

## EXECUTIVE SUMMARY

### i Background: Forest and Tree Cover Monitoring in India

**India places a great commitment on protecting, regenerating and growing its forests.** India's Forest Conservation Act, 1980 is one of the most progressive forest conservation legislations in the world, which puts severe restrictions on the diversion of forest land for non-forestry purposes. The National Forest Policy, 1988 lays out clear directions and guidelines for forest conservation and afforestation. The pressure on India's forests continues to be very high, with more than 200 million people being dependent on forests for livelihood. The rapid growth of the Indian economy puts additional demands on forests for infrastructure and industrial development. There is an ever increasing demand for diverting forest lands for construction activities like dams, roads, power stations, townships etc.

**In this context, scientific monitoring of the country's forest and tree cover is an important national priority.** India has been undertaking a regular systematic programme of monitoring its forest cover since 1987, using remote sensing techniques. Remote sensing technology has provided an appropriate and cost effective method of monitoring our forests. While providing a synoptic view of a large area, it also captures bio-physical properties of the land features through the reflected electro-magnetic radiations, often called signature in the remote sensing parlance.

**The Forest Survey of India (FSI), an organisation under the Ministry of Environment and Forests, is responsible for monitoring the forest and tree cover of India.** FSI has been regularly assessing the forest cover of the country every two years since 1987. This is the eleventh State of Forest Report produced by the FSI. As there has been rapid advancement in the field of remote sensing in the last two decades, FSI has kept pace with these advancements in making its assessments. Accordingly, suitable improvements in the methodology of forest cover mapping have been made by the FSI. Assessment of tree cover, which includes smaller patches of plantations and scattered trees, also started following a sampling based approach since 2001.

#### Box A Biennial cycle of forest & tree cover assessment: the rationale

India is among very few countries in the world to have an operational system for wall-to-wall mapping of forest cover on a cycle of two years. The work involves interpretation of over 300 satellite images, each covering about 20,000 km<sup>2</sup> area. Besides a series of steps of digital interpretation, the mapping includes ground truthing on a large number of points spread across the country. Tree cover assessment is a sampling based exercise using data of about 10,000 sample plots. The enormity of the process makes the period of two years just adequate for the assessment.

The two-year cycle of forest cover at the national level is considered sufficient for the purpose of policy and planning as the changes in periods shorter than this are unlikely to be significant.

### ii Key Results

The following are some key results of India SFR 2009 (the results are based on the interpretation of satellite data of the period Oct 2006 - Mar 2007):

- Forest & tree cover of the country as per this assessment is 78.37 million ha in 2007, which is 23.84% of the geographical area and includes 2.82% tree cover. This becomes 25.25%, if the areas above tree line i.e. 4,000m are excluded from the total geographical area.

- The net increase in the forest & tree cover between current and previous assessments (2 year data interval) is 0.18 million ha (0.23%).
- The decadal increase, i.e., the increase in the forest cover between 1997 and 2007 is 3.13 million ha (4.75%).
- The growing stock of India's forests and trees outside forests is estimated as 6,098 million m<sup>3</sup> in 2007.
- The increase in forest cover is particularly significant in hill and tribal districts, where the forest cover has increased by 66,300 ha and 69,000 ha respectively compared with the previous assessment. Mangrove cover in India has increased by 5,800 ha in the same period.
- The seven north eastern States of India have nearly one fourth of the country's forest cover. The region has gained 59,800 ha of forest cover as compared to the previous assessment of 2005.

## iii Forest Cover in Different Density Classes

The forest cover assessed is classified into three canopy density classes:

- Very Dense Forest (VDF) with canopy density more than 70%,
- Moderately Dense Forest (MDF) with canopy density between 40-70%, and,
- Open Forest (OF) with canopy density between 10-40%.

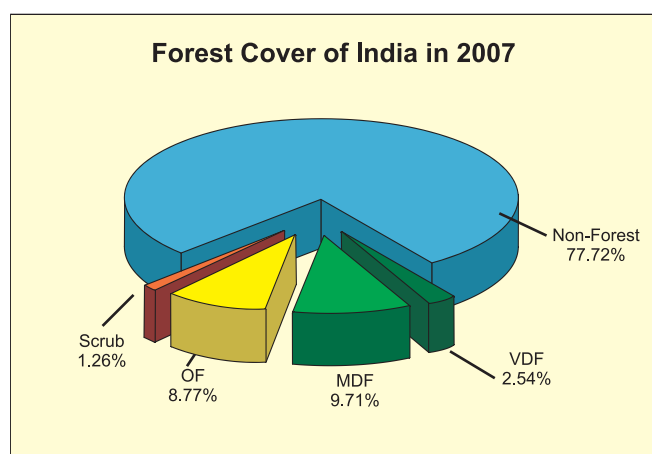
Scrub, which is a degraded forest land with canopy density less than 10%, is not considered a part of forest cover.

The area under each of these density classes is shown in Table 1.

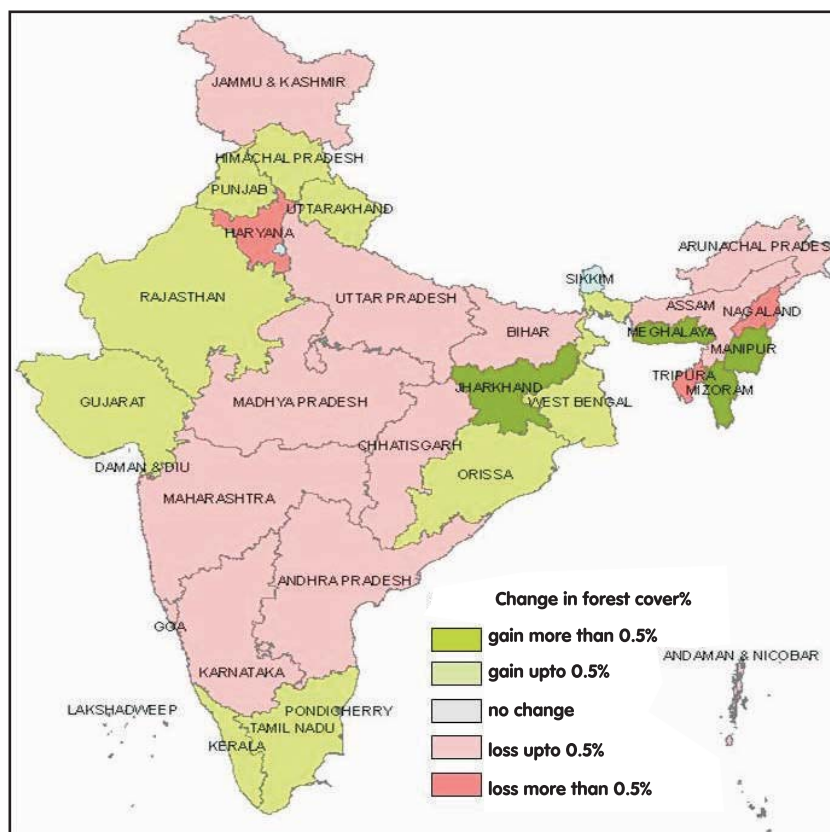
**Table 1: Forest & Tree Cover of India in 2007**

Class	Area (million ha)	% of Geographical Area (G.A.)
<b>Forest Cover</b>		
VDF	8.35	2.54
MDF	31.90	9.71
OF	28.84	8.77
<b>Total Forest Cover</b>	<b>69.09</b>	<b>21.02</b>
<b>Tree Cover*</b>	<b>9.28</b>	<b>2.82</b>
<b>Total Forest &amp; Tree Cover</b>	<b>78.37</b>	<b>23.84</b>
<b>Non-forest</b>		
Scrub	4.15	1.26
Non-forest	255.49	77.72
<b>Total G.A.</b>	<b>328.73</b>	<b>100.00</b>

\* Tree cover is defined as tree patches less than 1 ha with canopy density >10%.



It is noteworthy that there are significant inter-state variations in the increment to the forest cover. While some States have substantially gained forest cover, other States have lost forest cover. These variations are shown in the map given ahead.



Gain and loss of forest cover in States and UTs between 2005 and 2007

#### iv Decadal Change in Forest Cover of the Country

Forest cover of India has shown an increasing trend in the last decade despite the ever increasing pressure on forests due to population growth. The increase in the forest cover of the country is reflected in the time series of forest cover assessments done by FSI on a biennial basis since 1987. As seen in the Table 2, the forest cover of India has increased from 65.96 million ha in 1997 assessment (satellite data pertaining to 1994) to 69.09 million ha in the current assessment (satellite data pertaining to 2006-07) i.e. an increase of 3.13 million ha (4.75%). It is worth noting here that because of significant changes in the resolution and quality of satellite data, methodology of interpretation, scale of mapping and classification scheme, the decadal data may not be strictly comparable. An attempt has been made to reduce (normalize) the effects of methodology and technology changes, so that an estimate of the real change in the forest cover can be elicited, although such an exercise is bound to have its own limitations and the results can be only taken as best approximations.

The technological advancement and methodological refinements over the years as mentioned above have resulted in three significant changes viz. change of scale, inclusion of smaller patches of forest cover up to 1 ha and switching over from raster to vector approach. However, by suitable mathematical treatment using a logical basis, an effort has been made to make the assessment results of different years comparable by factoring in these changes.

**Table 2. Decadal change in forest cover**

Year of Assessment	1997	2007	Change*
Forest cover (million ha)	65.96*	69.09	3.13
Satellite data period	1994	2006	
Satellite data (sensor)	IRS 1B, LISS II	IRS P6, LISS III	
Resolution	36.25 m	23.5 m	
Scale of mapping	1:250,000	1:50,000	
Minimum mappable area	25 ha	1 ha	
Mode of interpretation	visual	digital	

\*The forest cover of 65.96 million ha has been obtained by applying the correction factors to account for the methodological changes.

## v New Features in India SFR 2009

The India State of Forest Report 2009 has four significant new features, which are briefly described below:

### v (a) Refinement in the Methodology for Forest Cover Mapping

FSI has switched over to a vector approach from a raster approach while interpreting the satellite imagery in the current assessment of forest cover. Under this methodology, the focus of interpretation is to capture *changes* in the forest cover by comparing the previous forest cover map with the current satellite data. This approach provides more objectivity in the interpretation as every change is incorporated after evaluation. The focus of interpretation in the new methodology shifts to every polygon of change. The new method also facilitates generation of forest cover map in vector form which is quite helpful for analysis in a GIS framework. The forest cover maps in vector form also provide improved cartographic output.

### v (b) Forest Cover in Different Altitude Zones

FSI has carried out classification of forest cover of the country as per the altitudinal zone using SRTM DEM\*. The data was analysed in GIS format for all the States and UTs to determine the forest cover in different altitudinal zones. The zones for analysis have been taken as 0-500m, 500-1000m, 1000-2000m, 2000-3000m and above 3000 meters. The DEM used in the analysis has a resolution of 90m, which is appropriate for national and sub national level information of this kind. It is found that about 55.51 million ha forest cover lies below 1000m, 11.67 million ha between 1000 to 3000 m and only 1.91 million ha above 3000 meter altitude (see Box D).

\* Shuttle Radar Topography Mission Digital Elevation Model.

### v (c) Distribution of Forest Cover in Forest Types

The area of forests by forest types is useful information which provides a basis for characterizing forests in terms of floristic composition and ecological value. Recently, FSI has done mapping of forests by forest types of India, according to Champion & Seth classification (1968) on 1:50,000 scale. There are 16 type groups further divided into 200 types. In the first ever such attempt at the national level, an extensive study was carried out in GIS framework using relevant layers like soil, rainfall, temperature along with the remote sensing data, details from the working plans, thematic maps of FSI, inventory information etc.

In the India SFR 2009, this information is being presented up to 16 type groups. Broadly, about 12% of the country's forests fall in the Tropical Evergreen category, 34% in the Tropical Moist Deciduous, 30% in the Tropical Dry Deciduous, 5% Tropical Thorn, 6% Subtropical Pine and about 11% in Himalayan Temperate category.

#### v (d) State-wise Growing Stock

India SFR 2009 provides estimates of Statewise growing stock. The methodology of National Forest Inventory (NFI) is designed to provide estimates of growing stock at national level. In the national level inventory design, the distribution of sample plots is not adequate to generate State level estimates directly. However, considering the requirement of State level estimates of growing stock, a special statistical technique has been applied for the first time, for generating the State level estimates.

#### vi National Forest Inventory

Forest inventory is primarily aimed at estimating the growing stock of the woody volume of forests. It is one of the important indicators of forest health and productivity. In the recent past, it has gained further importance due to its role in estimation of forest biomass and carbon. FSI has been conducting the forest inventory in the country using a statistically robust approach since 1965.

The national level inventory of forests and trees outside forests (TOF) was started by FSI with modified sampling design in 2002. According to the present assessment, the volume of growing stock in India's forest and TOF is 6,098 million m<sup>3</sup>. The growing stock (volume) of woody biomass based on about 50,000 sample plots is presented in the following table:

**Table 3: Growing stock of forests & trees outside forests of India in 2007**

Category	Growing Stock (million m <sup>3</sup> )
Forests	4,499
TOF	1,599
<b>Total</b>	<b>6,098</b>

#### vii Area above Tree Line

Beyond 4000 meters altitude, the cold climatic conditions are not favourable for growth of trees. For all practical purposes, the area above this altitude, which is also referred to as 'tree line', is not suitable for increasing forest cover through afforestation activities. There is sizable area in the Himalayan region of the country in the States of Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Sikkim and Uttarakhand which is above 4000m. If we remove this area above tree line i.e 183,135 km<sup>2</sup> from the geographical area (GA) of the country, then forest cover of the country as per the current assessment becomes 22.26% of the geographical area and if the tree cover of the country is also taken into consideration, the forest & tree cover of the country becomes 25.25% of the geographical area.



### Box B

### India's Forest and Tree Cover

Contribution as a Carbon Sink

Over the last two decades, progressive national forestry legislations and policies in India aimed at conservation and sustainable management of forests have reversed deforestation and have transformed India's forests into a significant net sink of CO<sub>2</sub>.

Carbon stocks stored in India's forest & tree cover (In million tonnes)	1995	2005	Annual increment of Carbon Stock
	6,245	6,622	38 (equivalent to 138 million tonnes of CO <sub>2</sub> )

The CO<sub>2</sub> removal by India's forest and tree cover is enough to neutralise 11.25% of India's total GHG emissions (CO<sub>2</sub> equivalent) at 1994 levels, the most recent year for which comparable data is available for developing countries based on their respective National Communications (NATCOMs) to the United Nations Framework Convention on Climate Change (UNFCCC). This is equivalent to offsetting 100% emissions from all energy in residential and transport sectors; or 40% of total emissions from the agriculture sector. Clearly, India's forest and tree cover is serving as a major mode of carbon mitigation for India and the world.

Source : India's Forest and Tree Cover: Contribution as a Carbon Sink, MoEF, 2009

## NEW FEATURES

### Box C Forest cover mapping based on a new methodology

- focuses on each polygon
- subjectivity is minimized
- easier to prepare change map
- vector maps make the layer usable in GIS
- cartographic presentation of the map is better

### Box E Forest cover in different forest types

- characterizes forests in terms of floristic composition and ecological value
- forest cover distribution given up to type groups based on Champion & Seth Classification (1968)
- the exercise is based on forest type mapping done by FSI at the national level on 1: 50,000 scale
- nearly one third of India's forest cover falls in the Tropical Moist Deciduous type group, followed by Tropical Dry Deciduous (30.16%)
- Tropical Wet Evergreen type group occupies 8.75% of the country's forest cover

### Box D Forest cover in different altitude zones

- a useful information for policy and planning
- broadly helps in monitoring national forest policy norm for the hills

Altitude Zones (m)	Area (million ha)				% of GA in diff. zones
	VDF	MDF	OF	Total	
0-500	2.96	15.67	17.21	35.84	15.62
500-1000	2.15	9.71	7.81	19.67	33.58
1000-2000	1.45	3.71	2.46	7.62	72.19
2000-3000	1.42	1.93	0.70	4.05	66.04
above 3000	0.37	0.88	0.66	1.91	7.98
<b>Total</b>	<b>8.35</b>	<b>31.90</b>	<b>28.84</b>	<b>69.09</b>	<b>21.02</b>

### Box F State wise growing stock

- important parameter for productivity and health of forests
- appropriate statistical methods have been used to generate state level estimates
- improved precision because of higher sampling size
- useful in generating State level estimates of carbon stock