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Research Article

LAND SUITABILITY EVALUATION AND LANDUSE PLANNING USING REMOTE SENSING DATA AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES

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ABSTRACT
A study was undertaken to prepare an inventory of the present landuse/landcover of the area using Satellite data and a landuse map for landuse planning from satellite data, interpreted physiography and soils and terrain information, by following a land evaluation approach through GIS environment. The results indicated the immense potential of multispectral satellite remote sensing and Geographic Information System (GIS) for effectively monitoring regional changes in landuse/landcover over a period of time and for preparing a suggested optimum landuse map for landuse planning. Land evaluation is formally defined as 'the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of land forms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation. Land is a non-renewable natural resource, so it must be used judiciously. Hence, it is necessary to prepare suitable suggested land-use maps on a scientific basis to prevent the deterioration of the land and the environment. The optimum land-use planning of a region should suggest alternate land uses, primarily based on land characteristics like physiography, soil, surface and subsurface water resources, natural vegetation, existing landuse and socio-economic conditions, without disturbing the ecological balance of the region. Geographic information system (GIS) can serve a diverse and growing set of applications such as natural resources and environmental assessment and monitoring, deforestation analysis and land capability/suitability mapping among others.

Key Words: *Land suitability, Land Use Planning, Land Evaluation, Geographic Information System, Satellite Data*

INTRODUCTION
Land evaluation using a scientific procedure is essential to assess the potential and constraints of a given land parcel for agricultural purposes (Rossiter, G. D., 1996) In the recent past, the ill-effects of land use on the environment and environmental sustainability of agricultural production systems have become an issue of concern **(**Fresco, L. O., 1990.)The problems of declining soil fertility, stagnant yield level and unfettered soil erosion are associated with intensive agriculture in industrialized countries, while over-exploitation of natural resources and scarcity of inputs like chemical fertilizers denote intensive agriculture in the developing areas (Lanen Van, et al, 1992.)
Remote sensing (RS) data are used for estimating biophysical parameters and indices besides cropping systems analysis, and land-use and land-cover estimations during different seasons. However, RS data alone cannot suggest crop suitability for an area unless the data are integrated with the site-specific soil and climate data. RS data can be used to delineate various physiographic units besides deriving ancillary information about site characteristics, slope, direction and aspect of the study area (Rao, D. P., 1996 & Panigrahy, et al, 2006) However, detailed information of soil profile properties is essential for initiating crop suitability evaluation. Hence, soil survey data are indispensable for generating a soil map of the given region, which helps in deriving crop suitability and cropping system analysis. RS data coupled with soil survey information can be integrated in the geographical information system (GIS) to assess crop suitability for various soil and biophysical conditions. The present study was undertaken to demonstrate

the usefulness of RS and GIS technologies coupled with soil data to assess crop suitability in order to implement sustainable cropping systems in a watershed. The potential of the integrated approach in using GIS and RS data for quantitative land evaluation has been demonstrated earlier by several researchers (Beek, et al 1997& Merolla, 1994). Therefore, the objective of this study was land evaluation using RS and GIS environments, to suggest suitable cropping patterns for a watershed area.

Study Area

The MohanRao watershed has been delineated on the SOI toposheet no. 53 F/16 on scale 1:50,000. The watershed is located in between latitude of 30°3’37” to 30°15’ N and 77°E.It exists between two states Uttar Pradesh and Uttarakhand. Major part of the watershed is situated in the Haridwar district, Uttarakhand and some parts of the area lie in the Saharanpur district Uttar Pradesh. The area in the watershed is 1439.74 hectares. The climate of the area is sub tropical semi arid of India’s central and northern belt. The mean annual rainfall and the mean annual temperature is about 1004 mm and 24.27°C respectively. The area includes upper siwalik side slope, middle siwalik side slope, piedmont and alluvial plain. The area represents many distinctive lithological units having grey sandstone, red mud stone with many structural variations. Many examples of fold and faults can be seen. The piedmont and alluvial plains have been formed from the deposition of numerous rivulets and rivers. The depositional material in piedmont zone is coarser than the alluvial plain. The rainfall and temperature data shows that the area qualifies the ustic soil moisture regime. Nearly 80% of the people are under cultivation.

MATERIALS AND METHODS

Remotely sensed data IRS -1C LISS – III data of MohanRao watershed at the scale of 1:50,000 was interpreted based on the photo elements like tone, texture, size, shape, pattern, association, etc for delineation of physiographic units. The physiographic map was generated and the ground truth were collected. For each mapping unit representative soil profiles, auger bores were studied. The soils were classified using standard procedure as Soil Taxonomy (Soil survey Staff 1998). Various thematic maps of soil characteristics were also created in the GIS environment. Soil survey data which describes the land qualities of the physiographic units ex. Texture, drainage condition, slope, relief, erosion hazards, coarse fragments were crossed with land requirement land utilization types(LUT’s) ex. Paddy, wheat, sugarcane, mustard , maize, mango, to evaluate the soil site suitability of each units for sustainable land use planning.

RESULTS AND DISCUSSION

Landuse/Land cover Map

Landuse/landcover mapping was carried out using two approaches combination, Visual image interpretation and digital image classified ground-truth data with FCC (band 4 to Red, band 3 to green and band 2 to blue, geocorrected at 1:50,000 of scale). The landuse classification scheme adopted was primarily based on the dominant landuse/landcover in the area such as dense forests, moderate forest, open forest, double cropped area, single cropped area, fallow/scrub, mixed cropped area, plantation, river.

Physiographic/Soils Mapping

A collective approach comprising satellite data, topographic maps, geological information and limited fieldwork was followed for physiographic/soils mapping.

Based on variations in FCC image characteristics with respect to terrain variability (hills, plains, valleys and slopes), soil conditions, natural vegetation and land use, among others, the physiographic units and subunits were delineated and mapped.

The topographic details taken from the topographic map sheets were helpful in this correlation, supported by ground-checking. The soil association of each physiographic unit was established by studying soil profiles, minipits and boreholes in sample strips, by random checking outside the sample strip areas and by classifying the soils according to the United States Department of Agriculture soil taxonomy (USDA 1975).

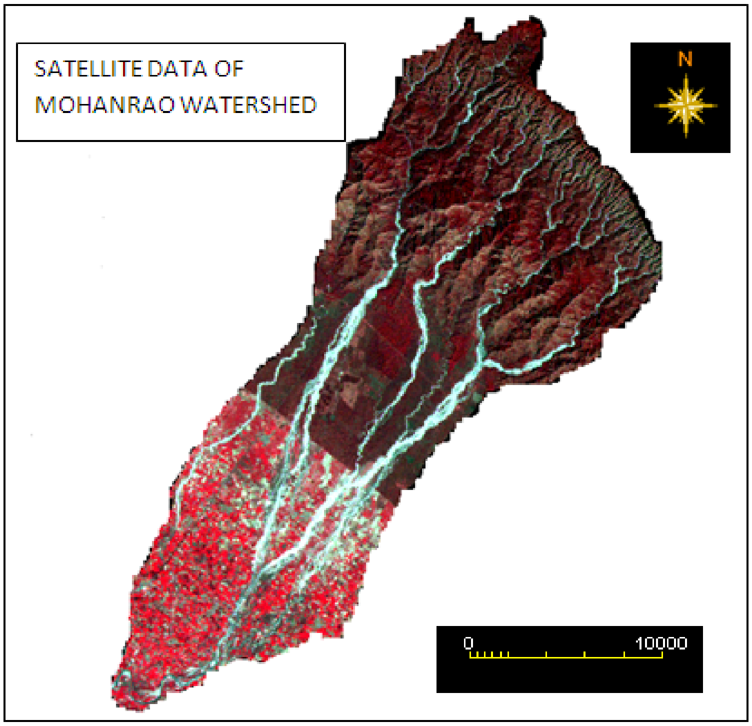

Figure 1: Study area as viewed on satellite data

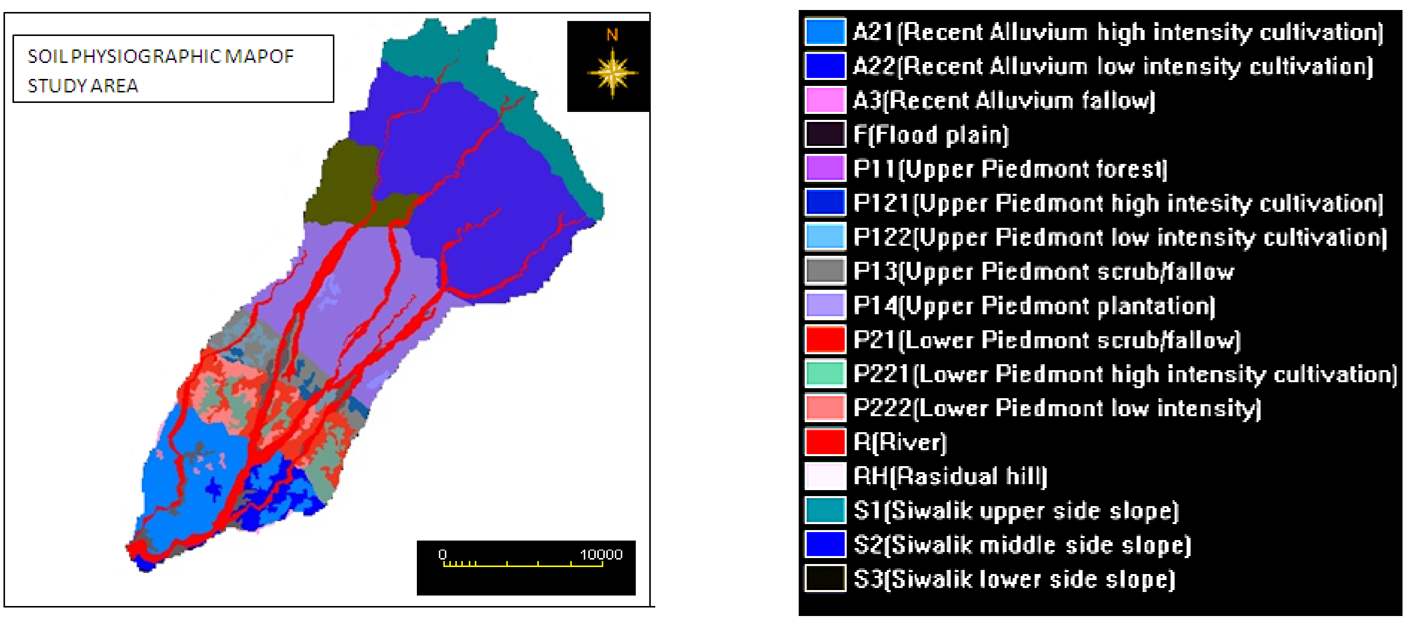

Figure 2: Physiographic/Soils Map

Table 1: Statistics Showing Land Suitability Classes

Suitability class	**LUT-1 (Paddy)**	**LUT-2 (Wheat)**	**LUT-3 (Sugarcane)**	**LUT-4 (Maize)**	**LUT-5 (Mustard)**	**LUT-6 (Mango)**
Highly suitable	Nil	Nil	F	A3,F,P21, P221	F	F
Moderately suitable	A21,A22	F,P221	P221	Nil	P221	P221,P22 2
Marginally suitable	F,P121,P122, P13,P14,P21, P221,P222	A21,A22,A3, P121,P122, P13,P14,P21, P222,RH	A21,A22,A3, P121,P122, P13,P14,P21, P222	A21,A22, P121,P122, P13,P14, P222	P121,P122, P13,P14, P222	A21,A22, A3,P121, P122, P13,P14, P21,P222
Not suitable	A3	Nil	A3		A3,P21	Nil

Table 2: Land Characteristics Of Different Physiographic Units

Mapping unit	Texture	Drainage	Slope	Erosion	Coarse-Fragments
A21	Sl-l	Imperfectly drained	N.Level	Nil	Nil
A22	Sl	Imperfectly drained	N.Level	Nil	Nil
A3	S-l	Well drained	N.Level	Nil	Nil
F	Sil-Sl	Well drained	N.Level	Nil	Nil
P11	Sl-S	Somewhat Excessive	V.Gentle	Slight	Moderate
P121	Ls-sl	Somewhat Excessive	V.Gentle	Slight	Moderate
P122	Sl	Somewhat Excessive	V.Gentle	Slight	Moderate
P13	Sl	Somewhat Excessive	V.Gentle	Slight	Moderate
P14	Ls-sl	Somewhat Excessive	V.Gentle	Nil	Moderate
P21	S-l	Excessive	V.Gentle	Slight	Moderate
P221	Sl-l	Well drained	V.Gentle	Nil	Slight
P222	Ls-sl	Well drained	V.Gentle	Slight	Slight
RH	Sil-ls	Well drained	V.Gentle	Moderate	Slight
S1	Grl	Somewhat Excessive	Steep	Moderate	Severe
S2	Grsl	Somewhat Excessive	Steep	Moderate	Severe
S3	Sl	Somewhat Excessive	Steep	Moderate	Severe

Finally, a soil map at 1:50,000 scale was prepared by combining the soil information in each delineated physiographic unit.
The study area comprises of four major landforms-
1 Siwalik hills
2 Piedmont plain
3 Alluvial plain
4 Residual hills
Siwalik Hills(S) is further divided into three classes

i) Upper side slope of the Siwalik (S1)
ii) Middle side slope of the Siwalik (S2)
iii) Lower side slope of the Siwalik (S3)

Piedmont plain is sub divided into two categories based on slope-

i) Upper Piedmont
ii) Lower Piedmont

Upper Piedmont is further divided into four sub categories-

a) Upper Piedmont Forest (P11)
b) Upper Piedmont – High intensity cultivation (P121)
c) Upper Piedmont – Low intensity cultivation (P122)
d) Upper Piedmont –Scrub/ Fallow (P13)
e) Upper Piedmont –Plantation (P14)

Lower Piedmont is further divided into two sub categories-

a) Lower Piedmont - High intensity cultivation(P221)
b) Lower Piedmont - Low intensity cultivation(P222)

Alluvial Plain is divided into three sub categories-

a) Recent alluvium – High intensity cultivation (A21)
b) Recent alluvium – High intensity cultivation (A22)
c) Recent alluvium – Scrub/Fallow

Flood plain (F)and Residual Hill (RH) is another class included in physiographic unit.

Generation of different thematic maps for GIS analysis

For the land evaluation with different thematic maps including landuse, physiographic/soil, slope and aspect maps, firstly the base map prepared which include the boundary of study area, Main River, main road and railway, and other cultural features. And then details of all thematic maps as each data layer were transferred, which have the same boundary of the study area.

Spatial database of various thematic maps created by digitization, vectorization using ILWIS software. Based on input thematic maps to GIS, the necessary thematic component maps viz. soil characteristic maps (soil depth, soil texture, soil drainage, soil erosion, etc.), terrain information maps (like slope and aspect) are generated.

According to different thematic maps and each mapping units, the corresponding attribute data were created by using ILWIS software. When creating attribute tables, all field contents of records are encoded by numerical values which represent attribute of respective units, it is easy to deal with further spatial analysis.

Land Suitability Evaluation and Landuse Planning by GIS Approach

Considering the agro-climatic conditions, topography, physical and chemical properties of soils and the soil problems, the mapping units of survey have been classified into four suitability classes.

1. Highly suitable
2. Moderately suitable
3. Marginally suitable
4. Not suitable

Different alternate landuse types (LUTS) were chosen for land-use planning after carefully considering the present landuse practices climate, topography and soils. The suggested LUTs were LUT-1 (paddy), LUT-2 (wheat), LUT-3(sugarcane) and LUT-4 (maize) LUT-5 (mustard) and LUT-6 (mango). Each soilscape unit (physiography/soil association unit) was evaluated for its suitability regarding each of the above LUTs following the criteria for rating.

Conclusion

The study revealed that satellite remote sensing and GIS technique has been found to be most essential tool for the land suitability and land evaluation of Mohan Rao watershed. The visual interpretation of the

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FCC supplemented with ground truth is found to be most efficient and effective way to delineate the physiographic boundaries and soil classes within the boundary. The Land utilization type of different crops is also identified with this technique.

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