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The Lungs of the Earth

Remote Sensing Monitors Forest Resources in the Developing World

Forests often are referred to as the "lungs of the Earth" due to their significant role in keeping our environment clean. Due to rapid industrialization and increases in population pressure on forest-based resources, the forest cover is shrinking at a rapid pace. Therefore, there's an urgent need to periodically monitor these resources and develop appropriate location-specific conservation plans.

All of this wouldn't be possible without a detailed resource inventory. But in most underdeveloped and developing countries, where large amounts of forest resources are available, there's a dearth of detailed forest-inventory data and quality location-specific maps.

Considering such needs, a variety of organizations approached RMSI for satellite-based mapping and analysis in parts of Tripura and Manipur in the northeastern part of India and parts of central Mozambique for resource assessment and sustainable livelihood development.

Rapid Inventory

Conventional field-based techniques of forest-resource inventory typically are based on systematic random sampling, where an area is divided into square grids of equal size. A survey team visits systematically selected random grids in the field and collects sample-based information about the dominant type, species composition, number of trees, height, diameter at breast height (DBH), etc. After the data from sample plots are collected, the information is represented on a respective grid.

The problem with such generic quantification is that it's difficult to monitor, and all grids can't be surveyed due to inaccessibility and geopolitical situations. Also, there's no mechanism to validate field-based information collected or compiled during the inventory process.

In research work executed by RMSI, a rapid resource-inventory technique was developed in which satellite remote-sensing images were used and supported by sample field surveys.

Planning

The most important aspect of resource-inventory planning is having a clear understanding of the information required and the type of satellite data that can provide the most desirable results. Presently, multiple satellite-image sensors are available in the public domain, and they can acquire images of Earth ranging from very coarse to very high spatial resolutions.

Keeping in mind the project's objective, IRS LISS-III and panchromatic satellite images were used in Tripura and Manipur studies. However, Landsat-7 and IRS LISS-IV Mx images were used for mapping in Mozambique. An accompanying table (upper right) lists the details of the imagery used.

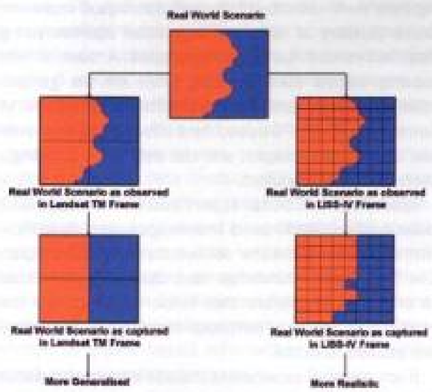

Figure 1a. A comparative account describes the interpretation of medium- and high-resolution images.

Figure 1b. Differences in land-use and land-cover class discrimination are shown for a one-hectare sample area.

Satellite Sensor Details

Project	Satellite sensor	Swath (km)	Total number of bands	Repetition (No. of days)	Spatial resolution (m)	Band region /name
Tripura & Manipur, India	IRS 1C (LISS-III)	141 x 141	4 MSS	24	23.5	Green Red Near Infrared SWIR
	IRS 1C (Pan)	70 x 70	1 Pan	5	5.8	Pan
Mozambique	Landsat-7	185 x 185	7 MSS	16	30	Blue Green Red Near Infrared Thermal Mid Infrared
	IRS P6 (LISS-IV)	23 x 23	3 MSS	5	5.8	Green Red Near Infrared

Using a combination of medium- and high-resolution images achieves better classifications of forest types and detailed mapping of small patches. The basic difference between medium- and high-resolution imagery is the ability to store micro variations. In high-resolution satellite images, generalization is less in comparison to medium- or coarse-resolution images (see Figures 1a and 1b).

After satellite image selection is finalized and preliminary classification is completed, it's important to plan the field work so training sets based on the representative signatures on satellite images can be identified and validated in the field.

Pre-Processing Images

Pre-processing of satellite images is one of the most important aspects of data creation. Because the raw satellite images don't relate to actual ground locations, they're georeferenced to real-world coordinates.

Georeferencing requires details of ground coordinates and their location on satellite images. Information about the geographical coordinates for georeferencing satellite images can be collected from georeferenced topographical maps.

In both study areas, the available topographical maps were relatively old and on a smaller scale. For easily identifiable control points visible on ground and satellite images, GPS-based geographical coordinates were recorded.

The representative ground locations were identified and located on satellite images, and respective geographical coordinates were assigned to each representative location. This technique can be effectively used in areas where there's a lack of existing information, as particularly seen in the study conducted in Mozambique.

In areas of heterogeneity with respect to forest type, it's better to go with high-resolution images. In the study conducted in Tripura and Manipur, high-resolution single-band panchromatic satellite images (with a spatial resolution of 5.8 meters) were merged with IRS LISS-III images (with a spatial resolution of 23.5 meters).

This technique provides a single, merged multispectral image, where the spectral properties come from multispectral medium-resolution images and the visual details from panchromatic images.

Data Collection

The data collection activity should be planned to minimize cost, so well-distributed heterogeneous patches are visited in the field. For satellite-based classification and quantification of stock and biomass, training sites should be identified on the basis of different forest types, and density maps should be prepared using satellite data.

The basic principal behind such stratification is to identify homogenous stratum within heterogeneous patches. Each stratum represents a unique set of forest type.

In addition, proportional areas under each stratum can be assessed to estimate the number of sample plots based on probability proportional to area. The stratification can be further refined using cost and time factors, allowable error, and sampling intensity to estimate the number of sample plots for each forest type.

These sites act as a base for "training" software with information collected from the field during classification and analysis. The sample-based field information about forest type, species composition, number of trees, height and DBH is collected for the training sites through ground measurement. For each training site, 30- by 30-meter sample plots (approximately 0.1 hectare) are identified for each sample location in the field.

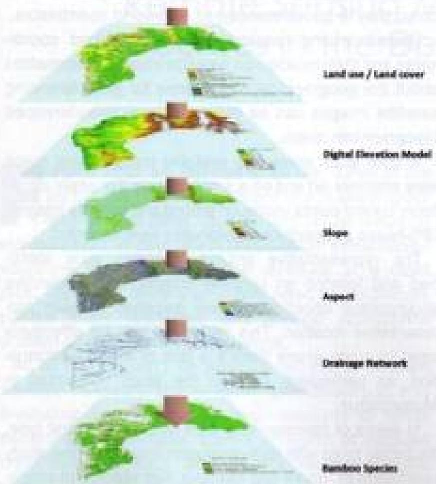

Figure 2. An image describes an overlay analysis for knowledge-based classification.

Data Interpretation

After images are pre-processed, they're interpreted, and pixels are grouped into different classes based on variations in spectral properties and/or using different vegetation indices. Previously, satellite images were interpreted through visual-interpretation techniques in which visually perceptible differences in pixel clusters are grouped manually over hardcopy satellite images or through onscreen digitization.

With the advent of digital image-processing techniques, the classification process has become much faster and now creates better-quality output, as minor differences in spectral signatures that aren't perceptible to human eyes can be detected by computers.

This study's classification methods include a combination of supervised, unsupervised and knowledge-based techniques. In supervised classification techniques, human inputs are provided to the software as training sets. Numerical information in all spectral bands becomes a basis to "train" computers to recognize spectrally similar areas for each class. In unsupervised classification, software groups the pixels into classes as provided by users based on the spectral properties through clustering algorithms.

After completing the preliminary classification, training sets were identified from well-distributed representative clusters of different vegetation classes using stratified random-sampling techniques. A team of field experts visited these training sites on the ground, collecting GPS coordinates and information related to forest type. The GPS-based field information was overlaid on satellite images, and the data are accordingly corrected when required.

Apart from traditional supervised and unsupervised classification, RMSI used knowledge-based classification to further refine the derived classification output. The field-based knowledge and observations related to physical parameters that influence or control the spatial distribution of particular forest types or species are studied in detail.

Such physical parameters include information about the collective response of elevation, slope, aspect, vicinity to water bodies, association with other forest types, etc., in controlling the spatial distribution of different species. The aforementioned parameters were modeled in a GIS through overlay analysis (see Figure 2) for classification of bamboo species in the study conducted in Tripura and Manipur.

Analysis

Forest type and stock are the most important inputs for assessing carbon sequestration. In the study, mainly in Mozambique, satellite-derived forest-type maps and sample field-based information are correlated for biomass estimation/stock assessment (see Figure 3).

The field-based stock assessment for the sample sites was overlaid on forest-type and density maps and extrapolated to the entire forest to derive a forest-stock map.

One study objective was to assess carbon balance in the region, so carbon-sequestration factors for different forest types and land-use classes were incorporated from secondary sources in a GIS to generate a carbon-sequestration map.

Because the main source of livelihood in the region is based on forest resources and, to some extent, agriculture, there's no major industry in the region. The main source of carbon emission was attributed to natural and manmade forest fires.

To assess the level of carbon emission due to forest fire, the MODIS satellite-based Active Fire Product was used to map the extents of burnt areas. A map showing the extent of forest fires was overlaid on the forest-stock map, and the total carbon amount emitted was calculated via the method coined by Carlo Trozzi and Rita Vaccaro (2002): $C = M * B$ (C is carbon emitted; M is biomass; B is the carbon quantity in the biomass, which can be set equal to 0.45).

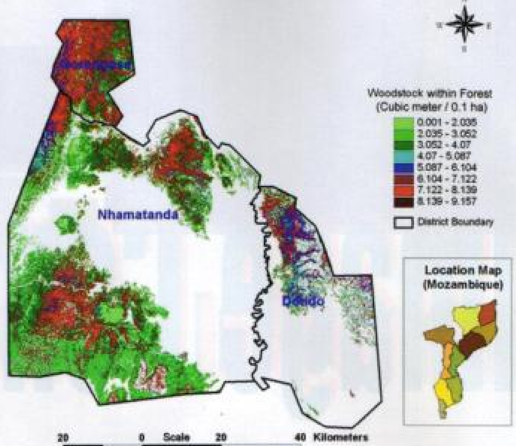

Figure 3. A wood-stock map was made of the sample area.

Data Verification

For any GIS and remote-sensing study, it's important to have stringent data quality checks at every stage of data collection, creation and analysis. It's estimated that roughly 5 percent of the total effort should be spent on quality checks. Considering the data gaps in the study area, an additional effort was put into such checks.

Image georeferencing was one of the largest challenges during the data creation stage. Due to a lack of large-scale topographical maps in the study areas, Landsat mosaic images and ground-based GPS points were used as reference data for georeferencing satellite images. If imaging georeferences aren't perfect, an image point can be displaced from its true ground point, leading to misinterpretation and the wrong correlation of ground-based information with respective signatures on satellite images.

After a final classification map is produced, an accuracy assessment should be made to measure a map's reliability. Generally, several GPS-based random points or areas are selected on a map, and their class assignments are checked. The number of points checked is determined by analysts, but more points yield a more robust conclusion.

Ideally, each point's real-world location is visited to determine its composition. Problems arise when there's not enough time and/or locations are inaccessible. This is where prior field planning would help determine training sites by identifying the representative forest types/patches in accessible areas for inaccessible sites.

To effectively use available remote-sensing and GIS tools, it's always better to analyze the ultimate objectives and suitable options that provide desired results. Detailed planning about the effective use of input data as well as forming robust methodologies and effective data quality checks go a long way in making such projects successful, and they'll help create logical outputs for planners.

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