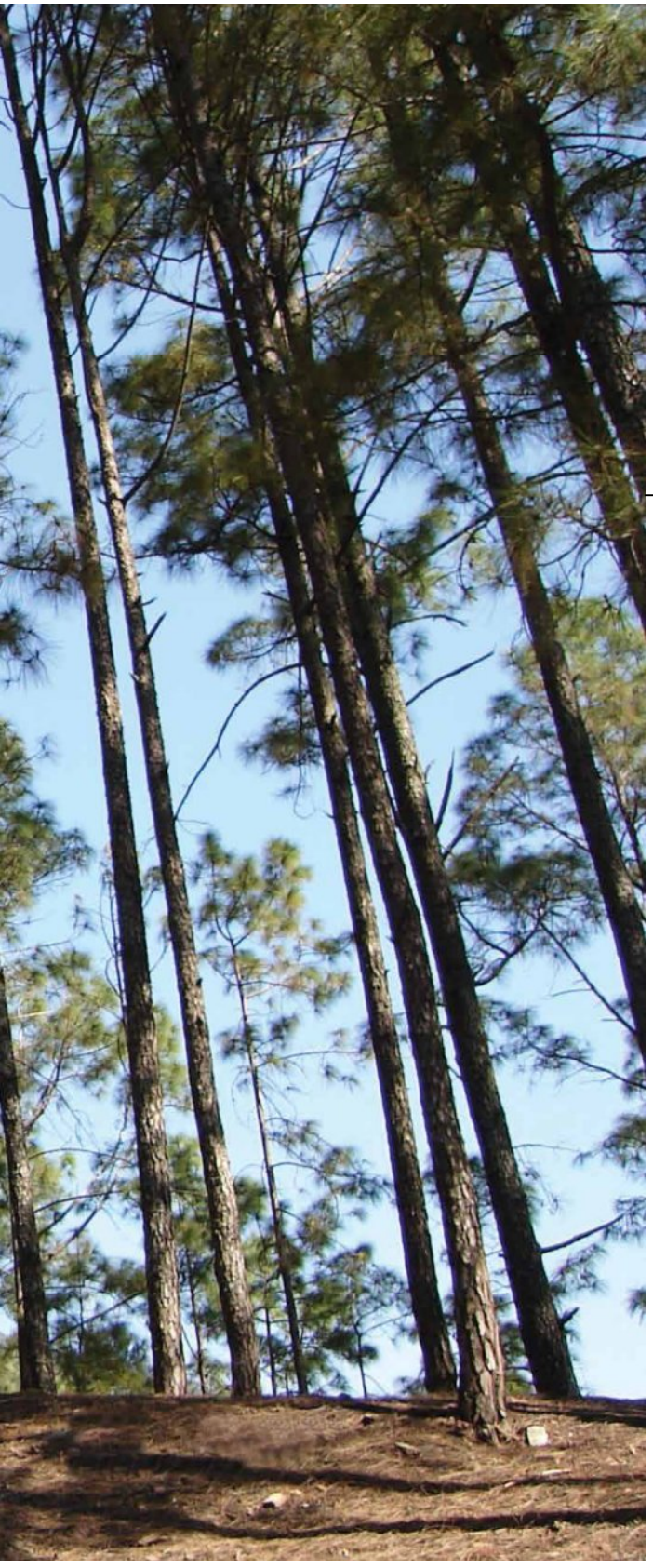


7 Chapter

Growing Stock

7.1 INTRODUCTION

Forest managers, planners and policy makers often need the detailed information about different forestry parameters such as distribution of timber species, volume, biomass, carbon stock, regeneration status, population and structures etc. in different regions of the country for strategic planning and management of forest resources. Growing stock is one of the most important parameters which quantifies forest resources. It is also an indicator of forest productivity. Forest inventories are primarily aimed at assessing the growing stock and other quantitative and qualitative parameters of the forests. In Working Plans, growing stock has traditionally been used for calculation of sustainable yield of timber from forests. In the recent past, growing stock estimation has gained further importance due to the significant role of forest in climate change mitigation. The growing stock data forms the basis for calculation of biomass and carbon stock in the forests. Further, the United Nations Framework Convention on Climate Change (UNFCCC) guidelines for implementation

of REDD+ require that every country should have a National Forest Monitoring System (NFMS) consisting of satellite based forest monitoring system and National Forest Inventory.

FSI has a long experience and expertise in carrying out inventory in the forest areas. In 1965, the Pre-Investment Survey of Forest Resources (PISFR) was established as a joint project of FAO, UNDP and Govt of India, to estimate availability of wood from forest rich areas of the country for establishing wood-based industries. The forest inventory in selected parts of the country continued after creation of FSI in 1981 following a uniform sampling design. About three-fourth of the country's forests had been inventoried till 2001 with some areas inventoried twice. About 140 reports have been published by FSI on forest inventory for the selected States and districts during this period.

Forest inventories carried out by FSI during the above period were limited to the selected areas at different times and hence were not suitable for generating national level estimates of growing stock. Therefore, FSI modified its sampling design in 2002 and launched National Forest Inventory (NFI) including both forest and TOF inventory. Under the modified design, the country was stratified in different physiographic zones based on the physiography, climate, vegetation etc. The NFI was based on systematic sampling approach wherein sixty districts, spread across the county used to be selected in the first stage distributed in different physiographic zones for the inventory on the systematically laid sample plots in 1 ¼‘ X 1 ¼‘ grids. This sampling design continued till 2016 when it was again modified with the objectives of generating National and State level estimates at acceptable precision level, reduce the revisit time to 5 years for forest and 10 years for TOF and meet the requirements of information on additional parameters.

7. 2 NEW NATIONAL FOREST INVENTORY (NFI) DESIGN

The NFI has three components, Forest Inventory, TOF (Rural) Inventory and TOF (Urban) Inventory. A brief overview of the methodology of each of the three components is presented in the following sub sections.

7.2.1 Forest Inventory

FSI has switched over to a grid based sampling design from a district based design since 2016. The new design is based on country wide uniform grids of size 5 km x 5 km and each year inventory of forest and TOF is carried out in systematically selected grids from the total grids across the country as shown in Fig 7.3. The plot configuration has also been changed from a single square plot to cluster of circular plots. Before launching of the new design, extensive technical discussions were held within FSI and also involving other stake holders like SFDs. A pilot study was conducted in all the zones of FSI to ascertain the size of the circular plots and distance between central subplots and other sub-plots. Additional parameters such as NTFPs, invasive species, water bodies near sample plots, diseases etc have also been included in the forest inventory.

For forest inventory, the revisit time to the same grid has been fixed at 5 years and for TOF at 10 years. Accordingly, for forest inventory, all grids are numbered as 1 to 5 and for TOF inventory, the grids are numbered as 1 to 10. The digital layer of RFA/Green Wash boundaries have been used to determine the grids for forest inventory. Since generation of State level estimates is one of the main objectives of the new sampling design, the optimum sample size has been calculated at State level using past inventory data and the digital layer of RFA/Green Wash. Grids having a specific number in the panel are covered in a single survey year.

Within the selected forest grids, random points are generated using Geographical Information System (GIS). These points form the plot centre of the sample point around which a sub-plot of radius 8 m is laid out. Other three sub-plots of the cluster are laid out at a distance of 40 m from the plot centre at a specified angle as shown in the Fig 7.4. Further micro plots within each sub-plot are laid out for collection of data on herbs, shrubs, regeneration and dead wood. The list of sample plots are generated in GIS and sent to the zonal offices of FSI for field survey, data collection from each sub-plots and recording in the specified field forms. A schematic diagram of plot design is shown in Fig 7.4

7.2.2 Trees Outside Forest (TOF)

Since the cycle for the TOF inventory in the new design has been kept at 10 years, all TOF grids are marked with numbers 1 to 10. Grids of a particular number are taken for inventory in the corresponding year. TOF grids consist of both TOF (Rural) and TOF (Urban). As generation of State level estimates is one of the main objectives of the new sampling design, the optimum sample size has been calculated at State level separately for rural and urban areas using past inventory data.

For urban TOF inventory, urban centers defined by the Registrar General of India are considered as study area. The sampling unit for urban inventory is taken as Urban Frame Survey (UFS) from National Sample Survey Office (NSSO). The urban centers of a district are delineated into blocks called 'UFS blocks', which are shown on maps with well-defined boundaries and generally cover 600 to 800 population size or 120-160 households. These blocks put together cover the whole area within the geographical boundary of a town including vacant lands.

The list of all urban towns and cities with the names and area as per census 2011 have been used to identify the urban grids. The latitude and longitude of centroid of all such towns have been arrived at using BHUVAN and Google Earth portals. Using the latitude and longitude of centroid and area of the towns, a circular buffer zone of appropriate radius is created. At State level, this layer of buffer is considered as a proxy of digital urban area of that State. In a GIS framework, this urban layer is overlaid on the 5km x 5km NFI grid layer. All such grids intersecting the urban buffer layer are termed as urban grids for TOF Urban inventory. All urban grids which are numbered 'one' will be considered for 1st year TOF (Urban) inventory and number 5 in the second year and likewise in the subsequent years. Within the selected urban grid, the name of town (s) is communicated to the zonal offices for obtaining UFS block maps from NSSO. One UFS block is selected randomly from each grid for urban TOF inventory. Remaining grids are covered under TOF (Rural) inventory.

FIGURE 7.1 Measurements during forest inventory

FIGURE 7.2 Recording field observations during forest inventory

FIGURE 7.3 Map of India showing NFI grids of 5 km x 5 km

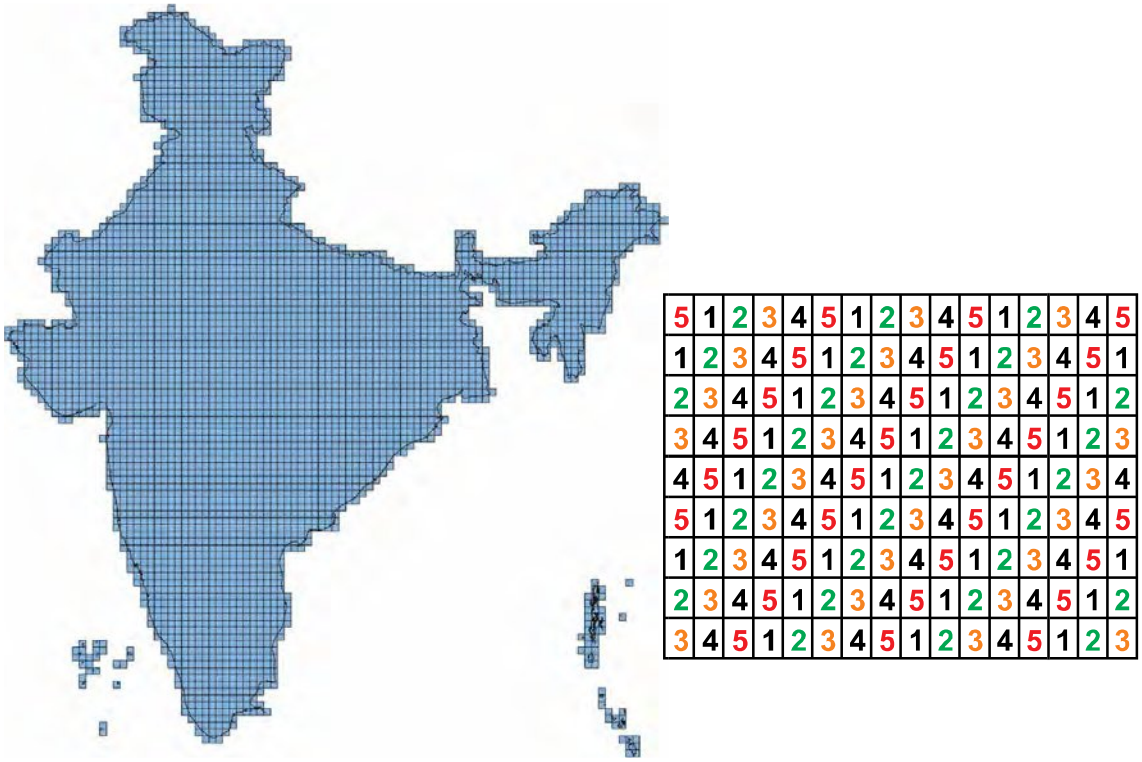
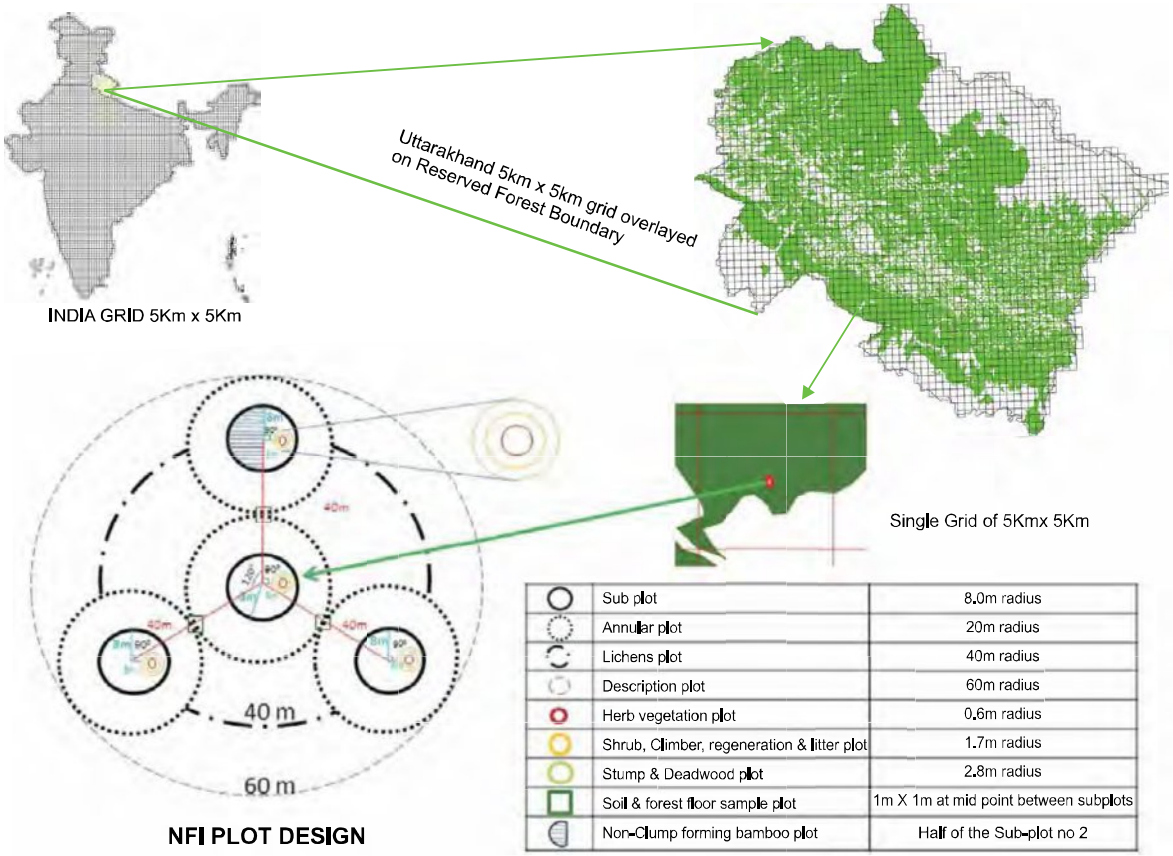


FIGURE 7.4 Plot Configuration



For TOF (Rural) inventory, a two phase sampling design is used. In the first phase, the selected grid areas are stratified into block, linear and scattered strata using high resolution remote sensing satellite data. In the second phase, optimum number of sample points are generated in the selected grids. The latitude and longitude of all the random points are sent to the zonal offices for field data collection. The methodology used for stratification of tree resources of the grid into block, linear and scattered strata is described in the following schematic diagram.

The Multispectral data of Sentinel-2 with spatial resolution of 10m and swath of 290 km has been used for classification of the selected grids. The sentinel satellite data is downloaded and geo-rectified with the help of Survey of India (SOI) open series map toposheets on 1:50,000 scale. The image is then classified into settlement, water bodies, tree patches, agriculture and other land cover classes. This classification enables the interpreter to distinguish between tree patches and other classes. The classified image is visually analysed for editing and refinement. Since the minimum mappable area for stratification of block and linear strata is 0.1 ha, pixels are clumped and cluster of pixels having area less than 0.1 ha are eliminated. After editing of the classified image, the final classified map is generated having three classes in TOF areas, namely Block, Linear and Scattered. From the classified TOF map, area under each category (stratum) is calculated. In addition, areas which do not support tree vegetation, like rivers and water bodies, riverbeds, snow covered mountains etc which are termed as Un-Culturable Non Forest Area are also calculated. The schematic chart of the methodology of TOF using remote sensing is depicted in the Fig 7.7.

The optimum size of the plot for each stratum has been determined by FSI after conducting a pilot study. The optimum plot size for Block and Linear strata is 0.1 ha square plot and 10 m ×125 m strip, respectively. In case of scattered stratum, square plots of the optimum size 3.0 ha for non-hilly and 0.5 ha for hilly areas are laid out. In the new grid based design, the scattered plots are identified as hilly or non-hilly based on altitude of a particular plot in the grid and same is mentioned against each plot.

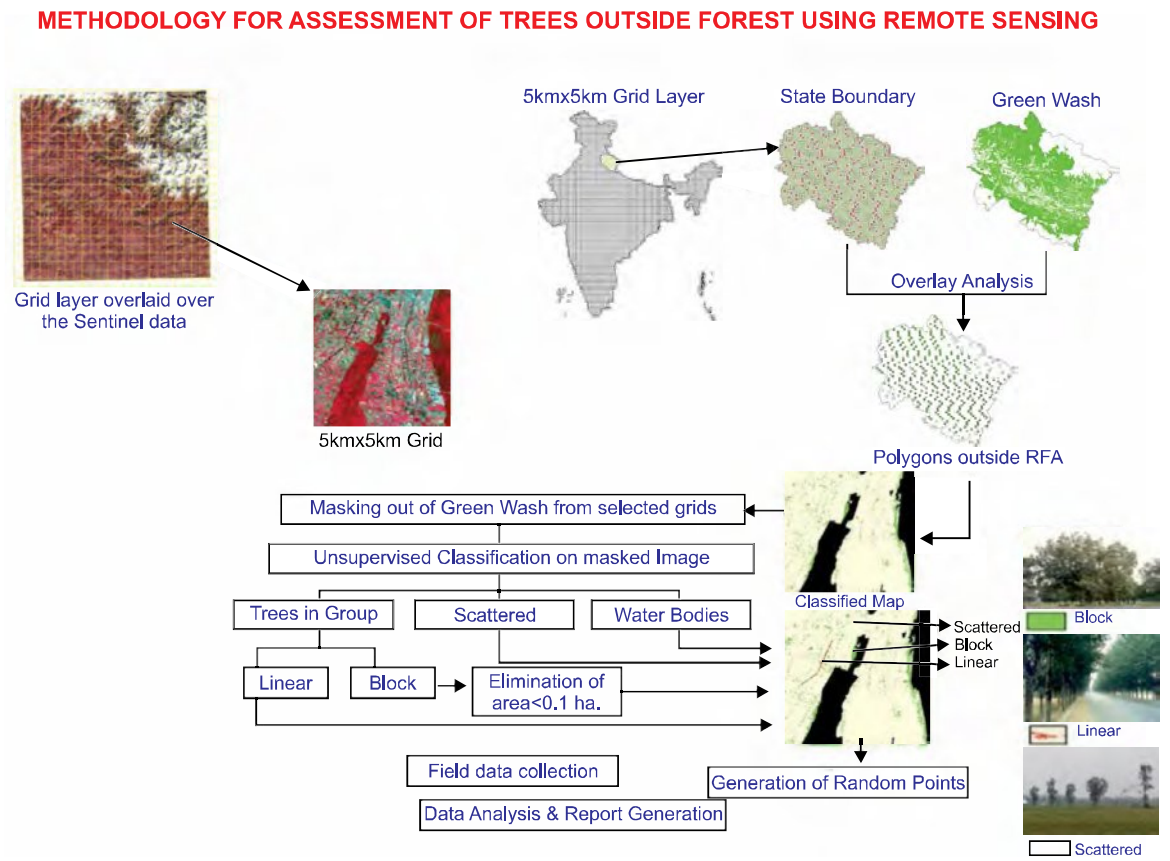
7.3 DATA PROCESSING

The data is entered using a data entry module, which has been designed and developed separately for Forest, TOF (Rural), and TOF (Urban) inventories by FSI. The entered data is checked thoroughly for any inconsistency and cleaned prior to processing. Data processing is carried out separately for forest, TOF (rural) and TOF (urban) as the steps involved to them are little different.

FIGURE 7.5 Measurements for TOF inventory

FIGURE 7.6 Field observations during TOF inventory

FIGURE 7.7 Schematic diagram of the methodology of TOF



For processing of forest inventory data, the inventoried plots in the States are classified according to legal status, i.e. recorded forests and private forests and per plot area (area factor) is calculated on the basis of plots in recorded forest area. These plots are further classified into different crop composition and other land use classes. They are 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 are calculated using corresponding area factors. The plots corresponding to vegetated areas are post-stratified according to crop composition (stratum) based on dominant species appearing in a particular State. Plot volume is calculated with the help of volume equations developed by FSI for each tree species found in the plot. The list of volume equations of important species for each State has been given in Annexure-II. At the State level, all sample plots are grouped according to crop composition to estimate growing stock for the State. This process is repeated for all the States. Aggregation of growing stock of all the States gives the national estimate.

In case of TOF inventory, the data processing has been carried out separately for rural and urban areas. In rural areas, the estimation of growing stock at the State level has been carried out separately for Block, Linear and Scattered strata. The area figures for block and linear strata have been obtained from the digital interpretation of remote sensing data, whereas the area of scattered stratum has been obtained by subtracting the area of block and linear patches from rural Culturable Non Forest Area (CNFA). In case of urban stratum, the area was taken from the Registrar General

of India (RGI). Species and diameter class wise number of stems enumerated in sample plots have been used for calculating stems per ha under each stratum. The corresponding volume for each stratum has been calculated using volume equations developed by FSI. Estimates of the Growing stock in TOF of the States has been calculated using per ha figures of stems volume and respective areas of each stratum. The national growing stock estimate of TOF has been generated by adding the estimates of growing stock of all the States.

7.4 RESULTS

Data from around 30,000 plots surveyed during the last two years i.e. 2016-18 has been processed following the statistical procedures with the help of customized software. The results of growing stock estimation for forest and TOF are presented in the following sub-sections.

7.4.1 State/UT wise Growing Stock

The growing stock estimates of forests and trees outside forests have been generated at the National level and State level. The estimates presented in the current report are based on 9,628 sample plots laid inside forests and 20,612 sample plots outside. As compared to the last assessment, the number of sample plots inside forest and TOF are almost double in number for the corresponding period and spread over the entire country under the new inventory design unlike previous design wherein the plots used be laid in sixty districts in two years. As a result, the precision of growing stock both at the National and State level is higher than the previous estimates. The Standard Error (SE) of estimate for Forest Inventory at the National level is 7.21%. The SE for TOF at the National level is 6.65%. At the State level, SE varies from 2.69% to 15.73% for forest. For the TOF, the SE at State level varies from 2.92% to 14.10%. The State wise SE of growing stock for forest and TOF is given at annexure IV.

The total growing stock of wood in the country is estimated 5,915.76 m cum comprising 4,273.47 m cum inside forest areas and 1,642.29 m cum outside recorded forest areas (TOF). There is a total increase of 93.38 m cum (1.6%) in the growing stock of the country as compared to the estimates reported in ISFR 2017. Out of this, the increase in growing stock inside the forest is 55.09 m cum (1.3%) and 38.30 (2.4%) outside the forest area.

The estimates of growing stock in Forests and TOF in the States and UTs are presented in table 7.1.

FIGURE 7.8 Growing Stock of Forest & TOF

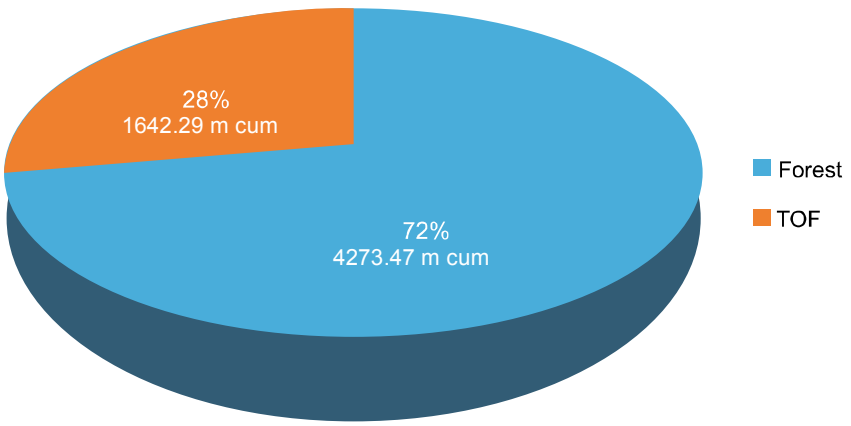


TABLE 7.1 State/UT wise Growing Stock

S.No.	State/UTs	Geographical Area (sq km)	Volume of Growing Stock (million cum)			Growing Stock in Forest (cum /ha)	Growing Stock in TOF (cum / ha)
			Forest	TOF	Total		
1.	Andhra Pradesh	162,968	119.02	67.68	186.70	31.94	5.69
2.	Arunachal Pradesh	83,743	458.00	75.08	533.08	89.09	43.01
3.	Assam	78,438	115.40	22.96	138.36	43.01	5.03
4.	Bihar	94,163	26.73	40.46	67.19	38.87	4.81
5.	Chhattisgarh	135,192	358.96	99.92	458.88	60.05	14.19
6.	Delhi	1,483	0.54	1.69	2.23	52.94	12.31
7.	Goa	3,702	11.16	4.03	15.19	91.10	20.37
8.	Gujarat	196,244	48.31	82.60	130.91	22.32	5.28
9.	Haryana	44,212	4.22	17.56	21.78	27.07	4.17
10.	Himachal Pradesh	55,673	347.07	25.19	372.26	93.72	17.27
11.	Jammu & Kashmir*	222,236	291.63	125.14	416.77	144.16	17.72
12.	Jharkhand	79,716	96.22	71.93	168.15	40.76	13.41
13.	Karnataka	191,791	334.08	103.03	437.11	87.26	7.05
14.	Kerala	38,852	147.10	55.26	202.36	130.07	20.99
15.	Madhya Pradesh	308,252	342.62	106.39	449.01	36.18	6.48
16.	Maharashtra	307,713	231.76	177.12	408.88	37.64	7.41
17.	Manipur	22,327	42.03	6.07	48.10	24.13	12.52
18.	Meghalaya	22,429	31.28	18.84	50.12	32.94	16.34
19.	Mizoram	21,081	21.30	44.11	65.41	37.76	28.94
20.	Nagaland	16,579	29.52	13.72	43.24	34.23	17.33
21.	Odisha	155,707	299.04	95.02	394.06	48.86	10.55
22.	Punjab	50,362	11.12	18.56	29.68	36.06	3.96
23.	Rajasthan	342,239	24.39	89.07	113.46	7.45	5.33
24.	Sikkim	7,096	35.32	1.94	37.26	60.47	56.28
25.	Tamil Nadu	130,060	96.97	76.30	173.27	42.39	7.18
26.	Telangana	112,077	80.96	41.45	122.41	30.09	5.02
27.	Tripura	10,486	19.74	6.76	26.50	31.36	16.67
28.	Uttar Pradesh	240,928	96.04	97.62	193.66	57.92	4.45
29.	Uttarakhand	53,483	406.08	19.13	425.21	106.86	15.31
30.	West Bengal	88,752	54.87	32.63	87.50	46.19	4.66
31.	A & N Islands	8,249	90.82	2.75	93.57	126.65	25.08
32.	Chandigarh	114	0.29	0.50	0.79	82.86	49.56
33.	Dadra & Nagar Haveli	491	0.74	1.16	1.90	36.27	32.32
34.	Daman & Diu	111	0.09	0.15	0.24	112.50	14.42
35.	Lakshadweep	30	0.00	0.07	0.07	0.00	44.61
36.	Puducherry	490	0.05	0.40	0.45	38.46	11.79
Total		**3,287,469**	**4,273.47**	**1,642.29**	**5,915.76**	**55.69**	**7.87**

*includes area outside LOC that is under illegal occupation of Pakistan and China

From Table 7.1, it is observed that the growing stock per hectare at the national level has been estimated as 55.69 cum. The highest per hectare growing stock in forest has been found in J&K followed by Kerala and A & N Islands. In respect of total growing stock Arunachal Pradesh has maximum growing stock of 458.00 m cum in forests followed by Uttarakhand 406.08 m cum, Chhattisgarh 358.96 m cum and Himachal Pradesh 347.07 m cum. In TOF, Maharashtra has maximum growing stock of 177.12 m

cum followed by Jammu & Kashmir (125.14 m cum), Madhya Pradesh (106.39 m cum) and Karnataka (103.03 m cum).

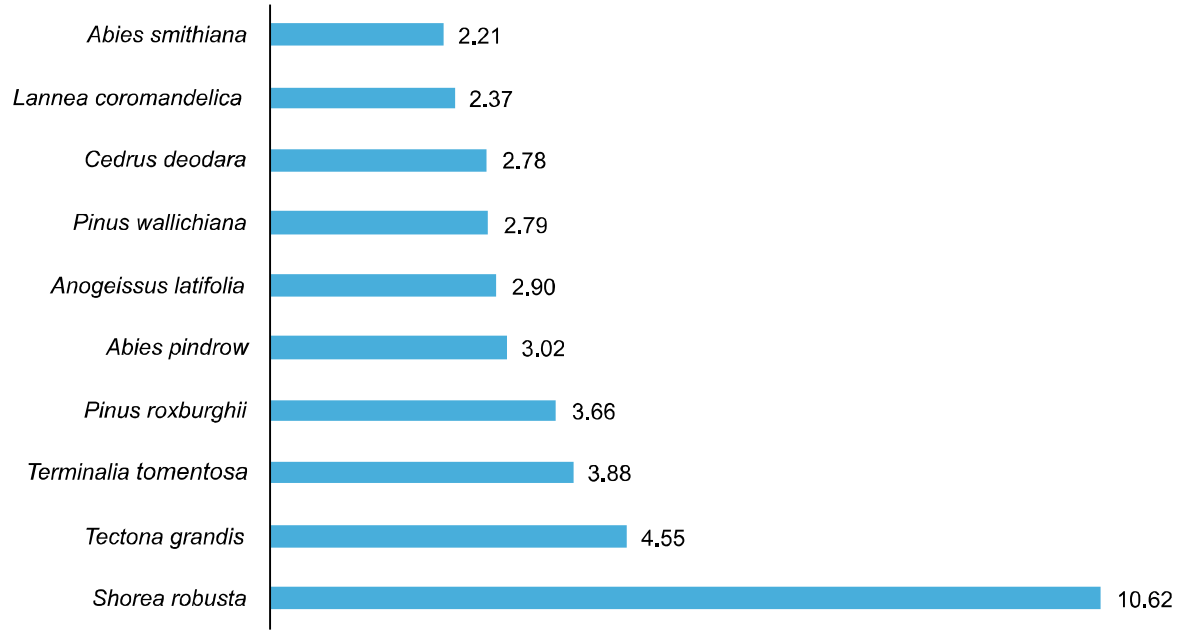
7.4.2 Growing Stock of top ten species in forests and TOF

National level estimates of number of trees and their volume for major species by diameter class in forest and TOF has been presented in Annexure III A and III B. The growing stock of top 10 species of forest & TOF and their percentage in total growing stock of the country has been presented in Table 7.2 and Table 7. 3 respectively.

TABLE 7.2 Growing Stock in Forest for top ten species in the country

S.No.	Name of the Species	Total volume (m cum)	Percentage of total GS in country's forests (%)
1.	*Shorea robusta*	453.81	10.62
2.	*Tectona grandis*	194.54	4.55
3.	*Terminalia tomentosa*	165.71	3.88
4.	*Pinus roxburghii*	156.52	3.66
5.	*Abies pindrow*	129.20	3.02
6.	*Anogeissus latifolia*	124.12	2.90
7.	*Pinus wallichiana*	119.27	2.79
8.	*Cedrus deodara*	118.71	2.78
9.	*Lannea coromandelica*	101.41	2.37
10.	*Abies smithiana*	94.45	2.21

FIGURE 7.9 Percentage volume of top ten species in forest



It is observed that *Shorea robusta* has the maximum contribution in total volume (10.62%) followed by *Tectona grandis* (4.55%), *Terminalia tomentosa* (3.88%) *and Pinus roxburghii* (3.66%).

TABLE 7.3 Growing stock in TOF for top ten species

S.No	Nameof the Species	Total volume (m cum)	Percentage of total volume (%)
1.	*Mangifera indica*	207.24	12.62
2.	*Azadirachta indica*	133.23	8.11
3.	*Madhuca latifolia*	81.46	4.96
4.	*Cocos nucifera*	63.93	3.89
5.	*Borassus flabelliformis*	62.42	3.80
6.	*Acacia arabica*	52.34	3.19
7.	*Butea monosperma*	45.65	2.78
8.	*Tamarindus indica*	42.50	2.59
9.	*Pinus wallichiana*	42.45	2.58
10.	*Ficus religiosa*	40.07	2.44

In TOF, *Mangifera indica* contributes maximum volume of 12.62% to total volume followed by *Azadirachta indica* (8.11%), *Madhuca latifolia* (4.96%) and *Cocos nucifera* (3.89%).

The estimates of growing stock at the State level are given in Table 7.1. As mentioned earlier also, one of the objectives of new sampling design is to generate the State level estimates at an acceptable precision level. In the new design, sample plots in both forest and TOF fall in all the States. The state wise standard error percentage both forest and TOF is given in Annexure-4.

FIGURE 7.10 Percentage volume of top ten species in TOF