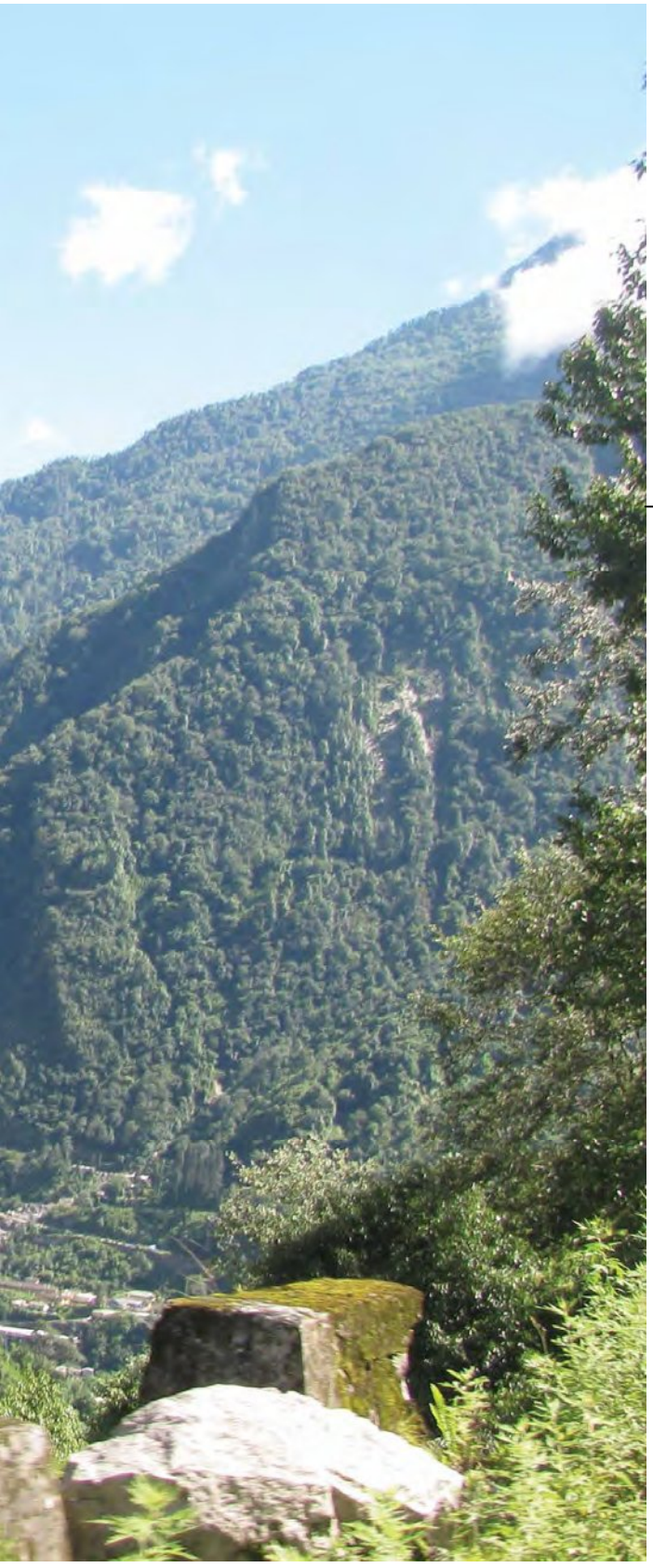


2

Chapter

Forest Cover

2.1 INTRODUCTION

Forest cover broadly signifies the expanse of forest resources in a country or region. The periodic assessment of forest cover by Forest Survey of India (FSI) started in the year 1987 using remote sensing technique. The current assessment in the biennial cycle of forest cover mapping is 16th in the series providing a continuous monitoring of forest cover and its change across the country in the last 32 years. All tree stands with canopy density over 10% and having an extent of more than one hectare, including tree orchards, bamboo, palms etc within recorded forests, on other government lands, private, community or institutional lands are included in the assessment of forest cover.

Remote sensing based forest cover assessment in a periodic manner helps in knowing a broad trend of forest cover in the country. FSI has used latest Indian satellite data suitable for the purpose of forest cover mapping (FCM) in all the past assessments and has regularly upgraded the methodology in tune with the technological development.

The forest cover assessment published in India State of Forest Reports (ISFR) is a very important source of primary information on forests of the country and is widely used across the Central Government, State Governments, forestry professionals of the State Forest Departments, academia, international organizations and other stakeholders. National Forest Policy of India, 1988 envisages a goal of achieving 33% of geographical area of the country under forest and tree cover. Nation-wide forest cover mapping done by FSI serves as a monitoring mechanism towards this policy goal.

2.2 OBJECTIVES OF THE NATION-WIDE FOREST COVER MAPPING

Periodic forest cover assessment using medium resolution satellite data (23.5m) is an effective strategy, as it is both time and cost efficient, compared to other methods. The process of wall-to-wall forest cover mapping on 1:50,000 scale takes two full years due to the vast size of the country as well as the scientific rigour of the exercise to achieve high levels of accuracy.

The main objectives of the biennial forest cover mapping exercise done by FSI are as follows:

- to monitor forest cover and changes therein at the National, State and District levels
- to generate information on forest cover in different density classes and changes therein
- to produce forest cover and other thematic maps derived from it for the whole country
- to provide primary base layer for assessment of different parameters including growing stock, forest carbon etc
- to provide information for international reporting

The forest cover assessment reflects, in general, the status of forests in the country and its trend and provides inputs for broad evaluation of the forest related policies, legislations, programs and activities in the country.

2.3 SATELLITE DATA AND PERIOD

The wall-to-wall mapping of forest cover of the country since 1999 is based on data from the indigenous LISS III sensor of IRS Resourcesat series of satellites from Indian Space Research Organization (ISRO). For the current cycle, data from the latest LISS III sensor onboard Resourcesat-2 satellite has been used. The advantage of the LISS III data from Resourcesat-2 is its higher radiometric resolution at 10 bits as compared to 8 bit data of Resourcesat-1, giving more levels of reflectance values. The details of the satellite data used in the current cycle (16th) of forest cover mapping exercise are presented 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 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 current assessment was procured from National Remote Sensing Centre (NRSC), Hyderabad in digital form. Most of the satellite data pertain to the period October to December, 2017 as better foliage conditions are observed in the forests during this period and the images are also generally cloud free. However, some parts of the country especially the North Eastern region and A&N Islands have cloud cover even during this period and in such cases additional images were obtained for the period January to March, 2018. Period of satellite data used for forest cover mapping for different States & UTs is given in the Annexure I. A total of 306 scenes of IRS Resourcesat 2 LISS III covering the whole country have been used for forest cover mapping exercise.

The choice of satellite data of 23.5 m x 23.5 m resolution is optimally suited for forest cover mapping of the country's vast size in a short cycle of two years. Use of higher resolution satellite image would require much longer time span to interpret the data and therefore would have a bearing on the periodicity of the exercise. Since 2001, continuity of sensor and scale based on LISS III data renders the forest cover estimates comparable.

2.4 FOREST COVER

Forest cover reported in ISFR includes all lands having trees more than one hectare in area with tree canopy density of more than 10%, irrespective of ownership, legal status of the land and species composition of trees. LISS III data with the resolution 23.5m allows mapping at the maximum scale of 1:50,000, at which the minimum mappable unit (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 depicted 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)

2.5 FOREST COVER ASSESSMENT: BROAD APPROACH

The wall-to-wall forest cover mapping of the country is done following a set of sequential steps which involve 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. The broad approach followed in forest cover assessment is depicted in the Fig 2.2 below.

As shown above, the major steps involved in FCM are data preparation, interpretation to identify change areas, ground truthing and post classification correction, followed by generation of output. The approach involves comparison of the current satellite data with the previous forest cover map and discerning changes in the forest cover by on-screen visual analysis.

FIGURE 2.1 Pictorial depiction of different forest cover classes and scrub

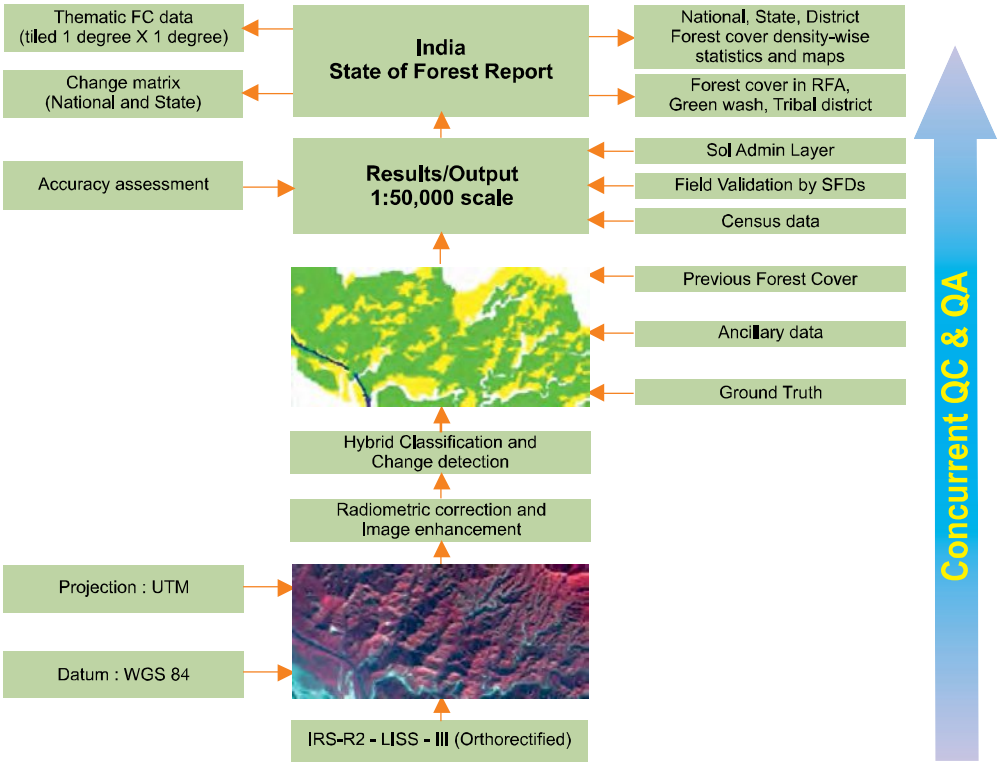
Very Dense Forest

Moderately Dense Forest

Open Forest

Scrub

FIGURE 2.2 Schematic diagram of the broad approach followed in forest cover mapping



2.6 IMPROVEMENTS IN THE METHODOLOGY OF FCM

Methodology of forest cover mapping has undergone regular improvements over the previous cycles. In the current cycle, significant improvements have been incorporated in the methodology with the objectives of achieving higher accuracy, minimize subjectivity, improved information extraction from satellite data and improved cartography & projection. Important improvements in the methodology are briefly described below.

2.6.1 Use of Ortho rectified LISS III imagery

Ortho-rectification is a process of removing distortions of image perspective i.e. tilt and relief (terrain) on the satellite image for the purpose of creating a planimetric image. The resultant ortho-rectified image has a constant scale wherein features are represented in their true positions irrespective of altitudinal variations on the ground. This allows accurate measurement of distances, angles and areas. For the current forest cover mapping exercise, ortho-rectified LISS III data was procured for the entire country from NRSC, Hyderabad. It is for the first time that ortho-rectified satellite images have been used for forest cover mapping of the whole country by FSI. Use of ortho-rectified images in FCM has helped in improving the accuracy of FCM output.

2.6.2 Radiometric correction of ortho-rectified satellite data

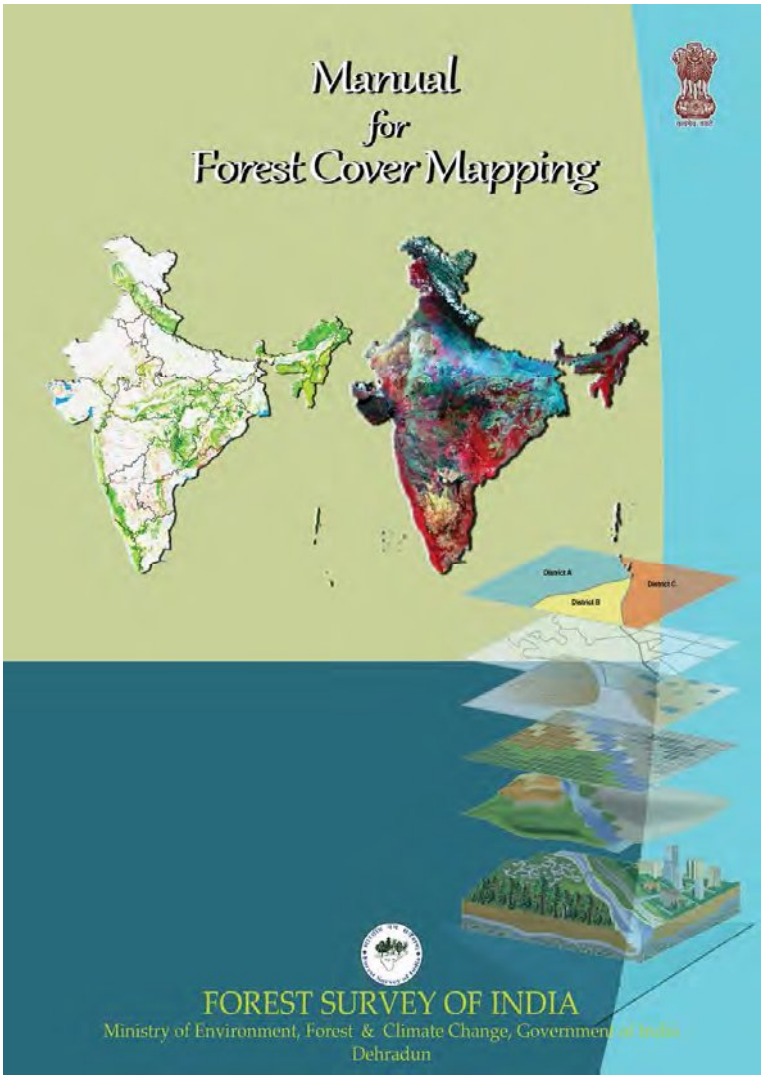
Optical sensors of the satellite record intensity of the reflected electromagnetic radiations from different features on the earth surface as digital numbers (DN) associated with each pixel in different spectral bands. Radiometric correction is carried out to reduce the radiometric distortions, which creep in at the time of satellite data acquisition. Sensor specific information embedded in the metadata file of the satellite image is used to carry out this calibration.

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.

2.6.3 Refinement in FCM Methodology and publishing a Manual of FCM

The methodology of forest cover mapping has been further refined during the current FCM cycle in order to capture the latest developments in image interpretation techniques. The new approach is based on a judicious combination of digital image processing algorithms and on-screen visual analysis of the changes with respect to previous satellite image by the analysts. This approach involves use of NDVI transformation on satellite data for masking out non-vegetated areas from the images and preparing a classified image through unsupervised classification of the masked FCC after performing Maximum Likelihood Estimation algorithm (MLE). The steps of the refined methodology have been standardised as a protocol for which a detail manual has been prepared. The FCM manual, as shown in Fig 2.3, also ensures uniform application of the methodology in the organization. The change areas are discerned by on-screen visual analysis comparing the current classification with the FCM of previous cycle. During this analysis, the discerned changes are categorised into two broad categories based on clarity of discernment. Relatively confirmed changes are categorised as 'Real change' and the ones that are not so confirmed and need further analysis using collateral data such as high resolution images, ground truthing etc are categorised as 'interpretational changes'. The change polygons are digitized using the vector tools. These change polygons are then saved as a shape file with the attribute showing change in forest cover category. The change layer for the present cycle is generated

FIGURE 2.3 Forest Cover Mapping Manual



with respect to the previous cycle, irrespective of the fact that the changes are real or interpretational (after confirmation). Fig 2.4 shows the workflow of the forest cover mapping methodology.

2.6.3.1 Concurrent Quality Check & Quality Assurance (QC&QA) and its implementation

The implementation plan of the current FCM cycle was updated to provide enhanced focus on the Quality Check & Quality Assurance (QC&QA) standards and steps to be followed to ensure the same. At every step of the methodology, adherence to the defined quality standards was ensured through concurrent monitoring.

The QC&QA activities are defined and monitored using the formats provided in the published manual. At every stage, the supervising officers check whether the methodology followed by the analyst is as per the Manual and also check whether the defined quality standards have been achieved. At the classification stage which is the most important stage and pertains to image interpretation, all the scenes are thoroughly checked at different levels. The QC&QA teams track the progress of these activities. A final round of QC&QA has been carried out at the headquarters in which all analysts and supervisory officers from the Headquarters and Regional Offices participated.

2.6.3.2 Ground Truthing and Use of Mobile Application

Ground truthing is an integral part of remote sensing based mapping of natural resources. After classifying the forest cover as per the FCM manual, the analysts mark those points which require ground verification of the changes. Ground truthing also helps in collecting signatures of different forest types in different regions. More than 2,200 ground truth points were visited by the analysts during the current FCM cycle, Fig 2.9 shows the locations of the ground truth points.

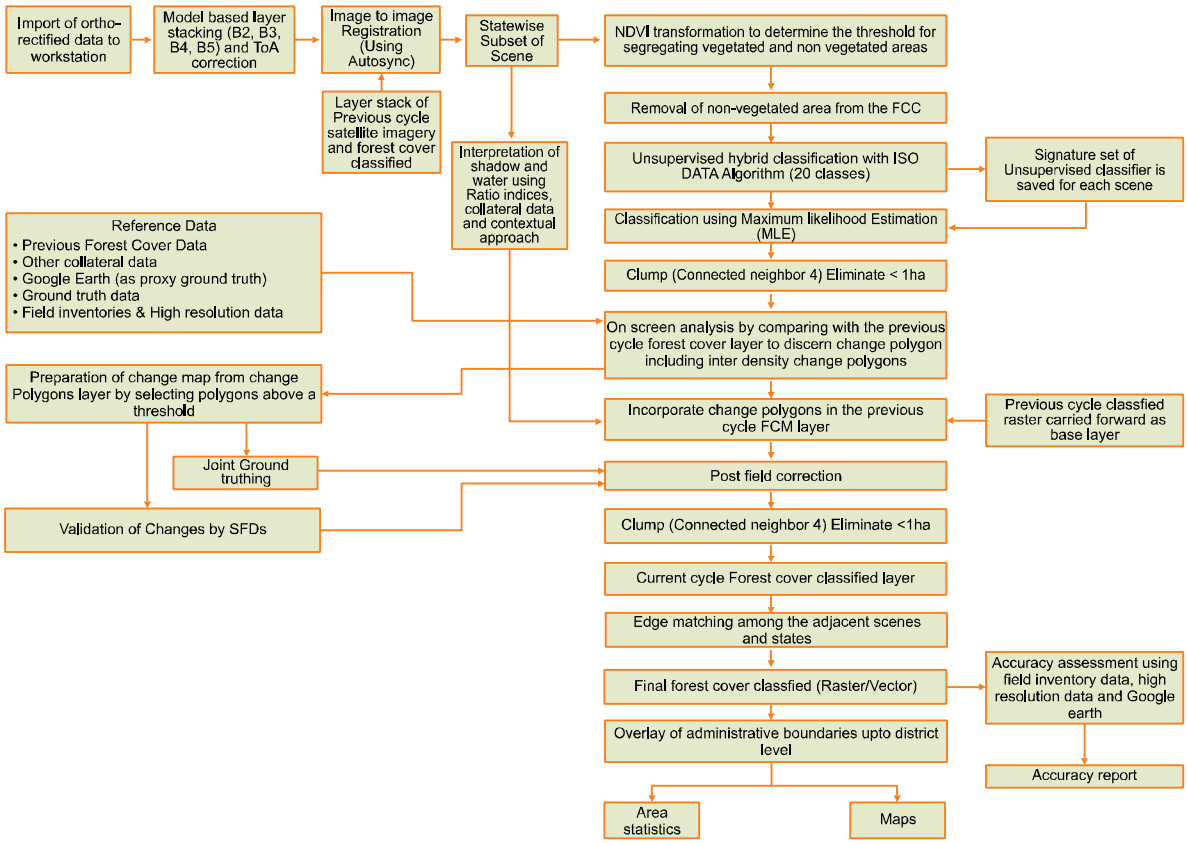
An open source Transerve Data Collector (TDC) mobile application was customized for ground truthing in the current FCM exercise for collection, storage and analysis of Ground Truth observations. The analysts captured the ground data such as geo-tagged photographs, canopy density, tree species and observations related to change and stored them on the mobile application and transmitted the same to the cloud server. 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.

2.7 FOREST COVER MAPPING METHODOLOGY

The schematic diagram of the forest cover mapping methodology is given in the Fig 2.4.

The previous FCM layer was made compatible with the current satellite data using digital image processing tools of geo-rectification. Registering 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.

FIGURE 2.4 Forest Cover Mapping Methodology



There is a significant shift in the method of interpretation. In the new approach, change polygons are delineated and the previous FCM layer is updated with the discerned change polygons to create the new forest cover map. The change polygons are captured by comparison of the previous FCM with the intermediate classification derived from the current satellite data (Fig 2.5). Ground knowledge of the analyst and collateral data like ground truth details, forest inventory plot data and Google earth images play a very important role in image interpretation.

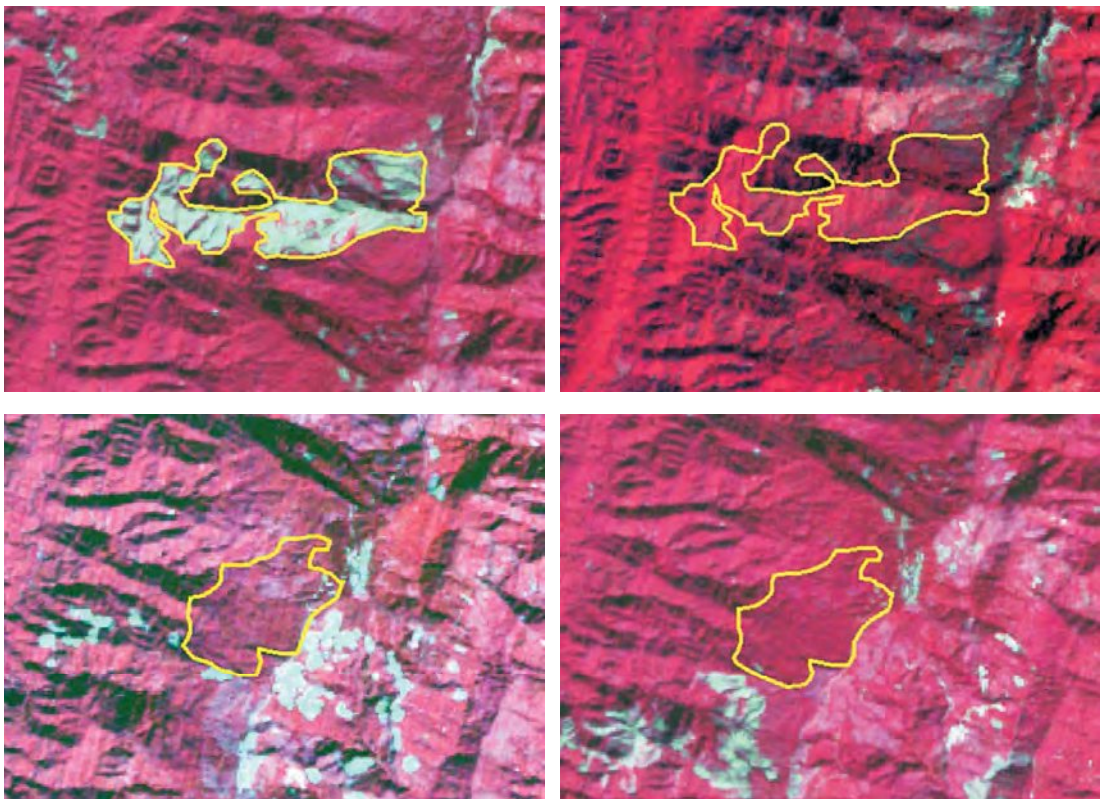
2.7.1 Use of Collateral data to aid interpretation

Interpretation becomes very difficult in certain cases like areas with thick cloud cover, hilly areas with deep hill shadows, mixing of bushy and agricultural vegetation with forest, areas with water logging, forests under senescence during the data period, area under thick haze etc. In such cases, use of collateral data is very important to aid the analysis. While interpretation is carried out using LISS III data, images from certain collateral sources like Google Earth, Sentinel-2 data of European Space Agency, Landsat 8 data OLI from US Geographical Survey (USGS) and inventory data of FSI are also referred to, wherever necessary, in order to help resolve the doubts and add value to the interpretation.

2.7.2 Validation of Change Maps

The change maps depict changes in current forest cover with respect to previous forest cover. As part of methodology the change maps showing polygons above 5 ha in size are sent to SFDs for validation. After receiving the feedback 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.

FIGURE 2.5 Illustration of change polygons



2.7.3 Post Field Correction

Corrections are incorporated in the interpreted layers of forest cover as per the ground truth observations, ancillary data and inputs from the State Forest Departments. 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 of the patches of area less than 1 ha for smoothening of the FCM layer.

2.8 LIMITATIONS OF THE FOREST COVER MAPPING

Every remote sensing based mapping exercise has certain limitations. The inherent limitations affect the accuracy of the Forest Cover Mapping which is assessed and reported through an independent accuracy assessment exercise.

Some of the significant limitations are as follows:

- since the resolution of the LISS III sensor data is 23.5 m, land cover features having a geometric dimension less than 23.5 m on the ground are not discernible
- considerable ground details may sometimes be obscured due to clouds and shadows. Such areas can be discerned to a certain extent with the help of collateral data and image processing techniques, but not always
- non-availability of appropriate season data sometimes puts constraints on the interpretation of the features owing to poor reflectance of data and phenological changes in forests
- occurrence of weeds like lantana in forest areas and agricultural crops like sugarcane, cotton, etc adjacent to forests, causes mixing of spectral signatures and often make precise forest cover delineation difficult
- young plantations and tree species with less chlorophyll or inadequate foliage, many a times are not discernable on satellite images due to inadequate reflectance
- haze and other atmospheric distortions pose difficulty in interpretation, especially in the coastal areas

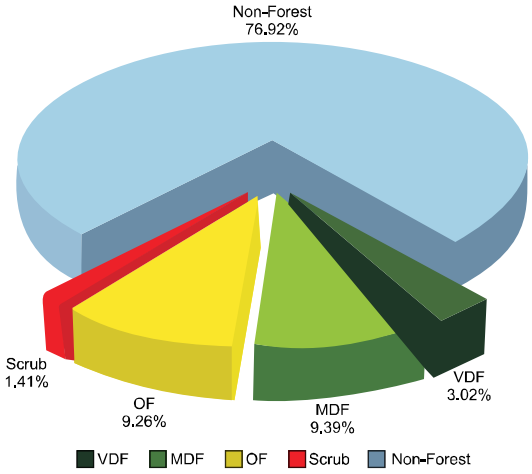
2.9 FOREST COVER: 2019 ASSESSMENT

The forest cover of the country has been mapped into three canopy density classes viz Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF). Scrub areas though not part of the forest cover, have also been 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 is depicted in the pie chart (Fig 2.6)

TABLE 2.3 Forest Cover of India

Class	Area (sq km)	Percentage of Geographical Area
Very Dense Forest	99,278	3.02
Moderately Dense Forest	3,08,472	9.39
Open Forest	3,04,499	9.26
Total Forest Cover	**7,12,249**	**21.67**
Scrub	46,297	1.41
Non-Forest	25,28,923	76.92
Total Geographical Area	**32,87,469**	**100.00**

FIGURE 2.6 Pie-chart showing Forest Cover of India



The total forest cover of the country, as per current assessment is 7,12,249 sq km which is 21.67% of the total geographic area of the country. In terms of canopy density classes, area covered by VDF is 99,278 sq km (3.02%), MDF is 3,08,472 sq km (9.39%) and OF is 3,04,499 sq km (9.26%). It may be seen that very dense forests and moderately dense forest constitute over 57% of the total forest cover of the country. Forest cover map of India is shown in Fig 2.7.

2.10 STATE/UT WISE FOREST COVER

Forest cover in the States and UTs of the country according to 2019 assessment and change therein as compared to the previous assessment of 2017 has been presented in the Table 2.4.

FIGURE 2.7 Forest Cover Map of India 2019

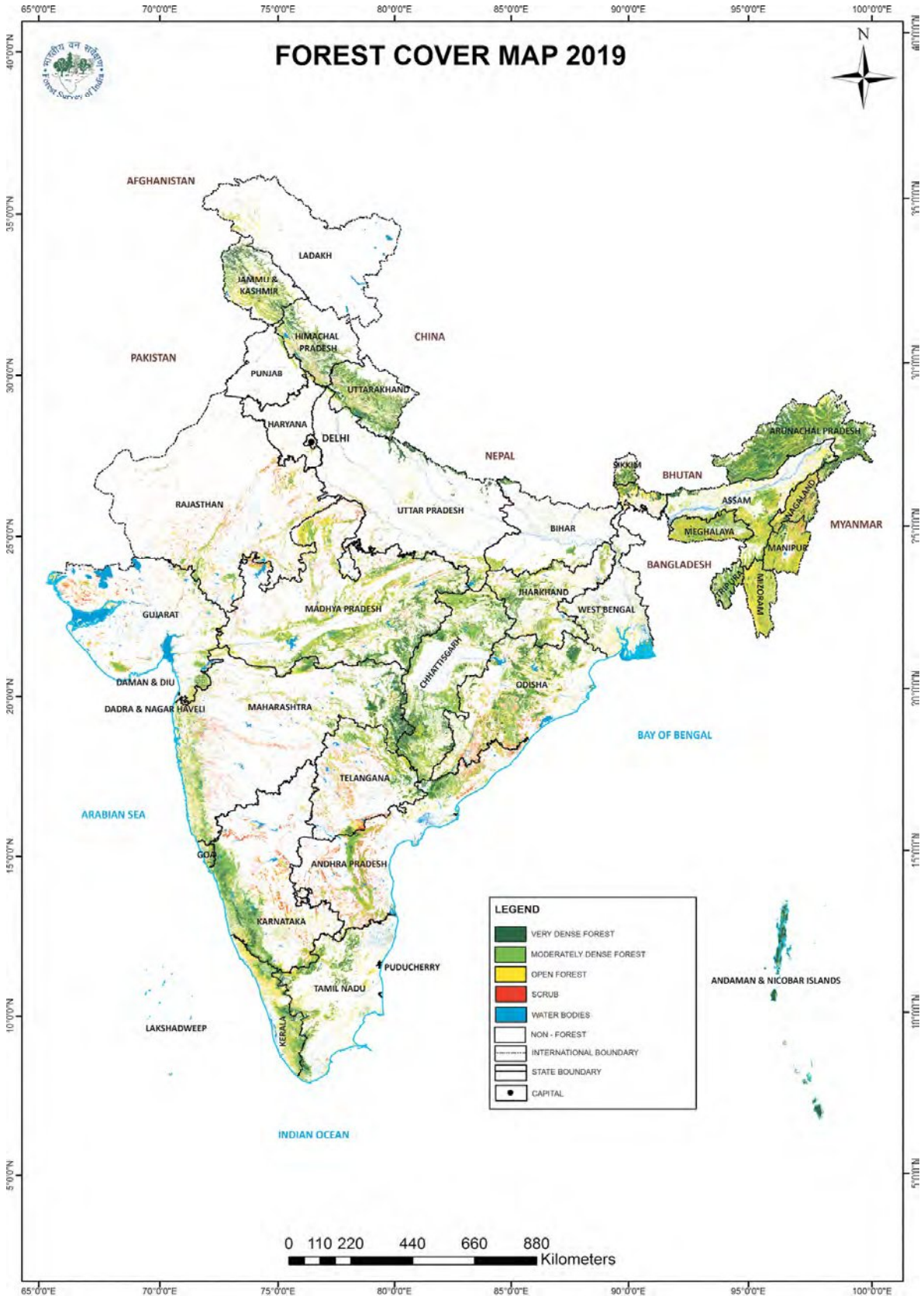


TABLE 2.4 Forest Cover in the States/UTs in India

(area in sq km)

S. No.	State/UT		Geo. Area (GA)	2019 Assessment				% of GA	Change in forest cover w.r.t ISFR 2017	Change % w.r.t ISFR 2017	Scrub
				VDF	MDF	OF	Total Forest Cover				
1.	Andhra Pradesh		1,62,968	1,994	13,938	13,205	29,137	17.88	990	3.52	8,255
2.	Arunachal Pradesh		83,743	21,095	30,557	15,036	66,688	79.63	-276	-0.41	229
3.	Assam		78,438	2,795	10,279	15,253	28,327	36.11	222	0.79	173
4.	Bihar		94,163	333	3,280	3,693	7,306	7.76	7	0.10	250
5.	Chhattisgarh		1,35,192	7,068	32,198	16,345	55,611	41.13	64	0.12	610
6.	Delhi		1,483	6.72	56.42	132.30	195.44	13.18	3.03	1.57	0.30
7.	Goa		3,702	538	576	1,123	2,237	60.43	8	0.36	0
8.	Gujarat		1,96,244	378	5,092	9,387	14,857	7.57	100	0.68	2,994
9.	Haryana		44,212	28	451	1,123	1,602	3.62	14	0.88	154
10.	Himachal Pradesh		55,673	3,113	7,126	5,195	15,434	27.72	334	2.21	315
11.	Jammu & Kashmir #	UT of J&K	53,258*	4,203	7,952	8,967	21,122	39.66	348	1.68	250
		UT of Ladakh	1,69,421*	78	660	1,752	2,490	1.47	23	0.93	298
		Total	2,22,236	4,281	8,612	10,719	23,612	10.62	371	1.60	548
12.	Jharkhand		79,716	2,603	9,687	11,321	23,611	29.62	58	0.25	688
13.	Karnataka		1,91,791	4,501	21,048	13,026	38,575	20.11	1,025	2.73	4,484
14.	Kerala		38,852	1,935	9,508	9,701	21,144	54.42	823	4.05	13
15.	Madhya Pradesh		3,08,252	6,676	34,341	36,465	77,482	25.14	68	0.09	6,002
16.	Maharashtra		3,07,713	8,721	20,572	21,485	50,778	16.50	96	0.19	4,256
17.	Manipur		22,327	905	6,386	9,556	16,847	75.46	-499	-2.88	1,181
18.	Meghalaya		22,429	489	9,267	7,363	17,119	76.33	-27	-0.16	600
19.	Mizoram		21,081	157	5,801	12,048	18,006	85.41	-180	-0.99	1
20.	Nagaland		16,579	1,273	4,534	6,679	12,486	75.31	-3	-0.02	635
21.	Odisha		1,55,707	6,970	21,552	23,097	51,619	33.15	274	0.53	4,327
22.	Punjab		50,362	8	801	1,040	1,849	3.67	12	0.65	33
23.	Rajasthan		3,42,239	78	4,342	12,210	16,630	4.86	58	0.35	4,760
24.	Sikkim		7,096	1,102	1,552	688	3,342	47.10	-2	-0.06	307
25.	Tamil Nadu		1,30,060	3,605	11,030	11,729	26,364	20.27	83	0.32	715
26.	Telangana		1,12,077	1,608	8,787	10,187	20,582	18.36	163	0.80	3,615
27.	Tripura		10,486	654	5,236	1,836	7,726	73.68	0	0.00	29
28.	Uttar Pradesh		2,40,928	2,617	4,080	8,109	14,806	6.15	127	0.87	587
29.	Uttarakhand		53,483	5,047	12,805	6,451	24,303	45.44	8	0.03	383
30.	West Bengal		88,752	3,019	4,160	9,723	16,902	19.04	55	0.33	146
31.	A & N Islands		8,249	5,678	684	381	6,743	81.74	1	0.01	1
32.	Chandigarh		114	1.36	14.24	6.43	22.03	19.32	0.47	2.18	0.10
33.	Dadra & Nagar Haveli		491	0	80	127	207	42.16	0	0.00	5
34.	Daman & Diu		111	1.40	5.69	13.40	20.49	18.46	0	0.00	0.19
35.	Lakshadweep		30	0	16.09	11.01	27.10	90.33	0	0.00	0.00
36.	Puducherry		490	0	17.66	34.75	52.41	10.70	-1.26	-2.35	0.00
Total			**32,87,469**	**99,278**	**3,08,472**	**3,04,499**	**7,12,249**	**21.67**	**3,976**	**0.56**	**46,297**

* Area of shape file provided by Survey of India (December, 2019). Notified geographical area from SOI awaited.

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

As given in the table above Madhya Pradesh has the largest forest cover in the country followed by Arunachal Pradesh, Chhattisgarh, Odisha and Maharashtra. In terms of forest cover as percentage of total geographical area, the top five States are Mizoram (85.41%), Arunachal Pradesh (79.63%), Meghalaya (76.33%), Manipur (75.46%) and Nagaland (75.31%), which are all from the northeastern region of the country. Forest Cover of J & K has been updated for UTs of J & K and Ladakh after the notification about the reorganization of the erstwhile State of J & K on 31st October 2019. The Forest Cover information for the two UTs has been derived using shape file provided by Survey of India (SOI) in December 2019.

2.11 CHANGE IN FOREST COVER

Change in forest cover between the two successive assessment periods is an important indicator reflecting state of forests in a State/UT or the country as a whole. The change in forest cover is analysed with respect to forest cover of previous assessment which signifies actual change in forest cover on the ground. Besides the change between forests to non-forest and vice versa, the change within the forests between different canopy density classes has also been analysed.

Table 2.5 gives the change in forest cover for each States/UTs for the three density classes. It is seen that there is an overall gain of 3,976 sq km of forest cover in the country as compared with the previous assessment reported in the ISFR 2017. The States/UTs showing significant gain in forest cover are Karnataka (1,025 sq km), Andhra Pradesh (990 sq km), Kerala (823 sq km) and J&K (371 sq km) whereas States showing loss in forest cover are Manipur (499 sq km), Arunachal Pradesh (276 sq km) and Mizoram (180 sq km).

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 whereas, loss in forest cover and impairment of forest canopy may be attributed to shifting cultivation, forest fires, felling of trees, natural calamities,anthropogenic pressure and developmental activities.

TABLE 2.5 Change in Forest Cover of States/UTs between 2017 and 2019 assessments

S. No.	State/UT	Geographical Area	2017 Assessment			
			VDF	MDF	OF	Total
1.	Andhra Pradesh	1,62,968	1,957	14,051	12,139	28,147
2.	Arunachal Pradesh	83,743	20,721	30,955	15,288	66,964
3.	Assam	78,438	2,797	10,192	15,116	28,105
4.	Bihar	94,163	332	3,260	3,707	7,299
5.	Chhattisgarh	1,35,192	7,064	32,215	16,268	55,547
6.	Delhi	1,483	6.72	56.24	129.45	192.41
7.	Goa	3,702	538	576	1,115	2,229
8.	Gujarat	1,96,244	378	5,200	9,179	14,757
9.	Haryana	44,212	28	452	1,108	1,588
10.	Himachal Pradesh	55,673	3,110	6,705	5,285	15,100
11.	Jammu & Kashmir *	2,22,236	4,075	8,579	10,587	23,241
12.	Jharkhand	79,716	2,598	9,686	11,269	23,553
13.	Karnataka	1,91,791	4,502	20,444	12,604	37,550
14.	Kerala	38,852	1,663	9,407	9,251	20,321
15.	Madhya Pradesh	3,08,252	6,563	34,571	36,280	77,414
16.	Maharashtra	3,07,713	8,736	20,652	21,294	50,682
17.	Manipur	22,327	908	6,510	9,928	17,346
18.	Meghalaya	22,429	453	9,386	7,307	17,146
19.	Mizoram	21,081	131	5,861	12,194	18,186
20.	Nagaland	16,579	1,279	4,587	6,623	12,489
21.	Odisha	1,55,707	6,967	21,370	23,008	51,345
22.	Punjab	50,362	8	806	1,023	1,837
23.	Rajasthan	3,42,239	78	4,340	12,154	16,572
24.	Sikkim	7,096	1,081	1,575	688	3,344
25.	Tamil Nadu	1,30,060	3,672	10,979	11,630	26,281
26.	Telangana	1,12,077	1,596	8,738	10,085	20,419
27.	Tripura	10,486	656	5,246	1,824	7,726
28.	Uttar Pradesh	2,40,928	2,617	4,069	7,993	14,679
29.	Uttarakhand	53,483	4,969	12,884	6,442	24,295
30.	West Bengal	88,752	2,994	4,147	9,706	16,847
31.	A & N Islands	8249	5,678	684	380	6,742
32.	Chandigarh	114	1.36	13.82	6.38	21.56
33.	Dadra & Nagar Haveli	491	0	80	127	207
34.	Daman & Diu	111	1.40	5.82	13.27	20.49
35.	Lakshadweep	30	0.00	17.04	10.06	27.10
36.	Puducherry	490	0.00	17.60	36.07	53.67
Total		**32,87,469**	**98,158**	**3,08,318**	**3,01,797**	**7,08,273**

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

(area in sq km)

2019 Assessment				Change			
VDF	MDF	OF	Total	VDF	MDF	OF	Total Change
1,994	13,938	13,205	29,137	37	-113	1,066	990
21,095	30,557	15,036	66,688	374	-398	-252	-276
2,795	10,279	15,253	28,327	-2	87	137	222
333	3,280	3,693	7,306	1	20	-14	7
7,068	32,198	16,345	55,611	4	-17	77	64
6.72	56.42	132.30	195.44	0.00	0.18	2.83	3.03
538	576	1,123	2,237	0	0	8	8
378	5,092	9,387	14,857	0	-108	208	100
28	451	1,123	1,602	0	-1	15	14
3,113	7,126	5,195	15,434	3	421	-90	334
4,281	8,612	10,719	23,612	206	33	132	371
2,603	9,687	11,321	23,611	5	1	52	58
4,501	21,048	13,026	38,575	-1	604	422	1,025
1,935	9,508	9,701	21,144	272	101	450	823
6,676	34,341	36,465	77,482	113	-230	185	68
8,721	20,572	21,485	50,778	-15	-80	191	96
905	6,386	9,556	16,847	-3	-124	-372	-499
489	9,267	7,363	17,119	36	-119	56	-27
157	5,801	12,048	18,006	26	-60	-146	-180
1,273	4,534	6,679	12,486	-6	-53	56	-3
6,970	21,552	23,097	51,619	3	182	89	274
8	801	1,040	1,849	0	-5	17	12
78	4,342	12,210	16,630	0	2	56	58
1,102	1,552	688	3,342	21	-23	0	-2
3,605	11,030	11,729	26,364	-67	51	99	83
1,608	8,787	10,187	20,582	12	49	102	163
654	5,236	1,836	7,726	-2	-10	12	0
2,617	4,080	8,109	14,806	0	11	116	127
5,047	12,805	6,451	24,303	78	-79	9	8
3,019	4,160	9,723	16,902	25	13	17	55
5,678	684	381	6,743	0	0	1	1
1.36	14.24	6.43	22.03	0.00	0.42	0.05	0.47
0	80	127	207	0	0	0	0
1.40	5.69	13.40	20.49	0.00	-0.13	0.13	0.00
0.00	16.09	11.01	27.10	0.00	-0.95	0.95	0.00
0.00	17.66	34.75	52.41	0.00	0.06	-1.32	-1.26
99,278	**3,08,472**	**3,04,499**	**7,12,249**	**1,120**	**154**	**2,702**	**3,976**

2.12 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% within it. On the other hand, there are areas outside the recorded forests with tree stands of more than 10% 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 is not necessarily due to changes within the recorded forest areas (RFA) but also because of changes outside recorded forest area. The information of forest cover inside and outside RFA/ Green Wash is presented in the Table 2.6.

2.12.1 Recorded Forest Areas (RFA)

Recorded forest areas 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.

However, due to non-availability of digitized boundaries of RFAs from all the States/UTs in the country, it was not possible to assess and monitor forest cover within such areas. At present only 23 State Forest Departments (SFDs) have provided usable digitized boundaries of RFAs to FSI, these boundaries have been used as provided by the respective SFDs.

2.12.2 Green Wash

In the Survey of India (SOI) topographic sheets, area shown by green colour, which is generally referred to as green wash, represents the forested areas at the time of survey for preparing such topographic sheets. The green wash has been used as substitute to RFA in respect of those States and UTs from where the usable digitized boundaries of recorded forest areas could not be made available to FSI.

In order to carry out this exercise, the green wash boundaries of the country have been digitized largely on 1:50,000 scale using Open Series Maps (OSM) topo-sheets of SOI. Based on the green-wash boundary, the forest cover inside and outside green-wash for the identified States and UTs were 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 Area / Green Wash Area

S. No.	State / UT	Geographical area	Recorded forest area as per the State's records	Recorded forest / Green Wash as per area of digitized RFA/ GW boundary
1.	Andhra Pradesh	1,62,968	37,258	37,920
2.	Arunachal Pradesh	83,743	51,407	63,838
3.	Assam	78,438	26,832	27,548
4.	Bihar**	94,163	6,877	6,302
5.	Chhattisgarh*	1,35,192	59,772	52,580
6.	Delhi**	1,483	102	102.04
7.	Goa	3,702	1,225	1,309
8.	Gujarat*	1,96,244	21,647	30,354
9.	Haryana**	44,212	1,559	566
10.	Himachal Pradesh	55,673	37,033	14,025
11.	Jammu & Kashmir**	2,22,236	20,230	27,728
12.	Jharkhand*	79,716	23,605	19,097
13.	Karnataka	1,91,791	38,284	31,037
14.	Kerala*	38,852	11,309	11,421
15.	Madhya Pradesh	3,08,252	94,689	88,956
16.	Maharashtra*	3,07,713	61,579	56,374
17.	Manipur	22,327	17,418	17,542
18.	Meghalaya	22,429	9,496	17,563
19.	Mizoram	21,081	5,641	20,663
20.	Nagaland	16,579	8,623	10,633
21.	Odisha*	1,55,707	61,204	42,430
22.	Punjab	50,362	3,084	924
23.	Rajasthan*	3,42,239	32,737	33,072
24.	Sikkim	7,096	5,841	2,737
25.	Tamil Nadu*	1,30,060	22,877	21,654
26.	Telangana*	1,12,077	26,904	26,989
27.	Tripura**	10,486	6,294	5,838
28.	Uttar Pradesh	2,40,928	16,582	13,434
29.	Uttarakhand*	53,483	38,000	25,494
30.	West Bengal*	88,752	11,879	13,419
31.	A & N Islands*	8,249	7,171	6,747
32.	Chandigarh**	114	35	9.85
33.	D & N Haveli**	491	204	211
34.	Daman & Diu	111	8	-
35.	Lakshadweep	30	0	-
36.	Puducherry	490	13	3.05
Grand Total		**32,87,469**	**7,67,419**	**7,28,520**

(area in sq km)

Forest cover inside RFA/GW 2017				Forest cover inside RFA/GW 2019			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
1,929	12,988	9,495	24,412	1,965	12,821	9,333	24,119
19,219	27,786	11,926	58,931	19,640	27,384	11,697	58,721
2,542	8,824	8,789	20,155	2,540	8,840	8,764	20,144
313	2,440	2,050	4,803	314	2,451	2,004	4,769
5,349	26,392	10,642	42,383	5,356	26,384	10,676	42,416
3.19	16.05	39.85	59.09	3.19	16.05	39.83	59.07
500	316	357	1,173	500	316	358	1,174
357	4,098	5,281	9,736	356	4,055	5,374	9,785
22	156	190	368	22	156	195	373
2,771	4,941	2,818	10,530	2,771	4,948	2,919	10,638
2,480	5,085	4,651	12,216	2,664	5,046	4,512	12,222
1,410	5,185	5,579	12,174	1,415	5,185	5,609	12,209
3,646	12,687	6,054	22,387	3,646	12,754	6,071	22,471
1,549	5,250	2,776	9,575	1,791	5,300	2,546	9,637
6,149	30,426	27,904	64,479	6,259	30,270	28,223	64,752
8,212	14,519	11,963	34,694	8,200	14,477	11,962	34,639
900	5,977	8,606	15,483	897	5,864	8,257	15,018
411	7,806	6,600	14,817	442	7,743	6,659	14,844
130	5,768	12,004	17,902	156	5,708	11,872	17,736
1,171	3,314	4,286	8,771	1,166	3,279	4,282	8,727
5,563	15,126	12,064	32,753	5,567	15,250	11,992	32,809
7	451	326	784	7	451	326	784
72	3,925	8,272	12,269	72	3,931	8,279	12,282
949	1,064	334	2,347	966	1,046	334	2,346
3,381	8,508	5,641	17,530	3,330	8,578	5,681	17,589
1,529	8,314	8,309	18,152	1,541	8,365	8,363	18,269
412	3,912	1,132	5,456	410	3,903	1,138	5,451
2,455	3,026	3,714	9,195	2,455	3,039	3,701	9,195
4,184	9,345	3,256	16,785	4,261	9,269	3,260	16,790
2,589	2,353	2,115	7,057	2,608	2,353	2,116	7,077
5,408	560	253	6,221	5,408	560	254	6,222
1.29	4.50	2.42	8.21	1.29	4.93	2.05	8.27
0	70	90	160	0	70	90	160
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	1.02	1.02	0	0	1.00	1.00
85,613	**2,40,632**	**1,87,520**	**5,13,766**	**86,729**	**2,39,817**	**1,86,890**	**5,13,436**

S. No.	State / UT	Forest cover outside RFA/GW 2017			
		VDF	MDF	OF	Total
1.	Andhra Pradesh	28	1,063	2,644	3,735
2.	Arunachal Pradesh	1,502	3,169	3,362	8,033
3.	Assam	255	1,368	6,327	7,950
4.	Bihar**	19	820	1,657	2,496
5.	Chhattisgarh*	1,715	5,823	5,626	13,164
6.	Delhi**	3.53	40.19	89.60	133.32
7.	Goa	38	260	758	1,056
8.	Gujarat*	21	1,102	3,898	5,021
9.	Haryana**	6	296	918	1,220
10.	Himachal Pradesh	339	1,764	2,467	4,570
11.	Jammu & Kashmir**	1,595	3,494	5,936	11,025
12.	Jharkhand*	1,188	4,501	5,690	11,379
13.	Karnataka	856	7,757	6,550	15,163
14.	Kerala*	114	4,157	6,475	10,746
15.	Madhya Pradesh	414	4,145	8,376	12,935
16.	Maharashtra*	524	6,133	9,331	15,988
17.	Manipur	8	533	1,322	1,863
18.	Meghalaya	42	1,580	707	2,329
19.	Mizoram	1	93	190	284
20.	Nagaland	108	1,273	2,337	3,718
21.	Odisha*	1,404	6,244	10,944	18,592
22.	Punjab	1	355	697	1,053
23.	Rajasthan*	6	415	3,882	4,303
24.	Sikkim	132	511	354	997
25.	Tamil Nadu*	291	2,471	5,989	8,751
26.	Telangana*	67	424	1,776	2,267
27.	Tripura**	244	1,334	692	2,270
28.	Uttar Pradesh	162	1,043	4,279	5,484
29.	Uttarakhand*	785	3,539	3,186	7,510
30.	West Bengal*	405	1,794	7,591	9,790
31.	A & N Islands*	270	124	127	521
32.	Chandigarh**	0.07	9.32	3.96	13.35
33.	D & N Haveli**	0	10	37	47
34.	Daman & Diu	1.40	5.82	13.27	20.49
35.	Lakshadweep	0.00	17.04	10.06	27.10
36.	Puducherry	0.00	17.60	35.05	52.65
Grand Total		**12,545**	**67,685**	**1,14,277**	**1,94,507**

*States /UTs have updated the RFA boundaries, accordingly the RFA area has also changed and it is different than the figures reported in ISFR 2017

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

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.

(area in sq km)

Forest cover outside RFA/GW 2019				% of forest cover inside RFA/GW	Change inside RFA/ GW	Change outside RFA/GW	Net change
VDF	MDF	OF	Total				
29	1,117	3,872	5,018	63.60	-293	1,283	990
1,455	3,173	3,339	7,967	91.98	-210	-66	-276
255	1,439	6,489	8,183	73.12	-11	233	222
19	829	1,689	2,537	75.67	-34	41	7
1,712	5,814	5,669	13,195	80.67	33	31	64
3.53	40.37	92.47	136.37	57.89	-0.02	3.05	3.03
38	260	765	1,063	89.69	1	7.00	8
22	1,037	4,013	5,072	32.24	49	51	100
6	295	928	1,229	65.92	5	9	14
342	2,178	2,276	4,796	75.85	108	226	334
1,617	3,566	6,207	11,390	44.00	6	365	371
1,188	4,502	5,712	11,402	63.93	35	23	58
855	8,294	6,955	16,104	72.40	84	941	1,025
144	4,208	7,155	11,507	84.38	62	761	823
417	4,071	8,242	12,730	72.79	273	-205	68
521	6,095	9,523	16,139	61.45	-55	151	96
8	522	1,299	1,829	85.61	-465	-34	-499
47	1,524	704	2,275	84.52	27	-54	-27
1	93	176	270	85.84	-166	-14	-180
107	1,255	2,397	3,759	82.07	-44	41	-3
1,403	6,302	11,105	18,810	77.32	56	218	274
1	350	714	1,065	84.85	0	12	12
6	411	3,931	4,348	37.14	13	45	58
136	506	354	996	85.71	-1	-1	-2
275	2,452	6,048	8,775	81.23	59	24	83
67	422	1,824	2,313	67.69	117	46	163
244	1,333	698	2,275	93.38	-5	5	0
162	1,041	4,408	5,611	68.45	0	127	127
786	3,536	3,191	7,513	65.86	5	3	8
411	1,807	7,607	9,825	52.74	20	35	55
270	124	127	521	92.22	1	0	1
0.07	9.31	4.38	13.76	83.96	0.06	0.41	0.47
0	10	37	47	76.00	0	0	0
1.40	5.69	13.40	20.49	0	0	0	0
0.00	16.09	11.01	27.10	0	0	0	0
0.00	17.66	33.75	51.41	32.79	-0.02	-1.24	-1.26
12,549	**68,655**	**1,17,609**	**1,98,813**	**70.48**	**-330**	**4,306**	**3,976**

2.13 CHANGE MATRIX

Change in forest cover is a dynamic process. A change matrix gives a quantitative account of class wise change and also the flux of changes among the classes between the current and previous assessment. Change Matrix has been prepared by aggregating the change polygons pertaining to different cells in the matrix, for example the first cell in the MDF column shown in red colour is the aggregated area of polygons which have changed from VDF to MDF, whereas the second cell in the VDF column shown in green is the aggregated area of the polygons which have improved from MDF to VDF. The values shown in green colour represent improvement whereas those shown in red colour indicate impairment or loss of forest cover in the three density classes, scrub and non-forest areas. Change matrix for the country is given in the Table 2.7.

TABLE 2.7 Forest cover change matrix for India between 2017 and 2019 assessments.

(area in sq km)

Class	2019 Assessment					Total ISFR 2017
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	97,309	626	50	2	171	98,158
Moderately Dense Forest	1,755	3,03,781	699	109	1,974	308,318
Open Forest	127	2,244	2,89,358	1,069	8,999	301,797
Scrub	2	48	1,732	41,831	2,366	45,979
Non Forest	85	1,773	12,660	3,286	25,15,413	25,33,217
Total ISFR 2019	**99,278**	**3,08,472**	**3,04,499**	**46,297**	**25,28,923**	**32,87,469**
Net Change	1,120	154	2,702	318	-4,294	

▪ Gain ▪ Loss

2.14 FOREST COVER IN HILL DISTRICTS

Forest cover plays an important role in the mountain ecology and socio-economic life of the hill people. Forests are critical from the point of view of soil, water and environmental conservation in the hills. The forest cover in the hill districts has been given separately. The hill districts have been identified following definition given by the erstwhile Planning Commission of India. There are 140 hill districts as marked by superscript ('H') in the district-wise tables of forest cover in Chapter 11 (Vol II). 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 an increase of 544 sq km in the hill districts of the country.

TABLE 2.8 State wise summary of Forest Cover in Hill districts

(area in sq km)

State	No. of Hill Districts	Geographical Area	VDF	MDF	OF	Total	% of GA	Change	Scrub
Arunachal Pradesh	16	83,743	21,095	30,557	15,036	66,688	79.63	-276	229
Assam	3	19,295	843	5,649	6,515	13,007	67.41	-96	97
Himachal Pradesh	12	55,673	3,113	7,126	5,195	15,434	27.72	334	315
Jammu & Kashmir*	24	2,22,236	4,281	8,612	10,719	23,612	10.62	371	548
Karnataka	6	48,353	3,911	15,403	4,502	23,816	49.25	132	792
Kerala	10	29,552	1,542	7,238	8,065	16,845	57.00	541	13
Maharashtra	7	69,905	316	7,231	8,285	15,832	22.65	212	1,427
Manipur	9	22,327	905	6,386	9,556	16,847	75.46	-499	1,181

State	No. of Hill Districts	Geographical Area	VDF	MDF	OF	Total	% of GA	Change	Scrub
Meghalaya	7	22,429	489	9,267	7,363	17,119	76.33	-27	600
Mizoram	8	21,081	157	5,801	12,048	18,006	85.41	-180	1
Nagaland	11	16,579	1,273	4,534	6,679	12,486	75.31	-3	635
Sikkim	4	7,096	1,102	1,552	688	3,342	47.10	-2	307
Tamil Nadu	5	19,384	1,447	2,682	2,446	6,575	33.92	26	71
Tripura	4	10,486	654	5,236	1,836	7,726	73.68	0	29
Uttarakhand	13	53,483	5,047	12,805	6,451	24,303	45.44	8	383
West Bengal	1	3,149	721	654	993	2,368	75.20	3	9
Total	**140**	**7,04,771**	**46,896**	**1,30,733**	**1,06,377**	**2,84,006**	**40.30**	**544**	**6,637**

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

2.15 FOREST COVER IN TRIBAL DISTRICTS

Forests play an important role in the socio-cultural and economic life of the tribal people. It is therefore important to monitor and analyze the forest cover situation in the tribal districts. An overview of forest cover in the tribal districts of the country has been presented in this section. There are 218 tribal districts in 27 States/UTs as identified by the Government of India under the Integrated Tribal Development Programme. These are marked with superscript ('T') in the district-wise Table of forest cover in the Chapter 11 (Vol II). Table 2.9 gives an abstract of forest cover and its change in the tribal districts of the country. As shown in the following table, there is an over all increase in forest cover in the tribal districts by 1,181 sq km, however the forest cover inside the recorded forest areas / green wash areas in tribal districts shows a decrease of 741 sq km.

TABLE 2.9 Abstract of Forest Cover in tribal district

State	No. of Tribal Districts	Geo-graphical area	RFA/GW Digital Area	Forest Cover Inside RFA / GW 2017				Forest Cover inside RFA / GW 2019			
				VDF	MDF	OF	TOTAL	VDF	MDF	OF	TOTAL
Andhra Pradesh	5	44,849	13,297	1,489	4,789	2,850	9,128	1,525	4,631	2,673	8,829
Arunachal Pradesh	16	83,743	63,838	19,219	27,786	11,926	58,931	19,640	27,384	11,697	58,721
Assam	19	49,489	9,888	1,400	2,737	2,371	6,508	1,400	2,781	2,398	6,579
Chhattisgarh	11	92,645	35,564	4,805	16,810	6,876	28,491	4,810	16,803	6,899	28,512
Gujarat	9	49,885	7,718	304	2,349	2,417	5,070	303	2,327	2,428	5,058
Himachal Pradesh	3	26,764	3,143	751	913	574	2,238	751	913	585	2,249
Jharkhand	17	58,677	11,658	819	3,250	3,454	7,523	829	3,244	3,465	7,538
Karnataka	5	26,054	6,612	1,964	2,938	697	5,599	1,964	2,981	694	5,639
Kerala	9	27,207	8,625	1,150	3,854	2,087	7,091	1,354	3,876	1,895	7,125
Madhya Pradesh	24	1,52,132	51,919	5,609	19,251	14,427	39,287	5,719	19,129	14,612	39,460
Maharashtra	12	1,44,233	40,412	6,902	9,850	8,360	25,112	6,891	9,813	8,345	25,049
Manipur	9	22,327	17,542	900	5,977	8,606	15,483	897	5,864	8,257	15,018
Meghalaya	7	22,429	17,563	411	7,806	6,600	14,817	442	7,743	6,659	14,844
Mizoram	8	21,081	20,663	130	5,768	12,004	17,902	156	5,708	11,872	17,736
Nagaland	11	16,579	10,633	1,171	3,314	4,286	8,771	1,166	3,279	4,282	8,727
Odisha	12	86,091	24,685	3,879	9,238	6,838	19,955	3,883	9,307	6,770	19,960
Rajasthan	5	29,601	8,958	0	2,056	2,438	4,494	0	2,060	2,439	4,499
Sikkim	4	7,096	2,737	949	1,064	334	2,347	966	1,046	334	2,346
Tamil Nadu	6	25,607	5,346	802	2,304	1,424	4,530	797	2,318	1,417	4,532
Telangana	3	42,217	16,997	1,120	6,558	4,204	11,882	1,132	6,510	4,339	11,981
Tripura	4	10,486	5,838	412	3,912	1,132	5,456	410	3,903	1,138	5,451
Uttar Pradesh	1	7,680	1,191	752	118	90	960	752	118	90	960
West Bengal	12	69,403	13,087	2,575	2,327	2,080	6,982	2,594	2,327	2,081	7,002
A & N Islands	3	8,249	6,747	5,408	560	253	6,221	5,408	560	254	6,222
D & N Haveli	1	491	211	0	70	90	160	0	70	90	160
Daman & Diu	1	72	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lakshadweep	1	30	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**218**	**11,25,117**	**4,04,661**	**62,921**	**1,45,599**	**1,06,418**	**3,14,938**	**63,789**	**1,44,695**	**1,05,713**	**3,14,197**

(area in sq km)

Forest Cover Outside RFA / GW 2017				Forest Cover Outside RFA / GW 2019				Change Inside RFA / GW	Change Outside RFA / GW	Net Change
VDF	MDF	OF	TOTAL	VDF	MDF	OF	TOTAL			
21	723	1,546	2,290	22	769	2,606	3,397	-299	1,107	808
1,502	3,169	3,362	8,033	1,455	3,173	3,339	7,967	-210	-66	-276
113	825	4,386	5,324	113	890	4,491	5,494	71	170	241
1,704	5,092	4,663	11,459	1,700	5,082	4,694	11,476	21	17	38
20	622	1,254	1,896	21	593	1,197	1,811	-12	-85	-97
118	370	533	1,021	112	460	441	1,013	11	-8	3
1,050	4,004	4,842	9,896	1,050	4,005	4,848	9,903	15	7	22
632	4,499	2,549	7,680	632	4,953	2,392	7,977	40	297	337
87	2,902	4,740	7,729	117	2,954	5,215	8,286	34	557	591
328	2,845	4,954	8,127	331	2,796	4,876	8,003	173	-124	49
327	1,845	3,253	5,425	325	1,821	3,248	5,394	-63	-31	-94
8	533	1,322	1,863	8	522	1,299	1,829	-465	-34	-499
42	1,580	707	2,329	47	1,524	704	2,275	27	-54	-27
1	93	190	284	1	93	176	270	-166	-14	-180
108	1,273	2,337	3,718	107	1,255	2,397	3,759	-44	41	-3
1,235	5,037	7,979	14,251	1,235	5,089	8,047	14,371	5	120	125
0	100	680	780	0	98	681	779	5	-1	4
132	511	354	997	136	506	354	996	-1	-1	-2
51	467	652	1,170	45	447	647	1,139	2	-31	-29
67	332	758	1,157	67	323	783	1,173	99	16	115
244	1,334	692	2,270	244	1,333	698	2,275	-5	5	0
53	40	221	314	53	40	220	313	0	-1	-1
405	1,380	5,828	7,613	411	1,393	5,844	7,648	20	35	55
270	124	127	521	270	124	127	521	1	0	1
0	10	37	47	0	10	37	47	0	0	0
0.00	2.04	8.92	10.96	0.00	1.93	8.98	10.91	0.00	-0.05	-0.05
0.00	17.04	10.06	27.10	0.00	16.09	11.01	27.10	0.00	0.00	0.00
8,518	**39,729**	**57,985**	**1,06,232**	**8,502**	**40,271**	**59,381**	**1,08,154**	**-741**	**1,922**	**1,181**

2.16 FOREST COVER IN THE NORTH EASTERN STATES

NorthEastern region of the country comprising eight States namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura is endowed with rich forest resources and is one of the 17 biodiversity hotspots of the world. The region, with just 7.98 per cent of the geographical area of the country, accounts for nearly one fourth of its forest cover. One distinct feature of the land use in this region is the prevalence of shifting cultivation in hilly parts of almost all the States. Shifting cultivation has traditionally been intricately linked to the socio-cultural life of tribal communities. The slash-and-burn practice of agriculture is mainly responsible for fluctuation in forest cover in this region.

TABLE 2.10 Forest Cover in North Eastern States

(area in sq km)

State	Geo. Area	2019 Assessment								Change	Scrub
		VDF	% VDF	MDF	% MDF	OF	% OF	Total	% Forest Cover to GA		
Arunachal Pradesh	83,743	21,095	25.19	30,557	36.49	15,036	17.95	66,688	79.63	-276	229
Assam	78,438	2,795	3.56	10,279	13.10	15,253	19.45	28,327	36.11	222	173
Manipur	22,327	905	4.05	6,386	28.60	9,556	42.80	16,847	75.46	-499	1,181
Meghalaya	22,429	489	2.18	9,267	41.32	7,363	32.83	17,119	76.33	-27	600
Mizoram	21,081	157	0.74	5,801	27.52	12,048	57.15	18,006	85.41	-180	1
Nagaland	16,579	1,273	7.68	4,534	27.35	6,679	40.29	12,486	75.31	-3	635
Sikkim	7,096	1,102	15.53	1,552	21.87	688	9.70	3,342	47.10	-2	307
Tripura	10,486	654	6.24	5,236	49.93	1,836	17.51	7,726	73.68	0	29
Total	**2,62,179**	**28,470**	**10.86**	**73,612**	**28.08**	**68,459**	**26.11**	**1,70,541**	**65.05**	**-765**	**3,155**

2.17 FOREST COVER IN DIFFERENT ALTITUDE ZONES

Altitude zonation of forest cover has special ecological significance which is useful from the policy and planning perspective for hill States. Digital Terrain Model (DTM) data of SRTM at 30 m resolution has been used to determine forest cover in different altitude zones in all the States and UTs. The altitude zones for the purpose of analysis have been taken as 0-500m, 500-1000m, 1000-2000m, 2000-3000m, 3000-4000m and above 4000m. Altitude zone wise forest cover of the country is given in Table 2.11. The State wise information has been given in the respective sections of Chapter 11 (Vol II).

TABLE 2.11 Forest Cover in different Altitude Zones at the National level

(area in sq km)

Altitude Zone	Geo. Area	VDF	MDF	OF	Forest Cover (FC)	Scrub	% of Total FC	% of GA
0-500 m	23,29,321	39,227	1,51,466	1,88,720	3,79,413	28,275	53.27	16.29
500-1000 m	5,41,747	25,523	95,563	77,597	1,98,683	14,560	27.89	36.67
1000-2000 m	1,17,835	15,579	35,135	24,913	75,627	2,336	10.62	64.18
2000-3000 m	56,891	15,339	18,414	6,885	40,638	327	5.71	71.43
3000-4000 m	59,298	3,556	7,633	5,850	17,039	510	2.39	28.73
Above 4000 m	1,82,377	54	261	534	849	289	0.12	0.47
Total	**32,87,469**	**99,278**	**3,08,472**	**3,04,499**	**7,12,249**	**46,297**		**21.67**

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

2.18 FOREST COVER ON DIFFERENT SLOPE CLASSES

Forests play an important role in the stability of mountain ecosystems. Mountain slopes which are well covered with the forests are less affected from soil erosion and landslides. Forest cover on hill slopes is therefore a good indicator of soil stability and state of soil and water conservation in general in an ecosystem. The following table presents forest cover in different slope classes based on the SRTM DEM of 30 m resolution. Monitoring of this parameter *interalia* could be an effective way of monitoring health of ecosystems in different States. Extent of forest cover on slopes may also provide an important input in planning catchment area treatment.

TABLE 2.12 Forest cover on different slope classes at the National level

(area in sq km)

Slope	Geo. Area	VDF	MDF	OF	Forest Cover	Scrub	% of Total FC	% of GA
0°-5°	24,81,537	30,806	1,11,667	1,48,359	2,90,832	25,883	40.83	11.72
5°-10°	2,33,672	14,197	54,176	45,895	1,14,268	7,113	16.04	48.90
10°-15°	1,42,564	12,478	40,344	32,608	85,430	4,580	11.99	59.92
15°-20°	1,19,813	11,394	32,309	26,077	69,780	3,462	9.80	58.24
20°-25°	1,00,940	9,916	25,381	20,149	55,446	2,489	7.79	54.93
25°-30°	79,661	8,092	18,671	14,137	40,900	1,530	5.74	51.34
Above 30°	1,29,282	12,395	25,924	17,274	55,593	1,240	7.81	43.00
Total	**32,87,469**	**99,278**	**3,08,472**	**3,04,499**	**7,12,249**	**46,297**		**21.67**

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

2.19 WETLANDS AND THEIR EXTENT INSIDE RECORDED FOREST AREAS OR GREEN WASH

Wetlands within forest areas form important ecosystems. Such wetlands add richness to the biodiversity in forest areas, both of faunal and floral species. It is important to protect these wetlands from siltation, pollution and encroachment for maintaining ecosystem services from forests. Well managed and protected forests also ensure conservation and good health of wetlands located within them. In view of the importance of wetlands within the forests and the emphasis being laid on wetland conservation in the country, an exercise has been done by FSI to inventorise wetlands within the recorded forest areas and within the green wash (GW) where boundaries of RFAs are not available. Space Application Center (SAC), Ahmedabad carried out the mapping of wetlands from 2006 to 2010 and released an Atlas of Wetlands of India in the year 2011, which is the latest information showing spatial distribution of wetlands in India. An overlay analysis of the wetland layer over the RFA/Green Wash layer has been carried out to know category wise number and extent of wetlands within the recorded forest areas in each State and UT of the country. The Table 2.13 gives a summary of this analysis.

TABLE 2.13 Wetlands within Recorded Forest Area/Green Wash

(area in ha)

S. No.	State/UT	Inland Wetlands Natural		Inland Wetlands man-made		Coastal Wetlands Natural		Wetlands (<2.25 ha)		Total Wetlands		Wetlands Area as % of RFA
		No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	
1.	Andhra Pradesh	99	9,802	559	19,956	213	42,297	303	303	1,174	72,358	1.91
2.	Arunachal Pradesh	507	67,096	32	122	0	0	804	804	1,343	68,022	1.07
3.	Assam	1,038	65,067	19	2,263	0	0	527	527	1,584	67,857	2.46
4.	Bihar	72	2,573	50	1,256	0	0	163	163	285	3,992	0.63
5.	Chhattisgarh	101	39,987	1,182	21,996	0	0	2,415	2,415	3,698	64,398	1.22
6.	Delhi	1	2	0	0	0	0	16	16	17	18	0.18
7.	Goa	15	527	24	226	5	245	27	27	71	1,025	0.78
8.	Gujarat	560	37,958	1,677	44,454	681	11,27,652	611	611	3,529	12,10,675	39.88
9.	Haryana	16	1,700	27	150	0	0	35	35	78	1,885	3.33
10.	Himachal Pradesh	50	6,227	14	1,945	0	0	49	49	113	8,221	0.59
11.	Jammu & Kashmir	269	35,084	4	970	0	0	208	208	481	36,262	1.31
12.	Jharkhand	249	10,100	551	5,566	0	0	862	862	1,662	16,528	0.87
13.	Karnataka	123	15,344	633	36,488	21	26	1,261	1,261	2,038	53,119	1.71
14.	Kerala	143	10,073	76	12,944	0	0	140	140	359	23,157	2.03
15.	Madhya Pradesh	249	71,116	2,655	85,821	0	0	5,636	5,636	8,540	1,62,573	1.83
16.	Maharashtra	686	29,947	4,257	73,062	432	10,382	3,446	3,446	8,821	1,16,837	2.07
17.	Manipur	26	12,075	9	178	0	0	171	171	206	12,424	0.71
18.	Meghalaya	138	20,627	32	769	0	0	74	74	244	21,470	1.22
19.	Mizoram	72	12,297	2	27	0	0	132	132	206	12,456	0.60
20.	Nagaland	75	11,385	3	18	0	0	119	119	197	11,522	1.08
21.	Odisha	393	13,389	795	40,227	170	8,242	2,769	2,769	4,127	64,627	1.52
22.	Punjab	46	1,446	37	1,586	0	0	36	36	119	3,068	3.32
23.	Rajasthan	284	21,519	1,275	28,064	4	4,495	2,263	2,263	3,826	56,341	1.70
24.	Sikkim	36	2,571	0	0	0	0	38	38	74	2,609	0.95
25.	Tamil Nadu	248	8,494	743	19,432	104	16,865	428	428	1,523	45,219	2.09
26.	Telangana	59	13,086	654	14,796	0	0	357	357	1,070	28,239	1.05
27.	Tripura	167	1,683	8	1,661	0	0	535	535	710	3,879	0.66
28.	Uttar Pradesh	792	31,828	660	9,497	0	0	899	899	2,351	42,224	3.14
29.	Uttarakhand	95	39,007	10	15,006	0	0	116	116	221	54,129	2.12
30.	West Bengal	353	2,20,751	863	5,542	239	2,02,123	10,060	10,060	11,515	4,38,476	32.68
31.	Andaman & Nicobar Is.	47	1,636	7	278	2,153	87,048	60	60	2,267	89,022	13.19
32.	Chandigarh	4	60	0	0	0	0	0	0	4	60	6.09
33.	Dadra & Nagar Haveli	3	58	1	263	0	0	1	1	5	322	1.53
34.	Puducherry	1	6	0	0	7	121	0	0	8	127	41.64
Total		**7,017**	**8,14,521**	**16,859**	**4,44,563**	**4,029**	**14,99,496**	**34,561**	**34,561**	**62,466**	**27,93,141**	**3.83**

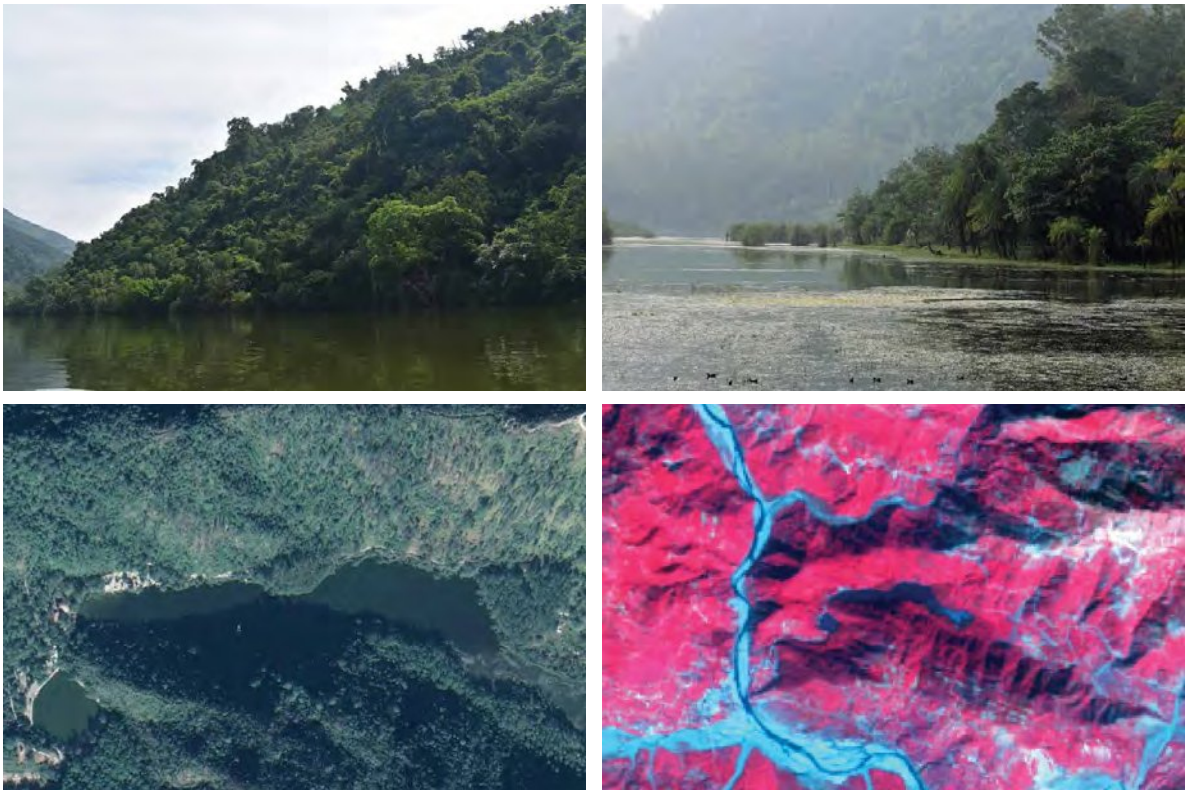
It is seen that among the big States, Gujarat has the largest area of the wetlands within RFA/GW in the country followed by West Bengal. Among the smaller States/UTs Puducherry followed by A&N Islands have large areas of wetlands within RFA/GW. In the country as a whole there are 62,466 wetlands covering 3.83% of the area within the recorded forest areas/green wash areas of the country and 8.13% of the total number of wetlands are located within the RFA/GW.

FIGURE 2.8 Photographs of Wetlands inside the forest area along with the satellite image of the same

Ranjit Sagar Dam Lake, Pathankot, Punjab

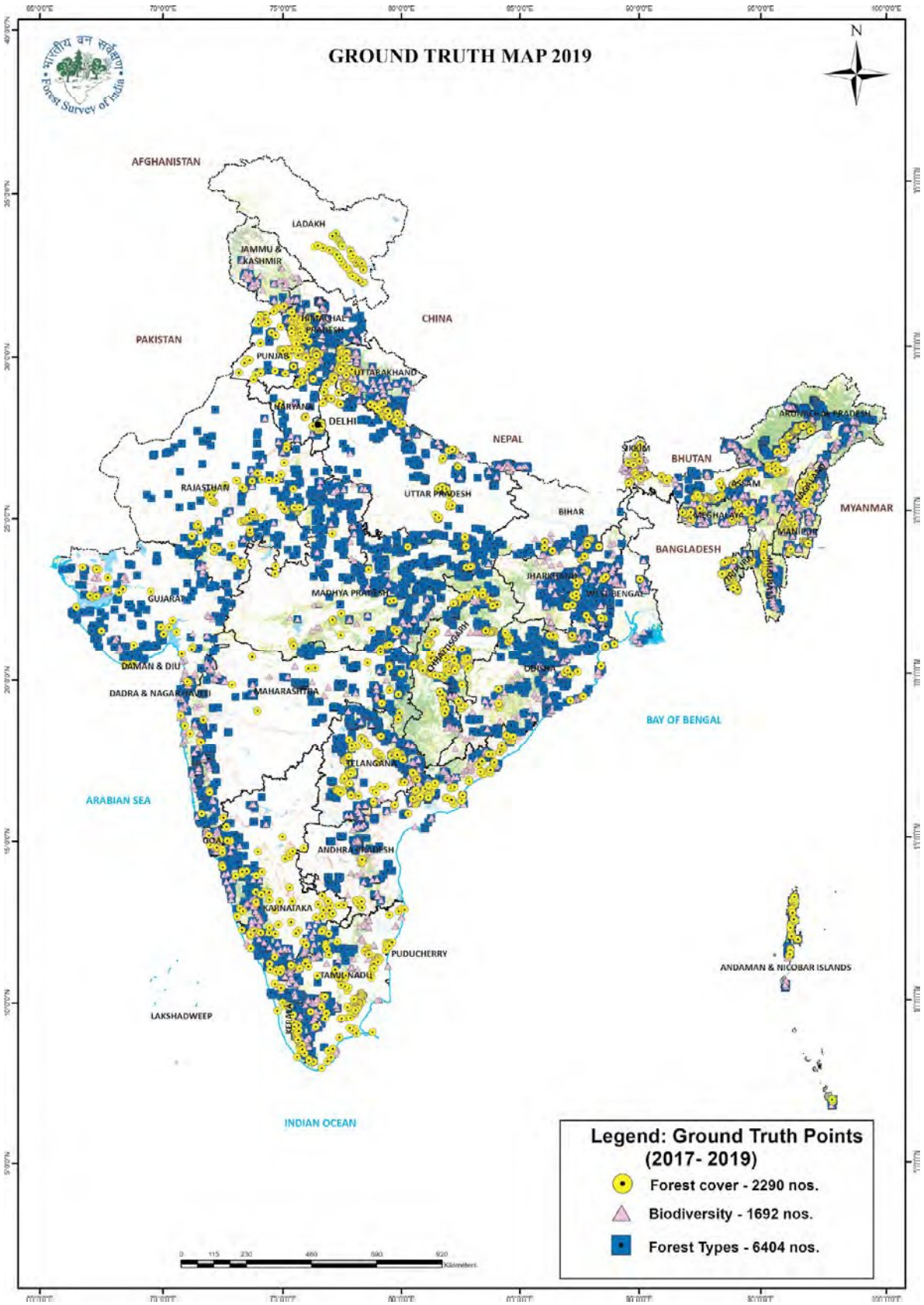
Google Earth imagery of Sep 2018 | LISS III imagery of Oct 2015

Renuka Lake, Sirmaur. Himachal Pradesh



Google Earth imagery of Dec 2018 | LISS III imagery of Oct 2015

FIGURE 2.9 Map showing Ground Truth locations of Forest Cover, Biodiversity & Forest Types



2.20 ACCURACY ASSESSMENT OF FOREST COVER

Accuracy assessment is an essential part of remote sensing based mapping. It is carried out to assess accuracy of interpreting a ground feature using satellite image. This is done by comparing the interpreted satellite image i.e. classification with the reference data which is collected from the ground. FSI under its National Forest Inventory (NFI) programme collects data from a large number of sample plots. Part of this data is used as reference data for accuracy assessment. Accuracy assessment of forest cover mapping is done in an independent manner by a team of FSI which is not involved in the mapping.

Accuracy assessment is presented in the form of an error or confusion matrix prepared by comparing agreement and disagreement between the remote sensing based classification with the reference data on a class-by-class basis at randomly selected locations. Error matrix is an array of numbers arranged in rows (map classification) and columns (reference data). It is a square matrix with number of rows and columns equal, representing different classes of mapping. However, the accuracy of mapping is assessed only for the classes comprising forest cover i.e. VDF, MDF and OF. The numbers along the major diagonal of the error matrix imply agreement between the classification and the ground reality. 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 these percentage of correctly classified random points out of the total number of sample points pertaining to a particular class.

2.20.1 Methodology

The sampling design used for assessing the accuracy of classification should ensure proper representation of all the classes of mapping. Similarly, the selection of appropriate sampling size is also very important. 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.

For the purpose of preparing error matrix, a total of 5,283 sample points spread across the country have been selected giving proportionate representation to both forests and TOF. Out of the total 5,283 sample points, 1,305 sample points have been selected from TOF. To record canopy density class at each point, a buffer of 1 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.

2.20.2 Findings

The error matrix is given in the Table 2.14. It shows that out of the total 5,283 sample points, classification on 4,922 sampling points (the sum of the elements along the main diagonal of the matrix) was found correct. The 'overall accuracy' of classification when all the classes of FCM are taken into account is calculated to be 93.17%.

TABLE 2.14 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	411	15	14	0	0	440	93.41
MDF	3	1,547	87	6	23	1,666	92.86
OF	5	70	1,299	5	16	1,395	93.12
Scrub	0	3	9	152	5	169	89.94
NF	2	18	66	14	1,513	1,613	93.80
Total	421	1,653	1,475	177	1,557	5,283	
Producer's Accuracy (%)	97.62	93.59	88.07	85.88	97.17		
Overall Accuracy	93.17%						
Overall Kappa Statistics	0.91						

A simplified error matrix has also been prepared by grouping the classification into two broad "forest" and "non-forest" classes. 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 2.15. In the simplified error matrix, classification of 5,135 points has been found to be correct, yielding an overall accuracy of 97.20 %.

TABLE 2.15 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	3,451	50	3,501	98.57
Non-Forest	98	1,684	1,782	94.50
Total	3,549	1,734	5,283	
Producer's Accuracy (%)	97.24	97.12		
Overall Accuracy	97.20 %			
Overall Kappa Statistics	0.94			

Besides the overall accuracy, accuracy of individual classes has also been determined by calculating producer's accuracy and user's accuracy. The producer's accuracy measures how well a certain area has been classified. The user's accuracy is a measure of the reliability of the map. It informs the user 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 divided 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.

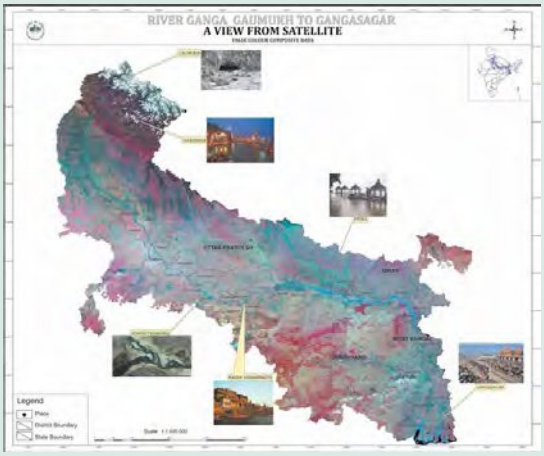
User's accuracy can be obtained by dividing the correct classified units in a class by the total number of units that were classified in that class. One class in the map can have two types of classes on the ground. The 'right' class, refers to the same land-cover-class in the map and on the ground, and 'wrong' classes, show a different land-cover on the ground than 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 2.14, it is found that the producer's accuracy for VDF, MDF, OF, Scrub and Non-forest classes are 97.62%, 93.59%, 88.07%, 85.88% and 97.17% respectively. Similarly, user's accuracy for these classes are 93.41%, 92.86%, 93.12%, 89.94% and 93.80% respectively. The producer's accuracy for forest and non-forest classes are found to be 97.24% and 97.12% respectively while user's accuracy for these classes are 98.57% and 94.50% respectively.

To further authenticate the results of accuracy, 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 2.14 is equal to 0.91, which indicates that an observed classification is 91% better than one resulting from chance. For the simplified matrix of forest and non-forest classes, the K_{HAT} value is 0.94.

BOX 2

Forest Cover along Ganga river under Namami Gange Programme



'Ganga' the second largest river of the country, originates from Gangotri in the Himalayas, traversing 2,525 km in south east direction through the States of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal and merges with the Bay of Bengal. It forms a huge basin of 0.86 million sq km, in the above States. **'Namami Gange Programme'**, is an Integrated Conservation Mission, launched in June, 2014 as a 'Flagship Programme' of the Government of India with the main objectives of abatement of pollution, conservation and rejuvenation of National River Ganga.

In its initial phase, the programme covers 139 districts in five States i.e. Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. The key activities under the programme are sewerage treatment plants, riverfront development, river surface cleaning, bio-diversity conservation, afforestation, public awareness, Industrial effluent monitoring and Ganga Gram. FSI has done an analysis of forest cover mapping in a buffer of 5 km on both sides of the main river and in buffer of 2 km on both sides of the tributaries.

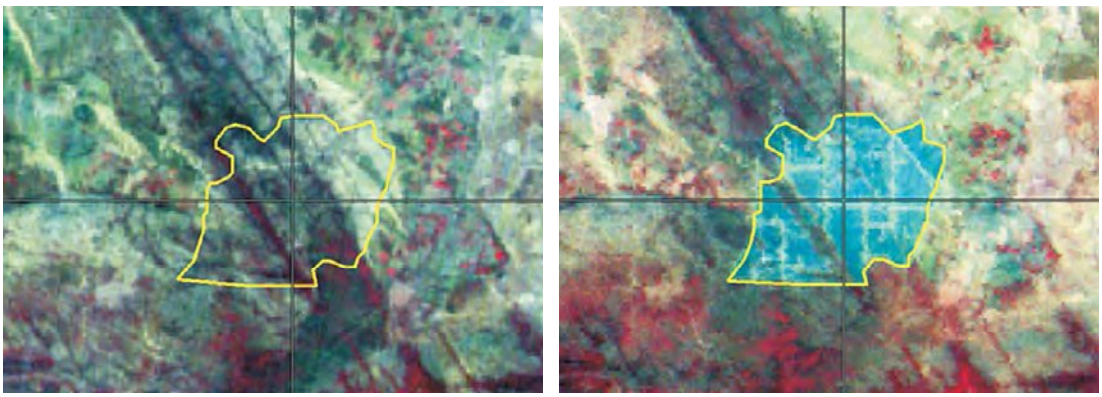
REGION	SPECIES
Himalayan Region	*Pinus wallichiana, Cedrus deodara, Betula utilis, Quercus dilatata, Shorea robusta*
Gangetic Plains	*Dalbergia sissoo, Shorea robusta, Terminalia arjuna, Acacia catechu, Terminalia alata, Tectona grandis*
Deltaic Plains	*Heritiera spp, Ceriops spp, Sonneratia spp, Avicennia spp , Excoecaria spp*

Forest cover in the above buffers as per the 2019 assessment is presented in the following table.

area in sq km

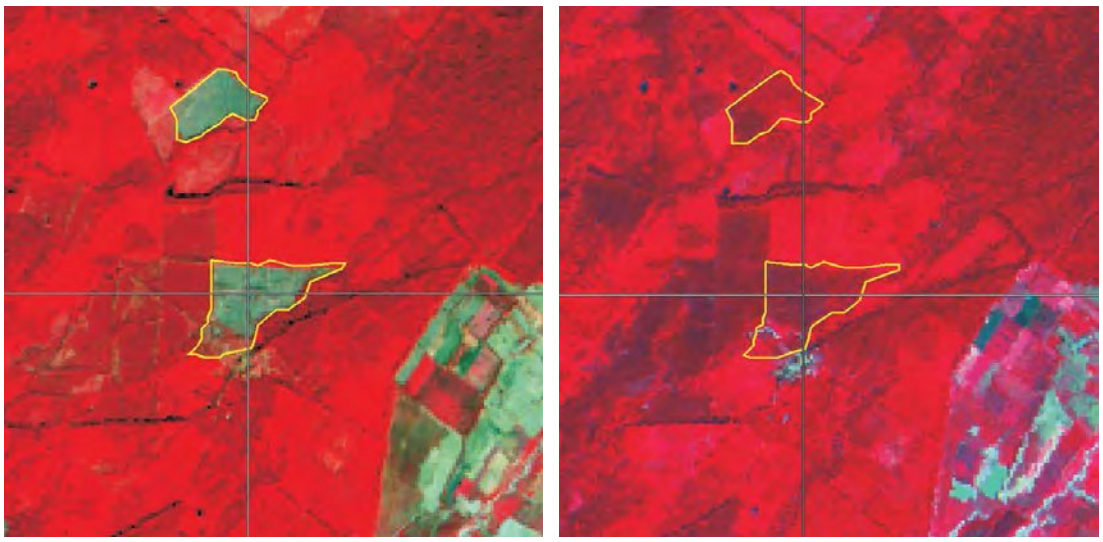
States	Area of River scape	2019 Assessment				
		VDF	MDF	OF	Total Forest Cover	Forest cover as % of River scape area
Uttarakhand	24,189.47	1,689.21	5,283.28	2,885.80	9,858.29	40.75
Uttar Pradesh	26,851.05	66.12	205.20	695.86	967.18	3.60
Bihar	13,466.91	0.00	145.86	133.43	279.29	2.07
Jharkhand	3,599.79	7.53	239.02	274.74	521.29	14.48
West Bengal	18,724.09	990.89	949.14	1,514.30	3,454.33	18.45
Total	**86,831.30**	**2,753.75**	**6,822.50**	**5,504.13**	**15,080.38**	**17.37**

FIGURE 2.10 Establishment of solar power plant in Mirzapur District (UP) as seen on satellite image



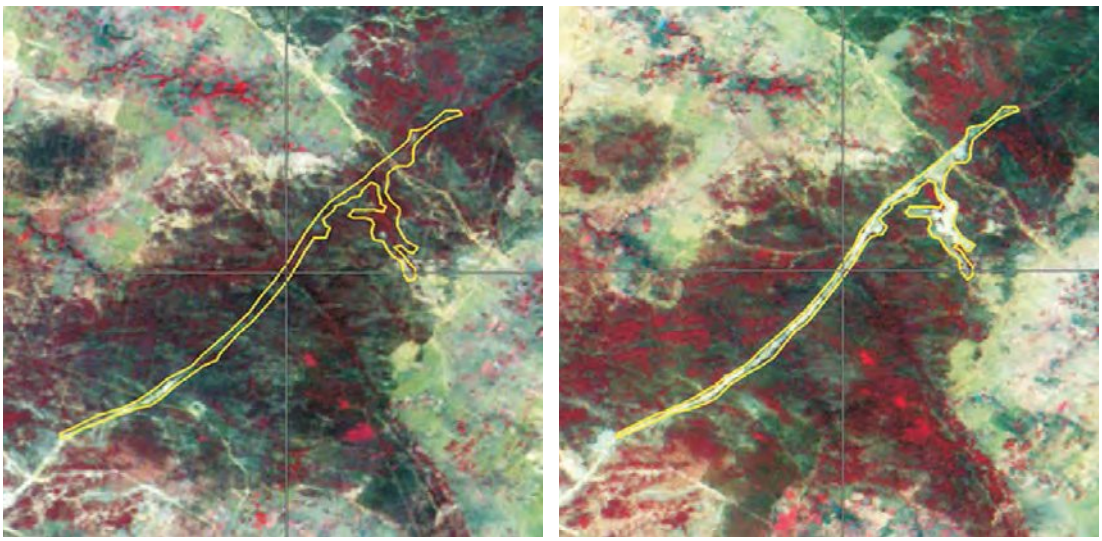
2017 2019

FIGURE 2.11 Afforestation in Bijnor District (UP) as seen on the satellite image



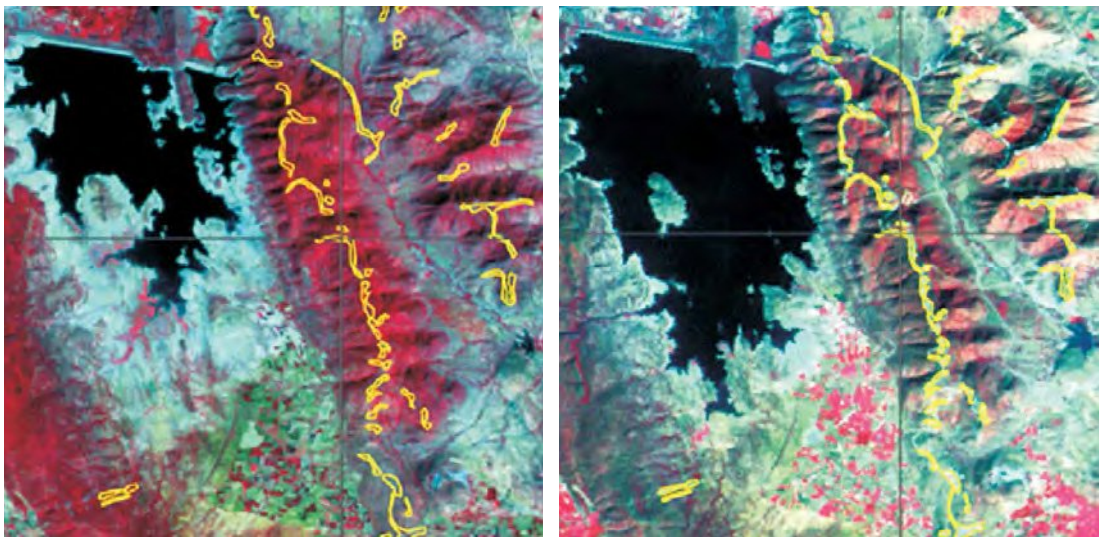
2017 2019

FIGURE 2.12 Canal construction in Mirzapur district, Uttar Pradesh as seen on satellite image



2017 2019

FIGURE 2.13 Setting up windmill farm in Andhra Pradesh as seen on satellite image



2017 2019