Geoinformation Perspectives for Managing Change in Ecological Economy of Rainfed Regions

GIRISH PUJAR

National Remote Sensing Agency, Hyderabad – 500 037

1. Why ecological economy?

Geoinformation and ecological economy share a strong attribute viz., scale. Scale of entities acting therewith and their role as key development influences. Ecological economy as a process, dealing with products realised at various scales of aggregation of stakes, can have a strong parallel with geoinformation systems capable of representing range of natural and manmade entities as well as their juxtapositions. Agricultural economy generally pertains to generation of assets based on performance of cropped lands and excludes often, the asset generation accomplished using other associated natural resources like forest , fish and recreation. Asset generation based on these latter activities using ecologically non invasive approaches may be considered along with agricultural economy, as a true context of ecological economy or a strongly ecology based economy. Farm economy in most of the rainfed contexts retains for better part, remains at times, a conventional approach of selecting crops and modest level of external inputs due to individuals' investment capacity. Global level changes either physical or fiscal in nature are increasingly influencing the cropping pattern and related land use initiatives and is pushing near subsistence systems to change.

Possible attributes inherent to the system may explain why it is important to perceive the phenomeon as strongly ecology oriented

i. Autecological and synecological processes of a crop strongly determines the asset creation for an average farmer.
ii. Asset generation as influenced by biotic, climatic and other locality factors acquire stronger ecological connotations. Since any intervention of innovation does not gain significance unless it crosses threshold of either a spatial or temporal scale, in terms of asset generation/ecological amelioration, it is essential to retain intrinsic scale reference.
iii. As trends in rainfed farming either with regard to man or his biota related actions have huge impact on the regional market/policy, by virtue of a success or a failure otherwise, it would be naïve to consider the case as a fit candidate under ecological economy.

2. Geoinformation and its critical significance

State-of-the-art strategic planning relies on three major pillars of content handling – remote sensing based imaging, satellite based positioning and satellite communication and its intensity or capacity determines the success over the antagonist. Potential of geoinformation is increasingly being realized in multitude of fields ranging from defense strategy to epidemiology covering range of issues like food security, disaster management, ecological status to name a few. Derivation of this content is accomplished from various sources using diverse sensors situated on satellite, aircrafts, balloons, chutes, towers, handheld radiometers, signal receivers and other biophysical measuring instruments employing different parts of electromagnetic spectrum in moderate to very narrow energy windows. Evolution of sensors and platforms has brought unprecedented level of information in to the domain of scientific as well as operational use, which can be evident from the quantum of spatial information and meta-information on this information, available across internet. Another well perceived but least quoted attribute of a spatial information is ability go beyond language barriers when used in participatory approaches, since entities of interest for decision making can be identified, named according to the choice of major stakeholders and process understanding built over it.

Geoinformation by virtue of its integrative ability inherent in maps, rather dynamic as opposed to the conventional static ones, creates a baseline to plug in data on range of phenomenon at differing details/resolutions. Continuum of information built in these systems with logical connectivity would bring in the convergence of information in to a near virtual reality, helping to analyse, understand, question, store strongly or weakly spatial data for decision making. In the context of assessing change happening across geographical scale and predicting it , geoinformation provides mammoth scope to realize situations as conceptualized below:

a. Sense the possibility of change : Model the land use change using

1. Time compositing of image analysis
2. Prediction using slew of change causes

b. Suggest the change pockets : Model the possible pockets of realizable and essential changes using approaches involving principles of

1. Farmer oriented, possible participatory
2. Policy oriented, empirical , rapid

c. Detect the change : Marking and mapping the change areas/positions using

- Rapid automatic semi-intelligent systems
- Hierarchical and field intensive procedure aiming to involve variations

3. Evolution of Indian remote sensing

Indian Space Programme has two major streams of platforms viz, polar orbiting and geostationary satellites to which lunar programme is now added. Polar orbiting satellites are the key workhorses for Earth Observation while geostationary satellites provide transponders for communication , hence disaster warning as well as platform for meterological/very coarse land cover observation. Lunar programme is established and proven beyond doubt of its caliber to be sustainable.

3.1 Early Sensors

Initiation of remote sensing use in field of natural resources was accomplished with the use of data from foreign satellites like LANDSAT , NOAA , SPOT. Satellite data reception of Landsat started in 1979 and acted as first milestone in partially indigenized technology development. The launch of India's first civilian remote sensing satellite IRS-1A in March 1988, marked the beginning of a successful journey in the course of the Indian Space Programme. The two LISS sensors aboard IRS-1A beamed down valuable data that aided in large scale mapping applications.

Subsequently, IRS-1B , having similar sensors, was launched in August 1991, and together, they provided better repetivity. The LISS-III, PAN and WiFS sensors on IRS-1C (December 1995) and IRS-1D (September 1997) further strengthened the scope of remote sensing, with increased coverage and foray into application areas like resources survey and management, urban planning, forest studies, disaster monitoring and environmental studies. To test the launch vehicle programme, IRS-P3 and IRS-P4 satellites were launched. IRS-P3 carried an X-ray astronomy payload for space science studies (data was available only for 6 months, while other 6 months it was seeing deep space), besides a WiFS and MOS sensors. IRS-P4, a satellite dedicated for ocean applications was launched in May 1999. Its OCM (Ocean color Monitor) and MSMR sensors have opened new vistas in ocean studies.

The launch of IRS-P6 (Resourcesat-1) in October 2003, provided an excellent opportunity to obtain high resolution multi-spectral data and moderate resolution data in 10-bit (means better differentiation of dark to bright regions), while providing continuity(for monitoring compatibility) of data. IRS-P5 (Cartosat-1), launched on May 5, 2005, catapulted the Indian Remote Sensing program into the world of large scale mapping and terrain modeling applications.

3.2 Foreign Satellites

Apart from the Indian Remote Sensing Satellites, NRSC acquires and distributes data from a number of foreign satellites. Currently, NRSC is acquiring data from NOAA-17, NOAA-18, TERRA, AQUA and ERS. Apart from acquiring NRSC also distributes data collected by RADARSAT, IKONOS, QUICKBIRD , ORBIMAGE and ENVISAT (each one used as search term in google engine would lead to volumes of high quality and interesting information).

3.3 Future IRS Satellites

Continuing the journey, the Indian Space Research Organization is planning to offer much more to the user community through its future IRS missions. Cartosat-2, RISAT and Oceansat-2 are the next few missions which are scheduled to be launched during 2006-2007. RISAT is a RADAR satellite operating in electromagnetic region meant for mapping crop covers under cloud cover and has potential to be used for low biomass natural vegetation. (www.nrsa.gov.in)

Above diagram depicts the pictorial evolution of spatial resolution over decades in Indian remote sensing programme. A schematic tree overlaid indicates whether a pixel would contain several trees in an image pixel or one tree is made of more than one pixel which defines the core analogy of information generation. It is also notable that how panchromatic domains envisage different bands in case of 1D and P6, wherein latter covers only red region of the spectrum while former covered green, red and NIR regions. Two boxes of PAN data depicts the stereoscopic ability while single box refers to mono imaging.

4. Deriving information from Satellite images

Image analysis is generally perceived to be an arduous analytical domain dominated by mathematical procedures, since most of the build up efforts focus on automated routines aimed at extraction of contents, themes and objects from images. However, reotes based imaging produces variety of images, usually in stacks of coregistered data. This data is represented as numbers derived from a conversion of amount of light impinging upon charge couple devices. Remote sensing images can intuitively connect to the skill of the interpreter due to correspondence built against patterns on field. Images can be subjected to conventional aerial photograph oriented approaches, involving skills of a human interpreter. Otherwise, images can be subjected to complete automated routines to derive content at much faster pace. Intermediate approaches also prevail fusing the principles of both approaches, rather dominating most of the currently adopted procedures meant for operational use of remote sensing in context of Indian programmes (Fig. 1).

Procedural categories addressed here cover the key steps in each. Manual image analysis techniques rely on analogue steps and are carried out as on screen procedures, in contrast with the fading technique of interpreting hardcopy images, which had their limitation of dull representation and frozen color combinations. Steps involved include setting up of proper image contrast, using standard/tailor made look up table to image. Look up table refers to a brighness profile to be assigned to original image DN (digital number) values based on a linear or non-linear logic. The process can be iterative till better contrast is achieved in entire image/target area. Advent of range of digital imaging in day to day use coupled with their use interfaces (say photoshop) having basic tools of image handling, might already have helped in erasing the initial resistance to get in to domain of image processing. The core process of image analysis , requires setting of interpretation key based on image elements like color, texture, size, shape, association, aspect etc. This key acts as reference to solve ambiguities and enables repeatable process. Delineation of individual objects based on image elements accomplishes the mapping.

Extending the principles of manual information extraction in predefined/predetermined 'boxes'(situations) of automated origin would form the basic step of semij-automated approach. These would use on screen interpretation steps over already available GIS layer or image clusters (cluster means similar behaving DN number sets as per specific algorithm).

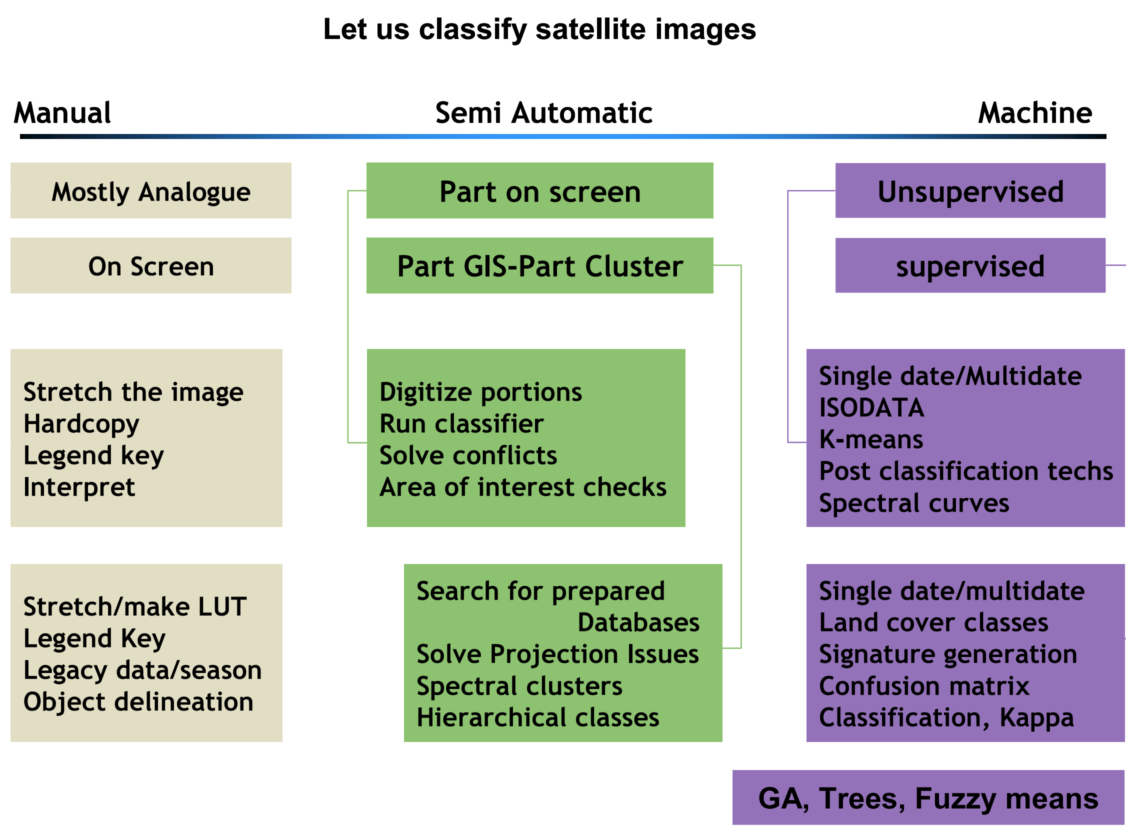

Fig.1. Alternate processes available for preparation of land use/cover databases

Image clusters are derived from fully automated steps whereas GIS layers procured from existing geodatabase of probably differing interest. GIS layer should be coregistrable and should have minimum metadata to understand the quality constraints. GIS layer might have been prepared for different objective and might have different accuracy standards. It should be made clear before had whether layer used has some correspondence for the current study objective say of detecting alternative land uses or not. Since availability of several biophysical databases based on coarse resolution imaging is high of late over internet, proper decision on sensitivity and suitability for the scale of intended study of extant geodatabase can only adds to the real value of study.

Completely automated procedure are generally most suited for land covers of simple ontogeny or high homogeneity observed in medium to high resolution images. Hihg to very high resolution images do need to use automated techniques for extraction of specific objects , occurring abundantly in a given region (say trees of similar shape spread across) which otherwise would be tedious to extract with manual efforts. Conventional remote sensing image processing would involve supervised or unsupervised methods. Superevised method uses ability of interpreter to communicate to algorithm meant for clustering and proceeds with a priori information. On the other hand, supervised methods can incorporate multiple seasons, GIS layers even to prepare the spatial product. Spectral overlaps handled at early stage using signature purification facility of supervised classification help to brace the variability in a systematic fashion.
Unsuprevised techniques rely on building image fractions, which when corresponded with meaningful ground covers result in to final spatial product. As geographic extents of a land cover mapping exercise assume larger extents, unsupervised approaches turn essential procedure. This is due to the fact that at such coverage, same land cover may form differing spectral signatures due to the fact that imaging atmospheric columns itself would differ. Techniques like k-means clustering combine guided seeding of image cluster with conventional unsupervised means to arrive at best possible results.

All the methodologies discussed may need continual improvement for newer cased of complex imaging techniques. Tools like genetic algorithms, decision tree classifiers are being attempted to derive better performance in image classification. Methods lead to a procudt an it should in turn be subjected to proper accuracy assessment based on kappa accuracy assessment. Kappa accuracy may be of normal method or fuzzy approach. Kappa accuracy essentially derives its principle from chi-square method, wherein strengths of different classification methods can also be compared, which is a must while assessing land cover change across time.

5. Alternative Land uses and cover changes

Theory of the land use reveals that most of the tracts cultivated today might have been wooded to varying canopy cover, be it low land tropical evergreen forests or drier arbores cent varieties. Since the land showed fertility of acceptable degree, communities cleared it for food production, which must have been aided by the growth of enough grass or weedy species in gregarious manner. Initial phases of this conversion, or change must have been marked by extensive low external input agricultural practices, which can still be witnessed wherein much energy of farmer motivation needs to be invested. Such cases are abundant and this subsistence practice leads to land cover of confusing remote sensing returns, since a fallow or a weakly farmed vegetation may not differ much in spectral interaction, especially in a moisture stressed vulnerable contexts. Intensive, commercialized or more systematized form of farming high in external inputs, responds far better in physiological status and is amenable for better sensing. However, by reasons obvious to most, these both categories of farming, considered in sequence or in parallel, seem to bear the brunt of global scale changes, and hence require intervention of alternative land use systems. Links between the possible pristine or intact systems and requirements of alternative land use systems need to be explored since resource sharing patterns in the latter may be of key significance to arrive at sustainability. Spatial observation capable of panoramic views would readily give a first hand assessment of such contexts and help to put them in a larger framework of observation, monitoring and sampling.

6. Assessment alternatives for ALUS

For an initiate in remote sensing, word like ease and use of remote sensing may be an oxymoron, given the wide ranging information presented up front. However, amount of satellite data available, even as gratis, coupled with efforts like google earth, which represents one of the most far reaching innovations of current years, might certainly motivate the use of remote sensing for the purpose of assessing land cover alternatives observed. Amazing detail of land cover information, especially in complex land cover/use contexts like degraded forest, gullied farms, scrub laiden wastelands are amenable for a clear familiarization. Though H-res images may be with wall to wall coverage, enough samples are available for a familiarization exercise and paving the way for capacity enhancement. With this background and application of some simple rules of land cover change, following table is presented wherein ease of information is argued. An urge to use the term “difficulty” of interpretation is held back, so that initiates move towards use of technology. The rating shown puts the process on a scale of ease in terms of image use and ground truthing numbered between 1 to 5 (Table 1). Highest rank depicts involvement of intensive ground data collection so as achieve results amenable for translation in to operation.

General thumbrule of this matrix provided herewith is that uniform, homogenous and/or gregarious land covers of fairly large size formulated over time stand as easy candidates for image based detection, when observed using medium to coarse resolution. Conversely, only high resolution images can detect discrete, sporadic and ephemeral land cover changes need to be observed using high spectral/spatial resolution capacity. Major agronomic manipulation seem to occur between crops of similar appearance or slightly different form,habit and phenology (crop to shrubs/trees), instances of alteration to more intense, water based activities like culturing biofertilisers or algae may not ruled in next half to full decade. Land use scenarios like agroforestry which in its generic sense covers patch formations of block, line, point or striped geometry, do deserve special attention by virtue of their form diversity. High resolution Carotsat-1 images which, of late, seem to have attracted rather a very large number of users in biological as well as physical applications, are becoming fast accepted in to preparation of spatial solutions. Sheer intensity of content apparent at casual observation, drives home the need and relevance of using a very high resolution, yet modest priced alternative for natural resource assessment.

Though much needs to be done towards full scale implementation of participatory forest management as an alternate land use itself, specific instances of repeatable successes have been notable across arid contexts. In such cases, signals were amenable to remote sensing observations which corroborated with ground reality (NRSA, 2006). Degree to which only remote sensing proves useful is while debatable for such application, it should be realized that no alternate observation and recording technique of such unbiased quality, can be available otherwise. It helps to prove that things have happened on the positive note in participatory forestry at least in some instances!

Table 1. Showing the potential of detecting/mapping alternative land use scenarios (ALUS) using remote sensing

			Satellite Imaging		
			Coarse Resolution	Medium Resolution	High Resolution
ALUS category			High temporality 1-5 days	Medium Temporality 16-24 days	Medium to Low Temporality 24 - 100+ days
Vegetation					
Same Crop	Differing Strain			**5**	
Different Crop					
	Herbaceous				
		Other season		**5**	**4**
	Shrubby				
		Same season	**5**	**2**	**3**
		Other season	**3**	**1**	**3**
	Woody				
		All season	**4**	**3**	**1**
Non Crop					
	Conservation				
		Soil	**5**	**2**	**1**
		Least tillage		**4**	**3**
	Farm forestry				
		Agroforests	**3**	**4**	**1**
		Block planting	**2**	**2**	**1**
	Aquaculture				
		SCP/Azolla	**3**	**1**	**1**
		Fish	**3**	**1**	**1**
Participatory Forestry					
		JFM			**3**
		CFM		**5**	**3**
REDD				**4**	**4**
Animal husbandry					**5**

Category of approach	Process
1	Direct imaging amenability with minimum ground truth
2	More than one field visit circuits needed
3	Moderate ground campaign needed
4	Ground information decides key steps
5	Highly ground intensive

Future land use alternatives like REDD and extant CDM would have greater satellite data component. Satellite data in this sense is inevitable both as imaging and positioning, to build a convincing protocol for international certification. CDM methodologies based on affoerstation/reforestation required imaging to address "when" of the land cover change and GPS position to ascertain 'where' or 'in whose parcel' of the change. REDD, the new approach, abbreviation for Reduction of Emission from Degradation and Deforestation, formed post-Bali discussions, is posed strongly over the use of satellite data. Essence of the process is to prove that intact currently available have not experienced any degradation or deforestation when compared with regional rates. This comparison has to be accomplished using remote sensing data of at least two time periods. Nevertheless, since stakes in terms of huge profits may be involved a thorough confirmation of the candidacy and its future sustenance needs to be proved using either medium or high resolution datasets.

Animal husbandry when incorporated as component of agroforestry, has shown great promise of ameliorating rainfed livelihoods (www.goodnewsindia.org). Its signatures at satellite observation level may be of differing contrast depending upon whether we are looking at tree components or grasslands. In either case, sufficient ground information needs to go in to accuracy assessment as well as geodatabase creation.

7. Studies of Monitoring Land Use Alternatives

7.1 Assessing the land cover changes under LULUCF category

Social / Farm forestry through intensive energy plantation is a promising venture yielding proper remuneration for investment, especially in fast rotation categories. Promotion of growing genetically improved and high yielding tree species by ITC Bhadrachalam has opened up a new vista in Farm Forestry initiatives. Utilization of marginal lands in potential areas aided by the strength of nursery stocks of ITC has led to increase of Eucalyptus/ Acacia plantation area in the districts of Khammam, Prakasam, Krishna, West Godavari , Nellore, Nalgunda, Guntur in Andhra Pradesh. Short rotation of these plantations is supporting the need of raw materials in Paper manufacturing in a steady fashion. Such a growth of plantations supporting paper industry as well as helping to use marginal lands was studied in terms of its temporal sequences and the changes it has brought in over all land cover situation. Global functions of such a mass scale effort would be of significance in terms of potential of certified emission reductions. In view of this objective of proving the validity of social forestry plantations planted in tribal land holding as carbon sinks remote sensing based inputs as well as query clearances were provided. Essence of the approach was to prove that land parcel containing plantations today were actually degraded forest land in 1989 end scenario and planting eucalyptus was the only alternative for the poor farmers during this period. Approach adopted was as following.

Image procurement/preparation

Satellite images were procured (Fig.2) for the essential time points by taking care of a) seasonal variations of phenology (anniverisary dates) b) cloud free status for requisite critical land cover potions, c)quadrant compatibilities across sensors. Highest resolution dataset was rectified against the geometric master data derived from GLCF database. Other datasets would be coregistered against the rectified base. Accuracy evaluation of registration was done and needed correction were done.

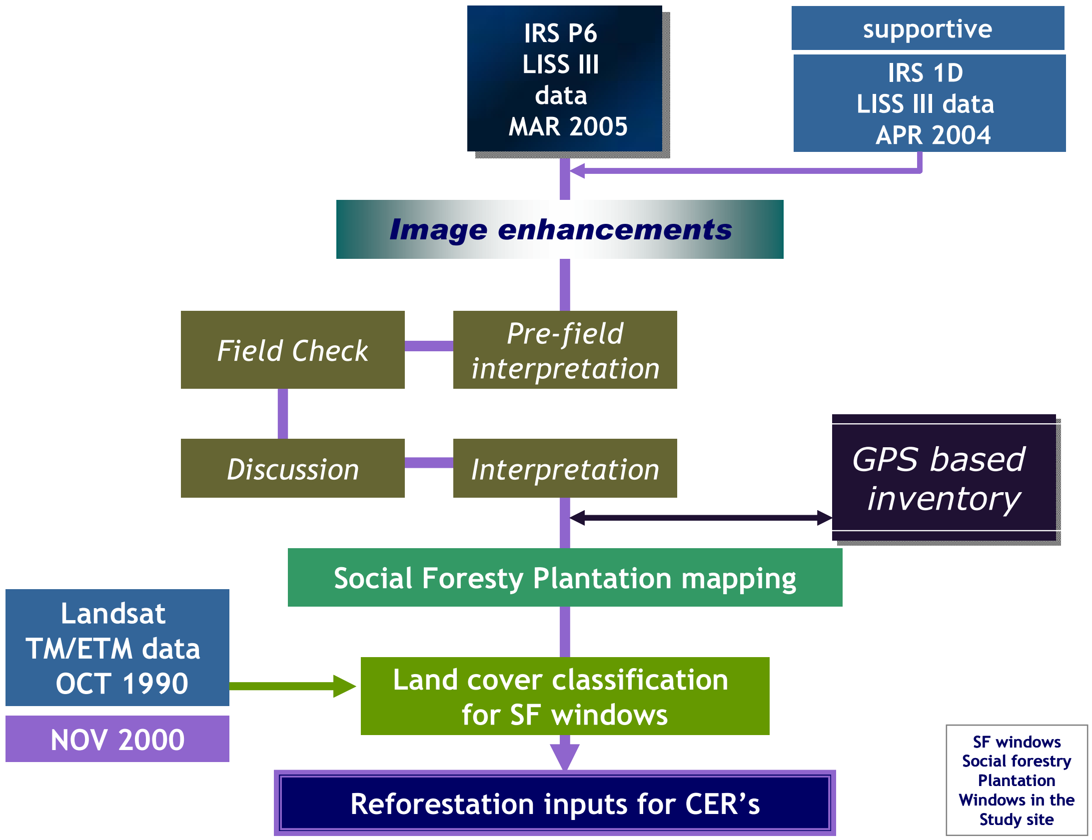

Fig 2. Interpretation of Vegetation and Land cover for year 2005 and 1990

The vegetation and land cover for current status (2005) was carried out using the onscreen interpretation methods. The mapping was done by exploring full image enhancement potential. Interpretation produced level 1 classification of the land covers. Vegetation and land cover for 1990 image was carried out after overlaying the 2005 vegetation layer on to it. The status in 1990 was confirmed and wherever changes were found, incorporated in to the database.

Land covers interpreted were forest, forest plantations (forest corporation), orchards (horticulture), degraded vegetation(scrubs), agriculture, settlements, water and eucalyptus plantations. Degraded vegetation at places was aslo referred as scrub since scrub structure is resultant of degradation processes prevalent in forest edges. Plantations carried out by forest corporation were large sized essentially within main forest patches of the study area. The approach relied in majority on the veracity of interpretation key prepared and the phonological matching of the data available. Since baseline year is considered as End of 1989, data corresponding to this time point or just later was considered for change assessment.

7.1.1 Land cover change studies

The changes were assessed using two time visual classification of the satellite data to show the change in land cover contents. Vegetation land cover layer was overlaid on to time period images corresponding to year 1990 to derive the land cover patterns of the respective period. It is desirable to derive the land cover schemes independently. However, in view of the sensitivity of the current study, land cover delineation was done with special regard to forest – agriculture interface edges, scrub covers and orchards. Change polygons were specially mapped for each of the area based on the satellite image with case specific image understanding. The change polygons were assigned identification for change and no-change cases to extract the change areas. Change statistics was generated accordingly (Fig. 3).

Issue of the land parcels was addressed using Global Positioning System. Handheld 12 channel GPS instruments were used to derive the exact boundaries of the land holding and total amount of the sink eligible was mapped. The exclusion in terms of later land occupation , which were forests in 1990 was done.

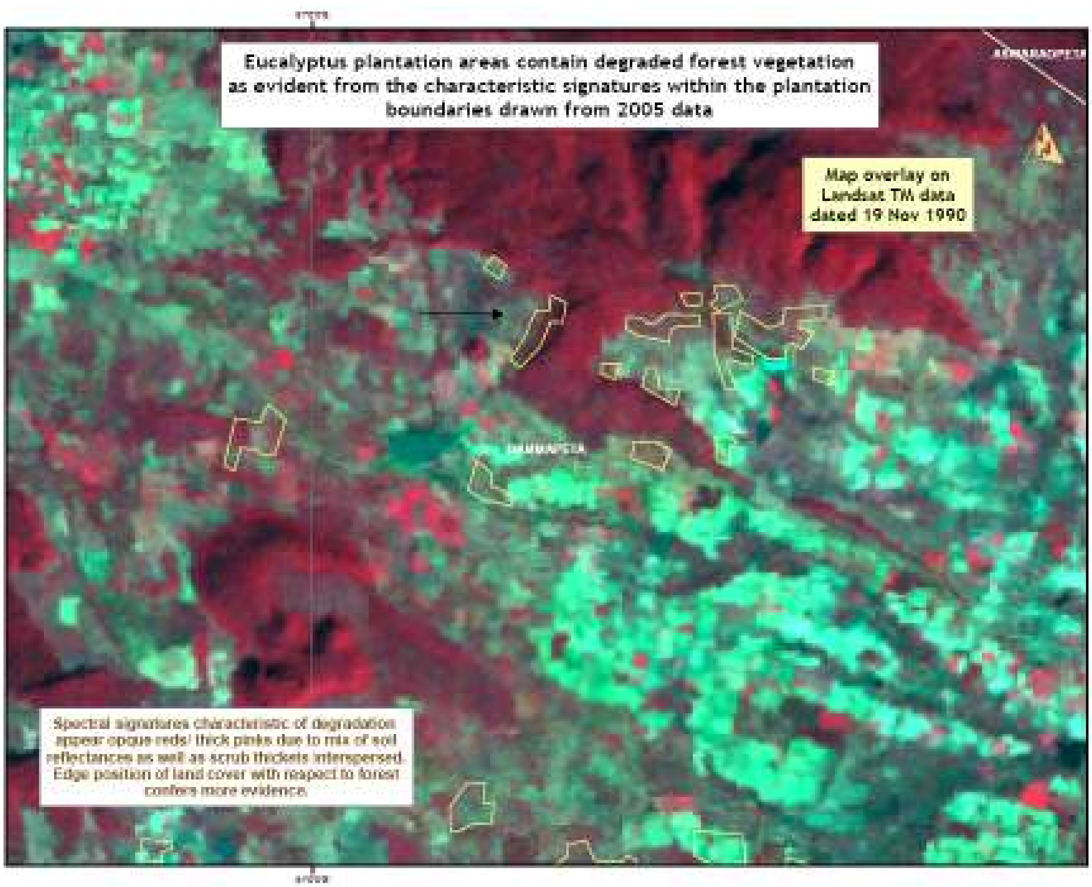

Fig 3. Showing the evidence of plantations areas being degraded lands at the end of 1989

The exercise showed a standing eucalyptus crop observable in remote sensing to the tume of around 1020 ha while the sink mapped , containing freshly planted stock was found to be around 3000 ha. The sink proved was submitted to UNFCCC verification and the process of procuring the CER’S is in an advanced stage.

7.2 Community Forest Management

Graduation of Joint Forest management (JFM) to Community Forest management (CFM) in Andhra Pradesh seemed to mark beginning of new vista of sustainable forest management. AP Forest Department initiated 'Vana Samrakshana Samithi' (VSS, Forest Protection Committees) Program during the last decade, to sustain the resource development in conjunction with the resource demands. These committees were redesigned in to CFM process with further financial and technical independence. State retained the stake as member for technical guidance and monitoring. Significant strides in forest protection and production were made possible through multidisciplinary approaches under these committees. Quantum of land cover changes was observed and a need to assess it was felt.

Approach included visual observation for the change confounded by detailed ground verification for omission and commission of land covers. Each of the selected 20 sites were significant in terms of agroclimatic affiliation and the patterns of human interaction. Overall trend depicted that six out of twenty samitis showed positive changes (Fig. 4).

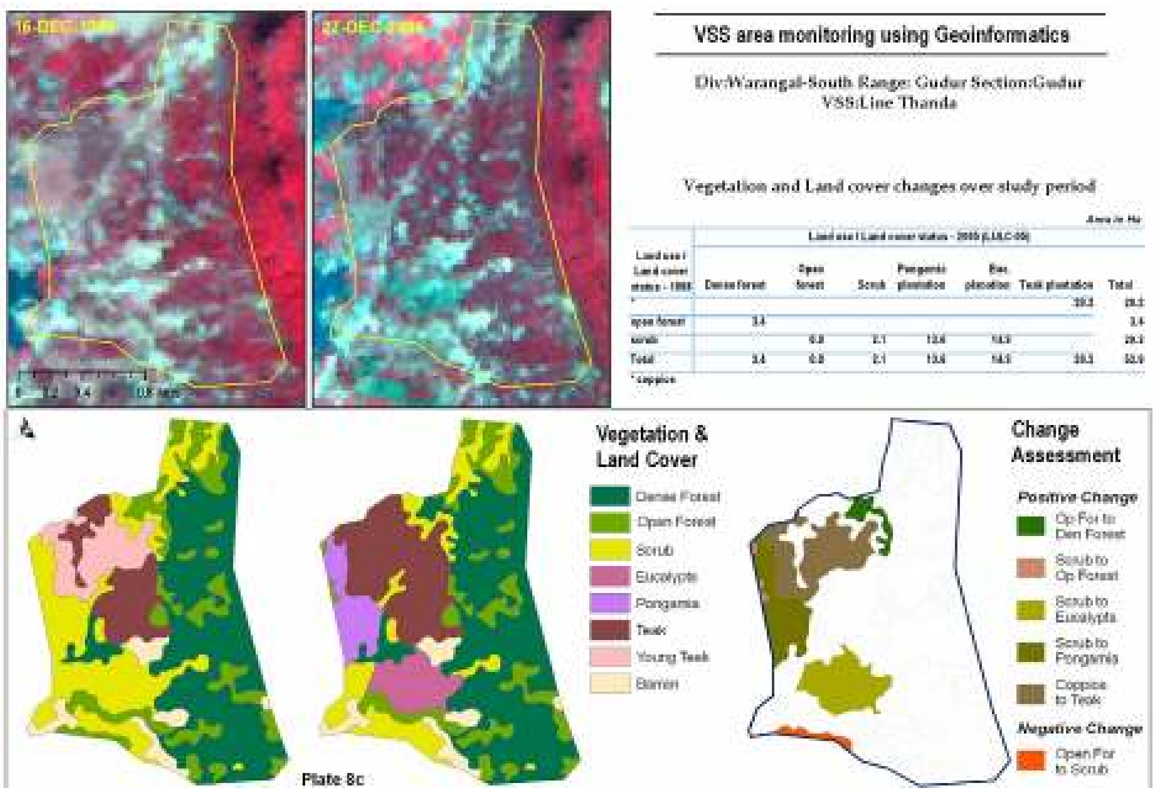

Fig 4. Spatial analysis of the impact of CFM in Andhra Pradesh using IRS satellite data.

8. Conclusions

Remote sensing techniques have great scope of being employed in detecting and mapping land use alternatives realized on the ground. Since the change induced may vary from vary from fine scale orientation to medium scale , it is better to use suitable dataset for the objective in hand. Advent of recent very high resolution sensor datasets available at modest price would enable incorporation in to regular protocol involving monitoring alternative land use oriented changes. Newer land use options in the offing would invariably require use of remote sensing , hence, need to understand and use this technology is all more imminent. Geospatial database prepared out of such process would be of unique value to integrate natural resource management decisions in holistic fashion.

REFERENCES

Johnson, S (2007). The road forks for tropical forests. ITTO Tropical Forest update 17/2. pp 1-2.

NRSA, 2006 Monitoring Vana Samrakshana Samithi Areas of Andhra Pradesh using Geoinformatic Approach Department of Space, Govt.of India, Remote Sensing and GIS Application Area, Hyderabad, REPORT No. NRSA/FED/TR-06-07. 98pp.

FURTHER READING

Congalton, 1991 Congalton, R. 1991. A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. Remote Sensing of Environment 37: 35-46.

Jensen, J. R. 1996. Introductory Digital Image Processing: A Remote Sensing Perspective. 2d ed. Englewood Cliffs, New Jersey: Prentice-Hall.

Lillesand and Kiefer, 1987 Lillesand, T. M., and R. W. Kiefer. 1987. Remote Sensing and Image Interpretation. New York: John Wiley & Sons, Inc.

Patil V.C, Dasog,G.S.,Alagwadi, A.R, Shashidhar, K.C., Biradar,D.P (Ed) (2002) Agro-informatics: Proceeding of the First National Conference on Agro-informatics (NCAI).INSAIT., Dharwad. 148 pp

Mitta .S.P (Ed)(2004) Alternative Land Use Systems for Sustainable Production, Oriential Enterprises, Dehradun.493pp.