

Remote Sensing Satellite Based Forest Cover Mapping: Some Recent Developments

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ABSTRACT

Cartographic depiction of status of a natural resource plays an important role in its management. Forests being natural resources are no exception. Maps showing distribution of forest cover are of immense value not only for management of forests and wildlife but also for environmental conservation. Forest Survey of India (FSI), an organisation under Ministry of Environment & Forests, Government of India, assesses and monitors the state of the forest cover of the country using satellite data on a two year cycle and prepares forest cover maps. Till recently, FSI was preparing forest cover maps of the entire country on 1:250,000 scale showing areas having forest cover down to 25ha in extent but in its latest assessment (2001 assessment) it has generated maps on 1:50,000 scale showing areas with forest cover down to 1ha in extent. With improvement in cartographic resolution, these maps are now useful for micro-level planning also. Forest Cover maps show forests in three density classes- Dense- having forests with a canopy density of more than 40%; Open- forests with canopy density between 40-70% and Scrub- forest lands with less than 10% canopy density. In addition, FSI also prepares thematic maps based on aerial photographs. These maps depict not only forest cover but also land use classes with information on major forest species composition. FSI has also prepared forest fire maps of the entire country for the year 1995 and for the state of Uttaranchal for the year 1999 using satellite data. In a collaborative programme with the Indian Bureau of Mines, it is also contributing significantly in generation of forest maps overlaid on mineral maps. Such maps are very useful in evaluation of mining leases for clearance under Forest Conservation Act. Forest Survey of India is also developing a methodology for preparation of forest types map of the country using remote sensing and GIS (Geographic Information System).

INTRODUCTION

Forests are not only important source of subsistence, employment, revenue earnings, raw materials to a number of industries but also play vital role in ecological balance, environmental stability, biodiversity conservation, food security and sustainable development of a country. The forest resources, in general, have been under mounting pressure owing to increasing human and livestock population. Excessive withdrawals of produce from the forests are much beyond their carrying capacity and are no more sustainable. This has resulted in the depletion and degradation of country's forests and has become a cause of serious concern for the government and the people. It is essential for the policy makers, planners and forest managers to know where, what and how much remedial measure is needed to restore degraded forest crop and to manage forest resources in a sustainable manner. It is imperative for this purpose to conduct assessment and monitoring of forest cover on a regular basis.

Forest Survey of India, Dehradun (FSI), an organisation under the Ministry of Environment and Forests (Government of India), is mandated to carry out fresh assessment of forest cover in the country every two years. This is done using satellite based remote sensing data. Remote Sensing technology has

provided users the means to create numerous maps quickly and efficiently. The findings of FSI's assessments are published in the State of Forest Report (SFR), a biennial publication. Forest cover maps of the country, the states and Union Territories are also prepared. These maps are also used for carrying out other spatial studies, such as monitoring shifting cultivation, assessment of forest density, mining leases, wildlife habitats, forest fragmentation, forest fire affected areas, etc. In this paper, a brief account of such forest cover mapping by FSI is presented.

HISTORY OF FOREST MAPPING BY FSI

The Forest Survey of India (FSI) is a premier national forest resources survey organization in the country. It was created with effect from June 1, 1981 as a successor to Pre-investment Survey of Forest Resources (PISFR) to furnish data through countrywide comprehensive forest resources survey at regular intervals. Application of satellite-based remote sensing in mapping, monitoring and management of natural resources has been recognized long ago. In India, use of satellite data in mapping forest cover of the country was first demonstrated in 1982 by the National Remote Sensing Agency, Hyderabad (Department of Space). Almost simultaneously, the Forest Survey of India (FSI), an organization under the Ministry of

Environment and Forests, Government of India, also developed the capacity to interpret and classify the satellite data for assessment and mapping of forest cover.

FSI used Landsat (MSS) imagery pertaining to the period 1981-83 for the first assessment of forest cover. The technique used for interpretation of satellite data was visual interpretation and scale of interpretation was 1:1 million. Interpretation was followed by extensive ground truthing. The forests were classified into dense forest (crown cover of more than 40%) and open forests (crown cover between 10-40%). Mangroves were delineated as a separate class. Degraded forests having crown cover of less than 10% were classified as scrub (a non-forest category). As per this assessment forest cover of the country was estimated to be 642,041 sq. km (19.52% of country's geographic area).

Landsat (TM) imageries of 1985-87 were used for the second cycle of forest cover assessment. Interpretation was done visually at 1:250,000 scale. With better spectral and spatial resolution of satellite data, higher scale of interpretation and more extensive ground truthing led to improvement in estimation of forest cover. The results published in the form of SFR 1989 estimated forest cover of the country as 640,134 km² (19.47% of country's geographical area). Same satellite data and scale of interpretation was used for the third and fourth assessments. However, a significant development during this period had been the procurement of the then state of art computer (VAX-11/780) in 1989 for digital interpretation of satellite data. During the fourth assessment, satellite data of some parts of four states namely Bihar, Himachal Pradesh, Madhya Pradesh and Uttar Pradesh were also interpreted digitally.

In the mean time, India launched its remote sensing satellite

(IRS). The fifth assessment (1995) was based on visual interpretation of imageries from IRS-1B (LISS-II) data was used, while subsequent assessments (1997 and 1999) were based on data from IRS-1C (LISS-III). Scale of interpretation remained same (1:250,000 scale) and interpretation technique was largely visual with increasing input of digital interpretation.

Development of efficient digital image processing software (such as, ERDAS Imagine) and availability of reasonably priced powerful workstations and capacity building of its technical manpower, enabled FSI to completely switch over to digital interpretation of satellite data. Consequently, FSI interpreted the satellite data of the entire country through digital image processing at 1:50,000 scale during its latest assessment of forest cover assessment (2001), the eighth in the series. This improvement in the methodology has led to generation of a new baseline data on forest cover as for the first time FSI could map forested areas as small as 1 ha in extent while in the previous assessments this limit was 25 ha. As per SFR 2001, the forest cover of the country has been assessed to be 675,538 sq. km (20.55% of the geographic area of the country).

A summary of important features of satellite data, sensors and their properties used for various assessments carried out so far for monitoring the forest cover of the country is given in table 1.

PRESENT METHODOLOGY OF FOREST COVER MAPPING

The present methodology of forest cover mapping from satellite data using DIP software on 1:50,000 scale involves the following steps:

Acquisition of satellite data: The digital data of IRS-1C and 1D LISS III is acquired from NRSA in CD. The data should be

Table 1: Satellite Data for Forest Cover Assessments from 1987 to 2001

Assessment and Year	Data Period	Sensor	Data Form Resolution	Spatial Resolution	Spectral	Scale of Interpretation
I 1987	1981-83	Landsat - MSS	Hard Copy FCC	80 m	4 Bands	1:1 million
II 1989	1985-87	Landsat - TM	Hard Copy FCC	30 m	7 Bands	1:250,000
III 1991	1987-89	Landsat - TM	Hard Copy FCC	30 m	7 Bands	1:250,000
IV 1993	1989-91	Landsat - TM	Hard Copy FCC	30 m	7 Bands	1:250,000
V 1995	1991-93	IRS-1B LISS II	Hard Copy FCC	36.25 m	4 Bands	1:250,000
VI 1997	1993-95	IRS-1B LISS II	Hard Copy FCC	36.25 m	4 Bands	1:250,000
VII 1999	1996-98	IRS-1C/1D LISS III	Hard Copy FCC	23.5 m	4 Bands	1:250,000
VIII 2001	2000	IRS-1C/1D LISS III	Digital	23.5 m	4 Bands	1:50,000

cloud free with suitable period from October-December. India

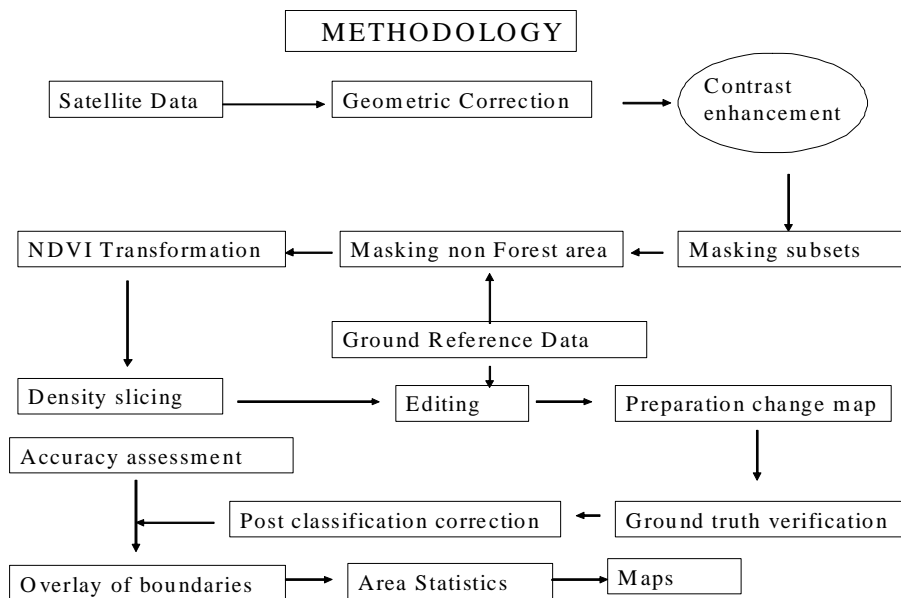


Figure1.- Flow chart of Forest cover mapping using remote sensing

is covered in about 340 scenes, of IRS 1C and 1D. One scene covers an area of about 20000 km², having an overlap of about 10% with adjoining scenes.

Importing of the data into system: The data along with the required information is downloaded.

Geometric Rectification of raw data: The rectification is carried out in each image to image to provide latitude and longitude information into raw satellite scene using raster based geometric corrections. Rectification carried out in geographic projection is re-projected in shape of polygonal projection and the scene is geo-coded with using SOI toposheets.

Mosaicing of rectified scenes: Different scenes, which are already rectified, may have to be merged together to get one combined FCC (False Colour Composite). FCC of sheet is extracted from mosaiced scene in a chosen area of interest. Image is displayed in three bands 3, 2, 1. Masking of non-forest areas is done separately to extract forest areas on the basis of ground knowledge, cover map of previous cycles and on the basis of information available through SOI toposheets in the area of interest.

Classification of forest mapping using NDVI: Interactive method of display is used for assigning threshold values for each class (open, dense and scrub) on the basis of the ground

knowledge to highlight forest/vegetated areas. Density class of forest cover and colour is accordingly allocated. Survey of India toposheets is used for delineating boundaries of each district and classified map of forest cover is generated.

Flow chart of methodology of dynamic forest cover mapping using remote sensing is shown in Figure-1

OTHER SPATIAL STUDIES BASED ON FOREST COVER MAPS

Forest Survey of India has been involved in several forest resource mapping studies in the past. Some of the resources mapping studies are described below:

Mining in Forest Areas: - As a part of special study in 1998, FSI, look up the exercise of estimating the effect of mining activities in the three mineral rich states of India viz- Jharkhand, Orissa and Chattisgarh. The study aimed at formulating long-term strategy on forest conservation *vis-à-vis* mining activities. One of the objectives was to assess the extent of forest cover in areas leased for mining. FSI in collaboration with the Indian Bureau of Mines (IBM), Nagpur, undertook this study, focusing on five important minerals (Bauxite, Copper, Iron, Chromite and Manganese). The Indian Bureau of Mines prepared maps of mineral resources delineating the boundaries of leased areas of these minerals on SOI toposheets on 1:50,000 scale. These maps were used as base maps by FSI. The boundaries

of the leased areas were digitized and overlaid on classified forest cover maps. The forest cover maps were prepared using IRS-I B (LISS-II) and IRS I C (LISS-III) satellite data of 1996-1998. A total of 353 mining leases of these minerals covered an area of 90, 695 ha in 1994. Using GIS study it has been found that 53, 217 ha of the leased area is under forest cover of which 75% is dense forest and 29% is open forest. Jharkhand, Orissa and Chattisgarh accounted for 19%, 36% and 45% respectively.

Shifting Cultivation in North Eastern Region: - As a part of special study in 1998 FSI undertook a study to assess the extent of actual area under shifting cultivation in the North eastern region. The assessment was done on 1:250,000 scale relating to the period between 1987-1997, the region is covered by 33 SOI toposheets. The Satellite data on 2 years interval corresponding to the periods 1987-89, 1989-91, 1991-93, 1993-95, 1995-97 have been used. The sensors were Landsat-(**TM**) and IRS-IB (**LISS II**). Visual interpretation was followed. The interpreted details were transferred on the base maps, which were prepared using SOI toposheets. Thus, the forest cover maps were prepared separately for the above five data periods. In addition to forest cover these maps also show permanent non-forest areas including cultivation, habitation, roads etc. The transient non-forest areas are the areas of shifting cultivation. By superimposing the cover maps of five different periods, area under shifting cultivation has been assessed by subtracting the permanent non-forest area from the total non-

forest area. Cumulative area affected by shifting cultivation during the stated period was found to be 1.73 million ha.

Spatial Distribution of forest species composition and growing stock: FSI developed a methodology in 1995 for assessment of growing stock of forest in the country by integrating its three main activities which are forest cover mapping using satellite data, thematic (Forest land use) mapping using aerial photographs and field inventory. The methodology involved interpretation of satellite data (pertaining to the period 1991-93) and aerial photographs pertaining to different years and processing of forest inventory data collected from over 170,000 grids of $21\frac{1}{2}' \times 21\frac{1}{2}'$ grids spread all over the country. The methodology was recently used by Forest Survey of India to assess changes in growing stock, biomass and carbon stock for the forests of India between 1984 and 1994 under NATCOM project. The methodology can be further used in generating biomass and carbon maps of specific areas.

CONCLUSION

The aim of Forest Survey of India in monitoring forest resources is to know the dynamic changes of forest resources in terms of forest quantity and quality over a period of time. Remote Sensing Based Forest Cover Mapping can enrich the content of traditional forest resource monitoring and has a bright future in the areas where sufficient remote sensing data can be obtained and little shadow exists.