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LAND CAPABILITY CLASSIFICATION AND CROP SUITABILITY ASSESSMENT IN A WATERSHED USING RS AND GIS – A CASE STUDY OF WATERSHED IN DEHRADUN, UTTARAKHAND

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Abstract

Remote sensing plays a key role in generation of spatial information and mapping of natural resources and inventory, especially for soil resource mapping for optimal land use for sustainable development of agriculture. A study was conducted in the watershed of Tons river to ascertain crop suitability assessment for mango and wheat using land capability classification through appropriate GIS techniques. Based on the slope map, land characteristics of each physiographic unit and land capability criteria for land qualities, land capability classes and sub-classes were assigned. These assignments were translated into a land capability map. From the slope map, a slope suitability map was generated, which was combined with land characteristics and crop suitability criteria to generate crop suitability maps for mango and wheat. For this study, the GIS software used was ARCGIS10 and image processing software used was ERDAS9.2.

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I. Introduction

There is a strong correlation between climate and vegetation on a global scale.[1,2] The main contention about plant ecology is that climate exerts dominant control on the spatial distribution of vegetation types on a global scale. Secondary factors like soil type and topography contribute on a smaller scale through moisture retention capacity and nutrient availability. Climate (temperature, rainfall, seasonal course of solar radiation) determines the predominant type of terrestrial vegetation (e.g. broadleaved forest, grassland etc) and biogeochemical properties (CO_2 flux, carbon storage in biomass and soil). The term 'vegetation' includes evergreen forests to grassy meadows and cropland. Vegetation cover also exerts an important effect on climate by controlling the hydrological cycle and earth's energy balance. They affect climate via biogeophysical mechanisms (albedo, roughness, water conductivity) and biogeochemical mechanisms (atmospheric gas composition, e.g., CO_2 and CH_4). Uttarakhand being a hilly state has a wide variety of topography, physiography, geology and climates at close intervals.[3] This in turn offers scope for growing a plethora of crops. However, each crop requires specific soil and climactic conditions for optimal growth. For economic production of crops, it is essential to conduct an assessment of the potential and limitations of the land parcel.[4]

Remote sensing data can be used to delineate various physiographic units in addition to obtaining supplementary information about site characteristics, watersheds, slope, direction and aspect information of study area.[5,6] However, soil survey data is essential for generating a soil map of the given region from which crop suitability and cropping system analysis can be derived. Remote sensing and soil survey can be incorporated in GIS to assess crop suitability for various soil conditions.[7] The objective of the current study is to conduct suitability assessments for mango and wheat in the Tons watershed of Dehradun, Uttarakhand.

II. Objectives

(i) To prepare physiographic soil map at 1:50,000 scale from LISS III data
(ii) To prepare land use and land cover (LULC) map
(iii) To prepare drainage map for watershed delineation
(iv) To digitize contour map to prepare DEM
(v) To categorize the study area according to Land Capability Classes (LCCs)
(vi) To evaluate the soil suitability for various Land Utilisation Types (LUTs)- wheat and mango cultivation- based on FAO framework of land evaluation.

III. General Description of the Area

The study area, a part of Dehradun district, Uttarakhand state, India, lies between 77°56'05"E to 78°01'01" East longitude and 30° 21'05"N to 30°26'51"North latitude approximately, covering an area of 5000 hectares (Fig. 1). It is a part of Dehradun district, Uttarakhand state, India. The study area is situated in between Tons river in the south west, Forest Research Institute and Tapakeshwar temple in the south east, Badshahibagh agricultural area in the east, Bakarna reserved forest in the North East, Batoli Block sal forest in the North West and Donga Block dense sal forest in the west. The climate of the area is sub-tropical with mild to hot summer and very cold winter. The annual rainfall of the area is 2051.4 mm. The main landscape *viz.* mountain and piedmont constitute the area. There are no alluvial plains in our study area. The northern and north western regions are dominated by mountains; Southern and eastern parts are dominated by piedmont plains, along Darer, Ghulatia and Nimi rivers. The major land uses of the area are cultivation, forest and settlement.[8]

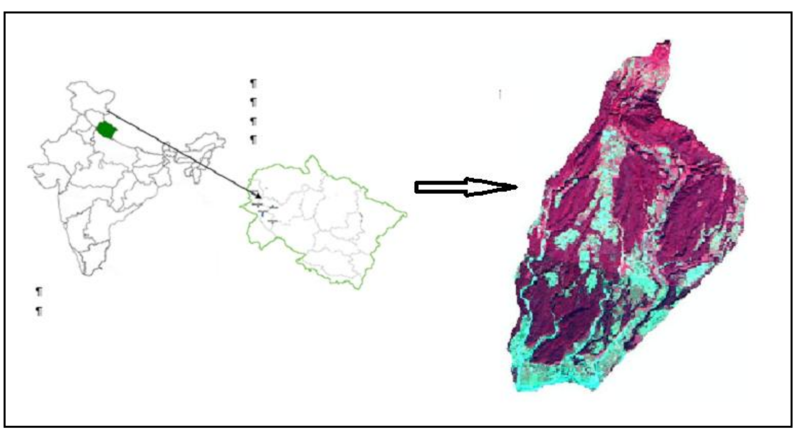


Fig. 1: Location map of the study area in Uttarakhand and its False Color Composite (FCC) obtained from LISSIII

IV. Methodology

The details of the methodology followed in the study, which included a combination of visual image interpretation and digital image analysis, land capability classification and land suitability analysis for wheat and mango, was conducted using ILWIS 9.3 and ArcGIS10.

(i) Digital image analysis and visual image interpretation[9]

Survey of India toposheets were georeferenced based on latitude and longitude values. The edges of the toposheet were matched and a digital mosaic depicting the entire study area was prepared. The satellite data was then geocoded and georeferenced by extracting the GCPs (Ground Control Points) from SOI toposheets. The digital data was then enhanced and correction models were applied to make it free from errors and distortions both radiometrically and geometrically.

The images are then visually interpreted based on several basic characteristics of features, *viz.,* colour, tone, texture, pattern, size, shape and so on and a spatial (especially topohraphical) database of maps is generated.

(ii) Land use/Land cover: Majority of the region is under forest cover mainly consists of Sal and Oak followed by agriculture and settlements. Mango orchards and tea plantation were also found in the middle and lower piedmont area and sugarcane is cultivated along with paddy and wheat. Sugarcane is grown in both Kharif and Rabi seasons.

(iii) Physiography and soils: Physiography of this region consists of Himalayan Mountains (higher and lower), Shiwalik hills, Piedmont plains, terraces and Flood plains. The FCC generated from LISS III was interpreted monoscopically along with SOI (Survey of India) toposheets (1:50,000 scale). Various landforms were identified based on physiographic variations. These landforms were further subdivided based on colour, tone, texture, pattern, association and land use. Subsequently,different features in the image were identified and boundaries of units were drawn. Simultaneously a physiographic legend was prepared.

(iv) DEM: Digital Elevation Model was prepared by digitizing contours lines of toposheet. After interpolation of the contours, we obtained the DEM map and from the DEM, we prepared the slope map.

(v) **Creation of Soil data base**: After creating the physiographic map and preparing its legends, the soil database was created. By inserting soil depth, Texture, Drainage, Coarse fragment and erosion column in the soil table, we created the respective map by using the physiographic map, soil table and the corresponding column.

(vi) Drainage and watershed: TONS river flows along the south-western border of the study area. A wide network of streams and tributaries flow into the TONS river. The drainage system of the study area was digitized in ILWIS. Three major watersheds were found in the region- Darer, Ghulatia and Nimi.

(vii) Land Capability Classification

Land capability classification involves an evaluation of the degree of limitation posed by permanent or semi-permanent attributes of land to one or more land use.[10] It is essentially a negative approach whereby the degree of constraint increases, the capability of land decreases. By combining the slope map, physiographic soil map and land capability criteria, land have been classified according to its capability as shown in Fig. 2.

Land capability classification scheme

The land is divided into eight capability classes, which are numbered in Roman numerals from I to VIII as shown in Table 1. Each class was assigned a standard colour. These eight classes grouped in two land uses suitability groups *viz.* i) "Land suited for cultivation and other uses (class I to class IV)", ii) "Land not suited for cultivation, but suitable for other uses" (Class V to Class VIII). The land capability classes are based on the degree of erosion hazards and the intensity of limitations for use.

Class I land is the best and the most easily farmed land and has no hazard or limitation for use, while in class VIII land nothing of economic value can be produced, and it may need protection and management to conserve other more valuable lands and watersheds.

Class I – land is the best and the most easily farmed. It has few limitations that restrict its use.

Class II- land has moderate limitations that reduce the choice of crops. It needs simple soil and water conservation practices and requires some attention to soil management

Class III- land has severe limitations for use, hence it needs intense soil and water conservation treatment and requires careful soil management. Graded terraces are made on moderate slopes.

Class IV- land has very severe limitations. The soil and water conservation practices are more difficult to apply and maintain

Class V- land has all the characteristics of class I land except for limitations of water-less and stoniness or rockiness or adverse climactic conditions which make it unsuitable for cultivation of crops. However, for grazing, pasture development and forestry, there are no limitations for use.

Class VI- land has the same limitations as class IV land except that they are more severe and the land is steeper
Class VII- land has severe limitations for grazing and forestry. The land is very steep and very severely eroded, cut up into gullies and is either too wet or too dry. The land is best utilized under forest and permanent vegetation and for limited grazing
Class VIII- lands are very steep or rough or stony or barren.
To determine the land capability classes, soil texture, soil depth, drainage, coarse fragments, erosion hazards and slope are taken in to consideration for study area. Criteria for land capability classification on Doon Valley area (adapted from Tejwani, 1976)[11] have been shown in the following table.

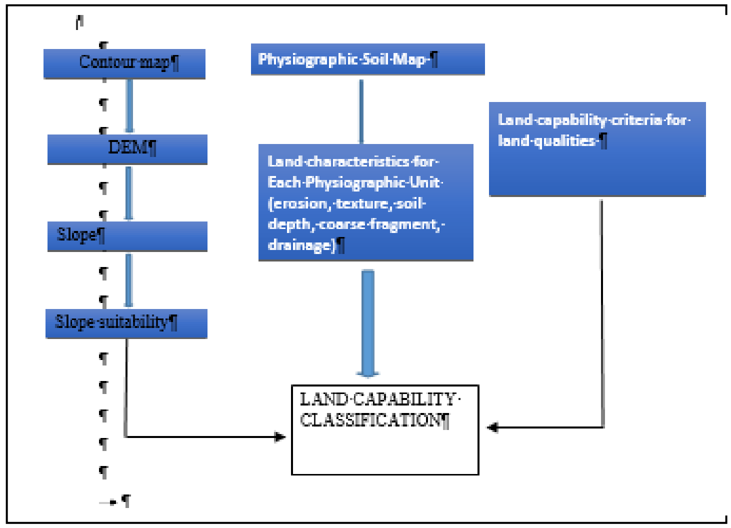


Fig. 2: Methodology for Land Capability Classification, Physiographic and Slope Map preparation

TABLE 1: CRITERIA FOR LAND CAPABILITY CLASSIFICATION[11]

Land capability class	S (rooting limitations)		E (topography and erosion)		W (water status)	C (climate)
	Soil Texture	Soil depth (cm)	Slope(%)	erosion	Flooding risk	
I	cl, l, sl, csl	>90	0-1	None (e0)	Very low	humid
II	Sicl, sil, scl	45-90	1-3	Slightly (e1)	Low	-
III	Sc, sic, c, ls	22.5-44	3-10	Moderate (e2)	Moderate	Sub humid
IV	Hc, s	7.6-22.4	10-25	Severe (e3)	Severe	Semi-arid and arid
V	-		10-25	Very severe (e4)	Very severe	-
VI	-	<7.6	25-50	-	-	-
VII	-		50-100	Bad lands	-	-
VIII	-	Rock	>100	-	-	-

Soil texture: csl, coarse sandy loam; sl, sandy loam; sil, silt

(viii) Land suitability for wheat and mango

In the field of land evaluation and scientific land use planning, remote sensing is frequently associated with GIS techniques.[7] The former provides information on actual land use/land cover, while the latter enables an integrated evaluation of land potential. This integration of GIS and Remote sensing methods is widely recognized as mutually beneficial[12], since both technologies are used in similar hardware and software.

FAO framework for land evaluation is a standard set of principles and concept on which regional land evaluation systems can be constructed.[13] The suitability classification is presented in different categories: Order, Classes, Sub-classes and units.

Soil site suitability is assessed following the FAO framework and each mapping unit was rated for each selected crop.

S1: Highly suitable land having no significant limitations, can sustain application for a given use
S2: Moderately suitable land having limitation moderately severe for sustained application for a given use
S3: marginally suitable land having limitation severe for sustained application

N: Not suitable land having limitation, which may be surmountable in time, but which can be corrected with existing knowledge at currently acceptable cost, the limitations are so severe as to preclude successful use of land in the given manner

Suitability Sub-class
The sub-class reflects the nature of limitations within a class. The limitation parameters that are used in the study are:
s- Soil texture; d– Drainage; c – Soil depth; t – Slope (topography);
e – Erosion; g- coarse fragment; f – Flood risk; and n – nutrient status.
By combining the slope suitability map, physiographic soil map and crop suitability criteria, crop suitability maps for LUT (land utilization type) - wheat and mango- have been determined as shown in Fig. 3.

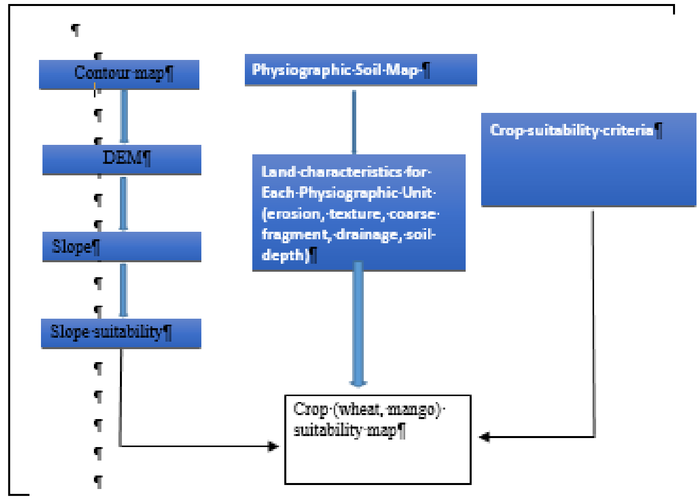


Fig.3: Methodology for Crop suitability

V.Results:

(i) **Land use/Land cover map**

Land use land cover of the study area showed that of the five LULCs, forests had the maximum cover of 60%, followed by agriculture (28.9%), waterbed (4.74%), flood plains (4.38%) and scrub (1.04%) as shown in Fig. 4.
Land use/land cover mapping was carried out using a combination of two approaches, visual image interpretation and digital image Classification of ground-truth data with FCC (geocorrected at 1:50,000 Scale). Unsupervised and supervised classified maps in ArcGIS 10 of the study area were generated as shown in Figs. 5 and 6, respectively.

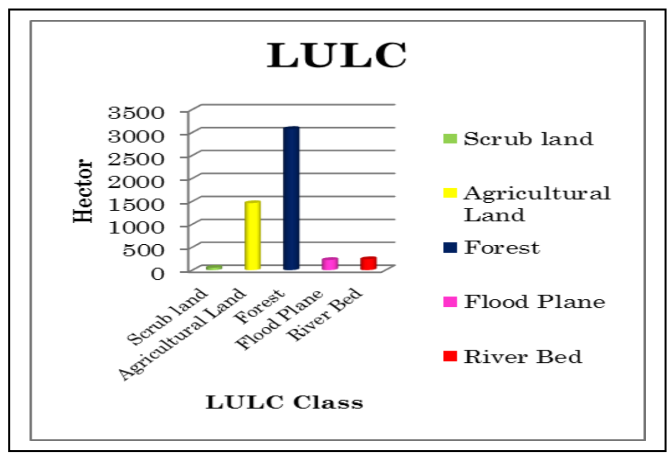


Fig. 4: Graphical representation of Land use land cover

(ii) Physiography and soils map: The study area was delineated into 3 landforms – hills, piedmont plains and flood plains. The three landforms were further delineated according to slope and finally according to vegetation cover to give 10 physiographic units as depicted in the following figure (Fig. 7).

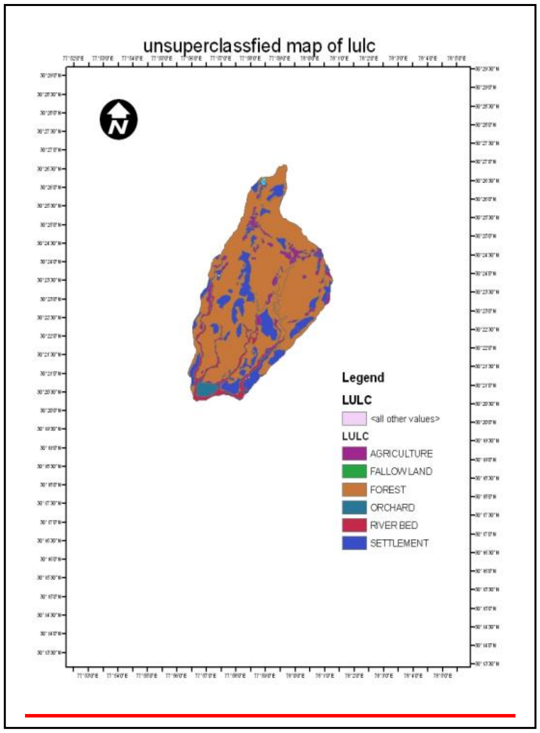


Fig.5: Unsupervised classified LULC prepared in ARC-GIS 10

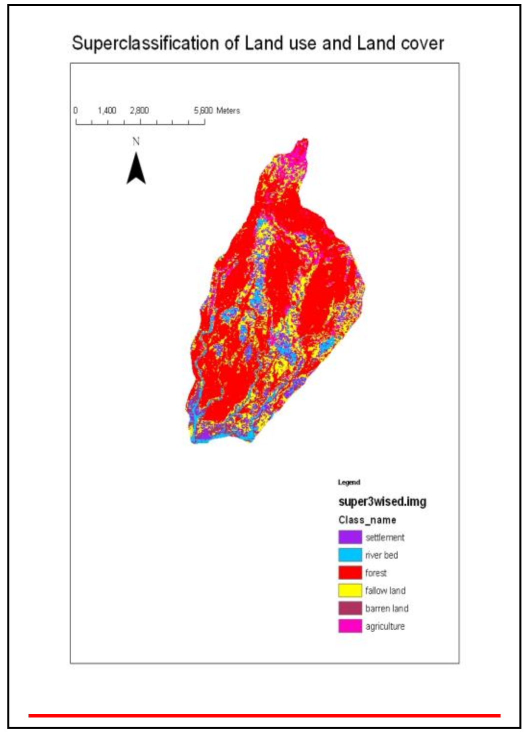
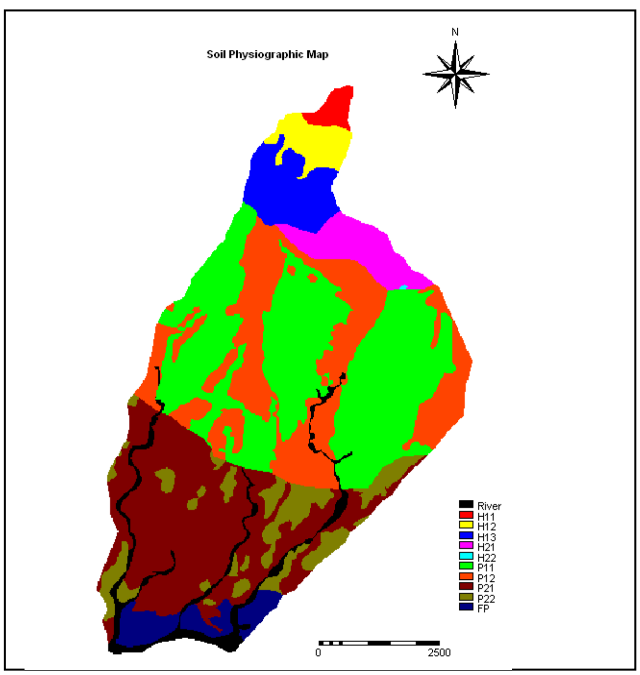


Fig.6: Supervised LULC prepared in ARC GIS 10.



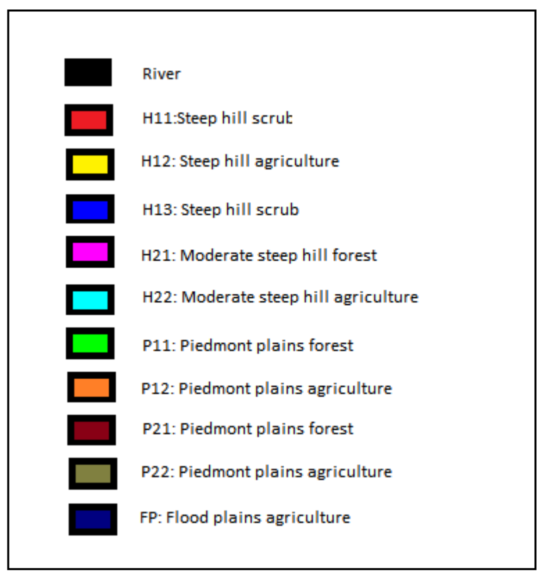


Fig.7: Physiographic soil map of study area

(iii) General characteristics of soil composition of the study area

There were three types of soil found in the study area – coarse sandy loam, sandy loam and silty as shown in Table 2.

The hilly areas had coarse sandy loam soils, while the piedmont plains had sandy loam or silty soils; the hilly areas had less soil depth, while piedmont plains had very deep soils; coarse fragment in hilly areas was very severe or severe, while in piedmont plains it was moderate or severe and in the flood plains, it was slight; drainage in the hilly areas was on an average excessive, while in the piedmont plains it was well and in the flood plains drainage was poor.

TABLE 2: Characteristics of soil composition in study area

Physiographic Unit	Texture	Depth	Coarse fragment	Drainage	Erosion hazard
H11	Csl	vs	Vs	Excessive	E4
H12	Csl	s	Vs	Well	E3
H13	Sl	md	S	Excessive	E3
H21	Sl	md	S	Excessive	E2
H22	Sl	s	M	Well	E2
P11	Sl	d	M	Well	E2
P12	Sl	d	M	Well	E2
P21	Sil	vd	S	Well	E2
P22	Sil	vd	S	Well	E2
FP	Sl	md	s	Poor	NIL

Texture: Csl, coarse sandy loam; Sl, sandy loam; Sil, silt

Soil depth: very severe (vs), 0-7.5; severe (s), 7.5-22.5; moderate (md), 22.5-50; deep (d), 50-90; very deep (vd), >90

Coarse fragment: Slight (s), 0-15%; Moderate (M), 15-35%; severe (S), 35-50%; very severe (Vs), >50%

Drainage: Excessive, >100; well, 75-100; moderate, 50-75; poor, 25-50; very poor, 0-25.

(iv) Land capability- assignment of classes and sub-classes for the study area

Land capability classes for the current study area are summarized in Table 3 and shown in Fig.8.

It was found that in hilly areas, land had severe limitations and soil and water conservation techniques are more difficult to apply; in piedmont plains, land had moderate limitations, which limited the choice of crops but conservation techniques can be applied; the flood plain also had severe limitations.

Table 3: Land Capability Classification for the study area

Physiographic Unit	Soil Texture	Soil depth	erosion	Drainage	Land Capability Class
H11	I	VI	V	VI	VI-e4
H12	I	IV	IV	I	IV-e3
H13	I	III	IV	VI	VI-e3
H21	I	III	III	VI	VI-e2
H22	I	IV	III	I	IV-e2
P11	I	II	I	I	II-e1
P12	I	II	III	I	III-e2
P21	II	I	I	I	II-e1
P22	II	I	III	I	III-e2
FP	I	III	NIL	IV	IV

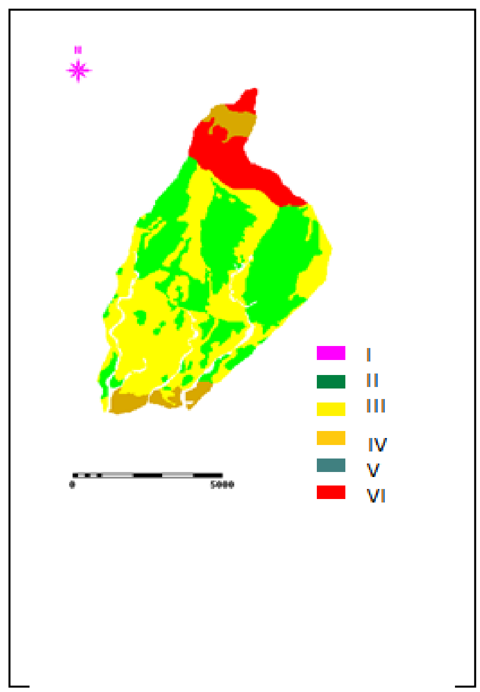


Fig. 8 : Land Capability map for the current study area

(v) Land suitability for wheat

The overall suitability of the various physiographic units are summarized in Table 4 and shown in Fig. 9. The hilly areas were not at all found suitable for growing wheat, while P12 and P22 physiographic units of the piedmont plains were found suitable.

TABLE 4: LAND SUITABILITY FOR WHEAT

Physio-Graphic unit	Soil texture	Soil depth	Erosion	Drainage	Coarse Fragment	Final suitability
H11	S1	N	N	N	N	S1
H12	S1	N	S3	S1	N	S3
H13	S1	S3	S3	N	S3	S3
H21	S1	S3	S2	N	S3	S3
H22	S1	N	S2	S1	S2	S2
P11	S1	S1	S1	S1	S2	S2
P12	S1	S1	S2	S1	S2	S2
P21	S2	S1	S1	S1	S3	S3
P22	S2	S1	S2	S1	S2	S2
FP	S1	S3	NIL	N	S3	S3

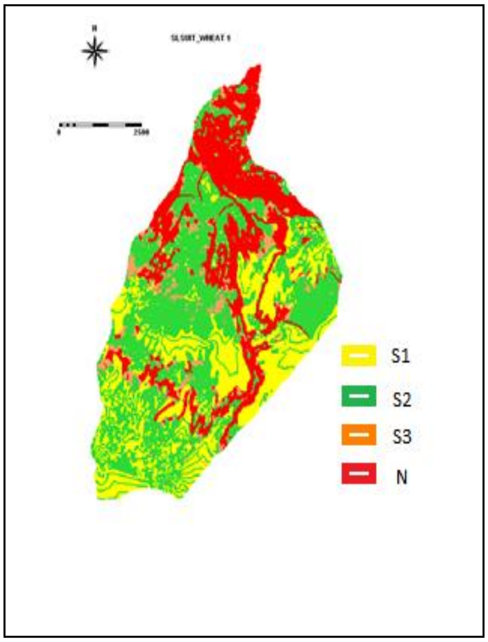


Fig. 9: Land suitability for wheat

(vi) Land suitability for mango

The overall suitability of the different physiographic units are summarized in Table 5 and shown in Fig. 10. P12 and P22 of the piedmont plains were found to be moderately suitable. H12, agricultural zone of the steep slopes, was also found to be moderately suitable for growing mango.

TABLE 5: LAND SUITABILITY FOR MANGO

Physiographic unit	Soil texture	Soil depth	Erosion	Drainage	Coarse Fragment	Final suitability
H11	S1	N	N	N	N	S1
H12	S1	N	N	S1	S3	S3
H13	S1	S2	S3	N	S3	S3
H21	S1	S2	S3	N	S2	S3
H22	S1	N	S2	S1	S2	S2
P11	S1	S1	S2	S1	S2	S2
P12	S1	S1	S2	S1	S1	S2
P21	S1	S1	S1	S1	S2	S2
P22	S1	S1	S2	S1	S1	S2
FP	S1	S2	S1	N	NIL	S2

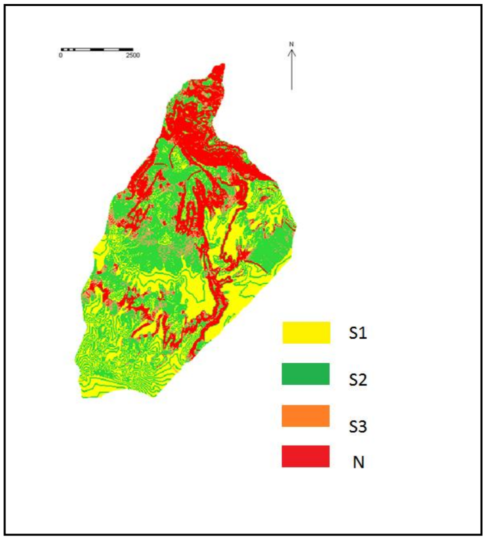


Fig.10: Land suitability for mango

VI. Conclusions

(i) Land use and land cover map of the study area gave the following results- forest, 60.9%; agriculture, 28.92%; waterbed, 4.74%; flood plain, 4.38%; and scrub, 1.04%.
(ii) The study area could be divided into two major landforms (hilly and plains) and further divided into 10 physiographic soil units. Most part of the study was covered by Himalayan mountain and piedmont plains.
(iii) The study area was placed under land capability classes II, III, IV and VI. The very steep slopes come under IV and VI. Most of the gentle slopes and piedmont plains came under classes II and III. Class II covered mainly forests and class III covered mainly agricultural land. Flood plains came under class IV.
(iv) The optimal land use for two land utilization types (LUTs) - mango and wheat- were considered. The choice of wheat and mango was based on the prevalent land uses of the area. The requirements of LUTs were matched with land qualities/land characteristics of the mapping units and subsequently, land suitability for the respective crops was determined. The study yielded the following five features.

For wheat

1. P12 and P22 are the most suitable physiographic soil units
2. H11, H12, H13 and H21 are not at all suitable.

For mango

3. P12, P22 are the most suitable physiographic soil units
4. H12 is also suitable (S2)
5. H11, H13 and H21 are not suitable

VII. Acknowledgements

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