06

TREE COVER

Introduction 6.1

The National Forest Policy 1988 mandates that 33% of the geographical area of India should be under forest or tree cover. FSI, has been assessing forest cover since 1987 and tree cover since 2001. For this purpose, isolated trees and small patches of trees, which are less than 1 hectare in area and found outside recorded forest areas (RFA), are considered for assessment. India is one of the few countries in the world to have a robust and scientific system of periodic forest cover assessment and inventory of Forests and Trees Outside Forest (TOF).

Figure 6.1
Linear young plantation along road

As explained in Chapter - 2, forest cover assessment is an activity based on analysis of remote sensing data, through which the countrywide mapping of forest cover is carried out. The forest cover mapping exercise includes all areas more than 1 hectare in extent, and having tree canopy density of 10% and more, irrespective of land use, legal status and ownership. However, there are many small patches of trees which are less than 1 ha in extent, in village woodlots, homesteads and trees along linear features such as roads, canals, bunds, trees in urban areas and also scattered trees etc. which do not get included in the forest cover due to technological limitations of satellite data used for the forest cover mapping. The extent of such small patches of the trees outside the RFA is estimated as tree cover using a methodology based on stratified random sampling, and estimated partly by using high-resolution data and partly from field inventory data.

Figure 6.2 Block plantation

6.2 Tree Cover and Trees Outside Forest (TOF)

Tree cover and Trees Outside Forest (TOF) are two different entities but are closely related to each other. TOF refers to all trees outside the RFA irrespective of size of the patch. Tree Cover, on the other hand, means patches of trees as well as isolated trees outside the RFA on areas less than one hectare. Hence, the trees included in Tree Cover constitute only a part of TOF and therefore, the former is a subset of the latter. The Figure 6.3 gives an illustrative relationship between the TOF and Tree Cover.

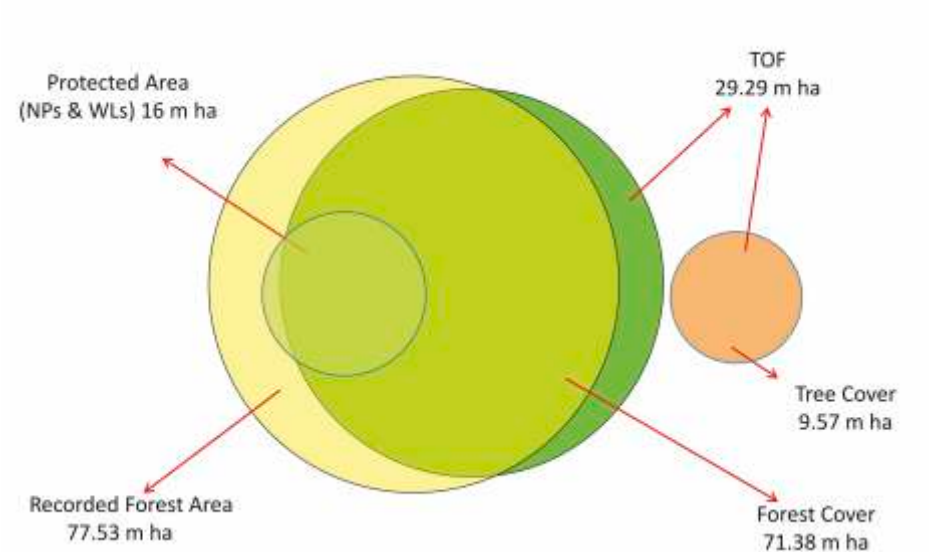

Figure 6.3 Relationship between the TOF and Tree Cover

6.3 Methodology for Tree Cover estimation

Since 2016, with the implementation of new NFI design, tree cover of the country has been estimated State-wise from the data collected during inventory of TOF in rural and urban areas by adopting the grid-based inventory design. Separate methodologies are followed for inventory of TOF (rural) and TOF (urban).

Estimation of Tree Cover in Rural Areas 6.3.1

For the TOF inventory in rural areas, high-resolution satellite image is used for stratification of TOF into three strata, namely block, linear and scattered. The methodology used for the estimation is given below.

The Multispectral data of Sentinel-II satellite having a spatial resolution of 10 meter and swath of 290 km has been used for classification of the selected grids. The satellite data is downloaded and geo-rectified with the help of Survey of India (SOI) Open Series Map (OSM) toposheets of 1:50,000 scale. Thereafter, the image is classified into various land use classes such as settlements, water bodies, tree cover, agriculture and other land cover classes. This classification enables the analyst to distinguish between the tree cover and other classes. The classified image is visually analysed for editing and refinement. Since the minimum mapping area is 0.1 ha, the pixels are clumped and cluster of pixels having area less than 0.1 ha are eliminated. After editing the classified image, final classified map is generated showing three classes in TOF areas, namely Block, Linear and Scattered. From the classified TOF map, area under each class is calculated. In addition, area of Un-Culturable Non-Forest Areas, which do not support tree vegetation, such as rivers and water bodies, riverbeds, snow covered mountains etc. is also calculated. The schematic (Flow) chart of the methodology of TOF using remote sensing is depicted in the Figure 6.4.

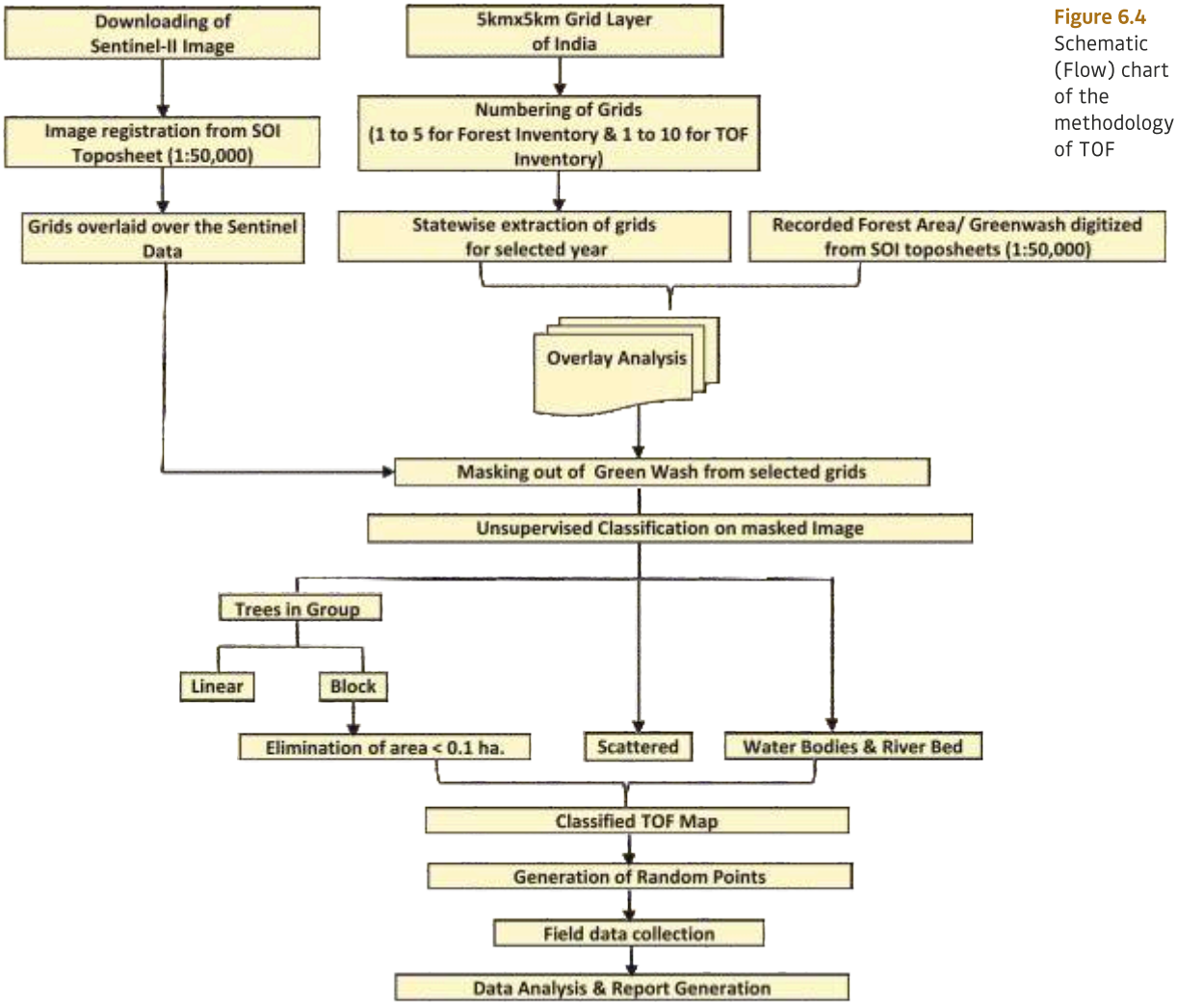

Figure 6.4 Schematic (Flow) chart of the methodology of TOF

For the fieldwork, the plot size for Block is 0.1 ha square plot and Linear strata is 10 m x 125 m strip, respectively. In case of scattered stratum, the plots size is 0.5 ha in hilly areas and 3 ha in non-hilly areas.

Figure 6.5
TOF Inventory - Scattered stratum

Sample points are randomly generated within selected grids for each stratum and the data of pre-decided variables like diameter at breast height (dbh), crown diameter, species and category of plantation etc. are collected in pre-designed formats. Complete enumeration of all the trees with dbh 5 cm and above is carried out.

The tree cover in rural areas comprises of the area of block and linear tree patches between 0.1 ha to 1.0 ha. For estimation of tree cover, the area of block and linear patches is computed from the classified map of the TOF for the selected grids. The blocks and linear patches having area more than 1.0 ha are eliminated as the same have already been included in the forest cover. The blocks and linear patches with less than 1.0 ha area are taken for the estimation of tree cover. The computed area of block and linear strata are estimated at the State level with rural Culturable Non-Forest Area (CNFA).

Figure 6.6
Trees along Canal

For estimation of tree cover under the scattered stratum, the crown area of each tree species recorded during the field inventory is used to calculate the crown cover of each plot in scattered stratum. The enumerated crown cover is then estimated at the State level with the help of CNFA of the scattered stratum of the entire state. The area so obtained from the scattered stratum is converted into equivalent notional area corresponding to 70% canopy density. The total tree cover of the State is obtained by adding the estimated area of block, linear and scattered tree formations.

Estimation of Tree Cover in Urban Areas 6.3.2

The tree cover in urban areas is estimated from the data collected while carrying out the inventory of Trees Outside Forests (Urban) i.e., TOF (U). For the TOF (U) inventory, urban centres defined by the office of Registrar General of India are considered as study area. For the TOF (U), the high-resolution satellite data is not used due to non-availability of digital boundaries of the urban areas. Moreover, configuration of an urban setting does not allow replication of the same design as is used for the rural inventory. Therefore, for urban areas, the sampling frame is taken from the National Statistical Office (NSO) which has stratified the urban areas into Urban Frame Survey (UFS) blocks. UFS blocks have well defined boundaries and they usually indicate a population size of 600-800 persons or 120 to 160 households. UFS blocks cover the whole area within the geographical boundary of a town and include vacant lands.

Figure 6.7
Trees in urban setting

The list of all urban towns and cities as per census 2011 has been used to identify the urban grids. For the selected urban grids, optimum numbers of UFS blocks are selected for the urban inventory. The data of pre-decided variables like dbh, crown diameter, species name and category of plantation, etc. are collected in pre-designed formats. The complete enumeration of all the trees with 5 cm and above dbh is carried out in the prescribed formats. The area of each surveyed UFS block is also measured with the help of GPS.

To compute the tree cover of the urban area, the urban blocks with area of more than 1 ha are eliminated, as the same have already been included in the forest cover. For the remaining trees in the urban areas, the tree cover is computed from crown diameter of trees recorded during the urban inventory. Using enumerated crown cover from the selected grids and the urban CNFA, the tree cover is estimated for the urban areas. The area of tree cover so obtained is converted into equivalent notional area corresponding to 70% canopy density. The total tree cover of the State is arrived at by adding the estimated tree cover of rural and urban areas.

6.4 State-wise estimates of Tree Cover

The total tree cover of the country has been estimated 95,748 sq km. There is an increase of 721 sq km in the extent of tree cover as compared to the previous assessment of 2019. The standard error of the tree cover estimate at the national level has been assessed at 4.01%. The State wise estimates of tree cover is given in Table 6.1. The standard error at the State level varies from 2.23% to 16.49%. As per Table 6.1, the State having maximum tree cover is Maharashtra (12,108 sq km) followed by Rajasthan (8,733 sq km), Madhya Pradesh (8,054 sq km), Karnataka (7,494 sq km) and Uttar Pradesh (7,421 sq km). Considering the percentage of geographical area of State/UTs, the UT of Chandigarh shows highest percentage of tree cover (13.16%) followed by Delhi (9.91%), Kerala (7.26%), and Goa (6.59%).

(in sq km)

Table 6.1 State/ UT wise Tree Cover Estimates

S. No.	Name of the State/UT	Geographical area	Tree cover	Percentage of geographical area
1.	Andhra Pradesh	162,968	4,679	2.87
2.	Arunachal Pradesh	83,743	1,001	1.20
3.	Assam	78,438	1,630	2.08
4.	Bihar	94,163	2,341	2.49
5.	Chhattisgarh	135,192	5,355	3.96
6.	Delhi	1,483	147	9.91
7.	Goa	3,702	244	6.59
8.	Gujarat	196,244	5,489	2.80
9.	Haryana	44,212	1,425	3.22
10.	Himachal Pradesh	55,673	675	1.21
11.	Jharkhand	79,716	2,867	3.60
12.	Karnataka	191,791	7,494	3.91
13.	Kerala	38,852	2,820	7.26
14.	Madhya Pradesh	308,252	8,054	2.61
15.	Maharashtra	307,713	12,108	3.93
16.	Manipur	22,327	169	0.76
17.	Meghalaya	22,429	698	3.11
18.	Mizoram	21,081	444	2.11
19.	Nagaland	16,579	365	2.20
20.	Odisha	155,707	5,004	3.21
21.	Punjab	50,362	1,138	2.26
22.	Rajasthan	342,239	8,733	2.55`
23.	Sikkim	7,096	39	0.55
24.	Tamil Nadu	130,060	4,424	3.40
25.	Telangana	112,077	2,848	2.54
26.	Tripura	10,486	228	2.17
27.	Uttar Pradesh	240,928	7,421	3.08
28.	Uttarakhand	53,483	1,001	1.87
29.	West Bengal	88,752	2,349	2.65
30.	Andaman & Nicobar Islands	8,249	23	0.28
31.	Chandigarh	114	15	13.16

(in sq km)

S. No.	Name of the State/UT	Geographical area	Tree cover	Percentage of geographical area
32.	Dadra & Nagar Haveli and Daman & Diu	602	32	5.48
33.	Jammu & Kashmir (Shape file area = 54,624) * #	222,236	3,511	6.43
34.	Ladakh (Shape file area = 1,68,055) #		954	0.57
35.	Lakshadweep	30	0.05	0.17
36.	Puducherry	490	23	4.69
	Total	**3,287,469**	**95,748**	**2.91**

* *includes Jammu & Kashmir area outside LOC that is under illegal occupation of Pakistan and China.*

\# *Area of shapefile provided by Survey of India (August. 2021). Notified geographical areas for individual UTs from SOI awaited.*

Trees Outside Forests 6.5

TOF refers to all trees growing outside recorded forest areas, irrespective of the patch size. The remote sensing based forest cover mapping includes all patches of more than one hectare within and outside the RFA. Sampling approach based tree cover estimates include tree patches between 0.1 to 1.0 hectare outside the RFA. Tree cover outside the forests is estimated by using the sampling based approach. Therefore, the patches of 1 ha and above outside the RFA and Tree Cover, both constitute the TOF.

During recent years, there has been a growing recognition of the importance of the Trees outside forests being a major source of forest produce in the country and timber, firewood and small wood supply coming from outside the forest areas is significant. They are one of the important renewable resources that contribute to climate change mitigation, as every patch of forest around the world is absorbing carbon. Currently, TOF is the main source of wood produced in the country, particularly from the agroforestry sector. As per an FAO Report[1] , about 1.6 billion people or 25% of the global population worldwide depend directly or indirectly on forests for food, shelter, energy, medicines, income and from the perspective of their ecological, socio-economic and cultural significance.

[1] *FAO (2014): The State of the world's forest genetic resources. FAO commission on genetic resources for food & agriculture. Rome.*

6.5.1 Extent of TOF

As per the current estimation, the extent of TOF has been found to be 29.29 million hectares which is about 36.18% of the total forest and tree cover of the country. The following table gives extent of TOF in the States and UTs of the country.

Table 6.2 State/UT wise extent of TOF

(in sq km)

S. No.	State / UT	Geog. area	Tree cover	Forest cover outside RFA	Extent of TOF	%of Forest & Tree Cover of the State/UTs	% of Geog. area of the State/UTs
1.	Andhra Pradesh	1,62,968	4,679	5,545	10,224	29.67	6.27
2.	Arunachal Pradesh	83,743	1,001	7,751	8,752	12.98	10.45
3.	Assam**	78,438	1,630	8,309	9,939	33.19	12.67
4.	Bihar*	94,163	2,341	2,550	4,891	50.31	5.19
5.	Chhattisgarh*	1,35,192	5,355	13,250	18,605	30.46	13.76
6.	Delhi	1,483	147	136	283	82.70	19.07
7.	Goa*	3,702	244	1,024	1,268	50.96	34.25
8.	Gujarat	1,96,244	5,489	5,091	10,580	51.82	5.39
9.	Haryana	44,212	1,425	1,229	2,654	87.65	6
10.	Himachal Pradesh	55,673	675	4,799	5,474	33.96	9.83
11.	Jharkhand	79,716	2,867	11,439	14,306	53.81	17.95
12.	Karnataka	1,91,791	7,494	16,182	23,676	51.22	12.34
13.	Kerala*	38,852	2,820	11,574	14,394	59.79	37.05
14.	Madhya Pradesh	3,08,252	8,054	12,721	20,775	24.28	6.74
15.	Maharashtra*	3,07,713	12,108	14,758	26,866	42.71	8.73
16.	Manipur	22,327	169	1,765	1,934	11.53	8.66
17.	Meghalaya**	22,429	698	2,248	2,946	16.60	13.13
18.	Mizoram	21,081	444	264	708	3.88	3.36
19.	Nagaland	16,579	365	3,623	3,988	31.61	24.05
20.	Odisha*	1,55,707	5,004	19,470	24,474	42.82	15.72
21.	Punjab	50,362	1,138	1,059	2,197	73.60	4.36
22.	Rajasthan*	3,42,239	8,733	4,095	12,828	50.53	3.75
23.	Sikkim**	7,096	39	1,287	1,326	39.23	18.69
24.	Tamil Nadu*	1,30,060	4,424	8,888	13,312	43.16	10.24
25.	Telangana*	1,12,077	2,848	2,518	5,366	22.30	4.79
26.	Tripura	10,486	228	2,289	2,517	31.66	24
27.	Uttar Pradesh	2,40,928	7,421	5,675	13,096	58.89	5.44
28.	Uttarakhand	53,483	1,001	7,520	8,521	33.67	15.93
29.	West Bengal*	88,752	2,349	9,720	12,069	62.92	13.6
30.	A & N Islands*	8,249	23	536	559	8.26	6.78
31.	Chandigarh*	114	15	14	29	77.03	25.6

(in sq km)

S. No.	State / UT	Geog. area	Tree cover	Forest cover outside RFA	Extent of TOF	%of Forest & Tree Cover of the State/UTs	% of Geog. area of the State/UTs
32.	Dadra & Nagar Haveli and Daman & Diu*	602	32	68	100	38.39	16.57
33.	Jammu & Kashmir* (Shape file Area= 54,624)	2,22,236	3,511	8,211	11,722	47.08	21.46
34.	Ladakh (Shape File Area = 1,68,055)		954	1,472	2,426	75.20	1.44
35.	Lakshadweep	30	0.05	27	27	100.00	90.5
36.	Puducherry	490	23	52	75	98.69	15.37
	Total	**32,87,469**	**95,748**	**1,97,159**	**2,92,907**	**36.18**	**8.91**

 # Area of shapefile provided by Survey of India (August, 2021). Notified geographical area from SOI is awaited.

*** The States/ UTs have provided RFA boundaries for the first time.*

** The States/ UTs have updated the RFA boundaries, accordingly the RFA area has also changed and it is different than the figures reported in ISFR 2019.*

The States/UTs which have provided RFA boundaries are shown in light green colour while the other States/ UTs where GW has been used are shown in dark green colour.

** Includes Jammu & Kashmir area outside LOC that is under illegal occupation of Pakistan and China.*

It is seen from the above table that the State of Maharashtra (26,866 sq km) is having largest extent of TOF in the country, followed by Odisha (24,474 sq km) and Karnataka (23,676 sq km). In terms of percentage of geographical area, the Union Territory of Lakshadweep (90.50%) has highest percentage of TOF, followed by Kerala (37.05%) and Goa (34.25%).

Extent of TOF may also be seen as the sum of extent of forest cover outside the RFA as given in the Section 2.10 of the Chapter 2, and tree cover as presented in the Section 6.4 of this chapter.

Tree Cover

6.6 Conclusion

Over the last 5 biennial assessments, the tree cover of the country has shown an increasing trend. The tree cover has risen from 90,844 sq km in the 2011 assessment to 95,748 sq km as per the current assessment, showing a decadal increase of 4,904 sq km.