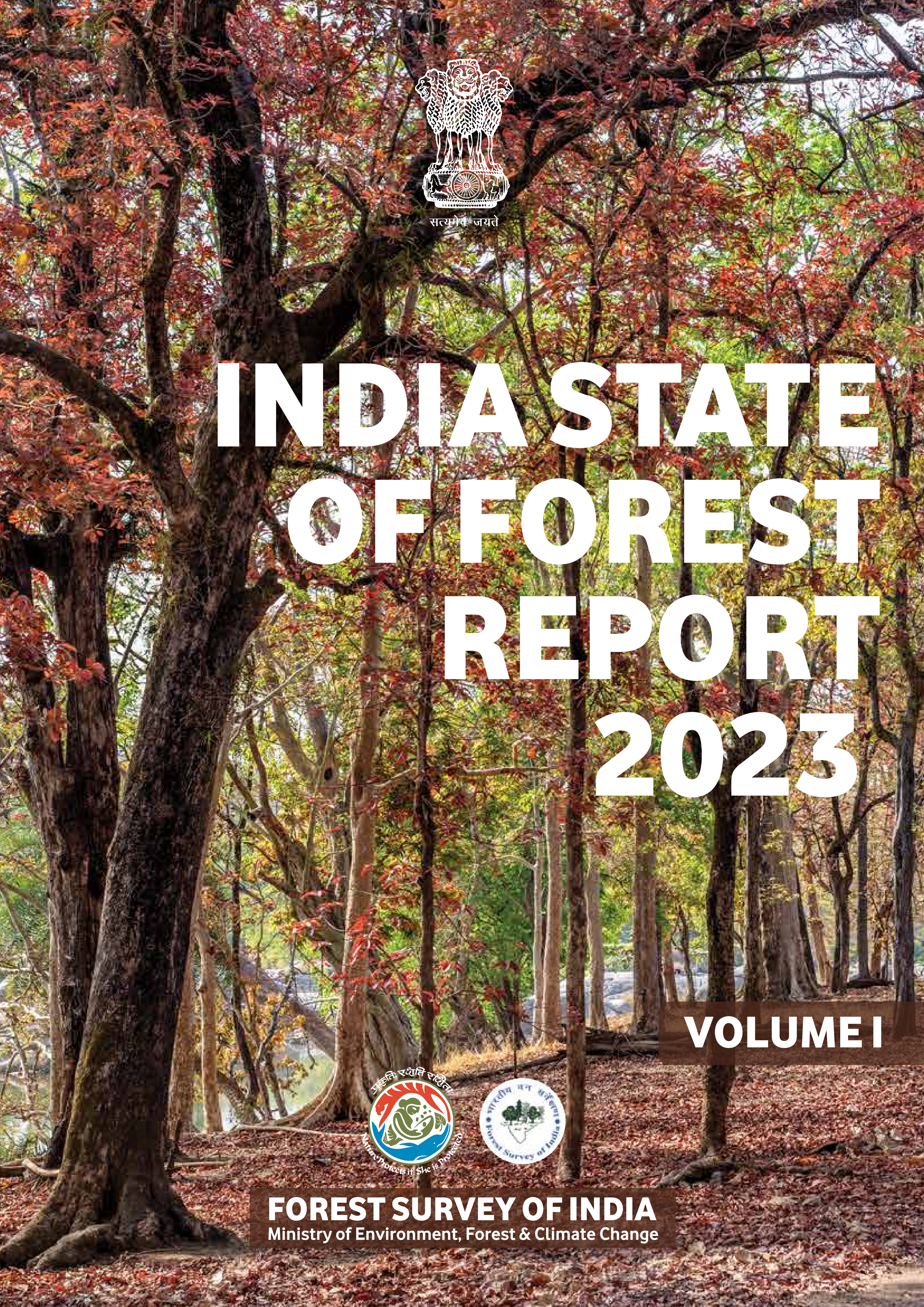


सत्यमेव जयते

INDIA STATE OF FOREST REPORT 2023

VOLUME I

FOREST SURVEY OF INDIA

Ministry of Environment, Forest & Climate Change


Photo: Subharanjan Sen, IFS

सत्यमेव जयते

INDIA STATE OF FOREST REPORT 2023

Volume I

Forest Survey of India
Ministry of Environment, Forest & Climate Change
Government of India

ISBN 978-81-950073-9-4

Published by
Forest Survey of India
(Ministry of Environment
Forest and Climate Change)
Kaulagarh Road, P.O. IPE
Dehradun – 248195,
Uttarakhand. India

Phone : (91) 0135-2756139
2754507
2755037
Fax: (91) 0135-2759104
2754507
2755037
Website: www.fsi.nic.in

Edition 18, 2023

Printed at Dehradun, India 2024

Maps are based on the Survey of India maps with the permission of the Surveyor General of India. The territorial waters of India extend into the sea to a distance of twelve nautical miles measured form the appropriate baseline.

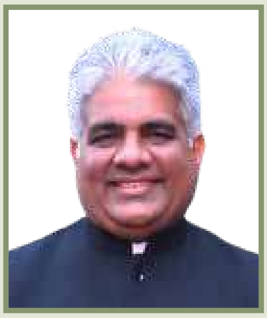
Design & Layout:
Asian Paper Products
Email.-asianpaper88@gmail.com

Front Cover Photo: Subharanjan Sen, IFS

Photo: Subharanjan Sen, IFS

सत्यमेव जयते

FOREWORD



भूपेन्द्र यादव
Bhupender Yadav
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्री
Minister for Environment, Forest and Climate Change
भारत सरकार
Government of India

India is one of the few countries in the world that regularly carries out assessment of its forest and tree resources, situated inside and outside the forested area. The result of this assessment is published as "India State of Forest Report (ISFR)". Forest Survey of India (FSI) has been carrying out countrywide monitoring and assessment of forest resources, biennially, since 1987. Over time, FSI has devised, developed and implemented novel technologies to improve precision and accuracy in assessment. I am delighted to release the "India State of Forest Report 2023", based on 18^{th} cycle of biennial assessment of forest and tree resources in the country.

In order to assess the precise impact of execution of government policies for protecition, conservation and augmentation of forest resources, a regular assessment and monitoring of country's forest resources is required. ISFR plays an important role in reporting the progress made by the county towards meeting the goals and commitments at the national and international level.

In these times of *Amrit kaal,* we all are committed to make India a developed nation by 2047, In the Nationally Determined Contriution (NDC) commitments made at the Paris Climate Change Agreement, India has resolved to create an additional carbon sink of 2.5 to 3 billion tones of CO_2 equivalent through additional forest and tree cover by 2030. We have also pledged to bring in 26 million hectares of degraded land under restoration by 2030, as part of Bonn Challenge. The present report reveals an increasing trend in forest and tree cover and in sequestered carbon, which is in line with our commitment to meet the NDC goals.

It gives me a profound sense of pride to look at our progress. Despite innumerable pressures on our forests, we have been able to protect and enhance them over the years. I congratulate Director General, FSI and his team for bringing out ISFR 2023. I am sure that the information given in the report will be highly useful for the planners, policy makers and other stakeholders alike.

(Bhupender Yadav)

सत्यमेव जयते

FOREWORD

कीर्ति वर्धन सिंह

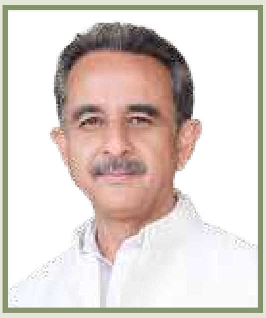
Kirti Vardhan Singh

पर्यावरण, वन एवं जलवायु परिवर्तन राज्य मंत्री

Minister of State for Environment, Forest and Climate Change

भारत सरकार

Government of India



India's forests support the livelihoods of about 17% of the global human population and 18% of the world's total livestock. Since ancient times, India has been managing its forest in a sustainable manner with people's participation. Due to meticulous planing and pro-active Goverment policies, the country has managed to manitain an upward trend in extent of forest cover.

As per Global Forest Resource Assessment (GFRA, 2020) published by FAO, India is ranked amongst the top 10 countries of the world, in terms of forest area and holds 3rd postion for highest annual net gain in forest cover between 2010-2020. Accordingly, India's forests act as a net sink of corbon. This shows the commitment of our country towards climate change mitigation and adaptaion.

At national level, Forest Survey of India under the Ministry of Enviornment, Forest and Climate Change, is doing a commendable job since last six decades and generating valuable information on status of forest resources of the country. Periodic assessments of the country's forest resources help in analysing the effectiveness of forest policies and provide valuable information on the status of forest cover, growing stock, carbon stock, agroforestry and many other important characteristics of our forests. The data given in the ISFR is crucial for reporting the greenhouse gas (GHG) inventory of forest land to United Nations Framework Convention on Climate Change (UNFCCC) and at other international fora.

I congratulate the Director General, Forest Survey of India, and his team for the hard work in bringing out the ISFR 2023. I am confident that FSI will continue to work with same energy for scientific management of forests in the country.

(Kirti Vardhan Singh)

सत्यमेव जयते

MESSAGE

लीना नंदन
Leena Nandan,
सचिव
Secretary
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
Ministry of Environment, Forest and Climate Change
भारत सरकार
Government of India

I am happy to note that the Forest Survey of India, a premier organisation of the Ministry for Environment, Forest and Climate Change, is releasing the biennial report “India State of Forest Report 2023”. Forest Survey of India has been carrying out the massive task of nation-wide biennial forest cover monitoring and assessment since 1987, FSI has established its excellence in the specialized field of forest cover mapping by keeping pace with the advancement of technology for such assessment, and validating it by widespread ground truthing. FSI also implements the National Forest Inventory involving survey and enumeration of more than 16,000 sample plots, distributed all over the country, every year. The findings of these two major activites, along with several others, are published in the biennial India State of Forest Report 2023.

In today’s era of climate change, the importance of conserving the environment and living in harmony with nature cannot be overemphasised. The ISFR 2023 provides forset cover information for each district and forest division of the country. Besides this, the ISFR also provides information on mangroves, growing stock of trees within and outside forests, and also contains dedicated chapters of forest fires, carbon stock, important characteristics of India’s forests, agroforestry, decadal change in forests, etc. It is thus a storeouse of useful data for meeting the information needs of different stakeholders of the forestry sector.

I congratulate the Director General of Forest Survey of India and his team for bringing out this comprehensive Report. I am confident that in the years to come, FSI will continue to fulfil its mandate efficiently and meticulously.

(Leena Nandan)

MESSAGE

जितेंद्र कुमार
Jitendra Kumar,
महानिदेशक वन एवं विशेष सचिव
Director General of Forests & Special Secretary
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
Ministry of Environment, Forest and Climate Change
भारत सरकार
Government of India

The India State of Forest Report (ISFR) 2023 is a biennial publication by Forest Survey of India which is a primary information document on Forest Resources of the country. The release of the ISFR 2023 is an important event for the forestry sector in India. The present document is 18th biennial assessment report, and with this the country has completed more than thirty-five years of regular assessment of its forest resources.

FSI has attained an exceptional niche through various initatives including enhancing forest cover mapping methods and forest fire alerts. Analzing data over different administrative units like Districts, Divisions, Municipal areas, Mega cities, Protected areas, Tiger reserves, etc., has made the report more useful. The updated data regrading recorded forest areas and forest cover distribution across districts, forest divisions, various slope classes etc., as outlined in this report, offers valuable insights for State Forest Department.

The Forest Fire Alert System at FSI has become the backbone of forest fire control in the country. Due to improvement in Forest fire models, and using Indian meteorological predictions for Indian Institute of Tropical Meteorology, the accurance of pre-fire alerts has been enhanced manifold. Country-level burnt area mapping is a new achievement of FSI.

FSI deserves commendation for completing first cycle of five year of Nationwide grid based National Forest Inventory of Forest and TOF areas. Similar to previous ISFRs. data from the grid based NFI design (2016-2022) has been used for assessment of growing stock, forest carbon stock, and several other parameters reported in the ISFR 2023.

It is a matter of pleasure that the digitized forest boundaries of 25 States and UTs have been used in the current ISFR to assess the extent of forest cover within the recorded forest areas. This will help the states to plan appropriately for areas within and outside recorded forest areas. In additon, this report will also fulfill information needs of different stakeholders of the forestry sector.

Finally, I take this opportunitily to congratulate the Director General, Forest Survey of India and his entire team for an excellent job done and hope that they will continue to enrich information content on forest resources of the conntry in future also.

(Jitendra Kumar)

सत्यमेव जयते

PREFACE

अनूप सिंह, महानिदेशक
Anoop Singh, Director General
भारतीय वन सर्वेक्षण
Forest Survey of India
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
Ministry of Environment, Forest and Climate Change
भारत सरकार
Government of India

The India State of Forest Report (ISFR) 2023 is the 18th report in the series of biennial assessment reports published by the Forest Survey of India (FSI). The report gives comprehensive assessment of the forest resources of the country based on interpretation of satellite data and field based National Forest Inventory (NFI). While satellite data gives forest cover, NFI provides Growing Stock and Carbon. The data period of the satellite used for this assessment is in general October 2021 to December 2021 and NFI used for this assessment is 2017-22.

Forest cover mapping/assessment is a biennial exercise in which wall to wall mapping is done using Indian remote sensing satellite data (IRS-LISS III sensor with 23.5 m resolution) as provided by NRSC. The report gives information on forest cover of country at state, district, and forest division level; and changes in forest cover in respect of the previous assessment of 2021. Information on forest cover inside and outside the recorded forest area, forest cover in hills districts, forest cover in North Eastern States, mangrove is also provided. For the first time, forest cover change matrix inside and outside forest areas have been provided separately for clarity in analysis. In the present report, FSI has given forest cover information for 751 districts including those created in the recent past, as against 636 districts given in ISFR 2021. Latest district boundaries were received from the Survey of India. In addition, to making the report more relevant to the Divisional Forest Officers, who are the primary administrative heads in forest administration, for the first time Division wise forest cover information has also been given for those States from where digitized division boundaries were received. FSI has perfected forest cover mapping methods, by enhancing ground truthing (GT). Data of National Forest inventory, as a ready to use KML file, has also been provided to the analysts carrying out Forest Cover mapping for improving quality of mapping. Concurrent monitoring of FCM work by supervisors and frequent visits to the field after every few scenes improved the perception of analysts. PDA based application for GT ensured data fidelity.

Contemporary issues have also been attempted e.g. Forest Cover change in Western Ghats.

The report also contains estimates of tree cover, growing stock, carbon stock and important characteristics of forests derived from the data collected from sample plots spread over the entire country under NFI. As another first, the trees between 5-10 cm have been included in the analysis for Tree Cover and Growing stock as they are a major contributor to paper and pulp industry. Bamboo cover has also been estimated for the first time and included in Tree cover. Agroforestry has been analyzed separately as it accounts for 1,27,590 km^2 of tree cover and 1,292 M m^3 of Growing stock and serves as livelihood enhancer. It has gained further importance due to earning carbon credits in Agroforestry.

An analysis on Forest cover degradation between 2011-2021 has been carried out for identifying 93,000 km^2 potential areas for upgradation of density and additionally sequestering 636 Mt of Carbon.

Forest fire alerts has become one of the most important activities of FSI. Pre-Fire alerts, near-real time alerts are being sent for several years. In the forest fire chapter we have given information on forest fires in 705 Protected areas for the first time. Similarly Burnt area assessment has been done for the first time at national level and can support course-correction for the policy makers.

A separate chapter has been given on decadal changes, highlighting changes in forest cover and other parameters over a decade. The information given in the report will also be very useful for forest planners and to monitor the NDC targets and making policy changes.

FSI has always endeavored to keep pace with the advancements in tools and technologies, and kept the methodology and sampling design of NFI abreast to meet the data requirement of the forestry sector both at national and international level. The data processed for the report is also used as inputs for GHG inventory of the forest land under the LULUCF sector, and reporting of country data to FAO for Global Forest Resource Assessment.

I take this opportunity to express my heartfelt thanks for the continuous support and guidance received from Shri Bhupender Yadav, Hon'ble Minister, EF&CC; Shri Kirti Vardhan Singh, Hon'ble Minister of State, EF&CC; Smt Leena Nandan, Secretary, MoEF&CC, Govt. of India and Shri C.P. Goel, former Director General of Forests & Special Secretary, and Shri Jitendra Kumar, present Director General of Forests & Special Secretary, Government of India.

On behalf of the organization, I reiterate our commitment to serve the nation by making available the most reliable and unbiased latest comprehensive information on the forest resources of the country that would enable the Government and other stakeholders to view this precious natural resource on a firm scientific footing.

(Anoop Singh)

Photo: Subharanjan Sen, IFS

ACKNOWLEDGEMENTS

We express our deep gratitude to all the individuals and organizations who contributed to the preparation of the "India State of Forest Report 2023." This comprehensive report would not have been possible without the collaborative efforts of the Forest Survey of India (FSI) and the Ministry of Environment, Forest, and Climate Change (MoEF&CC), Government of India.

We extend our sincere thanks to all the state forest departments for the technical and logistical help provided to the team of FSI in field validation of forest cover mapping and field works of National Forest Inventory. Their commitment and support were instrumental in ensuring the accuracy and reliability of the data presented in this report.

We also acknowledge the contributions of various scientific institutions and research organizations for their insights, recommendations, and technical expertise. Their guidance has enriched the analysis and findings of this report, helping to highlight the state of forests and green cover in India. The information and assistance provided by National Remote Sensing Centre, Hyderabad, related to satellite data and forest fire detections; National Statistical Office, for providing the UFS block maps for the urban inventory; Survey of India, for providing the boundaries of newly created districts; J & K forest Department for data collection of NFI in J & K; Forest Research Institute, for providing the wood density and list of invasive species; Botanical Survey of India for providing the taxonomical guidance, Directorate of Economics and Statistics, Ministry of Agriculture & Farmer's Welfare, for providing the information on Land use Statistics and Indian Institute of Tropical Meteorology for providing weather forecast are thankfully acknowledged.

We are grateful for the valuable advice of Dr. Devendra Pandey IFS Retd., in making the agroforestry chapter concise and precise. The contribution of Shri Arijit Banerjee IFS and Shri Noyal Thomas IFS Retd., in reviewing textual matters of few crucial chapters is highly appreciated.

The contributions of Sr. Consultants at FSI headquarters, all the officers and staff of FSI headquarters and zonal offices are gratefully acknowledged. We are grateful to the team of experts and professionals at the Forest Survey of India who worked tirelessly to analyze satellite imagery, conduct ground surveys, and compile the data that forms the foundation of this report. Their dedication and professionalism have been critical in maintaining the high standards of this publication.

This report was thoroughly and critically reviewed by Mr. Krishna Bahadur Singh, IFS, IG Forest, MoEF&CC; and his review was very helpful in improving the readability of the report. His efforts are really appreciated.

The quality photographs provided by Shri Anant Shukla, Shri Dharam Singh Meena, Shri Arun Kumar Thyadi, Shri Saurabh Kalia, Shri Arijit Banerjee, IFS, Shri Debal Ray IFS, Shri Subharanjan Sen IFS, Shri Sanjay Shukla IFS, and Shri Padmabhushan Rajguru, IFS are gratefully accredited.

EXECUTIVE SUMMARY

Periodic assessment of forest resources of the country based on robust scientific methodologies is a pre-requisite for monitoring of these resources and better planning for the forestry sector. Forest Survey of India, an organization under the Ministry of Environment, Forest and Climate Change, has been mandated to carry out a regular assessment of forest resources of the country using satellite data and field based information and publish the results in a biennial report named as India state of Forest Report (ISFR). The first report was published by FSI in 1987 and since then 17 such reports have been published by FSI. The ISFR 2023 is 18^{th} in the series. The information on various forestry parameters given in the ISFR are very useful for monitoring of the resources, evaluation of the various polices and making better planning for optimum utilization of the forest resources. In addition, the inputs given in the report are very useful for monitoring of NDC targets, reporting of Green House Gas (GHG) inventory to UNFCCC for the forest land under the LULUCF sector, and country reporting to FAO for the Global Assessment of Forest Resources.

The first major input that goes into the ISFR is forest cover mapping of the country based on nationwide forest cover mapping using satellite data. The forest cover is defined as "all lands, more than one hectare with a tree canopy density of more than or equal to 10% irrespective of ownership, legal status and land use. Such lands may not necessarily be a recorded forest area. It also includes orchards, bamboo and palm". In the current cycle, Forest Cover Mapping has been carried out using medium-resolution indigenous satellite data, with a spatial resolution of 23.5 m sourced from the Indian Space Research Organization's (ISRO) indigenous LISS-III sensor, part of the IRS Resourcesat satellite series, at a scale of 1: 50,000. This satellite data was acquired for all states within the timeframe of October 2021 to December 2021. In certain regions of the country, such as the North Eastern region, the coastal belt, and the Andaman and Nicobar Islands, additional satellite images were procured for the period from January 2022 to April 2022, to obtain better-quality satellite imagery. This specific time window was chosen because it typically offers cloud-free satellite data and full vegetation foliage, resulting in enhanced reflectance and precise satellite image interpretation.

The classification of forest cover used in the present report is based on tree canopy density, viz., Very Dense Forest (VDF) having canopy density equal to or more than 70%, Moderately Dense Forest (MDF) having canopy density equal to or more than 40% but less than 70%, and Open Forest (OF) having canopy density equal to or more than 10% but less than 40%.

The Forest Cover is assessed using an approach involving satellite digital image processing; visual image analysis; ground verification by the analysts and State Forest Departments; incorporation of post-field corrections; quality checks including ground validation by officers; followed by generation of output in the form of maps and area statistics.

Over the years, this methodology has continuously evolved and improved to keep pace with advancing technology and the latest image interpretation techniques. Since the initial forest assessment report in 1987, the methodology for Forest Cover Mapping has been consistently refined and updated. To ensure consistency, uniformity, and a high level of accuracy in the Forest Cover Mapping exercise, all steps of the methodology have been standardized. To minimize subjectivity, a comprehensive manual has been developed to guide and facilitate these processes, helping to maintain the quality and reliability of the mapping results.

The second major input that goes into ISFR is based on the inventory of Forests and Trees Outside Forests (TOF) under the National Forest Inventory (NFI) Programme of FSI. FSI launched a National Forest Inventory in 2002, with the onset of the 10th five-year plan, by developing a sampling design, to generate the national level estimates of growing stock and other parameters. Under this NFI design, the country was stratified into 14 physiographic zones and 60 districts were selected for the detailed inventory for a cycle of 2 years. About 3,500 sample plots were inventoried in the forest areas and 5000 sample plots were inventoried in TOF every year. FSI modified the sampling design of NFI in 2016, considering the data requirements at National and International level, to generate the precise estimates at the State level and to reduce the revisit time from 20 years to 5 years. Under the modified design, FSI has switched over to a grid based design having uniform grids of size 5 km x 5 km and selecting specified grids each year for the detailed inventory. Under this design, FSI is laying about 6,000 plots in forest area and 10,000 plots in TOF areas every year. The information of growing stock, tree cover, bamboo stock, carbon stock, agroforestry and important characteristics are derived from the field inventory data collected from forest and TOF.

The ISFR 2023 has been produced into two volumes considering the wealth of information generated from forest cover mapping and NFI. The Volume-I gives the national level assessment such as forest cover, mangrove cover, forest fires, growing stock, carbon stock, agroforestry, important characteristics of forest and decadal change. The Volume-II gives information about forest cover for each State/UT of the country, districts and divisions and state wise information derived from the field inventory.

Salient findings

The key findings of the ISFR 2023 are as follows:

- The total forest and tree cover of the country is 8,27,356.95 km^2 which is 25.17% of the geographical area of the country. The total Forest Cover has an area of 7,15,342.61 km^2 (21.76%) whereas the Tree Cover has an area of 1,12,014.34 km^2 (3.41%).

- The current assessment shows an increase of 156.41 km^2 in the Forest Cover at national level as compared to the previous assessment.

- The total forest and tree cover of the country has increased by 1445.81 km^2 as compared to the last assessment of 2021.

- The maximum increase in forest and tree cover has been observed in the States of Chhattisgarh (683.62 km^2) followed by Uttar Pradesh (559.19 km^2), Odisha (558.57 km^2) and Rajasthan (394.46 km^2). The maximum decrease in forest and tree cover has been noticed in the state of Madhya Pradesh (612.41 km^2) followed by Karnataka (459.36 km^2), Ladakh (159.26 km^2) and Nagaland (125.22 km^2).

- The States showing maximum increase of Forest Cover inside the RFA/GW are Mizoram (192.92 km^2) followed by Odisha (118.17 km^2), Karnataka (93.14 km^2), West Bengal (64.79 km^2) and Jharkhand (52.72 km^2), whereas the States showing the maximum decrease of Forest Cover inside the RFA/GW are Tripura (116.90 km^2) followed by Telangana (105.87 km^2), Assam (86.66 km^2), Andhra Pradesh (83.47 km^2) and Gujarat (61.22 km^2).

- The forest cover outside RFA has been shown maximum increase in the state of Gujarat (241.29 km^2) followed by Bihar (106.85 km^2), Kerala (95.19 km^2), Uttar Pradesh (79.27 km^2) and Assam (74.90 km^2). The states showing decrease in the forest cover outside RFA are Madhya Pradesh (344.77 km^2) followed by Rajasthan (110.65 km^2), Andhra Pradesh (55.19 km^2), Arunachal Pradesh (45.32 km^2) and Maharashtra (41.07 km^2).

- The extent of TOF (forest cover outside the RFA & GW and tree cover) has been found to be 30.70 M ha, which is 37.11% of the total forest and tree cover in the country.

- The maximum tree cover has been found in the State of Maharashtra (14,524.88 km^2) followed by Rajasthan (10,841.12 km^2) and Uttar Pradesh (8,950.92 km^2). The maximum positive change as compared to ISFR 2021 has been observed in Chhattisgarh (702.75 km^2) followed by Rajasthan (478.26 km^2) and Uttar Pradesh (440.76 km^2). In general, twenty-one States and UTs have shown an increasing trend in tree cover, which indicates that agroforestry, is being promoted in these States

- Western Ghats Eco-Sensitive Areas (WGESA) occupies an area of approximately 60,285.61 km^2 based on the digital boundary provided by MoEF & CC. Forest cover in all districts under WGESA has been estimated as 44,043.99 km^2 (73%).

- FSI has carried out a decadal changes analysis of forest cover of WGESA and observed that there has been an overall loss of 58.22 km^2 in forest cover during the last 10 years. Very Dense forest increased by 3,465.12 km², whereas Moderately Dense Forest and Open Forest decreased by 1,043.23 km² and 2,480.11 km².

- Forest cover in the hills districts of the country is 2,83,713.20 km², which is 40% of the total geographical area of these districts. In the current assessment, Forest Cover has in hill districts of the country has increased by 234.14 km².

- The total forest and tree cover in the North Eastern region is 1,74,394.70 km², which is 67% of geographical area of these states. The current assessment shows a decrease of forest cover of 327.30 km² in the region.

- The total Mangrove cover of the country is 4,991.68 km², which accounts for 0.15 % of the country's total geographical area. Among this, Very Dense Mangrove comprises 1,463.97 km² (29.33%) of the total Mangrove cover, Moderately Dense Mangrove is 1,500.84 km² (30.07%) while Open Mangroves constitute an area of 2,026.87 km² (40.60%). In comparison to the 2021 assessment, there has been a net decrease of 7.43 km² in the country's Mangrove coverage. Gujarat has a notable decrease of 36.39 km². Notable increase in Mangrove forest cover is observed in Andhra Pradesh (13.01 km²), followed by Maharashtra (12.39 km²).

- During the fire season 2023-24, the number of fire hotspots detected by SNPP-VIIRS sensor were 2,03, 544 as against 2,23,333 in 2021-22 seasons and 2,12,249 in 2022-23 season.

- Top three Stares where fire incidences have been observed the most in 2023-24 season are Uttrarakhand, Odisha and Chhattisgarh.

- The total growing stock of wood in the country is estimated at 6,429.64 M m³, which comprises of 4,478.89 M m³ inside forest areas and 1,950.75 M m³ outside recorded forest areas (TOF). There is a total increase of 262.32 M m³ (4.25%) in the growing stock of the country as compared to the estimates reported in ISFR 2021. Out of this, the increase in growing stock is 90.92 M m³ (2.07%) inside the forests, and 171.40 M m³ (9.63%) outside the forest areas.

- It is observed that the growing stock at the national level has been estimated as 86.10 m³ per ha in forest areas.

- Arunachal Pradesh has maximum growing stock (457.83 M m³) in forests, followed by Uttarakhand (400.02 M m³), Chhattisgarh (398.54 M m³) and Madhya Pradesh (387.18 M m³). In TOF, Maharashtra has maximum growing stock (213.93 M m³) followed by Karnataka (137.62 M m³), Madhya Pradesh (130.46 M m³) and Chhattisgarh (129.04 M m³).

- Among the States, the highest per ha growing stock in forest is in Himachal Pradesh (219.46 m^3) followed by Kerala (179.78 m^3) and Uttarakhand (164.39 m^3). Among the UTs, the highest per ha growing stock in forest is in Jammu & Kashmir (296.22 m^3) followed by A&N Islands (246.61 m^3) and Chandigarh (78.64 m^3).

- Inside the forests, *Shorea robusta* has the maximum contribution in total volume (11.43%), followed by *Tectona grandis* (4.46%), *Pinus roxburghii* (4.43%) and *Terminalia tomentosa* (3.59%).
- In the Trees Outside Forests, *Mangifera indica* contributes maximum volume of 13.25% to total volume followed by *Azadirachta indica* (7.00%), *Madhuca latifolia / Madhuca longifolia / Madhuca indica* (4.37 %) and *Cocos nucifera* (4.16 %).

- The potential production of industrial wood from TOF has been estimated as 91.51 M m^3 per year. There is an increase of 22.47 M m^3 in the potential production of industrial wood as compared to the estimates reported in ISFR 2017.

- The total bamboo bearing area of the country has been estimated to be 1,54,670 km^2. There is an increase of 5,227 km^2 in the bamboo bearing area of the country as compared to the previous assessment reported in ISFR 2021.

- Madhya Pradesh has maximum bamboo bearing area of 20,421 km^2, followed by Arunachal Pradesh (18,424 km^2), Maharashtra (13,572 km^2), and Odisha (12,328 km^2). It has been observed that bamboo-bearing area in Arunachal Pradesh has shown the highest increase of 2,685 km^2 followed by Madhya Pradesh (2,027 km^2). Similarly, Karnataka has shown the highest decrease of 1,290 km^2 in the bamboo bearing area, followed by Manipur (860 km^2).

- Total tree green cover under agroforestry at the national level has been estimated at 1,27,590.05 km^2 in 2023. There is a total increase of 21,286.57 km^2 (20.02%) in the total tree green cover under agroforestry of the country as compared to the estimates reported in ISFR 2013.

- The total growing stock under agroforestry in the country is estimated at 1,291.68 M m^3 in 2023. There is a total increase of 286.94 M m^3 (28.56 %) in the growing stock under agroforestry of the country as compared to the estimates reported in ISFR 2013.

- Among the States, the highest growing stock in agroforestry is observed in Maharashtra (136.45 M m^3) followed by Karnataka (98.31 M m^3), Odisha (88.53 M m^3) and Rajasthan (86.26 M m^3). Among the UTs, the highest growing stock is observed in Jammu & Kashmir (29.59 M m^3) followed by A&N Islands (0.90 M m^3) and Dadra & Nagar Haveli and Daman & Diu (0.53 M m^3).

- Top five prevalent species in agroforestry as given in ISFR 2013 were *Mangifera indica*, followed by *Areca catechu, Cocos nucifera*, *Azadirachta indica*, and *Acacia arabica / Acacia nilotica.* On the other hand, as per ISFR 2023 the top five prevalent species in agroforestry are *Mangifera indica*, followed by *Azadirachta indica, Prosopis juliflora / Neltuma juliflora, Areca catechu,* and *Eucalyptus species*.

- The carbon stock for 2023 has been estimated as 7,285.5 Mt. There is an increase of 81.5 Mt of carbon stock as compared to the estimates of previous assessment. The annual increase of carbon stock is estimated as 40.75 Mt, which is 149.42 Mt of CO_2 equivalent. Soil organic carbon is the largest pool of forest carbon accounting for (55.06%) followed by AGB (32.69%), BGB (10.09%), Litter (1.48%) and Dead Wood (0.78%).

- Arunachal Pradesh has maximum carbon stock of 1,021 Mt followed by Madhya Pradesh (608 Mt), Chhattisgarh (505 Mt) and Maharashtra (465 Mt). The per hectare carbon stock among different States/UTs indicates that Jammu & Kashmir is contributing maximum per hectare carbon stock of 174.10 t/ha, followed by Sikkim (169.20 t/ha), Himachal Pradesh (163.68 t/ha) and, Andaman & Nicobar Islands (161.62 t/ha).

- Regarding the monitoring of the target of NDC, the current assessment shows that India has reached to 30.43 billion tonnes of CO_2 eq, which indicates that as compared to the base year of 2005, we have already reached to 2.29 billion tonnes of additional carbon sink.

During the decades 2013-2023, the changes in different forestry parameters are positive and encouraging as given follows:

- The forest cover of the country has shown an increase of 16,630.25 km^2 out of which increase inside RFA/GW is 440.47 km^2 and increase outside RFA/GW is 16,189.78 km^2. In the hill districts of the country, the forest cover has increased by 2,649.04 km^2.

- Mangrove cover of the country has increased by 296.33 km^2.

- The tree cover has shown an increase of 20,747.34 km^2.

- The tree green cover in the agroforestry has increased by 21,286.57 km^2 and growing stock in agroforestry has increased by 286.94 M m^3.

- The growing stock in forest and TOF has increased by 305.543 M m^3 and 466.07 M m^3 respectively.

The important characteristics of forests have been analyzed for forest enabling conditions, disturbances in forests area, and status of forest vegetation; and given in a separate chapter. Some of the highlights are given as follows:

- There is a general improvement in soil health (87.16% of shallow to deep soil as against 83.53% in 2013) reflected by improvement in humus (18.04% medium to deep humus as against 11.43% in 2013) which is, in turn, reflected in better grass cover (17.21% dense to very dense grass cover as against 15.64% in 2013) and better undergrowth (25.58% dense to very dense undergrowth as against 20.32% in 2013).

- The soil organic carbon has also increased marginally during this period from 55.85 tonnes per hectare to 56.08 tonnes per hectare.

- The load of moderate to heavy grazing has come down to 35.79% as compared to 41.04% in 2013.

- Biotic influences on forests have also come down to 26.66% from 31.28% in 2013. All this has reflected in increase in forest areas under mixed size classes (38.11% as against 21.12% in 2013), which indicates improved floral biodiversity, and improved surroundings for faunal biodiversity.

Table: Forest and Tree Cover of India

in km^2

Class	Area	Percentage of GA
Forest Cover	7,15,342.61	21.76
Tree Cover	1,12,014.34	3.41
Total Forest and Tree Cover	**8,27,356.95**	**25.17**
Scrub	43,622.64	1.33
Non Forest	24,16,489.29	73.50
Geographical Area of the country	**32,87,468.88**	**100.00**

ABBREVIATIONS & ACRONYMS

ACZ	-	Agro-Climatic Zones
AFOLU	-	Agriculture, Forestry and Other Land Use
AFP	-	Agroforestry products
AGA	-	Alert Generating Agency
AGB	-	Above Ground Biomass
AICRP	-	All India Coordinated Research Project
APFC	-	Asia Pacific Forestry Commission
AWiFS	-	Advanced Wide Field Sensor
BGB	-	Below Ground Biomass
BTR		Biennial Transparency Reports
BUR	-	Biennial Update Reports
CAFRI	-	Central Agroforestry Research Institute
CAMPA	-	Compensatory Afforestation Fund Management and Planning Authority
CAP	-	Common Alerting Protocol
CBD	-	Convention on Biological Diversity
CFFDRS	-	Canadian Forest Fire Danger Rating System
CIFOR	-	Center for International Forestry Research
CNFA	-	Culturable Non-Forest Area
CO_2	-	Carbon Dioxide
CO_2eq	-	Carbon Dioxide equivalent
COP	-	Conference of the Parties
CSV	-	Comma-separated Values
DBH	-	Diameter at Breast Height
DEM	-	Digital Elevation Model
DNH	-	Dadra & Nagar Haveli
ESA	-	Ecologically Sensitive Area
FAO	-	The Food & Agriculture Organization
FC	-	Forest Cover
FCC	-	False Colour Composite
FCM	-	Forest Cover Mapping
FI	-	Forest Inventory
FSI	-	Forest Survey of India
FTG	-	Forest Type Group
FWI	-	Fire Weather Index
GA	-	Geographical Area
GEOS	-	Goddard Earth Observing System
GFRA	-	Global Forest Resource Assessment
GFWED	-	Global Fire Weather Database
GHG	-	Green House Gas
GIS	-	Geographical Information System
GOI	-	Government of India
GDP	-	Gross Domestic Product
GPG	-	Good Practices Guidance
GT	-	Ground Truth
GW	-	Green Wash

HLWG	-	High Level Working Group
ICAR	-	Indian Council of Agriculture Research
ICFRE	-	Indian Council of Forestry Research and Education
ICRAF	-	International Centre for Research in Agroforestry
INC	-	Initial National Communication
IPCC	-	Intergovernmental Panel for Climate Change
IRS	-	Indian Remote Sensing (Satellite)
ISFR	-	India State of Forest Report
ISODATA	-	Iterative Self-Organizing Data Analysis Technique
ISRO	-	Indian Space Research Organization
IUCN	-	International Union for Conservation of Nature
J&K	-	Jammu and Kashmir
JFM	-	Joint Forest Management
K_{HAT}	-	Cohen's kappa coefficient
KML	-	Keyhole Markup Language
LANDSAT		Land Satellite
LFF	-	Large Forest Fire
LiFE	-	Lifestyle for Environment
LISS	-	Linear Imaging and Self-scanning Sensor
LULC	-	Land Use Land Cover
LULUCF	-	Land Use, Land-Use Change and Forestry
MDF	-	Moderately Dense Forest
MGNREGS	-	Mahatma Gandhi National Rural Employment Guarantee Scheme
MISHTI	-	Mangrove Initiative for Shoreline Habitats & Tangible Incomes
MLE	-	Maximum Likelihood Estimator
MMU	-	Minimum Mappable Unit
MODIS	-	Moderate Resolution Imaging Spectroradiometer
MoEFCC	-	Ministry of Environment, Forest and Climate Change
MSS	-	Multi Spectral Scanner
NAP	-	National Agroforestry Policy
NASA	-	National Aeronautics and Space Administration
NATCOM	-	National Communication
NBSSLUP	-	National Bureau of Soil Survey & Land Use Planning
NDC	-	Nationally Determined Contributions
NDMA	-	National Disaster Management Authority
NDMP	-	National Disaster Management Plan
NDVI	-	Normalized Difference Vegetation Index
NESAC	-	North Eastern Space Applications Centre
NF	-	Non-Forest
NFI	-	National Forest Inventory
NMSA	-	National Mission for Sustainable Agriculture
NP	-	National Park
NPFFM	-	National Programme on Forest Fire Management
NRCAF	-	National Research Centre for Agroforestry
NRSC	-	National Remote Sensing Centre
NSO	-	National Statistical Office
NTFP	-	Non-Timber Forest Products
NWFP	-	Non-wood Forest Products

NYDF	-	New York Declaration on Forests
OF	-	Open Forest
PA	-	Protected Area
PDA	-	Personal Digital Assistant
PDF	-	Plot Description Form
PF	-	Protected Forest
PISFR	-	Pre-Investment Survey of Forest Resources
QCQA	-	Quality Check & Quality Assurance
REDD+	-	Reducing Emissions from Deforestation and Forest Degradation Plus
RF	-	Reserved Forest
RFA	-	Recorded Forest Area
RGI	-	Registrar General of India
SBSTA	-	Subsidiary Body for Scientific and Technological Advice
SDG	-	Sustainable Development Goals
SDMA	-	State Disaster Management Authority
SE	-	Standard Error
SFD	-	State Forest Department
SFR	-	State of Forest Report
SMAF	-	Sub-Mission on Agroforestry
SNC	-	Second National Communication
SNPP	-	Suomi National Polar orbiting Partnership
SOC	-	Soil Organic Carbon
SOI	-	Survey of India
SRTM	-	Shuttle Radar Topography Mission
ToA	-	Top of Atmospheric
TOF	-	Trees Outside Forests
TSFDC	-	Telangana State Forest Development Corporation
UFS	-	Urban Frame Survey
UN	-	United Nations
UNCCD	-	United Nations Convention to Combat Desertification
UNDP	-	United Nations Development Programme
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UNFCCC	-	United Nation Framework Convention on Climate Change
UT	-	Union Territory
UTM	-	Universal Transverse Mercator
VDF	-	Very Dense Forest
VIIRS	-	Visible Infrared Imaging Radiometer Suite
WFS	-	Web Feature Service
WGEEP	-	Western Ghats Ecology Expert Panel
WGESA	-	Western Ghats Eco-Sensitive Areas
WGS	-	World Geodetic System
WMS	-	Web Map Service

km^2	-	square kilometre
'000 t	-	thousand tonne
cm	-	centimetre
FY	-	financial year
gm	-	gram
Mha	-	million hectare
M m^3	-	million cubic meter
m^3	-	cubic meter
m^3/ha	-	cubic meter per hectare
Mt	-	million tonne
per ha	-	per hectare
t C/yr	-	tonne carbon per year
t/ha	-	tonnes per hectare

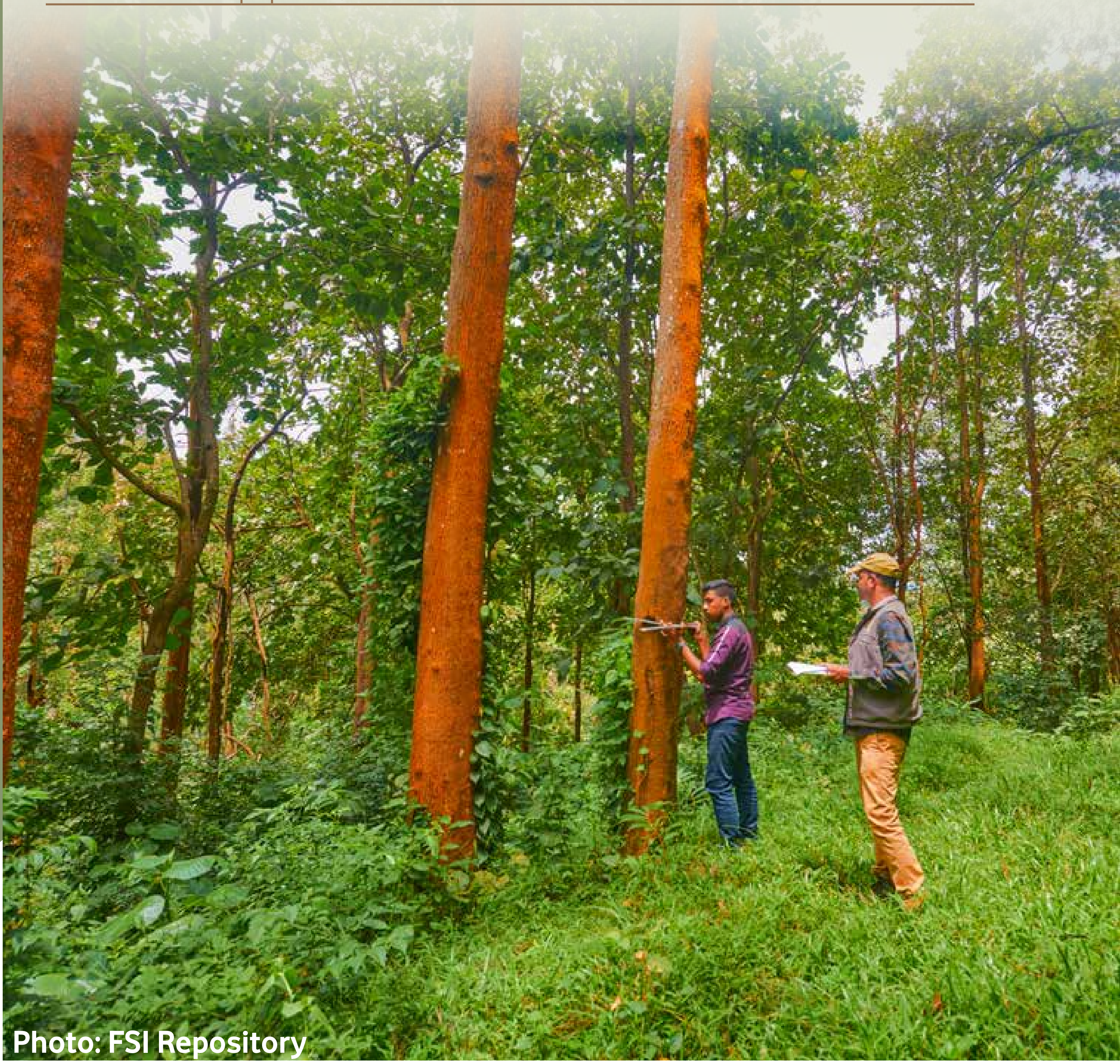


Photo: FSI Repository

GLOSSARY

Above-ground biomass (vegetation)	All biomass of living vegetation, both woody and herbaceous, above the soil, including stems, stumps, branches, bark, seeds, and foliage. *(Source – 2006 IPCC Guidelines for National Greenhouse Gas inventories)*
Aerial photographs	A photograph taken from an air-borne platform using a precision camera.
Afforestation	Establishment of forest through planting and/or deliberate seeding on land that, until then, was under a different land use, implies a transformation of land use form non-forest to forest.
Agroforestry	A land use system which integrates trees and shrubs on farm lands and rural landscapes to enhance productivity, profitability, diversity, and ecosystem sustainability. *(Source – National Agroforestry Policy, 2014)*
Anthropogenic	Resulting from or produced by human activities.
Bamboo density	Pure: 151 and more clump/ha for clump forming bamboo or 9001 and more culms / ha for non-clump forming. Dense: 51 to 150 clump/ha for clump forming or 3001 to 9000 culms / ha for non-clump forming. Scattered: 1 to 50 clump/ha for clump forming or 1 to 3000 culms / ha for non-clump forming.
Below-ground biomass (vegetation)	All biomass of live roots. Fine roots of less than 2 mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter. *(Source – 2006 IPCC Guidelines for National Greenhouse Gas inventories)*
Biodiversity	Biodiversity, or, "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. *(Source – Convention on Biological Diversity)*
Biomass	Biomass is the organic material that comes from plants or animal. Biomass can be above-ground, or below-ground, as defined above.
Biomass equations	Biomass equations are the regression equations which are mathematical functions that relate biomass per tree as a function of a single or a combination of tree dimensions such as dbh, tree height, etc.
Biotic influences	Any influence of living organisms. Usually restricted to the influence of animals including man. Usually in forests, the biotic influences could include grazing, browsing, man-made fire, pollarding, illicit felling, and lopping.
Block (of trees)	Patch of trees outside RFA, of size 0.1 ha or more
Canopy	The cover of branches and foliage formed by crown of trees.
Canopy density	Percent area of land covered by canopy of trees. It is expressed as a decimal coefficient, taking closed canopy as unity.
Carbon dioxide (CO_2) equivalent (eq.)	It is a metric measure used to compare the emissions from various greenhouse gases based on their global-warming potential, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.
Carbon pools	Carbon pools are major components of an ecosystem that can either accumulate or release carbon.
Carbon sequestration	It is a natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form.
Carbon stock	Carbon in all living and non-living biomass including Above Ground Biomass, Below Ground Biomass, Deadwood, Litter, and Soil carbon

Change matrix	It presents change in land use/forest cover classes for a given area during the period of two consecutive assessments in a tabular form by showing the changes of area from one class to another.
Climate change	Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. *(Source – UNFCCC)*
Coral reefs	Corals are colonial marine invertebrates. A coral reef is an underwater ecosystem characterised by structure-building stony corals.
Correlation	The correlation between two variables is the degree of association between two variables. This degree of association is expressed by a single value called a correlation coefficient (r), which can take values ranging between -1 and +1.
Crop composition	It refers to the type of species or group of species, which are contained in a forest. According to crop composition, forest can be either pure or mixed.
Culturable Non Forest Area	It is the net geographical area, lying outside recorded forest, which can support tree vegetation (thus, excluding areas under waterbodies, riverbeds, perennial snow covered mountains, Alpine pastures, Sand dunes etc.). CNFA is the area over which the sample data on TOF is aggregated for the assessment.
Dead wood	All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 5 cm in diameter. *(Source – 2006 IPCC Guidelines for National Greenhouse Gas inventories)*
Decomposition	It is the process by which dead organic material are broken down into simpler organic or inorganic substances such as carbon dioxide, water, simple sugars, and minerals.
Deforestation	The conversion of forest to other land use independently whether human-induced or not. It includes areas of forest converted to agriculture, pasture, water reservoirs, mining, and urban areas. *(Source – GFRA, 2020)*
Desertification	Land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. (Source - https://catalogue.unccd.int/1195_Desertification.pdf, 26.07.2024)
Ecological restoration	Ecological (Ecosystem) restoration means assisting in the recovery of ecosystems that have been degraded or destroyed, as well as conserving the ecosystems that are still intact. (source - www.decadeonrestoration.org - What is Ecosystem Restoration? | UN Decade on Restoration, 26.07.2024)
Edaphic factors	A condition of the soil, whether physical, biological or chemical, that influences the organisms and processes that occur in the soil.
Emission	The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time. (UNFCCC Article 1.4) *(Source - 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Glossary)*
Emission factor	A coefficient that quantifies the emissions or removals of a gas per unit activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions. *(Source - 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Glossary)*
Exotic species	Exotic species are organisms that have been introduced into an area outside their normal distribution.
Forest area	The area recorded as a forest in the Government records. It is also referred to as "Recorded Forest Area".
Forest Cover	All lands, more than or equal to one hectare in area, with a tree canopy of more than or equal to 10%, irrespective of ownership and legal status; and includes orchards, bamboo, and palm
Forest ecosystem	A forest ecosystem is a dynamic complex of plant, animal and micro-organism communities and their abiotic environment interacting as a functional unit, where trees are a key component of the system. Humans, with their cultural, economic and environmental needs, are an integral part of many forest ecosystems.

Forest health	From the Utilitarian standpoint, forest health is defined as the production of forest conditions which directly satisfy human needs. From an Ecosystem standpoint, it is defined by resilience, recurrence, perseverance, and biophysical processes which lead to sustainable ecological conditions *(Kolb et al., 1994) (detailed citation may be seen under chapter 8)*
Forest Inventory	Forest inventory is the systematic collection of data on the forestry resources within a given area. It allows assessment of the current status and lays the ground for analysis and planning, constituting the basis for sustainable forest management. *(Source - fao.org/sustainable-forest-management/toolbox/modules/forest-inventory/basic-knowledge/en/?type=111, 26.07.2024)*
Forest management	A system of practices for stewardship and use of forestland aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.
Forest phenology	The science that deals with time of appearance of characteristic periodic events, such as leaf shedding, etc., in the life cycle of organisms in nature; especially as those events are influenced by environmental factors. *(Source – Glossary of Technical Terms, FRI&C, Dehradun, 1983)*
Forest productivity	Forest productivity refers to the total biomass of the given forest area at a specific time, per unit area.
Forest resources	Forest resources encompass all the assets and elements derived from forests, including timber, non-timber products, biodiversity, clean water, recreational opportunities, and ecosystem services.
Forest stand	Forest stand is an aggregation of tree or other growth, possessing sufficient uniformity in composition, constitution, age arrangement or structure and to be distinguished from adjacent crops forming a silvicultural unit.
Geographic Information System	A computer based system for capturing, storing, manipulating, analysing and displaying data, which are spatially referenced to the earth.
Geospatial technologies	The geospatial technology is an emerging technique to study real earth geographic information using Geographical Information System (GIS), Remote Sensing (RS) and other ground information from various devices and instruments.
Girdling	The complete removal of a strip of bark (consisting of cork cambium or "phellogen", phloem, cambium and sometimes going into the xylem) from around the entire circumference of either a branch or trunk of a woody plant.
Global Forest Resource Assessment	It is led by Forestry Department of FAO of UN, for an assessment of status and trends of the global forest resources. It contains information on various thematic elements of sustainable forest management and conservation.
Green wash area	The extent of wooded areas generally shown in light green colour on the Survey of India topographic sheets.
Greenhouse effect	The greenhouse effect is the process through which heat is trapped near Earth's surface by substances known as 'greenhouse gases.' *(Source - https://science.nasa.gov/climate-change/faq - What is the greenhouse effect? - NASA Science, 26.07.2024)*
Greenhouse gas	Gases that has the property of absorbing infrared radiation (net heat energy) emitted from Earth's surface and reradiating it back to Earth's surface, thus contributing to the greenhouse effect. Greenhouse gases consist of carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and water vapour. Water vapour, which reacts to temperature changes, is referred to as a 'feedback', because it amplifies the effect of forces that initially caused the warming. *(Source - https://science.nasa.gov/climate-change/faq - What is the greenhouse effect? - NASA Science, 26.07.2024)*
Growing stock	The sum (by number or volume) of all the trees growing/living in the forest or a specified part of it.
Habitat	A physical portion of the environment that is inhabited by an organism or population of organisms. A habitat is characterized by a relative uniformity of the physical environment and fairly close interaction of all the biological species involved.
Herbs	Herb is a plant with no persistent stem (non-woody) above ground and usually not exceeding 1 meter in height.

Humus	The decomposed organic matter which remains associated with soil minerals is usually referred to as humus.
Illicit felling	Any felling of trees done in a state forest, without permission granted by authorized bodies.
Indicator species	An indicator species is a species or group of species chosen as an indicator of, or proxy for, the state of an ecosystem or of a certain process within that ecosystem.
Infiltration	Infiltration refers to the entry of water into the soil.
Invasive species	Species that are non-nature to a particular eco-system and whose introduction and spread causes, or is likely to cause socio-cultural, economic or environmental harm (including forest eco system) or harm to human health.
Land Use, Land-Use Change and Forestry (LULUCF)	Land use, land-use change, and forestry (LULUCF), also referred to as Forestry and other land use (FOLU) or Agriculture, Forestry and Other Land Use (AFOLU), is defined as a greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use such as settlements and commercial uses, land-use change, and forestry activities. *(Source: Glossary of Climate Change Acronyms and Terms, UNFCCC, 2006)*
Landscape	An area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values
Large forest fire alert	Alert generated when fire is detected in 3 Contiguous Pixels Connected in the Side or Corner, in any geometry
Linear (patch of trees)	Trees on a strip along the road, railway, and canal side having width between 10m to 20m (by and large) and length more than 150m
Litter	Woody material of trees having diameter <5cm and >2mm, which is not decomposed.
Lopping	The repeated removal of side branches on a short cycle, leaving just a tuft at the top of the tree.
Mangroves	Salt tolerant evergreen forest ecosystem found mainly in tropical and subtropical coastal and/or inter-tidal regions.
Microclimate	Local climate at or near the Earth's surface.
Minimum Mappable Unit (MMU)	The MMU is the size of the smallest feature of a class that can be reliably mapped (2mm x 2mm) which corresponds to 1 ha on 1:50,000 scale for LISS III.
Moderately Dense Forest	All lands with forest cover having a canopy density between > 40, and less than 70 percent.
NATCOM	National Communication to UNFCCC
Nationally Determined Contribution	NDC articulates commitments by each country to reduce its national emissions and adapt to the impacts of climate change. Countries across the globe adopted this international climate agreement at UNFCCC Conference of the Parties (COP21) in Paris in December 2015.
Natural forest	Natural forests are forests composed of indigenous trees, not planted by man. In other words forests excluding plantations.
Natural resources	Assets present in a particular area (below, surface or above) and available for potential use and utilization by its owners. These resources include renewable (reproducible) and non-renewable (non-reproducible, mined) resources, although many resources can be included in both, depending on region or specific conditions.
Niche	Niche is the role or job of a species in a habitat. The word niche comes from the French word nicher, which means "to nest." An ecological niche describes how a species interacts with, and lives in, its habitat.
Nutrient cycling	Biogeochemical cycle, in which inorganic nutrients move through the soil, living organisms, air and water. It refers to the return of nutrients absorbed by plants from the soil, back to the soil.

Open Forest	Lands with forest cover having a canopy density between ≥10 and <40 percent.
Physiographic Division	Physiographic divisions separate the Earth into different areas based on the predominant types of landforms found in each region. As example: Mountain, Plain, Plateau, Desert, Desert, Islands, etc. are different physiographic division.
Plantation	A stand composed primarily of trees established by planting or artificial seeding.
Protected Area	Protected area means a National Park, a Sanctuary, a Conservation Reserve or a Community Reserve notified under sections 18, 35, 36A and 36C of the Wildlife Protection Act.
Protected Forests	An area notified under the provisions of the Indian Forest Act or other State Forest Acts, having limited degree of protection. In protected forest, all activities are permitted unless prohibited.
Ramsar Convention	The Convention on Wetlands (Ramsar, Iran, 1971) is an intergovernmental treaty whose mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".
Recorded Forest Area	Area recorded as forest in Government records.
Regeneration	Process of replacing old crop with younger generation either naturally or artificially is called regeneration.
Remote Sensing	Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft) *(Source - https://www.usgs.gov/faqs - What is remote sensing and what is it used for? | U.S. Geological Survey, usgs.gov, 26.07.2024)*
Reserved Forest	An area so constituted under the provisions of the Indian Forest Act or other State Forest Acts, having full degree of protection. In Reserved forests all activities are prohibited unless permitted.
Rotation period	The planned number of years between the formation or regeneration of a crop and its final felling. In the case of Selection Forest, the average age at which a tree is considered mature for felling. (Source – Glossary of Technical Terms, FRI&C, 1983)
Scattered (trees)	Tress not included under Block, or Linear patches
Scrub	Forest lands having canopy density less than 10 percent, generally with Shrubs interspersed with trees.
Sedimentation	The entrained soil materials carried in water or air is known as sediment and the process of sediment deposition on the bottom layer is known as sedimentation.
Shrubs	A woody perennial plant differing from a perennial herb in its persistent and woody stem and less definite form a tree in its low structure and its habit of branching from the base and usually not exceeding 3 meter in height.
Silviculture	Silviculture is the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society such as wildlife habitat, timber, water resources, restoration, and recreation on a sustainable basis. *(Source – https://www.fs.usda.gov/forestmanagement/vegetation-managementSilviculture (usda.gov), 26.07.2024)*
Size class	It refers to average diameter class or girth class of the tree.
Soil erosion	The displacement of the soil by the action of water or wind. Soil erosion is a major process of land degradation.
Soil organic carbon	Carbon contained in soil organic matter.
Soil organic matter	It is the organic component of soil containing small plant residues, small living soil organism and decomposed organic matter.
Stratification	Stratification is the division of the area into more homogenous units. The purpose of stratification is to increase precision of estimates.

Succession	Sequential change in the relative abundances of the dominant species in a community (dominance based on biomass) over a long period.
Sustainability	A dynamic process that guarantees the persistence of natural and human systems in an equitable manner.
Sustainable Development Goals (SDGs)	It is known as global goals, and are adopted as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace as well as prosperity by 2030. All United Nations Member States adopted these goals in 2015.
Terrestrial ecosystem	Ecosystem present on the land including forest ecosystem.
Tree	A large woody perennial plant having a single well defined stem (bole or trunk) and more or less definite crown. It also includes bamboos, palms, fruit trees, etc., and excludes non-perennial non-woody species like banana and papaya, and tall shrubs or climbers.
Tree cover	Tree cover comprises all tree patches outside the forest area, which are less than one hectare in extent including all the scattered trees found in the rural and urban settings, and not captured under the forest cover assessment.
Tree Outside Forests (TOF)	It refers to all trees growing outside recorded forest areas irrespective of patch size.
Very Dense Forest	Lands with forest cover having a canopy density of 70 per cent and above.
Volume equations	Volume equation are the mathematical equation which provide estimates of individual tree volumes based on easily measureable characteristics of trees like tree diameter, height, or others.
WFS	The Web Feature Service (WFS) is an interface specified by the Open GIS Consortium (OGC) that allows for the exchange of geographic data across the Web. It defines the rules for requesting and retrieving geographic information using the Hyper Text Transmission Protocol (HTTP). WFS offers direct fine-grained access to geographic information at the feature and feature property level. Therefore, WFS describes discovery, query, or data transformation operations in the web platform.
WMS	A Web Map Service (WMS) defines an interface that allows a client to get maps of geospatial data and gain detailed information on specific features shown on the map, without the facility of editing. A “map” is defined here as a visual representation of geospatial data, not the geospatial data itself.

UNITS & DIMENSIONS

Sl. No.	Name of Unit	Symbol	Value
1	Metre	m	1 m = 100 cm
2	Micro Metre	µm	1 µm = 10^{-6} m
3	Square Kilometre	km^2	1 km^2 = 10^6 m^2
4	Tonnes	t	1 t = 1000 kg
5	Million Tonnes	Mt	1 Mt = 10^6 t
6	Giga Tonnes	Gt	1 Gt = 10^9 t = 1000 Million Tonne = 1 Billion Tonne
7	Hectare	ha	100 ha = 1 km^2; 1 ha = 0.01 km^2
8	Million Hectare	Mha	1 Mha = 10^6 ha
9	Million Cubic Metre	M m^3	1 M m^3 = 10^6 m^3
10	CO_2 Equivalent	CO_2 eq.	1 C eq. = 44/12 CO_2 eq. = 3.67 CO_2 eq.

CONTENTS

Photo: FSI Repository

Table of Contents

Table of Contents

Table of Contents

CONTRIBUTORS

List of Tables

List of Figures


Photo: Padmabhushan Rajguru, IFS

CHAPTER
01
Introduction

Photo: Padmabhushan Rajguru, IFS

Photo: Padmabhushan Rajguru, IFS

01

INTRODUCTION

Introduction 1.1

In the vast tapestry of India's diverse landscape, forests stand as sentinel guardians; nurturing life, preserving biodiversity, and safeguarding the delicate equilibrium of our ecosystems. Forests are much more than just clusters of trees. They are living, breathing entities, repositories of all life sustaining elements; be it air, water, soil, food, shelter, and much more. They are the cradle of diverse flora and fauna, where myriad species find sanctuary. From the dense canopies of the Western Ghats to the arid expanse of the Thar desert, from the mangroves of the Sundarbans to the alpine meadows of the Himalayas, India's forests embrace a rich diversity of ecosystems, each with its unique character and contribution to the nation's ecological wealth.

In order to manage our vast forest resources, it became imperative over time to assess, evaluate, and monitor these resources on an increasingly robust scientific footing at pan India level. The first and foremost requirement, therefore, was to undertake systematic aerial surveys of our forests, and prepare an inventory of the forest resources. This exercise started with a limited mandate of conducting a survey to assess availability of commercial wood to establish forest produce based industries. The 'Pre-Investment Survey of Forest Resources' (PISFR) was, thus, established in 1965 as an FAO/UNDP/GOI project. The scope of PISFR's activities was expanded and it was re-organized as the Forest Survey of India (FSI) in 1981. FSI has come a long way since then, and now offers various services, including forest resource assessment, forest cover mapping, forest inventory, e-green watch, decision support system, and forest fire monitoring.

India State of Forest Report 1.2

One of the major tasks assigned to FSI is to publish the biennial India State of Forests Report (ISFR). This report is the 18th report in this series. The ISFR stands as a testament to our nation's commitment towards the conservation and sustainable management of our invaluable forest resources. This report is not merely a compendium of statistics, but a chronicle of our collective efforts, an appraisal of challenges faced, and a blueprint for the future. It embodies the tireless work of foresters, conservationists, scientists, and communities who have dedicated themselves to the cause of forest conservation. It speaks of an evolving narrative of environmental stewardship, shaped by policies, scientific advancements, and the indefatigable spirit of those who believe in the sanctity of our forests.

Primary objective of the ISFR 2023 is to present an in-depth analysis of the current status of forests in India, providing critical insights into the health, extent, and distribution of forested areas. It definitely provides information on the results of our Forest Management practices. It aims to serve as a valuable resource for practicing foresters, policymakers, researchers, conservationists, and the public, fostering a holistic understanding of the challenges and opportunities surrounding forest management and biodiversity conservation.

The report draws upon a robust and multi-faceted methodology, integrating remote sensing technology, ground surveys, and advanced data analytics. This triangulation of methods ensures accuracy, reliability, and comprehensiveness in the assessment of forest cover, type, and quality across the Indian landscape.

India has made significant commitments to various global treaties and initiatives related to forests, climate change, sustainable development, biodiversity, mangroves, and landscape restoration. These commitments necessitate reporting of the state of country's forests on a periodic basis. Some of the relevant commitments include the following:

1. United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC is an international treaty aimed at addressing climate change and its impacts. India is a party to this convention, which requires member countries to report on their greenhouse gas emissions, as well as activities related to land use, land-use change, and forestry (LULUCF).

2. Kyoto Protocol

The Kyoto Protocol operationalizes the UNFCCC by committing industrialized countries and economies in transition to limit and reduce greenhouse gases (GHG) emissions in accordance with agreed individual targets.

3. Paris Agreement

Paris Agreement, under the UNFCCC, sets out ambitious goals to limit global warming well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit it to 1.5 degrees Celsius. It emphasizes the importance of forests in climate mitigation and adaptation strategies.

4. Sustainable Development Goals (SDG)

The 2030 Agenda for Sustainable Development, adopted by all United Nations members in 2015, created 17 world Sustainable Development Goals (SDGs). The SDG 15: "Life on Land", specifically targets the conservation, restoration, and sustainable use of terrestrial ecosystems, including forests. The SDG 14 "Life below Water" seeks to conserve and sustainably use the oceans, seas and marine resources for sustainable development. Targets 14.2.1, 14.5.2, 15.1.1, 15.1.2., 15.2.1, 15.2.3, 15.3.2, and 15.4.1 are directly relevant to Forest Statistics. Besides, SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 6 (Clean Water and Sanitation), and SDG 13 (Climate Action) are also relevant to the Forestry sector.

5. Convention on Biological Diversity (CBD)

The CBD aims to conserve biological diversity, ensure sustainable use of its components, and promote fair and equitable sharing of benefits arising from genetic resources. India, being a party to the CBD, is obligated to report on its efforts in conserving biodiversity, which includes forest ecosystems. The Aichi Biodiversity Targets have been established under the CBD to guide international efforts in biodiversity conservation. Aichi Target 5 specifically addresses the conservation of habitats, including forests.

6. New York Declaration on Forests (NYDF)

NYDF is a voluntary international declaration that aims to halve deforestation by 2020 and end it by 2030, while also restoring forests and enhancing sustainable management.

7. United Nations Convention to Combat Desertification (UNCCD)

Established in 1994, UNCCD is a legally binding convention that links development and environment to sustainable land management. The convention aims to combat desertification and the ill effects of drought.

8. Bonn Challenge

Bonn Challenge is a global effort to bring under restoration 150 million hectares of the world's deforested and degraded lands by 2020, and 350 million hectares by 2030. India has made commitment of bringing 26 million ha under this initiative to restore degraded landscapes. UN Decade on Ecosystem Restoration (2021-2030) calls for the scaling up of efforts to restore ecosystems and combat climate change, and India is a participant in this global initiative also.

9. Asia Pacific Forestry Commission (APFC)

India, as a member of APFC, is part of a regional body that aims to promote sustainable forest management in the Asia-Pacific region. Reporting on the state of forests is an integral part of this endeavour.

10. Ramsar Convention on Wetlands

India is a party to the Ramsar Convention, which recognizes the importance of wetlands, including mangroves, and commits to their conservation and sustainable use.

These commitments collectively highlight India's obligation to monitor, report, and take action on the state of its forests in the context of global efforts towards climate change mitigation, landscape restoration, biodiversity conservation, and sustainable development. These underscore India's role as a responsible stakeholder in the international community's efforts towards environmental conservation and sustainable development.

The India State of Forest Reports contribute towards all these goals, setting reporting benchmarks every two years.

1.3 Technology Advancements in Forest Resource Assessment

Over the years, several technological and methodological advances have significantly improved the forest cover mapping conducted by FSI. The advancements include use of better satellite data, higher scales of mapping, and improvement in methods of interpretation. Table 1.1 provides an overview of the technological and methodological improvements in forest cover mapping over the years.

Table 1.1 Forest Cover Mapping over the Years

Cycle of Assess-ment	Year	Data Period	Sensor	Spatial Resolution	Scale	Minimum Mappable Unit (ha)	Mode of Interpretation
I	1987	1981-83	LANDSAT- MSS	80 m	1:1 million	400	Visual
II	1989	1985-87	LANDSAT-TM	30 m	1:250,000	25	Visual
III	1991	1987-89	LANDSAT-TM	30 m	1:250,000	25	Visual
IV	1993	1989-91	LANDSAT-TM	30 m	1:250,000	25	Visual
V	1995	1991-93	IRS-1B LISSII	36.25 m	1:250,000	25	Visual
VI	1997	1993-95	IRS-1B LISSII	36.25 m	1:250,000	25	Visual & Digital
VII	1999	1996-98	IRS-1C/ 1D LISS III	23.5 m	1:250,000	25	Visual & Digital
VIII	2001	2000	IRS-1C/1D LISS III	23.5 m	1:50,000	1	Visual & Digital
IX	2003	2002	IRS-1D LISS III	23.5 m	1:50,000	1	Visual & Digital
X	2005	2004	IRS-1D LISS III	23.5 m	1:50,000	1	Visual & Digital
XI	2009	2006	IRS-P6-LISS III	23.5 m	1:50,000	1	Visual & Digital
XII	2011	2008-09	IRS-P6-LISS III	23.56 m	1:50,000	1	Visual & Digital
XIII	2013	2010-11	IRS-P6-LISS III & IRS-P6 AWiFS	23.5 m	1:50,000	1	Visual & Digital
XIV	2015	2013-14	IRS P6-LISS – III IRS-Resourcesat 2 – LISS III	23.5 m	1:50,000	1	Visual & Digital
XV	2017	2015-16	IRS P6-LISS – III IRS-Resourcesat 2 – LISS III	23.5 m	1:50,000	1	Visual & Digital
XVI	2019	2017-18	IRS P6 – LISS-III IRS-Resourcesat 2 – LISS III	23.5 m	1:50,000	1	Visual & Digital
XVII	2021	2019-20	IRS-Resourcesat 2 – LISS III	23.5 m	1:50,000	1	Visual & Digital
XVIII	2023	2021-22	IRS-Resourcesat 2 – LISS III	23.5 m	1:50,000	1	Visual & Digital

1.4 Land Use Pattern

Table 1.2 provides a brief information on the major land use patterns in the country, based on the data published by the Directorate of Economics and Statistics, Department of Agriculture and Farmer's Welfare, Ministry of Agriculture and Farmer's Welfare, Government of India (2022).

Table 1.2 Land Use Pattern of India

Land Use Type	Area (in '000 ha)	Percentage
Geographical Area	328747	
Reporting area for land utilization	306486	93.23
Forests	72000	21.9
Not available for land cultivation	44093	13.41
Permanent pastures and other grazing lands	10281	3.13
Land under miscellaneous tree crops and groves	3013	0.92
Culturable waste land	11920	3.63
Fallow land other than current fallows	10917	3.32
Current fallows	13255	4.03
Net sown area	141007	42.89

***Source:** Land Use Statistics – At a Glance | Official website of Directorate of Economics and Statistics, Department of Agriculture and Farmer's Welfare, Ministry of Agriculture and Farmer's Welfare, Government of India (desagri.gov.in)*

Relevant Important Terms Explained 1.5

1.5.1 Forest Cover

The report uses the term 'forest cover' extensively. 'Forest cover' refers to all lands, more than or equal to one hectare in area, with a tree canopy of more than or equal to 10%, irrespective of ownership and legal status; and includes orchards, bamboo, and palm. Thus, 'Forest cover' indicates presence of trees on any land, irrespective of ownership of land; and irrespective of the fact whether the land is notified as a forest land or not. It is not possible for FSI to distinguish a tree clad area on the basis of legal status of land using the remote sensing techniques. Hence, the 'forest cover' data, as captured and analysed using satellite imageries, is reported as such.

1.5.2 Recorded Forest Area

The 'recorded forest area' (RFA) (or forest area) refers to all the geographic area recorded as 'forest' in government records. The 'recorded forest area' largely consists of the 'Reserved Forests' (RF) and the 'Protected Forests' (PF), constituted under the provisions of the Indian Forest Act, 1927. Besides the RFs and PFs, the recorded forest area may also include all such areas which have been recorded as 'Unclassed Forests', 'Village Forests', or by any other nomenclature of such description, and all such areas which have been recorded as forest in the revenue records, or have been constituted so under any State Act or local law. A recorded forest area may, or may not, have tree cover. Besides being richly forested, recorded forest areas may have less than 10% canopy cover, pastures, desert lands, blanks, wetland, rivers, riverbeds, creeks, snow clad areas, etc. FSI obtains the information about the RFA from the respective State/ UT Governments, as they are the custodians of this information.

1.5.3 Tree Cover

For the purpose of this report, 'tree cover' refers to the area covered by trees outside recorded forest areas. These areas range from that covered by a single tree to patches of trees less than 1 ha, as areas more than 1 ha are already covered in the Forest cover. Such small patches may comprise of bock plantations, linear plantations, and scattered trees not delineated as forest cover during interpretation of satellite data.

While the information on the Forest Cover and Tree Cover is given under the next chapter, Table 1.3 provides information on the Recorded Forest Area (RFA) in different States/UTs.

Table 1.3 Recorded Forest Areas (RFAs) in States and UTs

Sl. No	State/ UTs	Notified Geographical Area (GA) (km²)	RFA (in different categories)			Total RFA (2023)	% of GA
			RF	PF	Unclassed Forests*		
1	Andhra Pradesh	1,62,923	31,959	5,069	230	37,258	22.87
2	Arunachal Pradesh	83,743	12,371	11,857	27,312	51,540	61.55
3	Assam	78,438	17,864	0	8,972	26,836	34.21
4	Bihar	94,163	693	6,183	566	7,442	7.90
5	Chhattisgarh	1,35,192	25,899	24,554	9,363	59,816	44.25
6	Delhi	1,483	85	13	6	104	7.01
7	Goa	3,702	119	755	397	1,271	34.33
8	Gujarat	1,96,244	14,574	2,898	4,398	21,870	11.14
9	Haryana	44,212	249	1,158	152	1,559	3.53
10	Himachal Pradesh	55,673	1,883	28,887	7,178	37,948	68.16
11	Jharkhand	79,716	4,500	18,922	1,696	25,118	31.51
12	Karnataka	1,91,791	28,690	3,931	5,663	38,284	19.96
13	Kerala	38,852	11,522	0	0	11,522	29.66
14	Madhya Pradesh	3,08,252	61,886	31,098	1,705	94,689	30.72
15	Maharashtra	3,07,713	50,865	6,433	4,654	61,952	20.13
16	Manipur	22,327	1,926	3,254	12,238	17,418	78.01
17	Meghalaya	22,429	1,125	12	8,371	9,508	42.39
18	Mizoram	21,081	4,499	1,823	1,157	7,479	35.48
19	Nagaland	16,579	234	9	8,389	8,632	52.07
20	Odisha	1,55,707	36,049	25,133	22	61,204	39.31
21	Punjab	50,362	44	1,137	1,903	3,084	6.12
22	Rajasthan	3,42,239	12,176	18,588	2,105	32,869	9.60
23	Sikkim	7,096	5,452	389	0	5,841	82.31
24	Tamil Nadu	1,30,060	20,523	1,053	1,612	23,188	17.83
25	Telangana	1,12,122	25,800	1,592	296	27,688	24.69
26	Tripura	10,486	3,588	2	2,705	6,295	60.03
27	Uttar Pradesh**	2,40,928	11,571	330	5,534	17,435	7.24
28	Uttarakhand	53,483	26,547	9,885	1,568	38,000	71.05
29	West Bengal	88,752	7,054	3,778	1,053	11,885	13.39
30	A & N Islands	8,249	5,613	1,558	0	7,171	86.93
31	Chandigarh	114	32	0	3	35	30.70
32	Dadra & Nagar Haveli and Daman & Diu	602	206	5	6	217	36.05
33	Jammu & Kashmir — Shapefile Area*** (54,633)	2,22,236	17,648	2,551	0	20,199	9.09
34	Ladakh — Shapefile Area*** (1,68,055)		7	0	0	7	-
35	Lakshadweep	30	0	0	0	0	-
36	Puducherry	490	0	2	11	13	2.65
	Total	**32,87,469**	**4,43,253**	**2,12,859**	**1,19,265**	**7,75,377**	**23.59**

Source: State / UTs Forest Departments

** Unclassed Forest includes all forest other than Reserve Forest and Protected Forest as reported by State / UTs Forest Departments.*

*** In case of Uttar Pradesh, the RFA excludes 9,662.76 km of linear plantations along Road, Railway line and Canal.*

**** Area of shape file provided by Survey of India (August 2021).*

National Forest Inventory (NFI) 1.6

Besides undertaking the forest cover mapping, FSI undertakes extensive inventory exercises to be included in the biennial ISFR. The NFI includes two major activities, viz., inventory inside forests (Forest Inventory), and Inventory of Trees outside Forests (TOF). The TOF is, in turn, sub-divided into Rural and Urban TOF inventory. Inventorisation of forest and tree resources is done primarily for precise estimation of the Growing Stock. In addition to growing stock, the NFI inputs are also used to estimate the Tree Cover, carbon pool, bamboo resources, Non-timber forest produce, regeneration status, invasive species, and several other parameters depicting the health of the forests.

1.6.1 Forest Inventory

The calculation of total wood volume, better known as the 'Growing Stock' in the forests, is a vital part of forest management practices. Since the inception of technical forestry practices in the country through formulation of Working Plans, the growing stock calculations have been undertaken at Forest Division levels. Remote sensing, using aerial photographs, was adopted by FSI from the very beginning, when PISFR was established. Due to changing information needs, the scope of PISFR's activities was expanded. Gradually, the sampling techniques were evolved, and satellite imageries were employed by FSI for increasingly more coverage and better estimations. National Forest Inventory was designed in the year 2002, and the first direct national level growing stock estimates for forests and trees outside forests were published in the ISFR 2003. The grid design for the NFI was modified and adopted in 2016. A major change in the plot design is splitting of the erstwhile 0.1 ha square plot into four circular subplots, to capture local variations, and for ease of laying sample plots. The design and methodology of the NFI is explained under chapter on 'Growing Stock'. Approximately 6000 sample plots are laid annually in forest areas

1.6.2 Trees Outside Forest (TOF) Inventory

The areas outside recorded forests were also included in the National Forest Inventory since 2002. Approximately 10000 sample plots are laid annually in areas outside forests, to capture data about the TOF. TOF inventory provides information on the 'Tree Cover', which includes patches of trees occurring outside RFA, less than 1 hectare, both in rural and urban areas. TOF inventory, besides producing data on biomass, carbon pool, etc., also provides estimates of annual potential production of industrial wood from outside the RFA.

1.7 The Global Scenario

Information regarding the global forest resources is compiled and collated by the FAO on a 5 year cycle, and published under the heading, 'Global Forest Resource Assessment' (GFRA). The last GFRA was published in the year 2020. Some of the relevant information; on the latest status and changes in Regional forest cover, and the latest status and changes in the country level forest cover of top 10 countries in the World is given under tables 1.4 to 1.7 below.

Table 1.4 Forest Area by Region and Sub-region, 2020

Region/Sub region	Forest area	
	1000 ha	Percentage of world forest area
Eastern and Southern Africa	295778	7
Northern Africa	35151	1
Western and Central Africa	305710	8
Total Africa	**636639**	**16**
East Asia	271403	7
South and Southeast Asia	296047	7
Western and central Asia	55237	1
Total Asia	**622687**	**15**
Europe excl. Russian Federation	202150	5
Total Europe	**1017461**	**25**
Caribbean	7889	0
Central America	22404	1
North America	722417	18
Total North America and Central America	**752710**	**19**
Total Oceania	**185248**	**5**
Total South America	**844186**	**21**
World	**4058931**	**100**

Source: *Global Forest resource assessment, 2020, FAO*

Table 1.5 Top Ten Countries for Forest Area, 2020

Ranking	Country	Forest area		
		1000 ha	Percentage of world forest area	Cumulative percentage
1	Russian federation	815312	20	20
2	Brazil	496620	12	32
3	Canada	346928	9	41
4	United State of America	309795	8	49
5	China	219978	5	54
6	Australia	134005	3	57
7	Democratic republic of the Congo	126155	3	60
8	Indonesia	92133	2	63

Table 1.5 Top Ten Countries for Forest Area, 2020

Ranking	Country	Forest area		
		1000 ha	Percentage of world forest area	Cumulative percentage
9	Peru	72330	2	64
10	India	72160	2	66

Source: *Global Forest resource assessment, 2020, FAO*

Table 1.6 Annual Average Net Change in Forest Area, By Region and Sub Region, 1990-2020

Region/Sub region	Forest area annual change					
	1990-2000		2000-2010		2010-2020	
	1000 ha / yr	percentage	1000 ha / yr	percentage	1000 ha / yr	percentage
Eastern and Southern Africa	-1345	-0.40	-1773	-0.55	-1907	-062
Northern Africa	-182	-0.47	-127	-0.34	-168	-0.47
Western and Central Africa	-1748	-0.50	-1503	-0.45	-1862	-0.59
Total Africa	**-3275**	**-0.45**	**-3403**	**-0.49**	**-3938**	**-0.60**
East Asia	1917	0.88	2332	0.97	1901	1.73
South and Southeast Asia	-1843	-0.58	-262	-0.09	-941	-0.31
Western and Central Asia	129	0.26	285	0.55	213	0.39
Total Asia	**202**	**0.03**	**2355**	**0.39**	**1173**	**0.19**
Europe excl. Russian Federation	763	0.40	585	0.30	330	0.16
Total Europe	**795**	**0.08**	**1171**	**0.12**	**348**	**0.03**
Caribbean	85	1.34	69	0.97	39	0.51
Central America	-218	-0.81	-211	-0.85	-130	-0.56
North America	-160	-0.02	327	0.05	-57	-0.01
Total North America and Central America	**-293**	**-0.04**	**184**	**0.02**	**-148**	**-0.02**
Total Oceania	**-165**	**-0.09**	**-231**	**-0.13**	**423**	**0.23**
Total South America	**-5102**	**-0.54**	**-5249**	**-0.58**	**-2597**	**-0.30**
World	**-7838**	**-0.19**	**-5173**	**-0.13**	**-4739**	**-0.12**

Source: *Global Forest resource assessment, 2020, FAO*

Table 1.7 Top Ten Countries for Average Annual Net Gain in Forest Area

Ranking	Country	Forest area	
		1000 ha / yr	Percentage
1	China	1937	0.93
2	Australia	446	0.34
3	India	266	0.38
4	Chile	149	0.85
5	Vietnam	126	0.90
6	Turkey	114	0.53
7	United States of America	108	0.03
8	France	83	0.50
9	Italy	54	0.58
10	Romania	41	0.62

Source: *Global Forest resource assessment, 2020, FAO*

Note: *the rate of change (%) is calculated as the compound annual change rate.*

As may be seen, India figures in the list of top 10 countries in terms of forest area. India also figures at 3rd rank in the list of top 10 countries with positive net change in forest area.

1.8 Contribution of FSI towards Monitoring of Environment and Climate Change

India is on the path of rapid all round development, and the pressure on our natural resources is extremely high. Therefore, it becomes essential to keep an eye on the changes taking place in the forests of the country not only from the point of view of forest resources, but also the interaction of forest ecosystems *vis-à-vis* the environment. Periodic and systematic collection of data, thus gains utmost importance. In the recently concluded COP 28, held at Dubai from 30th November to 13th December, 2023, the Subsidiary Body for Scientific and Technological Advice (SBSTA) also recognised the need to address the data gaps including in coastal regions, tropical forests, desert and mountain regions (COP 28, 2023)[1].

FSI has been using its primary mandate of enumerating the Forest and tree cover, and the inventory, to assess Carbon stock; and also reporting the same to relevant international organisations. Monitoring of forest and tree cover of the country by FSI reveals that the growing stock is continually showing a net rising trend despite immense pressure on our forests.

Afforestation through tree plantations and forest landscape restoration are the cheapest, most effective, and long lasting ways of carbon sequestration and purification of atmosphere. The plethora of data provided by FSI can be used as the key information for formulation of strategies for climate change mitigation actions. FSI has further geared up to capture information and trends in climate change vis-à-vis forests

[1]COP 28 (2023). Summary of the 2023 Dubai Climate Change Conference: 30 November – 13 December 2023. *Earth Negotiations Bulletin.* **Vol. 12** (842): 1-30.

by proposing a 'Climate Change Cell', and studying the impacts of climate change on biodiversity. FSI is in the process of narrowing down to establishment of baseline at pan India level with respect to indicator species, including the orchids, lichens, etc. Sensitive ecosystems as the Mangroves, and the timberline ecotones have also been included under the climate change studies.

What You Find in this Report 1.9

Following is a brief description of what to expect in the different chapters forming part of this report.

Chapter 2 – Forest and Tree Cover

The ISFRs are particularly awaited by all the stakeholders to have an authentic update on the status of the forest and tree cover in the country. Traditionally, the ISFRs have been reporting on the status of forest cover for the last 17 cycles; and the status of the tree cover, separately, for the last 11 cycles. This report has combined the two with the sole purpose of aligning the data to the National Forest Policy – which talks about the 'Forest or Tree cover'; and to emphasise that the ecological functions of green cover are fulfilled at all places, irrespective of the legal status of the land.

Besides providing the data for the country as a whole, State-wise information, and specific information on Hill Districts, Western Ghats, and North-Eastern States, is also available in the tables included in this chapter.

Chapter 3 – Mangroves

Mangroves are unique coastal ecosystems for variety of reasons, including their unique biology, adaptability, specific niche, their role in protection of coastlines, and their role in carbon sequestration; hence discussed separately in successive ISFRs. Besides providing the State-wise status of Mangrove cover, the chapter also includes the initiatives taken by the Government of India, and some of the States in restoration and enhancement of Mangrove cover.

Chapter 4 - Forest Fire

Forest fires are one of the national disasters in India requiring holistic approach to mitigate and control. FSI contributes in a big way in this direction, by undertaking regular assessment, and issuing alerts to the State Forest Departments, as given below:

- Assessment of fire prone forest areas

- WFS/WMS services
- Pre-Fire Alerts
- Near Real Time Forest Fire Alerts
- Large Forest Fire Alerts

The chapter on forest fires highlights the collective efforts of FSI and the State Forest Departments in effectively tackling the menace of forest fires, and provides an analysis of the results of these efforts.

Chapter 5 – Growing Stock

The data on growing stock in forests, as well as in trees growing outside forests is of utmost importance for not only the foresters, but also for the planners. While this data directly helps the practicing foresters in managing their forests, it is of use to other stakeholders also – particularly for supporting and promoting the Wood Based and bamboo based Industries. Hence, this chapter forms an important part of the ISFRs, and provides readily usable data on the availability of industrial wood across various stratifications, and bamboo bearing areas.

Chapter 6 – Carbon Stock

FSI started estimation of the carbon stock in forests and from trees outside forests for meeting the reporting requirement of the GHG inventory to the United Nations Framework Convention on Climate Change (UNFCCC). FSI contributes in reporting the GHG inventory to UNFCCC periodically through National Communication (NATCOM) and Biennial Update Report (BUR). Periodic forest carbon assessment done by FSI also helps in monitoring flow of carbon in different pools, and serves as an important indicator of ecosystem services from forests. The chapter provides an update on this front.

Chapter 7 – Agroforestry

The reporting of growing stock from Agroforestry plays a crucial role in sustainable forest management. It matters a lot in estimating, and planning for, the production potential (mainly of timber) of areas outside forests to meet the demand of people in general, and the wood based industries in particular. Sustaining an adequate supply of timber and other tree based resources from outside forests helps a great deal in easing the pressures on the forests. This chapter provides an update on our tree resources forming part of agroforestry practices.

Chapter 8 – Important Characteristics

As a part of the exercise of recording data for the National Forest Inventory, FSI collects information on various other parameters such as forest enabling conditions (soil depth, humus, soil organic carbon, soil erosion, status of ground flora); characteristics of forest vegetation (origin of forest stand, intensity of regeneration, size class, crop composition, canopy layer, basal area); threats to the forests (forest fire, injuries to crop, grazing incidence, biotic influence, invasive species, illicit felling, girdling, lopping), etc. All these characteristics interact amongst each other, and result into the given state of a forest at a given time. Periodic monitoring of such characteristics is vital to maintain the forest health. Last time, a status report on these aspects was included in ISFR 2013, and 2015. This report provides an update after that, and compares it with the national information of 2013.

Chapter 9 – Decadal Changes

This chapter provides interesting and much awaited consolidated updates on the changes that have taken place in our forest ecosystems in a span of the last decade.

Chapter 10 – State-wise details (Volume II)

The last chapter, Chapter 10 provides data pertaining to individual States and UTs. This data is given district wise and Forest Division wise.

What is new 1.10

This report features the following for the first time:

1. Since the National Forest Policy sets a vision of having a minimum of one third of the total land area of the country under ‘forest or tree cover’, it has been decided to report the figures on forest cover and tree cover, individually and jointly, to emphasise on the ecological significance of tree cover.
2. The forest cover data has been compiled for 751 districts. In earlier ISFRs the data was for 636 districts.
3. Forest Division wise forest cover data has been given for the first time, for the 16 States who have provided non-overlapping Division boundaries to FSI, to help the Divisional Forest Officers and Working Plan officers in managing the forests.
4. Earlier ISFRs used to have separate reporting on the ecological sensitive locations, viz., the North-eastern States, and Hill districts. Considering the unique ecological significance of the Western Ghats, this report includes separate information on forest cover in Western Ghats also.

5. Tree cover for 5 to 10 cm dbh trees has been estimated and given for the first time, as some of the species constituting the tree cover are harvested before reaching 10 cm dbh, but also have ecological significance.

6. Bamboo cover has also been estimated and included in the tree cover, as now sufficient data is available with FSI.

7. Growing Stock according to Forest Type Groups has been given for the first time.

8. A separate chapter has been given on Agroforestry after a decade.

9. A separate chapter on important characteristics of Indian forests has been included after a decade.

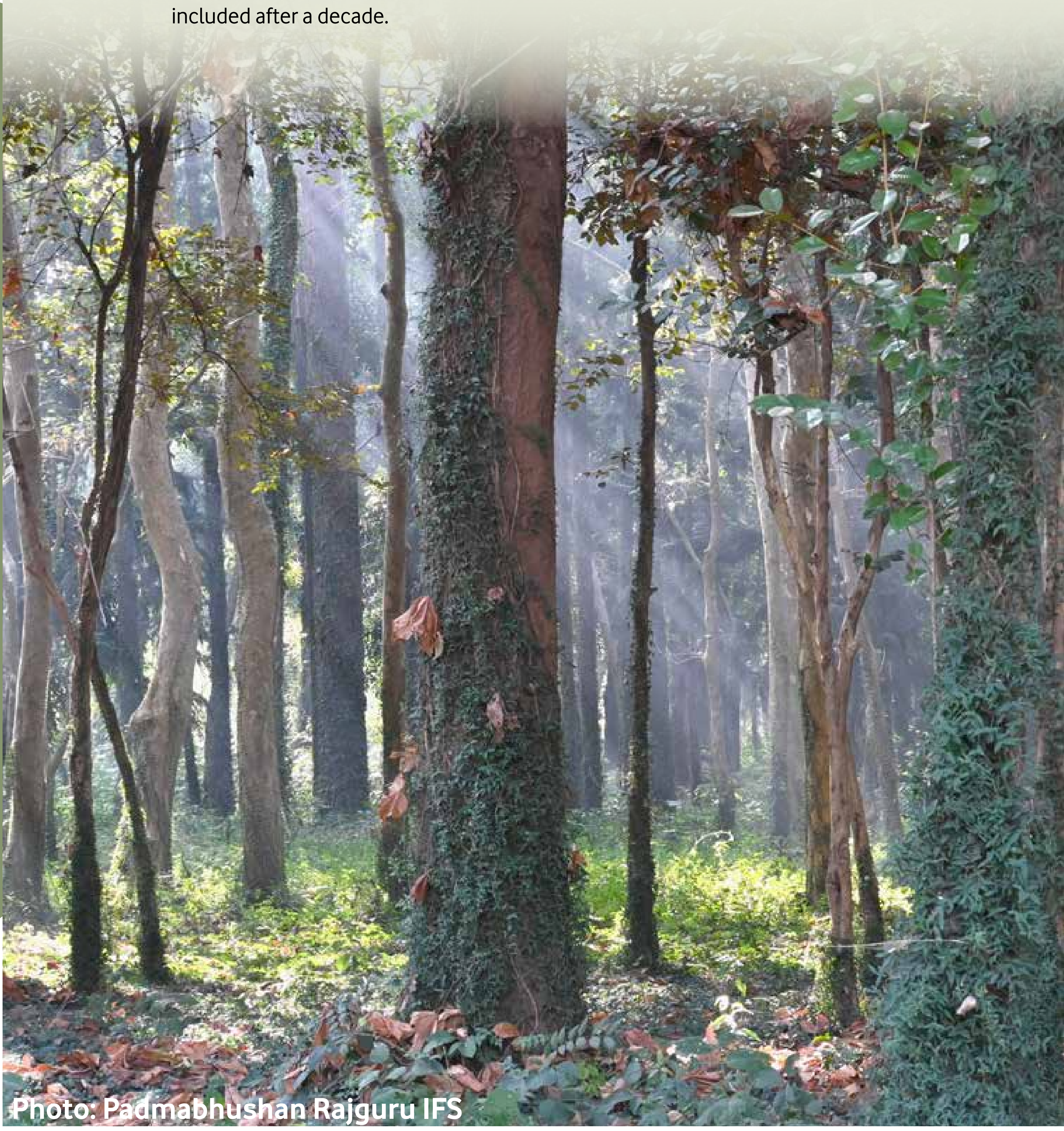


Photo: Padmabhushan Rajguru IFS


CHAPTER
02
Forest and
Tree Cover
Photo: Subharanjan Sen, IFS


Photo: FSI Repository

02

FOREST AND TREE COVER

Introduction 2.1

The National Forest Policy (1988) sets a vision of having a minimum of one third of the total land area of the country under forest or tree cover. The policy further envisions that in the hills and in mountainous regions, the aim should be to maintain two-third of the area under such cover in order to prevent erosion.

Forest Cover is defined as follows: “All areas having tree cover with canopy density more than or equal to 10% and above and area more than or equal to one ha”. It may be located within recorded forests, or on other government, private, or institutional lands.

Tree Cover is defined as follows: “Tree Cover implies patches of trees as well as isolated trees outside the RFA on areas less than one ha”.

Since 1987, Forest Survey of India (FSI) has been conducting biennial assessments of India’s Forest Cover through remotely sensed data. The tree cover is being assessed by FSI since the year 2001. The outcomes of these assessments are meticulously recorded in the India State of Forest Reports (ISFRs) released biennially. As of now, seventeen cycles of Forest Cover Mapping (FCM) have been executed with proficiency, and the current ISFR marks the 18th edition within this ongoing series. For Tree cover, this is the 11th assessment.

These periodic assessments of forest cover and tree cover offer a comprehensive view of the state of India’s forests and trees outside the forests; and, their overarching trends over the years. This report serves as a crucial and widely recognized source of information for forestry experts across various domains, including the Central Government, State Governments, State Forest Departments (SFDs), academic institutions, international organizations, media, and other stakeholders. It plays a pivotal role in the comprehensive evaluation and development of various forest-related policies, the formulation of working plans for State Forest Departments, the implementation of diverse programs, and formulation of legislations and regulations in the country.

Objectives of Forest and Tree Cover Mapping 2.2

2.2.1 Objectives of the Nationwide Forest Cover Mapping initiative

- **Assessment of Forest Resources:** To systematically evaluate and quantify the extent and distribution of forests across the entire nation.

- **Monitoring Changes:** To track changes in forest cover over time, identifying areas of deforestation, afforestation, or degradation, and understanding the reasons behind these changes.

- **Categorizing Forest Density:** To classify Forest Cover into distinct density classes and closely monitor alterations within each of these designated classes.

- **Analysing Forest Cover Variation:** To examine Forest Cover data with respect to criteria such as whether it falls within or outside Recorded Forest Areas (RFAs), the distribution of Forest Cover in relation to altitude zones and slopes, the extent of Forest Cover in regions characterized by hills and tribal populations, with special attention to the north-eastern States.

- **Supporting Policy Development:** To provide essential data and information for the development and modification of national, state and district level forest policies, strategies, and action plans.

- **Resource Planning:** To aid in the effective management and sustainable utilization of forest resources by assisting in the development of forest Working Plans and Management Plans. It also helps to identify potential areas suitable for afforestation activities using the Forest Cover map as a foundational layer.

- **Biodiversity Conservation:** To contribute to the conservation of biodiversity and the protection of critical habitats by assessing the status of forests.

- **Climate Change Mitigation:** To help in the understanding of forests' role in mitigating climate change by sequestering carbon.

- **Informed Decision-Making:** To provide decision-makers with up-to-date information for making informed choices regarding forest conservation and development.

- **International Reporting:** To fulfil international obligations and commitments related to forest cover and conservation, including reporting to international conventions and agreements.

- **Public Awareness:** To raise public awareness about the status of forests and their conservation.

- **Scientific Research:** To provide valuable support for scientific research focused on forests.

2.2.2 Objectives of the Nationwide Tree Cover Assessment

Estimation of small patches of trees or single tree is not feasible with medium resolution remote sensing data. However, their canopies also contribute to the tree cover in the country. Hence in order to compare the national goal of 33 % land area under forest or tree cover, separate estimates of tree cover is required.

Besides this, Carbon Stock Estimation in tree cover is required, especially to monitor the NDC targets and calculation of emission factors for all the land categories of LULUCF sector other than forestland.

Tree Cover also has uses in Urban-Forestry; such as in mitigating the adverse effects of climate change in urban areas.

These objectives collectively aim to enhance the understanding, management, and conservation of forests and trees in India, promoting their sustainable use and contributing to environmental as well as socio-economic well-being.

Satellite Data and Period for Forest Cover Mapping 2.3

In the current cycle, Forest Cover Mapping has been carried out using medium-resolution indigenous satellite data, with a spatial resolution of 23.5 m sourced from the Indian Space Research Organization's (ISRO) indigenous LISS-III sensor, part of the IRS Resourcesat satellite series, at a scale of 1: 50,000.

The details of the satellite data used in the current 18th cycle of Forest Cover Mapping are given in Table 2.1.

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

Resourcesat-2 Satellite, LISS-III Sensor	Specifications
Spatial 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 km^2 approx.

As mentioned above, the LISS-III satellite data utilized in the 18th cycle of Forest Cover Mapping (FCM) was procured from the National Remote Sensing Center (NRSC) in

Hyderabad. This satellite data was acquired for all states within the timeframe of October 2021 to December 2021. This specific time window was chosen because it typically offers cloud-free satellite data and full vegetation foliage, resulting in enhanced reflectance and precise satellite image interpretation.

In certain regions of the country, such as the North Eastern region, the coastal belt, and the Andaman and Nicobar Islands, additional satellite images were procured for the period from January 2022 to April 2022, to obtain better-quality satellite imagery.

In total, the Forest Cover Mapping exercise made use of 306 IRS Resourcesat 2 LISS-III Images, covering the entire geographical expanse of the country, to achieve comprehensive and accurate forest cover assessments.

The selection of medium spatial resolution LISS-III data at a 1:50,000 scale is influenced by several key factors. These factors include the vast geographical expanse of the country, the two-year time gap between consecutive mapping cycles, and the need for specific reporting of forest cover tailored to the country's requirements.

2.4 Forest Cover

The ISFR serves as a scientific document that offers updated assessments of the nation's forest resources and provides a comprehensive overview of India's forest and tree resources, employing a robust and established methodology.

Definition of Forest as per Kyoto Protocol, 1997

According to Decision 19/CP.9 of the Kyoto Protocol, the definition of a forest can vary from one country to another, depending on the country's capacities and capabilities. The structural definition of a forest is based on the following criteria:

Crown Cover Percentage: Minimum tree crown cover falling within the range of 10% to 30%. India adopted a 10% threshold.

Minimum Area of Stand: Forested areas should have a minimum area between 0.05 and 1 ha. India adopted 1 ha minimum.

Minimum Height of Trees: Trees in these areas should have the potential to reach a minimum height of 2 to 5m at maturity in their natural habitat.

Starting in 2001, the complete switch-over to digital interpretation methods enabled FSI to accurately delineate and document all forested areas, even down to a size as small as 1 ha. The Minimum Mapping Unit (MMU) serves as the cartographic threshold for the mapping scale, and it corresponds to a polygon that is discernible at 2 mm x 2 mm on a hard copy map on scale 1:50,000. This has greatly improved the precision and detail of forest data collection and analysis.

In the ISFR, there is no distinction made based on the origin of tree crops (whether natural or manmade) or the specific tree species present. It encompasses all types of lands without regard to their ownership, land use, or legal status. Therefore, the term "Forest Cover" in the ISFR, besides capturing natural forests, encompasses a wide range of tree species, including Bamboo, fruit orchards, Coconut, Oil-Palm, Subabul, Eucalyptus, Poplar, Acacia, Casuarina, Areca Nut, Rubber plantations, and shade-trees in Tea and Coffee plantations. It also includes areas that may be classified as forest, private land, community land, government-owned land, or institutional land; as long as they meet the criteria mentioned above.

The classification of forest cover based on tree canopy density is given under Table 2.2 below:

Table 2.2 Classification of Forest Cover

Class	Description
Very Dense Forest (VDF)	Canopy density ≥ 70 %
Moderately Dense Forest (MDF)	40 % ≤ Canopy density < 70 %
Open Forest (OF)	10 % ≤ Canopy density < 40 %
Scrub	Canopy density < 10 %, generally with shrubs interspersed with trees
Non Forest	Lands that do not fall into any of the above classes. It includes areas such as cropland, settlements, water bodies, grasslands, snow-clad areas, deserts, etc.

Very Dense Forest

Moderately Dense Forest

Open Forest

Scrub

Figure 2.1 Examples of Different Forest Cover Classes and Scrub

2.5 Forest Cover Assessment: Approach

The Forest Cover is assessed using an approach involving satellite digital image processing; visual image analysis; ground verification by the analysts and State Forest Departments; incorporation of post-field corrections; quality checks including ground validation by officers; 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 employed in Forest Cover mapping involves a combination of algorithms to create clusters of pixels that are correlated with each other. Subsequently, Forest Cover density classes are assigned to each of these clusters based on their characteristics and attributes. This approach leverages both automated algorithms and human expertise to achieve a more accurate and detailed classification of forested areas.

The analysis is enriched by combining the expertise of the interpreter with information from additional sources such as topographical maps (toposheets) and high-resolution images from sources like Google Earth. Furthermore, the methodology benefits from observations made during an extensive ground validation process, which involves a total of 8,494 data collection points spread over the forests in the country. This approach ensures the reliability and accuracy of the Forest Cover Mapping.

Over the years, this methodology has continuously evolved and improved to keep pace with advancing technology and the latest image interpretation techniques. Since the initial forest assessment report in 1987, the methodology for Forest Cover Mapping has been consistently refined and updated.

The process of Forest Cover Mapping involves the acquisition of ortho-rectified LISS III data from the National Remote Sensing Center (NRSC) in Hyderabad, covering the entire country. This data undergoes radiometric correction, which aims to reduce distortions in radiometric values that can occur during satellite data acquisition.

To ensure consistency, uniformity, and a high level of accuracy in the Forest Cover Mapping exercise, all steps of the methodology have been standardized. To minimize subjectivity, a comprehensive manual has been developed to guide and facilitate these processes, helping to maintain the quality and reliability of the mapping results.

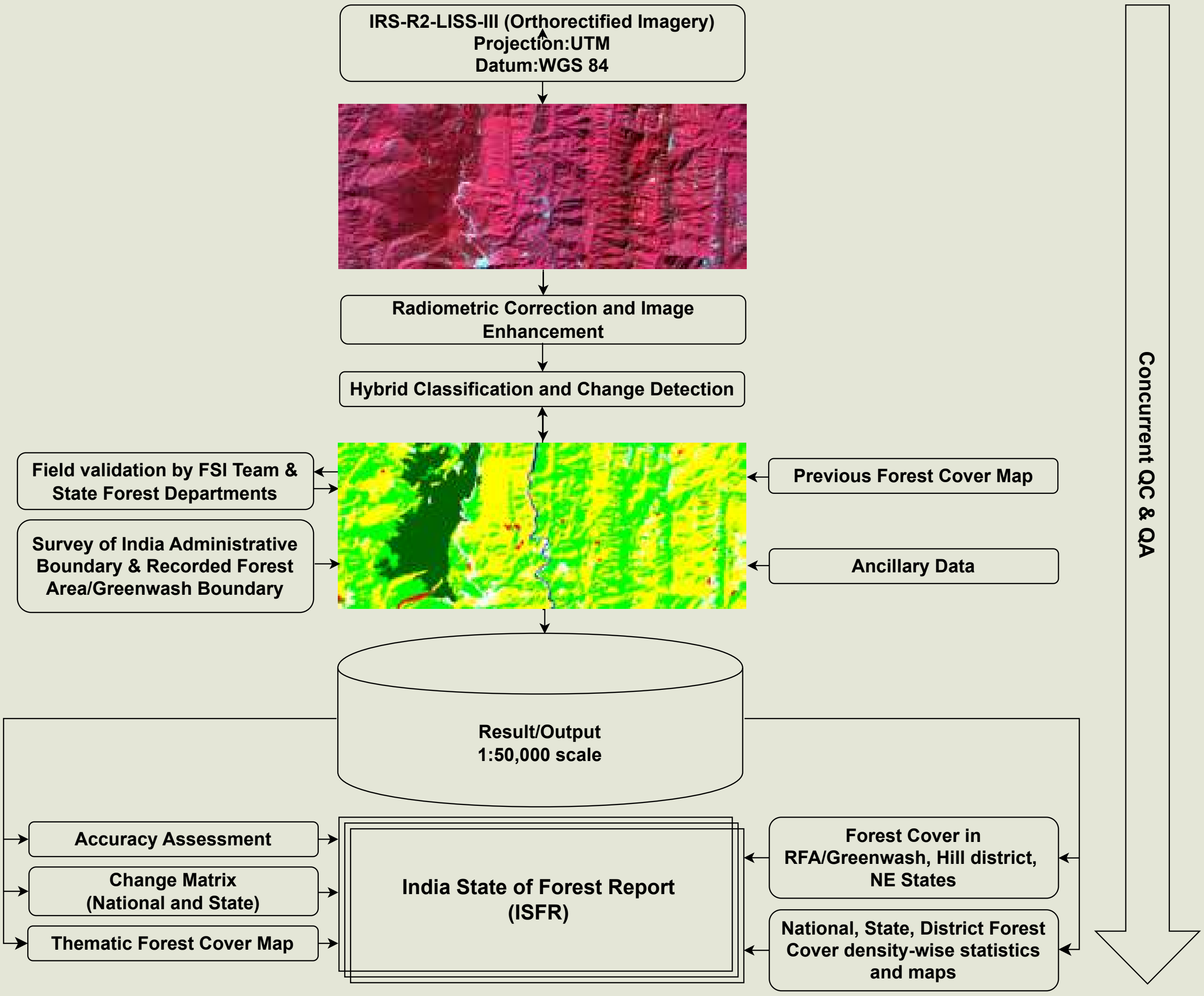


Figure 2.2 Schematic Diagram of the Broad Approach followed in Forest Cover Mapping (FCM)

2.6 Forest Cover Mapping Methodology

FCM layer of the previous, i.e., 17th cycle was compared with the current ortho-rectified satellite data using digital image processing tools. This is achieved through registration of the previous cycle imagery over the current cycle imagery, ensuring better image-to-image overlap. This is followed by image interpretation, which involves the following steps:

- **Normalised Difference Vegetation Index (NDVI) Transformation:** Current satellite data, after Top of Atmospheric correction (ToA correction), undergoes NDVI transformation for segregation of non-vegetated and vegetated areas.

- **Unsupervised Classification:** The parts of the image containing vegetation, which are obtained as a result of the previous step, are classified using the ISODATA algorithm. This classification process categorizes the vegetation into different classes, including VDF, MDF, OF, Scrub, and other categories that are considered as Non-Forest.

- **Maximum Likelihood Estimator (MLE):** For supervised classification, a signature set is preserved for each scene, and this set is subsequently employed in conducting Maximum Likelihood Estimator (MLE) on a masked NDVI image. This approach is chosen because MLE is well-suited for classifying input samples or clusters with a Normal distribution. Additionally, a clump elimination process is applied to this layer to ensure the retention of patches larger than 1 ha.

- **On-screen Visual Analysis:** NDVI-based Forest Cover layers are meticulously compared on-screen, alongside their corresponding satellite images, focusing on patches to identify areas of change. Water bodies are interpreted separately from the forest cover. In situations where challenges like cloud cover, shadows, haze, or the blending of non-woody vegetation with forested areas are encountered, supplementary data from collateral sources are employed to accurately distinguish and delineate the change polygons, as illustrated in Figure 2.3. The resulting change layer is stored and preserved in both raster and vector formats for subsequent analysis and utilization.

- **Final Classified Layer:** The change layer so generated is overlaid onto the classified layer from the previous cycle to create the classified layer for the current cycle. Forest Cover area statistics are then calculated on a district-wise basis for each State/Union Territory and aggregated to determine the overall Forest Cover for the entire country.

The area figures for forest cover, as published for this assessment cycle, are raster based estimates without any normalization factor. In order to make the comparison compatible between 2021 and 2023, the forest cover for 2021 was again estimated using raster without any normalization factor.

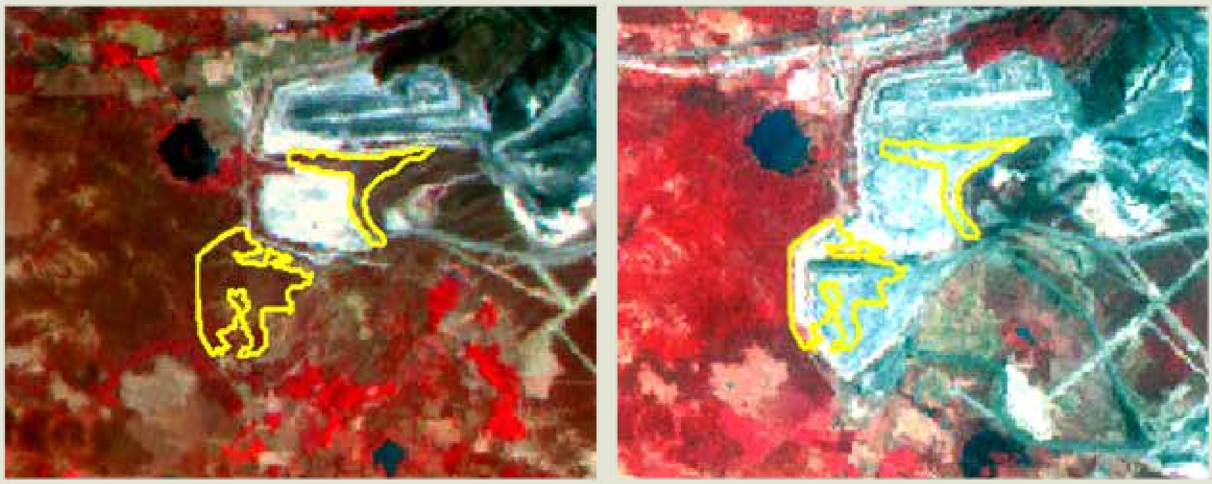


Figure 2.3 Illustration of Change Polygons

2.6.1 Use of Supplementary Data to Aid Interpretation

Interpreting areas with thick cloud cover, rugged terrain with deep hill shadows, areas where bushy and agricultural vegetation are merging with forests, waterlogged regions, ageing forests during the data period, and areas with dense haze can be quite challenging. In such scenarios, supplementary data from external sources like Google Earth, Sentinel-2 data, Landsat 8 data, and the National Forest Inventory (NFI) data of FSI play a crucial role. These provide interpreters with additional information to enhance their analysis.

2.6.2 Field Verification

Field verification or Ground truthing is essential for validating and refining the interpretations which were derived using remote sensing data, ultimately improving the accuracy of forest assessments and mapping. It helps ensure that remote sensing information aligns with the actual conditions on the ground.

2.6.2.1 Pre-Field Exercise

The process involves comparing current satellite imagery with previous imagery to identify changes in forest cover. Change polygons are delineated and assigned specific codes to categorize the nature of these changes. Change maps are created to visualize and communicate the changes, aiding field verification teams. Ground-truth data is collected in the field, and the observed changes are coded according to the classification. Finally, this ground-truth data is uploaded to a dedicated server, facilitating integration with remote sensing data.

2.6.2.2 Field Verification of Forest Cover Mapping

Once change polygons are selected, field verification teams visit these locations on the ground. During field verification, the survey teams collect data about the forest cover change, forest condition, and other relevant observations. This data is used to verify and refine the interpretation of remote sensing data. The ground-truth data also help to validate the accuracy of remote sensing models and algorithms used in forest cover assessment.

The ground-truth data collected during field verification is integrated with the remote sensing data. This integration helps to improve the accuracy of forest cover assessments and mapping by either confirming or correcting the interpretation of remote sensing imagery.

2.6.2.3 Ground Truthing in Current FCM Cycle

In the current Forest Cover Mapping cycle, analysts from FSI and officials of State Forest Departments visited a substantial number of ground truth points, totalling 8,494, which were evenly distributed across the country. This is a significant increase compared to the 3,414 change points visited in the previous cycle. While the analysts from FSI ground-truthed 4,780 points, the officials of State Forest Departments verified 3,714 points. The State Forest Departments received training on the Ground Truthing App of Forest Cover Mapping. The data collected during these visits was incorporated by the analysts.

By using this Android-based mobile application, FSI streamlined the process of collecting and managing ground-truth data, improving the accuracy and efficiency of their forest cover assessments (Figure 2.4). The ability to geo-tag photographs and store data offline was particularly valuable for fieldwork in remote or disconnected areas. The centralized server ensured data security and facilitated data integration for a more comprehensive understanding of forest changes.

Photo: FSI Repository

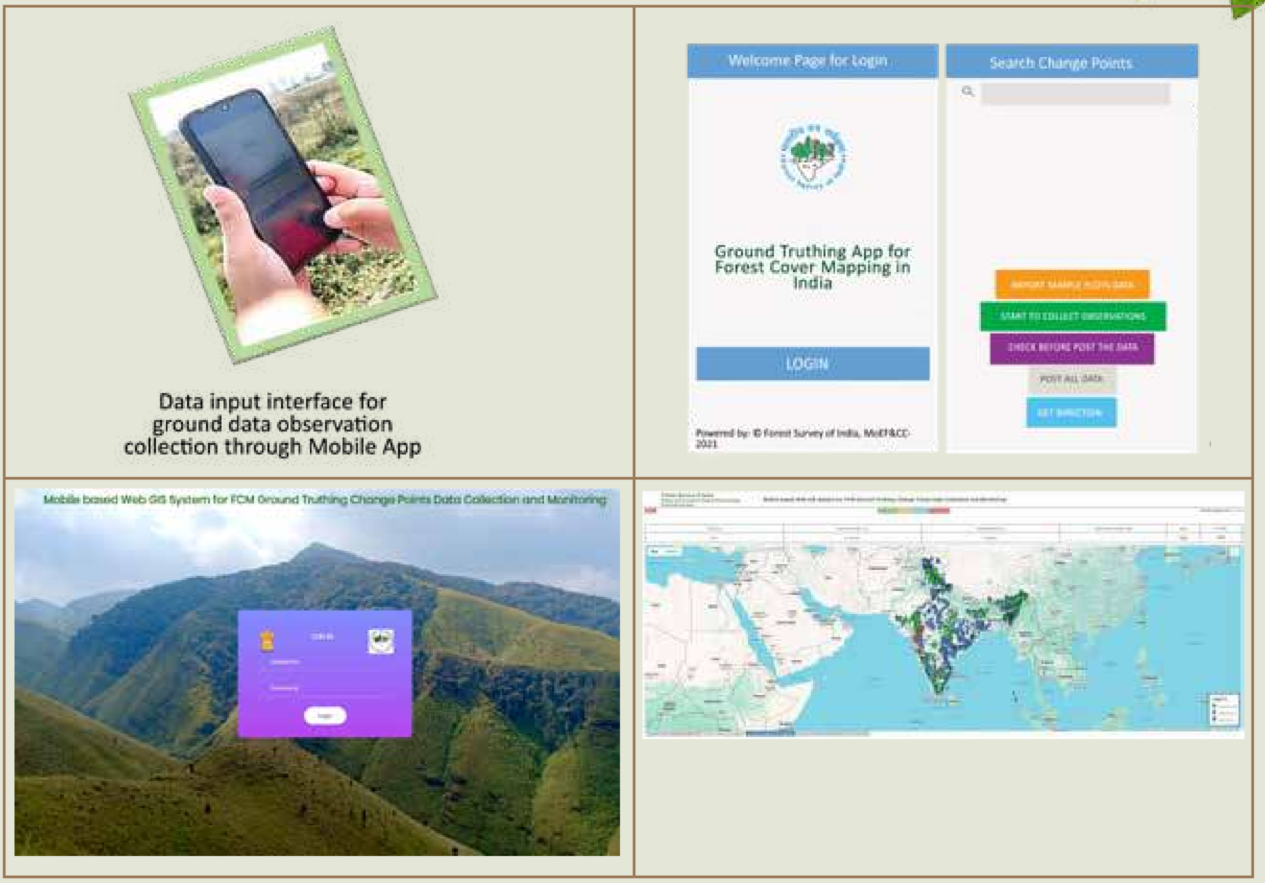


Figure 2.4 Field Data Collection Application for Ground Truth

To enhance the precision of crown density estimation in the field, densiometers were used. This extensive ground validation process has significantly strengthened the accuracy and reliability of the forest cover assessment in the current cycle.

Figure 2.5 displays the locations of the ground truth points, providing a visual representation of the widespread coverage achieved during this validation effort.

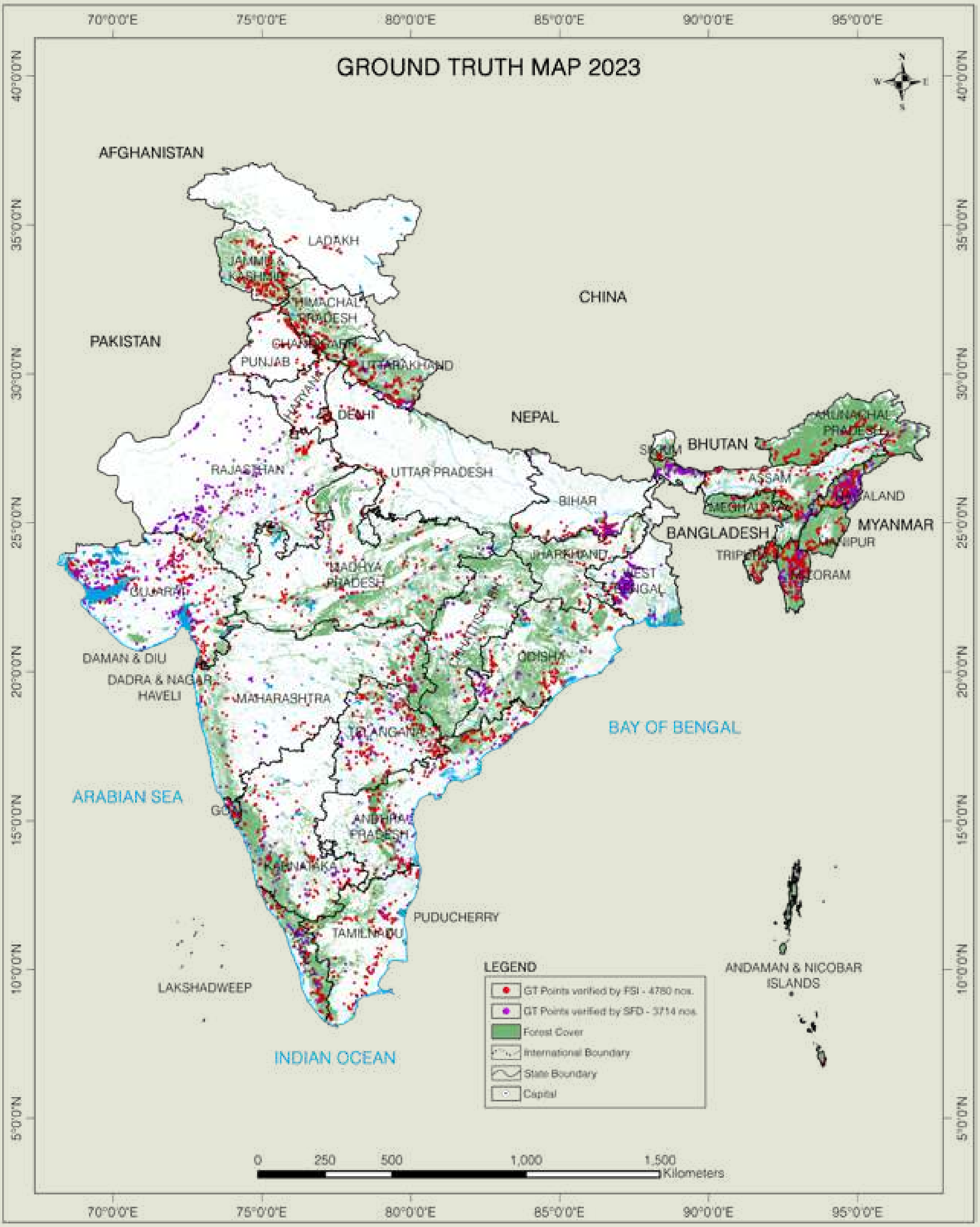


Figure 2.5 Map showing Distribution of Ground Truth locations on Forest Cover

2.6.3 Post Field Correction and Forest Cover Layer Generation

After the field validation process is finished, several steps were taken to integrate the collected ground truth data with remote sensing data and achieve an updated Forest Cover layer for the current assessment. This ensured that the assessment is comprehensive and reflects the actual conditions on the ground.

2.6.4 Concurrent Quality Assurance & Quality Control (QA&QC)

Concurrent monitoring and adherence to defined quality standards are critical aspects of the assessment process. Quality Assurance & Quality Control (QAQC) procedures are implemented at every step of the methodology to ensure the assessment meets the specified quality standards.

FSI has developed a manual for forest cover mapping, which includes clear cut definitions, concepts, and procedures; that helps in Quality Assurance. Supervisory oversight, periodic reviews, field verifications, and a final comprehensive assessment help ensure that the methodology aligns with defined standards and produces reliable results.

Challenges/ Constraints of Forest Cover Mapping 2.7

The limitations of Forest Cover Mapping are as follows:

- Size Limitations: Features on the ground with dimensions smaller than 23.5 m cannot be discerned and captured in the mapping process, due to limitation of the satellite data.
- Cloud Cover and Shadows: Satellite data can be obstructed by cloud cover and shadows, which may obscure significant ground details. Collateral data is used to mitigate these issues.
- Seasonal Data and Phenological Variations: Inadequate seasonal data and variations in forest phenology can hinder interpretation due to poor data reflectance.
- Mixed Spectral Signatures: The presence of agricultural crops like sugarcane and cotton near forests, as well as the presence of weeds like lantana within forested areas, can result in mixed spectral signatures, making accurate forest delineation challenging.
- Young Plants and Reduced Foliage: Young plants, tree species with reduced chlorophyll, or those lacking foliage, combined with soil-related factors, may not be visible on satellite imagery due to insufficient reflectance.
- Atmospheric Distortions: Digitally non-rectifiable haze and other atmospheric distortions can complicate the interpretation of satellite imagery.
- Land Use and Ownership: Forest cover mapping is based on satellite imagery and may not consider land use or ownership.

2.8 Tree Cover

Tree cover comprises all tree patches outside the forest area, which are less than one hectare in extent including all the scattered trees found in the rural and urban settings, and not captured under the forest cover assessment. As mentioned earlier in the Chapter, Forest Cover includes all areas more than or equal to 1 ha in extent and having canopy density of 10% and above irrespective of land use and legal status. However, there are many small patches of trees less than 1 ha in extent, such as trees in small scale plantations, compact block woodlots or trees along linear features, such as roads, canals, bunds, etc., and scattered trees; which are not captured by satellite sensors used for forest cover mapping, due to technological limitations. Figure 2.6 depicts the generalized concept of Forest, TOF and Tree Cover.

A complete picture of the forest and tree cover of the country is obtained by adding the Forest cover and the Tree cover assessed by FSI through two different methodologies. This information is required to compare with the goal of having a minimum of one third of the total land area of the country under forest or tree cover, as envisaged under National Forest Policy 1988. Forest cover is obtained from wall to wall mapping of the country using satellite data, whereas tree cover is estimated through sample survey using a combination of mid-resolution satellite data and field inventory data of Trees Outside Forests (TOF). FSI is publishing the information on forest cover since 1987 and tree cover since 2001.

Photo: FSI Repository

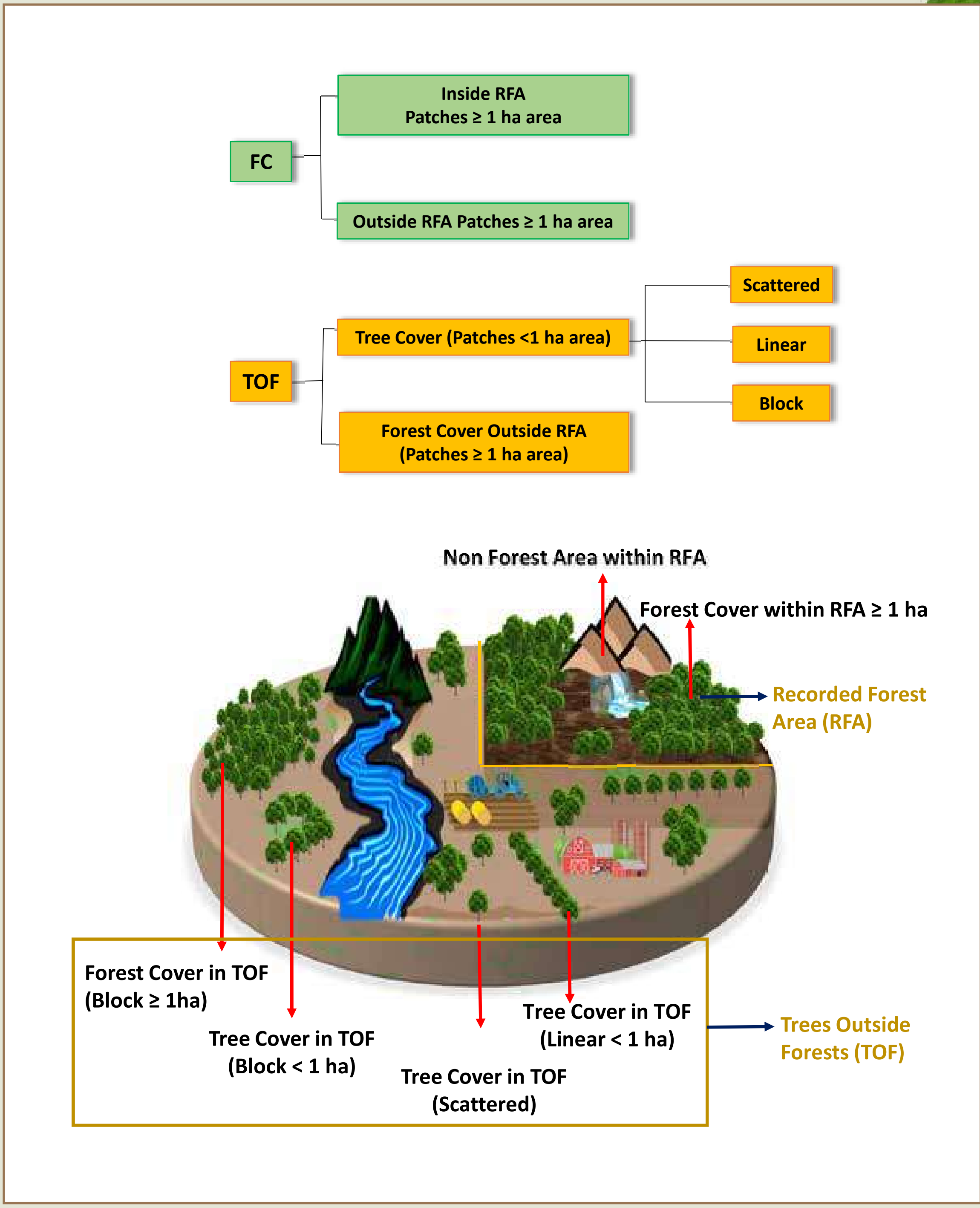


Figure 2.6 Concept of Forest, TOF and Tree Cover

2.8.1 Methodology for Tree Cover Estimation

TOF and tree cover are two distinct terms. TOF refers to all trees growing outside the recorded forest areas irrespective of size of patch. Tree cover, on the other hand, is comprised of tree patches and isolated trees outside the recorded forest which are less than one hectare. Thus, tree cover is a subset of TOF. For the TOF inventory, sample points are laid out in entire TOF area, falling in rural and urban settings as per the sampling design. For estimation of growing stock in TOF, entire TOF area area (all the area outside the RFA) is taken into consideration, whereas for the estimation of tree cover, tree patches less than 1 hectare in extent and scattered trees are taken into account. Tree cover of the country has been estimated State wise from the data collected during inventory of TOF in rural and urban areas following the grid based inventory design, which has been explained in detail in the chapter on Growing Stock. The TOF inventories of rural and urban areas are carried out in the grids selected for a particular year since 2016. The objective of TOF inventory is estimation of growing stock and tree cover. Detailed methodology is given in Chapter 5.

2.9 Forest and Tree Cover at a Glance

As pointed out earlier, 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 these three density classes, scrub areas, which are not included in the Forest Cover, have also been classified and mapped.

Tree cover, on the other hand, comprises all tree patches outside the forest area, which are less than one hectare in extent including all the scattered trees found in the rural and urban settings, and not captured under the forest cover assessment.

Table 2.3 presents area figures for Forest Cover, Tree Cover and Scrub. The percentage representation of the same is depicted in figure 2.7. Forest Cover Map of India is shown in Figure 2.8.

Table 2.3 Forest and Tree Cover of India

in km^2

Class	Area	Percentage of Geographical Area
Forest Cover	7,15,342.61	21.76
Tree Cover	1,12,014.34	3.41
Total Forest and Tree Cover	**8,27,356.95**	**25.17**
Scrub	43,622.64	1.33
Non Forest	24,16,489.29	73.50
Geographical Area	**32,87,468.88**	**100.00**

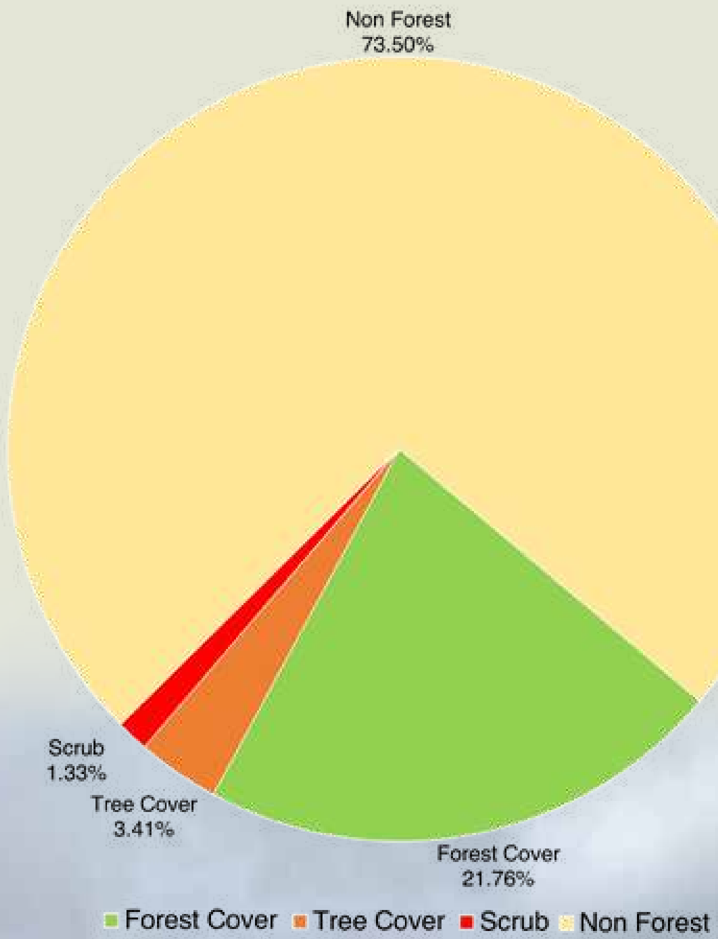


Figure 2.7 Forest and Tree Cover of India

Photo: FSI Repository

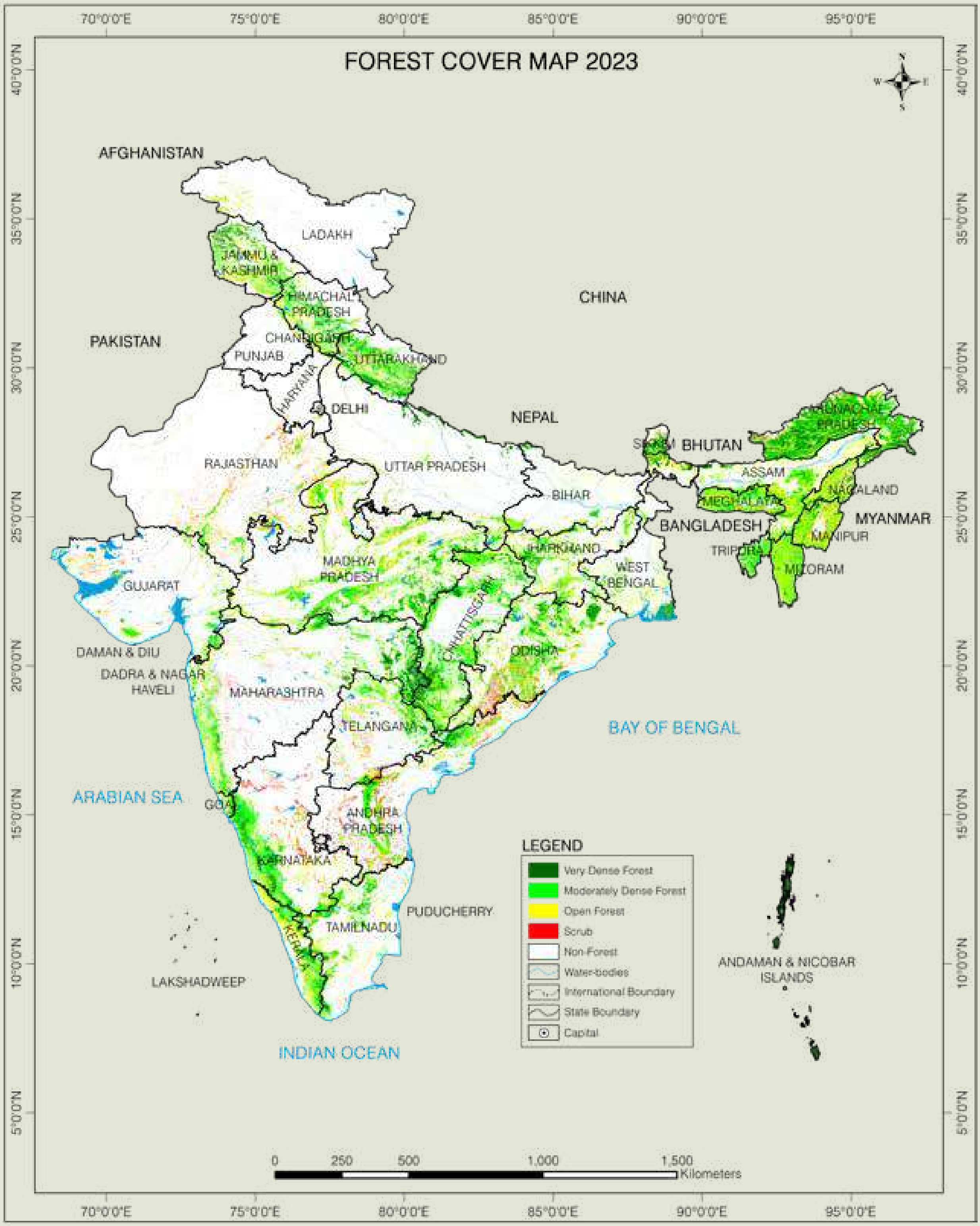


Figure 2.8 Forest Cover Map of India

Forest Cover Inside and Outside Recorded Forest Area or Green Wash 2.10

While assessing the Forest Cover, FSI considers both recorded forest areas and areas outside recorded forests. Here is a summary of how these areas are taken into account:

1. **Recorded Forest Areas:** Most of the recorded forest area is indeed covered with vegetation. However, within these recorded forest areas, there may be some areas with less than 10% canopy density. Such areas are excluded from the definition of forest cover.
2. **Areas Outside Recorded Forests:** Beyond the recorded forest areas, there can be tree stands with canopy densities exceeding or equal to 10% and sizes of 1 ha or more. These areas are also considered as part of the Forest Cover assessment by FSI.

The above approach ensured that Forest Cover assessment and monitoring could be conducted comprehensively for the entire country, even in the absence of specific RFA boundary data from State and UTs.

The information of Forest Cover within and outside of RFA/Green Wash is shown in Table 2.4.

The District and Division wise information on forest cover of all State and UTs as given in Chapter 10 (Forest and Tree Resources in State/UTs) has been used in this Chapter for compilation of State and Country level forest cover figures.

2.10.1 Recorded Forest Areas (RFA)

"Recorded Forest" refers to any area that is officially documented as a forest in government records. Typically, these recorded forest areas include Reserved Forests (RF) or Protected Forests (PF), which are established under the Indian Forest Act of 1927. Besides the RFs and PFs, the recorded forest area may also include all such areas which have been recorded as 'Unclassed Forests', 'Village Forests', or by any other nomenclature of such description, and all such areas which have been recorded forests in the revenue records, or have been constituted so under any State Act or local law. These areas are legally designated as forests and are subject to specific regulations and management practices.

It's important to note that Forest Survey of India (FSI) uses digitized boundaries of Recorded Forest Areas (RFAs) provided by State Forest Departments (SFDs) and Union Territories (UTs) for its assessments and monitoring activities.

Currently, FSI has received RFA digitized boundaries from 25 State Forest Departments (SFDs/ UTs). These have been used as per the information provided by the SFDs/ UTs. Due to non-availability of RFAs digitized boundaries from all State/UTs across the country, the assessment and monitoring of Forest Cover within RFA for the whole country could not be done. In such cases Green Wash Area is used as a proxy for

Recorded Forest Area. Details of Forest Cover inside Recorded Forest Area (RFA) in the State/UTs are provided in Table 2.4.

2.10.2 Green Wash (GW)

In cases where usable digitized boundaries of recorded forest areas (RFAs) were not available, FSI adopted an alternative approach, using the "green wash" boundaries, which are areas represented in green on the Survey of India topographic sheets, as a proxy for RFAs.

Green Wash Digitization: The green wash boundaries of the entire country were digitized on a 1:50,000 scale using Survey of India (SoI) topographic sheets. These maps display geographical features, including forested areas, represented in green. Forest Cover data both inside and outside the green wash areas was extracted for the State and UTs where RFA boundaries were not available, and is included in Table 2.4.

Photo: FSI Repository


Photo: FSI Repository

Table 2.4 State/UT wise Forest Cover inside and outside Recorded Forest Area (RFA)/Green Wash (GW)

State /UT	Geographical Area	Forest Cover Inside RFA/GW 2021*				Forest Cover Inside RFA/GW 2023				Forest Cover Change Inside RFA/GW	Forest Cover Outside RFA/GW 2021*		
		VDF	MDF	OF	Total	VDF	MDF	OF	Total		VDF	MDF	OF
	(A)				(B)				(C)	(C-B)			
Andhra Pradesh	1,62,922.57	1,925.22	12,588.26	9,437.75	23,951.23	1,925.32	12,469.70	9,472.74	23,867.76	-83.47	72.45	1,324.76	4,875.18
Arunachal Pradesh	83,743.22	19,633.01	26,867.22	11,719.58	58,219.81	19,637.05	26,699.94	11,836.97	58,173.96	-45.85	1,372.87	2,971.29	3,408.77
Assam	78,438.00	2,789.68	8,468.10	8,525.61	19,783.39	2,833.31	8,333.78	8,529.64	19,696.73	-86.66	357.15	1,431.29	6,753.48
Bihar	94,163.00	319.32	2,477.28	2,046.80	4,843.40	375.79	2,445.25	2,044.70	4,865.74	22.34	11.61	819.02	1,729.23
Chhattisgarh	1,35,192.00	5,449.44	26,367.76	10,616.60	42,433.80	5,796.08	26,070.85	10,553.46	42,420.39	-13.41	1,605.33	5,935.11	5,856.64
Delhi	1,483.00	4.06	18.75	47.65	70.46	4.02	18.24	49.94	72.20	1.74	2.66	37.74	84.50
Goa	3,702.00	518.19	325.85	380.03	1,224.07	532.61	340.31	351.01	1,223.93	-0.14	22.56	237.61	782.98
Gujarat	1,96,244.00	356.23	3,961.48	5,133.38	9,451.09	400.31	3,948.17	5,041.39	9,389.87	-61.22	18.62	955.52	4,411.34
Haryana	44,212.00	23.99	259.08	448.63	731.70	23.99	258.77	446.17	728.93	-2.77	3.18	185.98	707.36
Himachal Pradesh	55,673.00	2,835.93	5,395.79	2,440.18	10,671.90	2,791.82	5,431.88	2,483.27	10,706.97	35.07	361.75	1,828.56	2,663.41
Jharkhand	79,716.00	1,444.93	5,260.88	5,744.00	12,449.81	1,447.53	5,261.05	5,793.95	12,502.53	52.72	1,183.38	4,380.88	5,692.90
Karnataka	1,91,791.00	3,735.18	12,885.56	6,300.02	22,920.76	3,737.90	12,876.97	6,399.03	23,013.90	93.14	799.82	8,294.93	7,091.06
Kerala	38,852.00	1,878.93	5,429.89	2,578.79	9,887.61	1,877.59	5,420.36	2,627.89	9,925.84	38.23	164.00	3,923.79	7,950.54
Madhya Pradesh	3,08,252.11	6,468.74	31,676.75	29,651.78	67,797.27	6,886.21	31,366.97	29,517.32	67,770.50	-26.77	189.37	2,462.26	6,996.08
Maharashtra	3,07,713.00	8,497.78	15,103.73	12,522.82	36,124.33	9,538.99	15,827.39	10,744.55	36,110.93	-13.40	303.75	5,516.60	8,968.32
Manipur	22,327.00	893.87	5,776.36	8,168.05	14,838.28	893.52	5,744.86	8,152.43	14,790.81	-47.47	10.68	484.15	1,307.18
Meghalaya	22,429.00	508.98	7,599.66	6,575.02	14,683.66	547.93	7,502.05	6,600.87	14,650.85	-32.81	46.47	1,537.75	728.96
Mizoram	21,081.00	193.73	8,648.64	8,594.31	17,436.68	259.83	8,438.53	8,931.24	17,629.60	192.92	0.36	190.89	120.80
Nagaland	16,579.00	1,159.01	3,172.73	4,219.21	8,550.95	1,156.13	3,168.30	4,195.60	8,520.03	-30.92	102.24	1,312.73	2,308.44
Odisha	1,55,707.00	5,706.07	14,800.09	12,416.14	32,922.30	5,709.16	14,834.51	12,496.80	33,040.47	118.17	1,521.14	6,227.68	11,610.55
Punjab	50,362.00	9.20	450.57	317.03	776.80	8.72	450.21	316.83	775.76	-1.04	0.72	335.03	733.99
Rajasthan	3,42,238.99	74.96	4,021.11	8,583.22	12,679.29	216.92	3,892.73	8,596.49	12,706.14	26.85	3.87	353.94	3,594.91
Sikkim	7,096.00	831.81	880.77	345.13	2,057.71	831.08	879.76	349.79	2,060.63	2.92	272.24	676.05	347.21
Tamil Nadu	1,30,060.00	3,346.49	8,689.97	5,720.84	17,757.30	3,344.13	8,681.60	5,708.57	17,734.30	-23.00	242.47	2,383.64	6,127.77
Telangana	1,12,122.44	1,548.47	8,632.59	8,380.92	18,561.98	1,544.81	8,520.97	8,390.33	18,456.11	-105.87	71.11	440.24	2,206.13
Tripura	10,486.00	408.31	3,885.15	1,179.63	5,473.09	393.77	3,719.84	1,242.58	5,356.19	-116.90	225.33	1,258.32	723.34
Uttar Pradesh	2,40,927.56	2,504.56	3,049.96	3,745.08	9,299.60	2,537.81	3,041.49	3,759.46	9,338.76	39.16	150.73	945.57	4,531.47
Uttarakhand	53,483.36	4,314.25	9,306.92	3,292.55	16,913.72	4,520.08	9,109.85	3,269.35	16,899.28	-14.44	726.93	3,439.86	3,246.30
West Bengal	88,752.00	2,763.59	2,623.20	2,236.98	7,623.77	2,781.11	2,654.27	2,253.18	7,688.56	64.79	253.67	1,506.87	7,397.80
A & N Islands	8,249.00	5,373.00	549.13	250.67	6,172.80	5,393.99	525.49	251.03	6,170.51	-2.29	309.80	127.93	126.41
Chandigarh	114.00	1.29	5.07	2.35	8.71	1.36	5.04	2.54	8.94	0.23	0.07	8.68	6.34
Dadra & Nagar Haveli and Daman & Diu	602.00	0.00	69.38	90.64	160.02	0.00	67.85	90.66	158.51	-1.51	1.36	11.62	52.94
Jammu & Kashmir**	2,22,236.00	3,073.01	5,351.35	4,652.89	13,077.25	3,073.86	5,352.73	4,685.44	13,112.03	34.78	1,133.39	2,639.37	4,412.83
Ladakh**		2.20	179.16	619.12	800.48	2.20	183.53	608.85	794.58	-5.90	0.07	333.12	1,144.88
Lakshadweep	29.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.97	10.09
Puducherry	490.00	0.00	0.61	2.41	3.02	0.00	0.61	2.47	3.08	0.06	0.00	10.15	30.98
Total	**32,87,468.88**	**88,593.43**	**2,44,778.80**	**1,86,985.81**	**5,20,358.04**	**91,024.93**	**2,43,543.85**	**1,85,796.54**	**5,20,365.32**	**7.28**	**11,541.15**	**64,545.90**	**1,18,741.11**

**Revised area figures calculated without normalization factor.*
*** Area for individual UTs of Jammu & Kashmir and Ladakh have not been received from SoI. The geographical area reported for the unified J&K in Census 2011 is 2,22,236 km^2.*
The States/UTs which have provided RFA boundaries are shown in light green colour while the other States/ UTs where GW have been used are shown in dark green colour.
#Tree cover also includes all bamboo clumps and trees of dbh of 5-10 cm which were not included in published figures reported in ISFR 2021. Therefore, Tree cover figures of 2021 have also been revised.

Forest Cover Outside RFA/GW 2023					Forest Cover Change Outside RFA / GW	Total Forest Cover 2021*	Total Forest Cover 2023	Total Forest Cover Change	Tree Cover 2021*	Total Forest Cover including Tree Cover 2021	Tree Cover 2023	Total Forest Cover including Tree Cover 2023	Change in Tree Cover	Net Change in Forest Cover and Tree Cover	Percentage of Forest and Tree Cover
Total	VDF	MDF	OF	Total											
(D)				(E)	(E-D)	(S=B+D)	(T= C+E)	(T-S)	(F)	(X=S+F)	(G)	(Y=T+G)	(G-F)	(Y-X)	Y*100/A
6,272.39	70.39	1,256.05	4,890.76	6,217.20	-55.19	30,223.62	30,084.96	-138.66	5,247.36	35,470.98	5,340.02	35,424.98	92.66	-46.00	21.74
7,752.93	1,348.27	2,915.15	3,444.19	7,707.61	-45.32	65,972.74	65,881.57	-91.17	1,162.95	67,135.69	1,201.63	67,083.20	38.68	-52.49	80.11
8,541.92	356.40	1,430.76	6,829.66	8,616.82	74.90	28,325.31	28,313.55	-11.76	2,173.62	30,498.93	2,101.46	30,415.01	-72.16	-83.92	38.78
2,559.86	11.21	838.96	1,816.54	2,666.71	106.85	7,403.26	7,532.45	129.19	2,623.38	10,026.64	2,370.21	9,902.66	-253.17	-123.98	10.52
13,397.08	1,620.49	5,912.95	5,857.92	13,391.36	-5.72	55,830.88	55,811.75	-19.13	5,835.95	61,666.83	6,538.70	62,350.45	702.75	683.62	46.12
124.90	2.45	35.31	85.32	123.08	-1.82	195.36	195.28	-0.08	171.06	366.42	176.03	371.31	4.97	4.89	25.04
1,043.15	22.85	249.12	769.82	1,041.79	-1.36	2,267.22	2,265.72	-1.50	260.08	2,527.30	257.82	2,523.54	-2.26	-3.76	68.17
5,385.48	19.40	954.03	4,653.34	5,626.77	241.29	14,836.57	15,016.64	180.07	6,648.28	21,484.85	6,632.29	21,648.93	-15.99	164.08	11.03
896.52	3.18	182.41	699.74	885.33	-11.19	1,628.22	1,614.26	-13.96	1,551.85	3,180.07	1,693.02	3,307.28	141.17	127.21	7.48
4,853.72	325.78	1,848.41	2,699.19	4,873.38	19.66	15,525.62	15,580.35	54.73	813.35	16,338.97	855.07	16,435.42	41.72	96.45	29.52
11,257.16	1,187.82	4,379.94	5,695.49	11,263.25	6.09	23,706.97	23,765.78	58.81	3,409.40	27,116.37	3,637.55	27,403.33	228.15	286.96	34.38
16,185.81	799.89	8,274.78	7,165.70	16,240.37	54.56	39,106.57	39,254.27	147.70	8,386.21	47,492.78	7,779.15	47,033.42	-607.06	-459.36	24.52
12,038.33	163.58	3,901.46	8,068.48	12,133.52	95.19	21,925.94	22,059.36	133.42	3,025.60	24,951.54	2,905.94	24,965.30	-119.66	13.76	64.26
9,647.71	135.10	2,141.67	7,026.17	9,302.94	-344.77	77,444.98	77,073.44	-371.54	8,891.01	86,335.99	8,650.14	85,723.58	-240.87	-612.41	27.81
14,788.67	326.63	5,750.40	8,670.57	14,747.60	-41.07	50,913.00	50,858.53	-54.47	14,413.67	65,326.67	14,524.88	65,383.41	111.21	56.74	21.25
1,802.01	10.53	472.69	1,311.43	1,794.65	-7.36	16,640.29	16,585.46	-54.83	217.19	16,857.48	209.82	16,795.28	-7.37	-62.20	75.22
2,313.18	46.91	1,521.76	747.32	2,315.99	2.81	16,996.84	16,966.84	-30.00	774.63	17,771.47	720.56	17,687.40	-54.07	-84.07	78.86
312.05	1.69	197.23	161.94	360.86	48.81	17,748.73	17,990.46	241.73	631.11	18,379.84	567.80	18,558.26	-63.31	178.42	88.03
3,723.41	100.25	1,293.51	2,308.68	3,702.44	-20.97	12,274.36	12,222.47	-51.89	467.35	12,741.71	394.02	12,616.49	-73.33	-125.22	76.10
19,359.37	1,515.26	6,231.04	11,646.79	19,393.09	33.72	52,281.67	52,433.56	151.89	5,756.77	58,038.44	6,163.45	58,597.01	406.68	558.57	37.63
1,069.74	0.72	334.68	734.93	1,070.33	0.59	1,846.54	1,846.09	-0.45	1,297.93	3,144.47	1,475.15	3,321.24	177.22	176.77	6.59
3,952.72	6.28	344.68	3,491.11	3,842.07	-110.65	16,632.01	16,548.21	-83.80	10,362.86	26,994.87	10,841.12	27,389.33	478.26	394.46	8.00
1,295.50	272.23	676.13	349.41	1,297.77	2.27	3,353.21	3,358.40	5.19	50.64	3,403.85	48.33	3,406.73	-2.31	2.88	48.01
8,753.88	242.06	2,345.43	6,128.43	8,715.92	-37.96	26,511.18	26,450.22	-60.96	5,323.73	31,834.91	5,370.72	31,820.94	46.99	-13.97	24.47
2,717.48	68.51	388.93	2,265.49	2,722.93	5.45	21,279.46	21,179.04	-100.42	3,478.88	24,758.34	3,517.66	24,696.70	38.78	-61.64	22.03
2,206.99	220.66	1,210.15	797.77	2,228.58	21.59	7,680.08	7,584.77	-95.31	252.95	7,933.03	247.56	7,832.33	-5.39	-100.70	74.69
5,627.77	150.92	959.92	4,596.20	5,707.04	79.27	14,927.37	15,045.80	118.43	8,510.16	23,437.53	8,950.92	23,996.72	440.76	559.19	9.96
7,413.09	746.50	3,407.78	3,250.27	7,404.55	-8.54	24,326.81	24,303.83	-22.98	1,201.59	25,528.40	1,231.14	25,534.97	29.55	6.57	47.74
9,158.34	255.99	1,521.11	7,366.67	9,143.77	-14.57	16,782.11	16,832.33	50.22	2,962.61	19,744.72	2,938.12	19,770.45	-24.49	25.73	22.28
564.14	308.88	127.71	125.82	562.41	-1.73	6,736.94	6,732.92	-4.02	24.51	6,761.45	26.97	6,759.89	2.46	-1.56	81.95
15.09	0.08	8.48	7.50	16.06	0.97	23.80	25.00	1.20	16.72	40.52	21.18	46.18	4.46	5.66	40.51
65.92	1.36	10.74	55.01	67.11	1.19	225.94	225.62	-0.32	34.87	260.81	36.83	262.45	1.96	1.64	43.60
8,185.59	1,134.93	2,653.83	4,445.60	8,234.36	48.77	21,262.84	21,346.39	83.55	3,659.27	24,922.11	3,666.97	25,013.36	7.70	91.25	12.69
1,478.07	0.07	325.54	1,165.73	1,491.34	13.27	2,278.55	2,285.92	7.37	1,059.65	3,338.20	893.02	3,178.94	-166.63	-159.26	
27.06	0.00	16.97	10.09	27.06	0.00	27.06	27.06	0.00	0.05	27.11	0.20	27.26	0.15	0.15	92.00
41.13	0.00	9.72	31.51	41.23	0.10	44.15	44.31	0.16	27.70	71.85	28.89	73.20	1.19	1.35	14.94
1,94,828.16	**11,477.27**	**64,129.43**	**1,19,370.59**	**1,94,977.29**	**149.13**	**7,15,186.20**	**7,15,342.61**	**156.41**	**1,10,724.94**	**8,25,911.14**	**1,12,014.34**	**8,27,356.95**	**1,289.40**	**1,445.81**	**25.17**

There has been a net increase of 156.41 km^2 in the Forest Cover at national level. The states namely Mizoram, Gujarat, Odisha, Karnataka and Kerala have contributed to an increase of 241.73 km^2, 180.07 km^2, 151.89 km^2, 147.70 km^2 and 133.42 km^2 respectively. From the table, it is inferred that the states showing major loss in Forest Cover are Madhya Pradesh (371.54 km^2), Andhra Pradesh (138.66 km^2), Telangana (100.42 km^2), Tripura (95.31 km^2) and Arunachal Pradesh (91.17 km^2).

2.10.3 Extent of Trees Outside Forests

The area within TOF, with size more than or equal to 1 ha is regarded as 'Forest Cover outside RFA' or 'Forest Cover within TOF' and the area less than 1 ha is regarded as the 'Tree Cover' existing within TOF.

The Table 2.4 shows the forest cover outside RFA together with tree cover of the State/ UTs, the sum of which corresponds to the 'extent of TOF' in the corresponding State/ UTs. In the current assessment, the extent of TOF has been found to be 30.70 Mha which is 37.11 % of the total forest and tree cover in the country. The total tree cover of the country as per ISFR 2023 has been estimated as 1,12,014.34 km^2 which includes 11,724 km^2 tree cover for the trees 5 to 10 cm dbh and 4,085 km^2 bamboo cover.

In order to make this estimate comparable with ISFR 2021, these two components, i.e., trees between 5 to 10 cm, and bamboo cover have been estimated separately for ISFR 2021; and estimated as 11,036 km^2 and 3,940 km^2 respectively. Thus, the revised tree cover for ISFR 2021 is estimated as 1,10,724.94 km^2. The total increase in the tree cover has been observed as 1,289.40 km^2 between 2021 and 2023 assessment reports.

2.10.4 State wise Estimates of Tree Cover

The maximum tree cover has been found in the State of Maharashtra (14,524.88 km^2) followed by Rajasthan (10,841.12 km^2) and Uttar Pradesh (8,950.92 km^2). In terms of percentage of geographical area, Chandigarh has maximum tree cover (18.58 %) followed by Delhi (11.87 %) and Kerala (7.48 %). The maximum positive change as compared to ISFR 2021 has been observed in Chhattisgarh (702.75 km^2) followed by Rajasthan (478.26 km^2) and Uttar Pradesh (440.76 km^2). In general, twenty-one State and UTs have shown an increasing trend in tree cover, which indicates that agroforestry, is being promoted in these States. Figure 2.9 depicts the State/UTs wise forest cover within RFA and extent of TOF. More details on Agroforestry are available in Chapter 7.

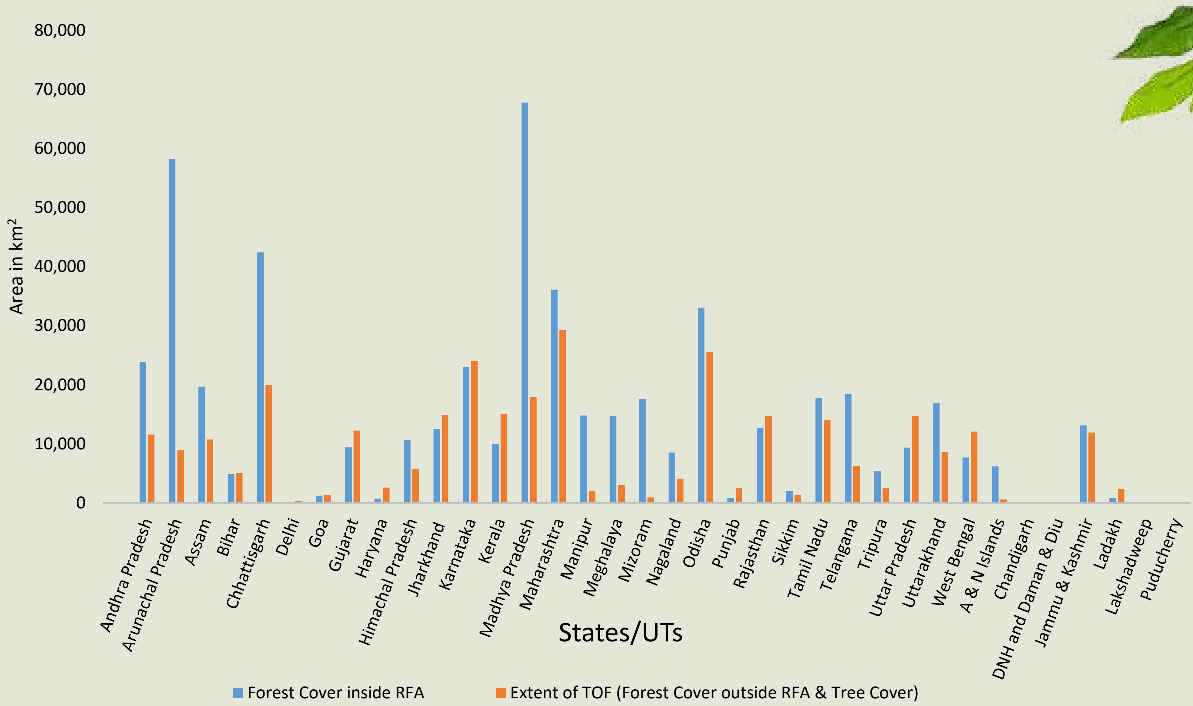


Figure 2.9 State/UT wise Forest Cover (inside RFA) & Extent of TOF

Change in Forest and Tree Cover 2.11

The Forest Cover changes observed during the two-year interval reflect actual changes on the ground. These changes encompass conversions between forest and non-forest areas and shifts among different canopy density classes. Here are the probable factors contributing to positive and negative changes in Forest Cover:

Positive Changes can be due to the following reasons:

- Natural growth of vegetation, often due to conservation efforts
- Establishment of new vegetation through afforestation initiatives
- Improved protection measures in plantation and traditional forest areas
- Increase in trees growing outside designated forest areas
- Regeneration of areas under shifting cultivation

Positive changes not discernible during previous cycle might also show up in the subsequent cycle due to growth in the intervening period.

Negative Changes can be due to the following reasons:

- Harvesting of short rotation plantations or other forms of logging
- Shifting cultivation practices
- Human activities, such as encroachment, etc.
- Natural Calamities like storms, floods, and landslides
- Titles given to beneficiaries under the Forest Rights Act (2006)

In summary, Forest Cover changes encompass various factors, including both natural processes and human activities. Collateral data and ground truthing efforts play a crucial role in refining and validating these changes.

In the current assessment, higher radiometric value of satellite data, greater intensity of ground truthing (8,494 points), considerable use of higher resolution collateral data and information from SFDs has helped in improving the quality of interpretation.

2.12 Change Matrix

The "Change Matrix" is a quantitative representation of Forest Cover changes between two consecutive assessments, highlighting alterations in density classes, scrub, and non-forest areas. It offers insights into land cover transitions and dynamics over time. The matrix is presented in a tabular format, displaying changes in area between different Forest Cover classes. This analysis provides valuable information for forest management and environmental monitoring. Details of Forest Cover change matrix for the country between 2021 and 2023 assessments inside and outside Recorded Forest Areas (RFA)/ Green Wash (GW) is given in Tables 2.5 and 2.6, respectively.

Table 2.5 Forest Cover Change Matrix Inside RFA/GW for India between 2021 (Raster based) and 2023 Assessments

(in km^2)

Class	2023 Assessment Inside RFA/GW					Total ISFR 2021 inside RFA / GW Raster based*
	VDF	MDF	OF	Scrub	NF	
VDF	85,568.45	2,570.74	201.20	21.86	231.18	**88,593.43**
MDF	4,930.17	2,33,135.56	4,232.44	233.80	2,246.83	**2,44,778.80**
OF	481.13	7,269.84	1,72,692.54	1,090.99	5,451.31	**1,86,985.81**
Scrub	0.75	72.08	2,910.18	19,155.54	1,578.35	**23,716.90**
NF	44.43	495.63	5,760.18	2,009.95	1,88,877.68	**1,97,187.87**
Total ISFR 2023 inside RFA /GW	**91,024.93**	**2,43,543.85**	**1,85,796.54**	**22,512.14**	**1,98,385.35**	**7,41,262.81**
Net Change	2,431.50	-1,234.95	-1,189.27	-1,204.76	1,197.48	

**Area figure calculated without normalization factor.*

Table 2.6 Forest Cover Change Matrix Outside RFA/GW for India between 2021 (Raster based) and 2023 Assessments

(in km^2)

Class	2023 Assessment Outside RFA/GW					Total ISFR 2021 outside RFA / GW Raster based*
	VDF	MDF	OF	Scrub	NF	
VDF	11,261.13	187.35	26.35	2.75	63.57	**11,541.15**
MDF	189.77	62,228.59	933.31	79.56	1,114.67	**64,545.90**
OF	15.22	1,340.62	1,10,188.87	636.88	6,559.52	**1,18,741.11**
Scrub	0.05	29.26	1,774.28	17,802.82	3,416.55	**23,022.96**
NF	11.10	343.61	6,447.78	2,588.49	23,18,963.97	**23,28,354.95**
Total ISFR 2023 outside RFA /GW	**11,477.27**	**64,129.43**	**1,19,370.59**	**21,110.50**	**23,30,118.28**	**25,46,206.07**
Net Change	-63.88	-416.47	629.48	-1,912.46	1,763.33	

**Area figure calculated without normalization factor.*

Forest Cover in Hill Districts 2.13

Hill areas are delicate and vulnerable ecosystems, particularly prone to challenges like soil erosion, land degradation, and landslides. Forests play a crucial role in mountainous regions by serving as natural defence against these problems and contributing to ecological stability.

Forests in hill areas act as natural barriers to soil erosion and landslides as their root systems bind soil. They support biodiversity, sustain water sources, and regulate microclimates. Besides giving environmental benefits, these forests also impact local livelihoods and traditions.

FSI has been reporting forest cover in hill districts in State of Forest Reports since 1997. A total of 95 hill districts were reported in SFR 1997. Since then, the number of hill districts has increased due to reorganisations and formation of new districts. ISFR 2021 featured 140 hill districts. Meanwhile, the districts have been further reorganised and new districts have been constituted, with alterations in boundaries and areas of the reported districts. In order to have continuity and comparison with data in the past, this report includes data for the same districts.

There are 172 hill districts marked by superscript ('H') in district-wise tables of Forest cover in Chapter 10. Table 2.7 provides a State-wise summary of Forest Cover in hilly districts. Forest Cover increased by 234.14 km^2 in the hill districts in the country.

Photo: FSI Repository

Table 2.7 State /UT wise Inside/Outside RFA/GW Forest Cover in Hill Districts

in km²

State /UT	No. of Hill dis-tricts	Calculat-ed Area by SoI*	Inside RFA/GW					Outside RFA/GW					Total Forest Cover (A+B)	Change in Forest Cover w.r.t. Revised Figure of ISFR 2021	Scrub
			VDF	MDF	OF	Total (A)	Percent-age of Calculat-ed Area by SoI	VDF	MDF	OF	Total (B)	Percent-age of Calculat-ed Area by SoI			
Arunachal Pradesh	25	83,743.22	19,637.05	26,699.94	11,836.97	58,173.96	69.47	1,348.27	2,915.15	3,444.19	7,707.61	9.20	65,881.57	-91.17	1,058.98
Assam	5	19,299.00	1,026.37	5,008.03	5,477.61	11,512.01	59.65	26.81	309.95	900.08	1,236.84	6.41	12,748.85	-79.09	85.91
Himachal Pradesh	12	55,673.00	2,791.82	5,431.88	2,483.27	10,706.97	19.23	325.78	1,848.41	2,699.19	4,873.38	8.75	15,580.35	54.73	308.69
Karnataka	6	48,353.00	3,211.56	9,179.70	1,781.58	14,172.84	29.31	721.30	6,362.61	2,925.96	10,009.87	20.70	24,182.71	54.68	770.93
Kerala	10	29,552.00	1,479.13	4,125.30	2,033.15	7,637.58	25.84	138.73	3,664.83	6,487.02	10,290.58	34.82	17,928.16	126.11	20.88
Maharashtra	7	69,905.00	300.34	2,999.89	2,146.98	5,447.21	7.79	122.26	4,420.28	5,854.24	10,396.78	14.87	15,843.99	73.94	1,192.81
Manipur	16	22,327.00	893.52	5,744.86	8,152.43	14,790.81	66.25	10.53	472.69	1,311.43	1,794.65	8.04	16,585.46	-54.83	973.65
Meghalaya	12	22,429.00	547.93	7,502.05	6,600.87	14,650.85	65.32	46.91	1,521.76	747.32	2,315.99	10.33	16,966.84	-30.00	620.41
Mizoram	11	21,081.00	259.83	8,438.53	8,931.24	17,629.60	83.63	1.69	197.23	161.94	360.86	1.71	17,990.46	241.73	314.54
Nagaland	11	16,579.00	1,156.13	3,168.30	4,195.60	8,520.03	51.39	100.25	1,293.51	2,308.68	3,702.44	22.33	12,222.47	-51.89	667.27
Sikkim	4	7,096.00	831.08	879.76	349.79	2,060.63	29.04	272.23	676.13	349.41	1,297.77	18.29	3,358.40	5.19	303.49
Tamil Nadu	6	19,384.00	1,266.01	1,788.60	908.58	3,963.19	20.45	163.91	879.64	1,560.15	2,603.70	13.43	6,566.89	14.56	86.68
Tripura	8	10,486.00	393.77	3,719.84	1,242.58	5,356.19	51.08	220.66	1,210.15	797.77	2,228.58	21.25	7,584.77	-95.31	173.27
Uttarakhand	13	53,483.36	4,520.08	9,109.85	3,269.35	16,899.28	31.60	746.50	3,407.78	3,250.27	7,404.55	13.84	24,303.83	-22.98	412.88
West Bengal	2	3,149.00	505.57	333.23	197.44	1,036.24	32.91	216.13	348.76	735.01	1,299.90	41.28	2,336.14	-2.45	7.72
Jammu & Kashmir**	22	2,22,236.00	3,073.86	5,352.73	4,685.44	13,112.03	6.26	1,134.93	2,653.83	4,445.60	8,234.36	4.38	21,346.39	83.55	262.27
Ladakh**	2		2.20	183.53	608.85	794.58		0.07	325.54	1,165.73	1,491.34		2,285.92	7.37	325.49
Total	**172**	**7,04,775.58**	**41,896.25**	**99,666.02**	**64,901.73**	**2,06,464.00**	**29.29**	**5,596.96**	**32,508.25**	**39,143.99**	**77,249.20**	**10.96**	**2,83,713.20**	**234.14**	**7,585.87**

**Calculated area provided by Survey of India (SoI)*

*** Notified areas for individual UTs of Jammu & Kashmir and Ladakh have not been received from SoI. The geographical area reported for the unified J&K in Census 2011 is 2,22,236 km².*

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

Forest Cover in Tribal Districts 2.14

Forests hold a vital position as a means of sustenance and income for tribal communities. To monitor and assess the forest cover in tribal districts, FSI has been reporting the forest cover change in Tribal districts since 1999.

As per the 2011 census, there were 218 tribal districts. However, districts have been bifurcated and new districts have been constituted in many States since 2011. FSI is using the latest boundary layer provided by Survey of India, which includes the newly formed districts. However, the notification of the districts as tribal district is not available with FSI and was not provided by the Ministry of Tribal Affairs. Hence, forest cover change in tribal districts is not given in this section. However, this information can be extracted from the district wise forest cover figures given in Chapter 10, using information on tribal districts available with the States.

Forest Cover in Eco-Sensitive Area of Western Ghats 2.15

Eco-Sensitive Areas (ESAs) are earmarked around National Parks, Wildlife Sanctuaries, and other Protected Areas. ESAs are notified by MoEF&CC under Environment Protection Act 1986. In case the boundary of the Eco sensitive area is not notified, it is taken as 10 km around a Protected Area.

The Western Ghats were granted the UNESCO World Heritage designation in 2012, acknowledging them as one of the planet's most biologically diverse hotspots. These Ghats stretch from Dang in Maharashtra-Gujarat to an area close to Kanyakumari in Tamil Nadu, running along the western coastline.

FSI received the boundaries of Western Ghats Eco-Sensitive Areas (WGESA) from the MoEF&CC for analysis of forest cover and changes therein. The Western Ghats runs into 6 States, viz., Goa, Gujarat, Karnataka, Kerala, Maharashtra, and Tamil Nadu; and 45 districts in total. The analysis of Forest Cover in WGESA districts is given in Table 2.8.

WGESA occupies an area of approximately 60,285.61 km^2 based on the digital boundary provided, against a notified area of 56,825 km^2. Forest cover in all districts under WGESA was estimated using latest forest cover assessment.

The district-wise extent of forests in the three density classes within the region for 2023 assessment, and decadal changes therein, with respect to the data of ISFR 2013 is given in Table 2.8. From the table, it is seen that there has been an overall loss of 58.22 km² in forest cover during the last 10 years. Very Dense forest increased by 3,465.12 km², whereas Moderately Dense Forest and Open Forest decreased by 1,043.23 km² and 2,480.11 km² respectively.

Notification of Eco-Sensitive Area in Western Ghats

On 4th March, 2010, the Ministry of Environment and Forests, Government of India, constituted the **Western Ghats Ecology Expert Panel (WGEEP)** designating entire 142 talukas, of Western Ghats, measuring **1,29,037 km²** to be declared as Ecologically Sensitive Area (ESA).

Later, the Ministry constituted a **High Level Working Group (HLWG)** on 17.08.2012, which recommended 37% of the Western Ghats as ESA covering an area of **59,940 km²** spanning across six states, viz., Kerala, Tamil Nadu, Goa, Karnataka, Maharashtra, and Gujarat. This is based on (i) high biological richness; (ii) low forest fragmentation; (iii) low population density; (iv) existing Protected Areas (PAs) or Wildlife Sanctuaries, National Parks, Tiger Reserves and Tiger/Elephant corridors, and notified forest areas and (v) World Heritage Sites. As per the HLWG report, out of the estimated 1,64,280 km2 of the Western-Ghats area, the natural landscape constitutes only 41%. The area identified as ecologically sensitive is about 37%, i.e., about 90% of the natural landscape. Taking cognizance of HLWG report (Kasturirangan Report), the Ministry published a draft Notification vide S.O. 733 (E) on 10.02.2014, notifying therein an area of 56,825 km² for the purpose of conservation and protection as Western Ghats Eco-Sensitive Area. The notification has been re-published periodically. The latest draft notification has been issued vide S.O. 3060(E) on 31.07.2024.

Photo: FSI Repository

Table 2.8 Forest Cover in Western-Ghats Eco-Sensitive Areas (WGESA)

Sl. No.	State	District	Area as per digitized Boundary*	2013 Assessment		
				VDF	MDF	OF
1	Goa	North Goa	413.37	116.86	108.92	155.04
2		South Goa	1,071.75	355.81	238.16	278.71
3	Gujarat	Navsari	36.02	12.03	15.86	1.34
4		Surat	134.74	20.02	56.63	26.46
5		The Dangs	295.04	55.07	136.68	48.27
6	Karnataka	Belgaum	887.48	16.26	555.14	131.34
7		Chamaraja Nagar	571.19	7.43	216.19	254.03
8		Chikmagalur	2,314.50	480.07	1,083.25	259.21
9		Coorg	2,078.24	236.80	1,126.39	516.86
10		Dakshina Kannada	1,445.44	244.50	586.74	452.30
11		Hassan	411.04	64.33	126.05	144.05
12		Mysore	840.16	3.80	500.62	171.92
13		Shimoga	3,892.54	197.95	1,991.21	675.51
14		Udupi	1,292.55	163.28	782.74	85.93
15		Uttara Kannada	7,090.72	179.69	4,630.77	1,290.13
16	Kerala	Idukki	4,426.63	345.63	1,858.88	1,220.48
17		Kannur	302.72	21.33	154.57	78.23
18		Kollam	917.23	99.51	471.22	218.85
19		Kottayam	154.15	5.14	48.73	39.54
20		Kozhikode	512.62	25.56	185.02	118.47
21		Malappuram	1,003.33	137.58	314.28	301.56
22		Palakkad	1,820.36	306.21	508.23	463.77
23		Pathanamthitta	1,503.92	163.10	924.90	281.92
24		Thiruvananthapuram	603.66	61.67	387.62	74.08
25		Thrissur	697.40	159.12	216.30	194.77
26		Wayanad	945.89	125.98	526.32	190.46
27	Maharashtra	Ahmednagar	467.79	0.00	50.63	76.07
28		Dhule	49.13	0.00	5.08	9.47
29		Kolhapur	2,318.97	56.97	882.22	386.31
30		Nandurbar	13.94	0.00	4.32	2.76
31		Nashik	1,429.85	0.00	190.94	332.88
32		Pune	2,734.54	0.00	647.73	664.90
33		Raigad	1,985.83	10.08	609.05	518.84
34		Ratnagiri	2,459.63	34.85	889.49	714.52
35		Sangli	206.34	0.00	88.14	25.07
36		Satara	1,689.33	115.06	491.73	344.54
37		Sindhudurg	2,019.60	43.24	733.66	505.03
38		Thane	2,455.11	0.00	503.63	606.28
39	Tamil Nadu	Coimbatore	1,464.42	339.08	577.60	312.09
40		Dindigul	883.74	179.59	285.85	230.17
41		Kanniyakumari	643.95	41.33	230.08	205.14
42		The Nilgiris	1,464.51	141.96	665.80	431.43
43		Theni	727.10	174.52	277.60	120.01
44		Tirunelveli	1,283.46	277.01	701.29	102.50
45		Virudhunagar	325.68	27.76	163.59	44.94
Total			**60,285.61**	**5,046.18**	**25,749.85**	**13,306.18**

Source: *The shape file of WGESA was received from the MoEF & CC vide letter No. 1/4/2012-RE-ESZ dated 24th May 2023.*

(in km²)

		2023 Assessment					Change in Forest Cover w.r.t ISFR 2013
Total Forest Cover	Scrub	VDF	MDF	OF	Total Forest Cover	Scrub	
380.82	0.00	118.81	110.74	143.42	372.97	1.38	-7.85
872.68	0.07	362.53	242.87	263.27	868.67	4.40	-4.01
29.23	0.00	11.92	14.07	1.36	27.35	0.00	-1.88
103.11	0.00	19.38	54.90	22.17	96.45	0.16	-6.66
240.02	0.73	54.32	124.65	32.51	211.48	1.00	-28.54
702.74	3.42	35.03	544.42	98.38	677.83	6.66	-24.91
477.65	5.35	35.68	222.40	216.44	474.52	7.62	-3.13
1,822.53	0.00	683.56	1,106.09	110.49	1,900.14	2.49	77.61
1,880.05	0.30	737.38	884.35	224.92	1,846.65	0.49	-33.40
1,283.54	0.00	470.76	624.77	200.12	1,295.65	1.09	12.11
334.43	0.00	133.10	159.94	38.85	331.89	0.07	-2.54
676.34	0.00	108.21	415.25	137.60	661.06	0.26	-15.28
2,864.67	0.04	453.33	1,880.65	456.15	2,790.13	2.38	-74.54
1,031.95	0.00	250.00	690.29	160.13	1,100.42	0.08	68.47
6,100.59	0.04	1,153.31	4,486.34	621.56	6,261.21	2.91	160.62
3,424.99	1.57	564.81	1,876.00	886.24	3,327.05	0.03	-97.94
254.13	0.00	55.15	165.76	50.88	271.79	0.00	17.66
789.58	0.00	103.73	473.91	225.68	803.32	0.00	13.74
93.41	0.00	4.63	47.97	55.85	108.45	0.00	15.04
329.05	0.00	68.44	218.71	166.11	453.26	0.44	124.21
753.42	0.84	135.76	316.64	401.00	853.40	6.45	99.98
1,278.21	36.58	390.74	474.45	433.95	1,299.14	11.49	20.93
1,369.92	0.00	165.96	904.91	307.46	1,378.33	0.97	8.41
523.37	0.00	63.93	373.74	89.11	526.78	0.08	3.41
570.19	0.00	229.20	250.46	110.95	590.61	0.00	20.42
842.76	0.51	163.33	503.52	107.99	774.84	0.61	-67.92
126.70	60.80	0.00	48.15	86.45	134.60	38.90	7.90
14.55	4.97	0.00	8.86	11.86	20.72	1.38	6.17
1,325.50	18.20	80.63	852.95	387.28	1,320.86	19.94	-4.64
7.08	0.00	0.00	3.88	2.93	6.81	0.00	-0.27
523.82	41.44	0.04	154.52	331.96	486.52	33.58	-37.30
1,312.63	170.28	0.52	675.79	553.67	1,229.98	123.63	-82.65
1,137.97	14.17	21.68	729.64	384.16	1,135.48	8.96	-2.49
1,638.86	1.33	42.25	898.02	704.70	1,644.97	2.00	6.11
113.21	4.65	46.22	46.24	20.76	113.22	6.73	0.01
951.33	19.11	166.13	481.05	288.00	935.18	22.82	-16.15
1,281.93	42.94	49.81	714.29	547.20	1,311.30	21.51	29.37
1,109.91	70.69	0.00	479.83	675.99	1,155.82	34.43	45.91
1,228.77	1.27	354.86	549.98	273.92	1,178.76	7.42	-50.01
695.61	13.63	98.96	362.49	234.27	695.72	14.29	0.11
476.55	20.48	129.07	228.14	75.05	432.26	0.61	-44.29
1,239.19	0.10	329.12	454.94	331.69	1,115.75	5.55	-123.44
572.13	14.90	140.20	250.10	164.52	554.82	13.74	-17.31
1,080.80	7.96	439.10	482.99	118.98	1,041.07	9.04	-39.73
236.29	7.81	39.71	116.96	70.09	226.76	1.95	-9.53
44,102.21	**564.18**	**8,511.30**	**24,706.62**	**10,826.07**	**44,043.99**	**417.54**	**-58.22**

2.16 Forest Cover in the North Eastern States

The north-eastern part of India, comprising eight states, namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, boasts of country's richest forest resources. It is acknowledged as one of India's four prominent biodiversity hotspots. While, covering 7.98% of the nation's land area, this region accounts for 21.08% of the total forest and tree cover in the country.

A prevalent agricultural technique in this region is known as shifting or Jhum cultivation. This method involves conversion of forest areas into agricultural areas by local communities.

The forest cover data for the north-eastern states is summarized in Table 2.9, indicating an overall decrease in forest cover (including tree cover) by 327.30 km^2.

Photo: FSI Repository

Table 2.9 Forest Cover in North Eastern States

(in km²)

State	Geographical Area	Inside RFA/GW				Outside RFA/GW					Total Forest and Tree Cover (A+B)	*Change in Forest Cover w.r.t. ISFR 2021 (Raster based, including Tree Cover)	Scrub
		VDF	MDF	OF	Total (A)	VDF	MDF	OF	Tree Cover	Total (including Tree Cover) (B)			
Arunachal Pradesh	83,743.22	19,637.05	26,699.94	11,836.97	58,173.96	1,348.27	2,915.15	3,444.19	1,201.63	8,909.24	67,083.20	-52.49	1,058.98
Assam	78,438.00	2,833.31	8,333.78	8,529.64	19,696.73	356.40	1,430.76	6,829.66	2,101.46	10,718.28	30,415.01	-83.92	240.93
Manipur	22,327.00	893.52	5,744.86	8,152.43	14,790.81	10.53	472.69	1,311.43	209.82	2,004.47	16,795.28	-62.20	973.65
Meghalaya	22,429.00	547.93	7,502.05	6,600.87	14,650.85	46.91	1,521.76	747.32	720.56	3,036.55	17,687.40	-84.07	620.41
Mizoram	21,081.00	259.83	8,438.53	8,931.24	17,629.60	1.69	197.23	161.94	567.80	928.66	18,558.26	178.42	314.54
Nagaland	16,579.00	1,156.13	3,168.30	4,195.60	8,520.03	100.25	1,293.51	2,308.68	394.02	4,096.46	12,616.49	-125.22	667.27
Sikkim	7,096.00	831.08	879.76	349.79	2,060.63	272.23	676.13	349.41	48.33	1,346.10	3,406.73	2.88	303.49
Tripura	10,486.00	393.77	3,719.84	1,242.58	5,356.19	220.66	1,210.15	797.77	247.56	2,476.14	7,832.33	-100.70	173.27
Total	**2,62,179.22**	**26,552.62**	**64,487.06**	**49,839.12**	**1,40,878.80**	**2,356.94**	**9,717.38**	**15,950.40**	**5,491.18**	**33,515.90**	**1,74,394.70**	**-327.30**	**4,352.54**

** Change in Forest Cover has been calculated from the revised figure of ISFR 2021.*

Rubber Plantation in Tripura

FSI carried out a study in the year 2019-20 on request of Tripura Forest Department to map Rubber (*Hevea brasiliensis*) plantations on wall to wall basis of the entire State using LISS-IV data along with extensive ground truth. The satellite imageries and field photographs show how large tracts of forest land have been converted into plantations. The study revealed that area under rubber plantations is 11.90% of the state's geographical area and 16.17% of state's total forest area. Among all the districts of Tripura, South Tripura has the maximum spatial extent of rubber plantations totalling 355.27 km^2. The total forest cover of the state, inside Recorded Forest Area (RFA) is 5,433 km^2, out of which 482.22 km^2 is rubber plantations which accounts for 8.88% of the RFA. Field visit photographs taken during the 18th cycle of forest cover mapping are testimony of the rapid extension of rubber plantations in the state.

Over the last decade Rubber plantations have been carried out on massive scale due to it being a fast growing species and its economic value. Rubber cultivation rapidly expanded due to the state's tropical climate and ideal growing conditions. Extensive cultivation of rubber has also led to concerns about its potential adverse impact on biodiversity, as vast areas of natural forests have been converted into monoculture plantations, impacting the ecological balance.

Photos: FSI Repository

Accuracy Assessment of Forest Cover 2.17

In remote sensing study, assessment of accuracy is required to corroborate the information retrieved from the satellite image interpretation and information collected from ground. The errors occur in image interpretation due to technological limitation and individual human perception. A team of FSI, who are not involved in mapping, assesses the errors vis-à-vis accuracy independently.

Accuracy assessment is presented in the form of an error matrix prepared by comparing agreement and disagreement between the 'Remote Sensing Based Classification' with the 'Ground Reference Data' on a class-by-class basis at randomly selected locations. The accuracy of mapping is assessed for all the 5 classes comprising of Forest Density Classes (i.e., VDF, MDF, and OF), Scrub, and Non-Forest.

The percentage of correctly classified sampling units (i.e., sum of 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 percentages of correctly classified random points out of the total number of sample points pertaining to a particular class.

2.17.1 Methodology

The sampling design and sample size are selected judiciously so that it could represent the spatial distribution of entire population. Ideally, the sampling units should be randomly selected from the entire assessment area, i.e., the country; and the ground truth data should be collected from all such points. The satellite data capture time and the NFI survey time should match with one another to remove the seasonal variations during error matrix generation.

In the present study, 6,383 number of sample points spread across the country have been selected, out of which 1,620 number of sample points are from TOF. To match the forest density between classified image and ground observed data, 1 ha buffer zone around each point has been created for one to one comparison.

2.17.2 Findings

Table 2.10 represents the detailed error matrix derived from 6,383 sample points for all 5 classes as mentioned above. It has been observed that out of 6,383 sampling points, 5,897 sampling points are found correct. Therefore, the overall accuracy in identifying forest density class through image classification technique is 92.39 %. The individual user's accuracy in classifying VDF, MDF, OF, Scrub, and NF is 88.93 %, 95.42%, 92.73%, 86.19% and 91.00% respectively. On the other hand, producer's accuracy in classifying VDF, MDF, OF, Scrub, and NF is 94.87%, 90.81%, 93.54%, 93.43% and 91.68% respectively.

Table 2.10 Error Matrix

Classification Classes	Ground Reference (based on field inventory data)						User's Accuracy (%)
	VDF	MDF	OF	Scrub	NF	Total	
VDF	426	37	10	1	5	479	88.93
MDF	14	1,731	40	2	27	1,814	95.42
OF	9	89	2,028	8	53	2,187	92.73
Scrub	0	7	12	356	38	413	86.19
NF	0	42	78	14	1,356	1,490	91.00
Total	449	1,906	2,168	381	1,479	6,383	
Producer Accuracy (%)	94.87	90.81	93.54	93.43	91.68		
Overall Accuracy	92.39%						
Overall Kappa Statistics	0.89						

Table 2.11 shows a relatively simplified error matrix. In this table, the accuracy of the satellite image interpreter is judged regarding classification of forests and non-forest area only. In the simplified error matrix classification, 6,148 sample points out of 6,383 were found to be correct. The overall accuracy is 96.32 %. The user's accuracy in identifying forest and non-forest is 97.86 % and 92.70 %, respectively; whereas, the producer's accuracy in determining forest and non-forest is 96.93% and 94.84%, respectively. In remote sensing parlance, accuracy of greater than 85% is considered as acceptable.

Table 2.11 Error Matrix (simplified) for Forest and Non-Forest Classes

Classification Classes	Ground Truth (Based on Field Inventory data)			User's Accuracy (%)
	Forest	Non-Forest	Total	
Forest	4,384	96	4,480	97.86
Non-Forest	139	1,764	1,903	92.70
Total	4,523	1,860	6,383	
Producer Accuracy (%)	96.93	94.84		
Overall Accuracy	96.32%			
Overall Kappa Statistics	0.91			

In order to authenticate the results of accuracy further, Cohen's Kappa analysis, has been performed. Kappa analysis is a multivariate analytical technique, which provides a statistic 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 systematic cause of agreement or chance cause of agreement. Any classification having kappa coefficient more than 0.6 is considered as statistically reliable.

The overall kappa values are 0.89 and 0.91 for density wise error matrix and simplified error matrix, respectively. This implies that the observed classification is not by chance, rather a systematic and robust methodological approach.

The State wise accuracy of the present assessment is given in Table 2.12.

Table 2.12 State/UT wise Accuracy Assessment

Sl. No.	Name of the State/ UT	Total Number of Plots	Sum of Diagonals	Accuracy (%)
1	Andhra Pradesh	355	321	90.42
2	Arunachal Pradesh	175	157	89.71
3	Assam	229	207	90.39
4	Bihar	126	114	90.48
5	Chhattisgarh	209	193	92.34
6	Delhi	50	44	88.00
7	Goa	96	88	91.67
8	Gujarat	265	257	96.98
9	Haryana	82	77	93.90
10	Himachal Pradesh	211	192	91.00
11	Jammu And Kashmir	182	170	93.41
12	Jharkhand	248	231	93.15
13	Karnataka	332	314	94.58
14	Kerala	151	140	92.72
15	Madhya Pradesh	385	367	95.32
16	Maharashtra	298	268	89.93
17	Manipur	112	107	95.54
18	Meghalaya	174	163	93.68
19	Mizoram	177	163	92.09
20	Nagaland	122	112	91.80
21	Odisha	379	357	94.20
22	Punjab	84	65	77.38
23	Rajasthan	280	260	92.86
24	Sikkim	119	107	89.92
25	Tamil Nadu	322	299	92.86
26	Telangana	234	215	91.88
27	Tripura	193	183	94.82
28	Uttar Pradesh	220	199	90.45
29	Uttarakhand	198	179	90.40
30	West Bengal	194	185	95.36
31	Andaman & Nicobar Islands	84	78	92.86
32	Chandigarh	5	4	80.00
33	Dadra & Nagar Haveli, and Daman & Diu	8	7	87.50
34	Lakshadweep	-	-	-
35	Puducherry	34	29	85.29
36	Ladakh	50	45	90.00
	Total	**6,383**	**5,897**	**92.39**

As regards the tree cover, the uncertainty has been calculated as State-wise Standard Error percentage (SE %), and given in Table 2.13. The SE % at the State/UTs level varies from 1.85% to 10.29%.

Table 2.13 State/UT wise Standard Error for Tree Cover

Sl. No.	Name of the State/UT	SE % for Tree Cover
1	Andhra Pradesh	2.62
2	Arunachal Pradesh	2.79
3	Assam	2.70
4	Bihar	4.66
5	Chhattisgarh	2.69
6	Delhi	4.72
7	Goa	4.51
8	Gujarat	5.56
9	Haryana	4.61
10	Himachal Pradesh	4.96
11	Jharkhand	2.81
12	Karnataka	3.03
13	Kerala	4.18
14	Madhya Pradesh	2.01
15	Maharashtra	2.81
16	Manipur	6.84
17	Meghalaya	7.17
18	Mizoram	7.36
19	Nagaland	5.07
20	Odisha	4.62
21	Punjab	4.72
22	Rajasthan	1.85
23	Sikkim	6.95
24	Tamil Nadu	3.58
25	Telangana	3.75
26	Tripura	5.52
27	Uttar Pradesh	1.87
28	Uttarakhand	3.78
29	West Bengal	3.95
30	Andaman & Nicobar Islands	10.29
31	Chandigarh	5.39
32	Dadra & Nagar Haveli and Daman & Diu*	-
33	Jammu & Kashmir	4.46
34	Ladakh*	-
35	Lakshadweep*	-
36	Puducherry	5.72
	Total	**3.60**

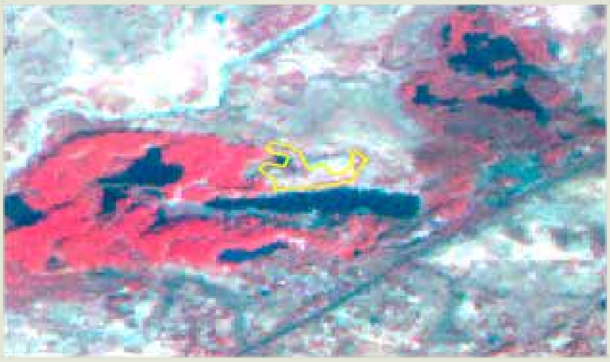
**Standard error is not given due to inadequate data*

Few examples of satellite data, field photographs and high resolution images showing increase/ decrease in the forest cover is given in figure 2.10 to 2.13

ISFR 2021

ISFR 2023

Figure 2.10 Increase in Forest Cover due to Natural Regeneration of Mangrove forest in Balasore District, Odisha



ISFR 2021

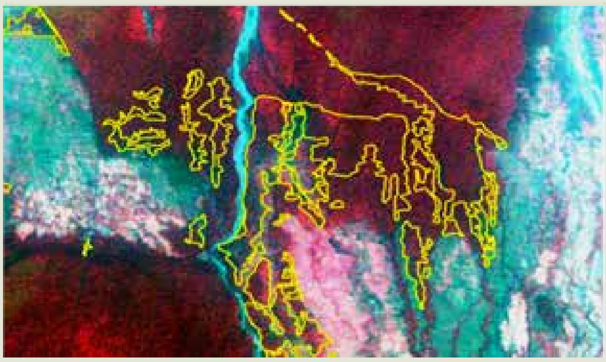
ISFR 2023

Figure 2.11 Increase in Forest Cover due to Plantations in Anuppur District, Madhya Pradesh

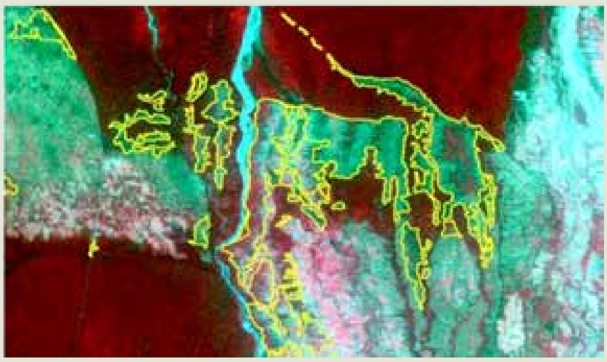
ISFR 2021

ISFR 2023

Figure 2.12 Decrease in Forest Cover due to Aquaculture in Krishna District, Andhra Pradesh



ISFR 2021



ISFR 2023

Figure 2.13 Decrease in Forest Cover due to Jhum/Shifting Cultivation in Chirang District, Assam

Forest Cover in Major Mega Cities 2.18

India has six major mega cities (Figure 2.14) as of September, 2023. As per the United Nations' criteria of urban agglomerations, a Mega city has a population of 10 million or more. The major mega cities are Bengaluru, Chennai, Delhi, Kolkata, Hyderabad, and Mumbai. Ahmedabad is also a rapidly growing city, on the verge of becoming a major mega city.

The forest cover in major mega cities can vary widely depending on the city's location, policies, and environmental priorities. Some cities have significant green spaces and forested areas, while others have limited greenery due to urbanization (Figure 2.15 to 2.21).

Figure 2.14 Map showing Locations of Mega Cities of India

According to the current assessment, the total forest cover in these cities is 511.81 km^2, which is 10.26% of the total geographical area (as per shape file) of the cities.

From the current assessment, it can be seen that Delhi has the largest forest cover (194.15 km^2) followed by Mumbai (110.84 km^2) and Bengaluru (89.61 km^2) (Table 2.14). There is an increase of 2.09 km^2 of forest cover during the two assessments. Maximum gain in forest cover is seen in Ahmedabad (5.48 km^2) followed by Bengaluru (0.59 km^2), while maximum loss in forest cover is seen in Chennai (2.64 km^2) and Hyderabad (1.61 km^2) cities respectively.

Table 2.14 Change in Forest Cover in major Mega Cities between ISFR 2021 and ISFR 2023

Name	State	Area as per digitized boundary*	ISFR 2021						ISFR 2023						Forest cover change between ISFR 2021 and ISFR 2023
			VDF	MDF	OF	Total Forest Cover	% of total Forest cover wrt area of digitized boundary	Scrub	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	0.00	1.73	13.16	14.89	3.27	3.18	5.48
Bengaluru	Karnataka	1,307.35	0.00	12.66	76.36	89.02	6.81	14.87	0.00	12.28	77.33	89.61	6.85	13.69	0.59
Chennai	Tamil Nadu	430.07	0.00	7.66	15.04	22.70	5.28	1.77	0.00	7.37	12.69	20.06	4.66	1.77	-2.64
Delhi	Delhi	1,540.63	6.74	56.34	131.15	194.23	12.61	0.45	6.49	53.40	134.26	194.15	12.60	2.39	-0.08
Hyderabad	Telangana	634.18	0.00	17.68	64.13	81.81	12.90	29.96	0.00	17.03	63.17	80.20	12.65	28.43	-1.61
Kolkata	West Bengal	186.55	0.00	0.10	1.67	1.77	0.95	0.00	0.00	0.10	1.96	2.06	1.10	0.00	0.29
Mumbai	Maharashtra	435.91	0.00	51.13	59.65	110.78	25.41	0.00	0.00	50.85	59.99	110.84	25.43	0.00	0.06
TOTAL		**4,990.01**	**6.74**	**147.16**	**355.82**	**509.72**	**10.21**	**51.90**	**6.49**	**142.76**	**362.56**	**511.81**	**10.26**	**49.46**	**2.09**

**Digitized boundaries as provided by NIC, Delhi in 2021*

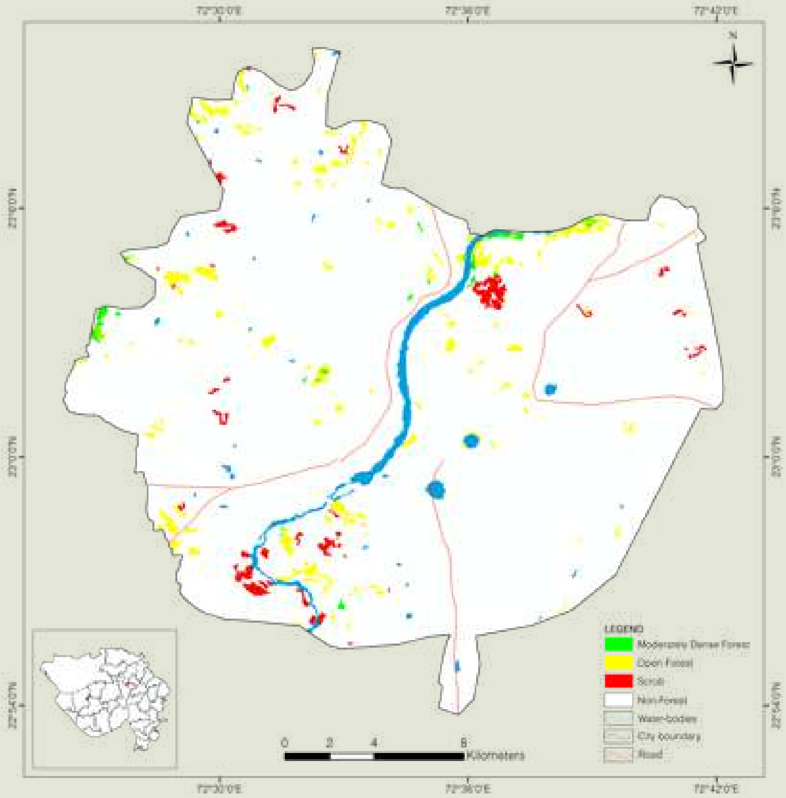


Figure 2.15 Map showing Forest Cover in Ahmedabad

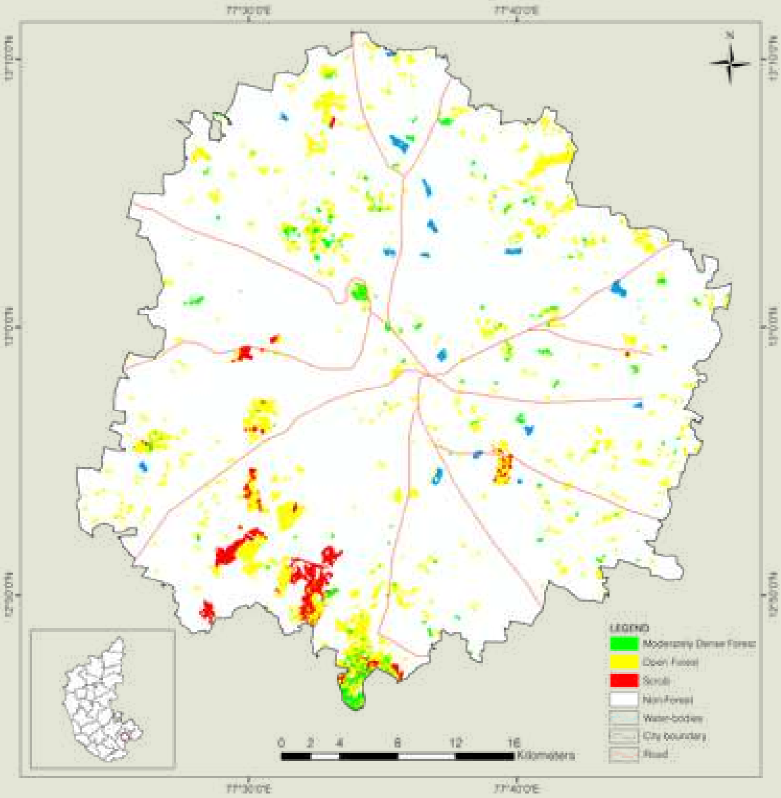


Figure 2.16 Map showing Forest Cover in Bengaluru

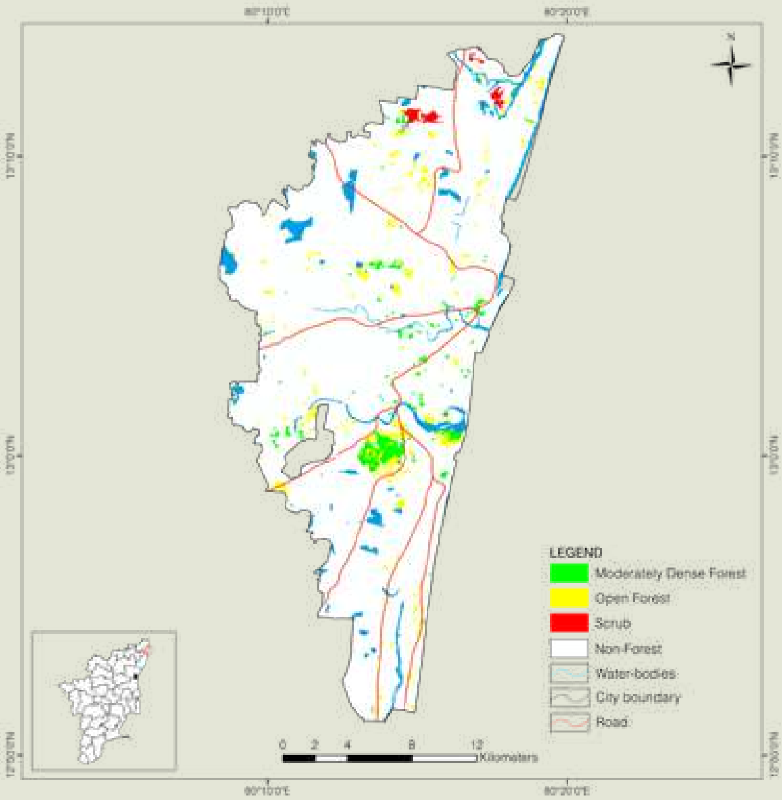


Figure 2.17 Map showing Forest Cover in Chennai

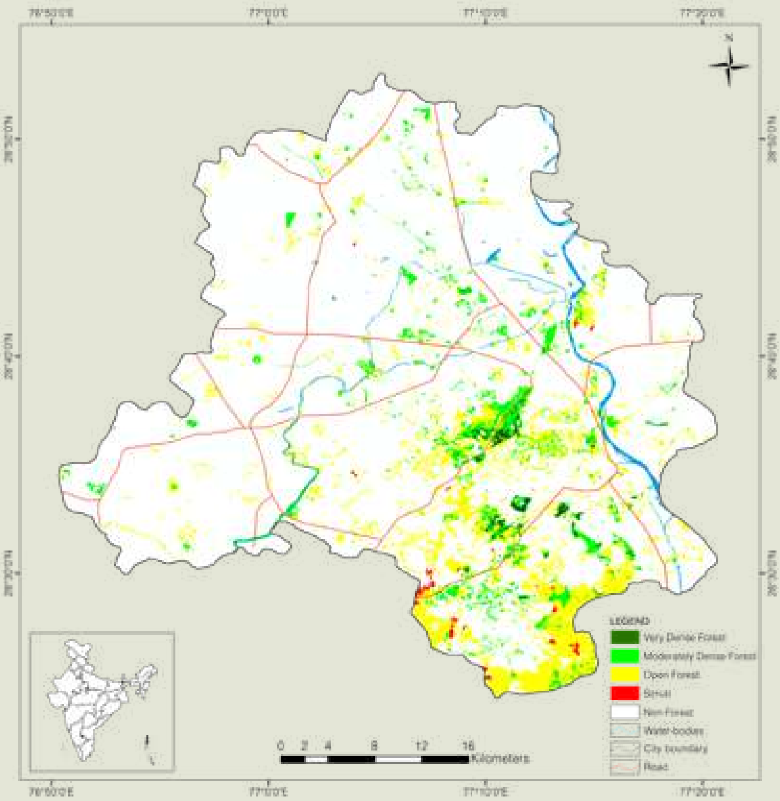


Figure 2.18 Map showing Forest Cover in Delhi

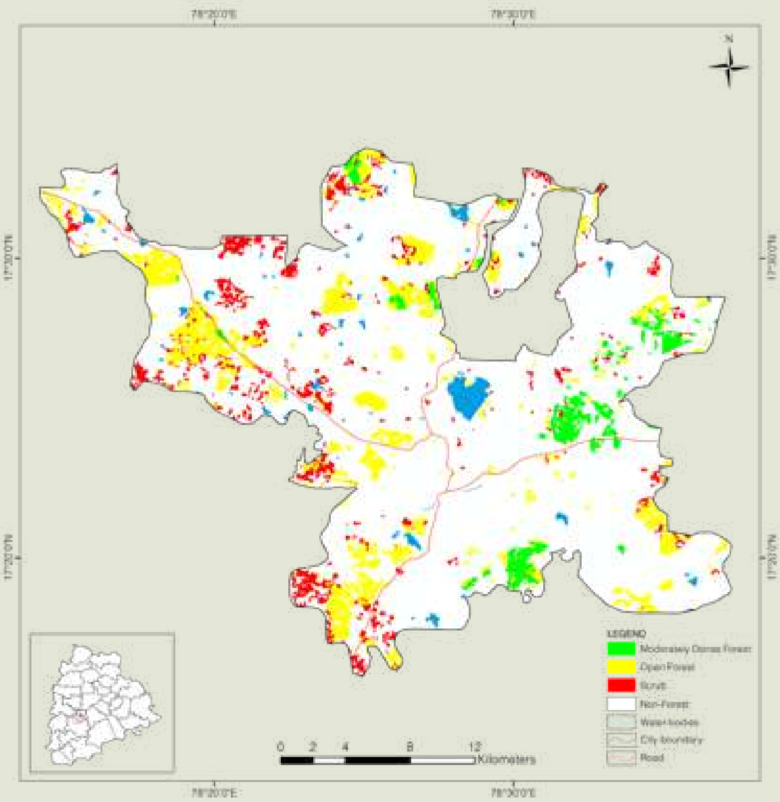


Figure 2.19 Map showing Forest Cover in Hyderabad

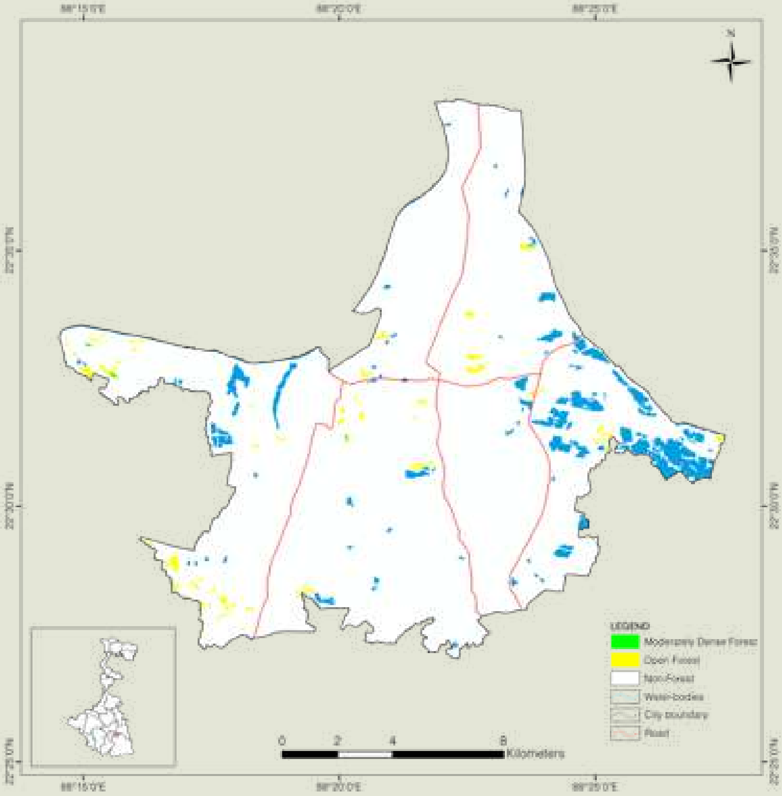


Figure 2.20 Map showing Forest Cover in Kolkata

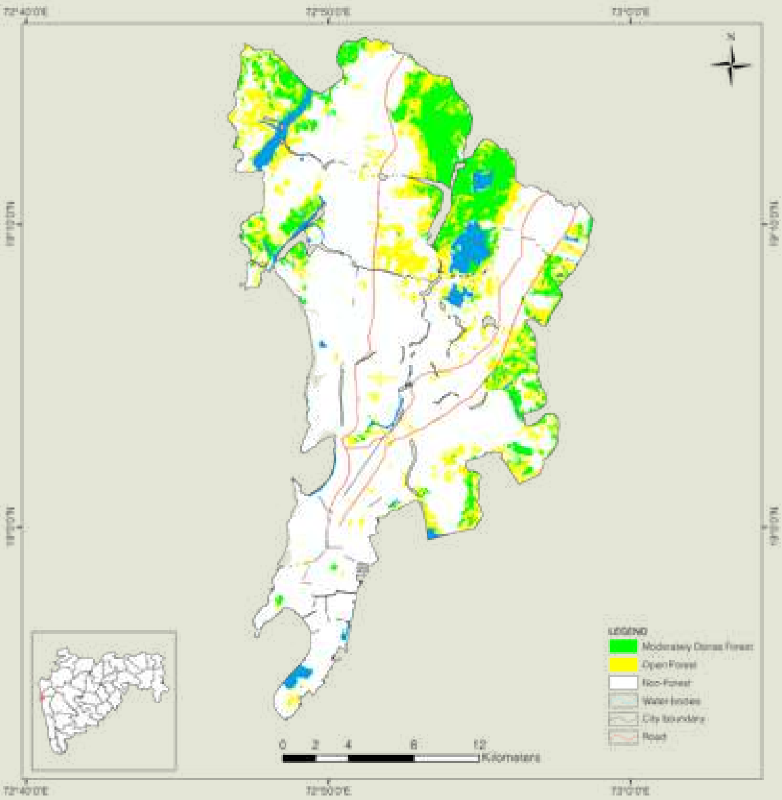


Figure 2.21 Map showing Forest Cover in Mumbai

2.19 Forest Cover in Different Altitude Zones

The zonation of the forest cover at different altitudes is of special ecological significance from planning point of view for hill states. The DEM data of the SRTM, at 30 m resolution, was used to identify the forest cover at various altitude zones in all the States and Union Territories. The altitude data were categorized into six altitude classes as follows: 0–500 m, 500–1000 m, 1000–2000 m, 2000–3000 m, 3000–4000 m, and above 4000 m for the purpose of the analysis. The altitude zone-wise forest cover of the country is given in **Annexure I.**

2.20 Forest Cover in Different Slope Classes

Forests play an important role in the stability of mountain ecosystems. Mountain slopes that are well covered with forests are less prone to soil erosion and landslides. Therefore, forest coverage on hill slopes is a good indicator for soil stability, state of soil and water conservation in an ecosystem. The tables below show forest cover on different slope classes according to SRTM 30 m resolution. Tracking this parameter intermittently could be an efficient way of monitoring the health of ecosystems in various states. The extent of forest on slopes can also be an important input in planning the treatment of the catchment area. **Annexure II** shows the details of Forest Cover at different predefined slope intervals.

2.21 Area of Tea, Coffee and Rubber Plantations in India

The classification scheme adopted by FSI makes no distinction between the origins of tree crops, whether they are naturally occurring or manmade, and includes all types of lands regardless of their ownership, land use, or legal status under forest cover. Consequently, this category encompasses various types of lands, such as private and community plantations, plantations along roads, railways, and canals, as well as rubber, tea, and coffee plantations, all of which are considered part of the overall forest cover.

To provide a more comprehensive assessment of forest cover, it was envisaged to provide forest cover in Coffee, Tea, Rubber plantation areas as well as areas under different State Forest Development Corporations. Hence letters were addressed to the heads of these organizations for providing their boundaries. However, no boundaries have been received for plantations (tea, coffee, rubber, etc.) from any of the organizations like Tea Board, Coffee Board and the State Forest Development Corporations, except for Goa (two plantation sites) (Table 2.15) and from Telangana State Forest Development Corporation (TSFDC) (Table 2.16). Their forest cover change analysis is given below

Table 2.15 Rubber Plantation in the State of Goa

(in km²)

Plantation Site	Forest Density Class	Forest Cover		Change w.r.t. previous assessment
		ISFR 2021	ISFR 2023	
Talsai	VDF	0.15	0.14	-0.01
	MDF	0.36	0.35	-0.01
	OF	0.77	0.79	0.02
Dargini	VDF	0.00	0.00	0.00
	MDF	0.01	0.01	0.00
	OF	0.03	0.03	0.00
Total		**1.32**	**1.32**	**0.00**

** Source: Goa Forest Development Corporation*

Table 2.16 Plantation sites in the State of Telangana

(in km²)

Forest Density Class	Forest Cover		Change w.r.t. previous assessment
	ISFR 2021	ISFR 2023	
VDF	0.67	0.67	0.00
MDF	70.33	68.05	-2.28
OF	160.32	167.09	6.77
Total	**231.32**	**235.81**	**4.49**

** Source: Telangana State Forest Development Corporation(TSFDC)*

2.22 Identification of potential areas for increase in Carbon Sequestration through Forestry Interventions

The Recorded Forest Area (RFA) invariably has forest cover of varying densities, besides having Scrub and non-forest areas. In order to increase the forest cover, and thereby increasing the sequestered Carbon, the following two approaches need to be considered –

1. Approach – 1: The areas with no forest cover inside RFA are already known. In these areas the plantable areas may be identified and afforested. Identification of plantable areas as per this approach is in progress.
2. Approach – 2: Those areas, which had higher canopy density in the past, and have degraded in the past one decade (2011-2021) have been identified. It is anticipated that these areas are available for upgradation of density by enrichment planting.

As per Approach – 2, the areas (polygons) have been identified following a systematic process. The change polygons have been converted from raster to vector, in order to achieve better overlay with other GIS layers of the states and for enriching the vector layer (change polygons) with more attribute values.

The difference between the area of raster and vector data area after interconversion arises due to the inherent nature of these data formats and the approximations that occur during conversion results in slight variation in the area figures. As such the figures as shown in table 2.5 and 2.17 are not comparable with each other.

2.22.1 Change from VDF and MDF to OF

As seen in Table 2.17 below, an area of 40,709.28 km^2 has been identified where degradation of density has taken place between 2011 and 2021, from VDF and MDF to OF.

Table 2.17 Identification of lands where canopy density has degraded from VDF & MDF to OF inside RFA

Area	Number of Polygons	Total area of polygons (km²)
0-10 ha	50,38,636	31,646.37
10-50 ha	32,557	5,834.37
More Than 50 ha	2,727	3,228.54
Total	**50,73,920**	**40,709.28**

Photo: FSI Repository

The same information has also been provided state wise in Table 2.18

Table 2.18 State/UT wise information on land where canopy density has degraded from VDF,MDF to OF inside RFA

(in km²)

Sl. No.	State/UT	0-10 ha		10-50 ha		More Than 50 ha		Total	
		Number of Poly-gons	Area	Number of Poly-gons	Area	Number of Poly-gons	Area	Number of Poly-gons	Area
1	Andhra Pradesh	1,92,745	1,339.13	1,119	192.62	87	123.91	1,93,951	1,655.66
2	Arunachal Pradesh	5,76,536	3,722.71	2,365	382.81	112	165.98	5,79,013	4,271.50
3	Assam	2,54,973	1,406.67	969	167.31	95	125.94	2,56,037	1,699.92
4	Bihar	31,634	274.96	696	130.52	45	57.66	32,375	463.14
5	Chhattisgarh	4,13,398	2,546.52	1,849	318.63	146	138.89	4,15,393	3,004.04
6	Delhi	517	1.44	0	0.00	0	0.00	517	1.44
7	Goa	11,640	108.18	71	10.59	1	0.54	11,712	119.31
8	Gujarat	1,45,454	475.97	137	23.76	18	23.29	1,45,609	523.02
9	Haryana	2,718	21.32	54	9.80	3	3.00	2,775	34.12
10	Himachal Pradesh	67,264	539.81	695	123.58	36	29.82	67,995	693.21
11	Jharkhand	1,61,997	824.50	392	67.82	27	24.95	1,62,416	917.27
12	Karnataka	80,701	728.30	1,465	281.10	153	149.74	82,319	1,159.14
13	Kerala	66,742	663.55	1,509	268.20	126	148.05	68,377	1,079.80
14	Madhya Pradesh	8,21,849	4,485.09	2,004	326.19	44	44.21	8,23,897	4,855.48
15	Maharashtra	4,25,640	1,867.31	757	139.04	49	49.21	4,26,446	2,055.56
16	Manipur	1,66,484	1,199.69	1,250	199.87	36	34.47	1,67,770	1,434.03
17	Meghalaya	1,94,494	1,525.03	1,479	242.68	32	23.75	1,96,005	1,791.46
18	Mizoram	2,60,015	1,291.46	1,607	281.41	115	102.59	2,61,737	1,675.46
19	Nagaland	90,979	725.23	807	132.20	24	20.35	91,810	877.78
20	Odisha	2,93,019	2,029.99	2,909	532.60	239	352.90	2,96,167	2,915.49
21	Punjab	12,645	62.77	49	9.33	9	7.57	12,703	79.67
22	Rajasthan	96,256	649.69	979	185.15	87	88.79	97,322	923.63
23	Sikkim	9,144	91.87	250	50.24	22	22.29	9,416	164.40
24	Tamil Nadu	78,002	746.62	2,045	399.29	268	317.01	80,315	1,462.92
25	Telangana	1,45,013	1,176.60	2,278	446.69	380	521.87	1,47,671	2,145.16
26	Tripura	75,632	360.09	268	48.26	23	21.72	75,923	430.07
27	Uttar Pradesh	49,671	379.80	1,076	219.38	180	205.97	50,927	805.15
28	Uttarakhand	1,08,092	912.84	1,592	295.92	170	179.10	1,09,854	1,387.86
29	West Bengal	45,795	462.88	1,272	243.23	139	170.80	47,206	876.91
30	Andaman & Nicobar	6,883	62.50	123	23.78	17	23.77	7,023	110.05
31	Chandigarh	122	0.38	0	0.00	0	0.00	122	0.38
32	DNH and Daman & Diu	4,353	14.74	39	6.90	10	15.09	4,402	36.73
33	Jammu and Kashmir	1,48,009	946.04	438	72.43	32	33.01	1,48,479	1,051.49
34	Ladakh	220	2.69	14	3.04	2	2.30	236	8.03
35	Puducherry	0	0.00	0	0.00	0	0.00	0	0.00
	Total	**50,38,636**	**31,646.37**	**32,557**	**5,834.37**	**2,727**	**3,228.54**	**50,73,920**	**40,709.28**

The information for the UT of Lakshadweep has not been provided as there is no RFA.

2.22.2 Change from VDF, MDF and OF to Scrub

Degradation from very dense forest, moderately dense forest, and open forest to scrub has also been studied between ISFR 2011 & ISFR 2021, and a total of 3,69,376 polygons having an area of 5,573.02 km^2 have been identified under three different area classes – 0 to 10 ha, 10 to 50 ha, and >50 ha, the details of which are given in Table 2.19

Table 2.19 Identification of lands where canopy density has degraded from VDF, MDF, OF to Scrub Inside RFA

Area	Number of Polygons	Total area of polygons (km²)
0-10 ha	3,60,510	2,899.59
10-50 ha	7,857	1,529.51
More Than 50 ha	1,009	1,143.92
Total	**3,69,376**	**5,573.02**

The state-wise information on land where canopy density has degraded from VDF, MDF, OF to Scrub is given in Table 2.20

Photo: FSI Repository

Table 2.20 State/UT wise information on land where canopy density has degraded from VDF, MDF, OF to Scrub inside RFA

(in km²)

Sl. No.	State/UT	0-10 ha		10-50 ha		More Than 50 ha		Total	
		Number of Poly-gons	Area	Number of Poly-gons	Area	Number of Poly-gons	Area	Number of Poly-gons	Area
1	Andhra Pradesh	61,538	500.45	1,355	267.99	183	223.82	63,076	992.26
2	Arunachal Pradesh	17,526	165.73	350	64.60	17	11.20	17,893	241.53
3	Assam	2,607	22.82	80	17.91	9	7.43	2,696	48.16
4	Bihar	3,040	31.50	131	27.37	16	15.05	3,187	73.92
5	Chhattisgarh	13,295	77.90	133	24.32	16	13.18	13,444	115.40
6	Delhi	1	0.03	0	0.00	0	0.00	1	0.03
7	Goa	0	0.00	0	0.00	0	0.00	0	0.00
8	Gujarat	9,400	60.88	222	45.60	35	37.03	9,657	143.51
9	Haryana	1,187	10.81	32	5.61	1	0.67	1,220	17.09
10	Himachal Pradesh	1,868	17.09	29	4.53	0	0.00	1,897	21.62
11	Jharkhand	4,583	30.92	61	11.18	4	4.09	4,648	46.19
12	Karnataka	20,012	176.49	483	96.24	124	259.99	20,619	532.72
13	Kerala	750	6.95	18	3.56	5	4.24	773	14.75
14	Madhya Pradesh	39,959	241.89	248	51.24	50	53.31	40,257	346.44
15	Maharashtra	8,951	77.52	199	35.78	9	6.92	9,159	120.22
16	Manipur	22,380	188.09	674	133.50	77	67.29	23,131	388.88
17	Meghalaya	33,927	265.38	474	86.28	62	63.19	34,463	414.85
18	Mizoram	60	0.37	2	0.35	1	0.61	63	1.33
19	Nagaland	17,590	150.32	558	112.75	67	58.42	18,215	321.49
20	Odisha	44,564	358.08	952	181.52	110	112.17	45,626	651.77
21	Punjab	155	1.68	5	1.09	0	0.00	160	2.77
22	Rajasthan	22,553	203.32	865	172.00	112	98.39	23,530	473.71
23	Sikkim	4,127	41.21	111	20.07	10	7.31	4,248	68.59
24	Tamil Nadu	6,631	67.15	221	42.99	33	36.69	6,885	146.83
25	Telangana	9,385	78.98	230	43.30	27	28.84	9,642	151.12
26	Tripura	741	5.38	21	4.08	1	0.61	763	10.07
27	Uttar Pradesh	5,380	49.81	178	33.09	20	16.54	5,578	99.44
28	Uttarakhand	2,347	20.72	74	13.60	8	5.58	2,429	39.90
29	West Bengal	2,293	21.47	101	19.45	7	5.62	2,401	46.54
30	Andaman & Nicobar	27	0.31	1	0.10	0	0.00	28	0.41
31	Chandigarh	4	0.05	0	0.00	0	0.00	4	0.05
32	DNH and Daman & Diu	84	0.51	4	0.73	1	2.51	89	3.75
33	Jammu and Kashmir	3,436	24.50	37	6.53	3	2.61	3,476	33.64
34	Ladakh	109	1.28	8	2.15	1	0.61	118	4.04
35	Puducherry	0	0.00	0	0.00	0	0.00	0	0.00
	Total	**3,60,510**	**2,899.59**	**7,857**	**1,529.51**	**1,009**	**1,143.92**	**3,69,376**	**5,573.02**

The information for the UT of Lakshadweep has not been provided as there is no RFA.

2.22.3 Change from VDF, MDF, OF and Scrub to Non Forest

A total of 45,69,420 polygons having an area of 46,707.11 km^2 have been identified under three different area classes – 0 to 10 ha, 10 to 50 ha, and >50 ha for the period of ISFR 2011 to ISFR 2021, in which VDF, MDF, OF, scrub has been degraded to NF. The details of which are given in Table 2.21.

Table 2.21 Identification of lands where canopy density has degraded from VDF, MDF, OF, Scrub to Non Forest inside RFA

Area	Number of Polygons	Total area of polygons (km^2)
0-10 ha	45,12,581	31,709.83
10-50 ha	52,178	9,531.09
More Than 50 ha	4,661	5,466.19
Total	**45,69,420**	**46,707.11**

The state-wise information on land where canopy density has degraded from VDF, MDF, OF, Scrub to Non Forest is given in Table 2.22.

Photo: FSI Repository

Table 2.22 State/UT wise information on land where canopy density has degraded from VDF, MDF, OF to Non Forest inside RFA

(in km²)

Sl. No.	State/UT	0-10 ha		10-50 ha		More Than 50 ha		Total	
		Number of Poly-gons	Area	Number of Poly-gons	Area	Number of Poly-gons	Area	Number of Poly-gons	Area
1	Andhra Pradesh	1,97,832	1,679.80	4,323	823.30	404	410.03	2,02,559	2,913.13
2	Arunachal Pradesh	1,98,836	1,532.87	1,975	351.77	138	142.98	2,00,949	2,027.62
3	Assam	1,48,269	1,244.76	1,862	329.36	107	129.77	1,50,238	1,703.89
4	Bihar	15,835	162.34	497	95.88	37	39.81	16,369	298.03
5	Chhattisgarh	3,77,377	2,343.86	2,467	410.12	93	79.80	3,79,937	2,833.78
6	Delhi	1,294	4.56	1	0.11	0	0.00	1,295	4.67
7	Goa	6,542	51.72	26	3.29	0	0.00	6,568	55.01
8	Gujarat	1,71,245	695.53	919	169.92	75	74.05	1,72,239	939.50
9	Haryana	3,202	22.33	44	8.62	0	0.00	3,246	30.95
10	Himachal Pradesh	1,68,197	1,099.95	686	107.65	16	9.64	1,68,899	1,217.24
11	Jharkhand	1,44,014	813.63	867	152.72	38	27.36	1,44,919	993.71
12	Karnataka	1,17,359	1,072.27	2,185	398.14	179	165.81	1,19,723	1,636.22
13	Kerala	62,555	647.33	1,457	260.58	83	78.94	64,095	986.85
14	Madhya Pradesh	6,53,493	3,994.77	5,448	980.30	407	378.15	6,59,348	5,353.22
15	Maharashtra	6,09,498	3,314.28	3,165	546.04	194	192.65	6,12,857	4,052.97
16	Manipur	75,275	667.81	1,801	348.35	219	207.80	77,295	1,223.96
17	Meghalaya	1,09,240	928.13	1,123	180.69	21	14.65	1,10,384	1,123.47
18	Mizoram	1,36,202	953.57	2,474	483.39	548	892.81	1,39,224	2,329.77
19	Nagaland	66,359	552.41	1,197	233.25	125	114.61	67,681	900.27
20	Odisha	2,12,264	1,534.63	1,910	322.30	57	43.20	2,14,231	1,900.13
21	Punjab	7,324	37.98	26	4.70	0	0.00	7,350	42.68
22	Rajasthan	2,11,078	1,588.55	3,880	749.21	505	558.67	2,15,463	2,896.43
23	Sikkim	14,027	128.33	347	69.79	70	114.63	14,444	312.75
24	Tamil Nadu	87,810	831.49	1,882	347.99	116	98.46	89,808	1,277.94
25	Telangana	1,70,449	1,397.47	3,516	675.18	474	557.64	1,74,439	2,630.29
26	Tripura	60,836	275.55	120	19.11	2	2.12	60,958	296.78
27	Uttar Pradesh	80,307	600.57	1,533	294.46	206	240.68	82,046	1,135.71
28	Uttarakhand	1,04,791	889.54	1,642	293.79	92	83.05	1,06,525	1,266.38
29	West Bengal	56,343	491.75	1,035	185.10	59	53.08	57,437	729.93
30	Andaman & Nicobar	24,699	181.25	171	28.20	7	6.70	24,877	216.15
31	Chandigarh	228	0.75	0	0.00	0	0.00	228	0.75
32	DNH and Daman & Diu	4,631	21.31	11	1.59	1	0.77	4,643	23.67
33	Jammu and Kashmir	2,07,932	1,858.99	3,187	574.70	249	235.82	2,11,368	2,669.51
34	Ladakh	7,204	89.45	401	81.49	139	512.51	7,744	683.45
35	Puducherry	34	0.30	0	0.00	0	0.00	34	0.30
	Total	**45,12,581**	**31,709.83**	**52,178**	**9,531.09**	**4,661**	**5,466.19**	**45,69,420**	**46,707.11**

The information for the UT of Lakshadweep has not been provided as there is no RFA.

2.22.4 Summary of Findings

It can be concluded that the total area available for density upgradation is approximately 92,989 km^2, with a Carbon sequestration potential of 636.50 Million Tonnes

- Total area available for upgradation of density from OF to MDF is 40,709 km^2
- Total area available for upgradation of density from Scrub to OF is 5,573 km^2
- Total area available for upgradation of density from Non Forest to OF is 46,707 km^2

Its breakup is given below:

Degradation Category	Area available (km²)	Upgradation category	Additional Carbon Sequestration Potential (Million Tonnes)
VDF to OF	3,484	OF to MDF	16.04
MDF to OF	37,225	OF to MDF	171.34
VDF to Scrub	75	Scrub to OF	0.58
MDF to Scrub	1,056	Scrub to OF	8.16
OF to Scrub	4,442	Scrub to OF	34.33
VDF to Non Forest	1,816	NF to OF	15.79
MDF to Non Forest	14,073	NF to OF	122.34
OF to Non Forest	25,304	NF to OF	219.98
Scrub to Non Forest	5,514	NF to OF	47.94
Grand Total	**92,989**		**636.50**

CHAPTER
03
Mangrove Cover

Photo: Arijit Banerjee, IFS

Photo: Anant Shukla

03

MANGROVE COVER

Introduction 3.1

'Mangrove' is a term used to describe a community of salt-tolerant plants that thrive in tropical and sub-tropical intertidal regions around the world. These plants serve as a natural barrier against ocean dynamics along coastlines. The range of occurrence of these plant communities spans from 30° North to 30° South latitude. These plants thrive in areas with high rainfall, typically ranging from 2,100 to 6,400 mm (Kathiresan and Qasim, 2005)[1]. Mangrove species are considered facultative halophytes, meaning they can tolerate saltwater ecologically while requiring freshwater physiologically. To survive in waterlogged soils, high salinity, and the frequent challenges of cyclonic storms and tidal surges, mangrove species have developed various adaptations in their morphology, anatomy, and physiology.

Mangroves, second only to coral reef ecosystems, are regarded as one of the most significant providers of ecosystem services for coastal communities. These unique coastal forests deliver a wide range of ecosystem goods and services, including essential protection to the tropical and subtropical coastlines worldwide. Recent research has unveiled additional valuable functions of mangroves, including their capacity to act as buffers against ocean acidification and coastal eutrophication, as well as their role as repositories for micro-plastics, further underscoring their ecological significance.

Mangroves also foster rich biodiversity, both in plant and animal life, while offering a diverse array of resources to the communities residing along these coasts. Large populations, primarily in rural areas, rely on mangrove ecosystems for various livelihood activities that depend on biomass resources. In recent years, the role of mangroves in carbon storage and fisheries production also has garnered substantial recognition among the scientific community and policymakers.

Global and National Status of Mangrove 3.2

3.2.1 Global Status

In Global Forest Resources Assessment (FRA 2020), the FAO examined worldwide mangrove coverage, revealing that mangrove forests span 14.72 Mha across 113 countries. This distribution is notably skewed. South and Southeast Asia dominate, accounting for 36.2% (5.33 Mha) of global mangrove cover, followed by South America with 2.12 Mha, Western and Central Africa at 2.30 Mha, North and Central America at 2.55 Mha, and Oceania with 1.26 Mha. The global status of mangroves as discussed above is summarized in Table 3.1.

[1] Kathiresan K. and Qasim S.Z. (2005) Biodiversity of Mangrove Ecosystems, Hindustan Publishing Corporation (India) New Delhi. pp 10-11, 19

Table 3.1 Global Status of Mangrove

Region/Sub-region	Mangrove area ('000 ha)				Annual change ('000 ha/yr)		
	1990	2000	2010	2020	1990 - 2000	2000 - 2010	2010 - 2020
Eastern and Southern Africa	929	902	883	905	-2.7	-1.9	2.2
Northern Africa	34	31	32	31	-0.3	0.1	-0.1
Western and Central Africa	2,436	2,400	2,349	2,304	-3.6	-5.1	-4.5
Total Africa	**3,398**	**3,332**	**3,264**	**3,240**	**-6.6**	**-6.9**	**-2.3**
East Asia	24	22	25	32	-0.2	0.3	0.7
South and Southeast Asia	6,117	6,108	5,713	5,330	-0.8	-39.6	-38.3
Western and Central Asia	190	190	190	184	0.0	0.0	-0.7
Total Asia	**6,331**	**6,320**	**5,928**	**5,545**	**-1.0**	**-39.3**	**-38.2**
Total Europe	0	0	0	0	0	0	0
Caribbean	787	789	774	891	0.2	-1.6	11.7
Central America	492	482	483	466	-1.0	0.1	-1.8
North America	1,152	1,167	1,190	1,195	1.5	2.3	0.5
Total North and Central America	**2,431**	**2,439**	**2,447**	**2,552**	**0.8**	**0.8**	**10.5**
Total Oceania	**1,447**	**1,150**	**1,314**	**1,255**	**-29.6**	**16.4**	**-5.9**
Total South America	**2,152**	**2,050**	**1,976**	**2,124**	**-10.2**	**-7.4**	**14.8**
WORLD	**15,759**	**15,292**	**14,928**	**14,717**	**-46.7**	**-36.3**	**-21.2**

Source: FRA 2020, FAO

According to the FAO's 2020 report, the global mangrove area witnessed a decline of approximately 1.04 Mha between 1990 and 2020. Interestingly, the rate of this reduction demonstrated a significant slowdown over the course of three decades. Initially, during 1990-2000, the annual loss stood at 46,700 ha, which subsequently decreased to 36,300 ha per year in 2000-2010. The most recent decade, from 2010-2020, saw the rate further drop to 21,200 ha annually. There have been substantial gains, particularly in river mouths and deltas.

Contrary to above, an alarming trend emerged in Asia, where the average annual rate of mangrove loss surged dramatically. In the earlier period of 1990-2000, the region experienced an average loss of 1,030 ha per year. In contrast, during the 2010-2020 span, Asia faced a considerable loss of 3,83,000 ha, primarily attributed to Indonesia, which reported an annual average loss of 6,800 ha in 1990-2000, surging to 21,100 ha per year in the most recent decade. This increased rate of decline underscores the urgency of addressing mangrove conservation and restoration efforts in Asia.

The primary driver of mangrove loss continues to be the conversion of mangrove areas for aquaculture and agriculture purposes, leading to the transformation of 2,193.92 km^2 of mangroves between 2000 and 2016. Erosion is the second most significant cause of mangrove loss, resulting in the disappearance of 927.87 km^2 of mangroves during the same period (Adame et al., 2021)[2].

[2] Adame M.F., Connolly R.M., Turschwell M.P., Lovelock C.E., Fatoyinbo T., Lagomasino D., Goldberg L.A., Holdorf J., Friess D.A., Sasmito S.D., Sanderman J., Sievers M., Buelow C., Kauffman J.B., Bryan-Brown D. and Brown C.J.(2021). Future carbon emissions from global mangrove forest loss. *Global Change Biology*. **27**(12):2856-2866. doi: 10.1111/gcb.15571. Epub 2021 Mar 17. PMID: 33644947; PMCID: PMC8251893.

3.2.2 National Status of Mangroves

The mangrove ecosystem, teaming with a multitude of plant and animal species, serves as a vital reservoir of biodiversity. India stands as the world's third richest nation in terms of mangrove diversity. According to the Champion & Seth (1968)[3] Classification, mangroves are categorized under Type Group-4, which includes Littoral & Swamp Forests. Within this classification, mangroves find their place in various types: 4A/L1 Littoral forest, 4B/TS1 Mangrove scrub, 4B/TS2 Mangrove forest, 4B/TS3 Saltwater mixed forest, and 4B/TS4 Brackish water mixed forest. These classifications highlight the ecological significance of mangroves and their vital role in India's diverse landscape.

In India, the entire mangrove habitat is broadly divided into three main regions: (i) the East Coast, (ii) the West Coast, and (iii) the islands of Andaman & Nicobar, along with the Lakshadweep atoll (Dagar et al., 1991)[4]. The East Coast has an impressive 40 mangrove species spanning 14 families and 22 genera. On the West Coast, there are 27 species from 11 families and 16 genera. The Andaman & Nicobar Islands host 38 species from 13 families and 19 genera. Lakshadweep has a limited presence of Mangroves, represented by 3 species. Among the 13 States/Union Territories, the highest mangrove diversity is found in the Andaman & Nicobar Islands, where unique species like *Rhizophora lamarckii, Lumnitzera littorea, Sonneratia ovata, S. lanceolata, S. urama, and S. gulngai* thrive exclusively (Ragavan *et al.*, 2021)[5].

India harbors two globally threatened mangrove species, *Heritiera fomes* and *Sonneratia griffithii*, out of a total of 11 species listed on the IUCN Red List. These two species are on the brink of local extinction due to challenges such as low seed viability and slow growth rates. The Sundarbans region in India derives its name from the splendid-looking 'Sundari' species (*H. fomes*), which, unfortunately, faces a looming threat of extinction in this very region. Additionally, the Andaman and Nicobar Islands are home to eight exclusive mangrove species, including *Lumnitzera littorea, Rhizophora lamarckii, Rhizophora mohanii, Rhizophora mucronata, Rhizophora apiculata, Sonneratia urama, Sonneratia gulngai, Sonneratia griffithii, Sonneratia lanceolata, Sonneratia alba and Sonneratia ovata*.

[3] Champion H.G. and Seth S.K. (1968). A revised survey of: The Forest Types of India. Forest Research Institute, Dehradun.
[4] Dagar J.C., Mongia A.D. and Bandyopadhyay A.K. (1991). Mangroves of Andaman and Nicobar Islands, Mohan Primlani for Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi. Pp 3.
[5] Ragavan P., Kathiresan K., Rana T.S., Saxena A., Mohan P.M., Jayaraj R.S.C., Ravichnadran K. and Mageswaran (2021). Indian Mangrove: A photographic field identification guide. New India Publishing Agency, New Delhi. Pp 33

A brief account of ecosystem benefits rendered by Mangroves in the country is given under figure 3.1.

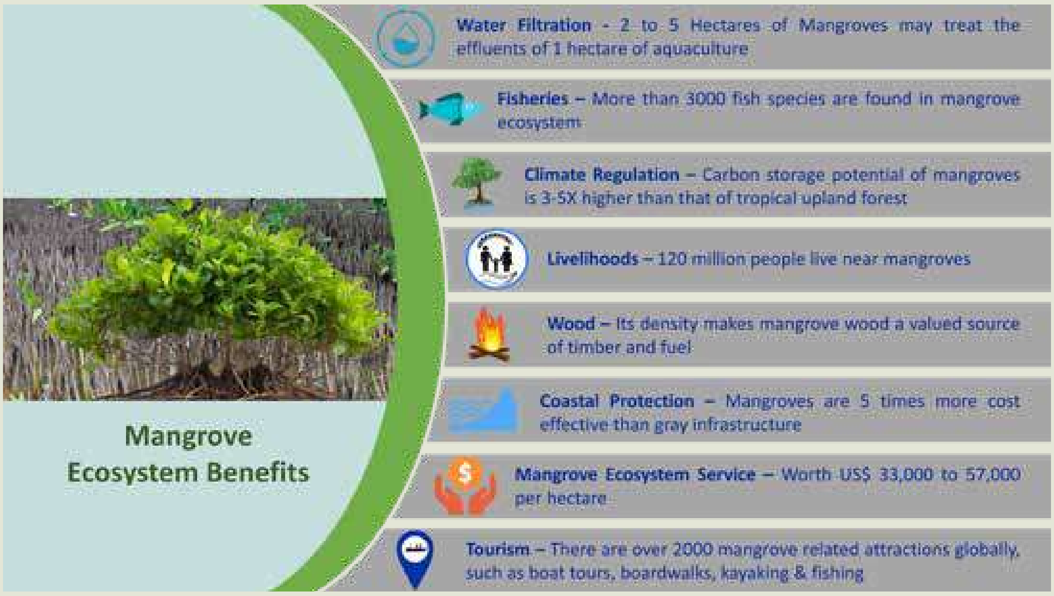


Figure 3.1 Mangrove Ecosystem Benefits

(Source: https://www.insightsonindia.com)

Since 1987, FSI has been consistently assessing the extent of mangrove cover using remote sensing data. The initial assessment was conducted on a 1:1 million scale. Following that, from 1989 to 1999, the assessment of mangrove cover occurred biennially and was synchronized with the country's forest cover mapping, but on a more detailed 1:2,50,000 scale. Starting in 2001 and continuing thereafter, the assessment of mangrove cover has been conducted at a finer scale of 1:50,000. This progressive approach allows for more precise monitoring of the dynamic mangrove ecosystems across India.

3.3 Conservation of Mangroves

Rapid coastal development and the consequences of climate change, such as rising sea levels and increasing frequency of natural disasters, have significantly contributed to mangrove degradation. Consequently, prioritizing efforts to enhance the ecological well-being of mangroves has become imperative to ensure their long-term sustainability.

India stands as a commendable example of natural ecosystem conservation and restoration at a regional level, particularly its dedication in preserving and managing mangrove ecosystems.

Figure 3.2 (A) – A coastline in Sundarbans **(B) – Pneumatophores**

Photos – Debal Ray, IFS

As already mentioned, India ranks as the world's third richest nation in terms of mangrove plant diversity, trailing behind Indonesia and Australia. India has 46 genuine mangrove species spanning 14 families and 22 genera. Notably, nine of these species hold global significance as "species of conservation importance," including *Sonneratia griffithii, Heritieria fomes, Excoecaria indica, Aglaia cucullata, Aegialitis rotundifolia, Brownlowia tersa, Ceriops decandra, Phoenix paludosa, and Sonneratia ovata.*

Furthermore, 188 plant species associated with mangroves often expand their range into the hinterland mangrove environments. India has the world's highest recorded biodiversity within mangrove forests, with a total of 4,107 species, encompassing 23% of floral and 77% of faunal species. Bhitarkanika in the State of Odisha is renowned as the 'Mangrove Genetic Paradise' on a global scale. Indian mangrove conservation initiatives have achieved notable success through innovative approaches. These include Canal Bank planting using the Fish Bone technique in areas with low tidal amplitude like Andhra Pradesh and Tamil Nadu. Maharashtra has established a dedicated "Mangrove Cell" to oversee conservation and management efforts. Furthermore, Maharashtra has declared "*Sonneratia alba*" as the State Mangrove Tree. Kerala's Kannuar Mission focuses on mangrove restoration. Gujarat employs the Raised Bed method for mangrove afforestation. Other than these, some of the innovative strategies adopted by States are Integrated aquaculture (also known as the Mitochondrial Model) and joint mangrove management involving local communities.

Figure 3.3 Conservation initiatives and measures

3.4 Climate Change and Carbon Sequestration

Mangrove ecosystems are carbon-dense, possibly second only to peat swamps in tropical forests. Despite occupying less than 1% of the total tropical forest area, mangroves sequester approximately 3% of the world's tropical forest carbon (Alongi, 2012)[6]. They serve as crucial carbon sink in the tropics.

Fatoyinbo *et al.* (2017)[7] highlighted the substantial carbon stocks and coastal buffering capacity of mangroves, making them ecologically and economically vital wetlands. Studies reveal that mangroves possess the highest carbon density of all terrestrial ecosystems, sparking interest in their potential for mitigating greenhouse gas emissions. Their extensive root systems store substantial biomass underground, supporting the towering trees in muddy coastal habitats (Komiyama *et al.*, 2008)[8]. Mangroves, as a deep-organic soil forest type, could benefit from initiatives like REDD+ and should be considered in climate change mitigation strategies (Murdiyarso *et al.*, 2009)[9].

[6] Alongi D.M. (2012) Carbon sequestration in mangrove forests, *Carbon Management,* **3**:3, 313-322, DOI: 10.4155/cmt.12.20.
[7] Fatoyinbo T., Feliciano E.A., Lagomasino D. L. S. K. and Trettin C. (2018). Estimating mangrove aboveground biomass from airborne LiDAR data: A case study from the Zambezi River delta. *Environmental Research Letters.* **13**. 10.1088/1748-9326/aa9f03.
[8] Komiyama, Akira & Ong, Jin & Poungparn, Sasitorn. (2008). Allometry, biomass, and productivity of mangrove forests: *A review. Aquatic Botany.* **89**. 128-137. 10.1016/j.aquabot.2007.12.006.
[9] Murdiyarso D., Donato D., Kauffman J.B., Kurnianto S., Stidham M. and Kanninen M. (2009) Carbon storage in mangrove and peat-land ecosystems: A preliminary account from plots in Indonesia. Pp.27-28.

3.5 Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI)

Studies indicate that the main driver of modern mangrove loss in the coming decades is expected to be the emergence of natural stressors. Additionally, projections suggest that with ambitious protection and restoration efforts, the net global expansion of mangroves could reach approximately 8,006 km^2 by 2050. This estimate aligns closely with the total global restorable area of mangroves, which is estimated to be around 8,120 km^2. These findings highlight the potential for mangrove conservation and restoration initiatives to have a significant positive impact on these crucial ecosystems (Buelow *et al*., 2022)[10].

Considering the above, and in line with the UN Decade of Ecosystem Restoration 2021–2030, Government of India has recently announced MISHTI program. MISHTI is a government-led initiative with an aim of increasing the mangrove cover along the coastline and on salt-pans along the country.

MISHTI envisages to comprehensively explore the possible area for development of Mangroves covering approximately 540 km^2 spreading across 11 States and 2 Union Territories during five years commencing FY 2023-24 onwards. The primary focus of the scheme is the Sundarbans delta, Hooghly estuary in West Bengal, other bay parts, and wetlands in the country. The scheme has the main objective to conserve and restore the mangrove ecosystem, which is critical in mitigating the effects of climate change, preventing coastal erosion, and sustaining local livelihoods.

Under the MISHTI scheme, the government is providing financial assistance to the State/UTs to undertake mangrove plantation activities. The scheme also involves awareness campaigns to educate people about the importance of mangroves and their role in protecting the environment. The plantation activities are carried out in a participatory manner, involving local communities and NGOs, to ensure sustainability and community ownership of the initiative. Overall, MISHTI is a significant step towards promoting sustainable development and protecting the vulnerable coastal areas of India.

[10] Buelow C.A. , Connolly R.M., Turschwell M.P., Adame M.F., Ahmadia G.N., Andradi-rown D.A., Bunting P., Canty S.W., Dunic J.C., Friess D.A., Lee S., Lovelock C., McClure E.C., Pearson R.M., Sievers M., Sousa A.I., Worthington T.A., Brown C.J. (2022). Ambitious global targets for mangrove and seagrass recovery, *Current Biology*, **32** (1641–1649) (2022), Article e1643.

Figure 3.4 Fishbone structure of Mangrove Plantation

Photos – Arun Kumar Thyadi

The sharing of best practices on plantation techniques, conservation measures, management practices and resources mobilization through Public Private Partnership are objectives of the MISHTI scheme. MISHTI is to be implemented by converging CAMPA Fund, MGNREGS, and other sources.

3.6 Status of Mangrove Cover in India

The State/UT wise information on Mangrove cover assessment from 1987 to 2021 is given under Table 3.2.

Table 3.2 Mangrove Cover Assessment in State/UT from 1987 - 2021

(in km^2)

State/UT	State of Forest Report															
	1987	1989	1991	1993	1995	1997	1999	2001	2003	2005	2009	2011	2013	2015	2017	2019	2021*
Andhra Pradesh	495	405	399	378	383	383	397	333	329	354	353	352	352	367	404	404	408.42
Goa	0	3	3	3	3	5	5	5	16	16	17	22	22	26	26	26	29.39
Gujarat	427	412	397	419	689	901	1,031	911	916	991	1,046	1,058	1,103	1,107	1,140	1,177	1,200.45
Karnataka	0	0	0	0	2	3	3	2	3	3	3	3	3	3	10	10	11.66
Kerala	0	0	0	0	0	0	0	0	8	5	5	6	6	9	9	9	9.43
Maharash-tra	140	114	113	155	155	124	108	118	158	186	186	186	186	222	304	320	302.70
Odisha	199	192	195	195	195	211	215	219	203	217	221	222	213	231	243	251	257.51
Tamil Nadu	23	47	47	21	21	21	21	23	35	36	39	39	39	47	49	45	41.91
West Ben-gal	2,076	2,109	2,119	2,119	2,119	2,123	2,125	2,081	2,120	2,136	2,152	2,155	2,097	2,106	2,114	2,112	2,117.75
A&N Islands	686	973	971	966	966	966	966	789	658	635	615	617	604	617	617	616	612.94
Daman& Diu	0	0	0	0	0	0	0	0	1	1	1	2	2	3	3	3	3.30
Puducherry	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	3.65
Total	**4,046**	**4,255**	**4,244**	**4,256**	**4,533**	**4,737**	**4,871**	**4,482**	**4,448**	**4,581**	**4,639**	**4,663**	**4,628**	**4,740**	**4,921**	**4,975**	**4,999.11**

** Area figure calculated on raster basis without using correction factor.*

Mangrove Cover (2023 Assessment) 3.7

As per the current assessment, the total Mangrove cover of the country is 4,991.68 km^2, which accounts for 0.15 % of the country's total geographical area. Among this, Very Dense Mangrove comprises 1,463.97 km^2 accounting for 29.33 % of the total Mangrove cover, extent of Moderately Dense Mangrove is 1,500.84 km^2 (30.07 %) while Open Mangroves constitute an area of 2026.87 km^2 (40.60%). In comparison to the 2021 assessment, there is a decrease of 7.43 km^2 in the country's Mangrove coverage. Andhra Pradesh has a notable increase of 13 km^2, followed by Maharashtra with an increase of approximately 12 km^2. In Andhra Pradesh, the increase in Mangrove cover is primarily attributed to natural regeneration, plantation initiatives, conservation activities and addition of the left over patches. This increase is particularly noticeable in the Krishna, Bapatla and Kakinada districts of Andhra Pradesh. In Maharashtra, the expansion in Mangrove cover is predominantly due to natural regeneration and plantation done by State Forest Department. Growth in Mangrove cover has been observed in the Raigarh and Palghar district of Maharashtra. There is a prominent decrease of 36 km^2 in Gujarat. Detailed information on the extent of Mangrove cover in different States and Union Territories, categorized by canopy density classes, and the changes compared to the 2021 assessment can be found in Table 3.3.

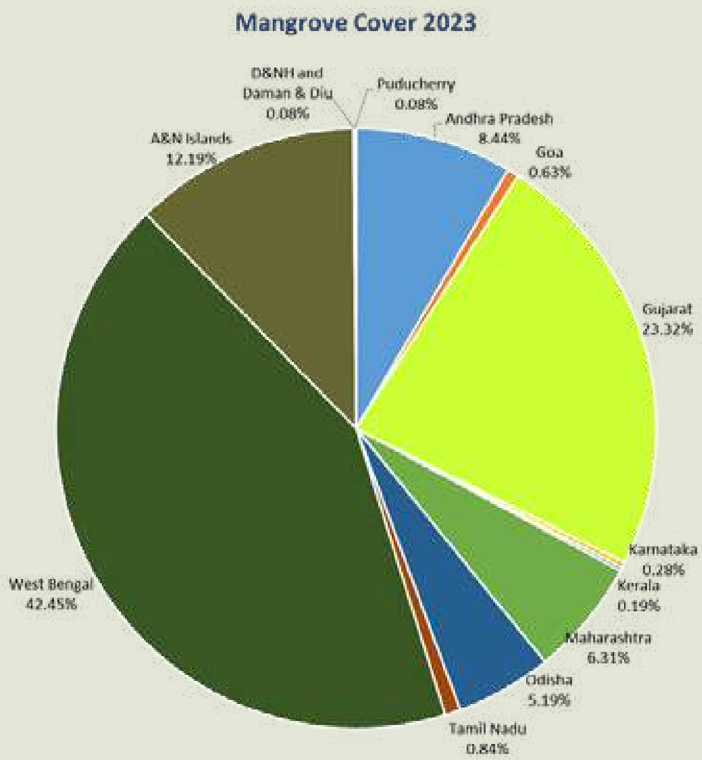


Figure 3.5 Pie chart showing Mangrove Cover in different States/UTs

Table 3.3 State/UT wise Mangrove Cover Assessment 2023

(in km²)

Sl. No.	State/UT	2021 Assessment Raster based				2023 Assessment Raster based				Change with respect to revised ISFR 2021
		Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	
1	Andhra Pradesh	0.00	212.73	195.69	408.42	0.00	213.90	207.53	421.43	13.01
2	Goa	0.00	23.92	5.47	29.39	0.00	23.75	7.59	31.34	1.95
3	Gujarat	0.00	167.52	1,032.93	1,200.45	0.00	179.09	984.97	1,164.06	-36.39
4	Karnataka	0.11	2.21	9.34	11.66	0.11	3.15	10.94	14.20	2.54
5	Kerala	0.00	4.71	4.72	9.43	0.00	4.73	4.72	9.45	0.02
6	Maharashtra	0.00	86.21	216.49	302.70	0.00	89.82	225.27	315.09	12.39
7	Odisha	81.67	94.61	81.23	257.51	81.67	94.61	82.78	259.06	1.55
8	Tamil Nadu	1.16	25.01	15.74	41.91	1.19	25.07	15.65	41.91	0.00
9	West Bengal	983.65	703.49	430.61	2,117.75	981.63	703.79	433.74	2,119.16	1.41
10	A & N Islands	398.64	165.36	48.94	612.94	399.37	162.64	46.28	608.29	-4.65
11	D & NH and Daman & Diu	0.00	0.21	3.09	3.30	0.00	0.21	3.65	3.86	0.56
12	Puducherry	0.00	0.08	3.57	3.65	0.00	0.08	3.75	3.83	0.18
	Total	**1,465.23**	**1,486.06**	**2,047.82**	**4,999.11**	**1,463.97**	**1,500.84**	**2,026.87**	**4,991.68**	**-7.43**

District wise Mangrove cover of 2021 and 2023 assessments is given under table 3.4.

Table 3.4 District-wise Mangrove Cover Assessment 2023

(in km²)

Sl. No.	State/UT and Districts	2021 Assessment Raster based				2023 Assessment Raster based				Change with respect to revised ISFR 2021
		Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	
1	**Andhra Pradesh**									
	Bapatla	0.00	35.25	35.82	71.07	0.00	35.26	37.66	72.92	1.85
	Eluru	0.00	0.00	0.02	0.02	0.00	0.00	0.02	0.02	0.00
	Kakinada	0.00	79.17	33.60	112.77	0.00	79.17	34.62	113.79	1.02
	Konaseema	0.00	47.08	28.01	75.09	0.00	46.95	27.47	74.42	-0.67
	Krishna	0.00	49.43	89.14	138.57	0.00	50.74	97.71	148.45	9.88
	Prakasam	0.00	0.09	0.60	0.69	0.00	0.09	0.66	0.75	0.06
	Sri Potti Sriramulu Nellore	0.00	1.61	7.04	8.65	0.00	1.59	7.07	8.66	0.01
	Srikakulam	0.00	0.00	0.28	0.28	0.00	0.00	0.82	0.82	0.54
	Tirupati	0.00	0.10	1.13	1.23	0.00	0.10	1.19	1.29	0.06
	Visakhapatnam	0.00	0.00	0.05	0.05	0.00	0.00	0.31	0.31	0.26
	Total	**0.00**	**212.73**	**195.69**	**408.42**	**0.00**	**213.90**	**207.53**	**421.43**	**13.01**

Table 3.4 District-wise Mangrove Cover Assessment 2023

(in km²)

Sl. No.	State/UT and Districts	2021 Assessment Raster based				2023 Assessment Raster based				Change with respect to revised ISFR 2021
		Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	
2	**Goa**									
	North Goa	0.00	19.13	3.67	22.80	0.00	18.96	5.05	24.01	1.21
	South Goa	0.00	4.79	1.80	6.59	0.00	4.79	2.54	7.33	0.74
	Total	**0.00**	**23.92**	**5.47**	**29.39**	**0.00**	**23.75**	**7.59**	**31.34**	**1.95**
3	**Gujarat**									
	Ahmadabad	0.00	1.46	28.01	29.47	0.00	1.46	38.80	40.26	10.79
	Amreli	0.00	0.00	1.67	1.67	0.00	0.00	1.78	1.78	0.11
	Anand	0.00	0.00	8.67	8.67	0.00	0.00	8.39	8.39	-0.28
	Bharuch	0.00	14.33	35.29	49.62	0.00	14.33	42.51	56.84	7.22
	Bhavnagar	0.00	4.63	23.78	28.41	0.00	4.63	25.99	30.62	2.21
	Devbhumi Dwarka	0.00	6.96	67.79	74.75	0.00	6.96	71.04	78.00	3.25
	Gir Somnath	0.00	0.00	7.17	7.17	0.00	0.00	9.87	9.87	2.70
	Jamnagar	0.00	24.41	148.09	172.50	0.00	43.96	118.57	162.53	-9.97
	Junagadh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Kachchh/ Kutch	0.00	110.84	658.72	769.56	0.00	102.86	605.56	708.42	-61.14
	Morbi	0.00	0.58	5.40	5.98	0.00	0.58	4.36	4.94	-1.04
	Navsari	0.00	0.05	15.91	15.96	0.00	0.05	17.39	17.44	1.48
	Porbandar	0.00	0.28	0.98	1.26	0.00	0.28	1.07	1.35	0.09
	Rajkot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Surat	0.00	3.70	23.96	27.66	0.00	3.70	31.93	35.63	7.97
	Vadodara	0.00	0.00	1.70	1.70	0.00	0.00	1.70	1.70	0.00
	Valsad	0.00	0.28	5.79	6.07	0.00	0.28	6.01	6.29	0.22
	Total	**0.00**	**167.52**	**1,032.93**	**1,200.45**	**0.00**	**179.09**	**984.97**	**1,164.06**	**-36.39**
4	**Karnataka**									
	Dakshin Kannada	0.08	0.16	0.37	0.61	0.08	0.71	0.48	1.27	0.66
	Uttar Kannada	0.00	0.00	8.75	8.75	0.00	0.08	8.88	8.96	0.21
	Udupi	0.03	2.05	0.22	2.30	0.03	2.36	1.58	3.97	1.67
	Total	**0.11**	**2.21**	**9.34**	**11.66**	**0.11**	**3.15**	**10.94**	**14.20**	**2.54**
5	**Kerala**									
	Ernakulum	0.00	0.77	1.30	2.07	0.00	0.77	1.30	2.07	0.00
	Kannur	0.00	3.87	2.57	6.44	0.00	3.87	2.57	6.44	0.00
	Kasaragod	0.00	0.07	0.85	0.92	0.00	0.07	0.85	0.92	0.00
	Kollam	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.02
	Total	**0.00**	**4.71**	**4.72**	**9.43**	**0.00**	**4.73**	**4.72**	**9.45**	**0.02**

Table 3.4 District-wise Mangrove Cover Assessment 2023

(in km²)

Sl. No.	State/UT and Districts	2021 Assessment Raster based				2023 Assessment Raster based				Change with respect to revised ISFR 2021
		Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	
6	**Maharashtra**									
	Mumbai city	0.00	0.42	2.43	2.85	0.00	0.38	2.44	2.82	-0.03
	Mumbai Sub-urban	0.00	25.29	31.69	56.98	0.00	25.15	31.65	56.80	-0.18
	Palghar	0.00	2.27	31.99	34.26	0.00	2.28	36.12	38.40	4.14
	Raigarh	0.00	14.66	104.29	118.95	0.00	18.75	107.57	126.32	7.37
	Ratnagiri	0.00	13.71	15.29	29.00	0.00	13.78	16.72	30.50	1.50
	Sindhudurg	0.00	4.98	5.82	10.80	0.00	4.64	6.68	11.32	0.52
	Thane	0.00	24.88	24.98	49.86	0.00	24.84	24.09	48.93	-0.93
	Total	**0.00**	**86.21**	**216.49**	**302.70**	**0.00**	**89.82**	**225.27**	**315.09**	**12.39**
7	**Odisha**									
	Baleshwar	0.00	0.57	4.19	4.76	0.00	0.57	4.25	4.82	0.06
	Bhadrak	0.12	8.92	23.42	32.46	0.12	8.92	23.35	32.39	-0.07
	Jagatsinghpur	0.00	1.32	7.10	8.42	0.00	1.32	7.10	8.42	0.00
	Kendrapara	81.55	83.80	45.67	211.02	81.55	83.80	47.34	212.69	1.67
	Puri	0.00	0.00	0.85	0.85	0.00	0.00	0.74	0.74	-0.11
	Total	**81.67**	**94.61**	**81.23**	**257.51**	**81.67**	**94.61**	**82.78**	**259.06**	**1.55**
8	**Tamil Nadu**									
	Chennai	0.00	0.00	0.39	0.39	0.00	0.00	0.39	0.39	0.00
	Cuddalore	0.00	7.21	1.25	8.46	0.00	7.21	1.25	8.46	0.00
	Mayiladuthurai	0.00	0.17	2.36	2.53	0.00	0.17	2.38	2.55	0.02
	Nagapattinam	0.03	0.48	0.50	1.01	0.03	0.48	0.65	1.16	0.15
	Pudukkottai	0.62	0.15	0.76	1.53	0.62	0.15	0.76	1.53	0.00
	Ramanathapuram	0.40	0.54	1.43	2.37	0.43	0.56	1.47	2.46	0.09
	Thanjavur	0.11	8.81	4.47	13.39	0.11	8.80	4.43	13.34	-0.05
	Thiruvallur	0.00	0.00	0.56	0.56	0.00	0.00	0.39	0.39	-0.17
	Thiruvarur	0.00	7.13	1.04	8.17	0.00	7.15	1.05	8.20	0.03
	Thoothukkudi	0.00	0.52	2.79	3.31	0.00	0.52	2.69	3.21	-0.10
	Villupuram	0.00	0.00	0.19	0.19	0.00	0.03	0.19	0.22	0.03
	Total	**1.16**	**25.01**	**15.74**	**41.91**	**1.19**	**25.07**	**15.65**	**41.91**	**0.00**
9	**West Bengal**									
	Purba Medinipur	0.00	0.79	2.86	3.65	0.00	0.79	2.86	3.65	0.00
	North 24 Parganas	13.44	11.47	1.72	26.63	13.44	11.47	1.72	26.63	0.00
	South 24 Parganas	970.21	691.23	426.03	2,087.47	968.19	691.53	429.16	2,088.88	1.41
	Total	**983.65**	**703.49**	**430.61**	**2,117.75**	**981.63**	**703.79**	**433.74**	**2,119.16**	**1.41**

Table 3.4 District-wise Mangrove Cover Assessment 2023

(in km²)

Sl. No.	State/UT and Districts	2021 Assessment Raster based				2023 Assessment Raster based				Change with respect to revised ISFR 2021
		Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total Mangrove Cover	
10	**Andaman & Nicobar**									
	North Andaman	285.66	109.56	28.14	423.36	285.21	107.58	25.39	418.18	-5.18
	South Andaman	112.98	54.36	20.74	188.08	113.94	53.29	20.51	187.74	-0.34
	Nicobar	0.00	1.44	0.06	1.50	0.22	1.77	0.38	2.37	0.87
	Total	**398.64**	**165.36**	**48.94**	**612.94**	**399.37**	**162.64**	**46.28**	**608.29**	**-4.65**
11	**D&NH and Daman & Diu**									
	Daman	0.00	0.21	0.79	1.00	0.00	0.21	1.14	1.35	0.35
	Diu	0.00	0.00	2.30	2.30	0.00	0.00	2.51	2.51	0.21
	Total	**0.00**	**0.21**	**3.09**	**3.30**	**0.00**	**0.21**	**3.65**	**3.86**	**0.56**
12	**Puducherry**									
	Karaikal	0.00	0.08	0.00	0.08	0.00	0.08	0.02	0.10	0.02
	Puducherry	0.00	0.00	0.41	0.41	0.00	0.00	0.54	0.54	0.13
	Yanam	0.00	0.00	3.16	3.16	0.00	0.00	3.19	3.19	0.03
	Total	**0.00**	**0.08**	**3.57**	**3.65**	**0.00**	**0.08**	**3.75**	**3.83**	**0.18**

3.7.1 Mangrove Cover in Eastern Coast of India

Table 3.5 Mangrove Cover in Eastern Coast

(in km²)

Sl. No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change with respect to ISFR 2021 Raster based
1	Andhra Pradesh	0.00	213.90	207.53	421.43	13.01
2	Odisha	81.67	94.61	82.78	259.06	1.55
3	Tamil Nadu	1.19	25.07	15.65	41.91	0.00
4	West Bengal	981.63	703.79	433.74	2,119.16	1.41
5	Puducherry	0.00	0.08	3.75	3.83	0.18
	Total	**1,064.49**	**1,037.45**	**743.45**	**2,845.39**	**16.15**

3.7.2 Mangrove Cover in Western Coast of India

Table 3.6 Mangrove Cover in Western Coast

(in km²)

Sl. No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change with respect to ISFR 2021 Raster based
1	Goa	0.00	23.75	7.59	31.34	1.95
2	Gujarat	0.00	179.09	984.97	1,164.06	-36.39
3	Karnataka	0.11	3.15	10.94	14.20	2.54
4	Kerala	0.00	4.73	4.72	9.45	0.02
5	Maharashtra	0.00	89.82	225.27	315.09	12.39
6	D&NH and Daman & Diu	0.00	0.21	3.65	3.86	0.56
	Total	**0.11**	**300.75**	**1,237.14**	**1,538.00**	**-18.93**

3.7.3 Mangrove Cover in Andaman and Nicobar Islands

Table 3.7 Mangrove Cover in Andaman & Nicobar Islands

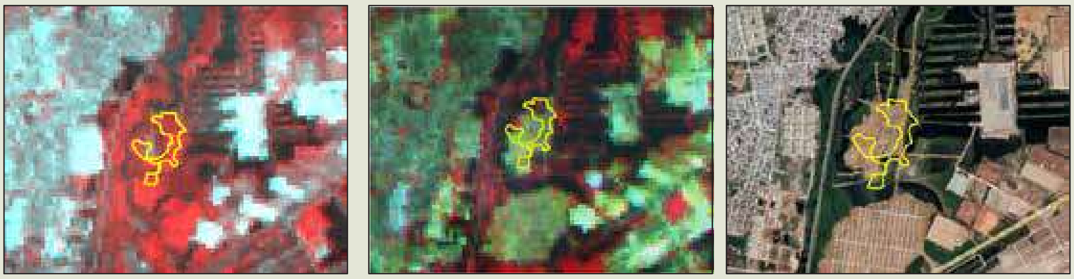
(in km²)

Sl. No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change with respect to ISFR 2021 Raster based
1	A&N Islands	399.37	162.64	46.28	608.29	-4.65
	Total	**399.37**	**162.64**	**46.28**	**608.29**	**-4.65**

** Mangrove cover in Lakshadweep is below measurable limits.*

State: Andhra Pradesh

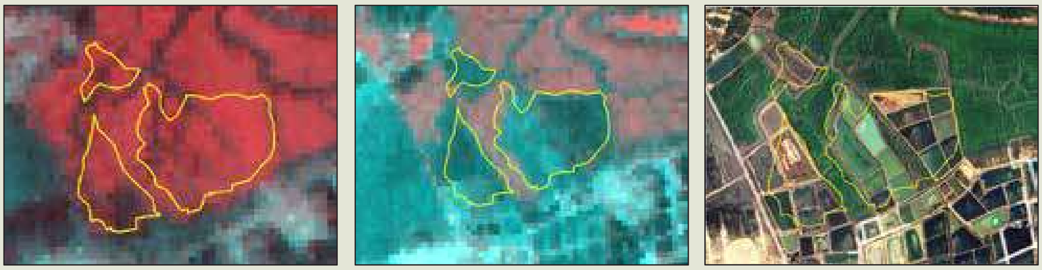
District: East Godavari, **Change Type**: Real Change, **Change Class**: Mangrove-Open to Non-forest, **Area:** 3.46 ha, **Reason:** Clearing of Mangrove Forest



17th Cycle FCC, 16 November,2019 | 18th Cycle FCC, 23 December,2022 | Google Earth Imagery: 07 March,2022

State: Andhra Pradesh

District: Krishna, **Change Type**: Real Change, **Change Class**: Mangrove-Open to Non-forest, **Area:** 23.43 ha, **Reason:** Aquaculture



17th Cycle FCC, DOP 21 May,2020 | 18th Cycle FCC, DOP 18 December,2021 | Google Earth Imagery: 15 April,2023

Figure 3.6 Illustration of change polygons of Mangrove using collateral data

Photo: Anant Shukla


Photo: FSI Repository

CHAPTER 04

Forest Fire

Photo: FSI Repository


Photo: FSI Repository

FOREST FIRE

Introduction 4.1

Forest fires have been an integral part of forest ecosystems, playing a pivotal role in shaping their conservation and management. Despite their benefits in terms of facilitating regeneration and clearing forest floors, the losses associated with fires far outweigh these benefits. Managed forest fires are utilized as crucial tools for resource management, improving ecological conditions, and reducing excessive fuel accumulation. Forest fires, however, significantly contribute to forest degradation and incur immeasurable losses in terms of floral and faunal biodiversity thus causing environmental decline. The main parameters to assess the loss due to forest fire consists of timber loss, carbon loss, loss of NWFP, loss of microflora & fauna, loss of habitat, people's dependency on forest resources, etc. Majority of fires, intentional or accidental, are caused by human activities. While India mainly experiences surface fires confined to the forest floor, their intensity and frequency fluctuate due to factors like dry fuel accumulation, prolonged droughts, and local influences.

Whether managed or unmanaged, fires within an ecosystem can result in alterations to the habitat and species composition, as noted by the Global Wildfire Information System (2019)[1]. These changes often occur under circumstances of heightened fire risk, influenced by meteorological factors such as minimal precipitation, strong winds, low humidity, and increased temperatures. Dry winters and delayed monsoons lead to heightened fire events causing extensive damage. Additionally, human negligence frequently leads to forest fires. The consequences of such fires are substantial, encompassing human casualties, biodiversity depletion, habitat destruction, reduced production and productivity, landscape degradation, and disturbances to livelihoods.

The anthropogenic activities play a major role in forest fire incidences in the country. During global COVID-19 pandemic, due to reduced human movement in and around the forest areas, the fire detections using SNPP-VIIRS sensor across the country reduced significantly from 2,10,286 in fire season 2018-19 to 1,24,473 in the fire season 2019-20.

4.1.1 Global Scenario

According to the Global Forest Resource Assessment (GFRA) of 2020, forests are increasingly confronting challenging fire weather conditions, prolonged fire seasons, and extensive fires that are influenced by climate change. These conditions are likely to result in significant costs in the form of biodiversity loss, diminished ecosystem

[1] Global Wildfire Information System (2019), https://gwis.jrc.ec.europa.eu/

services, adverse effects on human well-being, livelihoods, and national economies. Globally, around 98 Mha of forests were impacted by fires in 2015, accounting for 3% of the total global forest area. The majority of these occurrences took place in tropical regions, with approximately 4% of the tropical forest area affected (GFRA 2020)[2]. The consequent release of greenhouse gases and the carbon stored within trees are contributing to global warming and environmental deterioration. The Fifth Assessment Report of the Inter-governmental Panel on Climate Change also highlights that exposure to smoke from landscape fires, including forest fires, leads to an estimated 2,60,000 to 6,00,000 premature human and wildlife deaths annually. Moreover, the report indicates that forest fires emit between 2.5 billion to 4.0 billion tons of CO_2 annually, significantly increasing the volume of greenhouse gases in the atmosphere.

Persistent hotter and drier weather due to climate change and other human factors such as land conversion for agriculture are the main drivers of increase in forest fires. WWF International in its 2020 report has estimated that humans are responsible for around 75% of all wildfires and much of the increase in fire incidents during 2020 can be directly linked to human actions. In April 2020, the number of fire alerts across the globe were up by 13% as compared to the previous year – which was already a record year for fires (WWF, 2020)[3].

From 2001 to 2022, there was a total of 126 Mha tree cover loss from fires globally and 333 Mha from all other drivers of loss. The year with the most tree cover loss due to fires during this period was 2016 with 9.63 Mha lost to fires - 32% of all tree cover loss for that year. From 2001 to 2022, Russia had the highest rate of tree cover loss due to fires with an average of 2.54 Mha lost per year, followed by Canada (1.28 Mha) and United States (566 kha)[4].

4.1.2 Indian Scenario

In India, severe fires are prevalent in numerous forest types, especially dry deciduous forests; whereas evergreen, semi-evergreen, and montane temperate forests are relatively less susceptible (FSI, 2015)[5]. As per ISFR 2021, more than 36% of the country's forest cover was estimated to be prone to frequent forest fires. 2.81 % of the country's forest cover was extremely prone to fires, whereas 7.85% of forest cover is found to be very highly fire prone[6].

Pandey *et al.* (2016)[7] reported that around 275 million rural people in India depend on forests for livelihood security. People living in the vicinity of the forest areas are di-

[2] Global Forest Resources Assessment (2020), Main Report, Report by Food and Agriculture Organization of the United Nations (https://doi.org/10.4060/ca9825en)

[3] WWF (2020). Fires, forests and the future: A crisis raging out of control (2020), Joint Report by the World Wide Fund for Nature (WWF), Switzerland and Boston Consulting Group (BCG), US.

[4] https://www.globalforestwatch.org/

[5] FSI (2015), India State of Forest Report, MoEF&CC), Govt. of India. ISBN: 978-81-929285-2-4.

[6] FSI (2021), India State of Forest Report, MoEF&CC), Govt. of India. ISBN: 978-81-950073-1-8.

[7] Pandey, A. K., Tripathi, Y. C. and Kumar, A. (2016). Non-Timber Forest Products (NTFPs) for Sustained Livelihood: Challenges and Strategies. *Research Journal of Forestry*, **10** (1): 1-7.

rectly dependent on the forest for their livelihood based on Non-Timber Forest Products (NTFPs) and numerous other ecological services. The unsustainable practices involved in harvesting these forest resources, coupled with growing human activities, present a significant risk to the integrity of the forest ecosystem[8].

In regions spanning central, northern, and eastern India, the gathering of tendu leaves (*Diospyros melanoxylon*) and mahua flowers (*Madhuca longifolia*) represents a significant contributor to forest fires. Pan-India, an estimated 4.35 Mha area is affected by the fires due to shifting cultivation practices by the local farmers (Chandra and Bhardwaj, 2015)[9]. In North-Eastern region of India, one of the major causes of forest fire and forest degradation is Jhum cultivation. Due to shortening of the Jhum cycles, every year, large forest areas are slashed and burnt for cultivation, enhancing chances of frequent and severe fires across ecologically sensitive and biodiversity rich forests in the region.

Although there are multiple reasons for occurrence of human induced forest fires, forest fires in the country can be segregated in four prominent clusters:

a) fires in the Western Himalayan region (Jammu & Kashmir, Uttarakhand, and Himachal Pradesh) on account of fires in pine forests and by transhumance pastoralists;

b) fires in western part of the country on account of drier vegetation and extensive grassland habitats;

c) fires in Central Indian states, Western and Eastern Ghats on account of large scale collection of NTFPs; and

d) wide spread fires in North-Eastern states due to shifting cultivation (NDMA, 2023)[10].

In 2019, National Disaster Management Plan (NDMP) by National Disaster Management Authority (NDMA) recognised forest fires as one of the national disasters. In view of the adverse consequences posed by severe forest fires to human lives, property, ecosystem stability, climate patterns, and sustainable progress, the NDMA, in collaboration with MoEF&CC developed the National Programme on Forest Fire Management (NPFFM). This program is designed as a comprehensive blueprint for implementing an all-encompassing strategy for forest fire management. Its ultimate aim is to enhance the resilience of India's diverse forests against future forest fire threats and impacts, thereby initiating a transformation in the way forest fires are managed in the country (NDMA, 2023)[11].

[8] Compendium of best practices and indigenous technical knowledge with regards to management of forest fire (2023), Forest Research Institute, Dehradun

[9] Chandra, K. K. and Bhardwaj, A. K. (2015). Incidence of forest fire in India and its effect on terrestrial ecosystem dynamics, nutrient and microbial status of soil. *International Journal of Agriculture and Forestry*. **5**(2), 69-78.

[10] National Programme on Forest Fire Management in India (2023), National Disaster Management Authority (NDMA) and Ministry of Environment, Forest, and Climate Change (MoEFCC), Government of India.

[11] Citation is same as 10.

4.2 Role of FSI in Forest Fire Monitoring

Since 2004, Forest Survey of India (FSI) has been alerting the State Forest Departments and other agencies regarding forest fire detections using remote sensing and latest Information Technology. Chronology of evolution of the FSI forest fire alert system is given in Table 4.1. Currently during fire season, the following countrywide forest fire related services are being provided:

- **NEAR REAL-TIME FOREST FIRE MONITORING:** The activity is carried out using MODIS and SNPP-VIIRS sensor detections. Based on these sensor detections, the alerts are generated and disseminated to the subscribers. The detailed information regarding this activity is provided in para 4.2.1

- **LARGE FOREST FIRE MONITORING:** The activity involves use of SNPP-VIIRS sensor for large forest fire detections. The system identifies three contiguous SNPP-VIIRS sensor detections and regularly monitors using the subsequent satellite passes over a buffer as long as the fire is active. The detailed information regarding this activity is provided in para 4.2.2

- **PRE-FIRE ALERT BASED ON FOREST FIRE DANGER RATING SYSTEM:** Pre-fire alerts are generated on weekly basis using forest fire danger rating. The Forest Fire Danger Rating involves overlaying and analysis of layers including Canadian Fire Weather Index (FWI) module, Forest Types and Indian Meteorological data for categorizing forest into different danger ratings. For generating pre-fire alerts, only two top classes - Extreme and Very High danger ratings are selected for further dissemination. The detailed information regarding this exercise is provided in para 4.2.3

- **FOREST FIRE RISK ZONATION MAPPING IN WEST HIMALAYAN STATES:** A study has been carried out to zonate different risk areas based on static factors for better management and prevention of forest fires in the West Himalayan region. For this purpose, different layers including forest cover, forest type, topographical gradients and plot-level field inventory data of the National Forest Inventory has been used to derive the causative factors for the spread of forest fires and to generate forest fire risk zone maps. The detailed information regarding this study is provided in para 4.2.4.
  Forest Fire Risk Zonation Mapping for the entire country has been carried out and will be published in a separate chapter in the Forest Fire Burnt Area Report.

- **FSI VAN AGNI GEO-PORTAL:** The geo-portal is a user-friendly, interactive portal for visualizing the forest fire data (Near Real-Time Detections of MODIS and SNPP-VIIRS, Large Forest Fire Detections, Forest Fire Danger Rating and Fire Prone Forest Areas) generated by FSI. The detailed information regarding this activity is provided in para 4.2.5

- **IDENTIFICATION OF FIRE PRONE FOREST AREAS:** Based on the archival near real-time forest fire detections, 5 km X 5 km grid layer covering the entire forest area of the country is categorised into different fire prone regions. The detailed information regarding this activity is provided in para 4.2.6

- **SHARING OF WMS (WEB MAP SERVICE) & WFS (WEB FEATURE SERVICE) SERVICES WITH STATE FOREST DEPARTMENTS:** WMS and WFS is created and shared with the SFDs, so that SFDs can synchronize FSI information with their respective portals. The detailed information regarding this activity is provided in para 4.2.7

Table 4.1 Timeline of Evolution of FSI Forest Fire Alert System

Year	Milestone
2004	Dissemination of forest fire alerts based on MODIS data up to district level through e-mail/ FAX
2008	SMS alerts on number of fires in State/ District
2012	- KML files in e-mail alerts up to district level along with SMS alerts - Publication of "Vulnerability of India's forests to fires" report
2016	Pilot study on country-wide burnt scar assessment for 2015 and 2016
2017	- Automation of FSI Forest Fire Alert System - SNPP-VIIRS sensor added to FSI forest fire monitoring system - Forest Fire Alert dissemination up to Beat level - Pre-warning alerts piloted for pan-India
2018	Improved feedback system for forest fire alerts
2019	- Satellite based large forest fire monitoring program - FSI Van Agni Geo-portal - Early-warning alert system based on Fire Weather Index
2020	WMS, WFS and API to State Forest Departments
2022	Daily forest fire reports on Near-Real Time Detections, Large Forest Fire Detections, Large Forest Fires greater than 5 days and Forest Fire Detections in Tiger Reserves
2023	- Fortnightly Report on Near-Real Time Detections since start of fire season, Near-Real Time Detections of previous fortnight, detections in Tiger Reserves since start of fire season and detections in Tiger Reserves of previous fortnight - Broadcasting of Pre-Fire Alerts using SACHET Portal - Forest Fire Risk Zonation in West Himalayan States - Daily dissemination of reports through WhatsApp group of PCCF & HoFF and officers from Ministry
2024	- Burnt Area Assessment in forest areas - Fuel Load Estimation and Mapping - Forest Fire Risk Zonation at national level

4.2.1 Near Real-Time Forest Fire Monitoring

Currently, Forest Survey of India (FSI) has been alerting State Forest Departments about forest fire incidences detected by MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor on-board Aqua and Terra Satellite of NASA and based on SNPP- VIIRS sensor. The approximate time of satellite pass of MODIS and SNPP-VIIRS sensor over Indian region is shown in Figure 4.1. It can be observed from the figure that generally between 01:30 am to 10:30 am and from 1:30 pm to 10:30 pm, there is no satellite pass. Therefore, during these gap periods, no fire hotspots can be detected and disseminated to the SFDs.

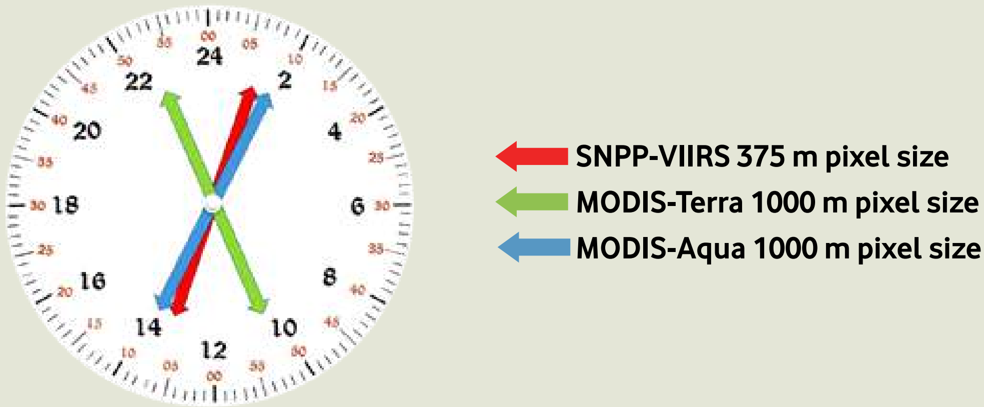


Figure 4.1 Approximate Time of Satellite Pass of MODIS and SNPP-VIIRS Sensor over Indian Region

The fire hotspots detected by MODIS (1 km X 1 km resolution) and SNPP-VIIRS (375 m X 375 m resolution) sensors are received at Shadnagar Earth station (National Remote Sensing Centre) and processed using standard algorithm. The fire hotspots are electronically shared with FSI, which are further processed automatically at FSI headquarters in Dehradun and alerts are generated and disseminated to the registered end users as SMS (Figure 4.2). The same is also disseminated in the form of KML and CSV through e-mail (Figure 4.3). Automation of the entire process has reduced the processing time to a great extent, which has resulted in information being disseminated to SFDs in the shortest possible time for facilitating quick responses by the field teams in fire containment activities.

The forest fire detections generated by FSI are primarily thermal anomalies captured by the satellites and as such, the number of fire incidences on ground may vary from the detections sent as alerts, owing to various reasons. This may be due to fire detections being reported on successive days for the same fire incident owing to satellite's repeativity. Therefore, one incidence of fire may show multiple detections. An incident of forest fire reported in Sariska Tiger Reserve in 2022, had 24 detections of SNPP-VIIRS sensor as shown in Figure 4.4.

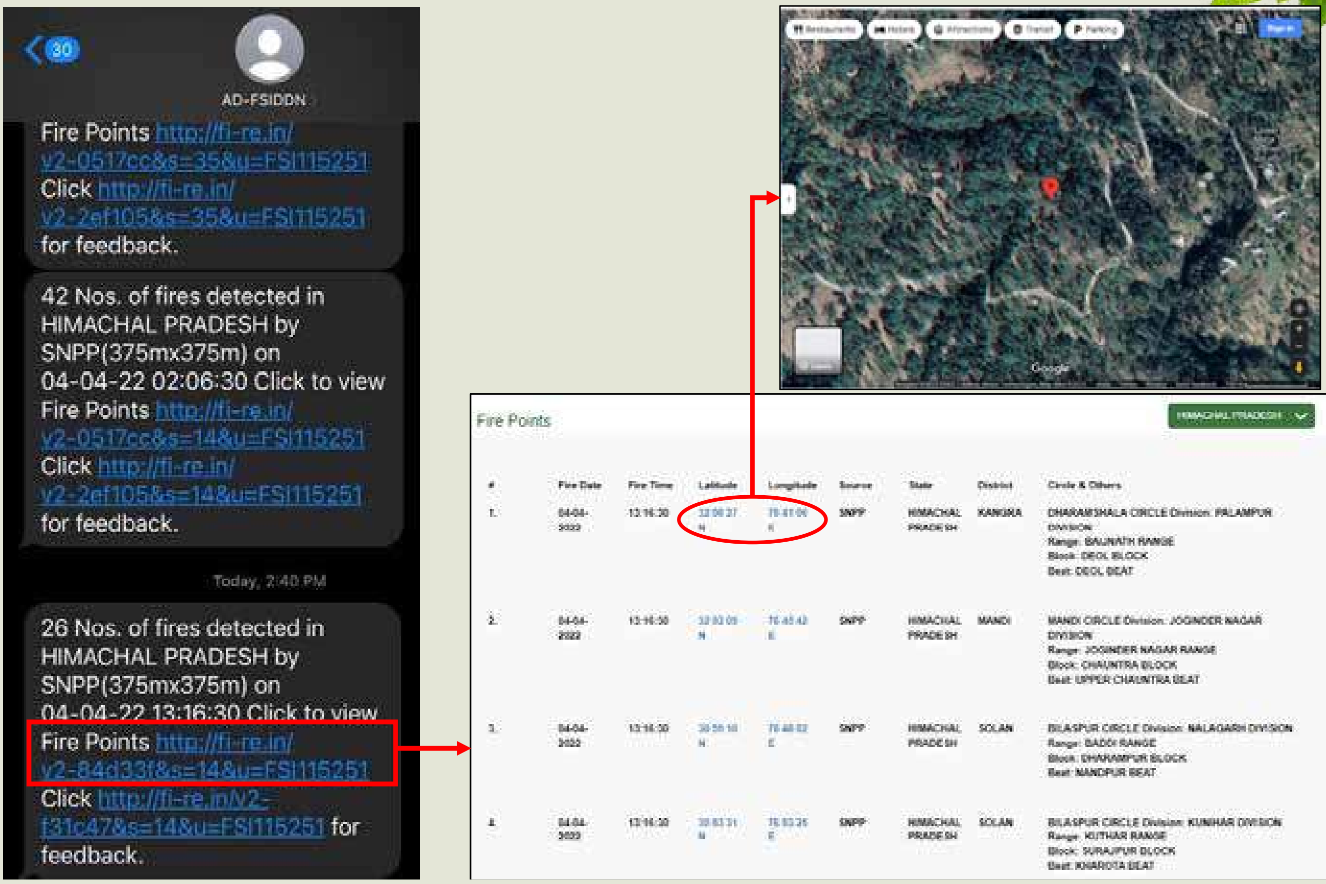


Figure 4.2 Example of SMS Alert

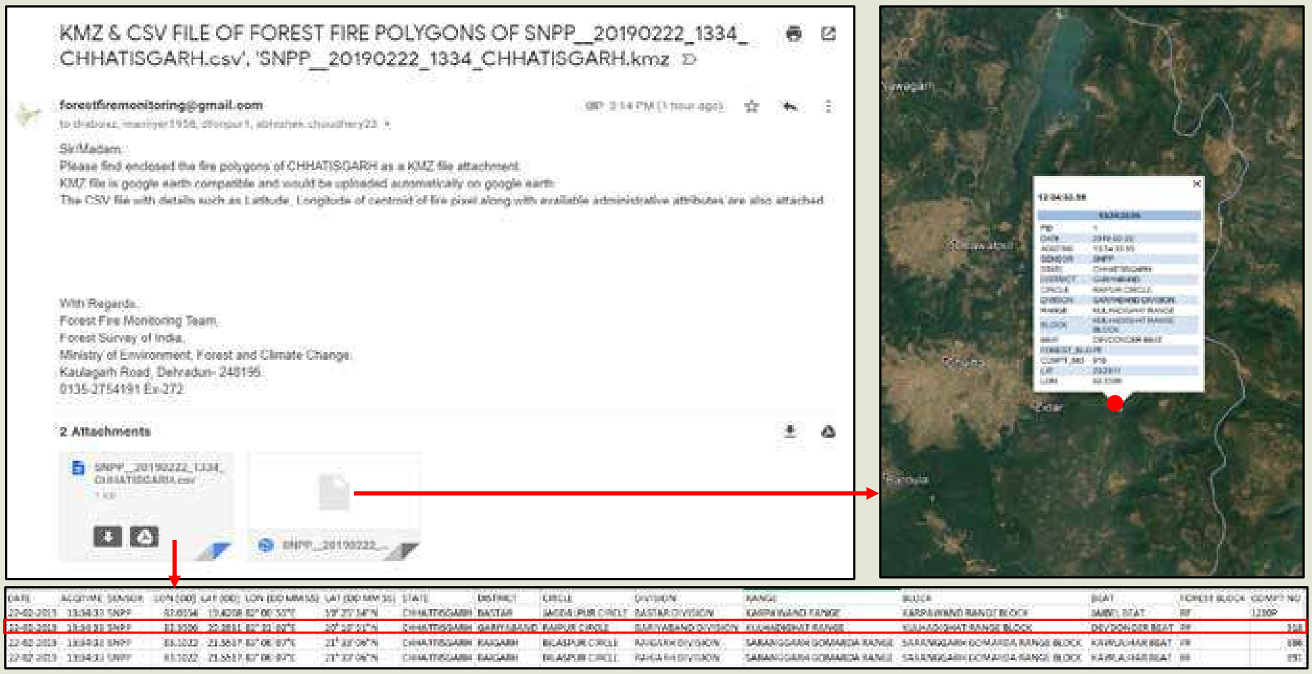


Figure 4.3 Example of e-mail Alert

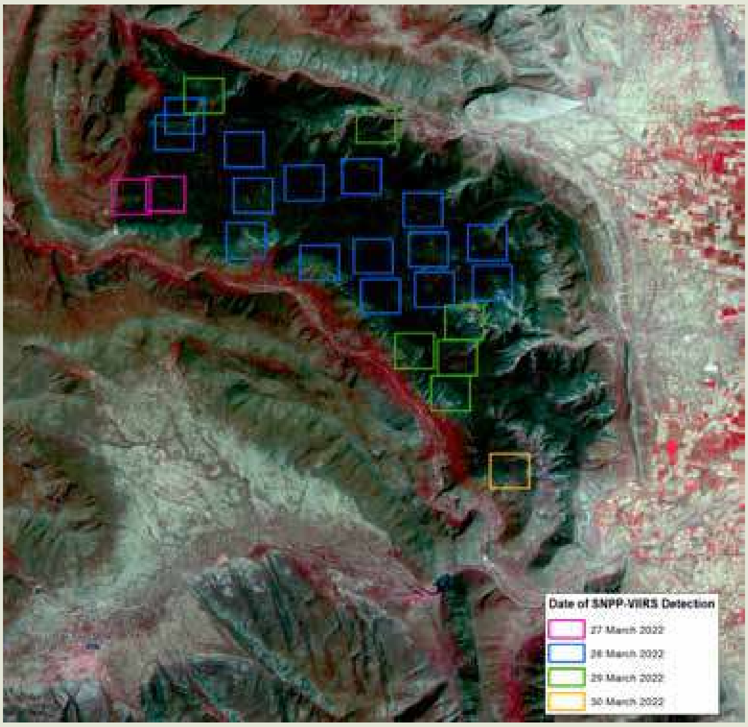


Figure 4.4 SNPP-VIIRS Detections of Forest Fire in Sariska Tiger Reserve Overlaid on Sentinel 2 Satellite Data

Period 27th March 2022 to 30th March 2022

A comparison between the two sensors, viz., MODIS and SNPP-VIIRS is at Table 4.2.

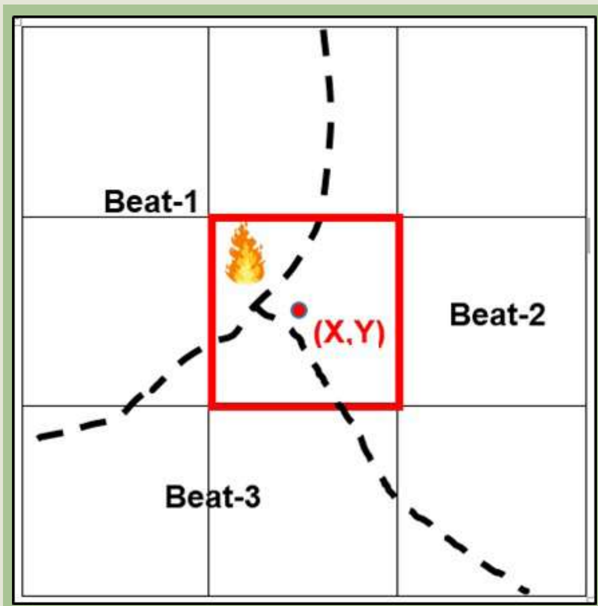
Table 4.2 Comparison between the Two Sensors viz. MODIS and SNPP-VIIRS

Feature	MODIS	SNPP-VIIRS
	Moderate Resolution Imaging Spectro-radiometer	Visible Infrared Imaging Radiometer Suite
Sensor	36 spectral bands (channel 21, 22, 31)	5 HR Imagery channels (I-bands), 16 moderate resolution channels (M-bands), and a D/N Band (M13 and M15)
Satellite	Aqua and Terra	Suomi National Polar-orbiting Partnership (NPP) satellite
Launch	Dec 1999 and May 2002	Oct 2011
Algorithm	Contextual	Thresholding and Contextual (Hybrid)
Equatorial Pass	Terra- 10:30 am & 10:30 pm; Aqua- 01:30 am & 01:30 pm	01:30 am and 01:30 pm
Resolution	1 km x 1 km	375 m x 375 m

The process of generation and dissemination of forest fire alerts is described below:

i. The fire hotspots received from National Remote Sensing Centre (NRSC) comprise all the hotspots detected by the sensors, i.e., the features on the ground above certain threshold temperature, irrespective of whether they fall within forests or outside. Initially, the point data is converted into square polygons representing pixels, based on the spatial resolution of MODIS and SNPP-VIIRS sensor. Further, these forest fire pixels are filtered using a custom filter, which is a combination of Recorded Forest Area boundaries and Forest cover data. State/UT wise details of the level of customization in forest fire alerts is shown in Table 4.3. Forest fire information is enriched by adding attributes like State, District, Circle, Division, Range, Block, Beat, Compartment number, etc., to the filtered forest fire pixels.

Figure 4.5 depicts the pixel-based analysis and dissemination of forest fire alerts being carried out by FSI currently. From the Figure, it is clear that irrespective of the number of administrative levels (beat, compartment, etc.) falling over the pixel in which the fire hotspot is detected, the forest fire alerts communicating the location of the centroid of the affected pixel is sent to the subscribers irrespective of administrative levels.



- As per ground observation, the forest fire is observed in Beat-1
- Forest fire alerts giving location of centroid of the pixel (X, Y) in which the fire hotspot is observed by sensor are sent to all three Beats (Beat 1, 2 & 3)

Figure 4.5 Pixel based Analysis and Dissemination of Forest Fire Alerts

ii. Based on the analysis of the near real-time forest fire data and feedback from the SFDs, FSI has developed a filter to mask out fires from mining areas, industrial areas, etc., which may otherwise add false alarms to the forest fire alert system. After filtering, all the subscribers are notified through SMS about the forest fires that have been detected within their area of interest. This information is also shared with State Nodal Officers through e-mail. The information is also uploaded online on the FSI website (www.fsi.nic.in) and Van Agni Geo-portal. Workflow for alerts' generation and dissemination is presented in the following schematic diagram given at Figure 4.6. Time taken from receipt of data at NRSC to sending alerts by email is approx. 1 hr.

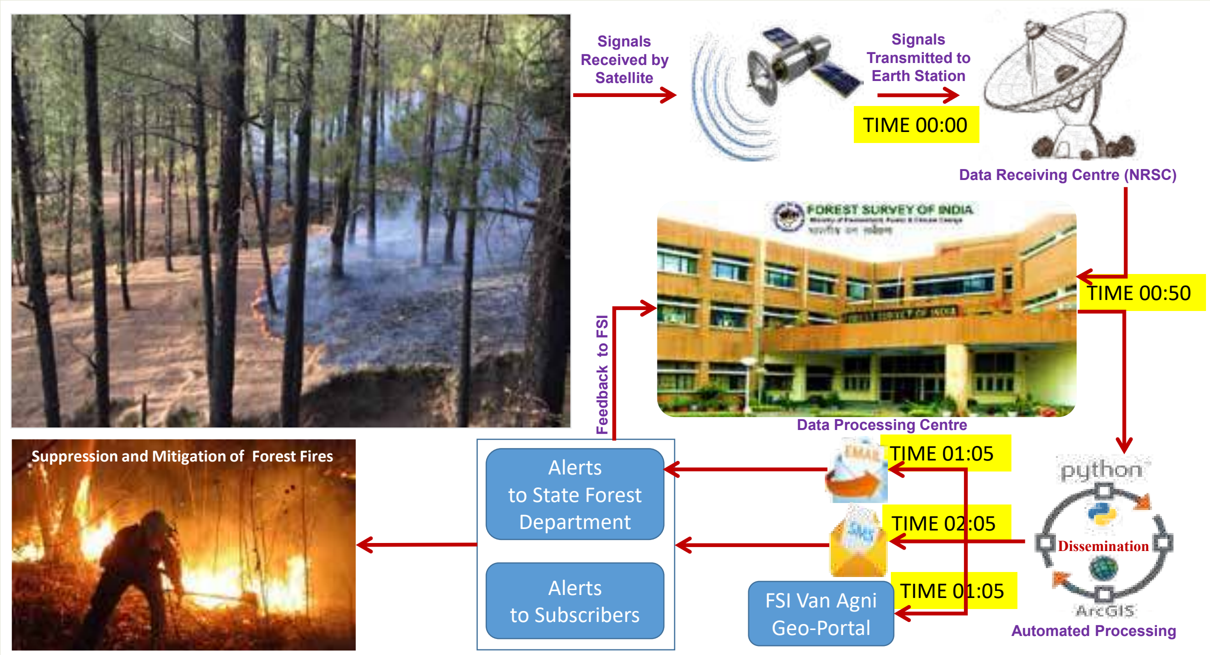


Figure 4.6 Work Flow of Near Real-Time Forest Fire Monitoring

Table 4.3 Details of Levels of Customization in Forest Fire Alerts

Sl. No.	State/UT	Alert Level	RFA details included in alerts (Yes/No)
1	Andhra Pradesh, Chhattisgarh, Goa, Haryana, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Telangana, Uttarakhand, West Bengal	Beat	Yes
2	Bihar, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Manipur, Mizoram, Punjab, Tripura, Uttar Pradesh	Beat	No
3	Meghalaya	Block	No
4	Jammu & Kashmir	Range	Yes
5	Kerala, Rajasthan	Range	No
6	Arunachal Pradesh, Assam, Delhi, Nagaland, Sikkim, Andaman & Nicobar Islands, Chandigarh, Dadra & Nagar Haveli and Daman & Diu, Ladakh, Lakshadweep, Puducherry	District	No

4.2.1.1 Analysis of number of forest fires detected using MODIS & SNPP-VIIRS sensors for fire seasons 2021-2022, 2022-2023 and 2023-2024

During the forest fire season 2021-2022, the number of hotspots detected by MODIS sensor were 29,675 & those by SNPP-VIIRS sensor were 2,23,333. In the fire season 2022-2023, the total hotspots detected by MODIS sensor were 31,145 & by SNPP-VIIRS sensor were 2,12,249 and in the fire season 2023-2024, the total hotspots detected by MODIS sensor were 26,390 & by SNPP-VIIRS sensor were 2,03,544. State/UT wise details of number of forest fires detected by FSI using MODIS & SNPP-VIIRS sensors for fire season 2021-2022, 2022-2023 and 2023-2024 are given in Table 4.4. This includes large, continuous and repeated forest fires.

Table 4.4 Number of Forest Fire Detected by FSI using MODIS & SNPP-VIIRS Sensors (This includes large, continuous and repeated forest fires) for Fire Season 2021-2022, 2022-23 and 2023-2024

Sl. No.	State/UT	MODIS Detections			SNPP-VIIRS Detections		
		Nov 2021 to Jun 2022	Nov 2022 to Jun 2023	Nov 2023 to Jun 2024	Nov 2021 to Jun 2022	Nov 2022 to Jun 2023	Nov 2023 to Jun 2024
1	Andhra Pradesh	1,716	2,526	1,793	14,138	19,367	18,174
2	Arunachal Pradesh	1,116	659	687	3,449	2,447	2,053
3	Assam	2,305	2,741	2,106	8,158	9,830	7,639
4	Bihar	222	390	273	3,024	3,793	2,763
5	Chhattisgarh	1,942	1,581	1,347	25,792	20,306	18,950
6	Delhi	5	0	2	3	7	16
7	Goa	5	7	3	20	147	36
8	Gujarat	236	260	287	2,769	2,342	3,182
9	Haryana	37	34	30	135	82	166
10	Himachal Pradesh	601	97	985	5,280	704	10,136
11	Jharkhand	630	753	381	9,419	11,923	7,525
12	Karnataka	800	1,935	853	4,973	13,074	5,500
13	Kerala	61	231	149	504	1,550	1,110
14	Madhya Pradesh	3,908	1,887	1,592	32,728	17,142	15,878
15	Maharashtra	2,309	1,485	1,515	22,052	16,119	16,008
16	Manipur	1,638	2,295	1,318	5,544	10,127	4,498
17	Meghalaya	1,431	1,378	1,082	6,322	6,604	4,319
18	Mizoram	2,105	2,635	2,366	8,734	5,798	6,627
19	Nagaland	1,309	1,030	761	3,471	3,882	2,609
20	Odisha	2,086	4,024	2,047	22,014	33,461	20,973
21	Punjab	128	59	124	428	119	605
22	Rajasthan	238	232	469	2,703	2,059	4,352
23	Sikkim	11	17	21	26	49	101
24	Tamil Nadu	151	359	624	1,035	1,998	3,380
25	Telangana	1,372	1,457	1,085	13,737	13,117	13,479
26	Tripura	310	1,220	441	2,609	4,332	2,089
27	Uttar Pradesh	905	568	916	5,428	3,235	4,424
28	Uttarakhand	1,337	576	2,442	12,985	5,351	21,033
29	West Bengal	233	679	355	1,520	3,096	2,020
30	A & N Islands	3	10	6	33	20	21
31	Chandigarh	0	0	0	0	1	1
32	Dadra & Nagar Haveli and Daman & Diu	1	1	0	18	16	16
33	Jammu & Kashmir	523	19	327	4,255	131	3,829
34	Ladakh	1	0	3	27	20	32
35	Lakshadweep	0	0	0	0	0	0
36	Puducherry	0	0	0	0	0	0
	Total	**29,675**	**31,145**	**26,390**	**2,23,333**	**2,12,249**	**2,03,544**

Map showing SNPP-VIIRS detections during 2023-2024 forest fire season is given as Figure 4.7.

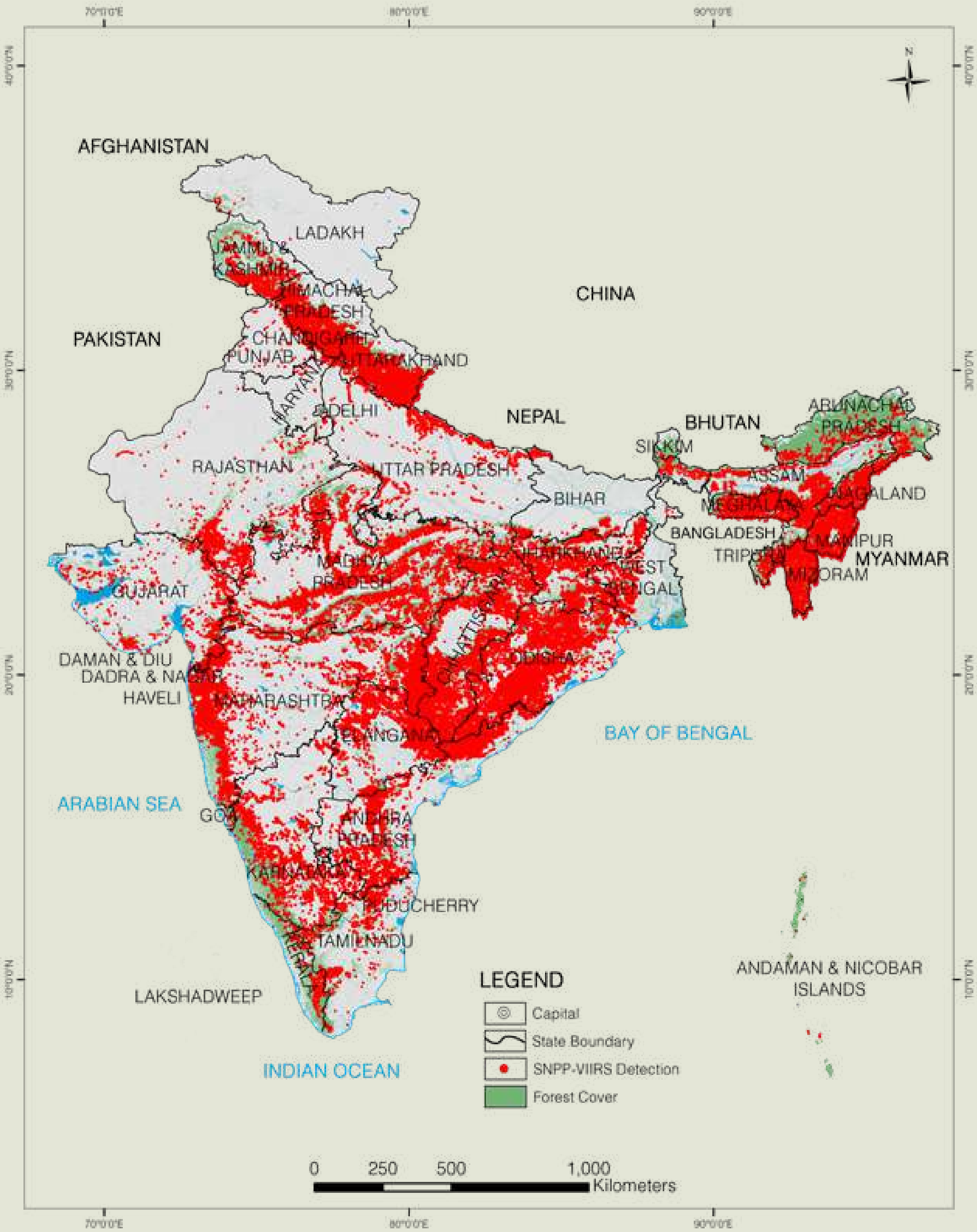


Figure 4.7 Map Showing SNPP-VIIRS Sensor detections during 2023-2024 Forest Fire Season

Pan-India graphical depiction of month-wise forest fire detections using SNPP-VIIRS sensors during fire season 2021-2022, 2022-2023 and 2023-2024 is shown in Figure 4.8

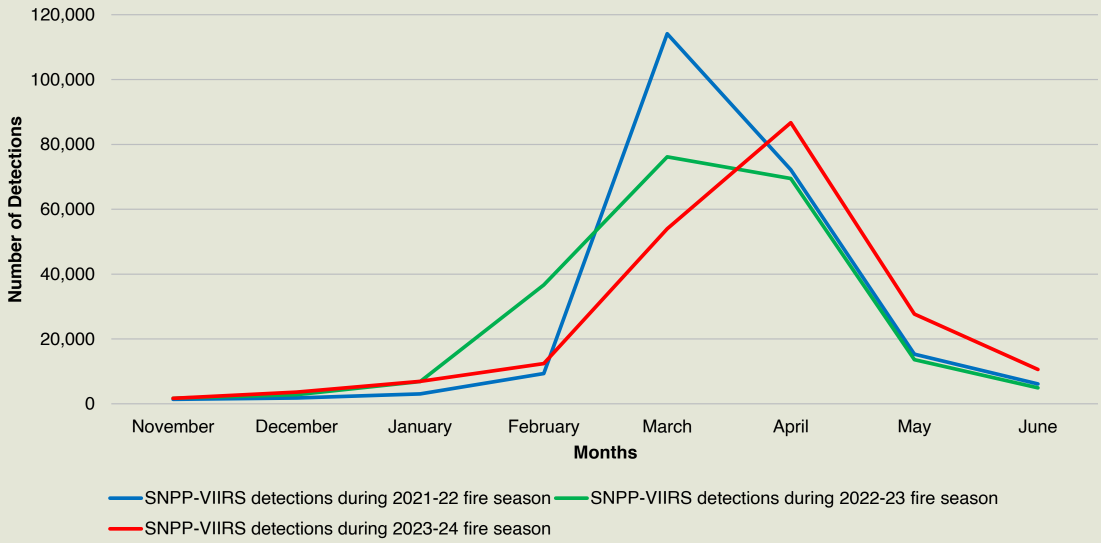


Figure 4.8 Comparative Graph Showing Month-wise Number of Detections by SNPP-VIIRS Sensor during 2021-2022, 2022-2023 & 2023-2024 Forest Fire Season

The SNPP-VIIRS forest fire data for the 2023-2024 fire season was analysed for assessing the top 10 States and top 20 districts of the country w.r.t forest fire detections as shown in Table 4.5 and Table 4.6, respectively. The following observations were made:

- Amongst States, maximum number of SNPP-VIIRS forest fire detections were observed in Uttarakhand (21,033) followed by Odisha (20,973) and Chhattisgarh (18,950).
- Amongst districts, maximum number of SNPP-VIIRS forest fire detections were observed in Gadchiroli in Maharashtra (7,042), followed by Alluri Sitharama Raju in Andhra Pradesh (6,399), and Bijapur in Chhattisgarh (5,018).

Table 4.5 Top Ten States According to Number of Forest Fire Detected by FSI using SNPP-VIIRS Sensor

State	Rank as per current Season	Fire detections Nov 2023 - June 2024	Fire detections Nov 2022 - June 2023	Rank as per previous Season
Uttarakhand	1	21,033	5,351	13
Odisha	2	20,973	33,461	1
Chhattisgarh	3	18,950	20,306	2
Andhra Pradesh	4	18,174	19,367	3
Maharashtra	5	16,008	16,119	5
Madhya Pradesh	6	15,878	17,142	4
Telangana	7	13,479	13,117	6
Himachal Pradesh	8	10,136	704	24
Assam	9	7,639	9,830	10
Jharkhand	10	7,525	11,923	8

Rank 1 denotes the State with the highest number of detections

Table 4.6 Top 20 Districts According to Number of Forest Fire Detected by FSI using SNPP-VIIRS Sensor

Districts	State	Rank as per current Season Nov 2023-June 2024	Fire detections Nov 2023-June 2024	Fire detections Nov 2022-June 2023	Rank as per previous Season Nov 2022-June 2023
Gadchiroli	Maharashtra	1	7,042	6,093	1
Alluri Sitharama Raju	Andhra Pradesh	2	6,399	3,639	2
Bijapur	Chhattisgarh	3	5,018	2,940	7
Nainital	Uttarakhand	4	3,320	570	112
Garhwal	Uttarakhand	5	3,193	928	65
Almora	Uttarakhand	6	2,810	786	78
Rayagada	Odisha	7	2,646	2,541	11
Bhadradri Kothagudem	Telangana	8	2,600	1,942	19
Mulugu	Telangana	9	2,597	1,783	23
Kandhamal	Odisha	10	2,591	3,090	4
Tehri Garhwal	Uttarakhand	11	2,589	310	198
Malkangiri	Odisha	12	2,582	1,107	55
Uttarkashi	Uttarakhand	13	2,457	324	187
Narayanpur	Chhattisgarh	14	2,316	1,466	31
Prakasam	Andhra Pradesh	15	2,226	2,958	6
Koraput	Odisha	16	1,994	1,447	32
Nandyal	Andhra Pradesh	17	1,934	2,494	12
Dima Hasao	Assam	18	1,843	2,315	14
West Singhbhum	Jharkhand	19	1,835	2,858	8
Shimla	HimachalPradesh	20	1,823	199	243

The number of State wise forest fire detections since 2017 have been given in Annexure III.

4.2.1.2 Users of FSI Forest Fire Alert System

Forest fire alert service of FSI is provided to all subscribers who have registered for receiving this service. Any individual can subscribe to this service, which is free of cost. Users can register using the link https://fsiforestfire.gov.in/registration.php and subscribe for maximum of three administrative levels and up to beat level, depending upon availability of the administrative boundary, as provided by the State/UT Forest Department. During the forest fire season 2023-2024, more than 112.67 lakh forest fire SMS alerts were disseminated to the subscribers.

From a subscriber base of 1,31,102 at the end of forest fire season 2020-2021, the number of subscribers has increased to 3,07,137 at the end of forest fire season 2023-2024. Maximum increase in subscribers has taken place in the States of Madhya Pradesh, followed by Jharkhand and Andhra Pradesh. Details of user subscriptions across different levels of administrative hierarchy is given in Figure 4.9.

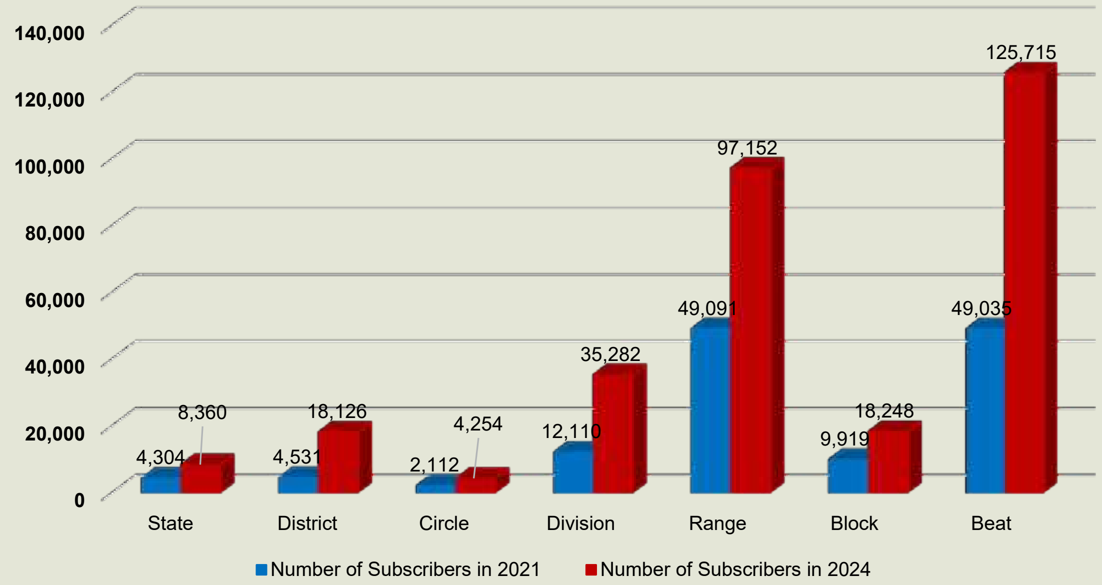


Figure 4.9 User Subscriptions across Different Levels of Administrative Hierarchy

State/UT wise status of SMS subscriptions is given in Table 4.7. The detailed table showing number of subscriptions at different administrative levels is attached as Annexure IV. Madhya Pradesh has the maximum number of subscribers to the FSI forest fire alert service, followed by Himachal Pradesh and Jharkhand.

Table 4.7 State/UT wise SMS Subscribers till 30th June, 2024

Sl. No.	State/UT	No. of Subscribers	Sl. No.	State/UT	No. of Subscribers
1	Madhya Pradesh	88,526	20	Tripura	749
2	Himachal Pradesh	66,874	21	Bihar	746
3	Jharkhand	32,701	22	Haryana	631
4	Andhra Pradesh	21,719	23	Goa	530
5	Telangana	18,180	24	A & N Islands	430
6	Uttarakhand	9,686	25	Sikkim	357
7	Maharashtra	9,671	26	Mizoram	174
8	Manipur	9,414	27	Ladakh	91
9	Chhattisgarh	7,309	28	Meghalaya	90
10	Kerala	6,301	29	Assam	47
11	Tamil Nadu	5,247	30	Delhi	36
12	Odisha	5,189	31	Arunachal Pradesh	29
13	Karnataka	4,794	32	Nagaland	28
14	Rajasthan	4,057	33	Dadra & Nagar Haveli	26
15	Jammu & Kashmir	3,408	34	Daman & Diu	12
16	Gujarat	3,365	35	Lakshadweep	11
17	Uttar Pradesh	2,975	36	Puducherry	9
18	Punjab	2,383	37	Chandigarh	6
19	West Bengal	1,336		**Total**	**3,07,137**

Top 10 States with highest increase in the number of subscribers are shown in Figure 4.10.

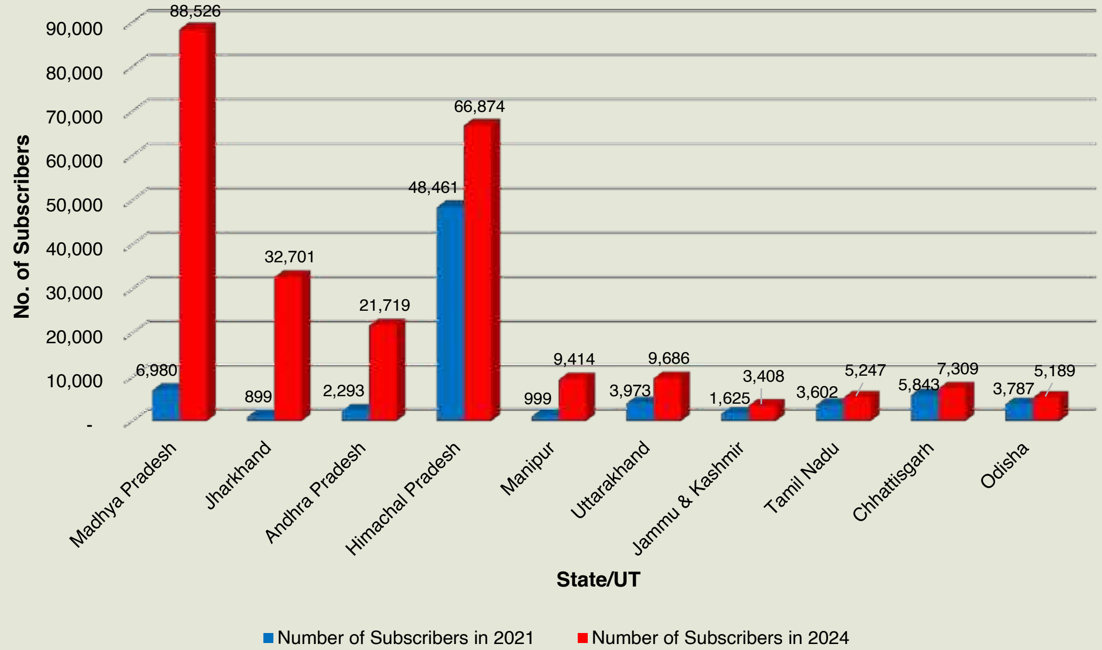


Figure 4.10 Top 10 States with Highest Increase in Number of User Subscriptions

An analysis of the State/UT wise number of subscribers has been carried out to understand their relationship with the fire detections. Table 4.8 describes the number of subscribers along with the number of SNPP-VIIRS detections for the last four years.

Table 4.8 Number of Subscribers along with Number of SNPP-VIIRS Detections for Last Four Years

Sl. No.	State/UT	Fire Season 2020-2021		Fire Season 2021-2022		Fire Season 2022-2023		Fire Season 2023-2024	
		No. of Detections	No. of Subscribers	No. of Detections	No. of Subscribers	No. of Detections	No. of Subscribers	No. of Detections	No. of Subscribers
1	Andhra Pradesh	19,328	2,293	14,138	2,539	19,367	7,034	18,174	21,719
2	Arunachal Pradesh	3,914	19	3,449	20	2,447	26	2,053	29
3	Assam	10,718	30	8,158	36	9,830	44	7,639	47
4	Bihar	5,179	258	3,024	377	3,793	534	2,763	746
5	Chhattisgarh	38,106	5,843	25,792	6,586	20,306	6,881	18,950	7,309
6	Delhi	14	27	3	34	7	32	16	36
7	Goa	45	502	20	502	147	516	36	530
8	Gujarat	3,803	2,339	2,769	2,819	2,342	3,140	3,182	3,365
9	Haryana	152	621	135	622	82	622	166	631
10	Himachal Pradesh	4,110	48,461	5,280	48,966	704	49,006	10,136	66,874
11	Jharkhand	21,713	899	9,419	10,087	11,923	22,622	7,525	32,701
12	Karnataka	5,784	4,439	4,973	4,503	13,074	4,727	5,500	4,794
13	Kerala	296	5,229	504	5,533	1,550	5,974	1,110	6,301
14	Madhya Pradesh	47,795	6,980	32,728	20,101	17,142	43,538	15,878	88,526
15	Maharashtra	34,025	12,424	22,052	6,513	16,119	7,793	16,008	9,671
16	Manipur	10,457	999	5,544	4,541	10,127	8,569	4,498	9,414
17	Meghalaya	7,658	65	6,322	67	6,604	85	4,319	90
18	Mizoram	12,846	129	8,734	163	5,798	169	6,627	174
19	Nagaland	4,975	16	3,471	17	3,882	25	2,609	28

Table 4.8 Number of Subscribers along with Number of SNPP-VIIRS Detections for Last Four Years

Sl. No.	State/UT	Fire Season 2020-2021		Fire Season 2021-2022		Fire Season 2022-2023		Fire Season 2023-2024	
		No. of Detec-tions	No. of Sub-scribers	No. of Detec-tions	No. of Sub-scribers	No. of Detec-tions	No. of Sub-scribers	No. of Detec-tions	No. of Sub-scribers
20	Odisha	51,968	3,787	22,014	4,248	33,461	4,818	20,973	5,189
21	Punjab	635	1,373	428	1,481	119	2,139	605	2,383
22	Rajasthan	3,402	3,618	2,703	3,718	2,059	3,875	4,352	4,057
23	Sikkim	63	9	26	332	49	334	101	357
24	Tamil Nadu	1,220	3,602	1,035	4,007	1,998	4,596	3,380	5,247
25	Telangana	18,237	17,853	13,737	18,502	13,117	21,432	13,479	18,180
26	Tripura	5,015	106	2,609	107	4,332	530	2,089	749
27	Uttar Pradesh	8,608	2,243	5,428	2,430	3,235	2,659	4,424	2,975
28	Uttarakhand	21,487	3,973	12,985	6,106	5,351	9,028	21,033	9,686
29	West Bengal	3,287	913	1,520	979	3,096	1,108	2,020	1,336
30	Andaman & Nicobar Islands	16	398	33	401	20	429	21	430
31	Chandigarh	0	6	0	6	1	5	1	6
32	Dadra & Nagar Haveli and Daman & Diu	34	16	18	37	16	30	16	38
33	Jammu & Kashmir	1,098	1,625	4,282	1,875	131	2,393	3,829	3,408
34	Ladakh					20	89	32	91
35	Lakshadweep	0	1	0	1	0	1	0	11
36	Puducherry	1	6	0	7	0	7	0	9
	Total	**3,45,989**	**1,31,102**	**2,23,333**	**1,58,263**	**2,12,249**	**2,14,810**	**2,03,544**	**3,07,137**

An analysis between number of subscribers and number of detections indicates that the number of fire detections have come down to a sizeable extent in the states of Madhya Pradesh, Jharkhand, Andhra Pradesh, Chhattisgarh etc., whereas, there has been no impact of the increase in number of subscribers in the states of Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Rajasthan, etc.
The reasons for the decrease in the number of fire detections may be attributed to the following two reasons:

1. Faster response to the fire detections due to the increased number of subscribers and subsequent management response might have resulted in decreased fire detections.
2. Active participation of the local communities apart from the SFDs might have controlled and doused the fires at the nascent stage even before their detection by the passing satellite.

4.2.1.3 Number of detections in the Protected Areas in fire season 2023-24

The analysis has been carried out using SNPP-VIIRS detections over 705 Protected Areas. Table 4.9 shows number of SNPP-VIIRS detections in each Protected Area category.

Table 4.9 Number of SNPP-VIIRS Detections in Each Protected Area Category

Protected Area	No. of PAs	No. of fire detections in fire season 2023-2024*
National Park	96	6,046
Sanctuary	511	19,436
Conservation Reserve	22	306
Community Reserve	76	5

* 226 detections are found to be duplicate due to overlapping of Protected Area boundary

Table 4.10 shows the number of SNPP-VIIRS detections in National Parks. The detailed table showing number of SNPP-VIIRS detections in each Sanctuary, Conservation Reserve and Community Reserve is attached as Annexure V.

Table 4.10 Number of SNPP-VIIRS Detections in National Parks

Sl. No.	Name of the National Park	State/UT	No. of SNPP-VIIRS Detections*
1	Anamudi Shola	Kerala	1
2	Anshi	Karnataka	0
3	Balpakram	Meghalaya	5
4	Bandhavgarh	Madhya Pradesh	15
5	Bandipur	Karnataka	27
6	Bannerghatta	Karnataka	13
7	Bansda	Gujarat	0
8	Betla	Jharkhand	141
9	Bhitarkanika	Odisha	0
10	Bison (Rajbari)	Tripura	0
11	Blackbuck	Gujarat	0
12	Buxa NP	West Bengal	19
13	Campbell Bay	Andaman & Nicobar Islands	0
14	Chandoli	Maharashtra	8
15	Clouded Leopard	Tripura	0
16	Corbett	Uttarakhand	229
17	Dachigam	Jammu & Kashmir	0
18	Desert	Rajasthan	0
19	Dibru-Saikhowa	Assam	6
20	Dudhwa	Uttar Pradesh	330
21	Eravikulam	Kerala	24
22	Fossil	Madhya Pradesh	0
23	Galathea Bay	Andaman & Nicobar Islands	0
24	Gangotri	Uttarakhand	2

Table 4.10 Number of SNPP-VIIRS Detections in National Parks

Sl. No.	Name of the National Park	State/UT	No. of SNPP-VIIRS Detections*
25	Gir	Gujarat	21
26	Gorumara	West Bengal	0
27	Govind	Uttarakhand	68
28	Great Himalayan	Himachal Pradesh	5
29	Gugamal	Maharashtra	10
30	Guindy	Tamil Nadu	0
31	Gulf Of Mannar Marine	Tamil Nadu	0
32	Guru Ghasi Das	Chhattisgarh	291
33	Hemis	Ladakh	0
34	Inderkila	Himachal Pradesh	0
35	Indira Gandhi	Tamil Nadu	69
36	Indira Priyadarshini Pench	Madhya Pradesh	0
37	Indravati	Chhattisgarh	1,038
38	Intanki	Nagaland	22
39	Jaldapara	West Bengal	21
40	Kalesar	Haryana	29
41	Kangaer Valley	Chhattisgarh	121
42	Kanha	Madhya Pradesh	28
43	Kasu Brahmananda Reddy	Telangana	0
44	Kaziranga	Assam	147
45	Keibul-Lamjao	Manipur	0
46	Keoladeo Ghana	Rajasthan	0
47	Khangchendzonga	Sikkim	1
48	Khir Ganga	Himachal Pradesh	4
49	Kudremukh	Karnataka	52
50	Madhav	Madhya Pradesh	9
51	Mahatma Gandhi Marine	Andaman & Nicobar Islands	0
52	Mahaveer Harina Vanasthali	Telangana	0
53	Manas	Assam	814
54	Marine	Gujarat	2
55	Mathikettan Shola	Kerala	0
56	Mollem	Goa	0
57	Mouling	Arunachal Pradesh	0
58	Mount Harriett	Andaman & Nicobar Islands	0
59	Mrugavani	Telangana	0
60	Mudumalai	Tamil Nadu	2
61	Mukurthi	Tamil Nadu	6
62	Murlen	Mizoram	1
63	Namdapha	Arunachal Pradesh	3
64	Nameri	Assam	12
65	Nanda Devi	Uttarakhand	0
66	Neora Valley	West Bengal	0
67	Nokrek Ridge	Meghalaya	1
68	Orang	Assam	54
69	Pambadum Shola	Kerala	1
70	Panna	Madhya Pradesh	50

Table 4.10 Number of SNPP-VIIRS Detections in National Parks

Sl. No.	Name of the National Park	State/UT	No. of SNPP-VIIRS Detections*
71	Papikonda	Andhra Pradesh	1,113
72	Pench	Maharashtra	2
73	Periyar	Kerala	17
74	Phawngpui (Blue Mountain)	Mizoram	0
75	Pin Valley	Himachal Pradesh	0
76	Rajaji	Uttarakhand	108
77	Nagarahole (Rajiv Gandhi)	Karnataka	0
78	Rajiv Gandhi (Rameswaram)	Andhra Pradesh	1
79	Rani Jhansi Marine	Andaman & Nicobar Islands	0
80	Ranthambhore	Rajasthan	0
81	Saddle Peak	Andaman & Nicobar Islands	0
82	Sanjay	Madhya Pradesh	20
83	Sanjay Gandhi	Maharashtra	8
84	Sariska	Rajasthan	1
85	Satpura	Madhya Pradesh	1
86	Silent Valley	Kerala	0
87	Col. Sherjung Simbalbara	Himachal Pradesh	3
88	Simlipal	Odisha	340
89	Singalila	West Bengal	0
90	Sri Venkateswara	Andhra Pradesh	25
91	Sultanpur	Haryana	0
92	Sundarbans	West Bengal	0
93	Tadoba	Maharashtra	0
94	Valley Of Flowers	Uttarakhand	0
95	Valmiki	Bihar	705
96	Van Vihar	Madhya Pradesh	0
	Total		**6,046**

** 173 detections are found to be duplicate due to overlapping of National Park boundaries*

4.2.2 Large Forest Fire Monitoring

Forest fires, if undetected and not extinguished on time, may turn into large forest fires that cause wide spread destruction. Such fires require extensive resources in terms of firefighting force, materials, equipment, and other logistical support for containment. Timely information and tracking of such large fire events helps in devising strategies for planning and resource mobilization for their effective containment, thereby minimizing losses to forests.

To assist the SFDs in effective management of large forest fire (LFF) events, a satellite based automated system of monitoring was developed and launched in 2019. The objectives of this programme are given below:

1. Continuous monitoring and tracking of large forest fires in near real-time.
2. Timely containment of such fires by SFDs.

3. Escalation of alerts to higher level for timely additional support from agencies such as District Administration, SDMA, NDMA, Armed forces, etc.
4. Development of a National Large Forest Fire Database for future planning; especially in development of State Crisis Management Plans and Working Plans.
5. For planning of burnt area restoration programmes.

The LFF programme uses the SNPP-VIIRS sensor (375 m X 375 m resolution) fire hotspot data. The application identifies a candidate large fire through an automated algorithm, which identifies large fire comprising of at least three contiguous SNPP-VIIRS pixels in any geometry having area more than ~40 ha, as shown in Figure 4.11. Once the candidate large fire is detected, it is continuously monitored using data from subsequent satellite passes as long as the fire is active. The continuous tracking of the identified event is achieved by monitoring the estimated fire boundary, which is also continuously updated as per the changes in direction of the fire event. The program scans the area for additional three days after its inactivity to detect dormant fires, if any, restarting in the same area again.

Information on the number of fire affected active pixels, total number of fire affected pixels, administrative and management boundaries, KMZ file, and web-linked *.png map of the fire location, etc., are provided as e-mail to the Principal Chief Conservator of Forests (Head of Forest Force), and Nodal Officers of SFDs; and as SMS to all the registered subscribers.

During fire season 2023-2024, 11,928 LFF events were detected and tracked by FSI. Out of these, about 67.10% LFF were extinguished or contained within 24 hours, 31.34% of LFF were active for one to five days, 1.41% were active for six to ten days, and only 10 LFF (0.15%) continued to burn for eleven to fifteen days.

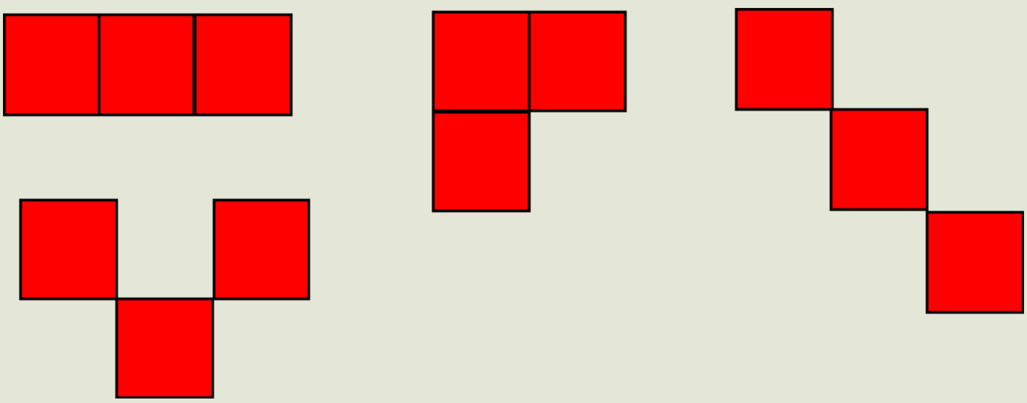


Figure 4.11 Candidate Large Forest Fire Detection in 3 Contiguous Pixels Connected in the Side or Corner

Since the commencement of the LFF monitoring programme in 2019, FSI is preparing a database of all the LFF events detected. A unique system for naming the large forest fire events has been developed. In every fire season, individual LFF event is recorded by the name of the Range of the State Forest Department where it was first detected. If the State has not provided the administrative boundary, the LFF event is recorded after the name of the District. In cases, where multiple LFF events are detected in the same Range, the numerical numbering is suffixed after the name of the Range. For example, if 4th LFF event is detected in Range Paukhal, then this LFF event will be recorded as Paukhal - 4 in the large forest fire database.

Based on the large forest fire events detected, a report card is prepared, which indicates the response of the SFD in dousing the large forest fire event. Table 4.11 shows the top 10 large forest fire affected states and their responses.

Annexure VI shows the entire table with percentage of number of active days of large forest fire events, arranged in the descending order of percentage, of <24 hrs. Only those State/UT have been selected for comparison, for which the number of large forest fire events is greater than 10 during the 2023-24 fire season.

Photo: FSI Repository

Table 4.11 Top 10 State wise Number of Large Forest Fire Events Detected During Fire Season 2023-2024

State	Number of active days of large forest fire events															
	< 24 Hrs.	1 < Day < 2	2 < Day < 3	3 < Day < 4	4 < Day < 5	5 <Day < 6	6 < Day < 7	7 < Day < 8	8 < Day < 9	9 < Day < 10	10 < Day < 11	11 < Day < 12	12 < Day < 13	13 <Day < 14	14 < Day < 15	> 15 days	Total
Uttarakhand	821	216	112	82	37	17	13	9	3	2	1	0	0	0	0	0	**1,313**
Odisha	737	181	96	63	23	17	6	2	3	2	0	0	0	1	0	0	**1,131**
Andhra Pradesh	675	192	80	58	26	14	10	6	3	2	2	2	1	1	0	1	**1,073**
Madhya Pradesh	682	144	62	50	11	5	2	0	2	2	1	0	0	0	1	0	**962**
Chhattisgarh	536	169	87	63	33	11	10	7	8	1	0	1	1	0	1	0	**928**
Telangana	507	134	87	58	21	10	6	6	2	1	0	1	0	0	0	0	**833**
Himachal Pradesh	485	118	52	44	17	5	5	4	1	1	0	0	0	0	0	0	**732**
Maharashtra	479	79	41	31	16	6	9	1	3	0	1	1	1	0	0	0	**668**
Mizoram	351	71	41	24	4	7	2	1	0	0	0	0	0	0	0	0	**501**
Assam	332	76	31	17	10	1	3	0	0	1	0	0	0	0	0	0	**471**

Photo: FSI Repository

4.2.3 Pre-Fire Alert Based on Forest Fire Danger Rating

Early warnings about susceptible forest fire regions are useful in taking timely preventive measures to avoid their occurrence and related losses. Since 2016, FSI is working on developing danger rating system based on daily weather data, forest fuel load, and terrain conditions.

FSI is currently working on a system similar to Canadian Forest Fire Danger Rating System (CFFDRS), based on Fire Weather Index (FWI) for forest fire danger rating in India. All information regarding FWI is downloadable from Goddard Earth Observing System (GEOS-5) daily data from NASA's Global Fire Weather Database (GFWED), which is satellite calibrated weather data. Additionally, Forest Type Layer information, Forest Fire Archival information, and other data shown in Figure 4.13 are also being used to generate Forest Fire Danger Rating. The parameters are quantified and overlaid on grids of 5 km X 5 km. The process flow diagram for generation of forest fire danger rating and Pre-Fire alerts is shown in Figure 4.12.

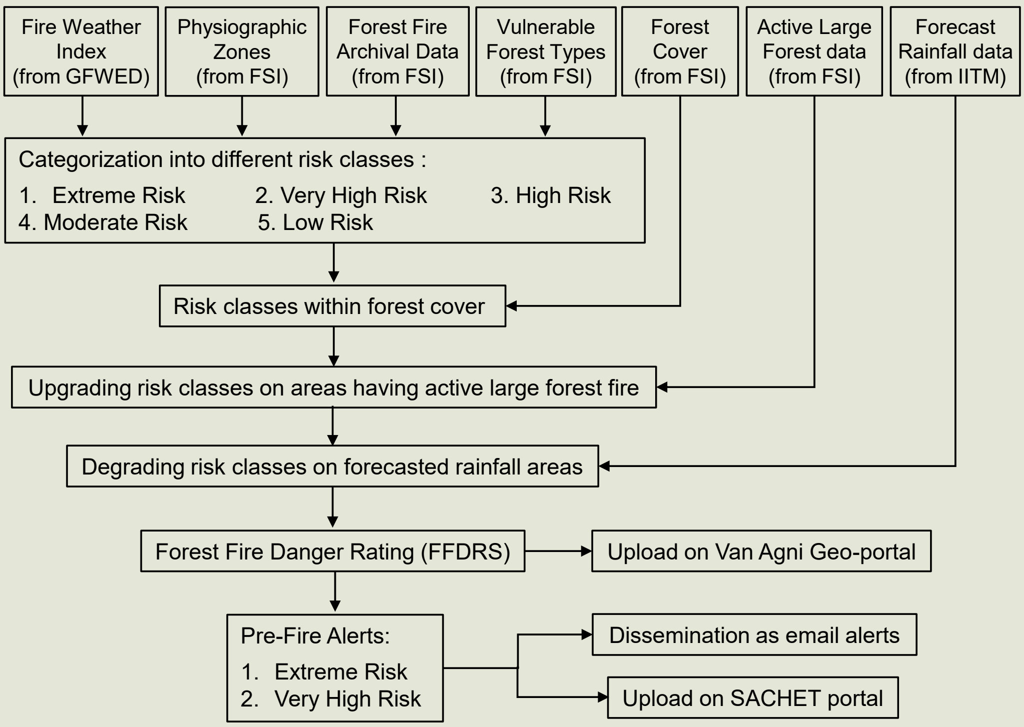


Figure 4.12 Process Flow of Pre-Fire Alert Generation

FWI consists of six components that accounts for the effect of fuel moisture and weather conditions on fire behaviour. The first three components comprise of fuel moisture codes, which are numeric ratings of the moisture content of the forest floor and other dead organic matter. Their value rises as the moisture content decreases. The remaining three components comprise of fire behaviour indices, which represent the rate of fire spread, the fuel available for combustion, and the frontal fire intensity. These three values rise as the fire danger increases.

The FWI values from GEOS-5 daily database from NASA's GFWED database are downloaded and thresholds are customized for different physiographic zones of the country as shown in Table 4.12, using past archive data on a weekly basis. On the basis of various sets of decisions, the FWI classes are again reclassified based on the vulnerability (based on Forest Types Maps), archival forest fire data, active large forest fire event, and forecast rainfall data as shown in Figure 4.13. The Fire Danger Rating is categorized into five classes- Extreme Risk, Very High Risk, High Risk, Moderate Risk, and Low Risk; and uploaded as Web Map Service (WMS) in the Van Agni Geo-portal of FSI.

Photo: FSI Repository

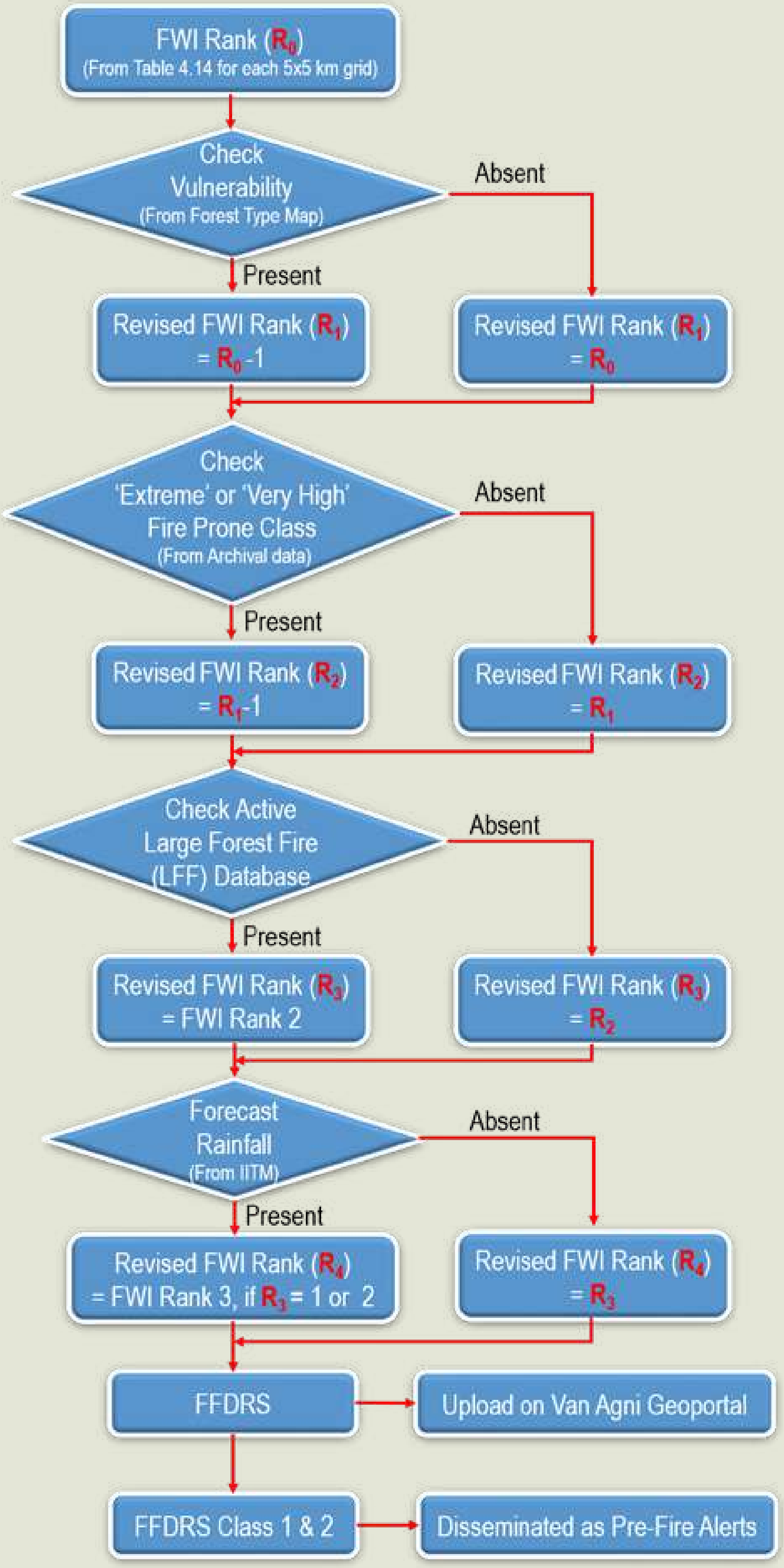


Figure 4.13 Reclassification of FWI Values Based on Various Set of Decisions

During Fire season, the Extreme Risk and Very High Risk categories of Forest Fire Danger Rating based on the above process are disseminated as Pre-Fire Alerts on every Thursday of the week to SFDs. Pre-Fire Alerts are disseminated through e-mail as shape file in keyhole markup language (KML) format, which is Google Earth compatible, to Principal Chief Conservator of Forests & Head of Forest Force, and Forest Fire Nodal Officers of respective state forest departments

Table 4.12 Physiographic Zone-Wise Threshold Criteria of FWI Values

Sl. No	Physiographic zone	FWI Rank				
		1 (Extreme)	2 (Very high)	3 (High)	4 (Moderate)	5 (Low)
1	Western Himalayas	Above 100	81-100	61-80	46-60	0-45
2	North East Ranges	Above 100	81-100	66-80	46-65	0-45
3	Central India	Above 110	91-110	71-90	46-70	0-45
4	Eastern Plains	Above 100	81-100	66-80	46-65	0-45
5	Eastern Himalayas	Above 100	81-100	66-80	46-65	0-45
6	Deccan	Above 110	91-110	71-90	46-70	0-45
7	Western Ghats	Above 105	86-105	61-85	46-60	0-45
8	Eastern Ghats	Above 100	81-100	66-80	46-65	0-45

4.2.3.1 Comparison of Generated Pre-Fire Alert Grids with Number of SNPP-VIIRS Detections Observed During the Ensuing Week

An analysis has been carried out to compare the generated pre-fire alert grids with the number of SNPP-VIIRS detections falling over these grids during the ensuing week. The peak fire season from 8th February 2024 to 30th June 2024 has shown a direct relation of the generated pre-fire alert grids with the number of SNPP-VIIRS detections as shown in the Figure 4.14.

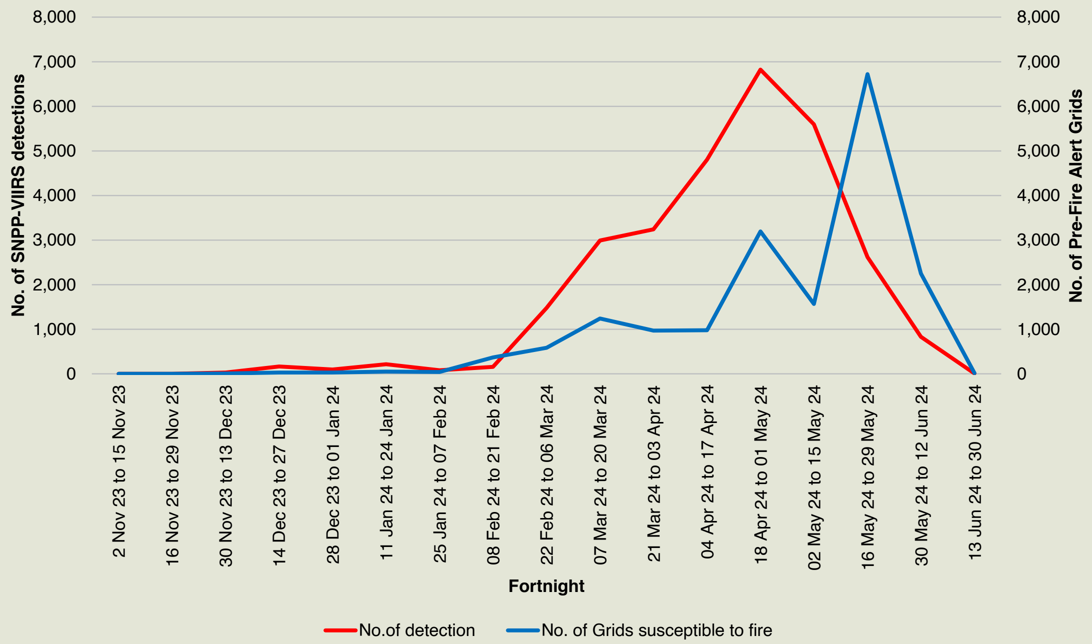


Figure 4.14 Graph Showing Fortnight-Wise Comparison of Number of pre-fire alert Grids (Extreme Risk Grids and Very High Risk Grids) with Number of SNPP-VIIRS Detections In the Ensuing Fortnight Falling Over these Grids

4.2.3.2 Upload of Pre-Fire Alert data on the SACHET Portal for Integrated Alert System

The National Disaster Management Authority (NDMA), has conceptualized a Common Alerting Protocol (CAP) based Integrated Alert System for disasters at pan-India level. This project entails timely dissemination of early warnings through various technological means, utilizing geo-information[12].

FSI established as one of the Alert Generating Agency (AGA) since March 2023, is responsible for uploading Pre-Fire Alert data onto the SACHET Portal. An illustration of the pre-fire alert data uploaded on SACHET portal is presented at Figure 4.15. This data is subsequently broadcast to public as Pre-Fire Alerts by the respective State Disaster Management Authorities (SDMA) after assessing the local environment, climatic and other related factors.

12 https://sachet.ndma.gov.in/

Figure 4.15 Illustration of Pre-Fire Alert Data Successfully Uploaded onto the SACHET Portal

4.2.4 Forest Fire Risk Zonation Mapping in West Himalayan States

Certain regions are more susceptible to forest fires due to factors like type of fuel load, local human activities, topographical features, forest type, and climatic conditions. In order to have a better and robust system for controlling and managing forest fires in a region, an effective fire risk zonation helps to delineate different risk areas for prioritizing management interventions in an effective manner.

A pilot study has been carried out for the West Himalayan State/UT comprising Himachal Pradesh, Uttarakhand, Jammu & Kashmir, and Ladakh to identify Fire Risk Zones and categorize them into different risk classes using suitable variables. The results of the study are given in Table 4.13, and fire risk zone map of the West Himalayan States is shown in Figure 4.16. The detailed study is provided in Annexure VII.

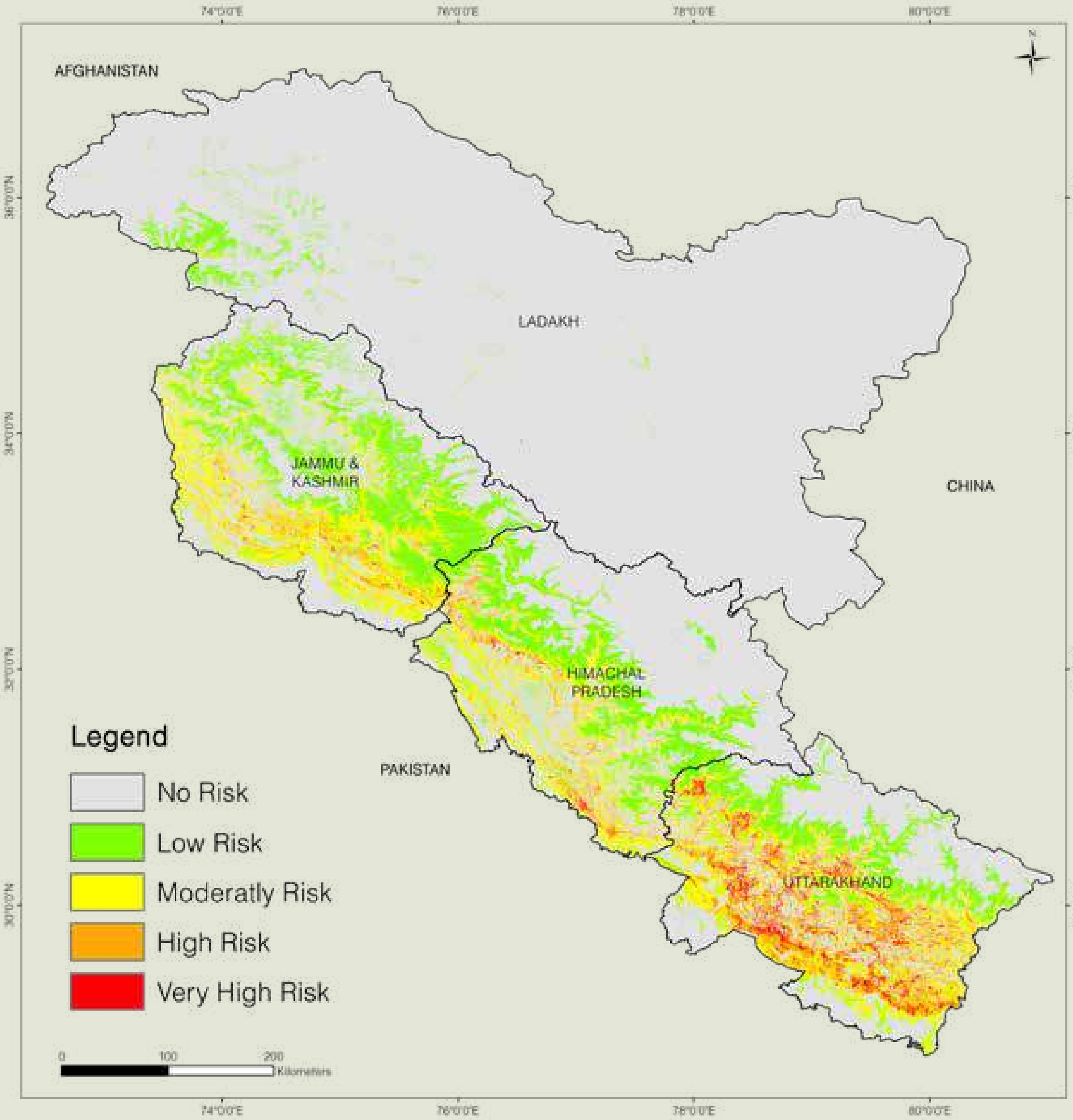


Figure 4.16 Forest Fire Risk Zone Map of the West Himalayan States

Table 4.13 Area of Fire risk classes with Number of Fire Detections by SNPP-VIIRS Sensor in the Last Five Years (2018-19 to 2022-23)

State/UT	Class	Area of risk zone (in km^2)	Number of Forest Fire detections by SNPP-VIIRS sensor in the last 5 years	Number of detections per unit area X 100
Ladakh	No Risk	1,65,783	19	0.01
Digitized	Low Risk	2,194	57	2.60
Boundary Area	Moderate Risk	78	2	2.56
(1,68,327 km^2)	High Risk	0	0	-
	Very High Risk	0	0	-
Jammu & Kashmir	No Risk	33,237	1,278	3.85
Digitized	Low Risk	10,606	1,183	11.15
Boundary Area	Moderate Risk	8,972	6,489	72.33
(54,634 km^2)	High Risk	1,747	2,660	152.26
	Very High Risk	62	115	185.48
Himachal Pradesh	No Risk	40,230	3,168	7.87
GA (55,673 km^2)	Low Risk	6,953	2,257	32.46
	Moderate Risk	6,677	8,347	125.01
	High Risk	1,621	3,279	202.28
	Very High Risk	192	433	225.52
Uttarakhand	No Risk	29,178	8,554	29.32
GA (53,483 km^2)	Low Risk	5,806	2,471	42.56
	Moderate Risk	9,293	16,854	181.36
	High Risk	7,185	24,434	340.07
	Very High Risk	2,021	7,691	380.55

It can be observed from the above table that the number of detections in Very High Risk class followed by High Risk, Moderate Risk, Low Risk, and No risk classes per unit area of each class in each State/UT is in the same order in all the States. In Himachal Pradesh, 68.97 % of the total SNPP-VIIRS detections of last 5 years fall under 15.25 % of the total geographical area (GA), which consists of Very High Risk class, High Risk class and Moderate Risk class. Similarly, in Jammu & Kashmir, 79.01 % of the detections fall under 19.74 % of the Digitized Boundary Area and in Uttarakhand, 81.63 % of the detections fall under 34.59 % of the GA. No Very High class and High Risk class has been observed in Ladakh. It is also observed that number of detections per unit area in Very High Risk and High Risk class in Uttarakhand is 3.49 per km^2 as compared to 2.05 per km^2 in Himachal Pradesh.

4.2.5 FSI Van Agni Geo-portal

FSI Forest Fire Geo-portal, VAN AGNI 2.0, is an in-house platform developed by FSI. The portal offers a user-friendly interactive interface, allowing users to access and visualize various forest fire-related data. This encompasses forest fires, tracking of large forest fire events, as well as additional thematic layers like forest administrative boundaries, forest cover, forest types, fire prone forest areas, and the Fire Weather Index (FWI) based fire danger ratings, all pertaining to the chosen area of interest.

The FSI Van Agni Geo-portal serves as a centralized hub for information regarding forest fires across India. Users can visualize the detection of near real-time forest fires through MODIS and SNPP-VIIRS sensors over the past three days, displayed in distinct pixels. Information about large forest fire events, displaying both active and inactive fire pixels, along with the Forest Fire Danger Rating processed for the ensuing week is illustrated in Figure 4.17.

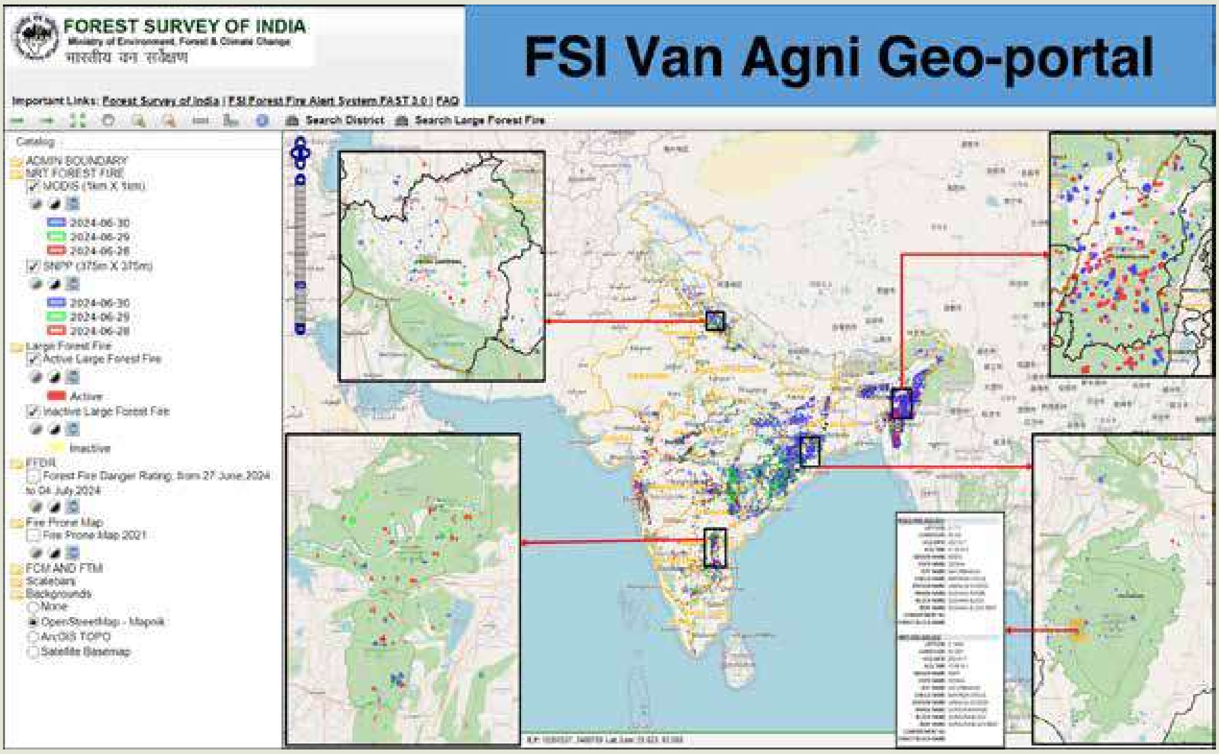


Figure 4.17 FSI Van Agni Geo-portal

4.2.6 Identification of Fire Prone Forest Areas

FSI has carried out a study based on spatial analysis of forest fire detections using SNPP-VIIRS sensor by FSI in the last seven years (2017-2023) to identify fire prone forest areas in the country. Extent of forest cover and scrub under different fire prone classes has also been determined for each State/UT.

Frequency of detected forest fires in an area over a period of time indicates proneness of the area to forest fires. Maps showing forest area in different classes of fire proneness can be an effective management tool for controlling forest fires. Such maps can be used for optimally utilizing scarce resources available for controlling forest fires in fire season. Increased vigil in highly fire prone forest areas may prevent forest fires effectively. Considering the usefulness of mapping fire prone forest areas, analysis of the detected forest fire points in GIS framework along with a grid coverage of 5 km X 5 km and latest forest cover has been carried out for the whole country.

Details of forest cover and scrub under different fire prone classes is given in Table 4.14. Map showing fire prone forest areas in the country under different categories is presented as Figure 4.18. State/UT wise details of forest cover and scrub under different fire proneness categories is presented in Table 4.15.

4.2.6.1 Highlights of the Study

- As per the long-term trend analysis performed by FSI, nearly 11.34% area of Forest Cover and scrub in India is under extremely to very highly fire prone zone.
- Parts of Assam, Meghalaya, Manipur, Mizoram and Tripura, under North-Eastern Region, showed the highest tendency of forest fire, and these states fall under extremely to very highly forest fire zone.
- Parts of Andhra Pradesh, Telangana, Chhattisgarh, Odisha, Madhya Pradesh, Jharkhand and Uttarakhand show patches of extremely and very highly fire prone zones.

Based on robust data of a fairly long period, the identification of fire prone forest areas of the country presents credible spatial data, which can be effectively utilized for policy formulation, planning and strategizing forest fire mitigation measures by the SFDs.

Table 4.14 Forest Cover and Scrub in Different Fire Prone Classes

Sl. No.	Category	Forest Cover and Scrub (in km^2)	% of total Forest Cover and Scrub
1	Extremely Fire Prone	11,018.24	1.45
2	Very Highly Fire Prone	75,084.02	9.89
3	Highly Fire Prone	1,26,187.87	16.63
4	Moderately Fire Prone	1,15,484.30	15.22
5	Less Fire Prone	4,31,190.82	56.81
	Total	**7,58,965.25**	**100**

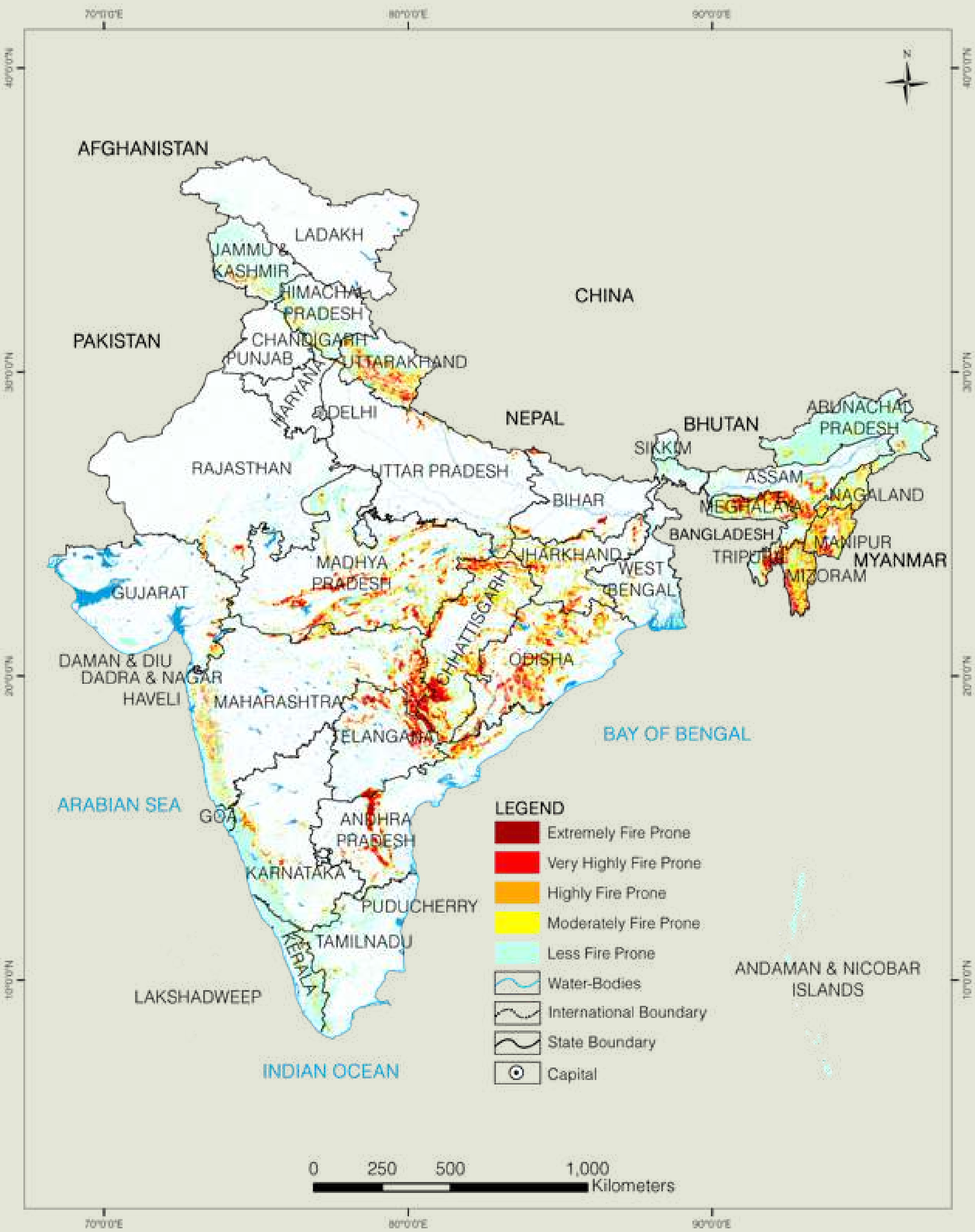


Figure 4.18 Map Showing Forest Areas under Different Fire Prone Classes

Photo: FSI Repository

Table 4.15 Forest Cover and Scrub of State/UT under Different Fire Prone Classes

Sl. No.	State/UT	Extremely Fire Prone		Very Highly Fire Prone		Highly Fire Prone	
		Forest Cover and Scrub (in km²)	% of total Forest Cover and Scrub	Forest Cover and Scrub (in km²)	% of total Forest Cover and Scrub	Forest Cover and Scrub (in km²)	% of total Forest Cover and Scrub
1	Andhra Pradesh	1,055.83	2.75	5,935.11	15.44	7,360.94	19.15
2	Arunachal Pradesh	26.52	0.04	122.04	0.18	1,074.78	1.61
3	Assam	400.95	1.40	3,352.77	11.74	4,798.75	16.81
4	Bihar	343.30	4.41	1,217.02	15.62	1,362.32	17.48
5	Chhattisgarh	2,265.19	4.01	10,453.80	18.53	16,324.65	28.93
6	Delhi	0.00	0.00	0.00	0.00	0.00	0.00
7	Goa	0.73	0.03	0.00	0.00	0.00	0.00
8	Gujarat	11.10	0.07	705.82	4.14	1,224.97	7.19
9	Haryana	0.00	0.00	0.00	0.00	28.89	1.62
10	Himachal Pradesh	0.00	0.00	69.77	0.44	1,100.12	6.92
11	Jharkhand	109.46	0.45	2,756.20	11.33	6,926.56	28.48
12	Karnataka	4.25	0.01	1,130.13	2.58	3,409.31	7.79
13	Kerala	0.00	0.00	62.13	0.28	513.06	2.32
14	Madhya Pradesh	1,135.38	1.42	10,478.22	13.07	14,910.49	18.59
15	Maharashtra	1,508.20	2.77	6,853.38	12.57	10,393.30	19.07
16	Manipur	39.45	0.22	2,787.33	15.87	6,799.43	38.72
17	Meghalaya	638.89	3.63	2,516.49	14.31	4,013.73	22.82
18	Mizoram	473.93	2.59	2,596.79	14.19	6,252.11	34.16
19	Nagaland	0.00	0.00	385.65	2.99	2,938.57	22.80
20	Odisha	575.40	1.01	10,261.95	17.98	18,296.36	32.06
21	Punjab	0.03	0.00	20.66	1.09	224.95	11.92
22	Rajasthan	92.64	0.42	622.77	2.83	964.79	4.38
23	Sikkim	0.00	0.00	0.00	0.00	0.00	0.00
24	Tamil Nadu	0.00	0.00	95.86	0.35	690.41	2.53
25	Telangana	1,517.74	6.32	6,003.97	25.01	4,319.76	17.99
26	Tripura	688.72	8.88	1,791.02	23.09	1,104.48	14.24
27	Uttar Pradesh	106.14	0.68	1,196.61	7.63	2,489.20	15.87
28	Uttarakhand	24.39	0.10	3,193.95	12.92	6,832.16	27.64
29	West Bengal	0.00	0.00	204.47	1.20	943.16	5.56
30	Andaman & Nicobar Islands	0.00	0.00	0.00	0.00	0.00	0.00
31	Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00
32	Dadra & Nagar Haveli and Daman & Diu	0.00	0.00	0.00	0.00	0.00	0.00
33	Jammu & Kashmir	0.00	0.00	270.11	1.25	890.62	4.12
34	Ladakh	0.00	0.00	0.00	0.00	0.00	0.00
35	Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00
36	Puducherry	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**11,018.24**	**1.45**	**75,084.02**	**9.89**	**1,26,187.87**	**16.63**

Moderately Fire Prone		Less Fire Prone	
Forest Cover and Scrub (in km²)	% of total Forest Cover and Scrub	Forest Cover and Scrub (in km²)	% of total Forest Cover and Scrub
5,602.78	14.58	18,481.92	48.08
3,007.80	4.49	62,709.41	93.68
3,521.25	12.33	16,480.76	57.72
986.21	12.65	3,884.40	49.84
13,239.33	23.46	14,139.19	25.07
0.00	0.00	197.67	100.00
68.09	2.98	2,218.59	96.99
1,492.81	8.76	13,611.89	79.84
79.71	4.46	1,680.04	93.92
2,545.35	16.02	12,173.80	76.62
5,948.19	24.45	8,583.69	35.29
4,361.42	9.96	34,862.31	79.66
1,322.05	5.99	20,184.00	91.41
14,519.68	18.10	39,153.87	48.82
11,128.85	20.42	24,620.47	45.17
5,016.92	28.57	2,915.98	16.62
3,752.65	21.34	6,665.49	37.90
5,164.07	28.21	3,818.10	20.85
4,410.46	34.22	5,155.06	39.99
12,617.42	22.11	15,315.11	26.84
202.71	10.74	1,439.35	76.25
1,299.19	5.90	19,045.57	86.47
29.72	0.81	3,632.17	99.19
1,699.73	6.22	24,842.51	90.90
3,041.05	12.67	9,126.40	38.01
975.94	12.58	3,197.88	41.21
2,077.08	13.24	9,816.28	62.58
4,946.88	20.01	9,719.33	39.33
1,159.94	6.84	14,662.68	86.40
1.83	0.03	6,735.25	99.97
0.00	0.00	25.78	100.00
0.00	0.00	230.28	100.00
1,244.13	5.76	19,203.80	88.87
21.06	0.81	2,590.35	99.19
0.00	0.00	27.06	100.00
0.00	0.00	44.38	100.00
1,15,484.30	**15.22**	**4,31,190.82**	**56.81**

Photo: FSI Repository

4.2.7 Sharing of WMS and WFS Service

An important component of the forest fire program is to generate Web Map Service (WMS) and Web Feature Service (WFS) of fire detections and disseminate them to the state forest departments for use of these services through their portals. FSI has provided these services to the states, including Andhra Pradesh, Jammu & Kashmir, Uttarakhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Telangana, Goa, and Delhi as requested by the SFD. North Eastern Space Applications Centre (NESAC) in Shillong also utilizes these services for the North-Eastern States.

The Web Feature Service (WFS) interface standard by the Open Geospatial Consortium enables a platform-independent method for requesting geographical features over the internet. The WMS/WFS service for near real-time forest fire monitoring comprises layers from MODIS and SNPP-VIIRS sensors, displaying detections from the last three days (including the current day) with distinct legends. The WMS/WFS resources for large forest fire events encompass incidents of considerable forest fires during the current fire season. The WMS service for FWI-based danger ratings presents various danger rating categories applicable for the upcoming week.

4.3 Analysis of Forest Fires in Tiger Reserves

Tiger reserves are important due to their significance in conserving the biodiversity, protecting the habitat, its population and promoting ecological balance. These reserves also protect the habitats of numerous other floral and faunal species, ensuring the preservation of diverse ecosystems. For sustaining the tiger population, a good prey base is required; which, in turn, depends on good spread of palatable grasses. Hence, fires play a major role in management of tiger reserves, both as a management tool to maintain grasslands, and as an ecological threat.

An analysis has been carried out on forest fires within the boundaries of Tiger Reserves based on the following criteria:

4.3.1 Number of Detections

The analysis has been conducted by considering the number of SNPP-VIIRS detections occurring within the confines of the Tiger Reserves. This comparative study spans the last five fire seasons, i.e., 2019-2020, 2020-2021, 2021-2022, 2022-2023 and 2023-24 as shown in Table 4.16 and has been sorted in decreasing order with number of detections in fire season 2023-24.

Table 4.16 Comparison of Number of SNPP-VIIRS Detections in the Tiger Reserves

Sl. No.	Name of Tiger Reserve	Number of SNPP-VIIRS sensor detections				
		2019-2020	2020-2021	2021-2022	2022-2023	2023-2024
1	Nagarjunsagar Srisailam Tiger Reserve	1,919	2,978	1,984	3,272	2,644
2	Indravati Tiger Reserve	1,173	2,513	2,363	1,475	1,969
3	Valmiki Tiger Reserve	74	1,438	39	1,524	1,470
4	Kawal Tiger Reserve Asifabad	1,583	2,588	1,947	2,008	1,243
5	Amrabad Tiger Reserve	897	1,544	1,140	1,256	1,224
6	Manas Tiger Reserve	652	369	749	582	1,033
7	Dudhwa Tiger Reserve	358	684	350	629	764
8	Similipal Tiger Reserve	534	3,490	229	1,423	514
9	Anamalai Tiger Reserve	77	30	82	312	500
10	Udanti Sitanadi Tiger Reserve	102	1,707	724	736	475
11	Palamau Tiger Reserve	49	1,833	1,445	631	473
12	Pilibhit Tiger Reserve	390	468	389	301	435
13	Kaziranga Tiger Reserve	306	219	370	378	399
14	Corbett Tiger Reserve	31	737	123	147	386
15	Dampa Tiger Reserve	372	484	484	269	285
16	Panna Tiger Reserve	108	522	236	136	260
17	Rajaji Tiger Reserve	14	537	329	193	208
18	Nawegaon Nagzira Tiger Reserve	76	518	473	227	189
19	Sanjay Dubri Tiger Reserve	7	196	393	505	188
20	Buxa Tiger Reserve	30	10	25	36	126
21	Sahyadri Tiger Reserve	173	182	139	124	122
22	Achanakmar Tiger Reserve	19	837	492	130	110
23	Bandhavgarh Tiger Reserve	95	611	746	582	102
24	Periyar Tiger Reserve	72	28	35	50	101
25	Mudumalai Tiger Reserve	5	3	2	22	95
26	Orang Tiger Reserve	36	68	110	70	88
27	Satkosia Tiger Reserve	47	621	52	189	80
28	Sathyamangalam Tiger Reserve	20	20	12	36	78
29	Melghat Tiger Reserve	49	346	509	288	75
30	Bandipur Tiger Reserve	62	50	26	71	71
31	Namdapha Tiger Reserve	76	144	176	83	58
32	Kanha Tiger Reserve	25	205	347	88	56
33	Kalakad Mundanthurai Tiger Reserve	39	14	22	60	54
34	Satpura Tiger Reserve	122	543	335	131	54
35	Biligiri Ranganatha Tiger Reserve	56	12	7	33	53
36	Kali Tiger Reserve	12	11	27	281	45
37	Srivilliputhur Megamalai Tiger Reserve	12	12	29	20	32
38	Pench Tiger Reserve Madhya Pradesh	20	160	104	46	31
39	Bhadra Tiger Reserve	26	19	16	236	30
40	Nameri Tiger Reserve	9	37	27	36	27
41	Tadoba Andhari Tiger Reserve	21	102	53	29	19
42	Parambikulam Tiger Reserve	0	0	4	43	17
43	Pakke Tiger Reserve	11	36	10	18	12
44	Ranthambore Tiger Reserve	4	2	9	14	8

Table 4.16 Comparison of Number of SNPP-VIIRS Detections in the Tiger Reserves

Sl. No.	Name of Tiger Reserve	Number of SNPP-VIIRS sensor detections				
		2019-2020	2020-2021	2021-2022	2022-2023	2023-2024
45	Nagarahole Tiger Reserve	4	7	6	21	7
46	Mukundara Hills Tiger Reserve	6	6	1	20	6
47	Pench Tiger Reserve Maharashtra	7	223	42	5	6
48	Bor Tiger Reserve	2	2	7	14	5
49	Kamlang Tiger Reserve	0	0	0	0	2
50	Ramgarh Vishdhari Tiger Reserve	10	8	8	53	2
51	Sariska Tiger Reserve	0	2	34	0	2
52	Sunderbans Tiger Reserve	0	0	0	0	0
	TOTAL	**9,792**	**27,176**	**17,261**	**18,833**	**16,233**

4.3.1.1 Tiger Reserves with maximum number of Forest Fire Detections

Fire incidents are influenced by the specific timeframe in which they occur. Since peak fire months vary among different Tiger Reserves, a detailed analysis of the top five reserves (identified based on number of SNPP-VIIRS detections) has been conducted over the past five seasons. This analysis is presented in the Table 4.17.

Table 4.17 Number of Forest Fire Detections During Last Five Fire Seasons Over the Top Five Tiger Reserves

Tiger Reserve	Fire Season	Number of SNPP-VIIRS detections								
		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Nagarjunsagar Srisailam Tiger Reserve	2019-20	1	0	31	125	1,043	649	70	0	1,919
	2020-21	1	6	39	216	2,432	256	27	1	2,978
	2021-22	0	0	11	246	1,497	195	30	5	1,984
	2022-23	0	2	42	1,123	1,722	325	14	44	3,272
	2023-24	3	4	46	713	1,179	665	34	0	2,644
Indravati Tiger Reserve	2019-20	0	0	1	0	20	918	234	0	1,173
	2020-21	0	0	2	17	1,966	523	5	0	2,513
	2021-22	0	0	2	9	1,486	839	27	0	2,363
	2022-23	0	0	16	25	201	1,085	98	50	1,475
	2023-24	0	0	0	5	481	1,462	21	0	1,969
Valmiki Tiger Reserve	2019-20	6	0	3	13	16	25	11	0	74
	2020-21	7	6	7	12	310	1,096	0	0	1,438
	2021-22	0	0	3	10	8	18	0	0	39
	2022-23	0	7	23	24	252	1,160	40	18	1,524
	2023-24	2	2	4	29	28	1,333	72	0	1,470
Kawal Tiger Reserve Asifabad	2019-20	0	0	3	15	730	663	170	2	1,583
	2020-21	3	3	0	459	1,805	304	14	0	2,588
	2021-22	0	5	1	1	1,614	278	45	3	1,947
	2022-23	2	5	2	625	946	401	22	5	2,008
	2023-24	2	4	1	131	711	310	80	4	1,243
Amrabad Tiger Reserve	2019-20	0	0	9	37	629	199	18	5	897
	2020-21	0	0	9	252	1153	122	8	0	1,544
	2021-22	0	1	1	115	966	47	5	5	1,140
	2022-23	1	2	3	465	541	240	2	2	1,256
	2023-24	0	0	35	564	403	204	18	0	1,224

4.3.2 Time taken to douse Large Forest Fire Event in tiger reserves with maximum tiger population

Managing and mitigating large forest fires is crucial to preserving the health of the reserve's ecosystem, protecting wildlife habitats, and ensuring the safety of nearby communities. Day-wise active large forest fire events detected during fire season 2023-2024 over the top 10 Tiger Reserves identified based on the number of tigers present in each reserve[13] is shown in Table 4.18.

Table 4.18 Time Taken to Douse Large Forest Fire Event in Tiger Reserves

Tiger Reserve	< 24 Hrs.	1 < Day < 2	2 < Day < 3	3 < Day < 4	4 < Day < 5	5 < Day < 6	Total
Corbett Tiger Reserve	8	0	1	1	2	0	12
Bandipur Tiger Reserve	2	0	0	0	0	0	2
Nagarahole Tiger Reserve	0	0	0	0	0	0	0
Bandhavgarh Tiger Reserve	4	0	0	1	0	0	5
Dudhwa Tiger Reserve	32	10	2	2	0	0	46
Mudumalai Tiger Reserve	1	0	1	0	0	1	3
Kanha Tiger Reserve	2	0	0	0	0	0	2
Kaziranga Tiger Reserve	8	2	1	1	0	0	12
Sunderbans Tiger Reserve	0	0	0	0	0	0	0
Tadoba Andhari Tiger Reserve	0	0	0	0	0	0	0

[13] Press Release 29 July 2023, MoEFCC, All India Tiger Esttimation-2022: Release of the detailed Report, Global Tiger Day, Release of comprehensive Tiger Report – at Corbett Tiger Reserve.
https://pib.gov.in/PressReleasePage.aspx?PRID=1943922

Forest fire engulfs the frontline staff of Binsar Wildlife Sanctuary – A tribute in Memoriam to the Heroes of Binsar

On 13th June, 2024, a report of forest fire in Binsar Wildlife Sanctuary in the district of Almora in Uttarakhand galvanized a team of eight forest personnel of Uttarakhand Forest Department to rush to the spot for controlling it.

On the scene, they were met with a chaotic and dangerous situation due to fuelling of the forest fire by heavy leaf litter from old Oak Forests surrounding the spot. Steep mountainous terrain coupled with an unprecedented dry summer aggravated the situation. Due to sudden change in the wind direction, the forest fire started advancing towards the team rapidly. Soon the foresters were engulfed by the fire. They displayed unparalleled bravery and dedication in the face of a devastating forest fire. The sudden conflagration left them no scope for the escape. Four team members namely Shri Karan Arya, Fire Watcher; Shri Dewan Ram, Daily Wager; Shri Trilok Singh, Forest Guard; and Shri Puran Singh, PRD Worker attained martyrdom while the remaining team members were severely burnt. Two more officials, Shri Krishna Kumar, Fire Watcher and Shri Kundan Singh, PRD Worker later succumbed to their injuries.

This incidence is a testimony to the dedication of the forest frontline staff in protecting the country's forests often risking their lives in the phase of extreme dangers. This ultimate sacrifice of the forest team from Binsar in line of duty will always evoke a sense of tragedy and tribute in the hearts of those who care for conservation of forests, wildlife, and environment. These dedicated and committed forest personnel put their lives on the line of duty to protect our precious natural heritage, demonstrating a profound commitment to preserving the environment for future generations. Their sacrifice is a poignant reminder of the dangers faced by those who work tirelessly to safeguard our forests. We honour their sacrifice and commitment to duty, and express our deepest gratitude for their selfless service. May their legacy inspire us to continue the fight for our planet with the same unwavering resolve.

4.4 Burnt Area Assessment 2023-24 at national level

While it is important to timely detect forest fires for taking remedial measures, it is equally important to assess forest area affected by the forest fires to assess damage to forest and bio-diversity as well as to plan restoration measures. Remote Sensing and GIS techniques are being actively used for real-time forest fire monitoring and damage assessment. Multi-temporal satellite data plays an important role for identification of the changes in forest.

The present burnt area assessment has been carried out to assess the fire affected forest areas at country level using Sentinel 2 and Landsat 8/9 satellite data. Apart from high temporal and high spatial resolution satellite data, ancillary data has also been used to assess the accuracy of the satellite data. In the present assessment, the Near Real-Time Forest Fire Detections and Large Forest Fire Detections have been used for better identification and delineation of the burnt areas. While the geo-coordinates of the near real-time detections have helped in better identification of the locations of the burnt scars, the large forest fire polygons have helped in the identification of the extent of the scars.

A brief methodology is provided in the Figure 4.19

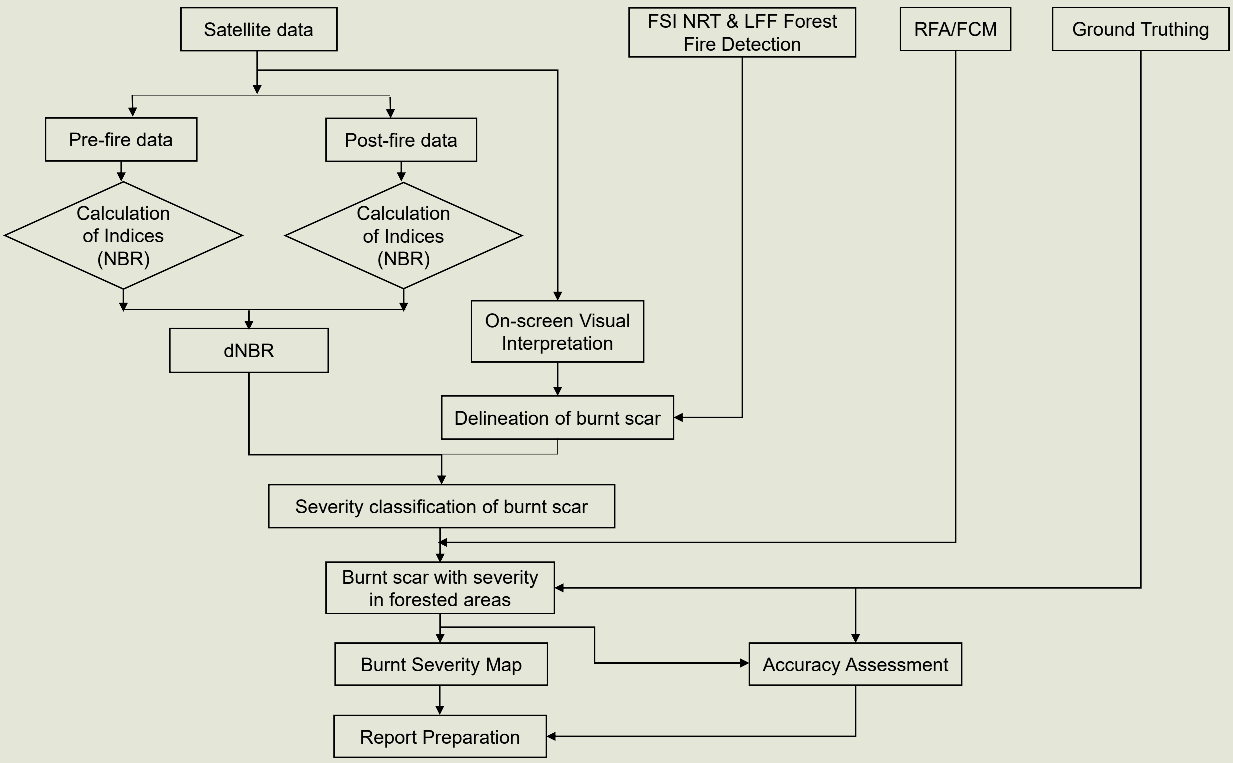


Figure 4.19 Methodology adopted for Burnt Area Mapping

Identification of burnt scars has been carried out using Differenced Normalized Burnt Ratio (dNBR) index image created from pre-fire and post-fire images of the Sentinel/ Landsat satellite data. To differentiate between burnt and unburnt areas, dNBR have been examined and found to have the highest distinguishable index values when compared with other indices. After the burnt scars are delineated, some of the areas are selected for further validation on the basis of certain criteria like mixing of signatures of burnt scars and shadows, dark features identification and its separation.

State/UT wise burnt area assessment has been shown in the Table 4.19. The State/UT have been sorted in descending order of burnt area.

Table 4.19 State/UT wise Burnt Area (In the fire season Nov 2023 - June 2024)

Sl. No.	State/UT	Total Burnt Area (in km²)
1	Andhra Pradesh	5,286.76
2	Maharashtra	4,095.04
3	Telangana	3,983.28
4	Chhattisgarh	3,812.28
5	Madhya Pradesh	3,172.13
6	Odisha	2,463.74
7	Karnataka	2,088.35
8	Uttarakhand	1,808.90
9	Tamil Nadu	1,322.74
10	Jharkhand	1,086.46
11	Himachal Pradesh	783.11
12	Bihar	682.74
13	Meghalaya	463.95
14	Jammu & Kashmir	438.86
15	Rajasthan	424.47
16	Assam	419.20
17	Gujarat	408.61
18	Manipur	285.20
19	West Bengal	259.93
20	Uttar Pradesh	257.88
21	Mizoram	243.76
22	Kerala	208.96
23	Tripura	190.47
24	Nagaland	161.77
25	Arunachal Pradesh	126.03
26	Haryana	44.63
27	Punjab	40.55
28	Sikkim	2.08
29	Goa	0.45
30	Delhi	0.00
31	Andaman & Nicobar Islands	0.00
32	Chandigarh	0.00
33	Dadra & Nagar Haveli & Daman & Diu	0.00
34	Ladakh	0.00
35	Lakshadweep	0.00
36	Puducherry	0.00
	TOTAL	**34,562.33**

From the table, it can be observed that maximum fire affected forest areas have been observed in the state of Andhra Pradesh (5,286.76 km^2) followed by Maharashtra (4,095.04 km^2) and Telangana (3,983.28 km^2). The highest percentage of RFA/GW area affected by forest fire has been observed in the state of Telangana (14.82%) followed by Andhra Pradesh (13.94%) and Bihar (10.71%).

Nearly 93% of the fires observed are surface fires and are classified as low burnt areas. The detailed State/UT wise analysis of burnt areas and their severity classes, fuel load estimates, and fire risk zones shall be published in a separate report.

Photo: FSI Repository


Photo: FSI Repository

CHAPTER 05

Growing Stock

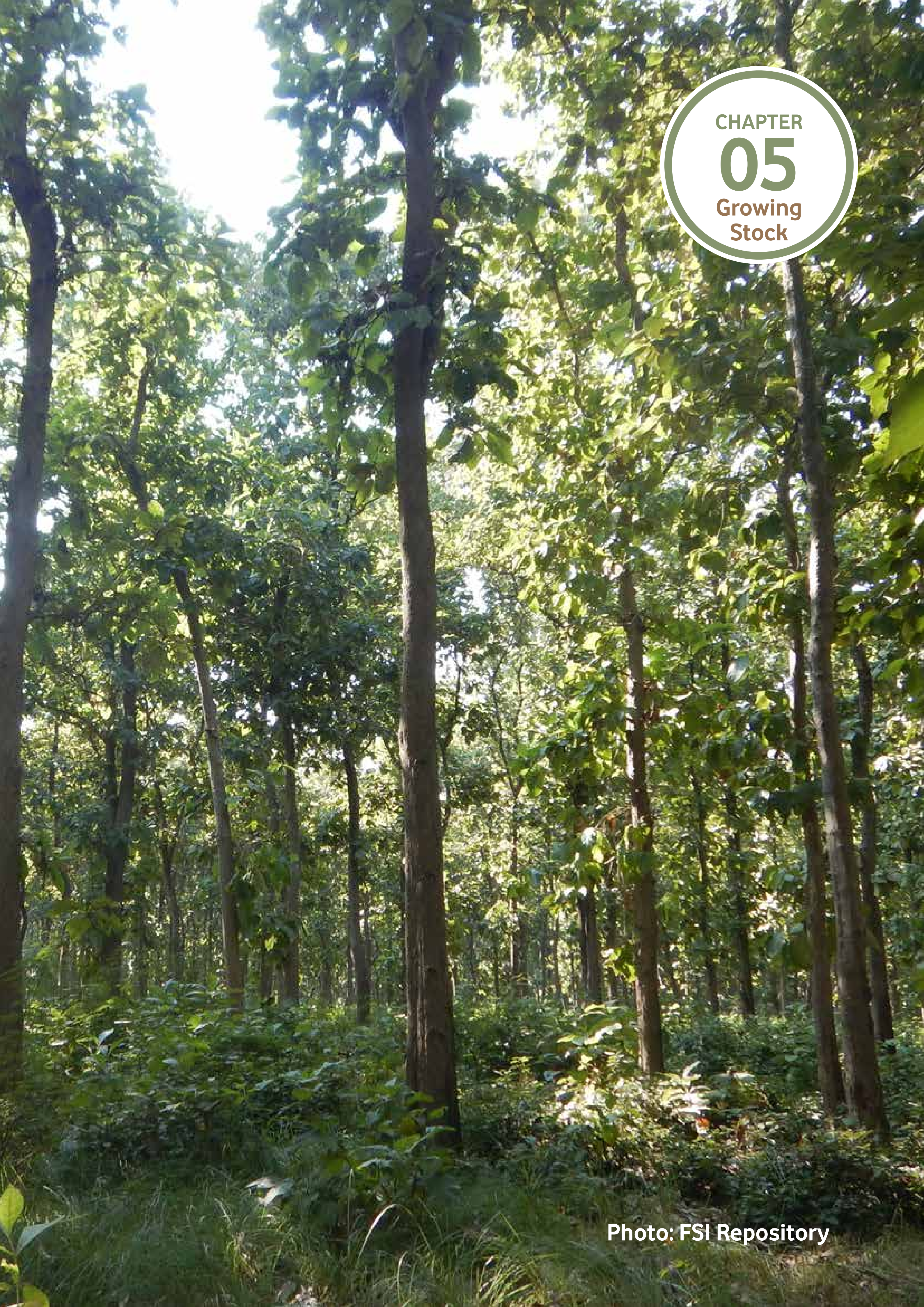


Photo: FSI Repository


Photo: FSI Repository

05

GROWING STOCK

5.1 Introduction

Growing stock has traditionally been considered as an important indicator of the health and productivity of the forest. Forest productivity has always been a central concern in forestry as it closely relates to the production of timber, biodiversity and more importantly the storage of the carbon stock in forest. The growing stock gives information about the composition of the species and their diameter class distribution, thus helping in study of population and structure of tree species. In the recent past, the information on growing stock has assumed significant importance as it is required for calculation of the emission factors, which are one of the essential constituents in carbon calculation. As per the Biennial Update Report (BUR-3) of India, LULUCF sector, under which forest land falls, offsets about 15% of CO_2 equivalent from the atmosphere.

The growing stock is generally estimated through the forest inventories which are essentially a 'field data collection' exercises following a suitable and robust sampling design. Forest inventory gives both qualitative and quantitative information about the forests. Qualitative information includes legal status, land use, biotic influence, grazing incidence, etc., whereas the quantitative information includes species and stratum wise growing stock, diameter class distribution of growing stock, number of trees, regeneration status, etc. In 1965, Pre-Investment Survey of Forest Resources (PISFR) started as a joint project launched by Government of India with FAO and UNDP. The major objective of the PISFR was to estimate the availability of wood and bamboo in large catchment and forest rich areas of the country for establishing the wood and/or bamboo based industries. PISFR followed different sampling designs in different parts of the country. The PISFR continued from 1965 to 1981, the year it was converted as a full fledge government organisation and renamed as Forest Survey of India (FSI), under the Ministry of Environment and Forests; and its mandate was expanded. Inventory of forests, following a uniform sampling design in the entire country, remained as one of the important mandates of the organisation. Each year selected districts, group of districts or States were taken for the detailed inventory. About three-fourth of the country's forests had been inventoried till 2001 with some areas being inventoried twice. About 140 reports have been published by FSI on forest inventory for the selected States and districts/divisions/catchments during this period. During early 1990s, FSI also started the inventory of Non Forest areas, which was later termed as Trees Outside Forest (TOF) following a sampling design having villages as sampling units for the rural areas and Urban Frame Survey (UFS) Blocks as sampling units for the urban areas.

The forest inventories conducted by FSI during 1965 to 2001 pertained to different parts of the country at different time period. As such, these inventories could not be used for estimation of growing stock and other parameters at the country and State level. Therefore, FSI launched a National Forest Inventory in 2002, with the onset of the 10th five-year plan, by developing a sampling design, to generate the national level estimates of growing stock and other parameters. Under this NFI design, the country was stratified into 14 physiographic zones and 60 districts were selected for the detailed inventory for a cycle of 2 years. About 3,500 sample plots were inventoried in the forest areas and 5000 sample plots were inventoried in TOF every year. The revisit time for the same district was approximately 20 years.

FSI modified the sampling design of NFI in 2016 considering the data requirements at National and International level, to generate precise estimates at the State level, and to reduce the revisit time from 20 years to 5 years. Before the launch of NFI (2016) design, extensive studies of international practices were undertaken, and detailed technical discussions were held within FSI and with other stakeholders like SFDs. A pilot study was conducted by all the regional offices of FSI to ascertain the size of the circular plots and distance between central sub-plot and other sub-plots.

Under the modified design, FSI has switched over to a grid based design, on distance basis, having uniform grids of size 5 km x 5 km and selecting specified grids each year for the detailed inventory. Under this design, FSI is laying about 6,000 plots in forest area and 10,000 plots in TOF areas every year. FSI also changed the configuration of the sample plot for forest inventory from single square plot to cluster of four circular sub-plots. Based on the data collected through NFI, national and State level estimates of tree cover, growing stock, bamboo area, carbon stock, important characteristic of forests, etc., are estimated. Figure 5.1 and 5.2 depict field teams recording the measurements during forest inventory. The latest NFI design, data processing methodology, and results of the NFI have been discussed in the following sections.

Figure 5.1 Recording Field Observations during Forest Inventory

Figure 5.2 Measurement of DBH during Forest Inventory

National Forest Inventory (NFI) Design 5.2

5.2.1 Forest Inventory

As pointed out earlier, FSI switched over to a distance based grid sampling design from district based design in 2016. The design is based on country wide uniform grids of size 5 km x 5 km. Each grid is marked serially with 1 to 5 number for forest inventory and 1 to 10 for TOF inventory. In this way, there are 5 panels corresponding to marked numbers for inventory of forest and similarly there are 10 panels for TOF inventory. Every year one panel each for forest and TOF inventory is selected for field data collection. Additional parameters such as NTFPs, invasive species, water bodies near sample plots, diseases, etc., have also been included in the forest inventory (Tiwari *et al.*, 2020)[1].

For forest inventory, 50% of the sample plots are revisited after five years. The remaining 50% plots are randomly selected in grids every year. The digital layer of RFA/Green Wash boundaries have been used to determine the grids for forest inventory. These grids (having RFA/Green Wash) are numbered as 1 to 5 (for panels) (Figure 5.3).

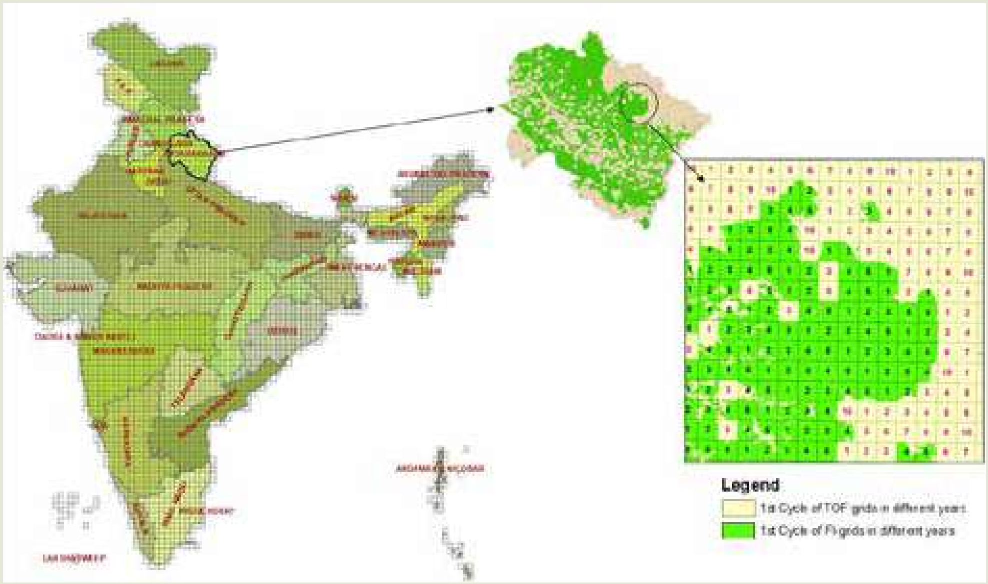


Figure 5.3 Map of India showing NFI Grids of 5 km x 5 km

Since generation of State level estimates is one of the main objectives of the new sampling design (NFI), the optimum sample size has been calculated at State level using past inventory data and the digital layer of RFA/Green Wash. For few small States, the 5 km x 5 km grids have been sub-divided further into 2.5 km x 2.5 km, and 1.25 km x 1.25 km to accommodate the desired sample size. Grids having the same grid number in the panel are covered in a single survey year.

Within the RFA of selected forest grids, random points are generated using Geographical Information System (GIS). These points form the plot centre of the sample plot around which a sub-plot of radius 8 m is laid out. Other three sub-plots of the cluster are laid out at a distance of 40 m from the plot centre, a specified angle (120°) apart, starting from 360° Azimuth. The list of sample plots is generated in GIS and sent to the zonal offices of FSI for field survey, data collection from each sub-plots and recording in the specified field forms. Further micro plots within each sub-plot are laid out for collection of data on herbs, shrubs, regeneration and dead wood. The data on NTFPs species, regeneration and stump, dead wood as well as litter (woody) from all the subplots are collected from the three concentric circular micro plots, within the respective subplot.

[1]Tiwari V.P., Kumar R. and Gadow K.V. (2020). National Forest Inventory in India: Developments Toward a New Design to Meet Emerging Challenges. Eds. Chandra G., Nautiyal R. and Chandra H. (2020). *Statistical Methods and Applications in Forestry and Environmental Sciences*, in Forum for Interdisciplinary Mathematics. ISBN 978-981-15-1475-3.

The concentric micro plots of radii 0.6 m (herb), 1.7 m (shrubs, climbers, tree regeneration, and woody litter) and 2.8 m (stump, dead wood) are laid out / marked at a distance of 5 meter from the centres of the subplots at 90^{o} in east direction. Soil sample plots are also laid out at the mid points of the line joining the peripheral sub-plots to the central sub-plot. Sample of non-woody litter (commonly known as forest floor) and soil sample is collected from this plot. A schematic diagram of plot design is shown in Figure 5.4.

The flowchart as depicted in Figure 5.5 describes the various parallel and chronological steps followed in performing forest inventory and report generation.

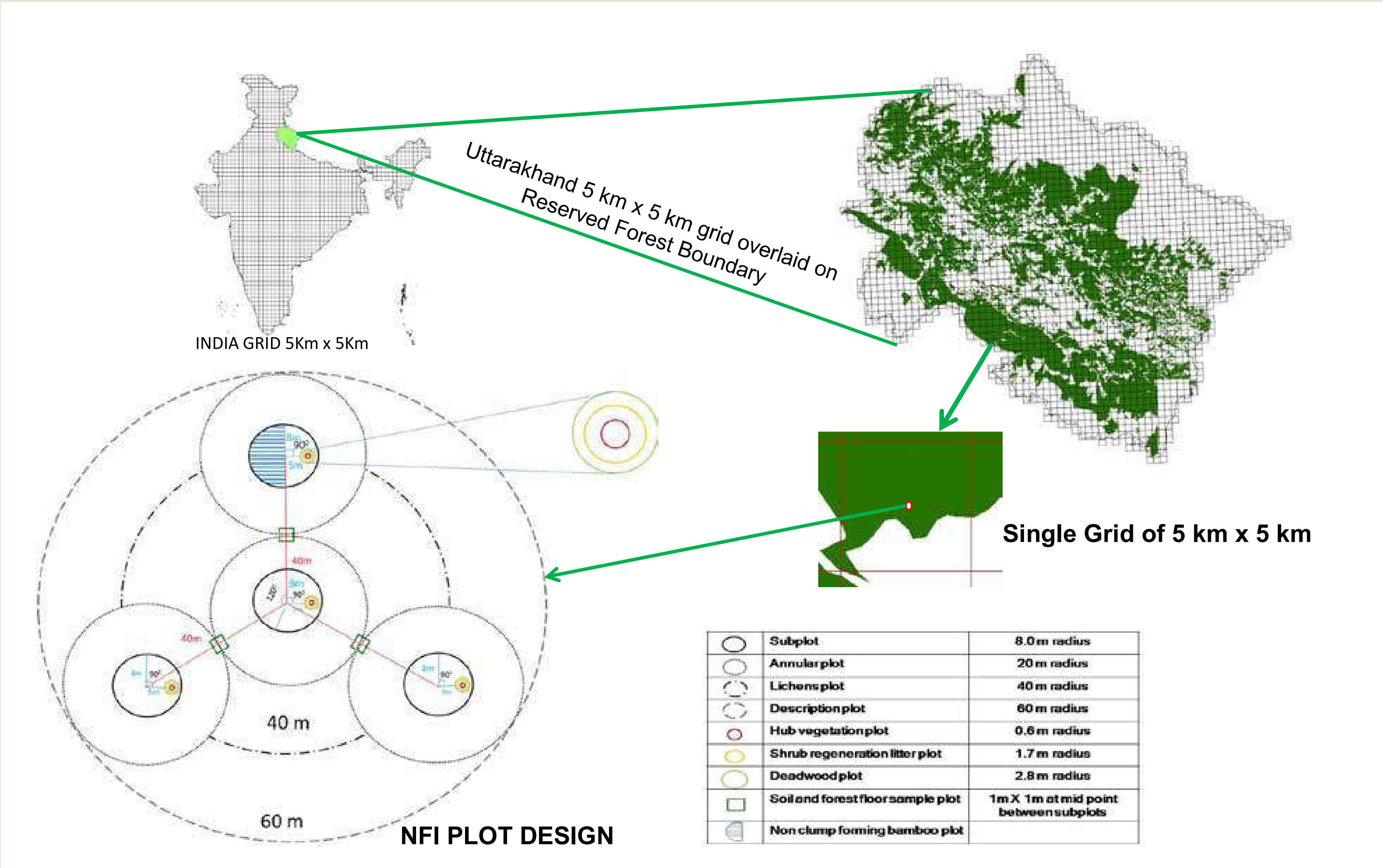


Figure 5.4 Plot Configuration of NFI

Schematic (Flow) Chart of the Methodology of FI

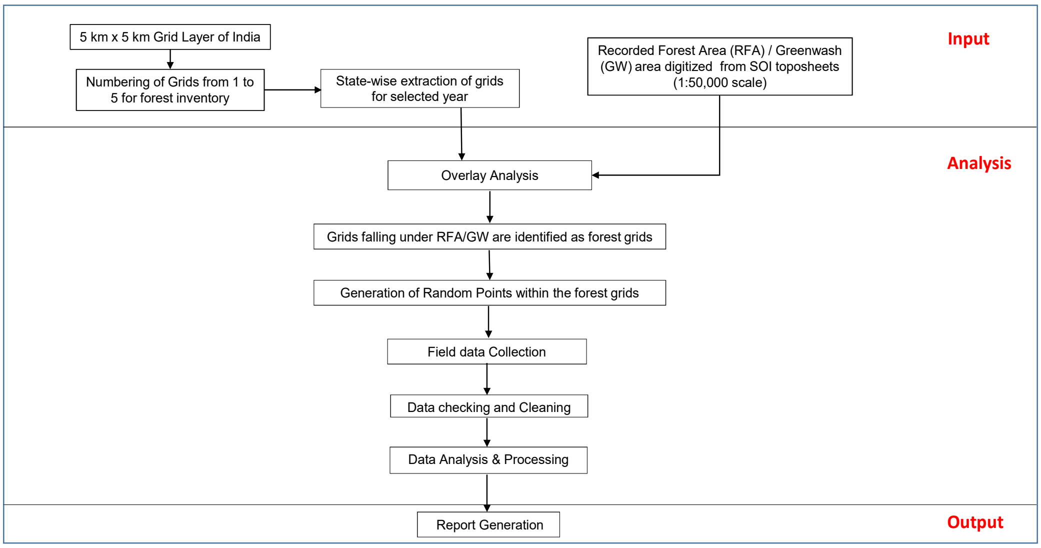


Figure 5.5 Schematic Flowchart of the Methodology of Forest Inventory (FI)

5.2.2 Trees Outside Forest (TOF) Inventory

In India, requirement of wood and wood based products to a great extent is met from Trees Outside Forests. In addition, TOF are important from the perspective of their ecological, socio- economic and cultural significance. TOF are also seen as an important carbon sink. Information on the extent of TOF and its dynamics is important for policies, planning and programme formulation for management and enhancement of areas/landscapes.

As pointed out in section 5.2.1 that the revisit time for the same grid of TOF inventory in the NFI design has been fixed at 10 years, all TOF grids are marked with numbers 1 to 10 (ten panels). Grids of a particular number are taken for inventory in a particular year. TOF grids consist of both TOF (Rural) and TOF (Urban). As generation of State level estimates is one of the main objectives of the new sampling design, the optimum sample size has been calculated at State level separately for rural and urban areas using past inventory data.

5.2.2.1 Urban TOF Inventory

For urban TOF inventory, urban centres defined by the Registrar General & Census Commissioner of India are considered as area of interest/ population. The sampling unit for urban inventory is taken as Urban Frame Survey (UFS) from National Statistical Office (NSO). The area of every town is delineated into blocks called 'UFS blocks', which are shown on maps with well-defined boundaries, and generally cover a population of 600 to 800 individuals or 120 to 160 households. These blocks cover the whole area within the geographical boundary of a town including vacant lands.The list of all urban towns and cities, with name and area as per census 2011, have been used to identify the urban grids. The latitude and longitude of centroid of all such towns have been arrived at using BHUVAN and GOOGLE EARTH portals. Using the coordinates of centroid and the area of the towns, a circular buffer zone of appropriate radius is created. At the State level, this layer of buffer is considered as a proxy of digital urban area of that State. In a GIS framework, this urban layer is overlaid on the 5 km x 5 km NFI grid layer. All such grids intersecting the urban buffer layer are termed as urban grids for TOF Urban inventory. All urban grids which are numbered 'one' are considered for 1st year TOF (Urban) inventory, number 'five' in the second year, and likewise all the ten panels will be covered in the subsequent years. Within the selected urban grid, the name of town(s) is communicated to the zonal offices for obtaining UFS block maps from NSO. One UFS block is selected randomly from each grid for urban TOF inventory.

5.2.2.2 Rural TOF Inventory

Remaining grids of TOF panels are covered under TOF (Rural) inventory. The sampling design used for TOF (Rural) inventory is two-phase sampling design. The stratification of selected grid area into Block, Linear and Scattered strata using mid-resolution remote sensing satellite data being the first phase; and generation of optimum sample points in the selected grids being the second phase. The latitude and longitude of all random points are sent to the zonal offices for field data collection. The methodology used for stratification of tree resources of the grid into Block, Linear and Scattered strata is described in the following paragraph.

5.2.3 Tree Cover and TOF

It has already been mentioned in chapter 1 and 2, that TOF and Tree Cover are two distinct terms. TOF refers to all trees growing outside the recorded forest areas irrespective of size of patch. Tree cover, on the other hand, is comprised of tree patches and isolated trees outside the recorded forest which are less than one hectare. Thus, Tree Cover is a subset of TOF. Tree Cover also contributes towards Growing Stock. For estimation of growing stock in TOF, entire TOF area is taken into consideration, whereas for the estimation of tree cover, tree patches less than 1 hectare in extent and scattered trees are taken into account. During the field visits it was observed that the rotation age of many species like Eucalyptus and Subabul have been reduced to 3 to 4 years. During this period the trees attain a dbh of 5 to 10 cm. Although these trees are making a major contribution to the paper and pulp industries, neither their cover, nor their growing stock was being accounted in the previous ISFRs. Considering the importance of trees of less than 10 cm diameter at breast height (dbh) in planning of TOF resources, FSI started collecting data of trees starting from 5 cm dbh since 2016-17. This report provides information on tree cover starting from 5 cm and above from the current

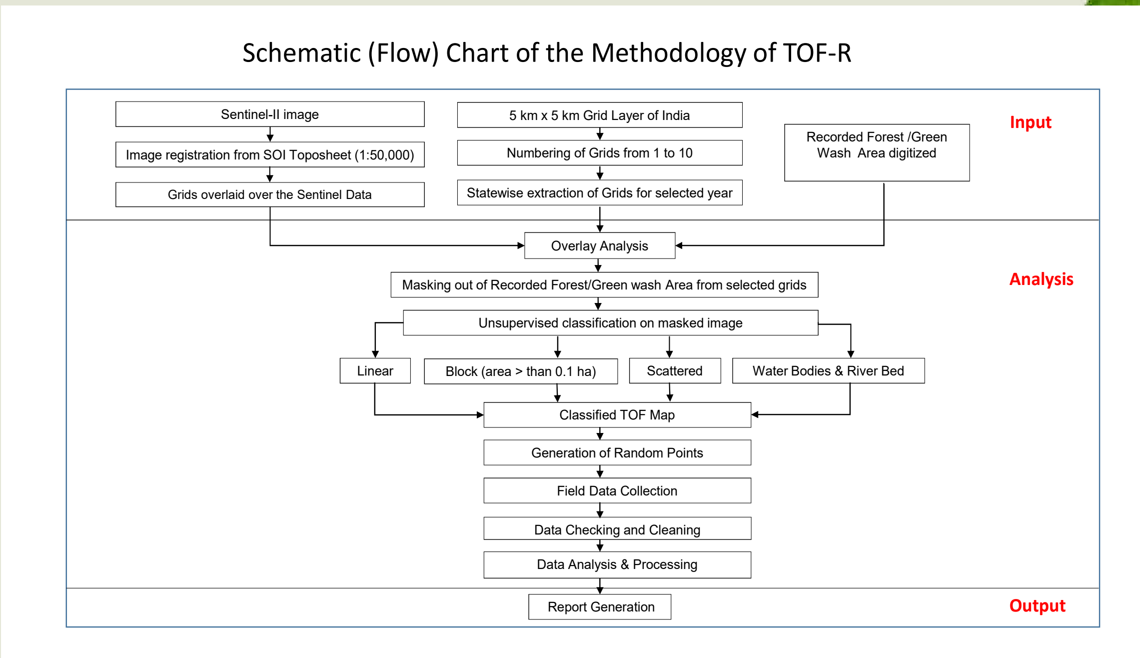


Figure 5.6 Schematic Flowchart of the methodology of Trees Outside Forest – Rural (TOF-R)

ISFR. In addition, information about bamboo cover in Culturable Non forest Area (CNFA) is also included in tree cover. For classification of the selected grids, the Multispectral data of Sentinel-2 satellite having a spatial resolution of 10 m and swath of 290 km has been used. The satellite data is downloaded and used.

As mentioned earlier, selection of State wise grids for a particular year is carried out by using 5 km x 5 km grids of India. The forest area (RFA/GW) is masked out to get the TOF area. The satellite image of TOF area is then classified into different classes, i.e., Tree patches, Water bodies, River beds, Snow, Alpine pastures, Sand dunes, etc., using unsupervised classifier. The classified image is visually analysed with respect to images for editing and refinement for inclusion and omissions. Since a cluster of trees having 0.1 ha area or more is defined as part of block class, pixels are clumped and re-classified as blocks. Cluster of pixels having area less than 0.1 ha are eliminated. Out of this block area, the linear patches of trees, viz., along the road, railway, and canal side having width between 10m to 20m (by and large) and length more than 150 m are reclassified as linear class. Remaining area are classified as scattered class. After editing of the classified image, the final classified map is generated having three classes (strata) in TOF areas, viz., Block, Linear, and Scattered.

In addition, areas which do not support tree vegetation; like Water bodies, River beds, Snow, Alpine pastures, Sand dunes, etc., which are termed as Un-Culturable Non Forest Areas (as against the CNFA) are also interpreted, and are not considered for estimation purpose to avoid over estimation. The schematic chart of the methodology of TOF using remote sensing is depicted in the Figure 5.6 & 5.7, respectively.

The individual trees cannot be classified by mid-resolution image interpretation. Hence, they are captured through field study. For the fieldwork, the optimum plot sizes for Block and Linear strata are 0.1 ha square plot and 10 m x 125 m strip, respectively. In case of Scattered stratum, the square plot size of 0.5 ha in hilly areas and 3.0 ha in non-hilly areas are used.

Sample points are randomly generated within selected grids for each stratum and the data in pre-decided variables like ownership, category of plot, dbh, crown diameter, species, categories of trees (Farm Forestry, Village Woodlot, Block Plantation, Roadside Plantation, Homestead, etc.), are collected in pre-designed formats. Complete enumeration of all the trees having dbh 5cm and above is carried out.

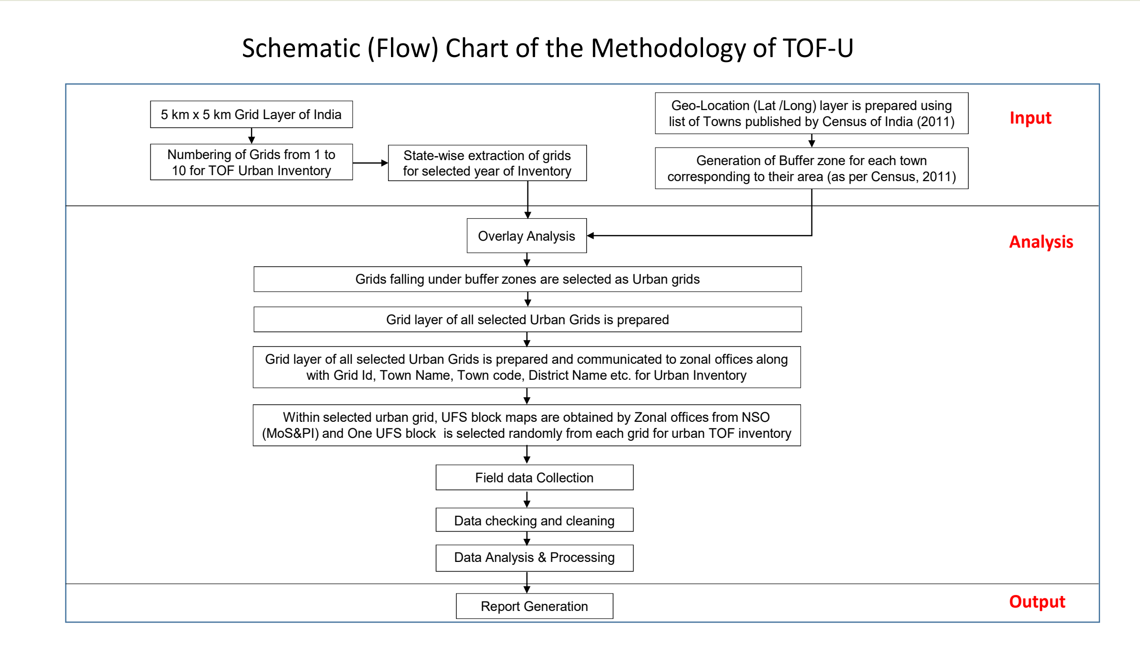


Figure 5.7 Schematic Flowchart of the methodology of Trees Outside Forest – Urban (TOF-U)

5.3 Data Processing Methodology

The field data is collected from the sample plots with the help of Personal Digital Assistant (PDA). The PDA contains all the field forms of the forest and TOF inventory. The data collected through the PDA is transferred directly to Central Database server, located at FSI headquarters at Dehradun. The entered data is checked thoroughly for any inconsistency, and is cleaned prior to processing. Data processing is carried out separately for forest, TOF (rural), and TOF (urban).

5.3.1 Data Processing for Forest Inventory

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

5.3.2 Data Processing for TOF Inventory

In case of TOF inventory, the data processing is carried out separately for rural and urban areas. In rural areas, the estimation of growing stock (of all the trees above 5 cm dbh) at State level is carried out separately for Block (B), Linear (L), and Scattered (S) strata. The area figures for Block and Linear strata are obtained from the digital interpretation of remote sensing data. The area of scattered stratum is obtained by subtracting the area of Block and Linear patches from rural CNFA of the selected grids. On the basis of area of B, L and S of these grids, the strata sizes for the State(s) are estimated. In case of urban stratum, the area is taken from the office of Registrar General of India (RGI). Species and diameter class wise number of stems enumerated in sample plots is used for calculating stems per ha under each stratum, Viz., B, L, S, and Urban. The corresponding volume for each stratum is also calculated using volume equations developed by FSI. Estimates of the Growing stock in TOF of the States is calculated using per ha figures of stems, its volume, and respective areas of each stratum. The national growing stock estimate of TOF is generated by adding the estimates of growing stock of all the States.

5.3.3 Tree Cover Estimation

For estimation of tree cover, the area of block and linear patches is computed from the classified map of the TOF for the selected grids. The blocks and linear patches having area more than 1 ha are not considered as the same has been included in the forest cover. The tree patches of block and linear stratum, which are less than 1 ha are considered for tree cover. In addition the enumerated crown width of each tree at sample point of scattered stratum provide tree cover at each sample plot, which is used then to estimate tree cover provided by scattered stratum. The area so obtained from the scattered stratum is converted into equivalent notional area corresponding to a well-considered value of 70 percent canopy density (SFR, 2001)[2]. To compute urban tree cover, the enumerated crown width of each tree in the selected UFS block provide the tree cover at the UFS block level, which is used to estimate per ha area covered by tree crown within the same. This area is then multiplied with urban CNFA to estimate urban tree cover at the State level. The area so obtained from the urban stratum is converted into equivalent notional area of 70 percent canopy density. The total tree cover of the State is obtained by adding the estimated area of block, linear and scattered tree formations (TOF-R) and urban tree cover (TOF-U). Tree cover estimates has already been produced in chapter 2 at Table 2.4.

5.4 Results & Discussions

5.4.1 State/UTs wise Growing Stock

The growing stock estimates of forests and trees outside forests have been generated at the National and State level. The estimates presented in the current report are based on 27,917 sample plots laid inside forests during 2017 to 2022 and 62,056 sample plots outside forests during 2016 to 2022. The Standard Error (SE) of estimate for Forest Inventory at National level is 4.44 % and varies from 2.05 % to 19.22 % at State level. The SE for TOF at National level is 3.32 % and ranges from 1.50 % to 12.61 % at State level.

As compared to the previous assessment, the number of sample plots inside forests and TOF are almost 1.5 times in number for the corresponding period and are spread over the entire country. As a result, the precision of growing stock, both at the National and State level, is higher than the previous estimates.

The total growing stock of wood in the country is estimated at 6,429.64 M m^3 which comprises of 4,478.89 M m^3 inside RFA and 1,950.75 M m^3 outside RFA (TOF) (Figure 5.8). There is a total increase of 262.32 M m^3 (4.25 %) in the growing stock of the country as compared to the estimates reported in ISFR 2021. Out of this, the increase in growing stock is 90.92 M m^3 (2.07 %) inside the forests areas, and 171.40 M m^3 (9.63 %) outside recorded forest areas (TOF).

The increase in growing stock inside the forest areas is observed statistically insignificant with respect to ISFR 2021 result, as the increase is less than twice the Standard Error (SE) of the estimate. On the other hand, the increase in growing stock outside the forest areas (TOF) is observed statistically significant with respect to ISFR 2021 result, as the increase is more than twice the Standard Error (SE) of the estimate.

[2]SFR (2001). State of Forest Report, Forest Survey of India, Ministry of Environment and Forest, Govt. of India. Pp 31.

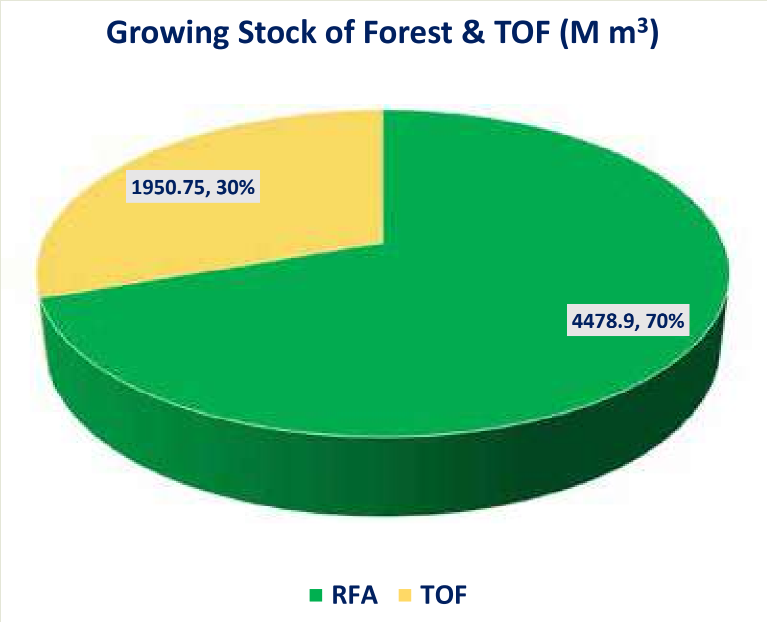


Figure 5.8 Growing Stock of RFA & Trees Outside Forests

State/UTs wise Growing Stock (in terms of Volume), in Forest Cover within RFA and TOF, for 2021 and 2023 assessments, is given under table 5.1.

Table 5.1 State/UTs wise Growing Stock (Volume) in Forest Cover within RFA and TOF

Sl. No.	State/UTs	Geographical Area (km²)	2021 Volume (M m³)			2023 Volume (M m³)
			Forest	TOF	Total	Forest
1	Andhra Pradesh	1,62,923	115.71	73.16	188.87	122.26
2	Arunachal Pradesh	83,743	418.99	73.48	492.47	457.83
3	Assam	78,438	112.68	23.94	136.62	120.27
4	Bihar	94,163	30.52	41.04	71.56	27.63
5	Chhattisgarh	1,35,192	389.64	117.30	506.94	398.54
6	Delhi	1,483	0.51	1.75	2.26	0.36
7	Goa	3,702	12.87	4.15	17.02	15.69
8	Gujarat	1,96,244	51.22	78.74	129.96	42.11
9	Haryana	44,212	4.31	19.26	23.57	4.16
10	Himachal Pradesh	55,673	345.62	28.30	373.92	303.94
11	Jharkhand	79,716	100.80	74.35	175.15	108.03
12	Karnataka	1,91,791	302.14	121.72	423.86	297.02
13	Kerala	38,852	160.53	61.04	221.57	168.80
14	Madhya Pradesh	3,08,252	374.44	118.05	492.49	387.18
15	Maharashtra	3,07,713	235.50	187.69	423.19	227.07
16	Manipur	22,327	54.99	5.10	60.09	69.40
17	Meghalaya	22,429	35.54	20.82	56.36	40.04
18	Mizoram	21,081	28.87	46.05	74.92	37.67
19	Nagaland	16,579	30.28	15.60	45.88	35.97
20	Odisha	1,55,707	276.78	106.87	383.65	259.75
21	Punjab	50,362	12.61	20.31	32.92	11.07
22	Rajasthan	3,42,239	26.56	90.63	117.19	25.41
23	Sikkim	7,096	33.91	1.73	35.64	34.49
24	Tamil Nadu	1,30,060	92.27	82.21	174.48	98.38
25	Telangana	1,12,122	80.20	43.76	123.96	85.47
26	Tripura	10,486	23.13	7.46	30.59	25.31
27	Uttar Pradesh	2,40,928	104.39	106.75	211.14	104.90
28	Uttarakhand	53,483	401.01	18.40	419.41	400.02
29	West Bengal	88,752	61.19	38.70	99.89	58.00
30	A & N Islands	8,249	121.72	5.55	127.27	134.74
31	Chandigarh	114	0.21	0.29	0.50	0.18
32	Dadra & Nagar Haveli Daman & Diu	602	0.45	0.67	1.54	0.66
33	Jammu & Kashmir* (shape file area = 52,633)	2,22,236	348.35	109.04	457.39	376.51
34	Ladakh* (Shape file area= 1,68,055)$		–	35.01	35.01	–
35	Lakshadweep@	30	–	0.05	0.05	–
36	Puducherry	490	0.03	0.38	0.41	0.03
	Total	**32,87,469**	**4,387.97**	**1,779.35**	**6,167.32**	**4,478.89**

**Notified areas for individual UTs of Jammu & Kashmir and Ladakh have not been received from SoI. The geographical area reported for the unified J&K in Census 2011 is 2,22,236 km².*
$ RFA boundary was not made available and hence no data could be collected inside RFA.
@ There is no RFA existing in the UT of Lakshadweep.

2023		Change			Volume in Forest (m^3/ha	Volume in TOF (m^3/ha)
Volume (M m^3)		Volume (M m^3)				
TOF	Total	Forest	TOF	Total		
80.04	202.30	6.55	6.88	13.43	49.54	8.29
71.62	529.45	38.84	-1.86	36.98	97.16	25.11
24.94	145.21	7.59	1.00	8.59	63.52	5.31
43.97	71.60	-2.89	2.93	0.04	46.41	5.20
129.04	527.58	8.9	11.74	20.64	93.51	17.56
2.11	2.47	-0.15	0.36	0.21	55.65	15.60
5.27	20.96	2.82	1.12	3.94	134.73	24.96
88.27	130.38	-9.11	9.53	0.42	37.83	5.43
21.97	26.13	-0.15	2.71	2.56	43.39	5.21
34.37	338.31	-41.68	6.07	-35.61	219.46	40.28
87.35	195.38	7.23	13.00	20.23	60.05	16.45
137.62	434.64	-5.12	15.90	10.78	105.20	9.13
68.33	237.13	8.27	7.29	15.56	179.78	26.61
130.46	517.64	12.74	12.41	25.15	59.53	7.29
213.93	441.00	-8.43	26.24	17.81	55.04	8.92
5.05	74.45	14.41	-0.05	14.36	46.69	10.48
23.36	63.40	4.50	2.54	7.04	48.74	19.37
44.34	82.01	8.80	-1.71	7.09	59.34	32.53
19.06	55.03	5.69	3.46	9.15	51.33	24.57
117.69	377.44	-17.03	10.82	-6.21	77.40	13.04
20.32	31.39	-1.54	0.01	-1.53	73.14	4.34
99.16	124.57	-1.15	8.53	7.38	19.66	5.81
1.68	36.17	0.58	-0.05	0.53	145.74	35.61
93.69	192.07	6.11	11.48	17.59	51.75	8.92
49.84	135.31	5.27	6.08	11.35	45.14	6.12
8.46	33.77	2.18	1.00	3.18	43.50	21.50
108.67	213.57	0.51	1.92	2.43	97.45	4.94
20.05	420.07	-0.99	1.65	0.66	164.39	15.91
44.32	102.32	-3.19	5.62	2.43	65.02	6.04
5.45	140.19	13.02	-0.10	12.92	246.61	59.05
0.33	0.51	-0.03	0.04	0.01	78.64	42.20
0.66	1.32	0.21	-0.01	0.20	39.33	17.92
118.99	495.50	28.16	9.95	38.11	296.22	40.81
29.79	29.79	–	-5.22	-5.22	–	49.26
0.09	0.09	–	0.04	0.04	–	43.76
0.46	0.49	0.00	0.08	0.08	62.70	11.23
1,950.75	**6,429.64**	**90.92**	**171.40**	**262.32**	**86.10**	**9.50**

From Table 5.1, it is observed that the growing stock at the national level has been estimated as 86.10 m^3 per ha in Forest Cover within RFA. For calculation of growing stock per ha inside RFA, the forest cover within RFA, estimated using sample points from the forest inventory, has been used as denominator. In past, gross area of recorded forests was used for this calculation. In TOF the growing stock per ha has been calculated as 9.50 m^3 per ha. For this calculation the CNFA has been used as denominator. Among the States, the highest per ha growing stock in Forest Cover within RFA is in Himachal Pradesh followed by Kerala and Uttarakhand. Among the UTs, the highest per ha growing stock in Forest Cover within RFA is in Jammu & Kashmir followed by A&N Islands and Chandigarh. In respect of total growing stock, Arunachal Pradesh has maximum (457.83 M m^3) in Forest Cover within RFA, followed by Uttarakhand (400.02 M m^3), Chhattisgarh (398.54 M m^3) and Madhya Pradesh (387.18 M m^3). In TOF, Maharashtra has maximum growing stock (213.93 M m^3), followed by Karnataka (137.62 M m^3), Madhya Pradesh (130.46 M m^3), and Chhattisgarh (129.04 M m^3).

Table 5.2 provides Forest Type Group (FTG) wise information of growing stock in the Country. The total growing stock is estimated at 4,897.65 M m^3 (76.55 m^3/ha) at the national level. This is to clarify that the Forest Types include some of the areas outside RFA as well as Scrub. Therefore, the figures of Growing Stock given under table 5.1 do not match with those under table 5.2. From table 5.2, it is observed that Tropical Dry Deciduous Forests has maximum growing stock (1,067.55 M m^3), followed by Tropical Moist Deciduous Forests (1,057.85 M m^3), Himalayan Moist Temperate Forests (736.59 M m^3), and Tropical Semi-Evergreen Forests (442.32 M m^3). In unit terms, the highest per ha growing stock is observed in Sub Alpine Forests (296.84 m^3 /ha) followed by Himalayan Moist Temperate Forests (247.05 m^3/ha), and Himalayan Dry Temperate Forests (191.21 m^3/ha). The forest type group wise percentage distribution of growing stock is given in figure 5.9.

Table 5.2 Forest Type Group wise Growing Stock in the Country.

Sl. No.	Forest Type Group (FTG)	Area under FTG (km²)	Volume (M m³)	Volume in Forest Type (m³/ha)
1	Group 1- Tropical Wet Evergreen Forests	23,888	379.02	158.67
2	Group 2- Tropical Semi-Evergreen Forests	63,886	442.32	69.24
3	Group 3- Tropical Moist Deciduous Forests	1,33,187	1,057.85	79.43
4	Group 4- Littoral and Swamp Forests	5,611	20.91	37.26
5	Group 5- Tropical Dry Deciduous Forests	2,80,580	1,067.55	38.05
6	Group 6- Tropical Thorn Forests	13,755	18.81	13.68
7	Group 7- Tropical Dry Evergreen Forests	801	2.86	35.76
8	Group 8- Subtropical Broadleaved Hill Forests	31,017	210.79	67.96
9	Group 9- Subtropical Pine Forests	18,108	175.18	96.74
10	Group 10- Subtropical Dry Evergreen Forests	138	2.26	163.87
11	Group 11- Montane Wet Temperate Forests	19,445	295.86	152.15
12	Group 12- Himalayan Moist Temperate Forests	29,815	736.59	247.05
13	Group 13- Himalayan Dry Temperate Forests	4,487	85.80	191.21
14	Group 14- Sub Alpine Forests	12,498	371.01	296.84
15	Group 15- Moist Alpine Scrub	534	6.16	115.53
16	Group 16- Dry Alpine Scrub	2,082	24.68	118.51
	Total	**6,39,834**	**4,897.65**	**76.55**

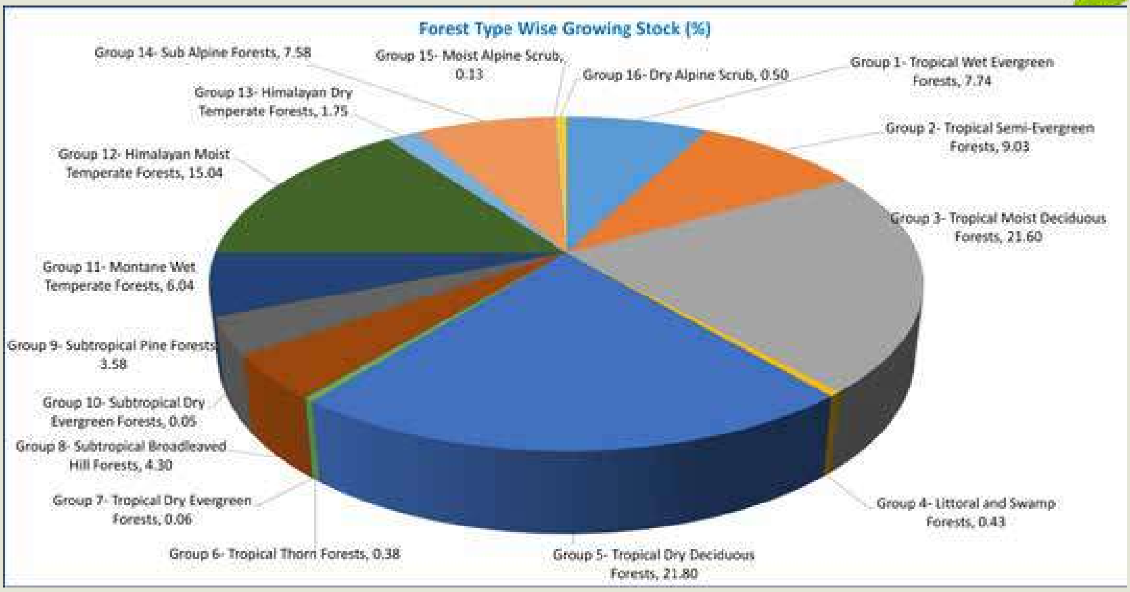


Figure 5.9 Growing Stock in different Forest Type Group

5.4.2 Growing Stock of top ten species in RFA and TOF

National level estimates of number of trees and their volume for major species by diameter classes in RFA are presented in Annexures IX and X respectively. The growing stock of top 10 species in RFA and TOF and their percentage in total growing stock has been presented in Table 5.3 and Table 5.4, respectively. Figure 5.10 represents top 10 species contributing to growing stock in forests.

Table 5.3 Growing Stock in RFA for Top Ten Species in the Country

Sl. No.	Name of the Species	Total Growing Stock (M m^3)	Percentage of total Growing Stock in RFA
1	*Shorea robusta*	511.96	11.43
2	*Tectona grandis*	199.61	4.46
3	*Pinus roxburghii*	198.52	4.43
4	*Terminalia tomentosa*	160.88	3.59
5	*Pinus wallichiana*	144.89	3.23
6	*Abies pindrow*	138.98	3.10
7	*Anogeissus latifolia*	124.34	2.78
8	*Lannea coromandelica*	110.24	2.46
9	*Cedrus deodara*	101.56	2.27
10	*Picea smithiana*	78.87	1.76

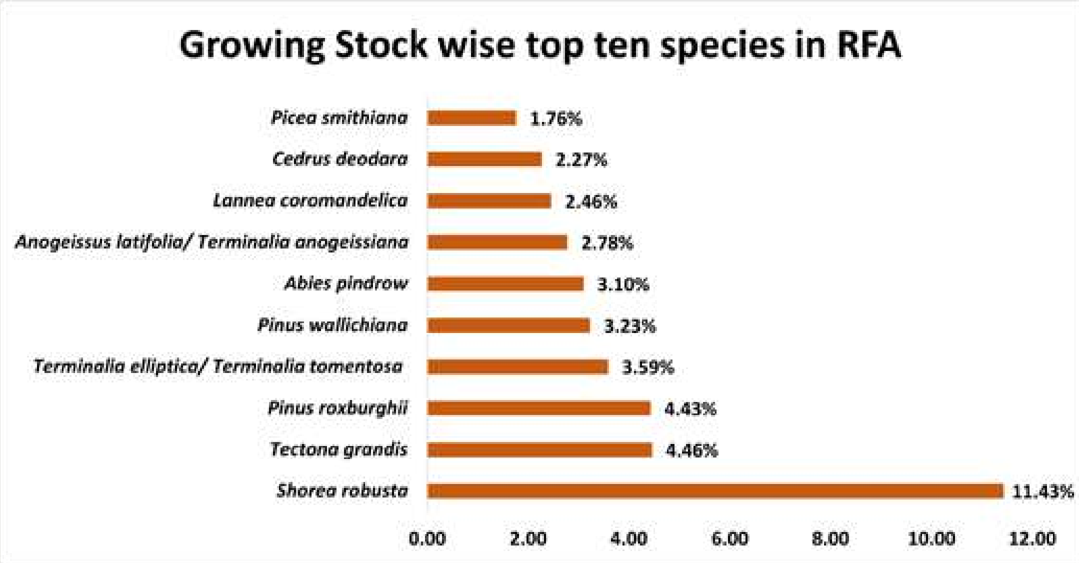


Figure 5.10 Percentage of Top Ten Species in Growing Stock in RFA

From the above figure, it is seen that inside the RFA, Shorea robusta has the maximum contribution in total volume (11.43 %), followed by *Tectona grandis* (4.46%), *Pinus roxburghii* (4.43%), and *Terminalia tomentosa* (3.59%).

Table 5.4 Growing Stock in TOF for Top Ten Species

Sl. No.	Name of the Species	Total Growing Stock (M m³)	Percentage of total Growing Stock in TOF
1	*Mangifera indica*	258.50	13.25
2	*Azadirachta indica*	136.59	7.00
3	*Madhuca latifolia*	85.23	4.37
4	*Cocos nucifera*	81.25	4.16
5	*Tamarindus indica*	53.25	2.73
6	*Acacia arabica*	50.92	2.61
7	*Borassus flabelliformis*	50.90	2.61
8	*Butea monosperma*	48.69	2.50
9	*Shorea robusta*	39.56	2.03
10	*Ficus benghalensis*	39.00	2.00

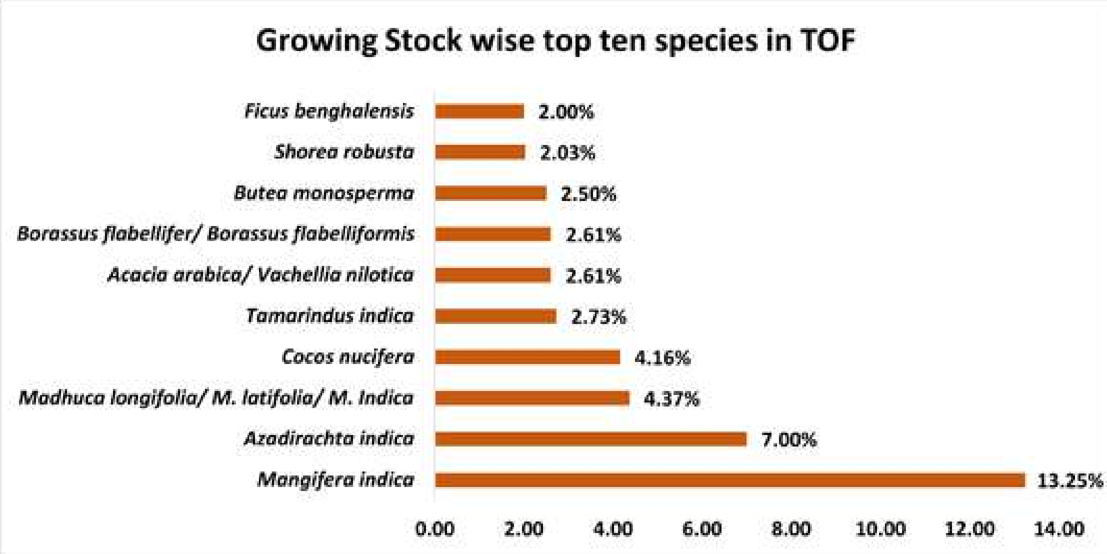


Figure 5.11 Percentage of Top Ten Species in Growing Stock in TOF

As per the above figures, in the TOF, Mangifera indica contributes maximum volume of 13.25% followed by *Azadirachta indica* (7.00 %), *Madhuca latifolia* (4.37 %), and *Cocos nucifera* (4.16 %).

The "Estimated Number of Trees by Species and Diameter Class in TOF at Country Level" and "Estimated Volume by Species and Diameter Class in TOF at Country Level" are presented in **Annexures XI and XII**, respectively.

As mentioned earlier also, one of the objectives of new sampling design is to generate the State level estimates at an acceptable precision level. In the new design, optimum number of sample plots in both RFA and TOF are laid out in all the States/UTs. The State/UTs wise standard error percentage of Growing Stock (in RFA & TOF) and Tree Cover is given in **Annexure XIII**.

5.4.3 Annual Potential Production of Industrial Wood from TOF

Considering the importance of the TOF, FSI has been carrying out inventory of the TOF regularly since 2002 and generating the estimates of growing stocks in TOF at the national and state level. The methodology of assessment has already been described in section 5.2.2 of this chapter. Though the estimates of growing stock are published in successive reports of FSI, the estimates of annual potential production from TOF was attempted for the first time in ISFR 2011.

Trees growing outside the forests in the form of block plantations, on homesteads, private lands, farmlands, bunds of agricultural farms, and other non-forest lands play a significant role in fulfilling the demand of industrial wood and fuelwood of the country. With implementation of many social/community forestry programmes in the country, the production from such areas has increased manifold. Since no record of production of timber from TOF is maintained by the SFDs, an attempt has been made by FSI to estimate the annual potential production of timber from TOF using the data collected under NFI.

To estimate the annual potential production of timber from TOF, inventory data of TOF for six years pertaining to period 2016 to 2022 has been used. Estimates have been generated State wise. For each State, the estimates of growing stock were arranged according to species, which were further arranged according to Industrial wood producing species and other species. For calculation of potential production, only Industrial wood producing species were considered. The rotation period of different species is available with FSI from State Forest Departments and other sources. Using estimates of growing stocks and rotation period of the species, annual potential production has been calculated for each State by applying Von Mantel's formula. Adding the estimates of all the States, total annual estimated production of industrial wood for the country has been arrived at. The estimate of annual production of industrial wood was 42.77 M m^3, as reported in ISFR 2011; which was updated to 69.04 M m^3 in ISFR 2017. The main reason of this increase was due to revised rotation period for each species. Earlier only three rotation periods, i.e., short, medium and long rotation were used for estimation of production.

The current estimates of annual potential production of Industrial Wood at State/ UTs level has been estimated as 91.51 M m^3, and is presented in the Table 5.5 with respective Standard Error.

Table 5.5 State/UTs wise Annual Potential Production of Industrial Wood from TOF Area with % Standard Error

Sl. No.	State/UTs	Annual potential production of Industrial wood (M m^3)	Standard Error (%)
1	Andhra Pradesh	2.77	3.67
2	Arunachal Pradesh *	0.76	11.69
3	Assam	1.13	5.67
4	Bihar	2.07	4.24
5	Chhattisgarh	5.71	3.02
6	Delhi	0.15	6.27
7	Goa	0.16	6.12
8	Gujarat	4.72	5.50
9	Haryana	2.62	3.82
10	Himachal Pradesh	1.62	5.86
11	Jharkhand	3.71	4.19
12	Karnataka	6.22	4.92
13	Kerala	2.52	8.59
14	Madhya Pradesh	7.07	2.38
15	Maharashtra	12.38	2.30

Table 5.5 State/UTs wise Annual Potential Production of Industrial Wood from TOF Area with % Standard Error

Sl. No.	State/UTs	Annual potential production of Industrial wood (M m³)	Standard Error (%)
16	Manipur *	0.19	10.16
17	Meghalaya	0.78	7.09
18	Mizoram *	1.47	10.20
19	Nagaland	0.81	9.54
20	Odisha	5.11	6.15
21	Punjab	2.79	4.15
22	Rajasthan	6.05	2.49
23	Sikkim	0.08	6.96
24	Tamil Nadu	3.18	3.98
25	Telangana	2.26	4.94
26	Tripura	0.37	5.44
27	Uttar Pradesh	8.56	2.23
28	Uttarakhand	1.13	4.85
29	West Bengal	2.27	4.77
30	A & N Islands *	0.09	23.21
31	Chandigarh	0.02	8.09
32	Dadra & Nagar Haveli Daman & Diu ***	0.03	12.48
33	Jammu & Kashmir* (shape file area = 52,633#)	2.44	9.13
34	Ladakh** (Shape file area= 1,68,055#)	0.25	18.17
35	Lakshadweep ***	0.00	17.17
36	Puducherry	0.02	8.52
	Total	**91.51**	**3.70**

** Inadequate data due to terrain and other issues in these states.*

*** Inventory has been done only for two years due to Covid restrictions.*

**** Due to inadequate data, standard error is high.*

To illustrate the enormity of the task of National Forest Inventory, the spatial distribution of about 89,991 sample points taken up for RFA inventory (2017-2022), and TOF Inventory (2016 - 2022) across the country is shown in the Figure 5.12. The number of plots surveyed by FSI, in each State /UTs along with enumerated trees across the country are exhibited in Table 5.6. It may be seen that a total of 78,26,353 trees (of ≥ 5 cm dbh) have been enumerated for the purpose of this report.

Table 5.6 State/UTs wise number of plots surveyed and enumerated trees by FSI across the country

Sl. No.	State/UTs	RFA Inventory (2017-22)		TOF-R (2016-22)		TOF-U (2016-22)	
		Sample Plots	Enumerated Trees	Sample Plots	Enumerated Trees	Sample Plots	Enumerated Trees
1	Andhra Pradesh	1,516	27,466	2,641	1,46,349	325	72,049
2	Arunachal Pradesh	877	3,577	543	12,593	29	13,315
3	Assam	1,163	8,849	1,118	40,067	209	2,06,395
4	Bihar	482	5,469	1,936	60,444	277	61,523
5	Chhattisgarh	1,229	20,191	2,159	1,36,631	301	52,164
6	Delhi	90	777	182	14,029	384	70,732
7	Goa	260	6,892	318	37,087	120	1,51,578
8	Gujarat	1,251	11,295	3,320	2,17,295	516	57,389
9	Haryana	161	1,766	942	54,159	213	56,377
10	Himachal Pradesh	1,002	18,310	696	41,125	86	2,64,095
11	Jharkhand	1,118	17,908	1,405	76,212	113	29,792
12	Karnataka	1,445	28,681	2,999	1,24,028	566	3,65,899
13	Kerala	593	14,780	611	44,822	311	8,23,753
14	Madhya Pradesh	1,713	27,511	4,323	1,90,827	775	79,079
15	Maharashtra	1,461	21,772	4,977	3,23,356	855	93,145
16	Manipur	720	2,478	520	8,374	87	39,941
17	Meghalaya	844	8,217	631	16,892	58	45,994
18	Mizoram	1,004	4,618	426	14,192	88	66,490
19	Nagaland	456	3,252	701	17,995	58	32,179
20	Odisha	1,744	29,334	1,859	88,015	380	1,63,488
21	Punjab	140	1,832	900	52,164	308	1,84,826
22	Rajasthan	1,173	10,958	6,307	5,12,522	565	2,15,572
23	Sikkim	358	2,533	372	15,380	13	4,190
24	Tamil Nadu	1,320	22,212	2,174	1,56,290	737	3,83,337
25	Telangana	1,011	17,814	1,958	1,18,124	259	48,947
26	Tripura	816	7,763	483	23,686	122	1,79,140
27	Uttar Pradesh	884	9,114	4,689	2,43,738	878	1,71,824
28	Uttarakhand	952	16,954	949	59,806	116	1,02,273
29	West Bengal	784	13,055	1,160	54,163	415	2,97,065
30	A & N Islands	309	4,594	123	7,148	11	18,754
31	Chandigarh	26	685	18	1,902	135	40,158
32	Dadra Nagar Haveli & Daman and Diu	43	798	64	5,437	15	2,235
33	Jammu and Kashmir	966	11,738	687	27,298	106	48,583
34	Ladakh	4	0	230	9,043	6	15,183
35	Lakshadweep	-	-	42	1,980	4	12,554
36	Puducherry	2	24	127	9,986	43	9,959
	Total	**27,917**	**3,83,217**	**52,590**	**29,63,159**	**9,484**	**44,79,977**

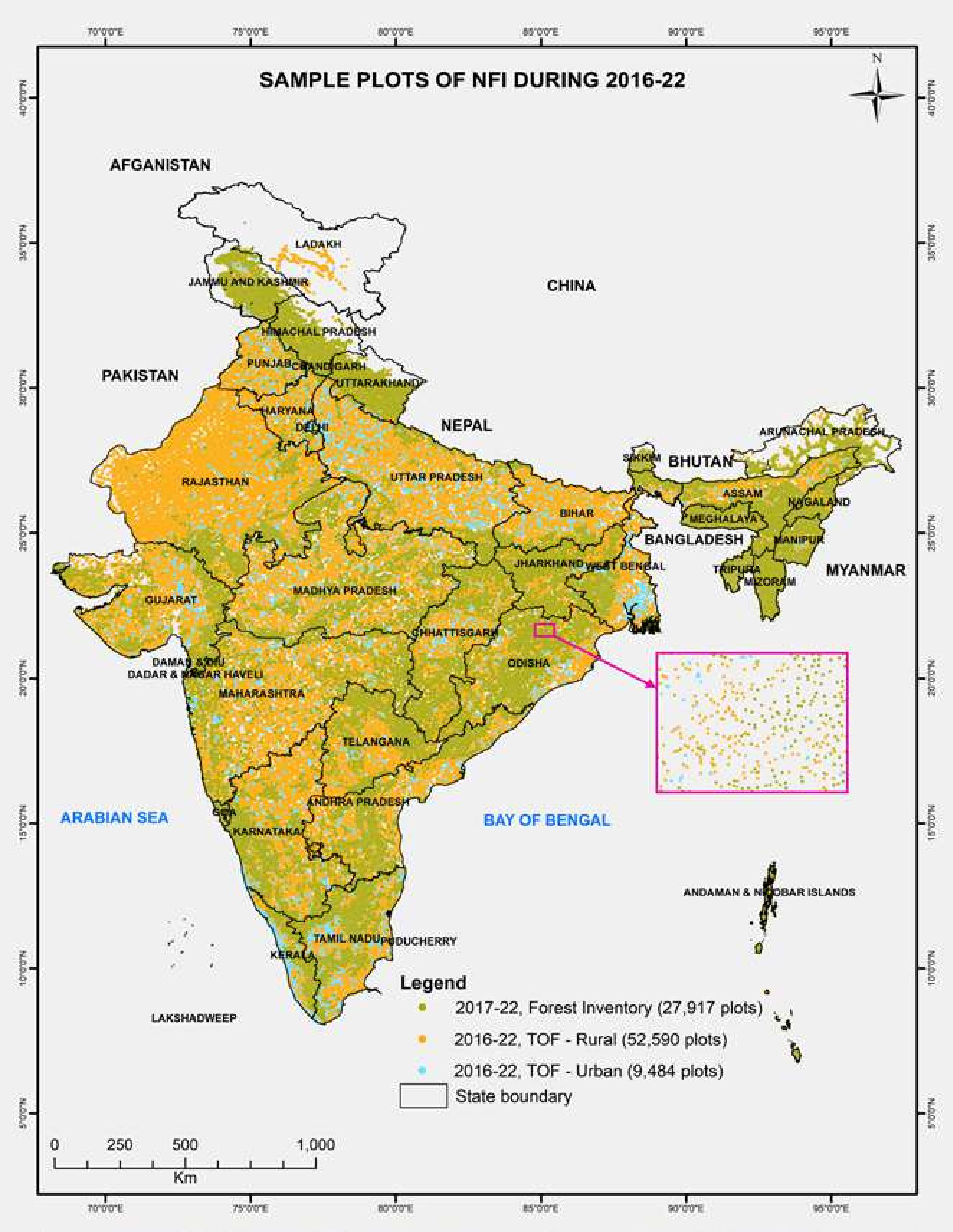


Figure 5.12 Sample Plots of NFI during 2016 – 2022

Bamboo Bearing Area

FSI collects information on bamboo during the National Forest Inventory. The State/UTs wise bamboo bearing area has been estimated on the basis of the inventoried plots. The distribution of bamboo bearing area has been presented in the following table.

State/UTs wise Distribution of Bamboo Area in RFA

(km^2)

Sl. No.	State/UTs	Bamboo bearing area as per ISFR 2023	Bamboo bearing area as per ISFR 2021	Change in area with respect to ISFR 2021	Change % in area with respect to ISFR 2021
1	Andhra Pradesh	6,370	6,104	266	4.36
2	Arunachal Pradesh	18,424	15,739	2,685	17.06
3	Assam	11,246	10,659	587	5.51
4	Bihar	1,109	1,103	6	0.54
5	Chhattisgarh	11,139	10,467	672	6.42
6	Goa	235	288	-53	-18.40
7	Gujarat	3,895	3,547	348	9.81
8	Haryana	42	39	3	7.69
9	Himachal Pradesh	1,154	1,027	127	12.37
10	Jharkhand	3,746	3,717	29	0.78
11	Karnataka	7,334	8,624	-1,290	-14.96
12	Kerala	2,443	2,404	39	1.62
13	Madhya Pradesh	20,421	18,394	2,027	11.02
14	Maharashtra	13,572	13,526	46	0.34
15	Manipur	7,517	8,377	-860	-10.27
16	Meghalaya	5,347	5,007	340	6.79
17	Mizoram	4,772	4,561	211	4.63
18	Nagaland	3,980	3,947	33	0.84
19	Odisha	12,328	11,199	1,129	10.08
20	Punjab	311	280	31	11.07
21	Rajasthan	1,706	1,555	151	9.71
22	Sikkim	1,010	994	16	1.61
23	Tamil Nadu	3,217	4,001	-784	-19.60
24	Telangana	3,801	4,535	-734	-16.19
25	Tripura	4,466	4,201	265	6.31
26	Uttar Pradesh	1,598	1,832	-234	-12.77
27	Uttarakhand	1,307	1,201	106	8.83
28	West Bengal	754	702	52	7.41
29	A & N Islands	1,426	1,413	13	0.92
	Total	**1,54,670**	**1,49,443**	**5,227**	**3.50**

Note: Information of bamboo bearing area for Chandigarh, Dadra & Nagar Haveli and Daman & Diu, Delhi, Lakshadweep, J&K, Ladakh, and Puducherry is not given due to inadequate number of plots having bamboo.

The above table reveals that the total bamboo bearing area of the country has been estimated to be 1,54,670 km^2. Madhya Pradesh has maximum bamboo bearing area of 20,421 km^2, followed by Arunachal Pradesh (18,424 km^2), Maharashtra (13,572 km^2), and Odisha (12,328 km^2). As compared to the estimates of ISFR, 2021, the total bamboo bearing area in the country has increased by 5,227 km^2. It has been observed that bamboo-bearing area in Arunachal Pradesh has shown the highest increase of 2,685 km^2 followed by Madhya Pradesh (2,027 km^2). Similarly, Karnataka has shown the highest decrease of 1,290 km^2 in the bamboo bearing area, followed by Manipur (860 km^2).


Photo: FSI Repository


Photo: Dharam Singh Meena

CHAPTER

06

Carbon Stock in India's Forest

Photo: Subharanjan Sen, IFS


Photo: Sanjay Shukla, IFS

06

CARBONS STOCKS IN INDIA'S FORESTS

6.1 Introduction

Forests play a significant role in climate change scenario, as carbon sequestration by forests is a relatively inexpensive means of mitigation of climate change effects. Forests also face adverse impacts of climate change. Forest phenology and productivity is particularly sensitive to climate change impacts. Globally, carbon is held in a variety of different stocks; as oceans, fossil fuel deposits, terrestrial systems and the atmosphere. In the terrestrial systems, carbon is stored in rocks, sediments, swamps, wetlands, forests, soils, grasslands, and agriculture. About two-third of global terrestrial carbon is contained in forests and forest soils (IPCC, 2014)[1]. During the last one and a half century, the increased human activities, particularly burning fossil fuels, agriculture, and deforestation are increasing the concentrations of greenhouse gases (GHG) (IPCC, 2019)[2]. It is the enhanced greenhouse effect, which is contributing to warming of the earth causing Climate Change.

India, having varied topography and climate regimes, large geographical area, long coastline, and oceanic islands, is endowed with a diversity of natural biomes from deserts to alpine meadows, tropical rain forests to temperate pine forests, mangroves to coral reefs and marshlands to high altitude lakes. The multiple physiographies, agro-climatic zones and forest types result in diversity of forests in India, which makes it reasonably resilient to climate change and also an efficient sink of carbon.

The estimation of the carbon stock in forests started in 2004 with reporting requirements of the GHG inventory to the United Nations Framework Convention on Climate Change (UNFCCC). All members of the UNFCCC have to report their GHG inventory to UNFCCC periodically through National Communication (NATCOM) and Biennial Update Report (BUR). The NATCOM/BUR not only contain the information on GHG inventory but also provide various policy measures, actions and programmes undertaken by the respective parties to address the issues of climate change mitigation and adaptation. India is also a Party to the Convention and, therefore, is required to periodically submit greenhouse gas inventory for the country from all the sectors including Land Use, Land-Use Change and Forestry (LULUCF) under NATCOM and BUR. Forestland is one of the category under the LULUCF sector. So far, India has submitted following reports to UNFCCC:

[1] IPCC (2014). Fifth Assessment Report (AR5), Intergovernmental Panel on Climate Change.

[2] IPCC (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. ISBN 978-1-009-15801-5.

- Initial National Communication (INC) in June 2004, containing national GHG inventory of 1994 (1984 – 1994).
- Second National Communication (SNC) in May 2012, containing national GHG inventory for the year 2000 (1994 – 2004).
- First Biennial Update Report (BUR-1) in January 2016, containing national GHG inventory for the year 2010 (2005 – 2010).
- Second Biennial Update Report (BUR-2) in December 2018, containing national GHG inventory for the year 2014 (2005 - 2014).
- Third Biennial Update Report (BUR-3) in February 2021, containing national GHG inventory for the year 2016 (2005 – 2016).

As per the Paris Agreement (2015), India submitted its 'Nationally Determined Contribution' (NDC) with various commitments of achieving targets. According to the forestry target under NDC, India has committed to create additional carbon sink of 2.5 to 3.0 billion tonnes of CO_2 eq., through additional forest and tree cover by 2030. The country is making concerted efforts to meet the Paris commitments and on the way to achieve the NDC target.

Amrit Tatva

During COP 26 meeting at Glasgow, Hon'ble Prime Minister of India announced to the world the five commitments or 'Amrit Tatva' that India would meet as it works "very hard" to tackle climate change-related issues. While communicating an update to its first NDC in August 2022, India has further ambitioned its commitment towards reducing its emissions intensity of its GDP by 45% by 2030, from 2005 level. Forests are going to play an important role in achieving this target. (PIB, 2023)[3]

As per the Global Forest Resources Assessment 2020 published by the FAO (FAO, 2020)[4], the total forest carbon stock (including all carbon pools) is estimated at 662.08 Gt (163.10 t/ha), comprising 299.50 Gt in soil organic matter, 294.54 Gt in living biomass and 68.04 Gt in dead wood and litter (Figure 6.1). Soil organic matter constitutes the biggest pool, with 45.2 % of the total carbon, followed by above-ground biomass, below-ground biomass, litter, and dead wood. The report also mentions that between 1990 and 2020 the global forest carbon stock decreased from 668.39 Gt to 662.08 Gt due to an overall decrease in forest area. However, there were considerable regional and sub-regional differences in the trend of carbon stock in various parts of different continents. For example, the carbon stock in forest biomass increased significantly in East Asia,

[3] PIB (2023). Press Information Bureau, 28 November, 2023. Ministry of Science & Technology, Government of India.
[4] FAO. 2020. Global Forest Resources Assessment 2020: Main report. Rome. https://doi.org/10.4060/ca9825en

Western and Central Asia, Europe, and North America (where forest area has increased) and decreased considerably in South America, and Western and Central Africa.

The primary data required for estimation of carbon stock comes from the National Forest Inventory (NFI). Since 2003, FSI has been estimating growing stock in both forests and Trees Outside Forests. Subsequently, suitable modifications were also made in the plot design to collect information required for calculation of the carbon stock in different carbon pools. The NFI design presently followed was adopted in the year 2016. In this design, the square grids of 5 km x 5 km are spread over the entire country, to meet the data needs at the national and international levels. In addition, the information on forest cover in different forest types is used for the estimation of carbon stock.

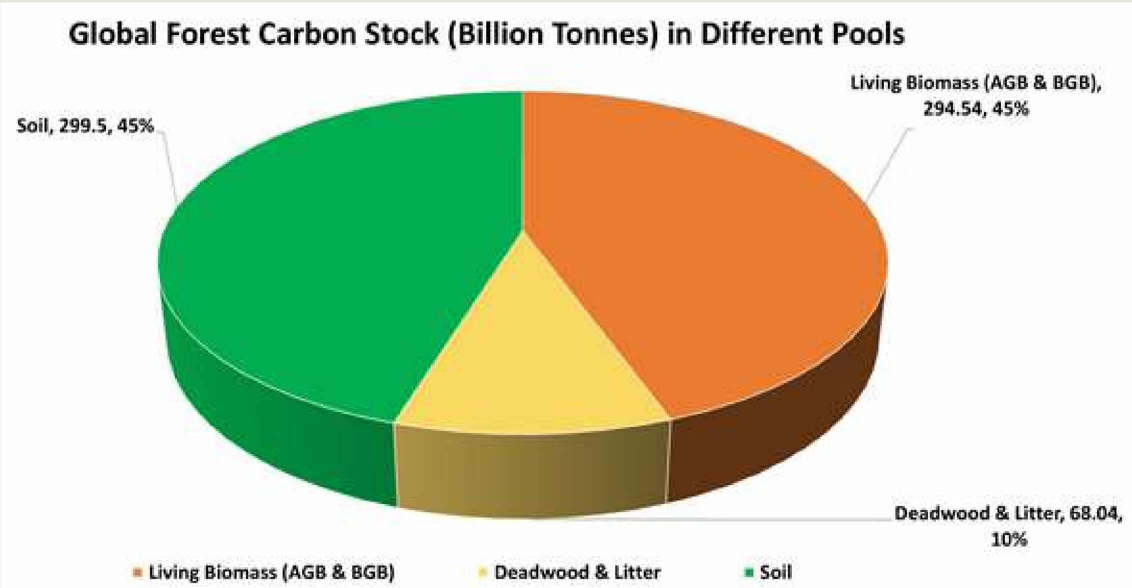
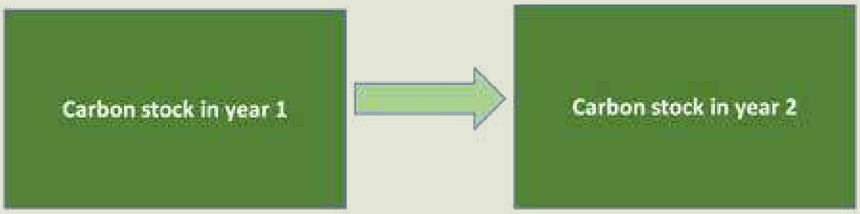


Figure 6.1 Global Forest Carbon Stock (Billion Tonnes) in Different Pools

6.2 Methodology for Forest Carbon Estimation

IPCC (2003)[5] "Good Practices Guidelines" has been used for estimation of carbon stock in country's forests. Information of activity data (Area) and emission factors (stock per unit area) are required for calculation of the carbon stock. Activity data is obtained from wall to wall forest cover mapping, and emission factors are obtained from the NFI. GIS based approach is used for estimation and synthesis of the activity data and emission factors.

Method for calculating biomass for different pools is described in the following sub sections. Change analysis in forest carbon between the current and previous assessment has been done following stock difference approach of Good Practices Guidelines (GPG) as shown in Figure 6.2.



$$\Delta C = (C_{t2} - C_{t1}) / (t_2 - t_1)$$

Where:

ΔC = annual carbon stock change in pool (t C/yr)

C_{t1} = carbon stock in pool at time t_1

C_{t2} = carbon stock in pool at time t_2

Figure 6.2 Stock Difference Method for Determining Change in Forest Carbon Stock

6.2.1 Stratification of Forest Area (activity data) by Forest Type and Canopy Density

Stratification helps in improving the precision of the estimates by splitting a heterogeneous population into relatively homogeneous sub-populations based on certain stratification criteria. Since carbon stored in the vegetation largely depends upon canopy density and forest type; these two layers have been used for stratification during assessment of forest carbon in the country. Overlaying of forest cover layer with 3 canopy density classes and forest type with the 17 type groups including TOF and plantations – has resulted into 51 strata (3 X 17 = 51). Area statistics for each stratum has been generated using GIS (Figure 6.3).

[5] IPCC (2003). Good Practices Guidelines. Intergovernmental Panel on Climate Change.

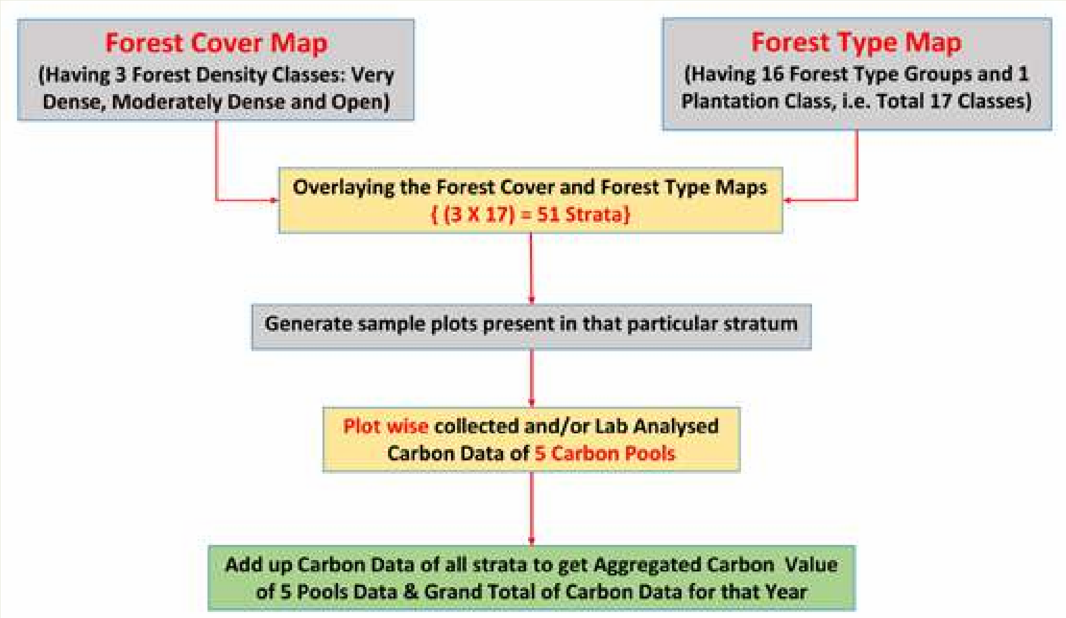


Figure 6.3 Post Sampling Stratification Approach for Forest Carbon Assessment

FSI had earlier mapped Forest Types of India, according to Champion & Seth classification (1968)[6] on 1: 50,000 scale in 2011. The second exercise for refining the previous Forest Type map has been completed by FSI in 2020. For calculation of the carbon stock, the latest forest type map has been used (FSI, 2020)[7].

6.2.2 Estimation of Biomass and Carbon in different Pools (Emission factors)

Estimation of carbon stock is carried out for all the carbon pools, as shown in Figure 6.4. The data collected during the NFI has been used for estimation of carbon stock. Volume and biomass equations developed by FSI for different species, under a special study by FSI, have been used for calculation of the plot level carbon stock. Specific gravity and carbon content percent of different species have been used for calculation of the carbon stock (Hidayat and Simpson, 1994)[8]. The methodology of estimation of biomass/carbon in different pools is described in brief in the following sub sections. Table 6.1 describes the three tiers of forest carbon assessment under the IPCC framework.

[6] Champion H.G. and Seth S.K. (1968). A Revised Survey of Forest Types of India, Govt. of India Press, New Delhi.
[7] FSI (2020). Forest Type Atlas of India. Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India.Press, Cambridge, UK and New York, NY, USA. ISBN 978-1-009-15801-5.
[8] Hidayat S. and Simpson W.T. (1994). Use of Green Moisture Content and Basic Specific Gravity to Group Tropical Woods for Kiln Drying. Unite States Department of Agriculture. Forest Service. Forest Products Laboratory. Research Note: FPL-RN-0263.

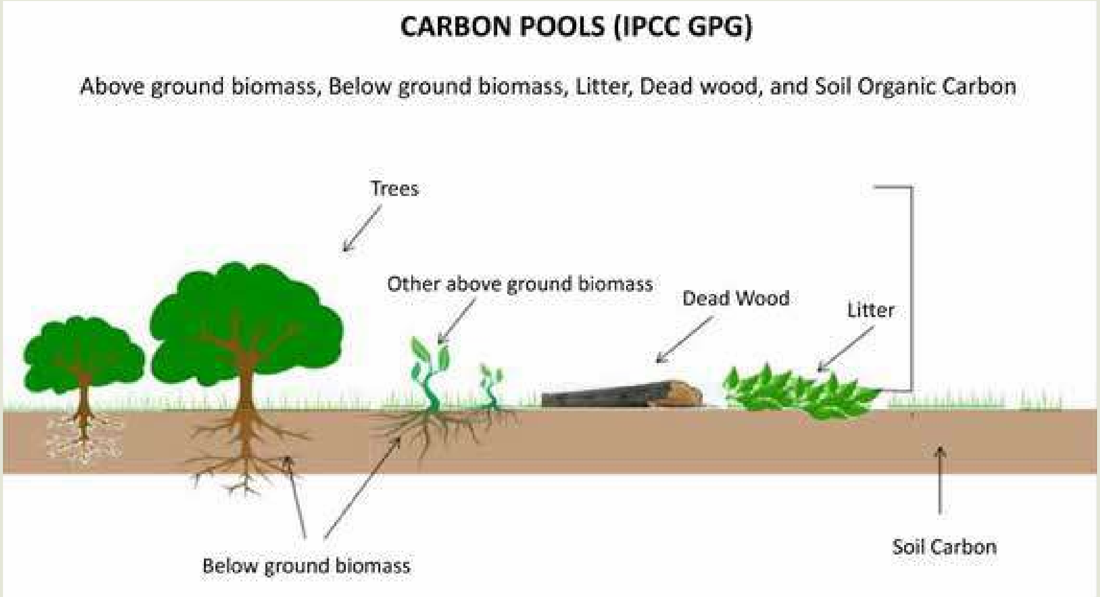


Figure 6.4 Diagram Showing Five Different Pools of Forest Carbon

Table 6.1 Different Forest Carbon Pools

Pools		Description
Living Biomass	Above Ground Biomass (AGB)	All biomass of living vegetation, both woody and herbaceous, above the soil, including stems, stumps, branches, bark, seeds, and foliage.
	Below Ground Biomass (BGB)	All biomass of live roots. Fine roots of less than 2 mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter.
Dead Organic Matter	Dead wood	All non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 5 cm in diameter.
	Litter	Woody material of trees having diameter <5cm and >2mm, which is not decomposed.
Soil	Soil organic Carbon	Carbon contained in soil organic matter.

6.2.2.1 Above Ground Biomass (AGB)

FSI has developed 5 different sets of volume equations for different tree species, distributed across various physiographies of India, to compute the AGB with maximum accuracy. These different sets of equations are:

- A Species wise equations for woody volume of trees (woody volume of trees above 10 cm dbh)
- B Species wise biomass equations for foliage of trees above 10 cm dbh
- C Species wise biomass equations for branches (of upto 5 cm diameter) of trees above 10 cm dbh
- D Species wise biomass equations for foliage of trees below 10 cm dbh
- E Species wise biomass equations for wood of trees below 10 cm dbh

A. Woody Above Ground Biomass (AGB) of Trees having DBH ≥ 10 cm

Forest inventory data collected from 27,917 sample plots in the last five years as per the new sampling design has been used for calculation of AGB of trees above DBH 10 cm. At each sample plot, all trees of diameter 10 cm and above were measured. The woody volume of trees for each sample plot is calculated using volume equations developed by FSI for various species. The volume equation provides above ground woody volume, which includes volume of main stem measured upto 10 cm diameter and volume of all branches having diameter 5 cm or more (biomass of small wood less than these thresholds have been dealt in following section B). Data of specific gravity and percentage carbon content of most of the tree species have been obtained from different published literature. For some important species with respect to biomass contribution, percentage carbon content was ascertained by experimentation; and for remaining an average of all other species has been used. Standard formulae are used to calculate biomass and carbon content of each tree.

For estimating volume of the bark, the double bark thickness of trees measured during forest inventory, and volume equation of trees have been used. Using species-wise, DBH and bark thickness, bark volumes were calculated and were adjusted for 'bark void'. With the help of the specific gravity of bark, the volume was converted into biomass. Using carbon content percent of wood, carbon stored in bark was estimated.

B. Biomass of Branches, and Foliage of Trees having DBH ≥ 10 cm

FSI, under a special study conducted in 2008-2010, developed around 760 biomass equations for 188 species, across the physiographic zones of India. These equations are used to estimate biomass of small wood and foliage of trees having dbh 10 cm or more and small wood and foliage of trees having dbh less than 10 cm also. These equations have been published by FSI in the report 'Carbon Stock of India's Forests' in 2011.

These equations were initially developed for Second National Communication to UNFCCC, for 20 important species in each of 14 physiographic zones. Using these equations, and plot level data of NFI, species wise carbon content of the above-mentioned AGB components at plot level has been calculated.

C. Biomass of Trees and Foliage having DBH < 10 cm

For arriving at the volume of trees of less than 10 cm dbh, and foliage; for each of such species, 3 trees each from all the diameter classes from 1 to 9 cm (at 1.37 m height) were felled. From the felled (9 X 3 = 27) trees of each species, separate biomass was calculated and recorded for wood, twigs and leaves in the prescribed format. Taking the dry biomass of wood/foliage as dependent variable and dbh as independent variable, best fit biomass equations were developed for each species. Using the plot level regeneration data from NFI, i.e., recruits, un-established, established regeneration, and all trees having DBH between 5 to 10 cm, biomass and carbon content at plot level is calculated.

D. Biomass of Shrubs, Herbs and Climbers

For this purpose, the data of past forest inventory has been used to develop State-wise factors for shrubs, herbs and climbers. These factors have been used to calculate biomass and carbon stock for shrubs, herbs and climbers.

6.2.2.2 Below Ground Biomass (BGB)

This is the most difficult pool to measure, and is generally not measured in forest inventory. It has been estimated using a relationship, root-to-shoot ratio, which gives a relationship between aboveground biomass (AGB) to the below ground biomass (BGB) which have been established by various researchers. IPCC (2003)[9] also provides default values of root-to-shoot ratios for six major global forest types. FSI has judiciously used these default values to arrive at the carbon estimates

6.2.2.3 Carbon Stock of Deadwood

For all dead wood of above 5 cm diameter, data on the diameter of the middle of the log, length (for dead trees/wood lying on the ground), and Height (for stump) were collected from the micro plots of radius 2.8 m out of three concentric micro-plots located in four sub-plots of radius 8 meter. Using the plot level data, the total biomass and carbon content at plot level has been calculated.

[9] IPCC (2003). Good Practices Guidelines. Intergovernmental Panel on Climate Change.

6.2.2.4 Carbon Stock of Woody Litter

From the micro plots of radius 1.7 m out of three concentric micro-plots, all woody litter, i.e., all branches below 5 cm diameter were collected, weighed and recorded. A portion of the same was sent to the standard labs for carbon analysis.

6.2.2.5 Soil Organic Carbon (SOC)

While carrying out forest inventory, the data on forest floor (non-woody litter and humus) and soil was also collected from each sample plot. For data collection on humus and soil carbon, two sub-plots of size 1m x 1m were laid out within the main plot. The forest floor from both the plots was first swept and material so collected was weighed and a portion of the same was kept for carbon analysis. Further, at the centre of these two sub-plots, where the ground is nearly uniform, a pit of 30 cm x 30 cm x 30 cm was dug and a composite sample of soil of approximately 200 gm was kept for organic carbon analysis. Samples of soil and non-woody litter collected from forest floor were analysed in the standard laboratories. The reported dry weight percent and the carbon content of soil as well as litter sample were used for carbon stock estimation in both the soil and forest floor pools.

6.2.3 Synthesizing Data for National Carbon Estimation

To determine the area under each strata, Geographic Information System (GIS) technique has been used. Forest cover layer with three canopy density classes namely Very Dense Forest (VDF), Moderately Dense Forest (MDF), and Open forest (OF) are overlaid with the forest type map layer with the 16 type groups, and 1 stratum of TOF / plantations. This generates the activity data.

The emission/removal factors have been generated by using field inventory plots along with forest type information, for each pool, per unit area basis. The multiplication of the activity data (area) with per ha carbon stock gives the estimate for each strata. Aggregation of the forest carbon stock derived for 5 carbon pools from all the strata can be segregated State/UTs wise. The summation of State/UTs wise carbon stock generates an estimate of carbon stock for the entire country.

Results 6.3

6.3.1 Forest Carbon Stock under Different Carbon Pools and Change w.r.t. Previous Assessment

The Forest Carbon Estimates at the national level under different carbon pools and change in respect to previous assessment have been given in Table 6.2. [For the purpose of Carbon Stock estimation, the term 'Forest' used in this Chapter, means 'Forest Cover'. This definition has been adopted from the Kyoto Protocol for international comparability of GHG inventory]

Table 6.2 Forest Carbon Stock under different pools and changes w.r.t. previous assessment (in Mt)

Carbon Pools	Carbon Stock in forest in 2023	Carbon stock in forest in 2021	Net change in Carbon stock	Annual change in Carbon stock
Above Ground Biomass	2,374.4	2,319.9	54.5	27.25
Below Ground Biomass	735.2	718.9	16.3	8.15
Dead wood	56.4	47.7	8.7	4.35
Litter	107.8	107.3	0.5	0.25
Soil	4,011.7	4,010.2	1.5	0.75
Total	**7,285.5**	**7,204.0**	**81.5**	**40.75**

The carbon stock for 2023 has been estimated 7,285.5 Mt. Figure 6.5 represents the forest carbon stock in different carbon pools, with its respective percentage. There is an increase of 81.5 Mt of carbon stock as compared to the estimates of previous assessment. The annual increase of carbon stock is estimated as 40.75 Mt, which is 149.42 Mt of CO_2 equivalent. Soil organic carbon is the largest pool of forest carbon accounting for (55.06 %) followed by AGB (32.59 %), BGB (10.09 %), Litter (1.48 %) and Dead Wood (0.78 %). On comparing the changes between present and previous assessment, maximum changes have been observed in AGB, followed by BGB.

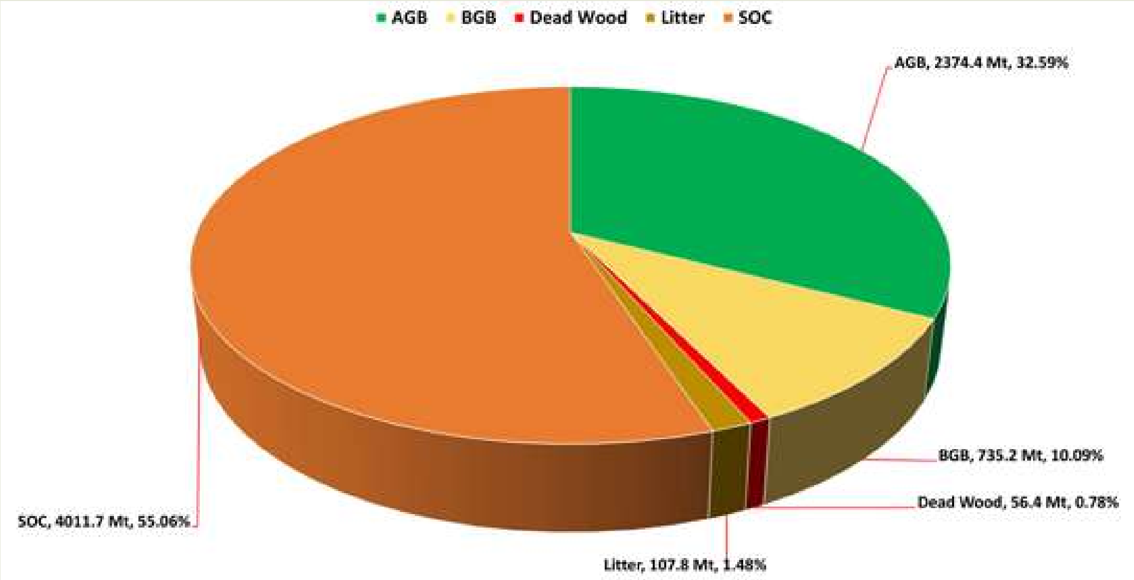


Figure 6.5 Forest Carbon Stock in different pools (in Mt)

6.3.2 Forest Carbon Stock of State and UTs

Forest carbon stock in different carbon pools in State and UTs are presented in Table 6.3. The tons per hectare value for each State/UTs under each pool has been given in parentheses.

Table 6.3 Forest Carbon Stock in States/UTs in different Carbon Pools in '000 t (Stock in t/ha given in parentheses)

Sl. No.	State/UTs	Forest Cover Area (km^2)	AGB	BGB	Dead Wood	Litter	SOC	Total
1	Andhra Pradesh	30,085	64,135 (21.32)	25,007 (8.31)	2,247 (0.75)	2,846 (0.95)	1,39,357 (46.32)	2,33,592 (77.65)
2	Arunachal Pradesh	65,882	3,55,100 (53.90)	1,05,818 (16.06)	4,542 (0.69)	11,133 (1.69)	5,44,567 (82.66)	10,21,160 (155.00)
3	Assam	28,314	88,653 (31.31)	21,816 (7.71)	2,683 (0.95)	4,795 (1.69)	1,54,363 (54.52)	2,72,310 (96.18)
4	Bihar	7,532	15,166 (20.13)	5,330 (7.08)	741 (0.98)	621 (0.82)	36,593 (48.58)	58,451 (77.59)
5	Chhattisgarh	55,812	1,55,051 (27.78)	49,428 (8.86)	3,498 (0.63)	9,643 (1.73)	2,86,994 (51.42)	5,04,614 (90.42)
6	Delhi	195	277 (14.16)	82 (4.18)	26 (1.31)	11 (0.55)	825 (42.22)	1,221 (62.42)
7	Goa	2,266	9,000 (39.72)	2,627 (11.59)	299 (1.32)	496 (2.19)	13,091 (57.78)	25,513 (112.60)
8	Gujarat	15,017	28,497 (18.98)	9,653 (6.43)	1,476 (0.98)	1,282 (0.85)	67,414 (44.89)	1,08,322 (72.13)
9	Haryana	1,614	2,406 (14.90)	858 (5.32)	189 (1.17)	91 (0.56)	6,932 (42.94)	10,476 (64.89)
10	Himachal Pradesh	15,580	1,12,461 (72.18)	31,390 (20.15)	1,041 (0.67)	2,717 (1.74)	1,07,407 (68.94)	2,55,016 (163.68)
11	Jharkhand	23,766	50,918 (21.42)	20,622 (8.68)	1,622 (0.68)	2,843 (1.20)	1,10,429 (46.47)	1,86,434 (78.45)
12	Karnataka	39,254	1,37,529 (35.04)	44,567 (11.35)	4,500 (1.15)	7,759 (1.98)	2,13,900 (54.49)	4,08,255 (104.01)
13	Kerala	22,059	65,241 (29.58)	18,284 (8.29)	3,217 (1.46)	3,319 (1.50)	1,24,023 (56.22)	2,14,084 (97.05)
14	Madhya Pradesh	77,073	1,69,594 (22.00)	66,213 (8.59)	5,047 (0.65)	8,354 (1.08)	3,59,212 (46.61)	6,08,420 (78.93)
15	Maharashtra	50,859	1,43,901 (28.29)	44,265 (8.70)	3,245 (0.64)	10,012 (1.97)	2,63,259 (51.76)	4,64,682 (91.36)
16	Manipur	16,585	47,529 (28.66)	14,175 (8.55)	679 (0.41)	2,505 (1.51)	1,11,037 (66.95)	1,75,925 (106.08)
17	Meghalaya	16,967	55,437 (32.67)	15,853 (9.34)	1,096 (0.65)	3,313 (1.95)	1,07,531 (63.38)	1,83,230 (107.99)
18	Mizoram	17,990	55,376 (30.78)	12,212 (6.79)	736 (0.41)	3,430 (1.91)	96,723 (53.76)	1,68,477 (93.65)

Table 6.3 Forest Carbon Stock in State/UTs in different Carbon Pools in '000 t (Stock in t/ha given in parentheses)

Sl. No.	State/UTs	Forest Cover Area (km²)	AGB	BGB	Dead Wood	Litter	SOC	Total
19	Nagaland	12,222	38,779 (31.73)	10,231 (8.37)	631 (0.52)	1,863 (1.52)	81,125 (66.37)	1,32,629 (108.51)
20	Odisha	52,434	1,34,214 (25.60)	41,387 (7.89)	3,898 (0.74)	8,254 (1.57)	2,65,925 (50.72)	4,53,678 (86.52)
21	Punjab	1,846	3,414 (18.49)	1,275 (6.91)	176 (0.95)	99 (0.53)	8,631 (46.75)	13,595 (73.63)
22	Rajasthan	16,548	26,374 (15.94)	10,646 (6.43)	1,493 (0.90)	930 (0.56)	70,728 (42.74)	110,171 (66.57)
23	Sikkim	3,358	19,576 (58.29)	5,893 (17.55)	242 (0.72)	536 (1.59)	30,580 (91.05)	56,827 (169.20)
24	Tamilnadu	26,450	61,872 (23.39)	21,053 (7.96)	2,866 (1.08)	3,123 (1.18)	1,28,646 (48.64)	2,17,560 (82.25)
25	Telangana	21,179	43,554 (20.56)	18,028 (8.51)	1,420 (0.67)	2,062 (0.97)	96,668 (45.64)	1,61,732 (76.35)
26	Tripura	7,585	24,417 (32.19)	5,371 (7.08)	617 (0.81)	1,630 (2.15)	42,219 (55.66)	74,254 (97.89)
27	Uttar Pradesh	15,046	33,597 (22.33)	10,469 (6.96)	1,615 (1.07)	1,620 (1.08)	72,833 (48.41)	1,20,134 (79.85)
28	Uttarakhand	24,304	1,59,353 (65.57)	42,777 (17.60)	1,416 (0.58)	4,749 (1.95)	1,68,317 (69.26)	3,76,612 (154.96)
29	West Bengal	16,832	45,200 (26.85)	13,949 (8.29)	2,142 (1.27)	1,663 (0.99)	91,412 (54.31)	1,54,366 (91.71)
30	Andaman Nicobar Islands	6,733	47,115 (69.98)	15,240 (22.63)	1,569 (2.33)	2,215 (3.29)	42,678 (63.39)	1,08,817 (161.62)
31	Chandigarh	25	51 (20.58)	16 (6.56)	3 (1.15)	2 (0.88)	127 (50.96)	199 (80.13)
32.	Dadra & Nagar Haveli and Daman and Diu	226	547 (24.24)	127 (5.63)	18 (0.81)	32 (1.42)	1,238 (54.89)	1962 (86.99)
33	Jammu & Kashmir	21,346	1,66,654 (78.07)	46,631 (21.85)	1,386 (0.65)	3,416 (1.60)	1,53,542 (71.93)	3,71,629 (174.10)
34	Ladakh	2,286	13,275 (58.07)	3,839 (16.80)	60 (0.26)	435 (1.90)	13,042 (57.05)	30,651 (134.08)
35	Lakshadweep	27	52 (19.20)	11 (4.21)	4 (1.62)	2 (0.56)	148 (54.82)	217 (80.41)
36	Puducherry	44	61 (13.84)	14 (3.15)	8 (1.84)	2 (0.44)	230 (51.84)	315 (71.11)
Total		**7,15,343**	**23,74,376 (33.19)**	**7,35,157 (10.28)**	**56,448 (0.79)**	**1,07,803 (1.51)**	**40,11,746 (56.08)**	**72,85,530 (101.85)**

The table shows that Arunachal Pradesh has maximum carbon stock of 1,021.16 Mt followed by Madhya Pradesh (608.42 Mt), Chhattisgarh (504.61 Mt) and Maharashtra (464.68 Mt). The per hectare carbon stock among different State/UTs indicates that Jammu & Kashmir is contributing maximum per hectare carbon stock of 174.10 t/ha, followed by Sikkim (169.20 t/ha), Himachal Pradesh (163.68 t/ha) and Andaman & Nicobar Islands (161.62 t/ha).

6.3.3 Carbon Stock in different Carbon Pools under different Forest Type Groups and Density

Carbon stock in different carbon pools under different forest types and density is given in Table 6.4. The tons per hectare carbon stock for each forest type group and pool has been given in parentheses.

Table 6.4 Forest Type Group and Density wise Carbon Stock in Different Carbon Pools in '000 t (Stock in t/ha given in parentheses)

Forest Type Strata	Density	Forest Cover Area (km^2)	AGB	BGB	Dead Wood	Litter	SOC	Total
Tropical Wet Evergreen Forests	VDF	10,128	88,958 (87.83)	32,917 (32.50)	3,666 (3.62)	5,743 (5.67)	70,372 (69.48)	2,01,656 (199.10)
	MDF	10,846	74,945 (69.10)	27,733 (25.57)	380 (0.35)	4,067 (3.75)	71,452 (65.88)	1,78,577 (164.65)
	OF	2,914	11,349 (38.95)	4,199 (14.41)	583 (2.00)	105 (0.36)	18,403 (63.16)	34,639 (118.88)
	Total	**23,888**	**1,75,252 (73.36)**	**64,849 (27.15)**	**4,629 (1.94)**	**9,915 (4.15)**	**1,60,227 (67.07)**	**4,14,872 (173.67)**
Tropical Semi-Evergreen Forests	VDF	8,160	49,227 (60.33)	10,828 (13.27)	1,485 (1.82)	555 (0.68)	47,105 (57.73)	1,09,200 (133.83)
	MDF	28,757	1,31,102 (45.59)	28,843 (10.03)	1,035 (0.36)	9,806 (3.41)	1,58,076 (54.97)	3,28,862 (114.36)
	OF	26,970	52,349 (19.41)	11,516 (4.27)	566 (0.21)	1,268 (0.47)	1,33,933 (49.66)	1,99,632 (74.02)
	Total	**63,887**	**2,32,678 (36.42)**	**51,187 (8.01)**	**3,086 (0.48)**	**11,629 (1.82)**	**3,39,114 (53.08)**	**6,37,694 (99.81)**
Tropical Moist Deciduous Forests	VDF	25,302	1,22,513 (48.42)	26,947 (10.65)	2,960 (1.17)	7,110 (2.81)	1,51,180 (59.75)	3,10,710 (122.80)
	MDF	66,468	2,26,456 (34.07)	49,851 (7.50)	5,450 (0.82)	22,865 (3.44)	3,84,184 (57.80)	6,88,806 (103.63)
	OF	41,417	92,235 (22.27)	20,294 (4.90)	1,657 (0.40)	2,237 (0.54)	2,31,727 (55.95)	3,48,150 (84.06)
	Total	**1,33,187**	**4,41,204 (33.13)**	**97,092 (7.29)**	**10,067 (0.76)**	**32,212 (2.42)**	**7,67,091 (57.60)**	**13,47,666 (101.20)**
Littoral and Swamp Forests	VDF	1,562	12,216 (78.22)	4,520 (28.94)	6 (0.04)	181 (1.16)	9,700 (62.11)	26,623 (170.47)
	MDF	1,671	10,142 (60.69)	3,753 (22.46)	3 (0.02)	58 (0.35)	9,930 (59.42)	23,886 (142.94)
	OF	2,379	4,698 (19.75)	1,739 (7.31)	457 (1.92)	74 (0.31)	13,006 (54.68)	19,974 (83.97)
	Total	**5,612**	**27,056 (48.21)**	**10,012 (17.84)**	**466 (0.83)**	**313 (0.56)**	**32,636 (58.15)**	**70,483 (125.59)**

Table 6.4 Forest Type Group and Density wise Carbon Stock in Different Carbon Pools in '000 t (Stock in t/ha given in parentheses)

Forest Type Strata	Density	Forest Cover Area (km²)	AGB	BGB	Dead Wood	Litter	SOC	Total
Tropical Dry Deciduous Forests	VDF	25,333	90,642 (35.78)	38,076 (15.03)	1,165 (0.46)	16,441 (6.49)	1,31,554 (51.93)	2,77,878 (109.69)
	MDF	1,24,800	352,561 (28.25)	1,48,138 (11.87)	1,872 (0.15)	7,488 (0.60)	6,22,379 (49.87)	11,32,438 (90.74)
	OF	1,30,446	159,014 (12.19)	66,789 (5.12)	13,697 (1.05)	6,001 (0.46)	5,33,395 (40.89)	7,78,896 (59.71)
	Total	**2,80,579**	**602,217 (21.46)**	**2,53,003 (9.02)**	**16,734 (0.60)**	**29,930 (1.07)**	**12,87,328 (45.88)**	**21,89,212 (78.03)**
Tropical Thorn Forests	VDF	160	400 (25.03)	168 (10.51)	6 (0.36)	35 (2.17)	760 (47.64)	1,369 (85.71)
	MDF	3,554	5,285 (14.87)	2,221 (6.25)	668 (1.88)	146 (0.41)	13,285 (37.38)	21,605 (60.79)
	OF	10,042	7,913 (7.88)	3,324 (3.31)	552 (0.55)	402 (0.40)	19,330 (19.25)	31,521 (31.39)
	Total	**13,756**	**13,598 (9.89)**	**5,713 (4.15)**	**1,226 (0.89)**	**583 (0.42)**	**33,375 (24.26)**	**54,495 (39.61)**
Tropical Dry Evergreen Forests	VDF	133	645 (48.57)	271 (20.39)	16 (1.21)	13 (0.97)	1,182 (89.02)	2,127 (160.16)
	MDF	413	1,749 (42.34)	734 (17.78)	15 (0.37)	29 (0.69)	1,450 (35.11)	3,977 (96.29)
	OF	255	499 (19.56)	210 (8.22)	5 (0.20)	11 (0.44)	888 (34.79)	1,613 (63.21)
	Total	**801**	**2,893 (36.12)**	**1,215 (15.17)**	**36 (0.45)**	**53 (0.66)**	**3,520 (43.95)**	**7,717 (96.35)**
Subtropical Broad-leaved Hill Forests	VDF	7,512	49,165 (65.45)	20,650 (27.49)	714 (0.95)	285 (0.38)	69,664 (92.74)	1,40,478 (187.01)
	MDF	13,868	43,434 (31.32)	18,236 (13.15)	513 (0.37)	3,897 (2.81)	1,20,249 (86.71)	1,86,329 (134.36)
	OF	9,637	17,356 (18.01)	7,286 (7.56)	193 (0.20)	569 (0.59)	68,596 (71.18)	94,000 (97.54)
	Total	**31,017**	**109,955 (35.45)**	**46,172 (14.89)**	**1,420 (0.46)**	**4,751 (1.53)**	**2,58,509 (83.34)**	**4,20,807 (135.67)**
Subtropical Pine Forests	VDF	1,702	15,749 (92.54)	4,253 (24.99)	204 (1.20)	277 (1.63)	12,902 (75.81)	33,385 (196.17)
	MDF	8,964	48,065 (53.62)	12,980 (14.48)	332 (0.37)	1,147 (1.28)	64,075 (71.48)	1,26,599 (141.23)
	OF	7,443	24,717 (33.21)	6,676 (8.97)	149 (0.20)	908 (1.22)	49,091 (65.96)	81,541 (109.56)
	Total	**18,109**	**88,531 (48.89)**	**23,909 (13.20)**	**685 (0.38)**	**2,332 (1.29)**	**126,068 (69.62)**	**2,41,525 (133.38)**

Table 6.4 Forest Type Group and Density wise Carbon Stock in Different Carbon Pools in '000 t (Stock in t/ha given in parentheses)

Forest Type Strata	Density	Forest Cover Area (km²)	AGB	BGB	Dead Wood	Litter	SOC	Total
Subtropical Dry Evergreen Forest	VDF	5	58 (106.46)	24 (44.70)	1 (1.43)	0 (0.27)	61 (112.50)	144 (265.36)
	MDF	45	401 (89.33)	168 (37.52)	1 (0.33)	5 (1.02)	286 (63.76)	861 (191.96)
	OF	88	386 (43.90)	162 (18.44)	1 (0.17)	12 (1.37)	481 (54.81)	1,042 (118.69)
	Total	**138**	**845 (61.23)**	**354 (25.65)**	**3 (0.22)**	**17 (1.24)**	**828 (60.00)**	**2,047 (148.34)**
Montane Wet Temperate Forests	VDF	8,389	49,380 (58.86)	13,331 (15.89)	1,141 (1.36)	1,225 (1.46)	1,07,946 (128.67)	1,73,023 (206.24)
	MDF	9,056	33,146 (36.60)	8,948 (9.88)	326 (0.36)	1,494 (1.65)	1,01,685 (112.28)	1,45,599 (160.77)
	OF	1,999	3,921 (19.61)	1,058 (5.29)	40 (0.20)	114 (0.57)	8,578 (42.90)	13,711 (68.57)
	Total	**19,444**	**86,447 (44.46)**	**23,337 (12.00)**	**1,507 (0.78)**	**2,833 (1.46)**	**2,18,209 (112.22)**	**3,32,333 (170.92)**
Himalayan Moist Temperate Forests	VDF	8,795	1,28,095 (145.65)	34,590 (39.33)	1,196 (1.36)	2,638 (3.00)	74,174 (84.34)	2,40,693 (273.68)
	MDF	14,270	1,45,325 (101.84)	39,242 (27.50)	528 (0.37)	3,625 (2.54)	1,14,545 (80.27)	3,03,265 (212.52)
	OF	6,751	46,870 (69.43)	12,657 (18.75)	135 (0.20)	837 (1.24)	48,247 (71.47)	1,08,746 (161.09)
	Total	**29,816**	**3,20,290 (107.42)**	**86,489 (29.01)**	**1,859 (0.62)**	**7,100 (2.38)**	**2,36,966 (79.48)**	**6,52,704 (218.91)**
Himalayan Dry Temperate Forests	VDF	1,182	19,657 (166.28)	5,701 (48.22)	142 (1.20)	202 (1.71)	12,490 (105.65)	38,192 (323.06)
	MDF	1,836	24,440 (133.15)	7,087 (38.61)	66 (0.36)	270 (1.47)	14,124 (76.95)	45,987 (250.54)
	OF	1,470	9,839 (66.95)	2,854 (19.42)	29 (0.20)	185 (1.26)	9,993 (68.00)	22,900 (155.83)
	Total	**4,488**	**53,936 (120.18)**	**15,642 (34.85)**	**237 (0.53)**	**657 (1.46)**	**36,607 (81.57)**	**1,07,079 (238.59)**
Sub-Alpine Forests	VDF	2,579	42,093 (163.21)	12,202 (47.31)	309 (1.20)	482 (1.87)	29,930 (116.05)	85,016 (329.64)
	MDF	5,224	36,723 (70.29)	10,642 (20.37)	193 (0.37)	517 (0.99)	43,065 (82.43)	91,140 (174.45)
	OF	4,695	22,432 (47.78)	6,507 (13.86)	94 (0.20)	446 (0.95)	36,042 (76.77)	65,521 (139.56)
	Total	**12,498**	**1,01,248 (81.01)**	**29,351 (23.48)**	**596 (0.48)**	**1,445 (1.16)**	**1,09,037 (87.24)**	**2,41,677 (193.37)**

Table 6.4 Forest Type Group and Density wise Carbon Stock in Different Carbon Pools in '000 t (Stock in t/ha given in parentheses)

Forest Type Strata	Density	Forest Cover Area (km²)	AGB	BGB	Dead Wood	Litter	SOC	Total
Moist Alpine Scrub	VDF	67	347 (51.45)	101 (14.92)	8 (1.20)	6 (0.90)	436 (64.80)	898 (133.27)
	MDF	196	550 (28.03)	159 (8.13)	7 (0.36)	21 (1.09)	1,113 (56.77)	1,850 (94.38)
	OF	270	557 (20.64)	159 (5.89)	23 (0.84)	22 (0.80)	1,478 (54.71)	2,239 (82.88)
	Total	**533**	**1,454 (27.28)**	**419 (7.86)**	**38 (0.71)**	**49 (0.92)**	**3,027 (56.79)**	**4,987 (93.56)**
Dry Alpine Scrub	VDF	106	1,046 (98.45)	303 (28.55)	13 (1.18)	13 (1.18)	685 (64.49)	2,060 (193.85)
	MDF	488	3,174 (65.02)	921 (18.86)	18 (0.36)	62 (1.26)	3,066 (62.82)	7,241 (148.32)
	OF	1,488	7,506 (50.45)	2,177 (14.63)	30 (0.20)	491 (3.30)	4,159 (27.95)	14,363 (96.53)
	Total	**2,082**	**11,726 (56.32)**	**3,401 (16.34)**	**61 (0.29)**	**566 (2.72)**	**7,910 (37.99)**	**23,664 (113.66)**
Planta-tion/TOF	VDF	1,387	5,378 (38.78)	1,183 (8.53)	158 (1.14)	104 (0.75)	8,331 (60.07)	15,154 (109.27)
	MDF	17,217	42,422 (24.64)	9,312 (5.41)	2,428 (1.41)	1,154 (0.67)	99,514 (57.80)	1,54,830 (89.93)
	OF	56,904	57,246 (10.06)	12,517 (2.20)	11,212 (1.97)	2,160 (0.38)	2,83,449 (49.81)	3,66,584 (64.42)
	Total	**75,508**	**1,05,046 (13.91)**	**23,012 (3.05)**	**13,798 (1.83)**	**3,418 (0.45)**	**3,91,294 (51.82)**	**5,36,568 (71.06)**
Grand Total		**715,343**	**2,374,376 (33.19)**	**735,157 (10.28)**	**56,448 (0.79)**	**107,803 (1.51)**	**4,011,746 (56.08)**	**7,285,530 (101.85)**

Figure 6.6 shows the density wise carbon stock in t/ha in various carbon pools. The forest carbon stock (t/ha) in various forest type group is shown in Figure 6.7.

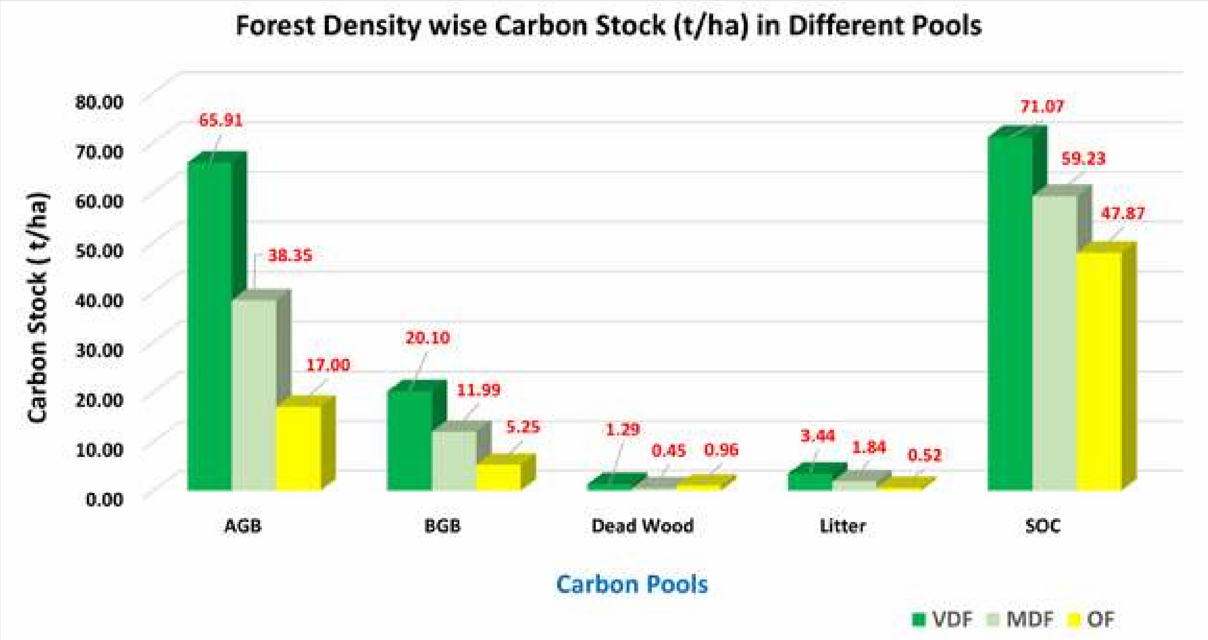


Figure 6.6 Density wise Carbon Stock (t/ha) in Different Pools

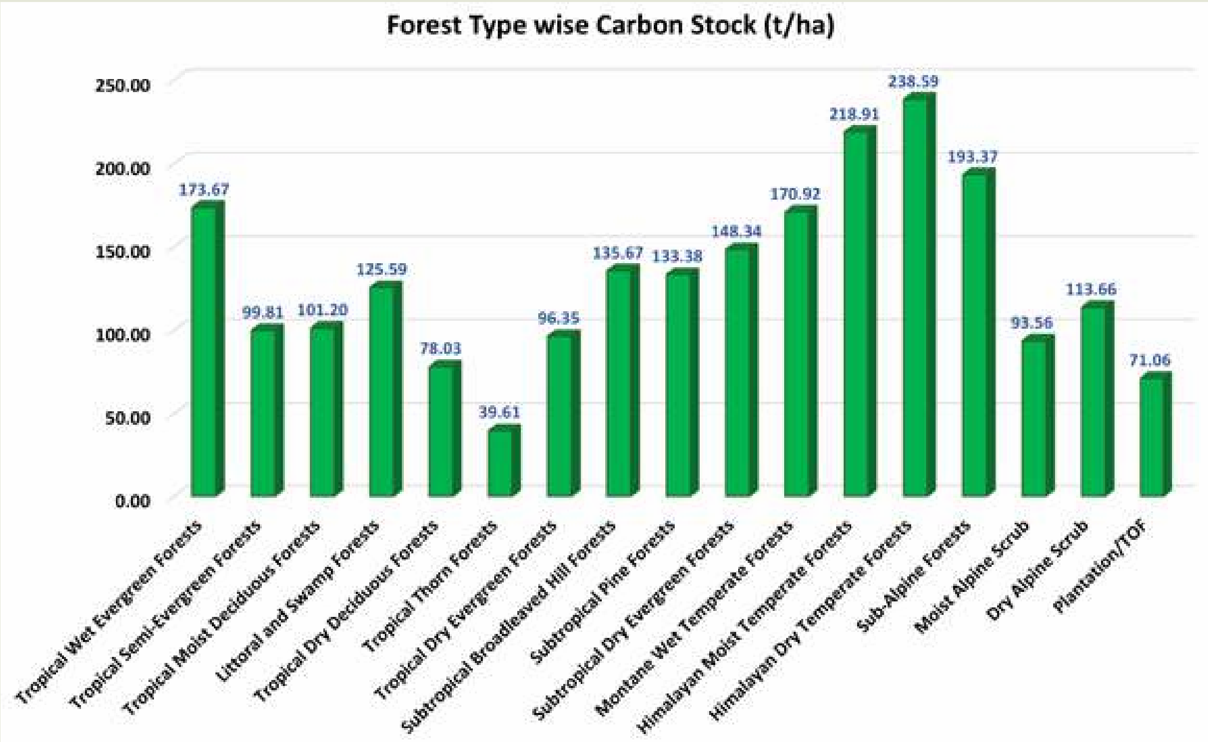


Figure 6.7 Forest Type Group wise Carbon Stock (t/ha)

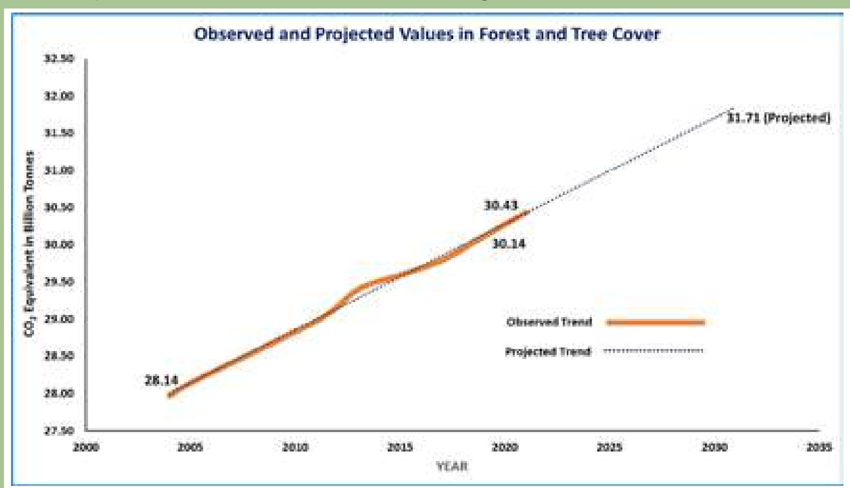
6.4 Conclusion

Over the last 5 biennial assessments, the carbon stock of the country's forests has shown an increasing trend. The carbon stock has risen from 6,941 Mt in the 2013 assessment to 7,285.5 Mt in the present assessment showing an increase of 344.5 Mt between the period 2013 to 2023. In addition, the carbon stock in tree cover has separately been estimated to monitor the target of NDC. In the year 2015, India had committed for creating an additional carbon sink of 2.5 to 3.0 Billion tonne. With the current assessment, the country has achieved an additional carbon sink of 2.29 Billion tonne with respect to 2005 as 'Base Year' in forest and tree cover (given in box item below). With these trends, India will be having 31.71 Billion tonne of carbon stock in forest and tree cover by the year 2030.

Trend of Carbon Stock in Forest & Tree Cover in India

Trend of Carbon Stock in Forest & Tree Cover in India vis-à-vis India's Nationally Determined Contribution (NDC) target of creating 'an additional carbon sink of 2.5 to 3.0 billion tonnes of CO_2 equivalent through forest and tree cover by 2030'

India's NDC makes a commitment to create an additional carbon sink of 2.5 to 3.0 billion tonnes of CO_2 equivalent through improvement and addition of forest and tree cover by 2030. FSI has been assessing the carbon stock of India's forests on a regular basis, the same has also been reported on UNFCCC under different National Communications (NATCOM). In order to understand the magnitude and scale of actions required to achieve the target vis-à-vis trend of carbon stock in forest & tree cover over and above of base line of 2005, FSI has carried out a study using time series data on forest cover, its projected changes and change matrix. The details of the study has been given in FSI Technical Information Series Volume 1 No. 3. Using estimates of forest carbon of different years in the past, projections of forest carbon upto 2030 have been made using trend line.



It is seen from the above graph that with the baseline year 2005, the total carbon stock in forest and tree cover has been estimated as 30.43 billion tonnes (ISFR, 2023). Thus as compared to the base year of 2005, we have already achieved a target of 2.29 billion tonnes.

Based on the projection, it is observed that the carbon stock in forest & tree cover of India which was 28.14 billion tonnes CO_2 eq in 2005 would rise to 31.71 billion tonnes CO_2 eq in 2030 showing an increase of 3.57 billion tonnes CO_2 eq in 25 years.

Photo: Subharanjan Sen IFS


Photo: FSI Repository

CHAPTER 07

Trees in Agroforestry Systems in India

Photo: FSI Repository


Photo: FSI Repository

TREES IN AGROFORESTRY SYSTEMS IN INDIA

07

Introduction 7.1

The term 'Agroforestry' is commonly understood as a mix-land use system integrating woody perennials (trees, shrubs, palms, bamboo, etc.) within agriculture systems. The traditional practice of agroforestry has played a significant role in enhancing land productivity, improving livelihoods, and socio-economic well-being of the people. Agroforestry is being practiced globally since time immemorial, but it has gained considerable momentum in recent decades because of its multi-functional role to provide goods (food, fuel, timber, fodder, etc.); benefits (soil nutrition & health, water recharge, reduced pressure on forests, carbon sequestration, etc.) and services (employment generation, increase in farmer's income, livelihood improvement, etc.) in a sustainable manner. Besides, agroforestry systems are very important for fulfilling commitments set out in Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs).

The National Agroforestry Policy (NAP, 2014)[1] defines agroforestry as a 'land use system which integrates trees and shrubs on farmlands and rural landscapes to enhance productivity, profitability, diversity, and ecosystem sustainability. It is a dynamic, ecologically based, natural resource management system that, through integration of woody perennials on farms and in the agricultural landscape, diversifies and sustains production and builds social institutions'. The policy also recognises potential of agroforestry to provide employment to rural and urban population through production, industrial application, and value addition ventures.

According to FAO[2], 'agroforestry is a collective name for land-use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence'. On similar lines, Centre for International Forestry Research – World Agroforestry (erstwhile International centre for Research in Agroforestry) (CIFOR-ICRAF)[3] define agroforestry as 'land-use systems and practices in which woody perennials are integrated with crops, livestock, or both (crops & livestock) on the same area of land. The integration can be either in a spatial mixture or in temporal sequence'. It is pertinent to mention here that these systems resort to interdependence of three components, viz., trees, crops, and livestock, providing benefits such as bio-fertilizer, timber, fuel, food, fruit, fodder, and fibre.

[1] National Agroforestry Policy, Ministry of Agriculture, GoI, 2014

[2] IPCC FAO (2015): Agroforestry definition by Food and Agriculture Organisation of the UN. https://www.fao.org/forestry/agroforestry/80338/en/

[3] ICRAF: Agroforestry definition by CIFOR-ICRAF. https://www.cifor-icraf.org/publications/pdf/books/Agroforestry-primer-01.pdf

Considering its significance, it is thought important to include one chapter on information of tree resources in agroforestry systems in India and revisit the earlier estimates prepared by FSI (ISFR, 2013)[4]. This chapter includes the decadal assessment of change in tree green cover, and growing stock under Agroforestry systems in India; and will certainly help in assessing the impacts of management interventions that have been implemented over the years to promote agroforestry in India.

7.2 Agroforestry Systems in India

India has a long tradition of agroforestry. The farmers and other land-owners integrate and practice agroforestry as a historical way of life in Indian culture. The scientific foundation and research in the agroforestry started in eighties simultaneously by Indian Council of Forestry Research and Education (ICFRE), and Indian Council of Agriculture Research (ICAR). Further, the All India Coordinated Research Project (AICRP) on Agroforestry was established by the ICAR in 1983, marking the beginning of coordinated research on agroforestry. In addition, the commencement of forestry education programmes in State Agricultural Universities during 1985-86, and establishment of the National Research Centre for Agroforestry (NRCAF) at Jhansi, Uttar Pradesh in 1988 which was renamed to Central Agroforestry Research Institute (CAFRI) in 2014 gave it an impetus. The AICRP is continuing the efforts along with 37 centres representing all agro-climates of the country.

7.2.1 National Agroforestry Policy (2014)

The National Agroforestry Policy (NAP) was launched by Government of India in 2014 to improve productivity, employment, income, and livelihood opportunities of rural households, especially small farmers. As a follow-up to NAP, Sub-Mission on agroforestry (SMAF) under National Mission for Sustainable Agriculture (NMSA) was also launched in 2016-17 to encourage and expand tree plantation on farmland, with the motto of “Har Med Par Ped”. This has further contributed to the government’s strategy to promote millets, participatory environmental protection, and conservation for Mission LiFE (Lifestyle for Environment), increasing green cover, aboveground, and soil carbon stock for Nationally Determined Contribution (NDCs) and Sustainable Development Goals (SDGs).

NAP 2014 is a pioneering policy in making agroforestry an instrument for transforming the lives of the rural farming population, protecting ecosystem, and ensuring food security through sustainable means. The objectives of National Agroforestry Policy are to:

1. Encourage and expand tree plantation in complementarity and integrated manner with crops and livestock to improve productivity, employment, income and livelihoods of rural households, especially the small holder farmers;

[4] ISFR (2013). India State of Forest Report, Forest Survey of India, MoEF&CC, Govt. of India.

2. Protect and stabilize ecosystems, and promote resilient cropping and farming systems to minimize the risk during extreme climatic events;
3. Meet the raw material requirements of wood based industries and reduce import of wood and wood products to save foreign exchange;
4. Supplement the availability of agroforestry products (AFPs), such as the fuel-wood, fodder, non-timber forest produce and small timber of the rural and tribal populations, thereby reducing the pressure on existing forests;
5. Complement achieving the target of increasing forest/tree green cover to promote ecological stability, especially in the vulnerable regions;
6. Develop capacity and strengthen research in agroforestry and create a massive people's movement for achieving these objectives and to minimize pressure on existing forests.

7.2.2 Agroforestry Models Developed by CAFRI and ICFRE

Central Agroforestry Research Institute (CAFRI) and World Agroforestry (erstwhile ICRAF), in 2019, presented information on about 40 successfully tested and demonstrated agroforestry models for 20 different agro-ecological regions, using map of National Bureau of Soil Survey & Land Use Planning (NBSSLUP). The NBSSLUP has stratified the country into 20 agro-ecological regions based on the integrated criteria of effective rainfall, soil groups, and other parameters (Sehgal *et al.,* 1992)[5]. The various agroforestry models highlighted in the book are consisting of different combinations of agricultural, silvicultural, horticultural, and pastoral systems. Apart from this, Agar based agroforestry systems, mini clonal technology for mass multiplication, block plantation of Burma wood and Sandalwood are also discussed.

Indian Council of Forestry Research and Education (ICFRE) with its nine research institutes and five advanced centres located all over the country have compiled agroforestry models developed by the institution (ICFRE, 2020)[6]. It provides comprehensive knowledge about the 34 agroforestry models clubbed under 7 regions.

Assessment of Various Parameters for Agroforestry Systems by Forest Survey of India 7.3

The information on area under agroforestry, important species prevalent in agroforestry, and their volume was first attempted by FSI and the results of this exercise were presented in ISFR 2013 in the chapter on 'Trees in Agroforestry Systems in India'. The findings, in ISFR 2013, were based on 21,543 rural TOF plots of block and scattered stratum (having private ownership) inventoried in 179 districts across the country, during 2006-2012. The State/UTs wise and physiographic zone-wise estimates of tree green cover, growing stock, and carbon stock of the trees observed in agroforestry were given in this chapter.

[5] Sehgal, J., Mandal, D.K., Mandal, C. and Vadivelu, S. (1992). Agro-Ecological Regions of India. Second Edition, Tech. Bull. No. 24, NBSS and LUP. 130p.
[6] ICFRE (2020). Agroforestry Models Developed by Indian Council of Forestry Research and Education (A compilation).

Realizing the importance of agroforestry, it is felt appropriate to present information about tree green cover area, species composition, their volume under agroforestry in this report based on the latest National Forest Inventory (NFI) data. A brief overview of the scope of study for estimation of tree green cover area, growing stock, and important species in the State/UTs under agroforestry has been given in section 7.3.1 and 7.3.2. Under the inventory of TOF resources, FSI is collecting data from about 10,000 plots every year, out of which about 8,500 plots belong to rural TOF. Further, about 7,500 plots pertain to private ownership having trees which are being considered for agroforestry. The detailed methodology for inventory of TOF and estimation procedure is given in chapter 5 (Growing Stock). It is pertinent to mention that the tree green cover in agroforestry includes tree patches having area 0.1 ha & above (in block and linear stratum) and smaller patches upto single trees in scattered strata

7.3.1 Scope of Assessment of Area under Agroforestry Systems

The purpose of this study is to estimate tree green cover, important species, and their growing stock in agroforestry systems in India. For this, only rural TOF plots have been taken into consideration.

The present estimates are based on 42,972 sampled plots of TOF-rural, inventoried during 2016 to 2022. Out of these plots, about 40,042 plots have atleast one tree of size 5 cm dbh and above.

As per the methodology given in chapter 5, satellite data of Sentinel-2 having a spatial resolution of 10 meter, has been used for stratification of Culturable Non Forest Area (CNFA) in three strata, viz., Block, Linear, and Scattered. CNFA excludes all areas which do not support tree vegetation, like rivers and water bodies, riverbeds, snow covered mountains, etc., which is termed as Un-culturable Non Forest Area. In these three strata, trees outside forest plots with private ownership are accounted for agroforestry parameter estimation. The strata relating to urban area are excluded as they do not qualify the definition of agroforestry. The information collected from the field plots of these strata has been used for estimating the tree green cover area and growing stock under agroforestry.

During the field inventory, the data on a number of parameters are recorded. The parameters which are significant in the context of agroforestry, and which describe the sample plot are; ownership, category of plot, and category of plantation, described below:

1. **Ownership status:**
   - i. Private individual,
   - ii. Private others, such as Communities/organizations,
   - iii. Forest departments,
   - iv. Other Government Departments
   - v. Panchayat lands,

   vi. Institutions (Government) and
   vii. Others.

2. **Category of plot:** Hilly or plain, irrigated/unirrigated and proximity of plot to RFA.
3. **Category of plantation/tree:**
   i. Farm forestry: trees in small patches up to 0.1 ha in area,
   ii. Village woodlots: Naturally growing trees/planted trees on community land,
   iii. Block plantations: Patches covering an area of more than 0.1 ha and not falling in any of the above,
   iv. Road side plantations,
   v. Pond side plantations,
   vi. Railway line side plantations,
   vii. Canal side plantations,
   viii. Homestead: Trees appearing in the house premises and not covered in the above mentioned first three categories, and
   ix. Others: Trees which do not fall in any of the above category.

This information is very helpful in discarding the trees which do not come under agroforestry and therefore, it increases the accuracy of the assessment. A review of methodology adopted by other institutions/organisations is given in the box item, given below.

7.3.2 Estimation Procedure

The area under tree green cover is estimated through sample survey partly using medium resolution satellite data and partly from field inventory data of TOF. For field inventory in rural areas of TOF, the medium-resolution satellite data is used for stratification into three strata, viz., block, linear, and scattered. The tree green cover in rural areas comprises area of block and linear patches between 0.1 ha & above. However, in case of scattered strata, the crown diameter of each tree recorded from all field plots which qualify the definition of agroforestry has been used to estimate the area of tree green cover. The recorded crown diameter has been converted into equivalent notional area corresponding to 70 per cent canopy density. However, the area under block & linear stratum (with private ownership) has been considered as such for estimation of various parameters under agroforestry.

The estimate at the State/UTs level has been generated by using the tree green cover area of sampled plots, separately in the block, linear, and scattered stratum using CNFA area in the State/UTs. The tree green cover under agroforestry in each State has been estimated by aggregating the tree green cover under agroforestry of each stratum. The tree green cover at State/UTs level has been aggregated leading to the estimation of tree green cover under agroforestry of the whole country.

Review of Methodology (Mapping and Inventory) Adopted by Various Agencies

Use of geospatial technologies to estimate agroforestry area was attempted by Central Agroforestry Research Institute (CAFRI), Jhansi, using medium/high resolution data with a methodology in which areas under agroforestry, forest, and plantation are separately identified.

A group of scientists from NRCAF (National Research Center for Agro-forestry, old name of CAFRI), on the basis of secondary data, has estimated that the current area under agroforestry in India in 2013, is 25.32 Mha which is 8.2% of the total geographical area of the country. They have mentioned that there is a scope of increasing the area under agroforestry in future by another 28.0 Mha. The obvious choice of inclusion of land for agroforestry is from fallows, cultivable fallows, pastures, groves and rehabilitation of problem soils. Thus, a total of 53.32 Mha, representing about 17.5% of the total reported geographical area of the country, could potentially be brought under agroforestry by the year 2050 **(Dhyani *et al.*, 2013)**[7].

Central Agroforestry Research Institute (CAFRI) carried out mapping of areas under agroforestry using medium-resolution LISS III (23.5 m) and high-resolution LISS IV (5.8 m)/Sentinel 2 (10 m) remote sensing data respectively, for all the 15 agro-climatic zones (ACZs) of India in 2016-18. It estimated 28.427 Mha area under agroforestry in all 15 ACZs of India, which is about 8.65% of the total geographical area of the country. The accuracy of the estimation was >75% and >90% for sub-pixel classification and object-based image analysis methods respectively **(Arunachalam *et. al.*, 2022)**[8].

In 2020, CAFRI and World Agroforestry (ICRAF, Kenya) proposed a methodology for mapping and estimation of extent of agroforestry area in the country, using medium-resolution (>10 m spatial resolution) and high-resolution (<10 m spatial resolution) remote sensing satellite data. The report on 'Mapping of agroforestry & TOF' has been developed by CAFRI (Jhansi), World Agroforestry (ICRAF, Kenya). The document provides a compilation of harmonized techniques and geospatial methodologies used to map TOF/agroforestry.

FSI is estimating 'tree green cover' area by adding remote sensing based estimates of block & linear plantation as well as field inventory based estimates of scattered trees. A brief procedure is elaborated in above para 7.3.2

[7] Dhyani, S.K., Handa, A.K. and Uma (2013): Area under agroforestry in India: An assessment for present status and future perspective. Indian Journal of Agroforestry. **Vol 15** (1): 1-11.

[8] Arunachalam, A., Rizvi, R.H., Handa, A.K., Ramanan, S. (2022): Agroforestry in India: area estimates and methods. Scientific correspondence in Current Science. **Vol 123** (6).

7.4 Results & Discussions

7.4.1 State/UTs wise Tree Green Cover, Growing Stock under Agroforestry Systems

The tree green cover and growing stock estimates under agroforestry, generated at the national and state level, are presented in Table 7.3. From the table, it is observed that total tree green cover under agroforestry at the national level in 2023 has been estimated at 1,27,590.05 km^2, which includes tree green cover of trees dbh 5 to 10 cm and bamboo cover. The standard error percentage of tree green cover of 2023 assessment is 1.82%.

Table 7.1 Change in Tree Green Cover (TGC) with respect to last assessment at National level (in km^2)

2023				2013*		Actual Change (A – B)	Change %
TGC of Trees ≥ 10 cm DBH (A)	TGC of Trees 5 cm ≤ DBH < 10 cm and Bamboo Cover	Total	% of Geographical Area	TGC of Trees ≥ 10 cm DBH (B)	% of Geographical Area		
1,18,241	9,349	1,27,590	3.88	1,06,303	3.23	11,938	11.23

* In 2013, Tree Green Cover of Trees DBH 5-10 cm and Bamboo cover was not estimated.

For State of the Gujarat, assessment Tree Green Cover under agroforestry published in ISFR 2013 has been revised.

The total growing stock under agroforestry in the country in 2023 is estimated at 1,291.68 M m^3, which includes Growing stock of trees dbh 5 to 10 cm. The growing stock due to trees of 5 to 10 cm dbh contributes only 2.40% with respect to the total estimated growing stock of the year 2023 (Table 7.2). The standard error of estimates for growing stock under agroforestry is observed 2.65% for the year 2023.

Table 7.2 Change in Growing Stock (GS) with respect to last assessment at National level (in M m^3)

2023			2013*	Actual Change (A – B)	Change %
GS of Trees ≥ 10 cm DBH (A)	of Trees 5 cm ≤ DBH < 10 cm	Total	GS of Trees ≥ 10 cm DBH (B)		
1,260.77	30.91	1,291.68	1,004.74	256.03	25.48

*In 2013, Growing Stock of Trees DBH 5-10 was not estimated.

For State of the Gujarat, assessment Growing Stock under agroforestry published in ISFR 2013 has been revised.

Among the States, the highest growing stock in agroforestry is observed in Maharashtra (136.45 M m^3) followed by Karnataka (98.31 M m^3), Odisha (88.53 M m^3), and Rajasthan (86.26 M m^3). Among the UTs, the highest growing stock is observed in Jammu & Kashmir (29.59 M m^3) followed by A&N Islands (0.90 M m^3), and Dadra & Nagar Haveli and Daman & Diu (0.53 M m^3).

Table 7.3 State/UTs wise Decadal Change in Tree Green Cover (km²) and Growing Stock (M m³) under Agroforestry Systems

State/UTs	2023		2013***		Decadal Change		Decadal Change %	
	Tree Green Cover (km²)	Growing Stock (M m³)	Tree Green Cover (km²)	Growing Stock (M m³)	Tree Green Cove (km²)	Growing Stock (M m³)	Tree Green Cover (km²)	Growing Stock (M m³)
*Andhra Pradesh	6,006.15	69.36	4,976	57.47	1,030.15	11.89	20.70	20.69
Arunachal Pradesh	3,080.94	20.6	2,610	16.66	470.94	3.94	18.04	23.65
Assam	4,262.68	30.68	3,922	31.81	340.68	-1.13	8.69	-3.55
Bihar	4,756.85	41.46	4,570	37.48	186.85	3.98	4.09	10.62
Chhattisgarh	5,646.12	82.49	4,535	64.75	1,111.12	17.74	24.5	27.4
Delhi	15.3	0.13	23	0.2	-7.7	-0.07	-33.48	-35
Goa	339.77	2.43	280	1.88	59.77	0.55	21.35	29.26
**Gujarat	7,485.49	78.87	6,340	63.94	1,145.49	14.93	18.07	23.35
Haryana	1,400.94	12.66	1,333	11.33	67.94	1.33	5.1	11.74
Himachal Pradesh	2,687.6	19.55	2,303	15.81	384.6	3.74	16.7	23.66
Jharkhand	4,227.47	65.63	3,358	47.94	869.47	17.69	25.89	36.9
Karnataka	7,875.45	98.31	6,090	69.82	1,785.45	28.49	29.32	40.8
Kerala	5,213.98	38.41	3,803	28.1	1,410.98	10.31	37.1	36.69
Madhya Pradesh	7,658.1	81.81	6,745	60.17	913.1	21.64	13.54	35.96
Maharashtra	14,494.99	136.45	11,806	98.95	2,688.99	37.5	22.78	37.9
Manipur	612.2	4.5	606	5.05	6.2	-0.55	1.02	-10.89
Meghalaya	2,361.14	18.6	1,876	15.66	485.14	2.94	25.86	18.77
Mizoram	712.44	6.21	464	3.83	248.44	2.38	53.54	62.14
Nagaland	1,353.28	12	1,037	8.66	316.28	3.34	30.5	38.57
Odisha	5,591.5	88.53	5,136	65.19	455.5	23.34	8.87	35.8
Punjab	1,725.24	16.77	1,635	13.73	90.24	3.04	5.52	22.14
Rajasthan	10,581.39	86.26	8,373	64.77	2,208.39	21.49	26.38	33.18
Sikkim	147.74	1.04	128	0.8	19.74	0.24	15.42	30
Tamil Nadu	5,370.9	61.18	4,590	47.39	780.9	13.79	17.01	29.1
*Telangana	3,923.1	42.02	3,248.48	34.82	674.62	7.2	20.77	20.68
Tripura	659.36	5.8	576	4.8	83.36	1	14.47	20.83
Uttar Pradesh	8,975.4	80.22	7,082	60.56	1,893.4	19.66	26.74	32.46
Uttarakhand	2,130.63	16.9	1,966	14.28	164.63	2.62	8.37	18.35
West Bengal	4,763.13	41.41	4,018	33.51	745.13	7.9	18.54	23.58
Andaman & Nicobar Islands	73.4	0.9	49	0.5	24.4	0.4	49.8	80
Chandigarh	0.18	0.01	-	-	0.18	0.01	-	-
Dadra &Nagar Haveli and Daman & Diu	41.47	0.53	65	0.58	-23.53	-0.05	-36.2	-8.62
Jammu & Kashmir	3,377.51	29.59	2,728	24.09	649.51	5.5	23.81	22.83
Ladakh	14.09	0.12	-	-	14.09	0.12	-	-
Lakshadweep	5.35	0.04	16	0.04	-10.65	0	-66.56	0
Puducherry	18.77	0.21	16	0.17	2.77	0.04	17.31	23.53
Total	**1,27,590.05**	**1,291.68**	**1,06,303**	**1,004.74**	**21,286.57**	**286.94**	**20.02**	**28.56**

** The published data of Growing Stock under agroforestry in ISFR 2013 for the State of Andhra Pradesh is proportionally distributed for the states of Andhra Pradesh and Telangana as per the ISFR 2023 estimates.*

*** For State of the Gujarat, assessment of Growing Stock and Tree Green Cover under agroforestry published in ISFR 2013 has been revised.*

**** Sizable number of trees in 2023 also include the dia-class of 5 – 10 cm dbh which was not enumerated in 2013.*

7.4.2 State/UTs wise Trees and their Growing Stock (Volume) under Agroforestry Systems

The total number of trees and their contribution in growing stock or volume (in M m^3) across the diameter classes under agroforestry is given in Table 7.4. From Table 7.4, it is observed that there are 8,289 million trees under agroforestry. Among the States, Maharashtra has highest number of trees under agroforestry (1,165 million), followed by Karnataka (901 million), Uttar Pradesh (547 million) and Rajasthan (542 million).

Table 7.4 State/UTs wise Number of Stems ('000) and Volume (M m^3) of Trees under Agroforestry Systems in India

State/UTs	Notified Geographical Area (km^2)	Total No. of Trees ('000)	Total Volume (M m^3)	Top 3 Species as per number of stems
Andhra Pradesh	1,62,923	4,17,389	69.36	*Mangifera indica, Prosopis juliflora, Azadirachta indica*
Arunachal Pradesh	83,743	1,77,323	20.60	*Castanopsis species, Macaranga species, Citrus species*
Assam	78,438	1,74,831	30.68	*Areca catechu, Tectona grandis, Gmelina arborea*
Bihar	94,163	1,47,775	41.46	*Mangifera indica, Dalbergia sissoo, Borassus flabelliformis*
Chhattisgarh	1,35,192	2,66,369	82.49	*Shorea robusta, Butea monosperma, Mangifera indica*
Delhi	1,483	811	0.13	*Prosopis juliflora, Azadirachta indica, Ficus species*
Goa	3,702	29,509	2.43	*Areca triandra, Anacardium occidentale, Cocos nucifera*
Gujarat	1,96,244	4,17,116	78.87	*Azadirachta indica, Prosopis juliflora, Mangifera indica*
Haryana	44,212	68,217	12.66	*Eucalyptus species, Dalbergia sissoo, Prosopis cineraria*
Himachal Pradesh	55,673	1,97,099	19.55	*Grewia oppositifolia, Pyrus species, Pinus roxburghii*
Jharkhand	79,716	1,96,328	65.63	*Butea monosperma, Acacia auriculiformis, Shorea robusta*
Karnataka	1,91,791	9,01,361	98.31	*Areca catechu, Cocos nucifera, Azadirachta indica*
Kerala	38,852	4,85,988	38.41	*Hevea brasiliensis, Areca catechu, Cocos nucifera*
Madhya Pradesh	3,08,252	3,81,949	81.81	*Butea monosperma, Acacia arabica, Ziziphus mauritiana*
Maharashtra	3,07,713	11,65,388	136.45	*Azadirachta indica, Mangifera indica, Ziziphus mauritiana*
Manipur	22,327	36,295	4.50	*Quercus species, Castanopsis species, Schima wallichii*
Meghalaya	22,429	1,94,263	18.60	*Pinus kesiya, Schima wallichii, Pinus roxburghii*
Mizoram	21,081	54,277	6.21	*Schima wallichii, Macaranga species, Areca catechu*
Nagaland	16,579	1,09,925	11.99	*Alnus nepalensis, Macaranga species, Schima wallichii*
Odisha	1,55,707	2,64,981	88.53	*Mangifera indica, Anacardium occidentale, Butea monosperma*
Punjab	50,362	93,167	16.77	*Eucalyptus species, Melia azedarach, Citrus species*
Rajasthan	3,42,239	5,42,127	86.26	*Prosopis juliflora, Prosopis cineraria, Ziziphus mauritiana*
Sikkim	7,096	8,967	1.04	*Schima wallichii, Ficus species, Alnus species*
Tamil Nadu	1,30,060	5,25,034	61.19	*Cocos nucifera, Prosopis juliflora, Azadirachta indica*
Telangana	1,12,122	2,96,544	42.01	*Mangifera indica, Azadirachta indica, Prosopis juliflora*
Tripura	10,486	43,163	5.81	*Hevea brasiliensis, Tectona grandis, Areca catechu*
Uttar Pradesh	2,40,928	5,47,300	80.22	*Eucalyptus species, Mangifera indica, Populus species*
Uttarakhand	53,483	1,86,017	16.90	*Grewia oppositifolia, Quercus leucotrichophora, Mangifera indica*
West Bengal	88,752	2,32,239	41.41	*Acacia auriculiformis, Mangifera indica, Areca catechu*
Andaman & Nicobar Islands	8,249	11,411	0.90	*Areca catechu, Cocos nucifera, Mangifera indica*

Table 7.4 State/UTs wise Number of Stems ('000) and Volume (M m³) of Trees under Agroforestry Systems in India

State/UTs	Notified Geographical Area (km²)	Total No. of Trees ('000)	Total Volume (M m³)	Top 3 Species as per number of stems
Chandigarh	114	20	0.01	*Mangifera indica, Morus species, Syzygium cumini*
Dadra & Nagar Haveli, and Daman & Diu	602	2,359	0.53	*Mangifera indica, Phoenix sylvestris, Manihot utilissima*
Jammu & Kashmir	2,22,236	1,10,146	29.59	*Pyrus species, Quercus leucotrichophora, Grewia oppositifolia*
Ladakh		1,202	0.12	*Salix species, Prunus species, Populus ciliata*
Lakshadweep	30	247	0.04	*Cocos nucifera, Thespesia populnea, Muntingia Calabura*
Puducherry	490	1,735	0.21	*Prosopis juliflora, Casuarina equisetifolia, Cocos nucifera*
Total	**32,87,469**	**82,88,872**	**1,291.68**	

State/UTs wise Estimated Number of Trees, and Volume of Trees (diameter class wise) under Agroforestry System in India is presented in **Annexure XIV**

7.4.3 Decadal Change in Agroforestry from 2013-2023

Table 7.5 provides decadal change (from 2013 to 2023) of top 30 species across the country under agroforestry, ranked as per the presence of the number of respective trees.

Top 50 Species according to Number of stems of Trees and Top 50 Species according to Volume of Trees under Agroforestry system in India as in 2023 are presented in **Annexures XV and XVI** respectively.

Table 7.5 Decadal Change in Top 30 Species (as per 2023) by Number of Stems ('000) and their respective Volume (M m³) under Agroforestry Systems in India

Rank 2023	Species	Respective Rank in 2013	ISFR 2023			ISFR 2013			Decadal Change from 2013 to 2023			
			No. of Trees	Vol.	% of Vol. of 2023	No. of Trees	Vol.	% of Vol. of 2013	No. of Trees	Vol.	Change %	
											No. of Trees*	Vol.
1	*Mangifera indica*	1	6,86,775	196.84	15.24	3,45,055	149.35	13.29	3,41,720	47.49	99.03	31.80
2	*Azadirachta indica*	4	5,91,880	101.86	7.89	2,08,467	75.98	6.76	3,83,413	25.88	183.92	34.06
3	*Prosopis juliflora*	-	4,87,625	9.89	0.77	Not reported in top 40 species in 2013						
4	*Areca catechu*	2	3,91,717	8.21	0.64	2,71,003	7.32	0.65	1,20,714	0.89	44.54	12.13
5	*Eucalyptus species*	7	2,74,432	17.84	1.38	1,18,918	21.50	1.91	1,55,514	-3.66	130.77	-17.01
6	*Tectona grandis*	10	2,54,348	23.33	1.81	75,194	11.27	1.00	1,79,154	12.06	238.26	107.08
7	*Cocos nucifera*	3	2,53,926	53.00	4.10	2,11,762	60.08	5.34	42,164	-7.08	19.91	-11.78
8	*Butea monosperma*	6	2,41,369	36.94	2.86	1,31,976	28.49	2.53	1,09,393	8.45	82.89	29.65
9	*Acacia arabica/ Acacia nilotica*	5	2,32,987	34.77	2.69	1,52,668	29.03	2.58	80,319	5.74	52.61	19.79
10	*Ziziphus mauritiana/ Ziziphus jujuba*	21	2,18,818	16.29	1.26	45,191	8.44	0.75	1,73,627	7.85	384.21	93.10

Table 7.5 Decadal Change in Top 30 Species (as per 2023) by Number of Stems ('000) and their respective Volume (M m^3) under Agroforestry Systems in India

Rank 2023	Species	Respective Rank in 2013	ISFR 2023			ISFR 2013			Decadal Change from 2013 to 2023			
			No. of Trees	Vol.	% of Vol. of 2023	No. of Trees	Vol.	% of Vol. of 2013	No. of Trees	Vol.	Change % No. of Trees*	Change % Vol.
11	*Hevea brasiliensis*	12	2,00,463	16.39	1.27	57,120	9.07	0.81	1,43,343	7.33	250.95	80.81
12	*Leucaena leucocephala*	-	1,48,420	7.90	0.61	Not reported in top 40 species in 2013						
13	*Citrus species*	-	1,34,910	1.94	0.15	Not reported in top 40 species in 2013						
14	*Acacia auriculiformis*	-	1,18,765	7.46	0.58	Not reported in top 40 species in 2013						
15	*Prosopis cineraria*	25	1,03,055	34.92	2.70	28,021	9.58	0.85	75,034	25.34	267.78	264.51
16	*Borassus flabelliformis*	9	93,922	44.84	3.47	94,238	64.12	5.70	-316	-19.28	-0.34	-30.07
17	*Anacardium occidentale*	19	88,133	5.35	0.41	46,050	5.34	0.48	42,083	0.01	91.39	0.15
18	*Dalbergia sissoo*	14	80,628	19.56	1.51	53,829	18.01	1.60	26,799	1.55	49.79	8.62
19	*Terminalia tomentosa*	31	77,184	11.35	0.88	19,038	5.41	0.48	58,146	5.94	305.42	109.95
20	*Grewia oppositifolia*	23	72,506	3.45	0.27	42,391	5.20	0.46	30,115	-1.75	71.04	-33.69
21	*Syzygium cumini*	18	72,193	19.13	1.48	46,156	18.75	1.67	26,037	0.38	56.41	2.03
22	*Psidium guajava*	-	69,855	1.80	0.14	Not reported in top 40 species in 2013						
23	*Pongamia pinnata*	-	68,807	12.22	0.95	Not reported in top 40 species in 2013						
24	*Populus species*	20	67,855	3.47	0.27	45,494	7.49	0.67	22,361	-4.02	49.15	-53.67
25	*Shorea robusta*	15	67,673	21.96	1.70	50,062	21.52	1.91	17,611	0.44	35.18	2.03
26	*Annona squamosa*	-	66,048	0.97	0.08	Not reported in top 40 species in 2013						
27	*Acacia leucophloea/ Vachellia leucophloea*	11	61,173	7.42	0.57	67,915	8.36	0.74	-6,742	-0.94	-9.93	-11.25
28	*Holoptelea integrifolia*	32	57,364	8.25	0.64	16,388	4.71	0.42	40,976	3.55	250.04	75.35
29	*Madhuca longifolia/ M. latifolia/ M. indica*	28	57,355	67.05	5.19	24,586	63.94	5.69	32,769	3.11	133.28	4.86
30	*Pinus kesiya*	22	54,332	7.67	0.59	45,146	7.14	0.64	9,186	0.53	20.35	7.39

** Sizable number of trees in 2023 also include the dia-class of 5 – 10 cm dbh which was not enumerated in 2013.*

It is observed from Table 7.5 that the top five prevalent species in agroforestry as given in ISFR 2013 were *Mangifera indica,* followed by Areca catechu, Cocos nucifera, *Azadirachta indica,* and *Acacia nilotica.* On the other hand, as per ISFR 2023 the most prevalent species in agroforestry are *Mangifera indica,* followed by *Azadirachta indica, Prosopis juliflora, Areca catechu,* and *Eucalyptus species.* This reveals that the prevalence of the agroforestry species has changed from 2013 to 2023. It may be noted here that *Prosopis juliflora* has been found as third most prevalent species in the present assessment (ISFR 2023) among all the agroforestry species. The species *Prosopis juliflora* has been found mainly in the agricultural bunds in 5,896 number of plots considered for agroforestry estimation. This species contributes approximately 5.88 % of total number of trees (8,28,88,72,000) estimated across the country.

Green Credit Initiative by Govt. of India

Green Credit Initiative was launched by Hon'ble Prime Minister on the sidelines of COP 28 in 2023. It is an initiative within the Government's Lifestyle for Environment or LIFE movement. The Green Credit Rules have been notified by the Government of India on 12th October 2023 under the Environment Protection Act, 1986, as a mechanism to encourage voluntary plantation activity across the country, resulting in award of Green Credits, and to build an inventory of degraded land which can be utilised for Afforestation programmes.

Hon'ble Prime Minister of India mentioned in the G20 summit in 2023 that "I feel this is the time to talk about green credit, India is working in this direction by developing Green Credit Framework through which we can initiate climate positive actions." and "we should think towards how to develop business by using Green Credit Program, which is positive for developing 'Pro Planet People'."

Objectives of the Green Credit Programme (GCP)

GCP aims to establish a dynamic land bank for plantations accessible via a dedicated web portal. This facility enables the registration of degraded forest lands by Forest departments. The inventory thus formed becomes a valuable resource available for voluntary plantation activities.

Encouraging Public Sector Undertakings to select Plantation Blocks from the registered Plantation blocks for afforestation.

Issuance of Green Credits: Green Credits serve as a key incentive for entities engaging in tree plantation. The issuance follows specific methodologies and guidelines stipulated by the Administrator.

Digital Processes: The GCP streamlines its operations through technology-based tools like a web platform and a registry. These digital resources ensure seamless registration, verification, and monitoring of plantation-related activities.

Desirable Outcomes

- It aims to enhance India's forest and tree cover
- To build an inventory of degraded land under the control and management of Forest Departments suitable for plantation.
- To encourage participation of individuals and entities in pro-planet actions by rewarding Green Credits.

Photo: FSI Repository


Photo: FSI Repository

CHAPTER

08 Important Characteristics of India's Forests

Photo: Bhumesh Bharti


Photo: Padmabhushan Rajguru, IFS

IMPORTANT CHARACTERISTICS OF INDIA'S FORESTS

Introduction 8.1

For efficient management of forest resources, it is imperative to study the characteristics defining the health and productivity of the constituent species and the ecosystem. The meaning of "forest health" varies differently, depending on the context in which it is being used. Generally, there are two broad categories of definition of forest health, viz., Utilitarian perspective and Ecosystem perspective. From the Utilitarian standpoint, forest health is defined as the production of forest conditions which directly satisfy human needs. From an Ecosystem standpoint, it is defined by resilience, recurrence, perseverance and biophysical processes which lead to sustainable ecological conditions (Kolb *et al.*, 1994)[1]. A healthy forest can resist damages from devastating events like acute insect and disease attacks, fire, wind, and flooding, and fully recover from these catastrophic events to continue its life history functions over time.

To complete their life cycles, all species are able to grow at rates appropriate to the local climate, geographic location, and soil resource. The characteristics such as physical environment; biotic resources to support productive forests; functional equilibrium between supply and demand of water, nutrients, light, growing space, etc.; diversity of developmental stages; stand structures that provide habitat for many native species and cover types, make a forest ecosystem healthy.

Forest ecosystems across the world are facing significant and varied pressures due to climate change, anthropogenic and natural disturbances. In order to study the status of various important characetersitics of Forests, Forest Survey of India presented separate chapter on 'Important Characteristics of India's Forests' in ISFR 2013 and 'Important Characteristics of Different Forest Type Groups' in ISFR 2015, respectively. Considering its importance, the analysis of important characterisitics of forests has been given in this report also. This Chapter provides information about various characteristics of India's forests in different State/UTs in order to analyse health of forest ecosystems and to understand possible threats to forest health. It also compares these characterstics in India's forests in 2023 with those in 2013 and shows the decadal change. A lot of inferences can be drawn from the observed changes. Some of the important characterstics are being reported in this chapter for the first time.

[1] Kolb T.E., Wagner M.R. and Covington W.W. (1994). Concepts of forest health: utilitarian and ecosystem perspectives. *Journal of Forestry.* **92** (7): 10–15.

8.2 Important Characterstics of Forests

The diversity in flora and fauna for forest ecosystems is the resultant of the interaction of various physiographic, edaphic and climatic conditions which are found in the country. Variation in country's forests is seen from tropical evergreen forests in the Andaman & Nicobar Islands, the Western Ghats and the North-Eastern States, to dry alpine scrub high in the Himalayan region. Between the two extremes, the country has semi evergreen forests, moist deciduous forests, dry deciduos forests, thorn forests, sub tropical pine forests in the lower mountain zone, and temperate montane forests in mid-mountain zone having altitude of more than 3500 m (above mean sea level).

For formulating policies on management and assessment of forest resources, description of forests of any area like extent of Recorded Forest Area (RFA) in the State/UTs is a pre-requisite. In addition, information on existing conditions and characteristics in the forests, which include the species compositiion, species distribution, reletative dominance and abundance of species, inter-specific associatioins, growth dynamics, condition of enabling physical environment, etc., is very important from the point of view of policy, management and conservation priorities.

FSI adopted the new National Forest Inventory design in 2016. Under the inventory plot design of NFI, information on various important parameters such as forest enabling conditions (soil depth, humus, soil organic carbon, soil erosion, presence of ground flora (grasses and undergrowth); forest vegetation (origin of forest stand, intensity of regeneration, size class, crop composition, canopy layer, basal area); disturbances (forest fire, injuries to crop, grazing incidence, biotic influence, invasive species, illicit felling, girdling, lopping), etc., is recorded in the Plot Description Form (PDF) as an observation in the circular plot of 60 m radius (approx. 1.13 ha). Accordingly, the plot level data of NFI from the year 2017- 2022 collected from 27,917 sample plots has been used to generate the estimates presented here.

8.3 Data Processing Methdology

The details of sampling design, plot layout of NFI and methodology has already been explained in Chapter-5. Figure 8.1 shows the list of major parameters of National Forest Inventory (NFI), relating to various forestry characteristics. For processing of the data, the proportion of plot level information of vegetated plots (as recorded for each parameter) is distributed across the RFA of the respective State. In case of the UTs, apart from Andaman & Nicobar, and Jammu & Kashmir, the information of all other UTs have been clubbed to get stable estimates, as all of these have inadequate sample size. The combined group of UTs is, thus, named as 'Other UTs'. The aggregate proportion of these characteristics at the National Level is then classified according to recorded forest area.

The following land use classes are used during the NFI and are given in the NFI field manual: (01) Closed forest, (02) Dense forest, (03) Open forest, (04) Scrub, (06) Shifting cultivation, (07) Young crop including plantations of forestry species, (08) Trees in line, (09) Forest roads, (10) Govt. grass lands, (11) Barren lands, (12) Agricultural land without trees in surround, (13) Agricultural land with trees in surround, (14) Non forestry plantations, (15) Habitation, (16) Water bodies. While recording the parameters of characteristics of the forests many of the parameters will not be relevant for some of the land use classes. The aggregate area of these land use classes for that parameters have not be calculated and have been given as not applicable or NA. Details of these Land use Classes parameter-wise are given in **Annexure XVII.**

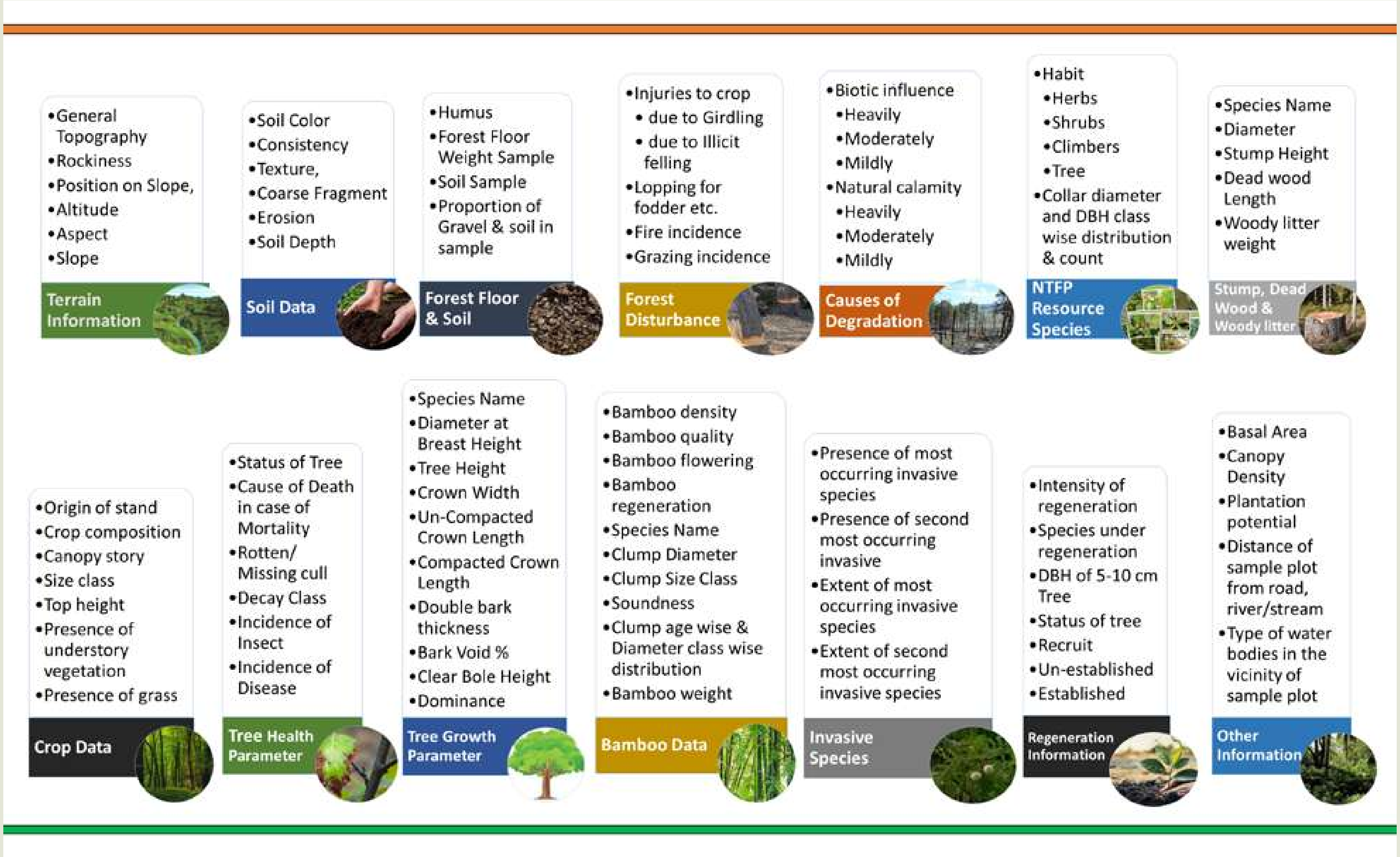


Figure 8.1 List of Parameters recorded under National Forest Inventory

8.4 Results & Discussions

8.4.1 Forests Enabling Conditions

Forest eco-systems (comprising flora, fauna, and forest soils) have complex interactive relationship. One of the important medium of regulating forest eco-system processes of nutrient uptake, decomposition, water availability, etc., is soil, which is very important for plant communities. At the same time, one of the important factors responsible for creation of new soil is the local flora; as the vegetation itself helps in weathering of rocks; and the vegetative parts decompose after expiry of their living cycle. Forests and forest soils interact in a manner, which creates and helps in maintaining the environmental conditions, including microclimate needed for thriving of the flora and fauna. For continuity of these positive effects for sustainability, forests and forest soils have to be properly managed. Towards this end, information on some important forest soil characteristics and ground flora for different State/UTs is given in following paragraphs.

8.4.1.1 Soil Depth

Soil depth is a critical factor for the health and sustainability of forests. It plays a significant role in determining the success of forest ecosystems and affects various aspects of forest growth and development. Deeper soils provide more space for roots to grow and explore greater access to nutrients, organic matter, and water. Soil depth influences the capacity of the soil to store water. Deep soils can retain more water, which is crucial during dry periods or droughts. Soil depth affects the variety of plant species that can thrive in a forest ecosystem. The depth of soil affects the microbial communities that play a crucial role in nutrient cycling and decomposition of organic matter in the forest. Forests with sufficient soil depth are more likely to have long-term productivity and sustainability. Shallow soils can limit the potential for long-term tree growth and regeneration, which can have detrimental effects on the overall health of the forest.

As per the practice of forest inventory, the different categories of soil depth are classified and recorded as shown in Table 8.1.

The information on soil depth for different State/UTs has been given in Table 8.2.

Table 8.1 Classification of Soil Depths

Soil depth	Classification
Less than 15 cm	Very shallow
15 to 30 cm	Shallow
30 to 90 cm	Medium
More than 90 cm	Deep

The table shows that Arunachal Pradesh, Assam, Chhattisgarh, Himachal Pradesh, Jharkhand, Manipur, Mizoram, Nagaland, Odisha, Punjab, Tripura, West Bengal, and A&N Islands having more than 90 % area with 15 cm soil depth or more. Arunachal Pradesh, Assam, Manipur, Mizoram, Nagaland, Punjab, Tripura, West Bengal, and A&N Islands having 80 % of area with 30 cm soil depth or more. Overall, at national level, about 64.85 % of forest area has medium to deep soils and about 28.86 % of forest area is having shallow to very shallow soil depth. A negligible portion has no soil. More or less, the situation has improved in the last decade.

Table 8.2 State/UTs wise Percentage Distribution of RFA by Soil Depth (in %)

State/UTs	RFA (km²)	No soil	Very shallow	Shallow	Medium	Deep	NA
Andhra Pradesh	37,258	1.76	17.92	47.29	20.66	7.53	4.84
Arunachal Pradesh	51,540	1.02	1.02	7.33	28.78	57.80	4.05
Assam	26,836	1.12	0.79	3.17	9.37	80.38	5.17
Bihar	7,442	2.37	15.73	25.65	24.57	25.43	6.25
Chhattisgarh	59,816	1.10	3.53	15.95	45.31	31.90	2.21
Delhi	104	0.00	2.69	12.07	36.21	28.16	20.87
Goa	1,271	0.00	12.19	11.54	52.62	19.26	4.39
Gujarat	21,870	0.42	7.56	28.13	37.88	16.54	9.47
Haryana	1,559	0.00	9.43	15.49	30.95	39.72	4.41
Himachal Pradesh	37,948	0.12	6.45	21.48	45.37	24.02	2.56
Jharkhand	25,118	0.84	3.27	14.65	27.21	48.83	5.20
Karnataka	38,284	1.20	15.53	42.79	28.53	9.18	2.77
Kerala	11,522	0.74	9.07	31.66	37.20	16.66	4.67
Madhya Pradesh	94,689	1.12	5.21	23.63	48.38	16.72	4.94
Maharashtra	61,952	0.40	5.53	28.70	43.13	16.68	5.56
Manipur	17,418	0.00	0.00	2.26	12.32	81.84	3.58
Meghalaya	9,508	0.31	2.33	12.57	22.51	53.06	9.22
Mizoram	7,479	0.22	0.45	5.58	34.13	52.21	7.41
Nagaland	8,632	0.00	1.42	4.24	27.36	60.38	6.60
Odisha	61,204	0.46	4.77	15.72	35.82	40.91	2.32
Punjab	3,084	0.00	4.44	2.21	28.83	63.21	1.31
Rajasthan	32,869	0.42	8.87	22.11	31.68	16.33	20.59
Sikkim	5,841	0.61	4.88	25.04	45.82	18.94	4.71
Tamil Nadu	23,188	0.62	13.05	39.53	30.99	12.51	3.30
Telangana	27,688	1.53	15.00	48.57	24.7	7.85	2.35
Tripura	6,295	0.32	0.15	0.62	3.11	94.35	1.45
Uttar Pradesh	17,435	0.34	6.39	16.24	26.33	44.7	6.00
Uttarakhand	38,000	0.13	5.68	21.52	40.87	17.41	14.39
West Bengal	11,885	0.46	0.92	3.99	9.52	78.32	6.79
Andaman & Nicobar Islands	7,171	0.00	0.00	8.71	21.43	65.63	4.23
Jammu & Kashmir	20,199	1.03	13.04	23.88	41.71	14.46	5.88
Other UTs	272	0.05	0.65	8.00	70.29	19.17	1.83
Total (as per ISFR 2023)	**7,75,377**	**0.77**	**6.59**	**22.27**	**34.30**	**30.55**	**5.51**
Total (as per ISFR 2013)	**7,71,821**	**0.46**	**4.63**	**17.58**	**32.38**	**33.57**	**11.38**

8.4.1.2 Humus

Soil organic matter, which consists of whole series of organic products ranging from un-decayed leaf litter, plant and animal tissues, as well as decomposed plant and animal materials, is an important constituent of soil. The decomposed organic matter which remains associated with soil minerals is usually referred to as humus. It is a crucial component of forest soils and is also a store house of organic carbon. Soil humus and clay lattice acts as reservoir of essential nutrients required for plant survival and growth. It supplies plant nutrients and improves physical and chemical properties of soil. Humus is regarded as the life blood of soil mass.

Being sponge-like, humus helps to retain moisture in the soil, ensuring resilience of forests by providing stable water supply for plants during dry periods. Humus also provides soil a structure which enhances good movement of air and water through it, thereby benefiting tree and plant roots. Humus plays a vital role in enhancing biodiversity functions by providing home for bacteria, fungi and other soil micro-organisms, which in turn break down organic matter into humus and provide available nutrients again.

The presence of humus is observed on land surface in circular plot of 60 m radius around the plot centre and is measured after removing un-decomposed leaf litter. The different classes of humus are classified and recorded as given in Table 8.3 below.

Table 8.3 Classification of Humus Depths

Humus depth	Classification
Humus layer absent	No humus
Less than 5 cm thick	Shallow
5 to 10 cm thick	Medium
More than 10 cm thick	Deep

The information on soil humus for each State/UTs has been given in Table 8.4. It reveals that 68.34 % forest area of the country is either having no humus or having shallow humus which may be affecting the productivity of forests. 18.04% of RFA has medium to deep humus. The situation w.r.t. depth of humus has improved in the last decade.

Table 8.4 State/UTs wise Percentage Distribution of RFA by Humus (in %)

State/UTs	RFA (km^2)	Shallow	Medium	Deep	No Humus	NA
Andhra Pradesh	37,258	68.57	9.78	1.48	10.15	10.03
Arunachal Pradesh	51,540	49.81	29.33	5.05	7.07	8.74
Assam	26,836	41.94	17.77	3.00	15.55	21.74
Bihar	7,442	50.91	18.46	0.61	18.66	11.37
Chhattisgarh	59,816	10.43	0.56	1.33	76.87	10.81
Delhi	104	39.67	19.27	1.13	6.80	33.13
Goa	1,271	39.49	6.27	1.88	45.75	6.62
Gujarat	21,870	4.98	1.17	0.42	68.01	25.42
Haryana	1,559	60.63	18.25	0.65	12.38	8.09
Himachal Pradesh	37,948	42.63	40.56	8.52	2.68	5.61
Jharkhand	25,118	45.95	11.51	0.93	26.2	15.41
Karnataka	38,284	60.13	19.37	2.65	9.35	8.50
Kerala	11,522	57.55	24.33	5.86	3.91	8.35
Madhya Pradesh	94,689	8.02	2.64	2.86	72.94	13.55
Maharashtra	61,952	9.38	1.87	1.29	71.89	15.57
Manipur	17,418	49.34	33.63	4.47	6.73	5.84
Meghalaya	9,508	56.53	20.58	2.32	5.23	15.34
Mizoram	7,479	54.48	28.09	1.06	3.37	13.00
Nagaland	8,632	51.25	28.58	3.62	4.98	11.57
Odisha	61,204	50.86	14.86	2.96	22.87	8.45
Punjab	3,084	76.91	12.64	2.10	2.10	6.25
Rajasthan	32,869	43.72	13.24	1.06	7.68	34.30
Sikkim	5,841	44.69	38.24	5.87	4.69	6.51
Tamil Nadu	23,188	67.97	8.08	2.41	9.64	11.91
Telangana	27,688	64.13	10.82	1.43	8.77	14.85
Tripura	6,295	55.61	25.29	1.83	13.71	3.57
Uttar Pradesh	17,435	54.92	12.35	1.45	18.27	13.01
Uttarakhand	38,000	42.19	29.47	6.03	2.01	20.30
West Bengal	11,885	41.93	16.66	2.57	7.71	31.13
Andaman & Nicobar Islands	7,171	45.42	30.26	3.29	15.13	5.90
Jammu & Kashmir	20,199	40.80	31.77	6.57	6.10	14.76
Other UTs	272	19.13	8.13	4.43	57.92	10.38
Total (as per ISFR 2023)	**7,75,377**	**38.43**	**15.07**	**2.97**	**29.91**	**13.60**
Total (as per ISFR 2013)	**7,71,821**	**43.00**	**9.57**	**1.86**	**32.73**	**12.84**

8.4.1.3 Soil Organic Carbon

Soil organic carbon (SOC) content generally depicts the soil fertility. Soil acquires resistance to erosion by an organic layer above the mineral soil which is developed by the forest vegetation over years. The organic layer so formed helps in improving soil aeration and water retention. It also helps considerably in developing soil micro-organisms and other nutrients, which enhances the productive capacity of the soil.

Soil contains carbon in both mineral and organic form. Forest soil is a major reserve of terrestrial carbon. SOC is influenced through land use and management activities that affect the litter input. In SOC accounting, factors affecting the estimates include the depth to which carbon is accounted, which is commonly taken as 30 cm. The time lag until the equilibrium of SOC stock is reached after a land use change is commonly considered as 20 years. To generate information on soil organic carbon content under NFI, three micro-plots of 1 m x 1 m are laid out at 20 m distance from the centre of Subplot-1 in the direction of the centres of sub plots 2, 3 and 4. Soil data is taken from any two plots from a pit of 30 cm x 30 cm x 30 cm in each micro plot.

State/UTs wise information on Soil Organic Carbon is given in Table 8.5. The table shows that Sikkim has highest SOC per unit area (91.05 t/ha), while Delhi has the lowest SOC per unit area (42.22 t/ha).

Photo: FSI Repository

Table 8.5 Soil Organic Carbon

State/UTs	SOC (t/ha)
Andhra Pradesh	46.32
Arunachal Pradesh	82.66
Assam	54.52
Bihar	48.58
Chhattisgarh	51.42
Delhi	42.22
Goa	57.78
Gujarat	44.89
Haryana	42.94
Himachal Pradesh	68.94
Jharkhand	46.47
Karnataka	54.49
Kerala	56.22
Madhya Pradesh	46.61
Maharashtra	51.76
Manipur	66.95
Meghalaya	63.38
Mizoram	53.76
Nagaland	66.37
Odisha	50.72
Punjab	46.75
Rajasthan	42.74
Sikkim	91.05
Tamil Nadu	48.64
Telangana	45.64
Tripura	55.66
Uttar Pradesh	48.41
Uttarakhand	69.26
West Bengal	54.31
Andaman & Nicobar Islands	63.39
Chandigarh	50.96
Dadra & Nagar Haveli and Daman & Diu	54.89
Jammu & Kashmir	71.93
Ladakh[$]	-
Lakshadweep[@]	-
Puducherry	51.84
Total (as per ISFR 2023)	**56.08**
Total (as per ISFR 2013)	**55.85**

[$] RFA boundary was not made available and hence no data could be collected inside RFA.

[@] There is no RFA existing in the UT of Lakshadweep.

8.4.1.4 Presence of Grasses

Presence of grasses in forests is important for various ecological and environmental functions. Availability of grasses in forests is essential for binding the soil; increasing infiltration of water and reducing runoff of the same; retention of and maintaining micro-climatic conditions; grazing for animals; nutrient cycling; and for preventing invasive species from outcompeting native vegetation. Balancing the presence of grasses with other components of the forest ecosystem is crucial for maintaining overall forest health and diversity.

To record the presence of grasses, the ground area of about 60 m radius around the plot centre is observed. Presence of grasses is recorded as per the classification given in Table 8.6.

Table 8.6 Classification of Grass Density

Grass density	Classification
No grass	Absent
Less than 10% surface covered with grass	Scanty
10-25% surface covered with grass	Moderate
25-50% surface covered with grass	Dense
More than 50% surface covered with grass	Very Dense

The state/UTs wise information on presence of grass has been given in Table 8.7. The table reveals that about 42.25 % of forest area is having moderate to very dense grass while 44.14 % of forest area is having scanty to no grass.

Photo: FSI Repository

Table 8.7 Distribution of RFA (in %) by Presence of Grasses

State/UTs	RFA (km²)	Very dense	Dense	Moderate	Scanty	Absent	NA
Andhra Pradesh	37,258	7.50	22.45	25.42	26.23	8.37	10.03
Arunachal Pradesh	51,540	2.87	6.45	19.82	38.23	23.89	8.74
Assam	26,836	2.48	5.49	17.24	37.76	15.29	21.74
Bihar	7,442	1.63	9.35	26.23	45.33	6.09	11.37
Chhattisgarh	59,816	3.12	12.36	28.73	40.42	4.56	10.81
Delhi	104	2.20	13.15	18.64	29.59	3.29	33.13
Goa	1,271	1.25	11.91	15.66	53.28	11.28	6.62
Gujarat	21,870	3.59	12.12	25.28	27.46	6.13	25.42
Haryana	1,559	2.60	15.65	35.85	34.55	3.26	8.09
Himachal Pradesh	37,948	4.58	22.66	36.41	27.49	3.26	5.60
Jharkhand	25,118	1.60	4.80	16.28	50.81	11.11	15.4
Karnataka	38,284	8.17	22.24	27.62	26.23	7.24	8.50
Kerala	11,522	4.25	10.63	21.80	40.61	14.36	8.35
Madhya Pradesh	94,689	5.49	12.86	28.10	34.02	5.98	13.55
Maharashtra	61,952	10.24	19.11	31.22	21.41	2.45	15.57
Manipur	17,418	3.23	3.23	25.66	52.40	9.64	5.84
Meghalaya	9,508	1.58	8.63	24.29	41.83	8.33	15.34
Mizoram	7,479	1.58	4.54	14.40	46.76	19.72	13.00
Nagaland	8,632	2.27	15.42	19.05	40.81	10.88	11.57
Odisha	61,204	1.29	5.82	15.66	54.33	14.45	8.45
Punjab	3,084	6.25	9.37	25.01	46.87	6.25	6.25
Rajasthan	32,869	1.95	8.78	20.99	30.66	3.32	34.30
Sikkim	5,841	3.47	6.92	16.73	59.44	6.92	6.52
Tamil Nadu	23,188	3.24	16.94	30.02	32.97	4.92	11.91
Telangana	27,688	2.52	13.23	29.62	31.86	7.92	14.85
Tripura	6,295	2.31	3.23	16.79	64.39	9.71	3.57
Uttar Pradesh	17,435	2.92	17.29	27.41	34.28	5.10	13.00
Uttarakhand	38,000	2.62	16.68	25.95	29.76	4.68	20.31
West Bengal	11,885	1.22	4.65	15.28	38.64	9.08	31.13
Andaman & Nicobar Islands	7,171	1.32	4.60	5.92	54.61	27.64	5.91
Jammu & Kashmir	20,199	8.11	21.40	32.46	19.28	4.00	14.75
Other UTs	272	6.93	17.84	35.67	27.58	1.60	10.38
Total (as per ISFR 2023)	**7,75,377**	**4.25**	**12.96**	**25.04**	**35.65**	**8.49**	**13.61**
Total (as per ISFR 2013)	**7,71,821**	**3.40**	**12.24**	**26.92**	**36.31**	**5.47**	**15.66**

8.4.1.5 Presence of Undergrowth (Other than Grasses)

Undergrowth is an important plant community in a particular forest stand. It ensures consolidation in biodiversity, provides habitat to wildlife, ensures porosity of soils, helps in retention of soil moisture, prevents runoff of rain water, helps in pollination, etc. Particularly, the availability of understory is considered as a measure of relative wetness of the stand at landscape scales. The undergrowth plant community accumulated over time is an indicator of an area's moisture regime. Within this community, herbaceous species that only grow within a narrow range of soil moisture levels are considered as the best indicators. However, the undergrowth may also inhibit regeneration of certain favoured species. Whether to favour the undergrowth, to what extent; or whether to favour regeneration of any other species depends on management objectives.

The presence of undergrowth is recorded through observations over an area of 60 m radius around the plot centre. The classification of status of undergrowth is given in table 8.8. This table should be read with Table no. 8.15, which provides information on distribution of invasive species.

Table 8.8 Classification of Undergrowth Density

Undergrowth density	Classification
No undergrowth	Absent
Less than 10% surface covered with undergrowth	Scanty
10-25% surface covered with undergrowth	Moderate
25-50% surface covered with undergrowth	Dense
More than 50% surface covered with undergrowth	Very dense

The information on density of undergrowth is given in Table 8.9. It reveals that about 55.42 % of forest area has very dense to moderate under growth while about 30.97 % area has scanty to no under storey growth.

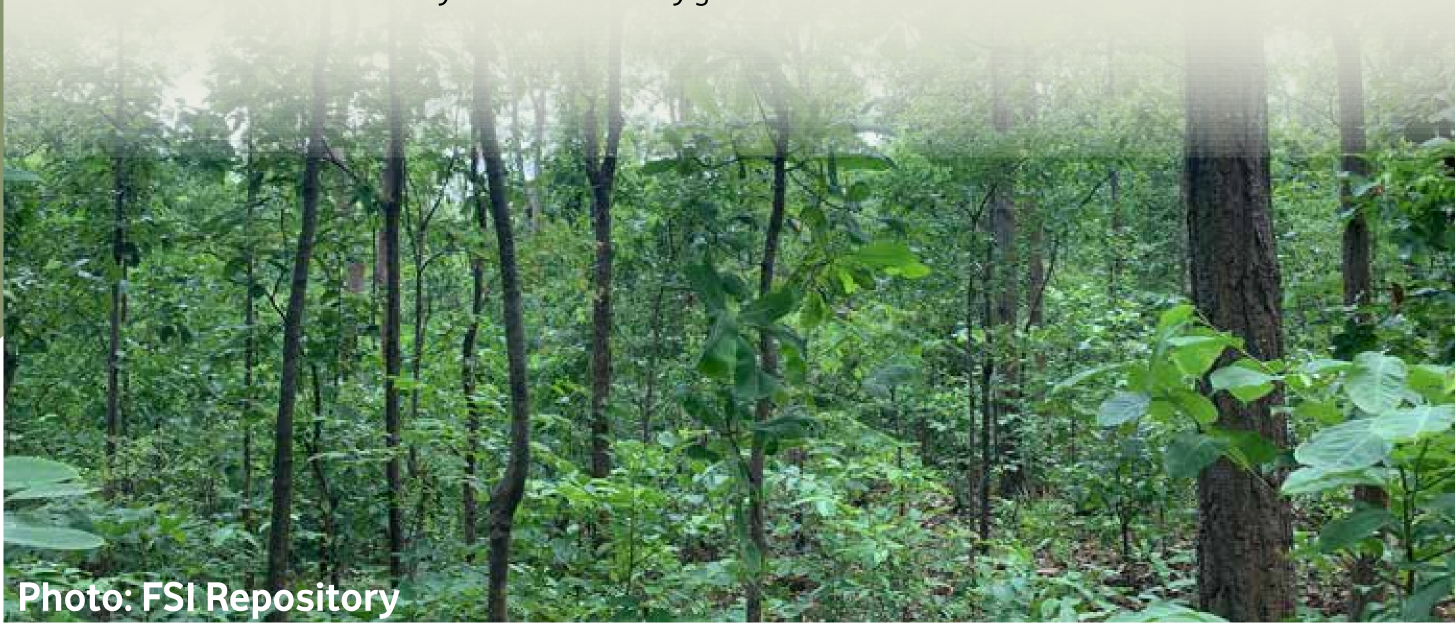


Photo: FSI Repository

Table 8.9 Distribution of RFA (in %) by Presence of Ground Flora - Undergrowth

State/UTs	RFA (km^2)	Very dense	Dense	Moderate	Scanty	Absent	NA
Andhra Pradesh	37,258	5.24	22.79	37.70	19.88	4.36	10.03
Arunachal Pradesh	51,540	11.29	19.46	25.69	27.61	7.21	8.74
Assam	26,836	4.13	11.96	22.01	30.40	9.77	21.73
Bihar	7,442	5.91	21.39	24.86	29.95	6.52	11.37
Chhattisgarh	59,816	6.15	26.04	36.66	18.78	1.56	10.81
Delhi	104	5.77	12.69	25.36	21.90	1.15	33.13
Goa	1,271	26.50	28.39	26.51	10.72	1.26	6.62
Gujarat	21,870	2.88	13.11	22.89	28.29	7.41	25.42
Haryana	1,559	6.56	19.69	32.83	22.98	9.85	8.09
Himachal Pradesh	37,948	12.27	22.35	34.14	20.65	4.98	5.61
Jharkhand	25,118	5.63	16.61	26.85	29.02	6.48	15.41
Karnataka	38,284	5.87	31.86	31.99	19.39	2.39	8.50
Kerala	11,522	3.21	35.66	31.38	19.08	2.32	8.35
Madhya Pradesh	94,689	4.74	15.20	31.43	30.18	4.90	13.55
Maharashtra	61,952	4.34	19.67	30.45	25.26	4.71	15.57
Manipur	17,418	6.27	26.15	35.58	25.11	1.05	5.84
Meghalaya	9,508	2.88	17.45	29.43	28.56	6.34	15.34
Mizoram	7,479	7.81	18.84	28.07	29.47	2.8	13.01
Nagaland	8,632	8.94	25.00	31.71	21.44	1.34	11.57
Odisha	61,204	4.74	18.08	30.85	33.22	4.67	8.44
Punjab	3,084	32.70	23.98	19.63	3.27	14.17	6.25
Rajasthan	32,869	1.58	8.01	21.13	29.45	5.53	34.30
Sikkim	5,841	14.02	14.02	26.30	34.48	4.67	6.51
Tamil Nadu	23,188	8.16	32.79	25.98	17.11	4.05	11.91
Telangana	27,688	2.93	21.15	30.85	24.99	5.23	14.85
Tripura	6,295	5.10	14.40	24.92	43.80	8.21	3.57
Uttar Pradesh	17,435	4.99	28.96	29.92	18.36	4.78	12.99
Uttarakhand	38,000	3.12	14.51	28.36	27.24	6.47	20.30
West Bengal	11,885	4.28	12.62	18.49	21.76	11.72	31.13
Andaman & Nicobar Islands	7,171	11.19	28.95	35.52	17.11	1.32	5.91
Jammu & Kashmir	20,199	1.80	10.56	27.37	31.82	13.69	14.76
Other UTs	272	4.14	16.26	27.87	28.98	12.37	10.38
Total (as per ISFR 2023)	**7,75,377**	**5.76**	**19.82**	**29.83**	**25.76**	**5.21**	**13.61**
Total (as per ISFR 2013)	**7,71,821**	**4.21**	**16.11**	**30.93**	**28.74**	**4.29**	**15.72**

8.4.2 Disturbance in forest areas

Forest disturbances are events, which cause change in the composition and structure in forest ecosystems other than the normal mortality and recruitment. It can be natural, e.g., outbreak of insects or pathogens, landslide, lightening, damage by wind, grazing or browsing by wild animals, etc., or anthropogenic, e.g., forest fire, grazing, logging, lopping, girdling, development activities, introduction of exotic species, etc. Some of such disturbances have been detailed in following paragraphs.

8.4.2.1 Soil Erosion

Soil erosion is the movement of soil components, especially topsoil, from one place to another. Wind, landslides, flowing water, etc., are the forces causing soil erosion. Excessive erosion of top soil reduces both the fertility and the water holding capacity of soil. The process of soil erosion involves a definite loss of valuable plant nutrients. Forests play a very important role in checking soil erosion. When there is a degradation of vegetation cover, water moves unchecked with a great force and carries soil particles with it resulting in loss of soil fertility, formation of gullies, nallah, etc. Thus, soil erosion is generally a concern that needs to be managed to prevent soil degradation and maintain the overall health and productivity of forests.

The extent of soil erosion is assessed around an area of 60 m radius of the plot centre. The classification of extent of soil erosion is given in Table 8.10.

Table 8.10 Classification of Extent of Soil Erosion

Extent of soil erosion	Classification
No sign of erosion	No erosion
Only surface erosion seen	Mild
Mild gullies and rills formed on top surface of soil	Moderate
Area has deep gullies, ravines, landslips, etc.	Heavy

State/UTs wise information on extent of erosion in RFA is given in Table 8.11. It reveals that 16.84 % area of Forest is not having soil erosion. 23.25 % area is experiencing moderate to heavy erosion, and 54.42 % is experiencing Mild erosion. It may be noted that the instances of heavy and moderate soil erosion have increased in last decade.

Table 8.11 Distribution of RFA (in %) by Soil Erosion

State/UTs	RFA (km²)	Heavy	Moderate	Mild	No erosion	NA
Andhra Pradesh	37,258	4.45	35.97	45.85	8.89	4.84
Arunachal Pradesh	51,540	5.45	21.3	46.29	23.02	3.94
Assam	26,836	1.73	7.54	57.15	28.41	5.17
Bihar	7,442	3.47	28.57	46.76	15.15	6.05
Chhattisgarh	59,816	3.29	21.67	52.49	20.33	2.22
Delhi	104	1.34	5.36	41.57	30.85	20.88
Goa	1,271	1.28	23.75	62.89	7.69	4.39
Gujarat	21,870	3.27	16.36	44.64	26.26	9.47
Haryana	1,559	1.35	12.2	61.02	21.02	4.41
Himachal Pradesh	37,948	11.04	22.10	62.02	2.38	2.46
Jharkhand	25,118	2.32	22.58	58.32	11.67	5.11
Karnataka	38,284	2.54	25.57	56.91	12.22	2.76
Kerala	11,522	6.48	29.99	56.27	2.59	4.67
Madhya Pradesh	94,689	3.61	15.14	47.58	28.73	4.94
Maharashtra	61,952	2.65	21.53	47.86	22.40	5.56
Manipur	17,418	0.00	18.13	71.48	6.81	3.58
Meghalaya	9,508	2.01	17.01	68.51	3.25	9.22
Mizoram	7,479	1.76	14.71	74.67	1.54	7.32
Nagaland	8,632	0.46	29.13	55.01	8.79	6.61
Odisha	61,204	1.46	16.15	66.23	13.85	2.31
Punjab	3,084	3.33	14.42	56.55	24.39	1.31
Rajasthan	32,869	1.35	10.32	54.72	13.02	20.59
Sikkim	5,841	6.39	36.61	47.66	4.64	4.70
Tamil Nadu	23,188	3.73	26.38	52.00	14.59	3.30
Telangana	27,688	1.75	15.62	67.84	12.44	2.35
Tripura	6,295	2.03	4.69	80.9	10.93	1.45
Uttar Pradesh	17,435	11.75	8.39	50.92	22.94	6.00
Uttarakhand	38,000	7.50	20.01	51.08	7.02	14.39
West Bengal	11,885	4.25	7.13	50.01	31.83	6.78
Andaman & Nicobar Islands	7,171	0.00	13.40	70.98	11.39	4.23
Jammu & Kashmir	20,199	3.36	22.88	50.94	16.94	5.88
Other UTs	272	0.17	19.32	69.36	9.33	1.83
Total (as per ISFR 2023)	**7,75,377**	**3.77**	**19.48**	**54.42**	**16.84**	**5.49**
Total (as per ISFR 2013)	**7,71,821**	**2.24**	**13.98**	**63.03**	**9.23**	**11.52**

8.4.2.2 Grazing Incidence

Grazing has a profound influence on forest vegetation. The impact of grazing in forests depends on several factors such as type of grazers, intensity and frequency of grazing, specific characteristics of the forest ecosystem, etc. Grazing by livestock, wild herbivores, or other animals in forests have significant ecological effects, both positive and negative, like creation and maintenance of open areas, clearings within forests, enhance plant and animal biodiversity, nutrient cycling, etc. In the present scenario, the grazing incidences are categorized within disturbances in forest area. Over grazing sometimes leads to potential hazards to forest ecosystem. Among the detrimental effects of overgrazing, a few are listed below:

- **Tree Seedling Suppression:** Herbivores can graze and browse on young tree seedlings, inhibiting forest regeneration.
- **Altered Plant Composition:** Grazing can lead to changes in the composition of the forest understorey, favouring less palatable or invasive plant species. This can negatively affect the diversity and structure of the forest.
- **Soil Compaction:** Intensive grazing can lead to soil compaction, which affects soil structure and can impede water infiltration and root growth,
- **Loss of Natural Regeneration:** In natural forests, grazing can disrupt natural regeneration processes, potentially leading to shifts in species composition and forest structure.

The grazing incidence is observed in an area of 60 m radius around the plot centre. The classification of grazing incidences is given in Table 8.12

Table 8.12 Classification of Extent of Grazing Classification

Extent of grazing	Classification
No sign of grazing seen	No grazing
Less than 10% area affected by grazing	Light grazing
10-50% area affected by grazing	Moderate grazing
More than 50% area/crop affected by grazing	Heavy grazing

The State/UTs wise information is given under Table 8.13. At national level, only about 22.05 % forest area is not prone to grazing. In general, the incidences of grazing have reduced in the past decade.

Table 8.13 Distribution of RFA (in %) by Grazing Incidence

State/UTs	RFA (km²)	Heavy grazing	Moderate grazing	Light grazing	NO grazing	NA
Andhra Pradesh	37,258	6.72	29.15	32.64	26.65	4.84
Arunachal Pradesh	51,540	3.01	18.06	31.11	43.88	3.94
Assam	26,836	3.80	19.83	39.80	31.40	5.17
Bihar	7,442	9.41	35.31	35.53	13.70	6.05
Chhattisgarh	59,816	12.33	35.65	38.82	10.99	2.21
Delhi	104	4.02	8.05	42.92	24.14	20.87
Goa	1,271	0.00	8.34	34.65	52.62	4.39
Gujarat	21,870	9.96	38.88	32.33	9.36	9.47
Haryana	1,559	2.02	33.65	53.86	6.06	4.41
Himachal Pradesh	37,948	3.76	29.55	56.35	7.88	2.46
Jharkhand	25,118	5.76	31.73	44.94	12.46	5.11
Karnataka	38,284	6.57	29.59	28.46	32.62	2.76
Kerala	11,522	0.74	6.25	14.91	73.43	4.67
Madhya Pradesh	94,689	20.32	34.47	27.30	12.97	4.94
Maharashtra	61,952	14.69	33.66	30.18	15.91	5.56
Manipur	17,418	1.09	8.68	47.66	38.99	3.58
Meghalaya	9,508	4.30	19.48	36.49	30.51	9.22
Mizoram	7,479	0.21	2.34	22.06	68.07	7.32
Nagaland	8,632	1.41	6.54	34.56	50.89	6.60
Odisha	61,204	2.74	23.28	46.48	25.19	2.31
Punjab	3,084	0.00	22.18	64.31	12.20	1.31
Rajasthan	32,869	4.48	34.11	34.32	6.50	20.59
Sikkim	5,841	2.39	5.95	59.56	27.40	4.70
Tamil Nadu	23,188	2.10	28.06	34.28	32.26	3.30
Telangana	27,688	14.94	38.81	31.04	12.86	2.35
Tripura	6,295	1.26	12.53	46.69	38.07	1.45
Uttar Pradesh	17,435	17.26	21.89	43.90	10.94	6.01
Uttarakhand	38,000	2.38	19.64	50.97	12.62	14.39
West Bengal	11,885	3.61	26.71	41.58	21.31	6.79
Andaman & Nicobar Islands	7,171	0.00	0.65	11.89	83.23	4.23
Jammu & Kashmir	20,199	9.51	33.25	36.72	14.64	5.88
Other UTs	272	36.85	32.26	15.82	13.24	1.83
Total (as per ISFR 2023)	**7,75,377**	**8.29**	**27.50**	**36.67**	**22.05**	**5.49**
Total (as per ISFR 2013)	**7,71,821**	**13.53**	**27.51**	**32.15**	**11.31**	**15.50**

8.4.2.3 Invasive Species

Invasive Species, as defined by FAO, are those species that are non-indigenous to a particular eco-system and whose introduction and spread causes, or is likely to cause socio-cultural, economic or environmental harm (including affecting the forest ecosystems) or harm to human health. Such species are non-native organisms that not only establish themselves in an area but also spread rapidly, often outcompeting or disrupting native species, thereby altering the ecosystem structure, disruption of succession and spread of diseases within forest areas. For identification of invasive species, a separate album of 45 major invasive species has been prepared by FSI.

The invasive species influence is observed on land surface of 60 m radius area around the plot centre. The extent of most occurring and second most occurring invasive species has been clubbed and recorded as per the classification given in Table 8.14.

Table 8.14 Classification of Extent of Occurrence of Invasive Species

Extent of most occurring and second most occurring invasive species	Classification
No invasive species seen	Absent
Less than 10% area infested	Scanty
10-25% area infested	Moderate
25-50% area infested	Dense
More than 50% area infested	Very dense

Table 8.15 reveals that occurrence of invasive species is very dense in 2.51 % forest area, and moderate to dense in 33.59% area. It also reveals that in 18.92 % area invasive species are scanty, and 23.61% area is free from invasive species. This data is not available for 2013.

Photo: FSI Repository

Table 8.15 Distribution of Invasive Species (%) in RFA

State/UTs	RFA (km^2)	Very Dense	Dense	Moderate	Scanty	Absent	NA
Andhra Pradesh	37,258	2.31	6.47	15.05	14.20	29.71	32.26
Arunachal Pradesh	51,540	1.47	10.89	23.54	18.84	27.96	17.30
Assam	26,836	3.28	7.83	21.77	31.8	19.42	15.90
Bihar	7,442	3.21	10.29	19.71	15.43	24.85	26.51
Chhattisgarh	59,816	1.82	12.56	30.47	24.77	13.78	16.60
Delhi	104	4.98	12.44	24.85	13.69	12.49	31.55
Goa	1,271	2.28	5.32	19.75	26.58	23.55	22.52
Gujarat	21,870	2.56	11.31	25.45	12.99	21.21	26.48
Haryana	1,559	2.02	18.85	18.18	8.75	41.07	11.13
Himachal Pradesh	37,948	4.11	10.81	12.47	8.37	33.46	30.78
Jharkhand	25,118	3.71	9.72	24.79	27.09	20.1	14.59
Karnataka	38,284	4.47	16.27	25.66	19.35	21.12	13.13
Kerala	11,522	0.79	9.79	23.5	24.87	16.44	24.61
Madhya Pradesh	94,689	4.55	14.54	31.22	17.82	14.40	17.47
Maharashtra	61,952	3.07	12.40	30.49	19.48	14.63	19.93
Manipur	17,418	0.00	6.83	39.67	17.79	28.76	6.95
Meghalaya	9,508	1.96	7.02	32.17	22.87	19.77	16.21
Mizoram	7,479	4.02	6.40	18.49	20.39	31.53	19.17
Nagaland	8,632	0.52	10.31	30.39	15.97	26.77	16.04
Odisha	61,204	1.66	8.29	23.69	24.39	33.38	8.59
Punjab	3,084	4.39	17.57	28.55	12.08	23.06	14.35
Rajasthan	32,869	0.93	5.04	18.95	24.25	14.18	36.65
Sikkim	5,841	0.00	4.44	10.34	19.18	50.17	15.87
Tamil Nadu	23,188	3.61	15.53	24.08	15.37	10.82	30.59
Telangana	27,688	0.82	6.14	23.28	15.83	42.32	11.61
Tripura	6,295	1.32	4.97	26.14	39.38	19.02	9.17
Uttar Pradesh	17,435	2.89	15.11	20.22	14.11	32.89	14.78
Uttarakhand	38,000	1.15	5.09	9.66	15.48	26.9	41.72
West Bengal	11,885	1.24	7.01	16.06	19.95	31.81	23.93
Andaman & Nicobar Islands	7,171	0.00	1.99	2.96	6.93	57.47	30.65
Jammu & Kashmir	20,199	1.47	2.95	3.44	1.97	32.95	57.22
Other UTs	272	3.86	15.30	13.16	28.50	30.42	8.76
Total	**7,75,377**	**2.51**	**10.21**	**23.38**	**18.92**	**23.61**	**21.37**

8.4.2.4 Illicit Felling

It refers to any felling of trees done in a State forest without any permission granted by authorized bodies. While carrying out NFI, illicit felling has been observed and recorded in a circular area of 60 m radius around the plot centre. The classification of extent of illicit felling is given in Table 8.16.

Table 8.16 Classification of Extent of Illicit Felling

Extent of Illicit Felling	Classification
No illicit felling	No injuries
Less than 5% area affected	Low
5-25% area affected	Moderate
More than 25% area/crop affected	Heavy

Results are given in Table 8.17. It is revealed that 6.17 % of forest area is heavily influenced by illicit felling, 25 % area experiences no illicit felling, and 21.42 % of Forest area is affected by moderate illicit felling.

Photo: Padmabhushan Rajguru

Table 8.17 Distribution of RFA (in %) by Illicit Felling

State/UTs	RFA (km²)	Heavy	Moderate	Low	No Injuries	NA
Andhra Pradesh	37,258	6.40	24.11	31.34	28.85	9.30
Arunachal Pradesh	51,540	4.91	16.24	31.46	40.23	7.16
Assam	26,836	4.03	14.87	38.72	26.02	16.36
Bihar	7,442	4.64	14.35	51.09	18.97	10.95
Chhattisgarh	59,816	6.70	31.95	42.57	8.38	10.40
Delhi	104	1.15	2.31	12.72	52.02	31.8
Goa	1,271	0.63	13.32	28.54	51.38	6.13
Gujarat	21,870	2.28	24.67	48.47	15.76	8.82
Haryana	1,559	2.72	15.66	42.20	31.98	7.44
Himachal Pradesh	37,948	1.73	21.23	48.37	23.45	5.22
Jharkhand	25,118	6.08	28.43	39.53	10.83	15.13
Karnataka	38,284	5.47	21.6	32.32	32.8	7.81
Kerala	11,522	2.04	8.35	15.97	66.13	7.51
Madhya Pradesh	94,689	7.29	27.26	38.85	14.34	12.26
Maharashtra	61,952	7.36	22.45	32.46	22.45	15.28
Manipur	17,418	1.06	14.69	54.55	24.11	5.59
Meghalaya	9,508	6.45	10.90	51.56	16.22	14.87
Mizoram	7,479	2.71	8.35	37.39	40.53	11.02
Nagaland	8,632	2.84	16.96	39.11	30.17	10.92
Odisha	61,204	3.76	19.97	41.09	26.91	8.27
Punjab	3,084	2.20	11.02	44.10	39.69	2.99
Rajasthan	32,869	1.49	18.72	32.89	14.95	31.95
Sikkim	5,841	0.63	8.74	50.57	36.20	3.86
Tamil Nadu	23,188	1.53	18.68	35.75	33.20	10.84
Telangana	27,688	8.95	27.26	37.64	13.23	12.92
Tripura	6,295	3.76	15.23	54.94	23.24	2.83
Uttar Pradesh	17,435	4.07	25.09	35.88	23.66	11.30
Uttarakhand	38,000	0.35	11.36	36.65	32.59	19.05
West Bengal	11,885	2.98	13.03	47.22	31.54	5.23
Andaman & Nicobar Islands	7,171	0.00	4.00	20.62	70.48	4.90
Jammu & Kashmir	20,199	1.79	7.71	29.03	55.7	5.77
Other UTs	272	17.56	20.14	32.70	20.17	9.42
Total	**7,75,377**	**6.17**	**21.42**	**35.69**	**25.01**	**11.71**

8.4.2.5 Girdling

Girdling is complete removal of a strip of bark (consisting of cork cambium or "phellogen", phloem, cambium, and sometimes going into the xylem) from around the entire circumference of either a branch or trunk of a woody plant. This reduces the overall timber volume and quality available for harvest. It's important to note that while girdling may have limited specific applications in forest management and ecological restoration, it is generally considered a disruptive and damaging practice when applied to healthy trees in natural forest ecosystems. Sustainable and ethical forest management practices aim to minimize the negative effects of such practices on the health and stability of forest ecosystems while achieving specific management objectives.

While carrying out NFI, girdling has been observed visually in a circular area of 60 m radius around the plot centre. The classification of girdling instances is given in Table 8.18.

Table 8.18 Classification of Extent of Girdling

Extent of Girdling	Classification
No girdling seen	No injuries
Less than 5% area affected	Occasional
5-25% area affected	Moderate
More than 25% area/crop affected	Heavy

Results are given in Table 8.19. It is revealed that 1.79 % of Forest area is heavily affected by Girdling. Moderate to Occasional Girdling affects 30.48 % of Forest area and in 56.02 % of forest area, there are no injuries due to Girdling. This data is not available for 2013.

Photo: FSI Repository

Table 8.19 Distribution of RFA (in %) by Girdling

State/UTs	RFA (km²)	Heavy	Moderate	Occasional	No Injuries	NA
Andhra Pradesh	37,258	2.24	15.61	19.07	53.79	9.29
Arunachal Pradesh	51,540	1.30	2.60	16.12	72.81	7.17
Assam	26,836	0.62	2.62	18.55	61.85	16.36
Bihar	7,442	3.91	18.24	13.25	53.65	10.95
Chhattisgarh	59,816	1.36	7.16	32.4	48.67	10.41
Delhi	104	0.00	1.15	5.78	61.27	31.80
Goa	1,271	0.00	1.9	12.68	79.29	6.13
Gujarat	21,870	2.88	5.41	26.19	56.7	8.82
Haryana	1,559	0.68	4.81	30.85	56.22	7.44
Himachal Pradesh	37,948	1.36	10.43	32.8	50.19	5.22
Jharkhand	25,118	0.39	3.74	17.44	63.29	15.14
Karnataka	38,284	1.85	10.99	23.84	55.51	7.81
Kerala	11,522	0.56	6.67	12.79	72.47	7.51
Madhya Pradesh	94,689	3.25	7.83	29.25	47.41	12.26
Maharashtra	61,952	1.95	3.74	17.21	61.82	15.28
Manipur	17,418	2.13	4.23	12.73	75.33	5.58
Meghalaya	9,508	1.65	9.47	30.69	43.32	14.87
Mizoram	7,479	0.85	1.50	10.64	75.99	11.02
Nagaland	8,632	0.47	6.13	26.86	55.62	10.92
Odisha	61,204	0.95	4.78	21.67	64.33	8.27
Punjab	3,084	0.00	0.00	23.15	73.86	2.99
Rajasthan	32,869	0.33	7.13	27.87	32.72	31.95
Sikkim	5,841	0.00	2.55	19.74	73.85	3.86
Tamil Nadu	23,188	1.31	12.51	27.42	47.92	10.84
Telangana	27,688	7.22	21.07	20.40	38.39	12.92
Tripura	6,295	0.15	3.15	29.51	64.36	2.83
Uttar Pradesh	17,435	1.10	5.32	22.84	59.43	11.31
Uttarakhand	38,000	1.51	6.26	25.75	47.44	19.04
West Bengal	11,885	0.94	5.64	25.38	62.81	5.23
Andaman & Nicobar Islands	7,171	0.00	0.00	7.97	87.12	4.91
Jammu & Kashmir	20,199	1.38	4.52	21.13	67.20	5.77
Other UTs	272	8.27	0.22	32.63	49.45	9.42
Total	**7,75,377**	**1.79**	**7.19**	**23.29**	**56.02**	**11.71**

8.4.2.6 Lopping Incidence

Lopping is the trimming of trees, cutting its branches, trunk and leaves for use while the trees are alive. This is primarily done for collection of fodder or other relevant uses. It is practiced for forage for livestock, additional source of income or sustenance for livestock farming. In forestry practices, lopping practices are planned with due careful consideration of the specific ecological and social context, and to balance the benefits of forage provision with the potential environmental impacts.

Lopping of trees is judged by ocular estimation in a plot of 60 m radius. The classification of lopping instances is given in Table 8.20.

Table 8.20 Classification of Extent of Lopping Instances

Extent of lopping	Classification
No lopping seen	No lopping
Less than 5% area affected	Occasional
5-25% area affected	Moderate
More than 25% area/crop affected	Heavy

Results are given in Table 8.21. It is revealed only 3.69 % of forest area is heavily affected by lopping incidence, and 29.61 % area has no lopping incidence. It is also revealed that 54.99 % of forests have Moderate to occasional lopping. This data is not available for 2013.

Photo: FSI Repository

Table 8.21 Distribution of RFA (in %) by Lopping Incidence

State/UTs	RFA (km²)	Heavy	Moderate	Occasional	No lopping	NA
Andhra Pradesh	37,258	4.22	22.4	31.37	32.71	9.30
Arunachal Pradesh	51,540	1.03	12.27	24.29	55.24	7.17
Assam	26,836	0.76	8.01	33.82	41.05	16.36
Bihar	7,442	6.41	29.46	31.82	21.36	10.95
Chhattisgarh	59,816	7.01	25.90	44.58	12.11	10.40
Delhi	104	0.00	2.35	16.46	49.38	31.81
Goa	1,271	0.00	6.34	32.35	55.18	6.13
Gujarat	21,870	6.15	27.54	40.64	16.85	8.82
Haryana	1,559	0.67	23.65	34.46	33.78	7.44
Himachal Pradesh	37,948	0.86	23.35	47.46	23.11	5.22
Jharkhand	25,118	1.90	22.40	47.75	12.82	15.13
Karnataka	38,284	4.02	21.34	32.87	33.96	7.81
Kerala	11,522	0.75	6.55	15.17	70.02	7.51
Madhya Pradesh	94,689	8.46	21.92	38.74	18.62	12.26
Maharashtra	61,952	4.93	17.5	36.40	25.89	15.28
Manipur	17,418	0.00	6.36	40.31	47.74	5.59
Meghalaya	9,508	1.50	14.74	38.06	30.83	14.87
Mizoram	7,479	0.84	1.67	18.28	68.19	11.02
Nagaland	8,632	0.00	9.81	26.58	52.69	10.92
Odisha	61,204	1.16	14.53	43.95	32.09	8.27
Punjab	3,084	0.00	16.53	46.3	34.18	2.99
Rajasthan	32,869	1.16	23.83	32.02	11.04	31.95
Sikkim	5,841	0.00	13.29	46.17	36.68	3.86
Tamil Nadu	23,188	1.39	18.04	34.83	34.9	10.84
Telangana	27,688	11.95	27.80	32.35	14.98	12.92
Tripura	6,295	0.00	3.62	38.11	55.44	2.83
Uttar Pradesh	17,435	4.29	24.98	37.53	21.9	11.3
Uttarakhand	38,000	0.69	11.65	35.41	33.21	19.04
West Bengal	11,885	1.58	20.43	43.53	29.23	5.23
Andaman & Nicobar Islands	7,171	0.00	0.66	11.31	83.13	4.90
Jammu & Kashmir	20,199	3.22	17.07	29.72	44.22	5.77
Other UTs	272	16.56	30.65	21.71	21.66	9.42
Total	**7,75,377**	**3.69**	**18.57**	**36.42**	**29.61**	**11.71**

8.4.2.7 Biotic Influence

Biotic influence can be characterized as over population of herbivores, invasive species, pathogens, grazing, fire, pollarding, illicit felling, lopping, etc., in a nutshell. Excessive influence can sometimes adversely affect health and biodiversity within forests, changes in composition and structure of forest, outcompeting the native vegetation, diminish forest's capacity to sequester carbon, cause runoff and sedimentation in streams and rivers, affecting water quality. These effects can disrupt the natural balance of the forest and may lead to ecological imbalances and long-term consequences.

The biotic influence is observed on land surface of 60 m radius area around the plot centre. The classification of instances of biotic influence is given in Table 8.22.

Table 8.22 Classification of Instances of Biotic Influence

Extent of biotic influence	Classification
No biotic influence seen	Not degraded
Less than 10% area affected	Mildly degraded
10-50% area affected	Moderately degraded
More than 50% area/crop affected	Heavily degraded

Results are given in Table 8.23. It is revealed that 5.93 % of Forest area is highly degraded and 12.26 % area in forests is not degraded. It also shows that 53.40 % of area is mildly degraded and 20.73 % of area is moderately degraded.

Photo: FSI Repository

Table 8.23 Distribution of RFA (in %) by Biotic Influence

State/UTs	RFA (km²)	Heavily degraded	Moderately degraded	Mildly degraded	Not degraded	NA
Andhra Pradesh	37,258	5.40	31.69	44.38	12.43	6.10
Arunachal Pradesh	51,540	4.92	16.92	50.51	19.49	8.16
Assam	26,836	3.03	15.93	56.00	12.44	12.60
Bihar	7,442	8.14	32.11	47.73	5.13	6.89
Chhattisgarh	59,816	9.68	27.31	54.15	5.75	3.11
Delhi	104	1.25	2.50	43.78	26.27	26.2
Goa	1,271	1.91	6.38	55.55	31.28	4.88
Gujarat	21,870	8.54	13.27	59.51	7.19	11.49
Haryana	1,559	2.00	12.7	60.82	16.04	8.44
Himachal Pradesh	37,948	1.94	19.34	60.79	12.69	5.24
Jharkhand	25,118	3.74	26.75	58.39	5.10	6.02
Karnataka	38,284	5.82	27.83	52.01	10.37	3.97
Kerala	11,522	2.55	13.86	35.92	41.39	6.28
Madhya Pradesh	94,689	14.63	21.69	51.37	6.08	6.23
Maharashtra	61,952	8.21	23.09	51.84	10.23	6.63
Manipur	17,418	0.00	17.81	64.98	13.63	3.58
Meghalaya	9,508	4.87	21.79	55.62	7.32	10.4
Mizoram	7,479	0.60	7.42	58.45	22.43	11.10
Nagaland	8,632	2.16	19.82	46.52	18.09	13.41
Odisha	61,204	1.46	19.67	59.16	16.92	2.79
Punjab	3,084	1.10	9.87	62.52	21.94	4.57
Rajasthan	32,869	1.95	10.34	52.53	10.41	24.77
Sikkim	5,841	0.58	9.25	69.91	14.44	5.82
Tamil Nadu	23,188	2.00	24.98	55.04	13.22	4.76
Telangana	27,688	15.76	32.85	43.06	5.06	3.27
Tripura	6,295	2.16	13.26	67.72	14.18	2.68
Uttar Pradesh	17,435	3.47	25.64	50.28	13.55	7.06
Uttarakhand	38,000	0.88	6.91	59.24	11.41	21.56
West Bengal	11,885	1.61	21.53	47.01	20.37	9.48
Andaman & Nicobar Islands	7,171	0.00	3.32	33.92	57.86	4.90
Jammu & Kashmir	20,199	3.31	17.46	51.75	18.61	8.87
Other UTs	272	41.09	7.68	38.19	10.54	2.49
Total (as per ISFR 2023)	**7,75,377**	**5.93**	**20.73**	**53.40**	**12.26**	**7.68**
Total (as per ISFR 2013)	**7,71,821**	**11.05**	**20.23**	**43.30**	**13.28**	**12.14**

8.4.3 Status of Forest Vegetation

The importance of forest vegetation cannot be overstated, as it plays a critical role in maintaining the health of ecosystems and providing numerous benefits to both the environment and society. Forests are home to a vast array of plant species, many of which are unique and found nowhere else. This biodiversity supports countless animal species, including insects, birds, mammals, and reptiles, creating complex and interconnected ecosystems.

Forest vegetation is organized into distinct vertical layers or strata, including the emergent layer, canopy, understory, and forest floor. Each layer has its own unique community of plants adapted to different levels of light, moisture, and other environmental conditions. Forest vegetation undergoes a process of succession, in which plant communities change over time in response to disturbances such as fire, logging, or natural events. Succession may lead to the gradual replacement of one type of vegetation with another, resulting in changes in species composition and ecosystem dynamics.

The ecological functions, biodiversity, socio-economic interactions of each type of forest ecosystem would be different from other. In this connection, information on some important forest vegetation characteristics is given in the following paragraphs.

8.4.3.1 Source of origin of Forest Stand

Forest Stand is an aggregation of community of tree species possessing sufficient uniformity in composition, constitution, age, arrangement/structure and to be distinguished from adjacent crops forming a silvicultural unit. The origin of stand may be 'natural' from seeds, or of coppice origin, or it may be raised artificially either by sowing or planting. This information indicates whether, the forest is natural or manmade and is important from the point of view of biodiversity conservation.

The source of origin of forest stand is observed on land surface of 60 m radius area around the plot centre and is classified and recorded as 'natural forest of seed/ coppice origin', or 'manmade forest'. The information has been given in Table 8.24.

Table 8.24 Distribution of RFA (in %) by source of origin of Stand

State/UTs	RFA (km^2)	Natural forest of seed / coppice origin	Man-made forest	NA
Andhra Pradesh	37,258	68.75	6.00	25.25
Arunachal Pradesh	51,540	77.02	9.83	13.15
Assam	26,836	71.92	15.43	12.65
Bihar	7,442	66.65	10.48	22.87
Chhattisgarh	59,816	80.06	1.96	17.98
Delhi	104	55.85	11.40	32.75
Goa	1,271	78.58	12.98	8.44
Gujarat	21,870	83.08	4.11	12.81
Haryana	1,559	69.35	16.54	14.11
Himachal Pradesh	37,948	88.7	1.16	10.14
Jharkhand	25,118	67.69	4.12	28.19
Karnataka	38,284	68.32	15.34	16.34
Kerala	11,522	70.19	12.45	17.36
Madhya Pradesh	94,689	73.23	1.19	25.58
Maharashtra	61,952	62.28	2.68	35.04
Manipur	17,418	87.34	0.93	11.73
Meghalaya	9,508	53.59	21.28	25.13
Mizoram	7,479	60	2.65	37.35
Nagaland	8,632	67.29	12.67	20.04
Odisha	61,204	80.12	6.06	13.82
Punjab	3,084	81.33	13.01	5.66
Rajasthan	32,869	32.08	0.83	67.09
Sikkim	5,841	89.55	4.08	6.37
Tamil Nadu	23,188	69.96	13.01	17.03
Telangana	27,688	64.36	5.86	29.78
Tripura	6,295	56.09	34.01	9.90
Uttar Pradesh	17,435	66.07	6.64	27.29
Uttarakhand	38,000	74.66	1.92	23.42
West Bengal	11,885	53.17	18.63	28.20
Andaman & Nicobar Islands	7,171	88.01	2.52	9.47
Jammu & Kashmir	20,199	60.42	1.50	38.08
Other UTs	272	71.76	9.65	18.59
Total (as per ISFR 2023)	**7,75,377**	**71.06**	**5.91**	**23.03**
Total (as per ISFR 2013)	**7,71,821**	**75.99**	**6.26**	**17.75**

8.4.3.2 Status of Regeneration

Intensity of regeneration refers to the extent the regeneration is established in an area for a given species or a group of species. The process of replacing old crop with younger generation either naturally or artificially is called regeneration or reproduction. Forest regeneration processes also include interventions like assisted natural regeneration, seed origin, enrichment planting, controls to reduce grazing and lopping activities, etc. This activity influences carbon storage through changes in the growth of above-ground and below-ground tree biomass. The regeneration depends on many factors such as presence of weeds, climatic conditions, soil and moisture regimes, grazing intensity, diseases and insect attacks, fire incidences and topographic factors like slope and aspect.

For recording status of regeneration, data from 1.7 m radius circular plots was recorded from within all four sub plots at a distance of 5 m from its centre towards east. For calculating established (tree) plant units, established, un-established and recruits are given weightage as 1, 1⁄2, and 1/4 respectively. The sample plots which have 9 or more established (tree) plant units (in 36 m^2) are termed as having 'adequate' regeneration. If the established plant units are less than 9 but are equal or more than 0.5 then the sample point is termed as having 'inadequate' regeneration. If it is less than 0.5 then regeneration is considered 'absent'. Regeneration status for each State/ UTs has been given in Table 8.25. According to this table, adequate regeneration is maximum in Goa (73.39%) followed by Chhattisgarh (71%) and Odisha (70.51%). Inadequate regeneration is maximum in Haryana (55.31%), followed by Arunachal Pradesh (52.32%) and Sikkim (51.92%). It may be noted that the regeneration status of the forests in the country has been adversely affected during this last decade.

Photo: FSI Repository

Table 8.25 Distribution of RFA (in %) by status of Regeneration

State/UTs	RFA (km^2)	Adequate	Inadequate	Absent	NA
Andhra Pradesh	37,258	49.67	21.88	4.72	23.73
Arunachal Pradesh	51,540	19.21	52.32	15.66	12.81
Assam	26,836	17.12	32.64	14.43	35.81
Bihar	7,442	39.81	27.49	13.84	18.86
Chhattisgarh	59,816	71.00	8.03	3.40	17.57
Delhi	104	21.24	34.22	11.8	32.74
Goa	1,271	73.39	16.18	2.48	7.95
Gujarat	21,870	27.93	36.35	19.84	15.88
Haryana	1,559	16.97	55.31	16.97	10.75
Himachal Pradesh	37,948	26.37	45.27	17.91	10.45
Jharkhand	25,118	52.48	14.99	5.52	27.01
Karnataka	38,284	52.68	26.21	5.97	15.14
Kerala	11,522	48.84	31.38	3.49	16.29
Madhya Pradesh	94,689	40.98	24.70	9.97	24.35
Maharashtra	61,952	33.95	20.03	11.98	34.04
Manipur	17,418	37.91	40.84	8.74	12.51
Meghalaya	9,508	26.3	41.33	7.95	24.42
Mizoram	7,479	22.49	33.64	6.82	37.05
Nagaland	8,632	26.36	46.01	6.71	20.92
Odisha	61,204	70.51	12.57	3.84	13.08
Punjab	3,084	42.55	39.09	13.79	4.57
Rajasthan	32,869	12.02	18.59	6.05	63.34
Sikkim	5,841	22.05	51.92	17.77	8.26
Tamil Nadu	23,188	33.08	40.92	9.50	16.50
Telangana	27,688	47.74	18.40	6.93	26.93
Tripura	6,295	27.78	50.64	12.66	8.92
Uttar Pradesh	17,435	40.97	23.59	10.72	24.72
Uttarakhand	38,000	32.98	32.28	11	23.74
West Bengal	11,885	62.28	24.24	5.78	7.70
Andaman & Nicobar Islands	7,171	68.54	18.10	3.89	9.47
Jammu & Kashmir	20,199	14.45	34.71	43.75	7.09
Other UTs	272	25.79	42.26	14.37	17.56
Total (as per ISFR 2023)	**7,75,377**	**40.62**	**27.24**	**10.20**	**21.94**
Total (as per ISFR 2013)	**7,71,821**	**48.06**	**24.30**	**9.72**	**17.92**

8.4.3.3 Size Class/Age Class

In general, there exist trees of different sizes in the forest areas which can be characterized by average size of the trees found in a Stand, and can be grouped into size classes. Size class refers to average diameter class or girth class of trees. Traditionally, the size class of trees in a Stand is an important indicator of readiness to harvest for the intended forest produce, and also maintaining the forest in a healthy condition. Size class is also useful to describe the forest's use for not only production functions, but other intended management purpose, e.g., wildlife management. Different wildlife species prefer different size class forests, depending upon their behavioural patterns.

The classification of size classes is given in Table 8.26.

Table 8.26 Classification of Size Classes

Type of crop in a Stand	Classification
Crop predominantly below 10cm dbh	Regeneration
Crop predominantly between 10-20 cm dbh	Pole crop
Crop predominantly between 20-30 cm dbh	Small timber
Crop predominantly with 30 cm or above dbh	Big timber
No marked domination of any particular size class	Mixed

The estimate for different categories of size class for each State/UTs is given in the Table 8.27. The table reveals that percentage area under 'big timber' size class is maximum in UT of Jammu & Kashmir (33.59%). Percentage area under 'Pole crop' size class is maximum in Punjab (54.67%). The UT of Andaman & Nicobar Islands is having maximum 85.42 % area under 'mixed size class' followed by Goa (70.54%), Arunachal Pradesh (68.87%) and Sikkim (56.07%) which may be considered as positive sign from population structure angle. It may be noted that the area under mixed size class has considerable increased during the last decade, indicating a positive impact on biodiversity.

Table 8.27 Distribution of RFA (in %) by Size Class

State/UTs	RFA (km²)	Regen-eration	Pole crop	Small timber	Big timber	Mixed size class	NA
Andhra Pradesh	37,258	14.85	36.43	9.06	1.53	12.95	25.18
Arunachal Pradesh	51,540	2.32	10.68	3.70	1.85	68.87	12.58
Assam	26,836	2.49	12.82	2.74	1.54	43.47	36.94
Bihar	7,442	15.46	33.89	8.56	2.98	14.34	24.77
Chhattisgarh	59,816	3.62	6.62	7.86	5.07	58.76	18.07
Delhi	104	6.73	39.23	6.73	0.00	14.56	32.75
Goa	1,271	0.00	10.51	10.51	0.00	70.54	8.44
Gujarat	21,870	21.77	23.55	3.33	1.86	31.16	18.33
Haryana	1,559	19.74	35.66	8.92	3.82	19.10	12.76
Himachal Pradesh	37,948	1.64	16.75	15.46	24.84	31.28	10.03
Jharkhand	25,118	4.60	26.04	6.61	1.05	33.05	28.65
Karnataka	38,284	17.32	29.90	11.67	4.12	20.15	16.84
Kerala	11,522	2.78	15.53	20.92	8.99	34.96	16.82
Madhya Pradesh	94,689	6.29	10.36	7.76	2.46	46.78	26.35
Maharashtra	61,952	8.48	14.00	3.64	0.69	38.72	34.47
Manipur	17,418	9.99	15.02	6.00	2.01	55.00	11.98
Meghalaya	9,508	3.08	23.4	8.62	0.64	39.36	24.90
Mizoram	7,479	2.40	14.75	3.01	0.60	41.69	37.55
Nagaland	8,632	2.02	25.79	5.64	0.00	46.73	19.82
Odisha	61,204	4.72	23.6	5.95	2.12	49.79	13.82
Punjab	3,084	0.00	54.67	27.88	2.14	9.65	5.66
Rajasthan	32,869	8.30	14	3.97	0.71	7.21	65.81
Sikkim	5,841	1.14	15.86	7.93	9.63	56.07	9.37
Tamil Nadu	23,188	13.33	39.58	9.00	2.37	18.61	17.11
Telangana	27,688	11.95	31.09	11.01	1.64	15.54	28.77
Tripura	6,295	2.96	30.36	6.07	2.82	50.21	7.58
Uttar Pradesh	17,435	21.46	18.83	8.27	8.55	16.19	26.7
Uttarakhand	38,000	0.75	16.89	13.45	16.89	28.83	23.19
West Bengal	11,885	12.07	38.62	6.19	2.26	32.74	8.12
Andaman & Nicobar Islands	7,171	0.00	2.55	1.28	1.28	85.42	9.47
Jammu & Kashmir	20,199	0.90	7.60	12.87	33.59	36.56	8.48
Other UTs	272	3.71	16.49	8.12	4.90	49.15	17.64
Total (as per ISFR 2023)	**7,75,377**	**7.21**	**18.65**	**7.81**	**5.09**	**38.11**	**23.13**
Total (as per ISFR 2013)	**7,71,821**	**13.66**	**27.10**	**12.10**	**7.62**	**21.12**	**18.40**

8.4.3.4 Crop Composition

The type of species or group of species which are contained in a forest constitutes 'Crop composition'. According to 'crop composition', forests may be classified in two types; pure forest in which a single particular species dominates; and mixed forest composed of trees of two or more species intermingled in the same canopy. A diverse and well-balanced crop composition is a key in maintaining ecological integrity and functionality of forest ecosystems.

Crop composition of the plot is recorded on the basis of predominance of a particular species which constitute more than 25 % of the area. There are 33 crop compositions which are identified by FSI and are recorded as per the crop composition found on land surface of 1.13 ha area around the plot centre. The Table 8.28 contains the information about different crop composition found in various State/UTs.

Table 8.28 Crop Composition (Parenthesis Value Indicates % of RFA)

Sl. No.	State/UTs	RFA (km^2)	Crop Composition (Parenthesis Value Indicates % of RFA)
1	Andhra Pradesh	37,258	Bamboo forest (1.73), Eucalyptus (2.35), Eucalyptus with Miscellaneous (0.69), Low land Hardwood (1.17), Mangrove (0.91), Miscellaneous forest (83.2), Mixed bamboo (3.25), Orchard (0.41), Sal (0.07), Salai with Misc (0.28), Teak (0.35), Teak mixed with Bamboo (0.14), Teak with Misc (0.35), Not Applicable (5.11)
2	Arunachal Pradesh	51,540	Bamboo forest (2.9), Blue pine (Kail) (1.29), Chir pine (0.97), Miscellaneous forest (64.52), Mixed bamboo (7.42), Oak Rhododendron Forest (0.32), Oaks (0.32), Orchard (1.94), Not Applicable (20.32)
3	Assam	26,836	Bamboo forest (3.25), Chir pine (0.17), Khair forest (0.17), Miscellaneous forest (56.85), Mixed bamboo (9.08), Oaks (0.17), Orchard (2.05), Sal (2.91), Sal with Misc (1.37), Teak (1.03), Teak with Misc (1.54), Not Applicable (21.4)
4	Bihar	7,442	Bamboo forest (0.46), Eucalyptus with Miscellaneous (0.23), Khair forest (0.23), Miscellaneous forest (69.98), Mixed bamboo (1.15), Sal (6.93), Sal with Misc (10.16), Teak (0.23), Teak mixed with Bamboo (0.23), Teak with Misc (0.23), Not Applicable (10.16)
5	Chhattisgarh	59,816	Bamboo forest (1.36), Khair forest (0.25), Low land Hardwood (0.25), Miscellaneous forest (47.89), Mixed bamboo (0.74), Sal (22.08), Sal with Misc (16.5), Salai with Misc (1.49), Teak (1.12), Teak with Misc (1.49), Not Applicable (6.82)
6	Delhi	104	Anogeissus pendula (Kardhai) (1.75), Low land Hardwood (3.51), Miscellaneous forest (91.23), Not Applicable (3.51),

Table 8.28 Crop Composition (Parenthesis Value Indicates % of RFA)

Sl. No.	State/UTs	RFA (km²)	Crop Composition (Parenthesis Value Indicates % of RFA)
7	Goa	1,271	Mangrove (0.2), Miscellaneous forest (94.36), Teak (1.36), Teak with Misc (2.04), Not Applicable (2.04)
8	Gujarat	21,870	Anogeissus pendula (Kardhai) (0.64), Bamboo forest (0.28), Eucalyptus (0.37), Eucalyptus with Miscellaneous (0.28), Khair forest (1.29), Low land Hardwood (0.55), Mangrove (2.59), Miscellaneous forest (55.53), Mixed bamboo (2.11), Orchard (0.09), Salai forest (0.28), Salai with Misc (0.18), Teak (3.67), Teak mixed with Bamboo (2.75), Teak with Misc (8.72), Not Applicable (20.66)
9	Haryana	1,559	Anogeissus pendula (Kardhai) (2.8), Bamboo forest (0.7), Eucalyptus (5.59), Eucalyptus with Miscellaneous (3.5), Khair and Shisham (2.1), Khair forest (3.5), Low land Hardwood (2.8), Miscellaneous forest (68.53), Sal (0.7), Sal with Misc (0.7), Teak (1.4), Teak with Misc (0.7), Not Applicable (6.99)
10	Himachal Pradesh	37,948	Bamboo forest (0.69), Blue pine (Kail), (7.17), Chir pine (18.9), Conifers mixed with hardwoods (2.21), Deodar (6.34), Eucalyptus (0.41), Eucalyptus with Miscellaneous (0.28), Fir (3.59), Fir spruce (3.17), Khair and Shisham (0.41), Khair forest (4.97), Low land Hardwood (6.62), Miscellaneous forest (11.86), Mixed bamboo (0.69), Mixed conifers (3.03), Oak Rhododendron Forest (5.52), Oaks (9.93), Sal (1.66), Sal with Misc (0.97), Salai forest (0.14), Spruce (5.24), Up land hardwoods (4.28), Not Applicable (1.93)
11	Jharkhand	25,118	Bamboo forest (0.34), Eucalyptus (0.11), Eucalyptus with Miscellaneous (0.22), Khair and Shisham (0.11), Khair forest (0.22), Low land Hardwood (0.11), Miscellaneous forest (47.98), Mixed bamboo (0.34), Sal (25.39), Sal with Misc (17.98), Salai with Misc (0.22), Not Applicable (6.97)
12	Karnataka	38,284	Bamboo forest (0.43), Eucalyptus (4.98), Eucalyptus with Miscellaneous (2.89), Mangrove (0.000178), Miscellaneous forest (76.46), Mixed bamboo (1.88), Orchard (0.07), Teak (1.08), Teak mixed with Bamboo (0.51), Teak with Misc (3.54), Not Applicable (8.16),
13	Kerala	11,522	Bamboo forest (0.99), Eucalyptus (0.4), Eucalyptus with Miscellaneous (0.4), Low land Hardwood (0.4), Miscellaneous forest (76.24), Mixed bamboo (3.96), Orchard (2.18), Teak (5.15), Teak mixed with Bamboo (0.59), Teak with Misc (3.17), Not Applicable (6.53)
14	Madhya Pradesh	94,689	Anogeissus pendula (Kardhai) (2.37), Bamboo forest (0.69), Khair forest (3.24), Low land Hardwood (0.25), Miscellaneous forest (46.1), Mixed bamboo (2.18), Orchard (0.06), Sal (5.8), Sal with Misc (2.74), Salai forest (1.12), Salai with Misc (1.43), Teak (11.6), Teak mixed with Bamboo (1.68), Teak with Misc (9.92), Not Applicable (10.79)

Table 8.28 Crop Composition (Parenthesis Value Indicates % of RFA)

Sl. No.	State/UTs	RFA (km²)	Crop Composition (Parenthesis Value Indicates % of RFA)
15	Maharashtra	61,952	Bamboo forest (1.19), Khair forest (1.19), Low land Hardwood (0.17), Miscellaneous forest (59.63), Mixed bamboo (1.87), Salai with Misc (0.26), Teak (10.9), Teak mixed with Bamboo (0.77), Teak with Misc (12.18), Not Applicable (11.84)
16	Manipur	17,418	Bamboo forest (6.35), Chir pine (1.59), Khasi pine (1.59), Miscellaneous forest (85.71), Oaks (1.59), Not Applicable (3.17)
17	Meghalaya	9,508	Bamboo forest (5.51), Chir pine (0.38), Fir (0.19), Khasi pine (0.76), Miscellaneous forest (51.52), Mixed bamboo (9.32), Orchard (6.46), Sal (0.19), Sal with Misc (0.95), Teak (0.19), Teak with Misc (0.57), Not Applicable (23.95)
18	Mizoram	7,479	Bamboo forest (15.26), Low land Hardwood (4.22), Miscellaneous forest (39.94), Mixed bamboo (21.75), Oaks (0.97), Orchard (0.65), Teak mixed with Bamboo (2.27), Teak with Misc (1.62), Not Applicable (13.31)
19	Nagaland	8,632	Bamboo forest (3.61), Chir pine (0.6), Miscellaneous forest (73.49), Mixed bamboo (6.02), Oaks (1.81), Orchard (1.81), Teak (0.6), Teak with Misc (0.6), Not Applicable (11.45)
20	Odisha	61,204	Bamboo forest (0.8), Eucalyptus with Miscellaneous (0.08), Low land Hardwood (0.24), Mangrove (0.25), Miscellaneous forest (57.92), Mixed bamboo (1.84), Orchard (0.24), Sal (11.54), Sal with Misc (16.51), Teak (0.72), Teak mixed with Sal (0.08), Teak with Misc (1.04), Not Applicable (8.73)
21	Punjab	3,084	Bamboo forest (2.41), Eucalyptus (2.41), Eucalyptus with Miscellaneous (6.02), Khair and Shisham (6.02), Khair forest (15.66), Low land Hardwood (27.71), Miscellaneous forest (38.55), Teak mixed with Bamboo (1.2)
22	Rajasthan	32,869	Anogeissus pendula (Kardhai) (21.55), Bamboo forest (0.56), Khair forest (2.99), Low land Hardwood (5.5), Miscellaneous forest (48.23), Mixed bamboo (1.12), Salai forest (1.59), Salai with Misc (2.33), Teak (4.01), Teak with Misc (4.01), Not Applicable (8.12)
23	Sikkim	5,841	Bamboo forest (2.31), Fir (1.54), Low land Hardwood (4.62), Miscellaneous forest (53.08), Oak Rhododendron Forest (0.77), Sal (5.38), Sal with Misc (1.54), Teak (0.77), Up land hardwoods (16.92), Not Applicable (13.08)
24	Tamil Nadu	23,188	Bamboo forest (0.49), Eucalyptus (7.47), Eucalyptus with Miscellaneous (1.89), Khair forest (0.25), Low land Hardwood (0.25), Mangrove (0.11), Miscellaneous forest (82.67), Mixed bamboo (1.15), Orchard (0.16), Teak (0.33), Teak with Misc (0.66), Not Applicable (4.59)

Table 8.28 Crop Composition (Parenthesis Value Indicates % of RFA)

Sl. No.	State/UTs	RFA (km^2)	Crop Composition (Parenthesis Value Indicates % of RFA)
25	Telangana	27,688	Bamboo forest (1.04), Eucalyptus (2.49), Eucalyptus with Miscellaneous (1.46), Low land Hardwood (0.1), Miscellaneous forest (59.46), Mixed bamboo (1.25), Orchard (0.1), Teak (8.21), Teak mixed with Bamboo (1.66), Teak with Misc (7.07), Not Applicable (17.15)
26	Tripura	6,295	Bamboo forest (2.63), Garjan with Miscellaneous (0.18), Miscellaneous forest (50.61), Mixed bamboo (10.86), Orchard (4.38), Sal (1.23), Sal with Misc (1.23), Teak (1.23), Teak mixed with Bamboo (0.35), Teak with Misc (4.55), Not Applicable (22.77)
27	Uttar Pradesh	17,435	Anogeissus pendula (Kardhai) (5.01), Bamboo forest (0.37), Eucalyptus (0.37), Eucalyptus with Miscellaneous (0.12), Khair and Shisham (0.24), Khair forest (3.05), Low land Hardwood (13.8), Miscellaneous forest (49.69), Mixed bamboo (0.98), Sal (10.62), Sal with Misc (4.15), Salai forest (0.37), Salai with Misc (0.98), Teak (3.3), Teak mixed with Bamboo (0.12), Teak mixed with Sal (1.34), Teak with Misc (1.95), Not Applicable (3.54)
28	Uttarakhand	38,000	Blue pine (Kail) (0.15), Chir pine (30.89), Conifers mixed with hardwoods (0.46), Deodar (1.07), Eucalyptus (0.76), Eucalyptus with Miscellaneous (0.15), Fir (1.07), Fir spruce (0.46), Khair and Shisham (0.46), Khair forest (0.61), Low land Hardwood (8.1), Miscellaneous forest (9.48), Mixed bamboo (0.15), Mixed conifers (0.46), Oak Rhododendron Forest (11.47), Oaks (12.54), Sal (10.7), Sal with Misc (5.5), Spruce (0.31), Teak (0.92), Teak mixed with Sal (0.15), Teak with Misc (0.76), Up land hardwoods (2.75), Not Applicable (0.61)
29	West Bengal	11,885	Bamboo forest (0.17), Eucalyptus (1.54), Eucalyptus with Miscellaneous (2.4), Fir spruce (0.17), Low land Hardwood (0.34), Mangrove (6.8), Miscellaneous forest (42.6), Mixed bamboo (0.34), Orchard (0.17), Sal (26.07), Sal with Misc (7.89), Teak (1.03), Teak mixed with Bamboo (0.17), Teak with Misc (1.89), Not Applicable (8.4)
30	Andaman & Nicobar Islands	7,171	Bamboo forest (0.71), Garjan forest (Dipterocarpus turbinatus) (0.71), Garjan with Miscellaneous (3.57), Mangrove (7.86), Miscellaneous forest (77.14), Mixed bamboo (1.43), Teak with Misc (1.43), Not Applicable (7.14)
31	Chandigarh	35	Khair and Shisham (16.67), Khair forest (16.67), Low land Hardwood (16.67), Miscellaneous forest (41.67), Not Applicable (8.33)
32	Dadra Nagar Haveli and Daman & Diu	217	Khair forest (2.84), Miscellaneous forest (54.70), Mixed bamboo (5.66), Teak mixed with Bamboo (2.83), Not Applicable (33.97)

Table 8.28 Crop Composition (Parenthesis Value Indicates % of RFA)

Sl. No.	State/UTs	RFA (km²)	Crop Composition (Parenthesis Value Indicates % of RFA)
33	Jammu and Kashmir	20,199	Blue pine (Kail), (19.57), Chir pine (18.71), Conifers mixed with hardwoods (0.29), Deodar (11.65), Fir (14.96), Fir spruce (3.02), Khair and Shisham (0.14), Khair forest (0.29), Low land Hardwood (2.3), Miscellaneous forest (9.78), Mixed conifers (3.31), Oak Rhododendron Forest (2.16), Oaks (4.17), Spruce (2.16), Up land hardwoods (3.02), Not Applicable (4.46)
34	Puducherry	13	Mangrove (6.98), Miscellaneous forest (93.02)
35	Ladakh	7	Not available
36	Lakshadweep	0	Not available

8.4.3.5 Canopy Layer

In general, forest canopy is significantly recognized as synonym for height of a forest stand and also for stratification of forest structure. The different canopy layers in forests collectively contribute for environmental interactions, regeneration, growth, and providing habitat. It is used to indicate stratum of plant life-form group, for example, the tree, shrub, and herb layers; or an age class, such as the tree, sapling, and seedling layers, that tend to exist at a characteristic height. It is also seen as a clumped distribution of various leaf area density in vertical space. Sometimes the relative coverage of these different forms is used to describe stands variability in plant community. Multiple canopy layers may indicate the continuous distribution of foliage surfaces from the top of the crown to the ground, which is considered as an important forest structural feature. Such canopy distributions are significant for greater diversity of animal habitat.

The NFI defines canopy layer as a horizontal stratum in a plant community, each layer being called a storey. 'No storey' is recorded if crop is absent or found young and canopy formation has not taken place. 'One storeyed forest' is recorded if there is no noticeable variation in height. 'Two storeyed forest' is recorded if variation in canopy layers is distinguishable into upper and lower storeys. 'Three or more storeyed forest' is recorded if the variation in height is very large and in most cases it is not possible to group the trees in above classes.

Table 8.29 depicts that maximum percentage area under 'three or more storeyed forest' is present in Kerala (28.56 %) followed by Arunachal Pradesh (12.78%) and Goa (12.62%). Similarly, maximum percentage area under 'two storeyed forest' is present in Sikkim (78.03%) followed by Manipur (77.29%) and Goa (75.09%). At the national level, it has been observed in the present assessment that about 4.62 % area is having three or more canopy layers and 71.25 % area is having one to two storeyed forests, whereas 10.88 % forest area has no storey. The table hints at habitat degradation at broad level.

Table 8.29 Distribution of RFA (in %) by Canopy Layer

State/UTs	RFA (km²)	No storey	One forest storeyed	Two storeyed	Three or more storeyed forest	NA
Andhra Pradesh	37,258	25.40	31.61	29.75	3.87	9.37
Arunachal Pradesh	51,540	2.32	4.42	68.13	12.78	12.35
Assam	26,836	4.58	7.89	59.28	2.63	25.62
Bihar	7,442	30.94	23.28	29.72	4.87	11.19
Chhattisgarh	59,816	3.36	12.75	69.11	3.02	11.76
Delhi	104	1.14	11.41	52.48	2.28	32.69
Goa	1,271	0.00	5.67	75.09	12.62	6.62
Gujarat	21,870	28.03	29.82	30.27	0.96	10.92
Haryana	1,559	30.98	25.9	29.85	2.82	10.45
Himachal Pradesh	37,948	3.45	18.47	65.25	6.87	5.96
Jharkhand	25,118	9.02	15.91	56.91	2.32	15.84
Karnataka	38,284	20.47	26.08	35.09	7.79	10.57
Kerala	11,522	3.19	10.12	49.50	28.56	8.63
Madhya Pradesh	94,689	10.35	18.95	54.77	1.68	14.25
Maharashtra	61,952	14.22	23.07	45.62	1.42	15.67
Manipur	17,418	2.99	10.89	77.29	2.99	5.84
Meghalaya	9,508	3.44	5.99	63.52	4.79	22.26
Mizoram	7,479	5.85	5.85	73.50	2.44	12.36
Nagaland	8,632	0.88	8.75	74.26	4.80	11.31
Odisha	61,204	4.19	9.49	74.30	2.84	9.18
Punjab	3,084	8.63	32.35	49.59	6.47	2.96
Rajasthan	32,869	12.94	19.59	32.07	2.6	32.8
Sikkim	5,841	4.06	7.51	78.03	4.61	5.79
Tamil Nadu	23,188	21.50	36.19	27.89	3.72	10.70
Telangana	27,688	17.21	30.41	34.17	5.10	13.11
Tripura	6,295	2.28	15.95	74.73	2.28	4.76
Uttar Pradesh	17,435	33.48	18.96	35.15	1.02	11.39
Uttarakhand	38,000	2.95	14.58	58.32	4.82	19.33
West Bengal	11,885	5.55	19.04	64.47	2.85	8.09
Andaman & Nicobar Islands	7,171	0.00	0.65	65.8	26.98	6.57
Jammu & Kashmir	20,199	7.04	31.6	43.81	8.06	9.49
Other UTs	272	7.03	18.34	64.11	0.40	10.12
Total (as per ISFR 2023)	**7,75,377**	**10.88**	**18.40**	**52.85**	**4.62**	**13.25**
Total (as per ISFR 2015)	**7,64,566**	**7.72**	**25.51**	**57.96**	**8.81**	**Not Reported**

8.4.3.6 Basal Area

The basal area of a tree is defined as the cross-sectional area in m^2 of a single tree at breast height (1.37 m) above ground. The cross-sectional area of all stems of a species or all stems in a stand measured at breast height and expressed as per unit (usually ha) of land area is called basal area/ha of that stand. Basal area is used to determine forest stand density and it is also linked with timber stand volume and growth.

The basal area pertaining to each state has been calculated on the basis of trees enumerated from the plots falling in respective state which is given in Table 8.30. The table gives us the information about the percentage area falling in different basal area classes (m^2) in different State/UTs. The basal area distribution gives us the information about the actual stocking in terms of using the site productivity potentiality when used along with the basal area of the corresponding forest type preservation plots. It thus helps us in quantifying the potential area for improvement of different State/UTs.

Table 8.30 State wise Percentage RFA in Different Basal Area Classes

State/UTs	RFA km^2	% of area in different Basal Area Classes (m^2)						
		00 - 05	05-10	10-20	20-30	30-40	40+	NA
Andhra Pradesh	37,258	31.38	21.35	15.89	4.42	0.97	0.55	25.44
Arunachal Pradesh	51,540	27.10	15.16	19.03	6.13	5.16	1.94	25.48
Assam	26,836	28.60	20.38	15.75	4.97	1.88	0.86	27.56
Bihar	7,442	32.10	16.40	11.78	4.62	0.23	0.46	34.41
Chhattisgarh	59,816	13.03	20.22	40.45	14.89	2.61	0.12	8.68
Delhi	104	47.37	28.07	8.77	3.51	0.00	0.00	12.28
Goa	1,271	8.16	8.84	38.78	25.85	12.93	4.76	0.68
Gujarat	21,870	29.84	14.88	9.09	0.55	0.09	0.00	45.55
Haryana	1,559	36.36	18.18	16.78	2.10	0.00	0.00	26.58
Himachal Pradesh	37,948	9.10	14.48	26.34	18.62	10.76	17.10	3.60
Jharkhand	25,118	29.21	24.38	26.52	4.27	0.79	0.00	14.83
Karnataka	38,284	28.01	8.30	14.15	11.62	6.71	5.85	25.36
Kerala	11,522	4.55	9.31	23.56	23.96	16.44	15.05	7.13
Madhya Pradesh	94,689	25.89	23.27	27.76	4.43	0.56	0.06	18.03
Maharashtra	61,952	25.89	19.25	24.28	4.77	0.51	0.09	25.21
Manipur	17,418	50.79	19.05	20.63	1.59	0.00	0.00	7.94
Meghalaya	9,508	35.93	22.24	14.64	3.42	0.76	0.95	22.06
Mizoram	7,479	40.26	19.16	18.83	5.19	2.27	0.97	13.32
Nagaland	8,632	32.53	27.71	18.67	6.63	1.81	0.60	12.05
Odisha	61,204	21.88	22.76	30.45	9.86	2.32	1.28	11.45

Table 8.30 State wise Percentage RFA in Different Basal Area Classes

State/UTs	RFA km²	% of area in different Basal Area Classes (m^2)						
		00 - 05	05-10	10-20	20-30	30-40	40+	NA
Punjab	3,084	40.96	28.92	25.30	2.41	0.00	0.00	2.41
Rajasthan	32,869	46.55	17.54	8.02	0.56	0.09	0.00	27.24
Sikkim	5,841	15.38	11.54	24.62	16.92	8.46	6.92	16.16
Tamil Nadu	23,188	34.13	18.29	15.50	3.77	1.48	2.30	24.53
Telangana	27,688	23.60	21.31	20.58	4.05	0.42	0.00	30.04
Tripura	6,295	39.05	28.90	14.36	2.28	0.70	0.00	14.71
Uttar Pradesh	17,435	29.91	14.16	12.58	10.26	3.54	0.73	28.82
Uttarakhand	38,000	7.65	13.30	30.43	25.54	11.31	8.87	2.90
West Bengal	11,885	35.33	24.87	18.01	4.29	1.89	0.51	15.10
Andaman & Nicobar Islands	7,171	2.14	2.14	20.00	22.14	21.43	27.86	4.29
Jammu & Kashmir	20,199	11.65	13.38	18.71	12.95	10.94	25.61	6.76
Other UTs	272	23.06	15.01	24.55	3.62	0.98	1.27	31.51
Total (as per ISFR 2023)	**7,75,377**	**25.03**	**18.56**	**22.80**	**8.46**	**3.43**	**3.20**	**18.52**
Total (as per ISFR 2015)	**7,64,566**	**31.80**	**24.09**	**28.01**	**9.71**	**4.16**	**2.23**	**Not Reported**

8.4.3.7 Plantation Potential

In the NFI, the plantation potential is judged by ocular estimation in a circular plot of 60 m radius and is recorded. While determining the potentiality of the land, due consideration is given to aspect, soil depth, drainage, crop in the surrounding area and other biotic as well as climatic factors. The maximum permissible slope up to which plantation can be raised is considered to be 40^0 and minimum soil depth should be 15 cm. Also, in the NFI sample plots where the crown density is 40% or more, plantation potential is not of any significance and hence, it is included in "Not Applicable" (NA) category. Results are given in Table 8.31, it is revealed that 33.21 % of forest area is having the potential of plantation.

Table 8.31 Distribution of RFA (in %) by Plantation Potential

State/UTs	RFA (km²)	Plantable	Un-plantable	NA
Andhra Pradesh	37,258	25.45	31.92	42.63
Arunachal Pradesh	51,540	46.41	12.78	40.81
Assam	26,836	42.73	3.52	53.75
Bihar	7,442	41.61	17.28	41.11
Chhattisgarh	59,816	30.47	11.3	58.23
Delhi	104	22.30	8.57	69.13
Goa	1,271	19.66	10.48	69.86
Gujarat	21,870	48.28	14.26	37.46
Haryana	1,559	50.30	8.70	41.00
Himachal Pradesh	37,948	25.46	14.58	59.96
Jharkhand	25,118	39.16	10.07	50.77
Karnataka	38,284	28.46	21.13	50.41
Kerala	11,522	9.11	19.41	71.48
Madhya Pradesh	94,689	26.97	8.36	64.67
Maharashtra	61,952	34.51	10.90	54.59
Manipur	17,418	43.56	27.85	28.59
Meghalaya	9,508	42.42	6.81	50.77
Mizoram	7,479	34.08	15.85	50.07
Nagaland	8,632	41.20	10.6	48.20
Odisha	61,204	37.52	8.62	53.86
Punjab	3,084	36.31	9.61	54.08
Rajasthan	32,869	29.37	6.71	63.92
Sikkim	5,841	31.02	13.72	55.26
Tamil Nadu	23,188	33.53	28.04	38.43
Telangana	27,688	36.66	16.65	46.69
Tripura	6,295	53.41	7.36	39.23
Uttar Pradesh	17,435	44.74	6.94	48.32
Uttarakhand	38,000	15.58	7.12	77.30
West Bengal	11,885	28.62	10.20	61.18
Andaman & Nicobar Islands	7,171	32.56	18.06	49.38
Jammu & Kashmir	20,199	35.64	20.70	43.66
Other UTs	272	41.49	6.90	51.61
Total (as per ISFR 2023)	**7,75,377**	**33.21**	**13.19**	**53.60**
Total (as per ISFR 2013)	**7,71,821**	**25.19**	**4.48**	**70.33**

Note: *Forest areas with more than 40% canopy density are not considered as available for plantation.*


Photo: Sanjay Shukla, IFS


Photo: Subharanjan Sen, IFS

CHAPTER 09
Decadal Change of Various Forest Parameters

Photo: Subharanjan Sen, IFS


Photo: Saurabh Kalia

DECADAL CHANGE OF VARIOUS FOREST PARAMETERS

09

Introduction 9.1

India is among the few countries in the world to achieve a positive trend of forest cover increase over two decades. This is even more creditable for the country that forest & tree cover has increased despite large dependence of human and cattle population living in the forest fringe villages for their day-to-day needs of fuel wood, fodder, small timber, and NTFPs. This could be possible because of high priority accorded to conservation and implementation of many schemes by the National and State governments in the country which is reflected in a strong framework of Policies, Acts & Rules and programmes like: The Indian Forest Act, 1927, Wildlife (Protection) Act, 1972, National Forest Policy, 1988, Van Sanrakshan Evam Samvardhan Adhiniyam, 1980, Central and State sponsored Schemes like Green India Mission (GIM), CAMPA, MGNREGA, National Afforestation Programme (NAP), Policy for enhancement of Urban Greens, National Agro-forestry Policy, Sub-Mission on Agro-forestry (SMAF), etc.

In order to study the impacts of above mentioned regulations and schemes, FSI has attempted to assess the changes in various forestry parameters such as forest cover, tree cover, growing stock, agroforestry, etc. The information given in this chapter highlights the impacts of government policies and planning on these forestry parameters.

Decadal Change in Forest Cover 9.2

The decadal change in forest cover is of significant importance due to its impact on various ecological, environmental, and socio-economic aspects. Monitoring these changes is essential as these affect biodiversity, climate and water cycles. The change in forest cover also has substantial implications on carbon sequestration, soil fertility, and watershed stability.

The decadal change analysis has been carried out based on Raster for the ISFR 2023, as mentioned in Para 2.6.5 under Chapter 2. The same methodology has been adopted for analysis of the data forming part of ISFR 2013 to ensure consistency and comparability. For this reason, the figures related to Forest Cover given under ISFR 2013 slightly vary with those reported hereunder. The analysis of decadal change in forest cover between 2013 and 2023 indicates an increase from 6,98,712.36 km² in 2013 to 7,15,342.61 km² in 2023, thus resulting into a net increase of 16,630.25 km² in forest cover. Further, State/UTs wise decadal change in forest cover is given in Table 9.1.

Table 9.1 Decadal Change in Forest Cover of State/UTs between 2013 and 2023 assessments

(km²)

State/UTs	Geographical Area	Forest Cover (2013)	Forest Cover (2023)	Change in Forest Cover	Change (%) w.r.t.2013
Andhra Pradesh	1,62,922.57	26,043.53	30,084.96	4,041.43	15.52
Arunachal Pradesh	83,743.22	66,966.09	65,881.57	-1,084.52	-1.62
Assam	78,438.00	27,564.90	28,313.55	748.65	2.72
Bihar	94,163.00	7,283.55	7,532.45	248.90	3.42
Chhattisgarh	1,35,192.00	55,606.96	55,811.75	204.79	0.37
Delhi	1,483.00	180.32	195.28	14.96	8.30
Goa	3,702.00	2,219.00	2,265.72	46.72	2.11
Gujarat	1,96,244.00	14,507.77	15,016.64	508.87	3.51
Haryana	44,212.00	1,583.38	1,614.26	30.88	1.95
Himachal Pradesh	55,673.00	14,683.00	15,580.35	897.35	6.11
Jharkhand	79,716.00	23,815.38	23,765.78	-49.60	-0.21
Karnataka	1,91,791.00	36,170.68	39,254.27	3,083.59	8.53
Kerala	38,852.00	18,383.95	22,059.36	3,675.41	19.99
Madhya Pradesh	3,08,252.11	77,522.00	77,073.44	-448.56	-0.58
Maharashtra	3,07,713.00	50,632.00	50,858.53	226.53	0.45
Manipur	22,327.00	16,961.16	16,585.46	-375.70	-2.22
Meghalaya	22,429.00	17,241.48	16,966.84	-274.64	-1.59
Mizoram	21,081.00	18,978.16	17,990.46	-987.70	-5.20
Nagaland	16,579.00	13,017.35	12,222.47	-794.88	-6.11
Odisha	1,55,707.00	50,544.71	52,433.56	1,888.85	3.74
Punjab	50,362.00	1,790.78	1,846.09	55.31	3.09
Rajasthan	3,42,238.99	16,086.00	16,548.21	462.21	2.87
Sikkim	7,096.00	3,358.00	3,358.40	0.40	0.01
Tamil Nadu	1,30,060.00	24,245.21	26,450.22	2,205.01	9.09
Telangana	1,12,122.44	19,956.62	21,179.04	1,222.42	6.13
Tripura	10,486.00	7,948.65	7,584.77	-363.88	-4.58
Uttar Pradesh	2,40,927.56	14,359.72	15,045.80	686.08	4.78
Uttarakhand	53,483.36	24,508.00	24,303.83	-204.17	-0.83
West Bengal	88,752.00	17,101.98	16,832.33	-269.65	-1.58
A & N Islands	8,249.00	6,711.00	6,732.92	21.92	0.33
Chandigarh	114.00	17.26	25.00	7.74	44.84
Dadra & Nagar Haveli and Daman & Diu	602.00	219.96	225.62	5.66	2.57
Jammu & Kashmir**	2,22,236.00	20,948.27	21,346.39	398.12	1.90
Ladakh**		1,478.00	2,285.92	807.92	54.66
Lakshadweep	29.63	27.02	27.06	0.04	0.15
Puducherry	490.00	50.52	44.31	-6.21	-12.29
Total	**32,87,468.88**	**6,98,712.36**	**7,15,342.61**	**16,630.25**	**2.38**

***Notified area for individual UTs of Jammu & Kashmir and Ladakh have not been received for SoI. The geographical area reported for the unified J&K in census 2011 is 2,22,236 km²*

9.2.1 Decadal Change in Forest Cover inside and outside RFA/Green wash between 2013 and 2023

The decadal assessment shows an increase of 440.47 km^2 in forest cover inside RFA/GW and an increase of 16,189.78 km^2 outside RFA/GW. The top 5 State/UTs showing an increase in forest cover inside RFA/GW are Andhra Pradesh, Karnataka, Ladakh, Himachal Pradesh, and Jharkhand. The bottom 5 State/UTs showing a decrease in forest cover inside RFA/GW are Mizoram, Jammu and Kashmir, Arunachal Pradesh, Nagaland, and Manipur. The top 5 State/UTs showing an increase in forest cover outside RFA/GW are Kerala, Andhra Pradesh, Tamil Nadu, Karnataka, and Odisha. The bottom 5 State/UTs showing a decrease in forest cover outside RFA/GW are Madhya Pradesh, Arunachal Pradesh, West Bengal, Jharkhand, and Nagaland. State/ UT wise details of decadal change in forest cover inside and outside RFA/GW is presented in the Table 9.2.

Table 9.2 Decadal Change in Forest Cover Inside and Outside RFA/ Green Wash between 2013 and 2023

(km^2)

State/UTs	Geographical Area	Forest Cover Inside the Recorded Forest Area (or Green Wash)		Change Inside RFA/GW	Forest Cover Outside the Recorded Forest Area (or Green Wash)		Change Outside RFA/GW
		2013 Assessment	2023 Assessment		2013 Assessment	2023 Assessment	
Andhra Pradesh	1,62,922.57	22,655.68	23,867.76	1,212.08	3,387.85	6,217.20	2,829.35
Arunachal Pradesh	83,743.22	58,748.11	58,173.96	-574.15	8,217.98	7,707.61	-510.37
Assam	78,438.00	19,995.84	19,696.73	-299.11	7,569.06	8,616.82	1,047.76
Bihar	94,163.00	4,698.19	4,865.74	167.55	2,585.36	2,666.71	81.35
Chhattisgarh	1,35,192.00	42,618.57	42,420.39	-198.18	12,988.39	13,391.36	402.97
Delhi	1,483.00	67.47	72.20	4.73	112.85	123.08	10.23
Goa	3,702.00	1,206.19	1,223.93	17.74	1,012.81	1,041.79	28.98
Gujarat	1,96,244.00	9,400.65	9,389.87	-10.78	5,107.12	5,626.77	519.65
Haryana	44,212.00	660.30	728.93	68.63	923.08	885.33	-37.75
Himachal Pradesh	55,673.00	10,374.77	10,706.97	332.20	4,308.23	4,873.38	565.15
Jharkhand	79,716.00	12,172.79	12,502.53	329.74	11,642.59	11,263.25	-379.34
Karnataka	1,91,791.00	22,127.46	23,013.90	886.44	14,043.22	16,240.37	2,197.15
Kerala	38,852.00	9,692.24	9,925.84	233.60	8,691.71	12,133.52	3,441.81
Madhya Pradesh	3,08,252.11	67,542.80	67,770.50	227.70	9,979.20	9,302.94	-676.26
Maharashtra	3,07,713.00	36,154.97	36,110.93	-44.04	14,477.03	14,747.60	270.57
Manipur	22,327.00	15,196.90	14,790.81	-406.09	1,764.26	1,794.65	30.39
Meghalaya	22,429.00	14,840.96	14,650.85	-190.11	2,400.52	2,315.99	-84.53
Mizoram	21,081.00	18,614.02	17,629.60	-984.42	364.14	360.86	-3.28
Nagaland	16,579.00	8,977.94	8,520.03	-457.91	4,039.41	3,702.44	-336.97
Odisha	1,55,707.00	32,907.33	33,040.47	133.14	17,637.38	19,393.09	1,755.71
Punjab	50,362.00	780.62	775.76	-4.86	1,010.16	1,070.33	60.17
Rajasthan	3,42,238.99	12,523.03	12,706.14	183.11	3,562.97	3,842.07	279.10
Sikkim	7,096.00	2,080.65	2,060.63	-20.02	1,277.35	1,297.77	20.42
Tamil Nadu	1,30,060.00	17,757.51	17,734.30	-23.21	6,487.70	8,715.92	2,228.22
Telangana	1,12,122.44	18,256.80	18,456.11	199.31	1,699.82	2,722.93	1,023.11
Tripura	10,486.00	5,574.31	5,356.19	-218.12	2,374.34	2,228.58	-145.76

Table 9.2 Decadal Change in Forest Cover Inside and Outside RFA/ Green Wash between 2013 and 2023

(km²)

State/UTs	Geographical Area	Forest Cover Inside the Recorded Forest Area (or Green Wash)		Change Inside RFA/GW	Forest Cover Outside the Recorded Forest Area (or Green Wash)		Change Outside RFA/GW
		2013 Assessment	2023 Assessment		2013 Assessment	2023 Assessment	
Uttar Pradesh	2,40,927.56	9,302.12	9,338.76	36.64	5057.60	5,707.04	649.44
Uttarakhand	53,483.36	17,101.09	16,899.28	-201.81	7,406.91	7,404.55	-2.36
West Bengal	88,752.00	7,464.37	7,688.56	224.19	9,637.61	9,143.77	-493.84
A & N Islands	8,249.00	6,079.33	6,170.51	91.18	631.67	562.41	-69.26
Chandigarh	114.00	7.40	8.94	1.54	9.86	16.06	6.20
Dadra & Nagar Haveli and Daman & Diu	602.00	171.02	158.51	-12.51	48.94	67.11	18.17
Jammu & Kashmir**	2,22,236.00	13,800.38	13,112.03	-688.35	7,147.89	8,234.36	1,086.47
Ladakh**		370.03	794.58	424.55	1,107.97	1,491.34	383.37
Lakshadweep	29.63	0.00	0.00	0.00	27.02	27.06	0.04
Puducherry	490.00	3.01	3.08	0.07	47.51	41.23	-6.28
Total	**32,87,468.88**	**5,19,924.85**	**5,20,365.32**	**440.47**	**1,78,787.51**	**1,94,977.29**	**16,189.78**

***Notified area for individual UTs of Jammu & Kashmir and Ladakh have not been received for SoI. The geographical area reported for the unified J&K in census 2011 is 2,22,236 km²*

9.2.2 Decadal Change in Forest Cover in Hill districts of relevant States between 2013 and 2023

Forest cover in hill districts play a vital role for biodiversity conservation, watershed management, climate regulation, preventing soil erosion, benefiting both local environments, and downstream regions. The decadal change in the forest cover over a longer period thereby facilitating better decision making. The details of the decadal change in the forest cover for the state/UTs with hill districts is provided in Table 9.3.

Table 9.3 Decadal Change in Forest Cover in Hill Districts of relevant States between 2013 and 2023

(km²)

State/UTs	Geographical Area	No of hill districts	Total Forest 2013 Assessment	Total Forest 2023 Assessment	Net
Arunachal Pradesh	83,743.22	25	66,966.09	65,881.57	-1,084.52
Assam	19,299.00	5	12,987.84	12,784.85	-238.99
Himachal Pradesh	55,673.00	12	14,683.00	15,580.35	897.35
Karnataka	48,353.00	6	23,490.22	24,182.71	692.49
Kerala	29,552.00	10	14,379.13	17,928.16	3,549.03
Maharashtra	69,905.00	7	15,518.00	15,843.99	325.99
Manipur	22,327.00	16	16,961.16	16,585.46	-375.70
Meghalaya	22,429.00	12	17,241.48	16,966.84	-274.64
Mizoram	21,081.00	11	18,978.16	17,990.46	-987.70
Nagaland	16,579.00	11	13,017.35	12,222.47	-794.88
Sikkim	7,096.00	4	3,358.00	3,358.40	0.40
Tamil Nadu	19,384.00	6	6,101.35	6,566.89	465.54
Tripura	10,486.00	8	7,948.65	7,584.77	-363.88
Uttarakhand	53,483.36	13	24,508.00	24,303.83	-204.17
West Bengal	3,149.00	2	2,378.31	2,336.14	-42.17

Table 9.3 Decadal Change in Forest Cover in Hill Districts of relevant States between 2013 and 2023

(km²)

State/UTs	Geographical Area	No of Hill districts	Total Forest 2013 Assessment	Total Forest 2023 Assessment	Net
Jammu & Kashmir	2,22,236.00	22	20,948.27	21,346.39	398.12
Ladakh		2	1,478.00	2,285.92	807.92
Total	**7,04,775.58**	**172**	**2,80,943.01**	**2,83,713.20**	**2,770.19**

9.2.3 Decadal Change in Forest Cover in North Eastern States between 2013 and 2023

Analysis of decadal change in forest cover between 2013 and 2023 for the entire North Eastern States reveals a net loss of 3132.27 km^2 in forest cover. Details of decadal change for North Eastern states is given in Table 9.4.

Table 9.4 Decadal Change in Forest Cover in North Eastern States between 2013 and 2023

(km^2)

State/UTs	Geographical Area	Total Forest 2013 Assessment	Total Forest 2023 Assessment	Change
Arunachal Pradesh	83,743.22	66,966.09	65,881.57	-1,084.52
Assam	78,438.00	27,564.90	28,313.55	748.65
Manipur	22,327.00	16,961.16	16,585.46	-375.70
Mizoram	21,081.00	18,978.16	17,990.46	-987.70
Nagaland	16,579.00	13,017.35	12,222.47	-794.88
Sikkim	7,096.00	3,358.00	3,358.40	0.40
Tripura	10,486.00	7,948.65	7,584.77	-363.88
Meghalaya	22,429.00	17,241.48	16,966.84	-274.64
Total	**2,62,179.22**	**1,72,035.79**	**1,68,903.52**	**-3,132.27**

9.2.4 Decadal Change in Forest Cover in Different Altitude Zones between 2013 and 2023

The altitude zones 0-500 m, and 500-1000 m show an increase of 16,604.04 km^2 and 1,125.30 km^2 in forest cover, respectively in decadal change assessment. The altitude zone 1000-2000 m, and above 4000 m have a significant decrease in forest cover of 937.86 km^2 and 416.31 km^2, respectively. The status of decadal change in forest cover in different altitude zones of the country is provided in Table 9.5.

Table 9.5 Decadal Change in Forest Cover in Different Altitude Zones between 2013 and 2023

(km^2)

Altitude Zone (m)	Total Forest 2013 Assessment	Total Forest 2023 Assessment	Net Change
0-500	3,68,175.80	3,84,779.84	16,604.04
500-1000	1,95,556.58	1,96,681.88	1,125.30
1000-2000	75,523.46	74,585.60	-937.86
2000-3000	39,683.44	39,862.95	179.51
3000-4000	17,302.99	17,378.56	75.57
Above4000	2,470.09	2,053.78	-416.31
Total	**6,98,712.36**	**7,15,342.61**	**16,630.25**

9.2.5 Decadal Change in Forest Cover in Mangrove between 2013 and 2023

The decadal change in mangrove cover of the country shows that there is an overall increase of 296.33 km^2. Further details of district wise decadal change in mangrove cover is given in Table 9.6.

Table 9.6 Decadal Change in Forest Cover in Mangrove between 2013 and 2023

(km^2)

State/UT and Districts	Total Mangrove Cover 2013 Assessment Raster based*	Total Mangrove Cover 2023 Assessment Raster based*	Change w.r.t ISFR 2013 Raster based*
Andhra Pradesh			
Bapatla	50.31	72.92	22.61
Eluru	0.00	0.02	0.02
Kakinada	112.94	113.79	0.85
Konaseema	77.96	74.42	-3.54
Krishna	108.42	148.45	40.03
Prakasam	0.49	0.75	0.26
Sri PottiSriramulu Nellore	4.03	8.66	4.63
Srikakulam	0.00	0.82	0.82
Tirupati	0.87	1.29	0.42
Visakhapatnam	0.00	0.31	0.31
Total	**355.02**	**421.43**	**66.41**
Goa			
North Goa	17.00	24.01	7.01
South Goa	5.00	7.33	2.33
Total	**22.00**	**31.34**	**9.34**
Gujarat			
Ahmedabad	41.73	40.26	-1.47
Amreli	1.65	1.78	0.13
Anand	10.56	8.39	-2.17
Bharuch	45.16	56.84	11.68
Bhavnagar	20.81	30.62	9.81
DevbhumiDwarka	72.02	78.00	5.98
GirSomnath	8.46	9.87	1.41
Jamnagar	101.15	162.53	61.38
Junagadh	0.00	0.00	0.00
Kachchh/Kutch	779.88	708.42	-71.46
Morbi	3.88	4.94	1.06
Navsari	16.73	17.44	0.71
Porbandar	1.33	1.35	0.02
Rajkot	0.00	0.00	0.00
Surat	27.63	35.63	8.00
Vadodara	2.29	1.70	-0.59
Valsad	6.19	6.29	0.10
Total	**1,139.47**	**1,164.06**	**24.59**
Karnataka			

Table 9.6 Decadal Change in Forest Cover in Mangrove between 2013 and 2023

(km²)

State/UT and Districts	Total Mangrove Cover 2013 Assessment Raster based*	Total Mangrove Cover 2023 Assessment Raster based*	Change w.r.t ISFR 2013 Raster based*
Dakshin Kannada	0.00	1.27	1.27
Uttar Kannada	1.00	8.96	7.96
Udupi	2.00	3.97	1.97
Total	**3.00**	**14.20**	**11.20**
Kerala			
Ernakulum	1.82	2.07	0.25
Kannur	8.65	6.44	-2.21
Kasaragod	0.54	0.92	0.38
Kollam	0.00	0.02	0.02
Total	**11.01**	**9.45**	**-1.56**
Maharashtra			
Mumbai city	2.00	2.82	0.82
Mumbai Sub-urban	43.00	56.80	13.80
Palghar	21.00	38.40	17.40
Raigarh	62.00	126.32	64.32
Ratnagiri	23.00	30.50	7.50
Sindhudurg	3.00	11.32	8.32
Thane	40.00	48.93	8.93
Total	**194.00**	**315.09**	**121.09**
Odisha			
Baleshwar	2.39	4.82	2.43
Bhadrak	27.39	32.39	5.00
Jagatsinghpur	6.74	8.42	1.68
Kendrapara	189.42	212.69	23.27
Puri	0.00	0.74	0.74
Total	**225.94**	**259.06**	**33.12**
Tamil Nadu			
Cuddalore	0.00	0.39	0.39
Mayiladuthurai	6.61	8.46	1.85
Nagapattinam	3.47	2.55	-0.92
Pudukkottai	2.17	1.16	-1.01
Ramanathapuram	0.90	1.53	0.63
Thanjavur	1.62	2.46	0.84
Thiruvallur	11.02	13.34	2.32
Thiruvarur	0.00	0.39	0.39
Thoothukkudi	11.89	8.20	-3.69
Villupuram	2.78	3.21	0.43
Total	**40.46**	**41.91**	**1.45**
West Bengal			
PurbaMedinipur	2.50	3.65	1.15
North 24 Parganas	25.46	26.63	1.17
South 24 Parganas	2,067.60	2,088.88	21.28
Total	**2,095.56**	**2,119.16**	**23.60**

Table 9.6 Decadal Change in Forest Cover in Mangrove between 2013 and 2023

(km^2)

State/UT and Districts	Total Mangrove Cover 2013 Assessment Raster based*	Total Mangrove Cover 2023 Assessment Raster based*	Change w.r.t ISFR 2013 Raster based*
A&N Islands			
North & Middle Andaman	428.43	418.18	-10.25
South Andaman	172.57	187.74	15.17
Nicobars	3.00	2.37	-0.63
Total	**604.00**	**608.29**	**4.29**
D&NH and Daman & Diu			
Daman	0.32	1.35	1.03
Diu	1.31	2.51	1.20
Total	**1.63**	**3.86**	**2.23**
Puducherry			
Karaikal	0.00	0.10	0.10
Puducherry	0.00	0.54	0.54
Yanam	3.26	3.19	-0.07
Total	**3.26**	**3.83**	**0.57**
Grand Total	**4,695.35**	**4,991.68**	**296.33**

**Area figure calculated without normalization factor.*

9.3 Decadal Change of Tree Cover

The decadal change in tree cover as reported in ISFR 2013 and 2023 for State and UTs is given in the Table 9.7. It reveals that the area under tree cover reported as 91,267 km^2 in 2013, has increased to 1,12,014.34 km^2 in 2023.

Table 9.7 Decadal Change of Tree Cover of State/UTs from 2013 to 2023

(km^2)

Sl. No.	States/UTs	Geographical Area	Tree cover (2013)	Tree cover (2023)	Change in Tree Cover	Change (%)
1	Andhra Pradesh*	1,62,922.57	4,375.00	5,340.02	965.37	22.07
2	Arunachal Pradesh	83,743.22	660.00	1,201.63	541.63	82.07
3	Assam	78,438.00	1,582.00	2,101.46	519.46	32.84
4	Bihar	94,163.00	2,164.00	2,370.21	206.21	9.53
5	Chhattisgarh	1,35,192.00	3,463.00	6,538.70	3,075.70	88.82
6	Delhi	1,483.00	118.00	176.03	58.03	49.18
7	Goa	3,702.00	334.00	257.82	-76.18	-22.81
8	Gujarat	1,96,244.00	8,358.00	6,632.29	-1,725.71	-20.65
9	Haryana	44,212.00	1,282.00	1,693.02	411.02	32.06
10	Himachal Pradesh	55,673.00	697.00	855.07	158.07	22.68
11	Jharkhand	79,716.00	2,629.00	3,637.55	1,008.55	38.36
12	Karnataka	1,91,791.00	5,920.00	7,779.15	1,859.15	31.40
13	Kerala	38,852.00	3,146.00	2,905.94	-240.06	-7.63
14	Madhya Pradesh	3,08,252.11	7,087.00	8,650.14	1,563.14	22.06
15	Maharashtra	3,07,713.00	9,142.00	14,524.88	5,382.88	58.88
16	Manipur	22,327.00	224.00	209.82	-14.18	-6.33

Table 9.7 Decadal Change of Tree Cover of State/UTs from 2013 to 2023

(km²)

Sl. No.	State/UTs	Geographical Area	Tree cover (2013)	Tree cover (2023)	Change in Tree Cover	Change (%)
17	Meghalaya	22,429.00	668.00	720.56	52.56	7.87
18	Mizoram ##	21,081.00	223.00	567.80	344.80	154.62
19	Nagaland	16,579.00	372.00	394.02	22.02	5.92
20	Odisha	1,55,707.00	4,013.00	6,163.45	2,150.45	53.59
21	Punjab	50,362.00	1,499.00	1,475.15	-23.85	-1.59
22	Rajasthan	3,42,238.99	7,860.00	10,841.12	2,981.12	37.93
23	Sikkim	7,096.00	31.00	48.33	17.33	55.90
24	Tamil Nadu	1,30,060.00	4,866.00	5,370.72	504.72	10.37
25	Telangana*	1,12,122.44	2,812.00	3,517.66	705.31	25.08
26	Tripura	10,486.00	213.00	247.56	34.56	16.23
27	Uttar Pradesh	2,40,927.56	6,895.00	8,950.92	2,055.92	29.82
28	Uttarakhand	53,483.36	703.00	1,231.14	528.14	75.13
29	West Bengal	88,752.00	2,144.00	2,938.12	794.12	37.04
30	Andaman & Nicobar Islands	8,249.00	41.00	26.97	-14.03	-34.22
31	Chandigarh	114.00	10.00	21.18	11.18	111.80
32	Dadra & Nagar Haveli, Daman & Diu	602.00	38.00	36.83	-1.17	-3.08
33	Jammu & Kashmir #	2,22,236.00	7,664.00	3,666.97	-3,997.03	-52.15
34	Ladakh		-	893.02	893.02	-
35	Lakshadweep	29.63	5.00	0.20	-4.80	-96.00
36	Puducherry	490.00	29.00	28.89	-0.11	-0.38
	Total	**32,87,468.88**	**91,267.00**	**1,12,014.34**	**20,747.34**	**22.73**

**Tree Cover data of Telangana and Andhra Pradesh for ISFR 2013 is obtained by proportionately dividing the same, estimated for undivided Andhra Pradesh State.*

 # Tree Cover data published in 2013 for J&K is based on very less number of sample plots due to poor accessibility; whereas, the same in 2023 for J&K is based on much higher number of sample plots.

RFA in Mizoram has changed from 16,717 km² in 2013 to 7,479 km² in 2023

There has been a net increase in tree cover of 20,747.34 km² at the national level between 2013 and 2023. In percentage terms, the tree cover has increased by 22.73 % during last one decade. From the above table, it is observed that Maharashtra has the highest increase in tree cover followed by Chhattisgarh and Rajasthan.

Decadal Change in Tree Green Cover under Agroforestry 9.4

The decadal change in tree green cover area under agroforestry between the published assessments obtained from ISFR 2013 and ISFR 2023 for all the State and UTs is given in Table 9.8. It reports that the tree green cover area under agroforestry has changed from 1,06,303.00 km² (ISFR 2013) to 1,27,590.05 km² (ISFR 2023) at the national level, i.e., there has been a net increase of 21,287.05 km² of tree green cover area in agroforestry. In percentage terms, it reveals that the tree green cover in agroforestry has increased by 20.02% during 2013-2023. Maharashtra has the highest increase of tree cover followed by Rajasthan and Uttar Pradesh.

Table 9.8 Decadal Change of Tree Green Cover in Agroforestry for State/UTs between 2013 to 2023

(km^2)

Sl. No.	State/UTs	Geographical Area	Tree Green Cover in Agroforestry (2013)	Tree Green Cover in Agroforestry (2023)	Change in Tree Green Cover in Agroforestry	Change (%)
1	Andhra Pradesh*	1,62,922.57	4,976.52	6,006.15	1,030.15	20.71
2	Arunachal Pradesh	83,743.22	2,610.00	3,080.94	470.94	18.04
3	Assam	78,438.00	3,922.00	4,262.68	340.68	8.69
4	Bihar	94,163.00	4,570.00	4,756.85	186.85	4.09
5	Chhattisgarh	1,35,192.00	4,535.00	5,646.12	1,111.12	24.50
6	Delhi	1,483.00	23.00	15.30	-7.70	-33.48
7	Goa	3,702.00	280.00	339.77	59.77	21.35
8	Gujarat**	1,96,244.00	6,340.00	7,485.49	1,145.49	18.07
9	Haryana	44,212.00	1,333.00	1,400.94	67.94	5.10
10	Himachal Pradesh	55,673.00	2,303.00	2,687.60	384.60	16.70
11	Jharkhand	79,716.00	3,358.00	4,227.47	869.47	25.89
12	Karnataka	1,91,791.00	6,090.00	7,875.45	1,785.45	29.32
13	Kerala	38,852.00	3,803.00	5,213.98	1,410.98	37.10
14	Madhya Pradesh	3,08,252.11	6,745.00	7,658.10	913.10	13.54
15	Maharashtra	3,07,713.00	11,806.00	14,494.99	2,688.99	22.78
16	Manipur	22,327.00	606.00	612.20	6.20	1.02
17	Meghalaya	22,429.00	1,876.00	2,361.14	485.14	25.86
18	Mizoram ##	21,081.00	464.00	712.44	248.44	53.54
19	Nagaland	16,579.00	1,037.00	1,353.28	316.28	30.50
20	Odisha	1,55,707.00	5,136.00	5,591.50	455.50	8.87
21	Punjab	50,362.00	1,635.00	1,725.24	90.24	5.52
22	Rajasthan	3,42,238.99	8,373.00	10,581.39	2,208.39	26.38
23	Sikkim	7,096.00	128.00	147.74	19.74	15.42
24	Tamil Nadu	1,30,060.00	4,590.00	5,370.90	780.90	17.01
25	Telangana*	1,12,122.44	3,248.48	3,923.10	674.62	20.77
26	Tripura	10,486.00	576.00	659.36	83.36	14.47
27	Uttar Pradesh	2,40,927.56	7,082.00	8,975.40	1,893.40	26.74
28	Uttarakhand	53,483.36	1,966.00	2,130.63	164.63	8.37
29	West Bengal	88,752.00	4,018.00	4,763.13	745.13	18.54
30	A & N Islands	8,249.00	49.00	73.40	24.40	49.80
31	Chandigarh	114.00	0.00	0.18	0.18	0.00
32	D & N Haveli and Daman & Diu #	602.00	65.00	41.47	-23.53	-36.20
33	Jammu & Kashmir	2,22,236.00	2,728.00	3,377.51	649.51	23.81
34	Ladakh		0.00	14.09	14.09	0.00
35	Lakshadweep #	29.63	16.00	5.35	-10.65	-66.56
36	Puducherry	490.00	16.00	18.77	2.77	17.31
	Total	**32,87,468.88**	**1,06,303.00**	**1,27,590.05**	**21,286.57**	**20.02**

**Agroforestry data of Telangana and Andhra Pradesh for ISFR 2013 is obtained by proportionately dividing the same, estimated for undivided Andhra Pradesh State.*

*** For the State of Gujarat, assessment of tree green cover under agroforestry published in ISFR 2013 has been re-estimated and revised estimates have been published in ISFR 2023*

#Tree Green Cover in agroforestry (2013) in Dadra & Nagar Haveli, Daman & Diu and Lakshadweep is based on less number of sample plots; whereas, the same for these UTs in 2023 has been assessed with greater number of sample plots.

RFA in Mizoram has changed from 16,717 km^2 in 2013 to 7,479 km^2 in 2023

Decadal Change of Growing Stock in Agroforestry 9.5

The decadal change of growing stock in agroforestry for all State and UTs is given in the Table 9.9. It is observed from the table that the growing stock in agroforestry has increased from 1,004.74 M m^3 in 2013 to 1,291.68 M m^3 in 2023, at the national level. It is also observed that there has been a net increase of 286.94 M m^3 of growing stock in agroforestry in the duration of last 10 years.

Maharashtra has highest increase in growing stock under agroforestry followed by Karnataka and Odisha.

Table 9.9 Decadal Change of Growing Stock in Agroforestry of State/UTs between 2013 to 2023

(M m^3)

Sl. No.	State/UTs	Geographical Area (Km^2)	Growing Stock (2013)	Growing Stock (2023)	Change in Growing Stock	Change (%)
1	Andhra Pradesh*	1,62,922.57	57.47	69.36	11.89	20.69
2	Arunachal Pradesh	83,743.22	16.66	20.60	3.94	23.65
3	Assam	78,438.00	31.81	30.68	-1.13	-3.55
4	Bihar	94,163.00	37.48	41.46	3.98	10.62
5	Chhattisgarh	1,35,192.00	64.75	82.49	17.74	27.40
6	Delhi	1,483.00	0.20	0.13	-0.07	-35.00
7	Goa	3,702.00	1.88	2.43	0.55	29.26
8	Gujarat**	1,96,244.00	63.94	78.87	14.93	23.35
9	Haryana	44,212.00	11.33	12.66	1.33	11.74
10	Himachal Pradesh	55,673.00	15.81	19.55	3.74	23.66
11	Jharkhand	79,716.00	47.94	65.63	17.69	36.90
12	Karnataka	1,91,791.00	69.82	98.31	28.49	40.80
13	Kerala	38,852.00	28.10	38.41	10.31	36.69
14	Madhya Pradesh	3,08,252.11	60.17	81.81	21.64	35.96
15	Maharashtra	3,07,713.00	98.95	136.45	37.50	37.90
16	Manipur	22,327.00	5.05	4.50	-0.55	-10.89
17	Meghalaya	22,429.00	15.66	18.60	2.94	18.77
18	Mizoram ##	21,081.00	3.83	6.21	2.38	62.14
19	Nagaland	16,579.00	8.66	12.00	3.34	38.57
20	Odisha	1,55,707.00	65.19	88.53	23.34	35.80
21	Punjab	50,362.00	13.73	16.77	3.04	22.14
22	Rajasthan	3,42,238.99	64.77	86.26	21.49	33.18
23	Sikkim	7,096.00	0.80	1.04	0.24	30.00
24	Tamil Nadu	1,30,060.00	47.39	61.18	13.79	29.10
25	Telangana*	1,12,122.44	34.82	42.02	7.20	20.68
26	Tripura	10,486.00	4.80	5.80	1.00	20.83
27	Uttar Pradesh	2,40,927.56	60.56	80.22	19.66	32.46
28	Uttarakhand	53,483.36	14.28	16.90	2.62	18.35
29	West Bengal	88,752.00	33.51	41.41	7.90	23.58
30	A & N Islands	8,249.00	0.50	0.90	0.40	80.00

Table 9.9 Decadal Change of Growing Stock in Agroforestry of State/UTs between 2013 to 2023

(M m³)

Sl. No.	State/UTs	Geographical Area (Km²)	Growing Stock (2013)	Growing Stock (2023)	Change in Growing Stock	Change (%)
31	Chandigarh	114.00	0.00	0.01	0.01	0.00
32	Dadra & Nagar Haveli, Daman & Diu	602.00	0.58	0.53	-0.05	-8.62
33	Jammu & Kashmir	2,22,236.00	24.09	29.59	5.50	22.83
34	Ladakh		0.00	0.12	0.12	0.00
35	Lakshadweep	29.63	0.04	0.04	0.00	0.00
36	Puducherry	490.00	0.17	0.21	0.04	23.53
	Total	**32,87,468.88**	**1,004.74**	**1,291.68**	**286.94**	**28.56**

**Growing Stock data of Telangana and Andhra Pradesh for ISFR 2013 is obtained by proportionately dividing the same, estimated for undivided Andhra Pradesh State.*

*** For the State of Gujarat, assessment of Growing Stock under agroforestry published in ISFR 2013 has been re-estimated and revised estimates have been published in ISFR 2023*

RFA in Mizoram has changed from 16,717 km² in 2013 to 7,479 km² in 2023

9.6 Decadal Change of Growing Stock in RFA

The decadal change in growing stock in RFA between the assessments ISFR 2013 and ISFR 2023 for all the State and UTs is given in Table 9.10. It reports that the growing stock in RFA has changed from 4,173.35 M m³ (ISFR 2013) to 4,478.90 M m³ (ISFR 2023) at the national level. There has been a net increase of 305.54 M m³ growing stock in RFA. In the percentage terms, it reveals that the growing stock in RFA has increased by 7.32 % during 2013-2023.

Table 9.10 Decadal Change of Growing Stock in RFA of State/UTs between 2013 to 2023

(M m³)

Sl. No.	State/UTs	Geographical Area (Km²)	Growing Stock (2013)	Growing Stock (2023)	Change in Growing Stock	Change (%)
1	Andhra Pradesh*	1,62,922.57	110.430	122.262	11.832	10.71
2	Arunachal Pradesh	83,743.22	439.510	457.833	18.323	4.17
3	Assam	78,438.00	151.904	120.274	-31.630	-20.82
4	Bihar	94,163.00	29.328	27.625	-1.703	-5.81
5	Chhattisgarh	1,35,192.00	347.106	398.541	51.435	14.82
6	Delhi	1,483.00	0.470	0.361	-0.109	-23.27
7	Goa	3,702.00	10.331	15.694	5.363	51.91
8	Gujarat	1,96,244.00	50.620	42.111	-8.509	-16.81
9	Haryana	44,212.00	5.388	4.161	-1.227	-22.78
10	Himachal Pradesh	55,673.00	317.295	303.936	-13.359	-4.21

Table 9.10 Decadal Change of Growing Stock in RFA of State/UTs between 2013 to 2023

(M m³)

Sl. No.	State/UTs	Geographical Area (Km²)	Growing Stock (2013)	Growing Stock (2023)	Change in Growing Stock	Change (%)
11	Jharkhand	79,716.00	103.734	108.030	4.296	4.14
12	Karnataka	1,91,791.00	294.631	297.018	2.387	0.81
13	Kerala	38,852.00	152.269	168.803	16.534	10.86
14	Madhya Pradesh	3,08,252.11	251.003	387.182	136.179	54.25
15	Maharashtra	3,07,713.00	208.495	227.069	18.574	8.91
16	Manipur	22,327.00	50.288	69.397	19.109	38.00
17	Meghalaya	22,429.00	39.882	40.041	0.159	0.40
18	Mizoram ##	21,081.00	59.359	37.670	-21.689	-36.54
19	Nagaland	16,579.00	37.076	35.973	-1.103	-2.98
20	Odisha	1,55,707.00	235.768	259.749	23.981	10.17
21	Punjab	50,362.00	13.018	11.074	-1.944	-14.94
22	Rajasthan	3,42,238.99	34.088	25.408	-8.680	-25.46
23	Sikkim	7,096.00	23.841	34.493	10.652	44.68
24	Tamil Nadu	1,30,060.00	116.042	98.383	-17.659	-15.22
25	Telangana*	1,12,122.44	85.390	85.473	0.083	0.10
26	Tripura	10,486.00	22.904	25.306	2.402	10.49
27	Uttar Pradesh	2,40,927.56	134.509	104.895	-29.614	-22.02
28	Uttarakhand	53,483.36	473.083	400.024	-73.059	-15.44
29	West Bengal	88,752.00	83.305	57.996	-25.309	-30.38
30	A & N Islands #	8,249.00	57.953	134.743	76.790	132.50
31	Chandigarh	114.00	0.262	0.180	-0.082	-31.22
32	Dadra & Nagar Haveli, Daman & Diu	602.00	1.807	0.659	-1.148	-63.51
33	Jammu & Kashmir	2,22,236.00	232.181	376.508	144.327	62.16
34	Ladakh$		-	-	-	-
35	Lakshadweep@	29.63	-	-	-	-
36	Puducherry	490.00	0.083	0.026	-0.057	-69.03
	Total	**32,87,468.88**	**4,173.353**	**4,478.896**	**305.543**	**7.32**

**Growing Stock (RFA) of Telangana and Andhra Pradesh for ISFR 2013 is obtained by proportionately dividing the same, estimated for undivided Andhra Pradesh State.*

#Growing Stock in RFA data (2013) in Andaman & Nicobar Islands is based on less number of sample plots; whereas, the same for this UT in 2023 has been assessed with greater number of sample plots.

RFA in Mizoram has changed from 16,717 km² in 2013 to 7,479 km² in 2023

$ RFA boundary was not made available and hence no data could be collected inside RFA.
@ There is no RFA existing in the UT of Lakshadweep.

In absolute terms, Jammu and Kashmir has the highest increase in growing stock, followed by Madhya Pradesh, and Andaman & Nicobar Islands. In terms of percentages, Andaman & Nicobar Islands is showing highest gain in Growing Stock in RFA (132.50 %), followed by Jammu & Kashmir (62.16 %), and Telangana (56.30 %).

9.7 Decadal Change of Growing Stock in TOF

The decadal change of growing stock in TOF between the assessment report published in ISFR 2013 and ISFR 2023 for all the State and UTs is given in the Table 9.11. As per the table, the growing stock in TOF for the year 2023 has been estimated 1,950.75 M m^3. The estimate of growing stock in TOF for the year 2013 is 1,484.68 M m^3. Therefore, there is an increase of 466.07 M m^3 in the growing stock in TOF in comparison with the ISFR 2013. In terms of percentage, it gives that the growing stock in TOF has increased by 31.39 % during the ten-year period from 2013 to 2023. However, the data is not exactly comparable as in the 2013 assessment, the trees with dbh 5 to 10 cm were not included. It may, However, be noted that in the current assessment, the total volume of trees with dbh 5 to 10 cm is only 2.42%.

Table 9.11 Decadal Change of Growing Stock in TOF of State/UTs between 2013 to 2023

(M m^3)

Sl. No.	State/UTs	Geographical Area (Km^2)	Growing Stock (2013)	Growing Stock (2023)	Change in Growing Stock	Change (%)
1	Andhra Pradesh*	1,62,922.57	64.45	80.04	15.59	24.19
2	Arunachal Pradesh	83,743.22	87.938	71.62	-16.32	-18.56
3	Assam	78,438.00	38.087	24.94	-13.15	-34.52
4	Bihar	94,163.00	41.66	43.97	2.32	5.54
5	Chhattisgarh	1,35,192.00	76.313	129.04	52.73	69.09
6	Delhi	1,483.00	1.047	2.11	1.06	101.53
7	Goa	3,702.00	3.909	5.27	1.36	34.82
8	Gujarat	1,96,244.00	109.012	88.27	-20.74	-19.03
9	Haryana	44,212.00	14.194	21.97	7.78	54.78
10	Himachal Pradesh	55,673.00	20.763	34.37	13.61	65.53
11	Jharkhand	79,716.00	55.945	87.35	31.41	56.14
12	Karnataka	1,91,791.00	89.531	137.62	48.09	53.71
13	Kerala	38,852.00	45.788	68.33	22.54	49.23
14	Madhya Pradesh	3,08,252.11	82.979	130.46	47.48	57.22
15	Maharashtra	3,07,713.00	139.704	213.93	74.23	53.13
16	Manipur	22,327.00	9.368	5.05	-4.32	-46.09
17	Meghalaya	22,429.00	20.047	23.36	3.31	16.53
18	Mizoram ##	21,081.00	8.165	44.34	36.18	443.05
19	Nagaland	16,579.00	11.89	19.06	7.17	60.30
20	Odisha	1,55,707.00	74.494	117.69	43.20	57.99
21	Punjab	50,362.00	17.061	20.32	3.26	19.10
22	Rajasthan	3,42,238.99	79.17	99.16	19.99	25.25
23	Sikkim	7,096.00	2.423	1.68	-0.74	-30.66
24	Tamil Nadu	1,30,060.00	62.139	93.69	31.55	50.77
25	Telangana*	1,12,122.44	37.70	49.84	12.14	32.22
26	Tripura	10,486.00	6.871	8.46	1.59	23.13
27	Uttar Pradesh	2,40,927.56	76.106	108.67	32.56	42.79

Table 9.11 Decadal Change of Growing Stock in TOF of State/UTs between 2013 to 2023

(M m³)

Sl. No.	State/UTs	Geographical Area (Km²)	Growing Stock (2013)	Growing Stock (2023)	Change in Growing Stock	Change (%)
28	Uttarakhand	53,483.36	19.336	20.05	0.71	3.69
29	West Bengal	88,752.00	41.737	44.32	2.58	6.19
30	Andaman & Nicobar Islands@	8,249.00	0.545	5.45	4.91	@
31	Chandigarh	114.00	0.082	0.33	0.25	302.44
32	Dadra & Nagar Haveli, Daman & Diu	602.00	0.824	0.66	-0.16	-19.90
33	Jammu & Kashmir	2,22,236.00	145.064	118.99	-26.07	-17.97
34	Ladakh			29.79	29.79	0.00
35	Lakshadweep	29.63	0.052	0.09	0.04	73.08
36	Puducherry	490.00	0.294	0.46	0.17	56.46
	Total	**32,87,468.88**	**1,484.684**	**1950.75**	**466.07**	**31.39**

Growing Stock (RFA) of Telangana and Andhra Pradesh for ISFR 2013 is obtained by proportionately dividing the same, estimated for undivided Andhra Pradesh State

RFA in Mizoram has changed from 16,717 km² in 2013 to 7,479 km² in 2023

@ There was no data collection in the UT of Andaman & Nicobar Islands to generate direct Growing Stock Estimate in 2013 and was predicted on the basis of East Coast estimates.

Maharashtra has the highest increase in growing stock in TOF, followed by Chhattisgarh, Karnataka and, Madhya Pradesh.

Photo: FSI Repository

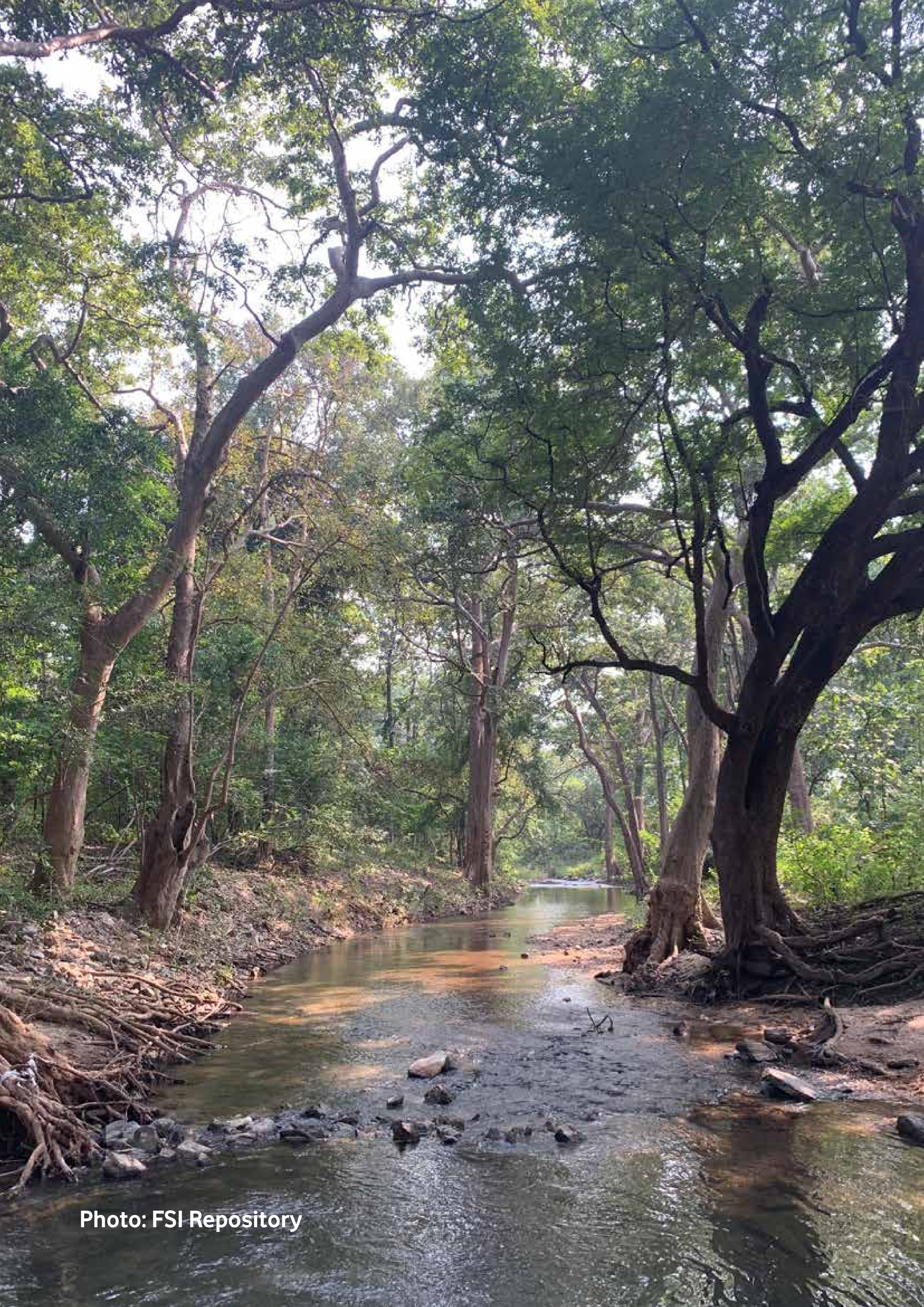


Photo: FSI Repository

Annexures

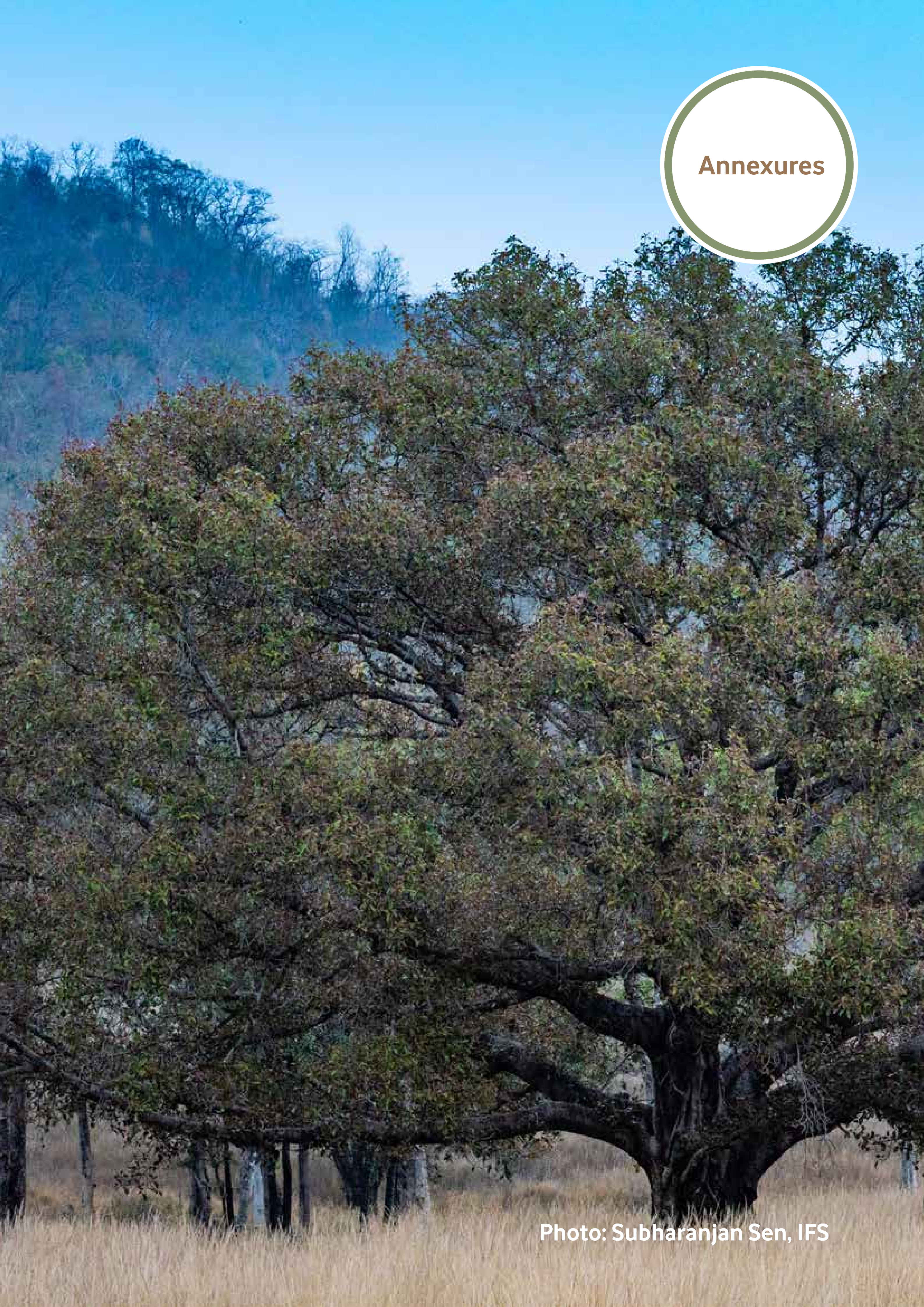


Photo: Subharanjan Sen, IFS

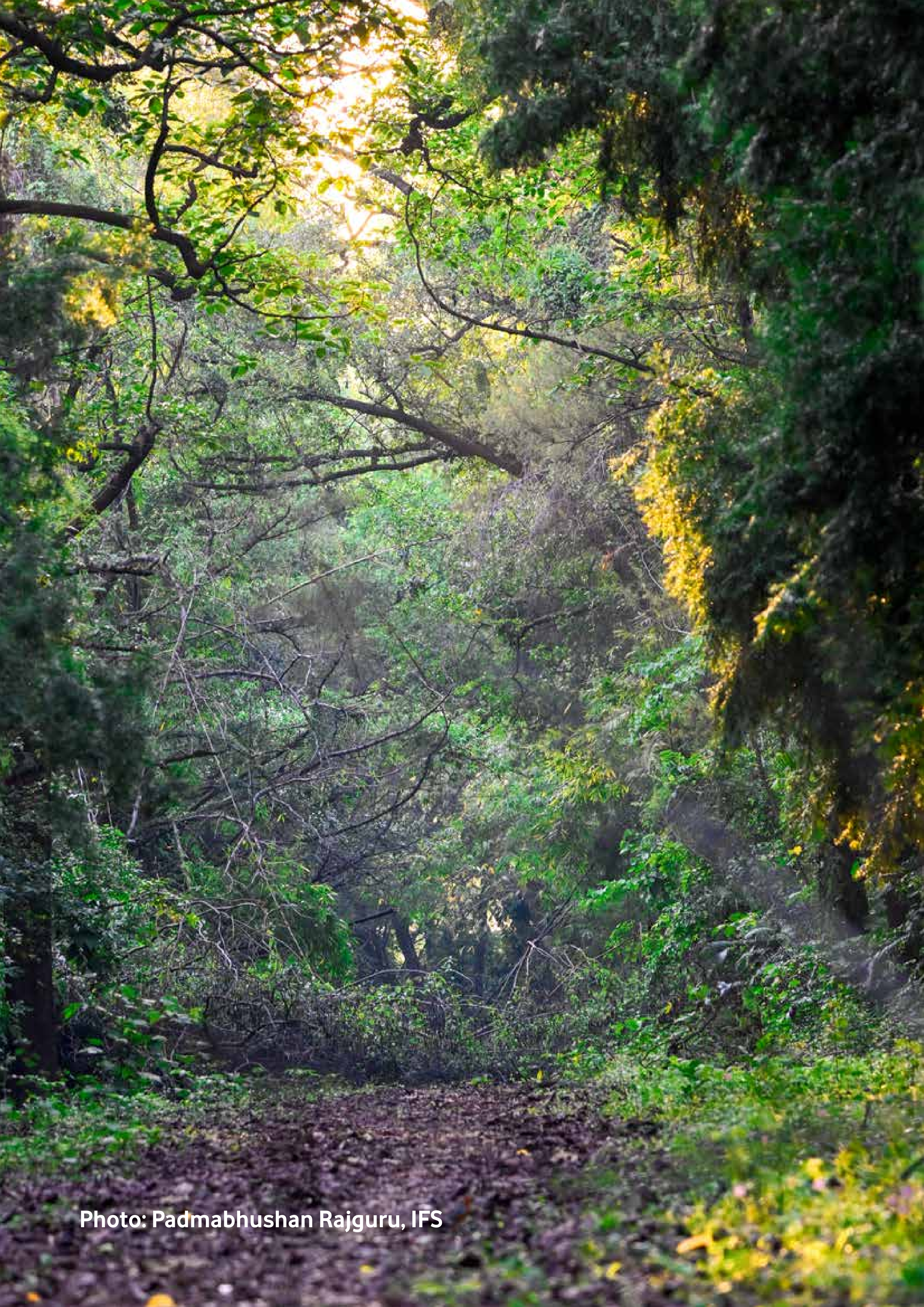


Photo: Padmabhushan Rajguru, IFS

ANNEXURE-I

Forest Cover in Different Altitude Zones

Forest Cover in Different Altitude Zones

Altitudinal Zone (m)	Digitized Boundary Area (SoI)	VDF	MDF	OF	Forest Cover (FC)	Percentage of Total FC	Percentage of Digitized Boundary Area (SoI)	Scrub
0-500	23,28,746.19	42,579.40	1,53,000.85	1,89,199.59	3,84,779.84	53.79	16.52	24,789.43
500-1000	5,41,650.58	26,068.45	93,446.80	77,166.63	1,96,681.88	27.49	36.31	14,692.05
1000-2000	1,17,157.28	15,451.03	34,787.77	24,346.80	74,585.60	10.43	63.66	2,407.03
2000-3000	56,464.63	14,544.72	17,688.81	7,629.42	39,862.95	5.57	70.60	278.18
3000-4000	59,376.05	3,570.27	7,893.51	5,914.78	17,378.56	2.43	29.27	839.37
Above 4000	1,84,074.15	288.33	855.54	909.91	2,053.78	0.29	1.12	616.58
Total	**32,87,468.88**	**1,02,502.20**	**3,07,673.28**	**3,05,167.13**	**7,15,342.61**	**100.00**	**21.76**	**43,622.64**

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

ANNEXURE-II

Forest Cover on Different Slope Classes

Forest Cover on Different Slope Classes

Slope (In degrees)	Digitized Boundary Area (SoI)	VDF	MDF	OF	Forest Cover (FC)	Percentage of Total FC	Percentage of Digitized Boundary Area (SoI)	Scrub
0^o-5^o	24,81,145.41	33,838.26	1,16,609.16	1,56,312.21	3,06,759.63	42.89	12.36	23,750.75
5^o-10^o	2,33,628.12	14,682.72	52,142.63	44,293.27	1,11,118.62	15.53	47.56	6,664.80
10^o-15^o	1,42,556.84	12,324.34	38,667.82	30,888.41	81,880.57	11.45	57.44	4,339.45
15^o-20^o	1,19,802.61	11,161.02	31,347.63	24,721.49	67,230.14	9.40	56.12	3,321.17
20^o-25^o	1,00,987.09	9,706.41	24,936.57	19,172.82	53,815.80	7.52	53.29	2,440.93
25^o-30^o	79,745.22	7,924.65	18,503.66	13,510.54	39,938.85	5.58	50.08	1,571.09
Above 30^o	1,29,603.59	12,864.80	25,465.81	16,268.39	54,599.00	7.63	42.13	1,534.45
Total	**32,87,468.88**	**1,02,502.20**	**3,07,673.28**	**3,05,167.13**	**7,15,342.61**	**100.00**	**21.76**	**43,622.64**

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

ANNEXURE-III

State/UTs- wise number of forest fire detected by Forest Survey of India using SNPP-VIIRS sensors since 2017. (This includes large, continuous and repeated forest fires)

Sl. No	State/UTs	SNPP-VIIRS Detections							
		Jan 2017 to June 2017	Jan 2018 to June 2018	Nov 2018 to Jun 2019	Nov 2019 to Jun 2020	Nov 2020 to Jun 2021	Nov 2021 to Jun 2022	Nov 2022 to Jun 2023	Nov 2023 to Jun 2024
1	Andhra Pradesh	12,150	11,028	15,746	9,996	19,328	14,138	19,367	18,174
2	Arunachal Pradesh	2,701	1,888	2,617	1,786	3,914	3,449	2,447	2,053
3	Assam	7,705	5,563	5,935	8,924	10,718	8,158	9,830	7,639
4	Bihar	2,448	2,305	2,450	614	5,179	3,024	3,793	2,763
5	Chhattisgarh	41,756	35,344	25,750	6,360	38,106	25,792	20,306	18,950
6	Delhi	22	22	20	21	14	3	7	16
7	Goa	162	122	140	47	45	20	147	36
8	Gujarat	3,933	5,431	2,885	2,770	3,803	2,769	2,342	3,182
9	Haryana	570	141	135	68	152	135	82	166
10	Himachal Pradesh	1,748	6,112	1,446	536	4,110	5,280	704	10,136
11	Jharkhand	13,718	9,913	6,221	2,613	21,713	9,419	11,923	7,525
12	Karnataka	8,118	5,772	8,078	4,232	5,784	4,973	13,074	5,500
13	Kerala	2,352	908	1,162	864	296	504	1,550	1,110
14	Madhya Pradesh	37,193	37,803	22,108	9,537	47,795	32,728	17,142	15,878
15	Maharashtra	25,729	33,790	26,939	14,018	34,025	22,052	16,119	16,008
16	Manipur	4,580	6,222	7,384	8,800	10,457	5,544	10,127	4,498
17	Meghalaya	6,402	6,469	5,797	6,762	7,658	6,322	6,604	4,319
18	Mizoram	6,215	7,422	7,597	7,361	12,846	8,734	5,798	6,627
19	Nagaland	2,836	3,165	2,898	2,905	4,975	3,471	3,882	2,609
20	Odisha	33,215	32,399	19,159	10,602	51,968	22,014	33,461	20,973
21	Punjab	964	1,494	214	153	635	428	119	605
22	Rajasthan	2,048	2,955	3,025	3,461	3,402	2,703	2,059	4,352
23	Sikkim	64	11	64	47	63	26	49	101
24	Tamil Nadu	1,699	1,405	4,402	1,368	1,220	1,035	1,998	3,380
25	Telangana	12,927	13,721	15,262	12,132	18,237	13,737	13,117	13,479
26	Tripura	2,049	3,231	3,083	4,369	5,015	2,609	4,332	2,089
27	Uttar Pradesh	5,523	6,347	4,428	1,548	8,608	5,428	3,235	4,424
28	Uttarakhand	3,623	11,808	12,965	759	21,487	12,985	5,351	21,033
29	West Bengal	2,321	322	1,653	1,320	3,287	1,520	3,096	2,020
30	A & N Islands	72	23	37	39	16	33	20	21
31	Chandigarh	0	2	0	2	0	0	1	1
32	Dadra & Nagar Haveli and Daman & Diu	4	7	21	21	34	18	16	16
33	Jammu & Kashmir	927	5,324	661	438	1,098	4,255	131	3,829
34	Ladakh*						27	20	32
35	Lakshadweep	0	0	0	0	0	0	0	0
36	Puducherry	9	11	4	0	1	0	0	0
	Total	**2,45,783**	**2,58,480**	**2,10,286**	**1,24,473**	**3,45,989**	**2,23,333**	**2,12,249**	**2,03,544**

** The number of forest fire detection in Ladakh are combined with the number of forest fire detections in Jammu & Kashmir for the fire season Jan. 2017 - Jun 2017 to Nov.2020 - June 2021*

ANNEXURE-IV

State-wise SMS subscriptions at different administrative levels								
State/UTs	State	District	Circle	Division	Range	Block	Beat	Total
Andhra Pradesh	101	9,667	723	2,178	1,692	1,475	5,883	**21,719**
Arunachal Pradesh	16	13	0	0	0	0	0	**29**
Assam	25	22	0	0	0	0	0	**47**
Bihar	59	28	19	93	293	18	236	**746**
Chhattisgarh	123	86	91	572	3,424	90	2,923	**7,309**
Delhi	29	7	0	0	0	0	0	**36**
Goa	493	9	4	8	16	0	0	**530**
Gujarat	144	169	42	373	667	718	1,252	**3,365**
Haryana	55	35	6	98	174	110	153	**631**
Himachal Pradesh	286	479	145	5,194	33,758	7,084	19,928	**66,874**
Jharkhand	818	381	158	6,550	8,052	706	16,036	**32,701**
Karnataka	217	72	225	812	2,476	244	748	**4,794**
Kerala	397	317	348	1,208	4,022	6	3	**6,301**
Madhya Pradesh	2,854	963	780	2,943	22,075	1,748	57,163	**88,526**
Maharashtra	394	150	333	1,142	2,475	1,820	3,357	**9,671**
Manipur	195	604	34	6,931	1,424	154	72	**9,414**
Meghalaya	14	0	2	19	10	45	0	**90**
Mizoram	35	12	1	18	106	0	2	**174**
Nagaland	15	13	0	0	0	0	0	**28**
Odisha	168	210	119	2,220	1,511	726	235	**5,189**
Punjab	67	21	9	269	479	340	1,198	**2,383**
Rajasthan	240	677	60	563	2,485	28	4	**4,057**
Sikkim	30	319	0	1	4	1	2	**357**
Tamil Nadu	604	431	697	1,360	1,387	138	630	**5,247**
Telangana	25	481	144	995	2,682	2,321	11,532	**18,180**
Tripura	39	28	2	79	313	3	285	**749**
Uttar Pradesh	176	1,748	52	266	424	150	159	**2,975**
Uttarakhand	307	246	130	758	4,690	306	3,249	**9,686**
West Bengal	63	46	20	256	296	2	653	**1,336**
A & N Islands	231	199	0	0	0	0	0	**430**
Chandigarh	4	2	0	0	0	0	0	**6**
Dadra & Nagar Haveli	21	5	0	0	0	0	0	**26**
Daman & Diu	8	4	0	0	0	0	0	**12**
Jammu & Kashmir	85	593	110	376	2,217	15	12	**3,408**
Ladakh	4	87	0	0	0	0	0	**91**
Lakshadweep	11	0	0	0	0	0	0	**11**
Puducherry	7	2	0	0	0	0	0	**9**
Total	**8,360**	**18,126**	**4,254**	**35,282**	**97,152**	**18,248**	**125,715**	**3,07,137**

ANNEXURE-V

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
1	Abohar	Sanctuary	Punjab	0
2	Abubshehar	Community Reserve	Haryana	0
3	Achanakmar	Sanctuary	Chhattisgarh	67
4	Adichunchunagiri Peacock	Sanctuary	Karnataka	0
5	Amba Barwa	Sanctuary	Maharashtra	1
6	Amchang	Sanctuary	Assam	18
7	Andhari	Sanctuary	Maharashtra	1
8	Aner Dam	Sanctuary	Maharashtra	6
9	Arabithittu	Sanctuary	Karnataka	0
10	Aralam	Sanctuary	Kerala	3
11	Arial Island	Sanctuary	Andaman & Nicobar Islands	0
12	Aruakgre	Community Reserve	Meghalaya	0
13	Aruakgre	Community Reserve	Meghalaya	0
14	Asan Wetland	Conservation Reserve	Uttarakhand	0
15	Askot Musk Deer	Sanctuary	Uttarakhand	203
16	Asola Bhati	Sanctuary	Delhi	2
17	Attiveri	Sanctuary	Karnataka	0
18	Badalkhol	Sanctuary	Chhattisgarh	12
19	Badarma	Sanctuary	Odisha	21
20	Bagdara	Sanctuary	Madhya Pradesh	1
21	Bagmara Pitcher Pant	Sanctuary	Meghalaya	0
22	Baisipalli	Sanctuary	Odisha	56
23	Bakhira	Sanctuary	Uttar Pradesh	0
24	Baladingre	Community Reserve	Meghalaya	0
25	Balaram Ambaji	Sanctuary	Gujarat	28
26	Ballavpur	Sanctuary	West Bengal	0
27	Balsri Adingi	Community Reserve	Meghalaya	0
28	Baltas-Thajwas	Sanctuary	Jammu & Kashmir	0
29	Balukhand Konark	Sanctuary	Odisha	0
30	Bamboo Island	Sanctuary	Andaman & Nicobar Islands	0
31	Bandarigre	Community Reserve	Meghalaya	0
32	Bandh Baratha	Sanctuary	Rajasthan	1
33	Bandli	Sanctuary	Himachal Pradesh	39
34	Bankapur Peacock	Conservation Reserve	Karnataka	0
35	Barail	Sanctuary	Assam	15
36	Barda	Sanctuary	Gujarat	1
37	Barela Jheel Salim Ali	Sanctuary	Bihar	0
38	Barnawapara	Sanctuary	Chhattisgarh	38

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
39	Barren Island	Sanctuary	Andaman & Nicobar Islands	0
40	Barsey Rhododendron	Sanctuary	Sikkim	0
41	Bassi	Sanctuary	Rajasthan	2
42	Basur Amruth Mahal Kaval	Conservation Reserve	Karnataka	0
43	Battimalv Island	Sanctuary	Andaman & Nicobar Islands	0
44	Bedthi	Conservation Reserve	Karnataka	8
45	Belle Island	Sanctuary	Andaman & Nicobar Islands	0
46	Bennett Island	Sanctuary	Andaman & Nicobar Islands	0
47	Bethuadahari	Sanctuary	West Bengal	0
48	Bhadra	Sanctuary	Karnataka	2
49	Bhagwan Mahavir	Sanctuary	Goa	2
50	Bhairamgarh	Sanctuary	Chhattisgarh	34
51	Bhamragarh	Sanctuary	Maharashtra	87
52	Bhensrodgarh	Sanctuary	Rajasthan	8
53	Bherjan-Borajan-Padumoni	Sanctuary	Assam	0
54	Bhimashankar	Sanctuary	Maharashtra	14
55	Bhimbandh	Sanctuary	Bihar	537
56	Bhimgad	Sanctuary	Karnataka	5
57	Bhindawas	Sanctuary	Haryana	1
58	Bhitarkanika	Sanctuary	Odisha	0
59	Bhoramdev	Sanctuary	Chhattisgarh	14
60	Bibhutibhusan	Sanctuary	West Bengal	0
61	Biligiri Rangaswami Temple	Sanctuary	Karnataka	37
62	Bingham Island	Sanctuary	Andaman & Nicobar Islands	0
63	Binsar	Sanctuary	Uttarakhand	32
64	Bir Aishvan	Sanctuary	Punjab	5
65	Bir Bara Ban	Conservation Reserve	Haryana	0
66	Bir Bhadson	Sanctuary	Punjab	1
67	Bir Bunerheri	Sanctuary	Punjab	1
68	Bir Dosanjh	Sanctuary	Punjab	1
69	Bir Gurdialpura	Sanctuary	Punjab	1
70	Bir Mehaswala	Sanctuary	Punjab	0
71	Bir Motibagh	Sanctuary	Punjab	0
72	Bir Shikargarh	Sanctuary	Haryana	1
73	Bisalpur	Conservation Reserve	Rajasthan	0
74	Blister Island	Sanctuary	Andaman & Nicobar Islands	0
75	Bluff Island	Sanctuary	Andaman & Nicobar Islands	0
76	Bondla	Sanctuary	Goa	0
77	Bondoville Island	Sanctuary	Andaman & Nicobar Islands	0
78	Bor	Sanctuary	Maharashtra	1

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
79	Bori	Sanctuary	Madhya Pradesh	6
80	Brahmagiri	Sanctuary	Karnataka	0
81	Brush Island	Sanctuary	Andaman & Nicobar Islands	0
82	Buchanan Island	Sanctuary	Andaman & Nicobar Islands	0
83	Burachapori	Sanctuary	Assam	4
84	Buxa	Sanctuary	West Bengal	67
85	Cauvery	Sanctuary	Karnataka	4
86	Chail	Sanctuary	Himachal Pradesh	119
87	Chakrasila	Sanctuary	Assam	3
88	Chandaka	Sanctuary	Odisha	36
89	Chandigre	Community Reserve	Meghalaya	1
90	Chandra Sekhar Bird	Sanctuary	Uttar Pradesh	0
91	Chandraprabha	Sanctuary	Uttar Pradesh	1
92	Chandratal	Sanctuary	Himachal Pradesh	0
93	Chanel Island	Sanctuary	Andaman & Nicobar Islands	0
94	Changthang	Sanctuary	Ladakh	0
95	Chaprala	Sanctuary	Maharashtra	0
96	Chapramari	Sanctuary	West Bengal	1
97	Chenggni	Community Reserve	Meghalaya	0
98	Chhilchila	Sanctuary	Haryana	0
99	Chilka (Nalaban)	Sanctuary	Odisha	0
100	Chimanpara	Community Reserve	Meghalaya	0
101	Chimitap	Community Reserve	Meghalaya	0
102	Chimmony	Sanctuary	Kerala	0
103	Chincholi	Sanctuary	Karnataka	5
104	Chinnar	Sanctuary	Kerala	28
105	Chintamani Kar Bird Sanctuary	Sanctuary	West Bengal	2
106	Chitrangudi	Sanctuary	Tamil Nadu	0
107	Chorao Island	Sanctuary	Goa	0
108	Chulannur	Sanctuary	Kerala	0
109	Churdhar	Sanctuary	Himachal Pradesh	4
110	Cinque Islands	Sanctuary	Andaman & Nicobar Islands	0
111	City Bird	Sanctuary	Chandigarh	0
112	Clyde Island	Sanctuary	Andaman & Nicobar Islands	0
113	Cone Island	Sanctuary	Andaman & Nicobar Islands	0
114	Coringa	Sanctuary	Andhra Pradesh	0
115	Cotigao	Sanctuary	Goa	0
116	Curlew (B.P.) Island	Sanctuary	Andaman & Nicobar Islands	0
117	Curlew Island	Sanctuary	Andaman & Nicobar Islands	0
118	Cuthbert Bay	Sanctuary	Andaman & Nicobar Islands	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
119	D' Ering Memorial (Lali)	Sanctuary	Arunachal Pradesh	7
120	Dadra & Nagar Haveli	Sanctuary	Dadra & Nagar Haveli	5
121	Dallenggittim	Community Reserve	Meghalaya	0
122	Dalma	Sanctuary	Jharkhand	90
123	Dambuk Attong	Community Reserve	Meghalaya	0
124	Dambuk Jongkol	Community Reserve	Meghalaya	0
125	Dampa	Sanctuary	Mizoram	13
126	Dandeli	Sanctuary	Karnataka	55
127	Dangkipara	Community Reserve	Meghalaya	0
128	Daranghati	Sanctuary	Himachal Pradesh	2
129	Daribokgre	Community Reserve	Meghalaya	0
130	Darlaghat	Conservation Reserve	Himachal Pradesh	5
131	Daroji Bear	Sanctuary	Karnataka	0
132	Darrah	Sanctuary	Rajasthan	1
133	Debrigarh	Sanctuary	Odisha	18
134	Defence Island	Sanctuary	Andaman & Nicobar Islands	0
135	Deulgaon-Rehkuri	Sanctuary	Maharashtra	0
136	Dhauladhar	Sanctuary	Himachal Pradesh	11
137	Dhyanganga	Sanctuary	Maharashtra	2
138	Dibang	Sanctuary	Arunachal Pradesh	14
139	Dihing Patkai	Sanctuary	Assam	0
140	Dot Island	Sanctuary	Andaman & Nicobar Islands	0
141	Dottrell Island	Sanctuary	Andaman & Nicobar Islands	0
142	Dumitdigre	Community Reserve	Meghalaya	0
143	Duncan Island	Sanctuary	Andaman & Nicobar Islands	0
144	Dura Kalakgre	Community Reserve	Meghalaya	0
145	Eagle Nest	Sanctuary	Arunachal Pradesh	0
146	East Island	Sanctuary	Andaman & Nicobar Islands	0
147	East Karbi Anglong	Sanctuary	Assam	15
148	East of Inglis Island	Sanctuary	Andaman & Nicobar Islands	0
149	Egg Island	Sanctuary	Andaman & Nicobar Islands	0
150	Elat Island	Sanctuary	Andaman & Nicobar Islands	0
151	Eman Asakgre	Community Reserve	Meghalaya	0
152	Entrance Island	Sanctuary	Andaman & Nicobar Islands	0
153	Eturnagaram	Sanctuary	Telangana	732
154	Fakim	Sanctuary	Nagaland	0
155	Fambong Lho	Sanctuary	Sikkim	0
156	Fudam	Sanctuary	Daman & Diu	0
157	Gaga Great Indian Bustard	Sanctuary	Gujarat	0
158	Gahirmatha	Sanctuary	Odisha	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
159	Galathea Bay	Sanctuary	Andaman & Nicobar Islands	0
160	Gamgul Siahbehi	Sanctuary	Himachal Pradesh	6
161	Gander Island	Sanctuary	Andaman & Nicobar Islands	0
162	Gandhi Sagar	Sanctuary	Madhya Pradesh	46
163	Garampani	Sanctuary	Assam	0
164	Gautala	Sanctuary	Maharashtra	14
165	Gautam Budha	Sanctuary	Jharkhand	37
166	Ghataprabha	Sanctuary	Karnataka	0
167	Ghatigaon	Sanctuary	Madhya Pradesh	14
168	Gir	Sanctuary	Gujarat	107
169	Girjan Island	Sanctuary	Andaman & Nicobar Islands	0
170	Girnar	Sanctuary	Gujarat	1
171	Gokagre	Community Reserve	Meghalaya	0
172	Gomardha	Sanctuary	Chhattisgarh	17
173	Goose Island	Sanctuary	Andaman & Nicobar Islands	0
174	Govind Pashu Vihar	Sanctuary	Uttarakhand	148
175	Great Indian Bustard	Sanctuary	Maharashtra	32
176	Gudavi Bird Sanctuary	Sanctuary	Karnataka	0
177	Gudekote Sloth Bear	Sanctuary	Karnataka	2
178	Gulmarg	Sanctuary	Jammu & Kashmir	0
179	Gumti	Sanctuary	Tripura	13
180	Gundla Brahmeswaram	Sanctuary	Andhra Pradesh	1,847
181	Hadgarh	Sanctuary	Odisha	0
182	Haliday Island	Sanctuary	West Bengal	0
183	Halwa Ambeng	Community Reserve	Meghalaya	0
184	Harike Lake	Sanctuary	Punjab	0
185	Hastinapur	Sanctuary	Uttar Pradesh	32
186	Hazaribagh	Sanctuary	Jharkhand	45
187	Hingolgarh	Sanctuary	Gujarat	0
188	Hirpora	Sanctuary	Jammu & Kashmir	0
189	Hollongapar Gibbon	Sanctuary	Assam	0
190	Hornbill	Conservation Reserve	Karnataka	27
191	Hump Island	Sanctuary	Andaman & Nicobar Islands	0
192	Idukki	Sanctuary	Kerala	44
193	Indira Gandhi (Annamalai)	Sanctuary	Tamil Nadu	43
194	Interview Island	Sanctuary	Andaman & Nicobar Islands	0
195	Itanagar	Sanctuary	Arunachal Pradesh	3
196	Jai Prakash Narayan Bird	Sanctuary	Uttar Pradesh	0
197	Jaikwadi	Sanctuary	Maharashtra	0
198	Jaisamand	Sanctuary	Rajasthan	14

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
199	Jaksongram	Community Reserve	Meghalaya	0
200	Jambughoda	Sanctuary	Gujarat	3
201	James Island	Sanctuary	Andaman & Nicobar Islands	0
202	Jamwa Ramgarh	Sanctuary	Rajasthan	0
203	Jasrota	Sanctuary	Jammu & Kashmir	0
204	Jawahar Sagar	Sanctuary	Rajasthan	0
205	Jawai Bandh Leopard	Conservation Reserve	Rajasthan	0
206	Jayamangali Blackbuck	Conservation Reserve	Karnataka	0
207	Jessore	Sanctuary	Gujarat	6
208	Jhajjar Bacholi	Sanctuary	Punjab	3
209	Jhilmi Jheel	Conservation Reserve	Uttarakhand	0
210	Jirang	Community Reserve	Meghalaya	1
211	Jor Beed Gadwala Bikaner	Conservation Reserve	Rajasthan	0
212	Jorepokhri Salamander	Sanctuary	West Bengal	0
213	Jungle Island	Sanctuary	Andaman & Nicobar Islands	0
214	Ka Khlaw Umthalong	Community Reserve	Meghalaya	0
215	Ka Khloo Blai Lyngdoh Sein Raij Mynso	Community Reserve	Meghalaya	0
216	Ka Khloo Langdoh Kur Pyrtuh	Community Reserve	Meghalaya	0
217	Ka Khloo Pohblai Mooshutia	Community Reserve	Meghalaya	0
218	Ka Khloo Thangbru Sula Lynter Sein Raij Mynso	Community Reserve	Meghalaya	0
219	Ka Khloo Thangbru Umsymphu	Community Reserve	Meghalaya	0
220	Ka Krem Labit Umkyrpong	Community Reserve	Meghalaya	0
221	Ka Law Lyngdoh	Community Reserve	Meghalaya	0
222	Ka Lum Luwe	Community Reserve	Meghalaya	0
223	Ka Wah Umpatho	Community Reserve	Meghalaya	0
224	Kachchh Desert	Sanctuary	Gujarat	39
225	Kadalundi Vallikkunnu	Community Reserve	Kerala	0
226	Kaimur	Sanctuary	Uttar Pradesh	2
227	Kaimur	Sanctuary	Bihar	255
228	Kais	Sanctuary	Himachal Pradesh	1
229	Kalakad	Sanctuary	Tamil Nadu	0
230	Kalatop-Khajjair	Sanctuary	Himachal Pradesh	7
231	Kalesar	Sanctuary	Haryana	16
232	Kalsubai	Sanctuary	Maharashtra	29
233	Kambalkonda	Sanctuary	Andhra Pradesh	1
234	Kamlang	Sanctuary	Arunachal Pradesh	2
235	Kanawar	Sanctuary	Himachal Pradesh	5
236	Kane	Sanctuary	Arunachal Pradesh	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
237	Kanwarjheel	Sanctuary	Bihar	0
238	Kanyakumari	Sanctuary	Tamil Nadu	118
239	Kapilash	Sanctuary	Odisha	13
240	Karaivetti	Sanctuary	Tamil Nadu	0
241	Karakoram	Sanctuary	Ladakh	0
242	Karanja Sohal	Sanctuary	Maharashtra	0
243	Karera	Sanctuary	Madhya Pradesh	0
244	Karlapat	Sanctuary	Odisha	99
245	Karnala	Sanctuary	Maharashtra	0
246	Katarniyaghat	Sanctuary	Uttar Pradesh	201
247	Katepurna	Sanctuary	Maharashtra	0
248	Kathlaur Kushlin	Sanctuary	Punjab	0
249	Kawal	Sanctuary	Telangana	665
250	Kedarnath	Sanctuary	Uttarakhand	60
251	Kela Devi	Sanctuary	Rajasthan	3
252	Ken Gharial	Sanctuary	Madhya Pradesh	0
253	Kesarbagh	Sanctuary	Rajasthan	0
254	Keshopur Chhamb	Community Reserve	Punjab	0
255	Khalasuni	Sanctuary	Odisha	50
256	Khaparwas	Sanctuary	Haryana	0
257	Khawnglung	Sanctuary	Mizoram	0
258	Kheoni	Sanctuary	Madhya Pradesh	32
259	Khijadia	Sanctuary	Gujarat	0
260	Khloo Amrawan	Community Reserve	Meghalaya	0
261	Khloo Blai Chyrmang Sein Raij Kongwasan Chyrmang	Community Reserve	Meghalaya	0
262	Khloo Blai Ka Raij U Langdohlonglang	Community Reserve	Meghalaya	0
263	Khloo Blai Sein Raij Tuber	Community Reserve	Meghalaya	0
264	Khokhan	Sanctuary	Himachal Pradesh	7
265	Kibber	Sanctuary	Himachal Pradesh	0
266	Kinnerasani	Sanctuary	Telangana	394
267	Kishanpur	Sanctuary	Uttar Pradesh	75
268	Kitam	Sanctuary	Sikkim	1
269	Kitmadamgre	Community Reserve	Meghalaya	0
270	Koderma	Sanctuary	Jharkhand	73
271	Kokkare Bellur	Community Reserve	Karnataka	0
272	Kolleru	Sanctuary	Andhra Pradesh	0
273	Koonthankulam-Kadankulam	Sanctuary	Tamil Nadu	0
274	Kothagarh	Sanctuary	Odisha	373
275	Kottiyoor	Sanctuary	Kerala	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
276	Koundinya	Sanctuary	Andhra Pradesh	338
277	Koyna	Sanctuary	Maharashtra	21
278	Kpoh Eijah	Community Reserve	Meghalaya	0
279	Krishna	Sanctuary	Andhra Pradesh	2
280	Kugti	Sanctuary	Himachal Pradesh	0
281	Kuldiha	Sanctuary	Odisha	0
282	Kumbhalgarh	Sanctuary	Rajasthan	28
283	Kuno	Sanctuary	Madhya Pradesh	37
284	Kurinjimala	Sanctuary	Kerala	94
285	Kusheshwar Asthan	Sanctuary	Bihar	0
286	Kwangtung Island	Sanctuary	Andaman & Nicobar Islands	0
287	Kyd Island	Sanctuary	Andaman & Nicobar Islands	0
288	Kyongnosla Alpine	Sanctuary	Sikkim	0
289	Lacchipora	Sanctuary	Jammu & Kashmir	8
290	Lakh Bahosi	Sanctuary	Uttar Pradesh	0
291	Lakhari Valley	Sanctuary	Odisha	43
292	Lala Great Indian Bustard	Sanctuary	Gujarat	0
293	Lalwan	Community Reserve	Punjab	0
294	Landfall Island	Sanctuary	Andaman & Nicobar Islands	0
295	Lanja Madugu Sivaram	Sanctuary	Telangana	6
296	Latouche Island	Sanctuary	Andaman & Nicobar Islands	0
297	Lawalong	Sanctuary	Jharkhand	23
298	Lawbah	Community Reserve	Meghalaya	0
299	Lawkhowa	Sanctuary	Assam	1
300	Lengteng	Sanctuary	Mizoram	4
301	Limber	Sanctuary	Jammu & Kashmir	5
302	Lippa Asrang	Sanctuary	Himachal Pradesh	0
303	Lohabarrack	Sanctuary	Andaman & Nicobar Islands	0
304	Lonar	Sanctuary	Maharashtra	1
305	Lothian Island	Sanctuary	West Bengal	0
306	Lotnagar	Community Reserve	Meghalaya	0
307	Lum Jusong	Community Reserve	Meghalaya	1
308	Lumkohkriah	Community Reserve	Meghalaya	0
309	Madei	Sanctuary	Goa	0
310	Maenam	Sanctuary	Sikkim	0
311	Mahananda	Sanctuary	West Bengal	35
312	Mahauaduar	Sanctuary	Jharkhand	64
313	Mahavir Swami	Sanctuary	Uttar Pradesh	0
314	Majathal	Sanctuary	Himachal Pradesh	132
315	Malabar	Sanctuary	Kerala	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
316	Malai Mahadeshwara	Sanctuary	Karnataka	6
317	Malvan Marine	Sanctuary	Maharashtra	0
318	Manali	Sanctuary	Himachal Pradesh	1
319	Mandalgre	Community Reserve	Meghalaya	0
320	Mangalavanam Bird	Sanctuary	Kerala	0
321	Mangrove Island	Sanctuary	Andaman & Nicobar Islands	0
322	Manjira	Sanctuary	Telangana	0
323	Marat Longri	Sanctuary	Assam	88
324	Marine	Sanctuary	Gujarat	0
325	Mask Island	Sanctuary	Andaman & Nicobar Islands	0
326	Matchirampat	Community Reserve	Meghalaya	0
327	Mayo Island	Sanctuary	Andaman & Nicobar Islands	0
328	Mayureswar Supe	Sanctuary	Maharashtra	0
329	Megamalai	Sanctuary	Tamil Nadu	3
330	Megapode Island	Sanctuary	Andaman & Nicobar Islands	0
331	Mehao	Sanctuary	Arunachal Pradesh	5
332	Melasalvanoor-Keelaselvanoor	Sanctuary	Tamil Nadu	0
333	Melghat	Sanctuary	Maharashtra	18
334	Melkote Temple	Sanctuary	Karnataka	0
335	Miewsyiar	Community Reserve	Meghalaya	0
336	Mikadogre	Community Reserve	Meghalaya	0
337	Mitiyala	Sanctuary	Gujarat	0
338	Mongalgre	Community Reserve	Meghalaya	0
339	Montogemery Island	Sanctuary	Andaman & Nicobar Islands	0
340	Mookambika	Sanctuary	Karnataka	2
341	Morni Hills	Sanctuary	Haryana	0
342	Mount Abu	Sanctuary	Rajasthan	6
343	Mudumalai	Sanctuary	Tamil Nadu	6
344	Mundanthurai	Sanctuary	Tamil Nadu	0
345	Mussoorie	Sanctuary	Uttarakhand	5
346	Nagarjunasagar Srisailam	Sanctuary	Andhra Pradesh	2,361
347	Nagi Dam	Sanctuary	Bihar	0
348	Nagzira	Sanctuary	Maharashtra	0
349	Nahar	Sanctuary	Haryana	0
350	Nahargarh	Sanctuary	Rajasthan	0
351	Naigaon Peacock	Sanctuary	Maharashtra	2
352	Naina Devi Himalayan Bird	Conservation Reserve	Uttarakhand	200
353	Nakti Dam	Sanctuary	Bihar	0
354	Nal Sarovar	Sanctuary	Gujarat	0
355	Nambor	Sanctuary	Assam	2

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
356	Nambor-Doigurung	Sanctuary	Assam	0
357	Nandankanan	Sanctuary	Odisha	0
358	Nandhaur	Sanctuary	Uttarakhand	388
359	Nandni	Sanctuary	Jammu & Kashmir	26
360	Nandur Madhameshwar	Sanctuary	Maharashtra	0
361	Narayan Sarovar	Sanctuary	Gujarat	7
362	Narcondam Island	Sanctuary	Andaman & Nicobar Islands	0
363	Nargu	Sanctuary	Himachal Pradesh	26
364	Narnala Bird	Sanctuary	Maharashtra	0
365	Narpuh	Sanctuary	Meghalaya	1
366	Narsingarh	Sanctuary	Madhya Pradesh	0
367	National Chambal	Sanctuary	Rajasthan	4
368	National Chambal	Sanctuary	Madhya Pradesh	2
369	National Chambal	Sanctuary	Uttar Pradesh	20
370	Nawegaon	Sanctuary	Maharashtra	4
371	Nellapattu	Sanctuary	Andhra Pradesh	0
372	Netravali	Sanctuary	Goa	1
373	Neyyar	Sanctuary	Kerala	3
374	Ngengpui	Sanctuary	Mizoram	0
375	Nitwatgre	Community Reserve	Meghalaya	0
376	Nongkhyllem	Sanctuary	Meghalaya	13
377	Nongsangu	Community Reserve	Meghalaya	1
378	Noradehi	Sanctuary	Madhya Pradesh	170
379	North Brother Island	Sanctuary	Andaman & Nicobar Islands	0
380	North Island	Sanctuary	Andaman & Nicobar Islands	0
381	North Reef Island	Sanctuary	Andaman & Nicobar Islands	0
382	Nugu	Sanctuary	Karnataka	0
383	Okhla	Sanctuary	Uttar Pradesh	0
384	Oliver Island	Sanctuary	Andaman & Nicobar Islands	0
385	Orcha	Sanctuary	Madhya Pradesh	0
386	Orchid Island	Sanctuary	Andaman & Nicobar Islands	0
387	Oussudu	Sanctuary	Puducherry	0
388	Overa-Aru	Sanctuary	Jammu & Kashmir	10
389	Ox Island	Sanctuary	Andaman & Nicobar Islands	0
390	Oyster Island-I	Sanctuary	Andaman & Nicobar Islands	0
391	Oyster Island-II	Sanctuary	Andaman & Nicobar Islands	0
392	Pabitora	Sanctuary	Assam	10
393	Pachmarhi	Sanctuary	Madhya Pradesh	9
394	Paget Island	Sanctuary	Andaman & Nicobar Islands	0
395	Painganga	Sanctuary	Maharashtra	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
396	Pakhal	Sanctuary	Telangana	1,142
397	Pakhui	Sanctuary	Arunachal Pradesh	2
398	Palamau	Sanctuary	Jharkhand	363
399	Palkot	Sanctuary	Jharkhand	4
400	Pamed	Sanctuary	Chhattisgarh	442
401	Pangolakha	Sanctuary	Sikkim	0
402	Pani-Dihing	Sanctuary	Assam	0
403	Paniya	Sanctuary	Gujarat	3
404	Panna (Gangau)	Sanctuary	Madhya Pradesh	14
405	Panpatha	Sanctuary	Madhya Pradesh	34
406	Parambikulam	Sanctuary	Kerala	1
407	Parasnath	Sanctuary	Jharkhand	85
408	Parkinson Island	Sanctuary	Andaman & Nicobar Islands	0
409	Parvati Aranga	Sanctuary	Uttar Pradesh	0
410	Passage Island	Sanctuary	Andaman & Nicobar Islands	0
411	Patna	Sanctuary	Uttar Pradesh	0
412	Patric Island	Sanctuary	Andaman & Nicobar Islands	0
413	Pawalgarh	Conservation Reserve	Uttarakhand	32
414	Peacock Island	Sanctuary	Andaman & Nicobar Islands	0
415	Peechi-Vazhani	Sanctuary	Kerala	5
416	Pench	Sanctuary	Madhya Pradesh	0
417	Peppara	Sanctuary	Kerala	6
418	Periyar	Sanctuary	Kerala	59
419	Phansad	Sanctuary	Maharashtra	5
420	Phen	Sanctuary	Madhya Pradesh	0
421	Phudja-Ud	Community Reserve	Meghalaya	0
422	Phulwari Ki Nal	Sanctuary	Rajasthan	278
423	Pitman Island	Sanctuary	Andaman & Nicobar Islands	0
424	Pitti	Sanctuary	Lakshadweep	0
425	Pocharam	Sanctuary	Telangana	51
426	Point Calimere	Sanctuary	Tamil Nadu	0
427	Point Island	Sanctuary	Andaman & Nicobar Islands	0
428	Pong Dam Lake	Sanctuary	Himachal Pradesh	16
429	Porbandar Lake	Sanctuary	Gujarat	0
430	Potanma Islands	Sanctuary	Andaman & Nicobar Islands	0
431	Pranahita	Sanctuary	Telangana	16
432	Pualreng	Sanctuary	Mizoram	0
433	Pulicat Lake	Sanctuary	Andhra Pradesh	1
434	Puliebadze	Sanctuary	Nagaland	0
435	Purna	Sanctuary	Gujarat	26

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
436	Pushpagiri	Sanctuary	Karnataka	2
437	Radhanagari	Sanctuary	Maharashtra	45
438	Raid Nongbri	Community Reserve	Meghalaya	0
439	Raid Nonglyngdoh/ Pdahkyndeng	Community Reserve	Meghalaya	1
440	Raiganj	Sanctuary	West Bengal	0
441	Rajgir	Sanctuary	Bihar	1
442	Rakh Sarai Amanat Khan	Conservation Reserve	Punjab	0
443	Raksham Chitkul	Sanctuary	Himachal Pradesh	0
444	Ralamandal	Sanctuary	Madhya Pradesh	0
445	Ramdevara Betta Vulture	Sanctuary	Karnataka	0
446	Ramgarh Vishdhari	Sanctuary	Rajasthan	1
447	Ramnabagan	Sanctuary	West Bengal	0
448	Ramnagar Rakha	Sanctuary	Jammu & Kashmir	0
449	Rampara Vidi	Sanctuary	Gujarat	0
450	Ramsagar	Sanctuary	Rajasthan	0
451	Ranebennur	Sanctuary	Karnataka	28
452	Ranganathittu	Sanctuary	Karnataka	0
453	Rangapahar	Sanctuary	Nagaland	0
454	Rangayyanadurga	Sanctuary	Karnataka	4
455	Ranger Island	Sanctuary	Andaman & Nicobar Islands	0
456	Ranipur	Sanctuary	Uttar Pradesh	90
457	Ratanmahal	Sanctuary	Gujarat	12
458	Ratapani	Sanctuary	Madhya Pradesh	528
459	Reef Island	Sanctuary	Andaman & Nicobar Islands	0
460	Renukaji	Sanctuary	Himachal Pradesh	0
461	Resu Haluapara	Community Reserve	Meghalaya	0
462	Rewak Daburam	Community Reserve	Meghalaya	0
463	Rewak Watregittim	Community Reserve	Meghalaya	0
464	Roa	Sanctuary	Tripura	0
465	Rollapadu	Sanctuary	Andhra Pradesh	0
466	Rongalgre	Community Reserve	Meghalaya	0
467	Rongcheng	Community Reserve	Meghalaya	0
468	Rongma Paromgre	Community Reserve	Meghalaya	0
469	Rongma Rekmangre	Community Reserve	Meghalaya	0
470	Roper Island	Sanctuary	Andaman & Nicobar Islands	0
471	Ross Island	Sanctuary	Andaman & Nicobar Islands	0
472	Rowe Island	Sanctuary	Andaman & Nicobar Islands	0
473	Rupi Bhaba	Sanctuary	Himachal Pradesh	42
474	Ryngibah	Community Reserve	Meghalaya	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
475	Ryngud	Community Reserve	Meghalaya	0
476	Sagareshwar	Sanctuary	Maharashtra	0
477	Sailana	Sanctuary	Madhya Pradesh	2
478	Sainj	Sanctuary	Himachal Pradesh	8
479	Sajjangarh	Sanctuary	Rajasthan	6
480	Sajnakhali	Sanctuary	West Bengal	0
481	Sakalgre	Community Reserve	Meghalaya	0
482	Saman	Sanctuary	Uttar Pradesh	0
483	Samaspur	Sanctuary	Uttar Pradesh	0
484	Sandi	Sanctuary	Uttar Pradesh	0
485	Sandy Island	Sanctuary	Andaman & Nicobar Islands	0
486	Sanjay Dubri	Sanctuary	Madhya Pradesh	83
487	Saraswati	Conservation Reserve	Haryana	4
488	Sardarpur	Sanctuary	Madhya Pradesh	0
489	Sariska	Sanctuary	Rajasthan	0
490	Sasatgre	Community Reserve	Meghalaya	0
491	Satkosia Gorge	Sanctuary	Odisha	25
492	Satyamangalam	Sanctuary	Tamil Nadu	4
493	Sawai Man Singh	Sanctuary	Rajasthan	0
494	Sawaimadhopur	Sanctuary	Rajasthan	0
495	Sea Serpent Island	Sanctuary	Andaman & Nicobar Islands	0
496	Sechu Tuan Nala	Sanctuary	Himachal Pradesh	0
497	Selbagre	Community Reserve	Meghalaya	0
498	Semarsot	Sanctuary	Chhattisgarh	7
499	Senchal	Sanctuary	West Bengal	2
500	Sepahijala	Sanctuary	Tripura	0
501	Sessa Orchid	Sanctuary	Arunachal Pradesh	0
502	Shakambhari	Conservation Reserve	Rajasthan	0
503	Shalmale Riparian Bio-system	Conservation Reserve	Karnataka	0
504	Sharavathi Valley LTM	Sanctuary	Karnataka	2
505	Shark Island	Sanctuary	Andaman & Nicobar Islands	0
506	Shearme Island	Sanctuary	Andaman & Nicobar Islands	0
507	Shendurney	Sanctuary	Kerala	0
508	Shergarh	Sanctuary	Rajasthan	0
509	Shettihalli	Sanctuary	Karnataka	12
510	Shikari Devi	Sanctuary	Himachal Pradesh	0
511	Shilli	Conservation Reserve	Himachal Pradesh	2
512	Shimla Catchment	Sanctuary	Himachal Pradesh	5
513	Shingba	Sanctuary	Sikkim	0
514	Shoolpaneswar	Sanctuary	Gujarat	148

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
515	Shri Nainadevi	Conservation Reserve	Himachal Pradesh	28
516	Siju	Sanctuary	Meghalaya	0
517	Siju Duramong I	Community Reserve	Meghalaya	0
518	Siju Duramong II	Community Reserve	Meghalaya	0
519	Simlipal	Sanctuary	Odisha	123
520	Singhori	Sanctuary	Madhya Pradesh	166
521	Sir Hugh Rose Island	Sanctuary	Andaman & Nicobar Islands	0
522	Sisters Island	Sanctuary	Andaman & Nicobar Islands	0
523	Sitamata	Sanctuary	Rajasthan	350
524	Sitanadi	Sanctuary	Chhattisgarh	40
525	Smaw Der Khli	Community Reserve	Meghalaya	0
526	Snake Island-I	Sanctuary	Andaman & Nicobar Islands	0
527	Snake Island-II	Sanctuary	Andaman & Nicobar Islands	0
528	Sohagibarwa	Sanctuary	Uttar Pradesh	301
529	Sohelwa	Sanctuary	Uttar Pradesh	522
530	Someshwara	Sanctuary	Karnataka	0
531	Son Gharial	Sanctuary	Madhya Pradesh	2
532	Sonai-Rupai	Sanctuary	Assam	7
533	Sonanadi	Sanctuary	Uttarakhand	4
534	South Brother Island	Sanctuary	Andaman & Nicobar Islands	0
535	South Reef Island	Sanctuary	Andaman & Nicobar Islands	0
536	South Sentinel Island	Sanctuary	Andaman & Nicobar Islands	0
537	Spike Island-I	Sanctuary	Andaman & Nicobar Islands	0
538	Spike Island-II	Sanctuary	Andaman & Nicobar Islands	0
539	Sri Lankamalleswaram	Sanctuary	Andhra Pradesh	434
540	Sri Penusila Narasimha	Sanctuary	Andhra Pradesh	174
541	Sri Venkateswara	Sanctuary	Andhra Pradesh	510
542	Srivilliputhur	Sanctuary	Tamil Nadu	32
543	Stoat Island	Sanctuary	Andaman & Nicobar Islands	0
544	Sukhna Lake	Sanctuary	Chandigarh	0
545	Sunabeda	Sanctuary	Odisha	100
546	Sundha Mata	Conservation Reserve	Rajasthan	0
547	Sur Sarovar	Sanctuary	Uttar Pradesh	0
548	Surat Island	Sanctuary	Andaman & Nicobar Islands	0
549	Surinsar Mansar	Sanctuary	Jammu & Kashmir	12
550	Swamp Island	Sanctuary	Andaman & Nicobar Islands	0
551	Table (Delgarno) Island	Sanctuary	Andaman & Nicobar Islands	0
552	Table (Excelsior) Island	Sanctuary	Andaman & Nicobar Islands	0
553	Taidang	Community Reserve	Meghalaya	0
554	Takhni-Rehampur	Sanctuary	Punjab	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve

Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
555	Tal Chhapar	Sanctuary	Rajasthan	0
556	Talabaicha Island	Sanctuary	Andaman & Nicobar Islands	0
557	Talakaveri	Sanctuary	Karnataka	0
558	Tale Valley	Sanctuary	Arunachal Pradesh	0
559	Talra	Sanctuary	Himachal Pradesh	9
560	Tamorpingla	Sanctuary	Chhattisgarh	223
561	Tansa	Sanctuary	Maharashtra	175
562	Tatta Kuti	Sanctuary	Jammu & Kashmir	23
563	Tawi	Sanctuary	Mizoram	0
564	Temple Island	Sanctuary	Andaman & Nicobar Islands	0
565	Thangkharang	Community Reserve	Meghalaya	0
566	Thattekadu	Sanctuary	Kerala	0
567	Therthangal Bird	Sanctuary	Tamil Nadu	0
568	Thokpara	Community Reserve	Meghalaya	0
569	Thol Lake	Sanctuary	Gujarat	0
570	Thorangtlang	Sanctuary	Mizoram	0
571	Tillongchang Island	Sanctuary	Andaman & Nicobar Islands	0
572	Tipeshwar	Sanctuary	Maharashtra	0
573	Tirthan	Sanctuary	Himachal Pradesh	11
574	Todgarh Raoli	Sanctuary	Rajasthan	18
575	Tokalo	Sanctuary	Mizoram	8
576	Topchanchi	Sanctuary	Jharkhand	10
577	Tree Island	Sanctuary	Andaman & Nicobar Islands	0
578	Trilby Island	Sanctuary	Andaman & Nicobar Islands	0
579	Trishna	Sanctuary	Tripura	0
580	Tuft Island	Sanctuary	Andaman & Nicobar Islands	0
581	Tundah	Sanctuary	Himachal Pradesh	26
582	Tungareshwar	Sanctuary	Maharashtra	22
583	Turtle	Sanctuary	Uttar Pradesh	0
584	Turtle Islands	Sanctuary	Andaman & Nicobar Islands	0
585	Udanti	Sanctuary	Chhattisgarh	85
586	Udayamarthandapuram Lake	Sanctuary	Tamil Nadu	0
587	Udaypur	Sanctuary	Bihar	0
588	Udhwa Lake	Sanctuary	Jharkhand	0
589	Umdeganj Bird	Conservation Reserve	Rajasthan	0
590	Umsum pitcher plant	Community Reserve	Meghalaya	0
591	Upper Dosogre	Community Reserve	Meghalaya	0
592	Vaduvoor	Sanctuary	Tamil Nadu	0
593	Valmiki	Sanctuary	Bihar	712
594	Van Vihar	Sanctuary	Rajasthan	0

Number of SNPP-VIIRS detections in the Sanctuary, Conservation Reserve and Community Reserve				
Sl. No	Name of the Protected Area	Status	State/UT	SNPP-VIIRS Detections*
595	Veerangna Durgavati	Sanctuary	Madhya Pradesh	3
596	Vellanadu Blackbuck	Sanctuary	Tamil Nadu	0
597	Vijai Sagar	Sanctuary	Uttar Pradesh	0
598	Vikramshila	Sanctuary	Bihar	0
599	Wan	Sanctuary	Maharashtra	31
600	Wayanad	Sanctuary	Kerala	11
601	West Island	Sanctuary	Andaman & Nicobar Islands	0
602	West Sundarban	Sanctuary	West Bengal	0
603	Wharf Island	Sanctuary	Andaman & Nicobar Islands	0
604	White Cliff Island	Sanctuary	Andaman & Nicobar Islands	0
605	Wild Ass	Sanctuary	Gujarat	29
606	Yangoupokpi-Lokchao	Sanctuary	Manipur	52
607	Yawal	Sanctuary	Maharashtra	18
608	Yedsi Ramlin Ghat	Sanctuary	Maharashtra	0
609	Yorde-Rabe-Supse	Sanctuary	Arunachal Pradesh	0
	Total			19,747

* 119 detections has been observed as duplicate due to overlapping of Sanctuary, Conservation Reserve and Community Reserve boundary

Photo: FSI Repository

ANNEXURE-VI

Percentage of Number of Active Days of Large Forest Fire Events

State/UTs	Percentage of number of active days of large forest fire events										
	< 24 Hrs	1 < Day < 2	2 < Day < 3	3 < Day < 4	4 < Day < 5	5 < Day < 6	6 < Day < 7	7 < Day < 8	8 < Day < 9	9 < Day < 10	> 10 Days
Haryana	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nagaland	88.04	5.74	2.87	2.39	0.48	0.00	0.00	0.00	0.48	0.00	0.00
Sikkim	87.50	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arunachal Pradesh	85.83	11.81	1.57	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Karnataka	84.57	9.00	3.54	2.25	0.00	0.32	0.32	0.00	0.00	0.00	0.00
Manipur	81.99	8.33	5.38	3.49	0.27	0.54	0.00	0.00	0.00	0.00	0.00
Gujarat	78.44	13.77	4.19	1.80	1.20	0.60	0.00	0.00	0.00	0.00	0.00
Meghalaya	75.40	10.99	4.71	6.28	1.05	1.05	0.00	0.00	0.52	0.00	0.00
Tripura	74.83	4.76	4.08	14.29	0.68	1.36	0.00	0.00	0.00	0.00	0.00
Kerala	72.85	14.29	8.57	1.43	0.00	1.43	0.00	1.43	0.00	0.00	0.00
Maharashtra	71.69	11.83	6.14	4.64	2.40	0.90	1.35	0.15	0.45	0.00	0.45
Madhya Pradesh	70.89	14.97	6.44	5.20	1.14	0.52	0.21	0.00	0.21	0.21	0.21
Assam	70.49	16.14	6.58	3.61	2.12	0.21	0.64	0.00	0.00	0.21	0.00
Punjab	70.27	8.11	2.70	8.11	5.41	2.70	2.70	0.00	0.00	0.00	0.00
Mizoram	70.06	14.17	8.18	4.79	0.80	1.40	0.40	0.20	0.00	0.00	0.00
West Bengal	70.01	18.33	7.50	2.50	0.83	0.83	0.00	0.00	0.00	0.00	0.00
Uttar Pradesh	69.48	16.14	8.77	3.86	0.35	0.35	1.05	0.00	0.00	0.00	0.00
Rajasthan	69.17	19.76	6.32	2.37	1.58	0.40	0.40	0.00	0.00	0.00	0.00
Tamil Nadu	68.79	14.68	6.88	5.05	0.92	1.38	0.46	0.46	0.46	0.46	0.46
Himachal Pradesh	66.26	16.12	7.10	6.01	2.32	0.68	0.68	0.55	0.14	0.14	0.00
Odisha	65.16	16.00	8.49	5.57	2.03	1.50	0.53	0.18	0.27	0.18	0.09
Andhra Pradesh	62.91	17.89	7.46	5.41	2.42	1.30	0.93	0.56	0.28	0.19	0.65
Uttarakhand	62.52	16.45	8.53	6.25	2.82	1.29	0.99	0.69	0.23	0.15	0.08
Telangana	60.87	16.09	10.44	6.96	2.52	1.20	0.72	0.72	0.24	0.12	0.12

ANNEXURE-VII

Forest Fire Risk Zonation Mapping in West Himalayan States

Certain regions are more susceptible to forest fires due to factors like type of fuel load, local human activities, topographical features and climatic conditions. In order to have a better and robust system for controlling and managing forest fires in a region, an effective fire risk zonation helps to delineate different risk areas for prioritizing management interventions in an effective manner.

The factors responsible for initiation and spread of forest fire are modelled to prepare risk zone map indicating the regions where management interventions are required in a varied manner. Such zonation is helpful for the forest department officials, National Disaster Management Authority (NDMA), National Disaster Recovery Force (NDRF), State Disaster Management Authority (SDMA), etc., to prevent and minimize fire risk within the forest and take proper action during a fire outbreak.

A pilot study has been carried out for the West Himalayan States/UTs comprising Himachal Pradesh, Uttarakhand, Jammu & Kashmir, and Ladakh to identify Fire Risk Zones and categorize them into different risk classes using suitable variables. The plot-level field inventory data collected under National Forestry Inventory has been used to find out the causative factors of the spread of forest fires. A log linear Regression Method has been used to find the multi-way effects between the field variables. In the present case, forest fire incidences have been termed as dependent variable and other associated variables in the sample plot as independent variables. Detailed flow chart of the study is shown in following figure.

Based on the linear regression analysis, six independent variables have been identified having a close correlation with fire incidences. A high chi square value and low probability value (probability >0.05) indicates a good fit model. The independent variables identified are Forest Type, Altitude, Slope, Aspect, Biotic influence and Grazing incidences.

On the basis of the analysis of forest fire archival data, different weights have been assigned to each layer. The numeric calculation as shown in the equation given below has been performed using spatial modular tool.

$$Rz = 10*Vt + 9*Al + 8*Fp + 7*Bi + 6*As + 4*(S + Gz)$$

In this equation, Rz is the numerical index of forest fire risk zones

Where,

Vt: indicates Forest Type,

Al: indicates Altitude,

Fp: indicates Fire prone map,

Bi: indicates Biotic Influence,

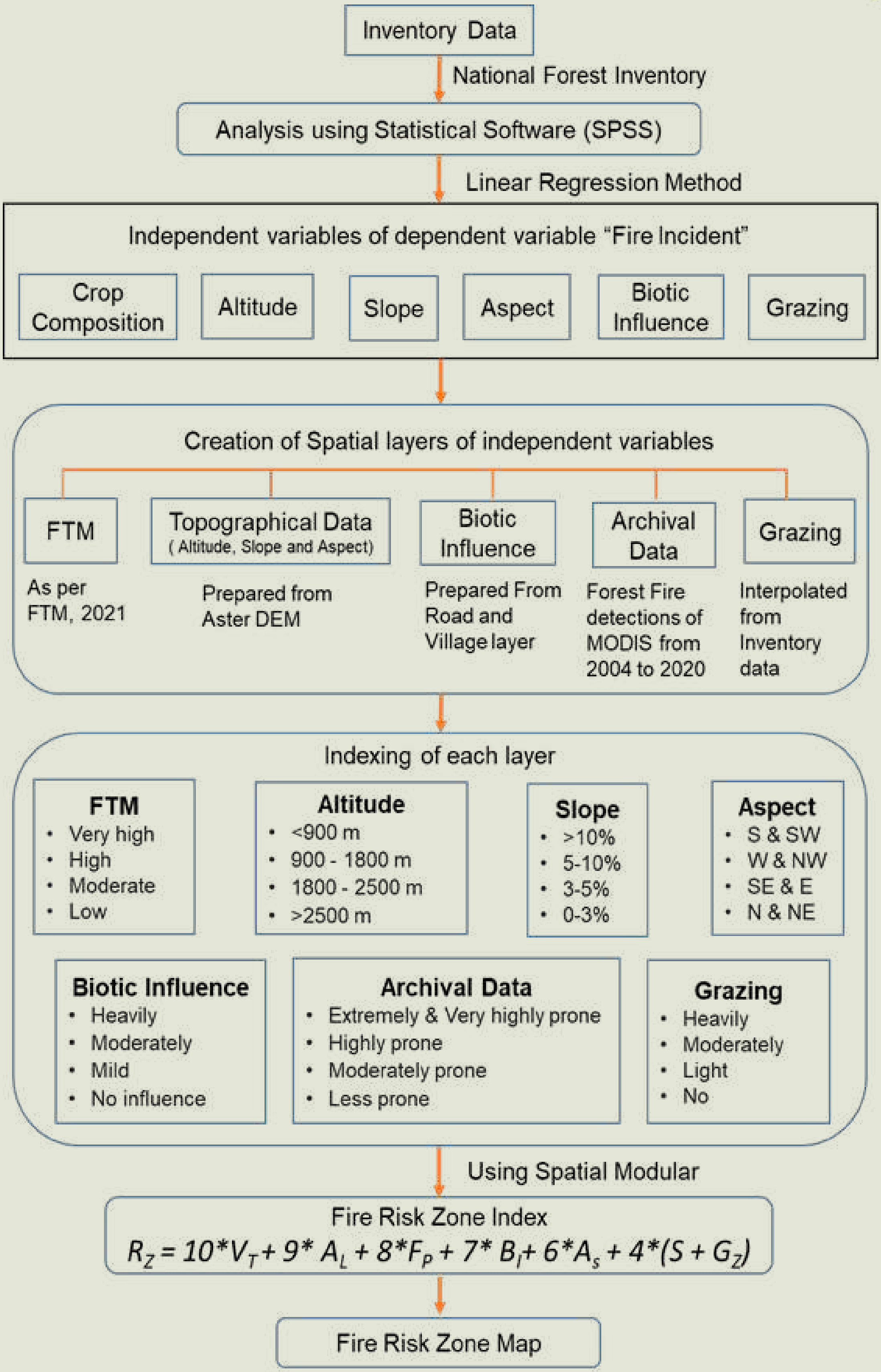
As: indicates aspect,

S: indicates slope and

Gz: indicates Grazing incidence

Based on the analysis, the forest fire risk zone map of the West Himalayan States has been created as shown in Figure 4.16 in the chapter on forest fire. The generated fire risk zonation map has been further validated using the available forest fire detections using SNPP-VIIRS data of the last five years as shown in Table 4.13.

Photo: Sanjay Shukla IFS



Flow Chart of Fire Risk Zonation Mapping

ANNEXURE-VIII

Volume equations to compute volume of wood in predominate trees in each State/ UTs are provided in the following tables:
V = Volume in m^3, D = Diameter at Breast Height in m

Andhra Pradesh

Sl. No.	Species Name	Volume Equation
1	*Albizia amara*	$V = 0.0200645487525004-0.78681649062609*D+6.80315298169127*D^2$
2	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = 0.034725-0.78412*D+7.1873*D^2+6.9495*D^3$
3	*Chloroxylon swietenia*	$\sqrt{V} = -0.2303 + 3.3915*D$
4	*Hardwickia binata*	$\sqrt{V} = -0.2161 + 2.9509*D$
5	*Hardwickia pinnata/ Prioria pinnata*	$V = 0.025091-0.185618*D+3.561089*D^2+10.80139*D^3$
6	*Lannea coromandelica*	$V = 0.057424-1.153088*D+8.542648*D^2$
7	*Pterocarpus marsupium*	$V = 0.058424-1.233468*D+9.433633*D^2$
8	*Syzygium cumini*	$Log_e V = 2.132776+2.479397*LogeD$
9	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.05061-1.11994*D+8.77839*D^2$
10	*Xylia xylocarpa*	$V = 0.098-1.52*D+8.963*D^2$

Arunachal Pradesh

Sl. No.	Species Name	Volume Equation
1	*Aglaia spectabilis*	$V = -0.10099+0.93273*D+5.28022*D^2$
2	*Bischofia javanica*	$\sqrt{V} = -0.00273+2.56199*D$
3	*Castanopsis indica*	$V = 0.05331-0.87098*D+6.52533*D^2+1.74231*D^3$
4	*Castanopsis species*	$V = 0.05331-0.87098*D+6.52533*D^2+1.74231*D^3$
5	*Duabanga grandiflora*	$\sqrt{V} = 0.13199+3.35856*D-0.79250*\sqrt{D}$
6	*Macaranga species*	$V = 0.13333-2.18825*D+13.12678*D^2$
7	*Quercus species*	$V = 0.14153-2.27358*D+12.9049*D^2$
8	*Anthoshorea assamica/ Shorea assamica*	$\sqrt{V} = -0.24358+3.58273*D$
9	*Sterculia villosa*	$\sqrt{V} = 0.35895+4.99513*D-2.14135*\sqrt{D}$
10	*Terminalia myriocarpa*	$V = -0.096981+10.65*D^2$

Assam

Sl. No.	Species Name	Volume Equation
1	*Albizia species*	$\sqrt{V} = -0.07109+2.99732*D-0.26953*\sqrt{D}$
2	*Artocarpus chama/ Artocarpus chaplasha*	$V = -0.079733-0.0021006*D*100+0.001114*D^2*10000$
3	*Bombax ceiba*	$V = 0.04507-0.93461*D+5.48513*D^2+9.16037*D^3$
4	*Careya arborea*	$\sqrt{V} = 0.23738+2.33289*D+0.48512*\sqrt{D}$
5	*Dipterocarpus retusus/ Dipterocarpus macrocarpus*	$\sqrt{V} = 0.30518+5.89533*D-2.14269*\sqrt{D}$
6	*Gmelina arborea*	$V = 0.1156+0.21230*D+5.10448*D^2$
7	*Lannea coromandelica*	$\sqrt{V} = -0.32985+2.21152*D+0.78769*\sqrt{D}$
8	*Schima wallichii*	$\sqrt{V} = -0.4319+1.7358*D^2+1.6093*\sqrt{D}$
9	*Shorea robusta*	$\sqrt{V} = -0.22388+3.29474*D$
10	*Tectona grandis*	$\sqrt{V} = -0.405890+1.98158*D+0.987373*\sqrt{D}$

Bihar

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$\sqrt{V} = -0.07738+2.592167*D$
2	*Bombax ceiba*	$V = -0.032-0.0619*D+7.208*D^2$
3	*Boswellia serrata*	$V = 0.03356-1.124*D+10.306*D^2$
4	*Buchanania lanzan/ Buchanania latifolia*	$V = 0.1025-1.8645*D+10.9625*D^2$
5	*Diospyros melanoxylon*	$V = 0.12401-2.00966*D+10.87747*D^2$
6	*Lagerstroemia parviflora*	$\sqrt{V} = -0.153687+2.975938*D$
7	*Lannea coromandelica*	$\sqrt{V} = -0.32985+2.21152*D+0.78769*\sqrt{D}$
8	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = -0.00092-0.55547*D+7.3446*D^2$
9	*Shorea robusta*	$V = 0.1563-2.45104*D+11.90581*D^2$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.08565-1.51685*D+10.24871*D^2$

Chhattisgarh

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = -0.02958+8.05003*D^2$
2	*Boswellia serrata*	$V = 0.044621-1.25694*D+10.86801*D^2-3.009085*D^3$
3	*Cleistanthus collinus*	$V = -0.03915+0.16295*D+4.09182*D^2$
4	*Diospyros melanoxylon*	$V = 0.12401-2.00966*D+10.87747*D^2$
5	*Lagerstroemia parviflora*	$V = 0.0568-1.19611*D+9.11319*D^2$
6	*Lannea coromandelica*	$\sqrt{V} = -0.11751+2.86874*D$
7	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = -0.00092-0.55547*D+7.3446*D^2$
8	*Pterocarpus marsupium*	$V = -0.04659+8.06901*D^2$
9	*Shorea robusta*	$V = 0.17279-2.54241*D+13.08048*D^2-3.49087*D^3$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.00376-0.77604*D+8.35533*D^2$

Delhi

Sl. No.	Species Name	Volume Equation
1	*Acacia nilotica/ Acacia arabica/ Vachellia nilotica*	$V = 0.16609-2.78851*D+17.22127*D^2-11.60248*D^3$
2	*Acacia catechu/ Senegalia catechu*	$V = 0.16609-2.78851*D+17.22127*D^2-11.60248*D^3$
3	*Acacia lenticularis/ Senegalia lenticularis*	$\sqrt{V} = -0.00142+2.61911*D-0.54703*\sqrt{D}$
4	*Azadirachta indica/ Melia indica*	$V = -0.03510+5.32981*D^2$
5	*Cassia fistula*	$V = 0.05159-0.53331*D+3.46016*D^2+10.18473*D^3$
6	*Dalbergia sissoo*	$V = 0.00331+6.36*D^2$
7	*Ehretia aspera/ Ehretia laevis*	$V = -0.03844+0.946490*D-5.40987*D^2+33.17338*D^3$
8	*Ficus virens*	$\sqrt{V} = 0.03629+3.95389*D-0.84421*\sqrt{D}$
9	*Holoptelea integrifolia*	$\sqrt{V} = 0.21569+4.329878*D-1.504977*\sqrt{D}$
10	*Prosopis juliflora/ Neltuma juliflora*	$\sqrt{V} = -0.2528+3.4327*D$

Goa

Sl. No.	Species Name	Volume Equation
1	*Anacardium occidentale*	$V = 4.5899*D^2-0.422*D+0.0148$
2	*Careya arborea*	$V = 0.106966651199002-2.12376499033923*D+13.1751187459997*D^2$
3	*Dillenia pentagyna*	$V = 0.070-1.295*D+9.429*D^2$
4	*Lagerstroemia microcarpa/ Lagerstroemia lanceolata*	$\sqrt{V} = -0.13034+2.824203*D$
5	*Lannea coromandelica*	$\sqrt{V} = 0.404153+5.555051*D-2.545525*\sqrt{D}$
6	*Syzygium cumini*	$\sqrt{V} = 0.30706+5.12731*D-2.0987*\sqrt{D}$
7	*Terminalia bellirica*	$V = 0.074706-1.430082*D+10.18197*D^2$
8	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$\sqrt{V} = -0.203947+3.159215*D$
9	*Terminalia paniculata*	$\sqrt{V} = -0.1713+3.1872*D$
10	*Xylia xylocarpa*	$\sqrt{V} = -0.0990+2.6224*D$

Gujarat

Sl. No.	Species Name	Volume Equation
1	*Acacia nilotica/ Acacia arabica/ Vachellia nilotica*	$V = -0.048108+5.873169*D^2$
2	*Acacia catechu/ Senegalia catechu*	$V = -0.048108+5.873169*D^2$
3	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = 0.030502-1.105937*D+12.261268*D^2$
4	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
5	*Diospyros melanoxylon*	$V = 0.033867-0.975148*D+8.255412*D^2$
6	*Lannea coromandelica*	$\sqrt{V} = 0.404153+5.555051*D-2.545525*\sqrt{D}$
7	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = 0.074069-1.230020*D+7.726902*D^2$
8	*Tectona grandis*	$V = 0.032011-0.995414*D+9.91129*D^2$
9	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.060344-1.569539*D+12.090296*D^2$
10	*Wrightia tinctoria*	$\sqrt{V} = 0.050294+3.115497*D-0.687813*\sqrt{D}$

Haryana

Sl. No.	Species Name	Volume Equation
1	*Acacia nilotica/ Acacia arabica/ Vachellia nilotica*	$V = 0.16609-2.78851*D+17.22127*D^2-11.60248*D^3$
2	*Acacia catechu/ Senegalia catechu*	$V = 0.02384-0.72161*D+7.46888*D^2$
3	*Acacia tortilis/ Vachellia tortilis*	$V = 0.16609-2.78851*D+17.22127*D^2-11.60248*D^3$
4	*Anogeissus latifolia/ Terminalia anogeissiana*	$\sqrt{V} = 0.2122+4.947663*D-1.5929*\sqrt{D}$
5	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
6	*Dalbergia sissoo*	$V = 0.00331+0.000636*D^2*10000$
7	*Eucalyptus species*	$V = 0.02894-0.89284*D+8.72416*D^2$
8	*Lannea coromandelica*	$V = 0.14004-2.3599*D+11.90726*D^2$
9	*Prosopis juliflora/ Neltuma juliflora*	$\sqrt{V} = -0.2528+3.4327*D$
10	*Shorea robusta*	$\sqrt{V} = 0.16306+4.8991*D-1.57402*\sqrt{D}$

Himachal Pradesh

Sl. No.	Species Name	Volume Equation
1	*Abies densa*	$\sqrt{V} = -0.084305+3.060072*D$
2	*Abies pindrow*	$V = 7.92*D^2+0.244*D-0.061$
3	*Cedrus deodara*	$V = 10.03982*D^2-1.28303*D+0.07367$
4	*Pinus wallichiana/ Pinus excelsa*	$V = 10.44*D^2-0.851*D+0.020$
5	*Pinus roxburghii*	$\sqrt{V} = 0.05131+3.9859*D-1.0245*\sqrt{D}$
6	*Quercus floribunda/ Quercus dilatata*	$V = 0.0988-1.5547*D+10.1631*D^2$
7	*Quercus leucotrichophora*	$\sqrt{V} = -0.1522+2.6407*D$
8	*Quercus semecarpifolia*	$V = 0.098800-1.55471*D+10.16317*D^2$
9	*Rhododendron arboreum*	$\sqrt{V} = 0.306492+4.31536*D-1.749908*\sqrt{D}$
10	*Shorea robusta*	$\sqrt{V} = 0.16306+4.8991*D-1.57402*\sqrt{D}$

Jharkhand

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$\sqrt{V} = -0.07738+2.592167*D$
2	*Boswellia serrata*	$V = 0.03356-1.124*D+10.306*D^2$
3	*Buchanania lanzan/ Buchanania latifolia*	$V = 0.1025-1.8645*D+10.9625*D^2$
4	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
5	*Lagerstroemia parviflora*	$V = 0.0568-1.19611*D+9.11319*D^2$
6	*Lannea coromandelica*	$\sqrt{V} = -0.11751+2.86874*D$
7	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = -0.00092-0.55547*D+7.3446*D^2$
8	*Schleichera oleosa/ Schleichera trijuga*	$V = 0.010-0.912*D+11.396*D^2$
9	*Shorea robusta*	$V = 0.022585-0.70158*D+8.714*D^2$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.08565-1.51685*D+10.24871*D^2$

Karnataka

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = 0.030502-1.105937*D+12.261268*D^2$
2	*Eucalyptus species*	$V = 0.02894-0.89284*D+8.72416*D^2$
3	*Lagerstroemia microcarpa/ Lagerstroemia lanceolata*	$V = 0.066188-1.334512*D+9.403257*D^2$
4	*Olea dioica/ Tetrapilus dioicus*	$V = -0.03001+5.75523*D^2$
5	*Schleichera oleosa/ Schleichera trijuga*	$V = 0.01-0.912*D+11.396*D^2$
6	*Syzygium cumini*	$\sqrt{V} = 0.30706+5.12731*D-2.0987*\sqrt{D}$
7	*Tectona grandis*	$\sqrt{V} = -0.40589+1.98158*D+0.987373*\sqrt{D}$
8	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = -0.203947+3.159215*D*-0.203947+3.159215*D$
9	*Terminalia paniculata*	$V = 0.131-1.87132*D+9.47861*D^2$
10	*Xylia xylocarpa*	$\sqrt{V} = -0.0990+2.6224*D$

Kerala

Sl. No.	Species Name	Volume Equation
1	*Artocarpus hirsutus*	$V = 0.076-1.319*D+11.37*D^2$
2	*Diospyros species*	$\sqrt{V} = -0.184139+2.892723*D$
3	*Lagerstroemia microcarpa/ Lagerstroemia lanceolata*	$V = -0.06183+0.411348*D+1.84813*D^2+12.43582*D^3-4.26661*D4$
4	*Macaranga peltata*	$V = 0.11097-1.60658*D+10.15473*D^2$
5	*Syzygium cumini*	$\sqrt{V} = 0.30706+5.12731*D-2.0987*\sqrt{D}$
6	*Tectona grandis*	$\sqrt{V} = -0.40589+1.98158*D+0.987373*\sqrt{D}$
7	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$\sqrt{V} = -0.203947+3.159215*D$
8	*Terminalia paniculata*	$V = 0.131-1.87132*D+9.47861*D^2$
9	*Vateria indica*	$\sqrt{V} = -0.15493+3.1119*D$
10	*Xylia xylocarpa*	$\sqrt{V} = -0.0990+2.6224*D$

Madhya Pradesh

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = 0.145667-2.704089*D+17.4656*D^2-10.4903*D^3$
2	*Boswellia serrata*	$V = 0.050452-1.228748*D+9.123381*D^2$
3	*Chloroxylon swietenia*	$\sqrt{V} = -0.2303 + 3.3915*D$
4	*Diospyros melanoxylon*	$V = 0.033867-0.975148*D+8.255412*D^2$
5	*Lagerstroemia parviflora*	$V = 0.0568-1.19611*D+9.11319*D^2$
6	*Lannea coromandelica*	$\sqrt{V} = -0.11751+2.86874*D$
7	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = -0.00092-0.55547*D+7.3446*D^2$
8	*Shorea robusta*	$\sqrt{V} = 0.19994+4.57179*D-1.56823*\sqrt{D}$
9	*Tectona grandis*	$V = -0.003673-0.379175*D+6.368282*D^2$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.060344-1.569539*D+12.090296*D^2$

Maharashtra

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = -0.061856+7.952136*D^2$
2	*Boswellia serrata*	$V = 0.050452-1.228748*D+9.123381*D^2$
3	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
4	*Chloroxylon swietenia*	$\sqrt{V} = -0.2303 + 3.3915*D$
5	*Lannea coromandelica*	$V = 0.093318-1.531417*D+9.011590*D^2$
6	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = 0.074069-1.230020*D+7.726902*D^2$
7	*Pterocarpus marsupium*	$V = 0.028252-0.833643*D+8.033788*D^2$
8	*Syzygium cumini*	$\sqrt{V} = 0.30706+5.12731*D-2.0987*\sqrt{D}$
9	*Tectona grandis*	$\sqrt{V} = -0.106720+2.562418*D$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.048532-1.05615*D+8.204564*D^2$

Manipur

Sl. No.	Species Name	Volume Equation
1	*Albizia species*	$\sqrt{V}$ = -0.07109+2.99732*D-0.26953*$\sqrt{D}$
2	*Castanopsis species*	V = -0.02301+0.12721*D+2.4127*D^2+8.12834*D^3
3	*Duabanga grandiflora*	$\sqrt{V}$ = -0.01217+3.3993*D-0.28981*$\sqrt{D}$
4	*Ficus species*	$\sqrt{V}$ = 0.03629+3.95389*D-0.84421*$\sqrt{D}$
5	*Lannea coromandelica*	$\sqrt{V}$ = -0.32985+2.21152*D+0.78769*$\sqrt{D}$
6	*Macaranga species*	V = 0.13333-2.18825*D+13.12678*D^2
7	*Pinus kesiya*	V = -0.01523+5.65779*D^2
8	*Quercus species*	V = 0.14153-2.27358*D+12.9049*D^2
9	*Schima wallichii*	$\sqrt{V}$ = -0.4319+1.7358*D^2+1.6093*$\sqrt{D}$
10	*Tectona grandis*	V = 0.19112-3.25372*D+17.9194*D^2-1.66117*D^3

Meghalaya

Sl. No.	Species Name	Volume Equation
1	*Anacardium occidentale*	V = 4.5899*D^2-0.422*D+0.0148
2	*Areca catechu*	V = 0.0239-0.6266*D+5.4067*D^2
3	*Artocarpus heterophyllus/ Artocarpus integrifolia*	$\sqrt{V}$ = -0.15154+2.79983*D
4	*Careya arborea*	$\sqrt{V}$ = 0.23738+2.33289*D+0.48512*$\sqrt{D}$
5	*Ficus species*	$\sqrt{V}$ = 0.03629+3.95389*D-0.84421*$\sqrt{D}$
6	*Lannea coromandelica*	$\sqrt{V}$ = -0.32985+2.21152*D+0.78769*$\sqrt{D}$
7	*Pinus kesiya*	V = -0.01523+5.65779*D^2
8	*Schima wallichii*	$\sqrt{V}$ = -0.4319+1.7358*D^2+1.6093*$\sqrt{D}$
9	*Shorea robusta*	V = 0.16019-2.81861*D+16.19328*D^2
10	*Tectona grandis*	V = 0.19112-3.25372*D+17.9194*D^2-1.66117*D^3

Mizoram

Sl. No.	Species Name	Volume Equation
1	*Albizia species*	$\sqrt{V}$ = -0.07109+2.99732*D-0.26953*$\sqrt{D}$
2	*Castanopsis species*	V = 0.05331-0.87098*D+6.52533*D^2+1.74231*D^3
3	*Dysoxylum gotadhora/ Dysoxylum binectariferum*	V = -0.04752+0.50667*D+1.88433*D^2+11.30632*D^3
4	*Ficus species*	$\sqrt{V}$ = 0.03629+3.95389*D-0.84421*$\sqrt{D}$
5	*Gmelina arborea*	$\sqrt{V}$ = -0.00189+2.10033*D
6	*Macaranga species*	V = 0.13333-2.18825*D+13.12678*D^2
7	*Quercus species*	V = 0.14153-2.27358*D+12.9049*D^2
8	*Schima wallichii*	$\sqrt{V}$ = -0.4319+1.7358*D^2+1.6093*$\sqrt{D}$
9	*Sterculia villosa*	$\sqrt{V}$ = 0.35895+4.99513*D-2.14135*$\sqrt{D}$
10	*Tectona grandis*	V = 0.19112-3.25372*D+17.9194*D^2-1.66117*D^3

Nagaland

Sl. No.	Species Name	Volume Equation
1	*Albizia species*	$\sqrt{V}$ = -0.07109+2.99732*D-0.26953*$\sqrt{D}$
2	*Alnus species*	V = 0.0741-1.3603*D+10.9229*D^2
3	*Cedrela toona/ Toona ciliata*	$\sqrt{V}$ = -0.05514+2.67753*D
4	*Ficus species*	$\sqrt{V}$ = 0.03629+3.95389*D-0.84421*$\sqrt{D}$
5	*Hevea brasiliensis*	V = 0.1334-2.1584*D+11.2457*D^2
6	*Lannea coromandelica*	$\sqrt{V}$ = -0.32985+2.21152*D+0.78769*$\sqrt{D}$
7	*Macaranga species*	V = 0.13333-2.18825*D+13.12678*D^2
8	*Melia azedarach*	V = -0.03510+5.32981*D^2
9	*Schima wallichii*	$\sqrt{V}$ = -0.4319+1.7358*D^2+1.6093*$\sqrt{D}$
10	*Terminalia myriocarpa*	$\sqrt{V}$ = 0.30858+4.35664*D-1.64694*$\sqrt{D}$

Odisha

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$\sqrt{V}$ = -0.357373+2.430449*D+0.794626*$\sqrt{D}$
2	*Buchanania lanzan/ Buchanania latifolia*	V = 0.1025-1.8645*D+10.9625*D^2
3	*Diospyros melanoxylon*	V = -0.009124-0.494103*D+7.610416*D^2
4	*Lannea coromandelica*	V = 0.057424-1.153088*D+8.542648*D^2
5	*Madhuca longifolia/ M. latifolia/ M. indica*	$\sqrt{V}$ = -0.1808+2.8409*D
6	*Mangifera indica*	V = 0.108-1.706*D+7.559*D^2
7	*Schleichera oleosa/ Schleichera trijuga*	$\sqrt{V}$ = -0.24358+3.58273*D
8	*Shorea robusta*	$\sqrt{V}$ = 0.19994+4.57179*D-1.56823*$\sqrt{D}$
9	*Syzygium cumini*	LogeV = 2.132776+2.479397*LogeD
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	V = 0.05061-1.11994*D+8.77839*D^2

Punjab

Sl. No.	Species Name	Volume Equation
1	*Acacia catechu/ Senegalia catechu*	V = 0.16609-2.78851*D+17.22127*D^2-11.60248*D^3
2	*Butea monosperma*	$\sqrt{V}$ = 1.6007+15.6578*D-6.7295*D^2-9.2184*$\sqrt{D}$
3	*Dalbergia sissoo*	V = 0.00331+6.36*D^2
4	*Emblica officinalis/ Phyllanthus emblica*	$\sqrt{V}$ = -0.1737 + 3.0240*D
5	*Eucalyptus species*	V = 0.02894-0.89284*D+8.72416*D^2
6	*Grewia optiva/ Grewia oppositifolia*	V = 0.05858-1.20414*D+9.80167*D^2
7	*Lannea coromandelica*	V = 0.14004-2.3599*D+11.90726*D^2
8	*Mallotus philippensis*	$\sqrt{V}$ = -0.1120+2.4764*D
9	*Prosopis juliflora/ Neltuma juliflora*	$\sqrt{V}$ = -0.2528+3.4327*D
10	*Ziziphus mauritiana*	V = 0.027354+4.66371*D^2

Rajasthan

Sl. No.	Acacia catechu/ Senegalia catechu	$V = 0.26949-1.61804*D+8.79495*D^2+2.49489*D^3$
1	*Acacia catechu/ Senegalia catechu*	$V = 0.26949-1.61804*D+8.79495*D^2+2.49489*D^3$
2	*Acacia lenticularis/ Senegalia lenticularis*	$V = -0.048108+5.873169*D^2$
3	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = -0.01662+4.4268*D^2$
4	*Anogeissus acuminata/ Anogeissus pendula/ Terminalia pendula*	$V = 0.00085-0.35165*D+4.77386*D^2-0.90585*D^3$
5	*Boswellia serrata*	$\sqrt{V} = -0.11629+2.4254*D$
6	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
7	*Holoptelea integrifolia*	$\sqrt{V} = 0.21569+4.329878*D-1.504977*\sqrt{D}$
8	*Lannea coromandelica*	$\sqrt{V} = 0.404153+5.555051*D-2.545525*\sqrt{D}$
9	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = 0.074069-1.230020*D+7.726902*D^2$
10	*Tectona grandis*	$V = 0.062108-0.927983*D+6.613031*D^2$

Sikkim

Sl. No.	Species Name	Volume Equation
1	*Abies pindrow*	$V = 7.92*D^2+0.244*D-0.061$
2	*Alnus nepalensis*	$V = 0.9041+9.2172*D-5.7697*\sqrt{D}$
3	*Alnus species*	$V = 0.0741-1.3603*D+10.9229*D^2$
4	*Bombax ceiba*	$V = 0.2219-0.02827*D*100+0.001284*D^2*10000$
5	*Castanopsis species*	$V = 0.05331-0.87098*D+6.52533*D^2+1.74231*D^3$
6	*Cryptomeria japonica*	$V = -0.01097+5.30991*D^2$
7	*Eurya japonica*	$V = -0.01097+5.30991*D^2$
8	*Schima wallichii*	$\sqrt{V} = -0.4319+1.7358*D^2+1.6093*\sqrt{D}$
9	*Shorea robusta*	$\sqrt{V} = -0.22388+3.29474*D$
10	*Symplocos theifolia*	$V = -0.03754+5.87*D^2$

Tamil Nadu

Sl. No.	Species Name	Volume Equation
1	*Albizia amara*	$V = 0.0200645487525004-0.78681649062609*D+6.80315298169127*D^2$
2	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = 0.045731-1.020606*D+9.656667*D^2$
3	*Chloroxylon swietenia*	$\sqrt{V} = -0.2303 + 3.3915*D$
4	*Eucalyptus species*	$V = 0.02894-0.89284*D+8.72416*D^2$
5	*Hardwickia binata*	$\sqrt{V} = -0.2161 + 2.9509*D$
6	*Pterocarpus marsupium*	$V = 0.058424-1.233468*D+9.433633*D^2$
7	*Syzygium cumini*	$\sqrt{V} = 0.30706+5.12731*D-2.0987*\sqrt{D}$
8	*Tamarindus indica*	$V = 0.131-1.87132*D+9.47861*D^2$
9	*Tectona grandis*	$\sqrt{V} = -0.405890+1.98158*D+0.987373*\sqrt{D}$
10	*Terminalia paniculata*	$V = 0.131-1.87132*D+9.47861*D^2$

Telangana

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = -0.061856+7.952136*D^2$
2	*Chloroxylon swietenia*	$\sqrt{V} = -0.2303 + 3.3915*D$
3	*Dalbergia lanceolaria/ Dalbergia paniculata (Old name)*	$\sqrt{V} = -0.1373 + 2.7819*D$
4	*Hardwickia binata*	$\sqrt{V} = -0.2161 + 2.9509*D$
5	*Lagerstroemia parviflora*	$V = 0.066188-1.334512*D+9.403257*D^2$
6	*Lannea coromandelica*	$V = 0.091153-1.66153*D+10.24624*D^2$
7	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = 0.046883-0.894379*D+7.220441*D^2$
8	*Tectona grandis*	$V = 0.023613-0.531006*D+6.731036*D^2$
9	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.051812-1.076790*D+7.991280*D^2$
10	*Xylia xylocarpa*	$\sqrt{V} = -0.0990+2.6224*D$

Tripura

Sl. No.	Species Name	Volume Equation
1	*Albizia species*	$\sqrt{V} = -0.07109+2.99732*D-0.26953*\sqrt{D}$
2	*Anogeissus acuminata/ Anogeissus pendula/ Terminalia pendula*	$LogeV = 1.999+2.26*LogeD$
3	*Artocarpus chama/ Artocarpus chaplasha*	$\sqrt{V} = -0.15154+2.79983*D$
4	*Artocarpus heterophyllus/ Artocarpus integrifolia*	$\sqrt{V} = -0.15154+2.79983*D$
5	*Careya arborea*	$\sqrt{V} = 0.23738+2.33289*D+0.48512*\sqrt{D}$
6	*Gmelina arborea*	$\sqrt{V} = -0.00189+2.10033*D$
7	*Hevea brasiliensis*	$V = 0.1334-2.1584*D+11.2457*D^2$
8	*Schima wallichii*	$\sqrt{V} = -0.4319+1.7358*D^2+1.6093*\sqrt{D}$
9	*Shorea robusta*	$\sqrt{V} = -0.22388+3.29474*D$
10	*Tectona grandis*	$V = 0.19112-3.25372*D+17.9194*D^2-1.66117*D^3$

Uttar Pradesh

Sl. No.	Species Name	Volume Equation
1	*Acacia catechu/ Senegalia catechu*	$V = 0.16609-2.78851*D+17.22127*D^2-11.60248*D^3$
2	*Anogeissus latifolia/ Terminalia anogeissiana*	$\sqrt{V} = -0.07738+2.592167*D$
3	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
4	*Lannea coromandelica*	$V = 0.14004-2.3599*D+11.90726*D^2$
5	*Mallotus philippensis*	$\sqrt{V} = -0.1120+2.4764*D$
6	*Prosopis juliflora/ Neltuma juliflora*	$\sqrt{V} = -0.2528+3.4327*D$
7	*Shorea robusta*	$\sqrt{V} = 0.16306+4.8991*D-1.57402*\sqrt{D}$
8	*Syzygium cumini*	$V = 0.08481-1.81774*D+12.63047*D^2-6.9555*D^3$
9	*Tectona grandis*	$V = 0.08847-1.46936*D+11.98979*D^2+1.970560*D^3$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.18149-2.85865*D+18.60799*D^2$

Uttarakhand

Sl. No.	Acacia catechu/ Senegalia catechu	$V = 0.26949-1.61804*D+8.79495*D^2+2.49489*D^3$
1	*Abies pindrow*	$V = 7.92*D^2+0.244*D-0.061$
2	*Lyonia ovalifolia*	$\sqrt{V} = -0.1994+2.7286*D$
3	*Picea smithiana*	$V = 11.770869*D^2+0.163269-2.232068*D+1.06041*D^3$
4	*Pinus roxburghii*	$\sqrt{V} = 0.05131+3.9859*D-1.0245*\sqrt{D}$
5	*Quercus floribunda/ Quercus dilatata*	$V = 0.0988-1.5547*D+10.1631*D^2$
6	*Quercus leucotrichophora*	$\sqrt{V} = -0.1522+2.6407*D$
7	*Quercus semecarpifolia*	$V = 0.098800-1.55471*D+10.16317*D^2$
8	*Rhododendron arboreum*	$\sqrt{V} = 0.306492+4.31536*D-1.749908*\sqrt{D}$
9	*Shorea robusta*	$\sqrt{V} = 0.16306+4.8991*D-1.57402*\sqrt{D}$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.08658-2.04096*D+13.28405*D^2-3.58047*D^3$

West Bengal

Sl. No.	Species Name	Volume Equation
1	*Acacia auriculiformis*	$V = 0.0969104069887445-1.82691953677535*D+10.9747598076157*D^2$
2	*Aglaia spectabilis*	$\sqrt{V} = 0.00905+3.7648*D-0.64993*\sqrt{D}$
3	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
4	*Eucalyptus species*	$V = 0.02894-0.89284*D+8.72416*D^2$
5	*Lagerstroemia speciosa*	$V = 0.11740-1.58941*D+9.76464*D^2$
6	*Madhuca longifolia/ M. latifolia/ M. indica*	$\sqrt{V} = -0.1808+2.8409*D$
7	*Schima wallichii*	$\sqrt{V} = -0.4319+1.7358*D^2+1.6093*\sqrt{D}$
8	*Shorea robusta*	$V = 0.16019-2.81861*D+16.19328*D^2$
9	*Tectona grandis*	$V = 0.19112-3.25372*D+17.9194*D^2-1.66117*D^3$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$V = 0.022389-0.84158*D+9.4721*D^2$

Andaman & Nicobar Islands

Sl. No.	Species Name	Volume Equation
1	*Artocarpus chama/ Artocarpus chaplasha*	$\sqrt{V} = -0.15154+2.79983*D$
2	*Bombax ceiba*	$V = 0.136196-2.07674*D+10.1566*D^2$
3	*Canarium euphyllum*	$V = 0.004338-0.7315*D+11.1750*D^2$
4	*Cinnamomum species*	$V = 0.089-1.242*D+9.732*D^2$
5	*Dillenia pentagyna*	$V = 0.070-1.295*D+9.429*D^2$
6	*Dipterocarpus species*	$V = -0.045595+8.576*D^2$
7	*Elaeis guineensis*	$V = 0.0239-0.6266*D+5.4067*D^2$
8	*Pterocymbium tinctorium*	$V = 0.019795-0.99448*D+10.101*D^2$
9	*Terminalia bialata*	$V = 0.05061-1.11994*D+8.77839*D^2$
10	*Terminalia procera*	$V = 0.05061-1.11994*D+8.77839*D^2$

Chandigarh

Sl. No.	Species Name	Volume Equation
1	*Acacia catechu/ Senegalia catechu*	$V = 0.02384-0.72161*D+7.46888*D^2$
2	*Dalbergia sissoo*	$V = 0.00331+6.36*D^2$
3	*Emblica officinalis/ Phyllanthus emblica*	$V = -0.022635+4.889163*D^2$
4	*Eucalyptus species*	$V = 0.02894-0.89284*D+8.72416*D^2$
5	*Melia azedarach*	$V = -0.03510+5.32981*D^2$
6	*Morus species*	$V = -0.0351+5.32981*D^2$
7	*Populus species*	$\sqrt{V} = -0.143393+3.040067*D$
8	*Prosopis juliflora/ Neltuma juliflora*	$\sqrt{V} = -0.2528+3.4327*D$
9	*Syzygium cumini*	$V = 0.09809-1.94468*D+13.36728*D^2-6.33263*D^3$
10	*Terminalia bellirica*	$\sqrt{V} = -0.14017+3.36423*D$

Dadra & Nagar Haveli and Daman & Diu

Sl. No.	Species Name	Volume Equation
1	*Acacia catechu/ Senegalia catechu*	$V = -0.048108+5.873169*D^2$
2	*Anogeissus latifolia/ Terminalia anogeissiana*	$V = 0.030502-1.105937*D+12.261268*D^2$
3	*Butea monosperma*	$\sqrt{V} = 1.6007+15.6578*D-6.7295*D^2-9.2184*\sqrt{D}$
4	*Lagerstroemia parviflora*	$\sqrt{V} = 0.027366+3.668008*D-0.718475*\sqrt{D}$
5	*Lannea coromandelica*	$\sqrt{V} = 0.404153+5.555051*D-2.545525*\sqrt{D}$
6	*Madhuca longifolia/ M. latifolia/ M. indica*	$V = 0.074069-1.230020*D+7.726902*D^2$
7	*Schleichera oleosa/ Schleichera trijuga*	$\sqrt{V} = -0.2355+3.4705*D$
8	*Tectona grandis*	$\sqrt{V} = -0.40589+1.98158*D+0.987373*\sqrt{D}$
9	*Terminalia bellirica*	$V = 0.074706-1.430082*D+10.181971*D^2$
10	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	$\sqrt{V} = -0.203947+3.159215*D$

Jammu and Kashmir

Sl. No.	Species Name	Volume Equation
1	*Abies densa*	$V = 0.10774-2.09529*D+12.62008*D^2-1.61065*D^3$
2	*Abies pindrow*	$V = 0.10774-2.09529*D+12.62008*D^2-1.61065*D^3$
3	*Acacia catechu/ Senegalia catechu*	$V = 0.02384-0.72161*D+7.46888*D^2$
4	*Cedrus deodara*	$V = 10.03982*D^2-1.28303*D+0.07367$
5	*Dalbergia sissoo*	$V = 0.00331+6.36*D^2$
6	*Lannea coromandelica*	$\sqrt{V} = -0.13498+2.57874*D$
7	*Mallotus philippensis*	$\sqrt{V} = -0.1120+2.4764*D$
8	*Pinus wallichiana/ Pinus excelsa*	$V = 0.02-0.851*D+10.44*D^2$
9	*Pinus roxburghii*	$V = 0.128812-2.285176*D+11.950158*D^2$
10	*Quercus leucotrichophora*	$\sqrt{V} = -0.1522+2.6407*D$

ANNEXURE-IX

Estimated Number of Trees by Species and Diameter Class in Forest at Country Level

(in '000)

Sl. No.	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1	*Abies densa*	5,066	9,831	3,588	18,485	0.13
2	*Abies pindrow*	20,635	26,978	15,632	63,246	0.44
3	*Adina cordifolia*	36,459	11,710	2,350	50,519	0.35
4	*Anogeissus latifolia/ Terminalia anogeissiana*	4,53,412	50,707	1,390	5,05,509	3.48
5	*Bischofia javanica*	24,572	7,239	1,679	33,490	0.23
6	*Bombax ceiba*	26,516	11,861	3,812	42,189	0.29
7	*Boswellia serrata*	52,916	41,131	857	94,904	0.65
8	*Buchanania lanzan/ Buchanania latifolia*	2,44,619	6,304	0	2,50,923	1.73
9	*Butea monosperma*	1,82,508	16,920	237	1,99,665	1.37
10	*Castanopsis species*	1,10,707	21,696	6,388	1,38,792	0.95
11	*Cedrus deodara*	50,281	30,082	11,194	91,556	0.63
12	*Chloroxylon swietenia*	2,60,341	13,369	58	2,73,768	1.88
13	*Cleistanthus collinus*	2,34,424	7,037	175	2,41,636	1.66
14	*Dalbergia lanceolaria/ Dalbergia paniculata (Old name)*	57,031	14,738	609	72,378	0.50
15	*Dillenia pentagyna*	35,099	11,168	1,424	47,691	0.33
16	*Diospyros melanoxylon*	2,47,408	27,066	1,138	2,75,612	1.90
17	*Ficus benghalensis*	4,543	1,715	2,454	8,712	0.06
18	*Ficus species*	73,787	9,543	3,463	86,793	0.60
19	*Lagerstroemia microcarpa/ Lagerstroemia lanceolata*	12,387	7,484	2,134	22,005	0.15
20	*Lagerstroemia parviflora*	2,81,260	20,360	786	3,02,407	2.08
21	*Lannea coromandelica*	3,43,172	57,156	1,797	4,02,124	2.77
22	*Madhuca longifolia/ M. latifolia/ M. indica*	1,39,289	36,392	4,143	1,79,824	1.24
23	*Picea smithiana*	15,116	11,953	7,604	34,673	0.24
24	*Pinus wallichiana/ Pinus excelsa*	80,238	47,875	11,588	1,39,701	0.96
25	*Pinus roxburghii*	2,11,443	1,09,318	11,824	3,32,586	2.29
26	*Pterocarpus marsupium*	85,351	21,066	1,982	1,08,399	0.75
27	*Quercus leucotrichophora*	2,12,536	36,751	3,285	2,52,572	1.74
28	*Quercus semecarpifolia*	17,215	10,226	3,734	31,175	0.21
29	*Quercus species*	98,763	12,742	1,848	1,13,353	0.78
30	*Rhododendron arboreum*	1,00,032	17,948	936	1,18,915	0.82
31	*Schima wallichii*	1,24,924	14,355	2,421	1,41,700	0.97
32	*Schleichera oleosa/ Schleichera trijuga*	65,313	20,191	1,869	87,372	0.60
33	*Shorea robusta*	10,82,555	2,32,627	20,239	13,35,422	9.19
34	*Syzygium cumini*	1,10,350	29,471	3,915	1,43,737	0.99
35	*Tectona grandis*	8,95,398	96,459	2,455	9,94,311	6.84
36	*Terminalia bellirica*	43,668	11,954	2,585	58,208	0.40
37	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	3,83,959	80,877	5,819	4,70,655	3.24
38	*Terminalia myriocarpa*	15,854	7,439	2,662	25,956	0.18
39	*Terminalia paniculata*	75,241	20,611	4,404	1,00,257	0.69
40	*Xylia xylocarpa*	1,40,701	27,050	1,898	1,69,649	1.17
41	*Rest of Species*	57,33,326	6,54,392	89,850	64,77,568	44.55
	Total	**1,23,88,417**	**19,03,792**	**2,46,226**	**1,45,38,435**	**100.00**

ANNEXURE-X

Estimated Volume of Trees by Species and Diameter Class in Forest at Country Level

(in M m^3)

Sl. No.	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1	*Abies densa*	1.35	13.42	18.33	33.11	0.74
2	*Abies pindrow*	5.40	36.79	96.79	138.98	3.10
3	*Adina cordifolia*	4.70	12.62	12.94	30.26	0.68
4	*Anogeissus latifolia/ Terminalia anogeissiana*	67.50	51.38	5.46	124.34	2.78
5	*Bischofia javanica*	4.78	8.57	10.76	24.11	0.54
6	*Bombax ceiba*	4.55	13.47	18.63	36.65	0.82
7	*Boswellia serrata*	10.24	37.03	2.55	49.82	1.11
8	*Buchanania lanzan/ Buchanania latifolia*	20.88	4.99	0.00	25.87	0.58
9	*Butea monosperma*	15.73	12.07	0.54	28.34	0.63
10	*Castanopsis species*	11.56	18.71	34.89	65.16	1.45
11	*Cedrus deodara*	9.49	39.14	52.92	101.56	2.27
12	*Chloroxylon swietenia*	26.48	13.45	0.21	40.14	0.90
13	*Cleistanthus collinus*	18.72	3.33	0.42	22.47	0.50
14	*Dalbergia lanceolaria/ Dalbergia paniculata (Old name)*	7.47	13.17	2.06	22.70	0.51
15	*Dillenia pentagyna*	5.11	10.83	5.65	21.59	0.48
16	*Diospyros melanoxylon*	23.90	24.55	4.49	52.95	1.18
17	*Ficus benghalensis*	0.52	1.58	21.19	23.30	0.52
18	*Ficus species*	8.12	9.38	20.75	38.25	0.85
19	*Lagerstroemia microcarpa/ Lagerstroemia lanceolata*	1.92	8.89	11.41	22.22	0.50
20	*Lagerstroemia parviflora*	29.67	17.01	3.29	49.97	1.12
21	*Lannea coromandelica*	52.03	51.28	6.93	110.24	2.46
22	*Madhuca longifolia/ M. latifolia/ M. indica*	17.27	33.57	14.22	65.05	1.45
23	*Picea smithiana*	2.54	16.52	59.80	78.87	1.76
24	*Pinus wallichiana/ Pinus excelsa*	17.81	67.16	59.91	144.89	3.23
25	*Pinus roxburghii*	34.00	113.44	51.08	198.52	4.43
26	*Pterocarpus marsupium*	14.00	22.93	8.66	45.59	1.02
27	*Quercus leucotrichophora*	20.48	28.73	11.02	60.23	1.34
28	*Quercus semecarpifolia*	3.12	12.04	17.39	32.56	0.73
29	*Quercus species*	11.21	13.82	10.47	35.50	0.79
30	*Rhododendron arboreum*	10.96	14.58	3.75	29.29	0.65
31	*Schima wallichii*	10.26	10.05	8.09	28.39	0.63
32	*Schleichera oleosa/ Schleichera trijuga*	11.79	25.22	10.78	47.78	1.07
33	*Shorea robusta*	149.28	263.02	99.66	511.96	11.43
34	*Syzygium cumini*	13.72	27.24	17.65	58.61	1.31
35	*Tectona grandis*	108.07	82.58	8.96	199.61	4.46
36	*Terminalia bellirica*	6.54	13.32	11.05	30.92	0.69
37	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	51.03	85.52	24.33	160.88	3.59
38	*Terminalia myriocarpa*	4.46	10.30	15.88	30.63	0.68
39	*Terminalia paniculata*	9.67	20.65	20.11	50.44	1.13
40	*Xylia xylocarpa*	18.52	23.16	5.87	47.55	1.06
41	*Rest of Species*	581.31	566.11	412.18	1,559.60	34.82
	Total	**1,426.18**	**1,851.64**	**1,201.08**	**4,478.90**	**100.00**

ANNEXURE-XI

Estimated Stems by Species and Diameter Class in TOF at Country Level

(in '000)

Sl. No.	Species	Diameter Class (cm)				Total	Percent
		5-10	10-30	30-60	60+		
1	*Acacia nilotica/ Acacia arabica/ Vachellia nilotica*	90,957	1,63,378	39,805	1,387	2,95,527	2.73
2	*Acacia auriculiformis*	66,072	1,02,825	4,811	183	1,73,891	1.61
3	*Areca catechu*	87,053	4,01,381	142	14	4,88,590	4.52
4	*Artocarpus heterophyllus/ Artocarpus integrifolia*	7,684	45,131	14,337	1,273	68,425	0.63
5	*Azadirachta indica/ Melia indica*	2,12,314	3,61,726	92,847	5,748	6,72,635	6.22
6	*Bombax ceiba*	12,642	31,798	9,617	1,012	55,069	0.51
7	*Borassus flabellifer/ Borassus flabelliformis*	333	16,090	87,453	798	1,04,674	0.97
8	*Butea monosperma*	83,850	1,56,775	30,732	1,318	2,72,675	2.52
9	*Castanopsis species*	25,345	44,564	4,631	280	74,820	0.69
10	*Cocos nucifera*	914	2,43,542	1,03,419	263	3,48,138	3.22
11	*Dalbergia sissoo*	22,448	60,162	14,154	860	97,624	0.90
12	*Elaeis guineensis*	646	537	5,775	9,538	16,496	0.15
13	*Eucalyptus species*	1,48,987	1,53,480	15,632	1,022	3,19,121	2.95
14	*Ficus benghalensis*	2,559	5,884	3,935	4,567	16,945	0.16
15	*Ficus racemosa/ Ficus glomerata*	6,948	12,282	6,236	1,892	27,358	0.25
16	*Ficus religiosa*	5,314	9,174	5,059	5,296	24,843	0.23
17	*Ficus species*	22,061	25,367	3,158	1,225	51,811	0.48
18	*Hevea brasiliensis*	28,980	1,88,921	8,111	103	2,26,115	2.09
19	*Holoptelea integrifolia*	25,205	34,164	7,107	516	66,992	0.62
20	*Leucaena leucocephala*	1,19,256	75,355	3,845	524	1,98,980	1.84
21	*Madhuca longifolia/ M. latifolia/ M. indica*	7,506	22,784	23,679	17,095	71,064	0.66
22	*Mangifera indica*	1,45,608	5,10,791	1,13,664	24,752	7,94,815	7.34
23	*Phoenix sylvestris*	281	40,779	17,178	39	58,277	0.54
24	*Pinus wallichiana/ Pinus excelsa*	2,590	18,924	9,939	1,913	33,366	0.31
25	*Pinus kesiya*	9,615	44,865	4,593	510	59,583	0.55
26	*Pinus roxburghii*	7,201	47,447	12,299	1,161	68,108	0.63
27	*Pongamia pinnata*	37,457	44,100	7,015	657	89,229	0.82
28	*Populus species*	37,346	63,713	4,082	341	1,05,482	0.97
29	*Prosopis cineraria*	10,499	59,049	36,674	1,215	1,07,437	0.99
30	*Prosopis juliflora/ Neltuma juliflora*	6,05,654	1,33,629	3,426	421	7,43,130	6.87
31	*Quercus leucotrichophora*	11,204	26,251	10,802	373	48,630	0.45
32	*Salix species*	20,636	23,978	4,704	492	49,810	0.46
33	*Schima wallichii*	24,638	48,022	5,458	516	78,634	0.73
34	*Shorea robusta*	23,400	91,900	18,627	3,221	1,37,148	1.27
35	*Syzygium cumini*	21,377	50,441	17,714	1,850	91,382	0.84
36	*Tamarindus indica*	7,130	23,343	18,461	6,666	55,600	0.51
37	*Tectona grandis*	1,01,345	2,04,597	13,491	523	3,19,956	2.96
38	*Terminalia arjuna*	7,761	31,473	13,455	1,184	53,873	0.50
39	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	25,377	56,148	8,572	995	91,092	0.84
40	*Ziziphus mauritiana*	1,15,863	1,17,808	9,463	452	2,43,586	2.25
41	*Rest of Species*	17,35,088	18,95,897	2,58,647	30,695	39,20,327	36.23
	Total	**39,27,144**	**56,88,475**	**10,72,749**	**1,32,890**	**1,08,21,258**	**100.00**

ANNEXURE-XII

Estimated Volume by Species and Diameter Class in TOF at Country Level

(in M m^3)

Sl. No.	Species	Diameter Class (cm)				Total	Percent
		5-10	10-30	30-60	60+		
1	*Acacia nilotica/ Acacia arabica/ Vachellia nilotica*	1.03	18.83	27.67	3.40	50.93	2.61
2	*Acacia auriculiformis*	0.86	7.06	2.68	0.43	11.03	0.57
3	*Areca catechu*	1.22	9.77	0.06	0.04	11.09	0.57
4	*Artocarpus heterophyllus/ Artocarpus integrifolia*	0.11	5.89	11.79	9.73	27.52	1.41
5	*Azadirachta indica/ Melia indica*	2.40	41.41	73.67	19.12	136.60	7.00
6	*Bombax ceiba*	0.28	4.11	8.42	4.88	17.69	0.91
7	*Borassus flabellifer/ Borassus flabelliformis*	0.01	3.02	46.44	1.44	50.91	2.61
8	*Butea monosperma*	0.70	18.67	24.36	4.96	48.69	2.50
9	*Castanopsis species*	0.31	5.06	3.53	1.15	10.05	0.52
10	*Cocos nucifera*	0.01	44.23	36.38	0.63	81.25	4.16
11	*Dalbergia sissoo*	0.32	10.68	12.53	3.04	26.57	1.36
12	*Elaeis guineensis*	0.01	0.05	4.87	15.04	19.97	1.02
13	*Eucalyptus species*	1.42	14.18	11.64	3.02	30.26	1.55
14	*Ficus benghalensis*	0.03	0.78	4.14	34.05	39.00	2.00
15	*Ficus racemosa/ Ficus glomerata*	0.08	1.63	6.28	6.84	14.83	0.76
16	*Ficus religiosa*	0.11	0.99	5.16	19.10	25.36	1.30
17	*Ficus species*	0.28	2.31	2.18	6.55	11.32	0.58
18	*Hevea brasiliensis*	0.25	18.00	3.72	0.49	22.46	1.15
19	*Holoptelea integrifolia*	0.37	3.44	5.39	1.91	11.11	0.57
20	*Leucaena leucocephala*	1.46	7.45	3.93	2.15	14.99	0.77
21	*Madhuca longifolia/ M. latifolia/ M. indica*	0.08	2.96	19.79	62.40	85.23	4.37
22	*Mangifera indica*	2.00	58.11	95.63	102.76	258.50	13.25
23	*Phoenix sylvestris*	0.00	6.47	6.84	0.08	13.39	0.69
24	*Pinus wallichiana/ Pinus excelsa*	0.03	4.15	10.81	11.62	26.61	1.36
25	*Pinus kesiya*	0.17	6.17	3.15	3.49	12.98	0.67
26	*Pinus roxburghii*	0.11	7.47	11.74	5.20	24.52	1.26
27	*Pongamia pinnata*	0.40	5.60	7.80	2.61	16.41	0.84
28	*Populus species*	0.94	6.51	4.45	1.82	13.72	0.70
29	*Prosopis cineraria*	0.11	8.48	23.81	4.10	36.50	1.87
30	*Prosopis juliflora/ Neltuma juliflora*	5.11	7.78	2.05	1.45	16.39	0.84
31	*Quercus leucotrichophora*	0.12	3.92	9.09	1.44	14.57	0.75
32	*Salix species*	0.79	4.33	5.54	3.26	13.92	0.71
33	*Schima wallichii*	0.42	8.01	5.95	2.76	17.14	0.88
34	*Shorea robusta*	0.18	12.03	16.14	11.21	39.56	2.03
35	*Syzygium cumini*	0.22	6.43	13.92	7.24	27.81	1.43
36	*Tamarindus indica*	0.07	3.51	16.56	33.12	53.26	2.73
37	*Tectona grandis*	1.54	22.36	9.72	2.96	36.58	1.88
38	*Terminalia arjuna*	0.08	4.64	10.31	4.42	19.45	1.00
39	*Terminalia elliptica/ T. crenulata/ T. tomentosa*	0.34	6.12	6.63	3.24	16.33	0.84
40	*Ziziphus mauritiana*	1.27	10.84	8.17	1.57	21.85	1.12
41	*Rest of Species*	21.91	192.59	192.37	117.57	524.44	26.88
	Total	**47.15**	**606.04**	**775.31**	**522.29**	**1,950.79**	**100.00**

ANNEXURE-XIII

State/ UTs wise Standard Error % for Growing Stock & Tree Cover

(in M m^3)

Sl. No.	States / UTs	SE % (Forest Growing Stock)	SE % (TOF Growing Stock)	SE % (Tree Cover)
1	Andhra Pradesh	3.89	2.74	2.62
2	Arunachal Pradesh	8.97	9.54	2.79
3	Assam	5.58	4.11	2.70
4	Bihar	6.77	4.15	4.66
5	Chhattisgarh	2.42	2.78	2.69
6	Delhi	19.22	5.59	4.72
7	Goa	5.67	4.02	4.51
8	Gujarat	4.25	5.57	5.56
9	Haryana	8.67	3.55	4.61
10	Himachal Pradesh	4.04	4.23	4.96
11	Jharkhand	3.09	3.84	2.81
12	Karnataka	2.97	2.76	3.03
13	Kerala	3.23	2.88	4.18
14	Madhya Pradesh	2.05	2.62	2.01
15	Maharashtra	2.67	2.85	2.81
16	Manipur	16.86	8.25	6.84
17	Meghalaya	7.28	5.46	7.17
18	Mizoram	9.06	7.48	7.36
19	Nagaland	12.05	7.20	5.07
20	Odisha	2.88	5.65	4.62
21	Punjab	8.52	4.35	4.72
22	Rajasthan	4.07	2.05	1.85
23	Sikkim	12.44	4.63	6.95
24	Tamil Nadu	4.91	2.08	3.58
25	Telangana	3.01	3.62	3.75
26	Tripura	5.56	4.70	5.52
27	Uttar Pradesh	4.34	1.50	1.87
28	Uttarakhand	3.31	3.50	3.78
29	West Bengal	6.25	4.00	3.95
30	Andaman Nicobar Islands #	5.72	12.61	10.29
31	Chandigarh	13.38	6.60	5.39
32	Dadra & Nagar Haveli and Daman & Diu	11.48	8.34	-
33	Jammu and Kashmir	5.25	5.33	4.46
34	Ladakh * $	-	10.12	-
35	Lakshadweep #	-	12.06	-
36	Puducherry	-	6.12	5.72
	Total	**4.44**	**3.32**	**3.60**

**Due to inadequate data, Standard error is not given*

$ Inventory has been done only for two years due to Covid.

 # Due to inadequate data, Standard error is high

ANNEXURE-XIV

States/UTs wise Estimated Number of Stems ('000) and Volume (M cum) of Trees under Agroforestry System in India

State/UTs	Notified Geog. Area (in km²)	Diameter class in cm								Total No. of Stems	Total Volume
		05-10		10-30		30-50		50+			
		No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.		
Andhra Pradesh	1,62,923	1,67,056	2.46	1,88,901	17.32	47,355	21.87	14,077	27.71	4,17,389	69.36
Arunachal Pradesh	83,743	59,719	0.58	1,01,481	8.27	13,387	6.26	2,736	5.49	1,77,323	20.60
Assam	78,438	52,783	0.89	1,08,027	12.08	12,067	10.58	1,954	7.13	1,74,831	30.68
Bihar	94,163	34,632	0.72	84,875	11.40	23,750	17.16	4,518	12.18	1,47,775	41.46
Chhattisgarh	1,35,192	74,593	0.52	1,32,678	12.82	38,352	20.01	20,746	49.14	2,66,369	82.49
Delhi	1,483	331	0.01	405	0.05	61	0.03	14	0.04	811	0.13
Goa	3,702	7,064	0.05	19,820	0.96	2,200	0.72	425	0.70	29,509	2.43
Gujarat	1,96,244	1,91,500	2.29	1,85,218	22.44	32,981	27.41	7,417	26.73	4,17,116	78.87
Haryana	44,212	24,078	0.35	34,975	4.26	7,885	5.47	1,279	2.58	68,217	12.66
Himachal Pradesh	55,673	83,403	0.89	1,00,779	8.60	11,095	6.07	1,822	3.99	1,97,099	19.55
Jharkhand	79,716	42,132	0.27	1,13,973	11.92	28,892	16.75	11,331	36.69	1,96,328	65.63
Karnataka	1,91,791	3,10,901	1.99	5,03,871	35.49	74,659	33.67	11,930	27.16	9,01,361	98.31
Kerala	38,852	1,10,784	0.71	3,46,709	22.36	25,835	10.83	2,660	4.51	4,85,988	38.41
Madhya Pradesh	3,08,252	1,43,111	0.89	1,81,231	16.37	43,418	24.49	14,189	40.06	3,81,949	81.81
Maharashtra	3,07,713	5,20,285	4.30	5,33,343	40.88	90,648	45.22	21,112	46.05	11,65,388	136.45
Manipur	22,327	15,506	0.20	19,304	2.46	1,278	1.06	207	0.78	36,295	4.50
Meghalaya	22,429	62,554	0.67	1,21,008	10.61	10,045	5.79	656	1.53	1,94,263	18.60
Mizoram	21,081	19,090	0.21	31,891	2.68	2,820	1.79	476	1.53	54277	6.21
Nagaland	16,579	42,930	0.40	58,649	4.09	6,785	3.71	1,561	3.79	1,09,925	11.99
Odisha	1,55,707	76,224	0.67	1,43,555	17.63	32,620	23.78	12,582	46.45	2,64,981	88.53
Punjab	50,362	36,718	0.74	48,326	6.26	6,827	5.53	1,296	4.24	93,167	16.77
Rajasthan	3,42,239	2,30,156	1.69	2,43,540	26.96	59,474	35.74	8,957	21.87	5,42,127	86.26
Sikkim	7,096	3,044	0.04	4,922	0.42	878	0.40	123	0.18	8,967	1.04
Tamil Nadu	1,30,060	2,44,127	3.66	2,13,749	22.30	63,214	25.78	3,944	9.45	525,034	61.19
Telangana	1,12,122	1,22,958	1.05	1,46,606	14.61	22,189	13.55	4,791	12.80	2,96,544	42.01
Tripura	10,486	5,354	0.07	34,716	3.23	2,875	1.93	218	0.58	43,163	5.81
Uttar Pradesh	2,40,928	1,75,595	1.94	3,13,094	27.43	47,952	26.93	10,659	23.92	5,47,300	80.22
Uttarakhand	53,483	84,024	0.92	91,617	6.84	8,829	5.22	1,547	3.92	186,017	16.90
West Bengal	88,752	63,463	1.30	1,47,150	18.41	19,327	13.75	2,299	7.95	232,239	41.41
A & N Islands	8,249	2,619	0.05	8,127	0.26	552	0.26	113	0.33	11,411	0.90
Chandigarh	114	8	0.0001	8	0.0015	4	0.0036	0	0.00	20	0.01
Dadra Nagar Haveli	602	485	0.01	1,499	0.20	341	0.21	34	0.11	2,359	0.53
Jammu and Kashmir	2,22,236	25,641	0.34	62,037	6.02	16,933	8.77	5,535	14.46	1,10,146	29.59
Ladakh		601	0.01	513	0.04	69	0.04	19	0.03	1,202	0.12
Lakshadweep	30	19	0.01	182	0.02	45	0.01	1	0.00	247	0.04
Puducherry	490	868	0.01	663	0.08	192	0.09	12	0.03	1,735	0.21
Total	**32,87,469**	**30,34,356**	**30.91**	**43,27,44**	**395.77**	**7,55,83**	**420.88**	**1,71,240**	**444.11**	**82,88,872**	**1,291.68**

ANNEXURE-XV

Top 50 Species according to Number of stems (in '000) of Trees under Agroforestry System in India

Species Name	Diameter class in cm					
	05-10	10-30	30-50	50+	Total	Rank as per no. of Stems
Acacia nilotica/ Acacia arabica/ Vachellia nilotica	70905	127314	31131	3638	232988	9
Acacia auriculiformis	47505	68041	2983	237	118766	14
Acacia catechu/ Senegalia catechu	18409	24672	917	279	44277	39
Acacia lenticularis/ Senegalia lenticularis	20631	34751	5332	459	61173	27
Albizia amara	30475	13249	716	169	44609	38
Anacardium occidentale	30498	54216	3278	141	88133	17
Annona squamosa	60739	5153	61	95	66048	26
Areca catechu	65458	326136	120	3	391717	4
Artocarpus heterophyllus/ Artocarpus integrifolia	5623	31387	9973	1833	48816	33
Azadirachta indica/ Melia indica	191246	314811	73824	11999	591880	2
Bombax ceiba	11271	27351	6957	1548	47127	35
Borassus flabellifer/ Borassus flabelliformis	268	13528	73466	6660	93922	16
Butea monosperma	73564	138628	25943	3234	241369	8
Castanopsis species	16063	23272	2342	247	41924	41
Citrus sinensis	38885	5654	45	46	44630	37
Citrus species	116123	18664	37	86	134910	13
Cocos nucifera	797	170359	82458	312	253926	7
Coffea arabica	28793	6335	31	75	35234	48
Dalbergia sissoo	19203	49214	10698	1513	80628	18
Eucalyptus hybrid	16143	17431	2583	207	36364	46
Eucalyptus species	136524	129290	7599	1018	274431	5
Ficus species	16551	18030	1905	1145	37631	45
Gmelina arborea	9117	25654	3182	335	38288	44
Grevillea robusta	7942	23627	2245	239	34053	49
Grewia optiva/ Grewia oppositifolia	39797	31449	1184	76	72506	20
Hevea brasiliensis	26890	165978	7454	142	200464	11
Holoptelea integrifolia	21648	29374	5434	909	57365	28
Lannea coromandelica	13249	24104	2813	433	40599	43
Leucaena leucocephala	91629	54289	2079	423	148420	12
Madhuca longifolia/ M. latifolia/ M. indica	4969	17536	14594	20256	57355	29
Mangifera indica	128320	441417	84460	32578	686775	1
Melia azedarach	17537	27373	2386	165	47461	34
Morinda pubescens/ M. coreia/ M. tinctoria	20971	14195	425	71	35662	47
Phoenix sylvestris	233	34120	14850	170	49373	31

ANNEXURE-XV

Top 50 Species according to Number of stems (in '000) of Trees under Agroforestry System in India

Species Name	Diameter class in cm					
	05-10	10-30	30-50	50+	Total	Rank as per no. of Stems
Pinus kesiya	9231	41329	3544	228	54332	30
Pinus roxburghii	6332	30168	6430	790	43720	40
Pongamia pinnata	29805	33085	4836	1081	68807	23
Populus species	22861	43664	1226	103	67854	24
Prosopis cineraria	9435	56758	32767	4095	103055	15
Prosopis juliflora/ Neltuma juliflora	395927	89125	2127	446	487625	3
Psidium guajava	49766	19869	141	79	69855	22
Quercus leucotrichophora	10887	17717	3953	574	33131	50
Schima wallichii	16291	29259	2995	658	49203	32
Shorea robusta	12807	43856	8122	2888	67673	25
Syzygium cumini	16949	39980	12255	3010	72194	21
Tamarindus indica	6092	19607	12277	8359	46335	36
Tectona grandis	83685	160571	9360	732	254348	6
Terminalia arjuna	5886	24662	9583	1731	41862	42
Terminalia elliptica/ T. crenulata/ T. tomentosa	21795	47646	6271	1472	77184	19
Ziziphus mauritiana	104542	105330	8078	868	218818	10
Rest of Species	834088	1018213	148364	53387	2054052	51
Total	**3034355**	**4327441**	**755834**	**171242**	**8288872**	

ANNEXURE-XVI

Top 50 Species according to Volume (M m³) of Trees under Agroforestry System in India

Species Name	Diameter class in cm					
	05-10	10-30	30-50	50+	Total	Rank as per Volume
Acacia nilotica/ Acacia arabica/ Vachellia nilotica	0.66	12.51	16.39	5.2	34.76	9
Acacia auriculiformis	0.67	4.85	1.5	0.43	7.45	35
Acacia lenticularis/ Senegalia lenticularis	0.19	3.59	2.93	0.72	7.43	36
Albizia species	0.08	1.98	2.96	1.51	6.53	39
Albizia lebbeck	0.05	1.1	2.15	1.55	4.85	48
Albizia procera	0.03	1.27	2.36	1.28	4.94	47
Anacardium occidentale	0.32	3.67	1.18	0.17	5.34	44
Areca catechu	0.81	7.35	0.05	Negligible	8.21	30
Artocarpus heterophyllus/ Artocarpus integrifolia	0.07	3.69	6.55	8.13	18.44	15
Artocarpus hirsutus	0.03	1.23	2.41	1.73	5.4	41
Azadirachta indica/ Melia indica	1.89	31.65	44.84	23.49	101.87	2
Bombax ceiba	0.22	3.18	4.76	4.75	12.91	22
Borassus flabellifer/ Borassus flabelliformis	Negligible	2.46	35.24	7.13	44.83	5
Butea monosperma	0.54	14.28	15.48	6.64	36.94	7
Cocos nucifera	0.01	26.82	25.63	0.55	53.01	4
Dalbergia sissoo	0.26	8.07	7.84	3.39	19.56	13
Elaeis guineensis	Negligible	0.02	0.96	14.99	15.97	20
Eucalyptus species	1.15	9.97	4.55	2.16	17.83	16
Ficus benghalensis	0.02	0.5	1.57	24.88	26.97	10
Ficus racemosa/ Ficus glomerata	0.05	1.03	2.9	6.1	10.08	26
Ficus religiosa	0.08	0.72	2.24	13.35	16.39	18
Ficus species	0.17	1.29	0.92	4.47	6.85	37
Ficus virens	0.02	0.23	0.7	4.39	5.34	46
Gmelina arborea	0.16	3.87	1.87	0.6	6.5	40
Hevea brasiliensis	0.19	12.99	2.79	0.41	16.38	17
Holoptelea integrifolia	0.29	2.71	3.23	2.02	8.25	29
Lannea coromandelica	0.13	2.54	1.7	0.99	5.36	42
Leucaena leucocephala	0.93	4.45	1.36	1.16	7.9	32
Madhuca longifolia/ M. latifolia/ M. indica	0.05	2.1	8.88	56.03	67.06	3
Mangifera indica	1.64	46.11	55.39	93.69	196.83	1
Melia azedarach	0.39	3.05	1.49	0.43	5.36	43
Phoenix sylvestris	Negligible	5.23	5.3	0.21	10.74	25
Pinus wallichiana/ Pinus excelsa	0.01	1.21	2.62	3.7	7.54	34
Pinus kesiya	0.13	4.68	1.85	1.02	7.68	33
Pinus roxburghii	0.08	3.4	3.89	1.86	9.23	28
Pongamia pinnata	0.3	4.04	4.62	3.25	12.21	23
Prosopis cineraria	0.1	8.17	18.55	8.1	34.92	8

ANNEXURE-XVI

Top 50 Species according to Volume (M m^3) of Trees under Agroforestry System in India

Species Name	Diameter class in cm					
	05-10	10-30	30-50	50+	Total	Rank as per Volume
Prosopis juliflora/ Neltuma juliflora	3.1	4.74	1.03	1.02	9.89	27
Quercus leucotrichophora	0.09	1.74	2.42	1.09	5.34	45
Salvadora species	0.14	1.03	1.01	2.08	4.26	50
Schima wallichii	0.21	3.69	2.22	1.89	8.01	31
Schleichera oleosa/ Schleichera trijuga	0.01	0.32	0.64	3.4	4.37	49
Shorea robusta	0.11	6.22	6.43	9.2	21.96	12
Syzygium cumini	0.15	4.46	7.33	7.18	19.12	14
Tamarindus indica	0.05	2.57	8.23	30.87	41.72	6
Tectona grandis	1.14	14.81	5.52	1.86	23.33	11
Terminalia arjuna	0.06	3.42	5.84	3.94	13.26	21
Terminalia bellirica	0.05	1.37	2.11	3.2	6.73	38
Terminalia elliptica/ T. crenulata/ T. tomentosa	0.22	4.14	3.71	3.29	11.36	24
Ziziphus mauritiana	0.97	8.1	5.32	1.9	16.29	19
Rest of Species	12.89	93.15	69.42	62.71	238.18	51
Total	**30.91**	**395.77**	**420.88**	**444.11**	**1291.68**	

Photo: FSI Repository

ANNEXURE-XVII

The following land use classes are used during the NFI and are given in the NFI field manual: (01) Closed forest, (02) Dense forest, (03) Open forest, (04) Scrub, (06) Shifting cultivation, (07) Young crop including plantations of forestry species, (08) Trees in line, (09) Forest roads, (10) Govt. grass lands, (11) Barren lands, (12) Agricultural land without trees in surround, (13) Agricultural land with trees in surround, (14) Non forestry plantations, (15) Habitation, (16) Water bodies. While recording the parameters of characteristics of the forests many of the parameters will not be relevant for some of the land use classes. The aggregate area of these land use classes for that parameters have not be calculated and have been given as not applicable or NA. Details of these Land use Classes parameter-wise are given below.

Land Use Classes Applicable/Not Applicable for various parameters

Table No.	Parameter	Land Use Class														
		01	02	03	04	06	07	08	09	10	11	12	13	14	15	16
8.2	Soil Depth	A	A	A	A	A	A	A	NA	A	NA	A	A	A	NA	NA
8.4	Humus	A	A	A	A	A	A	A	NA	A	NA	NA	NA	A	NA	NA
8.7	Presence of Grasses	A	A	A	A	A	A	A	NA	A	NA	NA	NA	A	NA	NA
8.9	Presence of Ground Flora-Undergrowth	A	A	A	A	A	A	A	NA	A	NA	NA	NA	A	NA	NA
8.11	Soil Erosion	A	A	A	A	A	A	A	A	A	NA	A	A	A	NA	NA
8.13	Grazing Incidence	A	A	A	A	A	A	A	A	A	NA	A	A	A	NA	NA
8.15	Invasive Species	A	A	A	A	A	A	A	NA	NA	NA	A	A	A	NA	NA
8.17	Illicit Felling	A	A	A	A	A	A	A	NA	NA	NA	NA	NA	NA	NA	NA
8.19	Girdling	A	A	A	A	A	A	A	NA	NA	NA	NA	NA	NA	NA	NA
8.21	Lopping Incidence	A	A	A	A	A	A	A	NA	NA	NA	NA	NA	NA	NA	NA
8.23	Biotic Influence	A	A	A	A	A	A	A	NA	A	NA	A	A	A	NA	NA
8.24	Origin of Forest Stand	A	A	A	NA	A	A	NA	NA	NA	NA	NA	NA	A	NA	NA
8.25	Status of Regeneration	A	A	A	NA	A	A	NA	NA	NA	NA	NA	NA	A	NA	NA
8.27	Size Class	A	A	A	NA	NA	A	NA	NA	NA	NA	NA	NA	A	NA	NA
8.28	Crop composition	A	A	A	A	NA	A	NA	NA	NA	NA	NA	NA	A	NA	NA
8.29	Canopy Layer	A	A	A	A	NA	A	NA	NA	NA	NA	NA	NA	A	NA	NA
8.30	Basal Area	A	A	A	NA	A	A	NA	NA	NA	NA	NA	NA	A	NA	NA
8.31	Plantation Potential	NA	NA	A	A	A	A	NA	NA	NA	NA	NA	NA	NA	NA	NA

CONTRIBUTORS

Headquarters Execution, Analysis & Report Preparation

Anoop Singh, Director General (IFS)
Prakash Lakhchaura, Deputy Director General (ISS)
Meera Iyer, Joint Director (IFS)
Kamal Pandey, Deputy Director (FI) (ISS)
Arvind Munde, Deputy Director (IFS)
Dr. Ankur Awadhiya, Deputy Director (IFS)
Dr. Sunil Chandra, Deputy Director
Sanjay Kumar Agarwal, Deputy Director
Devi Singh, Deputy Director (FCM – I)
S.K. Singh, Deputy Director (FCM – II)
Savita Semwal, Assistant Director
Girija Arora, Assistant Director
Nagaraja S.V., Assistant Director
D. Sangolkar, Assistant Director (I/C)

Senior Consultants

Rajesh Kumar (ISS Retired), Senior Consultant (HQ)
S.P. Sharma (IFS Retired), Senior Consultant (HQ)

Zonal officers Execution & Analysis

Dr. Soma Das (IFS), Regional Director, EZ
Dr. S.H.K. Murti, Deputy Director, EZ
Sanjay S. Kumbhare, Assistant Director, EZ
Dr.G.Trinadh Kumar (IFS), Regional Director, SZ
Dr.H.Venuprasad (IFS), Sr. Deputy Director, SZ
Shivanand S. Talawar (IFS) Sr. Deputy Director, SZ
S.Elamurugannan (IFS), Deputy Director, SZ
S.Sampath, Assistant Director, SZ
Chaturbhuja Behera (IFS), Ex. Regional Director, CZ
Bhumidas H. Naik, Assistant Director, CZ

Hindi Translation

Anil Kumar, Jr. Translation Officer (EZ)
Geeta, Jr. Translation Officer (HQ)
Shuvangi Somvanshi, Jr. Translation Officer (NZ)

Image Interpretation

Anita Bhuwal, STA, HQ
Vikas Gusain, STA, HQ
Ekta Singh, STA, HQ
Imtijongshi, STA, HQ
Garima Sharma, STA, HQ
Preeti Topwal, STA, HQ
Sapna Ghai, STA, HQ
Prasant Kumar, JTA, HQ
Ashutosh Singh, JTA, HQ
Kusha Goyal, Deputy Ranger, HQ
Subrata Majumder, Ex-Sr. Draftsman, EZ
Gowdappagowda N M, JTA, SZ
Dr. Rohini Nachiket Naidu, STA, CZ
Aprajita Yadav, STA, CZ
Parikshit Agarkar, Deputy Ranger, CZ
Aditya Kumar Sain, STA, NZ
Joginder Kumar, Sr. Draftsman, NZ
Shivam Gupta, Deputy Ranger, NZ

Data Processing

Yogesh Kumar, DPA, HQ
Suvikram Prakash, DPA, HQ
Karuna Saini, DPA, HQ
Sudeshna Pal, DPA, EZ
Deepak Kumar Dibansee, DPA (A), EZ
Late. P. Somasundaram, DPA (A), SZ

Field Inventory

Durgesh Kumar, STA, FSI HQ,
Dr. Salman Khan, Deputy Ranger, HQ
Harshi Jain, Deputy Ranger, HQ
Bahir Marzooque A.S., STA, EZ
Durgesh Kumar Nagar, STA, EZ
Biplab Shaw, STA, EZ
Ranjeet Kumar, STA, EZ
Vikas Singh, JTA, EZ
Aarti Das, JTA, EZ
Palash Gorai, Deputy Ranger/ JTA, EZ
Uttam Pal, Dy. Ranger, EZ
Deen Ambedkar Modi, Deputy Ranger, EZ
Subash Kr. Pal, Deputy Ranger, EZ
Sukhen Pal, F.M, EZ
Joshimunddin Ahamed, F.M, EZ
Manik Gorai, F.M, EZ
Sova Pramanik, F.M. EZ
Abhishek Kumar, F.M, EZ
Sikendra Yadav, M.T.S., EZ
Nitesh Kumar, M.T.S., EZ
S.Krishnamoorthi, STA, SZ
Suresha T, STA, SZ
Rangasamy V, STA, SZ
Nandana Kumar H V, STA, SZ
N.U.Aruna, STA, SZ
G.S.Thiagaraj, SDM, SZ
K.P.Singh, JTA, SZ
Anil Ramesh, JTA, SZ
Avinash Karra, JTA, SZ
Bidyut Nayek, JTA, SZ
B.Vijayakumar, JTA, SZ

Mohamed Perveez, JTA, SZ
Peeli Shekar, Deputy Ranger, SZ
Ankam Vijay, Deputy Ranger, SZ
Vangala Sekhar, Deputy Ranger, SZ
Rajeev Kumar, Fieldsman, SZ
Sitaram Pawara, STA, CZ
Pradeep Kumar Kushwaha, STA
Rajesh Dhanawade, JTA, CZ
M. T. Siddiqui, JTA, CZ
Ashwinkumar Dhargave, JTA, CZ
Prashant Pimpale, JTA, CZ
Abhishek Kumar Singh, JTA, CZ
Devendra Gharpinde, JTA, CZ
Rahul Chauhan, JTA, CZ
Praveen Kumar Nag, JTA, CZ
Gaurang Panchal, JDM, CZ
Kartik Pramanik, Deputy Ranger, CZ
Raviprakash D. Patil, JTA, CZ
Fooldas Bhalavi, JTA, CZ
Pradip Nagose, JTA, CZ
Dr. Chandramohan K, Deputy Ranger, CZ
Ananta Kakade, Deputy Ranger, CZ
Bhushan Bhanarkar, Deputy Ranger, CZ
Amit Jarvekar, Deputy Ranger, CZ
Ritesh Ashtikar, Deputy. Ranger, CZ
Liladhar P. Vaidya, Deputy Ranger, CZ
Himalaya Putra, Fields Man, CZ
Vikas Singla, JTA, NZ
Pooja Thakur, JTA, NZ
Prince Lal Jangid, JTA, NZ
Naresh Kumar Bharti, JTA, NZ
Yashwant Singh Parihar, JTA, NZ
Subhash Singh, JTA, NZ
Pawan Kumar, JTA, NZ
Deepti Dhiman, JTA, NZ
Siddharath Kumar, JTA, NZ
Sandeep Singh, Deputy Ranger, NZ
Vijay Kumar, Deputy Ranger, NZ
Shivam Gupta, Deputy Ranger, NZ
Jyoti, Deputy Ranger, NZ
Pawan kumar, Deputy Ranger, NZ
Lakhwinder Singh, Deputy Ranger, NZ

Reprographic Support

Pratima Saini, Steno-I, HQ
Rahul Kumar, Steno-I, HQ
Mukesh Chauhan, Steno-II, HQ
Balbir Singh Bisht, DEO, HQ
Sajjan Singh, DEO, HQ
Ankuj Rana, MTS, HQ
Suman Bisht, Computer Operator, HQ
Manisha Chauhan, Computer Operator, HQ
Deepti, Computer Operator, HQ
Deepikaa, Computer Operator, HQ
Himanshi Dasila, Computer Operator, HQ
Anjali Saklani, Computer Operator, HQ
Jasveer Singh Chauhan, Computer Operator, HQ
Renu Rawat, Computer Operator, HQ
Manoj Chowdhury, Computer Operator, HQ
Babita, Computer Operator, HQ
Vijay Kumar Gupta, LDC, EZ
Saroj Mahato, DMO, EZ
Vinod M Lambodhari, Superintendent, SZ
S.Brinda, Superintendent, SZ
Abhinandan Tagore, Stenographer Gr-II, SZ

Project Scientists / Technical Associates

Dr. Sourav Ghosh, Project Scientist D, HQ
Manoj Uniyal, Project Scientist D, HQ
Sushila Tripathi, Project Scientist, HQ
Dr. Sharad Goyal, Project Scientist, HQ
Dr. Anuradha Tyagi, Sr. TA, HQ
Harender Singh Negi, Sr. TA, HQ
Prabhbir Singh, Sr. TA, HQ
Neetu Verma, Sr. TA, HQ
Kamlesh Khanduri, Sr. TA, HQ
Jagannath Mehatari, Sr. TA, HQ
Srikant Bhaya, Sr. TA, HQ
Rajendra Singh, Sr. TA, HQ
Sonia Sharma, Sr. TA, HQ
Deena Yadav, Sr. TA, HQ
Satyendra Kumar, Sr. TA, HQ,
Chander Mohan Bisht, Sr. TA, HQ
Akshay Joshi, Sr. TA, HQ
Sandeep Goel, Sr. TA, HQ
Abhishek Chaudhary, Sr. TA, HQ
Rashpal Singh, Sr. TA, HQ
Santanu Pani, Sr. TA, HQ
Biswajit Bera, Sr. TA, HQ
Vishal Singh, Sr. TA, HQ
Kaptan Singh, Sr. TA, HQ
Jayanta Karmakar, Sr. TA, HQ
Santosh Das, Sr. TA, HQ
Priyonath Adhikary, Sr. TA, HQ
Souvik Biswas, Sr. TA, HQ
Anupam Pal, Sr. TA, HQ
Pranab Khatua, Sr. TA, HQ
Biswajit Das, Sr. TA, HQ
Neeraj Kumar, Sr. TA, HQ
Vipin Rao, Sr. TA, HQ
Kiran Gupta, Sr. TA, HQ
Priyanka Kumari, Sr. TA, HQ
Akhilesh Panwar, TA, HQ
Shilpi Pal, Associate Programmer, HQ
Devansh Aggrawal, Associate Programmer, HQ
Anupam Ghosh, Sr. TA, EZ
Debangana Basu, Ex-Sr. TA, EZ
Tapan Dhar, Ex-Sr. TA, EZ
Somnath Maiti, Sr. TA, EZ
Tapas Biswas, Sr. TA, EZ
Soma Chakraborty, Sr. TA, SZ
Gautamee Bhaviskar, TA, SZ
Savita Khadse, Sr.TA, CZ
Anjana Kumari, Sr. TA, NZ


Photo: Sanjay Shukla, IFS

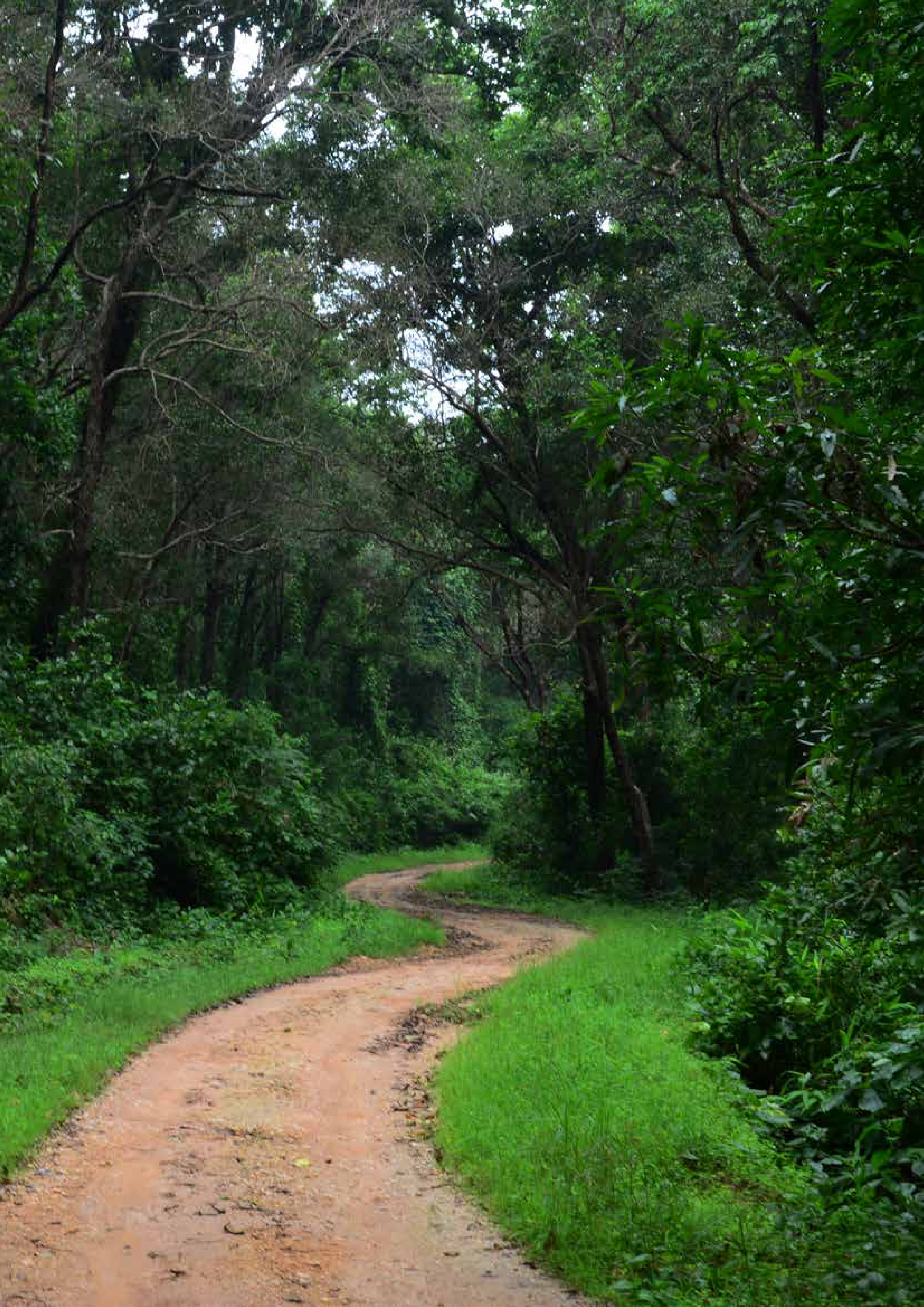



Photo: Subharanjan Sen, IFS


Photo: Subharanjan Sen, IFS

About FSI

Forest Survey of India (FSI) is a premier national organization under the Ministry of Environment, Forest and Climate Change, Government of India. It is responsible for assessment and monitoring of the forest resources of the country on regular basis. Established on 1st June 1981, Forest Survey of India succeeded the “Pre-investment Survey of Forest Resources” (PISFR), a project initiated in 1965 by Government of India with the sponsorship of FAO and UNDP. The main objective of PISFR was to ascertain the availability of raw material for establishment of wood based industries in selected areas of the country. In its report in 1976, the National Commission on Agriculture (NCA) recommended for the creation of a National Forest Survey Organization for a regular, periodic and comprehensive forest resources survey of the country leading to creation of FSI.

The major activities of FSI include remote sensing based nation-wide forest cover mapping in biennial cycle, National Forest Inventory based on large number of sample plots laid across the country, forest fire monitoring, forest carbon assessment, forest type mapping and several projects on emerging issues and State specific requirements. Since 1987, FSI is publishing biennial ’State of Forest Reports’ on the status of the forest resources of the country. These reports are widely acclaimed nationally and as well as internationally and are treasure trove of primary information on Indian Forests.

FSI has headquarters at Dehradun and has pan India presence with four regional offices at Shimla, Kolkata, Nagpur and Bangalore. The Eastern zone has a sub centre at Burnihat.

FOREST SURVEY OF INDIA
Ministry of Environment, Forest & Climate Change
Government of India

Ph: +91 135 2756139, +91 135 2754507,
+91 135 2755037
Fax: +91 135 2759104
e-mail: dgfsi@fsi.nic.in
website: www.fsi.nic.in

9 788195 007394