are characterised as class II t and IIIs lands having capability to support short duration crops with use of organic manures and some soil conservation measures. But A_{32} unit rated as sub-class IVe lands could be efficiently utilized for forest plantation comparatively to arable crops as these lands are very marginal for cultivation and devoid of irrigation infrastructure. The soils of uplifted terrace (R) are rated as IIIte lands having capability to support forest plantation (teak and eucalyptus) by adopting suitable conservation measures. These uplifted terraces are often subjected to moisture deficiency even during rainy season. This in turn led to non-remunerative arable farming.

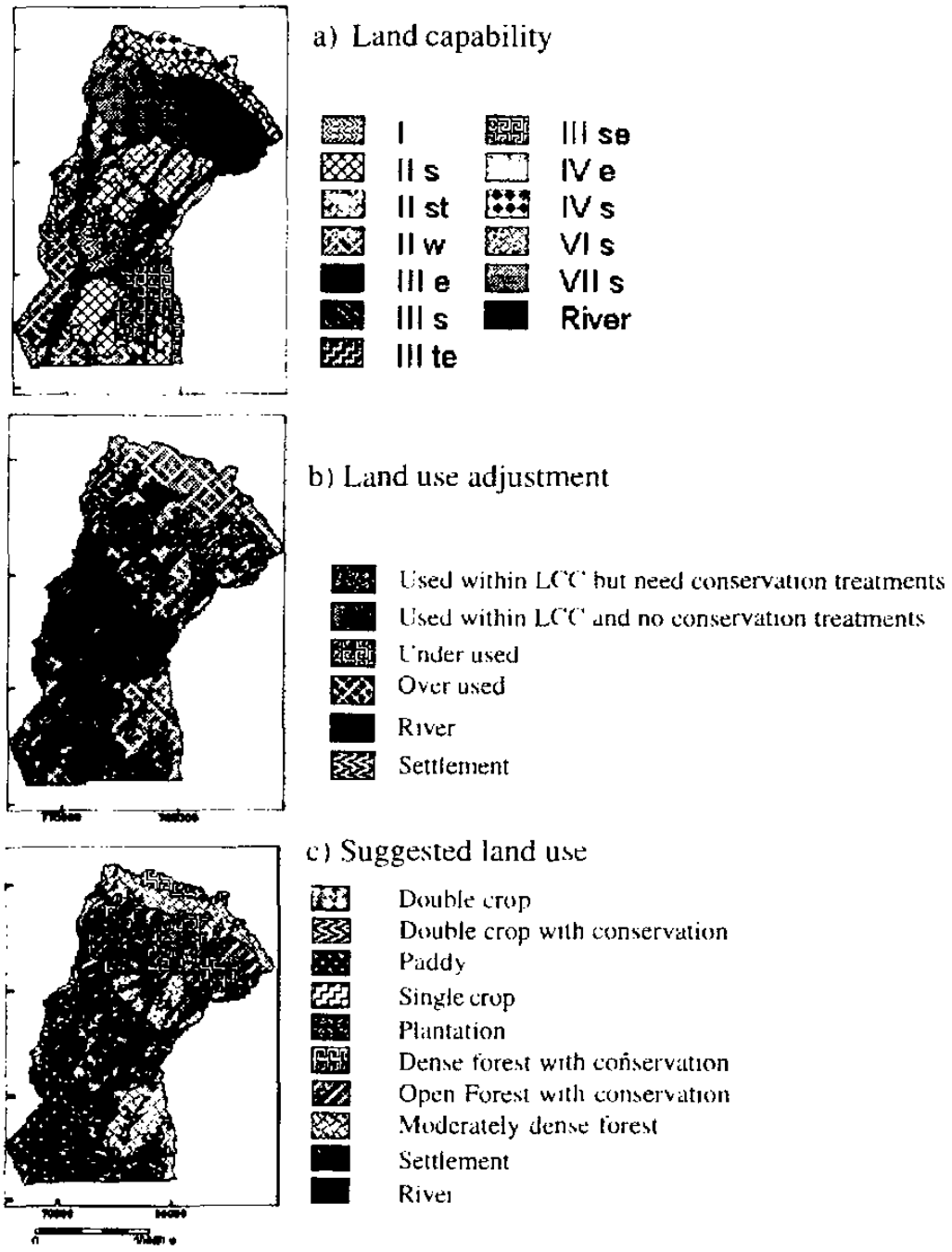

Fig. 1. Land capability, land use adjustment and suggested land use in part of Solani Watershed.

Land use Adjustment : A land use adjustment map was prepared by superimposing present composite land use map on land capability map through GIS. The areal extent under different land use adjustment categories such as 'Used within Capability' (W), 'Used within Capability but need conservation (W^+), 'Under-used land potential' (U), and Over-used land (O) were 44.5, 18.3, 24.9 and 0.02 per cent, respectively. This land use adjustment statistics (Table 3) for each soil-physiographic unit would help the watershed planner in making decisions on future land use, adjustment needs, conservation needs, and/or possible resettlement. It is observed that major part of the Shiwalik hills (S) falls under the category of 'Used within capability but need conservation treatment' (W^+). The area under land use adjustment categories W, W^+, and U on upper piedmont plain (P_1) are of 23, 47.5 and 29.3 per cent, respectively, whereas, in case of lower piedmont plain (P_2), the areal extents for the same categories are 35.6, 7.0 and 57.3 percent, respectively.

Table 3. Area under different land use adjustment class as per soil mapping unit (ha).

Map. Unit	W	W^+	U	O	Settlement	Suggested conservation measures
S_1	–	1103.5	–	–	–	Trenching & forest gap filling
S_2	85.6	2609.5	–	–	–	Trenching & forest gap filling
S_3	2993.9	5245.8	904.7	–	5.6	Trenching & forest gap filling
P_{11}	835.9	2287.1	571.9	–	35.4	Gully plugging & gap filling
P_{12}	368.1	–	694.8	–	61.2	Contour bunding
P_{13}	–	197.8	266.9	–	–	Bunding & gabbion structure
P_{21}	601.5	27.3	793.6	–	103.3	Contour bunding
P_{22}	83.8	107.9	306.3	–	2.4	Bunding & gabbion structure
A_1	484.7	–	2098.8	–	248.6	Contour bunding
A_{21}	40.5	110.6	504.5	–	40.1	Land filling
A_{22}	317.0	2434.4	1085.8	–	225.1	Land filling
A_{31}	1522.3	29.9	1919.7	–	127.8	Land filling
A_{32}	12.4	19.6	297.5	26.6	1.3	Land levelling & horticultural crops
A_4	24.1	253.2	217.8	65.9	24.4	Cover crops & embankment
R_1	8.65	3142.1	237.6	–	2.8	Forest gap filling
R_2	–	3.9	18.5	–	–	Bunding & trenching
R_3	–	82.0	10.9	–	–	Bunding & trenching
River*						

* Areal extent of river is 3843 hectares.

This indicates that land potentials of piedmont plains have not been fully utilized. More than half of the alluvial plains were found in under used (U') category. About 19 and 23.0 per cent area in alluvial plains were under W and W+ land use adjustment categories, respectively. It was also observed that majority of areas in uplifted terrace are used within capability but need appropriate conservation treatments.

Suggested land use and conservation measures : Appropriate land use and conservation measures form an important component to make optimal use of land for sustainable agricultural development. Therefore, proper land use and soil conservation measures (Figs. 1b, 1c & Table 3) have been suggested on the basis of land use adjustment and major soil constraints reducing the productive capacity of existing land use in different soil-physiographic units. Suggested land use has been generated by considering land capability, land use adjustment and present land use pattern.

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