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A remote sensing approach in appraisal of soils for sustainable land use plan - A case study in semi-arid region

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Abstract

Monoscopic visual interpretation of false colour composite (FCC) of IRS-1A LISS-II imagery at 1:50,000 scale for soil mapping was carried out in conjunction with field checks covering an area of 154.25 thousand hectares in a part of Mahendragarh district, Haryana. The soil map, thus prepared has nineteen mapping units indicating soil association at the family level. Soil and land resource units were evaluated for their suitability for major agricultural crops viz. wheat, mustard, gram, and pearlmillet by matching the relevant land qualities against the land requirements of these crops. The study showed that upper fluvial plains are moderately suitable (S2) for mustard, gram and pearlmillets whereas associated soils for wheat and gram. Lower fluvial plains and buried pediments are moderately suitable (S2) for wheat and gram whereas associated soils are moderately suitable (S2) for wheat. Interdunal depression and sandy plains are marginally suitable (S3) for pearlmillets and the associated soils of units are moderately suitable for mustard, gram and pearlmillets. Dissected buried pediments and sand dunes are not suitable (N) for agriculture, but by introduction of sprinkler irrigation, sand dunes can be brought under agriculture or arid-horticulture systems.

Additional keywords: Mahendragarh district, land evaluation.

Introduction

Recent advances in remote sensing technology have opened new vistas in the mapping of soils. A wide variety of satellite remote sensing data from LANDSAT -TM, SPOT, IRS-1A, IRS-1B and IRS-1C are now available to the earth resource scientists for the preparation of soil and land resource maps at 1:50,000 scale. These soil resource maps will serve as valuable input for generating various thematic maps that will help for preparing appropriate landuse plans for sustainable agriculture. Several workers have reported the utility of the technology for evaluating the land for agricultural land use planning (Manchanda *et al.* 1982; Kuhad and Karwasra 1987; Shiva Prasad *et al.* 1990; Ahuja *et al.* 1992).

In the present paper an attempt has been made to study the applicability of IRS-1A LISS-II data for land evaluation in semi-arid climatic zone comprising of aeolian, fluvial and pediment plains for crop planning.

Materials and methods

The study area lies between 27°48' to 28°28'N latitudes and 75°54' to 76°22'E longitudes covering an area of 1542.5 sq.km. in Mahendragarh district of Haryana. It falls in the semi-arid climatic zone of the country. The maximum and minimum air temperatures are 45.6°C and 2.0°C, respectively. The mean annual rainfall is 466 mm and about 82% of it is received during the monsoon period from July to September. The post monsoon months of October, November and December are relatively dry. Winter rains are scanty. The rainfall pattern is very erratic. The mean annual soil temperature is 24.5°C and therefore, the area qualifies for hyperthermic temperature regime. The moisture regime is ustic.

Geologically, the rocks of the area belong to Delhi super group comprising of Alwar and Ajabgarh groups of rocks. The Alwar group of rocks have predominantly arenaceous sediments consisting of quartzite, micaceous quartzite, schist and carbonaceous phyllite.

The Ajabgarh group of rocks are characterized by argillaceous sediment, shale, slate, phyllite, schist, crystalline and impure limestone.

IRS-1A, LISS-II geo-coded FCC product on 1:50,000 scale of October 25, 1993 was visually interpreted for physiographic delineation in conjunction with Survey of India (SOI) topographic map on 1:50,000 scale. Five major landforms were delineated and were further subdivided on the basis of image characteristics like tone, texture, pattern and association alongwith topographic variations into nineteen physiographic-landuse units. In order to prepare soil map, sample strips were selected covering all the physiographic-land use units and intensive soil studies were carried out in each of those to establish the soil association at family level (Soil Survey Staff 1992). Using this physiography - soil relationship, a soil map was prepared by extrapolation in the rest of the area. The total area and percentage of each mapping unit were also calculated.

The suitability of soils for growing wheat, mustard, gram, and pearl millet was evaluated using the methods and criteria given by FAO (1976) and Sys (1978).

Results and discussion

Physiography and soils

Physiographically, the area has been broadly divided into five landforms namely, hill, pediplain, aeolian plain, fluvial plain and abandoned river course. Each landform was further sub-divided based on topography and major land use for soil-physiographic units. Hills which are barren and rocky appear as dark gray tone with irregular shape on imagery. The pediplain comprising of pediment and buried pediment was delineated with the help of toposheets and image characteristics. Among pediment, barren pediment appears as yellowish white whereas pediment with forest appear as light red. Buried pediments are categorized into cultivated, forested and degraded area which depict very light red, red and bright white tone on respectively, imagery. The aeolian plains consisting of sand dune, interdune, sandy plains and dunal complex were further sub-divided based on tone, texture and pattern variations on imagery. Sand dune appears as light creamy white, interdune as creamy white, sandy plain as very light pink with smooth texture and dunal complex as creamy white to light red with red mottles of coarse texture. Fluvial plains were subdivided into upper and lower plains. Upper fluvial plains appear as light bluish green and moderately smooth texture whereas lower fluvial plains as dark bluish green with smooth texture. In fluvial plains, forest area is delineated with dark red tone. Abandoned river course appears as light red tone with linear pattern which was delineated with the help of toposheets. The physiography and soil map prepared in the scale of 1:50,000 has association of families as mapping units and the legend showing physiographic units, soils and their spatial distribution are given in table 1. Nineteen mapping units were formulated and their composition established. The soils belong to the orders, Entisol and Inceptisol.

The hills have thin layer of coarse fragments and at places there are only rock outcrops. The soils are very shallow, containing >50% coarse fragments, loamy sand in texture, well drained and severely eroded in the barren pediments (P11) whereas pediments with forest (P12) have moderately deep, well drained and moderately eroded loamy sand soils. Buried pediments (P21) have very deep, loam to clay loam, and well drained soils whereas dissected buried pediments (P23) are very severely eroded and have very deep, well drained soils with loamy texture. Sand dunes (A11) have very deep, excessively drained, moderately eroded sandy soils. Height of dunes ranges from 2 to 5 metres having 5-10 per cent slope. Uncultivated sand dunes (A13) have slope of >20%. Soils of this unit are fine

Table 1. Physiography and soils

Map Unit	Physiography - Landuse	Soil family association*	Area (ha)	Area (%)
H	Hill - Barren & Rocky	———	4589	2.97
P11	Pediment - barren	Loamy-skeletal, Lithic Ustorthents	772	0.50
P12	Pediment - forested	Loamy-skeletal, Lithic Ustorthents Loamy-skeletal, Aridic Ustochrepts	2943	1.90
P21	Buried pediment - cultivated	Coarse-loamy, Aridic Ustochrepts Fine-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustorthents	9952	6.45
P22	Buried pediment - forested	Coarse-loamy, Aridic Ustochrepts Fine-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustorthents	1935	1.25
P23	Buried pediment - dissected	Coarse-loamy, Aridic Ustorthents	995	0.65
A11	Sand dune - cultivated	Typic Ustipsamments	26136	16.90
A12	Sand dune - forested	Typic Ustipsamments	804	0.50
A13	Sand dune - uncultivated	Typic Ustipsamments	891	0.58
A21	Interdune depression - cultivated	Typic Ustipsamments Coarse-loamy, Aridic Ustorthents	2065	1.34
A22	Interdune depression - forested	Typic Ustipsamments Coarse-loamy, Aridic Ustorthents	579	0.37
A31	Sandy plain - cultivated	Coarse-loamy, Aridic Ustorthents Typic Ustipsamments	4665	3.02
A41	Dunal complex - cultivated	Typic Ustipsamments Coarse-loamy, Aridic Ustorthents	35033	22.70
A42	Dunal complex - forested	Typic Ustipsamments Coarse-loamy, Aridic Ustorthents	6348	4.10
F11	Upper fluvial plain - cultivated	Coarse-loamy, Aridic Ustochrepts Fine-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustorthents	39687	25.70
F12	Upper fluvial plain - forested	Coarse-loamy, Aridic Ustochrepts Fine-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustorthents	516	0.33
F21	Lower fluvial plain - cultivated	Fine-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustorthents	12591	8.16
F22	Lower fluvial plain - forested	Fine-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustochrepts Coarse-loamy, Aridic Ustorthents	33	0.02
R	Abandoned River Course - forested	Coarse-loamy, Typic Ustifluvents	2843	1.80
S	Settlements		867	0.56
		Total	1,54,251	100.00

* Soil moisture regime - Ustic; Soil temperature regime - Hyperthermic; Mineralogy class - Mixed

sand in texture, excessively drained and severely eroded. Soils of interdunal depression with cultivation (A21) are loamy sand to sandy loam in texture, very deep, somewhat excessively drained and have very gentle slope. Soils of the very gently sloping sandy plain (A31) are very deep, loamy sand to sandy loam in texture and somewhat excessively drained.

Dunal complex units (A41) consisting of small dunes have very deep, fine sand to loamy sand, excessively drained, and moderately eroded soils. This unit is partly under cultivation and partly under forest cover. Fluvial plains were delineated as upper and lower subunits. Soils developed in the upper fluvial plain are very deep, sandy loam to loam and are well drained whereas soils in the lower fluvial plains are very deep, loam to clay loam and are moderately well drained. Soils in the abandoned river channel (R) are very deep, well to excessively drained and consist of stratified layer of sand and clay loam. This unit is under forest cover.

Table 2. Soil-site characteristics of map units

Map Unit	Soil-site characteristics: Soil texture	Soil depth	Coarse fragments (%)	pH (1:2)	EC (dS m^{-1})	Organic matter %	Topography slope (%)	Relief	Drainage	Permeability	Erosion
P11	ls	Very shallow	>50	7.8	0.13	0.20	3-8	Normal	Well	Mod.rapid	Severe
P21	l	Very deep	Nil	7.8	0.15	0.55	2-7	Normal	Well	Mod.rapid	Slight
	cl	Very deep	Nil	8.1	0.28	0.47	2-7	Normal	Well	Moderate	Slight
P23	l	Very deep	Nil	7.7	0.10	0.43	5-8	Normal	Well	Mod.rapid	V.severe
A11	fs	Very deep	Nil	8.4	0.12	0.43	5-10	Excessive	Excessive	Very rapid	Moderate
A13	fs	Very deep	Nil	8.2	0.10	0.25	20-60	Excessive	Excessive	Very rapid	Severe
A21	ls	Very deep	Nil	8.4	0.25	0.87	1-3	Normal	Somewhat excess.	Mod.rapid	Slight
	sl	Very deep	Nil	8.1	0.28	0.78	1-3	Normal	Well	Mod.rapid	Slight
A31	ls	Very deep	Nil	8.4	0.12	0.77	1-2	Normal	Somewhat excess.	Mod.rapid	Slight
	sl	Very deep	Nil	8.4	0.10	0.42	1-2	Normal	Well	Mod.rapid	Slight
A41	ls	Very deep	Nil	7.8	0.10	0.25	2-8	Excessive	Excessive	Rapid	Moderate
	fs	Very deep	Nil	8.0	0.10	0.28	2-8	Excessive	Excessive	Rapid	Moderate
F11	sl	Very deep	Nil	8.6	0.25	0.74	1-2	Normal	Well	Mod.rapid	Slight
	l	Very deep	Nil	8.6	0.27	0.81	1-2	Normal	Well	Moderate	Slight
F21	l	Very deep	Nil	8.7	0.70	0.89	1-2	Subnormal	Mod well	Moderate	Slight
	cl	Very deep	Nil	8.3	0.50	0.61	1-2	Subnormal	Mod.well	Moderate	Slight

Note: Characteristics of the associated soils of mapping units are underlined.

Land use plan

The analysis showed that the mapping unit F21 is moderately suitable (S2) for gram and wheat (Table 3) with limitation of drainage whereas associated soils were found moderately suitable (S2) for wheat with the same limitation. F11 unit is moderately suitable for mustard, gram and pearlmillets having limitations of relief and permeability and the associated soils moderately suitable (S2) for wheat and gram with limitation of relief. The map unit P21 is moderately suitable (S2) for wheat and gram with limitation of relief and permeability and the associated soils are moderately suitable (S2) for wheat with limitation of relief. Map units A21 and A31 are marginally suitable (S3) for pearlmillet because of drainage limitation and associated soils are moderately suitable for mustard, gram and pearlmillets with limitation of relief and permeability whereas pearlmillet is the only crop which is marginally suitable (S3) for map unit A41 with limitation of drainage, relief and permeability.

Table 3. Evaluation of map units for some crops

Map Unit	Wheat	Mustard	Gram	Pearlmillet	Most suitable crops
P11*	N	N	N	N	N
P21	S2rp	S2trp	S2rp	S2trp	Wheat, gram
	S2r	S2tr	S2tr	S3t	Wheat
P23*	N	N	N	N	N
A11*	N	N	N	N	N
A13*	N	N	N	N	N
A21	S3dt	S3dt	S3dt	S3d	Pearl millets
	S2tpr	S2pr	S2pr	S2pr	Mustard,gram,pearlmillets
A31	S3dt	S3dt	S3dt	S3d	Pearl millets
	S2tpr	S2pr	S2pr	S2pr	Mustard,gram,pearlmillets
A41	N	N	N	S3drp	Pearlmillets
	N	N	N	N	N
F11	S2trp	S2rp	S2rp	S2rp	Mustard,gram,pearlmillets
	S2r	S2tr	S2r	S2tr	Wheat,gram
F21	S2d	S2td	S2d	S2dt	Wheat, gram
	S2d	S2td	S2td	S3t	Wheat

d-drainage, p-permeability, r-relief, t-texture
* Units can be vegetated with suitable grasses, shrubs and trees.
- Suitability of associated soils of mapping units are underlined.

The rocky and barren hills (H) of the area could be vegetated with *Acacia senegal, Acacia jacquemontee* and *Anogeissus pendula* shrubs. The mapping units P11, P23, A11 and A13 are not suitable (N) for crops due to stoniness, shallow soil depth, severe erosion, sandy texture, excessive relief, steep slope and very rapid permeability. The pediment (P11) may be put under grass species viz. *Sacchrum munja, Sacchrum spontaneum, Aristide adscensionis* and shrub species of *Capparis decidua, Acacia leuphloea, Acacia nilotica* and *Zizyphus nummularia.* Soils of dissected buried pediment (P23) may be put under suitable grass species viz. *Cenchrus ciliaris, Cenchrus setigerus* and *Cynodon dactylon* as soil conservation measure. Map unit A11 (Sand dune-cultivated) are not suitable for growing crops due to limitations of texture and topography, but introduction of sprinkler irrigation helps the farmer in growing wheat and coarse cereals (pearlmillet and sorghum crop). But this unit is required to be put under agro-forestry/arid-horticulture system to conserve the soil for sustained production. Barren sand dunes (A13), having steep slopes and elevation similar to hills in the area, are very much susceptible to wind erosion. They should be permanently stabilized with suitable grass species and trees to protect soil against wind erosion and also to meet the fuel and fodder needs of human beings and animals. Some suitable fuel and fodder trees are *Salvedore oleoides* (Jal), *Prosopis cineraria* (Khejri), *Acacia nilotica* (Kikar), *Ziziphus mauritiana* (Beri), *Zizyphus nummularia* and *Calotropis procera*. Grass species suitable for sand dunes are *Panicum spp., Cyperus arenaria* and *Cenchrus biflorus*.

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