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Application of Remote Sensing and GIS in Land Resource Management and Planning

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Abstract

The socio-economic development of any country is based on natural resources. The natural resources are essential to the economy of the nation since they play a critical role in the provision of employment; they are a source of raw materials for various industries, act as the source of food and income, medicine as well as energy. Due to increase in population, these resources are over stretched often leading to resource depletion. Ultimately the depletion of natural resources has led to increase in the cost of living ,changes in weather pattern and decline in economic , social and cultural benefits that were accrued as a result of their utilisation .It is essential for nations to learn how to use these resources in sustainable manner to ensure that benefits are enjoyed in present as well as future generations There is need to prudently manage these delicate resources with the current trend in the advancement in the field of information technology, natural resources managers have now laid a lot of emphasis on the use of remote sensing and GIS technology in the management of natural resources,. These technologies provide a platform through which managers can generate informative data and the information that can be used to make sound decisions for sustainable development. Thus, this paper presents an overview of the GIS and Remote Sensing applications in land resources management and sustainable development.

Kay Worlds: *Remote sensing, Geographical Information System (GIS), land resource management and Planning*

Introduction

A natural resource is any form of energy or matter essential for the fulfilment 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.

Definition and Scope

Remote Sensing: The term "***remote sensing***" first emerged in the 1950s and refers to "the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation". The era of satellite remote sensing began with the launching of Landsat-1 in July 1972 by the National Aeronautics and Space Administration (NASA), United States. It is based on the use of image data acquired by sensors of different types such as aerial camera, scanner or radar. The satellite remote sensing is used to interpret the images or numerical values obtained from a distance in order to acquire meaningful information of particular features on earth. The instruments used for this purpose may employ any of a variety of physical energy distributions. Sonars, for example, work on the principle of acoustic wave distribution, optical instruments such as the photographic camera and multi-spectral scanner use electromagnetic energy distribution. Remote sensing covers all techniques related to the analysis and use of data from satellites, such as Metaset, National Oceanic and Atmospheric Administration (NOAA)-Advanced Very High Resolution Radiometer (AVHRR), Landsat, (French: Satellite Pour observation de la Terre) SPOT, Earth Resources Satellite (ERS) -
Satellite Access Request (SAR) and from aerial photographs. The main objective of remote sensing is to map and monitor the earth's resources.

Geographical Information System (GIS) :The ***Geographical Information System*** (GIS) is computerized software that stores, retrieves, manipulates, analyses and displays geographically referenced data sets, which can be used for different applications. Here the word '***Geographic***' deals with spatial objects or features which can be referenced or related to a specific location on the earth surface. The object may be physical/natural or may be cultural / man made. Likewise the word '***Information***' deals with the large quantity of data about a particular object on the earth surface. The data include a set of qualitative and quantitative aspects which the real world objects acquire. The term ***'System'*** is used to represent systems approach where the environment consists of a large number of objects / features on the earth's surface and their complex characteristics are broken down into their component parts for easy understanding and handling. GIS data are represented and stored in the form of vector or raster. In a vector data structure, geospatial data are represented as points, lines or polygons. For examples, fire rings or campsites would be stored as points, trails or streams as lines and forests or recreation opportunity classes as polygons. In contrast, a raster data structure represents geospatial data in a regular grid of cells and the attribute applies to the entire cell. Raster data provide continuous coverage of an area. For example, Digital Elevation Model showing slope, aspect and elevation in a grid for an area is a raster data structure. Attribute data can be handled in rational database software comprised of records and fields. GIS, therefore, can offer the unique ability to link such spatial and attribute data and tries to manipulate and analyse the relationships among them. In implementing georeferenced data using GIS, three important stages are involved. These are data preparation and entry, analysis and presentation. GIS can store the voluminous amount of spatial (maps) and non-spatial (tabular data) information. It has potential uses in land resource management and inventory. The collection of remotely sensed data facilitates the synoptic analyses of Earth. Today, the data obtained is usually stored and manipulated using computers. The most common software used in remote sensing is *Earth Resource Data Analysis System (*ERDAS) Imagine, Environmental Systems Research Institute (ESRI), MapInfo, and ER Mapper.

Active and Passive Remote Sensing

Remote sensing uses devices known as sensors that can measure and record the electromagnetic energy. Active sensors such as radar and laser have their own source of energy and can emit a controlled beam of energy to the surface and can measure the amount of reflected energy. These sensors are used to measure the time delay between the emission and return and can determine the location, height, speed and direction of an object under investigation. As active sensors can emit their own controlled signals, they can be operated both day and night, regardless of the energy available from external sources. Passive sensors, on the contrary, can only work using the natural sources of energy. As a result, most passive sensors use the sun as a source of energy and can only work during daytime. However, passive sensors that measure the longer wavelengths related to the earth's temperature does not depend on the external source of illumination and can be operated at any time.

Methods in Remote Sensing

i. Remote sensing image data: Data can be used from different satellites such as Land Remote-Sensing Satellite (LANDSAT) (spatial resolution 30m), LISS III (spatial resolution

23.5m) and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) data (spatial resolution 15m). These images provided suitable cloud-free spatial coverage with relatively high spatial and spectral resolutions.

ii. Geometric correction: Accurate registration of multispectral remote sensing data is essential for analysing land use and land cover conditions of a particular geographic location. The geometric correction of remote sensing data is done for the distortions and degradations caused by the errors due to variation in altitude, velocity of the sensor platform, variations in scan speed and in the sweep of the sensor's field of view, earth curvature and relief displacement. The images are georeferenced using the polyconic projections with Root Mean Square Error (RMS) and LANDSAT-7 ETM+ data are re-projected to polyconic projections.

iii. Ground reference data: In image analysis, ground reference data play important roles to determine information classes, interpret decisions, and assess the accuracies of the results.
Substantial reference data and a thorough knowledge of the geographic area are required at this stage.

iv. Classification scheme: Classification schemes provide frameworks for organizing and categorizing information that can be extracted from image data. A proper classification scheme includes classes that are both important to the study and discernible from the data on hand. Image enhancement, contrast stretching and false colour composites are worked out and the interpretation of images are carried out using the various interpretation keys like the shape, size, pattern, tone, texture, shadows, location, association and resolution.

v. Image Classification Techniques: The overall objective of the image classification procedure is to automatically categorize all pixels in an image into land cover classes or themes. . Classes have to be distinguished in an image and classification needs to have different spectral characteristics. This can be analysed by comparing spectral reflectance curves. Image classification gives results to a certain level of reliability. The principle of image classification is that a pixel is assigned to a class based on its feature vector by comparing it to predefined clusters in the feature space. Doing so for all image pixels result in a classified image.

a. ***Unsupervised Classification*:** The unsupervised classification approach is an automated classification method that creates a thematic raster layer from a remotely sensed image by letting the software identifies statistical patterns in the data without using any ground truth data.

b. ***Supervised Classification*:** Here the image analyst supervises the pixel categorization process by specifying, to the computer algorithm, numerical descriptions of various land cover types present in the image. Training samples that describe the typical spectral pattern of land cover classes are defined. Pixels in the image are compared numerically to the training samples and are labelled to land cover classes that have similar characteristics.

c. *Fuzzy supervised classification approach*: This approach allows for multiple and partial class memberships at the level of individual pixels and accommodate fuzziness in all three stages of a supervised classification of remotely sensed imagery. This approach considers that each pixel might belong to several different classes without definite boundaries

***vi. Accuracy assessment*:** In thematic mapping from remotely sensed data, the term accuracy is used typically to express the degree of 'correctness' of a map or classification. A thematic map derived with a classification may be considered accurate if it provides an unbiased representation of the land cover of the region it portrays. In essence, therefore, classification accuracy is typically taken to mean the degree to which the derived image classification agrees with reality or conforms to the 'truth'. A set of reference pixels representing geographic points on the classified image is required for the accuracy assessment. Randomly selected reference pixels lessen or eliminate the possibility of bias. A random stratified sampling method was used to prepare the ground reference data. This sampling method allocates the sample size for each land use based on its spatial extent.

vii. Land Use Classification System: Different classes of Land use- covers like Settlements,
Forests, Agriculture, waste land etc. classified. By comparing the data of two different time interval the rate of increase, decrease and percent change can be estimated for each land use class. The map and data base generated from the technique itself has wide application like land use planning, flood management etc.

viii. Land Use Mapping and Distribution: A supervised maximum likelihood classification may be implemented for the two images and the final classification products provide an overview of the major land use / land cover features of lands for two time intervals and classifications like Water Body, Forest Reserve, Built up Area Vegetation and Farmland etc. can be done.

Advantages over conventional methods

The remote sensing techniques provide the synoptic view of large areas which is not possible by conventional ground survey methods. Satellite data are received periodically and the periodicity of data acquisition varies from one satellite to another. This capability of satellites helps in updating the information and monitoring the changes at short intervals. Remote sensing has a unique capability of recording data in visible as well as invisible (ultra-violet, infrared, thermal infrared, microwave etc.) parts of the electromagnetic spectrum. Therefore, certain phenomena which cannot be seen by the human eye can be observed through remote sensing techniques. Remote sensing concerns with electromagnetic energy from sun and its interaction with Earths features. But, quite often, similar spectral reflectance by different earth features and dissimilar spectral reflectance by similar earth features create spectral confusion leading to misclassification. These problems can be overcome by systematic ground truth information. It is, therefore, evident that although the conventional methods of data collection are essential and should be continued in the efficiency of data collection both in terms of cost and time will decrease if these are supplemented and/or complemented by remote sensing techniques. Nowadays one can easily survey, and do mapping of an area of interest such as village location map, plantation area, treatment area etc. within the shortest possible time. Administrative maps, soil maps, management maps etc. can also be prepared, stored and retrieved in digital form easily. Territorial units such as range, block, compartment, etc. can be easily mapped on the basis of visible/identifiable physical features such as streams, bridges, roads etc. by digitization.

Disadvantage of geospatial technology

Despite its invaluable applications in different areas of interest, the use of remote sensing technology in monitoring and managing habitats and ecosystems is likely to face some practical drawbacks. These include practical limitations, which are usually inherent in the technology itself, such as the limited ability of light to penetrate through water and atmosphere. The second limitation of remote sensing is the difficulties in assessing suitability in certain sensors. For example, remote sensing tends to provide geomorphological rather than ecological information on reef structures. This is because of the limited spectral and spatial resolution of the sensors caused by the presence of various external barriers like turbidity and water depth.

1. Data gaps – availability of the right data at the right time.
2. Cloud cover – particularly for biodiversity and land cover applications in the tropics.
3. Lack of systematic archiving of remote sensing images.
4. Regional disparities in data access and in the skills needed to interpret imagery.
5. Data costs, which are still significant, particularly for high-resolution imagery.
6. Costs of ground-trothing – remote sensing is seldom sufficient in its own right, but needs to be combined with selective ground-trothing.
7. Sovereignty concerns.
8. Most applications are still experimental, and costs of scaling up are significant.
9. Current lack of an international institution to coordinate among space agencies.
10. It requires skilled/committed manpower/labour.

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 and Planning

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, physicochemical 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 scales (NBSS&LUP) and 1:50,000 scale under the IMSD project of ISRO.

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 lithology’s,
iii) geo-botanical 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.

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 local 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.

Application in Agriculture

There has been increased emphasis on the potential utility of using remote sensing platforms to obtain real-time assessments of the agricultural landscape. Precision agriculture is a production system that promotes variable management practices within a field, according to site conditions. This system is based on new tools and sources of information provided by modern technologies. These include the global positioning system (GPS), geographic information systems (GIS), yield monitoring devices, soil, plant and pest sensors, remote sensing, and variable-rate technologies for applicators of inputs (Seelan et al., 2003). Satellite remote sensing, in conjunction with geographic information systems (GIS), has been widely applied and been recognized as a powerful and effective tool in detecting land use and land cover change. It provides cost-effective multi-spectral and multi-temporal data, and turns them into information valuable for understanding and monitoring land development patterns. GIS technology provides a flexible environment for storing, analysing, and displaying digital data necessary for change detection and database development. Satellite imagery has been used to monitor discrete land cover types by spectral classification or to estimate biophysical characteristics of land surfaces via linear relationships with spectral reflectance's or indices (Steininger, 1996). In Andaman Island it was used to identify and map rice growing areas and assessment of soil constraints.

Forest Management and wildlife habitat analysis

Forest is a vital organ of our ecosystem; they impact human lives in several ways, despite of having huge importance the world forest has been declining at an alarming rate. Being a renewable resource, forest cover can be regenerated through sustainable management. Hence, using remote sensing data and GIS techniques, a forest manager can generate information regarding forest cover; types of forest present within an area of interest, human encroachment extent into forest land / protected areas, encroachment of desert like conditions and so on. This information is crucial for the development of forest management plans and in the process of decision making to ensure that effective policies should put in place to control and govern the manner in which forest resources can be utilized. The suitability and status of sites / forest area for a particular species of wildlife can also be assessed using remote sensing data using multi criteria analysis.

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 centres started as trading towns cantered 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 centres. 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 centres 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-today 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.

Conclusions

In our country, explosive growth of population and their diverse needs has steadily increased the need for optimum utilization of our land resources. Now the country requires sufficient quantities of food grains to feed its huge population, various raw materials for a sound industrial base and creation of adequate job opportunities for the large majority of unemployed people. The systematically planned and proper way utilization of our land resources can play a major role in solving these problems. Sustainable land management technologies require reliable and repetitive information on the current status and utilization potential of natural resources. Satellite remote sensing data in conjunction with collateral data proved to be very effective in meeting these requirements. Geographic Information system (GIS) served as a very effective tool in the storage, manipulation, analysis, integration and retrieval of information. The synergistic use of these front line technologies helps to evolve a strategy that could be useful in planning for sustainable management of land resources. Data base on Soil types and erosion features, obtained from traditional sources, can be linked to each land cover mapped unit as attributes into a GIS system. This resulted in a comprehensive database, which provides useful information for agriculture, forestry and urban development planning, for environment protection, and for many other applications.

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