Chapter

5. Growing Stock

5.1 Introduction

The detailed information on availability and distribution of timber species, volume, biomass, number of stems, regeneration status, population structure etc within different zones and regions of the country is highly useful for forest managers, planners and policymakers. This information is captured through forest inventory under which different quantitative and qualitative parameters are measured. In the recent past, the precise information on growing stock has assumed a significant importance due to its role in estimation of biomass and carbon stock in the country's forests. In addition, the precise and time series information on growing stock has become essential for implementation of REDD+ strategy in the country. As per the FAO and UNFCCC guidelines for implementation of REDD+ strategy, every country should have a National Forest Monitoring System (NFMS) under which three essential components are satellite based land monitoring system, national forest inventories and Green House Gas (GHG) inventory.

Forest in Barpeta district of Assam

Forest Survey of India has been generating information on growing stock of forests since its inception in 1965 when it was known as the Pre-investment Survey of Forest Resources (PISFR). The immediate objective of PISFR was to estimate availability of wood from forest rich catchment areas for establishing wood based industries. The inventory was continued in different parts of the country till 1981, the year when PISFR was renamed as Forest Survey of India (FSI). Different sampling designs were followed in different parts of the country during PISFR. Even after the creation of FSI, inventory of forest in the country was one of the main activities following a uniform sampling design. Three - fourth part of the county's forests had already been inventoried till 2001 with some areas inventoried twice. Since the inventory was carried out in different parts of the country in different time periods, it was not possible earlier to have national level estimates of growing stock of the country which was imperative for strategic planning of the forestry sector. Therefore, in 2002, FSI revised its methodology so as to have national level estimates of growing stock for both inside and outside the forest areas at an interval of two years. FSI has been publishing information on national level estimates of growing stock both inside as well as outside forest areas in its biennial reports since 2003.

5.2 Methodology

For the purpose of forest and TOF inventory, the country has been stratified into 14 homogeneous physiographic zones based on the physiography, climate, vegetation and soil type. 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)

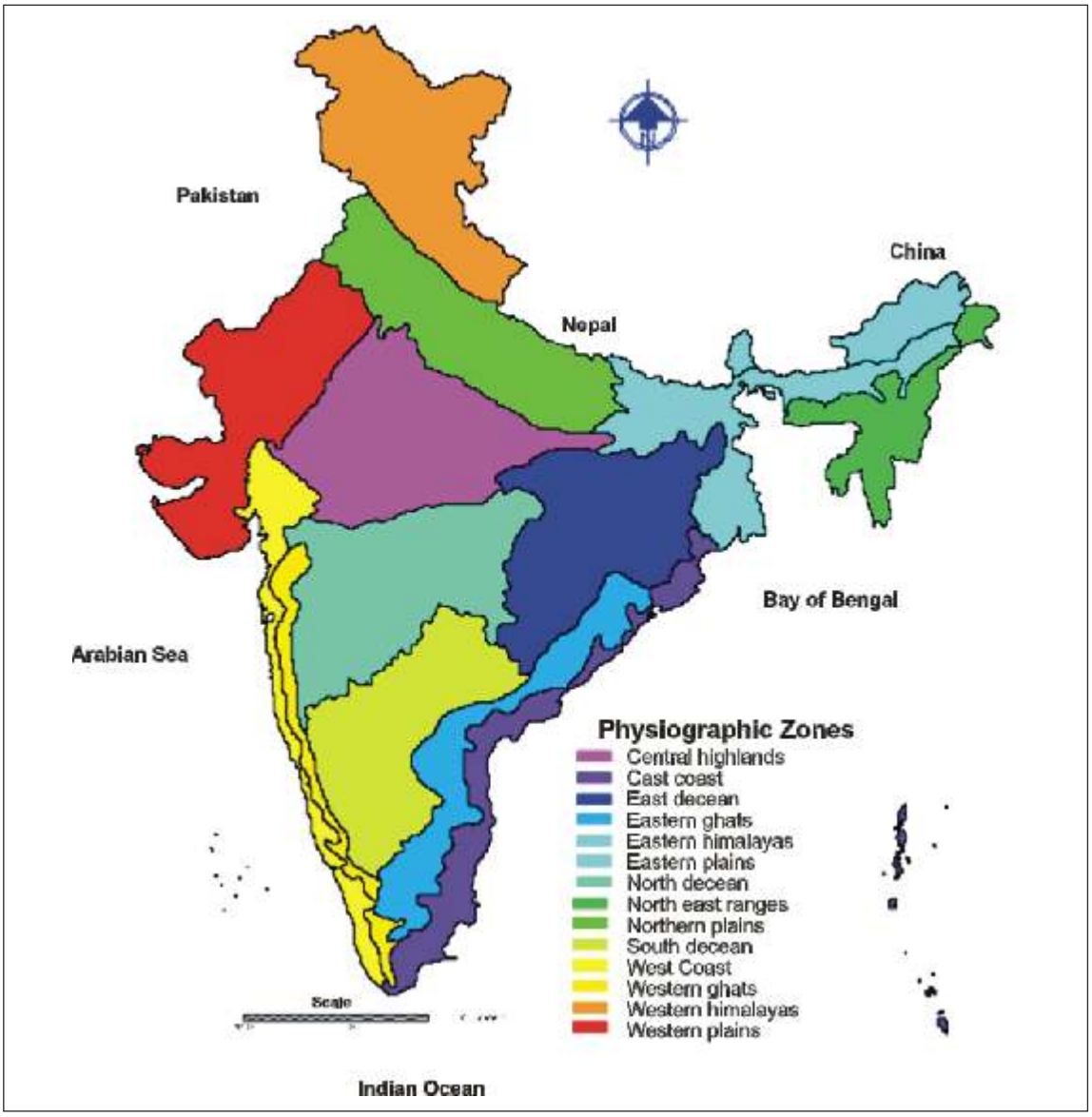

Fig. 5.1: Physiographic Zones of India

The list of districts falling within each Physiographic Zone, completely or partially has been given in Annexure-I.

5.2.1 Forest Inventory

The 60 districts selected in the first stage are taken for detailed inventory of forests. In the second stage, selected districts are divided into grids of 1¼' and 1¼' latitudes and longitudes respectively. These grids form the sampling units for the second stage. Systematic sampling is followed to conduct inventory in these grids.

For inventory of forests firstly, 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 districts are selected systematically taking first two sub-grids as random start. The intersection

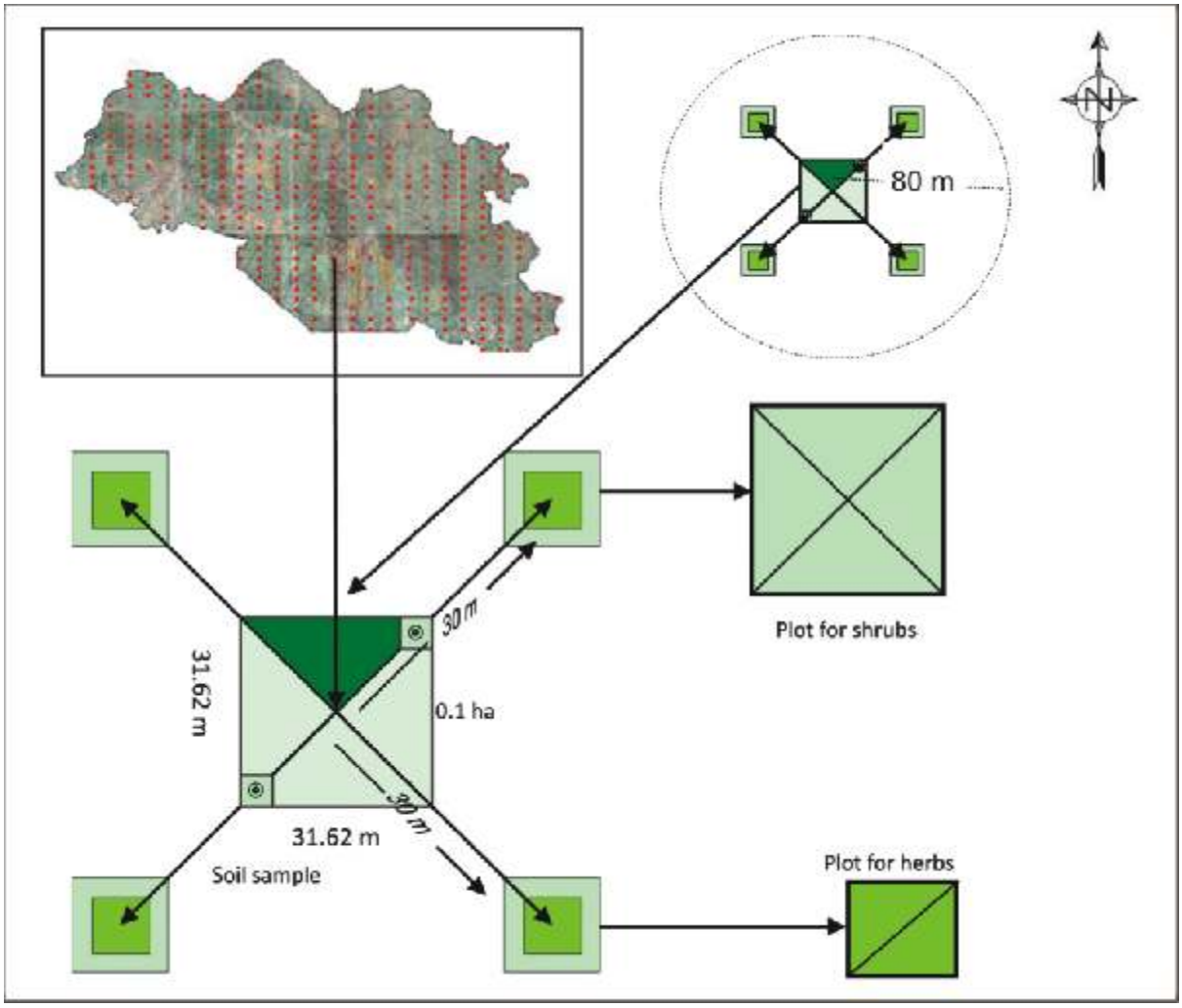

Fig. 5.2: Laying out of Forest Inventory Plot

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 (figure 5.2) to record the measurements on field forms as per the manual.

The quantitative information collected from the plot is name of the species, diameter, height of the selected trees, over bark thickness, crown diameter. The qualitative information collected is legal status, land use, topography, crop composition, bamboo, regeneration, biotic pressure, etc. In addition to this, the data on soil organic carbon is also collected from the plot.

5.2.2 Trees Outside Forests (TOF)

The inventory of TOF is carried out in both rural and urban areas of 60 randomly selected districts. Separate methodologies are followed for inventory of TOF (Rural) and TOF (Urban) which are described in detail in the following sections.

Layout of herbs plot in Assam

5.2.2.1 TOF (Rural)

For inventory of TOF (Rural), second stage involves sampling in two phases in the selected districts. In the first phase, high resolution remote sensing satellite data is used to stratify

Inventory of TOF rural in Jharkhand

TOF resources into three strata, namely block, linear and scattered. In the second phase, simple random sampling is followed to select optimum number of sample points from each stratum. The methodology used for stratification of tree resources in the selected district into block, linear and scattered is described in the following paragraphs.

Satellite data of IRS Resourcesat-II LISS IV Mx (5.8m) for the desirable period were acquired from National Remote Sensing Centre, Hyderabad for the selected districts. Thereafter, the images were geometrically rectified with the help of Survey of India toposheets on 1:50,000 scale. Mapping of TOF areas was carried out by digitizing the green wash area taking them as proxy of forest areas and masking them out. The image was then classified into vegetation, snow cover, alpine pasture, water bodies and river beds. 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 of the classified image, the final

classified map is generated having three classes in TOF areas, namely, Block, Linear and Scattered which are treated as strata for TOF inventory. From the classified TOF map, area under each stratum is calculated. In addition, area which does not support tree vegetation like rivers and water bodies, riverbeds, snow covered mountains, etc., which are termed as un-culturable Non Forest Area, was also calculated.

The optimum plot size and number of samples required for each stratum has been determined on the basis of pilot studies conducted earlier by FSI. The optimum plot size for Block and Linear strata are 0.1 ha and 10m ×125m strip respectively. In case of Scattered stratum, the optimum size of sample plot has been ascertained as 3.0 ha for non-hilly districts and 0.5 ha for hilly districts. 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.

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 designed formats. Data processing was carried out using data processing module developed by FSI. The schematic chart of methodology for TOF using remote sensing is depicted in Figure 5.3.

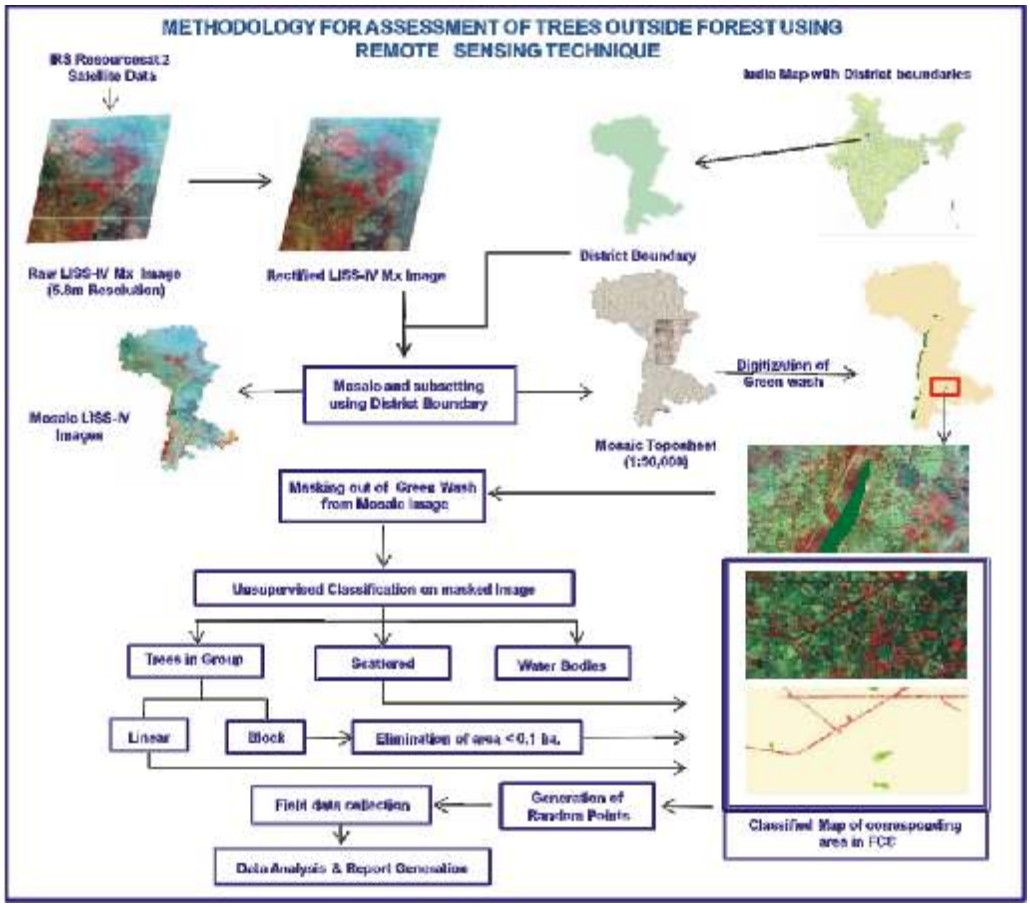

Fig. 5.3: Schematic Chart of Methodology of TOF

5.2.2.2 TOF (Urban)

The inventory of urban area is carried out in urban centers which are defined by office of Registrar General of India (RGI). The methodology used for inventory of TOF (rural) is not replicated for inventory of urban areas because the geo-referenced boundaries of urban areas are not available. Moreover, it is not possible to layout plots of desired size in urban areas due to residential configuration. A different sampling design is, therefore, used for urban areas in the second stage. The sampling frame for the selection of sampling unit is obtained from National Sample Survey Office (NSSO).

NSSO has prepared sampling frames for each urban area of the country. This office conducts regular surveys in urban areas by dividing all the urban centers of a district in blocks called Urban Frame Survey (UFS) blocks. These blocks have well defined boundaries 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 this survey.

The optimum numbers of UFS blocks as determined on the basis of pilot study are allocated in different town classes based on population as per Scheme given in Table 5.1:

Table 5.1: Categories of Towns

Town Class	Population Range
Class I	more than 100,000
Class II	50,000 to 100,000
Class III	20,000 to 50,000
Class IV	10,000 to 20,000
Class V	5,000 to 10,000

The sample blocks from each class of town (strata) were randomly selected based on the size. Complete enumeration of all the trees of dbh 10 cm and above was carried out in the selected UFS blocks and data were recorded in the prescribed formats having same parameters as in the rural inventory.

5.3 Data Processing

For the purpose of estimating growing stock presented in this report, the data of 179 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 processing. The data is entered in the computer using data entry module which has been designed and developed separately for forest, TOF (Rural) and TOF (Urban) inventories by FSI.

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 and plantations) and less vegetated (scrub, shifting cultivation areas, etc.). The areas under these classes were calculated using corresponding area factors. 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. The list of important volume equations for each physiographic zone has been given in Annexure-II. At district level, all sample plots were combined crop

composition wise 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 ha figure of growing stock for each stratum was used to estimate the growing stock of the physiographic zone. This process was repeated for all the physiographic zones. Summing up of growing stocks of all the physiographic zones yielded the growing stock of forests for the entire 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 figure for block and linear stratum was 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 Registrar General of India (RGI). Species and diameter class wise number of stems enumerated in sample plots were used for calculating stems per ha under each stratum. The corresponding volume per ha was also calculated using volume equations available with FSI. To obtain the growing stock in TOF of the district per ha, figures of stems and volume and area factor of each stratum were 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.

5.4 Results

The growing stock estimates of forests and trees outside forests have been generated at physiographic zone, national level and

Table 5.2: Physiographic Zone-wise Growing Stock (volume)

Physiographic Zone	Areas of Phy. Zone (sq km)	Growing Stock (m. cum)		
		Forest	TOF	Total
Western Himalayas	329,255	1,008.240	185.499	1,193.739
Eastern Himalayas	74,614	438.406	82.521	520.927
North East	133,990	280.782	87.485	368.267
Northern Plains	295,780	152.283	94.886	247.169
Eastern Plains	223,339	212.176	88.793	300.969
Western Plains	319,098	9.670	63.641	73.311
Central Highlands	373,675	104.270	99.980	204.250
North Deccan	355,988	289.840	84.076	373.916
East Deccan	336,289	636.084	208.836	844.920
South Deccan	292,416	202.255	113.319	315.574
Western Ghats	72,381	352.895	100.652	453.547
Eastern Ghats	191,698	262.280	63.401	325.681
West Coast	121,242	128.244	136.698	264.942
East Coast	167,494	95.938	74.897	170.835
TOTAL (ISFR 2013)	**3,287,263**	**4,173.362**	**1,484.684**	**5,658.046**
Growing Stock (ISFR 2011)	**3,287,263**	**4,498.731**	**1,548.427**	**6,047.158**
Change		**-325.369**	**-63.743**	**-389.112**

State level. The present estimates are based on 21,752 sample plots laid out inside forest and 31,326 sample plots outside forest areas in 179 districts.

The physiographic zone wise growing stock (volume) within forest and in TOF along with the total growing stock is presented in Table 5.2.

The total growing stock of wood in the country is estimated to be 5,658 m. cum comprising 4,173 m. cum inside forest areas and 1,485 m. cum outside recorded forest areas (TOF). The average per hectare growing stock in the forests works out to be 54 cum. Maximum growing stock within forest areas is found in Western Himalayas (1,008 m. cum) followed by East Deccan (636 m. cum) and Eastern Himalayas (438 m. cum). There is a total decrease of 389.112 m. cum in the growing stock of the country as compared to the estimates as reported in ISFR 2011. Out of this the decrease in growing stock inside the forest is 325.369 m. cum and 63.743 outside the forest area.

It is worth mentioning here that the growing stocks are estimated using local volume equations developed/available with FSI. For some of the physiographic zones for large number of species, volume equations were not available. The volumes of such species were estimated in the last report using volume equation developed for miscellaneous species of that zone. However, it was observed that the estimation of volume using miscellaneous species is either under or over estimated. To overcome this problem, such species were identified from each zone for which general volume equations were available and local volume equations were developed from general volume equations using inventory data. In the present ISFR, such local volume equations were used for estimation of volume. Due to change in volume equations, the growing stock of Western Ghat, Eastern Ghat and South Deccan has decreased compared to previous report.

National level estimate of number of stems and their volume for major species by diameter class in forest and TOF has been presented in Annexure IIIA, IIIB, IIIC & IIID. The percent distribution in growing stock of top 10 species of forest has been presented in Table 5.3 and for TOF in Table 5. 4. State/ UT wise growing stock in forest and TOF has been presented in Table 5.5.

It is observed that *Shorea robusta* has the maximum contribution in total volume(13.06 percent) followed by *Tectona grandis, Pinus roxburghii*, *Terminalia crenulata and Picea*

Table 5.3: Growing Stock in Forest for Top Ten Species

Nameof the Species	Total volume (Per cent)	Total stems (Per cent)
Shorea robusta	13.06	10.02
Tectona grandis	5.37	7.79
Pinus roxburghii	3.40	2.02
Terminalia crenulata	3.35	3.65
Picea smithiana	3.24	0.30
Anogeissus latifolia	3.12	3.97
Pinus excelsa	1.86	0.73
Lannea coromandellica	1.84	2.46
Quercus semecarpifolia	1.81	0.64
Boswellia serrata	1.71	1.28

Table 5.4: Growing Stock in TOF for Top Ten Species

Name of the Species	Total volume (Per cent)	Total stems (Per cent)
Mangifera indica	11.41	8.25
Azadirachta indica	7.08	5.44
Cocos nucifera	6.08	6.69
Borassus flabellifer	4.95	2.16
Madhuca latifolia	4.60	0.56
Pinus roxburghii	2.65	2.71
Acacia arabica	2.27	3.59
Bombax ceiba	2.23	0.90
Atrocarpus heterophyllus	2.11	1.32
Eucalyptus spp.	2.09	2.63

smithiana having a contribution of 5.37, 3.40, 3.35 and 3.24 per cent respectively.

In TOF, *Mangifera indica* contributes maximum volume of 11.41 percent of total volume followed by *Azadirachta indica, Cocos nucifera and Borassus flabellifer* having a contribution of 7.08, 6.08 and 4.95 percent respectively.

Among all the states, Uttarakhand has maximum growing stock of 473 m cum in forests followed by Arunachal Pradesh (439 m cum), Chhattisgarh (347 m cum) and Himachal Pradesh (317 m cum). In TOF, J & K has maximum growing stock of 145 m cum (forest cover outside LOC has been considered as TOF) followed by Maharashtra (140 m cum), Gujarat (109 m cum) and Andhra Pradesh (102 m cum).

5.5 Carbon Stock in India's Forests

FSI has been estimating the carbon stock in the India's forest as per the methodology of 'Good Practices Guidance' (GPG) developed by Inter-governmental Panel on Climate Change (IPCC). For estimation of the activity

Table 5.5: States/UTs-wise Growing Stock

States/UTs	Geographical Area (sq km)	RFA (sq km)	Volume of Growing Stock (m. cum)		
			In Forest	In TOF	Total
Andhra Pradesh	275,069	63,814	195.829	102.146	297.975
Arunachal Pradesh	83,743	51,541	439.510	87.938	527.448
Assam	78,438	26,832	151.904	38.087	189.991
Bihar	94,163	6,473	29.328	41.660	70.988
Chhattisgarh	135,191	59,772	347.106	76.313	423.419
Delhi	1,483	85	0.470	1.047	1.517
Goa	3,702	1,225	10.331	3.909	14.240
Gujarat	196,022	21,647	50.620	109.012	159.632
Haryana	44,212	1,559	5.388	14.194	19.582
Himachal Pradesh	55,673	37,033	317.295	20.763	338.058
Jammu & Kashmir	222,236	20,230	232.181	145.064	377.245
Jharkhand	79,714	20,605	103.734	55.945	159.679
Karnataka	191,791	38,284	294.631	89.531	384.162

States/UTs	Geographical Area (sq km)	RFA (sq km)	Volume of Growing Stock (m. cum)		
			In Forest	In TOF	Total
Kerala	38,863	11,309	152.269	45.788	198.057
Madhya Pradesh	308,245	94,689	251.003	82.979	333.982
Maharashtra	307,713	61,357	208.495	139.704	348.199
Manipur	22,327	17,418	50.288	9.368	59.656
Meghalaya	22,429	9,496	39.882	20.047	59.929
Mizoram	21,081	16,717	59.359	8.165	67.524
Nagaland	16,579	9,222	37.076	11.890	48.966
Odisha	155,707	58,136	235.768	74.494	310.262
Punjab	50,362	3,084	13.018	17.061	30.079
Rajasthan	342,239	32,737	34.088	79.170	113.258
Sikkim	7,096	5,841	23.841	2.423	26.264
Tamil Nadu	130,058	22,877	116.042	62.139	178.181
Tripura	10,486	6,294	22.904	6.871	29.775
Uttar Pradesh	240,928	16,583	134.509	76.106	210.615
Uttarakhand	53,483	34,651	473.083	19.336	492.419
West Bengal	88,752	11,879	83.305	41.737	125.042
Andaman & Nicobar Islands	8,249	7,171	57.953	0.545	58.498
Chandigarh	114	35	0.262	0.082	0.344
Dadra & Nagar Haveli	491	204	1.807	0.720	2.527
Daman & Diu	112	8	0.001	0.104	0.105
Lakshadweep	32	0	0.000	0.052	0.052
Puducherry	480	13	0.083	0.294	0.377
Total	**3,287,263**	**771,821**	**4,173.362**	**1,484.684**	**5,658.046**

data, FSI used results of wall to wall mapping of forest cover of the country using remote sensing data. For stratification of the activity data, FSI has used two variables namely forest types and canopy density. For estimation of emission factors for different strata, the data of National Forest Inventory (NFI) has been used. The emission factors for above ground woody biomass of trees having dbh 10 cm and more and soil organic carbon were developed from regular forest inventory. For emission factors of above ground biomass (AGB) of trees below 10cm dbh, AGB of branches, foliage of trees having dbh 10cm and above, biomass of shrubs, herbs, climbers and biomass of dead wood were derived from biomass equations/factors developed through a special study conducted by FSI. GIS techniques were used for synthesizing the data and to estimates carbon stock under different carbon pools. In the present assessment total carbon stock in forest is estimated to be 6,941 million tonnes. There is an increase of 278 million tonnes in the carbon stock of country as compared to the last assessment of the year 2004. The estimates of carbon stock as per present assessment corresponds to data year of 2011 and the changes in carbon stocks with respect to 2004 as given in ISFR 2011 are presented in Table 5.6.

Table 5.6: Change in Carbon Stock between 2004 and 2011 (m. tonnes)

Pools	Carbon Stock in Forests in 2004 as given in ISFR 2011	Carbon Stock in Forests in 2011 as given in ISFR 2013	Net Change in Carbon Stock	Percent Increase
Above ground	2,101	2,192	91	4.33
Below ground	663	694	31	4.68
Dead wood	25	27	2	8.00
Litter	121	130	9	7.49
Soil	3,753	3,898	145	3.86
Total	**6,663**	**6,941**	**278**	**4.17**

It is observed from the above table that there is a net increase of 278 m. tonnes (4.2 percent) of carbon stock in India's forest during the period 2004 to 2011.