Cropping Pattern Change Analysis And Optimal Landuse Planning By Integrated Use Of Satellite Remote Sensing And GIS

-A Case Study Of Barwala C.D. Block , Panchkula District, Haryana

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ABSTRACT

Agriculture resources considered to be one of the most important renewable and dynamic natural resources. Comprehensive, reliable and timely information on agricultural resources is very much necessary for a country like India as it is the mainstay of our economy. By 2050, the world's human population is expected to be increase almost by 75 percent of the present population. In some developing countries, demographic and economic growth will be so rapid that food requirements are expected to reach four to five times the present levels. But can existing methods of land use and management provide the necessary increases in food production? With increasing population, especially in the developing countries, the demand for food and fuel has grown alarmingly. At the same time, changing economic and social conditions have undermined or destroyed traditional systems of land resource management. Thus, not only is the land being cropped and grazed more intensively, with rest or fallow periods being drastically reduced or eliminated, but effective systems for maintaining fertility are no longer being applied. The result has been massive soil degradation on a world scale, through loss of plant nutrients and organic matter, erosion, build up of salinity, and damage to soils structure. Increasing demand for food, plus the fact that parts of the land most suited for crop production have been damaged or destroyed, has led to the expansion of cultivation and grazing into areas less suited to such uses, and ecologically more fragile. This has upset or destroyed natural ecosystems and modified or eliminated natural populations of flora and fauna.

As traditional systems of resource management and land husbandry are rapidly being abandoned, soil and environmental degradation are proceeding swiftly over large areas of the world, an alternative approach is essential.

In the context of land evaluation we may say a plot of land can often be put to any one of several possible uses - but rarely with the same degree of success. One of the objectives of land evaluation is to inform this choice by assessing the suitability of each use for each land unit, and vice versa.

The new technology that is available for land evaluation consists mainly of the use of remote sensing and Geographic Information System (GIS). Almost all of the applications of remote sensing to date have been based on observing crops in distinct areas of the electromagnetic spectrum. GIS as a powerful tool to process that data in conjunction with information collected using traditional field techniques helps to overcome traditional data volume constraints is an effective tool for land evaluation by virtue of its powerful integration capabilities of multi-source data. Remotely sensed data permits the preparation of base, terrain evaluation, land use classification and land degradation maps.

Against this backdrop, the present study is an attempt to develop an analytical framework, to evaluate the feasibility of utilizing the currently available IRS ID-LISS III as well as LANDSAT - TM digital data for cropping pattern analysis and land evaluation studies for suggesting optimal land use of Barwala community development block of Panchkula district, Haryana which is one of the better performing Indian states in terms of agricultural productivity. The average yields of major crops, like wheat, maize, sugarcane, sunflower and mustard and generally higher than those of other Indian states.

A supervised digital classification approach was adopted for the preparation of temporal crop and landuse inventory. Cropping pattern analysis was carried out by GIS aided integration of temporal crop inventory information. The FAO land evaluation approach using GIS based integration has been exercised to emphasize the possibility of raising the suitability of different cropping areas for a particular use with good management practices. In this process of matching land and use, all the constraints were examined and integrated with proper weight age according to their contribution and the possibility of making improvements considered. Finally, optimal landuse plan for the area were suggested by GIS aided integrated analysis.

Agriculture resources considered being one of the most important renewable and dynamic natural resources. Comprehensive, reliable and timely information on agricultural resources is very much necessary for a country like India as it is the mainstay of our economy. In some developing countries, demographic and economic growth will be so rapid that food requirements are expected to reach four to five times the present levels. But can existing methods of land use and management provide the necessary increases in food production? With increasing population, especially in the developing countries, the demand for food and fuel has grown alarmingly. At the same time, changing economic and social conditions have undermined or destroyed traditional systems of land resource management. Thus, not only is the land being cropped and grazed more intensively, with rest or fallow periods being drastically reduced or eliminated, but effective systems for maintaining fertility are no longer being applied. The result has been massive soil degradation on a world scale, through loss of plant nutrients and organic matter, erosion, build up of salinity and damage to soil structure. Increasing demand for food, plus the fact that parts of the land most suited for crop production have been damaged or destroyed. has led to the expansion of cultivation and grazing into areas less suited to such uses and ecologically more fragile. This has upset or destroyed natural ecosystems and modified or eliminated natural populations of flora and fauna.

There is an urgent need for a new approach. Traditional systems must be preserved and strengthened wherever possible, but it is clear that they are far from sufficient in view of the magnitude of the problem and the rate of destruction of the world's land resources.

The first step in the land evaluation approach therefore, is to determine which forms of land use are worth considering. The essence of land evaluation is to compare or to match the requirements of each potential land use with the characteristics of each kind of land.

The new technology that is available for land evaluation consists mainly of the use of remote sensing and Geographic Information System (GIS). Almost all of the applications of remote sensing to date have been based on observing crops in distinct areas of the electromagnetic spectrum. GIS as a powerful tool to process that data in conjunction with information collected using traditional field techniques helps to overcome traditional data volume constraints is an effective tool for land evaluation by virtue of its powerful integration capabilities of multi-source data. Remotely sensed data permits the preparation of base, terrain evaluation, land use classification and land degradation maps.

Against this backdrop, the present study is an attempt to develop an analytical framework, to evaluate the feasibility of utilizing the currently available IRS ID LISS III as well as LANDSAT- TM digital data for cropping pattern analysis and land evaluation studies for suggesting optimal land use for Barwala community development block of Panchkula district,Haryana which is one of the better performing Indian states in terms of agricultural productivity. The average yields of major crops like wheat, maize, sugarcane, sunflower and mustard are generally higher than those of other Indian states. Supervised digital classification approach was adopted for the preparation of temporal crop and landuse inventory. Cropping pattern analysis was carried out by GIS aided integration of temporal crop inventory information. The FAO land evaluation approach using GIS based integration has been exercised to emphasize the possibility of raising the suitability of different cropping areas for a particular use with good management practices. In this process of matching land and use, all the constraints were examined and integrated with proper weightage according to their contribution and the possibility of making improvements considered. Finally, optimal landuse plan for the area were suggested by GIS aided integrated analysis.

OBJECTIVES:

The specific objectives of this study are listed below:

To analyze *Kharif* and *Rabi* crop during the past 4-5 years and land use inventory by digital analysis of satellite data.

To analyze changes in cropping pattern, cropping intensity that occurred within a time period of 4-5 years in the C.D Block by GIS aided integration of temporal crop land inventory and

Land evaluation for suggesting suitable cropping pattern and optimal land use by GIS aided integrated analysis.

GEOGRAPHICAL ACCOUNT OF THE STUDY AREA

Barwala C.D. Block (Fig-1) under newly formed Panchkula district covers an area of about 184 sq. km. (184.01 sq. km. - census 1991) and extends roughly between north latitudes of 30^{0} 31´ and 30^{0} 43´ and east longitudes of 76^{0} 52´ and 77^{0} 03´. According to census 1991, the Barwala C.D. Block supported 48, 284 persons. The region is mostly a rolling plain except in the extreme north where the land is submountainous to the sharply rising Shiwaliks. Broadly the region lies on the northern margin of Indo-gangetic trough, the basement of which is covered with thick layer of sediments of recent origin. The elevation of this region varies between 300 - 600 m above msl.Ghaggar, Dangri with their numerous dry channels are the important rivers/streams here. They owe

Table 1

MAP UNIT	PHYSIOGRAPHY	DOMINANT SOILS	AREA (IN HA)
SHI	Soils of Siwalik hills	Typic Ustorthents	60.63
SH2	-Do-	Lithic Ustorthents	634.92
SH3	-Do-	-Do-	1539.01
SH4	-Do-	-Do-	113.98
P1	Piedmont Plain	Typic Ustochrepts	1791.49
P2 (Eroded)	-Do-	-Do-	2184.25
OAP1	Old Alluvial Plain	Fluventic Ustochrepts	2826.24
OAP2 (Eroded)	-Do-	-Do-	247.84
RFP1	Recent Flood Plain	Typic Ustochrepts	1419.39
RFP2 (Eroded)	-Do-	-Do-	730.95
RFP3	-Do-	Fluventic Ustochrepts	2126.54
RFP4 (Eroded)	-Do-	-Do-	36.66
RFP5	-Do-	Typic Ustifluvents	3427.70
RFP6 (Eroded)	-Do-	-Do-	239.51

their origin from the hills of the north and flow to the southwesterly direction following the land slopes. All the rivers/ streams in this region are rain fed and therefore remain dry almost throughout the year. The ground water in this region occurs under confined and semi confined conditions, which is suitable for drinking and irrigation purpose. The underground water level is relatively high in the plain areas and it is low in the hilly tract of the north. Seismically, the region is prone to earthquakes of moderate to high intensity as it lies close to the Himalayan Boundary Fault Zone. Climatically, the region experiences subtropical continental monsoon type with hot summer and cold winter. The rainy season sets in generally by early July and lasts for about three months The average annual rainfall is around 900 mm. The winter months normally remain dry. Sometimes scanty winter rainfall occurs from the temperate cyclones (western disturbances), which are believed to originate in the Mediterranean region and moves eastward all the way to India. The region is mainly characterized by soils of Siwalik Hills, soils of piedmont plains, soils of old alluvial plains and Soils of recent flood Plains, as shown in Table 1.

LANDUSE / LAND COVER

The major land/land cover in the study region is characterized by agriculture, forest, and horticulture/plantation, barren and scrub, settlement, wasteland and water body. Cultivation of agricultural crops mainly confined along the gentle to nearly level riverside of Ghaggar and Dangri areas. There are two main cropping seasons, namely *kharif* from June/July to October and *rabi* from November to February. The main crops grown in the area are wheat *(Triticum astivum)*, Paddy *(Sativa oryzac)*, Sugarcane *(Scharum officinerum)*, Maize *(zea maize),* Sunflower *(Helianthus annuusl)*, Mustard, Pulses and various oilseeds and a number of vegetables The forest in the study area is very less and mainly confined to dense to degraded or open forest. The major *Kharif* crops of Barwala are paddy, maize and sugarcane while *jowar,bajra*, groundnut ,taramera (a type of oil seed) seasom, *arhr* and fodder are occasionally grown. For these crops the ground is prepared in April and May and the seeds are sown at the commencement of rains in June. The crops are ready for harvesting by the beginning of November. The major *Rabi* crops are wheat, sunflower, mustard, phenugreek, tobacco, gram, linseed and rapseed. The farmers prepare the ground at end of October or the beginning of November and harvesting starts from early March. The forest in the study area is very less and mainly confined to dense to degraded or open forest harvests the crops.

DATABASE & METHODOLOGY

***SATELLITE HARD COPY DATA*:Type**: Standard Geocoded false colour composite (FCC) of IRS ID LISS III.

Band: 3 2 1 (Infrared, red, green) in RGB display

Scale: 1:50,000

Date of Acquisition: 15th Oct 1997, 2nd Feb 1998 and 28th Feb 2003. These have been used for ground truth data collection.

Table 2

SATELLITE	SENSOR	PATH & ROW	DATE OF ACQUISITION
IRS - 1D	LISS III	95/50	February 2nd 1998
IRS - 1D	LISS III	95/50	September 21st 2001
IRS - 1D	LISS III	95/50	February 28th 2003
LANDSAT	TM	147/39	October 15th 1997

DIGITAL SATELLITE DATA

The *kharif* season data for 2001 has been used for the analysis, instead of that for 2002, since the *Kharif* season of most parts of India including the study area was affected by severe drought during the latter year, as presented in Table 2.

METEOROLOGICAL DATA

Meteorological Data like temperature, rainfall etc. were collected from Indian Meteorological Department (IMD), District collectorate office, Panchkula and Directorate of Agriculture, Chandigarh and Directorate of Economics and Statistics, Chandigarh.

SOIL DATA

Soil map prepared by National Bureau of Soil Survey and Land Use Planning, Nagpur, on 1:500,000 scale was used.

COLLATERAL DATA

Survey of India (SOI) topographical sheets (53B/14B/15, 53F/2 and 53 F/3) on 1:50,000 scale were consulted for registration of satellite data, selection of ground control points, contour map generation and locating training sets as well as to identify and authenticate the various cultural features on the satellite image. We have also used available socio-economic data from census of India 1991,other allied data from District Collectorate Office, Chandigarh, Directorate of Agriculture, Directorate of Land Records Panchkula and from different "*Patwary*" offices of Barwala C.D.Block.

The methodology adopted in this study incorporates both the Digital Image Processing (DIP) and GIS based analysis.

IMAGE PROCESSING SYSTEM

Digital Image Processing and GIS analysis were carried out in the computer system with the help of mainly ILWIS (Integrated Land and Water Information System) Version 3.1 software package developed by International Institute for Aerospace Survey and Earth Sciences (ITC), the Netherlands. The methodology used in this study consists of the following stages.

PRE FIELD WORK

By using the survey of India topographical sheets in 1:50,000

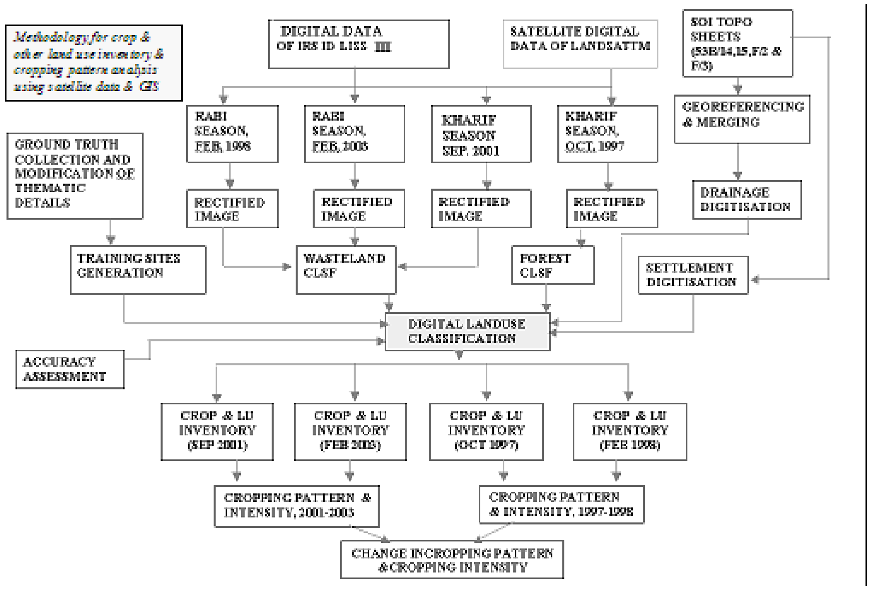

Fig. 1. Methodology for Crop, Other Landuse Inventory and Cropping Pattern Analysis Using Satellite Data and GIS

scales, a base map has been prepared on the same scale illustrating major communication network, villages etc. Then the study area was demarcated on the IRS ID LISS III FCC corresponding to the base map and based on visual interpretation. Some interpretation keys were developed to identify different land features by using their tone, texture, pattern, colour, shadow, associations etc. The basic aim was to identify different land use classes like agriculture, forest, barren and scrubs, orchard/plantation, settlement, water bodies etc, for generating *kharif* and *rabi* season land use map before going to the field.

FIELD WORK

A rapid reconnaissance survey of the study area was conducted during the field visit to understand and determine the general relationship between physiography, landform and soil. Sample soils were collected in such a way that maximum number of physiographic unit can be covered. For traversing and accessibility on the ground, SOI 1:50,000 topographical sheets were used. The observation sites were marked on the topographical sheet as well as on FCC. For the ground truth sites of various crop's condition and vigor, sowing and estimated harvesting date, agronomic practices, last year crop types and yield, this year expected yield, irrigation types etc were noted in the prescribed proforma. Pre-field interpretations were verified in the field and modifications were made wherever found necessary. Training sites for different land use were also identified.

POST FIELD ANALYSIS

Preparation Of Crop And Land Use Inventory

Digital image processing was carried out using ILWIS 3.1 software for the digital data acquired on 15th Oct 1997 and 21st Sept 2001 for *kharif* season and 2nd Feb 1998 and 28th Feb 2003 for *rabi* season.

GENERATION OF RECTIFIED MASK IMAGE

The four sets of satellite data were used for the study to develop the map to image affined transformation model and thus the raw digital data were geometrically rectified and resampled by nearest neighbour resampling technique to bring them under the common geographic database format for the study. Considering *rabi* 2003 as the master image other data were registered and later georeferenced with the topographical sheets. Scanning and screen digitizing generated digital vector image of the boundary of the study area. The census village boundary map of the CD block of Barwala was also georeferenced with the topographical sheet. But due to lack of accuracy after georeferencing the census map showed a higher RMS error than desirable. Vector image of the boundary was polygonised and rasterised and superimposed on the rectified sub master image and thus the Barwala mask image extracted.

TRAINING SIGNATURE GENERATION

The training sites such as high vigor, medium vigor, low vigor wheat, paddy, other crops, dense and open forests, riverbed, barren and scrub etc. were identified with the help of ground sites marked on topographical sheet.

CROPPING PATTERN AND CROPPING INTENSITY ANALYSIS

Cropping pattern and cropping intensity analysis were carried out by GIS aided integration of *kharif* and *rabi* digital crop inventory information. Change in cropping pattern and intensity was performed by using two periods (1997-98 and 2001-03) cropping pattern and intensity information using GIS. Cropping intensity for the villages as a whole can be quantitatively derived from the extent of double cropped and single cropped area and provides a useful measure of the land use intensity for cultivated areas. Using the area-weighted values for cropping intensity, i.e., 100 for single cropped area and 200 for double-cropped area has derived the measure of cropping intensity. This measure of cropping intensity takes only the cultivated area into account. This measure, however, does not include the duration for which the land is utilized by respective crops.

CLASSIFICATION ACCURACY ASSESSMENT

Accuracy of digital classification of various land use/land covers was assessed using the confusion matrix generated by crossing digital ground truth sample site images and the classified images. A stratified classification has been adopted as the reflectance of forest and paddy in the *Kharif* season was prone to some degree of mixing, whereby the hills dominantly covered with forest was classified separately. However, the mixing between riverbed and fallow could not be prevented even for this season like in the *rabi* season. The accuracy of these classes is low particularly in *kharif* 2001. The accuracy of crop classification generally ranges from 0.83 to 0.96. Only in the *kharif* season, there was a mixing between the two categories of paddy. This however did not affect my analysis, as while drawing conclusions different classes of paddy were not separated.

DIGITAL ELEVATION MODEL (DEM) GENERATION - The contour map and the spot height maps were rasterised, combined and interpolated to generate DEM. It was then masked with the rasterised study area boundary.

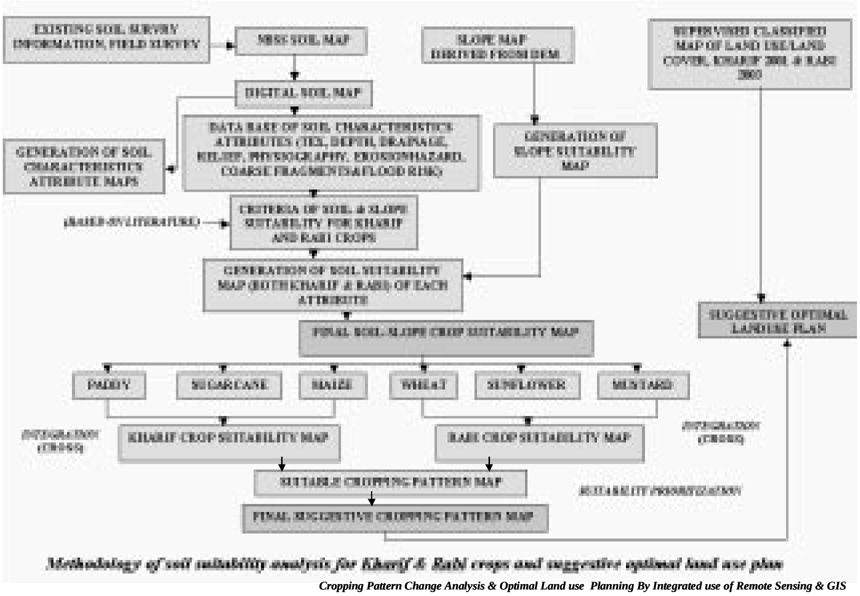

Fig. 2. Methodology for Soil Suitability Analysis for *Kharif* & *Rabi* Crops and Suggesting Optimal Landuse Plan

SLOPE MAP - From the DEM, "dx" and "dy "maps were first generated using "filter" operation "dfdx" and "dfdy" filters respectively. Then the slope in percentage was calculated using "Map Cal" operation using the expression slope_p=(hyp(dx,dy)/23.5)*100.

LAND EVALUATION: Land evaluation, may be defined as: "the process of assessment of land performance when the land is used for specified purposes"(Food and Agriculture Organization of the United Nations, 1985), key words of these definitions are method, process, assess, explain, predict, potential, opportunities, constraints and decision making.

PREPARATION OF SOIL MAP

A soil map was prepared by GIS aided digitization and rasterisation using the field soil sample information, and NBSS soil map .As the soil map was in medium scale 14-soil mapping units can be delineated each of which was characterized by land qualities like texture, soil depth, drainage, relief, physiography, erosion hazard, coarse fragments and flood risk possibility.

CROP CRITERIA AND RATINGS FOR DIFFERENT CROPS: The methodology for suitability analysis for different crops as follows:

Based on literature review, the crop criterion and ratings for wheat, paddy, sugar cane, maize, mustard and sunflower were selected considering the above-mentioned parameters of land qualities The four classes of crop suitability viz., S1-Highly suitable, S2-Moderately suitable, S3-Marginally suitable and N-Not suitable are assessed following FAO Land Evaluation approach based on the criteria table for the crops by logical operation. The methodology for soil suitability for both *kharif* and *rabi* crops is as follows.

PREPARATION OF CROPPING PATTERN SUITABILITY ANALYSIS

Maps for *kharif* and *rabi* season (based on the recommended crops for the respective season) were generated. The cropping pattern has been taken up by the mapping unit was obtained by integrating *kharif* and *rabi* crops separately by "cross" operation. Suggested crops for *kharif* and *rabi* seasons were obtained by reclassifying the map with newly created attribute table for *kharif* and *rabi* cropping sequences after cross operation. The cross operation was also performed on the *kharif* and *rabi* season crop suitability map for obtaining the cropping sequence for each unit. Attribute table was generated and finally reclassified map was prepared from the attribute table showing the suggested cropping system map for each unit. The final optimal land use map has been generated with the help of suggesting cropping system map and the current land use/land cover map (prepared from IRS LISS-III satellite digital data of *rabi*, 2003).

RESULTS AND DISCUSSIONS

The temporal-spectral behaviour of crops is related to their phonology and agronomic practices and can be monitored for various applications like crop discrimination, crop assessment, identifying crop rotation and cropping pattern practices, etc. Results from such an exercise, over Barwala community block of Panchkula district, Haryana for the four acquisitions of 15th October 1997, 2nd February 1998, 21st September2001 and 28th February 2003 are reported here. The result of the investigations presented and discussed in this chapter but before going into the final discussion it is worthy nothing to mention here that the time of the data sets for the two periods is not exactly suitable for agricultural analysis. For the *kharif* season, the data for the latter period (21st September) is available about 15 days ahead compared to the earlier period (15th October, 1997). As the data for the latter period under consideration related more with the peak period of the season, the positive and negative changes would likely to be over estimated and under estimated respectively for the *kharif* season. Again, for the *rabi* season there is a difference for data acquisition date of about 21 days and because of this the latter period correspond with peak wheat period. As subsidiary crops like gram and oilseeds are harvested earlier there has been always be a possibility of an underestimation of the change for the cultivated area, while it may lead to an overestimation of change in the wheat area. For my analysis I have used IRS-ID LISS-III data for both the *rabi* and *kharif* season, but for the *kharif* season because of the non-availability of same satellite data the first period for the *kharif* season has been supplemented with LANDSAT-TM data which was not identical to that of LISS-III data. An attempt of visual interpretation was made after the completion of digital classification for this area to minimize the error caused due to the cloud cover presence over some parts of the study area.

CROPS AND LAND USE INVENTORY

The crop and other land use- land cover pattern of a region is an outcome of both natural and socio-economic factors and their utilization by man in time and space. Land is becoming a scarce commodity due to immense agricultural and demographic pressure. Hence, information on land use-land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land uses schemes to meet the increasing demands for basic human needs and welfare. Increasing human interventions and unfavourable bio-climatic environment has led to transformation of large tracts of land into wastelands. Satellite remote sensing plays an important role in generating information about the latest land use-land cover pattern in an area and its temporal changes through times. The information being in digital form can be brought under Geographical Information System (GIS) to provide a suitable platform for data analysis, update and retrieval.

The crop and other land use/ land cover maps of the study area were prepared for *kharif* (15th Oct 1997 and 21st Sept 2001) and *rabi* seasons (2nd Feb 1998 and 28th Feb 2003) by digital analysis In *kharif* season it was possible to identify paddy field, other crops, fallow lands, dense forest, open forest, plantation (horticulture/forest), barren and scrub, river bed (dry), settlement, eroded land and water body. After analyzing both the *kharif* period data it has observed that the agricultural land-use has changed substantially over the two periods. At least part of this increase is due to the overestimation problem-but such a substantive change cannot be explained due to non-comparability between the dates or poor data quality for the first period of the *kharif* season. Though due to small aerial extent it has not been possible to classify and distinguish maize or sugarcane in the *kharif* season, the classification result implies that in totality these crops have declined in significance.

From the two *kharif* seasons dated 15th Oct, 97 and 21st Sept, 2001 it can be noticed that there has been a substantial increase in paddy area, which is 4.96 and 13.28% respectively for high and medium to low vigor paddy. The spread of paddy is not so much a recent phenomenon in many parts of Punjab and Haryana, but in this specific case it appears that the increase in the share of paddy production has come about within the last four to five years. Similarly other cropped areas like sugarcane, maize etc has increased 5.95% in between two periods. The crops like maize in the *kharif* season occupy a substantial portion of the agricultural area in Barwala, and are harvested earlier than paddy in the *kharif* season Therefore, the data that have been acquired for the peak periods paddy may not be suitable for estimating the extent of crops Other than crop land in *kharif* season area under fallow shows 5.68% increase in between periods, but as this land is left vacant for the particular years under consideration, it may be assumed that in other years, it would have some crop cover.

In *rabi* season wheat production has increased substantially like 1.54%, 3.99% and 8.4% for the high, medium and low vigour type respectively. Whereas the area under other crops like mustard, sunflower has previously occupied 22.61% but subsequently reduced to only 14.26% in the latter period which is not only a result of increase in yield growth but also by a shift in production from other crops to wheat and an increase in cropping intensity. The steady increase in the procurement price for wheat may also explain part of its growth. Though the production growth driven by yields is generally determined largely by use of fertilisers, high yielding varieties and irrigation, the local farmers of that region have said that in recent years the use of fertiliser appears to have less effect, and the expansion of irrigated and HYV area plays a more important role in it.

From both the seasons and for both the periods it has been observed that the study area reflects a noticeable change in terms of reduction in wasteland especially in the *kharif* season, which is about 19.09%. Considering the earlier mentioned fact that due to less-comparable data set, spectral seperability of fallow and waste or eroded land, there are strong chances of overestimation of change in cultivated area in the *kharif* season and wheat in the *rabi* season. However, analyzing data for both seasons, it is clear that a substantial portion of land that was earlier be categorized as eroded or barren land has been converted into cultivated land that cannot be solely the result of this irregularity. The proportion of forest area has declined by about 1.98% over the years. Apart from a forestation program, the differences in the forest cover appear to be exaggerated possibly due to the unavailability of the satellite data during identical periods.

CROPPING PATTERN ANALYSIS

The present study relies on data from remote sensing combined with ground observations and data collected in the field. All sources of information were integrated through GIS for correlation analysis. The analysis was supported and the results were validated by ground-truth campaigns conducted in the 1st week of April. During the field visits, sample sites representing target crops to be classified were selected along with crop-cutting plots where mainly wheat was then harvesting. The location of sample sites and crop-cutting plots was obtained within 100 meters accuracy with a hand-held global positioning system (GPS) receiver. I have used two *kharif* seasons (15 th Oct 1997 and 21st Sept 2001) and two *rabi* seasons (2nd Feb 1998 and 28th Feb 2003) data for cropping pattern and land use analysis. I have discussed that the time of the data sets for the two periods was not exactly suitable for agricultural analysis. Moreover because of the non-availability of same satellite data the first period for the *kharif* season has been supplemented with LANDSAT-TM data, which was not identical to that of LISS-III data. Considering these constraints an attempt has been taken to analyze the cropping pattern based on analysis of the spectral signatures on all four dates for which data was available and after evaluating a separability index developed. A review of spectral signatures of wheat, paddy, sugarcane, maize and other crops obtained by conventional supervised classification indicated a wide range and possible mix-up among classes. I have analyzed two cropping seasons, namely, *kharif* and *rabi*, though the study area is characterized by three seasons including summer.

After analyzing the two-time period cropping pattern change it can be said that the changes have taken place in favour of high value crops like paddy and wheat. The observation also reveals the strong impact of cropping pattern change on total agricultural output and that the change in the study area was rapid after 2001 than the early period. Judicious choice of crop-mix also leads to optimum use of resources. Though 44.72% of the total area shows no change between the two time periods, considerable increase of about 34.12% has occurred from single cropped area to double cropped land.

CROPPING INTENSITY AND ITS CHANGE

Cropping intensity for the villages as a whole can be quantitatively derived from the extent of double cropped and single cropped area and provides a useful measure of the land use intensity for cultivated areas. Using the area-weighted values for cropping intensity, i.e., 100 for single cropped area and 200 for double-cropped area has derived the measure of cropping intensity. This measure of cropping intensity takes only the cultivated area into account. This measure, however, does not include the duration for which the land is utilized by respective crops.The southern part of Barwala C.D Block, have performed better compared with the villages in the hills and the piedmont areas, the incidence of wasteland being very high in the latter. Much of these areas have the observed phenomenon of shifts from double crops to single crops or from single crop to fallow land. However, this phenomenon could be largely due to the mismatch of the dates of satellite data used for this study. The crops like maize in the *kharif* season and gram in the *rabi* season occupy a substantial portion of the agricultural area in these villages, and are harvested earlier than paddy in the *kharif* season and wheat in the *rabi* season. Therefore, the data that has been acquired for the peak periods of wheat and paddy may not be suitable for estimating the extent of crops other than these two. From the following table it can be seen that above 40% increase in cropping intensity have taken place in the villages namely Fatehpur Viran, Bharaili, Bhagwanpur, Barwala and Jitpur. The villages like Sangrana, Jitpur, Raipur alias Sundarpur, Palasra, Sultanpur, Jalauli Nagal, Khanesra, Toka, Kanauli, Syamtu, Batwal, Dhandru, Mankan, and Kzimpur have experienced 20 to 40% increase while Alipur, Kami, Khatauli, Sukhdarshanpur, Bhanun, Lana, Bila, Jaswantgarh, Kot and Dabkauri have gone through 0 to 20 % increase leaving rest of the villages showing 0 % or no change in cropping intensity pattern.

LAND EVALUATION & LAND SUITABILITY ASSESSMENT

Land suitability is the fitness of a given type of land for a defined use. FAO framework of land evaluation has been adopted in this study to assess the land utilization type. The framework has the same structure, i.e. recognizes the same categories, in all of the kinds of interpretative classification. Each category retains its basic meaning within the context of the different classifications and as applied to different kinds of land use. Four categories of decreasing generalization are recognized:

i.	Land Suitability Orders:	Reflecting kinds of 'Suitability'.
ii.	Land Suitability Classes.	Reflecting degrees of suitability within 'Orders'.
iii.	Land Suitability Sub Classes:	Reflecting kinds of Suitability within 'Classes'
iv.	Land Suitability Units:	Reflecting minor differences in required management within 'Subclasses'

LAND QUALITIES

For the present land evaluation analysis eight land qualities/ land characteristics have been considered, namely, soil texture, soil depth, slope, relief, drainage, coarse fragments, erosion and risk of floods. The different classes of these land qualities have been taken from literature review and to some extent on experience.

Soil Texture Classes: Loam, loamy sand, sandy loam and loamy skeleton.

Soil Depth Classes: Deep (50-100cm), moderately deep (25-50cm), shallow (10-25cm) and very shallow (less than 10 cm).

Slope Classes: very gentle slopping (1-3%), gentle slopping (3-8%), moderate slopping (8-15%) and steep slopping (15-30%).

Relief Classes: Normal or flat, sub-normal, concave and excessive.

Drainage Classes: Well drained, moderately well drained, moderately excessive and excessively drained.

Coarse Fragments Classes: None (free of stoniness), slight (less than 10% stoniness), moderate (10-35%) and severe (more than 35%).

Erosion Classes: None, slight, moderate and severe.

Risk of Flooding Classes: None, i.e. the land surface is higher than the highest water table in the area, low to very low, i.e., the land surface is occasionally flooded for 1 to 2 months, moderate or the land surface which is flooded for no longer than 2 to 3 months in more than 5 out of 10 years and high or the land surface which is lower than the highest water table and floods occur almost every year for 3 to 4 months in a year.

SUITABILITY CRITERIA AND RATINGS:

In general, land evaluation for agricultural land use is formulated by classifying lands with different capabilities. The suitability for various potential lands uses is identified in relation to individual crop requirements. Within the planning area, an assessment of crop combinations is needed in order or to lessen a price risk. This evaluation was then formulated with objective of classifying units of land as to their suitability for combining economic crops using GIS and remotely sensed data.

The major economic crops in the area are wheat, paddy, sugar cane, maize, mustard and sunflower. The suitability assessment for each crop was conducted using the method as described in FAO guidelines for land evaluation for rain fed agriculture. For each crop, land unit was created from overlay process of the defined theme layers or land qualities on which the suitability is based. As a result, suitability map layers with their associated class attributes for different crops were obtained. Furthermore, the overlay process was then performed on these suitability map layers with selection criteria of only highly and moderately suitable classes. The resultant map obtained is a result of combination of the defined suitability class of combining crops. (Wheat, paddy, sugar cane, maize, sun flower and mustard) within the area. Economically, the planning alternative that best matches land use to land suitability should therefore be the most valuable and efficient. The requirements for each LUTs are given in the following tables:

S.N.	LAND QUALITIES	S1	S2	S3	S4
1	Texture	Clay, clay loam silt clay loam	Sandy loam, loam Sandy clay, loam	Loamy sand, Fine skeletal clayey skeletal	Sand fragments
2	Drainage	Imperfectly to poorly drained	Moderate to well drained	Somewhat excessively drained	Excessively Drained
3.	Soil Depth	Very deep to deep	Moderately Deep	Shallow	Very Shallow
4.	Relief	Flat, Subnormal	Concave	Normal	Excessive
5.	Slope	Level	Very gently sloping	Gently sloping	Moderate steep to very steep
6.	Erosion Hazard	None	Slight	Moderate	Severe
7.	Coarse Fragments	None	Slight	Moderate	Severe
8.	Risk of Flooding	None, very low	Low	Moderate	High

Criteria of rating of land qualities for Wheat (LUT-1)

S.N.	LAND QUALITIES	S1	S2	S3	S4
1	Texture	Clay loam, Silt clay loam, sandy clay loam	Sandy loam, loam, clay, silt clay, sandy clay	Loamy sand, loamy skeletal, clayey skeletal	Sand, sandy skeletal
2	Drainage	Well drained	Moderate well drained	Somewhat excessively Imperfectly drained	Poorly drained Excessively Drained
3.	Soil Depth	Very Deep	Deep	Moderate Deep	Shallow
4.	Relief	Normal	Sub normal	Concave	Excessive
5.	Slope	Nearly level to very gently sloping	Gently sloping	Moderate sloping	Moderate steep to very steep
6.	Erosion Hazard	None	Slight	Moderate	Severe
7.	Coarse Fragments	None	Slight	Moderate	Severe
8.	Risk of Flooding	None, very low	Low	Moderate	High

Criteria of rating of land qualities for Paddy crop (LUT-2)

S.N.	LAND QUALITIES	S1	S2	S3	S4
1	Texture	Silt loam, Silt clay loam, clay, sandy clay, sandy clay loam	Silt clay, clay, Loamy Sand	Loamy sand, fine sand	Fragmental
2	Drainage	Well drained	Moderate well drained	Imperfectly to Excessively drained	Very poor to Excessive Drained
3.	Soil Depth	Deep	Moderate Deep	Moderate shallow	Shallow
4.	Relief	Normal, flat	Sub normal	Concave	Excessive
5.	Slope	Level to very gently sloping	Gently sloping to undulating	Moderate steep	Steep to very steep
6.	Erosion Hazard	Slight	Moderate	Severe	Severe
7.	Coarse Fragments	None	Slight	Moderate	Severe
8.	Risk of Flooding	None, very low	Low	Moderate	High

Criteria of rating of land qualities for Sugarcane (LUT-3)

S.N.	LAND QUALITIES	S1	S2	S3	S4
1.	Texture	Sandy loam, Loam silt loam	Clay loam sandy clay loam, silty clay loam	Sandy, clay, silty clay, loamy sand	Sand, fragmental
2.	Drainage	Well drained	Moderately well drained	Imperfectly well drained, somewhat excessively	Poorly Drained
3.	Soil Depth	Deep	Moderate by Deep	Moderately shallow	Shallow
4.	Slope	Nearly level	Very gently to gently sloping	Moderately low strongly sloping	Steep
5.	Erosion Hazard	Very low	Low	Moderate	High
6.	Coarse Fragments	None	Slight	Moderate	Severe
7.	Risk of Flooding	Very low	Low	Moderate	Severe
8.	Relief	Normal or flat	Concave	Sub-normal	Excessive

Criteria of rating of land qualities for Maize (LUT-4)

S.N.	LAND QUALITIES	S1	S2	S3	S4
1.	Texture	Sandy loam, loam silt loam	Clay loam sandy clay loam, silty clay loam	Sandy, clay, silty clay, loamy sand	Sand, fragmental
2.	Drainage	Well drained	Moderately well drained	Imperfectly well drained, somewhat excessively	Poorly drained
3.	Soil Depth	Deep	Moderately Deep	Moderately shallow	Shallow
4.	Relief	Normal, flat	Sub normal	Concave	Excessive
5.	Slope	Nearly level	Very gently to gently sloping	Moderately steep sloping	Steep
6.	Erosion Hazard	Very low	Low	Moderate	High
7.	Coarse Fragments	None	Slight	Moderate	Severe
8.	Risk of Flooding	Very low	Low	Moderate	Severe

Criteria of rating of land qualities for Sunflower (LUT-5)

S.N.	LAND QUALITIES	S1	S2	S3	S4
1	Texture	Sandy Loam, Loamy Sand, Fine Sand	Loam, Silt Loam	Clay Loam, Silt Clay Loam, Clay, Loamy Skeletal, Clayey Skeletal	Sand
2	Drainage	Well drained	Moderate well drained	Imperfectly to somewhat excessively Drained	Poorly drained
3.	Soil Depth	Deep	Moderate Deep	Moderate shallow	Shallow
4.	Relief	Normal, flat	Sub normal	Concave	Excessive
5.	Slope	Level to gently sloping	Undulating Sloping	Moderate Steep sloping	Steep to very steep Sloping
6.	Erosion Hazard	None	Slight	Moderate	Severe
7.	Coarse Fragments	None	Slight	Moderate	Severe
8.	Risk of Flooding	None, Very low	Low	Moderate	High

Criteria of rating of land qualities for Mustard (LUT-6)

Mapp-ing Unit	Land Utilization type					
	LUT1	LUT2	LUT3	LUT4	LUT5	LUT6
SH1	N2	N2	N2	N2	N2	N2
SH2	N2	N2	N2	N2	N2	N2
SH3	N2	N2	N2	N2	N2	N2
SH4	N2	N2	N2	N2	N2	N2
P1	S3rf	S3rf	S3rf	S3rf	S3rf	S3rf
P2	N2	N2	N2	N2	N2	N2
OAP1	S2drdffed	S2drff	S2rdff	S2rdff	S2tdrff	S2rdff
OAP2	N2	N2	N2	N2	N2	N2
RFP1	S2rdff	S2rff	S2rdff	S2rdff	Strdff	S2trdff
RFP2	N2	N2	N2	N2	N2	N2
RFP3	S1	S2d	S1	S2t	S2t	S2t
RFP4	N2	N2	N2	N2	N2	N2
RFP5	S3rf	S3rf	S3rf	S3rf	S3rf	S3rf
RFP6	N2	N2	N2	N2	N2	N2

Soil mapping units with suitability classes for various LUTs

Land requirements for different land utilization types were compared with land qualities and characteristics of land units to generate soil suitability for selected crops in GIS environment. Based on the analysis of land qualities and crop requirements, I have recommended the different LUTs for different soil mapping units.

From the table it can be seen that out of 14 land units 9 are not suitable for agricultural practices. Only LUT1 and LUT3 are found ideally suitable for cultivation along the gentle slopping land constitute mainly Raipur Alias-Sundarpur, Plasra, Jitpur, Barwala, Bharilli Sangrana, Fatehpur Viran and Bhagwanpur. The study reveals that only one soil unit is highly suitable for LUT1 and LUT3 under consideration. Nearly level plains along the river Dangri is not ideally suitable for agriculture only because of the fact it is much prone to flooding risk than desired. Other agricultural constraints are poor texture quality, soil depth, drainage, and presence of coarse fragments .33.3% of my study area falls under the category "Not suitable for agriculture" because of its steep slope, adverse relief condition, and presence of large amount of coarse fragments.

After integrating the present land use and land cover map and the suggesting cropping pattern map, I have generated the optimal land use map for the study area. The area which is characterized by barren & scrub can be utilized for horticulture /plantation practices. Only about 11.66% of the total geographical land is highly suitable for paddy and wheat cultivation and requires very little to almost no management practices, leaving rest of the land under moderate to high management practice.

CONCLUSION AND RECOMMENDATIONS

In conclusion it can be said that cropping pattern and agricultural land use system in the Barwala community block in Haryana has been developed to meet the demands of food supply for increasing population. The cropped area has been expanded over the land where the physical conditions of cultivation might be suitable. However in this area the land is prone to degrade its productivity and the distribution of cropped area may change temporarily. In order to investigate the temporal change of agricultural land use, satellite remote sensing data can be considered as the most effective data source.

Land Utilization Type	**Highly Suitable (S1)**		**Moderately Suitable (S2)**		**Marginally Suitable (S3)**		**Not Suitable**	
	Hec.	%	Hec.	%	Hec.	%	Hec.	%
Wheat (LUT1)	2126.54908	12.24	4245.64278	24.43	5219.2043	30.03	5787.8009	33.30
Paddy (LUT2)	0	0	6372.19186	36.67	5219.2043	30.03	5787.8009	33.30
Sugarcane (LUT3)	2126.54908	12.24	4245.64278	24.43	5219.2043	30.03	5787.8009	33.30
Maize (LUT4)	0	0	6372.19186	36.67	5219.2043	30.03	5787.8009	33.30
Sunflower (LUT5)	0	0	6372.19186	36.67	5219.2043	30.03	5787.8009	33.30
Mustard (LUT6)	0	0	6372.19186	36.67	5219.2043	30.03	5787.8009	33.30

Area statistics for different suitability classes

The study reveals that the areas under production of other crops has decreased from 22.61% to 14.26%, among which 5.65% area has been transformed to wheat area.

Although 44.72% of the total cultivated area shows no change, a considerable increase about 34.12% has occurred from single to double cropped area. The study also reflects that only an area of about 9.9% in the southern most part of the C.D Block is ideally suitable for wheat and sugar cane cultivation.

Suggestive optimal land use plan reflects that a substantial area of about 15.23% and 18.38% can be utilized for paddy-wheat and paddy -maize/wheat-sun flower-mustard cultivation respectively with moderate to high management practices. Impact of cropping pattern change on agricultural output has increased considerably after the year 2000.

Forests, especially the dense forest in the study area shows a significant decrease of about 14.56% over the areas, which is a result of ever increasing population and human encroachment to the forest land. The study also reflects a noticeable change of about 10.82% in terms of wasteland.

As demand for water has a direct relation with cropped area, precaution in the use of groundwater is essential for a long-term sustainable agriculture because aquifers in most parts of the study area are marginal and highly saline pumping water from greater depths could, therefore, result in the use of irrigation with saline water. Between April and June, the recommended cropping pattern should include only such crops which are less water-consuming, particularly in those agro climatic irrigation zones where there is already a negative water balance. The flood prone area along river Dangri is marginally suitable for paddy and wheat crops can produce a much better result with good management practices.

About 33.33% of the study area is characterized by barren and scrub lands which is not ideally suitable for cultivation, so we have recommended horticultural practices in these zones. Matching afforestation to maintain the environmental sustainability under control should compensate the alarming forest loss of about 14.56%.

The study points out that change in cropping pattern cannot be analysed in isolation from changes taking place in the farming system determined by factors such as land ownership, access to resources, labour relations, livelihood strategies, farming practices, traditions and culture.

The main causes of the changes may be grouped into (i) population growth and change in family structure, (ii) state intervention through land reforms, acquisition of land, deforestation, public distribution system etc. (iii) modernisation and commercialisation of agriculture, (iv) labour market conditions, and (v) price factors. The impacts of changes are (i) economic (changes in production, farm income, employment, women's participation etc.); (ii) social and cultural (cultivator-labour relation, negative attitude to agriculture, loss of traditional skills, etc.) and (iii). Environmental (loss of local varieties of seeds, breeds, and trees, receding water tables, decrease in biodiversity, etc.). Although it is required to evaluate the accuracy of estimation in detail, the method adopted in this study has a potential to accumulate the information on land use change, which is indispensable in environmental problems.

With the help of multi spectral, multi data satellite it is possible to prepare landuse/land cover map, to analyze cropping pattern and cropping intensity scenario. For change detection study satellite remote sensing and GIS plays an immense role towards the country's future development plan to be executed by decision makers.

In conclusion it can be said that through the concept of sustainable development, we can nourish the natural resources to meet the immediate needs of the present population and requirement of future generations without in any way endangering the ecology and environment.