





02

FOREST COVER



Introduction

2.1

Forest Cover refers to the extent of land area that is covered by forest resources in the country. Forest Survey of India (FSI) initiated assessment of Forest Cover of the country for the first time in the year 1987 and since then wall-to-wall Forest Cover Mapping (FCM) of the country is carried out using remote sensing based methodology at biennial interval. So far, 16 cycles have been completed and the current assessment is 17th in the series of continuous Forest Cover mapping in the country. All lands more than 1 hectare in area, with a tree canopy density of more than 10 percent, including tree orchards, bamboo, palms etc., occurring within recorded forest and other government lands, private community or institutional lands, are included in the assessment of Forest Cover.

The National Forest Policy of India 1988 envisages a goal of achieving 33 percent of the geographical area of the country under forest & tree cover. The remote sensing based nation-wide Forest Cover mapping at biennial interval, serves as a monitoring mechanism towards achievement of this goal. Periodic Forest Cover assessment at definite intervals helps in assessing the status of forests in the country and its broad trend. The results of the biennial Forest Cover assessment are published in the India State of Forest Report (ISFR) and is a widely used primary information source across the Central Government, State Governments and forestry professionals of the State Forest Departments, academia, international organizations and other stakeholders. These inputs about the forest resources of the country are used for broad evaluation and formulation of forest related policies, programmes, legislations and different activities in the country.

2.2

Objectives of the Nation-wide Forest Cover Mapping

The wall-to-wall mapping of the country's Forest Cover is carried out using a medium resolution satellite data (23.5 m) on a scale of 1:50,000. Each cycle is completed in two years due to the vastness of the country and scientific rigor of the methodology for ensuring high levels of accuracy.

The main objectives of the biennial Forest Cover Mapping are as follows:

- To monitor Forest Cover and changes therein at national, state and district level.
- To generate forest density class wise information about Forest Cover and changes therein.
- To generate Forest Cover information under different criteria (viz. Forest Cover inside and outside recorded forest areas, altitude zone and slope wise, Forest Cover in hill and tribal districts and north eastern states etc.).
- To prepare Forest Cover and other thematic maps derived from it for the whole country.
- To provide a primary base layer information for assessment of different parameters including growing stock, forest carbon etc.
- To provide information for international reporting.

2.3

Satellite Data and Period

In the current assessment, the wall-to-wall mapping of the forest of the entire country has been carried out using medium resolution satellite data (23.5 m) from the indigenous LISS-III sensor of IRS Resourcesat series of satellites from Indian Space Research Organization. The details of the satellite data used in the current cycle (17th cycle) of Forest Cover mapping are given in Table 2.1.

Table 2.1 Specifications of LISS-III Data from Resourcesat-2

Ground Resolution	23.5 m in all the 4 bands
Spectral Resolution	Green: 0.52 - 0.59 µm Red: 0.62 - 0.68 µm Near Infrared: 0.77 - 0.86 µm Short Wave Infrared: 1.55 - 1.70 µm
Radiometric Resolution	10 bits
Temporal Resolution (revisit period)	24 days
Swath (width of the strip)	141 km
Area coverage of one scene	20,000 sq km approx

The LISS-III satellite data used in the 17th cycle FCM has been procured in digital form from the National Remote Sensing Centre (NRSC), Hyderabad, which is the authorized agency for this purpose. The Satellite data for all the states pertains to the period of October to December, 2019, as these were the months when the cloud cover was low and the post monsoon vegetation with good foliage provided satisfactory reflectance. However, some parts of the country especially the North Eastern region, Eastern Coastal belts and Andaman & Nicobar Islands had cloud cover even during this period and in such cases, additional images were obtained for the period of January to March 2020. A total of 306 scenes of IRS Resourcesat 2 LISS III covering the entire country have been used for Forest Cover mapping exercise.

The use of LISS-III data, on a scale of 1:50,000 and 1 ha area as Minimum Mapping Unit (MMU) is based on various considerations like large area of the country to be mapped, short periodicity of two years between successive cycles, country level perspective of reporting and data availability. All these factors limit the data choice to medium spatial resolution, wherein indigenous LISS-III data of 23.5m X 23.5m is preferred for the exercise.

Forest Cover

2.4

The Forest Cover includes all lands more than one hectare in area with tree canopy density of more than 10 percent. The Forest Cover reported in the ISFR does not make any distinction between the origin of tree crops (whether natural or manmade) or tree species, and encompasses all types of lands irrespective of their ownership, land use and legal status. Thus all the tree species along with bamboos, fruit bearing trees, coconut palm trees etc. and all the areas including forest, private, community, government or institutional land, meeting the above defined criteria have been termed as Forest Cover. LISS-III data with the resolution of 23.5m allows mapping at the maximum scale of 1:50,000, at which the MMU becomes 1 ha. The MMU represents the cartographic limit of the mapping scale corresponding to a discernible polygon of 2 mm X 2 mm on the map. During the interpretation of the satellite images, Forest Cover is mapped in canopy density classes as given below in Table 2.2.

Table 2.2 Forest Cover classified in terms of canopy density classes

Class	Description
Very Dense Forest	All lands with tree canopy density of 70 percent and above.
Moderately Dense Forest	All lands with tree canopy density of 40 percent and more but less than 70 percent.
Open Forest	All lands with tree canopy density of 10 percent and more but less than 40 percent.
Scrub	Forest lands with canopy density less than 10 percent.
Non-forest	Lands not included in any of the above classes. (includes water)



Very Dense Forest



Moderately Dense Forest



Open Forest



Scrub

Figure 2.1
Pictorial depiction of different Forest Cover classes and scrub

2.5

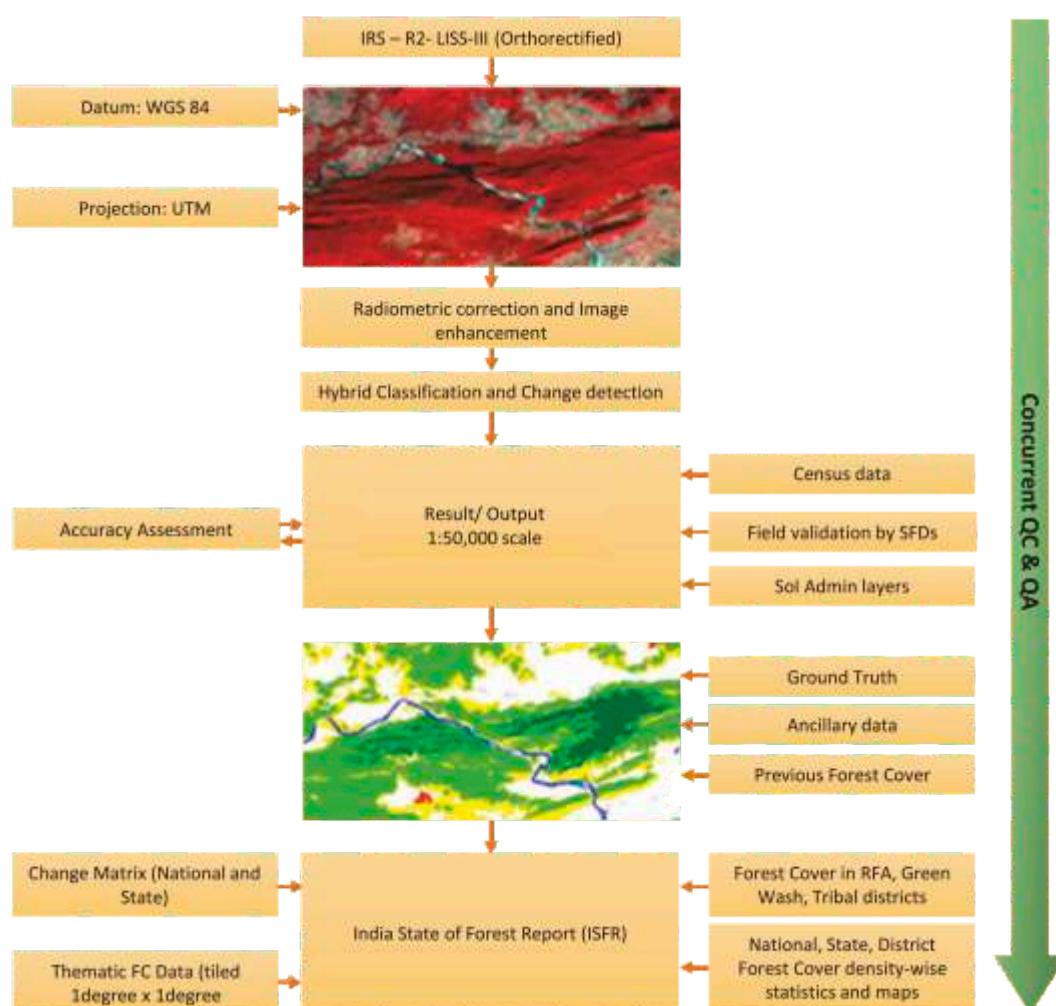
Forest Cover Assessment: Approach

The assessment of Forest Cover involves a hybrid approach for classification of satellite data using digital image processing, visual image analysis, post classification comparison, ground truthing and validation by the State Forest Departments, incorporation of post-field corrections, followed by generation of output in the form of maps and area statistics. Schematic diagram of the broad approach followed in FCM is given in Figure 2.2.

The hybrid classification approach followed in Forest Cover mapping utilizes the potential of the algorithms to generate cluster of pixels having close association and then assigning information class such as appropriated Forest Cover density class to each cluster. Further, it is supported by the knowledge of the analysts, information from collateral sources and the observations made during ground truthing at more than 3,400 points. Continuous refinement in the methodology of Forest Cover mapping has been carried out in successive FCM cycles in order to capture the latest developments in image interpretation techniques.

Ortho-rectified LISS III data is procured from NRSC, Hyderabad for the entire country on which radiometric correction is performed to reduce the radiometric distortions, which creep in at the time of satellite data acquisition.

Figure 2.2
Schematic diagram of the broad approach followed in Forest Cover Mapping (FCM)



The process adopted involves calibration of Digital Numbers (DN) to Reflectance, based on rescaling factors and further conversion to Top of Atmospheric (ToA) reflectance using a specific model developed for the sensor.

Radiometric correction is aimed at mathematically transforming DN values to have high degree of correspondence with the features on the ground.

To ensure uniformity, consistency and high level of accuracy in the FCM exercise as it involves work by a team of more than 40 analysts, all the steps of the FCM methodology have been standardized as a protocol and a detailed manual has been prepared.

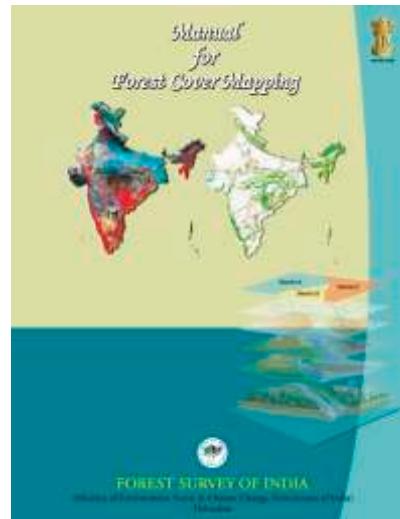


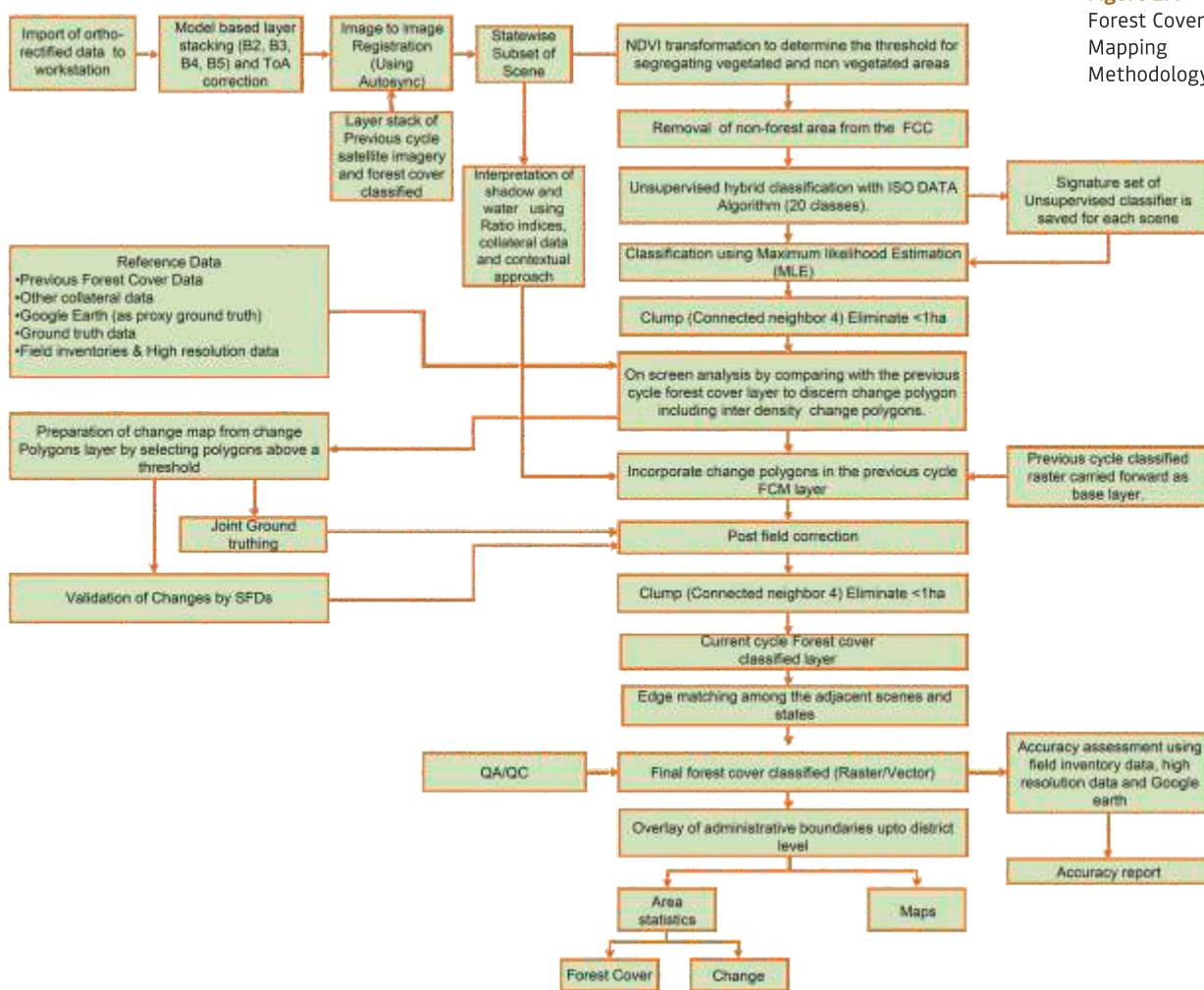
Figure 2.3
Forest Cover Mapping manual

Forest Cover Mapping Methodology

2.6

The schematic diagram of the Forest Cover mapping methodology is given in the Figure 2.4 below

Figure 2.4
Forest Cover Mapping Methodology

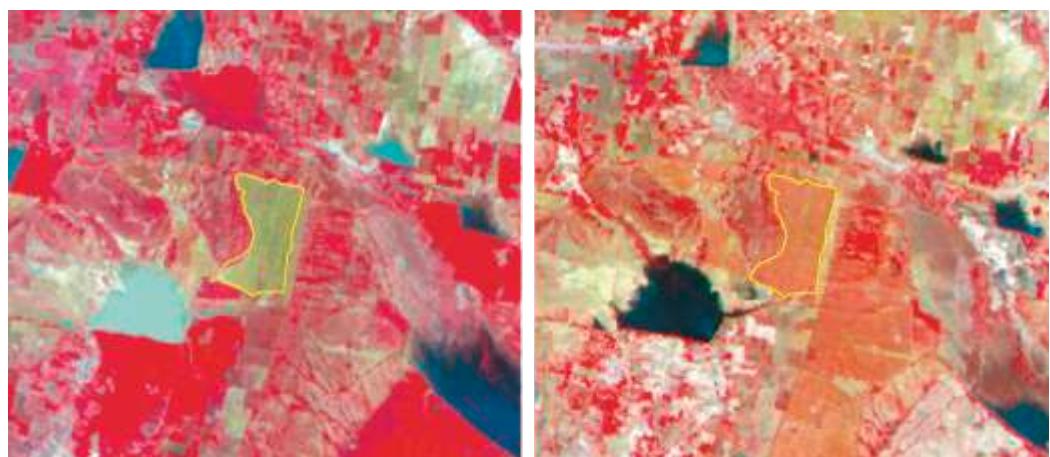




FCM layer of the previous assessment (16th cycle) was made compatible with the current satellite data using digital image processing tools of geo-rectification. Registration of the previous cycle imagery over the current cycle imagery ensures better image-to-image correspondence, comparability and minimization of errors due to shift over the corresponding Forest Cover maps. This is followed by image interpretation which broadly involves the following steps:

- (i) Normalised Difference Vegetation Index (NDVI) Transformation: Current satellite data after ToA is put to NDVI transformation for segregating non-vegetated and vegetated areas.
- (ii) Unsupervised classification: Vegetated part of the image resulting from the previous step is classified using ISODATA algorithm into VDF, MDF, OF, scrub and other classes attributed as Non-Forest.
- (iii) Maximum Likelihood Estimator (MLE): The signature set for unsupervised classification is saved for each scene which is further used to perform MLE on masked NDVI image. This is carried out as MLE is the most suitable classifier for the input samples/clusters with Normal distribution, as it takes most of the variables into account. The clump eliminate is carried out on this layer to retain patches above 1 ha.
- (iv) On-screen Visual Analysis: NDVI based Forest Cover layers are compared on screen, patch-wise, to capture change polygons. The interpretation for water is done separately. In case of cloud, shadow, haze, mixing of non woody vegetation with forest etc., the information from other collateral data is also used to discern the change polygons (Figure 2.4). The change layer is maintained in raster as well as vector formats.
- (v) The change layer so generated, is then overlaid on the previous cycle classified to obtain the classified layer for the present cycle. District-wise Forest Cover area statistics is generated for each State/UT and compiled together to determine the Forest Cover of the entire country.

Figure 2.5
Illustration of
change
polygons





Use of Collateral data to aid interpretation

2.6.1

Areas with thick cloud cover, hilly areas with deep hill shadows, mixing of bushy and agricultural vegetation adjoining to forest, water logged areas, forests under senescence during the data period, area under thick haze etc. are quite difficult to interpret. In such scenarios, the data from collateral sources like Google Earth, Sentinel-2 data of European Space Agency, Landsat 8 data of PSI from United States Geological Survey (USGS) and National Forest Inventory (NFI) of FSI plays a very vital role by facilitating the interpreter with additional information for analysis. Figure 2.6 depicts the results from different sensor data. It is seen that for the same area, collateral data of Sentinel-2 results in better delineation of ground features.

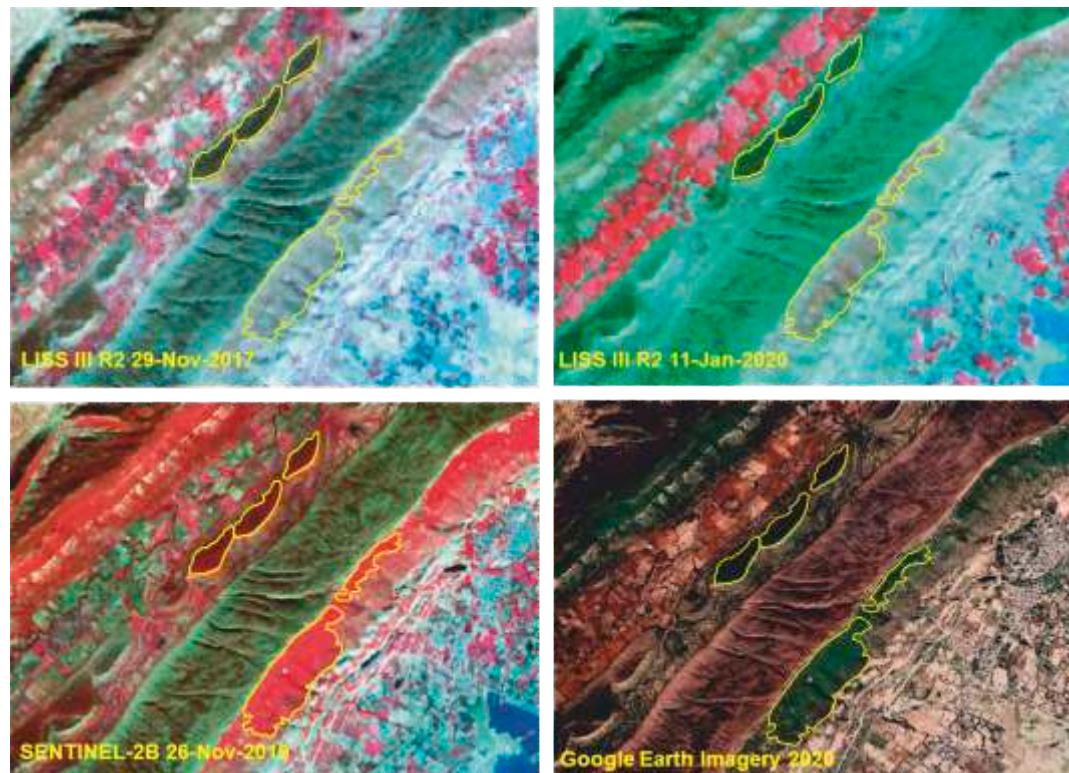


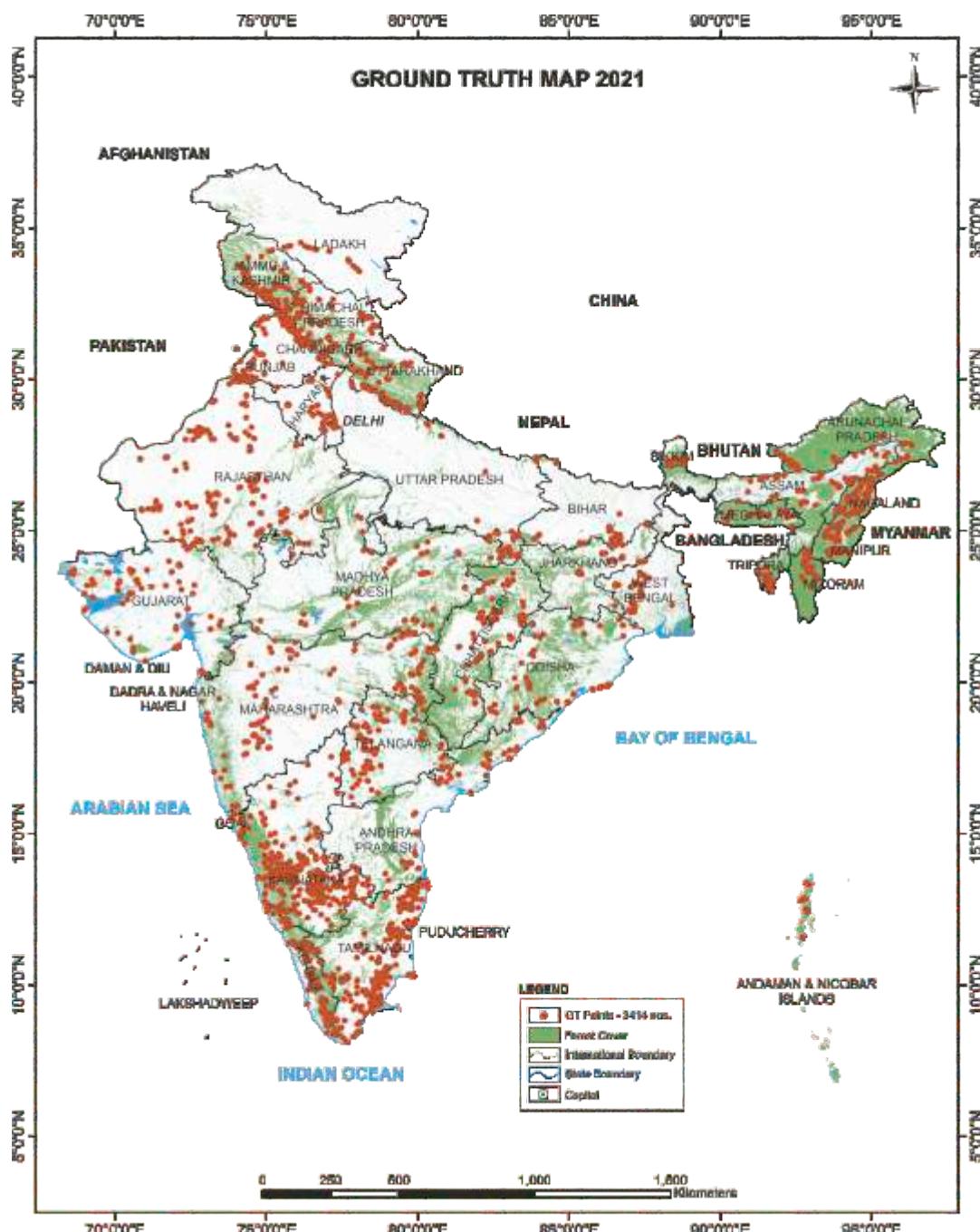
Figure 2.6
Illustration of
change
polygons using
Collateral data

2.6.2 Ground Truthing

Ground truthing is an essential part of remote sensing based assessment and mapping of forest resources. It enables linking of image data to the ground reality. After the change polygons are discerned, doubt points are selected by the analysts on the basis of certain criteria like significant change, mixing of signature and distortion in signature due to radiometry or phenological changes. More than 3,400 ground truth points were visited by the analysts during the current FCM cycle. Figure 2.7 shows the locations of the ground truth points.

Figure 2.7

Map showing
Ground Truth
locations of
Forest Cover
Mapping



Use of Mobile Application for ground truthing

2.6.3

An in-house android based ground truthing mobile application developed by FSI team was used for collection, storage and analysis of the information related to ground truthing exercise. Ground data information gathered in the form of geo-tagged photographs, canopy density, tree species and other observations related to change, is stored on the mobile application, and the same was transmitted to the server at FSI head quarter. The data stored in the server was retrieved and used as point GIS layer over the interpreted Forest Cover in order to incorporate changes observed during ground truthing.

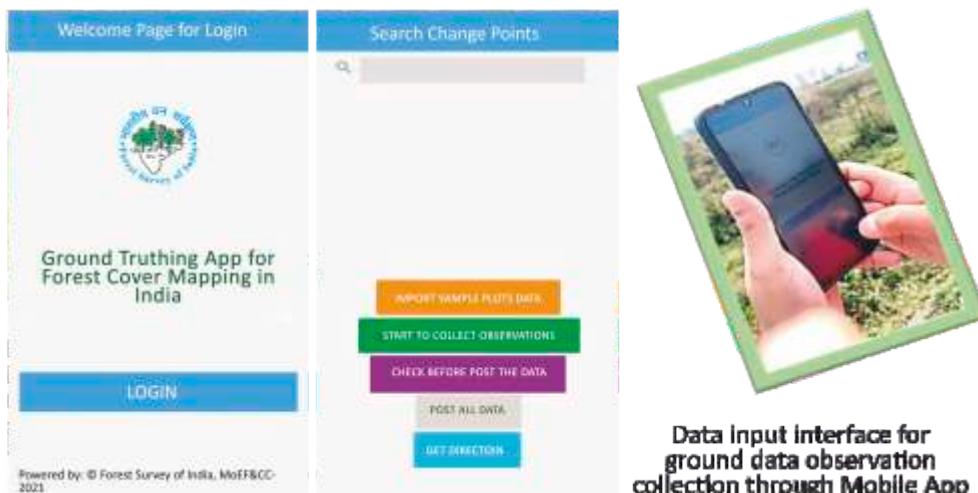


Figure 2.8
Field Data Collection Application for Ground Truth



Figure 2.9
Mobile based Web GIS System for FCM Ground Truthing Change Points Data Collection

Validation of Change Maps

2.6.4

The maps prepared using change polygons, depict changes in current Forest Cover with respect to previous Forest Cover. The change maps with polygons of area greater than 5 ha are sent to concerned SFDs for validation. Once the feedback is received from SFDs, necessary corrections are incorporated in the final change layer. The final layer for the change is retained in both raster and vector formats. Maintaining the layer in vector format helps in incorporating additional information in the attribute table. The vector layer also facilitates compatibility to the GIS environment for further analysis.

2.6.5

Post Field correction and Forest Cover layer generation

After completion of the field validation, necessary corrections are made in the change file as per the ground truth observations, ancillary data and inputs from the State Forest Departments. Once the post-field correction is completed, the change file is incorporated over the Forest Cover layer of the previous assessment to attain the Forest Cover layer for the current assessment. The classification is completed after edge matching with the adjacent scenes as well as with the adjacent States. A mosaic of the classified raster data is created for the entire State, followed by clump & elimination for removing the patches of area less than 1 ha.

2.6.6

Concurrent Quality Check & Quality Assurance (QC&QA)

Adherence to the defined quality standards is always ensured through concurrent monitoring at every step. The quality standard of the assessment is monitored at every step of the methodology by using the predefined formats provided in the manual. The supervising officers check whether the methodology followed by the analyst is as per the Manual and the defined quality standards have been achieved. During classification stage of the image interpretation, all the scenes are thoroughly checked at different levels. The QC&QA teams keep a track of progress at each step. A final round of QC&QA was carried out at the headquarters in which all analysts and supervisory officers from the Headquarters and Regional offices participated.

2.7

Limitations of the Forest Cover Mapping

Remote sensing data has certain inherent limitations which affect the accuracy of the Forest Cover mapping. Some of the limitations are mentioned below:

- Land cover features having a geometric dimension less than 23.5 m on the ground are not discernible, hence cannot be captured.
- Due to cloud cover and shadows in satellite data, considerable ground details may sometimes be obscured. Collateral data helps in the image processing of such areas to a certain extent.
- Non-availability of appropriate season data and phenological changes in forests sometimes puts constraints on the interpretation of the features owing to poor reflectance of data.
- Agricultural crops like sugarcane, cotton, etc. adjacent to forests and occurrence of weeds like lantana within forest areas causes mixing of spectral signatures and often make it difficult to interpret and delineate the Forest Cover precisely.
- Many a times, young plantations and tree species with less chlorophyll or inadequate foliage coupled with edaphic factor, are not discernable on satellite images due to inadequate reflectance.
- Haze and other atmospheric distortions pose difficulty in interpretation.



Forest Cover: 2021 Assessment

2.8

The Forest Cover of the country has been classified and mapped into three canopy density classes viz. Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF). In addition to the three density classes, scrub areas, which are not part of Forest Cover, have also been classified and mapped.

The Table 2.3 presents area figures for the above classes of Forest Cover and scrub. The relative composition of Forest Cover in different classes of Forest Cover is depicted in the pie chart (Figure 2.10).

Table 2.3 Forest Cover of India

(in sq km)

Class	Area	Percentage of Geographical Area
Very Dense Forest	99,779	3.04
Moderately Dense Forest	3,06,890	9.33
Open Forest	3,07,120	9.34
Total Forest Cover	7,13,789	21.71
Scrub	46,539	1.42
Non-Forest	25,27,141	76.87
Total Geographical Area	32,87,469	100.00

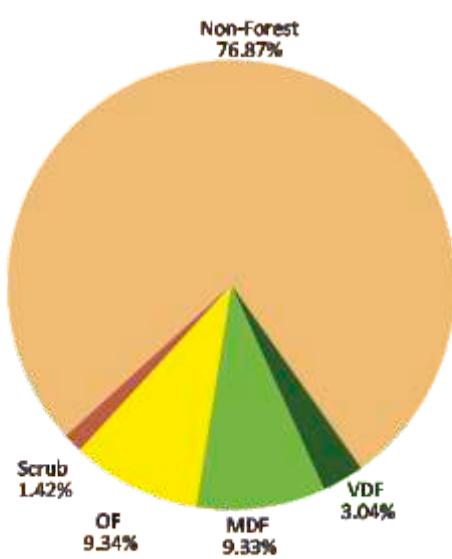
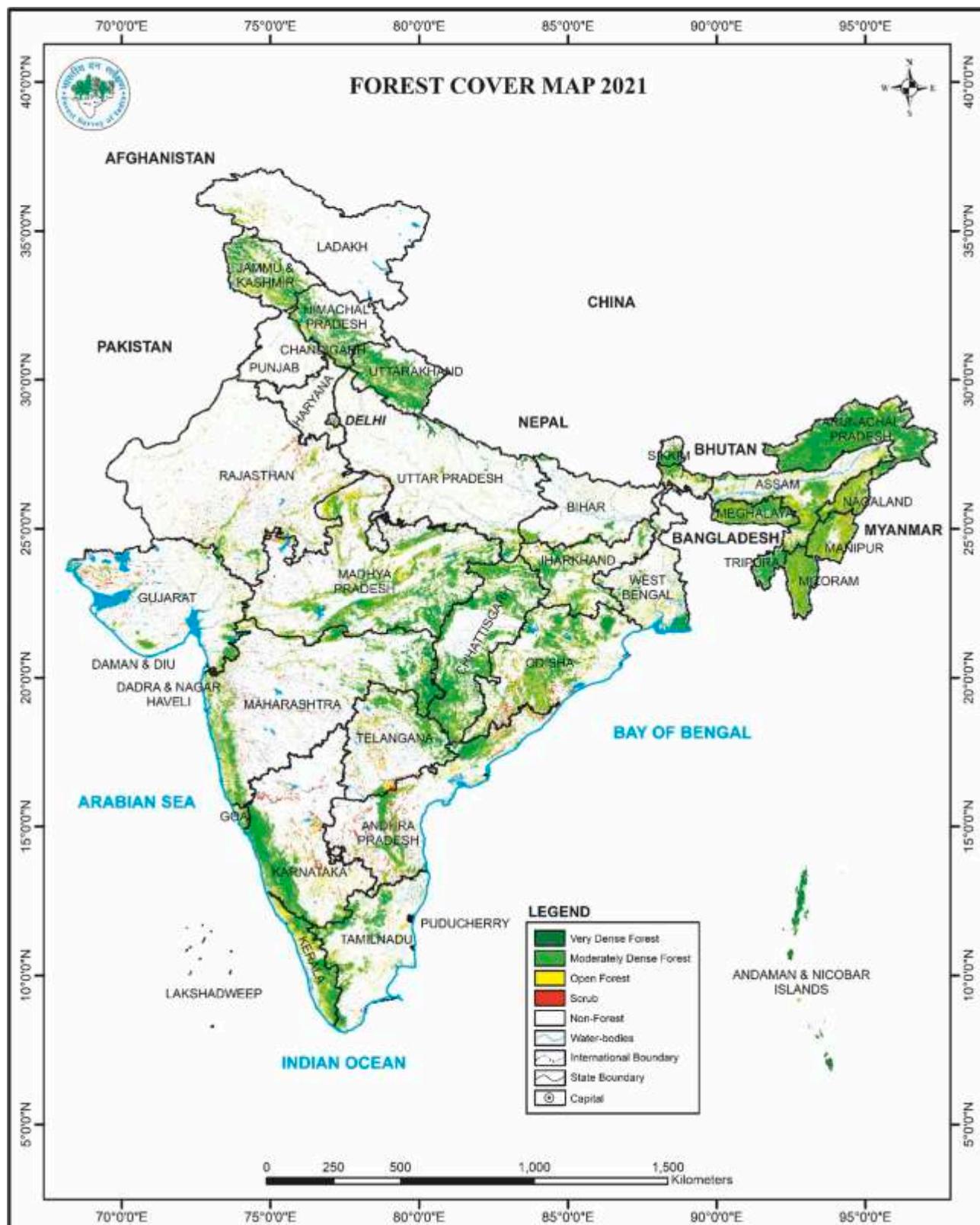
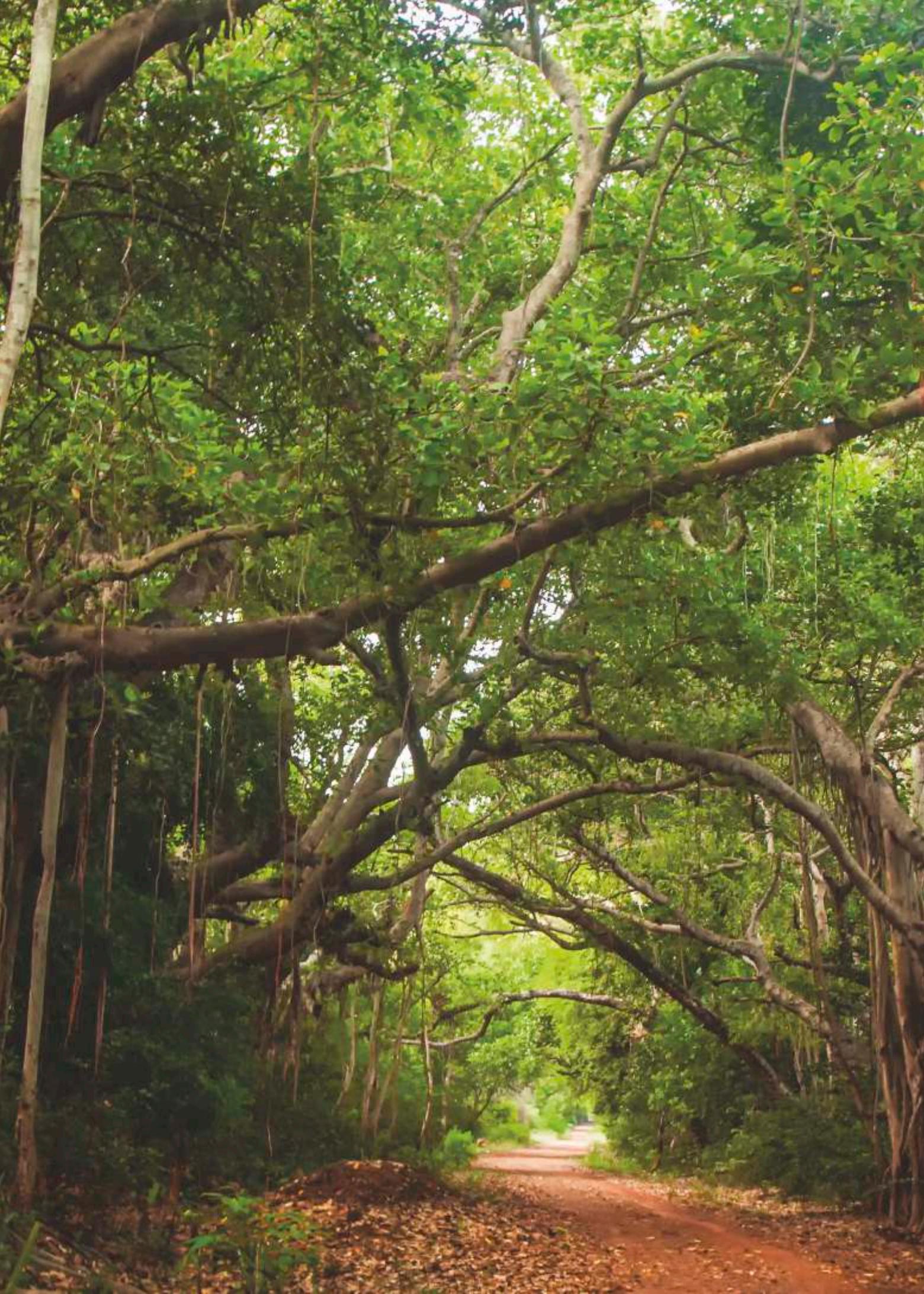


Figure 2.10
Pie-chart
showing Forest Cover of India

The total Forest Cover of the country, as per the current assessment is 7,13,789 sq km which is 21.71 percent of the total geographic area of the country. In terms of canopy density classes, area covered by VDF is 99,779 sq km (3.04 percent), MDF is 3,06,890 sq km (9.33 percent) and OF is 3,07,120 sq km (9.34 percent). In the current assessment, Very Dense Forest and Moderately Dense Forest together constitute 57 percent of the total Forest Cover of the country. Forest Cover map of India is shown in Figure 2.11

Figure 2.11
Forest Cover
Map of India
2021





2.9

State/UT wise Forest Cover

Forest Cover in the States & UTs of the country as per the 2021 assessment and change therein with respect to the previous assessment (2019) has been presented in the Table 2.4

Table 2.4
Forest Cover
in the
States/UTs in
India

State/UT	Geo-graphical Area (GA)	2021 Assessment		
		VDF	MDF	OF
Andhra Pradesh	1,62,968	1,994	13,929	13,861
Arunachal Pradesh	83,743	21,058	30,176	15,197
Assam	78,438	3,017	9,991	15,304
Bihar	94,163	333	3,286	3,762
Chhattisgarh	1,35,192	7,068	32,279	16,370
Delhi	1,483	6.72	56.60	131.68
Goa	3,702	538	576	1,130
Gujarat	1,96,244	378	5,032	9,516
Haryana	44,212	28	445	1,130
Himachal Pradesh	55,673	3,163	7,100	5,180
Jharkhand	79,716	2,601	9,689	11,431
Karnataka	1,91,791	4,533	20,985	13,212
Kerala	38,852	1,944	9,472	9,837
Madhya Pradesh	3,08,252	6,665	34,209	36,619
Maharashtra	3,07,713	8,734	20,589	21,475
Manipur	22,327	905	6,228	9,465
Meghalaya	22,429	560	9,160	7,326
Mizoram	21,081	157	5,715	11,948
Nagaland	16,579	1,272	4,449	6,530
Odisha	1,55,707	7,213	20,995	23,948
Punjab	50,362	11	793	1,043
Rajasthan	3,42,239	78	4,369	12,208
Sikkim	7,096	1,102	1,551	688
Tamil Nadu	1,30,060	3,593	11,034	11,792
Telangana	1,12,077	1,624	9,119	10,471
Tripura	10,486	647	5,212	1,863
Uttar Pradesh	2,40,928	2,627	4,029	8,162
Uttarakhand	53,483	5,055	12,768	6,482
West Bengal	88,752	3,037	4,208	9,587
A & N Islands	8,249	5,678	683	383
Chandigarh	114	1.36	13.51	8.01
Dadra & Nagar Haveli and Daman & Diu	602	1.40	85.56	140.79
Jammu & Kashmir Shapefile Area* (54,624)	2,22,236	4,155	8,117	9,115
Ladakh Shapefile Area* (1,68,055)		2	512	1,758
Lakshadweep	30	0.00	16.09	11.01
Puducherry	490	0.00	17.53	35.77
Total	32,87,469	99,779	3,06,890	3,07,120

* Area of shapefile provided by Survey of India (August, 2021). Notified geographical areas for individual UTs from Sol are awaited.

(in sq km)

Total Forest Cover	Percentage of Geographical area	Change in Forest Cover w.r.t ISFR 2019	Change Percentage w.r.t. 2019 assessment	Scrub
29,784	18.28	647	2.22	8,276
66,431	79.33	-257	-0.39	797
28,312	36.09	-15	-0.05	228
7,381	7.84	75	1.03	236
55,717	41.21	106	0.19	615
195.00	13.15	-0.44	-0.23	0.38
2,244	60.62	7	0.31	0
14,926	7.61	69	0.46	2,828
1,603	3.63	1	0.06	159
15,443	27.73	9	0.06	322
23,721	29.76	110	0.47	584
38,730	20.19	155	0.40	4,611
21,253	54.70	109	0.52	30
77,493	25.14	11	0.01	5,457
50,798	16.51	20	0.04	4,247
16,598	74.34	-249	-1.48	1,215
17,046	76.00	-73	-0.43	663
17,820	84.53	-186	-1.03	1
12,251	73.90	-235	-1.88	824
52,156	33.50	537	1.04	4,924
1,847	3.67	-2	-0.11	34
16,655	4.87	25	0.15	4,809
3,341	47.08	-1	-0.03	296
26,419	20.31	55	0.21	758
21,214	18.93	632	3.07	2,911
7,722	73.64	-4	-0.05	33
14,818	6.15	12	0.08	563
24,305	45.44	2	0.01	392
16,832	18.96	-70	-0.41	156
6,744	81.75	1	0.01	1
22.88	20.07	0.85	3.86	0.38
227.75	37.83	0.10	0.04	4.85
21,387	39.15	29	0.14	284
2,272	1.35	18	0.80	279
27.10	90.33	0.00	0.00	0.00
53.30	10.88	0.89	1.70	0.00
7,13,789	21.71	1,540	0.22	46,539

As per the table above, Madhya Pradesh is the state having largest Forest Cover in the country followed by Arunachal Pradesh, Chhattisgarh, Odisha and Maharashtra. The States from the north-eastern region of the country have the highest percentage of Forest Cover w.r.t. total geographical area of the state. Mizoram (84.53 percent) has the highest percentage of Forest Cover, followed by Arunachal Pradesh (79.33 percent), Meghalaya (76.00 percent), Manipur (74.34 percent) and Nagaland (73.90 percent).

2.10 Change in Forest Cover

Changes in Forest Cover between two consecutive assessments reflects the actual changes on the ground during the intervening period. In addition to changes between forest to non-forest and vice versa, changes within the forests between different canopy density classes are also analyzed. The positive changes are increase in vegetation, which can be attributed to conservation measures, afforestation activities, enhanced protection measures in plantation as well as in traditional forest areas, expansion of trees outside forest etc. Negative change corresponds to decrease in Forest Cover due to harvesting of short rotational plantations, shifting cultivation, biotic pressure, clearance in encroached areas, developmental activities etc. Some changes (interpretational) may also arise due to subjectivity involved in certain components of classification, which require further analysis using collateral data such as high resolution images, higher intensity of ground truthing etc. The Interpretational changes in classifications also pertains to the areas where the Forest Cover either went undetected due to snow or cloud cover, hill shadow effect, poor reflectance from trees due to leaf fall or poor image quality at the time of previous assessment or classified as forest due to poor tonal variation.

In the current assessment, higher radiometric value of satellite data, greater intensity of ground truthing (over 3,400 points), considerable use of higher resolution collateral data and information from SFDs has helped in minimizing the interpretational changes and ascertaining the ground features in doubtful areas.

The details of States/UTs wise change in Forest Cover for the three density classes is given in Table 2.5. There has been a net increase of 1,540 sq km in the Forest Cover at national level. The states namely Andhra Pradesh, Telangana, Odisha, Karnataka and Jharkhand have contributed to an increase of 647 sq km, 632 sq km, 537 sq km, 155 sq km and 110 sq km respectively. The Gain in Forest Cover or improvement in forest canopy density may be attributed to better conservation measures, protection, afforestation activities, tree plantation drives and agroforestry.

From the above table, it is seen that the states showing major loss in Forest Cover are, Arunachal Pradesh (257 sq km), Manipur (249 sq km), Nagaland (235 sq km), Mizoram (186 sq km) and Meghalaya (73 sq km). The loss in Forest Cover and deterioration of forest canopy may be attributed to shifting cultivation, felling of trees, natural calamities, anthropogenic pressure and developmental activities.



Table 2.5 Change in Forest Cover of States/UTs between 2019 and 2021 assessments

State/UT	Geo-graphical Area	2019 Assessment		
		VDF	MDF	OF
Andhra Pradesh	1,62,968	1,994	13,938	13,205
Arunachal Pradesh	83,743	21,095	30,557	15,036
Assam	78,438	2,795	10,279	15,253
Bihar	94,163	333	3,280	3,693
Chhattisgarh	1,35,192	7,068	32,198	16,345
Delhi	1,483	6.72	56.42	132.30
Goa	3,702	538	576	1,123
Gujarat	1,96,244	378	5,092	9,387
Haryana	44,212	28	451	1,123
Himachal Pradesh	55,673	3,113	7,126	5,195
Jharkhand	79,716	2,603	9,687	11,321
Karnataka	1,91,791	4,501	21,048	13,026
Kerala	38,852	1,935	9,508	9,701
Madhya Pradesh	3,08,252	6,676	34,341	36,465
Maharashtra	3,07,713	8,721	20,572	21,485
Manipur	22,327	905	6,386	9,556
Meghalaya	22,429	489	9,267	7,363
Mizoram	21,081	157	5,801	12,048
Nagaland	16,579	1,273	4,534	6,679
Odisha	1,55,707	6,970	21,552	23,097
Punjab	50,362	8	801	1,040
Rajasthan	3,42,239	78	4,342	12,210
Sikkim	7,096	1,102	1,552	688
Tamil Nadu	1,30,060	3,605	11,030	11,729
Telangana	1,12,077	1,608	8,787	10,187
Tripura	10,486	654	5,236	1,836
Uttar Pradesh	2,40,928	2,617	4,080	8,109
Uttarakhand	53,483	5,047	12,805	6,451
West Bengal	88,752	3,019	4,160	9,723
A & N Islands	8,249	5,678	684	381
Chandigarh	114	1.36	14.24	6.43
Dadra & Nagar Haveli and Daman & Diu	602	1.40	85.62	140.63
Jammu & Kashmir Shapefile Area* (54,624)	2,22,236	4,279	8,090	8,989
Ladakh Shapefile Area* (1,68,055)		2	522	1,730
Lakshadweep	30	0.00	16.09	11.01
Puducherry	490	0.00	17.66	34.75
Total	32,87,469	99,278	3,08,472	3,04,499

* Area of shapefile provided by Survey of India (August, 2021). Notified geographical areas for individual UTs from Sol are awaited.

(in sq km)

Total	2021 Assessment				Change				Total Change
	VDF	MDF	OF	Total	VDF	MDF	OF		
29,137	1,994	13,929	13,861	29,784	0	-9	656	647	
66,688	21,058	30,176	15,197	66,431	-37	-381	161	-257	
28,327	3,017	9,991	15,304	28,312	222	-288	51	-15	
7,306	333	3,286	3,762	7,381	0	6	69	75	
55,611	7,068	32,279	16,370	55,717	0	81	25	106	
195.44	6.72	56.60	131.68	195.00	0.00	0.18	-0.62	-0.44	
2,237	538	576	1,130	2,244	0	0	7	7	
14,857	378	5,032	9,516	14,926	0	-60	129	69	
1,602	28	445	1,130	1,603	0	-6	7	1	
15,434	3,163	7,100	5,180	15,443	50	-26	-15	9	
23,611	2,601	9,689	11,431	23,721	-2	2	110	110	
38,575	4,533	20,985	13,212	38,730	32	-63	186	155	
21,144	1,944	9,472	9,837	21,253	9	-36	136	109	
77,482	6,665	34,209	36,619	77,493	-11	-132	154	11	
50,778	8,734	20,589	21,475	50,798	13	17	-10	20	
16,847	905	6,228	9,465	16,598	0	-158	-91	-249	
17,119	560	9,160	7,326	17,046	71	-107	-37	-73	
18,006	157	5,715	11,948	17,820	0	-86	-100	-186	
12,486	1,272	4,449	6,530	12,251	-1	-85	-149	-235	
51,619	7,213	20,995	23,948	52,156	243	-557	851	537	
1,849	11	793	1,043	1,847	3	-8	3	-2	
16,630	78	4,369	12,208	16,655	0	27	-2	25	
3,342	1,102	1,551	688	3,341	0	-1	0	-1	
26,364	3,593	11,034	11,792	26,419	-12	4	63	55	
20,582	1,624	9,119	10,471	21,214	16	332	284	632	
7,726	647	5,212	1,863	7,722	-7	-24	27	-4	
14,806	2,627	4,029	8,162	14,818	10	-51	53	12	
24,303	5,055	12,768	6,482	24,305	8	-37	31	2	
16,902	3,037	4,208	9,587	16,832	18	48	-136	-70	
6,743	5,678	683	383	6,744	0	-1	2	1	
22.03	1.36	13.51	8.01	22.88	0.00	-0.73	1.58	0.85	
227.65	1.40	85.56	140.79	227.75	0.00	-0.06	0.16	0.10	
21,358	4,155	8,117	9,115	21,387	-124	27	126	29	
2,254	2	512	1,758	2,272	0	-10	28	18	
27.10	0.00	16.09	11.01	27.10	0.00	0.00	0.00	0.00	
52.41	0.00	17.53	35.77	53.30	0.00	-0.13	1.02	0.89	
712,249	99,779	3,06,890	3,07,120	7,13,789	501	-1,582	2,621	1,540	

2.11 Forest Cover Inside and Outside Recorded Forest Area or Green Wash

Although most of the recorded forest area has vegetation cover on it, yet there are blanks and areas with density less than 10 percent within it. On the other hand, there are areas outside the recorded forests with tree stands of more than 10 percent canopy density and size 1 ha or more. Such areas also constitute Forest Cover and are included in the Forest Cover assessment of FSI. Therefore, the changes taking place in the Forest Cover include changes both inside the recorded forest areas and changes outside recorded forest area. The information of Forest Cover inside and outside RFA/ Green Wash is presented in Table 2.6.

2.11.1 Recorded Forest Areas (RFA)

Recorded forest area includes all areas recorded as forest in government records. These largely consist of Reserved Forests (RF) and Protected Forests (PF), which have been constituted under the provisions of Indian Forest Act 1927 or its counterpart State Acts. Areas which have been recorded as forests in the revenue records or have been constituted under any other State Act or local law are also included in the RFA.

Currently FSI has received digitized boundaries of RFA from 24 State Forest Departments (SFDs)/UTs and these have been used as provided by the respective SFDs/UTs. Due to non-availability of digitized boundaries of RFA from all the States/UTs in the country, it was not possible to assess and monitor Forest Cover inside RFA for the entire country. The details of Forest Cover inside Recorded Forest Area (RFA) of these States are given in Table 2.6.

2.11.2

Green Wash (GW)

In respect of those States and UTs from where the usable digitized boundaries of recorded forest areas could not be made available to FSI, the Green Wash (area shown by green colour in Survey of India topographic sheets) is used as proxy for RFA. In order to carry out this exercise, the green wash boundaries of the country have been digitised on 1:50,000 scale using Open Series Maps (OSM) of Sol. Based on the green-wash boundary, the Forest Cover inside and outside green-wash for the remaining States and UTs was extracted using overlay in GIS, and the figures were generated separately for both the segments.





Table 2.6 Forest Cover Inside and Outside Recorded Forest /Green Wash area

State / UT	Geographic area (as per census)	Recorded Forest Area as per the State's records	Recorded Forest/ Green Wash as per area of digitized RFA/GW boundary	VDF
Andhra Pradesh	1,62,968	37,258	37,920	1,965
Arunachal Pradesh	83,743	51,540	63,838	19,640
Assam	78,438	26,836	27,548	2,540
Bihar*	94,163	7,442	6,374	314
Chhattisgarh*	1,35,192	59,816	52,926	5,356
Delhi	1,483	103	102.04	3.19
Goa*	3,702	1,271	1,326	516
Gujarat	1,96,244	21,870	30,354	356
Haryana	44,212	1,559	566	22
Himachal Pradesh	55,673	37,948	14,025	2,771
Jharkhand	79,716	25,118	19,097	1,415
Karnataka	1,91,791	38,284	31,037	3,646
Kerala*	38,852	11,522	11,555	1,792
Madhya Pradesh	3,08,252	94,689	88,956	6,259
Maharashtra*	3,07,713	61,952	57,725	8,466
Manipur	22,327	17,418	17,542	897
Meghalaya	22,429	9,496	17,563	442
Mizoram	21,081	7,479	20,663	156
Nagaland	16,579	8,623	10,633	1,166
Odisha	1,55,707	61,204	42,430	5,567
Punjab	50,362	3,084	924	7
Rajasthan*	3,42,239	32,863	35,265	73
Sikkim**	7,096	5,841	5,414	832
Tamil Nadu*	1,30,060	23,188	21,585	3,330
Telangana*	1,12,077	27,688	26,881	1,536
Tripura	10,486	6,294	5,838	410
Uttar Pradesh	2,40,928	17,384	13,434	2,455
Uttarakhand	53,483	38,000	25,494	4,261
West Bengal*	88,752	11,879	13,427	2,607
Andaman & Nicobar Islands*	8,249	7,171	6,829	5,409
Chandigarh*	114	35	10.18	1.28
Dadra & Nagar Haveli and Daman & Diu*	602	214	202	0.00
Jammu & Kashmir Shapefile Area# (54,624)	2,22,236	20,199	27,702	3,107
Ladakh Shapefile Area# (1,68,055)		7	3,185	2
Lakshadweep	30	-	-	0.00
Puducherry	490	13	3.05	0.00
Grand Total	32,87,469	7,75,288	7,38,373	87,319

(in sq km)

Forest Cover Inside RFA/GW 2019			Forest Cover Inside RFA/GW 2021			
MDF	OF	Total	VDF	MDF	OF	Total
12,821	9,333	24,119	1,965	12,814	9,460	24,239
27,384	11,697	58,721	19,637	27,171	11,872	58,680
8,840	8,764	20,144	2,748	8,566	8,689	20,003
2,451	2,003	4,768	314	2,457	2,060	4,831
26,384	10,676	42,416	5,358	26,478	10,631	42,467
16.05	39.83	59.07	3.19	16.05	39.93	59.17
328	374	1,218	516	329	375	1,220
4,055	5,374	9,785	356	4,016	5,463	9,835
156	195	373	22	155	197	374
4,948	2,919	10,638	2,820	4,923	2,901	10,644
5,185	5,609	12,209	1,414	5,186	5,682	12,282
12,754	6,071	22,471	3,679	12,721	6,148	22,548
5,311	2,530	9,633	1,804	5,299	2,576	9,679
30,270	28,223	64,752	6,251	30,195	28,326	64,772
15,033	12,500	35,999	8,476	15,068	12,496	36,040
5,864	8,257	15,018	895	5,743	8,195	14,833
7,743	6,659	14,844	512	7,652	6,634	14,798
5,708	11,872	17,736	156	5,624	11,776	17,556
3,279	4,282	8,727	1,169	3,203	4,256	8,628
15,250	11,992	32,809	5,649	14,636	12,401	32,686
451	326	784	10	451	327	788
3,959	8,469	12,501	74	3,999	8,487	12,560
879	345	2,056	832	879	343	2,054
8,578	5,600	17,508	3,320	8,580	5,631	17,531
8,321	8,475	18,332	1,551	8,651	8,494	18,696
3,903	1,138	5,451	407	3,886	1,140	5,433
3,039	3,701	9,195	2,463	3,002	3,678	9,143
9,269	3,260	16,790	4,269	9,241	3,275	16,785
2,388	2,135	7,130	2,624	2,391	2,097	7,112
546	253	6,208	5,409	546	253	6,208
4.99	2.26	8.53	1.28	5.08	2.34	8.70
69.35	90.2	159.55	0.00	69.38	90.64	160.02
5,300	4,832	13,239	3,036	5,432	4,708	13,176
179	616	797	2	179	619	800
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	1.00	1.00	0.00	0.00	1.00	1.00
2,40,666	1,88,613	5,16,598	87,742	2,39,564	1,89,324	5,16,630

Forest Cover Outside RFA/GW 2019				Forest Cover Outside RFA/GW 2021			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
29	1,117	3,872	5,018	29	1,115	4,501	5,545
1,455	3,173	3,339	7,967	1,421	3,005	3,325	7,751
255	1,439	6,489	8,183	269	1,425	6,615	8,309
19	829	1,690	2,538	19	829	1,702	2,550
1,712	5,814	5,669	13,195	1,710	5,801	5,739	13,250
3.53	40.37	92.47	136.37	3.53	40.55	91.75	135.83
22	248	749	1,019	22	247	755	1,024
22	1,037	4,013	5,072	22	1,016	4,053	5,091
6	295	928	1,229	6	290	933	1,229
342	2,178	2,276	4,796	343	2,177	2,279	4,799
1,188	4,502	5,712	11,402	1,187	4,503	5,749	11,439
855	8,294	6,955	16,104	854	8,264	7,064	16,182
143	4,197	7,171	11,511	140	4,173	7,261	11,574
417	4,071	8,242	12,730	414	4,014	8,293	12,721
255	5,539	8,985	14,779	258	5,521	8,979	14,758
8	522	1,299	1,829	10	485	1,270	1,765
47	1,524	704	2,275	48	1,508	692	2,248
1	93	176	270	1	91	172	264
107	1,255	2,397	3,759	103	1,246	2,274	3,623
1,403	6,302	11,105	18,810	1,564	6,359	11,547	19,470
1	350	714	1,065	1	342	716	1,059
5	383	3,741	4,129	4	370	3,721	4,095
270	673	343	1,286	270	672	345	1,287
275	2,452	6,129	8,856	273	2,454	6,161	8,888
72	466	1,712	2,250	73	468	1,977	2,518
244	1,333	698	2,275	240	1,326	723	2,289
162	1,041	4,408	5,611	164	1,027	4,484	5,675
786	3,536	3,191	7,513	786	3,527	3,207	7,520
412	1,772	7,588	9,772	413	1,817	7,490	9,720
269	138	128	535	269	137	130	536
0.08	9.25	4.17	13.50	0.08	8.43	5.67	14.18
1.40	16.27	50.43	68.10	1.40	16.18	50.15	67.73
1,172	2,790	4,157	8,119	1,119	2,685	4,407	8,211
0	343	1,114	1,457	0	333	1,139	1,472
0.00	16.09	11.01	27.10	0.00	16.09	11.01	27.10
0.00	17.66	33.75	51.41	0.00	17.53	34.77	52.30
11,959	67,806	1,15,886	1,95,651	12,037	67,326	1,17,796	1,97,159

#Area of shape file provided by Survey of India (August, 2021). Notified geographical areas for individual UTs from Sol are awaited.

*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 have provided RFA boundaries for the first time.

The States/UTs which have provided RFA boundaries are shown in 

The States/UTs which have GW have been shown in 

Percentage of Forest Cover Inside RFA/GW	Change Inside RFA/GW	Change Outside RFA/GW	Net Change
63.92	120	527	647
91.92	-41	-216	-257
72.61	-141	126	-15
75.79	63	12	75
80.24	51	55	106
57.99	0.10	-0.54	-0.44
92.01	2	5	7
32.40	50	19	69
66.08	1	0	1
75.89	6	3	9
64.31	73	37	110
72.65	77	78	155
83.76	46	63	109
72.81	20	-9	11
62.43	41	-21	20
84.56	-185	-64	-249
84.26	-46	-27	-73
84.96	-180	-6	-186
81.14	-99	-136	-235
77.04	-123	660	537
85.28	4	-6	-2
35.62	59	-34	25
37.94	-2	1	-1
81.22	23	32	55
69.55	364	268	632
93.06	-18	14	-4
68.06	-52	64	12
65.84	-5	7	2
52.97	-18	-52	-70
90.91	0	1	1
85.46	0.17	0.68	0.85
79.22	0.47	-0.37	0.10
47.56	-63	92	29
25.12	3	15	18
0.00	0.00	0.00	0.00
32.79	0.00	0.89	0.89
69.97	31	1,509	1,540



2.12 Change Matrix

Change matrix represents the change in the area of the Forest Cover in different density classes, scrub and non-forest, between two consecutive assessments. The changes are presented in a matrix form by showing the changes of area from one class to another. Based on the analysis of the changes observed across the country, a change matrix has been generated indicating the change in predefined Forest Cover classes. Details of Forest Cover change matrix for the country between 2019 and 2021 assessments is given in Table 2.7

Table 2.7 Forest Cover change matrix for India between 2019 and 2021 assessments. (in sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	97,770	982	348	28	150	99,278
Moderately Dense Forest	1,696	3,02,216	2,736	331	1,493	3,08,472
Open Forest	245	2,939	2,94,200	1,491	5,624	3,04,499
Scrub	31	241	3,048	40,977	2,000	46,297
Non Forest	37	512	6,788	3,712	25,17,874	25,28,923
Total ISFR 2021	99,779	3,06,890	3,07,120	46,539	25,27,141	32,87,469
Net Change	501	-1,582	2,621	242	-1,782	

● Gain ● Loss

2.13 Forest Cover in Hill Districts

The assessment of Forest Cover in hill districts of the country is done separately to monitor the progress of the country towards achieving the goal of maintaining two third of the area in hills under Forest Cover, as has been envisaged in the National Forest Policy 1988. Due to the fragility of hill areas and vulnerability to land degradation, the Forest Cover plays an important role in prevention of soil erosion, land degradation and also maintaining ecological balance and environmental stability. As per the definition given by the erstwhile Planning Commission of India, a hill district or taluka is one where altitude is above 500m from the mean sea level. Only the districts where the hill talukas exceed 50 percent of the total geographical area of the district are considered for the assessment. There are 140 hill districts as marked by superscript ("h") in the district-wise Tables of Forest Cover in Chapter 13. Table 2.8 gives a State wise summary of Forest Cover in the hill districts of the country. As seen in the table, there is a decrease of 902 sq km of Forest Cover in the hill districts of the country.



Table 2.8 State wise summary of Forest Cover in Hill Districts (in sq km)

State	No. of Hill Districts	Geo-graphical Area	VDF	MDF	OF	Total	Perce-n-tage of GA	Change in forest cover wrt ISFR 2019	Scrub
Arunachal Pradesh	16	83,743	21,058	30,176	15,197	66,431	79.33	-257	797
Assam	3	19,295	981	5,473	6,446	12,900	66.86	-107	104
Himachal Pradesh	12	55,673	3,163	7,100	5,180	15,443	27.73	9	322
Karnataka	6	48,353	3,940	15,364	4,554	23,858	49.34	42	780
Kerala	10	29,552	1,549	7,212	8,197	16,958	57.38	113	29
Maharashtra	7	69,905	320	7,223	8,303	15,846	22.67	14	1,446
Manipur	9	22,327	905	6,228	9,465	16,598	74.34	-249	1,215
Meghalaya	7	22,429	560	9,160	7,326	17,046	76.00	-73	663
Mizoram	8	21,081	157	5,715	11,948	17,820	84.53	-186	1
Nagaland	11	16,579	1,272	4,449	6,530	12,251	73.90	-235	824
Sikkim	4	7,096	1,102	1,551	688	3,341	47.08	-1	296
Tamil Nadu	5	19,384	1,439	2,679	2,458	6,576	33.92	1	76
Tripura	4	10,486	647	5,212	1,863	7,722	73.64	-4	33
Uttarakhand	13	53,483	5,055	12,768	6,482	24,305	45.44	2	392
West Bengal	1	3,149	721	682	947	2,350	74.62	-18	9
Jammu & Kashmir*	22	Shapefile Area* (54,624) 2,22,236	4,155 2	8,117 512	9,115 1,758	21,387 2,272	39.15 1.35	29	284 279
Ladakh*	2								
Total	140	7,04,771	47,026	1,29,621	1,06,457	2,83,104	40.17	-902	7,550

* Area of shape-file provided by Survey of India (August, 2021). Notified geographical areas for individual UTs from Sol are awaited.

Forest Cover in Tribal Districts

2.14

Tribal economy, society and culture are intricately linked with forests. Forests contribute significantly as source of sustenance and livelihood for the tribal community. FSI is regularly assessing Forest Cover in tribal districts under the Integrated Tribal Development Programme (ITDP) of the Govt. of India. All districts of Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura and Lakshadweep fall in the category of tribal districts due to their high tribal population. There are 218 tribal districts in 26 States/UTs as identified by the Government of India under the ITDP. These are marked with superscript ("†") in the district-wise Table of Forest Cover in Chapter 13. Table 2.9 gives an abstract of Forest Cover and its change inside and outside the RFA/Green Wash in the tribal districts of the country. As shown in the Table, there is an overall decrease in Forest Cover in the tribal districts by 55 sq. km, however, the Forest Cover inside the Recorded Forest Areas/Green wash areas in the tribal districts shows a decrease of 655 sq km.

Table 2.9 Abstract of Forest Cover Inside and Outside Recorded Forest /Green Wash area in Tribal Districts

State	No. of Tribal Districts	Geo-graphical area	RFA/GW Digital area	Forest Cover Inside RFA/GW 2019				Forest Cover Inside RFA/GW 2021		
				VDF	MDF	OF	TOTAL	VDF	MDF	OF
Andhra Pradesh	5	44,849	13,297	1,525	4,631	2,673	8,829	1,525	4,624	2,730
Arunachal Pradesh	16	83,743	63,838	19,640	27,384	11,697	58,721	19,637	27,171	11,872
Assam	19	49,489	9,888	1,400	2,781	2,398	6,579	1,486	2,676	2,395
Chhattisgarh	11	92,645	35,955	4,810	16,803	6,900	28,513	4,805	16,913	6,832
Gujarat	9	49,885	7,718	303	2,327	2,428	5,058	303	2,303	2,437
Himachal Pradesh	3	26,764	3,143	751	913	585	2,249	751	913	585
Jharkhand	17	58,677	11,658	829	3,244	3,465	7,538	828	3,244	3,517
Karnataka	5	26,054	6,612	1,964	2,981	694	5,639	1,965	2,977	698
Kerala	9	27,207	8,755	1,355	3,887	1,881	7,123	1,364	3,877	1,919
Madhya Pradesh	24	1,52,132	51,919	5,719	19,129	14,612	39,460	5,715	19,075	14,585
Maharashtra	12	1,44,233	41,590	7,136	10,268	8,810	26,214	7,138	10,301	8,785
Manipur	9	22,327	17,542	897	5,864	8,257	15,018	895	5,743	8,195
Meghalaya	7	22,429	17,563	442	7,743	6,659	14,844	512	7,652	6,634
Mizoram	8	21,081	20,663	156	5,708	11,872	17,736	156	5,624	11,776
Nagaland	11	16,579	10,633	1,166	3,279	4,282	8,727	1,169	3,203	4,256
Odisha	12	86,091	24,685	3,883	9,307	6,770	19,960	3,925	8,690	7,114
Rajasthan	5	29,601	9,016	0	2,064	2,482	4,546	0	2,066	2,468
Sikkim	4	7,096	5,414	832	879	345	2,056	832	879	343
Tamil Nadu	6	25,607	5,342	797	2,318	1,401	4,516	797	2,318	1,402
Telangana	3	42,217	16,933	1,130	6,486	4,381	11,997	1,144	6,736	4,229
Tripura	4	10,486	5,838	410	3,903	1,138	5,451	407	3,886	1,140
Uttar Pradesh	1	7,680	1,191	752	118	90	960	752	118	89
West Bengal	12	69,403	13,095	2,593	2,363	2,101	7,057	2,610	2,366	2,063
A&N Islands	3	8,249	6,829	5,409	546	253	6,208	5,409	546	253
Dadra & Nagar Haveli and Daman & Diu	2	563	202	0.00	69.35	90.20	159.55	0.00	69.38	90.64
Lakshadweep	1	30	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	218	11,25,117	3,92,106	63,899	1,44,995	1,06,264	3,15,158	64,125	1,43,970	1,06,408

The States/UTs which have provided RFA boundaries are shown in 

The States/UTs which have GW have been shown in 

(in sq km)

Forest Cover Outside RFA/GW 2019					Forest Cover Outside RFA/GW 2021				Change Inside RFA/GW	Change Outside RFA/GW	Net Change
TOTAL	VDF	MDF	OF	TOTAL	VDF	MDF	OF	TOTAL			
8,879	22	769	2,606	3,397	22	767	2,930	3,719	50	322	372
58,680	1,455	3,173	3,339	7,967	1,421	3,005	3,325	7,751	-41	-216	-257
6,557	113	890	4,491	5,494	112	893	4,597	5,602	-22	108	86
28,550	1,700	5,082	4,693	11,475	1,698	5,069	4,750	11,517	37	42	79
5,043	21	593	1,197	1,811	21	585	1,208	1,814	-15	3	-12
2,249	112	460	441	1,013	112	459	437	1,008	0	-5	-5
7,589	1,050	4,005	4,848	9,903	1,049	4,006	4,877	9,932	51	29	80
5,640	632	4,953	2,392	7,977	630	4,937	2,401	7,968	1	-9	-8
7,160	116	2,943	5,229	8,288	114	2,926	5,311	8,351	37	63	100
39,375	331	2,796	4,876	8,003	328	2,759	4,900	7,987	-85	-16	-101
26,224	80	1,366	2,783	4,229	81	1,358	2,785	4,224	10	-5	5
14,833	8	522	1,299	1,829	10	485	1,270	1,765	-185	-64	-249
14,798	47	1,524	704	2,275	48	1,508	692	2,248	-46	-27	-73
17,556	1	93	176	270	1	91	172	264	-180	-6	-186
8,628	107	1,255	2,397	3,759	103	1,246	2,274	3,623	-99	-136	-235
19,729	1,235	5,089	8,047	14,371	1,394	5,148	8,290	14,832	-231	461	230
4,534	0	94	638	732	0	92	633	725	-12	-7	-19
2,054	270	673	343	1,286	270	672	345	1,287	-2	1	-1
4,517	45	447	663	1,155	43	449	676	1,168	1	13	14
12,109	69	347	741	1,157	69	347	826	1,242	112	85	197
5,433	244	1,333	698	2,275	240	1,326	723	2,289	-18	14	-4
959	53	40	220	313	53	40	220	313	-1	0	-1
7,039	412	1,357	5,824	7,593	412	1,403	5,727	7,542	-18	-51	-69
6,208	269	138	128	535	269	137	130	536	0	1	1
160.02	0.00	12.51	46.01	58.52	0.00	12.42	45.74	58.16	0.47	-0.36	0.11
0.00	0.00	16.09	11.01	27.10	0.00	16.09	11.01	27.10	0.00	0.00	0.00
3,14,503	8,392	39,971	58,830	1,07,193	8,500	39,737	59,556	1,07,793	-655	600	-55



Forest Cover

2.15

Forest Cover in the North Eastern States

North Eastern region of the country comprising eight States namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura constitute 7.98 percent of the geographical area of the country. The forest resources in these States account for 23.75 percent of the total Forest Cover of the country. This region of the country is characterized by shifting / jhum cultivation where forest land is converted into agricultural land and the fields are cultivated for a relatively short time. Thereafter, the area is allowed to recover or is left fallow for a long time and this activity is repeated after certain years. Such agricultural practices mainly contribute to cause fluctuation in Forest Cover in this region. The Forest Cover in the north eastern States is given in Table 2.10. The Table shows that there is an overall decrease of 1,020 sq. km of Forest Cover in the north eastern States.

Table 2.10 Forest Cover in North Eastern States

(in sq km)

2021 Assessment												
State	Geo-Graphical Area	VDF	Per-cent-age of VDF	MDF	Per-cent-age of MDF	OF	Per-cent-age of OF	Total	Per-cent-age of Forest Cover to GA	Change in forest cover wrt ISFR 2019	Scrub	
Arunachal Pradesh	83,743	21,058	25.15	30,176	36.03	15,197	18.15	66,431	79.33	-257	797	
Assam	78,438	3,017	3.85	9,991	12.74	15,304	19.51	28,312	36.09	-15	228	
Manipur	22,327	905	4.05	6,228	27.90	9,465	42.39	16,598	74.34	-249	1,215	
Meghalaya	22,429	560	2.50	9,160	40.84	7,326	32.66	17,046	76.00	-73	663	
Mizoram	21,081	157	0.74	5,715	27.11	11,948	56.68	17,820	84.53	-186	1	
Nagaland	16,579	1,272	7.67	4,449	26.84	6,530	39.39	12,251	73.90	-235	824	
Sikkim	7,096	1,102	15.53	1,551	21.86	688	9.69	3,341	47.08	-1	296	
Tripura	10,486	647	6.17	5,212	49.70	1,863	17.77	7,722	73.64	-4	33	
Total	2,62,179	28,718	10.95	72,482	27.65	68,321	26.06	1,69,521	64.66	-1,020	4,057	

2.16

Forest Cover in Different Altitude Zones

Information about extent of Forest Cover at different altitude zones has been provided. Digital Elevation Model (DEM) data from SRTM with spatial resolution of 30m has been used to determine Forest Cover in different altitude zones in all the States and UTs. The DEM is categorized into six altitude zones i.e. 0-500m, 500-1000m, 1000-2000m, 2000-3000m, 3000-4000m and above 4000m for the purpose of analysis. According to Dutta *et al.* 2018, the timberline elevation in the Himalayan region ranges from 3300m to 4600m. This information may be used by hill states for policy formulation, planning and related activities. Altitude zone wise Forest Cover of the country is given in Table 2.11.

Table 2.11 Forest Cover in Altitude Zones (in sq km)

Altitude Zone (m)	Geo Graphical Area	VDF	MDF	Open	Total Forest Cover (FC)	Scrub	Percentage of Total FC	Percentage of GA
0-500 m	23,29,321	39,456	1,51,917	1,90,571	3,81,944	27,568	53.52	16.40
500-1000 m	5,41,747	25,956	94,259	77,747	1,97,962	14,836	27.73	36.54
1000-2000 m	1,17,835	15,743	34,599	24,919	75,261	2,498	10.54	63.87
2000-3000 m	56,891	15,241	18,500	7,162	40,903	370	5.73	71.90
3000-4000 m	59,298	3,356	7,458	6,304	17,118	823	2.40	28.87
Above 4000m	1,82,377	27	157	417	601	444	0.08	0.33
Total	32,87,469	99,779	3,06,890	3,07,120	7,13,789	46,539		21.71

based on SRTM Digital Elevation Model (DEM), 30 m, 2016

Forest Cover on Different Slope Classes

2.17

Forests play an important role in maintaining hill slope stability, prevention of soil erosion and overall protection of the fragile mountain ecosystems. Extent of Forest Cover on slopes considerably reduces the susceptibility of hill slopes to soil erosion and landslides and also contributes to water conservation in the ecosystem. Information about the extent of Forest Cover on slopes is an important input in planning catchment area treatment programmes. Table 2.12 shows the details of Forest Cover in different predefined slope intervals.

Table 2.12 Forest Cover on different slope classes (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Forest Cover(FC)	Scrub	Percentage of Total FC	Percentage of GA
0°-5°	24,81,537	30,838	1,11,343	1,50,670	2,92,851	25,477	41.03	11.80
5°-10°	2,33,672	14,264	54,079	46,314	1,14,657	7,169	16.06	49.07
10°-15°	1,42,564	12,470	40,184	32,648	85,302	4,534	11.95	59.83
15°-20°	1,19,813	11,474	32,079	26,234	69,787	3,572	9.78	58.25
20°-25°	1,00,940	10,055	25,106	20,235	55,396	2,637	7.76	54.88
25°-30°	79,661	8,184	18,520	14,158	40,862	1,663	5.72	51.29
Above 30°	1,29,282	12,494	25,579	16,861	54,934	1,487	7.70	42.49
Total	32,87,469	99,779	3,06,890	3,07,120	7,13,789	46,539		21.71

based on SRTM Digital Elevation Model (DEM), 30 m, 2016

Accuracy Assessment of Forest Cover

2.18

Accuracy assessment determines the quality of information derived from remotely sensed data. Assessment can be either qualitative or quantitative. The need for assessing the accuracy of a map generated from any remotely sensed product has become an integral part and a universal requirement of any classification project. Accuracy assessment is done by comparing the classified data with the reference data, which is collected from the ground under National Forest Inventory (NFI) programme. It is done in an independent manner by a team which is not involved in the mapping of Forest Cover using part of NFI data as reference data. The relationship between the

classified data and reference data set is commonly summarized as an error matrix.

Error matrix is an array of numbers arranged in rows (map classification) and columns (reference data). It is a square matrix with equal number of rows and columns, representing different classes of mapping. However, the accuracy of mapping is assessed for the three Forest Cover classes (namely VDF, MDF & OF), Scrub and Non Forest (NF). The diagonal values of the error matrix imply agreement between the classified and the reference data. Non-diagonal elements indicate disagreement or wrong classification.

The percentage of correctly classified sampling units (i.e. sum of all diagonal elements) out of the total considered sampling units in the error matrix provides overall accuracy of the mapping.

Similarly, accuracy of each class can be measured by calculating the percentage of correctly classified random points out of the total number of sample points pertaining to a particular class.

2.18.1 Methodology

Appropriate sampling design and sampling size are important elements of the accuracy assessment. Representation of all classes should be ensured along with appropriate sampling size. Literature suggests that if the area of assessment is large or the classification has large number of vegetation/ land use classes, then the minimum number of samples should be more than 50 sample points per class.

Error matrix has been prepared by selecting a total of 5,339 sample points spread across the country, giving appropriate representation to both forests and TOF. Out of the total 5,339 sample points, 1,337 sample points have been selected from TOF. To record canopy density class at each point, a buffer of 1.0 ha around the point was created and canopy density on each point is recorded from inventory data. Similarly canopy density from the classification has been determined for 1 ha buffer on each point. Comparison between the two data sets leads to error matrix.

2.18.2 Findings

The error matrix is given in the Table 2.13. It shows that out of the total 5,339 sample points, classification on 4,965 sampling points (the sum of the elements along the main diagonal of the matrix) was found correct. The 'overall accuracy' of classification, therefore, works out to be 92.99 percent.

Table 2.13 Error Matrix for Forest Cover Classes

Classification Classes	Ground truth (based on field inventory data)						User's Accuracy(%)
	VDF	MDF	OF	Scrub	NF	Total	
VDF	385	12	16	0	1	414	93.00
MDF	7	1,460	62	8	20	1,557	93.77
OF	4	28	1,282	6	34	1,354	94.68
Scrub	0	2	7	208	6	223	93.27
NF	2	32	113	14	1,630	1,791	91.01
Total	398	1,534	1,480	236	1,691	5,339	
Producer's Accuracy (%)	96.73	95.18	86.62	88.14	96.39		
Overall Accuracy	92.99 %						
Overall Kappa Statistics	0.90						

A simplified error matrix has also been prepared by grouping land use classes into "Forest" and "Non-forest". This is done by combining VDF, MDF and OF into one class i.e. "Forest". The scrub and the Non-forest class have been combined into "Non-forest". The simplified error matrix is given in Table 2.14. In the simplified error matrix, classification of 5,114 points has been found to be correct, yielding an overall accuracy of 95.79 percent.

Table 2.14 Error Matrix for Forest and Non-Forest Classes

Classification Classes	Ground truth (based on field inventory data)			User's Accuracy (%)
	Forest	Non-Forest	Total	
Forest	3,256	69	3,325	97.93
Non-Forest	156	1,858	2,014	92.25
Total	3,412	1,927	5,339	
Producer's Accuracy (%)	95.43	96.42		
Overall Accuracy		95.79 %		
Overall Kappa Statistics		0.91		

Producer's accuracy and user's accuracy are calculated to assess the accuracy of individual classes. Producer's accuracy measures how well a certain area has been classified and the user's accuracy is a measure of the reliability of the map. It provides information about how well the map represents what is really on the ground.

The producer's accuracy is derived by dividing the number of correct sampling points in one class by the total number of points as derived from reference data. It includes the error of omission, which refers to the proportion of observed features on the ground that is not classified in the map. The more is the error of omission, the lower is producer's accuracy.

User's accuracy is obtained by dividing the correct classified units in a class by the total number of units that were classified in that class. One class in the map can have two types of classes on the ground. The 'right' class, which refers to the same land-cover-class in the map and on the ground; and 'wrong' classes, which show a different land-cover on the ground that predicted on the map. The latter classes are referred to as errors of commission. The more is the error of commission, the lower is the user's accuracy.

From Table 2.13, it is found that the producer's accuracy for VDF, MDF, OF, Scrub and Non-forest classes are 96.73 percent, 95.18 percent, 86.62 percent, 88.14 percent and 96.39 percent respectively. Similarly, user's accuracy for these classes are 93.00 Percent, 93.77 percent, 94.68 percent, 93.27 percent and 91.01 percent respectively. The producer's accuracy for forest and non-forest classes are found to be 95.43 percent and 96.42 percent respectively while user's accuracy for these classes are 97.93 percent and 92.25 percent respectively.

Results of accuracy assessment are further authenticated by carrying out Kappa analysis, which is a multivariate technique, providing a statistics known as K_{HAT} . This coefficient gives a measure of overall agreement of error matrix. In contrast to the overall accuracy—the ratio of the sum of diagonal values to total number of sampling points in the error matrix, the Kappa coefficient takes also non-diagonal elements into account. This statistic usually ranges between 0 and 1 and is used to indicate whether the correct values of the error matrix are due to true or chance agreement. Any classification having kappa coefficient more than 0.6 is considered as statistically sound. K_{HAT} calculated from the error matrix given at Table 2.13 is equal to 0.90, which indicates that an observed classification is 90 percent better than one resulting from chance. For the simplified matrix of forest and non-forest classes, the K_{HAT} comes out to be 0.91.

Figure 2.12
Increase in
Forest Cover due
to agroforestry
plantation
Hoshiarpur
district, Punjab

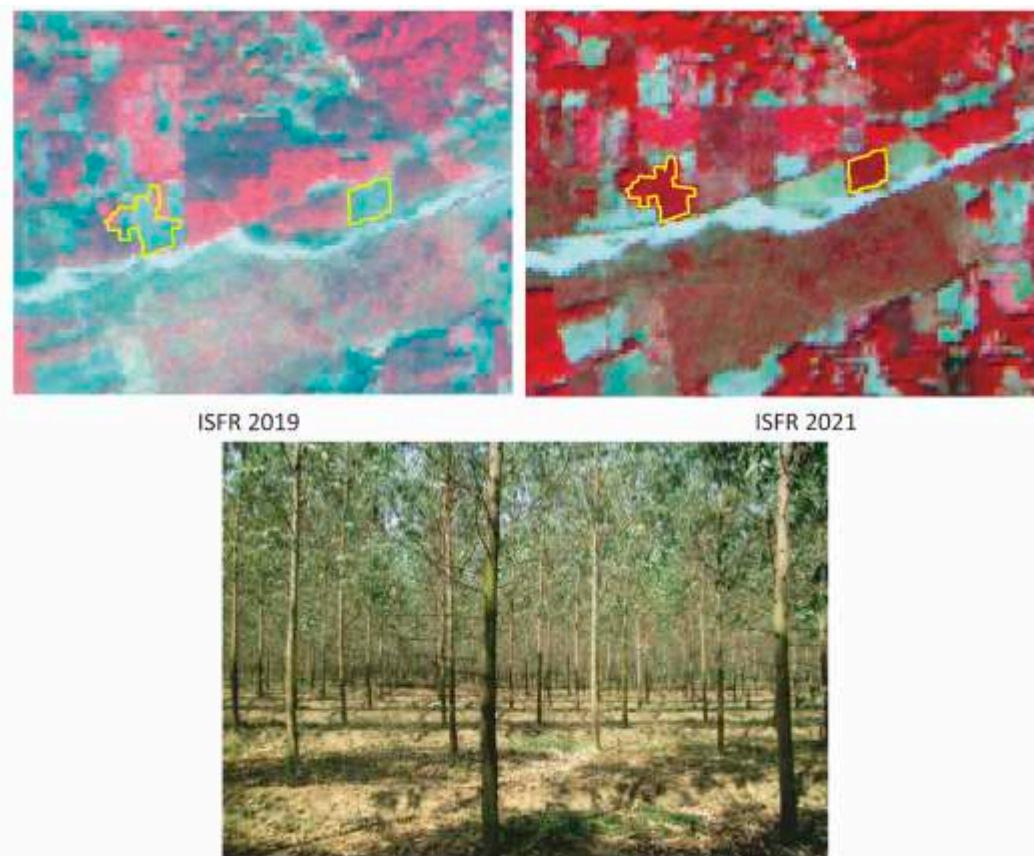
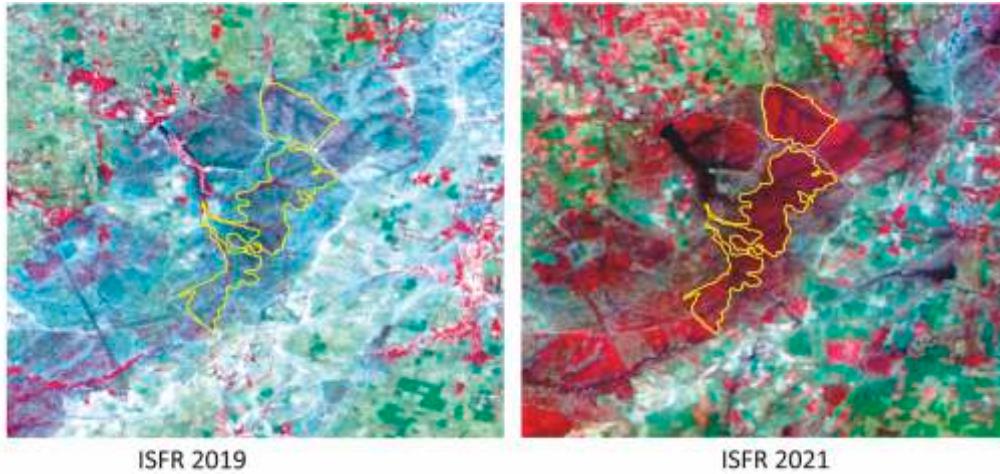


Figure 2.13
Increase in
Forest Cover due
to
afforestation
near Luni River
in Nagaur
district,
Rajasthan



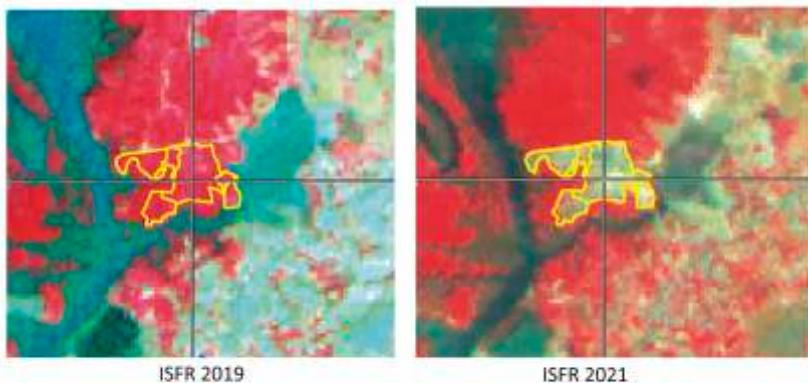
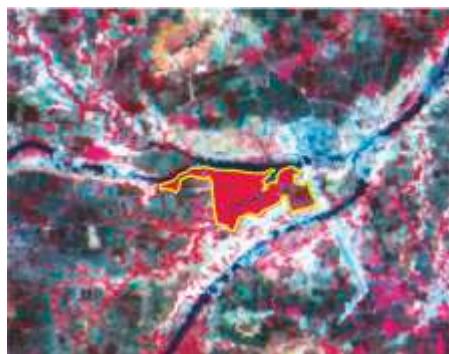


Figure 2.14
Decrease in Forest Cover due to construction of Solar panel in Port Blair (South Andaman district)



ISFR 2019



ISFR 2021



Figure 2.15
Decrease in Forest Cover due to construction of Dam in Jhalawar district, Rajasthan

2.19 Forest Cover in Major Mega Cities

Census 2011 defines very large Urban Agglomerations (UA) with a population of more than 10 million persons in the country as Mega City. Currently, India has five major megacities namely Greater Mumbai, Delhi, Kolkata, Bengaluru and Chennai. Ahmedabad and Hyderabad are two other major rapidly growing cities.

In the current assessment, extent of Forest Cover of Seven Major Cities has been carried out. The total Forest Cover in the seven major cities is 509.72 sq km which is 10.21% of total geographical area (as per shapefile) of the cities. It is seen that Delhi has the largest Forest Cover (194.24 sq km) followed by Mumbai (110.77 sq km) and Bengaluru (89.02 sq km).

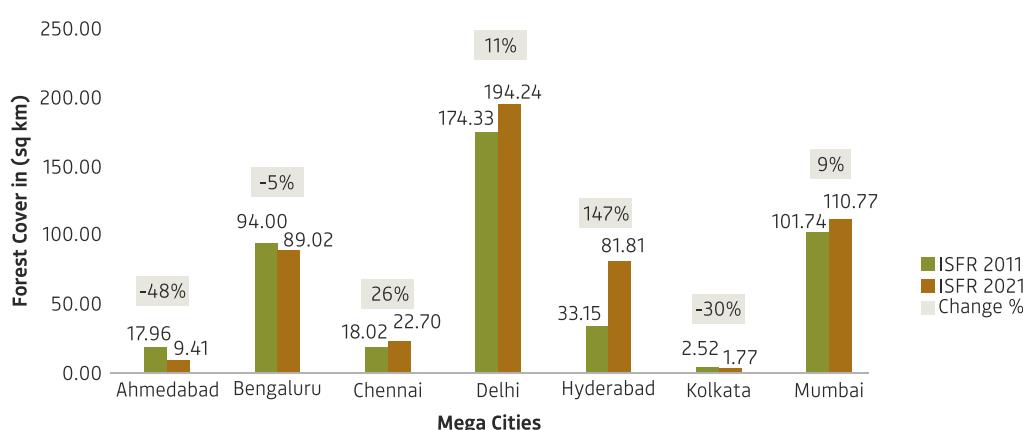
Table 2.15 Forest Cover in Major Mega Cities (ISFR 2021) (in sq km)

Name	State	Area as per digitized Boundary*	ISFR 2021					
			VDF	MDF	OF	Total Forest Cover	% of total Forest Cover wrt area of digitized boundary	Scrub
Ahmedabad	Gujarat	455.32	0.00	1.59	7.82	9.41	2.07	4.85
Bengaluru	Karnataka	1,307.35	0.00	12.66	76.36	89.02	6.81	14.87
Chennai	Tamil Nadu	430.07	0.00	7.66	15.04	22.70	5.28	1.77
Delhi	Delhi	1,540.63	6.74	56.34	131.15	194.24	12.61	0.45
Hyderabad	Telangana	634.18	0.00	17.68	64.13	81.81	12.90	29.96
Kolkata	West Bengal	186.55	0.00	0.10	1.67	1.77	0.95	0.00
Mumbai	Maharashtra	435.91	0.00	51.13	59.65	110.77	25.41	0.00
Total		4,990.01	6.74	147.16	355.82	509.72	10.21	51.90

* Shapefile of digitized boundaries as provided by NIC Delhi in 2021

Decadal change in Forest Cover between ISFR 2011 and ISFR 2021 has also been analysed and details are presented in Table 2.16 given below. There is an increase of 68 sq km of Forest Cover in the last ten years. Maximum gain in Forest Cover is seen in Hyderabad (48.66 sq km) followed by Delhi (19.91 sq km) while Ahmedabad and Bengaluru have lost Forest Cover of 8.55 sq km and 4.98 sq km respectively.

Figure 2.16
Forest Cover
between ISFR
2011 & ISFR
2021 in Mega
Cities





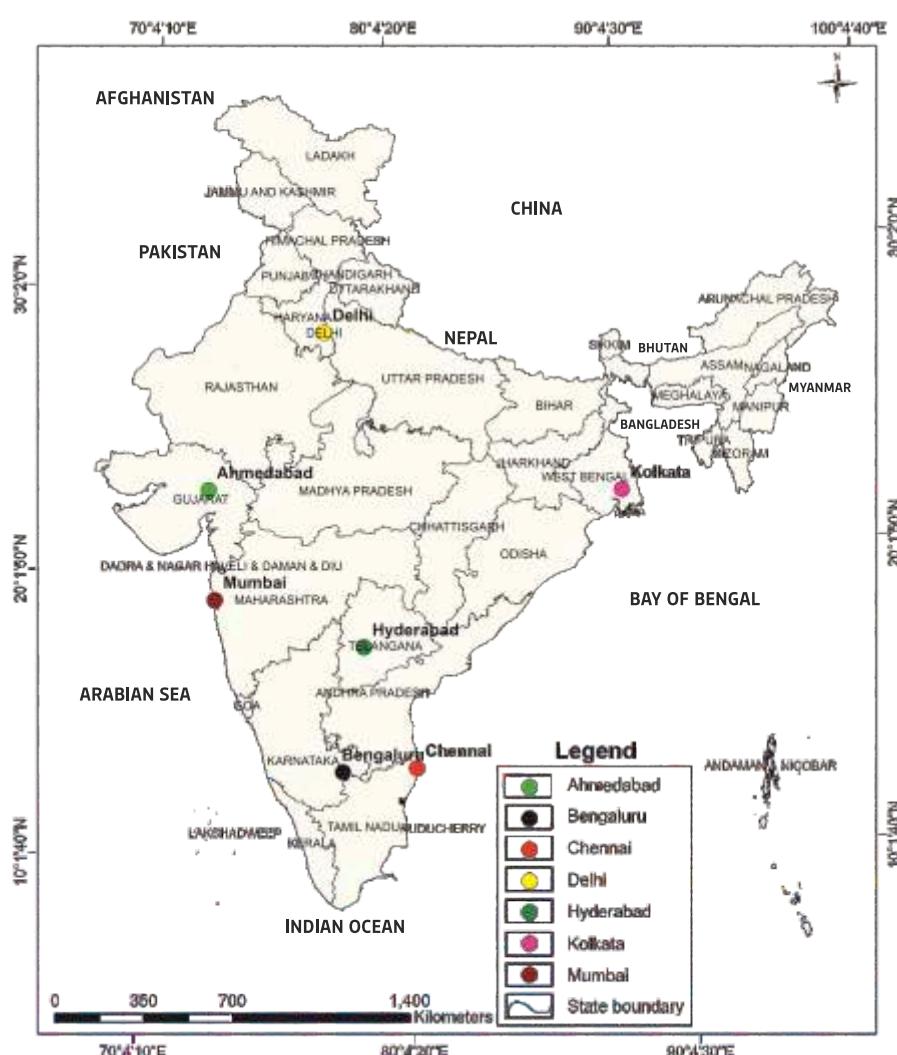
Forest Cover

Table 2.16 Decadal change in Forest Cover in Major Mega Cities between ISFR 2011 and ISFR 2021

Mega Cities Name	State	Area as per digitized Boundary*	ISFR 2011				% of total Forest Cover wrt area of digitized boundary
			VDF	MDF	OF	Total Forest Cover	
Ahmedabad	Gujarat	455.32	0.00	2.74	15.22	17.96	3.94
Bengaluru	Karnataka	1,307.35	0.00	25.53	68.47	94.00	7.19
Chennai	Tamil Nadu	430.07	0.00	7.84	10.18	18.02	4.19
Delhi	Delhi	1,540.63	6.82	49.53	117.98	174.33	11.32
Hyderabad	Telangana	634.18	0.00	9.15	24.00	33.15	5.23
Kolkata	West Bengal	186.55	0.00	0.39	2.13	2.52	1.35
Mumbai	Maharashtra	435.91	0.00	49.05	52.68	101.74	23.34
Total		4,990.01	6.82	144.23	290.66	441.72	8.85

* Shapefile of digitized boundaries as provided by NIC Delhi in 2021

Figure 2.17
Map showing Location of Mega cities



(in sq km)

Scrub	ISFR 2021						
	VDF	MDF	OF	Total Forest Cover	% of total Forest Cover wrt area of digitized boundary	Scrub	Forest Cover Change between ISFR 2011 to ISFR 2021
0.00	0.00	1.59	7.82	9.41	2.07	4.85	-8.55
19.31	0.00	12.66	76.36	89.02	6.81	14.87	-4.98
0.00	0.00	7.66	15.04	22.70	5.28	1.77	4.68
0.67	6.74	56.34	131.15	194.24	12.61	0.45	19.91
4.01	0.00	17.68	64.13	81.81	12.90	29.96	48.66
0.00	0.00	0.10	1.67	1.77	0.95	0.00	-0.75
0.00	0.00	51.13	59.65	110.77	25.41	0.00	9.03
23.99	6.74	147.16	355.82	509.72	10.21	51.90	68.00

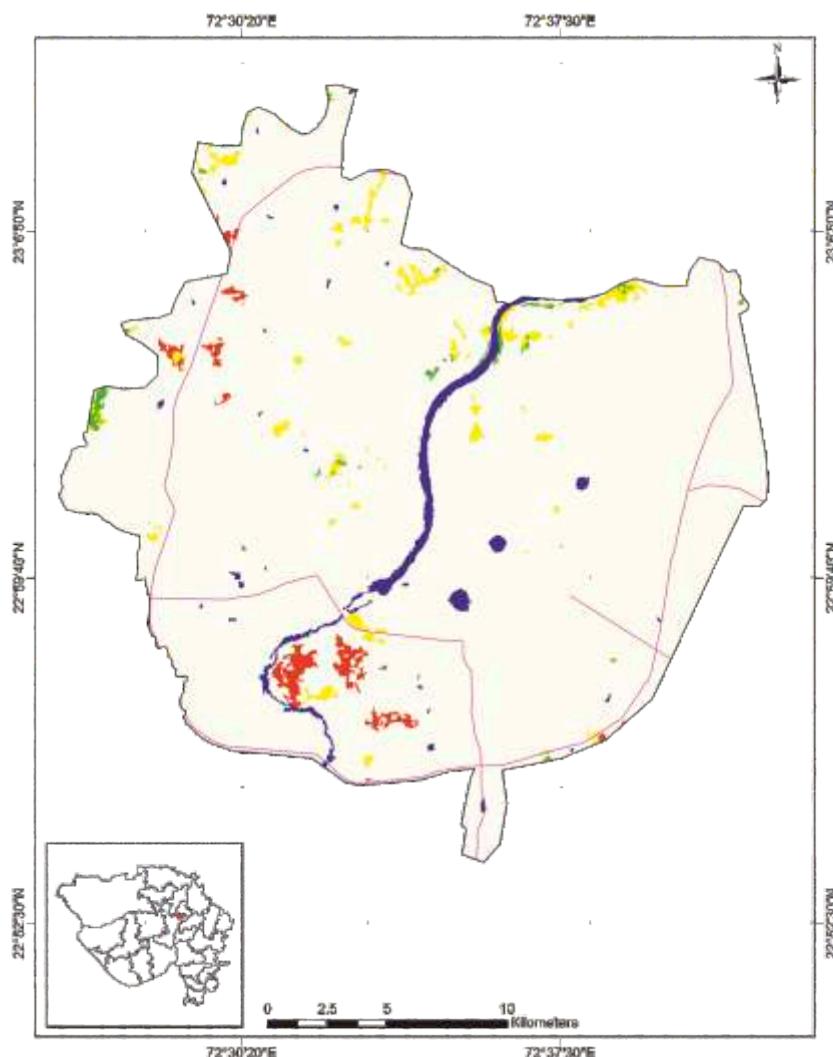


Figure 2.19
Map showing
Forest Cover in
Bengaluru

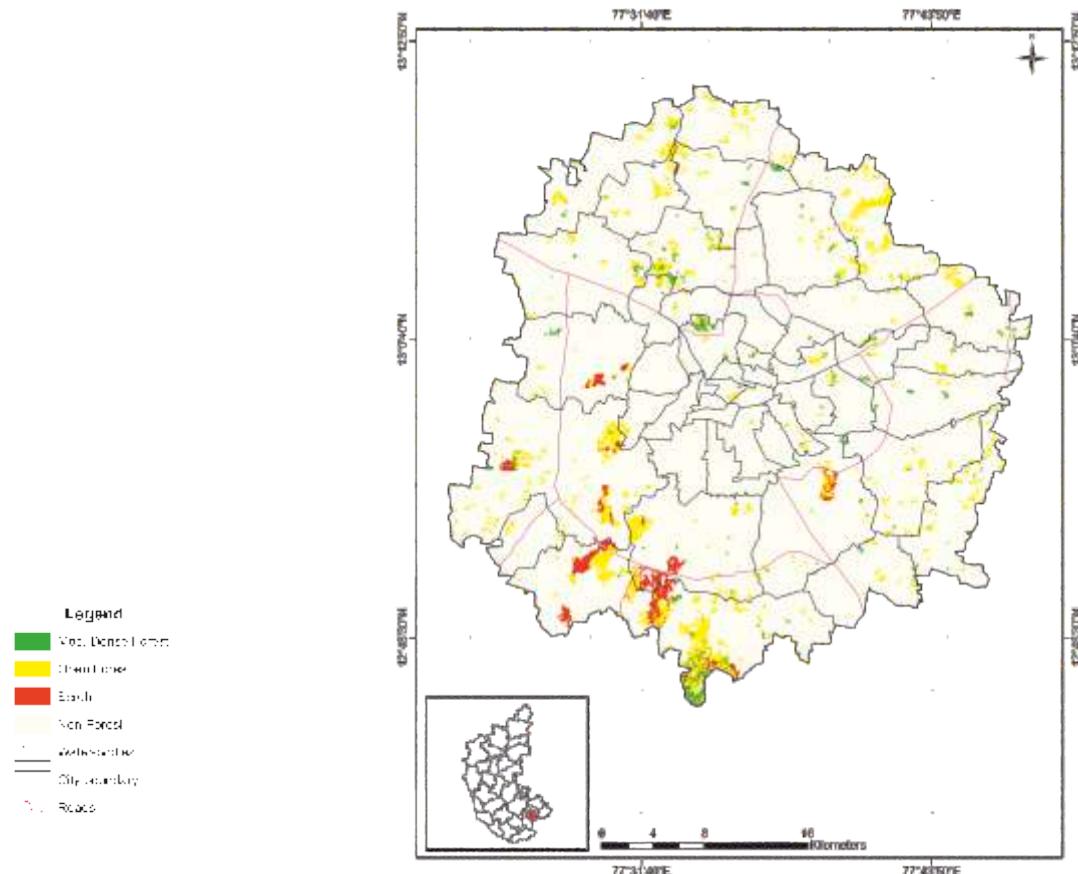
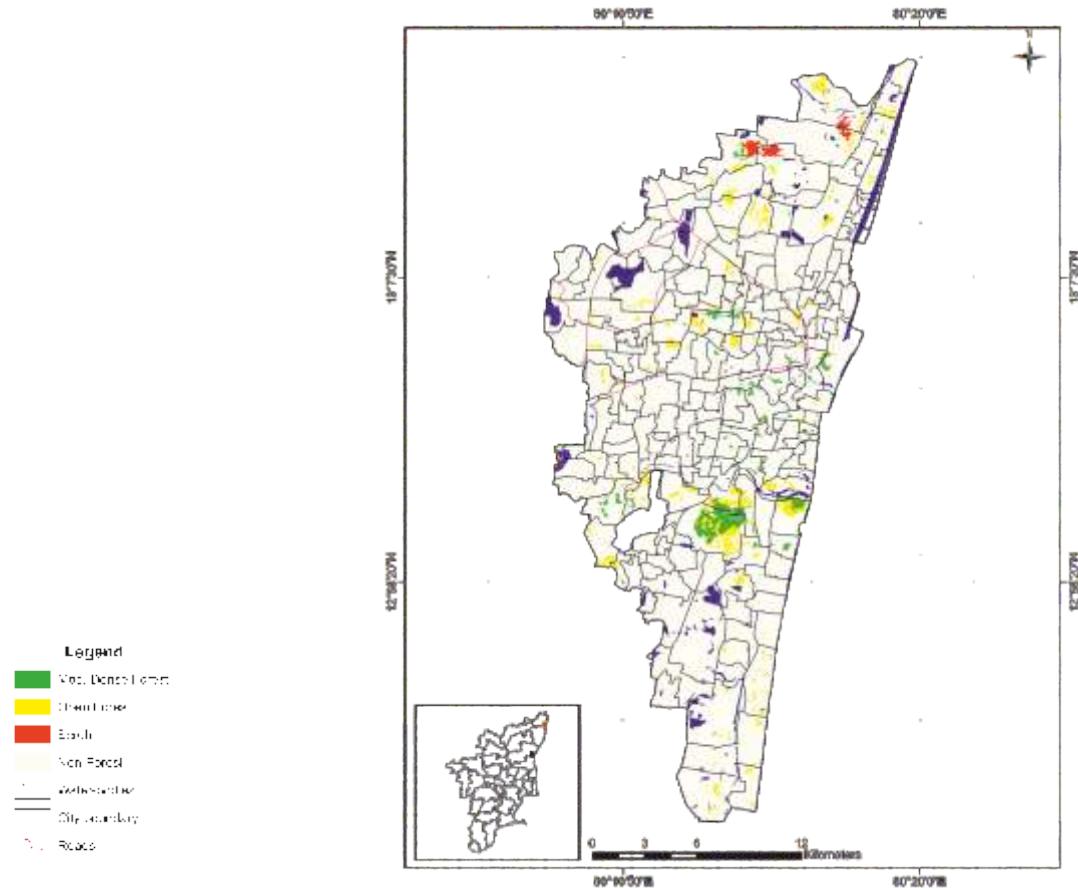


Figure 2.20
Map showing
Forest Cover in
Chennai



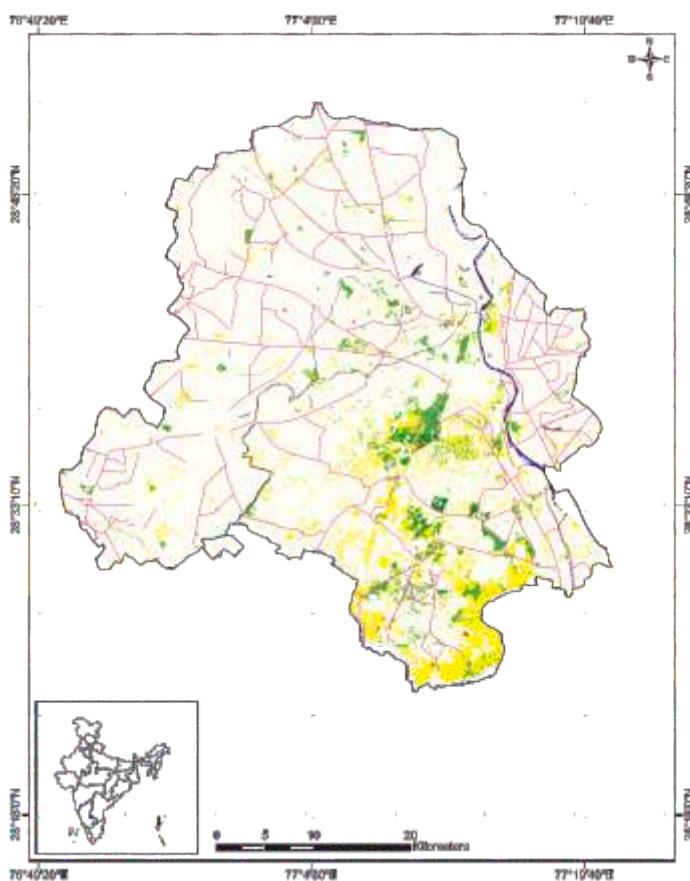


Figure 2.21
Map showing
Forest Cover in
Delhi

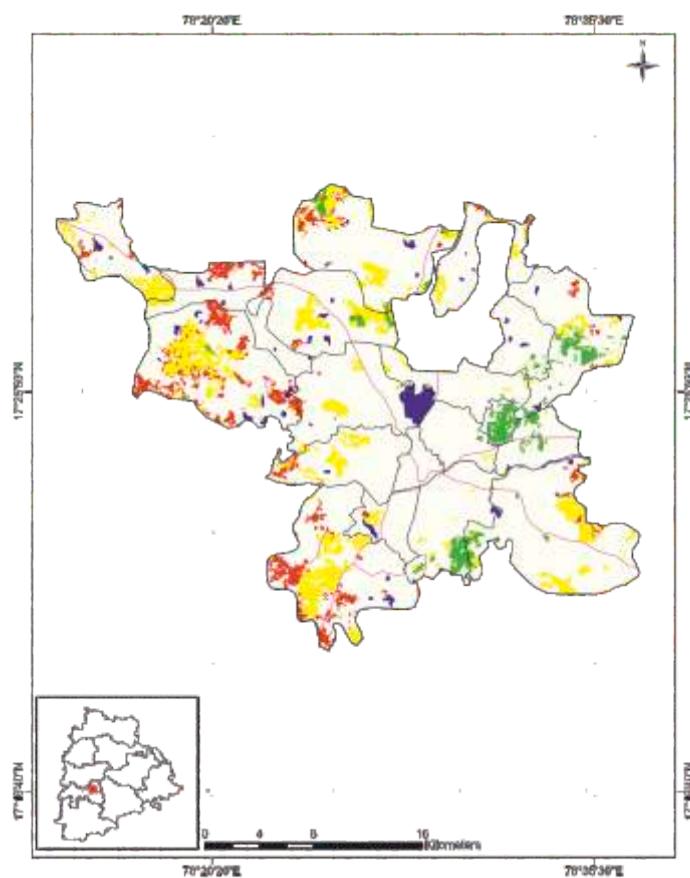


Figure 2.22
Map showing
Forest Cover in
Hyderabad

Figure 2.23
Map showing
Forest Cover in
Kolkata

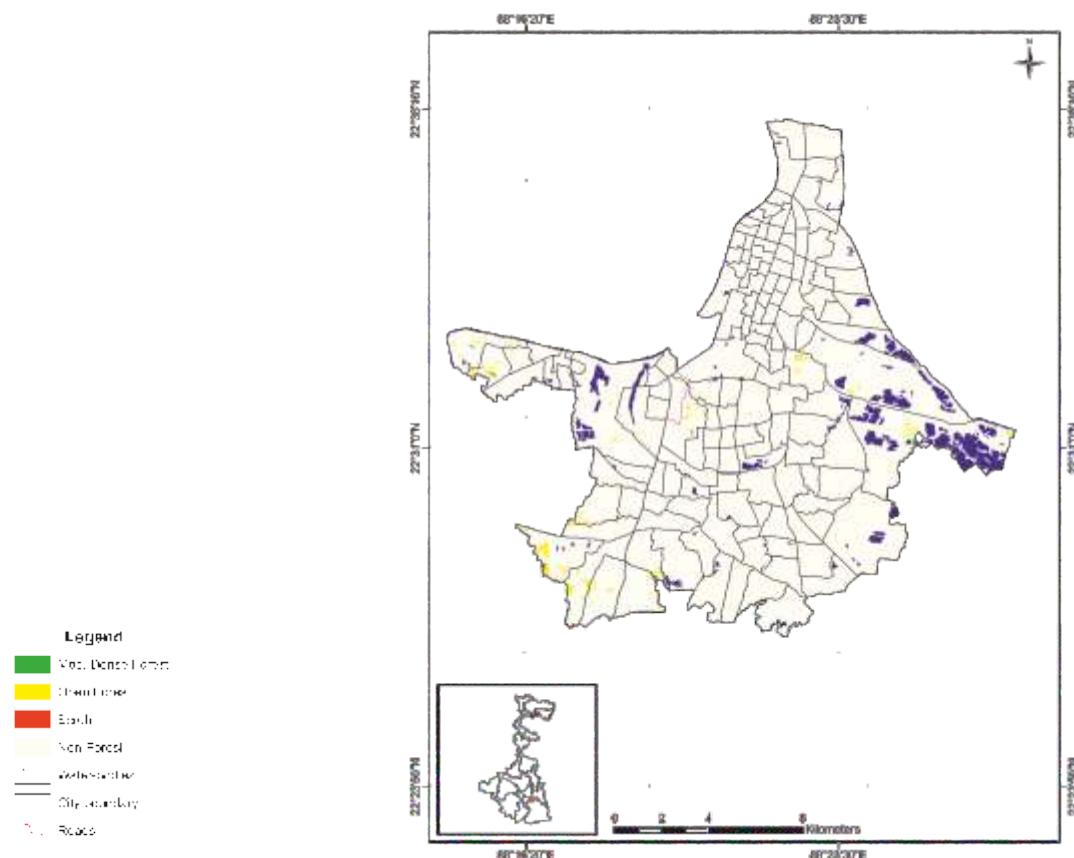


Figure 2.24
Map showing
Forest Cover in
Mumbai

