Land Evaluation by Integrated Use of Remote Sensing and Geographic Information System for Cropping Pattern Analysis.

K.Suthakar

Abstract

Land evaluation using Remote sensing and Geographic Information system (GIS) for suggesting suitable cropping pattern was taken as an objective to avoid over and under utilization of the land resources. The study area is a part of Bijnor district of the Uttar Pradesh, India, comprising diverse landforms of piedmont plain, alluvial plain and flood plain with sub humid and subtropical climate. Land evaluation was carried out by using FAO frame work and its subsequent guidelines (1976&1984). The deterministic land qualities such as soil texture, drainage, slope, erosion, coarse fragment, and flooding hazards were taken for GIS based suitability analysis for seven land utilization types (LUT) viz, paddy, wheat, sugarcane, maize, mustard, pigeonpea, and mango. Finally, crops suitability maps of two season both winter and rainy were generated. Integrating both season maps, the suggested suitable cropping pattern map was generated.

Introduction

Agriculture is the prime sector for economic development of many countries in the world. But its development trend has reached plateau due to the lack of proper land use planning, and necessary information to farmers and other decision makers involved in this sector.

When population were far smaller than today most societies were able to live in balance with their environment. As population increased man has a greater impact on the land through clearance for farming and in order to obtain fuel and construction material. More recently, human population have increased very rapidly, especially in developing countries, and demand for food and fuel has grown alarmingly. At the same time, changing economic and social condition have undermined or destroyed traditional system of land resources management. Soil and environmental degradation are proceeding rapidly over large area of the world. There is an urgent need for a new alternative approach. For making alternative approach, it is necessary to collect the right information about physical, social and economic aspect of land area in question and asses the land's relative suitability for different use. This process is known technically as land evaluation.

Land evaluation is an important component for land use planning, which helps to evaluate the productivity function of the area and suggesting suitable cropping pattern keeping in view the existing land use, physical, social and economic background of the area. Land evaluation may address some of the problems related to the land use by presenting favourable land use, that meets the objective of crop planners and farmers. The potential of integrated approach using remote sensing and GIS technology for quantitative and qualitative physical land evaluation was demonstrated widely by several researchers all over the world. Therefore, the objective was to accomplish the land evaluation by using remote sensing and GIS for suggesting suitable cropping pattern.

Grograpyh of the area

The study area is a part of Bijnor district of Uttar Pradesh, India with a subtropical to tropical with mild to severe summer and severe cold winter. The mean air temperature ranges from 25.60 c in summer to 14.00 c in winter. The mean annual rainfall is 1059 mm. The physiograghy of the study area comprises of

piedmont plain, alluvial plain and flood plain. The soils were dominantly of typic hapludolls, Udrothents and typic Agriudolls in different physiographic units The Malin, Ratnal and Pathrnal rivers are the main seasonal streams in the area and also many other small streams which originate from shiwalik hills and traverse through the area. The major agricultural crops are paddy, wheat, maize, sugarcane and mustard. Horticulture plantation s are also occupy in considerable area.

Materials and methods

Data set

The satellite data of IRS-IC LISS-III for the period of 09th October 1998 and 02nd March were used. Survey of India toposheets (53K/6 and 53K/5) at 1:50,000 scale were used for generating base map and contour map to the study area. PC based raster GIS software, Integrated land and water information system (ILWIS) windows version 2.2, was used for integrated analysis.

Physiographic-Soil map

A collective approach of combining satellite data, topographic information, supplement with the field data on soil survey information of the soil in the sampled areas was adopted. Physiographic soil map at 1:50,000 scale of the Bijnor district prepared by Agriculture and Soils division of Indian Institute of Remote Sensing (IIRS), Dehradun was used as a source map to prepare physiographic soil map.

Land use/Land cover map

IRS IC-LiSS III temporal images in the form of False Colour Composite (FCC) were interpreted monoscopically for land use/land cover using the image elements like colour, texture, pattern, shape size, and association. Land use/land cover types were drawn from imagery with the help of identification keys. The field work was undertaken to verify and check the pre-field interpreted land use/land cover map of the area and modification was made wherever necessary. Ground truth verification of each land use category was done intensively to cover the area of maximum heterogeneity. After completion of ground verification final land use/land cover map was prepared for both seasons of rainy and winter.

Land suitability analysis

Eight land utilization types (LUTs) were chosen for land evaluation. Each physiographic-soil unit was evaluated for the LUTs suitability. The selected LUTs, LUT-I (paddy), LUT-II (wheat), LUT-III (suguar cane), LUT-IV (maize), LUT-

V(mustard), LUT-VI (pigeon pea), LUT-VII (mango), were evaluated by using FAO framework of land evaluation. The deterministic land qualities such as soil texture, drainage, slope, erosion, coarse fragment, fertility, and risk of flooding were taken for suitability analysis (table 1 and 2). The methodology adopted is presented in figure 1. By incorporating the land utilization criteria (requirements) in map calculation module of the ILWIS, the suitability ratings for each land quality were generated. By further integration and reclassification each land quality with each LUT, the suitability maps were generated in max operation module. Rainy and winter season suitability map were generated separately by further integrating the respective seasonal crops in cross operation. By integrating rainy and winter season suitability maps, the suitable cropping pattern map for the agricultural crop calendar was generated.

Results and Discussion

Three major physiographic-soil units and 20 sub units have been found in the study area. These are Piedmont, alluvial plain and flood plain. Piedmont is found in the northern part of the area. The total area under this unit is 27710 hectare. Alluvial plain is formed as a result of fluvial deposition carried by rivers. 15833 hectors of area is under this physiographic unit. Flood plain is the low land in both sides of rivers. This unit has recent alluvial deposits. Total area of this unit is 528 hectares. The soils were found to be dominant by typic Hapludolls, Udrothents and typic Ustochrepts in different physiographic soil units. Soil units P221, P211, P231, P321, P311 and P331 are not assessed for crop suitability analysis because these units are today under forest cover.

The results on land use/land cover analysis by visual interpretation by temporal satellite imagery (table 3) showed that maximum area was predominantly under paddy, wheat, and sugar cane. Dense forest occupies 1.09 percent of the area. It is interesting to note that the area under degraded forest more than under dense forest (16.86%) which indicate the deforestation activities in the area. At the same time forest plantation covers 6.85 percent in the study area. River course also occupies 1.87 percent of the total area.

Table 1: Criteria and rating of soil and land qualities for seven LUTs

Soil and Land quality	Suitability Class	LUT-I (paddy)	LUT-II (wheat)	LUT-III (sugar care)	LUT-IV (maize)	LUT-V (mustard)	LUT-VI (pigeon pea)	LUT-VII (mango)
Texture	S1	CL	SI	CL	SL	SL	L	LS
	S2	SL	SL	SC	L	CL	SL	SC
	S3	coarse SL	LS	C	CL	SC	S	CL
	N	S	fragmental	S	S	S	fragmental	C
Drainage	S1	imperfectly to poor	well drained	well drained	well drained	well drained	well drained	well drained
	S2	Mod to well drained	mod well drained	mod well drained	mod well drained	mod well frained	mod well drained	mod well drained
	S3	some what excessively	imperfectly drained	imperfectly drained	imperfectly drained	imperfectly drained	excessively drained	imperfectly drained
	N	excessively	poorly drained	poorly drained	poorly drained	poorly drained	poorly drained	poorly drained
Slope	S1	level	level	level	nearly level	nearly level	flat to nearly flat	flat to mod slope
	S2	very gentle	gentle slope	v.gentle	mod.sloping	very gentle	gentle slope	strongly slope
	S3	gentle slope	mod. slope	gentle slope	mod.steep	mod.to strong slope	mod.slope	mod steep to steep
	N	moderate to steep	steep sloping	steep sloping	steep to very steep	steep sloping	steep to very steep	steep to very steep
Erosion hazard	S1	none	none	none	none	none	slight	slight
	S2	slight	slight	slight	slight	slight	moderate	moderate
	S3	moderate	moderate	moderate	moderate	moderate	Severe	Severe
	N	Severe	Severe	Severe	Severe	Severe	Very severe	Very severe
Risk of flooding	S1	Very severe	none	none	none	very low	low	none
	S2	low	low	low	low	low	moderate	moderate
	S3	moderate	moderate	moderate	moderate	moderate	high	high
	N	high	high	high	high	high	very high	high
Coarse fragment	S1	none	none	none	none	none	none	slight
	S2	slight	slight	slight	slight	slight	slight	moderate
	S3	moderate	moderate	moderate	moderate	moderate	moderate	Severe
	N	Severe	Severe	Severe	Severe	Severe	Severe	Very severe
Ferity status	S1	high	high	high	high	high	high	medium
	S2	medium	medium	medium	medium	medium	medium	low
	S3	low	low	low	low	low	low	very low
	N	very low	very low	very low	very low	very low	very low	very low

SL = sandy loam, CL=clay loam, L=loam, LS=loamy sand, S=sand,SI=highly suitable, S2=moderately suitable, S3=marginally suitable, N=not suitable.

Table 2 Soil and land characteristics of the mapping units.

No.	Mapping Unit	Texture		Drainage	Topography Slope	Erosion	Fertility	Coarse Fragment	Risk of Flooding
		Surface	Subsurface						
01	P11	sl	sl	well	v.gentle	none	high	moderate	nil
02	P12	sl	sl	well	v.gentle	slight	medium	moderate	nil
03	P221	sil	sil	well	level	none	high	none	nil
04	P222	l	sil/l	well	v.gentle	none	medium	slight	
05	P211	sl	l	mod well	level	slight	high	none	nil
06	P212	l	sil	mod well	level	none	medium	none	nil
07	P231	ls	sl	mod well	level	slight	high	none	nil
08	P232	sl	l	well to mod well	level	none	medium	none	nil
09	P321	sl	sl	well	Nearly level	none	high	none	nil
10	P322	sl	l	well	Nearly level	none	high	none	nil
11	P311	sl		well	v.gentle	none	high	none	nil
12	P312	sl	l	well	v.gentle	none	high	none	nil
13	P331	sl	l	well to mod well	level	none	medium	none	nil
14	P332	sl-l	lc-l	well to mod well	level	none	medium	none	nil
15	A12	sl	l	well	v.gentle	none	medium	none	nil
16	A11	sicl	l-sicl	modwell	level	none	medium	none	v. low
17	A13	cl	l	imperfect	level	none	medium	none	v. low,
18	A21	l	cl	mod well to well	level	none	medium	none	v. low
19	F1	ls	sl	well	v.gentle	none	medium	none	high
20	F2	fs	fs	excessive	v.gentle	slight	very low	none	v.high

Notations: fs-fine sand, is-loamy sand, sl-sandy loam, l-loam, scil-silty clay loam cl-clay loam, cultivation.

Figure 1.Methodology of Suitability analysis for land utilization types

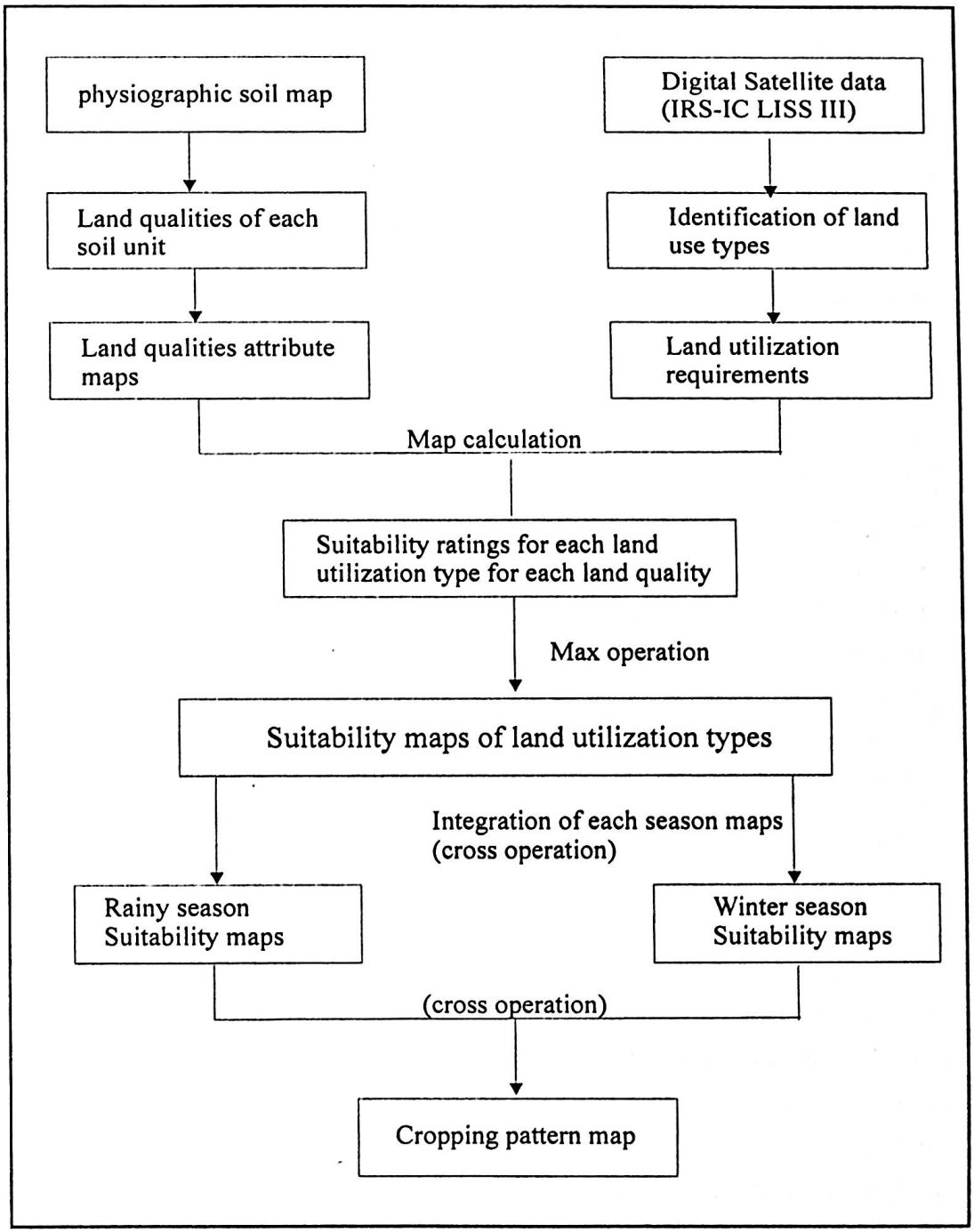


Table 3. Spatial extent of different land use/land cover of the study area.

Land use/Land cover	Rainy		Winter	
	Hectare	Percentage	Hectare	Percentage
Dominantly Paddy	11906	24.25	---	---
Dominantly Wheat	---	---	12652	25.79
Sugarcane	9426	19.19	10652	21.69
Mixed	6336	12.95	6170	12.59
Fallow	2728	5.56	922	1.88
Horticulture	200	0.42	200	0.42
Dense Forest	538	1.09	538	1.09
Degraded Forest	8313	16.86	8313	16.86
Opean Forest	4310	8.78	4310	8.78
Forest plantation	3378	6.87	3378	6.87
Habitatrian	1002	2.05	1002	2.05
Water bodies	58	0.11	58	0.11
River	919	1.87	919	1.87
Total	49114	100.00	49114	100.00

Crop Suitability Analysis

For paddy none of the physiographic-soil units were found highly suitable. Seven units are not suitable due to coarse fragment, texture and flooding hazard. Rest of the soil units are found to be moderately suitable for paddy which covered 29535.38 hectares (59.89%) of the total area.

For wheat, it is found that soil units, P221 and P322 are highly suitable and the area is 4341.84 ha(8.8%). Four units are found as not suitable, the limitation are coarse fragment, floods hazard and soil erosion. Most of the units are found moderately suitable and marginally suitable for sugarcane and the extent is 28667.89 ha, (56.92%) and 3040.80 ha, (6.26%) respectively.

Soil units P311 and P321 are found highly suitable for maize covering an area of 1519.85ha (3.08%). Nearly 50% of the total area belongs to moderately suitable for maize. It was observed that three land units are highly suitable (P221, P321, P322) for mustard and the area is 5254 ha, (10%). Soil units under piedmont plain were found highly suitable for mango, covering area of 6522.35ha. (13%)

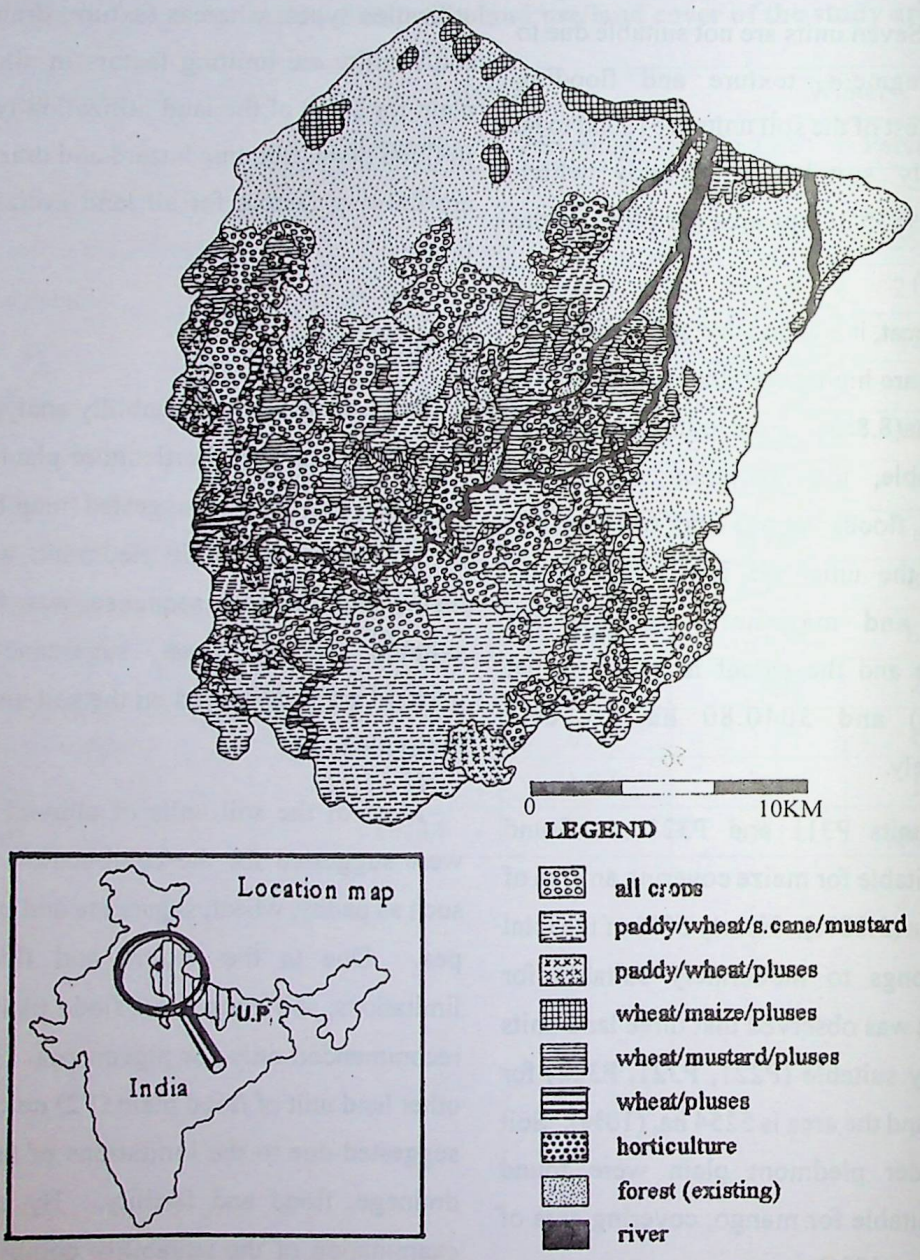
In piedmont plain coarse fragment, texture and erosion hazards were found as limiting factors for some of the land utilization types, whereas texture, drainage and fertility are limiting factors in alluvial plain for some of the land utilization types. In flood plain, flooding hazard and drainage are limiting factors for all land utilization types.

Cropping Pattern

As observed in the suitability analysis in the upper piedmont, horticulture plantation especially mango was suggested (map 1). In the soil units of middle piedmont, wheat, maize and mustard sequence was found suitable. Paddy, wheat, sugarcane and mustard were suggested on the soil units of lower piedmont.

Most of the soil units of alluvial plain were suggested for the combination crops such as paddy, wheat, sugarcane and pigeon pea. Due to the texture and flooding limitations, soil units F1 of flood plain was recommended only for pigeon pea. In the other land unit of flood plain (F2) no crop is suggested due to the limitations of texture, drainage, flood and fertility. By overall examination of the suitability combination wheat, mustard, pulses along with sugarcane

Map1 - Suggested Cropping Pattern for the Study Area
(Najibabad Block, Bijnor District, U.P, India)



as ratoon cultivation was found to be a wise suggestion for winter season. Similarly, for rainy season paddy, maize, with sugarcane as ratoon were found to be suitable. The suggested crop combination of paddy, wheat, sugarcane, mustard and pigen pea were occupied 30.35Percent of the total cropped area.

Conclusion

The study clearly demonstrates the petential use of satellite data in mapping of soil resources and land use/land cover types. On the other land, the multipe integration options and ease in analysis offered by GIS technology helped in land evaluation for cropping pattern analysis by incorporating variety of input parameters in interest.

References

Beek, K.J, de Bie, C.A and Driessen, P.M (1997) Land information and land evaluation for land use planning and sustainable development, The land 1:45-65.

Dela cruz, R.A (1992). The determination of suitable upland argicultural areas using GIS technology, Asian-Pacific Remote sensing Journal 5:123-132.

Davidson D.A (1992), The evaluation of land resources, Longman Scientific and Technical. New york.

FAO (1976), A framework of land evaluation, FAO soila Bulletion 32, Food and Agricultural Organization, United Nations, Rome, Italy.

Ilaco,B.V (1985), Agricultural compendium for rural development in the tropics and subtropics, Elsevier, Amsterdam.

Mitra, B(1994) Use of GIS and Remote sensing in interpreting land use, Geographical review of India 57:150-155.

Rossiter, G.D (1996), A theoretical framework for land evaluation, Goederam, 72:165-190.

Suthakar, K. (1999) Integrated use of Satellite Remote Sensing and GIS in optimal land use planning for agriculture development A case study, unpublished P.G.Diploma project report, Dehradun, India.