Applications of Remote Sensing and Geographical Indication System in Land Resources Management

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A natural resource is any form of energy or matter essential for the fulfillment of physiological, socio-economic and cultural needs of humanity and to sustain all the various activities leading to production. Natural resources may be renewable like solar energy, forests, crops, fisheries, etc. and non- renewable like oil, coal, natural gas, etc. Some of them are recoverable (all elemental minerals) and recyclable (metallic minerals). The availability of these resources depends on many factors (physiographic, climate, biotic and technological) that govern their accessibility and exploitability. Their distributions vary spatially because some are oceanic and some are land based in their origin. Their availability also varies over time depending on the limits of utilization.

Information on how much and where the resources are located, rates of change/use, and their quality are not adequately recorded. The current resources inventory systems are not repeatable over time. There are gaps in their data collection due to inaccessible terrain and boundaries. Poor documentation and data definitions leading to misuse of data, difficulty in identifying data sources for past data, difficulties in transfer of data between agencies because of different standards/formats are some of the constraints in land resource management.

It is in this context that the modern tools of Remote Sensing (RS) and Geographic Information System (GIS), and Satellite based positioning systems (popularly called GPS) are appropriate for natural resources assessment and management. RS is the acquisition of information about an object, a phenomena or a process by noncontact method, usually from airplanes or satellites, using sensors operating in any portion of the electromagnetic spectrum. The GIS allows inputting, management, analysis and display of the data collected by RS and other means. GPS instruments are used to obtain precise measurement of an object's location in terms of longitude, latitude and altitude. At global scale these technologies provide a cost effective means to study the biosphere, geosphere and atmospheric interactions. At micro scale, space technology is providing valuable inputs for developing land and water resources. Monitoring of changes in the forest cover using RS and drafting developmental plans for afforestation using GIS are good examples of macro and micro-level applications. Here, we discuss the information needs in land resources management and application of these modern tools.

Information needs in land resources management

Land resource consists of soil, forests, crops, livestock, etc., the land component of the earth's hydrologic cycle (snow cover, soil moisture and associated runoff, underground water) and mineral resources. Most of these land resources are used for production of food, fodder, fuel wood, fibre and for making improvements in productivity of land. Some of the basic land resources information needs are on soil characteristics; slope and degree of roughness; surface and groundwater availability; present land cover and use characteristics; biological conditions, such as disease and insect infestations of crops, grass land and forest land; urban development, etc. The important issues that need immediate attention and where remote sensing can play a significant role are:

- Inventory and mapping of resources.
- Evaluation of present land use practices and projections for the future.
- Assessment of land resources which are physically useable and economically relevant.

- Identification of strategies that offer sustained production and other benefits.
- Analysis of constraints related to resource development - physical, economic or social.
- Identification of appropriate corrective and conservative measures required for bringing about the desired production and minimizing the environmental damages.
- Evaluation of changes in the structure and function of land systems.

Remote sensing applications in land resource management

1. Remote sensing opportunities in the North Eastern region

Land resources management in the NER of our country has acquired a new dimension with the enhanced speed and reliability with which the spatial and temporal information is generated and disseminated using space technology in a cost-effective manner. A giant leap forward has occurred by the establishment of North Eastern Space Applications Centre (NESAC) at Umiam (Shillong), Meghalaya with the Indian Remote Sensing Satellites (IRS) providing an alternate data collection system and the INSAT based communication providing an information dissemination system. IRS-P5 (CARTOSAT-1) that was launched on 5th May 2005 has a cutting edge technology in terms of sensor systems and state-of-art PAN camera with about 2.5 m resolution with fore-aft stereo capability. This mission along with a suite of sensors on board IRS-P6 (RESOURCESAT) provides the much essential monitoring capability and in bringing accountability to the system of land resources management. There has been an appreciable acceleration in surveying and monitoring of land resources during the last few years as evidenced by a number of projects discussed here.

2. Agricultural statistical system

The data from IRS sensors have been used in generating district wise land use/land cover statistics for the whole country on 1:250,000 scale. This information was utilized in drafting land use planning strategies for 15 agro-climatic zones in the country. Mapping of lands lacking appropriate management and undergoing degradation ("wastelands") was carried out twice for the entire country including all the north eastern States. The district-wise maps and statistics on the wastelands are available for the planners to make use of them in preparing perspective plans. Satellite images could also be used for assessing the extent of crop damage due to floods and drought. For example, using the RS and GIS tools NESAC is studying the process of sand deposition, its depth, methods of reclamation etc. in the **Dhemaji** district of Assam.

Experiences with multispectral data show that with adequate ground truth, crops could be identified and their growth stage could be assessed (Navalgund *et. al.,* 1991). Recent satellites, IRS-IC, IRS-1D, etc have improved the accuracy of pre-harvest estimation of production of crops in the regions having small fields and mixed cropping patterns. Satellite-based crop forecasts are being used by the Central Directorate of Economics and Statistics in suggesting appropriate actions regarding food-grain management (Navalgund *et. al.,* 1996). Having successfully implemented a project called Crop Acreage and Production Estimation (CAPE) the Department of Space and Department of Agriculture and Co-operation have launched a new project called FASAL (Forecasting Agricultural output using Space, Agrometeorology and Land-based observations). The project FASAL is an integrated approach to generate timely and accurate estimates of crop size during *kharif* and *rabi* seasons, using remotely sensed crop area, crop vigour and conventional records of weather and yield variables. (Dadhwal and Ray, 1999). A remote sensing –based statistical data collection system is being developed for the State of Meghalaya. A pilot study, completed for Ri Bhoi district, during the last two years (2004-05 and 2005-06) shows that the area and productivity are over-estimated by the conventional eye-estimates. Efforts are on to extend the methodology to cover the entire state and major principal crops including horticultural crops.

Under the Natural Resources Census (NRC) Mission, the North Eastern Space Applications Centre (NESAC) is planning to provide periodic assessment and reporting on the status of our region's land resources. It also proposes to map those areas where the land use/cover is undergoing rapid changes ("hotspot"), identify the causative factors and suggest remedial measures. A repository of NRC will be created and made available to the public.

3. Management of Forest Resources

Forests are important for improving the genetic diversity of crops, better environment and for sustainable development. The effective management of forest resources requires. i) mapping of various forest types (species and extent), ii) detection, and delineation of damaged forest areas, and iii) estimation of production potential. For the first time, vegetation mapping on 1: 1 million scale for the entire country was carried out by NRSA (1983) using Landsat - MSS false colour composites. Later on, Forest Survey of India (FSI) started mapping the forest cover once every two years using the methodology developed by NRSA. The early studies revealed that the forest cover of the country is 19.41 per cent with closed forests accounting for 10.88 per cent only. The remaining forest area comprises open forests (8.41, per cent) and mangroves (0.12 per cent). So far seven cycles of vegetation cover assessment have been completed by FSI. The recent assessment on 1:250,000 scale shows that the country has vegetation cover of 19.39 percent of the geographical area of the country (FSI, 1999).

Methodologies have been developed for forest type and density mapping and for monitoring of afforestation and deforestation using multidate imagery. Encroachments into the forest areas in North Dhule area of Maharashtra have been detected at 1:50,000 scale with accuracy better than 90 per cent in each case (Jadhav *et. al*., 1990). By superposing forest block compartment boundaries their utility in the preparation of working plans and working schemes has been demonstrated. The components which can be measured by RS are correlated to the volume measured on the ground and stand volume estimates have been prepared for tree species in a few forest types (Udayalakshmi *et. al*., 1998).

As part of an international effort on Tropical Ecosystems Environment Observations by Satellite (TREES), the Indian Institute of Remote Sensing (IIRS) and Joint Research Centre (European Commission) have carried out forest cover assessment and mapping in northeastern India using IRS-IC/ID WiFS data. Their study showed that the rate of loss of forest cover (in sq.km per year) due to shifting cultivation was 192 during 1989-91, 225 during 1991-93 and 88 during 1993-95. This forest cover loss was also found to vary from state to state in the region. The major decline in forest cover (compared to 1980-82 estimation) was found in the Tripura state (Roy *et. al.,* 2002). They have also reported high degree of fragmentation that may lead to land degradation in near future. The fragmentation has caused loss of connectivity, ecotones, corridors and biodiversity. The fragmentation process is attributed to shifting cultivation, road construction, illicit felling, and urbanization. The level of fragmentation is much higher in the areas closer to human settlements and roads. Inaccessible areas in the states of Arunachal Pradesh, Meghalaya, Sikkim and Manipur remain least disturbed (Roy *et. al.,* 2002). These studies amply demonstrate that the modern tools like RS, GIS, GPS, etc. could be used to monitor the changes in the forest resources and to suggest conservation and protection measures.

4. Soil Resources Management

Soil is one of the important renewable natural resource that is the centre of all the activities controlling agricultural production. The production potential of soils varies with their fertility and inherent limitations. Therefore, reliable and accurate information on soil is of paramount importance for putting it to the best use. This calls for knowledge regarding their nature, extent, physico-chemical characteristics and limitations. This information is provided by soil survey wherein each soil unit is described in terms of its characteristics and presented in a map. LANDSAT and IRS satellites with improved spatial, spectral and radiometric resolutions have helped in mapping of soil families/association at 1: 250,000 scale (NBSS&LUP) and 1:50,000 scale under the IMSD project of ISRO.

5. Mineral Resource Management

Most of the mineral resources are non-renewable. To keep the reserves of these resources at an acceptable level to meet the future needs, it requires the discovery and evaluation of new sources of minerals. The role of airborne and, a space borne system in mineral exploration comprise four main fields of attention: i) structural control at regional scale, ii) spectral identification of lithologies, iii) geobotanical anomalies and iv)data integration. Geologic, geomorphic and tectonic maps are being prepared to identify features or guides associated with mineralization and to delineate target areas for exploration. Though remote-sensing methods cannot replace proven methods, they definitely provide useful inputs in recognition and delineation of mineral provinces and target areas by identifying indicators and geomorphologic features. For example, the lime stone formations and sand stone and shale formations in the Jaintia hills district of Meghalaya look very different on a satellite image.

6. Water Resources Management

From its modest beginning with surface water, inventory this technology has progressed to more complex management tasks such as irrigation system performance evaluation and diagnostics, country-wide drought monitoring, rainfall estimation, snowmelt runoff forecasts, reservoir sedimentation and watershed treatment, flood mapping and management and environmental impact assessment. National and locale specific programmes have utilized space-derived data to enhance the efficiency of water management. NESAC has prepared a district map of Ri Bhoi showing the surface water bodies larger than 0.22 ha that could be used for developing inland fisheries. These maps have been supplied to Directorate of Fisheries, Government of Meghalaya. NESAC also prepared a ground water potential zones map of East Khasi Hills district that could be used for drilling bore holes more successfully and provide water for irrigation and drinking.

7. Urban Planning and Development

More than 25 per cent of India's population lives in urban areas and consists of about 3500 towns of varying sizes. Over the last four decades, the urban population has more than quadrupled. Most of the urban centers started as trading towns centered in agricultural areas and grew with the pace of industrial development. In the process, some of the best agricultural lands were consumed for urbanization. According to an estimate, nearly 10 million hectares of productive agricultural land will be lost in the country by the year 2001 due to unplanned growth of the urban centers. This poses problems of housing, sanitation, supply of power and water, disposal of waste and environmental pollution. Hence, there is a need for integrated urban planning, which calls for information on the spatial distribution and extent of land and other natural resources in and around the urban centers and their dynamics. The tools of GIS can be used in a variety of ways to address the local problems of rapid urbanization combined with the high spatial resolution data of IRS-IC and ID sensors. Many new ways of looking at urban utilities and environment are possible. Day-to-day problems of the urban dwellings, i.e., traffic and transportation, greenery, solid waste disposal, pollution, location of new layout for urban growth, road alignments, etc., have been studied under the GIS environment. Large-scale satellite pictures and GIS techniques allow development of information system at the level of land ownership.

8. Integrated approach to land resources management with watershed as a unit

Sustainable development of natural resources is required to satisfy the human needs while maintaining or enhancing the quality of environment and conservation of resources for future generations. This could be achieved through practices, which are environmentally sound, economically viable and socially justified. The following are the four categories of land as identified by Dr M. S. Swaminathan for focusing the development strategies.

- Unsustainable land: these are the fragile ecosystems, which should be preserved in their natural state.
- Marginally sustainable: normally under degraded forest or scrub, but if cultivated should be brought under a conservation reserve program for recuperation. In the event of food shortages, they are cultivated.
- Conditionally sustainable: these are lands which require special attention, regarding soil erosion and degradation. Monitoring of degradation becomes an important activity for these lands.
- Prime land: this normally serves as the breadbasket of the nation and the goal of research support services is to maximize yields from this land.

Each of these four categories of land calls for a suitable strategy for their management because they are interchangeable depending on the management. Not only must the management be in tune with the local needs but also the quality of land must be continuously monitored to evaluate its condition. It is here the role of satellite remote sensing is very significant.

A unique approach where satellite remote sensing has been found very effective is in the management of land resources taking watershed as a unit of development. This approach advocates, as a first step, conduct of primary surveys to know the needs of people, present sources of data, their adequacy and gaps. The second step involves preparation of a set of resource maps using remotely sensed data such as (i) surface water bodies showing dry tanks, (ii) ground water potential zones showing favorable areas for immediate extraction of drinking water, (iii) potential zones for ground water recharge. (iv) Soil map including the nature and erosion status, (v) existing land use and distribution of wastelands and (vi) an integrated land and water resource map giving high priority areas for agriculture development, for fuel and fodder development, soil conservation and afforestation. The third step is suggestion of package of good practices and strategies to address the local problems. The fourth step is to monitor the implementation of the suggested action plan using the tools of RS and GIS. NESAC has tried this integrated approach to address the resource management problems of **Sater Mianar Hour**, a wetland rice ecosystem in north Tripura district. The entire ecosystem has been divided into micro watersheds of 500 ha size, prioritized into very high, high, medium and low based on normalized difference vegetation index (NDVI), soil brightness index (SBI) and recommended many alternatives to rice culture. Implementation of the suggested action plan would rejuvenate the region from perennial water logging and resultant crop failures. We advocate this watershed-based approach to land resource management in the State of Meghalaya.

Agro-Climatic Planning and Information Bank (APIB)

In order to provide a single window approach to supply of information to all the users and decision-makers at the grass root level, an Agricultural Planning and Information Bank (APIB) has been established. This bank is not only an information or data bank but also a facilitator by providing the users with tools required for preparing development plans. This bank has drawn its strength from the substantial information already generated district-wise. More details can be seen in Nageswara Rao (2005). APIB has been developed for the East Khasi Hills district of Meghalaya and users can access the planning inputs from the web site http://megapip.nic.in .

Conclusion

Accurate and timely information is necessary to evolve strategies for achieving long term management of natural resources. Satellite technology provides a multi-disciplinary and multi-organizational approach to resource management. This technology can provide important alternative to mitigate natural disasters which are major constraints in our efforts to develop natural resources. With more capable second generation remote sensing satellites and all weather microwave remote sensing capabilities, it should be possible for the resource managers to optimize the productivity of land and water resources. Our experience shows that an integrated approach based on remote sensing and GIS, taking watersheds as a unit, is more appropriate for land resource management and sustained development.

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