Chapter

5

GROWING STOCK

5.1 Introduction

Growing stock is the sum (by number or volume) of all the trees growing in the forest or a specified part of it. The information on growing stock is essential to understand the productive capacity of forest in order to develop national policies and strategies for the sustainable use of the forest resources. In addition, the growing stock estimate leads to quantification of biomass which, in turn, is essential to assess the amount of carbon stored in the forests. In the current scenario, reporting on carbon and greenhouse gas emission has become an important requirement for the countries. As per the estimates released by MoEF (2009), a total of 6,622 million tonnes of carbon is stored in India's forest & tree cover including herbs, shrubs, dead wood, litter and soil up to 30 cm depth (see Box 5.1).

FSI has been generating information on growing stock of forests since 1965 for different parts of the country following a robust statistical design. Initially, the inventory was confined to only specific forest rich areas with the objective of assessing harvestable timber. National level estimates of growing stock of forests and TOF based on a regular inventory programme was not available till 2003. FSI modified its sampling design in 2001 so as to obtain the information on growing stock both for forests and TOF at national level in a cycle of two years. The growing stock information has become an integral part of this report since 2003.

5.2 Methodology

For the assessment of growing stock of forests and TOF, the country has been stratified into 14 homogeneous physiographic zones based on physiography, climate, vegetation and soil. The 14 physiographic zones are listed below:

1. Western Himalayas (WH)
2. Eastern Himalayas (EH)
3. North East (NE)
4. Northern Plains (NP)
5. Eastern Plains (EP)
6. Western Plains (WP)
7. Central Highlands (CH)
8. North Deccan (ND)
9. East Deccan (ED)
10. South Deccan (SD)
11. Western Ghats (WG)
12. Eastern Ghats (EG)
13. West Coast (WC)
14. East Coast (EC)

A two-stage sampling design has been adopted for national forest inventory (NFI). In the first stage, the country is stratified into 14 physiographic zones as mentioned above and the districts are sampling units. A sample of 10% districts (approx. 60 districts in the country) distributed over all the physiographic zones in proportion to the areas, is selected randomly for detailed inventory of forests and TOF. The list of districts falling within each physiographic zone fully or partially has been given in Annexure-I.

In the second stage, separate sampling design is followed for detailed inventory of forests, TOF (rural) and TOF (urban).

5.3 Forest Inventory

The 60 districts selected in the first stage are

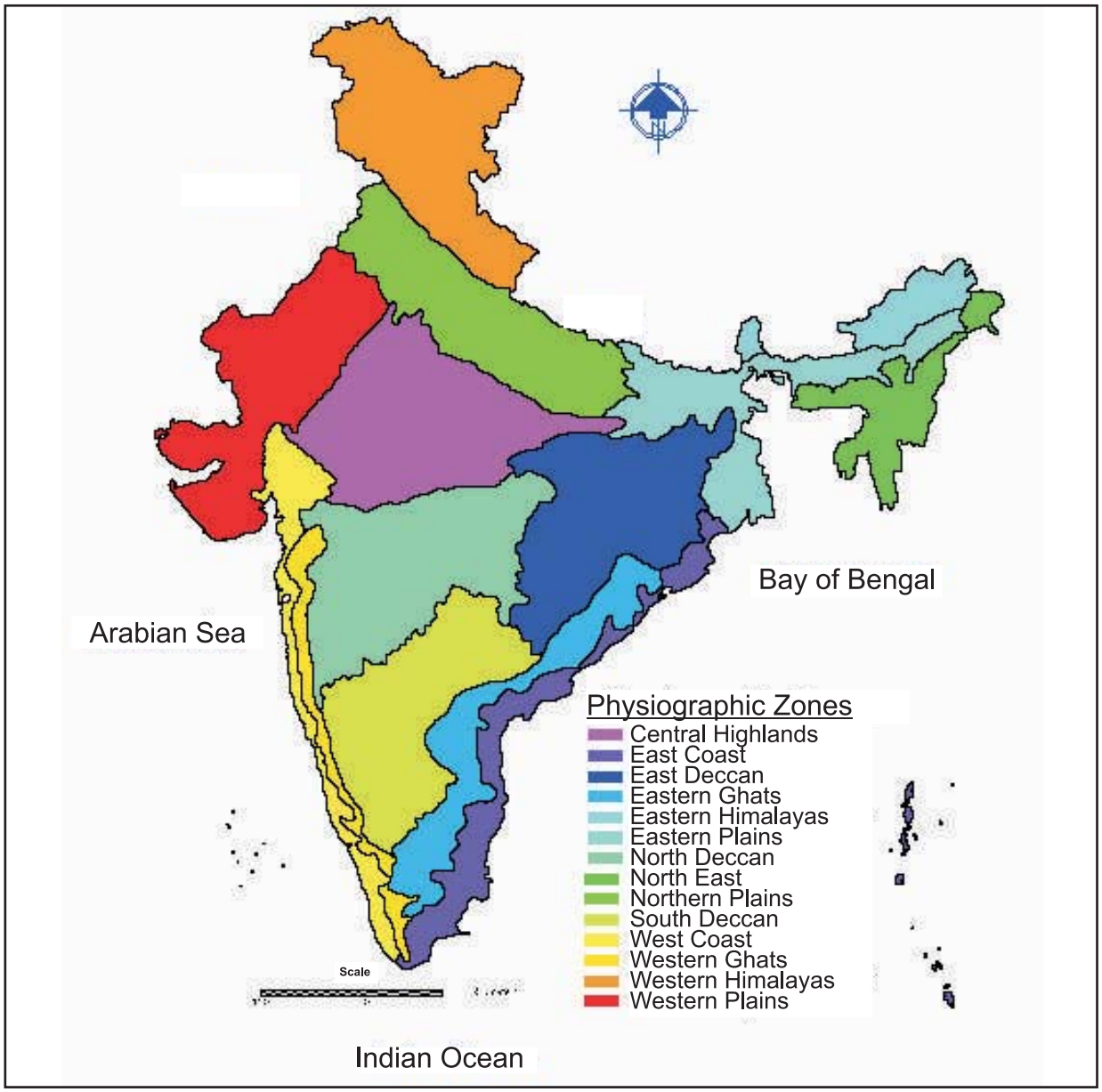

Fig. 5.1: Physiographic zones of India

taken for detailed inventory of forests. In the second stage, selected districts are divided into grids of 1¼' and 1¼' latitude and longitude intervals. These grids form the sampling units for the second stage. Systematic sampling is followed to conduct inventory in these grids.

For inventory of forests, first the forest area is delineated based on green wash areas shown on the Survey of India toposheets. Such areas depict notified and other forests. In addition, forest areas indicated by the local forest officials are also taken into account. For such forest areas, 36 grids of 2½'×2½' further sub-divided into sub-grids of 1¼'×1¼' are generated from the 15'×15' SOI toposheets on 1:50,000 scale. These 1¼'×1¼' grids form the basic sampling frame. Two of these sub-grids are then randomly selected to lay out the sample plots. Other forested sub-grids in the

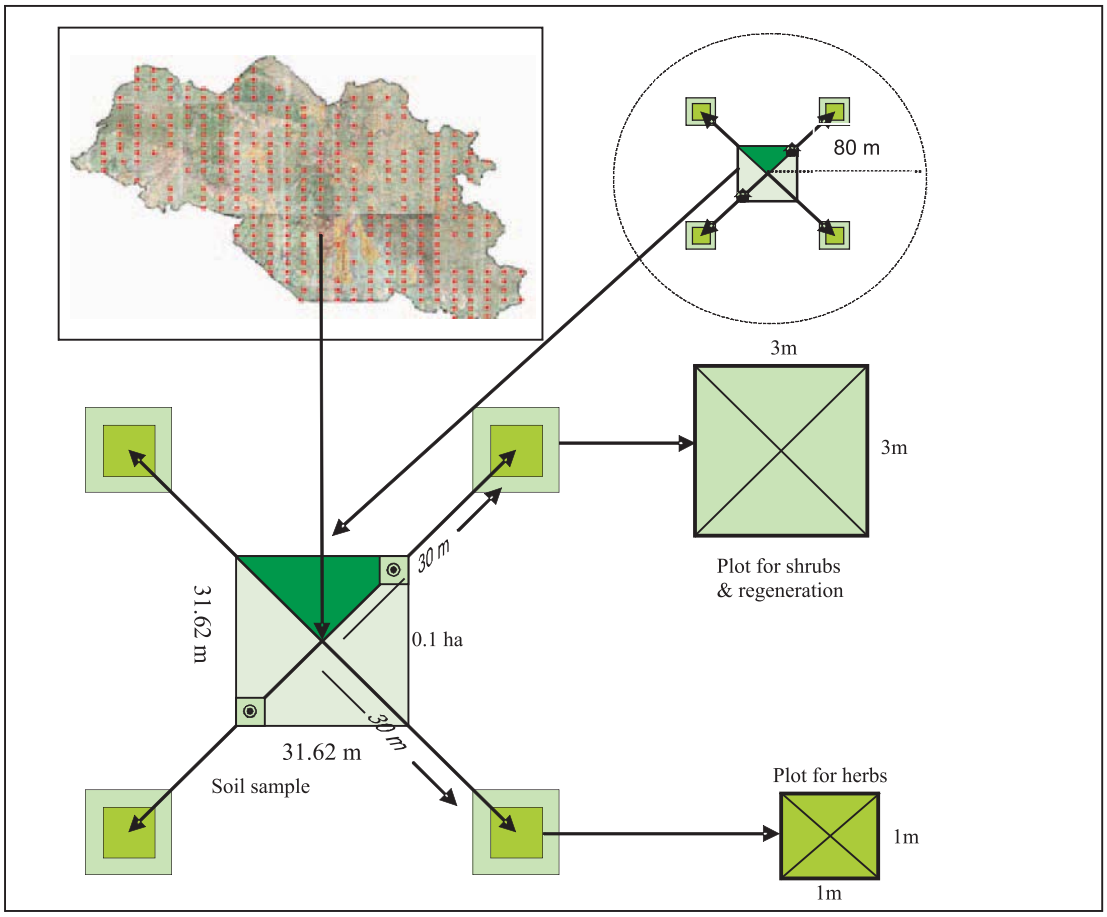

Fig. 5.2: Layout of forest inventory plot

districts are selected systematically taking first two sub-grids as random start. The intersection of diagonals of such sub-grids are marked as the centre of the plot at which a square sample plot of 0.1 ha area is laid out (Fig 5.2) to record the measurements on field forms as per the manual.

Besides the measurement of tree diameter (dbh) and height of selected trees, species name, data on legal status, land use, topography, crop composition, bamboo, regeneration, biotic pressure, etc, are also recorded. Soil samples from each plot are also collected for estimation of soil organic carbon.

5.4 Trees Outside Forests (TOF)

The 60 districts selected, spread in 14 physiographic zones, in the first stage are taken for detailed inventory of TOF rural and urban. Separate methodologies are followed for inventory of TOF (Rural) and TOF (Urban) which are described in detail in the following sections.

5.4.1 TOF (Rural)

Having selected a district in the first stage, the second stage involves sampling in two phases. In the first phase, the selected districts are stratified into block, linear and scattered strata using high resolution remote sensing satellite data. In the second phase, stratified random sampling is followed to select optimum number of sample points from each stratum. The methodology used for stratification of tree resources of the district into block, linear and scattered is described as follows:

Satellite data of IRS 1C/1D PAN (5.8m) and LISS III (23.5m) for the desirable period were acquired from

NRSC, Hyderabad for the selected districts. Thereafter, the PAN image was geometrically rectified with the help of Survey of India toposheets on 1:50,000 scale. The LISS III image was then co registered with the rectified PAN images. PAN and LISS III images were fused using appropriate algorithm to get a multispectral image with 5.8m spatial resolution. Since mapping of TOF areas is the objective, the boundary of green wash area on the Survey of India toposheets is considered as the boundary of forest which was digitized and masked out. The image was then classified into settlement, water bodies, tree cover, agriculture and other land covers. This classification enables the interpreter to distinguish between tree cover and other classes. The classified image is visually analysed for editing and refinement. Since the area of tree patches less than 0.1 ha is not qualified to be included into block, thus such pixels are clumped and cluster of pixels having area less than 0.1 ha were eliminated. After editing the classified image, the final classified map is generated having three classes in TOF areas, namely, Block, Linear and Scattered, which are treated as stratum for TOF inventory. From the classified TOF map, area under each stratum is calculated. In addition, areas which do not support tree vegetation, like rivers and water bodies, riverbeds, snow covered mountains, termed as Un-Culturable Non Forest Area were also calculated.

The optimum plot size and number of samples required for each stratum has been determined with the help of pilot studies conducted earlier by FSI. The optimum plot size for Block and Linear strata are 0.1 ha and 10m x 125m strip, respectively. In case of Scattered stratum, the optimum size of sample plot has been ascertained as 3.0 ha for non-hilly district and 0.5 ha for hilly district. The sample sizes for Block, Linear and Scattered strata have been determined as 35, 50 and 50 respectively for non-hilly districts and 35, 50 and 95 respectively for hilly districts. Shortfall of desired sample points in one stratum is compensated from other stratum.

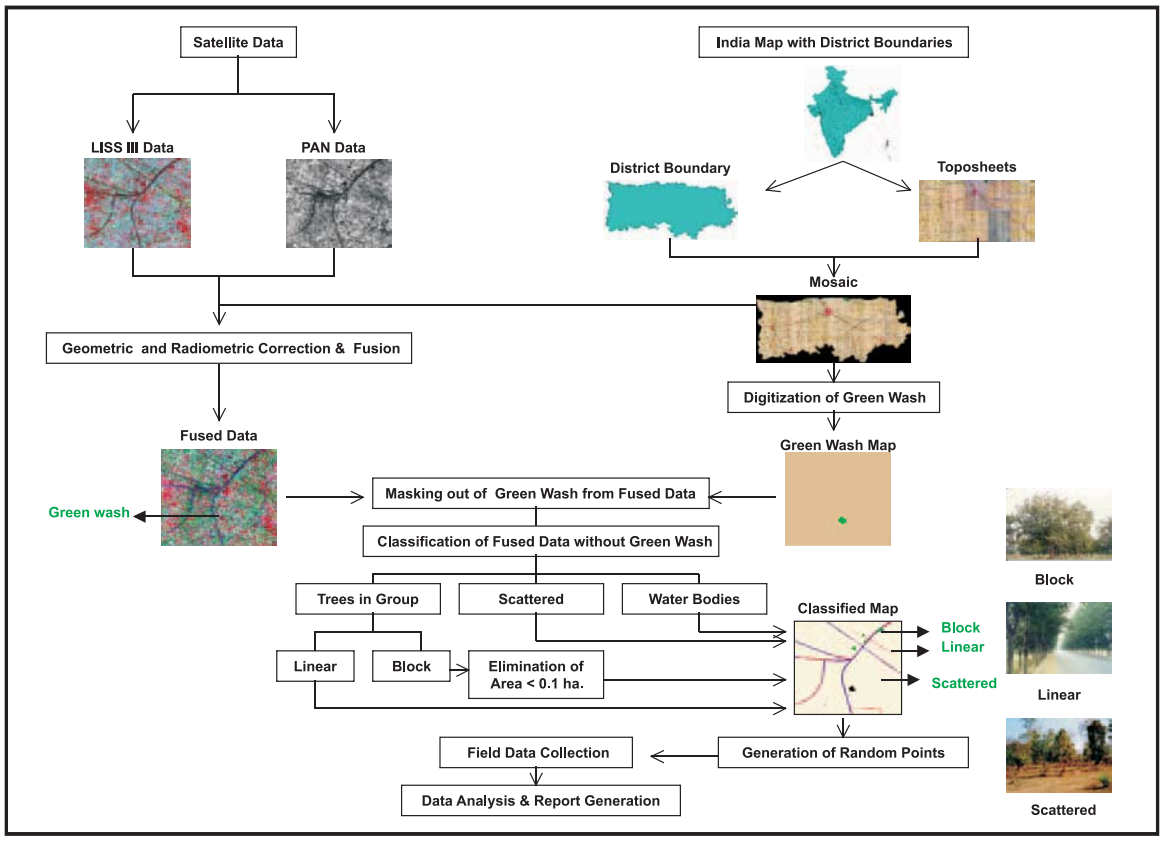

Fig. 5.3: Schematic chart of methodology of TOF

Desired number of sample points were randomly generated for each stratum and the data on pre-decided variables like dbh, crown diameter, species name and category of plantation, etc, were collected on pre-designed formats. Data processing was carried out using data processing module developed for this purpose by FSI.

The schematic chart of methodology of TOF using remote sensing is depicted in Figure 5.3.

5.4.2 TOF (Urban)

The study area for this survey are urban centers as defined by office of Registrar General of India. The methodology used for inventory of TOF (rural) is not replicated for inventory of urban area because the geo-referenced boundaries of urban areas are not available. In addition, it is not possible to lay out plots of desired size in urban areas due to residential configuration. This necessitated adoption of a different sampling design by using existing sampling frame for urban area.

National Sample Survey Organisation (NSSO), has prepared sampling frames for each urban area of the country. This organization conducts surveys by dividing all the urban centers of a district in blocks called Urban Frame Survey (UFS) blocks. These blocks have well defined boundaries (Fig 5.4) and are formed on the basis of population or number of households and cover the whole area within the geographical boundary of towns including vacant lands. UFS blocks are used as sampling units.

For the purpose of survey the towns have been classified on the basis of population as given below:

Class I: Population of 100 000 and above
Class II: Population between 50 000 and 99 999
Class III: Population between 20 000 and 49 999
Class IV: Population between 10 000 and 19 999
Class V: Population between 5 000 and 9999

The sample blocks in each class of town (strata) were randomly selected based on its size. Complete

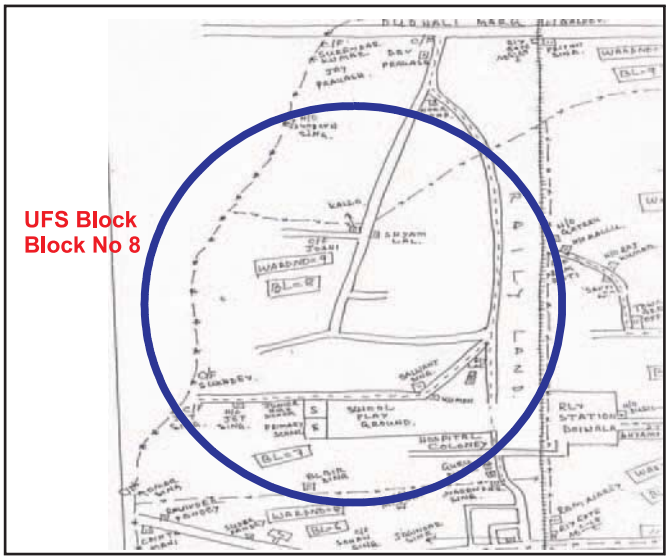

Fig. 5.4: UFS block map

enumeration of all the trees of dbh of 10 cm and above was carried out and data was recorded in the prescribed formats having similar parameters as in case of rural inventory.

5.5 Data Processing

For the purpose of estimating growing stock presented in this SFR, the data of 178 districts inventoried during last three cycles have been used.

The data collected in the field was checked manually to detect any inconsistency or recording error before entering into the computer. The data is entered in the computer using data entry module which was designed and developed separately for forests, TOF (Rural) and TOF (Urban) inventories.

For processing of forest inventory data, the inventoried plots in selected districts were classified according to legal status, i.e., recorded forest and private forest. Then per plot area (area factor) was calculated on the basis of plots in recorded forest area. These plots were further classified into different density classes and other land uses. They were then grouped into two broad classes; vegetated (very dense, moderately dense, open & plantations) and less vegetated (scrub, shifting cultivation areas etc.). The area under these classes was calculated using area

factor. The plots corresponding to vegetated area were post stratified according to crop composition (stratum) based on dominant species appearing in a particular district. Plot volume is then calculated with the help of volume equations developed by FSI for each tree species found in the plot. At district level, all sample plots were combined according to crop composition, which is used to estimate growing stock at different levels.

To estimate the growing stock at physiographic zone level, area under each stratum was first estimated. Thereafter, per hectare figure of growing stock for each stratum was used to estimate the growing stock of the physiographic zone. This process was repeated for all physiographic zones. Summing up of growing stocks of all the physiographic zones yielded the growing stock of forests for the whole country.

In case of TOF inventory, the data processing was carried out separately for rural and urban areas. In rural areas, the estimation of growing stock was carried out separately for Block, Linear and Scattered strata. The area figures for block and linear strata were obtained by digital interpretation of remote sensing data, whereas the area of scattered stratum was obtained by subtracting the area of block and linear patches from rural CNF area. In case of urban stratum, the area was taken from office of RGI. Species and diameter class wise number of stems enumerated in sample plots were used for calculating stems per hectare under each stratum. The corresponding volume per hectare was also calculated using volume equations available with FSI. To obtain the growing stock in TOF of the district per ha figures of stems & volume and area factor of each stratum was used and then growing stock of the physiographic zone was estimated. The country wide growing stock estimates of TOF were generated by adding the estimates of physiographic zones.

5.6 Results

The growing stock estimates of forests and trees outside forests have been generated at physiographic zone, national level and State level. The present estimates of growing stock of forests are based on 20,733 sample plots and that of TOF, are based on 30,166 sample plots laid out in 178 districts.

Table 5.6.1: Physiographic zone wise growing stock (volume)

Physiographic Zone	Areas of Phy. Zone (km^2)	Recorded Forest Area (km^2)	Growing Stock (million m^3)		
			Forest	TOF	Total
Western Himalayas	329,255	91,073	1,021.94	191.09	1,213.03
Eastern Himalayas	74,618	47,965	473.20	69.35	542.55
North East	133,990	79,431	341.14	102.85	443.99
Northern Plains	295,780	13,992	142.60	104.27	246.87
Eastern Plains	223,339	31,709	240.53	97.43	337.96
Western Plains	319,098	13,694	7.93	74.36	82.29
Central Highlands	373,675	80,788	109.37	110.86	220.23
North Deccan	355,988	87,260	281.07	83.47	364.54
East Deccan	336,289	128,757	622.18	198.74	820.92
South Deccan	292,416	49,451	224.42	134.28	358.70
Western Ghats	72,381	32,399	461.78	118.68	580.46
Eastern Ghats	191,698	74,418	360.65	75.26	435.91
West Coast	121,242	20,736	106.21	147.87	254.08
East Coast	167,494	17,839	105.63	91.06	196.69
Total	**3,287,263**	**769,512**	**4,498.66**	**1,599.57**	**6,098.23**

Table 5.6.2: Growing stock in forests for top ten species

S.No.	Species	Total volume %	Total stems %
1.	*Shorea robusta*	8.53	8.13
2.	*Tectona grandis*	4.59	7.32
3.	*Pinus roxburghii*	3.10	2.14
4.	*Terminalia crenulata*	3.06	3.74
5.	*Anogeissus latifolia*	2.80	4.26
6.	*Abies pindrow*	2.47	0.44
7.	*Quercus semecarpifolia*	2.15	0.96
8.	*Cedrus deodara*	2.05	0.59
9.	*Pinus excelsa*	2.03	0.83
10.	*Abies smithiana*	1.98	0.20

The physiographic zone wise growing stock (volume) within forests and in TOF along with the total growing stock is presented in Table 5.6.1.

The total growing stock of wood in the country is estimated to be 6,098.23 million m^3 (m. cum.) comprising 4,498.66 m. cum. inside forest area and 1,599.57 m. cum. outside recorded forest area (TOF). The average growing stock in the forest per hectare of forest area works out to be 58.46 m^3. Maximum growing stock in forest area is found in Western Himalayas followed by East Deccan and Eastern Himalayas.

The standard error percentage of growing stock inside and outside forests are estimated as 1.94% and 2.66% respectively. It may be noted that the estimates of growing stock given in the present SFR are not strictly comparable with those of previous SFR because the sample districts used for deriving growing stock estimates of SFR 2005 have been included in the sample districts used for deriving growing stock estimates in the present SFR. Since the growing stock estimated in the previous assessment lies within the 95% confidence interval of the present estimates, the difference in estimates of the two periods is not significant.

National level growing stock of major species by diameter class of forests and TOF has been presented in Annexure III. The percentage distribution of growing stock of top 10 species in forest has been presented in Table 5.6.2 and of TOF in Table 5.6.3.

In forests, it is observed that *Shorea robusta* has the maximum contribution in total volume (8.53%) followed by *Tectona grandis*, *Pinus roxburghii*, *Terminalia crenulata* and *Anogeissus latifolia* having a contribution of 4.59, 3.10, 3.06 and 2.80% respectively.

Table 5.6.3: Growing stock in TOF for top ten species

S.No.	Species	Total volume %	Total stems %
1.	*Mangifera indica*	10.36	7.11
2.	*Cocos nucifera*	5.71	4.99
3.	*Madhuca latifolia*	4.18	0.85
4.	*Azadirachta indica*	4.15	4.05
5.	*Borassus flabellifer*	3.64	1.89
6.	*Pinus roxburghii*	3.35	3.83
7.	*Syzygium cumini*	3.16	1.27
8.	*Ficus species*	2.42	0.64
9.	*Acacia arabica*	2.35	3.59
10.	*Prosopis cineraria*	2.33	2.58

Table 5.6.4: State/UT wise Growing Stock

State/UT	Geographical Area (km^2)	Recorded Forest Area (km^2)	Volume of Growing Stock (million m^3)		
			Forests	TOF	Total
Andhra Pradesh	275,069	63,814	242.39	122.76	365.15
Arunachal Pradesh	83,743	51,540	492.54	79.20	571.73
Assam	78,438	26,832	174.11	42.44	216.55
Bihar	94,163	6,473	34.83.	45.13	79.96
Chhattisgarh	135,191	59,772	335.47	72.64	408.11
Delhi	1,483	85	1.74	1.15	2.89
Goa	3,702	1,224	7.39	4.00	11.39
Gujarat	196,022	18,927	48.28	122.12	170.40
Haryana	44,212	1,559	4.89	15.58	20.47
Himachal Pradesh	55,673	37,033	322.40	21.23	343.63
Jammu & Kashmir	222,236	20,230	255.12	149.46	404.59
Jharkhand	79,714	23,605	103.78	53.32	157.11
Karnataka	191,791	38,284	314.57	105.26	419.83
Kerala	38,863	11,265	142.72	50.05	192.77
Madhya Pradesh	308,245	94,689	249.66	86.49	336.15
Maharashtra	307,713	61,939	294.17	151.40	445.58
Manipur	22,327	17,418	69.24	9.61	78.85
Meghalaya	22,429	9,496	44.97	23.47	68.45
Mizoram	2,1081	16,717	69.35	9.51	78.86
Nagaland	16,579	9,222	41.15	13.93	55.08
Orissa	155,707	58,136	285.32	77.21	362.53
Punjab	50,362	3,058	13.73	19.39	33.12
Rajasthan	342,239	32,639	34.64	90.46	125.10
Sikkim	7,096	5,841	19.82	2.53	22.35
Tamil Nadu	130,058	22,877	142.38	73.36	215.73
Tripura	10,486	6,294	22.21	8.04	30.25
Uttar Pradesh	240,928	16,583	122.96	83.44	206.40
Uttarakhand	53,483	34,651	459.26	19.34	478.60
West Bengal	88,752	11,879	92.46	44.85	137.31
Andaman & Nicobar	8,249	7,171	52.80	0.73	53.53
Chandigarh	114	34	0.29	0.10	0.39
Dadra & Nagar Haveli	491	204	3.93	0.85	4.79
Daman & Diu	112	8	0.01	0.11	0.11
Lakshadweep	32	0	0.00	0.05	0.05
Puducherry	480	13	0.08	0.33	0.41
Total	**3,287,263**	**769,512**	**4,498.66**	**1,599.57**	**6,098.23**

In TOF, *Magnifera indica* contributes the maximum volume of 10.36% of total volume followed by *Cocos nucifera*, *Madhuca latifolia* and *Azadirachta indica* having a contribution of 5.71, 4.18 and 4.15% respectively.

To estimate growing stock of each State/UT the physiographic zone level estimates of growing stock were processed further, using small area estimation technique. One State may fall in one or more physiographic zones. To estimate the growing stock of the State, the un-inventoried districts of state falling in a particular zone are estimated using average value of that physiographic zone. The same exercise was repeated for different physiographic zones falling in that state. Adding growing stock estimates of different physiographic zones, growing stock for the respective State was estimated. It may be noted that in some of the States/UTs, estimates for growing stock are only indicative in nature and may have lower levels of

Box 5.1 India's Forest and Tree Cover: Contribution as a Carbon Sink

Forest Survey of India is engaged in the forest inventory work since its inception in 1965. Till the year 2000, inventory of a large part of the country was completed in parts but at the national level no growing stock estimate based on regular inventory programme was available. In the year 2001, a new National Forest Inventory programme was launched with an inventory design which could provide national level estimate of growing stock of forests and TOF of the country at the regular interval of two years to coincide with the SFRs. Thus, first such preliminary estimates for the country for forests and TOF were available in SFR 2003. In the NFI, about 8000 plots are laid out every year (approximately 4000 for forests and 4000 for TOF). Besides tree volume, data on herbs and shrubs, climbers, litter, dead wood etc and samples of soil are also collected from the sample plots to generate estimates of these components and finally for the biomass of forests. Data of these plots are used in cumulative manner for generating estimates of successive cycles.

With the vast data on growing stock of forests and TOF of the country, FSI has been involved in the national level estimates of the carbon stock of the India's forests in the recent past. In the year 2002, while preparing India's first national communication to UNFCCC, (NATCOM), FSI along with the FRI had estimated carbon in India's forests and its change in the period from 1984 to 1994 based on the data available at that point of time. Now again, a similar exercise for the second national communication to UNFCCC is underway.

There is a limitation in the data of NFI for use in the estimation of carbon stock. The growing stock estimates under NFI pertains to all trees above 10 cm dbh and branches upto 5 cm. With the help of this data only woody biomass can be calculated whereas, other parts of forest biomass like branches, foliage of trees above 10 cm dbh and trees below 10 cm dbh, herbs, shrubs, climbers, deadwoods remain unaccounted. To overcome this gap in data, FSI has launched a seperate study in 2008 to collect the required data on the 'unaccounted component of forest biomass' with a special sampling design. At the end of this exercise, new biomass equations for the major species in different forest types, accounting for complete forest biomass would be available. It will provide tier two information for the country.

Recently Indian Council of Forestry, Research and Education (ICFRE) in collaboration with Forest Survey of India and Indian Institute of Remote Sensing (IIRS) carried out an exercise using existing data to estimate the carbon stock in India's forest and tree cover. The study based on the existing data from various sources, mainly from Forest Survey of India and using IPCC default values has led to an estimate of carbon stock stored in India's forest and tree cover. The results of the study are summarised below:

Carbon stock stored in India's	1995	2005	Annual increment of carbon stock
forests & tree cover (In million tonnes)	6,245	6,622	38 (equivalent to 138 million tonnes of CO_2)

precision since the sample size in such States/UTs is small. The estimates of growing stock in the States and UTs are given in Table 5.6.4.

Among the States/UTs, the maximum growing stock in forests is found in Arunachal Pradesh followed by Uttarakhand and Chhattisgarh. Similarly, the maximum growing stock of TOF is found in Maharashtra followed by J&K, Andhra Pradesh & Gujarat.