Chapter 1

INTRODUCTION

1.1 Biennial Monitoring of Forest Cover of the Country

The pressure on India's forests is very high because of high population. The rapid growth in the economy of the country in the last one decade or so has put additional demands on forests for infrastructure development. There is an ever increasing demand for diverting forest lands for the construction activities like dams, roads, power stations, townships etc. In this scenario of competing land uses and with the growing realization of the impacts of forests on climate change, the importance of monitoring of forest cover in the country is being appreciated more than ever.

The National Forest Policy of India, since 1952 has set a goal of bringing one-third area of the country under forest cover. The policy goal gives direction to the efforts of conservation, afforestation and tree planting outside the traditional forest areas. Realizing the need for a closer and scientific monitoring of forest cover, India started the regular programme for the same with the use of remote sensing technology way back in early 1980s. The Forest Survey of India was mandated for this activity and the first report on forest cover monitoring was published as State of Forest Report (SFR) 1987. Since then, biennial monitoring of the country's forest cover is being done regularly. India is among the few countries in the world to start such a unique system of monitoring of forest cover at national level. Brazil assesses its forest cover in Amazon basin every year. Most of the countries have assessed their forest cover intermittently on a project basis.

1.2 Technological Advancement

Remote sensing technology provides an appropriate and cost effective method of monitoring wide spread natural resource like 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.

Like in other technologies, there has been rapid advancement in the field of remote sensing also. Forest Survey of India has tried to keep pace with the technological advancement by using the latest satellite data available at different points of time and by upgrading the facilities of hardware and software used in the interpretation. Accordingly, suitable improvements in the methodology of forest cover mapping have also been made from time to time. The Table 1.2.1 gives an overview of this transition.

It can be seen that besides improvement in the resolution of the satellite data and the scale of interpretation over the years, the gap between data period and assessment year has reduced with the introduction of digital image processing (DIP). Though the DIP was introduced with SFR 1995, a complete switchover to this technology took place with the SFR 2001. It has now become possible to have one time data for the whole country, thus making the assessment specific to a reference year. For example, most of the data in the present assessment pertains to October-December 2006. For the limited areas of

Table 1.2.1: Application of remote sensing technology in forest cover mapping over two decades

Assessment	SFR Year	Data Period	Sensor	Resolution	Scale	Minimum Mappable Area (ha)	Mode of Interpretation
I	1987	1981-83	LANDSAT-MSS	80 m	1:1 million	400	Visual
II	1989	1985-87	LANDSAT-TM	30 m	1:250,000	25	Visual
III	1991	1987-89	LANDSAT-TM	30 m	1:250,000	25	Visual
IV	1993	1989-91	LANDSAT-TM	30 m	1:250,000	25	Visual
V	1995	1991-93	IRS-1B LISSII	36.25 m	1:250,000	25	Visual & Digital
VI	1997	1993-95	IRS-1B LISSII	36.25 m	1:250,000	25	Visual & Digital
VII	1999	1996-98	IRS-1C/1D LISS III	23.5 m	1:250,000	25	Visual & Digital
VIII	2001	2000	IRS-1C/1D LISS III	23.5 m	1:50,000	1	Digital
IX	2003	2002	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
X	2005	2004	IRS-P6 LISS III	23.5 m	1:50,000	1	Digital
XI	2009	2006	IRS-P6-LISS III	23.5 m	1:50,000	1	Digital

North-East region and for A&N Islands, data of January-March 2007 was used due to non-availability of cloud free scenes.

Due to enhancement in the scale of interpretation (1:50,000), it has been possible to capture forest cover patches down to 1 ha.

The digital interpretation has also made it possible to add one more canopy density class in the mapping of forest cover. Against the two density classes (dense forest between 40-100% and open forest between 10-40%) earlier, it is now possible to classify forest cover in three density classes (very dense between 70-100%, moderately dense 40-70% and open 10-40%) since 2003.

After reviewing the technological inputs in the forest cover assessments of the other countries, it appears that the spatial resolution and scale of interpretation currently used in India at the national and at the State level is optimal.

Necessary expansion in hardware and software infrastructure has taken place to make the switchover in technology possible.

1.3   Refinement in the Methodology

FSI has been following the raster-based approach in forest cover mapping until previous assessment. The satellite imagery being in the form of pixels (raster) makes the interpretation quick. But the interpretation in each cycle used to be done independently. This made the changes in forest cover prone to interpretational errors. Further, the raster based maps are also not fully compatible for GIS analysis. For the present assessment, FSI has switched over to vector based approach in which forest cover patches are mapped in polygons. This has improved the cartographic presentation of the output, mapped the changes more accurately and made the output available in GIS-ready format.

1.3.1   Revised Forest Cover of SFR 2005

In the new approach, the focus of interpretation of forest cover is on capturing changes in the forest cover by comparing the previous forest cover map with the current satellite data.

While following the new approach, it was required that the previous forest cover maps are brought in the compatible form. For this, the forest cover maps of the previous cycle i.e. of SFR 2005 were revisited with polygon centric focus which led to refinement in the interpretation at several locations. Accordingly, area figures of forest cover of SFR 2005 were also revised. The Table 1.3.1 presents State wise revised area figures of forest cover of SFR 2005.

1.3.2   Tree Cover

Tree cover comprises tree patches of size less than 1 ha outside the recorded forest area (represented by the 'green wash' area on the Survey of India toposheets). Such small patches consisting of block, linear and scattered trees are not delineated as forest

cover during interpretation of satellite data.

The methodology of tree cover estimation has been refined in this SFR. Until previous assessments, the tree cover area under scattered trees and trees in urban areas were calculated using a regression model developed between dbh and crown area for each prominent species in each physiographic zone. This was an indirect method of estimation of tree cover.

However, in the present SFR, tree cover of scattered and urban strata have been estimated directly from the crown diameter.

1.4 Forest Cover and Recorded Forest Area

The term 'Recorded Forest Area' refers to all the geographical areas recorded as 'forest' in government records. Recorded forest area largely consists of Reserved

Table 1.3.1: Original and revised area figures of forest cover of SFR 2005
(area in km^2)

S. No.	States/UTs	Forest Cover Reported in SFR 2005				Revised Forest Cover of SFR 2005			
		VDF	MDF	OF	Total	VDF	MDF	OF	Total
1	Andhra Pradesh	130	24,199	20,043	44,372	820	24,805	19,606	45,231
2	Arunachal Pradesh	14,411	37,977	15,389	67,777	20,859	31,632	14,981	67,472
3	Assam	1,444	11,387	14,814	27,645	1,464	11,653	14,641	27,758
4	Bihar	110	3,004	2,465	5,579	232	3,253	3,322	6,807
5	Chhattisgarh	2,256	36,472	17,135	55,863	4,166	35,146	16,617	55,929
6	Delhi	0	54	122	176	7	50	120	177
7	Goa	55	1,095	1,014	2,164	511	626	1,019	2,156
8	Gujarat	114	6,024	8,577	14,715	376	5,319	8,909	14,604
9	Haryana	3	523	1,061	1,587	26	488	1,090	1,604
10	Himachal Pradesh	1,097	7,831	5441	14,369	3,224	6,386	5,056	14,666
11	Jammu & Kashmir	2,135	8,394	10,744	21,273	4,298	8,977	9,414	22,689
12	Jharkhand	2,544	9,078	10,969	22,591	2,595	9,892	10,235	22,722
13	Karnataka	464	21,634	13,153	35,251	1,772	20,196	14,232	36,200
14	Kerala	1,024	8,636	5,935	15,595	1,443	9,404	6,437	17,284
15	Madhya Pradesh	4,239	36,843	34,931	76,013	6,648	35,035	36,056	77,739
16	Maharashtra	8,191	20,193	19,092	47,476	8,747	20,847	21,067	50,661
17	Manipur	923	5,541	10,622	17,086	689	5,522	10,741	16,952
18	Meghalaya	338	6,808	9,842	16,988	334	9,527	7,344	17,205
19	Mizoram	133	6,173	12,378	18,684	134	6,384	12,082	18,600
20	Nagaland	236	5,602	7,881	13,719	1,280	5,072	7,313	13,665
21	Orissa	538	27,656	20,180	48,374	7,077	21,421	20,257	48,755
22	Punjab	0	723	835	1,558	0	738	922	1,660
23	Rajasthan	14	4,456	11,380	15,850	72	4,454	11,486	16,012
24	Sikkim	498	1,912	852	3,262	500	2,161	696	3,357
25	Tamil Nadu	2,650	9,790	10,604	23,044	2,925	10,189	10,200	23,314
26	Tripura	61	4,969	3,125	8,155	113	4,816	3,244	8,173
27	Uttar Pradesh	1,297	4,682	8,148	14,127	1,626	4,569	8,151	14,346
28	Uttarakhand	4,002	14,396	6,044	24,442	4,762	14,170	5,561	24,493
29	West Bengal	2,302	3,777	6,334	12,413	2,992	4,646	5,332	12,970
30	A&N Islands	3,359	2,646	624	6,629	3,779	2,414	470	6,663
31	Chandigarh	1	8	6	15	1	10	6	17
32	Dadra & Nagar Haveli	0	130	91	221	0	115	101	216
33	Daman & Diu	0	2	6	8	0	1	5	6
34	Lakshadweep	0	15	10	25	0	16	10	26
35	Puducherry	0	17	25	42	0	14	28	42
	Total	**54,569**	**332,647**	**289,872**	**677,088**	**83,472**	**319,948**	**286,751**	**690,171**

Forests (RF) and Protected Forests (PF), which have been constituted under the provisions of the Indian Forest Act 1927. Besides RFs and PFs, the recorded forest area may include all such areas, which have been recorded as forests in the revenue records often called 'unclassed forests' or have been constituted under any State Act or local laws. On the other hand, the term Forest Cover as used in the SFR refers to all lands more than one hectare in area with a tree canopy density of more than 10%. Thus 'Recorded Forest Area' denotes the legal status of the land, which may or may not have tree/forest cover, whereas Forest Cover indicates presence of tree cover over any land irrespective of ownership.

The recorded forest area figures under three categories viz, Reserved Forests, Protected Forests and Unclassed Forests as reported by the Forest Departments of the States and UTs have been presented in Table 1.4.1.

1.5   National Forest Inventory (NFI)

Forest inventory is primarily aimed at assessing the growing stock of the 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 carbon stock.

Forest inventory in India on a relatively large area basis using statistically robust approach and aerial photographs of selected areas started in 1965 when Pre-Investment Survey of Forest Resources (PISFR) was launched with the assistance of FAO/UNDP. The forest inventory remained an important activity of Forest Survey of India after its creation in 1981 reconstituting PISFR. Till 2001, a large part of the country's forest area was inventoried. FSI also started inventory of Trees outside Forests (TOF) since 1991, realizing its importance in fulfilling the timber and fuel wood needs of society. The TOF inventory was initially confined to sub-regional level only. Until 2001, national level estimates were not available for growing stock of forest and TOF. Therefore, from the year 2002, FSI initiated National Forest Inventory (NFI) and developed a methodology to generate national level estimates of growing stock on a two year cycle.

In the survey design adopted by FSI in 2002, the country has been stratified into 14 physiographic zones, and 60 districts are selected for detailed inventory of forest and TOF to generate the national level estimates of growing stock of forests and TOF in a period of two years. The first national level estimates of growing stock of forest and TOF was published in SFR 2003. Another important outcome of TOF inventory is tree cover estimate to give a complete picture of the forest and tree cover of the country to compare with the national goal of 33%.

The growing stock estimates under NFI pertain to all trees above 10 cm dbh and branches up to 5 cm diameter. From this data, only woody biomass can be estimated. However, the other components of forest biomass viz trees below 10 cm dbh, branches, foliage of tree above 10 cm dbh were not included in NFI. Therefore, for estimating these components of biomass, FSI launched a separate study in 2008 using new methods of sample collection for these additional components of the forest biomass. The study will finally result in new allometric equations giving total above ground biomass of the forests.

1.6   New Features in this State of Forest Report

1.6.1   Altitude Zone wise Forest Cover

FSI has done a study to assess altitude zone wise forest cover of the country. For this, a Digital Elevation Model (DEM) of Shuttle Radar Topography Mission (SRTM) has been used, with contour interval of 90 m. Using overlay analysis in GIS, forest cover in the following five altitudinal zones was assessed:

i.   Up to 500 m
ii.   500 -1,000 m
iii.   1,000 - 2,000 m
iv.   2,000 - 3,000 m
v.   > 3,000 m

Along with climate and soil, altitude plays an important role in determining the type of forests. The information generated will be useful for biodiversity and wildlife habitat studies, working plans, productivity and plantation survival studies, and afforestation planning.

1.6.2 Forest Cover in Different Forest Types

Champion & Seth system of classification (1968) provides an elaborate description of forest types of India in six major groups which are further divided into sixteen type groups and finally into two hundred types including subtypes and variations of forests. The 'forest type' may be defined as a unit of vegetation with distinctive physiognomy and structure. As per Champion & Seth, the determining factors of the forest types are climate, soil, vegetation and the past treatment (including biotic interference). By way of geographical distribution, however, Champion & Seth gave a map showing only the zones where the 16

Table 1.4.1: Recorded forest area in States and UTs (area in km²)

State / UT	Geographical Area (G.A.)	Recorded Forest Area as in SFR 2005	Recorded Forest Area				% of G.A.
			Reserved Forests	Protected Forests	Unclassed Forests	Total	
Andhra Pradesh	275,069	63,821	61,210	1,967	637	63,814	23.20
Arunachal Pradesh	83,743	51,540	10,546	9,528	31,466	51,540	61.55
Assam	78,438	26,832	17,864	-	8,968	26,832	34.21
Bihar	94,163	6,473	693	5,779	1	6,473	6.87
Chhattisgarh	135,191	59,772	25,782	24,036	9,954	59,772	44.21
Delhi	1,483	85	78	7	-	85	5.73
Goa	3,702	1,224	253	845	126	1,224	33.06
Gujarat	196,022	18,962	14,122	479	4,326	18,927	9.66
Haryana	44,212	1,559	249	1,158	152	1,559	3.53
Himachal Pradesh	55,673	37,033	1,898	33,060	2,075	37,033	66.52
Jammu & Kashmir	222,236	20,230	17,643	2,551	36	20,230	9.10
Jharkhand	79,714	23,605	4,387	19,185	33	23,605	29.61
Karnataka	191,791	38,284	28,690	3,931	5,663	38,284	19.96
Kerala	38,863	11,265	11,123	142	-	11,265	28.99
Madhya Pradesh	308,245	94,689	61,886	31,098	1,705	94,689	30.72
Maharashtra	307,713	61,939	49,226	8,195	4,518	61,939	20.13
Manipur	22,327	17,418	1,467	4,171	11,780	17,418	78.01
Meghalaya	22,429	9,496	1,113	12	8,371	9,496	42.34
Mizoram	21,081	16,717	7,909	3,568	5,240	16,717	79.30
Nagaland	16,579	9,222	86	508	8,628	9,222	55.62
Orissa	155,707	58,136	26,329	15,525	16,282	58,136	37.34
Punjab	50,362	3,084	44	1,153	1,861	3,058	6.12
Rajasthan	342,239	32,488	12,454	17,416	2,769	32,639	9.54
Sikkim	7,096	5,841	5,452	389	-	5,841	82.31
Tamil Nadu	130,058	22,877	19,388	2,183	1,306	22,877	17.59
Tripura	10,486	6,294	4175	2	2117	6,294	60.02
Uttar Pradesh	240,928	16,796	11,660	1,420	3,503	16,583	6.88
Uttarakhand	53,483	34,651	24,638	9,882	131	34,651	64.79
West Bengal	88,752	11,879	7,054	3,772	1,053	11,879	13.38
Andaman & Nicobar	8,249	7,171	2,929	4,242	-	7,171	86.93
Chandigarh	114	33	31	-	3	34	29.82
Dadra & Nagar Haveli	491	204	199	5	-	204	41.55
Daman & Diu	112	6	0	8	0	8	7.38
Lakshadweep	32	0	0	0	0	0	0.00
Puducherry	480	0	4	2	7	13	2.71
Total	**3,287,263**	**769,626**	**430,582**	**206,219**	**132,711**	**769,512**	**23.41**

type groups could potentially occur.

Recently, FSI has mapped about 170 forest types of India on 1:50,000 scale under a national level project, in which remote sensing and GIS have been used. Forest types maps of districts, States and the country have been prepared. The information of the forest cover in different forest types is included in this SFR for the first time. The information will be useful for better forest and wildlife management, biodiversity studies, assessment of carbon, productivity, growing stock etc.

1.6.3   State wise Growing Stock

FSI designed the National Forest Inventory (NFI) in 2002 to estimate growing stock of forests at national level, the detailed methodology for which has been described elsewhere in this report. The sampling being without replacement, each year new areas (districts) are covered for inventory. In the last 6 years a large number of sampling units (districts) representing different States and physiographic zones have been measured. Though growing stock at State level cannot be generated directly using these sampling units, a statistical technique called 'small area estimation technique' has been used to do the same. Under the technique, it is assumed that the relation of the study character as well as the auxiliary character between larger (physiographic zone) and smaller area (part of physiographic zone within State) remains the same.

A State may fall in more than one physiographic zone. Many districts of each zone have already been inventoried in the last 6 years and their growing stock estimates are available. The growing stock of non-inventoried districts are estimated using the average value of the whole zone; then the growing stock of zonal areas falling in the State are estimated. By aggregating the zonal figures, the growing stock of forests and TOF of a State is generated.

1.7   Decadal Change in Forest Cover

The assessment of forest cover of India on a two year cycle using remote sensing technology began in the early 1980s, and the findings were first published in SFR 1987. Since then there has been continuous improvement in the remote sensing satellite technology, method of interpretation, and classification

scheme. Table 1.2.1 summarizes the technological and methodology developments since the first report.

Because of the technological and methodological changes, specially after 1999 when they were very significant, the area figures of forest cover of different assessments are strictly not comparable. Policy makers and planners, however, would like to use the successive assessments as a time series to look at the long term trend in the forest cover changes.

An attempt has been made here 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 effect of each successive change and the corresponding corrections made in the forest cover are described below:

(i) Change in scale of mapping - From 1989 to 1999 the scale of assessment was 1:250,000 with the minimum mappable area of 25 ha. From 2001 the interpretation of satellite imageries became fully digital and the scale of mapping was improved to 1:50,000 and the minimum mappable area became 1 ha.

During the SFR 1999, an exercise was done wherein satellite data of around half the country was interpreted, firstly, using the previous scale (i.e. 1:250,000 with the minimum mappable area of 25 ha) and then again using the new scale (1:50,000 with minimum mappable area of 1 ha). This exercise showed that the forest cover area got reduced by a factor 0.974 using the new scale. Assuming that this represents the bundled effect of the technology and methodology changes listed above, we arrived at the corrected (normalized) figures for the years 1989 to 1999 as shown in column 4 of Table 1.7.1. The forest cover area is reduced presumably because the blank areas between 25 ha to 1 ha are now captured with new scale.

(ii) Inclusion of smaller patches of forests up to 1 ha - In the SFR 2001, because the minimum mappable area came down to 1 ha, we were

able to capture forest cover for the first time in small patches outside the recorded forest areas (green wash areas as shown on Survey of India toposheets). This was repeated in SFR 2003, 2005, and current SFR. Thus, for each of the assessments from 2001 onwards we have two components i.e. forest cover in recorded forests and forest cover outside the recorded forests.

The ratio of the two components was computed for each of the assessment i.e SFR 2003, 2005 & the current SFR, and the average of the three was used for normalizing the area figures of the assessments from 1989 to 1999. The ratio was determined as 1.044, which indicated that the forest cover would increase by 4.4% if the forest cover outside the recorded forests is included. The area figures corrected (normalized) for this factor is shown in column 5 of the Table 1.7.1.

(iii) Vector based methodology - In vector based approach introduced in 2007, the new forest cover map generated by interpreting current satellite data uses the change polygon of forest cover of the previous cycle. Thus, the previous map serves as a reference map for the present interpretation. The interpretation is focused and changes are polygon centric. Instead of mapping of forest cover afresh (raster based

classification) in each cycle, without taking into account the previous map, a new 'change polygon centric' approach has been followed in the 2007 assessment (vector based approach). In the new method, new forest cover map is created by incorporating changes in the previous forest cover map with the help of current satellite data.

On account of the change over to vector based methodology, a ratio factor was determined using the forest cover of 2005 assessment done with vector and with raster approaches separately. The ratio worked out to be 1.019, which indicated that due to the new vector based approach, forest cover has increased by 1.9% mainly because of better precision of this approach in including the smaller patches of forest cover.

Smoothening - The area figures of forest cover in some assessment years show abrupt fluctuations; one reason for these fluctuations could be interpretational errors. To smoothen the time series of forest cover area figures for eliminating the uncontrollable fluctuations, a method of moving averages of three, was applied. The column 3 of the Table 1.7.1 gives the smoothened figures of forest cover for different assessment years. The corrections mentioned above have been applied on the

Table 1.7.1 Time series of forest cover of India showing the transformation with respect to methodology changes for making the area figures comparable

(area in km^2)

SFR year	Forest cover (as reported in SFR)	Smoothened forest cover (using moving average of three)	Forest cover corrected for change in scale	Forest cover corrected for change in scale and inclusion of small patches	Forest cover corrected for change in scale, inclusion of small patches and vector approach
1	2	3	4	5	6
1987	640,819	**			
1989	638,804	639,662	623,031	650,444	662,803
1991	639,364	639,185	622,566	649,959	662,308
1993	639,386	639,210	622,590	649,984	662,334
1995	638,879	637,221	620,653	647,962	660,273
1997	633,397	636,523	619,973	647,252	**659,550**
1999	637,293	641,529	624,850	652,343	664,737
2001	653,898	656,336			668,806
2003	677,816	673,962	*	*	686,767
2005	690,171	686,297			690,171
2009	690,899	**			**690,899**

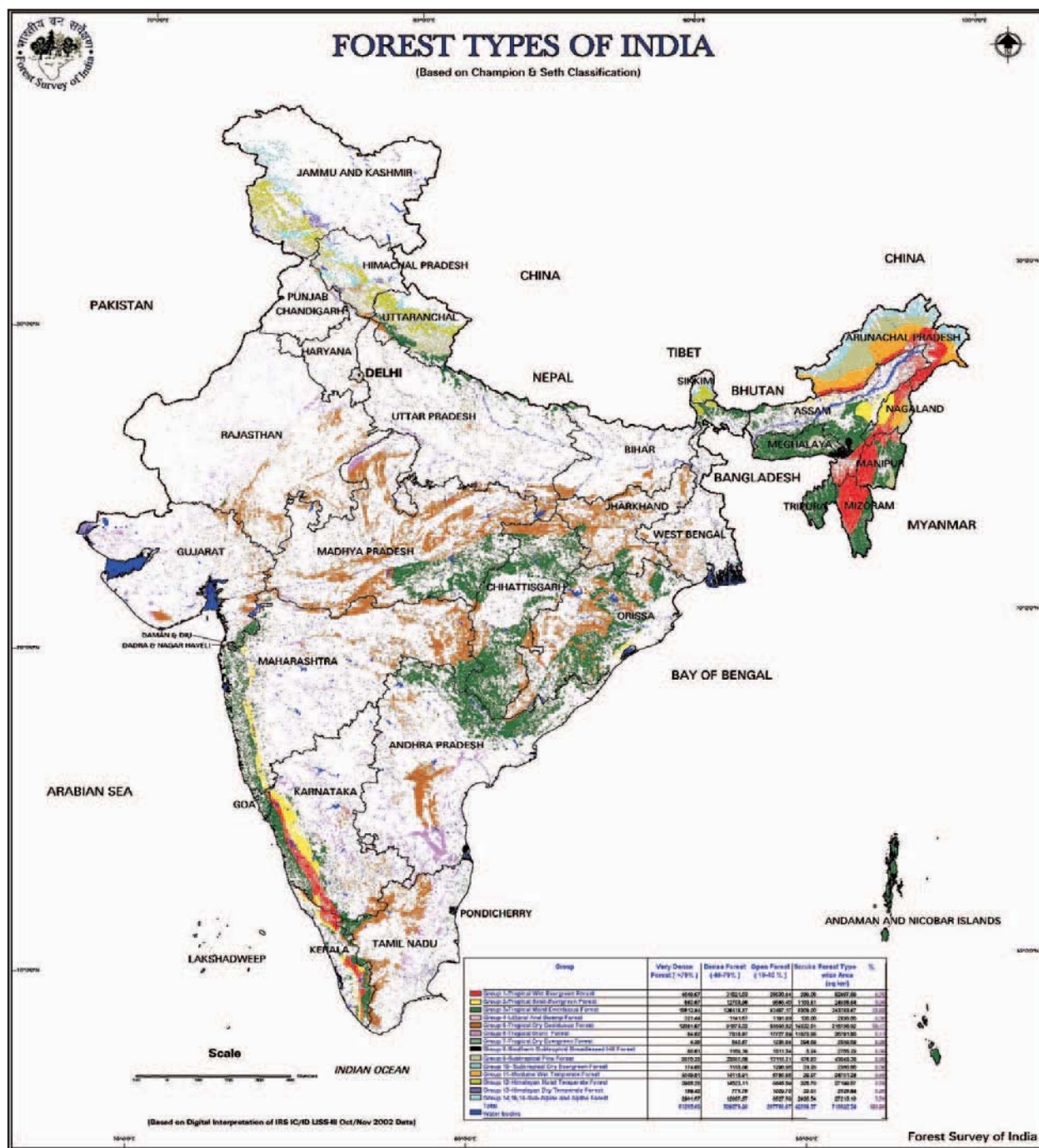* not required
** gap due to moving average

Fig. 1.1: Forest Types of India (Type Groups)

smoothened figures.

The resultant normalized area figures are given in column 6 of Table 1.7.1.

The decadal change in forest cover i.e. the difference between the forest cover area as per the assessment of 2007 (ISFR 2009) and that of 1997 assessment (SFR 1997) (shown in bold in column 6) is 31,349 km^2 (4.75%). It may be noted that the images used for the above SFRs pertain respectively, to the years 1994 and 2006-07.

1.8   About this Report

This State of Forest Report comprises seven chapters. The Chapter 1 'Introduction' provides an overview and highlights important features of the report. The Chapter 2 on 'Forest Cover' describes the methodology and results of forest cover assessment. 'Mangroves' which form unique ecosystem are described separately in the Chapter 3. The Chapter 4 on 'Tree Cover' describes the methodology and quantitative estimates of tree cover. The Chapter 5 is devoted to the information on 'Growing Stock' within and outside the forest area. In the Chapter 6 'Accuracy of Forest and Tree Cover Assessment' is described. The Chapter 7 on 'Forest & Tree Resources in States and Union Territories' provides State-wise forest cover maps, State and district wise forest cover and changes therein, State-wise forest types under different density classes, State-wise and density class-wise forest cover in different altitude zones and other important statistical information of the States and Union Territories.