

# Chapter

## 5 | Growing Stock



### 5.1 Introduction

The information on forest growing stock has traditionally been reckoned as a key indicator of forest health and productivity. Periodic estimate on forest growing stock is essential to develop national policies and strategies for a 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. The estimation of growing stock has, therefore, assumed significance in the existing climate change scenario.

The forest inventory on a relatively large area (catchment) basis began in 1965 when the Pre-Investment Survey of Forest Resources (PISFR) was established in the country with FAO/UNDP assistance. Even after the creation of the FSI in 1981, the field inventory remained the primary activity of FSI. Barring a study carried out in 1996 by the FSI, no estimation on growing stock was being carried out at national level on regular basis. FSI modified its sampling design in the year 2002 so as to obtain the information on growing stock both for forests as well as Trees Outside Forests (TOF) at national level in a cycle of two years. Since then, the growing stock information has become an integral part of SFR on biennial basis.

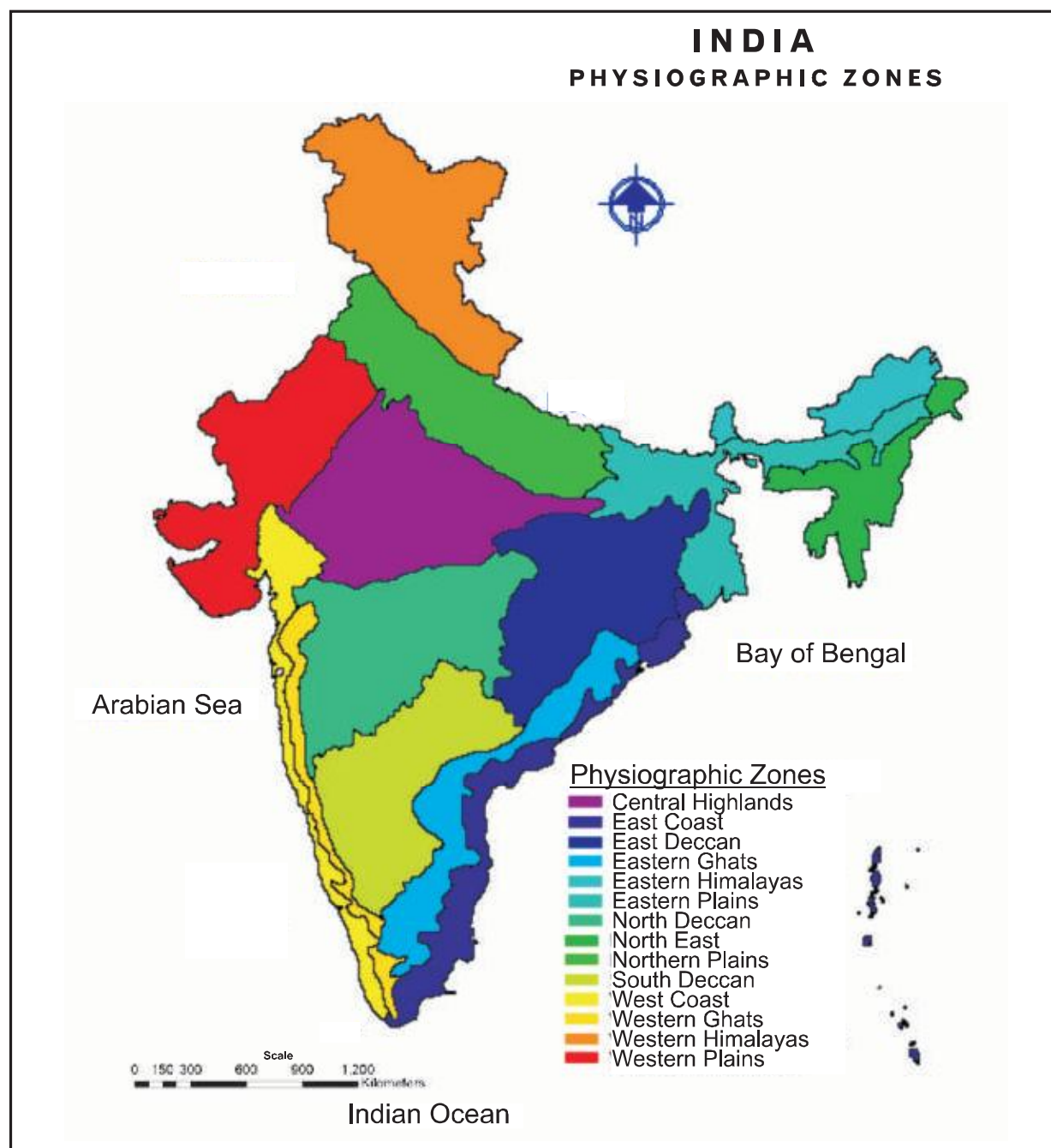
### 5.2 Methodology

For the assessment of growing stock of forest and TOF, the country has been stratified into

14 homogeneous physiographic zones based on physiography, climate, vegetation, soil etc. These physiographic zones depicted in Fig.5.1 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. In the first stage, the country is stratified into 14 physiographic zones as mentioned above and the districts therein are the sampling units. A sample of 10% districts (approx. 60 districts in the country) distributed over all the physiographic zones in proportion to the areas, are selected randomly for detailed inventory of forest and TOF in a cycle of two years. The list of districts falling fully or partially within each physiographic zone 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).



**Fig.5.1 Physiographic Zones**

### 5.2.1 Forest Inventory

Usually, 60 districts selected in the first stage are taken for detailed inventory of forests for a cycle of two years, but during 2008-10 the forest inventory was deferred on the recommendations of 'Technical Advisory Committee' of FSI to take up two important studies viz. 'Production and Consumption of Wood' and 'Missing Components of Forest Biomass'. Therefore, plot-wise primary data could not be made available for estimation of growing stock for the cycle 2008-10. Under this constraint, an alternative approach based on forest type groups and forest cover information (corresponding to year 2008-09) was developed and growing stock in forests has been estimated. This methodology has been advocated in 'Good Practices Guidance' of IPCC and discussed in details in Chapter 8. A brief account of methodology used for estimation of growing stock is, however, described in the paragraph given below.

FSI has recently completed a project on forest type mapping of the country from which information on 16 major type groups and about 178 forests types are available. Regrouping the major forest type groups into 14 type groups and one plantation category, a total 15 groups were created. Combining these groups with latest forest cover (in three canopy density classes) information, 45 strata were formed at the national level using GIS tools. The similar information has been generated for each state. For estimating growing stock, FSI has collected information on plot volume from about 21000 sample plots laid out during field inventory between the periods 2002-2008. These sample plots were overlaid on forest types and forest cover map. The sample points falling in different strata were then used for generating volume factors for each stratum. Since the growing stock is to be estimated for forest areas only, the area of forest cover outside the recorded forest

area from each stratum has to be excluded. For this purpose, all TOF patches of area 1.0 ha and more were separately estimated state-wise as forest cover includes all such patches. This information is used to exclude the area outside the recorded forest from each stratum. The stratum-wise area so obtained along with growing stock factor is used for estimating growing stock under a particular stratum. The similar exercise was carried out for all the strata falling in a state and by adding all the strata, growing stock of a particular state was obtained. By adding growing stock of all the states, estimate of growing stock has been obtained at national level.

### 5.2.2 Trees Outside Forests (TOF)

The selected 60 districts spread over 14 physiographic zones in the first stage sampling 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.

#### 5.2.2.1 TOF (Rural)

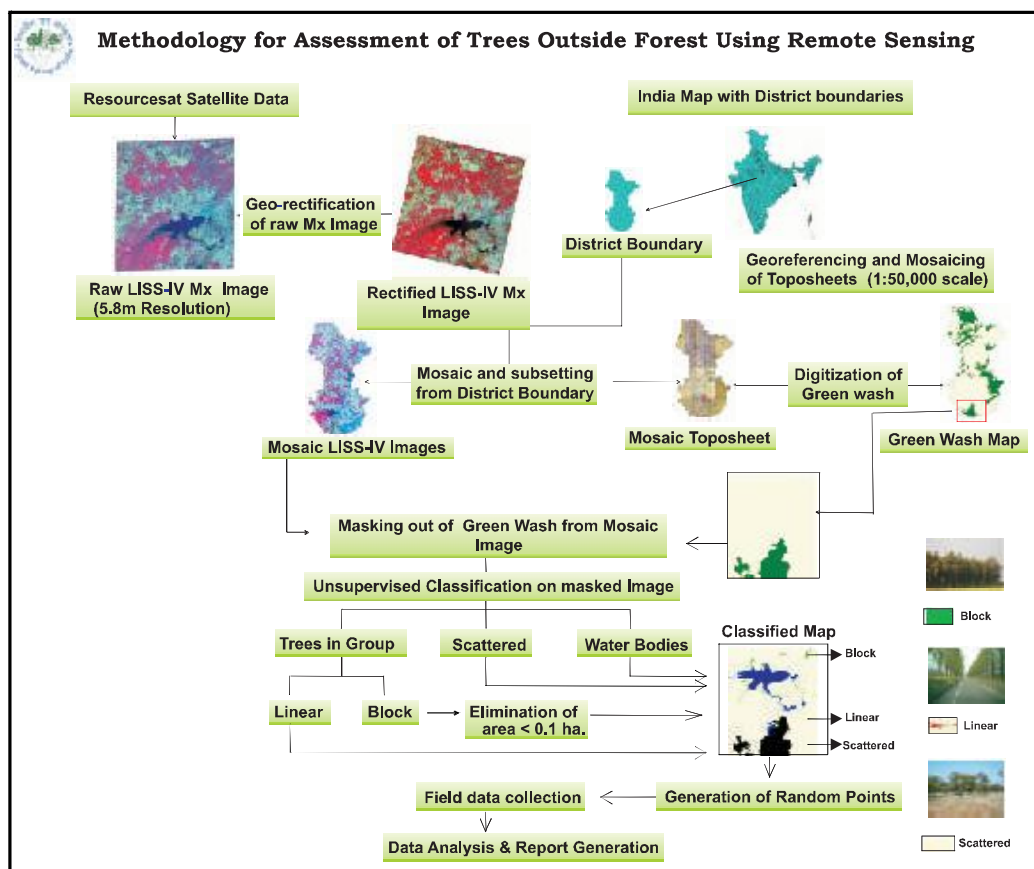
The second stage involves sampling in two phases in the selected districts. In the first phase, high resolution remote sensing satellite data is used for stratification of TOF resources in the selected districts into three strata namely, block, linear and scattered. In the second phase, simple random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

Satellite data of IRS P-6 LISS IV (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, were 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 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



**Fig. 5.2: Schematic Chart of Methodology of TOF**



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 of TOF using remote sensing is depicted in Figure 5.2.

### 5.2.2.2 TOF (Urban)

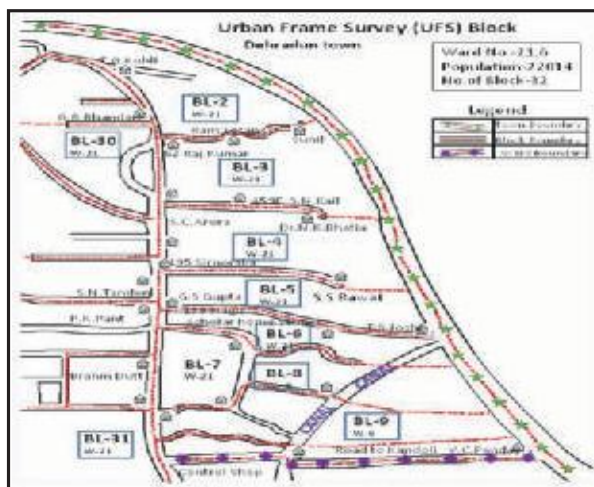
The inventory of urban area is carried out in urban centers as defined by office of Registrar General of India. The methodology used for inventory of TOF (rural) is not replicated for inventory of urban area because the geo-referenced boundaries of urban areas are not available. Moreover, it is not possible 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 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 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 number of UFS blocks as determined on the basis of pilot study are allocated in different town classes based on

population as per scheme given below:

- Class I : Population of 100 000 and above
- Class II : Population between 50000 and 99 999
- Class III : Population between 20000 and 49999
- Class IV : Population between 10000 and 19999
- Class V : Population between 5000 and 9999



**Fig. 5.3 UFS Block Map**

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

## 5.3 Data Processing

For the purpose of estimating growing stock of TOF presented in this SFR, the data of 178 districts inventoried during last three cycles from 2004 to 2010, have been used. The data collected in the field was checked manually to detect any inconsistency or error before entering into the computer. The data is entered in the computer using data entry module designed and developed by FSI for

TOF (Rural) and TOF (Urban) inventory separately.

The data processing was carried out separately for rural and urban areas. In rural areas, the estimation of growing stock was carried out 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 Registrar General of India. 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, the information on number of stems and volume per hectare and area of each stratum was

used. Using information of the selected districts, growing stock of the physiographic zone was estimated. The country wide growing stock estimate of TOF was generated by adding the estimates of physiographic zones.

## 5.4 Results

### 5.4.1 Physiographic Zone-wise Growing Stock of TOF

The physiographic zone-wise growing stock is estimated using the information on inventoried districts falling in that physiographic zone. For the current cycle, this information is available for TOF only as the forest inventory was not carried out during the years 2008-10. The estimates given in this ISFR are based on 30709 sample plots laid out in 178 districts during 2004 to 2010. The physiographic zone-wise growing stock (volume) in TOF is presented in Table 5.4.1.

**Table 5.4.1: Physiographic Zone-wise Growing Stock (Volume)**

Physiographic Zone	Area of Phy. Zone (km <sup>2</sup> )	Growing Stock (m cum)
Western Himalayas	329,255	191.23
Eastern Himalayas	74,618	67.11
North East	133,990	93.67
Northern Plains	295,780	101.96
Eastern Plains	223,339	102.36
Western Plains	319,098	66.10
Central Highlands	373,675	108.52
North Deccan	355,988	83.00
East Deccan	336,289	191.49
South Deccan	292,416	127.59
Western Ghats	72,381	117.47
Eastern Ghats	191,698	67.73
West Coast	121,242	141.98
East Coast	167,494	88.21
<b>TOTAL</b>	<b>3,287,263</b>	<b>1548.42</b>

The total growing stock of wood in TOF area of the country is estimated to be 1,548.42 m cum with a S.E.% of 2.64. The maximum growing stock in TOF is estimated in East Deccan (191.49 m cum) followed by Western Himalayas (191.23 m cum) and West Coast (141.98 m cum).

### 5.4.2 Growing Stock in TOF for top ten Species:

The percentage distribution of growing stock of top 10 species in TOF has been presented in Table 5.4.2. The top ten species have been determined on the basis of volume. The corresponding percentage of stems has also been given in the table. National level growing stock of major species by diameter class for TOF has been presented in Annexure III.

*Mangifera indica* contributes the maximum volume of 10.05 % followed by *Cocos nucifera* (8.14%) and *Borassus flabelliformis* (7.00 %)

### 5.4.3 State/UT-wise Growing Stock in Forests and TOF

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 were 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 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 5.4.3.

**Table 5.4.2 Growing Stock in TOF for top ten Species**

S.No.	Species	Total volume %	Total stems %
1.	<i>Mangifera indica</i>	10.05	6.32
2.	<i>Cocos nucifera</i>	8.14	6.38
3.	<i>Borassus flabelliformis</i>	7.00	3.24
4.	<i>Azadirachta indica</i>	4.53	4.85
5.	<i>Madhuca latifolia</i>	3.91	0.48
6.	<i>Pinus roxburghii</i>	3.21	3.82
7.	<i>Prosopis cineraria</i>	2.39	2.87
8.	<i>Eucalyptus species</i>	2.32	2.89
9.	<i>Acacia arabica</i>	2.34	3.62
10.	<i>Albizia species</i>	1.66	0.79

**Table 5.4.3: State/UT-wise Growing Stock in Forests and TOF**

State/UT	Geographical Area (km <sup>2</sup> )	Recorded Forest Area (km <sup>2</sup> )	Volume of Growing Stock (m. cum)		
			In Forest	In TOF	Total
Andhra Pradesh	275069	63814	255.082	115.683	370.765
Arunachal Pradesh	83743	51540	492.689	74.516	567.205
Assam	78438	26832	173.494	41.336	214.830
Bihar	94163	6473	35.186	47.195	82.381
Chhattisgarh	135191	59772	334.381	70.069	404.450
Delhi	1483	85	1.705	1.040	2.745
Goa	3702	1224	7.716	3.895	11.611
Gujarat	196022	18927	48.261	117.993	166.254
Haryana	44212	1559	4.893	15.268	20.161
Himachal Pradesh	55673	37033	321.314	21.146	342.460
Jammu & Kashmir	222236	20230	227.388	147.745	375.133
Jharkhand	79714	23605	116.308	51.308	167.616
Karnataka	191791	38284	315.156	101.733	416.889
Kerala	38863	11265	142.582	49.059	191.641
Madhya Pradesh	308245	94689	249.661	85.106	334.767
Maharashtra	307713	61939	293.669	147.029	440.698
Manipur	22327	17418	70.878	10.691	81.569
Meghalaya	22429	9496	45.411	20.964	66.375
Mizoram	21081	16717	68.042	9.392	77.434
Nagaland	16579	9222	40.955	12.681	53.636
Orissa	155707	58136	285.191	73.624	358.815
Punjab	50362	3084	15.710	19.305	35.015
Rajasthan	342239	32639	34.385	81.560	115.945
Sikkim	7096	5841	18.832	2.017	20.849
Tamil Nadu	130058	22877	144.404	70.328	214.732
Tripura	10486	6294	21.864	7.391	29.255
Uttar Pradesh	240928	16583	123.400	81.683	205.083
Uttarakhand	53483	34651	460.089	20.917	481.006
West Bengal	88752	11879	92.515	45.693	138.208
A & N Islands	8249	7171	53.185	0.666	53.851
Chandigarh	114	34	0.288	0.084	0.372
Dadra & Nagar Haveli	491	204	3.994	0.833	4.827
Daman & Diu	112	8	0.010	0.108	0.118
Lakshadweep	32	0	0.000	0.049	0.049
Puducherry	480	13	0.093	0.320	0.413
<b>Total</b>	<b>3287263</b>	<b>769538</b>	<b>4498.731</b>	<b>1548.427</b>	<b>6047.158</b>



## Growing Stock

The total growing stock in the country, both in forests and TOF, is estimated to be 6047.158 million cum of which forests contribute 4498.731 m cum and TOF accounts for 1548.427 m cum. Among the states/UTs, the maximum growing stock in forests is found in

Arunachal Pradesh (493 m cum) followed by Uttarakhand (460 m cum) and Chhattisgarh (334 m cum). In TOF, the maximum growing stock has been recorded in Jammu & Kashmir (148 m cum) followed by Maharashtra (147 m cum) and Gujarat (118 m cum).





