WE BOW TO
THE EARTH
COVERED
WITH TREES
AND PLANTS

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2754507,
2755087
Fax : (91) 0135-2759104,
2754507,
2755087
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INDIA STATE OF FOREST REPORT 2021

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

FOREWORD

Forests have a deep cultural connect to civilization and its evolution in Indian subcontinent. Since time immemorial, forests have been a crucible for growth of the mind, a resource base and a sanctuary. In today's time and age, the importance of forests has captured public imagination and a global understanding is slowly emerging that in order to survive, mankind has to ensure the sustainable use of forests and tree resources.

The National Forest Policy and other legislations prescribe the pathway of forest conservation and management for meeting the people's needs. Rapid progress on the economic front necessitates scientific balancing of the developmental needs with the requirements of conservation and ecological security of the nation. From a policy perspective, it is therefore imperative that the state of forest and tree cover in the country is regularly monitored.

India is one of the few countries of the world that has a robust and scientific system of periodic forest and tree cover assessment. Forest and Tree Cover assessment is done on a two-year cycle and the outcomes are published in a biennial report of Forest Survey of India (FSI) as India State of Forest Report (ISFR). The first such report was brought out in 1987 and since then FSI has published 16 reports. The biennial report is an exhaustive and authoritative review of the state of forests in the country. In recent years, the activities of FSI have expanded in their scope. Forest Decision Support System, Forest Fire monitoring, E-Green Watch, Very High Resolution mapping and modernization of forest inventory are additional areas where FSI is contributing to the forestry sector.

India is committed to engage actively in multilateral negotiations under the UNFCCC in a positive, creative and forward-looking manner. Our objective is to establish an effective, cooperative and equitable global architecture based on climate justice and the principles of Equity and Common but Differentiated Responsibilities and Respective Capabilities, under the UNFCCC.

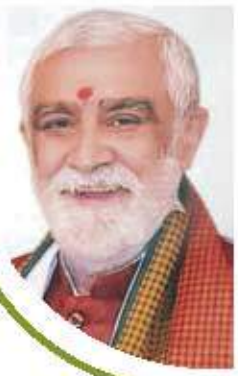
I am happy to share that despite the challenges posed by the COVID-19 pandemic, the task of preparing the 17th India State of Forest Report-2021 has been completed on schedule. I congratulate the Director General, FSI and his team for the preparation of this important document. I am confident that this report will serve as a convenient source of information for policy makers, planners, academicians and other stakeholders who are directly or indirectly involved in the management and conservation of the vast forest resources of the country.

With best wishes.

Bhupender Yadav

अश्विनी कुमार चौबे
Ashwini Kumar Choubey
पर्यावरण, वन एवं जलवायु परिवर्तन राज्य मंत्री
Minister of State for Environment,
Forest and Climate Change
भारत सरकार / Government of India

FOREWORD



India has a long history and tradition of harmonious co-existence between human and nature. In the Indian way of thinking, plants and animals are members of a family. A wide range of traditional practices and art forms that represent sustainable use of forest and tree resources, reflect such thinking. Encompassing the ecological, economic and social dimensions of the National Forest Policy, it is necessary to have monitoring and assessment of forest resources with regard to biological diversity, climate change and carbon emission / sequestration.

Forest Survey of India (FSI), Dehradun, under the Ministry of Environment, Forest and Climate Change is a premier institution of the country with the mandate to carry out periodic assessment of our country's forest resources. The data and reports of FSI serve as critical inputs for policy making for the forestry sector of the country.

The results of the current India State of Forest Report (ISFR) provide, assessments both at Country and State level. This document will be very useful for the States in formulating policies and strategies for conservation and management of their natural resources. I am happy to note that, FSI has adapted itself to methodology, application of SAR technology for biomass mapping of country, forest fire monitoring programmes, use of PDA devices with specialized applications for collection and processing of inventory data on real time basis and allied techniques. The use of New National Forest Inventory Design data in the current report, for the assessment of growing stock, carbon accounting and other parameters has yielded results with greater precision.

I congratulate the entire team of FSI for their dedicated effort in providing useful information which will help the user agencies to plan effective management of natural resources.

Ashwini Kumar Choubey

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

FOREWORD

It is indeed a pleasure to announce the release of the India State of Forest Report (ISFR) 2021 by the Forest Survey of India. This report gives an authoritative insight into the state of forests in the country and is therefore widely utilized by researchers, policy makers, planners, State Forest Departments and other institutions. The Forest Survey of India has been constantly improving the quality of the ISFR and the present report stands out for presenting a large amount of distilled data that opens up unique opportunities in analytics.

Forests play a crucial role in our ecosystem; with the constantly increasing pressures on the country's forests, there is an emerging need for detecting and tracking the changes taking place. Periodic assessment of our forestry parameters such as extent of forest and tree cover, distribution of timber species, volume, biomass, carbon stock, regeneration status etc. is vital not only for forest managers but also for planners and policy makers, to ensure strategic planning in the management of forest and land resources. Forest Survey of India has been doing a commendable job by carrying out biennial assessment of forest resource of the country for more than 35 years. The present report contains information not only on the forest cover, forest inventory and the changes with respect to the previous assessment, but also an estimation of Above Ground Biomass (AGB) using Synthetic Aperture Radar (SAR) and climate change hotspots in the forest areas of the country.

I am happy to note that in the current ISFR, digitized forest boundaries of 26 States and UTs have been used to assess the extent of forest cover within the recorded forest areas. I urge the remaining State/ UT Forest Departments to take up this activity on priority and provide accurate digital forest boundaries to FSI. This will help the States to plan appropriately for areas within and outside recorded forest areas.

Over the years, the roles and responsibilities of FSI have seen a change. Today, FSI is involved in many climate change related activities such as preparation of Forest Reference Level, reporting of GHG to UNFCCC, preparation of Biennial Update Report (BUR) and Sustainable Development Goals (SDG) Report etc. FSI also acts as a nodal agency for reporting of country data to FAO for Global Forest Resource Assessment (GFRA). Moreover, many initiatives such as monitoring of CAMPA activities under e-Green Watch portal, developing of Decision Support System (DSS) for taking expeditious decision on forest conservation related cases, issuance of pre-fire warning alerts etc. are also being undertaken by FSI.

I am confident that the Forest Survey of India would continue on its path of keeping up with technological advances and make a sterling contribution to the development of a robust National Forest Monitoring System. I wish the FSI team all the very best for their future endeavours.

Leena Nandan

चन्द्र प्रकाश गोयल
Chandra Prakash Goyal
वन महानिदेशक एवं विशेष सचिव
Director General of Forest & Special Secretary
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
Ministry of Environment, Forest and Climate Change
भारत सरकार / Government of India

FOREWORD

It gives me immense pleasure to learn that Forest Survey of India (FSI) is bringing out the India State of Forest Report 2021. FSI has been doing a yeoman service in generating a vast wealth of data on the extent and quality of forest and tree cover of India from last 35 years. Keeping pace with technological advancements and refinement in methodologies has been a continuous process at FSI.

Forests in India face a wide range of biotic pressures therefore it is important to monitor constantly the impact of such pressure on the ground and alert the State Forest Departments and related agencies about the risks involved.

Inventory of forests has been one of the most important activities of FSI since its inception. National Forest Inventory was launched in 2002 to estimate growing stock of forests and trees outside forest at the national level. In 2016 a grid based design involving 5km x 5km grids has been adopted both for forest inventory and for inventory of trees outside forests allowing for a reduction in revisit time of forest inventory from 20 years to 5 years, to generate national and state level estimates with better accuracy.

FSI has been estimating the carbon stock in India's forest as per the methodology of 'Good Practices Guidance' (GPG) developed by Inter-governmental panel on Climate Change (IPCC). For estimation of emission factors for different strata, data of National Forest Inventory (NFI) has been used. Biomass equations/ factors were developed through a special study conducted by FSI. GIS techniques have been used for synthesizing the data and to estimate carbon stock under different carbon pools.

Results of the Biomass estimation using SAR technology at PAN India level are being presented. For the first time a biomass map of the country has been prepared. Results of climate change hotspots study for forest areas are also being presented. This information will prove to be very important and relevant for SFDs and other agencies in designing mitigation and adaptation strategies and programmes for the forest areas under their management as well as act as a baseline for state governments to tune their land and development policies by factoring in climate change related requirements.

The entire team of the FSI deserves our congratulations and appreciation for another excellent job done.

I wish team FSI the very best.

Chandra Prakash Goyal

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

P R E

दशकूपसमा वापी, दशवापीसमो ह्रदः।
दशह्रदसमो पुत्रो, दशपुत्रसमो द्रुमः ।।

'Dasha-kupa sama vapi, dasha-vapi sama hradah I
Dasha-hradah samah putro, dasha-putra sama drumah' II

Matsya Purana 154:512

The ancient Indian text, Matsya Purana states that, "A pond is equal to ten wells. A reservoir of water is worth ten such ponds. Ten reservoirs of water are equal to a son. A tree is equal to ten such sons".

Trees and forests have held an important place in India since ancient times. Today, the entire world has started to appreciate the importance of forests and trees, not just as a resource base, but also as the key to survival of life on earth. The United Nations Organization has proclaimed its theme for 2021 as "Forest Restoration: a path to recovery and well-being." In this context, the role of Forest Survey of India (FSI) assumes great importance, since its principal mandate is to survey and assess forest resources of India.

FSI carries out the forest cover mapping of the country using satellite data, the findings of which are published in a biennial publication, known as India State of Forest Report (ISFR). I am happy to present the ISFR 2021, which contains nationwide results of forest cover mapping and estimation of the tree cover for the period 2019-20, using medium resolution satellite data (23.5m) from the indigenous LISS-III sensor of IRS Resourcesat series of satellites from Indian Space Research Organization.

The ISFR 2021 provides estimates of National Forest Inventory following a grid based design adopted by FSI since 2016.

Besides providing forest cover estimates of State and District level, the report also provides information on forest cover inside and outside Recorded Forest Areas (RFA), forest cover change analysis in Tribal districts, Hill districts and NE states and assessment of Forest Cover in Tiger Reserves.

Another major focus is on Forest Fire Monitoring by MODIS sensor on board Aqua and Terra Satellite of NASA and SNPP-VIIRS sensor. ISFR 2021 has given special importance to the estimation of carbon stock in the country's forests for providing valuable inputs to MoEF&CC in preparation of GHG inventory of the country and fulfilling of international reporting requirements to the conventions to which the country is a signatory.

ISFR 2021 also presents the results of a study by FSI, in collaboration with BITS Pilani (Goa Campus) to map, climate hot spots in the forest areas of the country. The enhanced understanding about the

F A C E

climate change hotspot areas due to projected adverse climatic impacts in Indian forests would assist in planning and strategizing preventive and adaptive measures against changing climate.

ISFR 2021 has made valuable additions to the existing forest assessment database by utilizing the latest technology and methodology for the assessment of forests and trees outside forests, including in-depth analysis of Mangrove and Bamboo forests.

FSI, in collaboration with Space Application Centre (SAC), ISRO, Ahmedabad, has conducted a special study for estimation of Above Ground Biomass (AGB) at pan-India level using Synthetic Aperture Radar (SAR) data. The interim results for AGB estimates and AGB map for the entire country are presented in this report.

The revamp of e-Green Watch Portal is also being carried out by FSI, in order to overcome the limitations of the existing portal. This will ensure concurrent monitoring as well as information system for monitoring and evaluation of various activities such as compensatory afforestation carried out through CAMPA funds.

On the occasion of the release of ISFR 2021, I would like to express my heartfelt thanks for the continuous support and guidance from Shri Bhupender Yadav, Hon'ble Minister, MoEF&CC, Shri Ashwini Kumar Choubey, Hon'ble Minister of State, MoEF&CC, Shri Rameshwar Prasad Gupta, Former Secretary & Smt. Leena Nandan Secretary, MoEF&CC, Govt. of India, Shri Subhash Chandra, Former Director General of Forests & Special Secretary & Shri C.P. Goyal Director General of Forests & Special Secretary, MoEF&CC, Govt. of India and Dr. Suneesh Buxy, Inspector General of Forests (SU), MoEF&CC.

I express my gratitude to Dr. Subhash Ashutosh and Mr. Pankaj Agrawal, the erstwhile Director Generals of FSI, who made valuable contribution in monitoring and giving direction to the entire exercise.

I also thank the officers and technical staff of FSI for their commitment and zealous efforts in preparing this report in a time bound manner despite the challenges posed by the COVID 19 pandemic.

I reiterate the commitment of my organization for making available relevant and updated information on forest resources of the country in future through the use of up-to-date methodology and technology and I rededicate myself and my team to the mandate given to FSI.

Anoop Singh

ACKNOWLEDGEMENT

In the 17th cycle of biennial assessment of India's forests, Forest Survey of India has received significant assistance and contributions from various organizations and individuals. Assistance provided by Space Application Centre, Ahmedabad, National Remote Sensing Centre, Hyderabad, Indian Institute of Remote Sensing, Dehradun, BITS Pilani, Goa Campus, Jammu & Kashmir Forest Department, National Sample Survey Organization, Survey of India and Forest Research Institute (FRI) are highly appreciated.

All the State Forest Departments have extended full support in field validation of forest cover mapping and other assessments. The assistance provided by all the SFDs to the officials of FSI during field visits, is gratefully acknowledged.

Contributions of Shri Rajesh Kumar, Ex-DDG, NSSO, Dehradun and Dr. Rajiv Chaturvedi, Faculty of BITS, Pilani, Goa Campus are acknowledged with gratitude. I would like to make a special mention of Mr. Arijit Banerjee, APPCF IT, Rajasthan, who has read and edited all the chapters and without his help timely completion would have been impossible. Mr. Arijit Banerjee & Mr. Rakesh Dogra, Dy. Director General, ICFRE have shared wholeheartedly their vast collection of photographs of forests, habitats and species. I look forward to receiving their continued support in the years to come. Contribution of Sh. P. Kalaivanan, IFS & Sh. Anurag Mishra, IFS are greatfully acknowledged.

The efforts made by Shri Sushant Sharma, Joint Director (TFI), Smt. Meenakshi Joshi, Joint Director (FGD), Shri Prakash Lakhchaura, Dy. Director General (TFI), Shri Dinesh Kumar, Ex. Dy. Director General (FI), Shri Kamal Pandey, Dy. Director (TFI), Dr. Sunil Chandra, Dy. Director (FGD), Shri Sanjay Kumar Agarwal, Dy. Director (FGD), & Shri Abhay Kumar Saxena, Dy. Director (FCM) for the ISFR 2021 are highly appreciated. Contribution of Shri H. Venuprasad, I/C Regional Director, SZ, Shri Chaturbhuja Bahera, Regional Director, CZ, Shri Satya Prakash Negi, Regional Director, NZ, Dr. Soma Das, Regional Director, EZ, Shri S. Elamurugannan, Dy. Director, SZ, FSI for the NFI are gratefully acknowledged.

EXECUTIVE SUMMARY

India is amongst one of the few countries having a robust scientific system for periodic assessment of Forest Cover, Forest Inventory and inventory of Trees Outside Forest. Forest Survey of India (FSI), an organization of Ministry of Environment, Forest & Climate Change carries out these assessments and publishes the findings in its biennial report as 'India State of Forest Report (ISFR)'. The first State of the Forest Report was published in 1987 and the current report (ISFR 2021) is 17th in the series. The ISFR provides valuable inputs for planning, policy formulation and evidence based decision making both at National and State level.

The ISFR 2021, having information on different parameters of the forest resources, is based on the regular nation-wide mapping of Forest Cover, National Forest Inventory and other studies conducted at the national level. The methodology adopted for Forest Cover and Forest Inventory has undergone regular improvements over time.

The Forest Cover as reported in ISFR includes all patches of land with a tree canopy density of more than 10% and with area having more than 1 ha, irrespective of land use, ownership and species of trees. It is assessed by a wall-to-wall mapping exercise using remote sensing followed by extensive ground truthing. Results of the nation-wide Forest Cover Mapping exercise are presented on 1:50,000 scale in three canopy density classes viz Very Dense Forest (canopy density > 70%), Moderately Dense Forest (canopy density 40-70%) and Open Forest (canopy density 10-40%). The tree cover is assessed following a methodology involving remote sensing based stratification and observations on sample plots laid in the strata as part of the National Forest Inventory. Tree cover includes all patches of trees less than 1 ha.

In the current assessment, ortho-rectified LISS III data of IRS Resourcesat-2 with a spatial resolution of 23.5 m for the period October to December 2019 have been used for Forest Cover Mapping. In order to ensure uniformity, consistency and accuracy in the mapping exercise, the procedure has been codified into a manual for Forest Cover Mapping. For the current assessment, ground truthing has been carried out at 3,414 locations across the country. Change matrix showing a quantitative account of class wise change and also the flux of changes among the classes between the current and previous assessment has been presented for all the States & UTs and country as a whole.

National Forest Inventory assesses the growing stock in forests and TOF, bamboo resource, carbon stock and several other parameters. Field data for the same is collected from approximately 30,000 sample plots laid in a 2 years period as per the standardized design. The growing stock and other assessments presented in ISFR 2021 are on the basis of a new grid based forest inventory design adopted by FSI in 2016. This ensures higher sampling intensity with uniformly spread sample plots across the country, leading to higher precision.

In the current ISFR, a new Chapter about 'Above Ground Biomass Estimation using SAR

Data' has been included containing information about spatial distribution of the forest biomass categories which are important for proper management of the forest resources. For this purpose, FSI has collaborated with Space Application Centre (SAC), ISRO, Ahmedabad. The result of this exercise represents that MLR model can be used for AGB estimation at country level. The use of ancillary data in combination with SAR data have been effective in improving coefficient of correlation (r) using MLR model.

Another new chapter on, 'Mapping of Climate Change Hotspots in Indian Forests' has also been included in this ISFR. Forest plants play a significant role in relation to climate change by reducing emission of Green House Gases (GHGs), through expanding the mitigation and adaptation actions with low cost interventions. Therefore, a collaborative study was carried out by FSI with BITS PILANI, Goa Campus to map the climatic hotspots over Indian forest cover using temperature and rainfall data, for the three future time periods i.e. year 2030, 2050 & 2085. To identify climatic hotspots in Indian forests two computer based models were used i.e. RCP 4.5 and RCP 8.5, where RCP 4.5 represents moderate emission scenarios and RCP 8.5 represents the highest emission scenario or worst case scenario.

SALIENT FINDINGS

The key findings of the ISFR 2021 are as follows:

- The total forest cover of the country is 7,13,789 sq km which is 21.71% of the geographical area of the country. The tree cover of the country is estimated as 95,748 sq km which is 2.91% of the geographical area. Thus, the total Forest and Tree cover of the country is 8,09,537 sq km which is 24.62% of the geographical area of the country.
- The current assessment shows an increase of 1,540 sq km (0.22%) of forest cover, 721 sq km (0.76%) of tree cover and 2,261 sq km (0.28%) of forest and tree cover put together, at the national level as compared to the previous assessment i.e. ISFR 2019.
- Forest cover inside the RFA/GW has shown a slight increase of 31 sq km whereas there is an increase of 1,509 sq km of forest cover outside the RFA/GW as compared to previous assessment of 2019.
- The top five States in terms of increase in forest cover are Andhra Pradesh (647 sq km), Telangana (632 sq km), Odisha (537 sq km), Karnataka (155 sq km) and Jharkhand (110 sq km).
- Forest cover in the hill districts of the country is 2,83,104 sq km, which is 40.17% of the total geographical area of these districts. The current assessment shows a decrease of 902 sq km (0.32%) in 140 hill districts of the country.
- The total forest cover in the tribal districts is 4,22,296 sq km, which is 37.53% of the geographical area of these districts. The current assessment shows a decrease of 655 sq km of forest cover inside the RFA/GW in the tribal districts and an increase of 600 sq km outside.

- Total forest cover in the North Eastern region is 1,69,521 sq km, which is 64.66% of its geographical area. The current assessment shows a decrease of forest cover to the extent of 1,020 sq km (0.60%) in the region.
- Mangrove cover in the country has increased by 17 sq km (0.34%) as compared to the previous assessment.
- The total growing stock of wood in the country is estimated as 6,167.50 million cum comprising 4388.15 million cum inside forest areas and 1779.35 million cum outside recorded forest areas (TOF). The average growing stock per hectare in forest has been estimated as 56.60 cum.
- Total bamboo bearing area of the country is estimated as 1,49,443 sq km. There is a decrease of 10,594 sq km in bamboo bearing area as compared to the estimate of ISFR 2019.
- In the present assessment, total carbon stock in forest is estimated as 7,204.0 million tonnes. There is an increase of 79.4 million tonnes in the carbon stock of the country as compared to the last assessment of 2019. The annual increase is 39.7 million tonnes, which is 145.6 million tonnes CO_2 eq.
- Soil Organic Carbon (SOC) represents the largest pool of carbon stock in forests, which has been estimated as 4,010.2 million tonnes. The SOC contributes 56% to the total forest carbon stock of the country.
- Fire prone forest areas of different severity classes have been mapped in the grids of 5km x 5km based on the frequency of forest fires. The analysis reveals that 22.27% of the forest cover of the country is highly to extremely fire prone.
- The correlation analysis between the AGB and the HV, HH and HV/HH polarized backscatter reveals that the HH, HV polarized backscatter has better correlation as compared to HH/HV polarization.
- As per the Climate Hotspot projections for the studied periods i.e. 2030, 2050 and 2085, it has been observed that Ladakh, Jammu & Kashmir, Himachal Pradesh and Uttarakhand are projected to witness highest temperature increase while Andaman & Nicobar Islands, West Bengal, Goa, Tamil Nadu and Andhra Pradesh are projected to witness the least temperature rise over these periods. The North-Eastern States and Upper Malabar Coast of India are projected to experience the highest increase in rainfall; whereas, part of North-Eastern States like Arunachal Pradesh, Sikkim; North-Western parts of the country namely Ladakh, Jammu & Kashmir and Himachal Pradesh are projected to experience least increase and sometimes even decline in rainfall.

Table 1 Forest and Tree Cover of India in 2021

Class	Area (sq km)	Percentage of Geographical Area
	Forest Cover	
Very Dense Forest	99,779	3.04
Moderately Dense Forest	3,06,890	9.33
Open Forest	3,07,120	9.34
Total Forest Cover*	**7,13,789**	**21.71**
Tree Cover	95,748	2.91
Total Forest and Tree Cover	**8,09,537**	**24.62**
Scrub	46,539	1.42
Non Forest#	25,27,141	76.87
Total Geographical Area	32,87,469	-

* Includes 4,992 sq km under Mangrove Cover
# Non-forest includes Tree Cover (Percentage rounded off)

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ACRONYMS AND ABBREVIATIONS

AFOLU	-	Agriculture, Forestry and Other Land Use
AGB	-	Above Ground Biomass
ALOS	-	Advanced Land Observing Satellite
AWIFS	-	Advanced Wide Field Sensor
BGB	-	Below Ground Biomass
BEF	-	Biomass Expansion Factor
BUR	-	Biennial Update Reports
CBD	-	Convention on Biological Diversity
CMIP	-	Coupled Model Inter-comparison Project
CNFA	-	Culturable Non-Forest Area
CNN	-	Convolutional Neural Network (model)
CO_2	-	Carbon Dioxide
CO_2 eq	-	Carbon Dioxide Equivalent
COP	-	Conference of the Parties
DBH	-	Diameter at Breast Height
DEM	-	Digital Elevation Model
DF	-	Dense Forest
DIP	-	Digital Image Processing
DN	-	Digital Number
DOM	-	Dead Organic Matter
FAO	-	The Food & Agriculture Organization of United Nations
FCC	-	False Colour Composite
FDC	-	Forest Development Corporation
FPC	-	Forest Protection Committee
FRL	-	Forest Reference Level
FSI	-	Forest Survey of India
FWI	-	Fire Weather Index
GA	-	Geographic Area
GCP	-	Ground Control Point
GFRA	-	Global Forest Resource Assessment
GHG	-	Green House Gas
GIS	-	Geographical Information System
GPG	-	Good Practices Guidance
GPM	-	Global Precipitation Measurement
GPS	-	Global Positioning System
GW	-	Green Wash
HH	-	Horizontal-Horizontal (Polarization)
HTTP	-	Hyper Text Transfer Protocol
HV	-	Horizontal-Vertical (Polarization)
IMD	-	India Meteorological Department

INC	-	Initial National Communication
IPCC	-	Intergovernmental Panel for Climate Change
IPPU	-	Industrial Processes and Product Use
IRDP	-	Integrated Rural Development Programme
IRS	-	Indian Remote Sensing (Satellite)
ISFR	-	India State of Forest Report
ISRO	-	Indian Space Research Organization
IUCN	-	International Union for Conservation of Nature
JAXA	-	Japan Aerospace Exploration Agency
JFM	-	Joint Forest Management
LIDAR	-	Light Detection and Ranging
LISS	-	Linear Imaging Self-scanning Sensor
LST	-	Land Surface Temperature
LULUCF	-	Land Use, Land-Use Change and Forestry
MDF	-	Moderately Dense Forest
MODIS	-	Moderate Resolution Imaging Spectroradiometer
MSS	-	Multi Spectral Scanner
NAEB	-	National Afforestation and Eco-development Board
NATCOM	-	National Communication to UNFCCC
NASA	-	National Aeronautics and Space Administration
NDC	-	Nationally Determined Contributions
NDVI	-	Normalized Difference Vegetation Index
NDMA	-	National Disaster Management Authority
NF	-	Non-Forest
NFMS	-	National Forest Monitoring System
NP	-	National Park
NRSC	-	National Remote Sensing Centre
NSO	-	National Statistical Office
NTCA	-	National Tiger Conservation Authority
NTFP	-	Non-Timber Forest Products
NWDB	-	National Wasteland Development Board
OF	-	Open Forest
PA	-	Protected Area
PALSAR	-	Phased Array type L-band Synthetic Aperture Radar
PAN	-	Pan-Chromatic
PF	-	Protected Forest
PISFR	-	Pre-Investment Survey of Forest Resources
POP	-	Permanent Observation Plots
RADAR	-	Radio Detection and Ranging
RCP	-	Representative Concentration Pathway
REDD+	-	Reducing Emissions from Deforestation and Forest Degradation Plus
RF	-	Reserved Forest

RFA	-	Recorded Forest Area
RGI	-	Registrar General of India
SAC	-	Space Application Centre
SAR	-	Synthetic Aperture RADAR
SDG	-	Sustainable Development Goals
SFD	-	State Forest Department
SFR	-	State of Forest Report
SNC	-	Second National Communication
SNPP-VIIRS	-	Suomi National Polar orbiting Partnership - Visible Infrared Imaging Radiometer Suite
SOC	-	Soil organic carbon
SOI	-	Survey of India
SOM	-	Soil organic matter
SRTM	-	Shuttle Radar Topography Mission
TAC	-	Technical Advisory Committee
TC	-	Tree Cover
TM	-	Thematic Mapper
TOF	-	Trees Outside Forests
TR	-	Tiger Reserve
UFS	-	Urban Frame Survey
UNFCCC	-	United Nations Framework Convention on Climate Change
UN-REDD	-	United Nations Reduced Emissions from Degradation and Deforestation
UT	-	Union Territory
VDF	-	Very Dense Forest
VFPC	-	Village Forest Protection Committee
VIIRS	-	Visible Infrared Imaging Radiometer Suite
VoL	-	Volume
WCRP	-	World Climate Research Programme
WFS	-	Web Feature Service
WII	-	Wildlife Institute of India
WLS	-	Wildlife Sanctuary
WMO	-	World Meteorological Organization
WMS	-	Web Map Service
WP	-	Working Plan
WPA	-	Wildlife Protection Act
WWF	-	World Wildlife Fund

GLOSSARY

Above-ground biomass	The AGB carbon pool consists of all living vegetation above the soil, inclusive of stems, stumps, branches, bark, seeds and foliage.
Activity / Flux	One of the main approaches to emissions accounting by estimating the net balance of additions to and removals from, a carbon pool.
Adaptation	Adjustment in natural or human systems to a new or changing environment.
Allometric Equation	Allometric equations are the best fitted regression models, used to estimate the biomass or volume of aboveground tree components based on diameter at breast height (DBH) and height data.
Asiatic Lion	The Asiatic Lion (also known as the Persian Lion or Indian Lion) is a member of the Panthera leo leo subspecies that is restricted to India.
Backscatter	Backscatter is the reflection of waves, particles, or signals back to the direction from which they came.
Base	A specification or product that has been formally reviewed and agreed upon, that thereafter serves as the basis for further development.
Bamboo	Pure: 200 and more clump/ha for clump forming bamboo or 12000 and more culms / ha for non-clump forming Dense: 51 to 200 clump / ha for clump forming or 3001 to 12000 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	The BGB carbon pool consists of the biomass contained within live roots.
Biodiversity	It refers to the variety of life on Earth at all its levels, from genes to ecosystems, and can encompass the evolutionary, ecological, and cultural processes that sustain life.
Biomass	Biomass is the organic material that comes from plant or animal and can be used as renewable bioenergy sources.
Biomass Expansion Factor (BEF)	The ratio of aboveground biomass and bole biomass (defined by a merchantable measure or a minimum DBH). It is used to quantify carbon stock in forests.
Block Plantation	Tree plantations in compact blocks of more than 0.1 ha on lands outside recorded forest areas.
Canopy	The cover of branches and foliage formed by crown of trees.
Canopy Cover	The percentage of ground covered by a vertical projection of outermost perimeter of natural spread of foliage of plants.
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 equivalent (CO_2 eq)	It is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.
Carbon Pool	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.
Carnivores	It is an organism that mostly eats meat, or the flesh of animals.
Cartographic Limit	The minimum area of a feature which can be presented on a map at a given scale.
Catchment	A catchment is an area where water is collected by the natural landscape.

Change Matrix	It presents change in forest cover classes for a given region (State or UT) during the period of two consecutive assessments in a matrix form by showing the changes of area from one class to another.
Climate change	Refers to any significant change in the measures of climate lasting for an extended period of time.
Convolutional Neural Network	Convolutional Neural Network (CNN) is a kind of deep learning neural network designed for structured data specifically for image data. It uses connections to extract features from local regions of the input based on the weights and biases of the input features.
Conservativeness	Where accounting relies on assumptions, values and procedures with high uncertainty, the most conservative option in the biological range should be chosen so as not overestimate sinks or underestimate sources of GHGs. Conservative carbon estimates are often achieved through omission of minor carbon pools.
Crown Area	It is the area of horizontal projection of a tree crown on the ground.
Culturable Non Forest Area	It is the net geographical area, lying outside recorded forest and forest cover, which can support tree vegetation (thus, excluding areas under wetlands, riverbeds, perennial snow covered mountains, etc.). CNFA is the area over which the sample data on tree cover is aggregated for the assessment.
Dead Organic Matter	The DOM carbon pool contains all non-living woody biomass and can be divided into wood (fallen trees, roots and stumps with diameter over 10cm) and litter (greater than 2mm and less than 10cm diameter) components.
Dense Forest	All lands with a forest cover having a canopy density of 40 percent and above.
Digital Image Processing	Interpretation and classification of digital satellite data using computer and a DIP software.
Drone	A drone, also known as Unmanned Aerial Vehicle (UAV), is a flying device that is controlled remotely. Such devices fly using multiple propellers and are capable to digitally scan and capture photos, record videos using cameras from the air.
Downscaling	Downscaling is a procedure to infer high-resolution information from low-resolution variables, more specifically it is the process of relocating coarse resolution climate model to fine spatial scale observed data.
Emissions	Release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.
Emission factor	Emission factor gives gains and losses in carbon stock as a standard rate of emissions per unit activity. It is used to scale emissions to activity data.
Endangered Species	It is considered to be facing a very high risk of extinction in the wild due to factors such as habitat loss, poaching and presence of invasive species.
Error Matrix (Confusion matrix)	It is a means to quantitatively assess the accuracy of classification of an interpreted satellite data. Under this, the reference data (ground truth) is compared with the corresponding results of the classification on the randomly selected locations on category-by-category basis. It is presented in a square matrix.
False Colour Composite	The image generated by projecting any three spectral bands of the satellite data on the red, green and blue channels and does not show features in true colours.
Farm Forestry	The practice of cultivating and managing trees in compact blocks on agricultural lands.
Forest Area	The area recorded as a forest in the Government records. It is also referred to as "Recorded Forest Area".

Forest Blank	A patch within a forest which bears few or no trees.
Forest Cover	All lands, more than one hectare in area, with a tree canopy density of more than 10 percent irrespective of ownership and legal status. Such lands may not necessarily be a recorded forest area. It also includes orchards, bamboo and palm.
Forest Fire Danger Rating	It is a system for rating the risk of forest fires on the basis of qualitative or numeric indices of fire potential. It is used as a guide in a wide variety of fire management activities.
Forest Inventory	The measurement of certain parameters of forests to assess the growing stock and other characteristics of forests.
Forest Reference Level	It is the base line emission levels from the forests. It is used for determining performance of the country towards REDD+ implementation.
Gain Loss Approach	A method to estimate annual emissions or removals of CO_2 as the sum of gains and losses in carbon pools occurring on areas of land subject to human activities.
Geographic Information System	A computer based system for capturing, storing, manipulating, analysing and displaying data, which are spatially referenced to the earth.
Global Forest Resources 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.
Greenhouse gases	Gases that has the property of absorbing infrared radiation (net heat energy) emitted from Earth's surface and re-radiating it back to Earth's surface, thus contributing to the greenhouse effect.
Green Wash	The extent of wooded areas generally shown in light green colour on the Survey of India topographic sheets.
Growing Stock	The sum (by number or volume) of all the trees growing/living in the forest or a specified part of it.
Hill District	A district with more than 50 percent of its geographic area under "hill talukas" based on criteria adopted by the NITI Aayog for Hill Area and Western Ghats Development Programmes.
Hotspot	An area which is prone to adverse climatic impact.
Inventory/Periodic Accounting	One of the main approaches to emissions accounting by measuring the difference in carbon stocks between two points in time.
IUCN Red List	The International Union for Conservation of Nature Red List of Threatened Species is the world's most comprehensive inventory of the global conservation status of biological species.
Land Cover	Broad land use classes interpreted from satellite data. It includes very dense forest, moderately dense forest, open forest, scrub and non-forest for the purpose of this report.
Litter	Woody material of trees having diameter <5cm which is not decomposed.
Land Use, Land-Use Change and Forestry	It is a category within UNFCCC accounting framework for greenhouse gas (GHG) emissions. It includes carbon pools of living biomass (above and below ground), dead organic matter (dead wood and litter) and organic soil carbon. The LULUCF sector covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change and forestry activities.
Mangroves	Salt tolerant evergreen forest ecosystem found mainly in tropical and subtropical coastal and/or inter-tidal regions.
Mangrove Cover	Area covered under mangrove vegetation as interpreted from remote sensing data. It is included in the forest cover.
Microwave Remote	It is the technology which uses electromagnetic radiation with a wavelength

Sensing	between 1 cm and 1 m (commonly referred to as microwaves) as a measurement tool. The sensor transmits a (radio) signal in the microwave bandwidth and records the part that is backscattered by the target towards the sensor itself.
Mitigation	Mitigation in context of climate change refers to efforts to reduce or prevent emission of greenhouse gases.
Moderately Dense Forest	All lands with forest cover having a canopy density between 40 to 70 percent.
Moderate Resolution Imaging Spectro-radiometer	It is an extensive program using sensors on two satellites (Terra and Aqua), each providing complete daily coverage of earth. With the MODIS sensor, it is generally possible to obtain images in the morning (Terra) and afternoon (Aqua) for any particular location. Night time data are also available in the thermal range of the spectrum. The data have a variety of resolutions; spectral, spatial and temporal.
Nationally Determined Contributions (NDC)	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.
Net Change (in Forest Cover)	The sum of positive and negative changes in forest cover over a period of two assessments for a given area.
Non Forest Land	Land without forest cover.
Open Forest	Lands with forest cover having a canopy density between 10 to 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, Islands etc. are different physiographic divisions. In early 20th century geomorphology is renamed as physiography at regional scale.
Precipitation	Precipitation is rain, snow, sleet, or hail - any kind of weather condition where something's falling from the sky.
Prey Species	The term prey species refers to an animal that is sought, captured, and eaten by a predator.
Pristine Area	Area that is original and pure; not spoiled or worn from use.
Protected Forest	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.
Recorded Forest Area	Area recorded as forest in Government records.
REDD+	REDD+ is a United Nations-backed framework that aims to curb climate change by stopping the destruction of forests. REDD stands for "Reducing Emissions from Deforestation and forest Degradation"; the "+" signifies the role of conservation, sustainable management of forests and enhancement of forest carbon stocks.
Reducing Emissions from Deforestation and Forest Degradation	A framework to reduce emissions from deforestation and degradation, conservation of existing carbon stocks and enhancement of carbon stocks.
Remote sensing	Remote sensing is the acquisition of data, such as total forest area, forest type, canopy cover and height, from sensors on board aircraft or space-based platforms.
Representative Concentration Pathways	The Representative Concentration Pathways (RCPs) describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use.

Reserved Forests	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.
Scrub	Degraded forest lands having canopy density less than 10 percent.
Shuttle Radar Topography Mission	An international research effort that generates the most complete, high resolution digital topographic database of the Earth.
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.
Sink	A carbon sink is a carbon pool from which more carbon flows in than out: forests can act as sink through the process of tree growth and resultant biological carbon sequestration.
Source (of carbon)	A carbon source is a carbon pool from which more carbon flows out than flows in: forests can often represent a net source of carbon due to the processes of decay, combustion and respiration.
Soil Organic Matter	It is the organic component of soil containing small plant residues, small living soil organism and decomposed organic matter.
Spatial Resolution	The minimum area on earth's surface that can be captured by a satellite sensor as being separate from its surroundings and is represented by a "pixel".
Speckle Noise	Speckle noise is the disturbance that arises due to the effect of environmental conditions on the imaging sensor during image acquisition. Speckle noise is mostly detected in case of medical images, active Radar images and Synthetic Aperture Radar (SAR) images.
Spectral Resolution	It refers to the width and number of spectral bands. The range of wave lengths that a satellite imaging system can detect. The narrower the bands, the greater the spectral resolution.
Stock Difference Approach	An approach to estimate mean annual carbon emissions for land subject to human activities such as deforestation and forest degradation. It is estimated as the ratio of difference in carbon stock at two points in time and the number of intervening years.
Stratification	Stratification is the division of the area into more homogenous units of carbon density. The purpose of stratification is to increase the accuracy and precision of accounting by reducing field data variability.
Sustainable Development Goals	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. These goals are adopted by all United Nations Member States in 2015.
Synthetic Aperture Radar	Synthetic Aperture Radar (SAR) is a type of active data collection where a sensor produces its own energy and then records the amount of that energy reflected back after interacting with the Earth. This technique is used for producing fine-resolution images from a resolution-limited radar sensor mounted either on an airplane or on a satellite platform in space.
Thematic Maps	Maps, generally showing forest cover, forest types, major species composition, crown density, other land uses etc. themes; prepared by interpretation of satellite images and verified by ground truth checking are commonly designated as thematic maps in forestry sector.
Tiger Census	National Tiger Conservation Authority (NTCA) in collaboration with the State Forest Departments, Conservation NGO's and coordinated by the Wildlife Institute of India (WII), has been conducting a National assessment for the "Status of Tigers, Co-predators, Prey and their Habitat" every four years. Such assessments are called 'Tiger Census'.

Tiger Corridors	A tiger corridor is a stretch of land linking tiger habitats, allowing movement of tigers, prey and other wildlife. Without corridors, tiger habitat can become fragmented and tiger populations isolated leaving the tigers vulnerable to localised extinction.
Tiger Reserves	A protected area statutorily designated for the conservation of the tigers is referred to as Tiger Reserve.
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 tall shrubs or climbers. For the purpose of assessing growing stock and tree cover, only those trees having diameter at breast height (dbh) of 10 cm or more are measured.
Tree Cover	It comprises of tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including linear, block and in scattered array.
Trees Outside Forests	It refers to all trees growing outside recorded forest areas irrespective of patch size.
Tribal Districts	The Districts identified as tribal districts under Tribal Sub-Plan (Government of India).
Uncertainty	Lack of knowledge of the true value of a variable. It is often expressed in terms of probability.
Unclassed Forests	An area recorded as forest but not included in reserved or protected forest category. Ownership status of such forests varies from state to state.
Very Dense Forest	Lands with forest cover having a canopy density of 70 per cent and above.
Visual Interpretation	A manual method of satellite data interpretation using on-screen technique.
Vulnerability	Vulnerability refers to the inability (of a system) to withstand the effects of a hazard (or hostile environment).
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, a 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 and their Dimensions used in ISFR 2021

Sl. No.	Name of Unit	Symbol	Value
1.	Meter	m	1 m = 100 cm
2.	Square Kilometer	sq km	1 sq km = 1,000,000 m
3.	Tonnes	t	1 t = 1,000 kg
4.	Hectare	ha	1 ha = 0.01 sq km, 100 ha = 1 sq km
5.	Million hectare	m ha	1 m ha = 1,000,000 ha, = 10^6 ha = 10,000 sq km
6.	Million Tonnes	Mt	1 Mt = 1,000,000 tonnes = 10^6 tonnes
7.	Million cubic meter	m cum	1 m cum = 1,000,000 m^3 = 10^6 m^3
8.	Giga tonnes	Gt	1 Gt = 1,000,000,000 tonnes = 10^9 tonnes = 1,000 million tonne = 1 billion tonnes
9.	CO_2 equivalent	CO_2 eq	1 C = 44/12 CO_2 eq = 3.67 CO_2 eq
10.	Decibel	dB	1 dB = 1/10 of a bel (B)
11.	Giga hertz	GHz	1 GHz = 10^9 Hz
12.	Micro meter	µm	

01
INTRODUCTION

Introduction 1.1

Forests and by extension trees are a resource vital to the existence of life on earth. Evaluating the nature of forests and monitoring their status are important from the perspective of national wealth and prosperity and germane to the fundamentals of a knowledge economy. Forest Survey of India (FSI), an organization of the Ministry of Environment, Forest & Climate Change, Government of India has been monitoring India's forest and tree resources through periodic assessments and presenting the findings in its biennial publication 'India State of Forest Report' (ISFR). The first State of Forest report was brought out in the year 1987. The current report, ISFR 2021 is 17th in the series. Over these years, successive reports present a continuous, comprehensive and comparative picture of India's forest and tree resources over time.

The information being presented in the latest ISFR 2021 has been derived by way of complete wall-to-wall mapping of the country's forest cover using remote sensing techniques, sample plot based national forest inventory and special studies carried out at national level. This information constitutes primary data on different parameters of the forest and tree resources of the country and the manner in which the resources have been changing over time.

The ISFR is widely used for formulation of policies, planning and management of forests as well as investments affecting country's forestry sector. The report also provides a significant amount of data which meets India's reporting requirements to international organizations like Food and Agriculture Organization (FAO) and also for the various conventions and commitments namely United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD) to which India is a signatory. The ISFR is also an important reference document for students and researchers in the field of natural resource management.

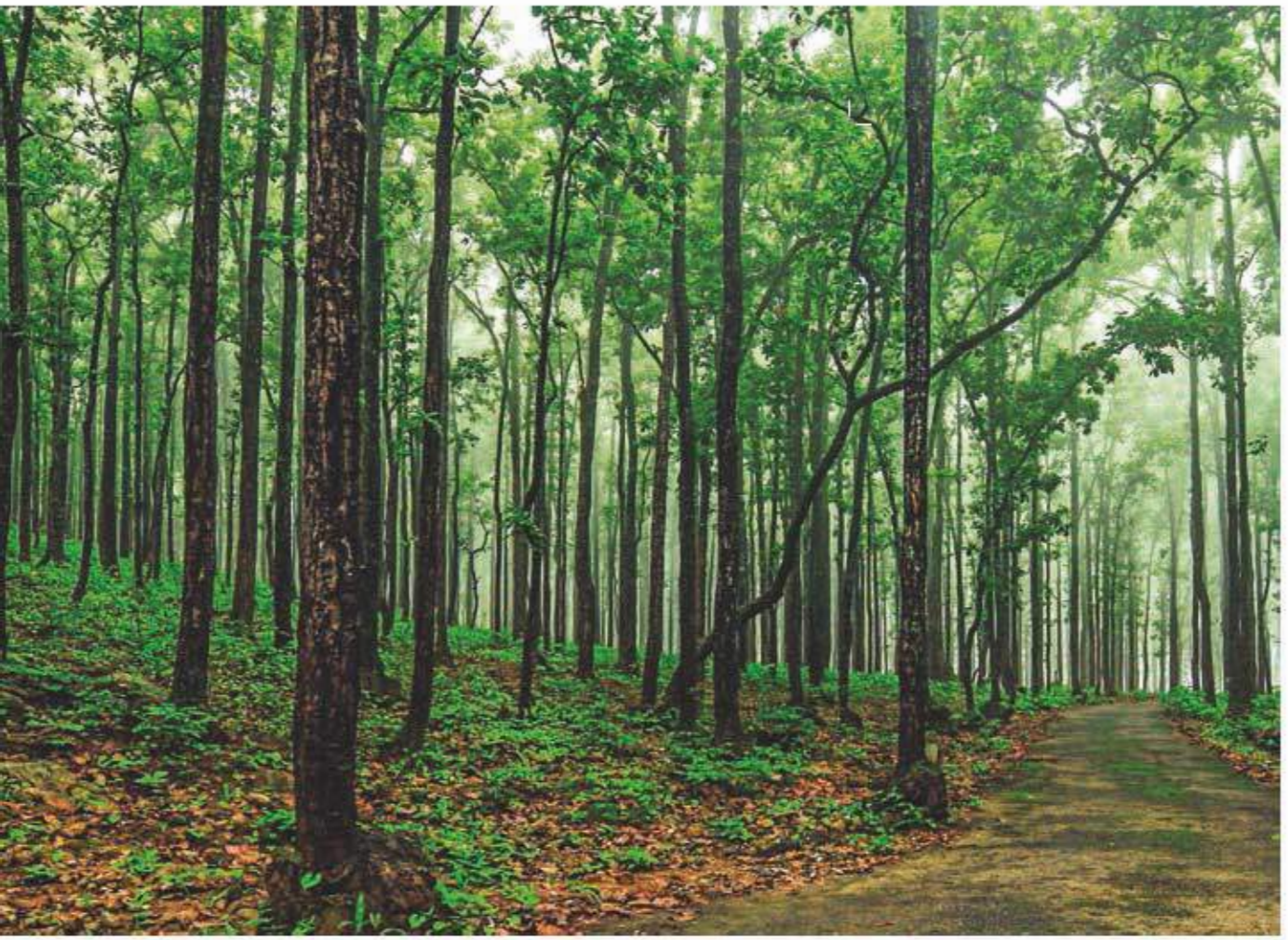
The ISFR 2021 presents the latest status of the 'Forest cover' and 'Tree cover' of the country, estimates of growing stock, extent of trees outside forests, mangrove cover, bamboo resources and assessment of forest carbon stock. In addition to the regular chapters, this time round, a special chapter on Forest Cover assessment in Tiger reserves and Tiger corridor areas of the country and decadal change in Forest Cover has also been included. This information is expected to be of value to park managers for monitoring impacts of conservation measures as well as to policy makers for inputs in devising appropriate conservation strategies and in their implementation. Results of the two special studies namely Above Ground Biomass Estimation using Synthetic Aperture Radar data (carried out in collaboration with ISRO) and Climate hot spots in forest areas studies (carried out in collaboration with BITS Pilani, Goa campus) are also being presented in this report. New initiatives taken up in the last two years by the FSI team, which has led to improvements in methodology and development of new techniques are also being presented as a special chapter. India's progress towards achieving the Nationally Determined Contribution commitments are also included as part of chapter on Forest carbon assessment.

1.2 Technology Trends in Forest Resource Assessment

Since the publication of first report in 1987, FSI has kept pace with the technological and methodological improvements associated with forest cover mapping owing to availability of better satellite data, higher scale 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. The first report of 1987 used LANDSAT-MSS satellite data with a spatial resolution of 80 meters, the scale of mapping was 1:1 million and interpretation was in visual mode with a Minimum Mappable Unit (MMU) of 400 hectares. Subsequently there were continuous improvements in the spatial resolution of satellite data and also scale of mapping and MMU. With the availability of indigenous satellite data from 1995 onwards, FSI started using the IRS-1B satellite data and in 2001 completely switched over to LISS III data with a spatial resolution of 23.5 m at 1:50,000 scale with MMU of 1 ha. The mode of interpretation also changed to digital mode.

Table 1.1 Forest Cover Mapping over the Years

Cycle of Assessment	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 & Digital
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	Digital
IX	2003	2002	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
X	2005	2004	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
XI	2009	2006	IRS-P6-LISS III	23.5 m	1:50,000	1	Digital
XII	2011	2008-09	IRS-P6-LISS III & IRS-P6 AWiFS	23.5 m 56 m	1:50,000	1	Digital
XIII	2013	2010-11	IRS P6-LISS-III IRS-Resourcesat 2- LISS III	23.5 m	1:50,000	1	Digital
XIV	2015	2013-14	IRS P6-LISS-III IRS-Resourcesat 2- LISS III	23.5 m	1:50,000	1	Digital
XV	2017	2015-16	IRS P6-LISS-III IRS-Resourcesat 2- LISS III	23.5 m	1:50,000	1	Digital
XVI	2019	2017-18	IRS P6-LISS-III IRS-Resourcesat 2- LISS III	23.5 m	1:50,000	1	Digital
XVII	2021	2019-20	IRS-Resourcesat 2- LISS III	23.5 m	1:50,000	1	Digital



Forest Cover and Recorded Forest Area 1.3

Both Forest Cover and Recorded Forest Area (RFA) describe the extent of forest but have different meanings. The 'Forest Cover' refers to all tree patches that have canopy density of more than 10% and area of one hectare or more in size, irrespective of land use, legal status and ownership. It may include orchards, bamboo, and palms etc. and is assessed through remote sensing. The 'Recorded Forest Area' or 'Forest Area' refers to all the geographical areas recorded as 'Forests' in government records irrespective of the actual trees growing on such lands. RFA mainly comprises of Reserved Forests (RF) and Protected Forests (PF) and Unclassed Forests notified under Indian Forest Act, 1927 or respective State Forest Acts. Additionally, RFA may also include all such areas, which have been recorded as 'Forest' in the revenue records or have been constituted so under any State Acts or local laws. Therefore, RFA may have blank areas with tree canopy density of less than 10% such as degraded lands, wetlands, rivers, creeks in mangroves, snow covered areas, glaciers and other snow covered areas, alpine pastures, cold deserts, grasslands etc. As per the definition of 'Forest cover' used in ISFR, such blank areas in RFA are excluded from the assessment of Forest cover. On the other hand, there are areas outside the RFA comprising tree patches of more than one hectare in area, with canopy density of 10% and above. Such areas include plantations on the private and community lands, road, rail, and canal side plantations, rubber, tea and coffee plantations etc. and are included in assessment of Forest cover. Thus, RFA and Forest cover overlap with each other but the two are not coterminous with each other. The diagram given in Figure 1.1 depicts the relationship between the two.

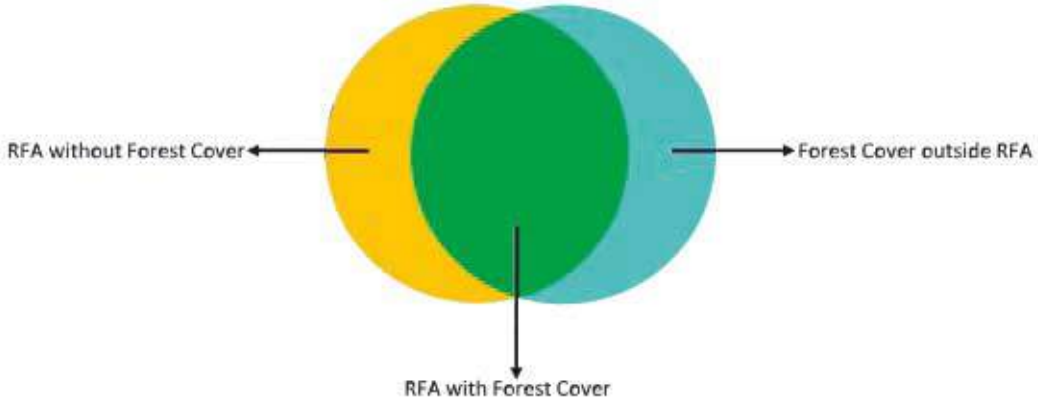
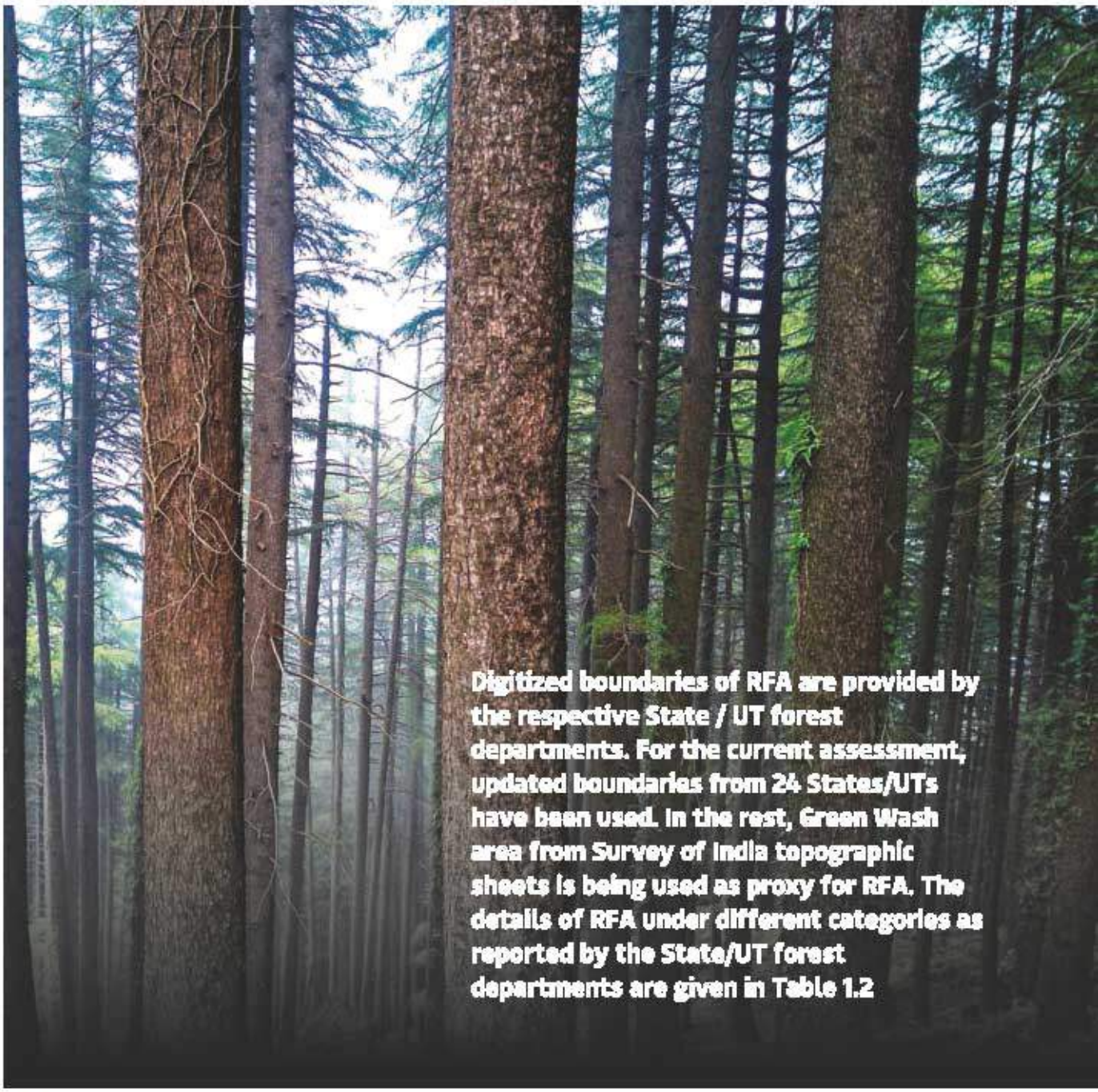


Figure 1.1
Forest Cover and Recorded Forest Area



Digitized boundaries of RFA are provided by the respective State / UT forest departments. For the current assessment, updated boundaries from 24 States/UTs have been used. In the rest, Green Wash area from Survey of India topographic sheets is being used as proxy for RFA. The details of RFA under different categories as reported by the State/UT forest departments are given in Table 1.2

Table 1.2 Recorded Forest Areas (RFAs) in States and UTs (In sq km)

Sl. No.	State/ UT	Geographical Area	RFA (in different categories)			Total RFA (2021)	% of GA
			RF	PF Forests*	Unclassed		
1.	Andhra Pradesh	1,62,968	31,959	5,069	230	37,258	22.86
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	25,897	24,036	9,883	59,816	44.25
6.	Delhi	1,483	78	25	0	103	6.95
7.	Goa	3,702	119	755	397	1,271	34.33
8.	Gujarat	1,96,244	14,574	2,896	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	191,791	28,890	3,931	5,863	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	984	3,254	13,180	17,418	78.01
17.	Meghalaya	22,429	1,113	12	8,371	9,496	42.34
18.	Mizoram	21,081	4,499	1,823	1,157	7,479	35.48
19.	Nagaland	16,579	234	0	8,389	8,623	52.01
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	18,543	2,144	32,863	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	1,12,077	25,600	1,592	296	27,688	24.70
26.	Tripura	10,486	3,588	2	2,704	6,294	60.02
27.	Uttar Pradesh**	2,40,928	11,560	296	5,528	17,384	7.22
28.	Uttarakhand	53,483	26,547	9,885	1,568	38,000	71.05
29.	West Bengal	88,752	7,054	3,772	1,053	11,879	13.38
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	203	5	6	214	35.55
33.	Jammu& Kashmir Shapefile Area*** (54,624)	2,22,236	17,648	2,551	0	20,199	36.98
34.	Ladakh Shapefile Area*** (1,66,055)		7	0	0	7	0.00
35.	Lakshadweep	30	0	0	0	0	0.00
36.	Puducherry	490	0	2	11	13	2.65
	Total	**32,87,469**	**4,42,276**	**2,12,259**	**1,20,753**	**7,75,288**	**23.58**

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 9,662.764 km of linear plantations along Road, Railway line and Canal.*

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

1.4 National Forest Inventory (NFI)

Knowledge of Growing Stock, or the volume of all living trees is essential to understand dynamics of forest stands, their productive capacity and their sustainable management. Such information is also important in the determination of the quantum of biomass existing in the forests and for further calculation of emission factors, carbon stock assessments and related information. This information is assessed through the National Forest Inventory (NFI) exercise, another major periodic forest resource assessment activity of FSI. Forest inventory is carried out following a standardized sampling design by which sample plots for field observations are laid across the country.

A new grid-based NFI design has been adopted in 2016, in which approximately 6,000 sample plots are laid annually in forest areas and about 10,000 plots are laid in Trees Outside Forest areas (TOF). In addition to Growing stock assessment, the NFI inputs are also used to assess bamboo resources, soil carbon, occurrence of Non-Timber Forest Product (NTFP) and invasive species and several other parameters depicting the general health of forests. TOF inventory provides information on 'tree cover', which includes patches of trees occurring outside RFA, less than 1 hectare, both in rural and urban areas. 'Forest cover' and 'tree cover' put together constitutes 'Forest & Tree Cover' which is the key parameter for monitoring progress as per the National Forest Policy[1] goal of achieving 33% of the country's geographical area under green cover. TOF inventory also provides estimates of the annual potential production of timber from outside the RFA. The design and methodology of the NFI has been described in detailed in the Chapter 6 of this report.

1.5 Special Features in ISFR 2021

Assessment of Forest Cover in Tiger Reserves and Lion Conservation Areas of India

The Royal Bengal Tiger (*Panthera tigris tigris*) and the Asiatic Lion (*Panthera leo persica*) are two of India's charismatic carnivores, and both are considered as umbrella species since their conservation indirectly helps in protecting many other species at the ecosystem and landscape levels. Both of these species are currently in the 'Endangered' category of the IUCN Red List of Threatened Species. The tigers in India account for 70% of the world's total tiger population (3,890), followed by tigers in Russia and Indonesia. India is home to the only surviving population of the Asiatic Lion in Gir National Park and Wildlife Sanctuary and surrounding areas in Gujarat. Project Tiger and the Lion Conservation Programme are flagship programmes in India aimed at in-situ conservation of these two keystone species respectively. In the current assessment, an attempt has been made to assess the forest cover in the fifty-two Tiger Reserves in the country and also assess decadal change in forest cover with respect to the 2011 assessment. Further, the assessment of wetlands within Tiger Reserves and Forest Type Mapping has also been carried out. Additionally, assessment of the extent of forest cover in the Tiger Corridors of the country has also been made, since corridors serve to connect tiger populations between Tiger Reserves and surrounding areas. The Tiger Corridors are multiple-use areas and face higher levels of anthropogenic pressures. Similarly Forest Cover assessment and decadal change analysis for the Asiatic Lion areas in the Gir National Park and Wildlife Sanctuary have been carried out. The detailed assessment of Forest Cover in Tiger Reserves and Lion Conservation Areas of India are described in the Chapter 4 of this report. The information should be helpful for further analyses of habitat parameters and devising appropriate conservation strategies to maintain biodiversity as well as to improve the ecosystem services emanating from these these pristine wildlife habitats.

[1] *National Forest Policy (1988), Ministry of Environment and Forests, Government of India*

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Above Ground Biomass (AGB) estimation using Synthetic Aperture Radar (SAR) data

Forest biomass comprises nearly 80% of the total terrestrial above ground biomass of the earth. Estimation of forest biomass helps in enhancing the understanding about global carbon sink, assessment of carbon stock and commercial significance of the forest. Information about spatial distribution of the forest biomass and their categories is important for proper management of the forest resources. Considering the importance of forest biomass, FSI in collaboration with Space Application Centre (SAC), ISRO, Ahmedabad has initiated a special study for estimation of Above Ground Biomass (AGB) at PAN-India level using Synthetic Aperture Radar (SAR) data in 2018.

The objectives of this study were as follows:

Explore the potential of Synthetic Aperture Radar (SAR) data for understanding forest structure and ultimately biomass within forest.

Generate estimates of forest biomass at state and country level.

To prepare AGB map of the country.

Synthesize National Forest Inventory data for generation of forest biomass at plot level.

Results of the study and AGB map, for the State of Assam and Odisha were presented in ISFR 2019. The interim results for AGB estimates and the resulting AGB map for the entire country are being presented in the Chapter 10 of this report. This is a first and should provide important insights about biomass within the forests of India.

Mapping of Climate Change Hotspots in Indian Forests

Life on earth is facing new challenges because of changing climate. Extreme climatic events such as more frequent and intense drought, storms, heat waves, rising sea levels, melting glaciers and warming of oceans are posing serious threats to habitats and livelihoods, world over. Intergovernmental Panel on Climate Change (IPCC) reports have been continuously highlighting the impacts of climate change.

The importance of forests in mitigation of climate change has been understood in recent years. Forests act as a sink of atmospheric carbon dioxide, they are the biggest terrestrial reservoir of carbon on the planet but become a source of CO_2 and other Green House Gases (GHGs) if they are cut, burnt or destroyed. Forestry interventions, especially afforestation and eco-restoration activities, play a significant role in mitigating negative effects of climate change and offer low cost opportunities to adapt to climate change outcomes. It is imperative to appreciate the likely impacts of climate change on forests using all available tools and techniques. FSI in tune with its mandate of monitoring and assessment of forests of the country has undertaken a collaborative study with BITS Pilani (Goa Campus) to map climate hotspots in the forest areas of the country. A climate hotspot refers to an area, which is prone to adverse climatic change. This study is based on the computer model projections of temperature and rainfall in three time horizons i.e. 2030, 2050 and 2085. The enhanced understanding about the climate change hotspot areas in Indian forests would assist in planning and strategizing preventive and adaptive measures against changing climate. The significant outcomes of the study on climate change hotspots in Indian forests have been presented in Chapter 11 of this report.

1.6 Recent Initiatives of FSI

FSI has always strived to keep pace with technological advancements to meet the information needs of the forestry sector. New technology and advanced methodology has lead to more accurate findings. Some of the new initiatives are given below:

- **Trees Outside Forest Resources in India**

  Trees Outside Forest (TOF) found in diverse rural and urban landscapes of the country have immense ecological and economic importance in rural and urban parts of the country. A new methodology has been developed to estimate the TOF resources and the extent of TOF area in the country. The major species found therein has been assessed using the newly developed methodology. Moreover, potential annual yield from timber from TOF has also been assessed.

- **India's Nationally Determined Contribution of creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 eq through additional forest & tree cover: Possibilities, scale and costs for formulating strategy**

  Nationally Determined Contributions (NDC) represents the commitment of each country to reduce greenhouse gas emissions for climate change impact mitigation and adaptation. These were agreed to by countries during the Conference of the Parties (COP 21) held in Paris in 2015, and is widely known as 'The Paris Agreement'. India is also a party to the Paris Agreement and has submitted country's NDC to the United Nations Framework Convention on Climate Change (UNFCCC) in October 2015. In order to provide important inputs in formulating a realistic strategy to achieve the NDC targets, FSI has undertaken a detailed exercise in exploring the possibilities, scale and cost implications, facts that are germane in formulating an appropriate national strategy.

- **Variability in forests and optimum sample size for estimation of Growing Stock in different districts of the country: a ready reckoner for Working Plan preparation or any other forest resource assessment exercise**

  In forestry, having an optimum sample size that allows timely completion of the data collection is rather important. This study provides optimum sample size for different districts of the country for conducting inventories to estimate the growing stock. This will be of immense use to the State Forest Department, especially in preparation of Working Plan.

- **A new grid-based algorithm for detecting locations of changes in forest vegetation in a pin-pointed manner over large landscapes**

  With mounting anthropogenic pressure on the country's forest, there is an emerging need for detecting the changes occurring in the forests accurately, early and with minimum cycle of revisit. A new index called 'Grid Vegetation Change Index' (GVCI) has been used to detect changes in the forests through a rapid, gird-based approach for operational use. GVCI helps in detecting change in vegetation over an area of interest between the two time periods.

- **Rapid assessment of fire-affected forest areas in the country based on MODIS-detections following a sampling approach**

  The recurrent annual forest fires in India cause damage to forests and have adverse impacts on ecosystems. Since 2004, FSI has been monitoring forest fires using remote sensing techniques and has been issuing forest fire alerts to State Forest Departments. Assessment of the fire-affected areas provides an estimate while planning for eco-restoration activities by the states. Since fire burnt forest areas show conspicuous signature on the satellite images, a cost-effective and time-efficient methodology has been developed for rapid assessment of forest areas affected by fire at a nation-wide scale based on a statistical sampling approach by using MODIS-based Near-Real Time - Forest Fire points (NRT - FFPs).

These new initiatives figure in the Technical Information Series of FSI. A brief about these initiatives is presented in the Chapter 12 of the report. It is expected that such initiatives will go a long way in meeting the data gaps in forestry sector in general and will be useful to State Forest Departments in particular

1.7 India's Forests vis-à-vis Forest Resources in the World

The Global Forest Resource Assessment (GFRA) by FAO provides information about the forest resources of almost all countries at five-year intervals. The latest report of GFRA was published in the year 2020. Status of the top ten countries in respect of forest area, change in forest area and growing stock as per the GFRA 2020 are presented in the Tables 1.3 (a) to (c) below:

Table 1.3(a) Top ten countries for forest area (2020)

Sl. No.	Country	Forest area (000 ha)	% of world forest area	% of country area
1.	Russian Federation	8,15,312	20	49.8
2.	Brazil	4,96,620	12	59.4
3.	Canada	3,46,928	9	38.7
4.	USA	3,09,795	8	33.9
5.	China	2,19,978	5	23.3
6.	Australia	1,34,005	3	17.4
7.	Democratic Republic of the Congo	1,26,155	3	55.6
8.	Indonesia	92,133	2	49.1
9.	Peru	72,330	2	56.5
10.	India	72,160	2	24.3
	Total	**4,85,438**	**66**	

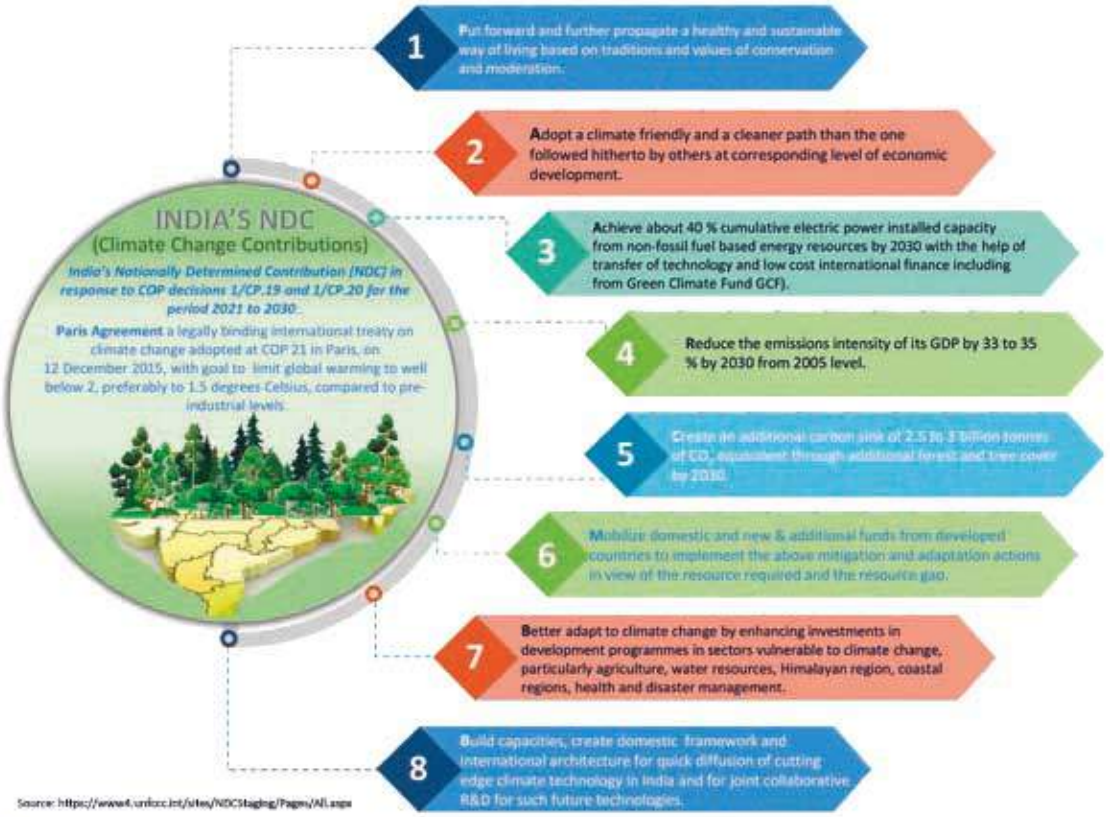
Table 1.3(b) Top ten countries for average annual net gain in forest area (2010–2020)

Sl. No.	Country	Annual Forest Area Gain	
		Area (000 ha)	% of 2010 forest area
1.	China	1,937	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.	USA	108	0.03
8.	France	83	0.50
9.	Italy	54	0.58
10.	Romania	41	0.62

Table 1.3 (c) Top ten countries for volume of forest growing stock (2020)

Sl. No.	Country	Growing Stock (m cum)
1.	Brazil	1,20,358
2.	Russian Federation	81,071
3.	Canada	45,108
4.	USA	41,269
5.	Democratic Republic of the Congo	30,782
6.	China	19,191
7.	Colombia	14,830
8.	Indonesia	12,727
9.	Peru	11,525
10.	Bolivarian Republic of Venezuela	10,254

Box-1.1 India's NDC (Climate Change Contribution)



Source: https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx

02

FOREST COVER

Introduction 2.1

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

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

2.2 Objectives of the Nation-wide Forest Cover Mapping

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

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

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

2.3 Satellite Data and Period

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

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

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

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

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

2.4 Forest Cover

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

Table 2.2 Forest Cover classified in terms of canopy density classes

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

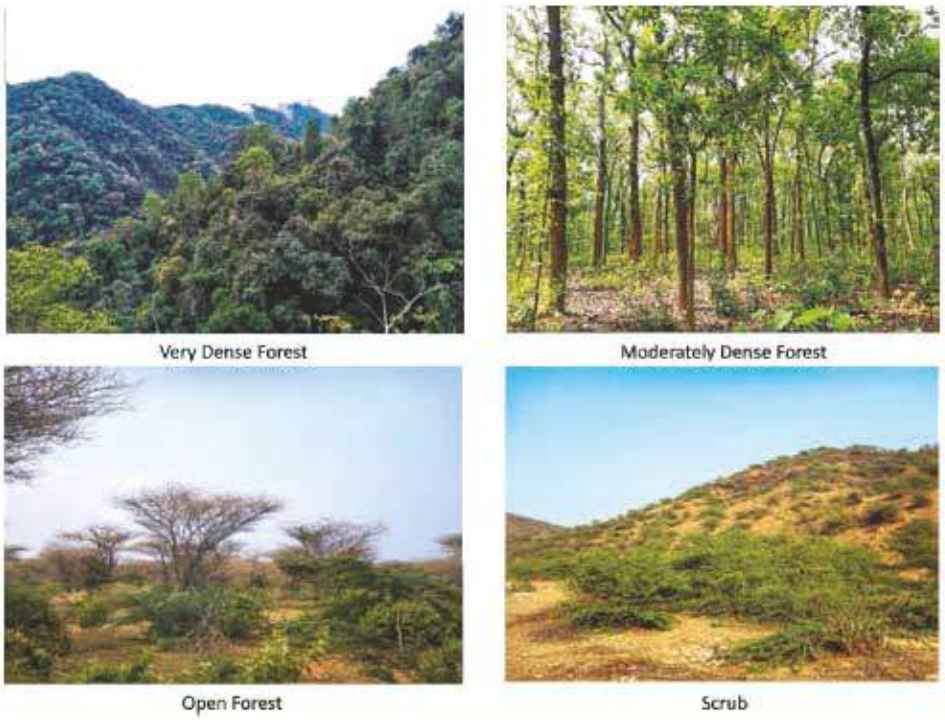


Figure 2.1 Pictorial depiction of different Forest Cover classes and scrub

2.5 Forest Cover Assessment: Approach

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

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

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

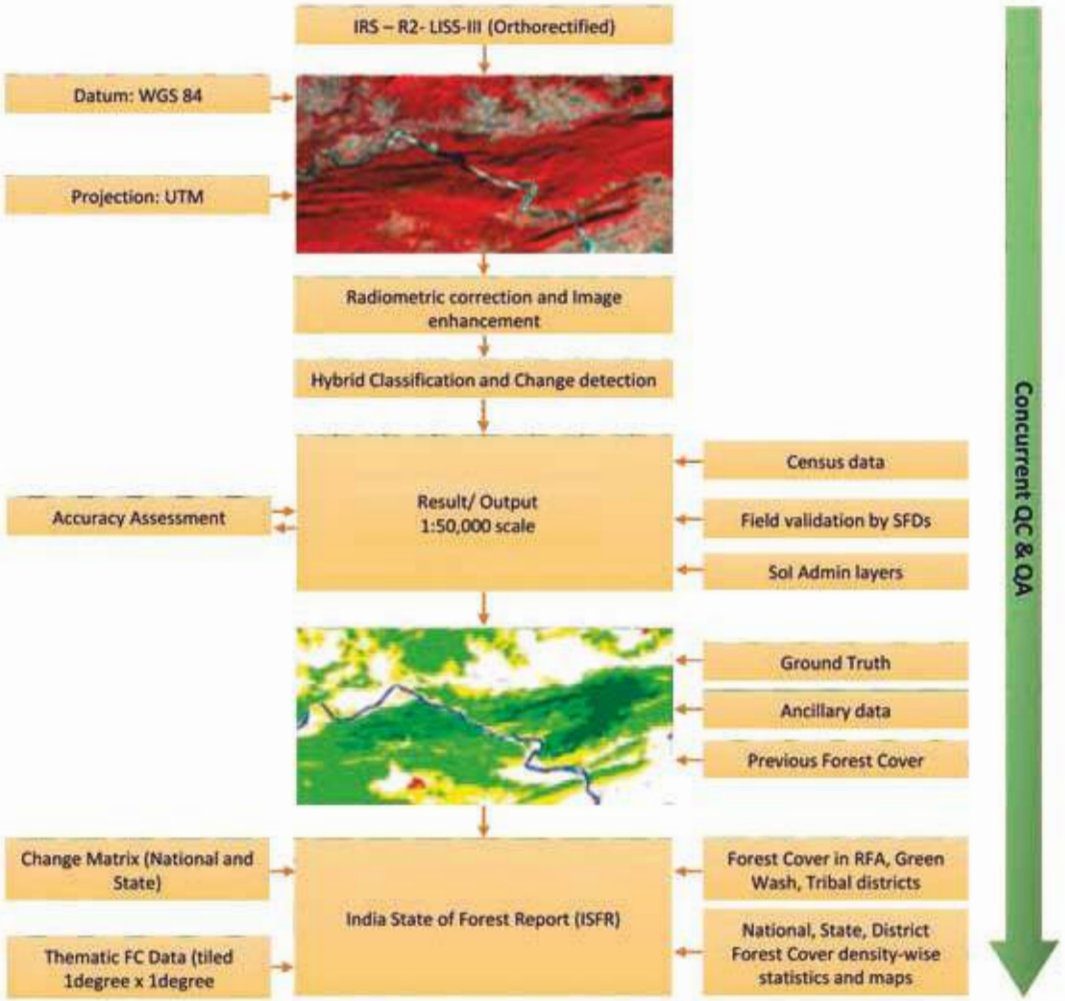


Figure 2.2 Schematic diagram of the broad approach followed in Forest Cover Mapping (FCM)

The process adopted involves calibration of Digital Numbers (DN) to Reflectance, based on rescaling factors and further conversion to Top of Atmospheric (ToA) reflectance using a specific model developed for the sensor. Radiometric correction is aimed at mathematically transforming DN values to have high degree of correspondence with the features on the ground.

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

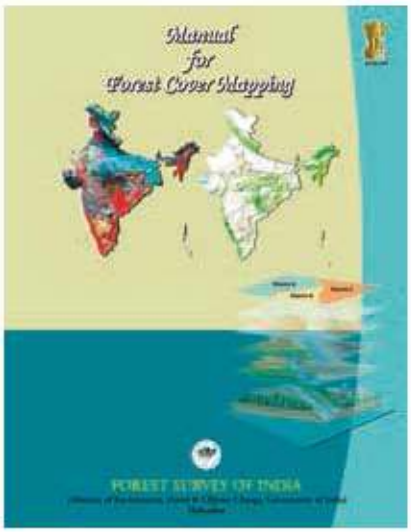
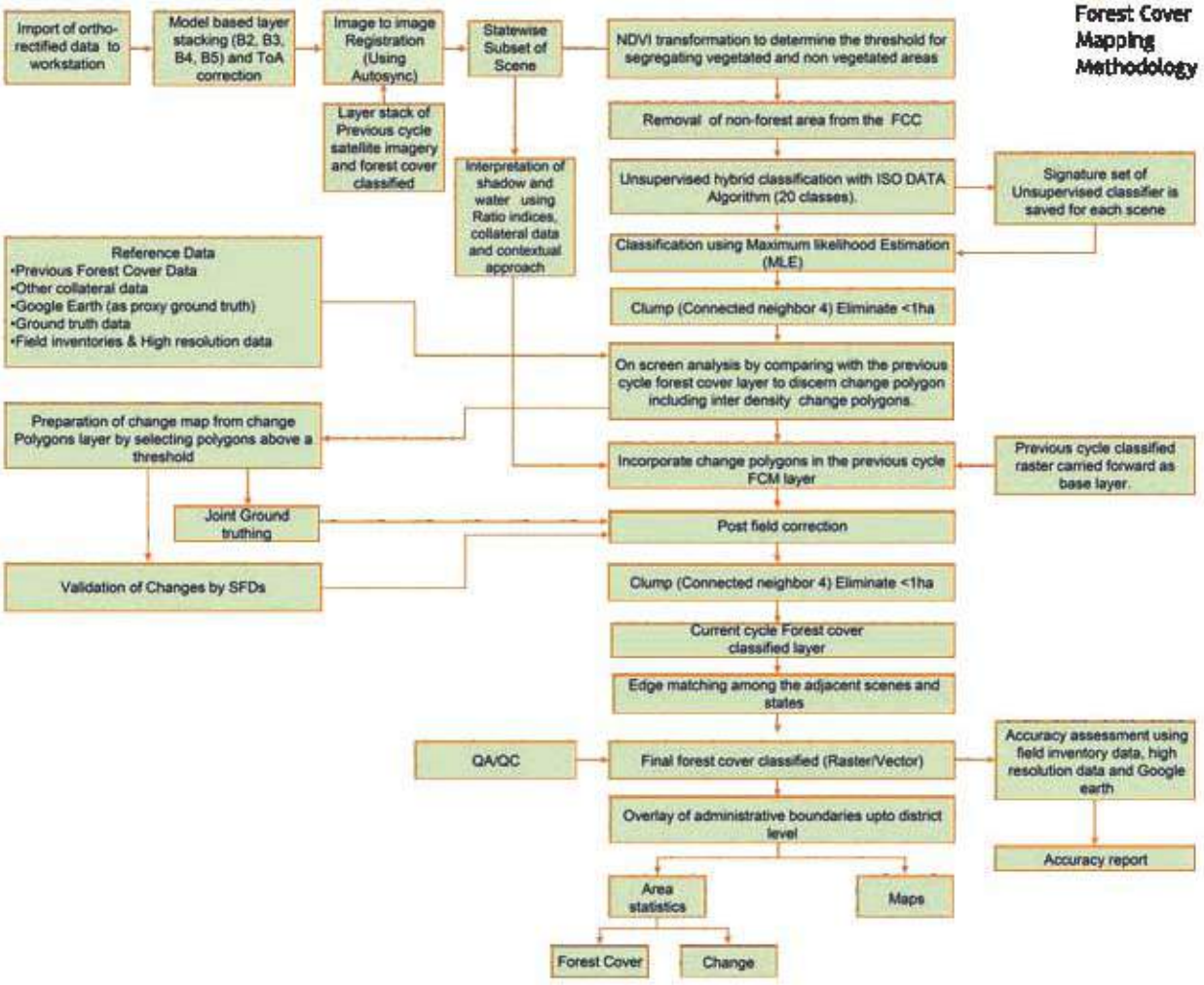


Figure 2.3 Forest Cover Mapping manual

Forest Cover Mapping Methodology 2.6

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

Figure 2.4 Forest Cover Mapping Methodology



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

(i) Normalised Difference Vegetation Index (NDVI) Transformation: Current satellite data after ToA is put to NDVI transformation for segregating non-vegetated and vegetated areas.

(ii) Unsupervised classification: Vegetated part of the image resulting from the previous step is classified using ISODATA algorithm into VDF, MDF, OF, scrub and other classes attributed as Non-Forest.

(iii) Maximum Likelihood Estimator (MLE): The signature set for unsupervised classification is saved for each scene which is further used to perform MLE on masked NDVI image. This is carried out as MLE is the most suitable classifier for the input samples/clusters with Normal distribution, as it takes most of the variables into account. The clump eliminate is carried out on this layer to retain patches above 1 ha.

(iv) On-screen Visual Analysis: NDVI based Forest Cover layers are compared on screen, patch-wise, to capture change polygons. The interpretation for water is done separately. In case of cloud, shadow, haze, mixing of non woody vegetation with forest etc., the information from other collateral data is also used to discern the change polygons (Figure 2.4). The change layer is maintained in raster as well as vector formats.

(v) The change layer so generated, is then overlaid on the previous cycle classified to obtain the classified layer for the present cycle. District-wise Forest Cover area statistics is generated for each State/UT and compiled together to determine the Forest Cover of the entire country.

Figure 2.5
Illustration of change polygons

Use of Collateral data to aid interpretation 2.6.1

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

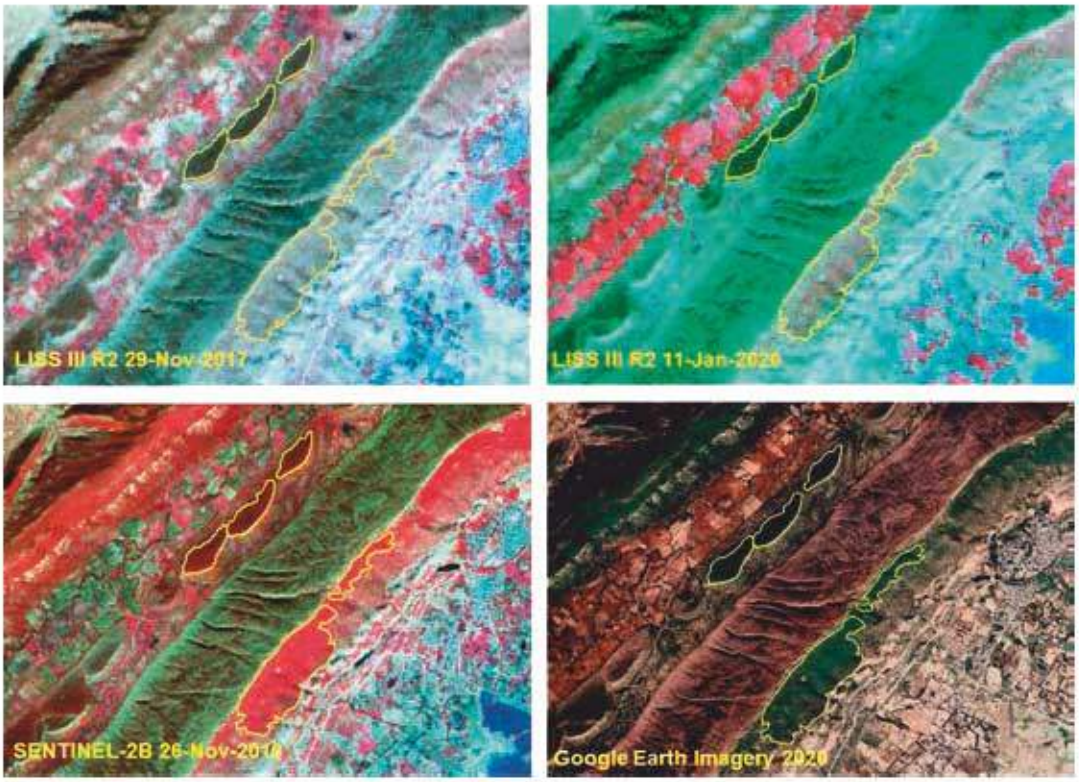


Figure 2.6 Illustration of change polygons using Collateral data

2.6.2 Ground Truthing

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

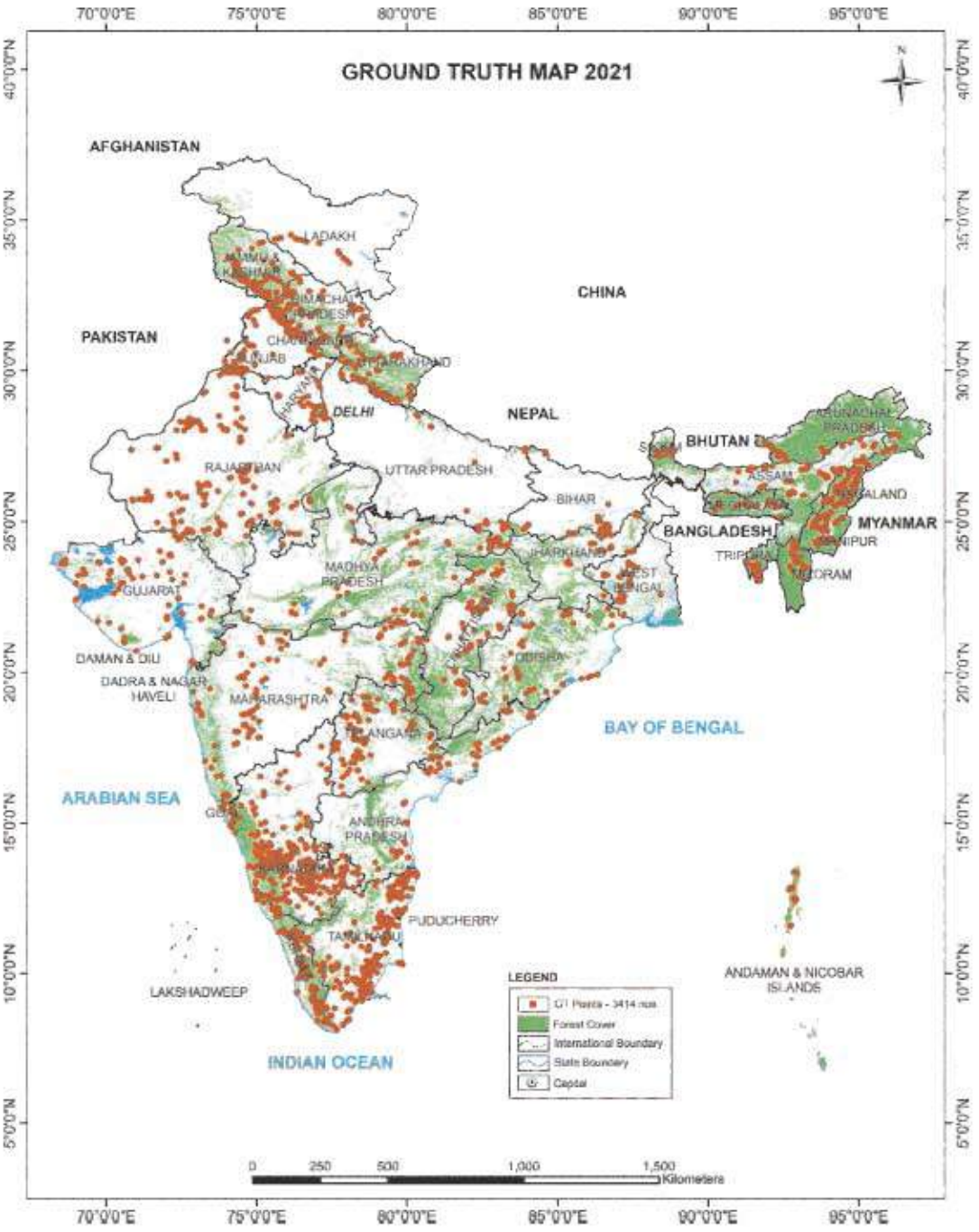


Figure 2.7 Map showing Ground Truth locations of Forest Cover Mapping

Use of Mobile Application for ground truthing 2.6.3

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

Figure 2.8 Field Data Collection Application for Ground Truth

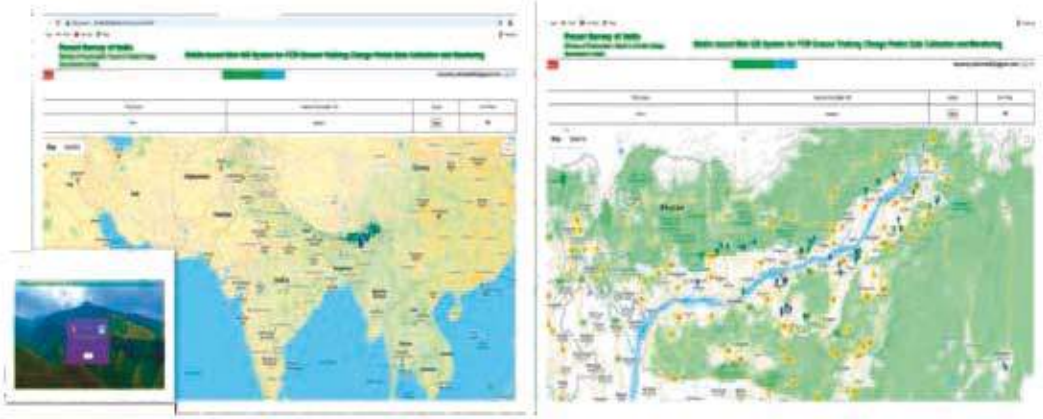


Figure 2.9 Mobile based Web GIS System for FCM Ground Truthing Change Points Data Collection

Validation of Change Maps 2.6.4

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

2.6.5 Post Field correction and Forest Cover layer generation

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

2.6.6 Concurrent Quality Check & Quality Assurance (QC&QA)

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

2.7 Limitations of the Forest Cover Mapping

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

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

Forest Cover: 2021 Assessment 2.8

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

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

Table 2.3 Forest Cover of India (In sq km)

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

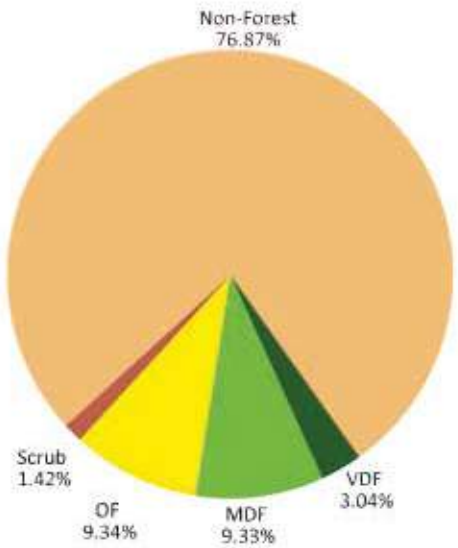
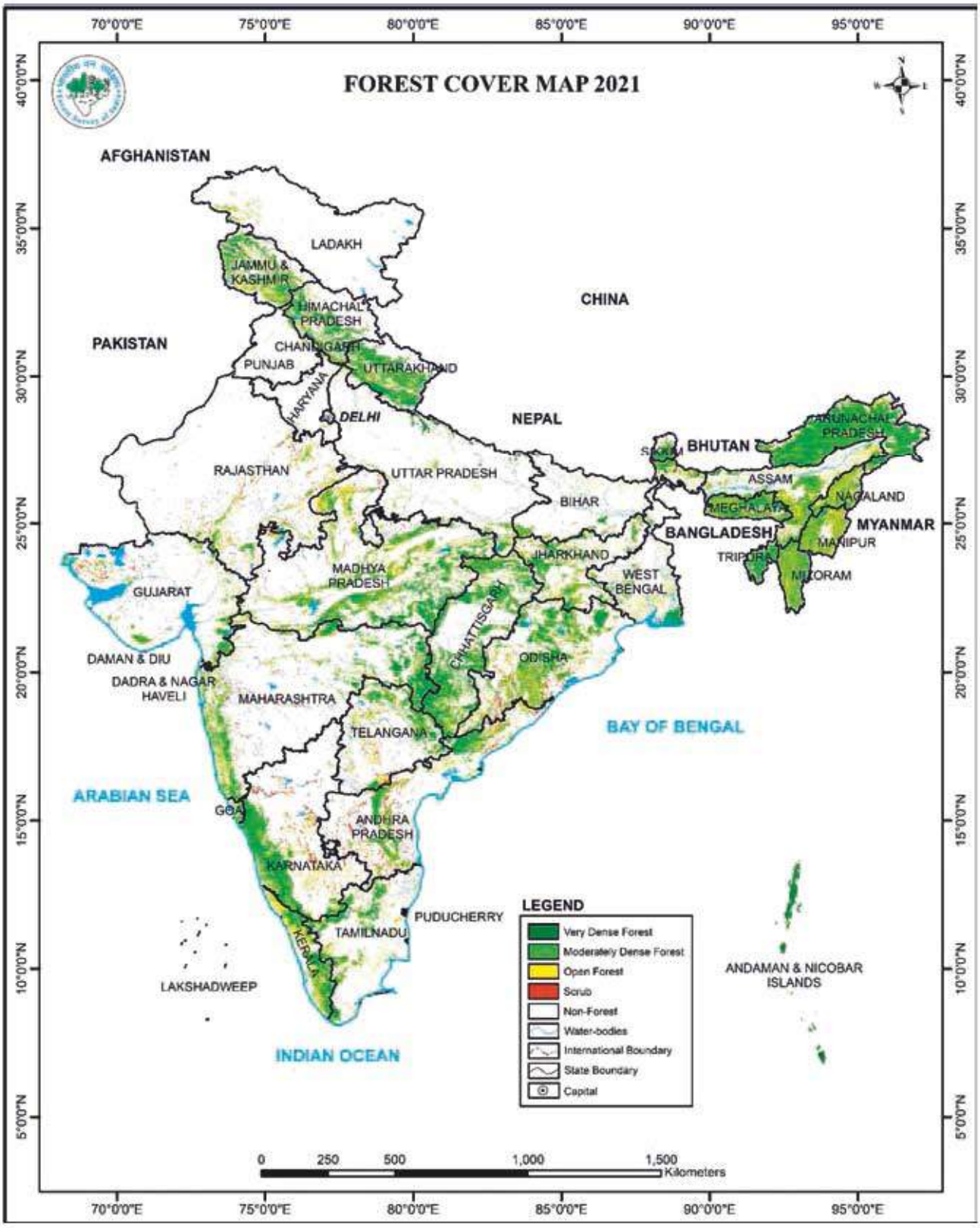


Figure 2.10 Pie-chart showing Forest Cover of India

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

Figure 2.11
Forest Cover Map of India 2021



2.9 State/UT wise Forest Cover

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

Table 2.4 Forest Cover in the States/UTs in India

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

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

(in sq km)

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

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

2.10 Change in Forest Cover

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

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

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

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

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

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

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

(in sq km)

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

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

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

2.11.1 Recorded Forest Areas (RFA)

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

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

2.11.2 Green Wash (GW)

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

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

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

(in sq km)

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

Forest Cover Outside RFA/GW 2019				Forest Cover Outside RFA/GW 2021			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
29	1,117	3,872	5,018	29	1,115	4,501	5,545
1,455	3,173	3,339	7,967	1,421	3,005	3,325	7,751
255	1,439	6,489	8,183	269	1,425	6,615	8,309
19	829	1,690	2,538	19	829	1,702	2,550
1,712	5,814	5,669	13,195	1,710	5,801	5,739	13,250
3.53	40.37	92.47	136.37	3.53	40.55	91.75	135.83
22	248	749	1,019	22	247	755	1,024
22	1,037	4,013	5,072	22	1,016	4,053	5,091
6	295	928	1,229	6	290	933	1,229
342	2,178	2,276	4,796	343	2,177	2,279	4,799
1,188	4,502	5,712	11,402	1,187	4,503	5,749	11,439
855	8,294	6,955	16,104	854	8,264	7,064	16,182
143	4,197	7,171	11,511	140	4,173	7,261	11,574
417	4,071	8,242	12,730	414	4,014	8,293	12,721
255	5,539	8,985	14,779	258	5,521	8,979	14,758
8	522	1,299	1,829	10	485	1,270	1,765
47	1,524	704	2,275	48	1,508	692	2,248
1	93	176	270	1	91	172	264
107	1,255	2,397	3,759	103	1,246	2,274	3,623
1,403	6,302	11,105	18,810	1,564	6,359	11,547	19,470
1	350	714	1,065	1	342	716	1,059
5	383	3,741	4,129	4	370	3,721	4,095
270	673	343	1,286	270	672	345	1,287
275	2,452	6,129	8,856	273	2,454	6,161	8,888
72	466	1,712	2,250	73	468	1,977	2,518
244	1,333	698	2,275	240	1,326	723	2,289
162	1,041	4,408	5,611	164	1,027	4,484	5,675
786	3,536	3,191	7,513	786	3,527	3,207	7,520
412	1,772	7,588	9,772	413	1,817	7,490	9,720
269	138	128	535	269	137	130	536
0.08	9.25	4.17	13.50	0.08	8.43	5.67	14.18
1.40	16.27	50.43	68.10	1.40	16.18	50.15	67.73
1,172	2,790	4,157	8,119	1,119	2,685	4,407	8,211
0	343	1,114	1,457	0	333	1,139	1,472
0.00	16.09	11.01	27.10	0.00	16.09	11.01	27.10
0.00	17.66	33.75	51.41	0.00	17.53	34.77	52.30
11,859	67,806	1,15,886	1,95,651	12,037	67,326	1,17,796	1,97,159

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

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

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

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

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

2.12 Change Matrix

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

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

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

• Gain • Loss

2.13 Forest Cover in Hill Districts

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

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

State	No. of Hill Districts	Geographical	VDF	MDF	OF	Total	Percentage of GA	Change in forest cover wrt ISFR 2019	Scrub
Arunachal Pradesh	16	83,743	21,058	30,176	15,197	66,431	79.33	-257	797
Assam	3	19,295	981	5,473	6,446	12,900	66.86	-107	104
Himachal Pradesh	12	55,673	3,163	7,100	5,180	15,443	27.73	9	322
Karnataka	6	48,353	3,940	15,364	4,554	23,858	49.34	42	780
Kerala	10	29,552	1,549	7,212	8,197	16,958	57.38	113	29
Maharashtra	7	69,905	320	7,223	8,303	15,846	22.67	14	1,446
Manipur	9	22,327	905	6,228	9,465	16,598	74.34	-249	1,215
Meghalaya	7	22,429	560	9,160	7,326	17,046	76.00	-73	663
Mizoram	8	21,081	157	5,715	11,948	17,820	84.53	-186	1
Nagaland	11	16,579	1,272	4,449	6,530	12,251	73.90	-235	824
Sikkim	4	7,096	1,102	1,551	688	3,341	47.08	-1	296
Tamil Nadu	5	19,384	1,439	2,679	2,458	6,576	33.92	1	76
Tripura	4	10,486	647	5,212	1,863	7,722	73.64	-4	33
Uttarakhand	13	53,483	5,055	12,768	6,482	24,305	45.44	2	392
West Bengal	1	3,149	721	682	947	2,350	74.62	-18	9
Jammu & Kashmir* Shapefile Area* (54,624)	22	2,22,236	4,155	8,117	9,115	21,387	39.15	29	284
Ladakh* Shapefile Area* (1,68,055)	2		2	512	1,758	2,272	1.35	18	279
Total	**140**	**7,04,771**	**47,026**	**1,29,821**	**1,06,457**	**2,83,104**	**40.17**	**-902**	**7,550**

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

Forest Cover in Tribal Districts 2.14

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

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

State	No. of Tribal Districts	Geographical area	RFA/GW Digital area	Forest Cover inside RFA/GW 2019				Forest Cover inside RFA/GW 2021			
				VDF	MDF	OF	TOTAL	VDF	MDF	OF	
Andhra Pradesh	5	44,849	13,297	1,525	4,631	2,673	8,829	1,525	4,624	2,730	
Arunachal Pradesh	16	83,743	63,838	19,640	27,384	11,697	58,721	19,637	27,171	11,872	
Assam	19	49,489	9,888	1,400	2,781	2,398	6,579	1,486	2,676	2,395	
Chhattisgarh	11	92,645	35,955	4,810	16,803	6,900	28,513	4,805	16,913	6,832	
Gujarat	9	49,885	7,718	303	2,327	2,428	5,058	303	2,303	2,437	
Himachal Pradesh	3	26,764	3,143	751	913	585	2,249	751	913	585	
Jharkhand	17	58,677	11,658	829	3,244	3,465	7,538	828	3,244	3,517	
Karnataka	5	26,054	6,612	1,964	2,981	684	5,639	1,965	2,977	698	
Kerala	9	27,207	8,755	1,355	3,887	1,881	7,123	1,364	3,877	1,919	
Madhya Pradesh	24	1,52,132	51,919	5,719	19,129	14,612	39,460	5,715	19,075	14,585	
Maharashtra	12	1,44,233	41,590	7,136	10,268	8,810	26,214	7,138	10,301	8,785	
Manipur	9	22,327	17,542	897	5,864	8,257	15,018	895	5,743	8,195	
Meghalaya	7	22,429	17,563	442	7,743	6,659	14,844	512	7,652	6,634	
Mizoram	8	21,081	20,663	156	5,708	11,872	17,736	156	5,624	11,776	
Nagaland	11	16,579	10,633	1,166	3,279	4,282	8,727	1,169	3,203	4,256	
Odisha	12	86,091	24,685	3,883	9,307	6,770	19,960	3,925	8,690	7,114	
Rajasthan	5	29,601	9,016	0	2,064	2,482	4,546	0	2,066	2,488	
Sikkim	4	7,096	5,414	832	879	345	2,056	832	879	343	
Tamil Nadu	6	25,607	5,342	797	2,318	1,401	4,516	797	2,318	1,402	
Telangana	3	42,217	16,933	1,130	6,486	4,381	11,997	1,144	6,736	4,229	
Tripura	4	10,486	5,838	410	3,903	1,138	5,451	407	3,886	1,140	
Uttar Pradesh	1	7,680	1,191	752	118	90	960	752	118	89	
West Bengal	12	69,403	13,095	2,593	2,363	2,101	7,057	2,610	2,366	2,063	
A&N Islands	3	8,249	6,829	5,409	546	253	6,208	5,409	546	253	
Dadra & Nagar Haveli and Daman &Diu	2	563	202	0.00	69.35	90.20	159.55	0.00	69.38	90.64	
Lakshadweep	1	30	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total	**218**	**11,25,117**	**3,92,106**	**63,899**	**1,44,985**	**1,06,264**	**3,15,158**	**64,125**	**1,43,970**	**1,06,408**	

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

(in sq km)

Forest Cover Outside RFA/GW 2019					Forest Cover Outside RFA/GW 2021				Change Inside RFA/GW	Change Outside RFA/GW	Net Change
TOTAL	VDF	MDF	OF	TOTAL	VDF	MDF	OF	TOTAL			
8,879	22	769	2,606	3,397	22	767	2,930	3,719	50	322	372
58,680	1,455	3,173	3,339	7,967	1,421	3,005	3,325	7,751	-41	-216	-257
6,557	113	890	4,491	5,494	112	893	4,597	5,602	-22	108	86
28,550	1,700	5,082	4,693	11,475	1,698	5,069	4,750	11,517	37	42	79
5,043	21	593	1,197	1,811	21	585	1,208	1,814	-15	3	-12
2,249	112	460	441	1,013	112	459	437	1,008	0	-5	-5
7,589	1,050	4,005	4,848	9,903	1,049	4,006	4,877	9,932	51	29	80
5,640	632	4,953	2,392	7,977	630	4,937	2,401	7,968	1	-9	-8
7,160	116	2,943	5,229	8,288	114	2,926	5,311	8,351	37	63	100
39,375	331	2,796	4,876	8,003	328	2,759	4,900	7,987	-85	-16	-101
26,224	80	1,366	2,783	4,229	81	1,358	2,785	4,224	10	-5	5
14,833	8	522	1,299	1,829	10	485	1,270	1,765	-185	-64	-249
14,798	47	1,524	704	2,275	48	1,508	692	2,248	-46	-27	-73
17,556	1	93	176	270	1	91	172	264	-180	-6	-186
8,628	107	1,255	2,397	3,759	103	1,246	2,274	3,623	-99	-136	-235
19,729	1,235	5,089	8,047	14,371	1,394	5,148	8,290	14,832	-231	461	230
4,534	0	94	638	732	0	92	633	725	-12	-7	-19
2,054	270	673	343	1,286	270	672	345	1,287	-2	1	-1
4,517	45	447	663	1,155	43	449	676	1,168	1	13	14
12,109	69	347	741	1,157	69	347	826	1,242	112	85	197
5,433	244	1,333	698	2,275	240	1,326	723	2,289	-18	14	-4
959	53	40	220	313	53	40	220	313	-1	0	-1
7,039	412	1,357	5,824	7,593	412	1,403	5,727	7,542	-18	-51	-69
6,208	269	138	128	535	269	137	130	536	0	1	1
160.02	0.00	12.51	46.01	58.52	0.00	12.42	45.74	58.16	0.47	-0.36	0.11
0.00	0.00	16.09	11.01	27.10	0.00	16.09	11.01	27.10	0.00	0.00	0.00
3,14,503	8,392	39,871	58,830	1,07,193	8,500	39,737	59,556	1,07,793	-655	600	-55

2.15 Forest Cover in the North Eastern States

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

Table 2.10 Forest Cover in North Eastern States (in sq km)

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

2.16 Forest Cover in Different Altitude Zones

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

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

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

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

Forest Cover on Different Slope Classes 2.17

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

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

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

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

Accuracy Assessment of Forest Cover 2.18

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

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

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

The percentage of correctly classified sampling units (i.e. sum of all diagonal elements) out of the total considered sampling units in the error matrix provides overall accuracy of the mapping. Similarly, accuracy of each class can be measured by calculating the percentage of correctly classified random points out of the total number of sample points pertaining to a particular class.

2.18.1 Methodology

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

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

2.18.2 Findings

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

Table 2.13 Error Matrix for Forest Cover Classes

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

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

Table 2.14 Error Matrix for Forest and Non-Forest Classes

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

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

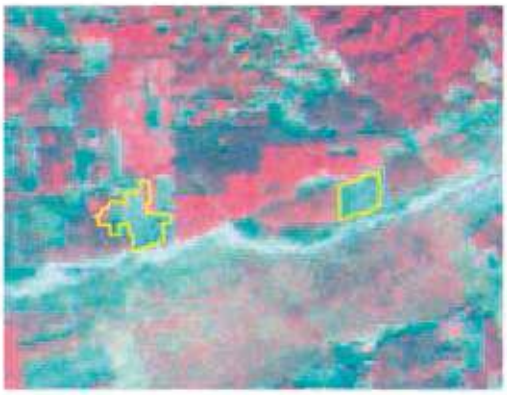
The producer's accuracy is derived by dividing the number of correct sampling points in one class by the total number of points as derived from reference data. It includes the error of omission, which refers to the proportion of observed features on the ground that is not classified in the map. The more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

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

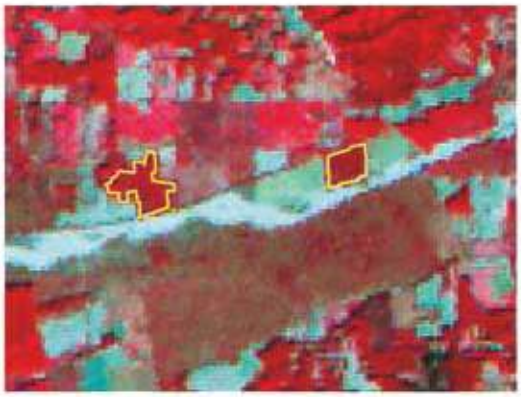
From Table 2.13, it is found that the producer's accuracy for VDF, MDF, OF, Scrub and Non-forest classes are 96.73 percent, 95.18 percent, 86.62 percent, 88.14 percent and 96.39 percent respectively. Similarly, user's accuracy for these classes are 93.00 Percent, 93.77 percent, 94.68 percent, 93.27 percent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

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

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



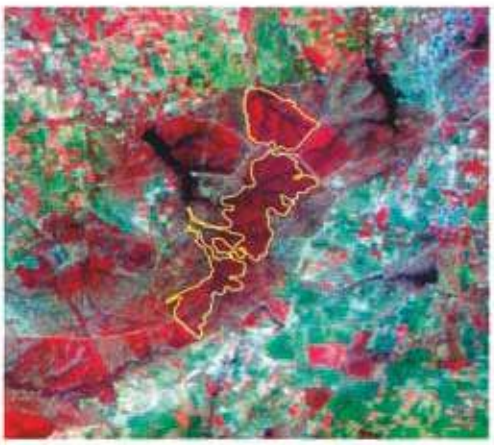
ISFR 2019



ISFR 2021

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

ISFR 2019



ISFR 2021

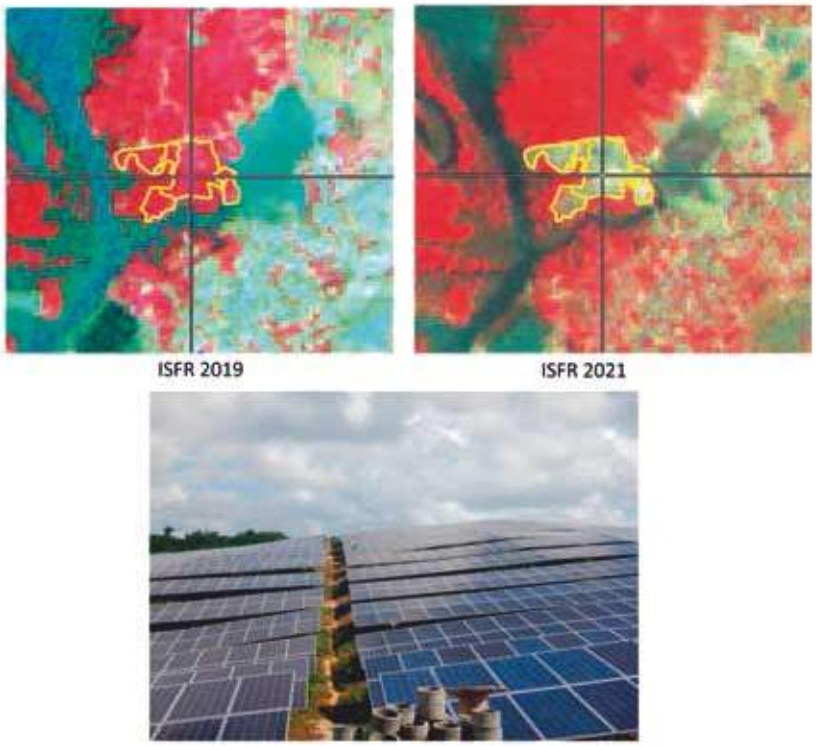


Figure 2.14
Decrease in Forest Cover due to construction of Solar panel in Port Blair (South Andaman district)

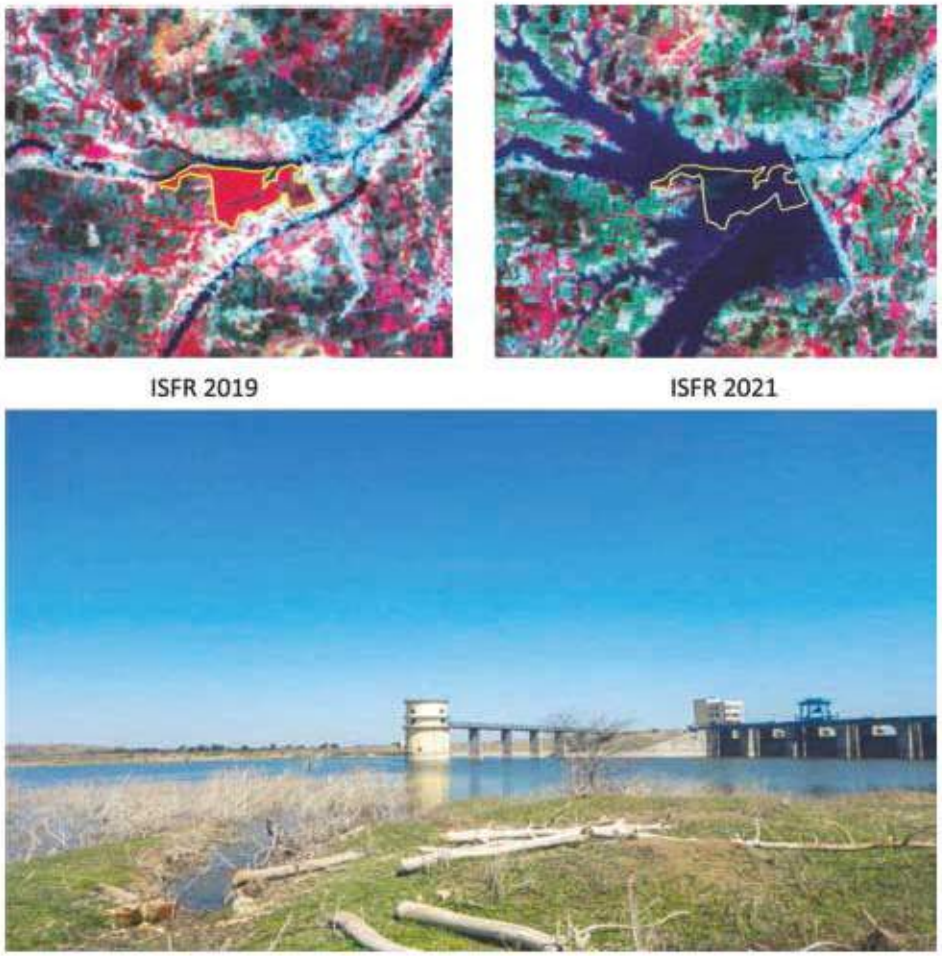


Figure 2.15
Decrease in Forest Cover due to construction of Dam in Jhalawar district, Rajasthan

2.19 Forest Cover in Major Mega Cities

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

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

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

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

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

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

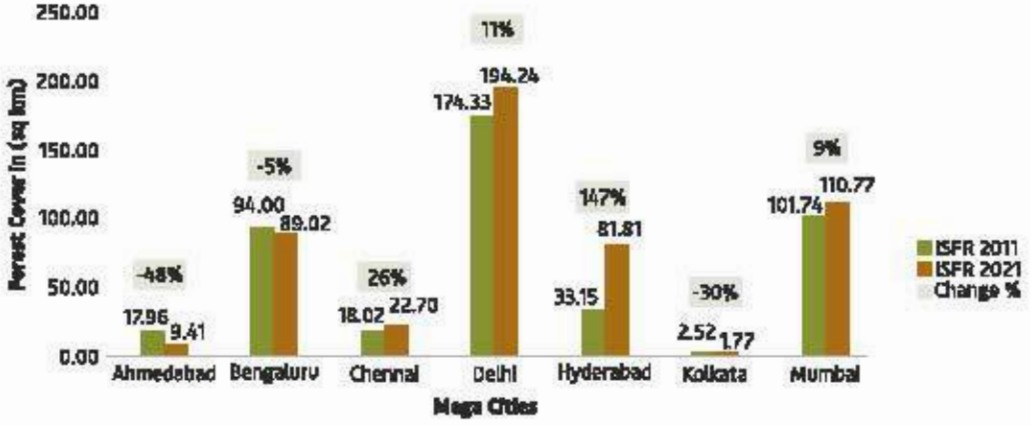


Figure 2.16 Forest Cover between ISFR 2011 & ISFR 2021 in Mega Cities

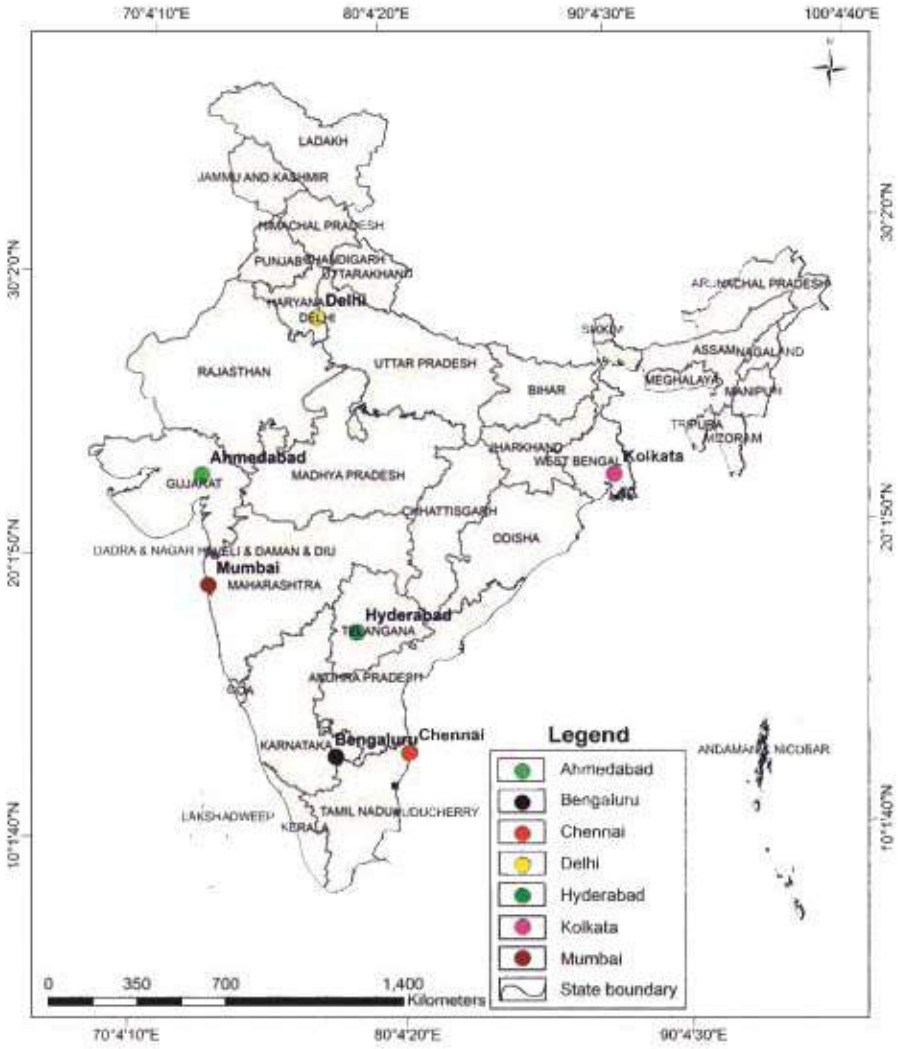

Forest Cover

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

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

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

Figure 2.17
Map showing Location of Mega cities



(in sq km)

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

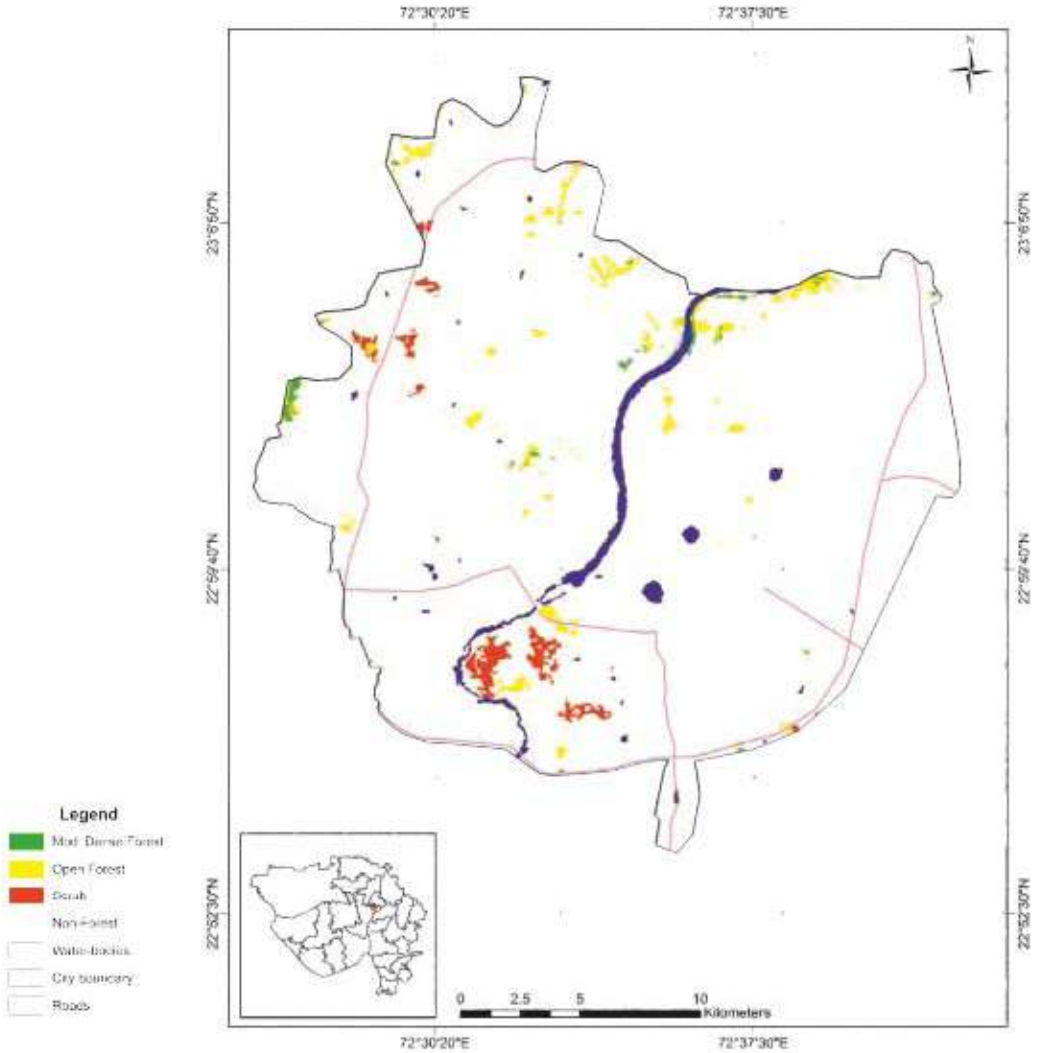


Figure 2.18
Map showing Forest Cover in Ahmedabad

Figure 2.19
Map showing Forest Cover in Bengaluru

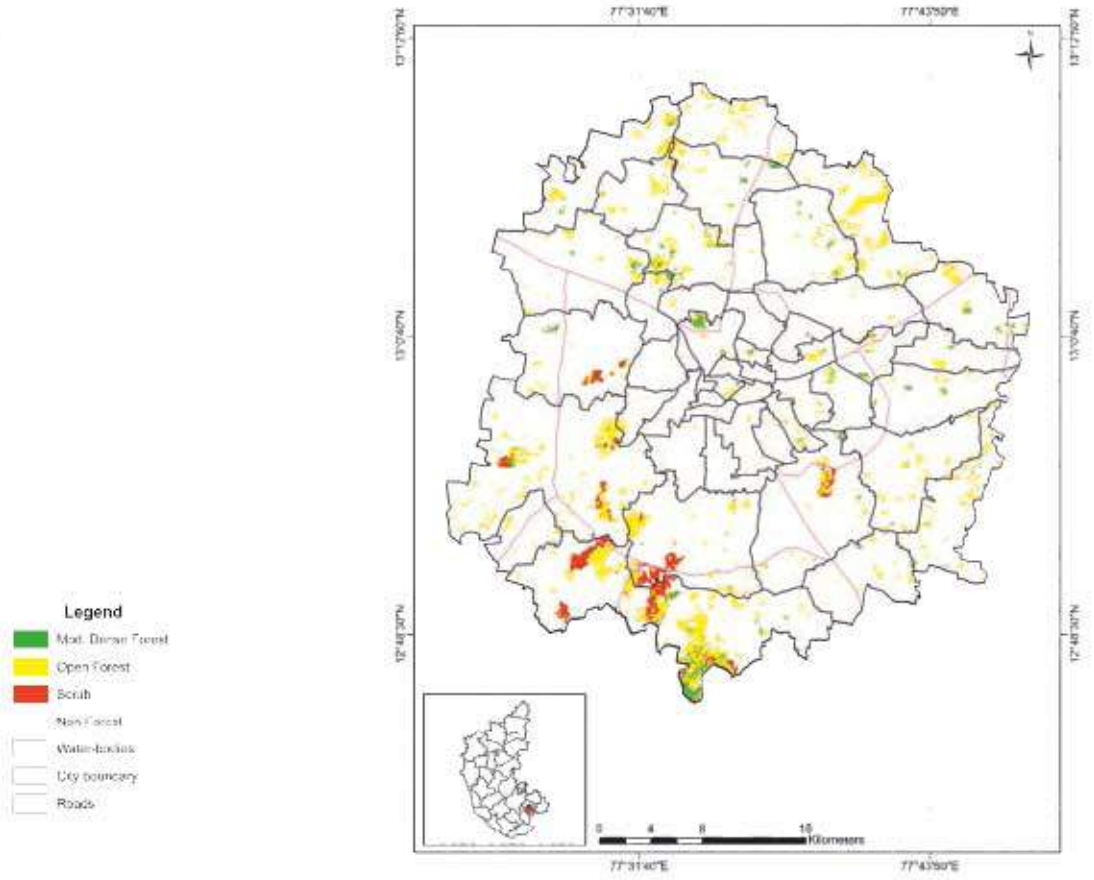
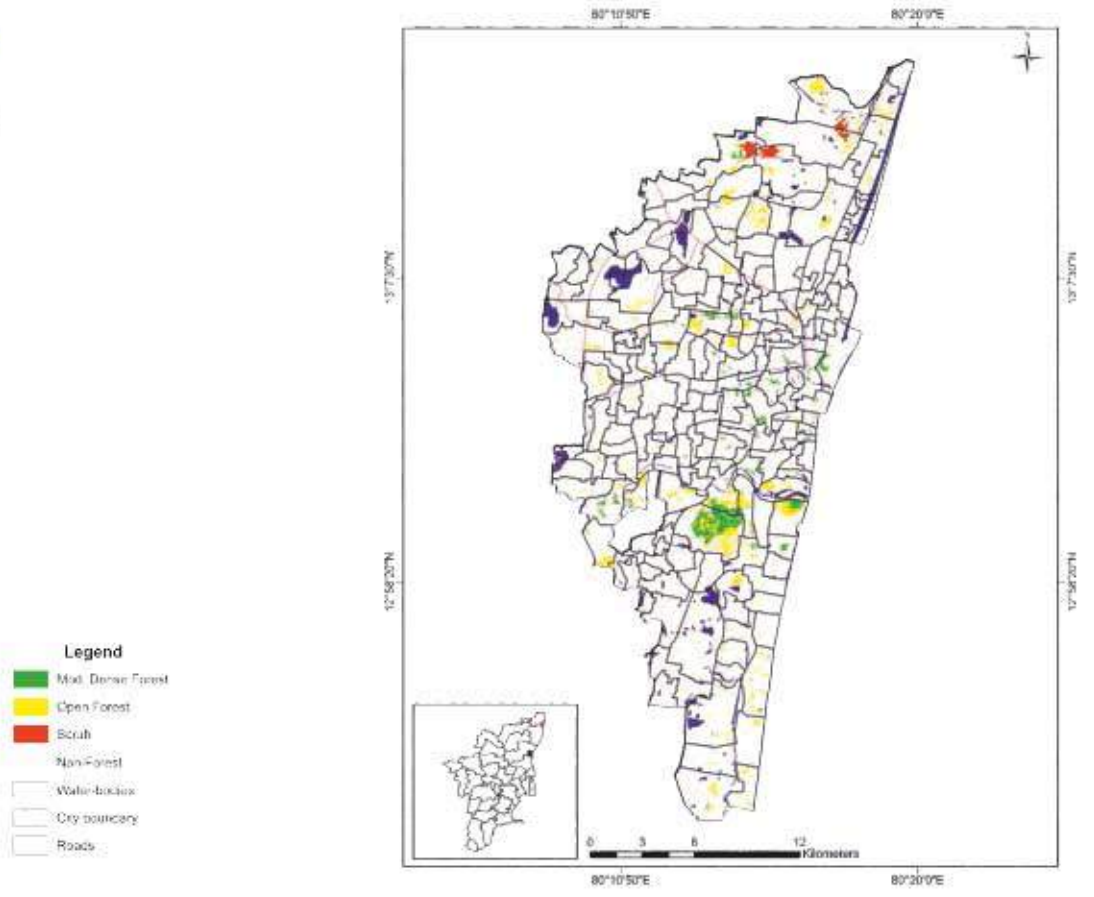


Figure 2.20
Map showing Forest Cover in Chennai



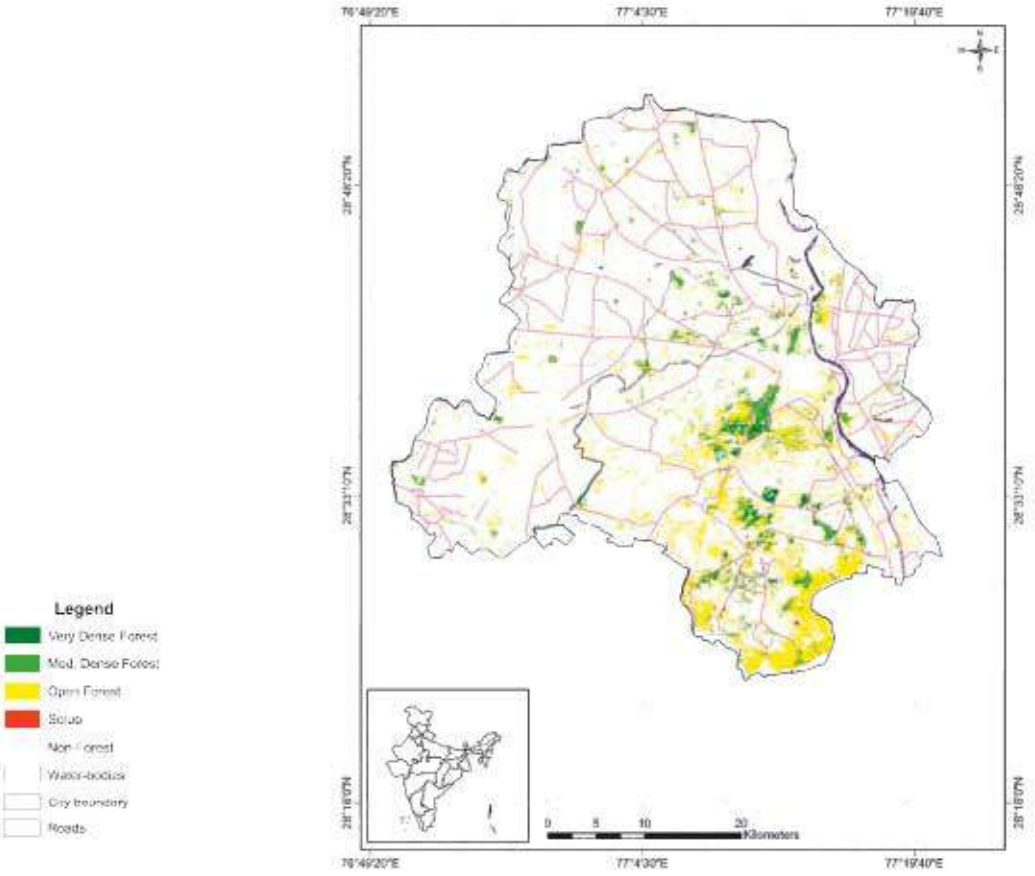


Figure 2.21
Map showing Forest Cover in Delhi

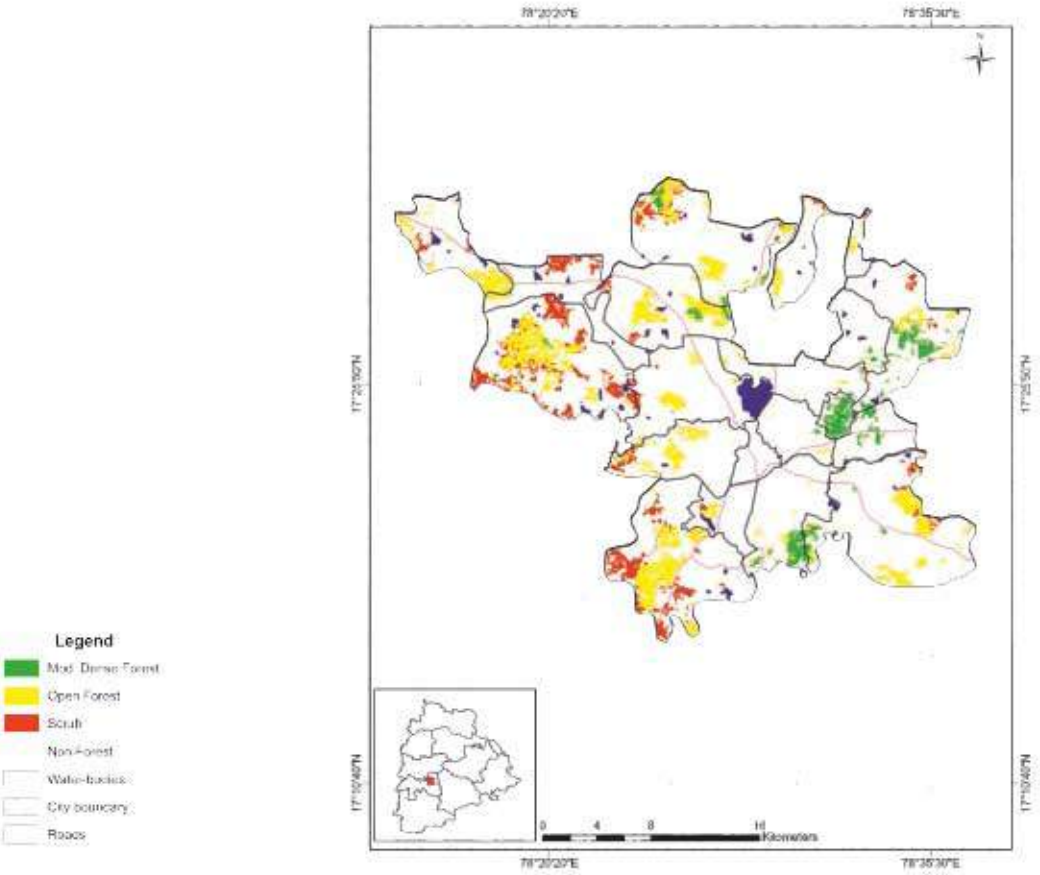


Figure 2.22
Map showing Forest Cover in Hyderabad

Figure 2.23
Map showing Forest Cover in Kolkata

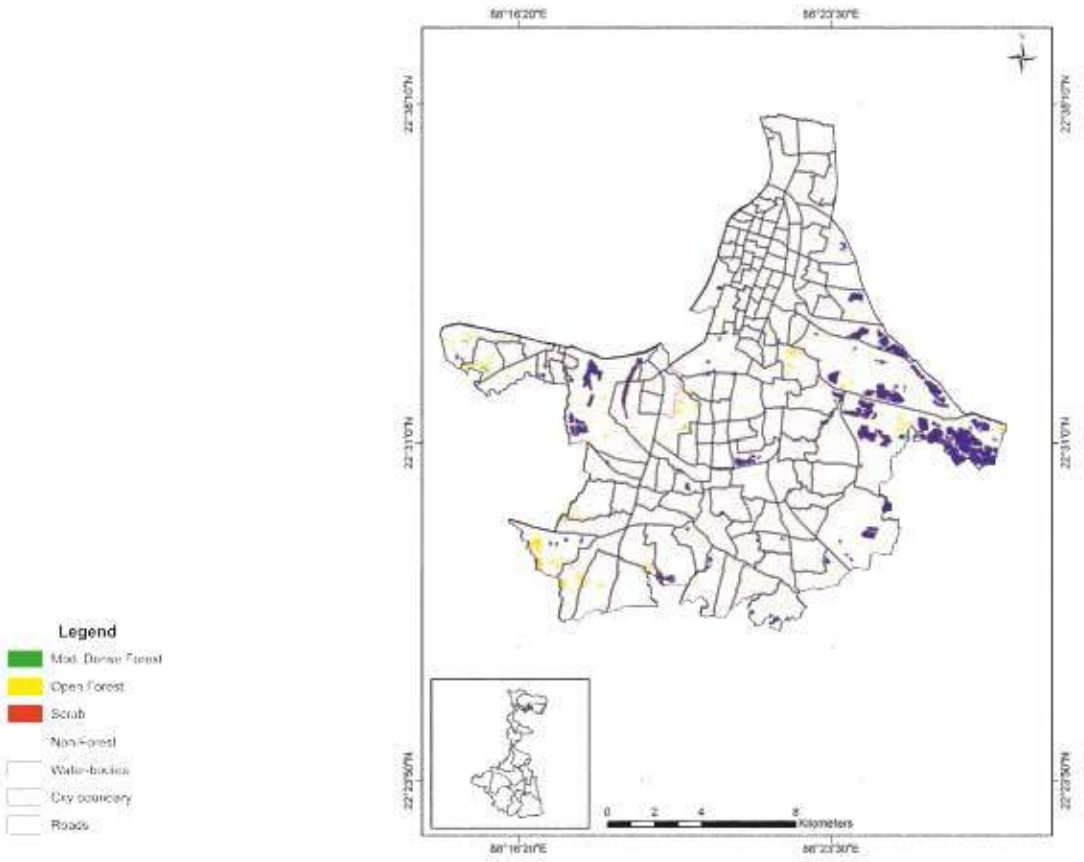
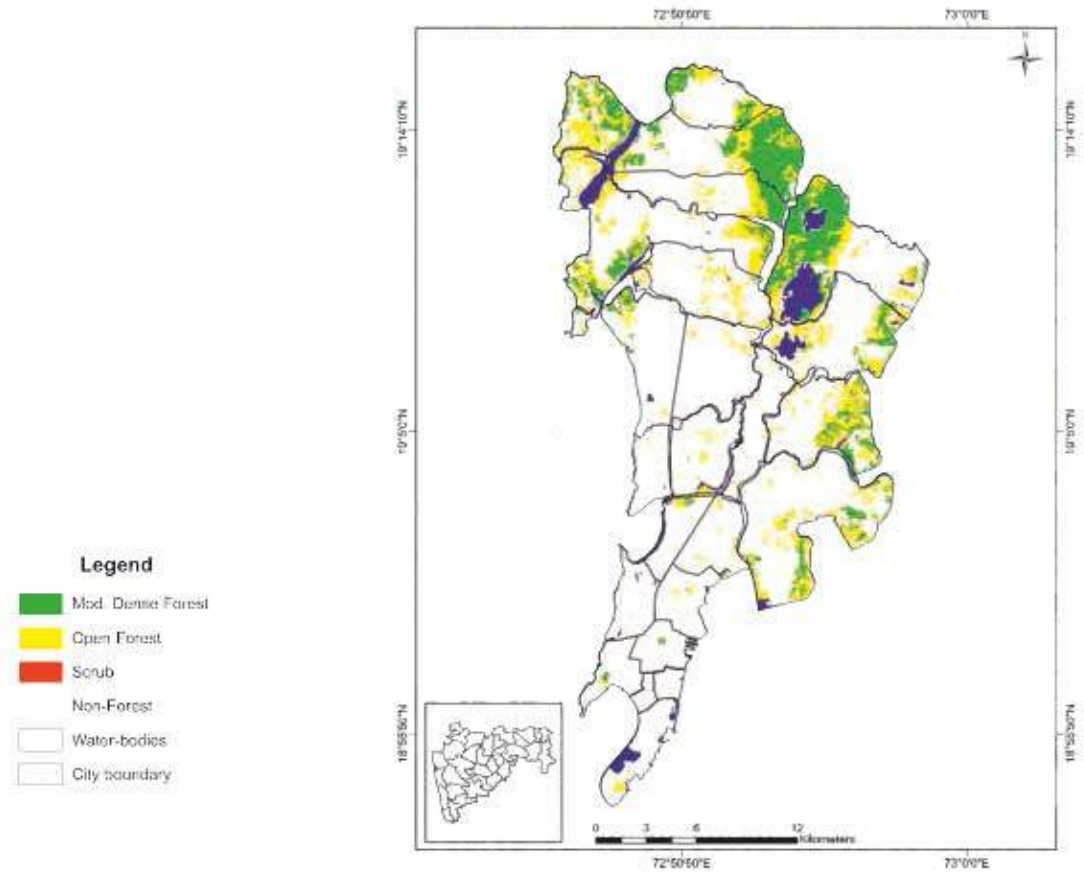
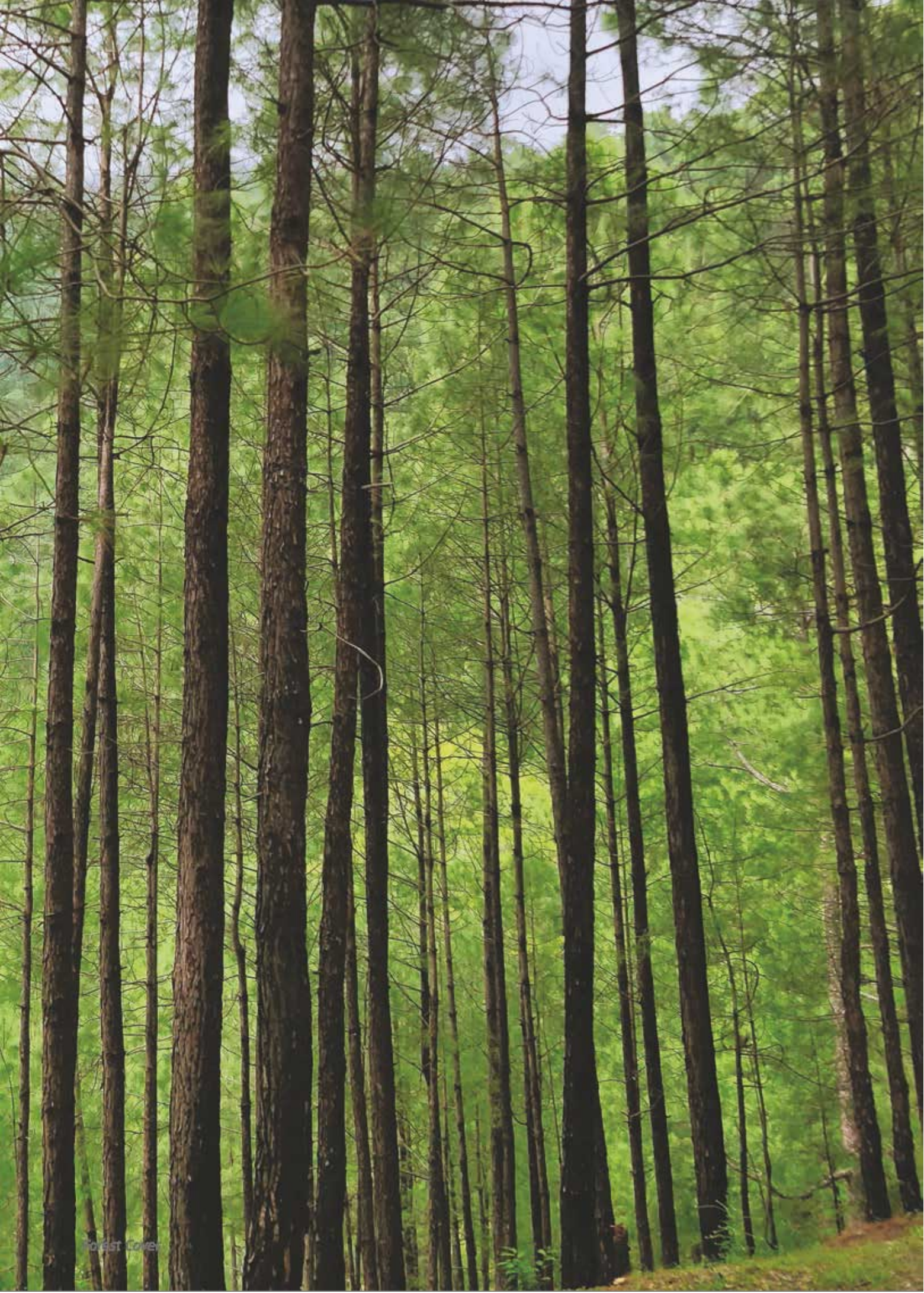


Figure 2.24
Map showing Forest Cover in Mumbai




Forest Cover

03

MANGROVE COVER

Introduction 3.1

Mangroves are salt tolerant plant communities found in tropical and sub-tropical intertidal regions of the world. Such areas are characterized by high rainfall (between 1,000 to 3,000 mm) and temperature (ranging between 26°C-35°C). Mangrove species exhibit a variety of adaptations in morphology, anatomy and physiology to survive in water logged soils, high salinity and frequent cyclonic storms and tidal surges. Mangroves are important refuges of coastal bio-diversity and also act as bio-shields against extreme climatic events. Large populations, primarily rural, depend on Mangrove ecosystems for a wide variety of biomass dependent livelihoods.

Biotic pressure and natural calamities play a major role in negatively impacting Mangrove ecosystems. Growing land reclamation for agriculture and industrialization along the coastlines and discharge of untreated domestic sewage and industrial effluents are damaging to these forests. Upstream activities related to river training and natural erosion and accretion also have an affect on the health of Mangroves since an adequate ecological flow in the rivers is essential for flushing of the Mangroves of silt and other wastes. Many studies have highlighted these problems and intensive conservation efforts are needed to ensure the survival of these sensitive ecosystems.

The Forest Survey of India has been assessing the Mangrove cover using remote sensing since 1987. In the first assessment, carried out at 1:1 million scale, the estimated extent of the Mangrove cover was 4,046 sq km. Subsequently, from 1989 to 1999 the Mangrove cover was assessed regularly on a two-year cycle at 1:250,000 scale. Assessment from 2001 onwards has been carried out at 1:50,000 scale.

3.2 Status of Mangrove Cover Worldwide

As per Global Forest Resource Assessment, 2020 (FRA 2020), world over, 113 countries have Mangrove forests covering an estimated 14.79 million hectares. The largest Mangrove area is reported in Asia (5.55 million hectares), followed by Africa (3.24 million hectares), North and Central America (2.57 million hectares) and South America (2.13 million hectares). Oceania has reported the smallest area of Mangroves (1.30 million hectares). More than 40 percent of the total area of Mangroves was reported to be in just four countries: Indonesia (19 percent of the total), Brazil (9 percent), Nigeria (7 percent) and Mexico (6 percent).[1]

3.3 Conservation of Mangroves

In most countries, Mangrove ecosystems face constant pressure due to increasing human population in coastal areas and the rising demand for land, timber, fodder, fuel-wood and other non-wood forest products. Appropriate management regimes are germane to effective conservation of Mangroves.

Mangroves are repositories of rich biodiversity. According to Champion & Seth Classification (1968)[2], Mangroves are included in Type Group- 4 Littoral & Swamp Forests and are covered under 4A/L1Littoral forest, 4B/TS1 Mangrove scrub, 4B/TS2 Mangrove forest, 4B/TS3 Saltwater mixed forest (*Heritiera*) and 4B/TS4 Brackish water mixed forest (*Heritiera*) types.

Important species of Mangrove ecosystems in India include *Avicennia officinalis, Rhizophora mucronata, Sonneratia alba, Avicennia alba, Brugulera cylindrica, Heritiera littoralis, Phoenix paludosa, Morinda citrifolia & Ceriops tagal.*

Sunderban, located in the northern Bay of Bengal is the world's largest single patch of Mangrove Forests. Spread over approximately 10,000 sq km, in Bangladesh and India, Sundarban is the first Mangrove forest in the world, which was brought under scientific management, as early as in 1892. Appreciating the importance of Mangroves, the Government of India set up a National Mangroves Committee in 1976 to advise the Government on issues related to conservation and development of Mangroves in the country. The Committee emphasized the need to conduct a survey of the extent of existing Mangrove areas within the country. Subsequently, the government formulated a scheme for Mangrove conservation and protection.

[1] *Source: Food and Agriculture Organisation, 2020.*
[2] *Champion H.G. and Seth S.K. (1968). A revised survey of: The Forest Types of India. Forest Research Institute, Dehradun.*

This scheme had the areas of focus:

- Identification of selected Mangrove areas for conservation;
- Preparation of a management plan;
- Promotion of research;
- Adoption of a multidisciplinary approach involving state governments, universities, research institutions and local organizations.

Due to the rich biodiversity and ecological and environmental significance of Mangrove ecosystems, the conservation of Mangroves is a focus area in India.

Status of Mangrove Cover in India 3.4

Mangroves show conspicuous tone and texture on the satellite images. The Mangrove cover in this assessment has been categorized into Very Dense (canopy density of 70% and above), Moderately Dense (canopy density of 40% and more but less than 70%) and Open categories (canopy density of 10% and more but less than 40%). Table 3.1 presents status of Mangrove cover since 1987 onwards.

Table 3.1 Mangrove Cover Assessment in States/UTs from 1987 - 2019

State/UT	1987	1989	1991	1993	1995	1997	1999
Andhra Pradesh	495	405	399	378	383	383	397
Goa	0	3	3	3	3	5	5
Gujarat	427	412	397	419	689	901	1,031
Karnataka	0	0	0	0	2	3	3
Kerala	0	0	0	0	0	0	0
Maharashtra	140	114	113	155	155	124	108
Odisha	199	192	195	195	195	211	215
Tamil Nadu	23	47	47	21	21	21	21
West Bengal	2,076	2,109	2,119	2,119	2,119	2,123	2,125
A&N Islands	686	973	971	966	966	966	966
Daman& Diu	0	0	0	0	0	0	0
Puducherry	0	0	0	0	0	0	0
Total	4,046	4,255	4,244	4,256	4,533	4,737	4,871

3.5 Mangrove Cover (2021 Assessment)

The current assessment shows that Mangrove cover in the country is 4,992 sq km, which is 0.15 % of the country's total geographical area. Very Dense Mangrove comprises 1,475 sq km (29.55 %) of the Mangrove cover; Moderately Dense Mangrove is 1,481 sq km (29.67 %) while Open Mangroves constitute an area of 2,036 sq km (40.78 %). There has been a net increase of 17 sq km in the Mangrove cover of the country as compared to 2019 assessment. The States that show significant gain in Mangrove cover are Odisha (8 sq km) and Maharashtra (4 sq km). The reason for the increase in Mangrove cover in Odisha, is mainly due to the natural regeneration, plantation activities in suitable land like on the banks of the rivers near the estuary and on intertidal mud-flats associated with the areas that are inundated by sea water on a daily cycle. The increase in Mangrove cover has been observed in the districts of Kendrapara, Jagatsinghpur and Balasore in Odisha. In Maharashtra, the increase in Mangrove cover is mainly due to natural regeneration. The increase has also been observed in the South 24 Parganas district of West Bengal. The State/ UT wise extent of Mangrove cover in the three canopy density classes along with the change in comparison to 2019 assessment is presented in the Table 3.2.

State of Forest Report								(In sq km)
2001	2003	2005	2009	2011	2013	2015	2017	2019
333	329	354	353	352	352	367	404	404
5	16	16	17	22	22	26	26	26
911	916	991	1,046	1,058	1,103	1,107	1,140	1,177
2	3	3	3	3	3	3	10	10
0	8	5	5	6	6	9	9	9
118	158	186	186	186	186	222	304	320
219	203	217	221	222	213	231	243	251
23	35	36	39	39	39	47	49	45
2,081	2,120	2,136	2,152	2,155	2,097	2,106	2,114	2,112
789	658	635	615	617	604	617	617	616
50	1	1	1	2	1.53	3	3	3
1	1	1	1	1	1	2	2	2
4,482	4,448	4,581	4,639	4,663	4,828	4,740	4,921	4,975

Mangrove Cover 2021

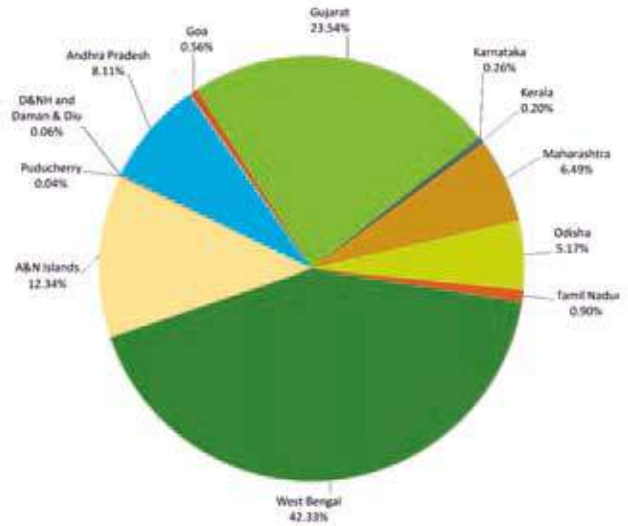


Figure 3.1 Pie chart showing Mangrove Cover in different State & UTs

Table 3.2 Mangrove Cover Assessment 2021 (In sq km)

Sl. No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change with respect to ISFR 2019
1.	Andhra Pradesh	0	213	192	405	1
2.	Goa	0	21	6	27	1
3.	Gujarat	0	169	1,006	1,175	-2
4.	Karnataka	0	2	11	13	3
5.	Kerala	0	5	4	9	0
6.	Maharashtra	0	90	234	324	4
7.	Odisha	81	94	84	259	8
8.	Tamil Nadu	1	27	17	45	0
9.	West Bengal	994	692	428	2,114	2
10.	A&N Islands	399	168	49	616	0
11.	D&NH and Daman & Diu	0	0	3	3	0
12.	Puducherry	0	0	2	2	0
	Total	1,475	1,481	2,036	4,992	17

Table 3.3 District wise Mangrove Cover

(in sq km)

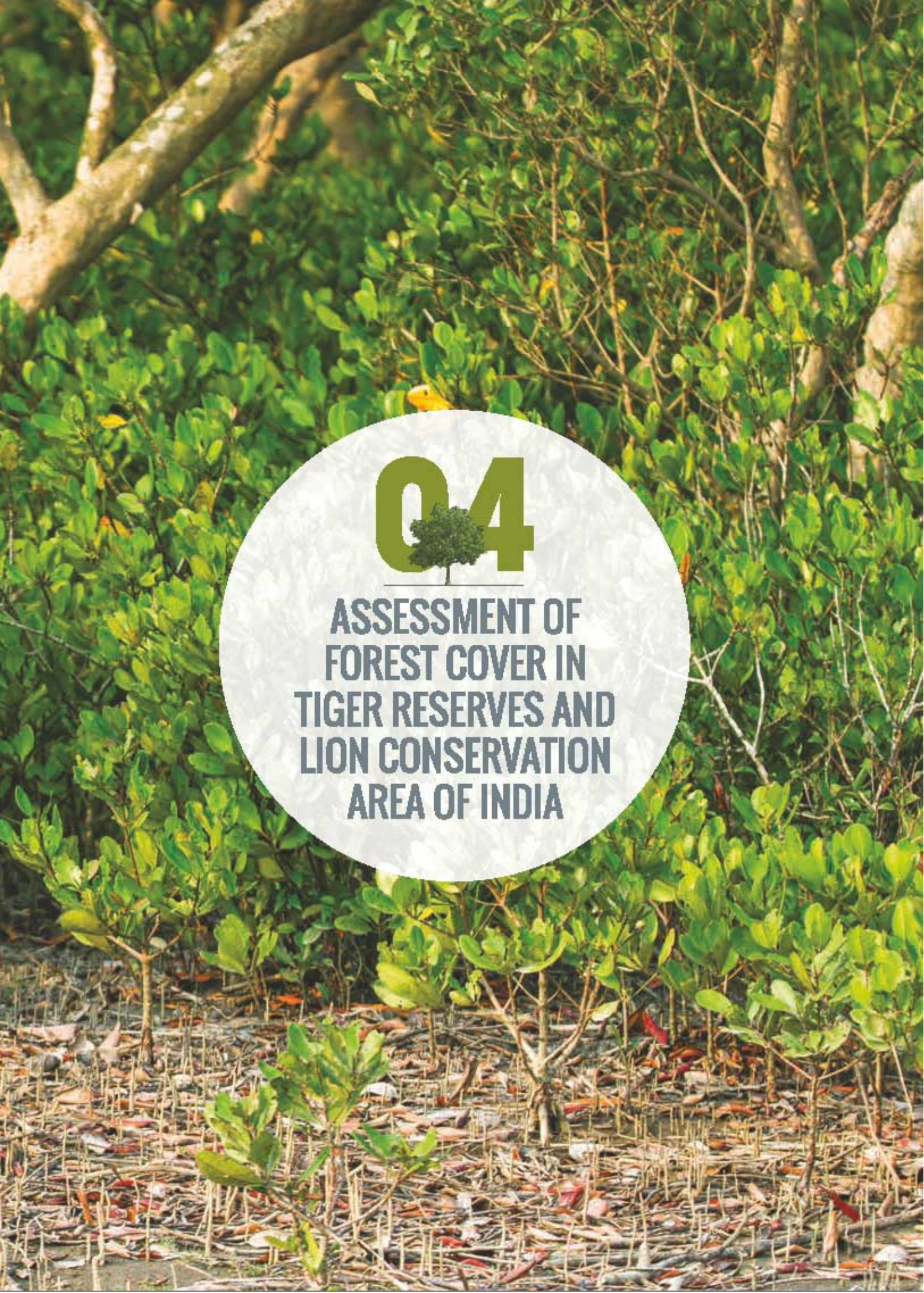
State/UTs and District	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change w.r.t. 2019 Assessment
Andhra Pradesh					
East Godavari	0.00	125.91	61.90	187.81	-0.25
Guntur	0.00	35.00	32.97	67.97	-0.03
Krishna	0.00	50.18	87.58	137.76	0.68
Sri Potti Sriramalu Nellore	0.00	2.00	8.24	10.24	0.24
Prakasham	0.00	0.00	1.00	1.00	0.00
West Godavari	0.00	0.00	0.00	0.00	0.00
Total	**0.00**	**213.09**	**191.69**	**404.78**	**0.64**
Goa					
North Goa	0.00	17.14	3.04	20.18	0.18
South Goa	0.00	3.58	3.58	7.16	1.16
Total	**0.00**	**20.72**	**6.62**	**27.34**	**1.34**
Gujarat					
Ahmedabad	0.00	0.71	25.67	26.38	-4.67
Amreli	0.00	0.00	2.61	2.61	0.24
Anand	0.00	0.00	5.72	5.72	-1.53
Bharuch	0.00	13.33	32.05	45.38	0.94
Bhavnagar	0.00	5.84	15.23	21.07	-0.56
Jamnagar	0.00	28.06	203.20	231.26	1.76
Junagarh	0.00	0.00	3.91	3.91	0.58
Kuchchh	0.00	116.14	682.60	798.74	3.97
Navsari	0.00	0.00	11.15	11.15	-1.82
Porbandar	0.00	0.00	1.00	1.00	0.00
Rajkot	0.00	0.90	2.63	3.53	0.00
Surat	0.00	3.87	15.45	19.32	-0.95
Vadodara	0.00	0.00	2.98	2.98	-0.02
Valsad	0.00	0.00	2.02	2.02	-0.14
Total	**0.00**	**168.85**	**1,006.22**	**1,175.07**	**-2.20**
Karnataka					
Dakshin Kannada	0.09	0.11	0.25	0.45	0.45
Uttar Kannada	0.00	0.28	10.19	10.47	1.97
Udupi	0.00	1.54	0.15	1.69	0.15
Total	**0.09**	**1.93**	**10.59**	**12.61**	**2.57**
Kerala					
Ernakulum	0.00	0.79	1.27	2.06	0.24
Kannur	0.00	3.89	2.50	6.39	0.15
Kasaragod	0.00	0.05	0.86	0.91	0.07
Total	**0.00**	**4.73**	**4.63**	**9.36**	**0.46**
Maharashtra					
Mumbai City	0.00	0.00	2.00	2.00	0.00
Mumbai Sub-urban	0.00	26.97	36.25	63.22	-1.08
Raigarh	0.00	15.30	111.69	126.99	6.02
Ratnagiri	0.00	14.96	15.37	30.33	0.18
Sindhudurg	0.00	5.00	7.07	12.07	-0.12
Thane	0.00	27.75	61.93	89.68	-0.98
Total	**0.00**	**89.98**	**234.31**	**324.29**	**4.02**

(in sq km)

State/UTs and District	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change w.r.t. 2019 Assessment
Odisha					
Baleshwar	0.00	1.00	4.40	5.40	0.33
Bhadrak	0.00	8.76	26.11	34.87	0.00
Jagatsinghpur	0.00	1.01	7.32	8.33	0.27
Kendrapara	80.43	83.54	45.28	209.25	7.76
Puri	0.00	0.00	1.13	1.13	-0.02
Total	**80.43**	**94.31**	**84.24**	**258.98**	**8.34**
Tamilnadu					
Cuddalore	0.00	7.05	0.68	7.73	0.00
Nagapattinam	0.00	1.10	1.87	2.97	-0.08
Pudukkottai	0.67	0.46	0.80	1.93	0.03
Ramanathapuram	0.44	0.71	1.37	2.52	0.18
Thanjavur	0.00	8.96	3.34	12.30	0.05
Thiruvallur	0.00	0.00	0.93	0.93	0.02
Thiruvarur	0.00	7.82	4.94	12.76	-0.09
Thoothukkudi	0.00	0.85	2.95	3.80	0.00
Total	**1.11**	**26.95**	**16.88**	**44.94**	**0.11**
West Bengal					
Purba Medinipur	0.00	1.01	3.00	4.01	0.01
North 24 Parganas	12.97	10.98	1.99	25.94	0.00
South 24 Parganas	981.34	680.03	422.45	2,083.82	1.65
Total	**994.31**	**692.02**	**427.44**	**2,113.77**	**1.66**
Andaman & Nicobar Islands					
North Andaman	285.08	111.43	28.15	424.66	0.14
South Andaman	113.65	54.91	21.20	189.76	0.03
Nicobar	0.00	2.00	0.03	2.03	0.00
Total	**398.73**	**168.34**	**49.38**	**616.45**	**0.17**
D&NH and Daman & Diu					
Daman	0.00	0.00	1.01	1.01	-0.01
Diu	0.00	0.00	2.08	2.08	0.00
Total	**0.00**	**0.00**	**3.09**	**3.09**	**-0.01**
Puducherry					
Yanam	0.00	0.00	1.64	1.64	0.00
Total	**0.00**	**0.00**	**1.64**	**1.64**	**0.00**
Grand Total	**1,474.67**	**1,480.92**	**2,036.73**	**4,992.32**	**17.10**

The above table shows that South 24 Parganas district of West Bengal alone accounts for 41.74 % Mangrove cover of the country.

Figure 3.2
Photo showing Mangrove Forest Ecosystem



04

ASSESSMENT OF FOREST COVER IN TIGER RESERVES AND LION CONSERVATION AREA OF INDIA

Introduction 4.1

The Royal Bengal Tiger (*Panthera tigris*) is one of the most charismatic carnivores in the Indian subcontinent inhabiting a wide variety of ecosystems including high mountains, mangrove swamps, grasslands, dry and moist deciduous forests, evergreen forests etc. It is considered as an umbrella species whose conservation indirectly protects many other species at the ecosystem and landscape level. It is an "Endangered species" on the International Union for Conservation of Nature (IUCN) Red List. The Royal Bengal Tiger was declared the national animal of India in April, 1973. The Tigers in India account for 70% of the world's total Tiger population (3,890) followed by Russia and Indonesia[1]. India is party to the TX2 agreement of World Wildlife Fund (WWF) which is a global commitment to double the world's wild Tigers by 2022, in thirteen Tiger range countries (i.e. India, Nepal, Bhutan, Bangladesh, Myanmar, Russia, China, Malaysia, Thailand, Cambodia, Lao PDR, Vietnam and Indonesia).

The Asiatic Lion (*Panthera leo persica*) is an equally charismatic carnivore in India, with natural and cultural values attributed to it. The Lion was widely spread over India earlier but now its natural habitat is restricted only to Gir area of Gujarat. It is listed as "Endangered species" on the IUCN Red List because of its small population size and area of occupancy. Section 4.8 of this chapter covers the status of forest cover of this habitat.

Anthropogenic activities leading to loss of habitat, hunting of prey animals and poaching led to a decline in the Tiger population and by early 1970s, less than 2,000 Tigers were estimated to be left in the wild. Thereafter, a Tiger Task Force was set up by the Indian Board for Wildlife (IBWL) to suggest conservation measures for saving the Tiger from extinction. On the recommendation of this task force, the 'Tiger Protection Program', popularly known as Project Tiger, was launched on April 1, 1973 with the aim of restoring Tiger habitats and to ensure the maintenance of a viable population of Tigers. The Wildlife Protection Act (1972) was amended in December, 2006 to provide for the constitution of the National Tiger Conservation Authority (NTCA), with the task of laying down guidelines for Tiger conservation in the Tiger reserves, apart from National Parks and Sanctuaries and to steer the future path for Tiger conservation.

Periodic Tiger estimation or census exercises are carried out to assess the status of Tiger population, which reflects the conservation efforts of a country. In India, the first Tiger census was conducted in the year 2006 by NTCA in collaboration with the State Forest Departments, NGOs working on Tiger conservation and Wildlife Institute of India (WII). The results of the first census were presented in the report titled "Status of Tigers, Co-predators, Prey and their Habitat -2006" and since then Tiger census is carried out at four year interval. The latest and the fourth cycle of Tiger census was undertaken during 2018-2019. From the first assessment to the latest one, there has been an estimated increase in India's Tiger population from 1,411 to 2,967.

[1]Global Wild Tiger Status 2016, World Wildlife Fund and Global Tiger Forum

4.2 Tiger Reserves of India

The Wildlife Protection Act, 1972 (2006 amendment) provides for the declaration of an area as Tiger Reserve for the in-situ conservation of Tigers. A Tiger reserve comprises of a core area, which is kept as inviolate for the purpose of Tiger conservation and the peripheral area constitutes the buffer, which is a multiple-use area, with preference to conservation over other land uses, thereby maintaining an equilibrium between wildlife and human activities for the purpose of livelihood, developmental, social and cultural rights of the local people.

Tigers in India are found in different ecological landscapes, each having unique geographical characteristics. The Tiger Reserves fall in eighteen states of the country, categorized into five landscapes, covering an area of 73,972.50 sq km. Ramgarh Vishdhari Tiger Reserve (RVTR) situated in Bundi district of Rajasthan, is the latest and fifty-second Tiger Reserve in the country and was declared so on July 5, 2021. According to Tiger Census, 2018, currently Tiger population within Tiger Reserves is 1,923, which is 65% of the total Tiger population of India. The notified area of Tiger Reserves and their constituent core and buffer areas with estimated Tiger population, estimated Tiger density (per 100 sq km) as per Tiger Census 2018 are given in Table 4.1

Table 4.1 Estimated number of Tigers in Tiger Reserves in India as per Tiger Census, 2018

Sl. No	Ecological Landscape	Name of Tiger Reserve	State	Notified Area (sq km)*			No of Tigers**	Estimated Tiger Density** (per 100 sq km)
				Core Zone	Buffer Zone	Total		
1	Shivalik Hills and Gangetic Plains Landscape	Corbett	Uttarakhand and UP	821.99	546.92	1,368.91	231	14.00
		Dudhwa	Uttar Pradesh	1,093.79	1,107.98	2,201.77	82	3.70
		Pilibhit	Uttar Pradesh	602.79	127.45	730.24	57	6.60
		Rajaji	Uttarakhand	819.54	255.63	1,075.17	38	8.00
		Valmiki	Bihar	598.45	300.93	899.38	32	2.50
2	Central India and Eastern Ghats Landscape	Achanakmar	Chhattisgarh	626.19	287.82	914.01	5	0.46
		Amrabad	Telangana	2,166.37	445.02	2,611.39	7	0.19
		Bandhavgarh	Madhya Pradesh	716.90	820.03	1,536.93	104	5.83
		Bor	Maharashtra	138.12	678.15	816.27	6	0.60
		Indravati	Chhattisgarh	1,258.37	1,540.70	2,799.07	3	-
		Kanha	Madhya Pradesh	917.43	1,134.36	2,051.79	88	4.40
		Kawal	Telangana	892.23	1,123.21	2,015.44	1	-
		Melghat	Maharashtra	1,500.49	1,268.03	2,768.52	46	1.49
		Mukundara Hills	Rajasthan	417.17	342.82	759.99	1	-
		Nagarjunasagar Srisailam	Andhra Pradesh	2,595.72	700.59	3,296.31	38	0.91
		Nawegaon Nagzira	Maharashtra	653.67	1241.27	1,894.94	6	0.49
		Palamau	Jharkhand	414.08	715.85	1,129.93	0	-
		Panna	Madhya Pradesh	576.13	1,021.97	1,598.10	25	1.41
		Pench	Madhya Pradesh	411.33	768.30	1,179.63	61	5.50
		Pench - MH	Maharashtra	257.26	483.96	741.22	53	4.64
		Ramgarh Vishdhari***	Rajasthan		307.00		-	-
		Ranthambore	Rajasthan	1,113.36	297.92	1,411.28	53	9.60
		Sahyadri	Maharashtra	600.12	565.45	1,165.57	3	-
		Sanjay Dubri	Madhya Pradesh	812.57	861.93	1,674.50	5	0.23

Sl. No.	Ecological Landscape	Name of Tiger Reserve	State	Notified Area (sq km)*			No of Tigers**	Estimated Tiger Density** (per 100 sq km)
				Core Zone	Buffer Zone	Total		
		Sariska	Rajasthan	881.11	332.23	1,213.34	11	-
		Satkosia	Odisha	523.61	440.26	963.87	1	-
		Satpura	Madhya Pradesh	1,339.26	794.04	2,133.30	40	1.39
		Simlipal	Odisha	1,194.75	1,555.25	2,750.00	8	1.02
		Tadoba Andhari	Maharashtra	625.82	1,101.77	1,727.59	83	6.09
		Udanti Sitanadi	Chhattisgarh	851.09	991.45	1,842.54	1	-
3	The Western Ghats Landscape	Anamalai	Tamil Nadu	958.59	521.28	1,479.87	20	1.11
		Bandipur	Karnataka	872.24	584.06	1,456.30	126	7.70
		Bhadra	Karnataka	492.46	571.83	1,064.29	30	2.86
		Biligiri Ranganatha Temple	Karnataka	359.10	215.72	574.82	52	4.96
		Kalakad Mundanthurai	Tamil Nadu	895.00	706.54	1,601.54	7	0.43
		Kali	Karnataka	814.88	282.63	1097.51	4	-
		Mudumalai	Tamil Nadu	321.00	367.59	688.59	103	6.19
		Nagarhole	Karnataka	643.35	562.41	1,205.76	127	11.82
		Parambikulam	Kerala	390.89	252.77	643.66	26	1.95
		Periyar	Kerala	881.00	44.00	925.00	26	1.38
		Sathyamangalam	Tamil Nadu	793.49	614.91	1,408.40	83	3.75
		Srivilliputhur Megamalai***	Tamil Nadu	641.86	374.70	1,016.56	-	-
4	North Eastern Hills and Brahmaputra Flood Plains	Buxa	West Bengal	390.58	367.32	757.90	0	-
		Dampa	Mizoram	500.00	488.00	988.00	0	-
		Kamlang	Arunachal Pradesh	671.00	112.00	783.00	4	-
		Kaziranga	Assam	625.58	548.00	1,173.58	104	13.06
		Manas	Assam	526.22	2,310.88	2,837.10	31	3.30
		Namdapha	Arunachal Pradesh	1,807.82	245.00	2,052.82	11	-
		Nameri	Assam	320.00	44.00	364.00	3	-
		Orang	Assam	79.28	413.18	492.46	21	10.62
		Pakke	Arunachal Pradesh	683.45	515.00	1,198.45	3	-
5	Sundarbans	Sundarbans	West Bengal	1,699.62	885.27	2,584.89	88	3.60
		Total				**73,972.50**		

** NTCA website*
***Tiger Census 2018.*
****Tiger count is not ovoilable for the Tiger reserves formed after Tiger Census 2018*
Source: Status of Tigers, Co-predators, Prey and their Habitat 2018

The highest number of Tiger reserves are found in the states of Madhya Pradesh and Maharashtra having six Tiger reserves each. In terms of extent, the largest Tiger reserve is Nagarjunasagar Srisailam in Andhra Pradesh (3,296.31 sq km) followed by Manas in Assam (2,837.10 sq km) and Indravati in Chhattisgarh (2,799.07 sq km). The smallest Tiger reserve is Orang in Assam (492 sq km).

The highest number of Tigers are found in Corbett Tiger Reserve (231) followed by Nagarhole (127) and Bandipur (126), while no Tigers are found in Dampa, Buxa and Palamau Tiger reserves. The Tiger density per 100 sq km is highest in Corbett Tiger Reserve (14), followed by Kaziranga Tiger Reserve (13.06) and Nagarhole Tiger Reserve (11.82). The lowest Tiger density is found in Amrabad Tiger reserve (0.19), followed by Sanjay Dubri (0.23) and a Kalakad Mundanthurai (0.43).

The estimates of Tiger populations and prey populations help us in understanding the ecological relationship between Tigers and its prey population in different Tiger reserves. Tiger Census 2018 has estimated density of prey species in Tiger reserves based on results of line transect based sampling. The estimated individual density of prey species for Tiger reserves are given in Table 4.2.

Table 4.2 Estimated Individual Density of Prey species (per sq km)

Sl. No.	Tiger Reserve	Individual Density of Prey species (per sq km)						
		Barking Deer	Chinkara	Chital	Gaur	Nilgai	Sambar	Wild Pig
1	Achanakmar	1.34	-	12.60	5.53	-	0.64	10.55
2	Amrabad*	-	-	-	-	-	-	-
3	Anamalai	-	-	3.06	0.04	-	1.67	-
4	Bandhavgarh	0.48	1.28	41.36	-	1.91	3.85	5.94
5	Bandipur	8.70	-	51.72	0.84	-	7.27	2.04
6	Bhadra	2.04	-	14.35	3.71	-	8.53	4.67
7	Biligiri Ranganatha Swamy Temple	2.07	-	8.41	1.46	-	6.63	-
8	Bor*	-	-	-	-	-	-	-
9	Buxa	6.41	-	5.74	-	-	-	3.68
10	Corbett	6.33	-	71.31	-	-	11.38	8.50
11	Dampa*	-	-	-	-	-	-	-
12	Dudhwa*	-	-	-	-	-	-	-
13	Indravati*	-	-	-	-	-	-	-
14	Kalakad Mundanthurai	-	-	-	0.02	-	4.55	4.28
15	Kali	0.49	-	1.78	1.79	-	0.70	-
16	Kamlang*	-	-	-	-	-	-	-
17	Kanha	2.57	-	38.14	3.87	-	6.95	4.88
18	Kawal*	-	-	-	-	-	-	-
19	Kaziranga*	-	-	-	-	-	-	-
20	Manas*	-	-	-	-	-	-	-
21	Melghat	1.76	-	-	2.03	1.73	2.55	-
22	Mudumalai	-	-	46.49	2.61	-	3.21	-
23	Mukundara Hills	-	2.05	-		3.59	-	-
24	Nagarhole	4.93	-	24.13	1.86	-	4.77	3.46
25	Nagarjunasagar Srisailam*	-	-	-	-	-	-	-
26	Namdapha*	-	-	-	-	-	-	-
27	Nameri*	-	-	-	-	-	3.54	-
28	Nawegaon Nagzira	-	-	5.16	7.47	4.24	2.81	-
29	Orang*	-	-	-	-	-	-	-
30	Pakke*	-	-	-	-	-	-	-
31	Palamau	0.78	-	1.33	-	-	-	2.84
32	Panna	-	1.45	13.78	-	11.96	4.97	6.20
33	Parambikulam	-	-	-	0.04	-	6.56	-
34	Pench	0.59	-	65.75	4.35	4.19	7.68	12.34
35	Pench - MH	-	-	20.87	-	3.37	5.41	7.15
36	Periyar	-	-	-	0.10	-	5.07	-
37	Pilibhit	-	-	40.71	-	12.78	-	12.43
38	Rajaji	1.91	-	66.03	-	4.18	18.06	7.38
39	Ramgarh Vishdhari**	-	-	-	-	-	-	-
40	Ranthambore	-	2.04	21.62	-	9.37	13.95	-
41	Sahyadri	3.98	-	-	8.07	-	3.22	-
42	Sanjay Dubri	-	6.85	9.67	-	10.08	-	3.17
43	Sariska	-	-	14.35	-	25.54	18.95	18.11
44	Sathyamangalam	-	-	39.66	9.81	-	8.97	6.32
45	Satkosia	8.63	-	14.06	-	-	4.94	4.17

Sl. No.	Tiger Reserve	Individual Density of Prey species (per sq km)						
		Barking Deer	Chinkara	Chital	Gaur	Nilgai	Sambar	Wild Pig
46	Satpura	2.49	-	4.24	6.84	2.56	6.48	11.41
47	Simlipal	-	-	7.41	-	-	11.24	6.16
48	Srivilliputhur Megamalai**	-	-	-	-	-	-	-
49	Sundarbans	-	-	3.65	-	-	-	1.09
50	Tadoba Andhari	-	-	14.37	3.18	3.08	3.23	7.57
51	Udanti Sitanadi	0.62	-	-	-	-	-	-
52	Valmiki*	-	-	-	-	-	-	-

**Data not available in Tiger Census, 2018*
***Data not available for the Tiger reserves formed after Tiger Census 2018*
Source: Status of Tigers, Co-predators, Prey and their Habitat 2018

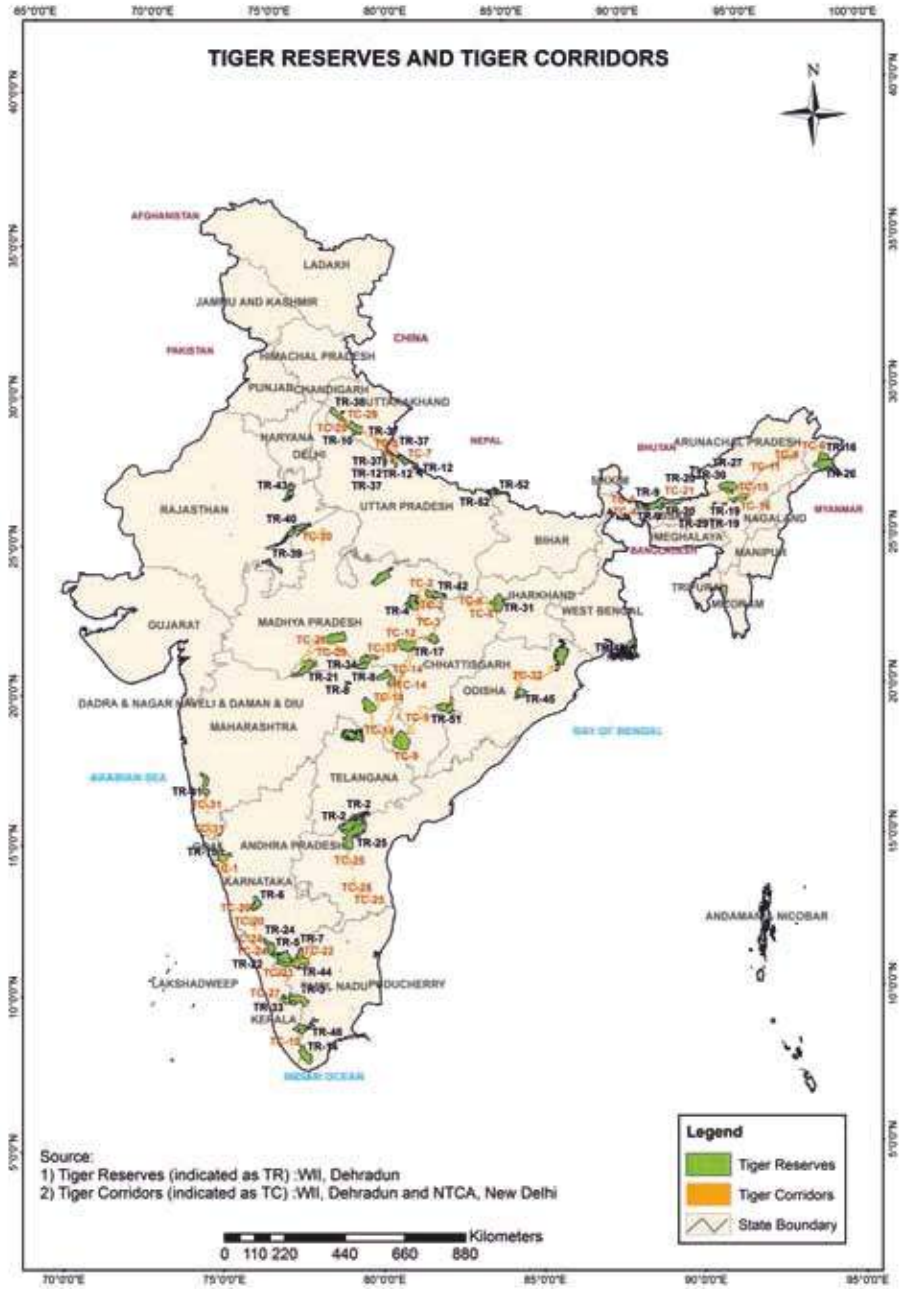


Figure 4.1
Tiger Reserves and Tiger Corridors of India

LIST OF TIGER RESERVES

TR-1	Achanakmar	TR-19	Kaziranga	TR-37	Pilibhit
TR-2	Amrabad	TR-20	Manas	TR-38	Rajaji
TR-3	Anamalai	TR-21	Melghat	TR-39	Ramgarh Vishdhari
TR-4	Bandhavgarh	TR-22	Mudumalai	TR-40	Ranthambore
TR-5	Bandipur	TR-23	Mukundara Hills	TR-41	Sahyadri
TR-6	Bhadra	TR-24	Nagarahole	TR-42	Sanjay-Dubri
TR-7	Biligiri Ranganatha Temple	TR-25	Nagarjunasagar Srisailam	TR-43	Sariska
TR-8	Bor	TR-26	Namdapha	TR-44	Sathyamangalam
TR-9	Buxa	TR-27	Nameri	TR-45	Satkosia
TR-10	Corbett (including Amangarh buffer)	TR-28	Nawegaon Nagzira	TR-46	Satpura
TR-11	Dampa	TR-29	Orang	TR-47	Similipal
TR-12	Dudhwa	TR-30	Pakke	TR-48	Srivilliputhur
TR-13	Indravati	TR-31	Palamau	TR-49	Sundarbans
TR-14	Kalakad-Mundanthurai	TR-32	Panna	TR-50	Tadoba-Andhari
TR-15	Kali Tiger Reserve	TR-33	Parambikulam	TR-51	Udanti-Sitanadi
TR-16	Kamlang_Boundary	TR-34	Pench-MH	TR-52	Valmiki
TR-17	Kanha Tiger Reserve	TR-35	Pench-MP		
TR-18	Kawal	TR-36	Periyar		

LIST OF TIGER CORRIDORS

TC-1	Anshi-Dandeli-Sharavathi Valley	TC-17	Kaziranga-Nameri
TC-2	Bandhavgarh-Sanjay-Dubri-Guru Ghasidas	TC-18	Kaziranga-Orang
TC-3	Bhandhavgarh-Achanakmar	TC-19	Kaziranga-Papumpare
TC-4	Buxa-Jaldapara	TC-20	Kudremukh -Bhadra
TC-5	Corbett-Dudhwa	TC-21	Manas
TC-6	Dibru Saikhowa-D'ering-Mehao	TC-22	Nagarahole-Bandipur-Mudumalai-Wayanad
TC-7	Durga-Kishanpur-Katarniaghat	TC-23	Nagarahole-Mudumalai-Wayanad
TC-8	Guru Ghasi Das- Palamau-Lawalong	TC-24	Nagarahole-Pushpagiri-Talakavery
TC-9	Indravati-Udanti-Sitanadi-Sunebeda	TC-25	Nagarjunsagar -Sri Venkateswara NP
TC-10	Kalakad_Mundanthurai-Periyar	TC-26	Paake-Nameri-Sonai-Rupai-Manas
TC-11	Kane WLS-Tale Valley WLS	TC-27	Parambikulam-Eranikulam-Indira_Gandhi
TC-12	Kanha-Achanakmar	TC-28	Pench-Satpura-Melghat
TC-13	Kanha-Pench	TC-29	Rajaji-Corbett
TC-14	Kanha to Navegoan-Nagzira-Tadoba-Indravati	TC-30	Ranthambore-Kuno-Shivpuri-Madhav
TC-15	Kaziranga-Itanagar WLS	TC-31	Sahyadri-Radhanagri- Goa
TC-16	Kaziranga-Karbi-Anlong	TC-32	Simlipal-Satkosia

Forest Cover Assessment in Tiger Reserves of India 4.3

The distribution of Tigers and their density in the forests vary because of several ecological factors such as forest cover, terrain and natural prey availability and also because of anthropogenic factors like presence of undisturbed habitat and management interventions. The extent of forest cover in Tiger Reserves is an important indicator of the health of the forest ecosystem. The forest cover determines the presence or absence of prey populations. Continuous, undisturbed and non-fragmented landscapes are essential for the survival of Tigers.

The Tiger generally requires habitat that includes forests, scrub, grasslands (part of non-forest in forest cover assessment) and water resources for their survival. An attempt has been made to assess the extent of forest cover in the Tiger reserves of the country. The latest digital boundaries of Tiger Reserves available with Wildlife Institute of India were used for the purpose of forest cover assessment within Tiger reserves. Numerous river streams either originate from the Tiger reserves or have their major catchments in Tiger reserves. Therefore, an assessment of the wetlands (both natural and man-made) within the Tiger reserves has also been made using the digitized boundary of wetlands of India from Space Application Center (SAC), Ahmedabad.

Methodology 4.3.1

The Forest Cover of 2021 assessment (data period 2018-2019), was analyzed within Tiger reserves in three canopy density classes namely, Open Forest (10-40%), Moderately Dense Forest (40-70%) and Very Dense Forest (>70%). Scrub, which is not a part of the forest cover, has also been recorded. The extent of Forest cover in the three density classes within the Tiger reserves for 2021 assessment is given in Table 4.3.

The Tiger reserves occupy an area of approximately 74,710.53 sq km, which is 2.27% of the country's geographical area. The current assessment shows that the forest cover in the Tiger reserves is 55,666.27 sq km, which is 7.80% of the country's total forest cover and 74.51% of the total area of Tiger reserves.

In terms of canopy density classes, the area covered by VDF is 16,444.51 sq km (22.01%), MDF is 26,856.71 sq km (35.95%) and OF is 12,365.05 sq km (16.55%). Scrub occupies a total area of 1,339.58 sq km (1.79%) (Table 4.3).

Table 4.3 Forest Cover in Tiger Reserves (2021)

Class	Area (sq km)	% of Area of Digitized Tiger Reserve Boundary
Very Dense Forest	16,444.51	22.01
Moderately Dense Forest	26,856.71	35.95
Open Forest	12,365.05	16.55
Total Forest Cover	**55,666.27**	**74.51**
Scrub	1,339.58	1.79
Non-Forest	17,704.68	23.70
Total Area of Tiger Reserves	**74,710.53**	**100.00**

The Tiger Reserve wise details of forest cover are given in Table 4.4.

Table 4.4 Forest Cover of Tiger Reserves (2021 assessment) (in sq km)

Sl. No.	Name of Tiger Reserve	State	Area as per digitized Tiger Reserve Boundary*	2021 Assessment					
				VDF	MDF	OF	Total	% of total forest cover wrt area of digitized Tiger Reserve Boundary	Scrub
1.	Achanakmar	Chhattisgarh	936.34	381.28	487.65	26.53	895.46	95.63	0.94
2.	Amrabad	Telangana	2,684.23	332.38	497.81	950.34	1,780.53	66.33	473.63
3.	Anamalai	Tamil Nadu	1,767.76	309.33	466.63	403.70	1,179.66	66.73	8.36
4.	Bandhavgarh	Madhya Pradesh	1,684.53	291.12	670.27	268.07	1,229.46	72.99	11.90
5.	Bandipur	Karnataka	1,784.47	62.95	459.50	432.78	955.23	53.53	19.76
6.	Bhadra	Karnataka	1,071.24	326.03	445.09	26.42	797.54	74.45	0.25
7.	Biligiri Ranganatha Temple	Karnataka	654.96	21.97	418.15	124.55	564.67	86.21	12.09
8.	Bor	Maharashtra	131.77	15.40	74.97	29.56	119.93	91.01	0.00
9.	Buxa	West Bengal	783.02	329.89	192.86	119.27	642.02	81.99	3.46
10.	Corbett	Uttarakhand & Uttar Pradesh	1,462.66	441.44	693.37	89.87	1,224.68	83.73	2.97
11.	Dampa	Mizoram	821.89	15.06	308.14	433.38	756.58	92.05	0.00
12.	Dudhwa	Uttar Pradesh	1,524.33	727.72	193.24	158.50	1,079.46	70.82	2.67
13.	Indravati	Chhattisgarh	2,922.39	1,167.39	809.78	400.11	2,377.28	81.35	0.50
14.	Kalakad Mundanthurai	Tamil Nadu	1,564.14	461.68	436.45	108.17	1,006.30	64.34	10.40
15.	Kali	Karnataka	1,411.75	273.74	962.33	69.15	1,305.22	92.45	0.12
16.	Kamlang	Arunachal Pradesh	792.03	307.84	302.31	102.86	713.01	90.02	1.26
17.	Kanha	Madhya Pradesh	2,070.63	598.72	714.04	152.72	1,465.48	70.77	1.06
18.	Kawal	Telangana	2,259.79	102.55	1,125.66	478.67	1,706.88	75.53	1.02
19.	Kaziranga	Assam	1,180.35	23.87	109.91	61.67	195.45	16.56	0.76
20.	Manas	Assam	3,030.24	1,086.36	296.27	244.09	1,626.72	53.68	13.56
21.	Melghat	Maharashtra	2,028.47	456.31	965.62	425.05	1,846.98	91.05	0.00
22.	Mudumalai	Tamil Nadu	750.81	143.29	260.98	285.61	689.88	91.88	3.18
23.	Mukundara Hills	Rajasthan	758.40	0.00	144.41	227.50	371.91	49.04	50.75
24.	Nagarhole	Karnataka	1,152.74	177.15	603.12	89.28	869.55	75.43	0.16
25.	Nagarjunasagar Srisailam	Andhra Pradesh	3,843.88	303.93	1,908.65	720.37	2,932.95	76.30	339.07
26.	Namdapha	Arunachal Pradesh	2,085.17	912.65	598.57	360.81	1,872.03	89.78	7.58
27.	Nameri	Assam	371.86	31.35	105.11	41.71	178.17	47.91	0.58
28.	Nawegaon Nagzira	Maharashtra	1,781.22	553.67	446.89	169.82	1,170.38	65.71	2.65

(in sq km)

Sl. No.	Name of Tiger Reserve	State	2021 Assessment: Area as per digitized Tigor Reserve Boundary*	VDF	MDF	OF	Total	% of total forest cover wrt area of digitized Tiger Reserve Boundary	Scrub
29.	Orang	Assam	80.21	0.00	6.34	11.05	17.39	21.68	0.87
30.	Pakke	Arunachal Pradesh	1,507.71	487.25	751.92	220.82	1,459.99	96.83	2.67
31.	Palamau	Jharkhand	1,980.64	433.33	713.39	292.75	1,439.47	72.68	0.90
32.	Panna	Madhya Pradesh	1,783.48	154.32	643.08	461.75	1,259.15	70.60	66.81
33.	Parambikulam	Kerala	652.21	287.08	246.72	47.78	581.58	89.17	0.00
34.	Pench - MP	Madhya Pradesh	1,168.66	192.98	586.69	49.18	828.85	70.92	2.25
35.	Pench - MH	Maharashtra	738.28	223.87	320.32	65.09	609.28	82.53	0.00
36.	Periyar	Kerala	935.30	176.05	500.51	110.25	786.81	84.12	0.00
37.	Pilibhit	Uttar Pradesh	758.64	416.07	78.90	70.23	565.20	74.50	1.21
38.	Rajaji	Uttarakhand	1,102.41	253.38	563.49	164.22	981.09	89.00	2.36
39.	Ramgarh Vishdhari	Rajasthan	294.67	0.00	75.64	94.89	170.53	57.87	14.73
40.	Ranthambore	Rajasthan	1,765.57	0.00	229.14	572.21	801.35	45.39	169.28
41.	Sahyadri	Maharashtra	1,169.60	75.49	438.51	211.09	725.09	61.99	13.62
42.	Sanjay Dubri	Madhya Pradesh	1,490.33	286.34	630.48	263.34	1,180.16	79.19	0.99
43.	Sariska	Rajasthan	1,145.80	61.12	283.80	420.79	765.71	66.83	37.13
44.	Sathyamangalam	Tamil Nadu	1,581.77	161.23	658.09	540.98	1,360.30	86.00	26.50
45.	Satkosia	Odisha	981.97	184.41	507.82	113.59	805.82	82.06	11.31
46.	Satpura	Madhya Pradesh	2,033.79	254.34	982.79	501.69	1,738.82	85.50	1.28
47.	Simlipal	Odisha	2,721.62	1,205.52	1,138.78	218.56	2,562.86	94.17	0.05
48.	Srivilliputhur Megamalai	Tamil Nadu	501.12	57.32	206.89	118.70	382.91	76.41	8.94
49.	Sundarbans	West Bengal	2,634.74	739.72	468.49	304.95	1,513.16	57.43	0.00
50.	Tadobha Andhari	Maharashtra	1,647.22	655.47	444.18	162.00	1,261.65	76.59	0.17
51.	Udanti Sitanadi	Chhattisgarh	1,794.91	48.17	1,186.91	284.49	1,519.57	84.66	0.60
52.	Valmiki	Bihar	928.80	235.98	496.05	64.09	796.12	85.71	9.23
		Total	**74,710.53**	**16,444.51**	**26,856.71**	**12,365.05**	**55,666.27**	**74.51**	**1,339.58**

**Source: WII, Dehradun*

From the Table it is seen that Nagarjunasagar Srisailam Tiger Reserve in Andhra Pradesh (adjacent to the Amrabad Tiger Reserve in Telangana), has the largest forest cover (2,932.95 sq km) followed by Similipal in Odisha (2,562.86 sq km) and Indravati in Chhattisgarh (2,377.28 sq km). In terms of forest cover as percentage of the area of Tiger reserves, the top five Tiger reserves are Pakke in Arunachal Pradesh (96.83%), Achanakmar in Madhya Pradesh (95.63%), Similipal in Odisha (94.17%), Kali in Karnataka (92.45%) and Dampa in Mizoram (92.05%). Similipal Tiger reserve has the highest area under VDF comprising 1,205.52 sq km, which is 47.04% of its total forest cover. Maximum area under MDF is in Nagarjunasagar Srisailam Tiger reserve comprising 1,908.65 sq km, which is 65.08% of its total forest cover. Open Forest is highest in Amrabad Tiger reserve comprising 950.34 sq km, which is 53.37% of its total forest cover.

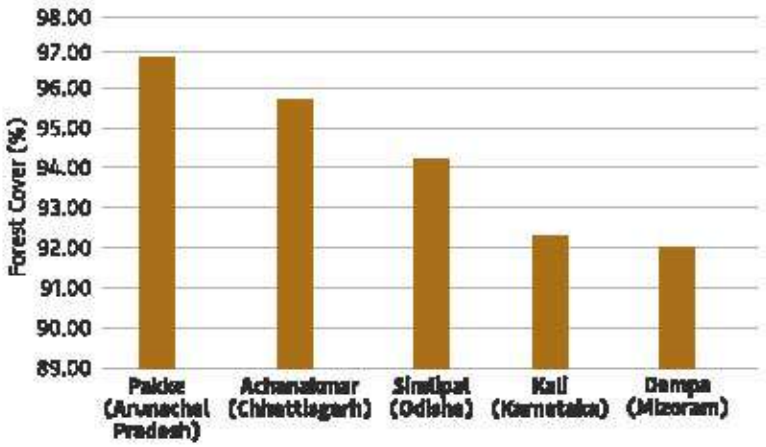


Figure 4.2 Top five Tiger Reserves in terms of forest cover as % of the area of the Tiger Reserve.

4.3.2 Decadal Change in Forest Cover (ISFR 2011 to ISFR 2021)

The decadal assessment of change in forest cover within Tiger Reserves helps in assessing the impact of conservation measures and management interventions that have been implemented over the years. For decadal assessment, change in forest cover, during the period between ISFR 2011 (data period 2008 – 2009) and the current cycle (ISFR 2021, data period 2019-2020) within each Tiger Reserve has been analyzed.

Table 4.5 depicts decadal change in Forest Cover between 2011 and 2021 assessments. It is seen that between 2011 and 2021, the forest cover has decreased by 22.62 sq km (0.04%). Twenty Tiger reserves have recorded an overall gain in forest cover during the past decade whereas thirty-two Tiger reserves have recorded an overall loss of forest cover. The Tiger reserves showing significant gain in forest cover are Buxa (238.80 sq km) followed by Anamalai (120.78 sq km) and Indravati (64.48 sq km). The maximum losses in forest cover are recorded from Kawal (118.97 sq km.) followed by Bhadra (53.09 sq km) and Sundarbans (49.95 sq km).

Table 4.5 Change in Forest Cover of Tiger Reserves between 2011 and 2021 assessment

Sl. No.	Name of Tiger Reserve	State	Area as per digitized Tiger Reserve Boundary*	2011 Assessment			
				VDF	MDF	OF	Total
1	Achanakmar	Chhattisgarh	936.34	321.75	521.01	60.13	902.89
2	Amrabad	Telangana	2,684.23	337.55	480.85	918.74	1,737.14
3	Anamalai	Tamil Nadu	1,767.76	347.25	387.92	323.71	1,058.88
4	Bandhavgarh	Madhya Pradesh	1,684.53	295.33	674.01	263.26	1,232.60
5	Bandipur	Karnataka	1,784.47	10.25	461.10	491.27	962.62
6	Bhadra	Karnataka	1,071.24	292.20	507.70	50.73	850.63
7	Biligiri Ranganatha Temple	Karnataka	654.96	0.68	306.23	240.99	547.90
8	Bor	Maharashtra	131.77	15.42	77.83	27.28	120.53
9	Buxa	West Bengal	783.02	204.03	86.55	112.64	403.22
10	Corbett	Uttarakhand and Uttar Pradesh	1,462.66	330.58	825.40	91.61	1,247.59
11	Dampa	Mizoram	821.89	23.64	210.93	532.80	767.37
12	Dudhwa	Uttar Pradesh	1,524.33	401.39	436.18	246.45	1,084.02
13	Indravati	Chhattisgarh	2,922.39	896.69	764.05	652.06	2,312.80
14	Kalakad Mundanthurai	Tamil Nadu	1,564.14	258.44	660.30	121.65	1,040.39
15	Kali	Karnataka	1,411.75	68.20	1,098.89	151.27	1,318.36
16	Kamlang	Arunachal Pradesh	792.03	316.15	283.73	119.96	719.84
17	Kanha	Madhya Pradesh	2,070.63	598.88	702.22	175.09	1,476.19
18	Kawal	Telangana	2,259.79	91.88	1,260.19	473.78	1,825.85
19	Kaziranga	Assam	1,180.35	7.61	127.64	46.53	181.78
20	Manas	Assam	3,030.24	291.21	1,034.75	293.98	1,619.94
21	Melghat	Maharashtra	2,028.47	481.39	954.27	430.68	1,866.34
22	Mudumalai	Tamil Nadu	750.81	62.73	382.65	255.19	700.57
23	Mukundara Hills	Rajasthan	758.40	0.00	139.79	229.22	369.01
24	Nagarhole	Karnataka	1,152.74	1.15	729.27	181.51	911.93
25	Nagarjunasagar Srisailam	Andhra Pradesh	3,843.88	250.31	1,819.36	903.05	2,972.72
26	Namdapha	Arunachal Pradesh	2,085.17	891.01	634.78	381.22	1,907.01
27	Nameri	Assam	371.86	19.23	93.66	69.23	182.12
28	Nawegaon Nagzira	Maharashtra	1781.22	551.03	450.39	180.68	1,182.10
29	Orang	Assam	80.21	0.00	5.03	12.42	17.45
30	Pakke	Arunachal Pradesh	1507.71	425.94	814.40	218.37	1,458.71
31	Palamau	Jharkhand	1980.64	433.63	713.76	289.75	1,437.14
32	Panna	Madhya Pradesh	1783.48	156.15	653.98	394.10	1,204.23
33	Parambikulam	Kerala	652.21	196.51	330.53	49.74	576.78
34	Pench - MP	Madhya Pradesh	1168.66	194.30	590.89	52.23	837.42
35	Pench - MH	Maharashtra	738.28	224.15	319.10	71.84	615.09
36	Periyar	Kerala	935.30	161.31	488.54	158.33	808.18
37	Pilibhit	Uttar Pradesh	758.64	339.56	137.11	133.78	610.45
38	Rajaji	Uttarakhand	1102.41	188.65	631.20	191.44	1,011.29
39	Ramgarh Vishdhari	Rajasthan	294.67	0.00	78.51	75.88	154.39
40	Ranthambore	Rajasthan	1765.57	0.00	215.98	629.94	845.92

**Source: WII, Dehradun*
Light green color depicts loss and dark green color depicts gain in forest cover within Tiger reserves.

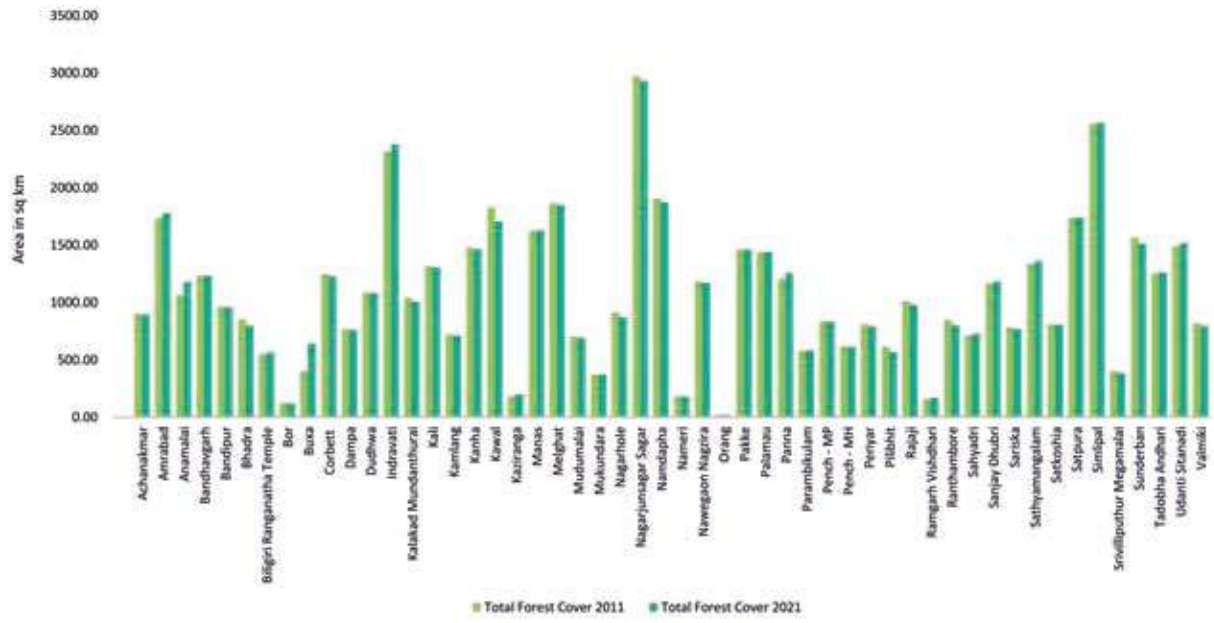
(in sq km)

		2021 Assessment						
% of total forest cover w.r.t area of digitized Tiger Reserve Boundary	Scrub	VDF	MDF	OF	Total	% of total forest cover w.r.t area of digitized Tiger Reserve boundary	Scrub	Change in Forest Cover w.r.t ISFR 2011
96.43	0.00	381.28	487.65	26.53	895.46	95.63	0.94	-7.43
64.72	177.82	332.38	497.81	950.34	1,780.53	66.33	473.63	43.39
59.90	4.61	309.33	466.63	403.70	1,179.66	66.73	8.36	120.78
73.17	9.63	291.12	670.27	268.07	1,229.46	72.99	11.90	-3.14
53.94	19.04	62.95	459.50	432.78	955.23	53.53	19.76	-7.39
79.41	0.00	326.03	445.09	26.42	797.54	74.45	0.25	-53.09
83.65	26.69	21.97	418.15	124.55	564.67	86.21	12.09	16.77
91.47	0.00	15.40	74.97	29.56	119.93	91.01	0.00	-0.60
51.50	0.00	329.89	192.86	119.27	642.02	81.99	3.46	238.80
85.30	0.00	441.44	693.37	89.87	1,224.68	83.73	2.97	-22.91
93.37	0.00	15.06	308.14	433.38	756.58	92.05	0.00	-10.79
71.11	3.65	727.72	193.24	158.50	1,079.46	70.82	2.67	-4.56
79.14	0.00	1,167.39	809.78	400.11	2,377.28	81.35	0.50	64.48
66.52	8.56	461.68	436.45	108.17	1,006.30	64.34	10.40	-34.09
93.38	0.00	273.74	962.33	69.15	1,305.22	92.45	0.12	-13.14
90.89	0.00	307.84	302.31	102.86	713.01	90.02	1.26	-6.83
71.29	3.27	598.72	714.04	152.72	1,465.48	70.77	1.06	-10.71
80.80	0.64	102.55	1,125.66	478.67	1,706.88	75.53	1.02	-118.97
15.40	0.00	23.87	109.91	61.67	195.45	16.56	0.76	13.67
53.46	2.12	1,086.36	296.27	244.09	1,626.72	53.68	13.56	6.78
92.01	0.02	456.31	965.62	425.05	1,846.98	91.05	0.00	-19.36
93.31	0.09	143.29	260.98	285.61	689.88	91.88	3.18	-10.69
48.66	34.67	0.00	144.41	227.50	371.91	49.04	50.75	2.90
79.11	1.80	177.15	603.12	89.28	869.55	75.43	0.16	-42.38
77.34	175.20	303.93	1,908.65	720.37	2,932.95	76.30	339.07	-39.77
91.46	0.23	912.65	598.57	360.81	1,872.03	89.78	7.58	-34.98
48.98	0.00	31.35	105.11	41.71	178.17	47.91	0.58	-3.95
66.36	2.21	553.67	446.89	169.82	1,170.38	65.71	2.65	-11.72
21.75	0.00	0.00	6.34	11.05	17.39	21.68	0.87	-0.06
96.75	0.14	487.25	751.92	220.82	1,459.99	96.83	2.67	1.28
72.56	0.77	433.33	713.39	292.75	1,439.47	72.68	0.90	2.33
67.52	51.76	154.32	643.08	461.75	1,259.15	70.60	66.81	54.92
88.43	0.00	287.08	246.72	47.78	581.58	89.17	0.00	4.80
71.66	3.41	192.98	586.69	49.18	828.85	70.92	2.25	-8.57
83.31	0.00	223.87	320.32	65.09	609.28	82.53	0.00	-5.81
86.41	0.00	176.05	500.51	110.25	786.81	84.12	0.00	-21.37
80.47	0.00	416.07	78.90	70.23	565.20	74.50	1.21	-45.25
91.73	0.00	253.38	563.49	164.22	981.09	89.00	2.36	-30.20
52.39	31.48							
47.91	145.47	0.00	229.14	572.21	801.35	45.39	169.28	-44.57

Sl. No.	Name of Tiger Reserve	State	Area as per digitised Tiger Reserve Boundary*	2011 Assessment			
				VDF	MDF	OF	Total
41	Sahyadri	Maharashtra	1168.60	76.64	433.21	203.83	713.68
42	Sanjay Dubri	Madhya Pradesh	1490.33	287.49	631.63	243.03	1,162.15
43	Sariska	Rajasthan	1145.80	59.83	284.74	437.09	781.66
44	Sathyamangalam	Tamil Nadu	1581.77	198.34	853.69	278.57	1,330.60
45	Satkosia	Odisha	981.97	184.80	502.43	119.48	806.71
46	Satpura	Madhya Pradesh	2033.79	258.56	970.40	505.94	1,734.90
47	Simlipal	Odisha	2721.62	1205.90	1,137.99	212.93	2,556.82
48	Srivilliputhur Megamalai	Tamil Nadu	501.12	46.69	285.39	68.51	400.59
49	Sundarbans	West Bengal	2634.74	942.70	568.21	52.20	1,563.11
50	Tadoba Andhari	Maharashtra	1647.22	660.78	431.43	160.23	1,252.44
51	Udanti Sitanadi	Chhattisgarh	1794.91	47.95	1,182.27	257.46	1,487.68
52	Valmiki	Bihar	928.80	216.51	482.62	120.03	819.16
		Total	74,710.53	13,872.37	28,854.69	12,961.83	55,688.89

Source: WII, Dehradun
Light green color depicts loss and dark green color depicts gain in forest cover within Tiger reserves.

Figure 4.3
Forest Cover in Tiger Reserves of India in 2011 and 2021



(In sq km)

		2021 Assessment						
% of total forest cover w.r.t area of digitized Tiger Reserve Boundary	Scrub	VDF	MDF	OF	Total	% of total forest cover w.r.t area of digitized Tiger Reserve Boundary	Scrub	Change in Forest Cover w.r.t ISFR 2011
61.02	9.22	75.48	438.51	211.09	725.08	61.99	13.62	11.41
77.98	0.05	286.34	630.48	263.34	1,180.16	79.19	0.99	18.01
58.22	17.89	61.12	283.80	420.79	765.71	66.83	37.13	-15.95
84.12	20.15	161.23	658.09	540.98	1,360.30	86.00	26.50	29.70
82.15	11.99	184.41	507.82	113.59	805.82	82.06	11.31	-0.89
85.30	0.50	254.34	982.79	501.69	1,738.82	85.50	1.28	3.92
93.94	1.83	1,205.52	1,138.78	218.56	2,562.86	94.17	0.05	6.04
79.94	29.50	57.32	206.89	118.70	382.91	76.41	8.94	-17.68
59.33	0.00	739.72	458.49	304.95	1,513.16	57.43	0.00	-49.95
76.03	0.45	655.47	444.18	162.00	1,261.65	76.59	0.17	9.21
82.88	0.08	48.17	1,186.91	284.49	1,519.57	84.66	0.60	31.89
88.20	0.07	235.98	496.05	64.09	796.12	85.71	9.23	-23.04
74.54	**795.01**	**10,444.51**	**28,856.71**	**12,385.08**	**51,686.27**	**74.51**	**1,359.58**	**-22.82**

4.4 Wetlands and their extent inside Tiger Reserves

Wetlands support rich floral and faunal biodiversity. In view of their importance, wetlands within Tiger Reserves were inventoried and the information is being presented in Table 4.6. Space Application Center (SAC), Ahmedabad carried out mapping of wetlands from 2006 to 2010 and released an Atlas of Wetlands of India in the year 2011, which is the latest information showing spatial distribution of wetlands in India. An overlay analysis of the wetland layer over the Tiger Reserve layer has been carried out to know category-wise number and extent of wetlands.

Table 4.6 Wetlands within Tiger Reserves

Sl. No.	Name of Tiger Reserve	Area as per digitized Tiger Reserve Boundary*	Inland Wetlands Man Made		Inland Wetlands Natural		Coastal Wetlands Natural	
			No.	Area	No.	Area	No.	Area
1	Achanakmar	93,634.00	14	114.89	2	770.96	0	0
2	Amrabad	2,68,423.00	10	6,624.32	6	1,890.94	0	0
3	Anamalai	1,76,776.00	23	2,665.14	12	1,113.72	0	0
4	Bandhavgarh	1,68,453.00	80	389.03	7	930.06	0	0
5	Bandipur	1,78,447.00	72	1,405.19	3	141.20	0	0
6	Bhadra	1,07,124.00	15	8,179.02	4	496.36	0	0
7	Biligiri Ranganatha Temple	65,496.00	8	370.21	3	172.65	0	0
8	Bor	13,177.00	1	224.89	0	0.00	0	0
9	Buxa	78,302.10	0	0.00	14	4,897.81	0	0
10	Corbett	1,46,266.00	7	7,909.20	29	4,795.70	0	0
11	Dampa	82,189.00	0	0.00	7	360.48	0	0
12	Dudhwa	1,52,433.00	3	2,044.14	128	9,918.91	0	0
13	Indravati	2,92,239.00	81	693.87	2	5,004.00	0	0
14	Kalakad Mundanthurai	1,56,414.00	170	3,853.01	34	1,973.56	0	0
15	Kali	1,41,175.00	5	2,752.47	6	873.52	0	0
16	Kamlang	79,203.00	0	0.00	4	316.58	0	0
17	Kanha	2,07,063.00	70	232.30	4	905.47	0	0
18	Kawal	2,25,979.00	38	1,571.48	10	3,093.12	0	0
19	Kaziranga	1,18,035.00	1	22.59	246	50,508.30	0	0
20	Manas	3,03,024.00	1	2.33	118	21,391.10	0	0
21	Melghat	2,02,847.00	11	435.22	13	2,543.45	0	0
22	Mudumalai	75,081.00	7	62.94	2	272.70	0	0
23	Mukundara Hills	75,840.00	24	373.95	8	1,645.92	0	0
24	Nagarhole	1,15,274.00	34	1,829.20	3	221.35	0	0
25	Nagarjunasagar Srisailam	3,84,388.00	18	10,044.60	5	1,458.12	0	0
26	Namdapha	2,08,517.00	0	0.00	22	5,365.17	0	0
27	Nameri	37,186.10	6	4,092.61	0	0.00	0	0
28	Nawegaon Nagzira	1,78,122.00	312	6,969.23	4	114.74	0	0
29	Orang	8,021.20	0	0.00	3	1,295.70	0	0
30	Pakke	1,50,771.00	0	0.00	1	2,722.67	0	0
31	Palamau	1,98,064.00	23	187.39	21	3,358.40	0	0
32	Panna	1,78,348.00	42	404.22	6	2,549.66	0	0
33	Parambikulam	65,220.90	6	3,248.66	10	499.16	0	0
34	Pench	1,16,866.00	95	5,406.82	3	475.65	0	0
35	Pench - MH	73,828.40	51	4,423.02	3	178.29	0	0
36	Periyar	93,530.00	4	26.20	10	2,607.87	0	0
37	Pilibhit	75,864.00	8	469.70	25	4,016.45	0	0
38	Rajaji	1,10,241.00	3	82.50	14	6,624.83	0	0

(in ha)

Wetlands (<2.25 ha)**		Total Wetlands		Wetland Area as % of TR Area
No.	Area	No.	Area	
62	62	78	947.85	1.01
3	3	19	8,518.26	3.17
47	47	82	3,825.86	2.16
137	137	224	1,456.09	0.86
179	179	254	1,725.39	0.97
86	86	105	8,761.36	8.18
38	38	49	580.86	0.89
0	0	1	224.89	1.71
0	0	14	4,897.81	6.26
16	16	52	12,720.90	8.70
12	12	19	372.48	0.45
101	101	232	12,064.10	7.91
104	104	187	5,801.87	1.99
85	85	289	5,911.57	3.78
18	18	29	3,643.99	2.58
9	9	13	325.58	0.41
387	387	461	1,524.77	0.74
25	25	73	4,689.60	2.08
74	74	321	50,604.9	42.87
25	25	144	21,418.4	7.07
9	9	33	2,987.67	1.47
10	10	19	345.64	0.46
59	59	91	2,078.87	2.74
136	136	173	2,186.55	1.9
5	5	28	11,507.7	2.99
30	30	52	5,395.17	2.59
11	11	17	4,103.61	11.04
3	3	319	7,086.97	3.98
2	2	5	1,297.70	16.18
2	2	3	2,724.67	1.81
282	282	326	3,827.79	1.93
126	126	174	3,079.88	1.73
0	0	16	3,747.82	5.75
197	197	295	6,079.47	5.20
24	24	78	4,625.31	6.26
3	3	17	2,637.07	2.82
12	12	45	4,498.15	5.93
16	16	33	6,723.33	6.10

Sl. No.	Name of Tiger Reserve	Area as per digitized Tiger Reserve Boundary*	Inland Wetlands Man Made		Inland Wetlands Natural		Coastal Wetlands Natural	
			No.	Area	No.	Area	No.	Area
39	Ramgarh Vishdhari	29,467.00	7	286.36	3	203.00	0	0
40	Ranthambore	1,76,557.00	43	428.10	12	1,388.53	0	0
41	Sahyadri	1,16,960.00	12	13,258.70	7	227.99	0	0
42	Sanjay Dubri	1,49,033.00	18	452.96	1	2,134.90	0	0
43	Sariska	1,14,580.00	36	638.58	4	543.04	0	0
44	Sathyamangalam	1,58,177.00	17	1,832.43	4	211.76	0	0
45	Satkosia	98,197.00	6	121.35	12	3,884.92	0	0
46	Satpura	2,03,379.00	36	16,821.50	8	2,292.09	0	0
47	Simlipal	2,72,162.00	4	411.21	13	815.90	0	0
48	Srivilliputhur Megamalai	50,112.00	2	14.66	2	55.48	0	0
49	Sundarbans	2,63,474.00	1	13.25	3	1,03,080.00	131	1,51,850
50	Tadoba Andhari	1,64,722.00	128	6,160.24	10	481.64	0	0
51	Udanti Sitanadi	1,79,491.00	22	1,753.71	7	1,558.80	0	0
52	Valmiki	92,880.00	0	0.00	14	1,529.41	0	0
	Total	**74,71,052.70**	**1,575**	**1,19,303.34**	**892**	**2,63,912.20**	**131**	**1,51,850.19**

*Source: WII, Dehradun
**Wetlands <2.25 ha are calculated from point feature layer of wetlands, where each point has an area of 1 ha

From Table 4.6 it is seen that the 5,821 wetlands cover a total area of 5,38,288.73 ha (5,382.89 sq km) which is 7.20% of the total area of the Tiger reserves. The Sundarban Tiger reserve has the largest area under wetlands 2,54,943.63 ha (2,549.44 sq km) accounting for 96.76% of its total area. These wetlands are mostly coastal and inland in nature. Kanha Tiger reserve has the highest number of wetlands, 461 wetlands, most of which are less than 2.25 ha in size.

4.5 Forest Types in Tiger Reserves

Information about Forest Types in Tiger Reserves provides a scientific basis for analyzing its biophysical attributes. This may serve as a basis for working plan preparation, silvicultural management, habitat management, biodiversity studies and other wildlife management practices.

FSI carried out the first ever mapping of Forest Types of India as per the classification of forests by Champion & Seth, 1968 and the results were presented in the Atlas of Forest Types of India published in the year 2011. Champion & Seth divided forest types of India into 6 Major Groups, further classified into 16 Forest Types Groups and 200 different Forest Types. Out of 200 Forest Types, FSI mapped 178 Forest Types. The work has been further updated in the revised Atlas of Forest Types of India, 2020, and 188 forest types out of the 200 described by Champion & Seth have been mapped.

Forest Types within Tiger Reserves have been mapped, based on the updated Atlas of Forest Types, 2020. It is seen that within Tiger Reserves, 103 different forest types belonging to 13 Type Groups occur. These comprise a varied spectrum of vegetation types indicative of rich biodiversity. The Forest Types include Moist Siwalik Sal forest in the North, Southern Dry Mixed deciduous forest and

(In ha)

Wetlands (<2.25 ha)**		Total Wetlands		Wetland Area as % of TR Area
No.	Area	No.	Area	
20	20	30	509.36	1.73
171	171	226	1,987.63	1.13
4	4	23	13,490.70	11.53
124	124	143	2,711.86	1.82
140	140	180	1,321.62	1.15
19	19	40	2,063.19	1.30
50	50	68	4,056.27	4.13
127	127	171	19,240.60	9.46
55	55	72	1,282.11	0.47
5	5	9	75.14	0.15
0	0	135	2,54,944	96.76
47	47	185	6,688.88	4.06
114	114	143	3,426.51	1.91
12	12	26	1,541.41	1.66
3,223	**3,223.00**	**5,821**	**5,36,269.79**	**7.20**

West Coast Tropical Evergreen forests and Semi Evergreen forests in the South, Northern Dry Mixed Deciduous forests and *Anogeissus pendula* forests in the west, to East Himalayan mixed coniferous forests and Mangrove forests in the east. The area of Forest Type Groups within Tiger Reserves is given in Table 4.7.

Figure 4.4 Photograph showing *Anogeissus pendula* forest in Ranthambore Tiger Reserve, Rajasthan

Table 4.7 Forest Type Groups in Tiger Reserves

Sl. No.	Tiger Reserve	Forest Type Group					
		Group 1: Tropical Wet Evergreen Forests	Group 2: Tropical Semi-Evergreen Forests	Group 3: Tropical Moist Deciduous Forests	Group 4: Littoral and Swamp Forests	Group 5: Tropical Dry Deciduous Forests	Group 6: Tropical Thorn Forests
1	Achanakmar	-	-	793.79		104.61	-
2	Amrabad	-	-	-	-	2,082.63	223.92
3	Anamalai	135.13	21.34	299.48	7.25	323.83	11.76
4	Bandhavgarh	-	-		0.06	1,251.63	-
5	Bandipur	0.01	5.56	152.46	-	811.11	-
6	Bhadra	14.32	43.90	478.93	-	141.26	-
7	Biligiri Ranganatha Temple	44.51	90.64	125.02	-	303.99	10.78
8	Bor	-	-	-	-	121.14	-
9	Buxa	-	191.54	274.58	-	75.91	-
10	Corbett (including Amangarh Buffer)	-	-	994.43	-	223.67	-
11	Dampa	-	687.32	59.90	-		-
12	Dudhwa	-	-	821.95	122.70	189.56	-
13	Indravati	-	-	1,839.82	-	511.07	-
14	Kalakad Mundanthurai	381.72	147.59	318.10	-	141.71	63.66
15	Kali	386.10	465.43	445.58	-	-	-
16	Kamlang	-	21.42	5.99	-	-	-
17	Kanha	-	-	1,391.76	-	117.13	-
18	Kawal	-	-	-	-	1,718.79	-
19	Kaziranga	-	19.75	174.44	127.30	-	-
20	Manas	-	172.34	1,363.70	-	22.97	-
21	Melghat	-	-	-	0.52	1,849.24	-
22	Mudumalai	-	24.54	143.51	25.59	491.01	4.93
23	Mukundara Hills	-	-	-	-	422.22	-
24	Nagarhole	4.33	0.08	324.01	-	508.78	0.04
25	Nagarjunsagar Srisailam	-	-	-	-	3,263.82	23.53
26	Namdapha	486.47	178.82	16.09	-	-	-
27	Nameri	4.77	171.45	-	-	-	-
28	Nawegaon Nagzira	-	-	-	-	1,172.98	-
29	Orang	-	-	20.00	26.12	-	-
30	Pakke	263.01	624.03	-	-	-	-
31	Palamau	-	-	22.91	-	1,394.73	-
32	Panna	-	-	-	0.14	1,328.57	-
33	Parambikulam	299.22	117.06	147.15	-	13.82	-
34	Pench - MH	-	-	-	-	599.89	-
35	Pench - MP	-	-	164.40	-	669.38	-
36	Periyar	600.97	139.16	40.81	-	-	-
37	Pilibhit	-	-	469.24	0.01	89.78	-

(in sq km)

Forest Type Group								
Group 8: Subtropical Broadleaved Hill Forests	Group 9: Subtropical Pine Forests	Group 11: Montane Wet Temperate Forests	Group 12: Himalayan Moist Temperate Forests	Group 14: Sub-Alpine Forests	Group 15: Moist Alpine Scrub	Group 16: Dry Alpine Scrub	TOF/ Plantation	Total
-	-	-	-	-	-	-	-	898.40
-	-	-	-	-	-	-	-	2,306.55
44.92	-	85.19	-	-	-	-	321.79	1,250.69
-	-	-	-	-	-	-	0.96	1,252.65
-	-	-	-	-	-	-		969.14
4.52	-	-	-	-	-	-	173.72	856.65
1.62	-	-	-	-	-	-	0.61	577.17
-	-	-	-	-	-	-		121.14
69.93	-	-	-	-	-	-	33.35	645.31
-	3.65	-	0.01	-	-	-	19.64	1,241.40
-	-	-	-	-	-	-	-	747.22
-	-	-	-	-	-	-	35.10	1,169.31
-	-	-	-	-	-	-	6.05	2,356.94
4.22	-	19.61	-	-	-	-	37.75	1,114.36
-	-	-	-	-	-	-	1.23	1,298.34
192.48		328.72	156.42	1.94	80.95	-	-	787.92
-	-	-	-	-	-	-	1.31	1,510.20
-	-	-	-	-	-	-	0.91	1,719.70
-	-	-	-	-	-	-	4.53	326.02
-	-	-	-	-	-	-	70.56	1,629.57
-	-	-	-	-	-	-	-	1,849.76
0.19	-	-	-	-	-	-	3.82	693.59
-	-	-	-	-	-	-	0.11	422.33
-	-	-	-	-	-	-	35.61	872.85
-	-	-	-	-	-	-	0.51	3,287.86
692.13	-	400.24	100.07	0.03	92.58	0.17	7.53	1,974.13
-	-	-	-	-	-	-	3.09	179.31
-	-	-	-	-	-	-	0.42	1,173.40
-	-	-	-	-	-	-	0.01	46.13
575.23	-	-	-	-	-	-	-	1,462.27
-	-	-	-	-	-	-	21.47	1,439.11
-	-	-	-	-	-	-	1.59	1,330.30
-	-	-	-	-	-	-	9.28	586.53
-	-	-	-	-	-	-	-	599.89
-	-	-	-	-	-	-	1.50	835.28
-	-	0.72	-	-	-	-	4.95	786.61
-	-	-	-	-	-	-	10.40	569.43

Sl. No.	Tiger Reserve	Forest Type Group					
		Group 1: Tropical Wet Evergreen Forests	Group 2: Tropical Semi-Evergreen Forests	Group 3: Tropical Moist Deciduous Forests	Group 4: Littoral and Swamp Forests	Group 5: Tropical Dry Deciduous Forests	Group 6: Tropical Thorn Forests
38	Rajaji	-	-	507.45	0.76	444.10	-
39	Ramgarh Vishdhari	-	-	-	-	184.76	-
40	Ranthambore	-	-	-	-	944.63	6.49
41	Sahyadri	-	142.85	253.84	-	41.10	0.07
42	Sanjay Dhubri	-	-	-	-	1,185.00	-
43	Sariska	-	-	-	-	805.92	1.84
44	Sathyamangalam	-	226.31	0.12	0.12	980.30	176.31
45	Satkoshia	-	4.61	520.08	-	292.29	-
46	Satpura	-	-	-	10.53	1,738.37	-
47	Simlipal	-	-	2,082.89	-	495.42	-
48	Srivilliputhur Megamalai	11.60	27.05	64.75	-	306.44	64.42
49	Sunderban	-	-	-	1,507.14	-	-
50	Tadoba Andhari	-	-	-	-	1,264.70	-
51	Udanti Sitanadi	-	-	981.03	-	538.21	-
52	Valmiki	-	1.65	421.34	15.92	367.84	-
	Total	**2,632.16**	**8,524.44**	**15,719.55**	**1,844.16**	**29,534.31**	**587.75**

(in sq km)

Forest Type Group							TOF/ Plantation	Total
Group 8: Subtropical Broadleaved Hill Forests	Group 9: Subtropical Pine Forests	Group 11: Montane Wet Temperate Forests	Group 12: Himalayan Moist Temperate Forests	Group 14: Sub-Alpine Forests	Group 15: Moist Alpine Scrub	Group 16: Dry Alpine Scrub		
-	1.76	-	-	-	-	-	31.01	985.08
-	-	-	-	-	-	-	-	184.76
-	-	-	-	-	-	-	0.17	951.29
303.92	-	-	-	-	-	-	0.75	742.53
-	-	-	-	-	-	-	0.24	1,185.24
-	-	-	-	-	-	-	0.61	808.37
-	-	-	-	-	-	-	1.11	1,384.27
-	-	-	-	-	-	-	2.55	819.53
1.35	-	-	-	-	-	-	3.34	1,753.59
-	-	-	-	-	-	-	3.04	2,581.35
-	-	-	-	-	-	-	0.66	474.92
-	-	-	-	-	-	-	0.62	1,507.76
-	-	-	-	-	-	-	0.45	1,265.15
-	-	-	-	-	-	-	1.16	1,520.40
-	-	-	-	-	-	-	0.29	807.04
1,890.51	**5.41**	**834.48**	**256.50**	**1.87**	**179.58**	**0.17**	**853.80**	**57,898.74**

4.6 Forest Cover in Tiger Corridors

Tiger Corridors constitute areas linking one Tiger Reserve with another Tiger Reserve, allowing movement of Tigers, prey and other wildlife. They provide connectivity between Tiger source populations. In the absence of corridors, the Tiger habitats may become isolated, making the Tigers vulnerable to inbreeding and local extinction. These areas may not be diverted for anthropological uses, except in public interest and with approval of the National Board for Wildlife and on advice of the NTCA. The map showing location of Tiger corridors in the country is given in Figure 4.1.

The extent of forest cover in the Tiger corridors of the country as per the latest assessment has been derived. The latest digital boundaries of Tiger corridors available from NTCA and Wildlife Institute of India were used. The Tiger corridors occupy an area of approximately 14,289.37 sq km, which is 0.43 % of the country's geographical area. The current assessment shows that the forest cover in the Tiger corridors is 11,575.12 sq km, which is 1.62 % of the country's total forest cover.

In terms of canopy density classes, the area covered by VDF is 2,908.54 sq km (20.36%), MDF is 6,074.19 sq km (42.51%) and OF is 2,592.39 sq km (18.14%). Scrub occupies a total area of 52.99 sq km (0.37%) (Table 4.8).

Table 4.8 Forest Cover in Tiger Corridors

Class	Area (sq km)	Percentage of Area of Digitized Tiger Corridor Boundary
Very Dense Forest	2,908.54	20.36
Moderately Dense Forest	6,074.19	42.51
Open Forest	2,592.39	18.14
Total Forest Cover	**11,575.12**	**81.01**
Scrub	52.99	0.37
Non-Forest	2,661.26	18.62
Total Area of Tiger Corridors	**14,289.37**	**100.00**

Table 4.9 depicts forest cover in Tiger corridors as per the latest assessment. From the table it is seen that Kanha to Navegoan-Nagzira-Tadoba-Indravati Tiger corridor passing through MP, Chhattisgarh & Maharashtra, has the largest forest cover (2,012.26 sq km), which is 86.50 % of the area of Tiger corridor, followed by Pench-Satpura-Melghat in MP and Maharashtra (1,195.79 sq km), which is 83.21% of the area of Tiger corridor and Simlipal-Satkosia in Odisha (810.23 sq km), which is 83.05% of the area of Tiger corridor. In terms of forest cover as percentage of the area of Tiger corridors, the top five Tiger corridors are Kane WLS-Tale Valley WLS Corridor in Arunachal Pradesh and Assam (97.03%), Nagarahole-Bandipur-Mudumalai-Wayanad in Karnataka and Tamil Nadu (94.87%), Kudremukh NP-Bhadra WLS Corridor (93.86%) in Karnataka, Anshi-Dandeli-Sharavathi Valley Corridor in Karnataka (93.67%) and Nagarahole-Pushpagiri-Talakavery Corridor (92.60%) in Karnataka and Kerala. Kanha to Navegoan-Nagzira-Tadoba-Indravati Tiger corridor has the highest area under VDF comprising 857.65 sq km, which is 42.62% of its total forest cover. It also has the maximum area under MDF comprising 882.87 sq km, which is 43.87% of its total forest cover. The highest area under Open Forest is found in Pench-Satpura-Melghat Tiger corridor comprising 392.25 sq km, which is 32.80 % of its total forest cover. The highest area under scrub is found in Ranthambore-Kuno-Shivpuri-Madhav Tiger corridor in Rajasthan and MP, covering an area of 15.68 sq km.

Decadal Change in Forest Cover (ISFR 2011 to ISFR 2021) 4.6.1

For decadal assessment, change in forest cover, during the period between ISFR 2011 (data period 2008 - 2009) and the current cycle (ISFR 2021, data period 2019-2020) within each Tiger corridor has been analyzed. Table 4.10 depicts decadal change in Forest Cover between 2011 and 2021 assessments. Between 2011 and 2021, the forest cover has increased by 37.15 sq km (0.32%).

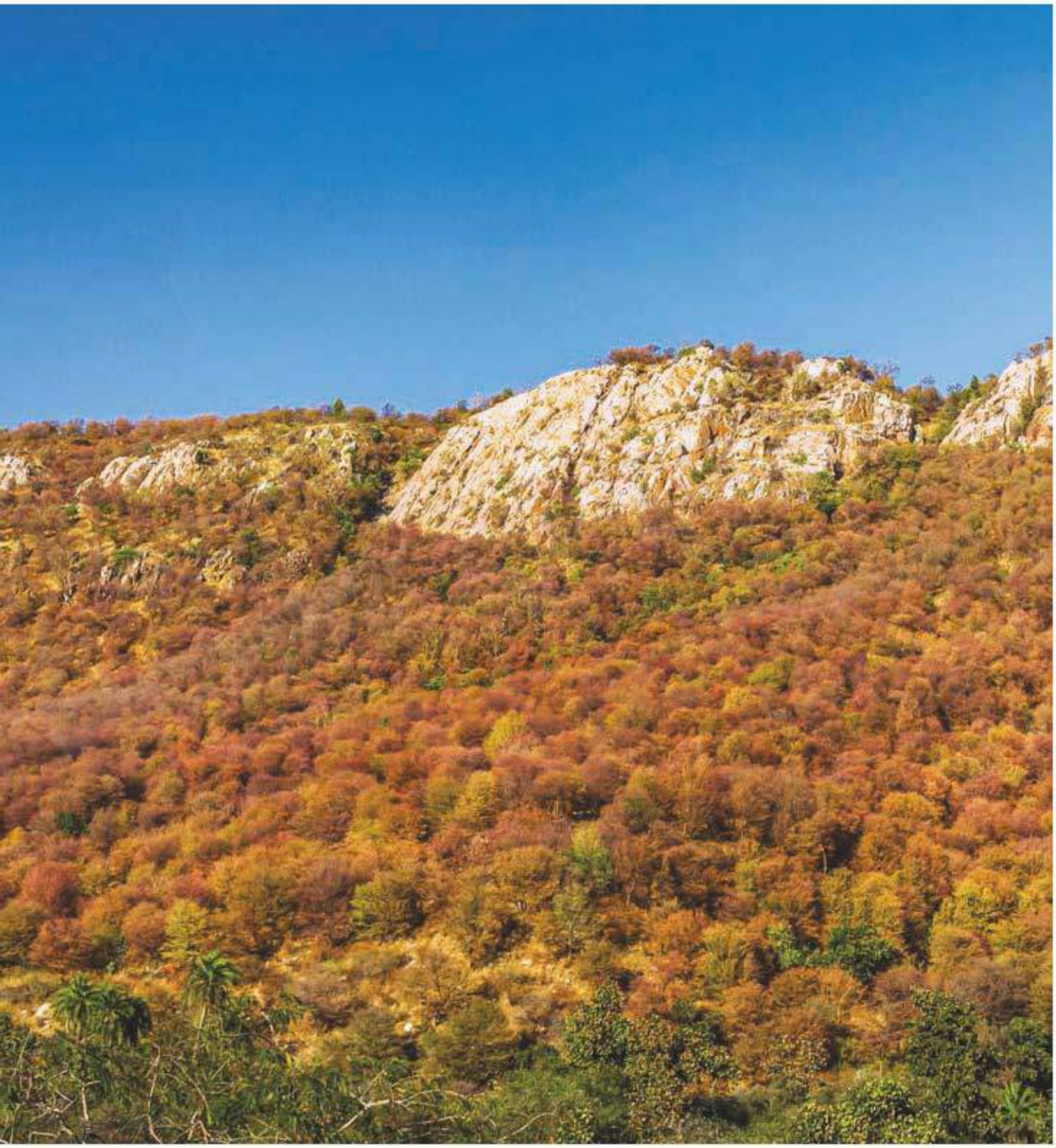


Table 4.9 Forest Cover in Tiger Corridors (ISFR, 2021)

Sl.No.	Name of Tiger Corridor	State	Area as per digitized Tiger Corridor Boundary**
1	Anshi-Dandeli-Sharavathi Valley	Karnataka	432.85
2	Bandhavgarh-Sanjay-Dubri-Guru Ghasidas	MP & Chhattisgarh	598.99
3	Bhandhavgarh-Achanakmar #	MP & Chhattisgarh	405.72
4	Buxa-Jaldapara	West Bengal	45.50
5	Corbett-Dudhwa*	Uttarakhand & UP	872.90
6	Dibru Saikhowa-D'ering-Mehao Corridor	Arunachal Pradesh & Assam	860.90
7	Durga-Kishanpur-Katamlaghat*	Uttar Pradesh	30.63
8	Guru Ghasi Das- Palamau-Lawalong	Jharkhand & Chhattisgarh	517.63
9	Indravati-Udanti-Sitanadi-Sunebeda	Odisha & Chhattisgarh	862.52
10	Kalakad-Mundanthurai-Periyar	Kerala and Tamil Nadu	137.48
11	Kane WLS-Tale Valley WLS	Arunachal Pradesh & Assam	139.29
12	Kanha to Navegoan-Nagzira-Tadoba-Indravati#	MP, Chhattisgarh & Maharashtra	2,326.38
13	Kanha-Achanakmar	MP & Chhattisgarh	264.46
14	Kanha-Pench	Madhya Pradesh	538.47
15	Kaziranga-Itanagar WLS Corridor	Arunachal Pradesh & Assam	236.39
16	Kaziranga-Karbi-Anglong	Assam	32.35
17	Kaziranga-Nameri	Arunachal Pradesh & Assam	171.77
18	Kaziranga-Orang	Assam	129.30
19	Kaziranga-Papumpare	Arunachal Pradesh & Assam	72.74
20	Kudremukh NP-Bhadra WLS	Karnataka	417.19
21	Manas*	Assam	5.50
22	Nagarahole-Mudumalai-Wayanad	Kerala & Tamil Nadu	180.18
23	Nagarahole-Bandipur-Mudumalai-Wayanad	Karnataka & Tamil Nadu	132.03
24	Nagarahole-Pushpagiri-Talakavery	Karnataka & Kerala	306.82
25	Nagarjunsagar -Sri Venkateswara NP	Andhra Pradesh	625.75
26	Pakke-Nameri-Sonai-Rupai-Manas*	Arunachal Pradesh & Assam	132.92
27	Pench-Satpura-Melghat	MP & Maharashtra	1,437.03
28	Parambikulum-Ernakulum-Indira Gandhi	Kerala	56.70
29	Rajaji-Corbett	Uttarakhand & UP	170.66
30	Ranthambore-Kuno-Shivpuri-Madhav	Rajasthan & MP	535.47
31	Sahyadri-Radhanagri	Maharashtra & Karnataka	637.23
32	Similipal-Satkosia #	Odisha	975.62
	TOTAL		14,289.37

* Part of Corridor falls outside India. Therefore the area of Forest Cover and the part of shapefile falling in India only are given.

** The area of Tiger corridor falling inside Tiger reserve has been excluded from the area of Tiger corridor to avoid duplicity in forest cover.

Tiger corridor boundary from NTCA website has been used. The rest of the boundaries are received from WII.

(In sq km)

ISFR 2021					
Very Dense Forest	Mod. Dense Forest	Open Forest	Total Forest Cover	% of total forest cover wrt area of digitized Tiger Corridor Boundary	Scrub
165.72	212.04	27.68	405.44	93.67	0.00
32.09	247.21	155.1	434.40	72.52	0.44
37.74	164.66	61.36	263.76	65.01	1.97
8.97	2.03	14.77	25.77	56.64	0.00
311.35	288.48	52.55	652.38	74.74	0.95
182.54	327.37	144.99	654.90	76.07	6.48
0.09	0.58	2.97	3.64	11.88	0.00
138.46	227.75	84.37	450.58	87.05	0.40
145.80	491.50	137.76	775.06	89.86	1.05
27.50	66.02	32.01	125.53	91.31	0.58
54.61	48.00	32.54	135.15	97.03	0.00
857.65	882.87	271.74	2,012.26	86.50	2.97
121.41	84.59	17.00	223.00	84.32	0.13
110.10	293.87	90.04	494.01	91.74	0.00
1.62	9.06	16.61	27.29	11.54	0.03
3.25	15.79	7.45	26.49	81.89	0.00
2.78	15.07	12.82	30.67	17.86	0.63
2.09	1.58	4.81	8.48	6.56	0.00
2.78	8.25	10.09	21.12	29.03	0.36
158.35	203.38	29.83	391.56	93.86	0.26
1.36	2.07	1.42	4.85	88.18	0.00
64.20	71.82	26.47	162.49	90.18	0.03
23.94	73.97	27.35	125.26	94.87	0.34
126.76	129.98	27.37	284.11	92.60	0.02
11.07	422.85	140.66	574.58	91.82	7.94
34.27	64.74	16.96	115.97	87.25	4.39
130.03	673.51	392.25	1,195.79	83.21	2.37
9.01	31.12	11.53	51.66	91.11	0.00
16.93	86.42	18.84	122.19	71.60	1.31
0.51	123.34	315.86	439.71	82.12	15.68
29.11	358.07	139.61	526.79	82.67	1.47
96.45	446.20	267.58	810.23	83.05	3.19
2,908.54	**6,074.19**	**2,592.39**	**11,575.12**	**81.01**	**52.98**

Table 4.10 Change in Forest Cover of Tiger Corridors of India between 2011 and 2021 Assessment

Sl.No.	Name of Tiger Corridor	State	Area as per digitized Tiger Corridor Boundary**	
1	Anshi-Dandeli-Sharavathi Valley	Karnataka	432.85	
2	Bandhavgarh-Sanjay-Dubri-Guru Ghasidas	MP & Chhattisgarh	598.99	
3	Bhandhavgarh-Achanakmar #	MP & Chhattisgarh	405.72	
4	Buxa-Jaldapara	West Bengal	45.50	
5	Corbett-Dudhwa*	Uttarakhand & UP	872.90	
6	Dibru Saikhowa-D'ering-Mehao Corridor	Arunachal Pradesh & Assam	860.90	
7	Durga-Kishanpur-Katarniaghat*	Uttar Pradesh	30.63	
8	Guru Ghasi Das- Palamau-Lawalong	Jharkhand & Chhattisgarh	517.63	
9	Indravati-Udanti-Sitanadi-Sunebeda	Odisha & Chhattisgarh	862.52	
10	Kalakad-Mundanthurai-Periyar	Kerala and Tamil Nadu	137.48	
11	Kane WLS-Tale Valley WLS	Arunachal Pradesh & Assam	139.29	
12	Kanha to Navegoan-Nagzira-Tadoba-Indravati#	MP, Chhattisgarh & Maharashtra	2,326.38	
13	Kanha-Achanakmar	MP & Chhattisgarh	264.46	
14	Kanha-Pench	Madhya Pradesh	538.47	
15	Kaziranga-Itanagar WLS Corridor	Arunachal Pradesh & Assam	236.39	
16	Kaziranga-Karbi-Anglong	Assam	32.35	
17	Kaziranga-Nameri	Arunachal Pradesh & Assam	171.77	
18	Kaziranga-Orang	Assam	129.30	
19	Kaziranga-Papumpare	Arunachal Pradesh & Assam	72.74	
20	Kudremukh NP-Bhadra WLS	Karnataka	417.19	
21	Manas*	Assam	5.50	
22	Nagarahole-Mudumalai-Wayanad	Kerala & Tamil Nadu	180.18	
23	Nagarahole-Bandipur-Mudumalai-Wayanad	Karnataka & Tamil Nadu	132.03	
24	Nagarahole-Pushpagiri-Talakavery	Karnataka & Kerala	306.82	
25	Nagarjunsagar -Sri Venkateswara NP	Andhra Pradesh	625.75	
26	Paake-Nameri-Sonai-Rupai-Manas*	Arunachal Pradesh & Assam	132.92	
27	Pench-Satpura-Melghat	MP & Maharashtra	1,437.03	
28	Parambikulum-Ernakulum-Indira Gandhi	Kerala	56.70	
29	Rajaji-Corbett	Uttarakhand & UP	170.66	
30	Ranthambore-Kuno-Shivpuri-Madhav	Rajasthan & MP	535.47	
31	Sahyadri-Radhanagri	Maharashtra & Karnataka	637.23	
32	Simlipal-Satkosia #	Odisha	975.62	
		TOTAL	**1,4289.37**	

**Part of Corridor falls autside India. Therefore the area of Forest Cover and the part of shapefile falling in India only are given.*

(in sq km)

ISFR 2011					
Very Dense Forest	Mod.Dense Forest	Open Forest	Total Forest Cover	% of total forest Cover wrt area of digitized Tiger Corridor Boundary	Scrub
17.36	315.82	72.64	405.82	93.76	0.00
32.46	246.21	149.08	427.75	71.41	1.19
37.95	165.60	57.93	261.48	64.45	3.37
0.00	5.21	6.15	11.36	24.97	0.00
218.72	375.77	79.31	673.80	77.19	0.00
201.73	322.73	133.27	657.73	76.40	0.28
0.00	0.64	2.48	3.12	10.19	0.00
67.47	332.07	54.71	454.25	87.76	0.16
79.48	515.42	177.31	772.21	89.53	1.05
23.44	58.51	41.64	123.59	89.90	0.12
37.47	63.31	34.63	135.41	97.21	0.00
836.18	917.96	270.85	2,024.99	87.04	0.13
119.79	85.36	18.32	223.47	84.50	0.00
110.25	296.16	90.08	496.49	92.20	0.00
1.84	12.32	12.50	26.66	11.28	0.00
2.26	17.34	6.45	26.05	80.53	0.00
2.96	16.56	9.72	29.24	17.02	0.00
0.79	3.30	6.85	10.94	8.46	0.00
3.31	7.50	7.59	18.40	25.30	0.00
111.30	191.11	7.59	310.00	74.31	0.00
2.84	1.56	0.95	5.35	97.27	0.33
46.14	79.75	40.53	166.42	92.36	0.24
19.14	72.55	29.69	121.38	91.93	0.36
41.11	151.01	96.04	288.16	93.92	0.00
10.08	389.54	151.08	550.70	88.01	22.80
37.68	71.26	12.17	121.11	91.11	0.04
135.29	687.24	392.43	1,214.96	84.55	2.80
10.78	21.32	22.70	54.80	96.65	0.00
39.85	80.26	19.45	139.56	81.78	0.00
0.59	123.72	326.20	450.51	84.13	10.83
26.75	355.84	145.08	527.67	82.81	2.40
83.46	437.73	283.40	804.59	82.47	3.00
2,358.47	**6,420.68**	**2,758.82**	**11,537.97**	**80.75**	**49.10**

***The area of Tiger Corridor falling within Tiger Reserves has been excluded from the area of the shapefile.*
 # The shapefile of NTCA has been used for analysis in accordance with NTCA report "Connecting Tiger Corridors" (2015)

ISFR 2021				
Very Dense Forest	Mod.Dense Forest	Open Forest	Total Forest Cover	
165.72	212.04	27.68	405.44	
32.09	247.21	155.1	434.40	
37.74	164.66	61.36	263.76	
8.97	2.03	14.77	25.77	
311.35	288.48	52.55	652.38	
182.54	327.37	144.99	654.90	
0.09	0.58	2.97	3.64	
138.46	227.75	84.37	450.58	
145.80	491.50	137.76	775.06	
27.50	66.02	32.01	125.53	
54.61	48.00	32.54	135.15	
857.65	882.87	271.74	2,012.26	
121.41	84.59	17.00	223.00	
110.10	293.87	90.04	494.01	
1.62	9.06	16.61	27.29	
3.25	15.79	7.45	26.49	
2.78	15.07	12.82	30.67	
2.09	1.58	4.81	8.48	
2.78	8.25	10.09	21.12	
158.35	203.38	29.83	391.56	
1.36	2.07	1.42	4.85	
64.20	71.82	26.47	162.49	
23.94	73.97	27.35	125.26	
126.76	129.98	27.37	284.11	
11.07	422.85	140.66	574.58	
34.27	64.74	16.96	115.97	
130.03	673.51	392.25	1,195.79	
9.01	31.12	11.53	51.66	
16.93	86.42	18.84	122.19	
0.51	123.34	315.86	439.71	
29.11	358.07	139.61	526.79	
96.45	446.20	267.58	810.23	
2,908.54	**6,074.19**	**2,592.39**	**11,575.12**	

(in sq km)

% of total forest cover w.r.t area of digitized Tiger Corridor Boundary	Scrub	Forest Cover Change between ISFR 2011 to 2021	Forest Cover Change % w.r.t 2011 Assessment
93.67	0.00	-0.38	-0.09
72.52	0.44	6.65	1.55
65.01	1.97	2.28	0.87
56.64	0.00	14.41	126.85
74.74	0.95	-21.42	-3.18
76.07	6.48	-2.83	-0.43
11.88	0.00	0.52	16.67
87.05	0.40	-3.67	-0.81
89.86	1.05	2.85	0.37
91.31	0.58	1.94	1.57
97.03	0.00	-0.26	-0.19
86.50	2.97	-12.73	-0.63
84.32	0.13	-0.47	-0.21
91.74	0.00	-2.48	-0.50
11.54	0.03	0.63	2.36
81.89	0.00	0.44	1.69
17.86	0.63	1.43	4.89
6.56	0.00	-2.46	-22.49
29.03	0.36	2.72	14.78
93.86	0.26	81.56	26.31
88.18	0.00	-0.50	-9.35
90.18	0.03	-3.93	-2.36
94.87	0.34	3.88	3.20
92.60	0.02	-4.05	-1.41
91.82	7.94	23.88	4.34
87.25	4.39	-5.14	-4.24
83.21	2.37	-19.17	-1.58
91.11	0.00	-3.14	-5.73
71.60	1.31	-17.37	-12.45
82.12	15.68	-10.80	-2.40
82.67	1.47	-0.88	-0.17
83.05	3.19	5.64	0.70
81.01	**52.99**	**37.15**	**0.32**

Box-4.1 Forest Cover Analysis in Nagarjunasagar-Sri Venkateswara NP Tiger Corridor, Andhra Pradesh

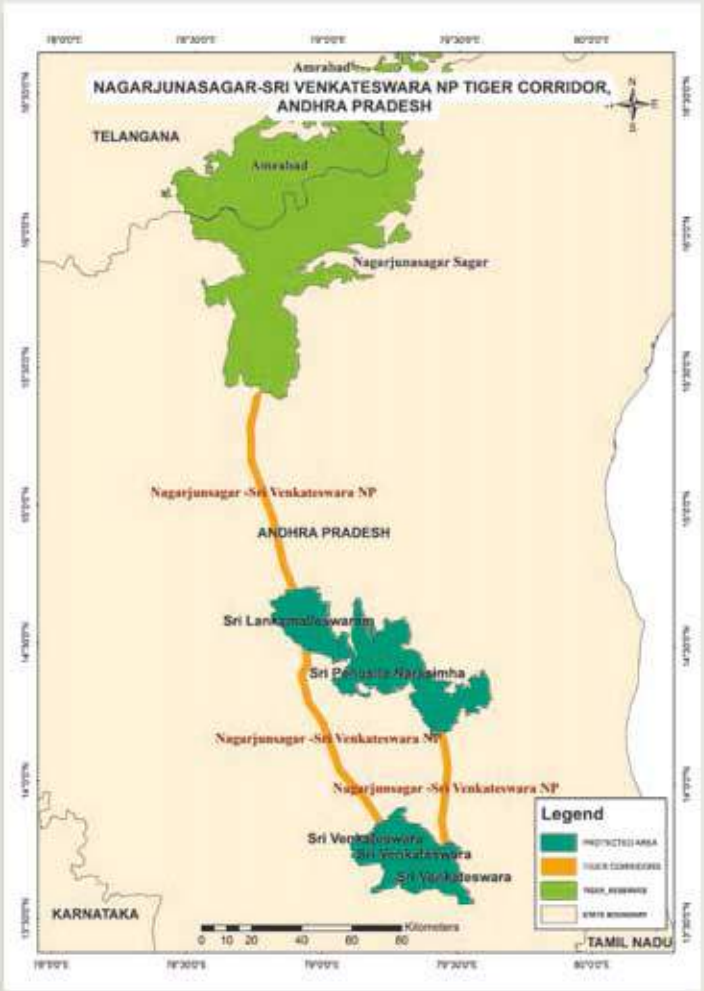
Forest Cover Analysis in Nagarjunasagar-Sri Venkateswara NP Tiger Corridor, Andhra Pradesh

Nagarjunasagar-Sri Venkateswara NP tiger corridor connects Nagarjun Sagar Sri Sailam Tiger Reserve (NSTR) and Sri Venkestwara National Park and passes through Sri Lankamalleswaram and Sri Penusila Narasimha wildlife sanctuaries. However, there are several national and state highways cutting across the corridor.

Figure represents map of the Nagarjunasagar-Sri Venkateswara NP Tiger Corridor.

The forest cover assessment for 2021 was carried out and thereafter compared with the 2011 assessment for decadal change analysis. As per the latest assessment, forest cover in the tiger corridor is 574.58 sq km, out of which VDF is 11.07 sq km, MDF is 422.85 sq km and OF is 140.66 sq km.

The decadal forest cover analysis done between ISFR 2021 and 2011 assessment shows that the forest cover has increased from a total of 550.70 sq km in 2011 assessment to 574.58 sq km in 2021 assessment, showing a net increase of 23.88 sq km (4.34%) wrt 2011 assessment.



Decadal Forest cover assessment between ISFR 2011 and ISFR 2021

Tiger Corridor	Digitized Area	Forest Cover 2011	% of total forest wrt digitized area	Forest Cover 2021	% of total forest wrt digitized area	Forest Cover Change between 2011 to 2021	Forest Cover Change %
Nagarjunasagar Sri Venkateswara	625.75	550.70	88.01	574.58	91.82	23.88	4.34

Box-4.2 Economic Evaluation of Tiger Reserves in India

Economic Evaluation of Tiger Reserves in India

Tiger reserves are effective tools of conservation of natural forests as well as support ecosystem services such as food, water, water, air and soil quality and other important human needs. A study on "Economic valuation of tiger reserves in India: A value + approach" was conducted by the Centre for Ecological Services Management (CESM) of the Indian Institute of Forest Management (IIFM) in collaboration with the National Tiger Conservation Authority (NTCA). The major objective of the study was to enhance tiger conservation by highlighting the economic benefits of Tiger reserves. The approach followed was a VALUE+ approach, where the 'value' indicates all benefits for which monetary economic valuation is possible, while the '+' represents all such benefits for which such valuation is currently not possible either on account of lack of accepted methodologies, knowledge and/or understanding and derived data. The study analyzed the economic valuation of selected tiger reserves in two phases:

		Stock and Flow Benefits (million USD per yr)		
Tiger Reserve	State	Stock	Flow	Investment Multiplier
Corbet	Uttarakhand	4026.90	226.50	401
Kanha	Madhya Pradesh	2973.50	253.10	273
Kaziranga	Assam	344.50	150.10	200
Periyar	Kerala	4869.20	271.10	459
Ranthambore	Rajasthan	756.90	127.90	273
Sunderbans	West Bengal	10088.80	197.00	530

Phase-I (2014) was carried out in 6 Tiger reserves namely Corbett Tiger Reserve, Kanha Tiger Reserve, Kaziranga Tiger Reserve, Periyar Tiger Reserve, Ranthambore Tiger Reserve and Sundarban Tiger Reserve

Phase-II (2019) was conducted in ten selected tiger reserves namely. Anamalai, Bandipur, Dudhwa, Melghat, Nagarjunasagar-Srisailam , Pakke, Palamau, Panna , Similipal and Valmiki Tiger Reserve

		Total Economic Value			Stock and Flow Benefits (million USD per yr)		
Tiger Reserve	State	Direct	Indirect	Option	Stock	Flow	Investment Multiplier
Anamalai	Tamil Nadu	22.71	6174.62	1579.19	46150.09	9776.50	3750.10
Bandipur	Karnataka	56.35	5085.57	1263.74	31476.15	6405.70	716.34
Dudhwa	Uttar Pradesh	8.97	4221.34	864.61	56106.31	5094.90	573.83
Melghat	Maharashtra	51.41	10312.99	1984.95	75043.33	12349.30	346.73
Nagarjunasagar Srisailam	Andhra Pradesh	101.87	12883.35	3216.19	50129.74	16202.10	7488.59
Pakke	Arunachal Pradesh	20.36	7214.75	1487.09	8722.20	32201.19	1946.49
Palamu	Jharkhand	46.03	11123.39	1785.01	96744.71	12954.40	3450.55
Panna	Madhya Pradesh	78.80	5310.76	1565.00	13745.53	6954.60	1939.36
Simlipal	Odisha	89.53	13317.50	623.08	49832.80	16030.10	3038.31
Valmiki	Bihar	39.70	5987.39	873.20	43682.86	6900.30	1235.60

PARAMETERS OF ECONOMIC EVALUATION

Total Economic Value is comprised of Direct, Indirect and Option Values -

1. **Direct Values:** These can be associated with goods having market value like timber, fuel, fish, etc.
2. **Indirect Values:** Ecological services that provide life support like watershed protection, nutrient cycling
3. **Option Values:** Placed on the potential future ability to use a resource even though it is not currently used and the likelihood of future use is very low, e.g.: future recreation and ecotourism options

Investment Multiplier: It is an indicative value of the quantum benefits returned by the tiger reserve and their natural systems into the human well-being. The aggregate flow benefit from forests is compared with its management costs to obtain the 'investment multiplier'.

Stock and Flow Benefits: The stock refers to natural resource stock serving as the base for generating benefits. Flow Benefits refer to the actual flow of benefits. In this study, standing timber and carbon storage are taken as Stock benefit and Carbon sequestration are taken as flow benefit

GROSS ECONOMIC BENEFITS FROM 10 TIGER RESERVES (PHASE-II)

Resources for Humans	Protection from Diseases, Insects, Parasites	Ecosystem Services	Sociocultural Benefits	Natural Assets
Rs. 1643 to 7042 crore	Rs. 7.7 to 24.15 Cr	Rs. 2567 to 8260 Cr	Rs.0.3 to 62,144 Cr	Rs. 15,310-98,530Cr

4.7 Assessment of Forest Cover in Lion Habitat area of Gir Wildlife Sanctuary (WLS) and National Park (NP), Gujarat

The Asiatic lion (*Panthera leo persica*) is listed as "Endangered species" on the IUCN Red List because of its small population size and area of occupancy. Gir forest of Gujarat (India) is the only natural habitat of the lion in India. Gir National Park and Wildlife Sanctuary comprising a total area of 1,412.13 sq km is located in the Junagadh district of Gujarat. Gir has the largest compact tract of dry deciduous forests in the country with a topography composed of successive rugged ridges, isolated hills, plateaus and valleys. It is part of the Indo-Malayan Ecoregion Kathiarbar-Gir Dry Deciduous Forests[3]. The Lion Census is conducted every five years by the Gujarat Forest Department for estimation of lion population. The latest Lion Census, 2020, reports the presence of 674 lions in the country.

4.7.1 Forest Cover Assessment and Decadal Assessment of Changes in Forest Cover

Analysis of forest cover, within Gir NP and WLS was carried out. The total forest cover was observed to be 1,295.34 sq km, accounting for 85.20% of the total area of the Gir NP and WLS.

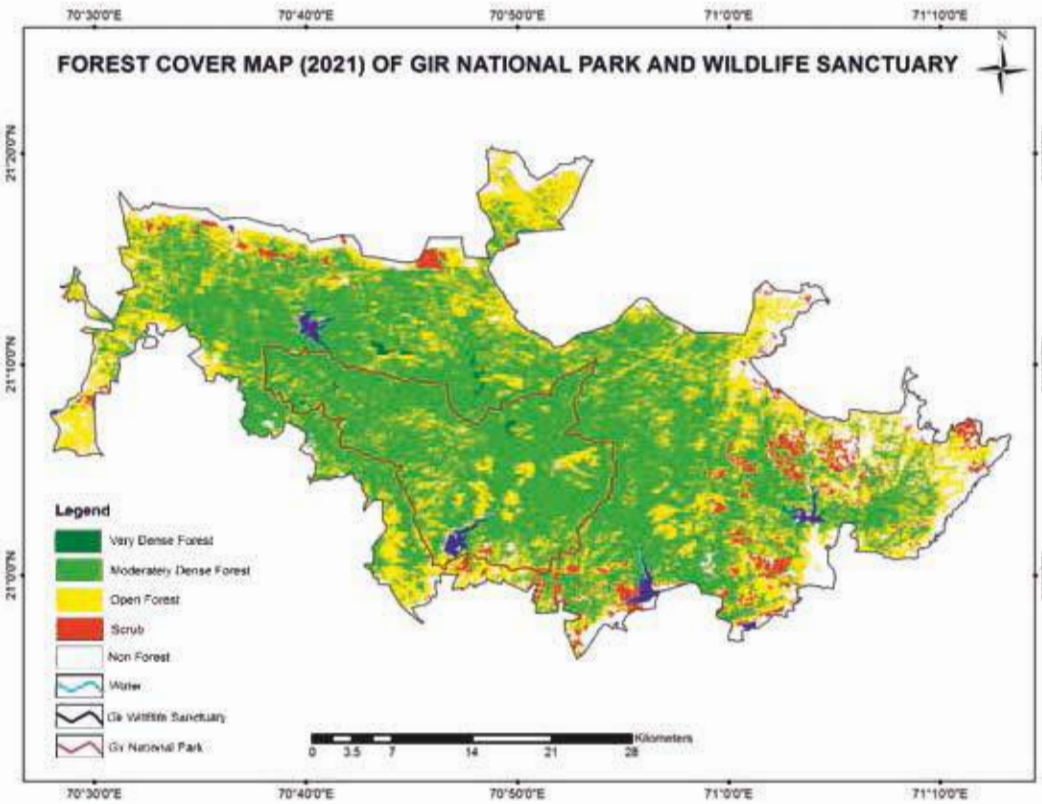


Figure 4.5 Forest Cover Map (2021) of Gir National Park and Wildlife Sanctuary

[3] "Kathiarbar -Gir dry deciduous forests". Terrestrial Ecoregions. World Wildlife Fund. Retrieved 16 September 2021.

(In sq km)

Table 4.11 Forest Cover in Gir Wildlife Sanctuary and National Park as per ISFR 2011

		2011 Assessment							
Sl. No.	Name	Notified Area*	Area as per digitized boundary**	Very Dense Forest	Mod. Dense	Open Forest	Total Forest Cover	% of total forest cover wrt area of digitized boundary	Scrub Forest
1	Gir National Park	258.71	288.67	1.73	239.06	43.20	283.99	98.38	0.00
2	Gir Wildlife Sanctuary	1,153.42	1,231.65	2.54	636.80	405.44	1,044.78	84.83	7.06
	Total	**1,412.13**	**1,520.32**	**4.27**	**875.86**	**448.64**	**1,328.77**	**87.40**	**7.06**

** Source: Gujarat SFD Website*
*** Source: WII, Dehradun*

(In sq km)

Table 4.12 Forest Cover in Gir Wildlife Sanctuary and National Park as per ISFR 2021

		2021 Assessment							
Sl. No.	Name	Very Dense Forest	Mod. Dense Forest	Open Forest	Total Forest Cover	% of total forest cover wrt area of digitized boundary	Change in Forest Cover w.r.t ISFR 2011	Change % w.r.t ISFR 2011	Scrub
1	Gir National Park	1.47	227.95	52.37	281.79	97.62	-2.20	-0.77	1.12
2	Gir Wildlife Sanctuary	2.55	625.57	385.43	1,013.55	82.29	-31.23	-2.99	52.26
	Total	**4.02**	**853.52**	**437.80**	**1,295.34**	**85.20**	**-33.43**	**-2.52**	**53.38**

** Source: Gujarat SFD Website*
*** Source: WII, Dehradun*

Table 4.11 and 4.12 depict the status of Forest cover in Gir National Pak and wildlife sanctuary in 2011 and 2021 assessment, respectively. Between the two assessments, there is a decrease of 33.43 sq km (2.52%) in forest cover.

The decrease in Forest cover is attributed to habitat improvement measures taken in the last decade like, removal of Prosopis juliflora from grassland areas and canopy manipulation for creating openings in the MDF and VDF areas.

4.8 Forest Types within Gir National Park and Wildlife Sanctuary

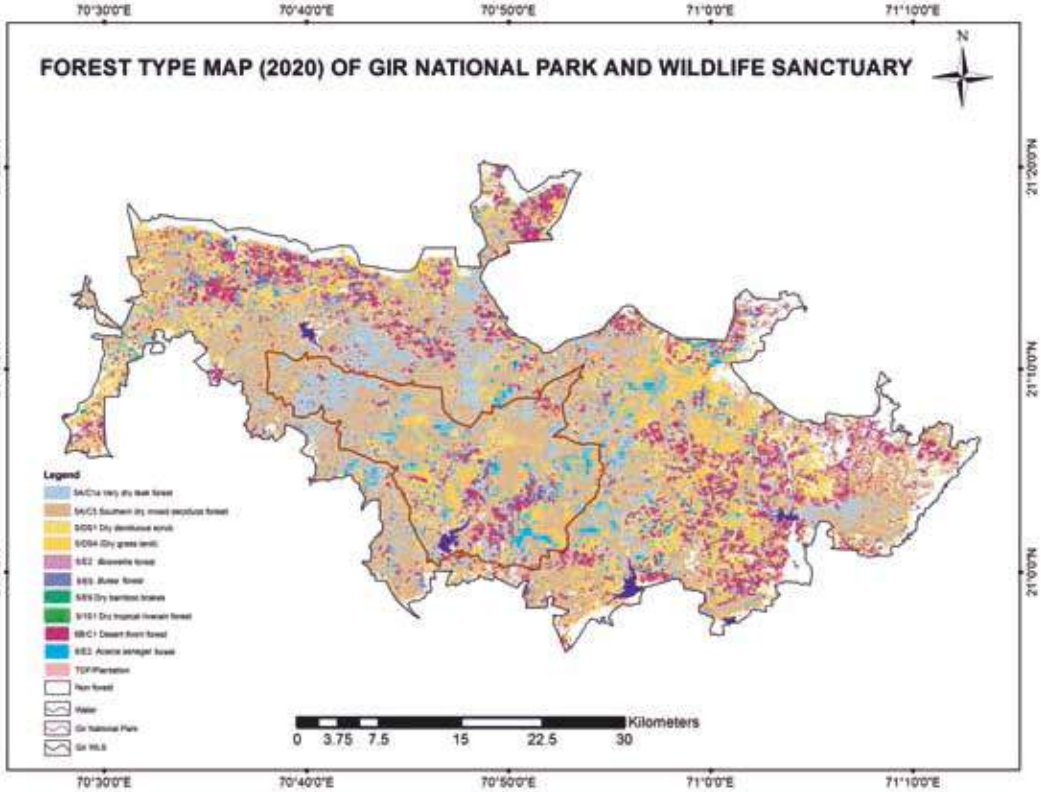
The prime habitat for Asiatic Lions is open woodlands, thick grassland and brush habitat, where there is sufficient cover for hunting and denning. These grasslands also provide food for the herbivorous animals that lions prey upon. According to the latest Atlas of Forest Types of India (2020), Gir wildlife sanctuary (excluding National Park), has 177.60 sq km of grassland whereas Gir National Park has 33.58 sq km of grassland, summing upto 211.18 sq km , which is 26.11% of the area of Gir National Park and WLS (Table 4.13). This grassland belongs to 5/DS4 Dry grassland Forest Type. Fig 4.5 depicts the forest type map of Gir WLS and NP.

Table 4.13 Forest Types in Gir National Park and WLS

(In sq km)

Sl. No.	Forest Type	Gir WLS	Gir NP	TotalArea	% vert digitized boundary
1	5A/C1a Very dry teak forest	126.44	44.32	170.76	11.23
2	5A/C3 Southern dry mixed deciduous forest	436.64	144.25	580.89	38.21
3	5/DS1 Dry deciduous scrub	93.73	16.52	110.25	7.25
4	5/DS4 Dry grass land	177.60	33.58	211.18	13.89
5	5/E2 *Boswellia* forest	1.30	0.00	1.30	0.09
6	5/E5 *Butea* forest	30.44	9.82	40.26	2.65
7	5/E9 Dry bamboo brakes	1.98	0.00	1.98	0.13
8	5/1S1 Dry tropical riverain forest	0.04	0.00	0.04	0.00
9	6/E2 *Acacia senegal* forest	39.00	18.10	57.10	3.76
10	6B/C1 Desert thorn forest	156.23	17.27	173.5	11.41
	Sub- Total	**1,063.40**	**283.86**	**1,347.26**	**88.62**
11	TOF/Plantation	0.93	2.06	2.99	0.20
	Total	**1,064.33**	**285.92**	**1,350.25**	**88.82**

Figure 4.6 Forest Type Map (2020) of Gir National Park and Wildlife Sanctuary



Wetlands in Gir Wildlife Sanctuary and National Park 4.9.

The Gir NP and WLS forms the catchment area of several major rivers, thereby providing ecological security to the surrounding drought prone region[3]. As per analysis of wetlands (National Wetlands Atlas, SAC, Ahmedabad), Gir National Park and Wildlife sanctuary have 31 wetlands occupying an area of 2,518 ha (25.81 sq km) which is 1.66% of their total area (Table 4.14).

(In ha)

Sl. No.	Name	Area as per digitized Boundary*	Inland Wetlands Man Made		Inland Wetlands Natural		Coastal Wetlands Natural		Wetlands (<2.25 ha)**		Total Wetlands		Wetland Area as % of Total Area
			No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	
1	Gir National Park	28,867.00	2	345.00	3	341.00	0	0.00	0	0.00	5	686.00	2.38
2	Gir Wildlife Sanctuary	1,23,165.00	10	1,084.00	16	744.00	0	0.00	4	4.00	26	1,832.00	1.49
	Total	1,52,032.00	12	1,429.00	19	1,085.00	0	0.00	4	4.00	31	2,518.00	1.66

Table 4.14 Wetlands in Gir Wildlife Sanctuary and National Park

Conclusion 4.10

There is an overall decrease in forest cover of 22.62 sq km (0.04%) in 52 Tiger reserves in the last decade. Out of 52 Tiger reserves, 20 have shown an increasing trend, ranging from 1.28 sq km (Pakke) to 238.80 sq km (Buxa) whereas 32 have registered a decline in the forest cover, ranging from 0.06 sq km (Orang) to 118.97 sq km (Kawal). In case of the Lion habitat, a decrease of 33.43 sq km (2.52%) of forest cover has been observed in the last ten years.

The information may be utilized for further analysis and devising appropriate conservation strategies to maintain the biodiversity, robustness and the ecosystem services flowing out of these pristine areas.

[3] *Estimation of the Status of Asiatic Lion (Panthera leo persica) Population in Gir Lion Landscape, Gujarat, India. A. P. Singh, Ram Ratan Nala. Volume 144, Issue 10, October 2018.*

05

FOREST FIRE MONITORING

Introduction 5.1

Forest Fires have long been an integral part of the forest environment and have played an important role in shaping the forest ecosystems, their conservation and management. Although, fire has benefits in terms of clearing the forest floor and paving way for regeneration of new grass, herbs and saplings, yet these are marginal when compared to the huge losses linked to it. Controlled forest fires are often used as important resource management tools for enhancing ecological conditions and eliminating excessive fuel build up in the forest areas.

Controlled or uncontrolled fire in an ecosystem may change the species mix, habitat structure and biodiversity (Global Wildfire Information System, 2019)[1] . These are associated with extreme fire-danger conditions driven by meteorological factors such as a lack of precipitation, high wind speeds, low humidity and high temperatures. Human carelessness is also a common cause of forest fires. Forest fires have severe impacts, causing the loss of human life, biodiversity, habitat, production and productivity; degradation of landscapes; and disruption of livelihoods.

Global Scenario 5.1.1

Global Forest Resource Assessment (GFRA) 2020 and other scientific studies have reported that the wild lands including forest areas are increasingly facing difficult fire weather conditions, extended fire seasons and large fires influenced by climate change, which is likely to have immense costs in terms of loss of biodiversity, ecosystem services, human well-being, livelihoods and national economies. Globally about 98 million ha of forest were affected by fire in 2015, which comprises 3 % of global forest area. This was mainly in the tropical domain, where about 4 percent of the total forest area was burnt (GFRA 2020)[2] . The resultant release of greenhouse gases (GHGs) and sequestrated carbon locked within trees is further leading to global warming and deterioration of the environment. The Fifth Assessment Report of the Inter-governmental Panel on Climate Change has also reported an estimated 260,000 to 600,000 premature deaths of human/ wildlife annually, due to exposure to smoke from landscape fires (including forest fires). The report also finds that annual carbon emissions from forest fires range between 2.5 billion to 4.0 billion tons of CO_2, adding large volumes of greenhouse gases to the atmosphere.

Persistent hotter and drier weather due to climate change and other human factors such as land conversion for agriculture and poor forest management are the main drivers behind the increase of forest fire. 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 last year - which was already a record year for fires[3].

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

[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] *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.*

5.1.2 Indian Scenario

In India, severe fires occur in many forest types particularly dry deciduous forest, while evergreen, semi-evergreen and montane temperate forests are comparatively less prone (ISFR 2015)[4] . More than 36% of the country's forest cover has been estimated to be prone to frequent forest fires. Nearly 4 % of the country's forest cover is extremely prone to fire, whereas 6% of forest cover is found to be very highly fire prone (ISFR 2019)[5] .

The forest fire season in the country is normally from Nov to June, and with majority of fires being caused due to man-made factors. The National Action Plan on Forest Fires (NAPFF)[6] was formulated by the MoEF&CC, Government of India in 2018 with the objective of revamping the forest fire management in the country. It aims to minimize forest fires from taking place by informing, enabling and empowering forest fringe communities, and also incentivizing them to work in tandem with the State Forest Departments (SFDs). This plan also aims at substantially reducing the vulnerabilities of forests across the diverse forest ecosystems in the Indian subcontinent against fire hazards, enhancing the capabilities of forest and other personnel and institutions in fighting fires, use of technology and speeding up recovery after a fire event.

Technology such as satellite based forest fire detection and alerts dissemination in near real-time, early warning information, tracking of large fires and related activities are of critical importance in timely prevention and control of forest fires.

5.2 Role of FSI in Forest Fire Monitoring

Since 2004, Forest Survey of India (FSI) has been assisting the State Forest Departments and other agencies to deal with the problems associated with forest fire by using the latest remote sensing and communication technology. Starting from providing forest fire alerts of fire incidences detected by MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor on-board Aqua and Terra Satellite of NASA, the Forest fire alert system of FSI has undergone significant improvement in the recent years. Chronology of evolution of the FSI forest fire system is given in Table 5.1. During fire season, the following country-wide forest fire related services are being provided:

- Near Real-Time Forest Fire Monitoring
- Large Forest Fire Monitoring
- Early Warning Alert based on Forest Fire Danger Rating System
- FSI Van Agni Geo-portal
- Identification of Fire Prone Forest Areas
- Sharing of WMS (Web Map Service) & WFS (Web Feature Service) services to State Forest Departments.

[4] *ISFR 2015, India State of Forest Report 2015, Forest Survey of India, Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India.*

[5] *ISFR 2019, India State of Forest Report 2015, Forest Survey of India, Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India.*

[6] *National Action Plan on Forest Fire (2018), Report by Forest Protection Division, Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India.*

Table 5.1 Evolution of FSI Forest Fire Alert System

Year	Milestone
2004	Started dissemination of forest fire alerts based on MODIS data up to district level through e-mail/ FAX
2006	Initiation of SMS alerts on number of fires in State/ District
2012	• Introduced 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	• Introduction of automated e-mail alerts to nodal officers using python script • Pilot study on country-wide burnt scar assessment for 2015 and 2016 • Pre-warning alerts piloted for Uttarakhand, Himachal Pradesh and Madhya Pradesh
2017	• Complete automation of entire 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	Introduction of improved feedback system for forest fire alerts
2019	• Initiation of satellite based Large forest fire monitoring program • FSI Van Agni Geo-portal • Early-warning alert based on Fire Weather Index • Identification of Fire prone forest area
2020	• Strengthening of large forest fire monitoring system and FSI Van Agni Geo-portal • WMS, WFS and API to State Forest Departments
2021	• Special monitoring of large forest fire events like Dzukou Valley, Simlipal TR, Bandhavgarh TR etc • Special reports on unusual increase of forest fire alert in the State

Near Real-Time Forest Fire Monitoring 5.2.1

Currently, Forest Survey of India (FSI) has been alerting State Forest Departments towards forest fire incidences detected by MODIS (Moderate Resolution Imaging Spectro-radiometer) sensor on-board Aqua and Terra Satellite of NASA and SNPP - VIIRS (Suomi National Polar-orbiting Partnership - Visible Infrared Imaging Radiometer Suite) sensor, at least six times in 24 hours. 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 headquarter Dehradun and alerts are generated and disseminated to the registered end users as SMS and also in the form of KML through e-mail to SFDs. Automation of the entire process has reduced the processing time, as a result of which the information is disseminated to SFDs in the shortest possible time, leading to quick responses by the field teams in fire containment activities.

A comparison between the two sensor viz. MODIS and SNPP-VIIRS has been given in Table 5.2.

Table 5.2 Comparison between the two sensor viz. MODIS and SNPP-VIIRS

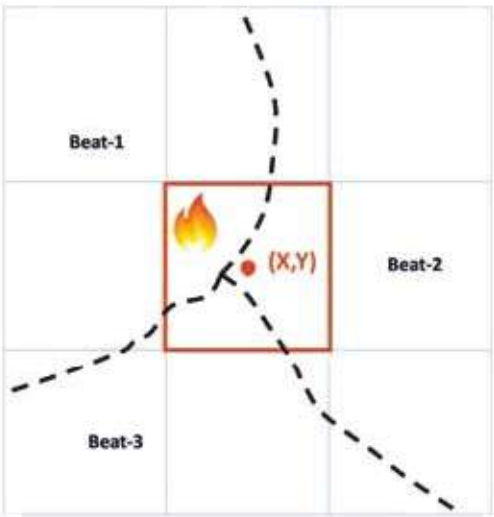
Feature	MODIS Moderate Resolution Imaging Spectro-radiometer	SNPP-VIIRS Visible Infrared Imaging Radiometer Suite
Sensor	36 spectral bands (channel 21, 22, 31)	5 HR Imagery channels (I-bands), 16 moderate resolution channels (M-bands), and a D/N Band (M13 and M15)
Satellite	Aqua and Terra	Suomi National 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.

a) 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 as well as Forest cover data. State/UT-wise details of the level of customization in forest fire alerts is shown in Table 5.3. 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 5.1 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 subscribers of all the administrative levels.

Figure 5.1 Pixel based analysis and dissemination of forest fire alerts



- 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)

b) Based on the analysis of the near real-time forest fire data and feedback from the SFD's, 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 (http://vanagniportal.fsiforestfire.gov.in/fsi_fire/fire.html). Work flow for alerts generation and dissemination of the information/SMS is presented in the following schematic diagram given at Figure 5.2.

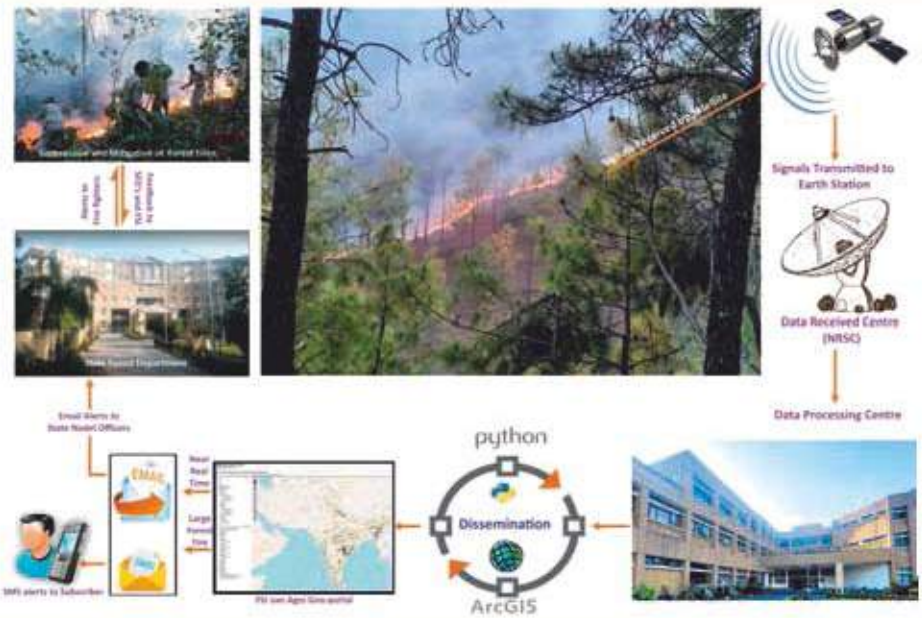


Figure 5.2 Work Flow of Near Real-Time Forest Fire Monitoring

Table 5.3 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	Beat	Yes
2	Arunachal Pradesh	District	No
3	Assam	District	No
4	Bihar	Beat	No
5	Chhattisgarh	Beat	Yes
6	Delhi	District	No
7	Goa	Beat	Yes
8	Gujarat	Beat	No
9	Haryana	Beat	Yes
10	Himachal Pradesh	Beat	No
11	Jammu & Kashmir	Range	Yes
12	Jharkhand	Beat	No
13	Karnataka	Beat	No
14	Kerala	Range	No
15	Madhya Pradesh	Beat	Yes
16	Maharashtra	Beat	No
17	Manipur	Beat	No

Sl. No.	State/UT	Alert Level	RFA details included in alerts (Yes/No)
18	Meghalaya	Block	No
19	Mizoram	Beat	No
20	Nagaland	District	No
21	Odisha	Beat	Yes
22	Punjab	Beat	No
23	Rajasthan	Range	No
24	Sikkim	District	No
25	Tamil Nadu	Beat	Yes
26	Telangana	Beat	Yes
27	Tripura	Beat	No
28	Uttar Pradesh	Beat	No
29	Uttarakhand	Beat	Yes
30	West Bengal	Beat	Yes
31	Andaman & Nicobar Islands	District	No
32	Chandigarh	District	No
33	Dadra & Nagar Haveli and Daman & Diu	District	No
34	Ladakh	District	No
35	Lakshadweep	District	No
36	Puducherry	District	No

5.2.1.1 Analysis of number of forest fire detected using MODIS & SNPP-VIIRS sensors for fire seasons 2019-2020 and 2020-2021

During the forest fire season 2019-2020, the number of hotspots detected by MODIS sensor were 22,447 & by SNPP-VIIRS sensor were 1,24,473. In fire season 2020-2021, the total hotspots detected by MODIS sensor were 52,785 & by SNPP-VIIRS sensor were 3,45,989. State wise details of number of forest fires detected by FSI using MODIS & SNPP-VIIRS sensors for fire season 2019-2020 and 2020-2021 are given in Table 5.4. This includes large, continuous and repeated forest fires.

Map showing MODIS and SNPP-VIIRS hot spots detected during 2020-2021 forest fire season are given in Figure 5.3 & Figure 5.4 respectively. Graphical depiction of month-wise forest fire detection from MODIS and SNPP-VIIRS sensors, for the entire country for the fire season 2019-20 and 2020-2021 is presented in Figure 5.5.

The SNPP-VIIRS forest fire data for the 2020-2021 season was analysed for assessing the top 10 States (Table 5.5) and top 20 districts (Table 5.6) of the country w.r.t forest fire incidences. The following observations were made:

- Amongst States, maximum number of fire detections were observed in Odisha (51,968) followed by Madhya Pradesh (47,795) and Chhattisgarh (38,106).
- Amongst districts, maximum number of SNPP-VIIRS forest fire detections were observed in Gadchiroli in Maharashtra (10,577) followed by Kandhamal in Odisha (6,156) and Bijapur in Chhattisgarh (5,499).

Table 5.4 Number of forest fire detected by FSI using MODIS & SNPP-VIIRS sensors (This includes large, continuous and repeated forest fires) for fire season 2019-2020 and 2020-2021.

SL No	State/UT	MODIS Detections		SNPP-VIIRS Detections	
		Nov 2019 to Jun 2020	Nov 2020 to Jun 2021	Nov 2019 to Jun 2020	Nov 2020 to Jun 2021
1	Andhra Pradesh	1,080	2,888	9,996	19,328
2	Arunachal Pradesh	660	1,109	1,786	3,914
3	Assam	3,000	3,387	8,924	10,718
4	Bihar	50	537	614	5,179
5	Chhattisgarh	416	3,112	6,360	38,106
6	Delhi	3	5	21	14
7	Goa	4	10	47	45
8	Gujarat	202	422	2,770	3,803
9	Haryana	39	25	68	152
10	Himachal Pradesh	80	533	536	4,110
11	Jammu & Kashmir*	62	131	438	1,098
12	Jharkhand	101	1,563	2,613	21,713
13	Karnataka	538	932	4,232	5,784
14	Kerala	142	51	864	296
15	Madhya Pradesh	1,383	7,103	9,537	47,795
16	Maharashtra	1,102	4,297	14,018	34,025
17	Manipur	2,475	3,252	8,800	10,457
18	Meghalaya	1,826	2,052	6,762	7,658
19	Mizoram	2,816	4,345	7,361	12,846
20	Nagaland	1,248	1,726	2,905	4,975
21	Odisha	1,326	5,307	10,602	51,968
22	Punjab	52	171	153	635
23	Rajasthan	420	447	3,461	3,402
24	Sikkim	5	17	47	63
25	Tamil Nadu	187	202	1,368	1,220
26	Telangana	1,042	2,566	12,132	18,237
27	Tripura	1,467	1,664	4,369	5,015
28	Uttar Pradesh	396	1,667	1,548	8,608
29	Uttarakhand	167	2,710	759	21,487
30	West Bengal	141	548	1,320	3,287
31	Andaman & Nicobar Islands	15	2	39	16
32	Chandigarh	0	0	2	0
33	Dadra & Nagar Haveli	1	3	21	33
34	Daman & Diu	0	0	0	1
35	Lakshadweep	0	0	0	0
36	Puducherry	1	1	0	1
	Total	**22,447**	**52,785**	**1,24,473**	**3,45,989**

**Combined figures of Jammu & Kashmir and Ladakh*

Figure 5.3
Map showing MODIS based hot spots detected during 2020-2021 forest fire season

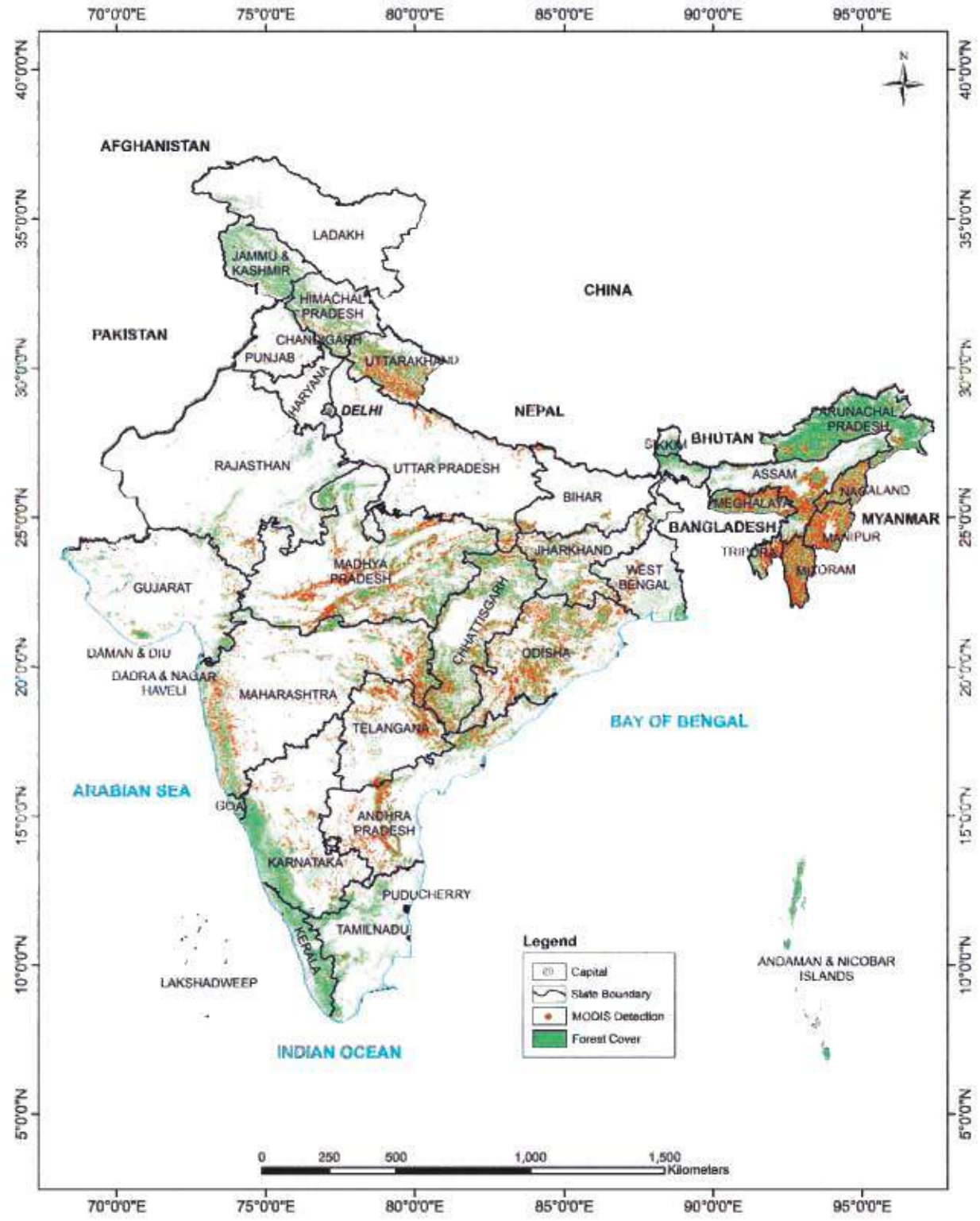


Figure 5.4
Map showing SNPP-VIIRS based hot spots detected during 2020-2021 forest fire season

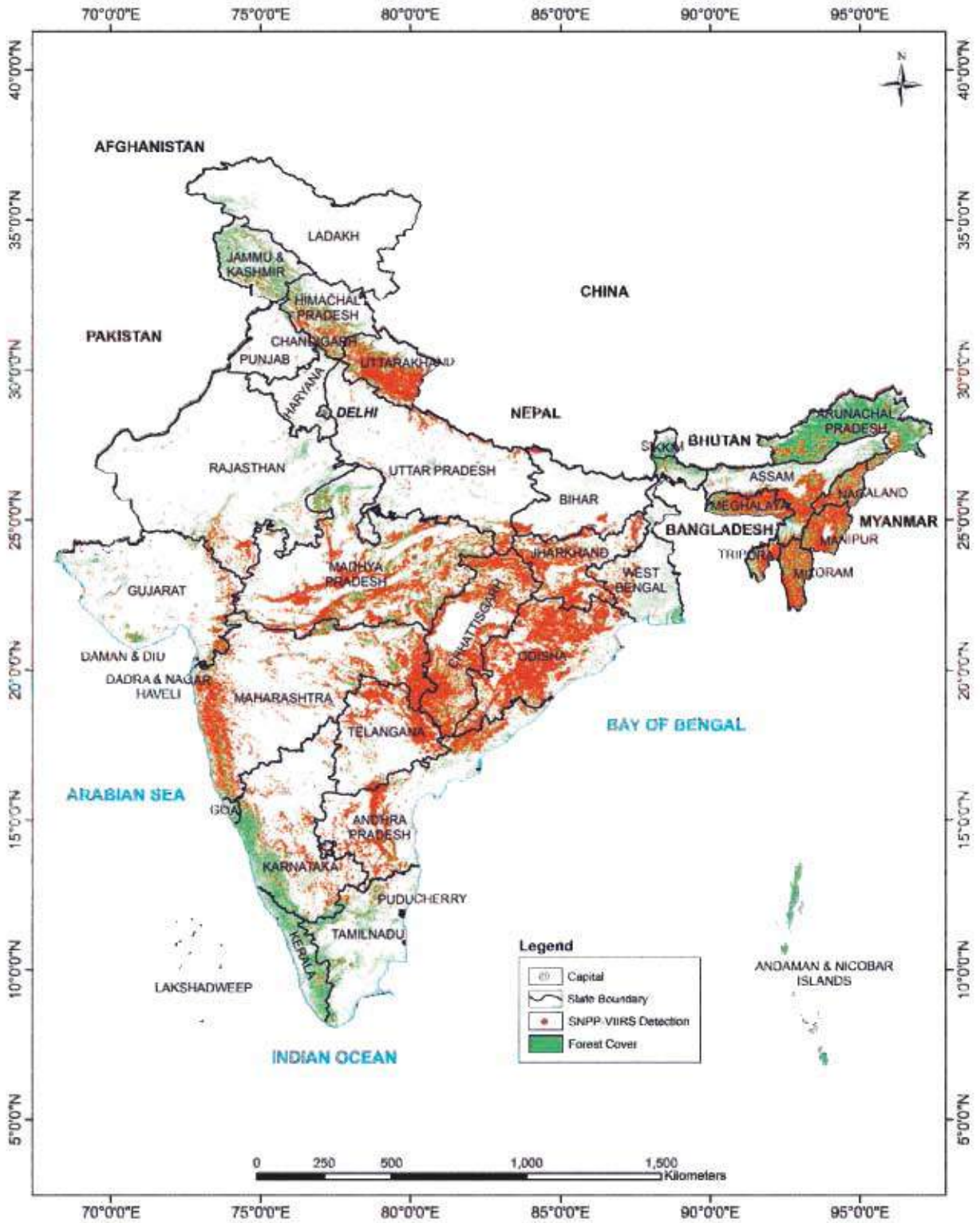
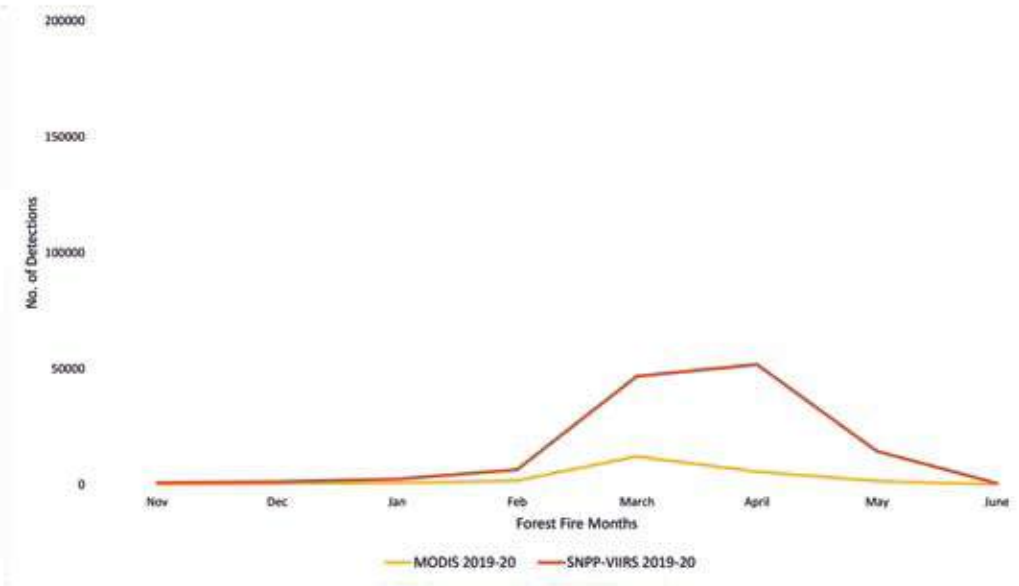


Figure 5.5 Comparative graph showing month-wise number of detections by MODIS and SNPP-VIIRS during the mentioned forest fire season



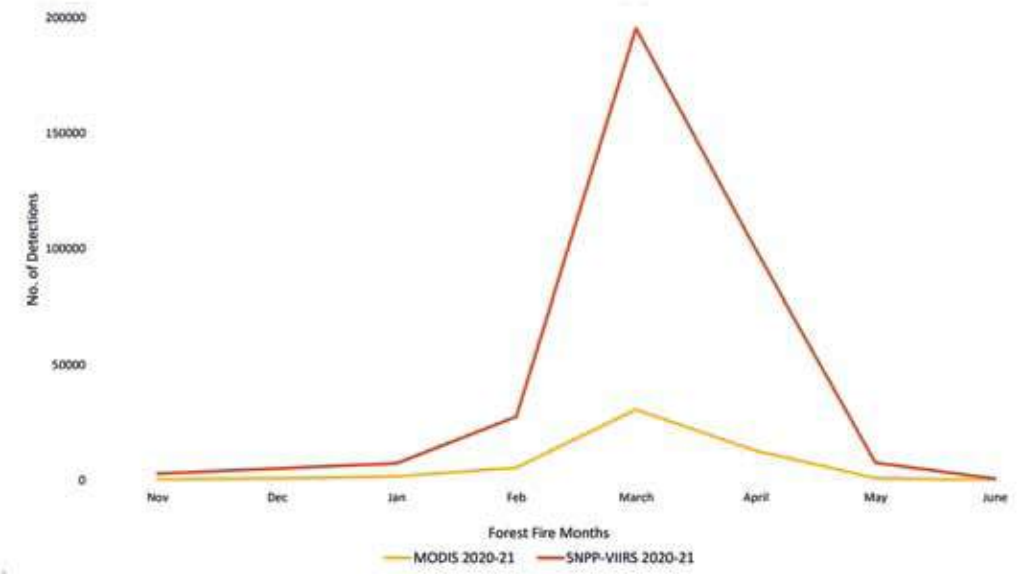


Table 5.5 Top ten states according to number of forest fire detected by FSI using SNPP-VIIRS sensors (This includes large, continuous and repeated forest fires)

Sl. No	State	Nov 2020 - June 2021
1	Odisha	51,968
2	Madhya Pradesh	47,795
3	Chhattisgarh	38,106
4	Maharashtra	34,025
5	Jharkhand	21,713
6	Uttarakhand	21,487
7	Andhra Pradesh	19,328
8	Telangana	18,237
9	Mizoram	12,846
10	Assam	10,718

SL No	District	State	Nov 2020 - June 2021
1	Gadchiroli	Maharashtra	10,577
2	Kandhamal	Odisha	6,156
3	Bijapur	Chhattisgarh	5,499
4	Karbi Anglong	Assam	4,881
5	Kadapa	Andhra Pradesh	4,872
6	West Singhbhum	Jharkhand	4,553
7	Pauri Garhwal	Uttarakhand	4,512
8	East Nimar	Madhya Pradesh	4,210
9	Mayurbhanj	Odisha	4,073
10	Sundargarh	Odisha	3,940
11	Nainital	Uttarakhand	3,802
12	Raisen	Madhya Pradesh	3,713
13	Kalahandi	Odisha	3,555
14	Chhindwara	Madhya Pradesh	3,535
15	Narayanpur	Chhattisgarh	3,510
16	Bhupalpally	Telangana	3,477
17	Aizawl	Mizoram	3,336
18	Kendujhar	Odisha	3,194
19	Dima Hasao	Assam	3,188
20	Rayagada	Odisha	3,172

Table 5.6 Top 20 districts according to number of forest fire detected by FSI using SNPP-VIIRS sensors (This includes large, continuous and repeated forest fires)

Subscription for FSI Forest Fire Alert System 5.2.1.2

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, as it is open to public also. User can register from the link http://fsiforestfire.gov.in/registration.php and subscribe for at most three administrative levels and up to Beat level depending upon the availability.

From a subscriber base of 66,870 at the end of forest fire season 2018-2019, the number of subscribers has risen to 1,31,102 at the end of forest fire season 2020-2021. Details of user subscriptions across different levels of administrative hierarchy is given in Figure 5.6. State wise status of SMS subscriptions is given in Table 5.7. Himachal Pradesh has the maximum subscribers to the FSI forest fire alert service followed by Telangana and Maharashtra. In the forest fire season 2020-2021, approximately 79,55,749 SMS were disseminated to the subscribers.

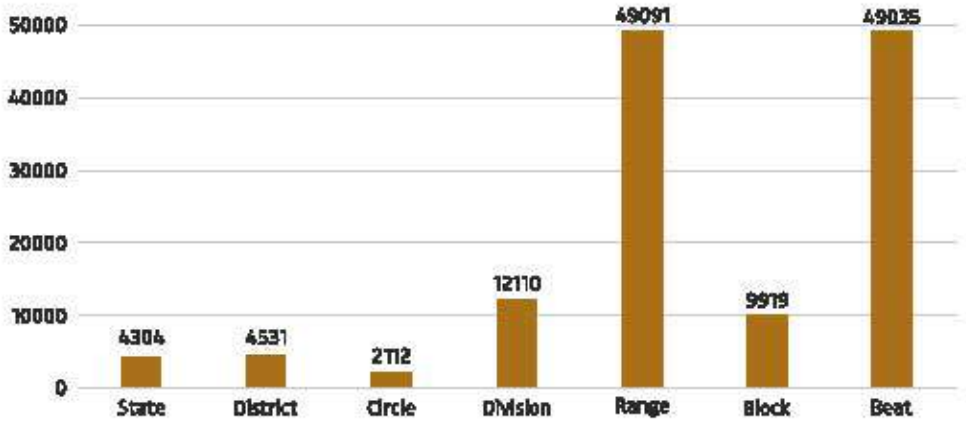


Figure 5.6 User subscriptions across different levels of Administrative Hierarchy

Table 5.7 State-wise SMS subscriptions at different administrative levels.

State/UT	State	District	Circle	Division	Range	Block	Beat	Total
Andhra Pradesh	78	64	49	261	648	292	901	2,293
Arunachal Pradesh	9	10	0	0	0	0	0	19
Assam	18	12	0	0	0	0	0	30
Bihar	29	20	8	42	67	7	85	258
Chhattisgarh	92	45	70	358	3,085	31	2,162	5,843
Delhi	22	5	0	0	0	0	0	27
Goa	473	7	4	5	13	0	0	502
Gujarat	100	83	34	241	455	474	952	2,339
Haryana	52	36	6	94	173	109	151	621
Himachal Pradesh	249	375	125	1,871	22,664	3,698	19,479	48,461
Jammu & Kashmir*	70	43	23	147	1,341	1	0	1,625
Jharkhand	45	31	21	203	242	17	340	899
Karnataka	197	56	211	725	2,342	224	684	4,439
Kerala	333	235	212	945	3,500	1	3	5,229
Madhya Pradesh	171	164	168	937	3,098	283	2,159	6,980
Maharashtra	658	54	426	1,507	2,926	1,949	4,904	12,424
Manipur	79	68	11	389	332	65	55	999
Meghalaya	8	0	0	15	3	39	0	65
Mizoram	10	4	7	15	93	0	0	129
Nagaland	12	4	0	0	0	0	0	16
Odisha	127	171	83	1,769	954	500	183	3,787
Punjab	63	8	6	113	235	230	718	1,373
Rajasthan	235	643	47	464	2,218	11	0	3,618
Sikkim	8	1	0	0	0	0	0	9
Tamil Nadu	484	304	437	870	956	107	444	3,602
Telangana	101	143	51	579	1,936	1,819	13,224	17,853
Tripura	7	5	0	30	45	0	19	106
Uttar Pradesh	143	1,655	22	135	167	44	77	2,243
Uttarakhand	156	74	89	199	1,397	16	2,042	3,973
West Bengal	36	27	2	194	199	2	453	913
Andaman & Nicobar Islands	217	177	0	2	2	0	0	398
Chandigarh	4	2	0	0	0	0	0	6
Dadra & Nagar Haveli	9	3	0	0	0	0	0	12
Daman & Diu	4	0	0	0	0	0	0	4
Lakshadweep	1	0	0	0	0	0	0	1
Puducherry	4	2	0	0	0	0	0	6
Total	**4,304**	**4,531**	**2,112**	**12,110**	**49,091**	**9,919**	**49,035**	**1,31,102**

**Combined figures of Jammu & Kashmir and Ladakh*

Large Forest Fire (LFF) Monitoring 5.2.2

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, 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 LFF was developed and launched in 2019. The objectives of this programme are given below:

i. Continuous monitoring and tracking of large forest fires in near real-time.
ii. Timely containment of such fires by SFDs.
iii. Escalation of alerts to higher level for timely additional support from agencies such as District Administration, SDMA, NDMA, Armed forces etc.
iv. Development of a National Large Forest Fire Database for future planning especially in development of State Crisis Management Plans and Working Plans.
v. 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 VIIRS pixels in any geometry as shown in Figure 5.7. 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.

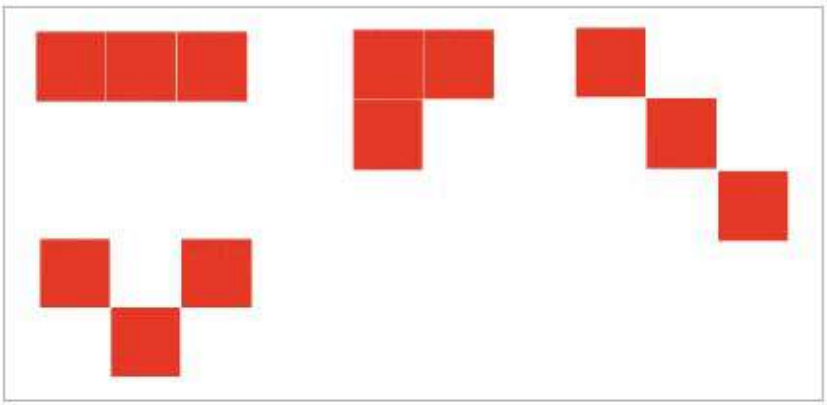


Figure 5.7
Candidate Large Forest Fire

Information on the number of fire affected active pixels, total number of fire affected pixels, administrative and management boundary, KMZ file and web-linked *.png map of the fire location etc. are provided to the subscribers through SMS. The LFF alerts are being sent as e-mail to the Principal Chief Conservator of Forests (Head of Forest Force) & Nodal Officer of SFD and as SMS to all the registered subscribers.

State-wise details of LFF events detected during fire season 2020-2021 (Nov 2020 to June 2021) is given in Table 5.8. Maps showing Large Forest Fire Events based on the number of days for which the LFF was active (viz. ≤ 5 days, between 6 to 10 days and >10 days) are given in Figure 5.8. From Table 5.8, it is seen that during the fire season 21,142 LFF events were detected and tracked by FSI. Out of this about 59.43% LFF were extinguished or contained within 24 hours, 37.72% of LFF were active for one to five days, 2.70% were active for six to ten days and only 32 LFF (0.15%) continued

to burn for more than eleven to fifteen days. The LFF (Gobardaha-1) detected in the State of Bihar (Nepal- Bihar border) was active for fifteen days.

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

Table 5.8 State-wise number of large forest fire events detected during fire season 2020-2021 (Nov 2020 to June 2021)

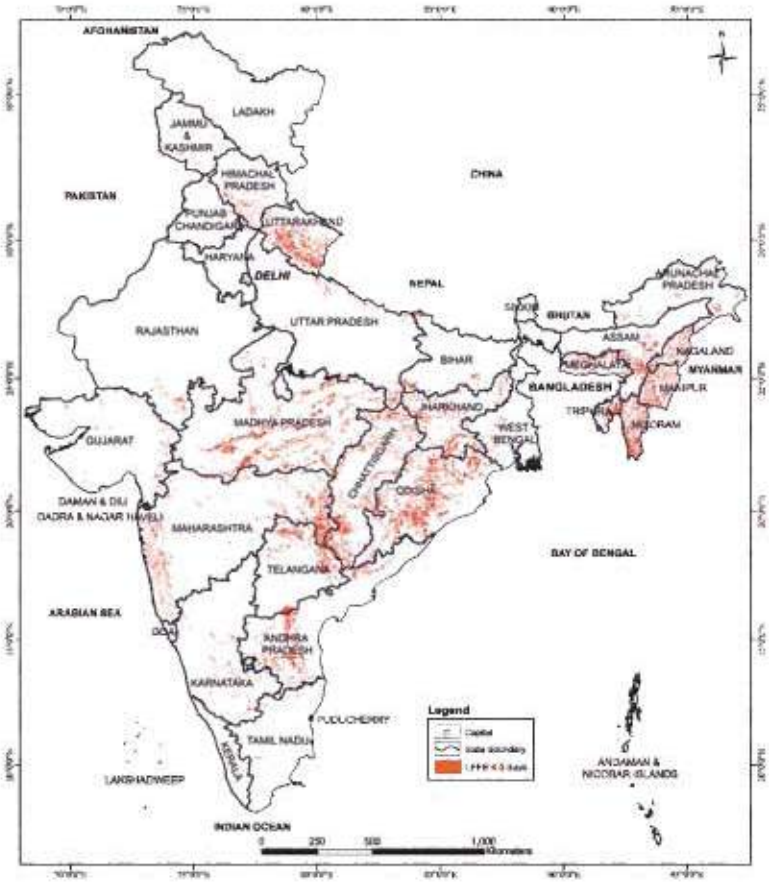
State/UT	Number of active Days for LFF					
	< 24 Hrs	1	2	3	4	5
Andhra Pradesh	834	235	112	72	28	16
Arunachal Pradesh	222	27	17	4	5	1
Assam	448	91	60	48	17	10
Bihar	122	62	37	18	15	6
Chhattisgarh	1,027	385	221	181	97	51
Delhi	0	0	0	0	0	0
Goa	2	1	0	0	0	0
Gujarat	151	34	9	10	5	1
Haryana	4	4	1	0	0	0
Himachal Pradesh	194	47	13	8	3	0
Jammu & Kashmir*	48	11	9	2	0	0
Jharkhand	519	247	118	69	47	33
Karnataka	349	34	12	9	2	0
Kerala	15	1	1	0	0	1
Madhya Pradesh	1,727	519	243	218	108	55
Maharashtra	1,456	320	154	120	54	36
Manipur	537	97	57	46	10	15
Meghalaya	283	58	31	32	10	13
Mizoram	508	158	73	49	18	9
Nagaland	317	53	18	10	5	3
Odisha	1,571	670	321	204	112	75
Punjab	24	4	4	3	1	0
Rajasthan	150	28	17	7	4	4
Sikkim	5	1	0	0	0	0
Tamil Nadu	74	15	2	1	0	1
Telangana	551	216	102	83	39	24
Tripura	228	40	58	28	13	9
Uttar Pradesh	280	63	46	21	23	17
Uttarakhand	798	250	127	80	44	17
West Bengal	119	25	9	17	6	2
Andaman & Nicobar Islands	0	1	0	0	0	0
Chandigarh	0	0	0	0	0	0
Dadra & Nagar Haveli	3	0	0	0	0	0
Daman & Diu	0	0	0	0	0	0
Lakshadweep	0	0	0	0	0	0
Puducherry	0	0	0	0	0	0
Total	**12,566**	**3,697**	**1,872**	**1,340**	**666**	**399**

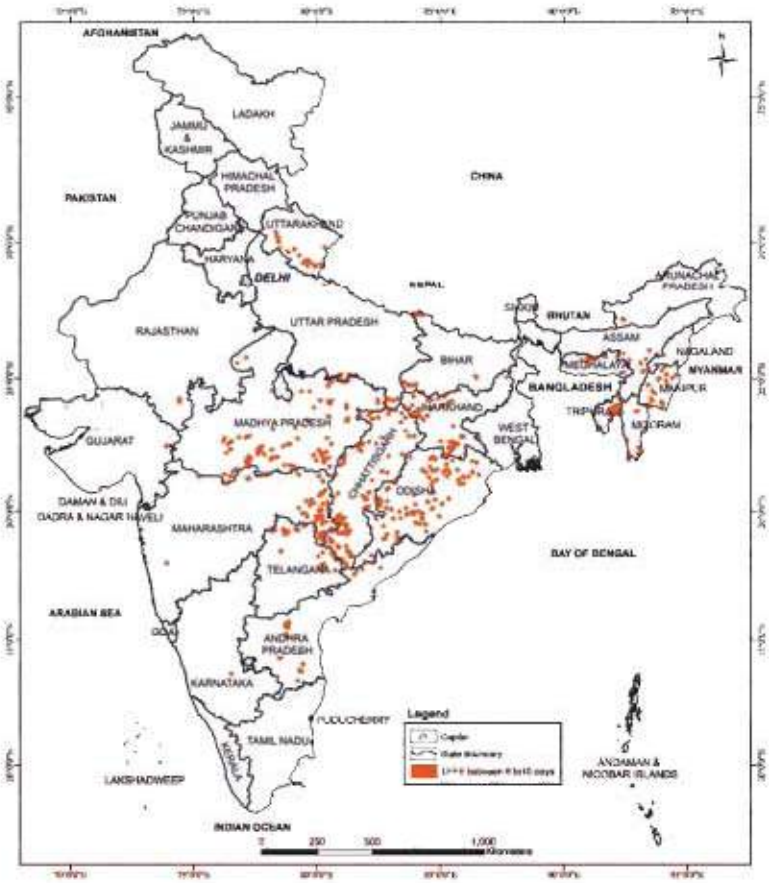
**Combined figures of Jammu & Kashmir and Ladakh*

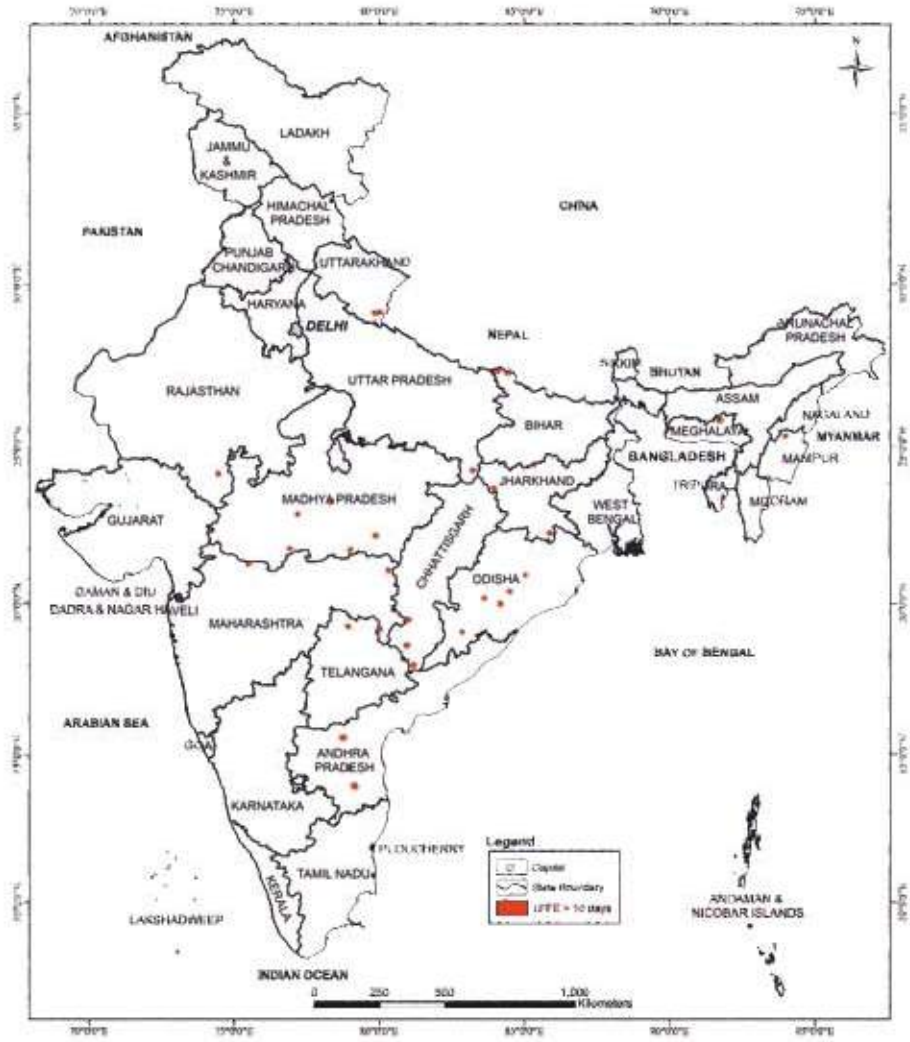
State Forest Department where it was first detected. If the State has not provided the administrative boundary, the LFF event is recorded after the name of the District. In cases, where multiple LFF events are detected in the same Range, the numerical numbering is suffixed after the name of the Range. 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.

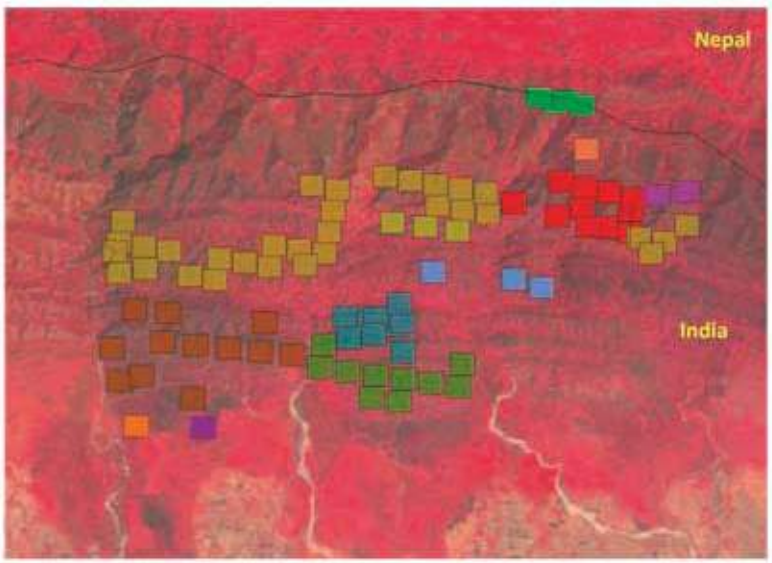
Number of active Days for LFF										
6	7	8	9	10	11	12	13	14	15	Total
9	6	2	1	1	0	2	0	1	0	1,319
1	0	0	0	1	0	0	0	0	0	278
7	2	1	4	0	0	0	0	0	0	688
8	4	0	0	0	0	0	1	0	1	274
51	21	12	5	3	3	0	0	0	0	2,057
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	3
0	1	0	0	0	0	0	0	0	0	211
0	0	0	0	0	0	0	0	0	0	9
0	0	0	0	0	0	0	0	0	0	265
0	0	0	0	0	0	0	0	0	0	70
18	20	5	2	1	1	0	1	1	0	1,082
0	1	0	0	0	0	0	0	0	0	407
0	0	0	0	0	0	0	0	0	0	18
45	24	14	8	4	4	1	0	0	0	2,970
28	11	7	7	5	1	1	1	0	0	2,201
11	6	4	0	0	0	1	0	0	0	784
10	5	3	0	0	1	0	0	0	0	446
5	4	1	1	0	0	0	0	0	0	826
2	1	0	1	0	0	0	0	0	0	410
44	21	15	4	2	3	2	0	0	0	3,044
0	0	0	0	0	0	0	0	0	0	36
2	0	0	0	0	1	0	0	0	0	213
0	0	0	0	0	0	0	0	0	0	6
0	0	0	0	0	0	0	0	0	0	93
14	7	8	4	3	1	0	0	0	0	1,052
6	6	1	1	2	1	0	0	0	0	393
4	4	3	1	2	0	1	0	0	0	465
10	5	4	2	0	1	0	1	0	0	1,339
0	0	1	0	0	0	0	0	0	0	179
0	0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	3
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
275	**149**	**81**	**41**	**24**	**17**	**8**	**4**	**2**	**1**	**21,142**

Figure 5.8
Map showing Large Forest Fire detections based on the number of active days of LFF









Date-wise SNPP - VIIRS Forest Fire Detection

2021/03/24	2021/03/27	2021/03/30	2021/04/04
2021/03/25	2021/03/28	2021/04/02	2021/04/07
2021/03/26	2021/03/29	2021/04/03	2021/04/08

Figure 5.9
Tracking of Large Forest Fire Event in Gobardaha-1 in the State of Bihar

Box 5.1
Monitoring Large Forest Fire in Dzukou Valley (Manipur-Nagaland)

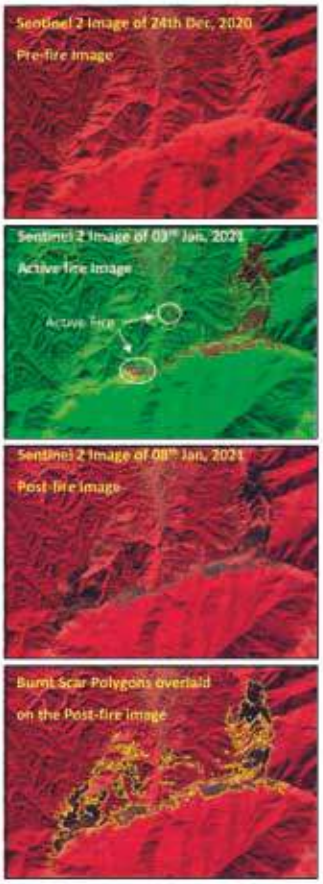
A large forest fire event was detected on 30th December in the Dzukou valley, which is located at the border of Manipur and Nagaland at an altitude of 2,452 m above sea level. Thereafter, it was continuously tracked by the LFF programme of FSI. To contain the forest fire, services of Army and paramilitary forces, NDRF & SDRF, Police and Forest (State government) and community volunteers were utilized. Four number of choppers from Indian Air Force were used actively.

Forest Fire detections in Dzukou valley

- First Detection: 30th Dec 2020, Time 00:50:28 (As per SNPP-VIIRS)
- Last Detection: 06th Jan 2021, Time 13:09:17 (As per SNPP-VIIRS)

Date	Detections by FSI		
	MODIS Pixels	SNPP-VIIRS Pixels	LFF Pixels
30.12.2020	2	5	#
31.12.2020	2	3	3
01.01.2021	1	#	#
02.01.2021	#	5	5
03.01.2021	#	5	5
04.01.2021	1	7	7
05.01.2021	5	6	6
06.01.2021	2	8	8

Data not received from NRSC



5.2.3 Early-Warning Alert based on Forest Fire Danger Rating

Early Warnings about potential forest fire situation in an area are useful in deciding upon 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 conditions 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 fire danger rating in India. Additionally Forest Type Layer information and Forest Fire Archival information are also being used to generate Forest Fire Danger Rating. The parameters are quantified and overlaid on grids of 5 km X 5 km.

FWI consists of six components that account for the effects of fuel moisture and weather conditions on fire behaviour. The first three components are fuel moisture codes, which are numeric ratings of the moisture content of the forest floor and other dead organic matter. Their values rise as the moisture content decreases. The remaining three components are 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. All information regarding FWI is downloadable from GEOS-5 daily data from NASA's GFWED database, which is satellite calibrated weather data. 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 using past archive data on a weekly basis. The Fire Danger Rating is categorized into five classes as 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 (http://vanagniportal.fsiforestfire.gov.in/fsi_fire/fire.html).

During Fire season, the Extreme Risk and Very High Risk categories of Forest Fire Danger Rating based on FWI values are disseminated as Early-warning Alerts (EWA) on every Thursday of the week to SFDs. EWA's are disseminated through e-mail as KML (Keyhole Markup Language) file, which is Google Earth compatible file, to Principal Chief Conservator of Forests (Head of Forest Force) and Forest Fire Nodal Officer of the SFD. Maps showing weekly detailed EWA disseminated to States and UTs are shown in Figure 5.10.

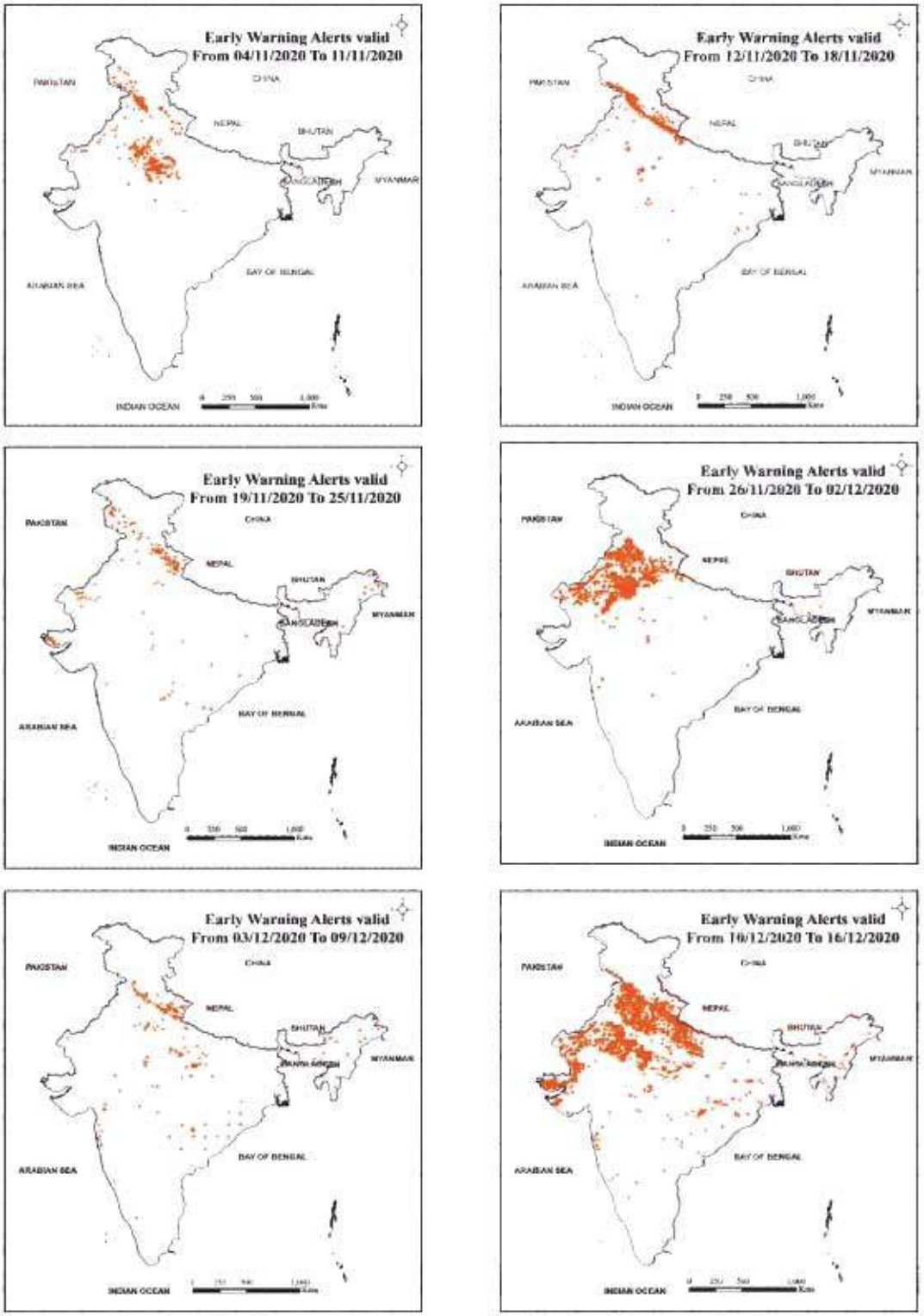
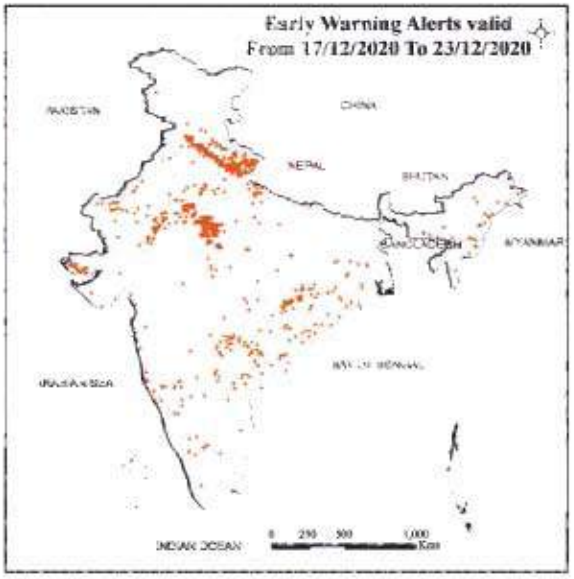


Figure 5.10
Weekly Early Warning Alerts disseminated in the fire season Nov 2020 - Jun 2021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BHUTAN
MYANMAR
INDIAN OCEAN
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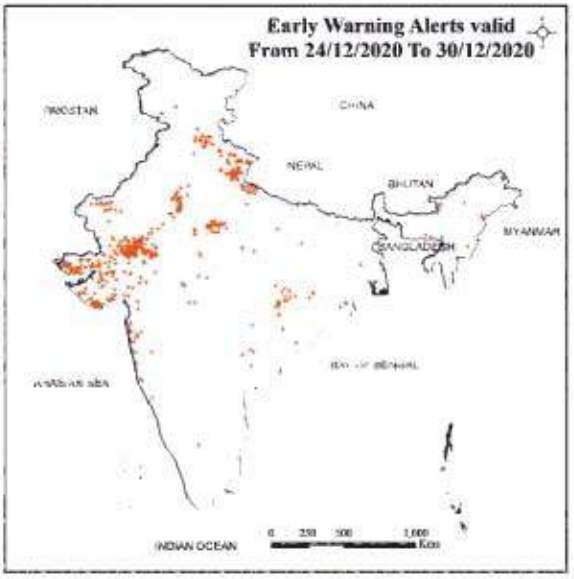
Kms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BHUTAN
MYANMAR
INDIAN OCEAN
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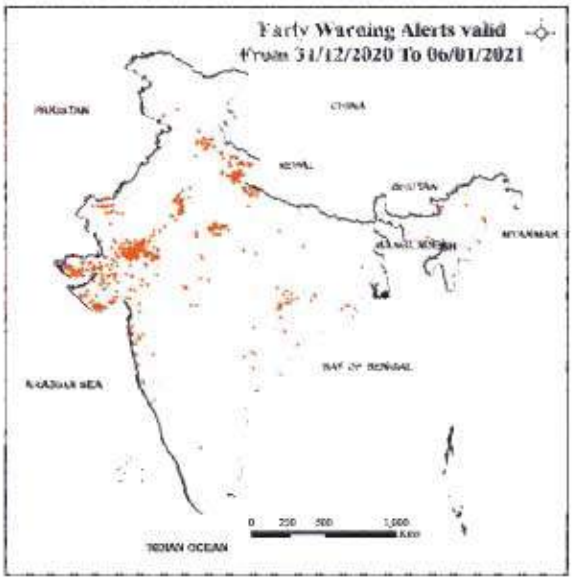
Kms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MYANMAR
BAY OF BENGAL
INDIAN OCEAN
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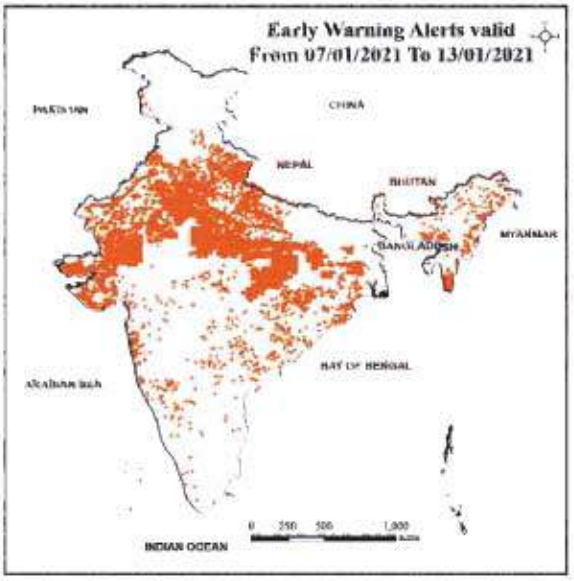
Kms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MYANMAR
BAY OF BENGAL
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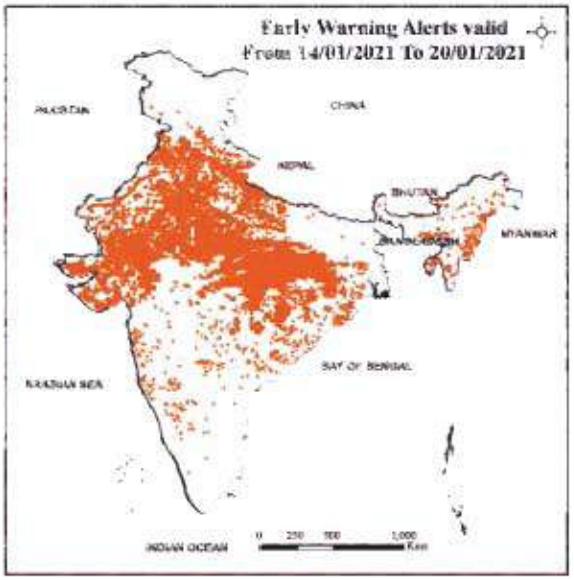
Kms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MYANMAR
BAY OF BENGAL
INDIAN OCEAN
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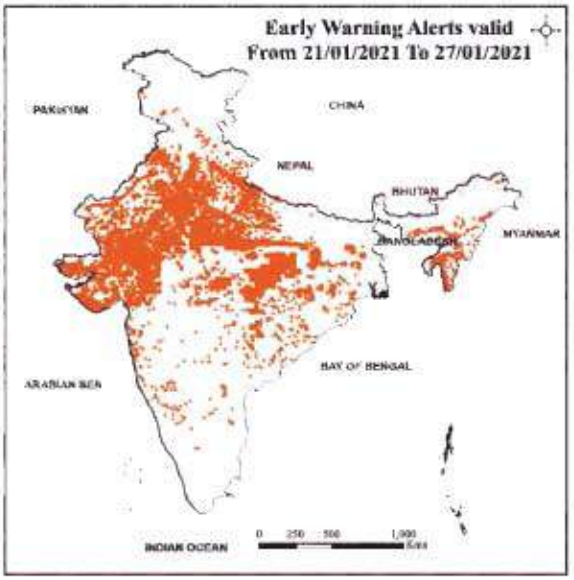
Kms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MYANMAR
BAY OF BENGAL
INDIAN OCEAN
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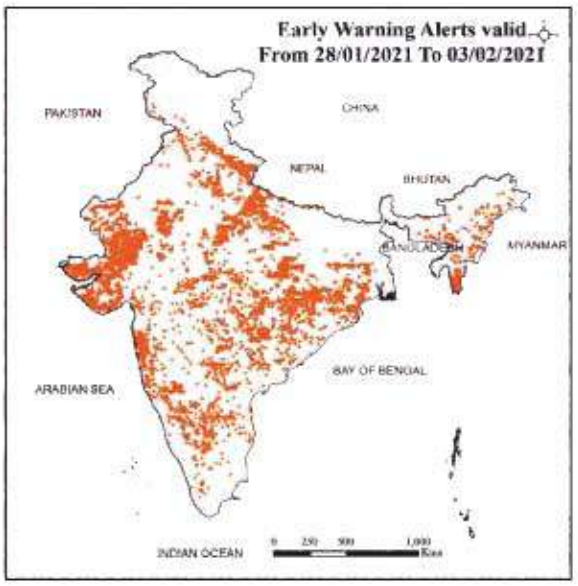
Kms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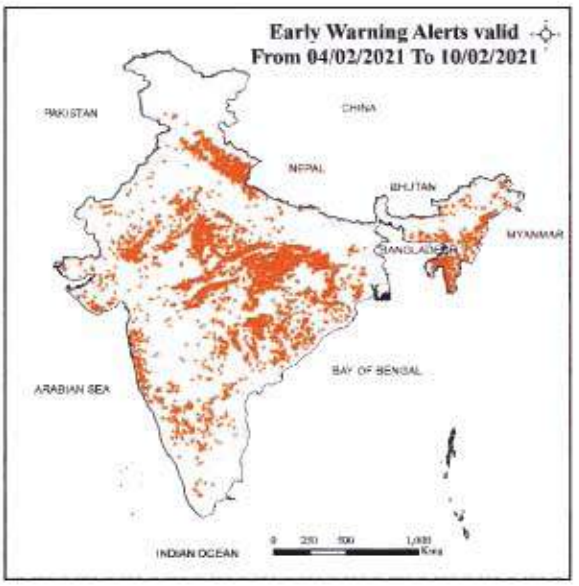
BHUTAN
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
0 250 500 1,000 Kms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NEPAL
BHUTAN
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
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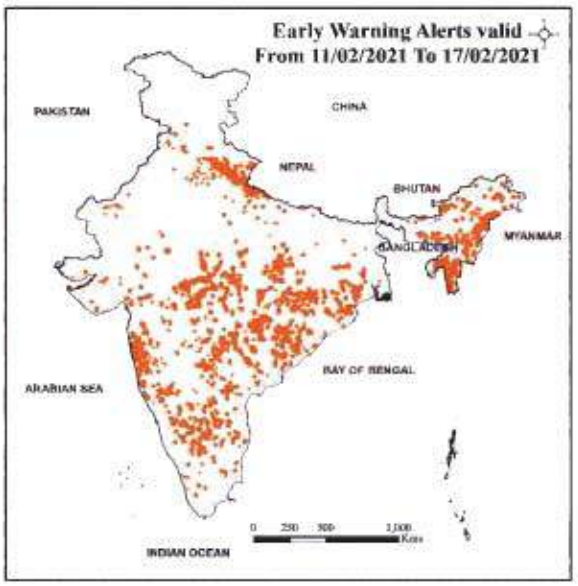
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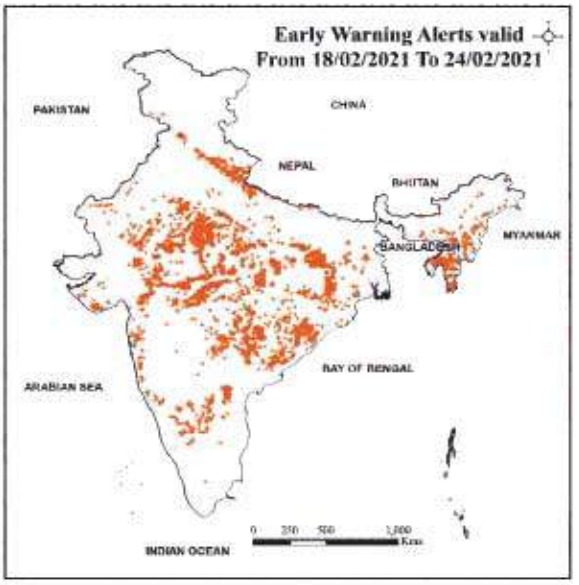
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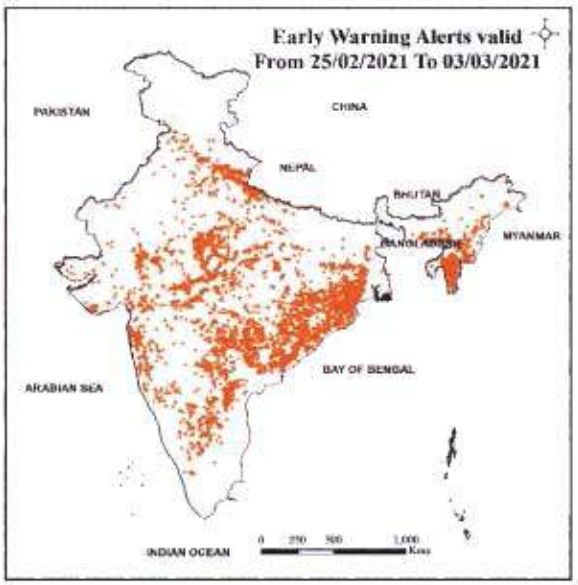
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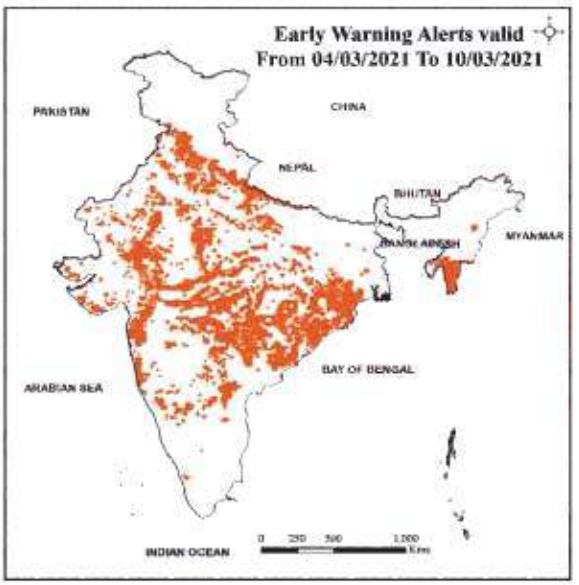
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INDIAN OCEAN
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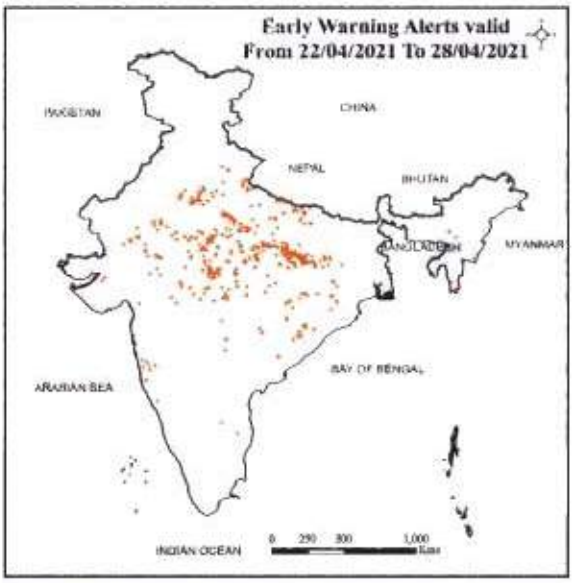
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BAY OF BENGAL
INDIAN OCEAN
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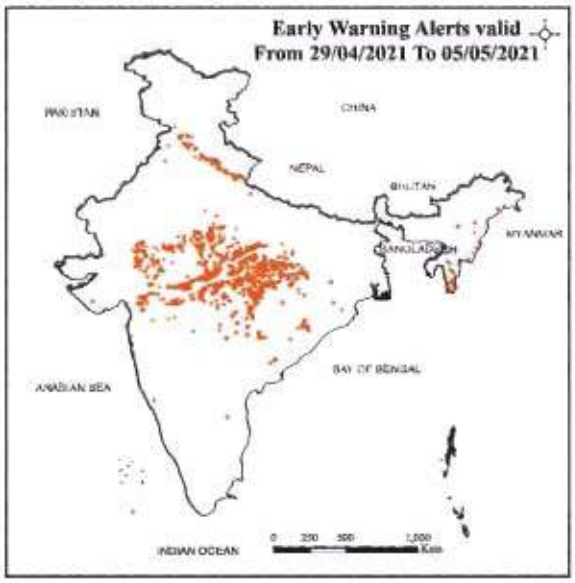
Kms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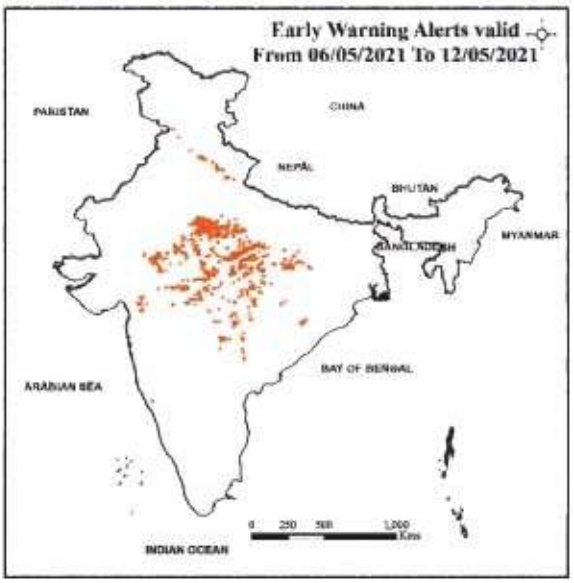
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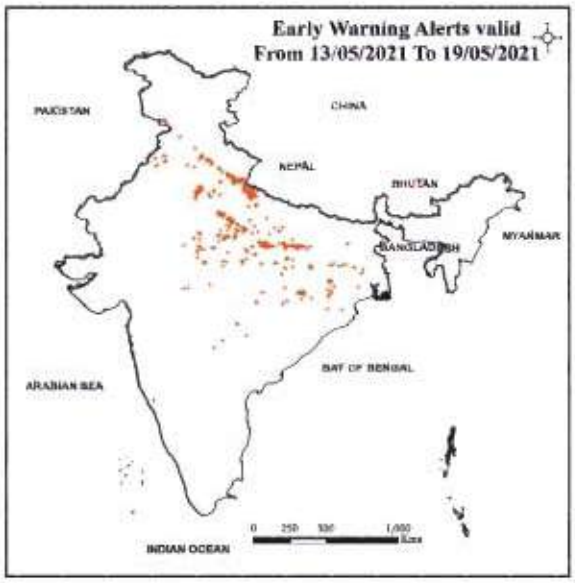
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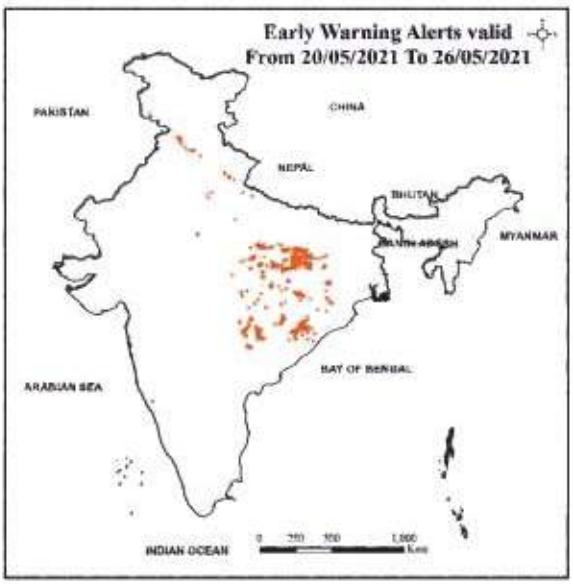
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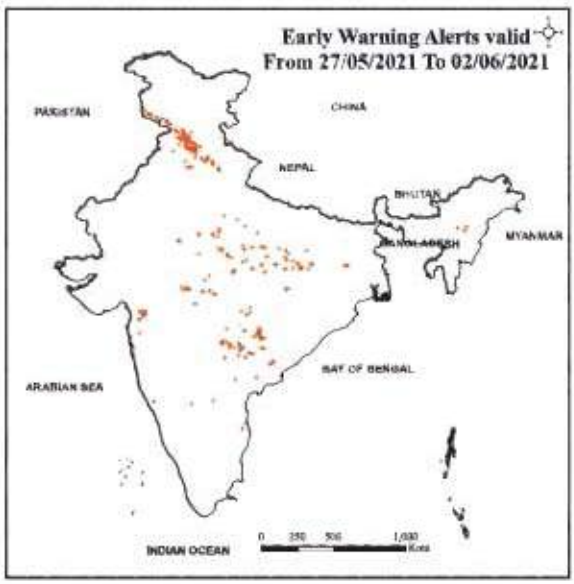
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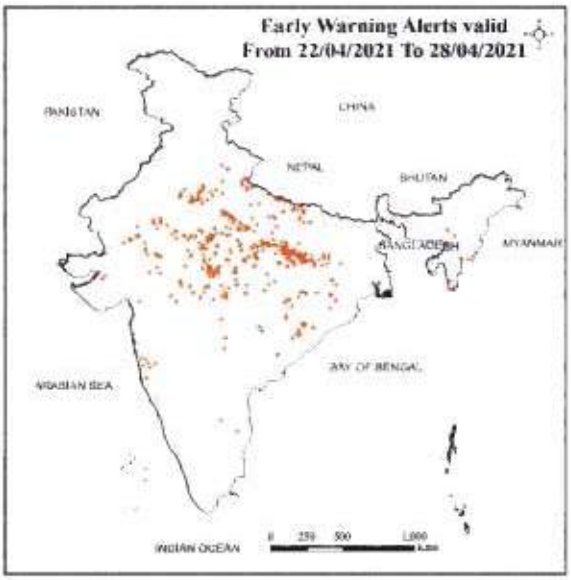
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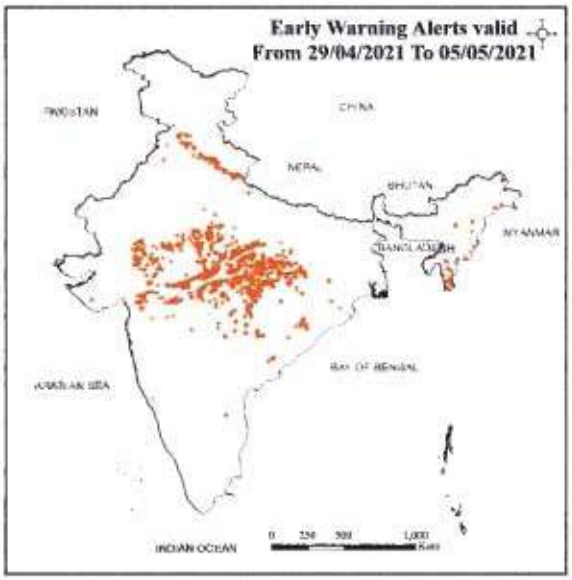
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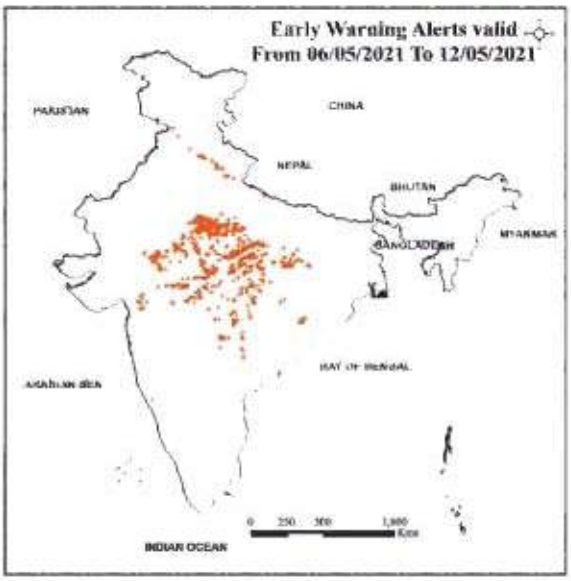
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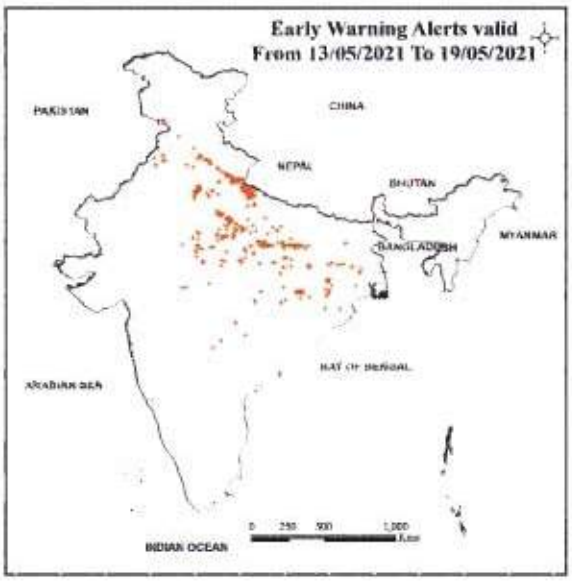
BAY OF BENGAL
INDIAN OCEAN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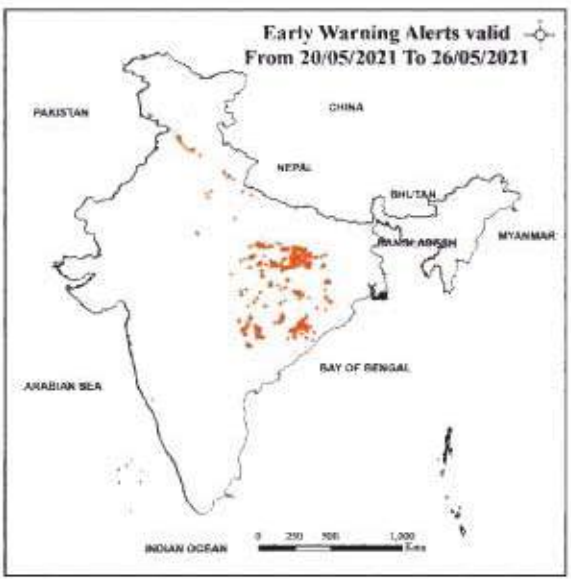
MYANMAR
ARABIAN SEA
INDIAN OCEAN


Early Warning Alerts valid
From 20/05/2021 To 26/05/2021
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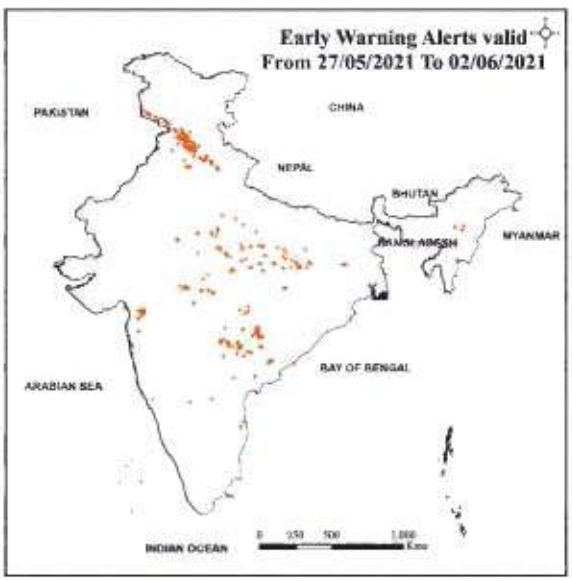
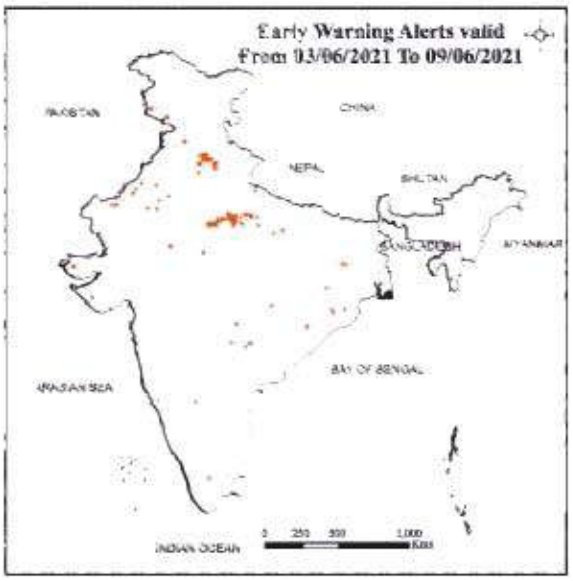
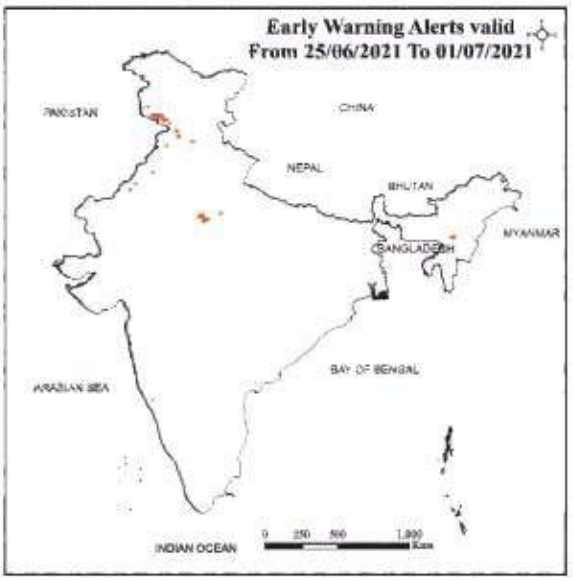
BHUTAN
MYANMAR
BAY OF BENGAL
ARABIAN SEA
INDIAN OCEAN


Early Warning Alerts valid
From 27/05/2021 To 02/06/2021
PAKISTAN
CHINA
NEPAL
BHUTAN
MYANMAR
BAY OF BENGAL
ARABIAN SEA
INDIAN OCEAN





5.2.4 FSI Van Agni Geo-portal

FSI Forest Fire Geo-portal, VAN AGNI 2.0 (http://vanagniportal.fsiforestfire.gov.in/fsi_fire/fire.html) is an in-house development of FSI, which was launched in 2019. It has been created using Open source Softwares viz. MapServer 7.0.7 & GeoMOOSE 2.9. The portal provides user-friendly interactive viewing where the user can view forest fire related data (forest fires, large forest fire events tracking etc. along with other thematic layers such as Forest administrative boundaries, Forest cover, Forest type, Fire prone forest area and FWI based fire danger rating etc.) pertaining to area of interest. Therefore, FSI Van Agni Geo-portal serves as a single point source for the information related to forest fires in India. A user can visualise Near Real-Time forest fire detected using MODIS & SNPP-VIIRS sensor of last three days in the portal. Besides this, Large Forest Fire Events showing active and inactive pixels and Forest Fire Danger Rating are available on the portal. This information is uploaded every Thursday of the fire season and is valid for the ensuing week.

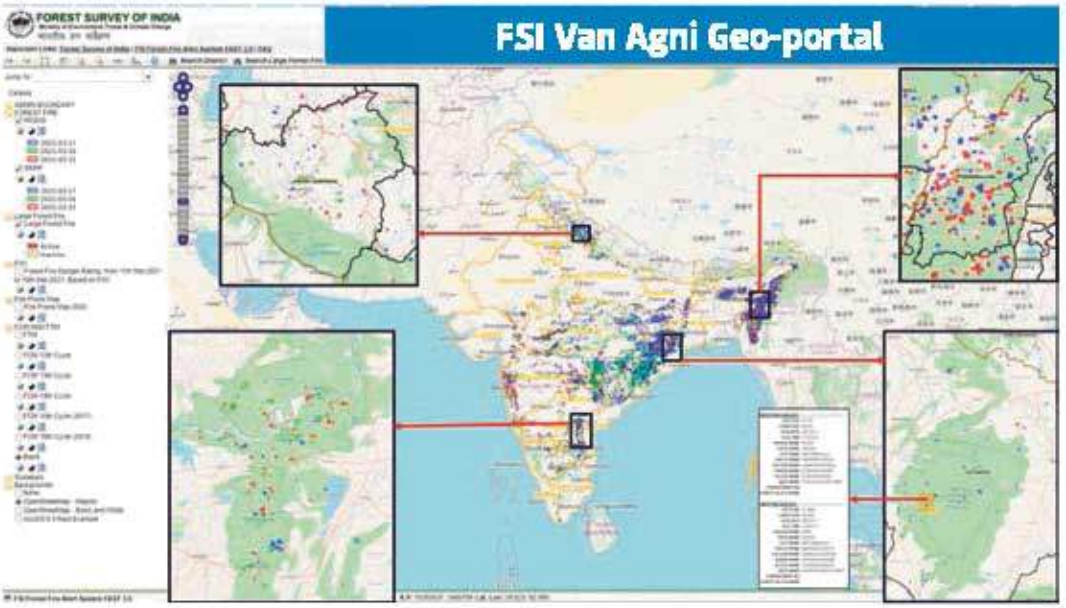


Figure 5.11
FSI Van Agni Geo-portal

Identification of Fire Prone Forest Areas 5.2.5

FSI has carried out a study based on spatial analysis of forest fire points detected by FSI in the last 17 years (2004-2021) to identify fire prone forest areas in the country. Extent of forest cover 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 effectively prevent forest fires. 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 under different fire prone classes is given in Table 5.9. Map showing fire prone forest areas in the country under different categories is presented as Figure 5.12. State/UT wise details of forest cover under different fire proneness categories is presented in Table 5.10.

Highlights of the study 5.2.5.1

- As per the long-term trend analysis performed by FSI, nearly 10.66% area of Forest Cover in India is under extremely to very highly fire prone zone.
- States under North-Eastern Region, showed the highest tendency of forest fire, and these states fall under extremely to very highly forest fire zone.
- States like Mizoram, Tripura, Meghalaya, and Manipur in North-Eastern Part of India exhibit the highest forest fire probability in terms of its frequency of event occurrence.
- Parts of Western Maharashtra, Southern part of Chhattisgarh, Central part of Odisha and few parts of Andhra Pradesh, Telangana and Karnataka are showing 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 5.9 Forest cover in different fire prone classes

SL No.	Category	Forest cover (in sq km)	% of Total forest cover
1.	Extremely Fire Prone	20,074.47	2.81
2.	Very Highly Fire Prone	56,049.35	7.85
3.	Highly Fire Prone	82,900.17	11.61
4.	Moderately Fire Prone	94,126.68	13.19
5.	Less Fire Prone	4,60,638.36	64.54
	Total	7,13,789.03	100.00

5.2.6 Sharing of WMS and WFS service

FSI creates and shares Web Map Service (WMS) and Web Feature Service (WFS) of near real-time monitoring of forest fires, large forest fires and FWI based danger rating on demand basis to the State Forest Department. States such as Uttarakhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Telangana etc. are consuming these services effectively. North Eastern Space Applications Centre (NESAC), Shillong is also using these service for entire North-Eastern States.

The Open Geospatial Consortium Web Feature Service (WFS) Interface Standard provides an interface, which allows requests for geographical features across the web, using platform-independent calls. One can think of geographical features as the "source code" behind a map,

Table 5.10 Forest cover of State & UTs under different fire prone classes

Sl.No.	State/ UT	Extremely Fire Prone		Very Highly Fire Prone	
		Forest cover	% of total Forest cover	Forest cover	% of total Forest cover
1.	Andhra Pradesh	1,150.13	3.86	3,832.50	12.87
2.	Arunachal Pradesh	35.16	0.05	959.78	1.44
3.	Assam	3,166.11	11.18	4,871.05	17.20
4.	Bihar	24.38	0.33	471.89	6.39
5.	Chhattisgarh	1,935.04	3.47	3,655.58	6.56
6.	Delhi	0.00	0.00	0.00	0.00
7.	Goa	0.00	0.00	0.00	0.00
8.	Gujarat	8.08	0.05	384.42	2.58
9.	Haryana	0.00	0.00	20.40	1.27
10.	Himachal Pradesh	0.00	0.00	6.81	0.04
11.	Jammu & Kashmir	0.00	0.00	17.90	0.08
12.	Jharkhand	47.36	0.20	480.45	2.03
13.	Karnataka	71.58	0.18	930.93	2.40
14.	Kerala	0.00	0.00	54.79	0.26
15.	Madhya Pradesh	336.52	0.43	4,730.92	6.10
16.	Maharashtra	470.68	0.93	3,585.37	7.06
17.	Manipur	1,636.46	9.85	6,167.06	37.16
18.	Meghalaya	1,588.24	9.32	3,505.49	20.56
19.	Mizoram	4,683.50	26.28	8,862.58	49.73
20.	Nagaland	352.24	2.88	3,129.20	25.54
21.	Odisha	1,226.66	2.35	3,930.36	7.54
22.	Punjab	0.00	0.00	53.86	2.92
23.	Rajasthan	0.00	0.00	197.33	1.18
24.	Sikkim	0.00	0.00	0.00	0.00
25.	Tamil Nadu	0.00	0.00	38.78	0.15
26.	Telangana	571.87	2.70	2,970.26	14.00

whereas the WMS interface returns only an image, which end-users cannot edit or spatially analyse.[7]

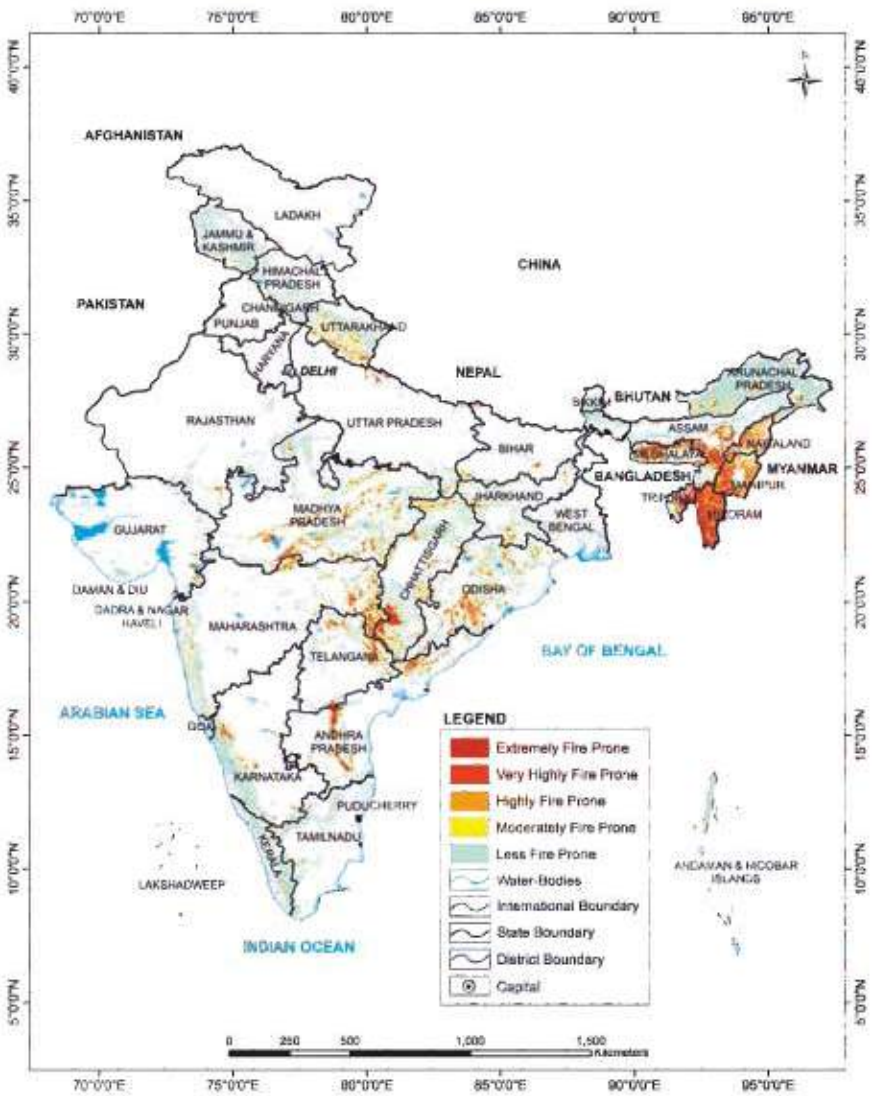
The WMS/ WFS of near real-time monitoring of forest fire consists of the layers of MODIS and SNPP-VIIRS sensor detections for last three days (including current day), represented by different legends. The WMS/WFS of large forest fire events consists of incidents of large forest fire of the current fire season. The WMS of the FWI based danger rating consists of different categories of danger rating which is applicable for ensuing week.

Highly Fire Prone		Moderately Fire Prone		Less Fire Prone	
Forest cover	% of total Forest cover cover	Forest cover	% of total Forest Cover	Forest cover	% of total Forest cover
4,915.11	16.50	4,153.69	13.95	15,732.57	52.82
2,744.51	4.13	4,459.73	6.71	58,231.82	87.67
3,400.46	12.01	2,653.93	9.37	14,220.45	50.24
984.48	13.34	1,173.58	15.90	4,726.67	64.04
8,159.70	14.64	11,275.57	20.24	30,691.11	55.09
0.00	0.00	0.00	0.00	195.00	100.00
0.00	0.00	0.00	0.00	2,244.00	100.00
523.32	3.51	975.10	6.53	13,035.08	87.33
66.81	4.17	154.50	9.64	1,361.29	84.92
305.56	1.98	999.03	6.47	14,131.60	91.51
321.68	1.50	857.95	4.01	20,189.47	94.41
2,159.16	9.10	4,227.02	17.82	16,807.01	70.85
2,506.25	6.47	2,989.30	7.72	32,231.94	83.23
461.06	2.17	1,266.42	5.96	19,470.73	91.61
10,889.70	14.05	15,231.85	19.66	46,304.01	59.76
8,540.70	16.81	9,377.92	18.46	28,823.33	56.74
5,423.48	32.68	2,096.16	12.63	1,274.84	7.68
3,716.73	21.80	2,900.24	17.02	5,335.30	31.30
3,369.82	18.91	543.28	3.05	360.82	2.03
4,849.90	39.59	2,477.96	20.23	1,441.70	11.76
7,634.76	14.64	10,086.77	19.34	29,277.45	56.13
254.95	13.80	375.30	20.32	1,162.89	62.96
366.57	2.20	705.56	4.24	15,385.54	92.38
0.00	0.00	25.30	0.76	3,315.70	99.24
470.00	1.78	1,910.94	7.23	23,999.28	90.84
3,920.18	18.48	3,522.07	16.60	10,229.62	48.22

[7] https://en.wikipedia.org/wiki/Web_Feature_Service

Sl.No.	State/ UT	Extremely Fire Prone		Very Highly Fire Prone		
		Forest cover	% of total Forest cover	Forest cover	% of total Forest cover	
27.	Tripura	2,491.90	32.27	1,249.76	16.18	
28.	Uttar Pradesh	209.30	1.41	1,043.54	7.04	
29.	Uttarakhand	49.21	0.20	757.92	3.12	
30.	West Bengal	20.05	0.12	120.03	0.71	
31.	Andaman & Nicobar Islands	0.00	0.00	20.39	0.30	
32.	Chandigarh	0.00	0.00	0.00	0.00	
33.	Dadra & Nagar Haveli and Daman & Diu	0.00	0.00	0.00	0.00	
34.	Ladakh	0.00	0.00	0.00	0.00	
35.	Lakshadweep	0.00	0.00	0.00	0.00	
36.	Puducherry	0.00	0.00	0.00	0.00	
	Total	20,074.47	2.81	56,049.35	7.85	

Figure 5.12
Map showing forest areas under different fire prone classes



Highly Fire Prone		Moderately Fire Prone		Less Fire Prone	
Forest cover	% of total Forest cover cover	Forest cover	% of total Forest Cover	Forest cover	% of total Forest cover
812.80	10.53	641.61	8.31	2,525.93	32.71
1,555.38	10.50	2,070.29	13.97	9,939.49	67.08
4,070.09	16.75	5,887.70	24.22	13,540.08	55.71
425.63	2.53	1,050.42	6.24	15,215.87	90.40
51.38	0.76	37.49	0.56	6,634.74	98.38
0.00	0.00	0.00	0.00	22.88	100.00
0.00	0.00	0.00	0.00	227.75	100.00
0.00	0.00	0.00	0.00	2,272.00	100.00
0.00	0.00	0.00	0.00	27.10	100.00
0.00	0.00	0.00	0.00	53.30	100.00
82,900.17	11.61	94,126.68	13.19	4,60,638.36	64.54

Box 5.2
Initiatives by National Disaster Management Authority on Forest Fire

National Disaster Management Authority (NDMA), under Ministry of Home Affairs, is the apex body mandated to lay down the policies, plans and guidelines for Disaster Management. India envisions the development of an ethos of Prevention, Mitigation, Preparedness and Response.

Following are some of the important initiatives taken by National Disaster Management Authority (NDMA) towards coordinating the work related to mitigation and management of Forest fires:

- Common Alert Protocol (CAP): Under NDMA, CAP is being implemented. Under CAP, a standard message format which contains all the relevant details like type of hazard, intensity, duration, area of impact and actions to be taken are clearly defined. CAP compliant systems and devices like the GSM network, Radio, Television etc. can plug and play with a CAP based alerting system. Forest fire alerts are proposed to be added to CAP.

- Awareness Generation: A list of do's and don'ts has been prepared by NDMA and has been shared with all the forest fire prone states. These do's and don'ts are being widely circulated on various official social media handles of NDMA like Facebook, Twitter etc.

- **Research on Forest Fire:**

1. NDMA has undertaken studies to understand forest fire management within India as well as globally. A report was compiled on international best practices on forest fire management across the globe. The report is available on NDMA's website www.ndma.gov.in under the link Resources -> Reports and Studies -> Forest Fire Management Global Best Practices.
2. A study to document indigenous forest fire management practices across India has been initiated in collaboration with Forest Research Institute.

- **Management of Active Forest Fire:** The massive forest fire break outs often cover multiple states. In order to contain/ manage these forest fires, the National Disaster Recovery Force (NDRF) was engaged in dousing the active fires. In the forest fire in Dzukou Valley in Manipur & Nagaland and in Uttarakhand in 2021, NDRF along with other armed forces and State agencies, played an active role in limiting the spread of fire as well as in search and rescue where required.

06

TREE COVER

Introduction 6.1

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

Figure 6.1 Linear young plantation along road

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

Figure 6.2 Block plantation

6.2 Tree Cover and Trees Outside Forest (TOF)

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

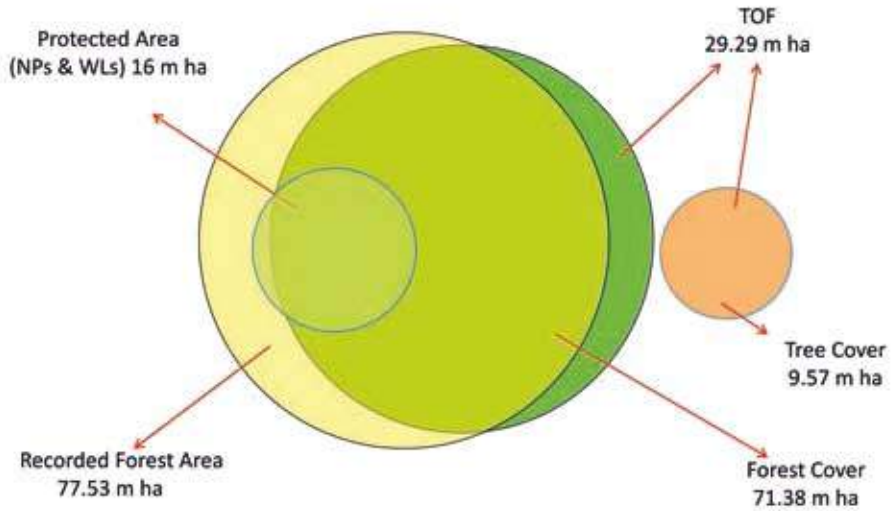


Figure 6.3 Relationship between the TOF and Tree Cover

6.3 Methodology for Tree Cover estimation

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

Estimation of Tree Cover in Rural Areas 6.3.1

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

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

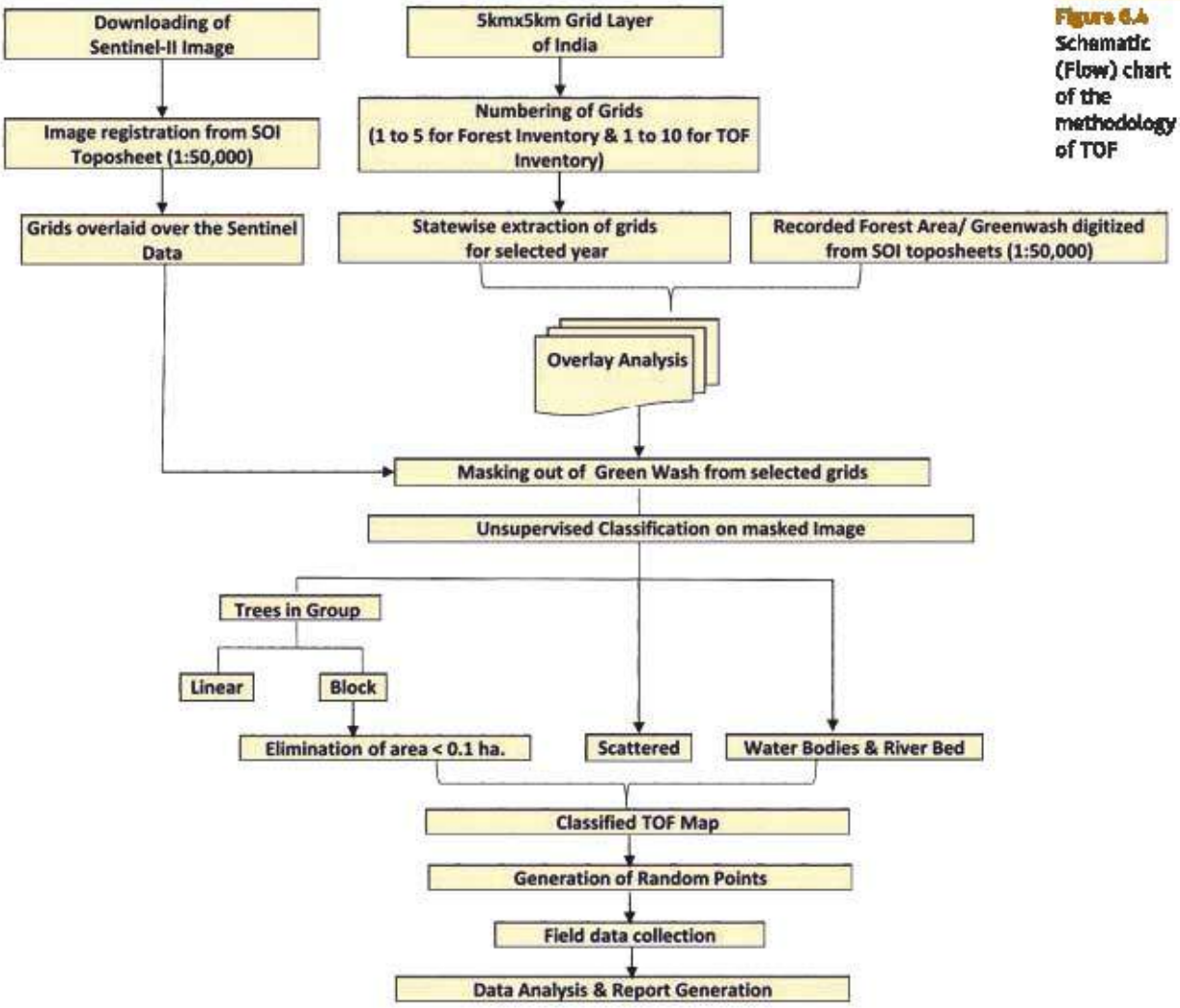


Figure 6.4 Schematic (Flow) chart of the methodology of TOF

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

Figure 6.5 TOF Inventory - Scattered stratum

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

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

Figure 6.6 Trees along Canal

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

Estimation of Tree Cover in Urban Areas 6.3.2

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

Figure 6.7
Trees in urban setting

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

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

6.4 State-wise estimates of Tree Cover

The total tree cover of the country has been estimated 95,748 sq km. There is an increase of 721 sq km in the extent of tree cover as compared to the previous assessment of 2019. The standard error of the tree cover estimate at the national level has been assessed at 4.01%. The State wise estimates of tree cover is given in Table 6.1. The standard error at the State level varies from 2.29% to 16.49%. As per Table 6.1, the State having maximum tree cover is Maharashtra (12,108 sq km) followed by Rajasthan (8,733 sq km), Madhya Pradesh (8,054 sq km), Karnataka (7,494 sq km) and Uttar Pradesh (7,421 sq km). Considering the percentage of geographical area of State/UTs, the UT of Chandigarh shows highest percentage of tree cover (13.16%) followed by Delhi (9.91%), Kerala (7.26%), and Goa (6.59%).

Table 6.1 State/ UT wise Tree Cover Estimates

(In sq km)

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

(In sq km)

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

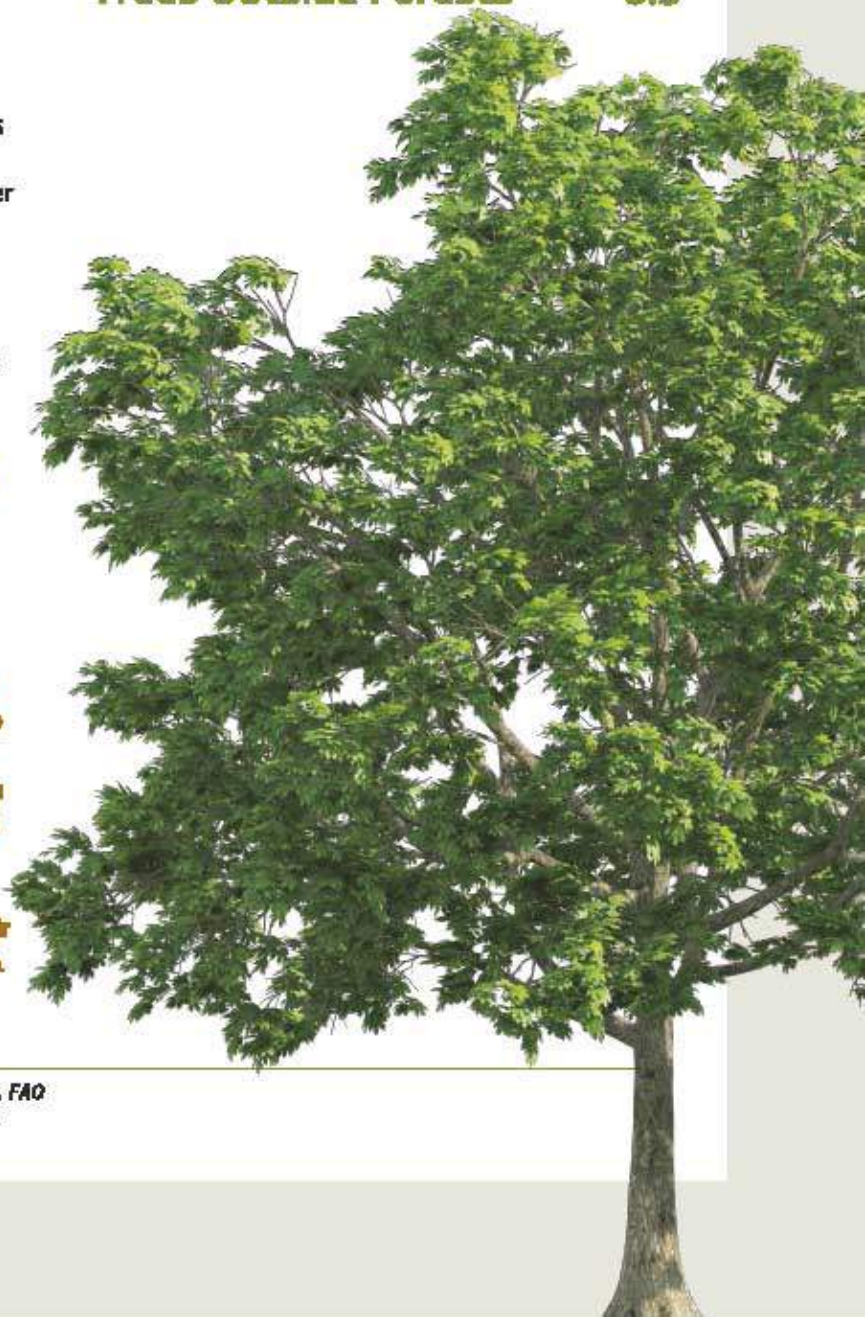
* *Includes Jammu & Kashmir area outside LOC that is under illegal occupation of Pakistan and China.*

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

6.5 Trees Outside Forests

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

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



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

6.5.1 Extent of TOF

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

Table 6.2 State/UT wise extent of TOF (In sq km)

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

(In sq km)

S. No.	State / UT	Geog. area	Tree cover	Forest cover outside RFA	Extent of TOF	%of Forest & Tree Cover of the State/UTs	% of Geog. area of the State/UTs
32.	Dadra & Nagar Haveli and Daman & Diu*	602	32	68	100	38.39	16.57
33.	Jammu & Kashmir* (Shape file Area= 54,624)	2,22,236	3,511	8,211	11,722	47.08	21.46
34.	Ladakh (Shape File Area = 1,68,055)		954	1,472	2,426	75.20	1.44
35.	Lakshadweep	30	0.05	27	27	100.00	90.5
36.	Puducherry	490	23	52	75	98.69	15.37
	Total	**32,87,469**	**95,748**	**1,97,159**	**2,92,907**	**38.18**	**8.91**

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

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

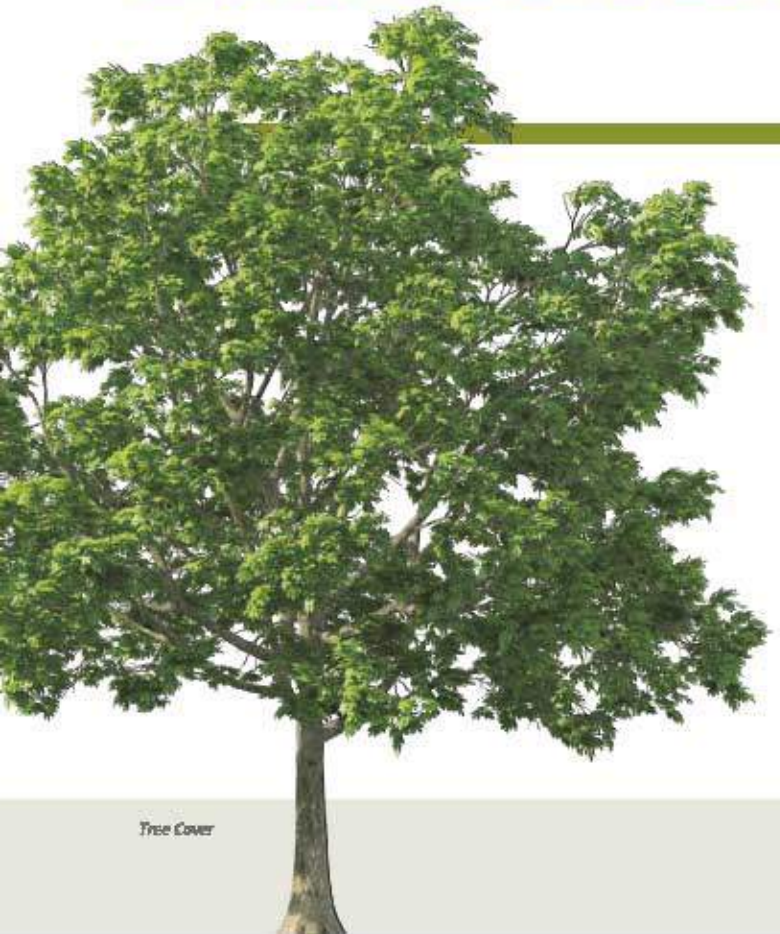
** The States/ UTs have updated the RFA boundaries, accordingly the RFA area has also changed and it is different than the figures reported in ISFR 2019.*

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

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

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

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



Tree Cover

6.6 Conclusion

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

07

GROWING STOCK

Introduction 7.1

In simple terms, Growing Stock is the volume of all living trees in a forested area. Periodic estimation of the growing stock of wood is essential for developing national policies and strategies for sustainable use of the forest resources. Growing stock is an important, quantifiable parameter and used to calculate the tangible economic value of forests, is an indicator of sustainability and productivity of forests and forms the basis for calculating biomass and carbon stock. Assessment of growing stock inside the forests provides information on the volume of wood available inside forests. Similarly, estimation of growing stock outside the forests is essential for the assessment of volume of timber availability outside the forests. Presently, in India, Trees Outside Forest (TOF) has become the major source of wood for different uses.

Forest Inventory, carried out by Forest Survey of India (FSI), is essentially aimed at assessing the growing stock and several other important quantitative and qualitative parameters of the forests. In the Working Plans, the growing stock is being used for calculation of sustainable yield of timber from forests. In the existing climate change scenario, the estimation of growing stock has assumed significance. Forest owners, planners, managers and policy makers often need the detailed information about different forestry parameters viz. distribution of timber species, volume, biomass, carbon stock, regeneration status, population and structures etc. within different regions of the country for strategic planning and sustainable management of the forest and forest resources. Furthermore, the United Nations Framework Convention on Climate Change (UNFCCC) guidelines for implementation of REDD+ requires that every country should have a National Forest Monitoring System (NFMS) comprising of satellite-based forest monitoring system and National Forest Inventory.

FSI's role in generating information on growing stock of forests dates back to 1965, when the Pre-Investment Survey of Forest Resources (PISFR), the precursor of FSI, was established as a joint project of FAO, UNDP and Government of India. Its main task was to estimate availability of wood from forest rich areas of the country for establishing wood-based industries. The inventory was carried out in specific regions and did not have a pan-Indian character. Different sampling designs were followed in different parts of the country. After the organization was renamed as Forest Survey of India in 1981 with a revised mandate, inventory continued to remain a key activity and was expanded to cover more forest areas by following a uniform sampling design. By the year 2001, about three-fourth of the country's forests had been inventoried and some areas had been inventoried twice.

Figure 7.1
Recording field observations during forest inventory

Figure 7.2
Measurement of crown diameter during forest inventory

The forest inventory carried out by FSI during the above period was limited to the selected areas. As the inventory in different parts of the country was carried out in different time periods, the results could not be used to produce national level estimates of growing stock. In view of this, FSI modified its sampling design and revised the methodology in 2002 in order to generate national level estimates of growing stock at an interval of two years from 2003 onwards. As per the design, the country was stratified into 14 different physiographic zones based on the physiography, climate, vegetation etc. The forest inventory was based on systematic sampling approach wherein 60 districts, spread across the country, used to be selected in each biennial cycle in different physiographic zones for the inventory. The sample plots were laid in 1 ¼' x 1 ¼' grids to cover the entire country in 20 years. This design was continued till 2016 when it was again modified with the objectives of generating National and State level estimates at acceptable precision level and reduce the revisit time from 20 years to 5 years for forest and 10 years for TOF to meet the requirements of information on additional parameters.

New National Forest Inventory (NFI) Design 7.2

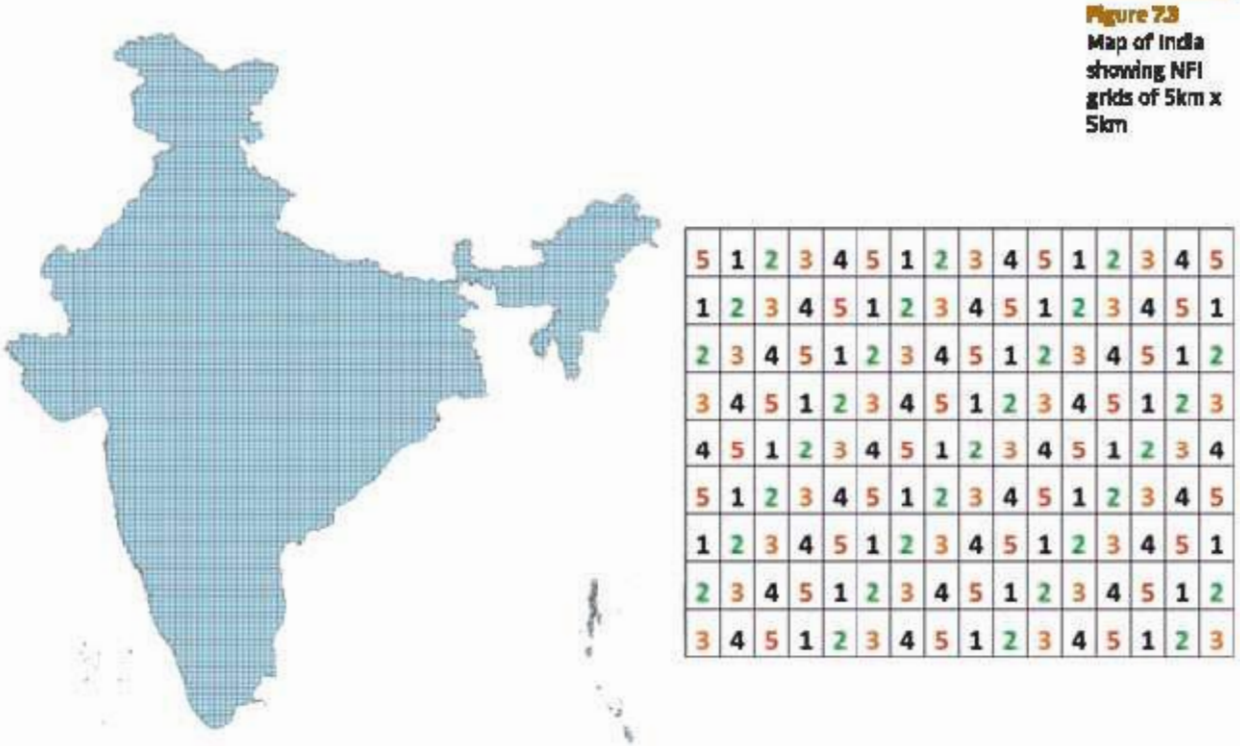
The three components of NFI are Forest Inventory, TOF (Rural) Inventory and TOF (Urban) Inventory. A brief overview of the methodology of each of the three components is given in the following sub sections.

Forest Inventory 7.2.1

As per the new inventory design of 2016, NFI is carried out in 5 km x 5 km systematically selected grids, uniformly distributed across the country as shown in Figure 7.3 below. The plot configuration for fieldwork has also been changed from a single square plot to a cluster of circular plots. Before shifting to the new design, extensive technical discussions were held in FSI, along with the representatives of some State Forest Departments. Pilot studies were carried out in the zonal offices of FSI to ascertain the size of the circular plots and distance between central sub-plots and other sub-plots. Additional parameters such as Non Timber Forest Produce (NTFP), invasive species, water bodies near sample plots, diseases etc. have also been included in the forest inventory.

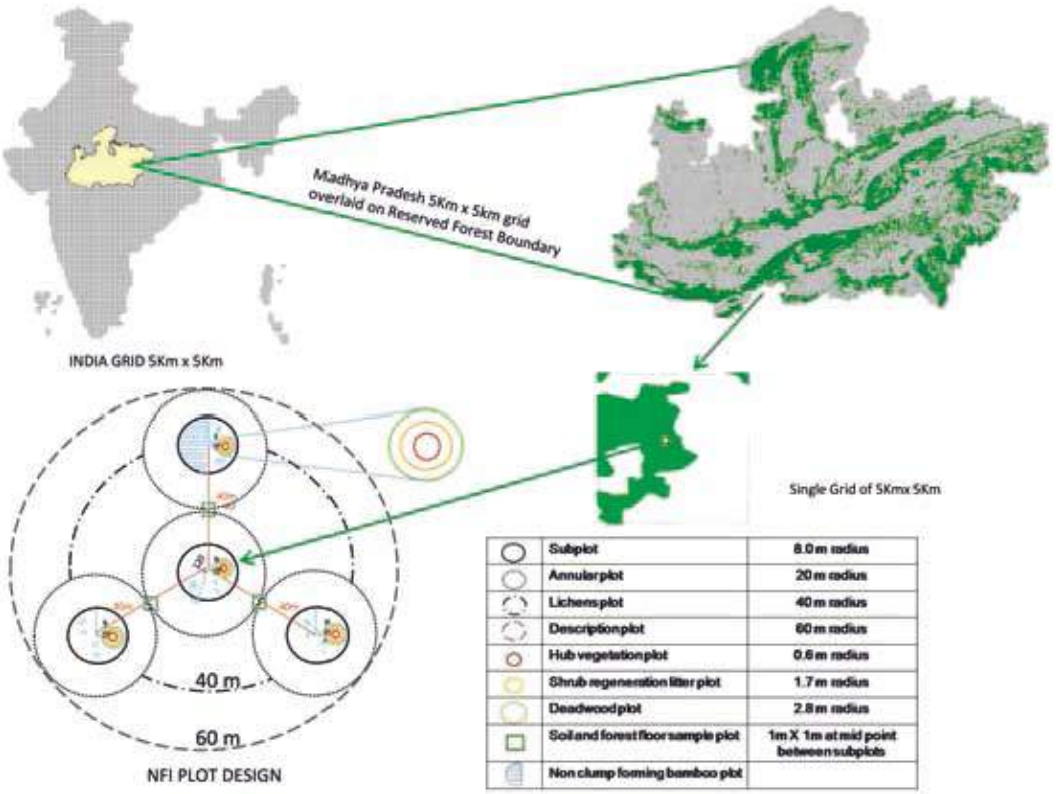
For forest inventory, the revisit time to the same grid has been fixed at 5 years and for TOF at 10 years. Accordingly, for forest inventory, all grids are numbered as 1 to 5 and for TOF inventory, the grids are numbered as 1 to 10. The digital layer of RFA/ Green Wash boundaries has been used to determine the grids for forest inventory. Since 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 using past inventory data and the digital layer of RFA/ Greenwash. Grids having specific number in the panel are covered in a single survey year.

Figure 7.3
Map of India showing NFI grids of 5km x 5km



Within the selected forest grids, random points are generated using Geographical Information System (GIS). These points form the plot centre of the sample point, 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 at a specified angle as shown in the Figure 7.4. Further micro plots within each sub-plot are laid out for collection of data on herbs, shrubs, regeneration and dead wood. The list of sample plots are 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.

Figure 7.4
Plot configuration of NFI



	Subplot	8.0 m radius
	Annular plot	20 m radius
	Lichens plot	40 m radius
	Description plot	60 m radius
	Hub vegetation plot	0.6 m radius
	Shrub regeneration litter plot	1.7 m radius
	Deadwood plot	2.8 m radius
	Soil and forest floor sample plot	1m X 1m at mid point between subplots
	Non clump forming bamboo plot	

7.2.2 Trees Outside Forest (TOF) Inventory

Since the cycle for the TOF inventory in the new design has been fixed at 10 years, all TOF grids are marked with numbers 1 to 10. 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. For urban TOF inventory, urban centres defined by the Registrar General & Census Commissioner of India are considered as study area. The sampling unit for urban inventory is taken as Urban Frame Survey (UFS) from National Statistical Office (NSO).

The urban centres of a district are delineated into blocks called 'UFS blocks', which are shown on maps with well-defined boundaries, and generally cover a population of 600 to 800 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 5km x 5km 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' will be considered for 1st year TOF (Urban) inventory and number 'five' in the second year and likewise 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. Remaining grids are covered under TOF (Rural) inventory.

For the TOF (Rural) inventory, a two-phase sampling design is used. In the first phase, the selected grid areas are stratified into block, linear and scattered strata using high resolution remote sensing satellite data. In the second phase, optimum sample points are generated in the selected grids. 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.

The Multispectral data of Sentinel-II satellite having a spatial resolution of 10 m and swath of 290 km has been used for classification of the selected grids. The satellite data is downloaded and geo-rectified with the help of Survey of India (SOI) Open Series Map (OSM) toposheets of 1:50,000 scale. Thereafter, the image is classified into various land use classes such as settlements, water bodies, tree cover, agriculture and other land cover classes. This classification enables the analyst to distinguish between the tree cover and other classes. The classified image is visually analysed for editing and refinement. Since the minimum mappable area is 0.1 ha, the pixels are clumped and cluster of pixels having area less than 0.1 ha are eliminated. After editing the classified image, final classified map is generated showing three classes in TOF areas, namely Block, Linear and Scattered. From the classified TOF map, area under each class is calculated. In addition, area of Un-Culturable Non-Forest Areas, which do not support tree vegetation, such as rivers and water bodies, riverbeds, snow covered mountains etc. is also calculated. The schematic chart of the methodology of TOF using remote sensing is depicted in the Figure 6.4 in Chapter - 6.

For the fieldwork, the plot size for Block and Linear strata is 0.1 ha square plot and 10m x 125m strip, respectively. In case of Scattered stratum, the plots size is 0.5 ha in hilly areas and 3.0 ha in non-hilly areas.

7.3 Data Processing

The data is entered using a data entry module, which has been designed and developed separately for Forest, TOF (Rural), and TOF (Urban) inventories by FSI. The entered data is checked thoroughly for any inconsistency and cleaned prior to processing. Data processing is carried out separately for forest, TOF (rural) and TOF (urban).

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. Thereafter, per plot area (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, open and plantations) 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 were post-stratified according to crop composition (stratum) based on dominant species appearing in a particular State. Plot volume is calculated with the help of volume equations developed by FSI for each tree species found in the plot. The list of volume equations of important species for each State has been given in Annexure-II. At the State level, all sample plots are grouped according to crop composition 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 national estimate.

In case of TOF inventory, the data processing has been carried out separately for rural and urban areas. In rural areas, the estimation of growing stock at State level was carried out separately for block, linear and scattered strata. The area for block and linear strata was obtained from the digital interpretation of remote sensing data, whereas the area of scattered stratum was obtained by subtracting the area of block and linear patches from rural Culturable Non Forest Area (CNFA). In case of urban stratum, the area was taken from the Registrar General of India (RGI). Species and diameter class-wise number of stems enumerated in sample plots were used for calculating stems per ha under each stratum. The corresponding volume for each stratum was also calculated using volume equations developed by FSI. Estimates of the Growing stock in TOF of the States were calculated using figures of stems per ha and volume per ha and respective areas of each stratum. The national growing stock estimate of TOF was generated by adding the estimates of growing stock of all the States.

7.4 Results

Data from about 60,000 plots was processed following the statistical procedures with the help of customized software. The results of growing stock estimation for forest and TOF are presented in the following sub-sections.

7.4.1 State/UT 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 18,218 sample plots laid inside forests and 41,630 sample plots outside forests. The Standard Error (SE) of estimate for Forest Inventory at National level is 4.60% and varies from 2.05% to 15.95% at the State/UT level. The SE for TOF at National level is 6.10% and ranges from 1.91% to 22.02% at State/UT level. As compared to the previous assessment, the number of sample plots inside forest and TOF are almost double 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 6,167.50 m cum which comprises of 4,388.15 m cum inside forest areas and 1,779.35 m cum outside recorded forest areas (TOF). There is a total increase of 251.74 m cum (4.26%) in the growing stock of the country as compared to the estimates reported in ISFR 2019. Out of this, the increase in growing stock inside the forest is 114.68 m cum (2.68%) and 137.06 m cum (8.35%) outside the forest area.

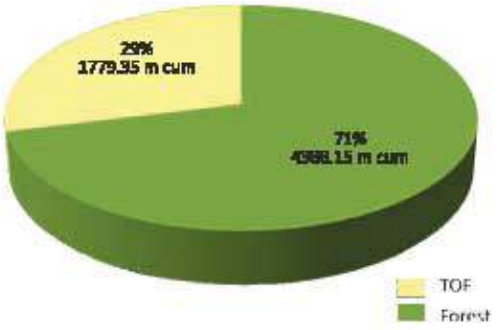


Figure 7.5 Growing Stock of Forest & TOF

The estimates of growing stock in Forests and TOF in the States & UTs are presented in Table 7.1 below.

Table 7.1 State/UT wise Growing Stock

S. No.	States/UT	Geog. Area (in sq km)	Volume of Growing Stock (m cum)			Growing Stock in Forest (cum/ha)	Growing Stock in TOF (cum/ha)
			Forest	TOF	Total		
1.	Andhra Pradesh	1,62,968	115.71	73.16	188.87	31.06	7.70
2.	Arunanchal Pradesh	83,743	418.99	73.48	492.47	81.29	42.36
3.	Assam	78,438	112.68	23.94	136.62	41.99	5.12
4.	Bihar	94,163	30.52	41.04	71.56	41.01	4.85
5.	Chhattisgarh	1,35,192	389.64	117.30	506.94	65.14	15.91
6.	Delhi	1,483	0.51	1.75	2.26	49.51	12.84
7.	Goa	3,702	12.87	4.15	17.02	101.26	19.71
8.	Gujarat	1,96,244	51.22	78.74	129.96	23.42	4.86
9.	Haryana	44,212	4.31	19.26	23.57	27.65	5.59
10.	Himanchal Pradesh	55,673	345.62	28.30	373.92	91.08	31.11
11.	Jharkhand	79,716	100.80	74.35	175.15	40.13	14.05
12.	Karnataka	1,91,791	302.14	121.72	423.86	78.92	8.04
13.	Kerala	38,852	160.53	61.04	221.57	139.32	24.51
14.	Madhya Pradesh	3,08,252	374.44	118.05	492.49	39.54	7.17
15.	Maharashtra	3,07,713	235.50	187.69	423.19	38.01	7.83
16.	Manipur	22,327	54.99	5.10	60.09	31.57	10.61
17.	Meghalaya	22,429	35.54	20.82	56.36	37.43	18.62
18.	Mizoram	21,081	28.87	46.05	74.92	38.60	34.64
19.	Nagaland	16,579	30.28	15.60	45.88	35.12	24.26
20.	Odisha	1,55,707	276.78	106.87	383.65	45.22	11.91
21.	Punjab	50,362	12.61	20.31	32.92	40.89	4.49
22.	Rajasthan	3,42,239	26.56	90.63	117.19	8.08	5.26
23.	Sikkim	7,096	33.91	1.73	35.64	58.06	33.80
24.	Tamil Nadu	1,30,060	92.27	82.21	174.48	39.79	7.80
25.	Telangana	1,12,077	80.20	43.76	123.96	28.97	5.32
26.	Tripura	10,486	23.13	7.46	30.59	36.75	19.62
27.	Uttar Pradesh	2,40,928	104.39	106.75	211.14	60.05	4.84
28.	Uttarakhand	53,483	401.01	18.40	419.41	105.53	14.74
29.	West Bengal	88,752	61.19	38.70	99.89	51.51	6.42
30.	A & N Islands	8,249	121.72	5.55	127.27	169.74	51.82
31.	Chandigarh	114	0.21	0.29	0.50	60.00	36.32
32.	Dadar & Nagar Haveli and Daman & Diu	602	0.45	0.67	1.54	21.03	17.80
33.	Jammu & Kashmir* (shape file area = 52,624#)	2,22,236	348.35	109.04	457.39	172.46	34.97
34.	Ladakh* (Shape file area= 1,68,055#)		0.18	35.01	35.19	257.14	3.61
35.	Lakshadweep	30	0.00	0.05	0.05	0.00	26.02
36.	Puducherry	490	0.03	0.38	0.41	23.08	11.31
	Total	**32,87,469**	**4,388.15**	**1,779.35**	**6,167.50**	**58.60**	**8.40**

* *Includes area outside LOC that is under illegal occupation of Pakistan and China*

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

From Table 7.1, it is observed that the growing stock at the national level has been estimated as 56.60 cum per ha. Among the States, the highest per ha growing stock in forest is in Kerala (139.32 per ha) followed by Uttarakhand (105.53 per ha) and Goa (101.26 per ha). Among the UTs, the highest per ha growing stock in forest is in Ladakh followed by Jammu & Kashmir and A & N Islands. In respect of the total volume of growing stock, Arunachal Pradesh has maximum growing stock (418.99 m cum) in forests, followed by Uttarakhand (401.01 m cum), Chhattisgarh (389.64 m cum) and Madhya Pradesh (374.44 m cum). In TOF, Maharashtra has maximum growing stock (187.69 m cum) followed by Karnataka (121.72 m cum), Madhya Pradesh (118.05 m cum) and Chhattisgarh (117.30 m cum).

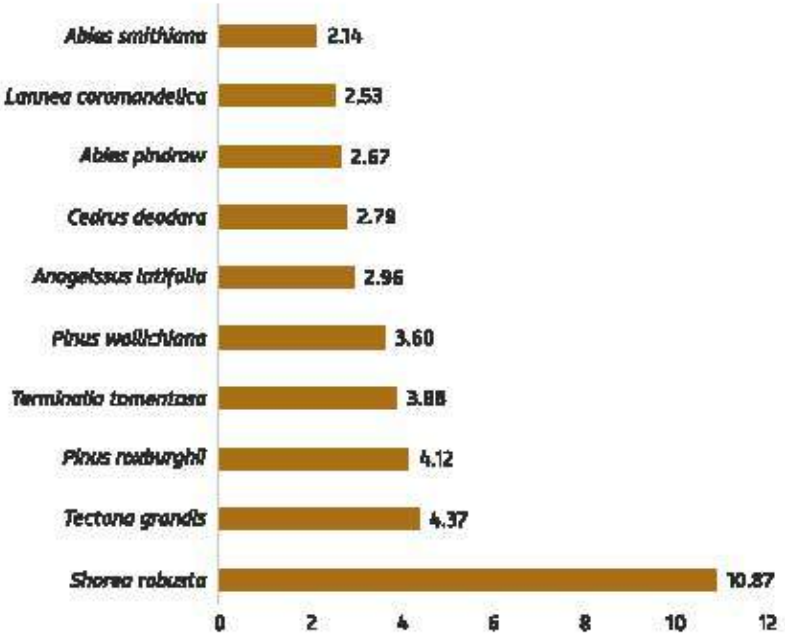
7.4.2 Growing Stock of top ten species in Forests and TOF

National level estimates of number of trees and their volume for major species by diameter class in forest and TOF is presented in Annexure III-A to III-D. The growing stock of top 10 species of forest & TOF and their percentage in total growing stock has been presented in Table 7.2 and Table 7. 3 respectively.

Table 7.2 Growing Stock in Forest for top ten species in the Country

S. No.	Name of the Species	Total Volume (m cum)	Percentage of total GS in country's forests
1.	*Shorea robusta*	476.94	10.87
2.	*Tectona grandis*	191.89	4.37
3.	*Pinus roxburghii*	180.85	4.12
4.	*Terminalia tomentosa*	170.08	3.88
5.	*Pinus wallichiana*	157.90	3.60
6.	*Anogeissus latifolia*	129.68	2.96
7.	*Cedrus deodara*	122.40	2.79
8.	*Abies pindrow*	117.30	2.67
9.	*Lannea coromandelica*	111.11	2.53
10.	*Abies smithiana*	94.07	2.14

Figure 7.6 Percentage volume of top ten species in forest



From the above figure, it is seen that inside the forests, *Shorea robusta* has the maximum contribution in total volume (10.87%) followed by *Tectona grandis* (4.37%), *Pinus roxburghii* (4.12%) and *Terminalia tomentosa* (3.88%).

Table 7.3 Growing Stock in TOF for top ten species in the Country

S. No.	Name of the Species	Total volume (m cum)	Percentage of total volume
1.	*Mangifera indica*	230.33	12.94
2.	*Azadirachta indica*	120.65	6.78
3.	*Madhuca latifolia*	82.70	4.65
4.	*Cocos nucifera*	80.26	4.51
5.	*Borassus flabelliformis*	52.24	2.94
6.	*Acacia arabica*	49.23	2.77
7.	*Butea monosperma*	43.96	2.47
8.	*Tamarindus indica*	39.82	2.24
9.	*Shorea robusta*	38.15	2.14
10.	*Ficus religiosa*	36.22	2.04

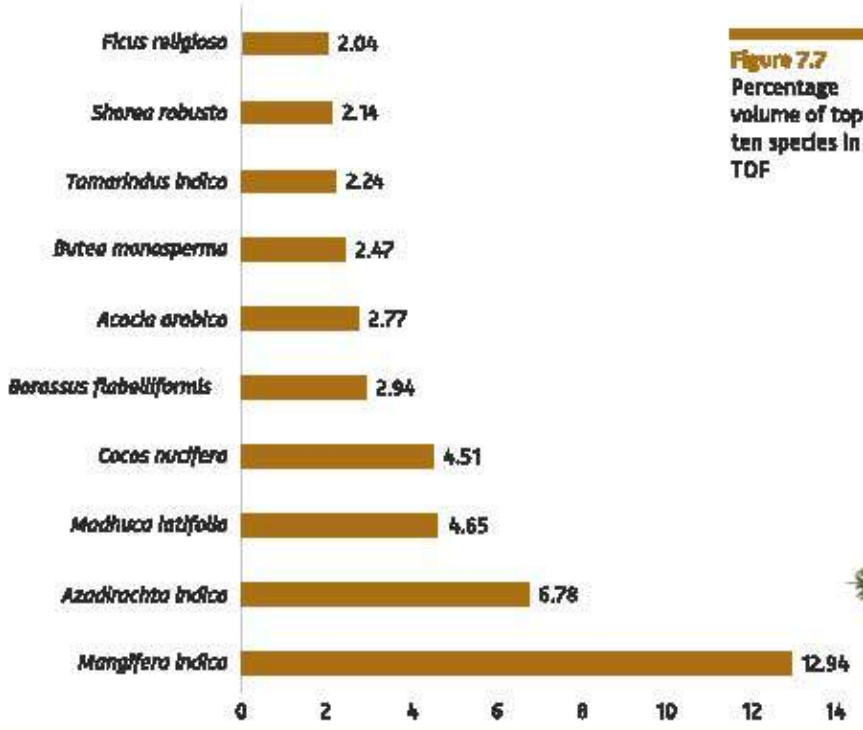


Figure 7.7 Percentage volume of top ten species in TOF

As per the above figures, in the Trees Outside Forests, *Mangifera indica* contributes maximum volume of 12.94% to total volume followed by *Azadirachta indica* (6.78%), *Madhuca latifolia* (4.65%) and *Cocos nucifera* (4.51%).

The estimates of growing stock at State level are presented in the Table 7.1. As mentioned earlier also, one of the objectives of new sampling design is to generate the state/UT level estimates at an acceptable precision level. In the new design, sample plots in both forest and TOF fall in all the States. The state/UT wise standard error percentage both forest and TOF is given in Annexure-IV.

To illustrate the enormity of the task of National Forest Inventory, the distribution of about 60,000 sample points taken up for Forest and TOF Inventory during 2016 to 2020 across the country are shown in the figures 7.8 below.

7.5 Conclusion

Over the last 3 biennial assessments, the growing stock within and outside forests has shown a steady increasing trend. The total growing stock has risen by 6.92 % from 5768.387 m cum in the 2015 assessment to 6167.50 m cum in the current assessment. The growing stock inside forests has risen by 4.60 % from 4,195.047 m cum in the 2015 assessment to 4,388.15 m cum in the current assessment. In the TOF, the growing stock has risen by 13.09 % from 1,573.340 m cum in the 2015 assessment to 1,779.35 m cum in the current assessment.

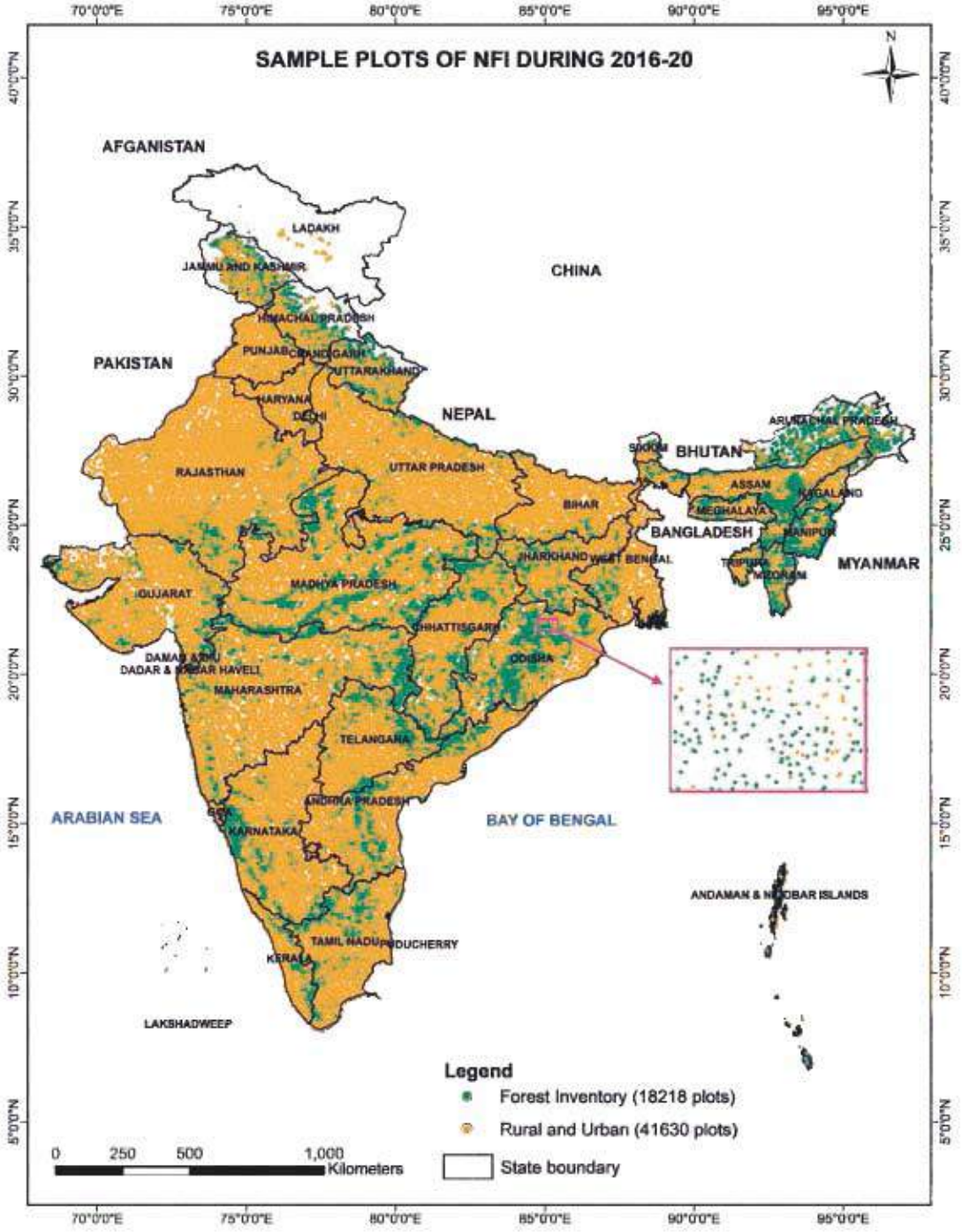


Figure 7.8
Map showing sample plots of NFI during 2016 - 2020

07

GROWING STOCK

Introduction 7.1

In simple terms, Growing Stock is the volume of all living trees in a forested area. Periodic estimation of the growing stock of wood is essential for developing national policies and strategies for sustainable use of the forest resources. Growing stock is an important, quantifiable parameter and used to calculate the tangible economic value of forests, is an indicator of sustainability and productivity of forests and forms the basis for calculating biomass and carbon stock. Assessment of growing stock inside the forests provides information on the volume of wood available inside forests. Similarly, estimation of growing stock outside the forests is essential for the assessment of volume of timber availability outside the forests. Presently, in India, Trees Outside Forest (TOF) has become the major source of wood for different uses.

Forest Inventory, carried out by Forest Survey of India (FSI), is essentially aimed at assessing the growing stock and several other important quantitative and qualitative parameters of the forests. In the Working Plans, the growing stock is being used for calculation of sustainable yield of timber from forests. In the existing climate change scenario, the estimation of growing stock has assumed significance. Forest owners, planners, managers and policy makers often need the detailed information about different forestry parameters viz. distribution of timber species, volume, biomass, carbon stock, regeneration status, population and structures etc. within different regions of the country for strategic planning and sustainable management of the forest and forest resources. Furthermore, the United Nations Framework Convention on Climate Change (UNFCCC) guidelines for implementation of REDD+ requires that every country should have a National Forest Monitoring System (NFMS) comprising of satellite-based forest monitoring system and National Forest Inventory.

FSI's role in generating information on growing stock of forests dates back to 1965, when the Pre-Investment Survey of Forest Resources (PISFR), the precursor of FSI, was established as a joint project of FAO, UNDP and Government of India. Its main task was to estimate availability of wood from forest rich areas of the country for establishing wood-based industries. The inventory was carried out in specific regions and did not have a pan-Indian character. Different sampling designs were followed in different parts of the country. After the organization was renamed as Forest Survey of India in 1981 with a revised mandate, inventory continued to remain a key activity and was expanded to cover more forest areas by following a uniform sampling design. By the year 2001, about three-fourth of the country's forests had been inventoried and some areas had been inventoried twice.

Figure 7.1
Recording field observations during forest inventory

Figure 7.2
Measurement of crown diameter during forest inventory

The forest inventory carried out by FSI during the above period was limited to the selected areas. As the inventory in different parts of the country was carried out in different time periods, the results could not be used to produce national level estimates of growing stock. In view of this, FSI modified its sampling design and revised the methodology in 2002 in order to generate national level estimates of growing stock at an interval of two years from 2003 onwards. As per the design, the country was stratified into 14 different physiographic zones based on the physiography, climate, vegetation etc. The forest inventory was based on systematic sampling approach wherein 60 districts, spread across the country, used to be selected in each biennial cycle in different physiographic zones for the inventory. The sample plots were laid in 1 ¼' x 1 ¼' grids to cover the entire country in 20 years. This design was continued till 2016 when it was again modified with the objectives of generating National and State level estimates at acceptable precision level and reduce the revisit time from 20 years to 5 years for forest and 10 years for TOF to meet the requirements of information on additional parameters.

New National Forest Inventory (NFI) Design 7.2

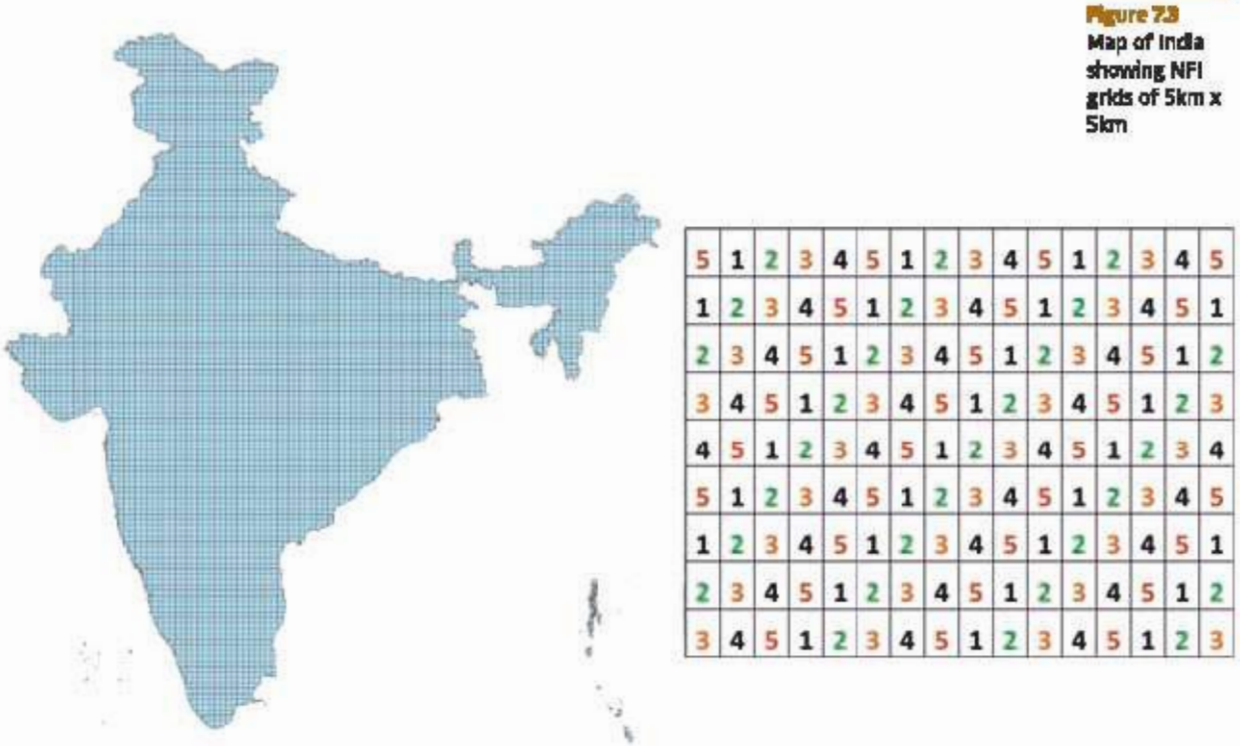
The three components of NFI are Forest Inventory, TOF (Rural) Inventory and TOF (Urban) Inventory. A brief overview of the methodology of each of the three components is given in the following sub sections.

Forest Inventory 7.2.1

As per the new inventory design of 2016, NFI is carried out in 5 km x 5 km systematically selected grids, uniformly distributed across the country as shown in Figure 7.3 below. The plot configuration for fieldwork has also been changed from a single square plot to a cluster of circular plots. Before shifting to the new design, extensive technical discussions were held in FSI, along with the representatives of some State Forest Departments. Pilot studies were carried out in the zonal offices of FSI to ascertain the size of the circular plots and distance between central sub-plots and other sub-plots. Additional parameters such as Non Timber Forest Produce (NTFP), invasive species, water bodies near sample plots, diseases etc. have also been included in the forest inventory.

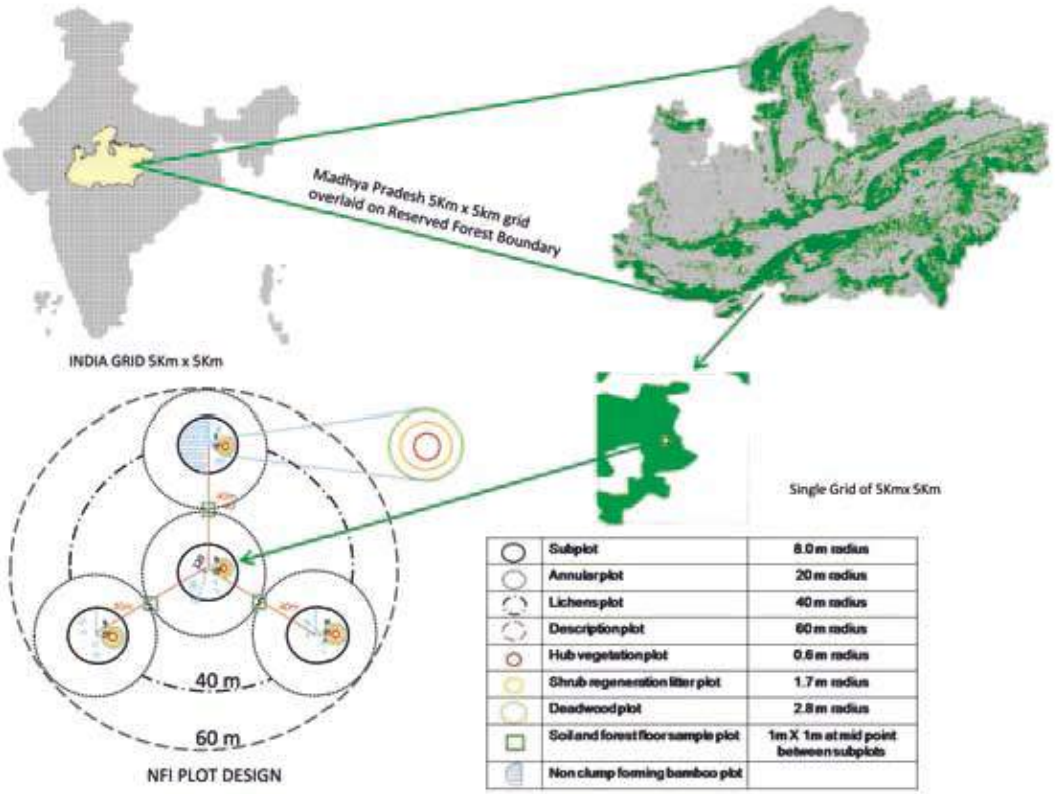
For forest inventory, the revisit time to the same grid has been fixed at 5 years and for TOF at 10 years. Accordingly, for forest inventory, all grids are numbered as 1 to 5 and for TOF inventory, the grids are numbered as 1 to 10. The digital layer of RFA/ Green Wash boundaries has been used to determine the grids for forest inventory. Since 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 using past inventory data and the digital layer of RFA/ Greenwash. Grids having specific number in the panel are covered in a single survey year.

Figure 7.3
Map of India showing NFI grids of 5km x 5km



Within the selected forest grids, random points are generated using Geographical Information System (GIS). These points form the plot centre of the sample point, 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 at a specified angle as shown in the Figure 7.4. Further micro plots within each sub-plot are laid out for collection of data on herbs, shrubs, regeneration and dead wood. The list of sample plots are 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.

Figure 7.4
Plot configuration of NFI



	Subplot	8.0 m radius
	Annular plot	20 m radius
	Lichens plot	40 m radius
	Description plot	60 m radius
	Hub vegetation plot	0.6 m radius
	Shrub regeneration litter plot	1.7 m radius
	Deadwood plot	2.8 m radius
	Soil and forest floor sample plot	1m X 1m at mid point between subplots
	Non clump forming bamboo plot	

7.2.2 Trees Outside Forest (TOF) Inventory

Since the cycle for the TOF inventory in the new design has been fixed at 10 years, all TOF grids are marked with numbers 1 to 10. 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. For urban TOF inventory, urban centres defined by the Registrar General & Census Commissioner of India are considered as study area. The sampling unit for urban inventory is taken as Urban Frame Survey (UFS) from National Statistical Office (NSO).

The urban centres of a district are delineated into blocks called 'UFS blocks', which are shown on maps with well-defined boundaries, and generally cover a population of 600 to 800 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 5km x 5km 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' will be considered for 1st year TOF (Urban) inventory and number 'five' in the second year and likewise 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. Remaining grids are covered under TOF (Rural) inventory.

For the TOF (Rural) inventory, a two-phase sampling design is used. In the first phase, the selected grid areas are stratified into block, linear and scattered strata using high resolution remote sensing satellite data. In the second phase, optimum sample points are generated in the selected grids. 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.

The Multispectral data of Sentinel-II satellite having a spatial resolution of 10 m and swath of 290 km has been used for classification of the selected grids. The satellite data is downloaded and geo-rectified with the help of Survey of India (SOI) Open Series Map (OSM) toposheets of 1:50,000 scale. Thereafter, the image is classified into various land use classes such as settlements, water bodies, tree cover, agriculture and other land cover classes. This classification enables the analyst to distinguish between the tree cover and other classes. The classified image is visually analysed for editing and refinement. Since the minimum mappable area is 0.1 ha, the pixels are clumped and cluster of pixels having area less than 0.1 ha are eliminated. After editing the classified image, final classified map is generated showing three classes in TOF areas, namely Block, Linear and Scattered. From the classified TOF map, area under each class is calculated. In addition, area of Un-Culturable Non-Forest Areas, which do not support tree vegetation, such as rivers and water bodies, riverbeds, snow covered mountains etc. is also calculated. The schematic chart of the methodology of TOF using remote sensing is depicted in the Figure 6.4 in Chapter - 6.

For the fieldwork, the plot size for Block and Linear strata is 0.1 ha square plot and 10m x 125m strip, respectively. In case of Scattered stratum, the plots size is 0.5 ha in hilly areas and 3.0 ha in non-hilly areas.

7.3 Data Processing

The data is entered using a data entry module, which has been designed and developed separately for Forest, TOF (Rural), and TOF (Urban) inventories by FSI. The entered data is checked thoroughly for any inconsistency and cleaned prior to processing. Data processing is carried out separately for forest, TOF (rural) and TOF (urban).

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. Thereafter, per plot area (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, open and plantations) 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 were post-stratified according to crop composition (stratum) based on dominant species appearing in a particular State. Plot volume is calculated with the help of volume equations developed by FSI for each tree species found in the plot. The list of volume equations of important species for each State has been given in Annexure-II. At the State level, all sample plots are grouped according to crop composition 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 national estimate.

In case of TOF inventory, the data processing has been carried out separately for rural and urban areas. In rural areas, the estimation of growing stock at State level was carried out separately for block, linear and scattered strata. The area for block and linear strata was obtained from the digital interpretation of remote sensing data, whereas the area of scattered stratum was obtained by subtracting the area of block and linear patches from rural Culturable Non Forest Area (CNFA). In case of urban stratum, the area was taken from the Registrar General of India (RGI). Species and diameter class-wise number of stems enumerated in sample plots were used for calculating stems per ha under each stratum. The corresponding volume for each stratum was also calculated using volume equations developed by FSI. Estimates of the Growing stock in TOF of the States were calculated using figures of stems per ha and volume per ha and respective areas of each stratum. The national growing stock estimate of TOF was generated by adding the estimates of growing stock of all the States.

7.4 Results

Data from about 60,000 plots was processed following the statistical procedures with the help of customized software. The results of growing stock estimation for forest and TOF are presented in the following sub-sections.

7.4.1 State/UT 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 18,218 sample plots laid inside forests and 41,630 sample plots outside forests. The Standard Error (SE) of estimate for Forest Inventory at National level is 4.60% and varies from 2.05% to 15.95% at the State/UT level. The SE for TOF at National level is 6.10% and ranges from 1.91% to 22.02% at State/UT level. As compared to the previous assessment, the number of sample plots inside forest and TOF are almost double 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 6,167.50 m cum which comprises of 4,388.15 m cum inside forest areas and 1,779.35 m cum outside recorded forest areas (TOF). There is a total increase of 251.74 m cum (4.26%) in the growing stock of the country as compared to the estimates reported in ISFR 2019. Out of this, the increase in growing stock inside the forest is 114.68 m cum (2.68%) and 137.06 m cum (8.35%) outside the forest area.

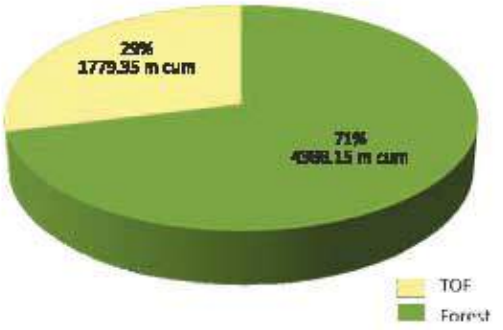


Figure 7.5 Growing Stock of Forest & TOF

The estimates of growing stock in Forests and TOF in the States & UTs are presented in Table 7.1 below.

Table 7.1 State/UT wise Growing Stock

S. No.	States/UT	Geog. Area (in sq km)	Volume of Growing Stock (m cum)			Growing Stock in Forest (cum/ha)	Growing Stock in TOF (cum/ha)
			Forest	TOF	Total		
1.	Andhra Pradesh	1,62,968	115.71	73.16	188.87	31.06	7.70
2.	Arunanchal Pradesh	83,743	418.99	73.48	492.47	81.29	42.36
3.	Assam	78,438	112.68	23.94	136.62	41.99	5.12
4.	Bihar	94,163	30.52	41.04	71.56	41.01	4.85
5.	Chhattisgarh	1,35,192	389.64	117.30	506.94	65.14	15.91
6.	Delhi	1,483	0.51	1.75	2.26	49.51	12.84
7.	Goa	3,702	12.87	4.15	17.02	101.26	19.71
8.	Gujarat	1,96,244	51.22	78.74	129.96	23.42	4.86
9.	Haryana	44,212	4.31	19.26	23.57	27.65	5.59
10.	Himanchal Pradesh	55,673	345.62	28.30	373.92	91.08	31.11
11.	Jharkhand	79,716	100.80	74.35	175.15	40.13	14.05
12.	Karnataka	1,91,791	302.14	121.72	423.86	78.92	8.04
13.	Kerala	38,852	160.53	61.04	221.57	139.32	24.51
14.	Madhya Pradesh	3,08,252	374.44	118.05	492.49	39.54	7.17
15.	Maharashtra	3,07,713	235.50	187.69	423.19	38.01	7.83
16.	Manipur	22,327	54.99	5.10	60.09	31.57	10.61
17.	Meghalaya	22,429	35.54	20.82	56.36	37.43	18.62
18.	Mizoram	21,081	28.87	46.05	74.92	38.60	34.64
19.	Nagaland	16,579	30.28	15.60	45.88	35.12	24.26
20.	Odisha	1,55,707	276.78	106.87	383.65	45.22	11.91
21.	Punjab	50,362	12.61	20.31	32.92	40.89	4.49
22.	Rajasthan	3,42,239	26.56	90.63	117.19	8.08	5.26
23.	Sikkim	7,096	33.91	1.73	35.64	58.06	33.80
24.	Tamil Nadu	1,30,060	92.27	82.21	174.48	39.79	7.80
25.	Telangana	1,12,077	80.20	43.76	123.96	28.97	5.32
26.	Tripura	10,486	23.13	7.46	30.59	36.75	19.62
27.	Uttar Pradesh	2,40,928	104.39	106.75	211.14	60.05	4.84
28.	Uttarakhand	53,483	401.01	18.40	419.41	105.53	14.74
29.	West Bengal	88,752	61.19	38.70	99.89	51.51	6.42
30.	A & N Islands	8,249	121.72	5.55	127.27	169.74	51.82
31.	Chandigarh	114	0.21	0.29	0.50	60.00	36.32
32.	Dadar & Nagar Haveli and Daman & Diu	602	0.45	0.67	1.54	21.03	17.80
33.	Jammu & Kashmir* (shape file area = 52,624#)	2,22,236	348.35	109.04	457.39	172.46	34.97
34.	Ladakh* (Shape file area= 1,68,055#)		0.18	35.01	35.19	257.14	3.61
35.	Lakshadweep	30	0.00	0.05	0.05	0.00	26.02
36.	Puducherry	490	0.03	0.38	0.41	23.08	11.31
	Total	**32,87,469**	**4,388.15**	**1,779.35**	**6,167.50**	**58.60**	**8.40**

* *Includes area outside LOC that is under illegal occupation of Pakistan and China*

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

From Table 7.1, it is observed that the growing stock at the national level has been estimated as 56.60 cum per ha. Among the States, the highest per ha growing stock in forest is in Kerala (139.32 per ha) followed by Uttarakhand (105.53 per ha) and Goa (101.26 per ha). Among the UTs, the highest per ha growing stock in forest is in Ladakh followed by Jammu & Kashmir and A & N Islands. In respect of the total volume of growing stock, Arunachal Pradesh has maximum growing stock (418.99 m cum) in forests, followed by Uttarakhand (401.01 m cum), Chhattisgarh (389.64 m cum) and Madhya Pradesh (374.44 m cum). In TOF, Maharashtra has maximum growing stock (187.69 m cum) followed by Karnataka (121.72 m cum), Madhya Pradesh (118.05 m cum) and Chhattisgarh (117.30 m cum).

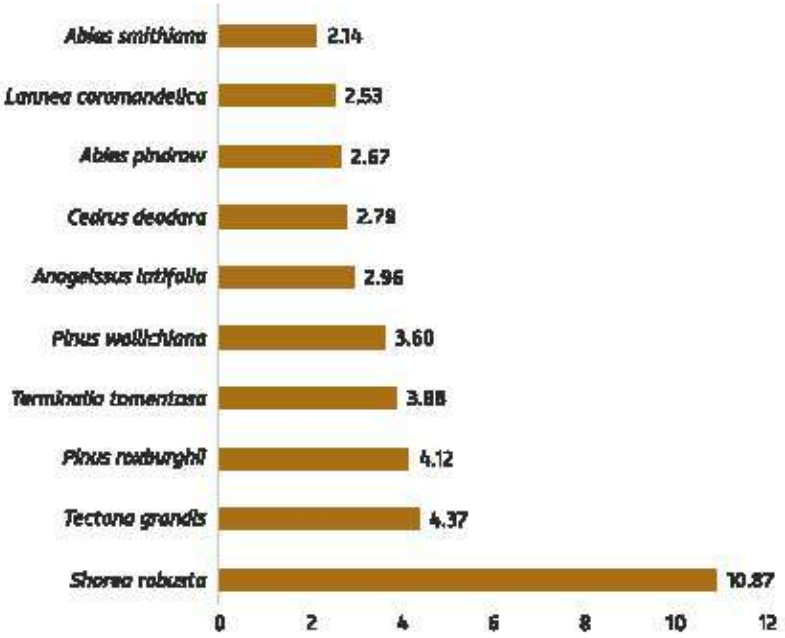
7.4.2 Growing Stock of top ten species in Forests and TOF

National level estimates of number of trees and their volume for major species by diameter class in forest and TOF is presented in Annexure III-A to III-D. The growing stock of top 10 species of forest & TOF and their percentage in total growing stock has been presented in Table 7.2 and Table 7. 3 respectively.

Table 7.2 Growing Stock in Forest for top ten species in the Country

S. No.	Name of the Species	Total Volume (m cum)	Percentage of total GS in country's forests
1.	*Shorea robusta*	476.94	10.87
2.	*Tectona grandis*	191.89	4.37
3.	*Pinus roxburghii*	180.85	4.12
4.	*Terminalia tomentosa*	170.08	3.88
5.	*Pinus wallichiana*	157.90	3.60
6.	*Anogeissus latifolia*	129.68	2.96
7.	*Cedrus deodara*	122.40	2.79
8.	*Abies pindrow*	117.30	2.67
9.	*Lannea coromandelica*	111.11	2.53
10.	*Abies smithiana*	94.07	2.14

Figure 7.6 Percentage volume of top ten species in forest



From the above figure, it is seen that inside the forests, *Shorea robusta* has the maximum contribution in total volume (10.87%) followed by *Tectona grandis* (4.37%), *Pinus roxburghii* (4.12%) and *Terminalia tomentosa* (3.88%).

Table 7.3 Growing Stock in TOF for top ten species in the Country

S. No.	Name of the Species	Total volume (m cum)	Percentage of total volume
1.	*Mangifera indica*	230.33	12.94
2.	*Azadirachta indica*	120.65	6.78
3.	*Madhuca latifolia*	82.70	4.65
4.	*Cocos nucifera*	80.26	4.51
5.	*Borassus flabelliformis*	52.24	2.94
6.	*Acacia arabica*	49.23	2.77
7.	*Butea monosperma*	43.96	2.47
8.	*Tamarindus indica*	39.82	2.24
9.	*Shorea robusta*	38.15	2.14
10.	*Ficus religiosa*	36.22	2.04

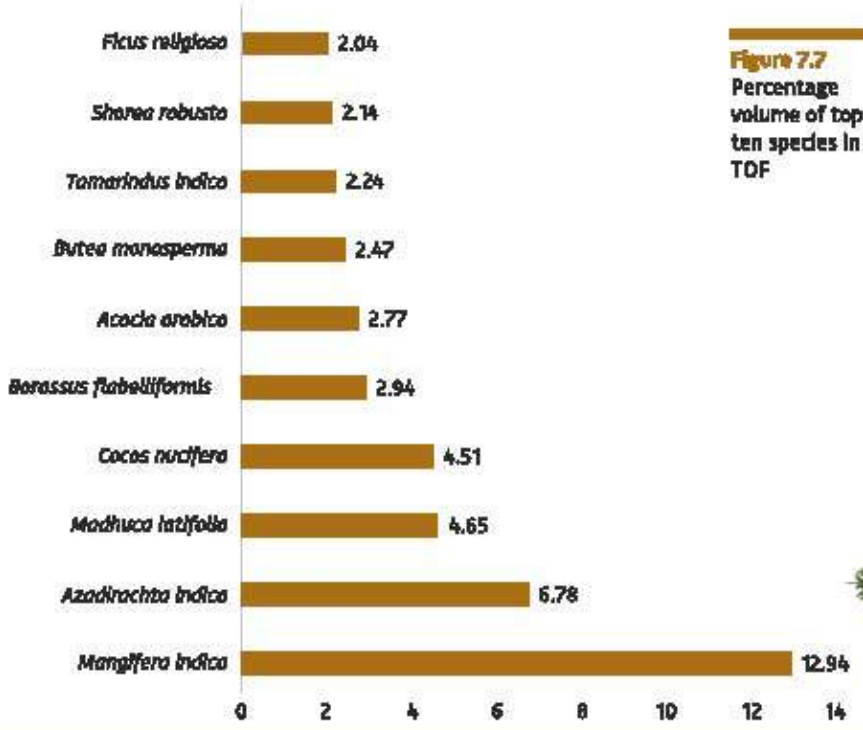


Figure 7.7 Percentage volume of top ten species in TOF

As per the above figures, in the Trees Outside Forests, *Mangifera indica* contributes maximum volume of 12.94% to total volume followed by *Azadirachta indica* (6.78%), *Madhuca latifolia* (4.65%) and *Cocos nucifera* (4.51%).

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To illustrate the enormity of the task of National Forest Inventory, the distribution of about 60,000 sample points taken up for Forest and TOF Inventory during 2016 to 2020 across the country are shown in the figures 7.8 below.

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Over the last 3 biennial assessments, the growing stock within and outside forests has shown a steady increasing trend. The total growing stock has risen by 6.92 % from 5768.387 m cum in the 2015 assessment to 6167.50 m cum in the current assessment. The growing stock inside forests has risen by 4.60 % from 4,195.047 m cum in the 2015 assessment to 4,388.15 m cum in the current assessment. In the TOF, the growing stock has risen by 13.09 % from 1,573.340 m cum in the 2015 assessment to 1,779.35 m cum in the current assessment.

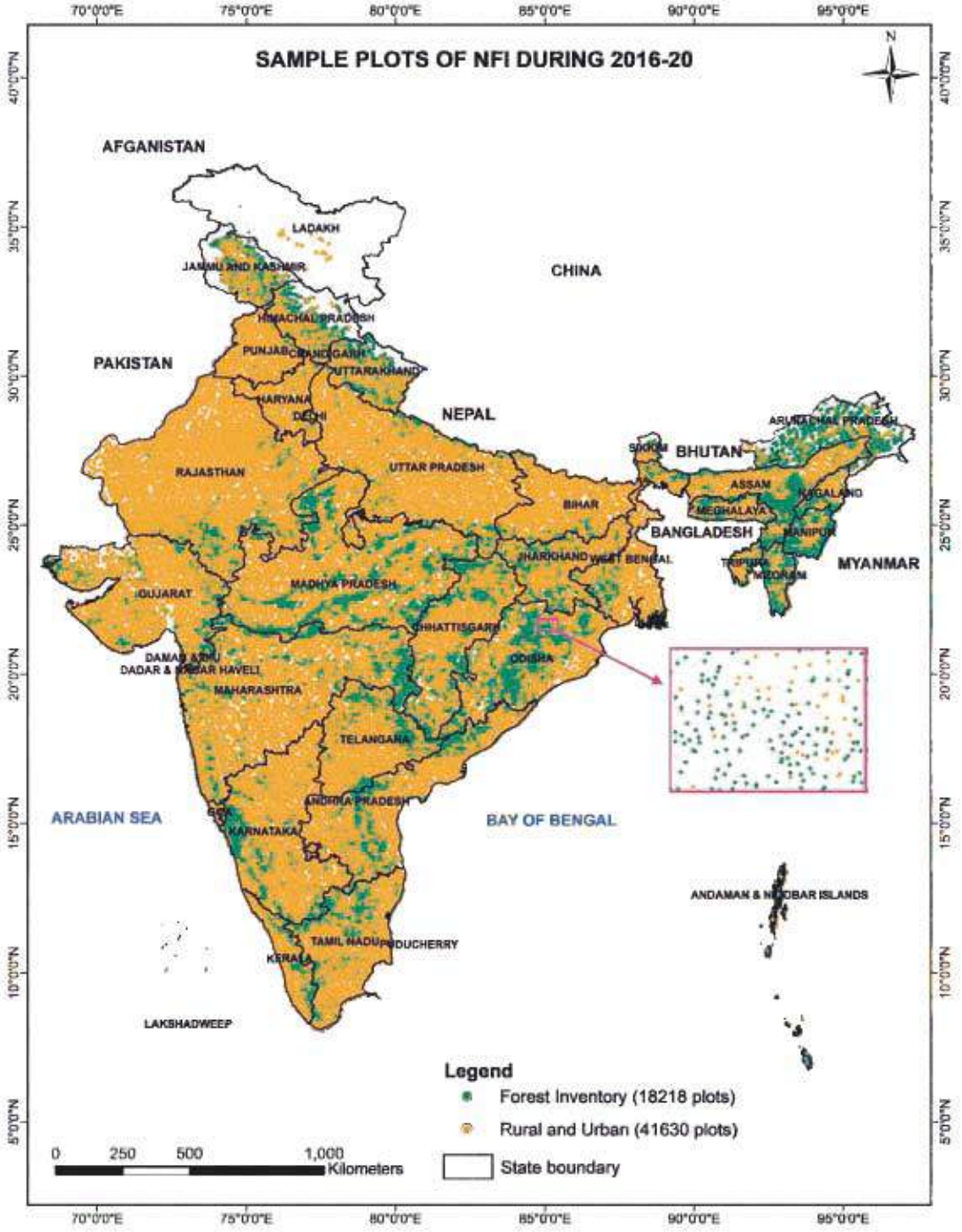
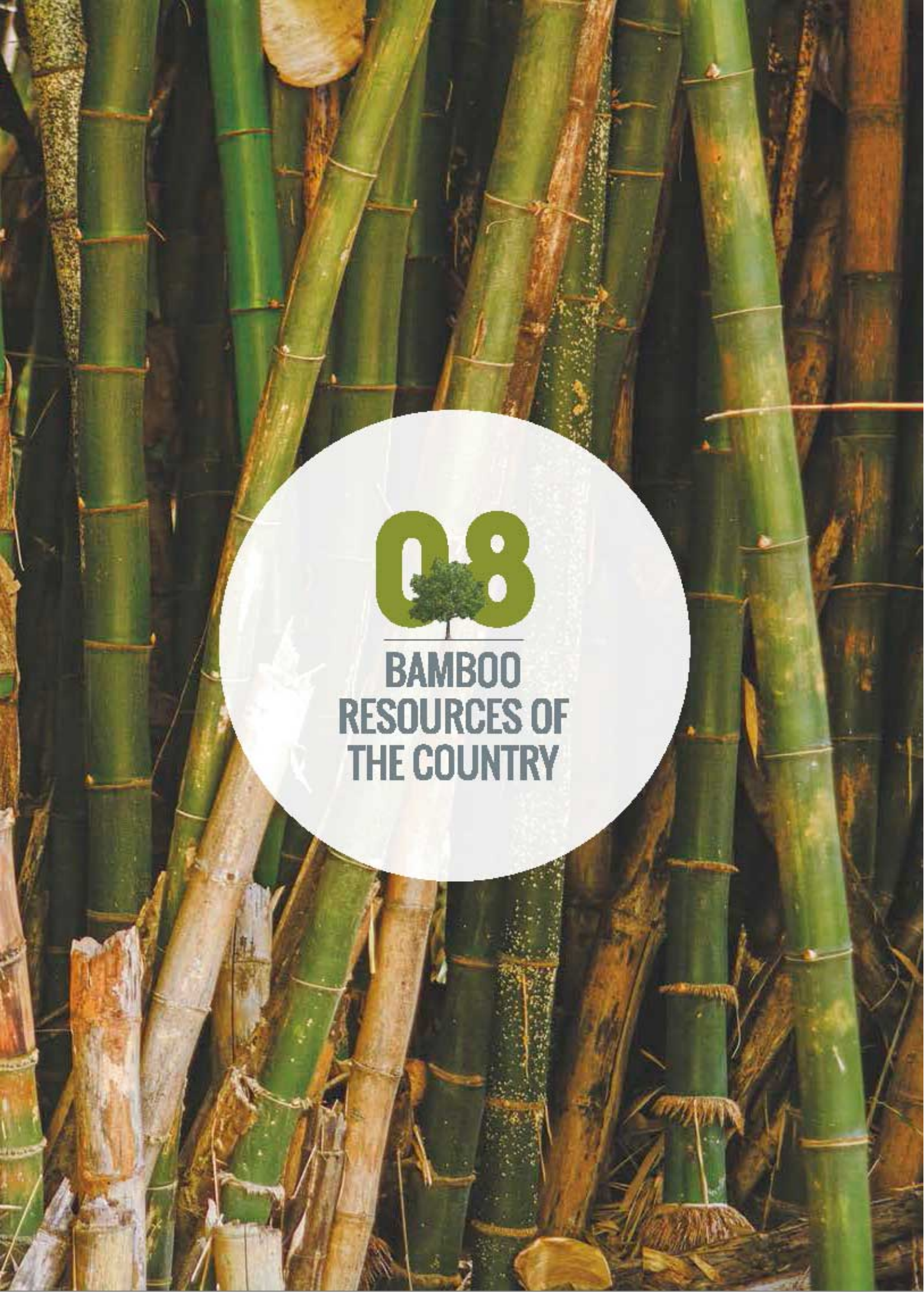
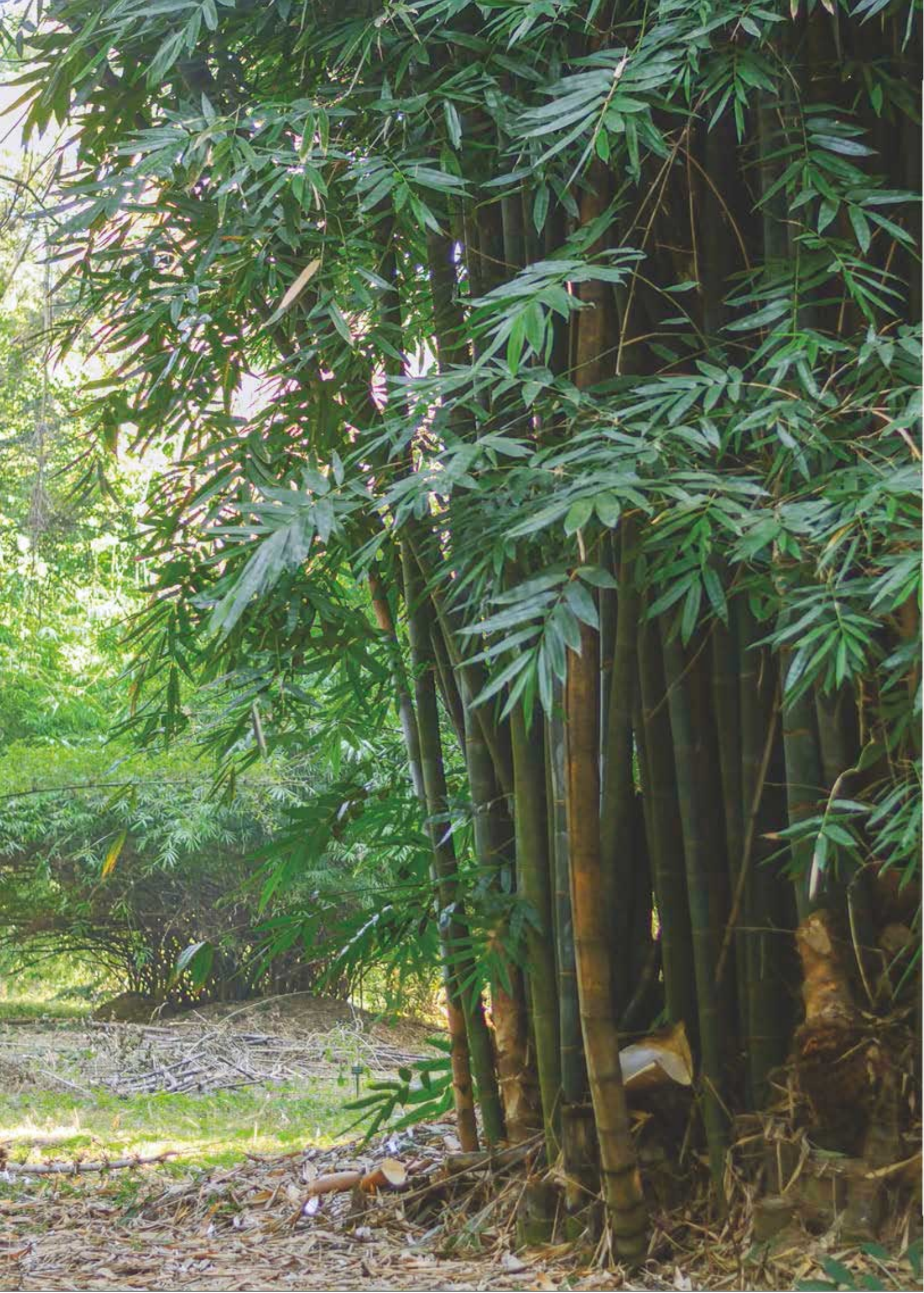


Figure 7.8
Map showing sample plots of NFI during 2016 - 2020



08

BAMBOO RESOURCES OF THE COUNTRY



Introduction 8.1

Bamboos, the most diverse group of plants in the grass family belong to the sub-family Bambusoidae of the family *Poaceae* (*Gramineae*). Bamboos are fast growing perennial plants and are found in the tropical, sub-tropical and mild temperate regions of the world. Geographical distribution of Bamboo largely depends on climatic factors such as precipitation, temperature, altitude and soil conditions. Large tracts of natural bamboo forest are found in tropical Asian countries between 15° and 25° North latitudes. In India, bamboo is found naturally almost throughout the country except in Kashmir region.

As per an FAO report (2007)[1], there are about 1,200 species of Bamboo in 90 genera across the world. India has about 125 indigenous and 11 exotic species of bamboo from 23 genera. Bamboos are found in abundance in the deciduous and semi-evergreen forests of the North-eastern region of the country and the tropical moist deciduous forests of Northern and Southern India. The major bamboo genera found in India are *Arundinaria, Bambusa, Chimonobambusa, Dendrocalamus, Dinochola, Gigantochloa* etc. The North-eastern States and West Bengal account for more than 50% of the bamboo resources of the country. Other bamboo rich areas of the country are the Andaman & Nicobar Islands, Chhattisgarh, Madhya Pradesh and the Western Ghats. Although, bamboo is found in almost every state of the country, its distribution and concentration varies primarily due to the climatic and edaphic conditions. *Bambusa* and *Dendrocalamus* are species of tropical conditions, whereas *Arundinaria* and its associates occur in the temperate region and are common at high altitudes in the Western and Eastern Himalayas. *Phyllostachys* is a genus of temperate to warm temperate regions. *Dendrocalamus strictus* is a predominant species of the dry deciduous forests, while *Bambusa bambos* thrives in the moist deciduous forests. *Gigantochloa rostrata* is the most important bamboo species in the semi evergreen forests of Andaman Islands. The commercially important bamboo species of the Eastern & the north-eastern India are *Bambusa tulda, Dendrocalamus hamiltonii* and *Melocanna bacciferra.*

Bamboo culms grow from the dense root rhizome system. There are two types of rhizomes i.e. monopodial and sympodial. The monopodial rhizome grows horizontally and the buds develop either upward, generating a culm, or horizontally, with a new tract of the rhizomal net. Some bamboos are non-clump forming with culms distant from each other and can be invasive. They are generally found in temperate regions and include the genera *Phyllostachys* and *Pleioblastus*. In other species, the sympodial rhizomes are short and thick, and the culms, which are above the ground are close together in a compact clump, which expands evenly around its circumference. Their natural habitat is tropical regions and they are not invasive. The main genera are *Arundinaria, Bambusa* & *Dendrocalamus.*

[1] *FAO (2007). World bamboo resources: A thematic study prepared in the framework of the Global Forest Resources Assessment. Non-wood forest products-18, Food and Agriculture Organization of the United Nations, Rome*

Contribution of Bamboos in the socio-economic, cultural and ecological development of certain geographies is significant. Bamboo, contributes to subsistence needs of about 2.5 billion people around the world, a majority of whom are tribals, forest dwellers or communities dependant on forest resources. It is estimated that in India, there are about 2 million traditional artisans whose livelihoods depend on harvesting, processing, value addition and selling of bamboo products such as baskets, mats, handicrafts etc. Major advantage of bamboo is its versatility in making a variety of products by small entrepreneurs without any major initial investment.

Figure 8.1 Bamboo Forest of North-eastern India Phyllostachys mannii

Bamboo thrives in a wide range of climatic and edaphic conditions. Owing to its worldwide distribution, bamboo plays a very important role in bio-diversity conservation, carbon sequestration and soil moisture conservation. The various properties of bamboos are availability in different sizes, light weight yet strong, hard, flexible, straight, fast growing, abundant, and hence having many uses such as in making normal and fine quality paper, fishing poles, furniture, flooring, handicrafts, walking sticks, etc. Young bamboo shoots are used as vegetables in some cuisines.

The Government of India promulgated the Indian Forest (Amendment) Ordinance, 2017 to exempt bamboo grown in non-forest areas from definition of tree, by amending the Section 2 (7) of the Indian Forest Act 1927 and thereby doing away with the requirement of felling/ transit permit for its transport and economic use. The major objective of the amendment is to promote cultivation of bamboo in non-forest areas to achieve the twin objectives of increasing the income of farmers and also increasing green cover of the country.

In this backdrop, the assessment of Bamboo has been an integral part of Forest Inventory and has been presented as a separate chapter in ISFRs. The data on bamboo resources are collected while carrying out the inventory of forest and TOF. Bamboo species are found in more than 18,000 inventoried grids during 2016-17 to 2019 - 20 and have been presented in a table at the end of this Chapter. Further, a comparison of bamboo bearing areas and its growing stock as compared to ISFR 2019[2] has also been given in this chapter.

[2] *India State of Forest Report (2019), Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India*

Sampling design 8.2

The two-stage stratified sampling design, which is used for inventory of forest and TOF, is also employed for the assessment of bamboo resources. The design of the first stage is same as that described in the chapter on Growing Stock of this report. The second stage comprises separate designs for the inventory of forests, TOF (Rural) and TOF (Urban), which are also described in the chapter dealing with Growing stock.

For forest inventory, a cluster of four-circular sub-plots is the sampling unit for enumeration of trees/bamboos. A circular plot of 60 m radius around the central sub-plot is used for recording data on plot description. In this form, data of trees and bamboo clumps is recorded from all sub-plots of 8 m radius. Plot Enumeration Form for each subplot of 8 m radius is maintained separately.

Data collection 8.3

Forest inventory 8.3.1

The data on bamboo is collected in every sample plot of the forest inventory. The information such as bamboo density, quality, flowering and regeneration is observed by the field crew, and recorded in the Plot Description Form (PDF). Bamboo density is classified into nine categories namely pure bamboo, very dense, dense, moderately dense, scattered, sparse, hacked, absent and regeneration for clump forming bamboo and for non-clump forming bamboo. For determining the bamboo production capacity of a site, bamboo areas are classified into bamboo-site quality classes on the basis of average height of culms of different bamboo species. For each enumerated bamboo clump, information is recorded on a number of parameters like species name, diameter of culm and crown width of the clump.

Bamboo Clump Analysis for Clump forming Bamboos 8.3.2

The data regarding total number of bamboo clumps and their respective diameters occurring in each sub-plot is recorded in the Plot Enumeration Form. The data is also collected in a separate field form called as Bamboo Clump Analysis Form in which data of each individual culm, occurring in certain selected clumps in each subplot is recorded. For analysis, it is first determined whether a culm is green-sound, green-damaged, dry or dry-damaged; these are then further classified as current years' culms, one to two-year-old culms and culms that are more than two year old. In case of dry and decayed culms, the age classification is not necessary. The culms, other than that of current year and decayed culms, both green and dry, are further grouped under different diameter classes i.e. 1 cm to under 2 cm, 2 cm to under 5 cm, 5 cm to under 8 cm and 8 cm and above.

All culms occurring in the clump selected for analysis are enumerated and each enumerated culm is recorded by 'dot-dash' method (dots represents counts from 1 to 4, lines 5 to 8, and diagonal lines 9 and 10) under its appropriate class. The total number of culms found under each class is recorded in two digits.

8.3.3 Bamboo Enumeration and Analysis for Non-Clump Forming Bamboo

The data is collected for non-clump forming bamboos occurring in the sample subplot 2 i.e. western half of the subplot 2. For the purpose of counting the culms, the subplot 2 is dissected by taking a bearing of 360° from the center of subplot. A rope is placed on this bearing upto the point where this bearing crosses the subplot circumference in North and South direction. All culms falling in western half of north subplot are counted and categorized in five classes viz. green-sound, green-damaged, dry-sound, dry-damaged & decayed.

These are further classified as current year's culms, one to two year old culms and culms more than two years old. In case of dry (both sound as well as damaged) and decayed culms, the age classification is not necessary. The culms, other than the current years and decayed culms, both green and dry are further grouped under diameter at breast height classes, 1 cm to under 2 cm, 2 cm to under 5 cm, 5 cm to under 8 and 8 cm and over.

8.3.4 Bamboo Weight

For determining correlation between green and dry weights for utilizable bamboo culm length, data is collected in 'Bamboo Weight Form'. This form is, however, to be filled up for plots, in which bamboo has actually been found in an area of 60 m radius from the center of subplot 1. One mature bamboo culm from each culm diameter class 1 cm to 2 cm, 2 cm to 5 cm, 5 cm to 8 cm, and 8 cm and over, is to be selected for felling from the first clump enumerated in the plot. If, however, the required number of culms of any diameter class is not available in the first clump, the shortfall is to be made good from the clump next in the serial order of enumeration. Further, if the necessary numbers of culms are not available from any other clump of the plot, the required number of culms is to be obtained from the area in the immediate vicinity of the plot.

8.3.5 Bamboo Assessment from TOF Inventory

As bamboo is not very common in urban areas, bamboo data is collected only from the rural areas of TOF. The information on bamboo is recorded in Plot Enumeration Form. The name of the bamboo species, the diameter of clumps and number of culms in each clump are recorded from each plot of rural inventory.

8.4 Data Processing for Assessment of Bamboo

Data processing is carried out separately for Forest and TOF inventory, which is described below.

Bamboo Assessment from Forest Inventory 8.4.1

The data collected from more than 18,000 points surveyed during four years from 2016-17 to 2019-20 has been used for processing. Data from five field forms namely Plot Description Form, Plot Enumeration Form, Bamboo Enumeration Form (Clump and Non-clump forming separately) and Bamboo weight form are entered in the database using data entry module developed in-house. The data is checked manually and also through computer-based software and cleaned wherever necessary. Once data is cleaned, it is processed at State level through the data processing software on the basis of an area factor (per plot area), which is determined for each State depending on the number of plots falling in the RFA. Thereafter, the bamboo plots surveyed in the States are listed according to bamboo density and quality. The bamboo plots, when multiplied with area factor, gives the species and quality-wise bamboo bearing area for that State. The information on estimated culms is classified into three categories namely green-sound, dry-sound and decayed. The estimated number of culms is converted into equivalent green weight using appropriate weight factors. The national level estimates are obtained by adding the estimates of all the States.

Results 8.5

Bamboo Resource assessment has been done for forest using NFI data. The bamboo resource assessment at the national level and for the State & UTs is presented in this section.

(in million)

Table 8.1 Number of culms at country level by Age and Soundness in Recorded Forest Area

Culm Size Class	Green Sound	Dry Sound	Decayed	Total no of culms as per ISFR 2021	Total culms as per ISFR 2019	change with respect to ISFR 2019
Current year	5,109	0	0	5,109	4,917	192
1-2 cm	8,001	3,105	0	11,106	8,456	2,650
2-5 cm	16,694	4,618	0	21,312	15,258	6,054
5-8 cm	6,842	1,323	0	8,165	5,409	2,756
8 cm +	2,504	306	0	2,810	2,079	731
	0	0	4,834	4,834	3,335	1,499
Total	**39,150**	**9,352**	**4,834**	**53,336**	**39,454**	**13,882**

The total number of culms at the national level has been estimated to be 53,336 million out of which the percentage of green sound, dry sound and decayed culms has been observed as 73.40%, 17.54% and 9.06% respectively. Size class 2-5 cm has contributed to the maximum number of culms. The total number of culms has increased by 13,882 million as compared to estimates of ISFR 2019.

Table 8.1 shows that the estimated number of culms has increased in all the age classes and for all the soundness class. On an average, there is an increase of 35.19% in number of culms at country level between ISFR 2019 & ISFR 2021.

(In '000 tonnes)

Table 8.2 Equivalent Green Weight of Bamboo at country level by Age and Soundness in Recorded Forest Area

Culm Size Class	Green sound	Dry Sound	Total Green weight as per ISFR 2021	Total Green weight as per ISFR 2019	Changes w.r.t. ISFR 2019
1-2 cm	36,847	28,519	65,366	61,347	4,019
2 - 5 cm	1,16,200	63,368	1,79,568	1,02,254	77,314
5 - 8 cm	77,783	35,826	1,13,609	80,112	33,497
8 + cm	32,726	10,731	43,457	33,874	9,583
Total	**2,63,556**	**1,38,444**	**4,02,000**	**2,77,587**	**1,24,413**

The total estimated green weight of bamboo culms at national level is 402 million tonnes of which green sound bamboos contribute 66 % and dry sound bamboos contribute remaining 34 %. As compared to the estimate of ISFR 2019, an increase of about 124 million tonnes equivalent green weight of bamboo has been observed in the present assessment.

(In sq km)

Table 8.3 State/UT wise Distribution of Bamboo area in Recorded Forest Area

S. No.	State/UT's	Bamboo bearing area as per ISFR 2021	Bamboo bearing area as per ISFR 2019	Change in area with respect to ISFR 2019
1.	Andhra Pradesh	6,104	7,003	-899
2.	Arunachal Pradesh	15,739	14,981	758
3.	Assam	10,659	10,525	134
4.	Bihar	1,103	1,136	-33
5.	Chhattisgarh	10,467	11,255	-788
6.	Goa	288	418	-130
7.	Gujarat	3,547	3,393	154
8.	Haryana	39	72	-33
9.	Himachal Pradesh	1,027	650	377
10.	Jharkhand	3,717	4,123	-406
11.	Karnataka	8,624	10,181	-1,557
12.	Kerala	2,404	2,849	-445
13.	Madhya Pradesh	18,394	20,867	-2,473
14.	Maharashtra	13,526	15,408	-1,882
15.	Manipur	8,377	9,903	-1,526
16.	Meghalaya	5,007	5,410	-403
17.	Mizoram	4,561	3,476	1,085
18.	Nagaland	3,947	4,284	-337
19.	Odisha	11,199	11,827	-628
20.	Punjab	280	255	25
21.	Rajasthan	1,555	1,874	-319
22.	Sikkim	994	1,176	-182
23.	Tamil Nadu	4,001	4,357	-356
24.	Telangana	4,535	5,438	-903
25.	Tripura	4,201	3,783	418
26.	Uttar Pradesh	1,832	1,235	597
27.	Uttarakhand	1,201	1,489	-288
28.	West Bengal	702	855	-153
29.	Andaman & Nicobar Islands	1,413	1,814	-401
	Total	**1,49,443**	**1,60,037**	**-10,594**

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 data

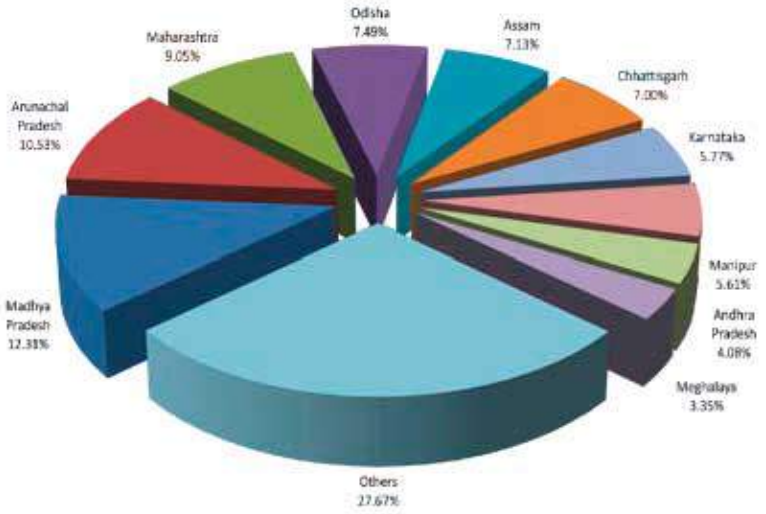


Figure 8.2
Top ten States in terms of bamboo bearing area (%)

The total bamboo bearing area of the country has been estimated to be 15.0 million ha. Madhya Pradesh has maximum bamboo bearing area of 1.84 m ha followed by Arunachal Pradesh (1.57 million ha), Maharashtra (1.35 million ha) and Odisha (1.12 million ha). As compared to the estimates of ISFR 2019, the total bamboo bearing area in the country has decreased by 1.06 million ha. Comparing state wise area of present assessment with ISFR 2021, it has been observed that bamboo bearing area in Mizoram has shown highest increase of 1,085 sq km followed by Arunachal Pradesh (758 sq km). Similarly, Madhya Pradesh has shown highest decrease of 2,473 sq km in the bamboo bearing area followed by Maharashtra (1,882 sq km).

(In sq km)

Table 8.4
State/UT wise bamboo bearing area under different classes in Recorded Forest Area

S. No.	State/UT's	Pure Bamboo	Dense	Scattered	Bamboo present but clumps completely hacked	Regeneration crop
1.	Andhra Pradesh	208	2,253	2,550	176	917
2.	Arunanchal Pradesh	274	3,148	11,906	0	411
3.	Assam	449	2,300	7,798	56	56
4.	Bihar	23	70	511	162	337
5.	Chhattisgarh	623	1,808	5,112	496	2,428
6.	Goa	0	0	137	38	113
7.	Gujarat	79	852	2,378	79	159
8.	Haryana	0	13	26	0	0
9.	Himachal Pradesh	100	276	576	25	50
10.	Jharkhand	32	96	2,793	366	430
11.	Karnataka	287	1,083	3,155	950	3,149
12.	Kerala	92	504	1,167	46	595
13.	Madhya Pradesh	847	4,046	8,327	1,928	3,246
14.	Maharashtra	767	2,705	6,903	1,475	1,676
15.	Manipur	161	1,450	6,766	0	0
16.	Meghalaya	484	750	3,676	0	97
17.	Mizoram	383	1,781	2,331	33	33
18.	Nagaland	172	772	2,917	0	86
19.	Odisha	117	1,723	8,302	117	940

(In sq km)

S. No.	State/UT's	Pure Bamboo	Dense	Scattered	Bamboo present but clumps completely hacked	Regeneration crop
20.	Punjab	0	112	149	19	0
21.	Rajasthan	19	226	602	414	294
22.	Sikkim	66	155	773	0	0
23.	Tamil Nadu	46	367	1,605	797	1,186
24.	Telangana	159	1,306	2,070	550	450
25.	Tripura	94	669	3,318	13	107
26.	Uttar Pradesh	0	351	1,255	25	201
27.	Uttarakhand	34	172	789	0	206
28.	West Bengal	0	43	638	0	21
29.	Andaman & Nicobar Islands*	0	177	1,118	0	118
	Total	**5,516**	**29,208**	**89,648**	**7,765**	**17,306**
	Total as per ISFR 2019	**4,332**	**30,575**	**1,02,139**	**8,260**	**14,731**
	Changes w.r.t. ISFR 2019	1,184	-1,367	-12,491	-495	2,575

Note: Information of bamboo density for Chandigarh, Dadar & Nagar Haveli and Daman & Diu, Delhi, Lakshadweep, J & K, Ladakh and Puducherry is not given due to inadequate data

Table 8.4 reveals that pure bamboo area has increased and dense bamboo area has reduced from the estimates published in ISFR 2019. It implies that part of this area has changed from low to high density area.

On analysing the forest area of different States according to bamboo density, it has been observed that the pure bamboo brakes are found in less than 1%, dense bamboos in about 4% and scattered bamboos in about 12% of the RFA. In about 1% of the bamboo area, bamboo was present but clumps were found to be completely hacked. Regeneration crop of bamboo was observed in only 2% of forest area.

Maximum occurrence of pure bamboo was observed in Madhya Pradesh (847 sq km) followed by Maharashtra (767 sq km) and Chhattisgarh (623 sq km). The area under dense bamboo was found to be highest in Madhya Pradesh (4,046 sq km) followed by Arunachal Pradesh (3,148 sq km) and Maharashtra (2,705 sq km). The area with hacked bamboo clumps was found to be highest in Madhya Pradesh (1,928 sq km) followed by Maharashtra (1,475 sq km) and Karnataka (950 sq km). Bamboo regeneration was maximum in Madhya Pradesh (3,246 sq km) followed by Karnataka (3,149 sq km) and Chhattisgarh (2,428 sq km).

Table 8.5 State/UT wise number of estimated culms by Soundness of culms in Recorded Forest Area

(In million)

S. No.	State/UT	Green Culms	Dry Culms	Decayed	Total as per ISFR 2021	Total as per ISFR 2019	Changes w.r.t. 2019
1.	Andhra Pradesh	1,362	676	206	2,244	1,820	424
2.	Arunachal Pradesh	7,455	812	557	8,824	5,769	3,055
3.	Assam	4,813	407	436	5,656	3,829	1,827
4.	Bihar	194	36	5	235	247	-12
5.	Chhattisgarh	1,542	860	398	2,800	2,114	686
6.	Goa	4	19	7	30	30	0
7.	Gujarat	625	149	104	878	677	201
8.	Haryana	13	1	1	15	0	15

(In million)

S. No.	State/UT	Green Culms	Dry Culms	Decayed	Total as per ISFR 2021	Total as per ISFR 2019	Changes w.r.t. 2019
9.	Himachal Pradesh	524	120	27	671	485	186
10.	Jharkhand	620	169	207	996	876	120
11.	Karnataka	1,884	549	220	2,653	1,910	743
12.	Kerala	800	229	58	1,087	1,030	57
13.	Madhya Pradesh	3,108	1,005	649	4,762	3,595	1,167
14.	Maharashtra	2,767	932	418	4,117	2,971	1,146
15.	Manipur	1,277	279	12	1,568	1,126	442
16.	Meghalaya	1,803	214	182	2,199	1,521	678
17.	Mizoram	1,219	173	98	1,490	1,074	416
18.	Nagaland	2,095	296	314	2,705	2,544	161
19.	Odisha	2,785	790	398	3,973	2,291	1,682
20.	Punjab	18	6	4	28	11	17
21.	Rajasthan	297	58	27	382	527	-145
22.	Sikkim	285	23	18	326	218	108
23.	Tamil Nadu	466	396	159	1,021	946	75
24.	Telangana	1,149	716	143	2,008	926	1,082
25.	Tripura	1,311	185	66	1,562	1,110	452
26.	Uttar Pradesh	200	80	30	310	236	74
27.	Uttarakhand	163	90	48	301	384	-83
28.	West Bengal	214	31	35	280	384	-104
29.	Andaman & Nicobar Islands	157	51	7	215	803	-588
	Total	**39,150**	**9,352**	**4,834**	**53,336**	**39,454**	**13,882**

Note:1. The difference in the total number of culms from ISFR 2019 is due to the fact that the culms of Dadar Nagar & Haveli is not included in ISFR 2021 due to inadequate area.

As per current assessment, maximum number of green culms are found in Arunachal Pradesh (7,455 million) followed by Assam (4,813 million) and Madhya Pradesh (3,108 million). Dry culms were found maximum in Madhya Pradesh (1,005 million) followed by Maharashtra (932 million) and Chhattisgarh (860 million). As compared to the estimates given in ISFR 2019, maximum increase in number of culms by soundness has been observed in Arunachal Pradesh (3,055 million) followed by Assam (1,827 million) and Odisha (1,682 million).

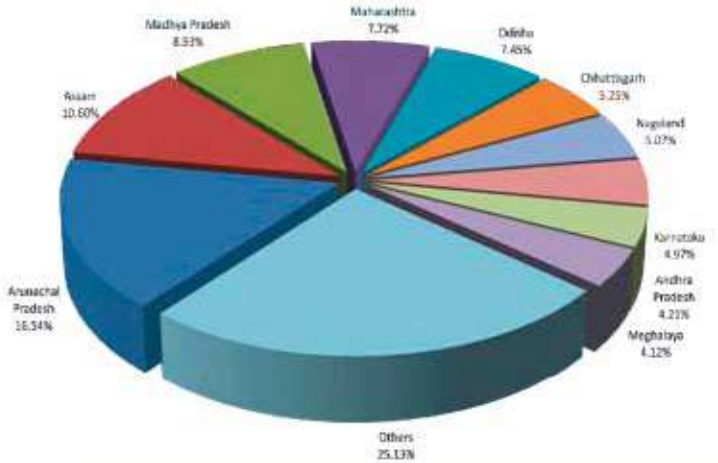


Figure 8.3
Top ten States in terms of bamboo culms (%)

(In '000 tonnes)

Table 8.6 State/UT wise Equivalent Green Weight by Soundness of culms in Recorded Forest Area

S. No.	State	Green soundness	Dry Sound	Total 2021	Total as per ISFR2019	Change w.r.t. ISFR2019
1	Andhra Pradesh	12,262	14,957	27,219	16,157	11,062
2	Arunachal Pradesh	38,083	8,463	46,546	27,932	18,614
3	Assam	33,978	4,622	38,600	24,064	14,536
4	Bihar	1,249	423	1,672	1,822	-150
5	Chhattisgarh	7,940	8,840	16,780	11,743	5,037
6	Goa	15	242	257	202	55
7	Gujarat	6,663	3,897	10,560	8,877	1,683
8	Haryana	29	4	33		33
9	Himachal Pradesh	1,833	1,043	2,876	1,975	901
10	Jharkhand	3,846	2,301	6,147	4,573	1,574
11	Karnataka	20,579	14,429	35,008	26,456	8,552
12	Kerala	9,109	5,572	14,681	13,092	1,589
13	Madhya Pradesh	12,501	9,783	22,284	14,088	8,196
14	Maharashtra	15,856	13,256	29,112	26,515	2,597
15	Manipur	7,778	3,543	11,321	7,754	3,567
16	Meghalaya	19,096	5,649	24,745	12,323	12,422
17	Mizoram	9,606	2,979	12,585	8,812	3,773
18	Nagaland	24,039	8,363	32,402	20,547	11,855
19	Orissa	14,556	9,160	23,716	16,131	7,585
20	Punjab	61	52	113	47	66
21	Rajasthan	1,709	931	2,640	2,520	120
22	Sikkim	533	91	624	429	195
23	Tamilnadu	2,842	6,373	9,215	7,779	1,436
24	Telangana	6,055	6,461	12,516	6,781	5,735
25	Tripura	9,193	3,220	12,413	6,295	6,118
26	Uttar Pradesh	759	775	1,534	974	560
27	Uttarakhand	1,172	1,667	2,839	1,390	1,449
28	West Bengal	1,013	458	1,471	1,110	361
29	Andaman & Nicobar Islands	1,201	890	2,091	7,199	-5,108
	Total	**268,556**	**138,444**	**402,000**	**277,587**	**124,413**

The Table 8.6 shows that the weight of green sound culms is maximum in Arunachal Pradesh (38.08 million tonnes) followed by Assam (33.98 million tonnes) and Nagaland (24.04 million tonnes). The weight of dry sound culms is maximum in Andhra Pradesh (14.96 million tonnes) followed by Karnataka (14.43 million tonnes) and Maharashtra (13.25 million tonnes).

Arunanchal Pradesh has shown maximum increase of 18.61 million tonnes in equivalent green weight as compared to the assessment given in ISFR 2019 followed by Assam (14.54 million tonnes) and Meghalaya (12.42 million tonnes).

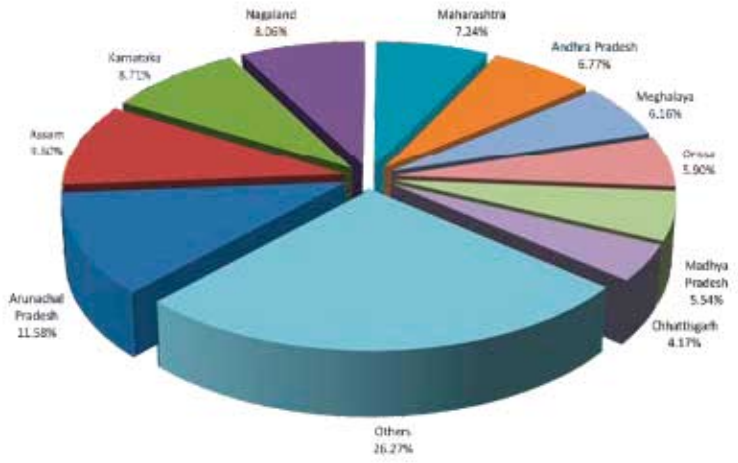


Figure 8.4
Top ten States in terms of bamboo bearing weight (%)

09

CARBON STOCK IN INDIAS FORESTS

Introduction 9.1

Carbon is the most abundant element and is essential for all known living systems. The carbon cycle comprises of a sequence of events, which enable life forms to exist and sustain on the earth. The carbon cycle can also be described in terms of sources and sinks. Sources are those parts of the cycle that add carbon to the atmosphere, and sinks are those parts that remove carbon from the atmosphere. When the sun's energy reaches the Earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases. The carbon cycle's sources and sinks help in regulating the amount of greenhouse gases in the atmosphere which are essential for life on earth. The Greenhouse gases include water vapors, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons (CFCs). The right amount of greenhouse gases in earth's surface keeps it warm enough for all forms of life to exist. Hypothetically, if there were no greenhouse gases in the earth's atmosphere, the average temperature on the earth's surface would become too low to support any floral/faunal life on the earth. On the other hand, more concentration of these on the earth would make it too warm to support life.

The key to keeping everything in balance is for the sources and sinks to have the same amount of CO_2. The most important sinks are the oceans, forests & soil on land. The forests and oceans each remove around one-fourth of the carbon that humans add to the atmosphere. 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. This is the enhanced greenhouse effect, which is contributing to warming of the Earth causing Climate Change.

Climate change has become a serious threat to the environment and the quality of life all over the world. Forests play very important role in mitigation and adaptation to climate change. Forests are considered as reservoir, sink and source of carbon. Forests sequester and store more carbon than any other terrestrial ecosystem and act as natural 'brakes' on climate change. Carbon sequestration by forests has attracted much interest globally as it is a relatively inexpensive means of mitigation of climate change. Varied topography and climate regimes, large geographical area, long coastline and oceanic islands have endowed India 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 diversity of forests in India makes it resilient to climate change and also an efficient sink of carbon.

The parties to the United Nations Framework Convention on Climate Change (UNFCCC) have undertaken many policy measures, actions and programmes 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) as National Communication (NATCOM). Towards the fulfillment of reporting obligations under the UNFCCC, India has so far submitted two full NATCOMs and three Biennial Update Reports (BUR) to the UNFCCC:

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

Apart from the international reporting, periodic forest carbon assessment helps in monitoring flow of carbon in different pools in the forests of the country and is an important indicator of ecosystem services from forests. India is committed at the highest level to meet its commitments under the Nationally Determined Contributions (NDC) made to the International community under the Paris Agreement (2015). 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 achieve the NDC target. Approximately 80 per cent of the country's terrestrial biodiversity exists in forests, and more than 300 million people have high dependency on the forest for their livelihood. Forests as a carbon sink have a prominent role in mitigating climate change. Various legislations and acts have been formulated by the Indian government for the conservation of forests and their resources.

As per the BUR-3, for the year 2016, India's total GHG emissions, excluding Land Use Land-Use Change and Forestry (LULUCF) were 2,838.89 million tonnes Co_2 eq and 2,531.07 million tonnes Co_2 eq with the inclusion of LULUCF. Carbon dioxide emissions accounted for 2,231 million tonnes (78.59 per cent), methane emissions for 409 million tonnes Co_2 eq (14.43 per cent) and nitrous oxide emissions for 145 million tonnes CO_2 eq (5.12 per cent). The LULUCF sector was a net sink of 307,820 Gg CO_2 eq in 2016, registering an increase in the net sink activity by 39 percent since 2000. Forest land, cropland and settlements categories were net sinks while grassland was a net source of CO_2. About 15 per cent of India's carbon dioxide emissions in 2016 were removed from the atmosphere by the LULUCF sector.

As per the Global Forest Resources Assessment 2020 published by the FAO, the total forest carbon stock (i.e. including all carbon pools) is estimated at 662 Gt (163 tonnes per ha), comprising 300 Gt in soil organic matter, 295 Gt in living biomass and 68.0 Gt in dead wood and litter. Soil organic matter constitutes the biggest pool, with 45.2 percent of the total carbon, followed by above-ground biomass, below-ground biomass, litter and dead wood. The report also mentions that globally, between 1990 and 2020 the global forest carbon stock decreased from 668 Gt to 662 Gt due to an overall decrease in forest area. There were considerable regional and sub-regional differences in the trend, however, for example, the carbon stock in forest biomass increased significantly in East Asia, Western and Central Asia, Europe and North America (where forest area increased) and decreased considerably in South America and Western and Central Africa.

Forest Carbon Estimation of India 9.2

FSI has been estimating carbon stock in the country's forests for various NATCOMs and providing valuable inputs to the MoEF&CC in preparation of GHG Inventory of the country. In Initial National Communication (INC, also referred as NATCOM-I) process under which estimation of carbon stock was to be done for the period 1984–1994, FSI estimated forest carbon of only woody growing stock as data for the other parameters was not available. For reporting for INC, the growing stock (volume) data was first converted into biomass by using species wise specific gravity of the wood. Thereafter, biomass expansion factors were used to convert woody biomass into total above ground biomass which included all other components like small wood and foliage of trees, shrub, herbs etc. Similarly, below ground biomass was computed using default root-shoot ratio given in GPG 2003. The total biomass so obtained was then converted into carbon using conversion factor.

For the Second National Communication (SNC) to UNFCCC, FSI conducted 'Greenhouse gas Inventory in Forest Land Remaining Forest Land & Land Converted into Forest Land for the period 1994 to 2004' under 'Land Use, Land-Use Change and Forestry (LULUCF)'. GHG fluxes in the LULUCF sector are generally estimated as net changes in carbon stocks over time. The increase in total carbon stocks over the time are equated with a net removal of CO_2 from the atmosphere and decreases in total carbon stocks (less transfer to other pools such as harvested wood products) are equated with net emissions of CO_2. FSI published a separate report on 'Carbon stock in India's Forests' in the year 2011. A separate chapter on carbon stock was given first time in ISFR 2011 highlighting the results of SNC. Since then, the information on total carbon stock and change with respect to previous assessment is a part of successive ISFRs.

With the launch of National Forest Inventory (NFI), FSI has been estimating growing stock in both forest and TOF since 2003. 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 was changed in the year 2016 again by switching over from district based to grid-based design 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.

Methodology for Forest Carbon Estimation 9.3

FSI estimates the forest carbon stock by following a post sampling stratification approach in which data of sample plots of national forest inventory has been used along with forest cover and forest type layers. Sample plots of inventory are overlaid on different strata and biomass for each pool is determined.

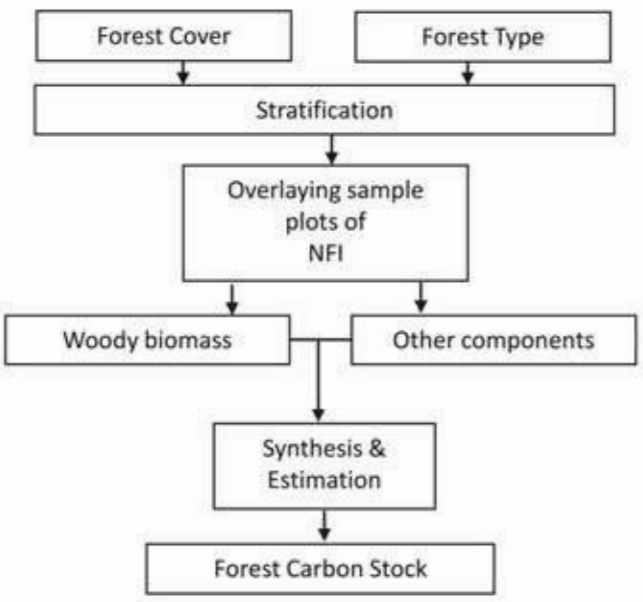
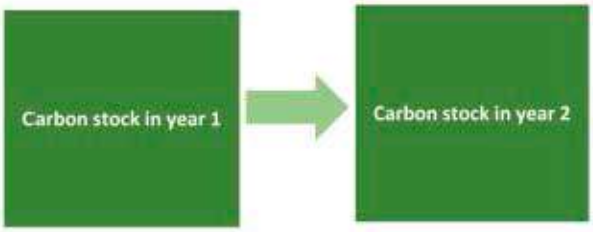


Figure 9.1 Schematic diagram showing methodology of forest carbon assessment

Method for calculating biomass for different pools is described in the following sub sections. Change in Forest Carbon between the current and previous assessment has been done following stock difference approach (GPG, 2003) as shown in Figure 9.2.

Figure 9.2 Stock difference methods for determining change in forest carbon stock



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

Where:

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

ΔC_{t1} = carbon stock in pool at time t_1 (t C)

ΔC_{t2} = carbon stock in pool at time t_1 (t C)

Stock difference method

9.3.1 Stratification of Forest area

Stratification helps in improving the precision of the estimates by dividing 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 for assessment of forest carbon in the country.

9.3.2 Forest Type Mapping

Forest Type is a unit of vegetation, which possesses broad characteristics in physiognomy and structure sufficiently pronounced to permit its differentiation from other such units. Forest type characterizes forests in terms of floristic composition and conditions of plant growth. FSI had earlier mapped Forest Types of India, according to Champion & Seth classification (1968) on 1: 50,000 scale in 2011. The second exercise for refining the previous Forest Type map has been completed by FSI recently. Using the Forest Type maps, distribution of forest cover in different forest types has been determined for the country. Forest cover map has been superimposed with the forest type map for creating the stratification. Overlaying of forest cover layer with three canopy density classes and forest type with the 17 type groups including TOF & plantations - has resulted into 51 strata. Area statistics for each stratum has been generated using GIS.

Estimation of Biomass and Carbon in different pools 9.3.3

FSI has developed volume equations for forest and TOF species. Through a special study done for different forest types, biomass equations have also been developed for important species. Using forest type specific volume equations and Biomass Expansion Factors (BEF), biomass in different pools have been determined. Specific gravity and carbon content in biomass for different forest types/species as available in different literature including IPCC Guidelines (2006)[1] have been used in estimation of forest carbon. Methods for estimation of biomass/carbon in different pools are described in short in the following sub sections.

Above Ground Biomass (AGB) of trees having dbh ≥ 10 cm. 9.3.3.1

Forest Inventory data collected at more than 23,500 sample plots in the last four 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 was calculated using volume equations developed by FSI for various species. The volume equation provides above ground woody volume i.e. above ground volume, which includes volume of main stem measured upto 10 cm diameter and volume of all branches having diameter 5 cm or more. 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, percentage carbon content was ascertained by experimentation and for remaining an average of all other species was used. Standard formula were 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 volume equations were developed and were adjusted for 'bark void factor' which were utilized to estimate bark volume. 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.

Above ground biomass of trees having dbh <10 cm 9.3.3.2

This information was initially derived by using biomass equations developed by FSI from a special study conducted during 2008 - 10 for Second National Communication to UNFCCC. These equations were developed for 20 important species in each of 14 physiographic zones. For each of such species, 3 trees of diameters 1- 9 cm (at 1.37 m. height) were felled. From the felled trees, 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 biomass equations were developed for each species. Using the plot level regeneration data from NFI i.e. recruits, un-established, established and all trees having dbh between 5 to 10 cm, biomass and carbon content at plot level is calculated.

[1] IPCC Guidelines for National Green House Inventories (2006), Intergovernmental Panel on Climate Change

9.3.3.3 Above Ground Biomass of shrubs, herbs, climbers, and biomass of dead organic matter (DOM: dead wood and litter)

For this purpose, the data of forest inventory conducted during 2002 - 2008 was analysed to ascertain the optimum number of plots required for each combination of forest type and forest density. It revealed that about 15 clusters of 2 sample plots for each combination, would suffice for estimating the biomass/carbon factors for these components if 15% permissible error is considered. This survey was conducted in the districts on randomly selected points which were already inventoried during 2002 - 2008 and for which forest type and density were known.

For the desired combinations of forest type and forest density, the exact geographical locations (latitude and longitude) of the optimum number of randomly selected sample plots were visited. Using this information, centre of sample point, three concentric plots of size 5m x 5m, 3m x 3m and 1m x 1m were laid out at a distance of 30 m away from the centre of sample point in North and South direction. In 5m x 5m plot, all dead wood above 5 cm diameter were collected, weighed and recorded. In 3m x 3m plot, all woody litter i.e. all branches below 5 cm diameter were collected, weighed and recorded. All shrubs & climbers in 3m x 3m plots were uprooted, weighed and recorded in the prescribed format. In 1m x 1m plot, all herbs were uprooted, weighed and recorded. Dry biomass was converted to carbon stock.

9.3.3.4 Above Ground Biomass of branches, foliage of trees having dbh ≥ 10 cm

This information was first derived by using biomass equations developed by FSI from a special study conducted during 2008 -10 for Second National Communication to UNFCCC. As described above, 20 important tree species in each physiographic zone were identified. For each such species other than palm like trees, in each of the diameter class, three normal trees were selected. Its diameter, height, crown length, crown width in two directions, blanks in canopy and shape of the crown were recorded.

For the purpose of biomass calculation, one normal tree of each diameter class of each species was selected. In the selected tree, partial destructive method was used to compute biomass of woody branches up to 5 cm dia, twigs and leaves. Biomass of all these parameters was separately recorded in the prescribed formats. Taking the dry biomass of small wood/foliage as dependent variable and dbh as independent variable biomass equations were developed for each species. Using the plot level data of NFI, species wise carbon content, the total biomass and carbon content at plot level was calculated.

9.3.3.5 Organic matter in soil and forest floor

While carrying out forest inventory, the data on forest floor (non-woody litter and humus) and soil carbon is also collected from each sample plot. For data collection on humus and soil carbon, two sub-plots of size 1m x 1m are laid out within the main plot. The forest floor from both the plots is first swept and material so collected is weighed and a portion of the same is kept for carbon analysis. Further, at the center of these two sub-plots, a pit of 30cm x 30cm x 30cm is dug and a composite sample of soil of 200gm is kept for organic carbon analysis. Samples of soil and humus are analysed from the standard soil labs and are used for the calculation.

Below ground biomass 9.3.3.6

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 above ground biomass (AGB) to the below ground biomass (BGB) which have been established by various researchers. GPG, 2003 also provides default values of root-to-shoot ratios for six major global forest types. FSI has selectively used these default values to arrive at the carbon estimates.

Synthesizing Data for National Carbon Estimation 9.3.4

The area under each strata has been determined using GIS. By aggregating biomass/carbon for each pool from each plot falling within a strata and dividing the same by area under that strata, 'carbon per ha' for each pool was determined for each strata. For each State/UT area under each strata was determined with the help of GIS. Multiplication of the strata area with the corresponding 'carbon per ha' value for each pool, the total carbon stock for each pool in the State has been calculated. Aggregation of the forest carbon stock of all the States/UTs has given the pool wise forest carbon stock and its total for the country.

Results 9.4

Forest Carbon Stock under different Carbon pools and change w.r.t previous assessment 9.4.1

The Forest Carbon Estimates at the national level under different carbon pools and change in respect to previous assessment has been given in table 9.1

(in million tonnes)

Component	Carbon Stock in forest in 2021	Carbon stock in forest in 2019	Net change in Carbon stock	Annual change in Carbon stock
Above Ground Biomass	2,319.9	2,256.5	63.4	31.7
Below Ground Biomass	718.9	700.8	18.1	9.1
Dead wood	47.7	35.8	11.9	6.0
Litter	107.3	127.9	-20.6	-10.3
Soil	4010.2	4,003.6	6.6	3.3
Total	**7,204.0**	**7,124.6**	**79.4**	**39.7**

Table 9.1 Forest Carbon Stock under different pools and changes wrt previous assessment

The carbon stock for 2021 has been estimated 7,204.0 million tonnes. There is an increase of 79.4 million tonnes of carbon stock as compared to the estimates of previous assessment. The annual increase of carbon stock is estimated 39.7 million tonnes which is 145.6 million tonnes of CO_2 equivalent. Soil organic carbon is the largest pool of forest carbon accounting for (55.67 %) followed by AGB (32.20 %), BGB (9.98 %), Litter (1.49 %) and dead wood (0.66%). On comparing the changes between present and previous assessment, maximum changes have been observed in AGB and dead wood.

Figure 9.3 Forest Carbon Stock in different pools (in million tonnes)

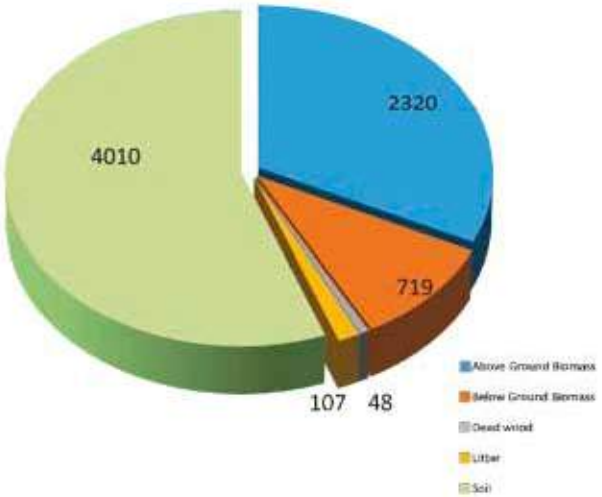
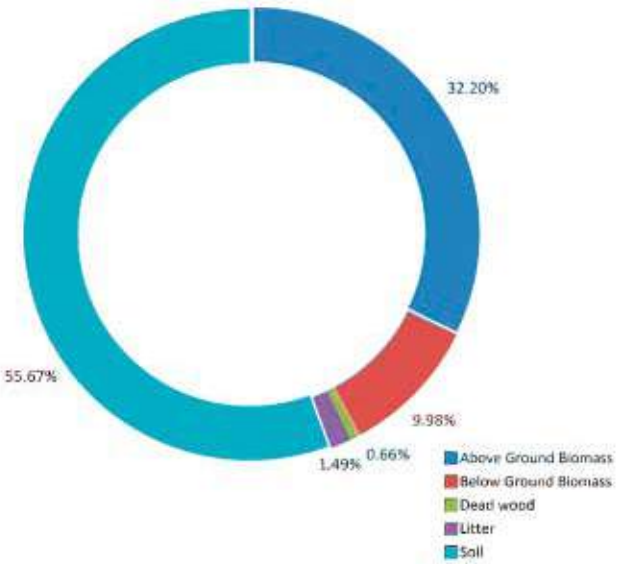


Figure 9.4 Forest Carbon Stock in different pools (%)



9.4.2 Forest Carbon Stock of State & UTs

Forest carbon stock in different carbon pools in States and UT's under different carbon pools are presented in table 9.2. The per hectare for each State/UT's under each pool has been given in parentheses.

(In '000 tonnes)

Table 9.2 Forest Carbon Stock in States & UTs in different carbon pools with stock in tonnes per ha given in parentheses

S. No.	State/ UT	Area sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
1.	Andhra Pradesh	29,784	63,951 (21.47)	25,064 (8.42)	979 (0.33)	3,171 (1.06)	1,37,057 (46.02)	2,30,222 (77.30)
2.	Arunachal Pradesh	66,431	3,40,351 (51.23)	1,02,229 (15.39)	9,163 (1.38)	11,802 (1.78)	5,60,298 (84.34)	10,23,843 (154.12)
3.	Assam	28,312	87,070 (30.75)	21,495 (7.59)	1,875 (0.66)	4,890 (1.73)	1,56,042 (55.12)	2,71,372 (95.85)
4.	Bihar	7,381	14,743 (19.97)	5,249 (7.11)	231 (0.31)	785 (1.06)	35,873 (48.60)	56,881 (77.05)

(In '000 tonnes)

S. No	State/ UT	Area sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
5.	Chhattisgarh	55,717	1,52,714 (27.41)	48,947 (8.78)	2,520 (0.45)	8,487 (1.52)	2,83,769 (50.93)	4,96,437 (89.09)
6.	Delhi	195	263 (13.49)	78 (3.99)	5 (0.24)	17 (0.87)	839 (43.03)	1,202 (61.62)
7.	Goa	2,244	8,863 (39.49)	2,606 (11.61)	232 (1.03)	448 (2.00)	13,095 (58.35)	25,244 (112.48)
8.	Gujarat	14,926	28,602 (19.16)	9,814 (6.58)	502 (0.34)	1,634 (1.09)	67,214 (45.03)	1,07,766 (72.20)
9.	Haryana	1,603	2,326 (14.50)	836 (5.22)	41 (0.26)	139 (0.87)	6,890 (42.97)	10,232 (63.82)
10.	Himachal Pradesh	15,443	1,14,269 (73.99)	31,880 (20.64)	2,657 (1.72)	3,328 (2.15)	1,05,937 (68.60)	2,58,071 (167.10)
11.	Jharkhand	23,721	51,017 (21.51)	20,819 (8.78)	774 (0.33)	2,536 (1.07)	1,09,665 (46.23)	1,84,811 (77.92)
12.	Karnataka	38,730	1,22,741 (31.69)	36,716 (9.48)	2,890 (0.75)	6,380 (1.65)	2,07,668 (53.62)	3,76,395 (97.19)
13.	Kerala	21,253	61,802 (29.08)	17,440 (8.21)	1,534 (0.72)	3,198 (1.50)	1,21,549 (57.19)	2,05,523 (96.70)
14.	Madhya Pradesh	77,493	1,71,587 (22.14)	67,160 (8.67)	2,676 (0.35)	8,653 (1.12)	3,59,174 (46.35)	6,09,250 (78.63)
15.	Maharashtra	50,798	1,37,831 (27.13)	42,353 (8.34)	2,316 (0.46)	7,928 (1.56)	2,61,178 (51.42)	4,51,606 (88.91)
16.	Manipur	16,598	47,590 (28.67)	14,101 (8.50)	880 (0.53)	2,652 (1.60)	1,11,708 (67.30)	1,76,931 (106.60)
17.	Meghalaya	17,046	55,241 (32.41)	15,820 (9.28)	1,238 (0.73)	3,075 (1.80)	1,08,014 (63.37)	1,83,388 (107.59)
18.	Mizoram	17,820	48,157 (27.02)	10,622 (5.96)	758 (0.43)	3,140 (1.76)	95,961 (53.85)	1,58,638 (89.02)
19.	Nagaland	12,251	39,339 (32.11)	10,618 (8.67)	854 (0.70)	2,006 (1.64)	82,115 (67.03)	1,34,932 (110.15)
20.	Odisha	52,156	1,31,015 (25.12)	40,441 (7.75)	2,252 (0.43)	7,671 (1.47)	2,63,451 (50.51)	4,44,830 (85.28)
21.	Punjab	1,847	3,420 (18.52)	1,284 (6.95)	56 (0.31)	175 (0.95)	8,623 (46.70)	13,558 (73.43)
22.	Rajasthan	16,655	26,714 (16.04)	10,803 (6.49)	462 (0.28)	1,476 (0.89)	71,319 (42.82)	1,10,774 (66.52)
23.	Sikkim	3,341	18,024 (53.95)	5,466 (16.36)	498 (1.49)	607 (1.82)	30,944 (92.62)	55,539 (166.24)
24.	Tamilnadu	26,419	60,459 (22.88)	20,671 (7.82)	1,198 (0.45)	3,102 (1.17)	1,29,183 (48.90)	2,14,613 (81.22)
25.	Telangana	21,214	44,413 (20.94)	18,415 (8.68)	675 (0.32)	2,169 (1.02)	96,314 (45.40)	1,61,986 (76.36)
26.	Tripura	7,722	24,349 (31.53)	5,358 (6.94)	477 (0.62)	1,486 (1.92)	43,304 (56.08)	74,974 (97.09)
27.	Uttar Pradesh	14,818	32,543 (21.96)	10,234 (6.91)	534 (0.36)	1,825 (1.23)	72,105 (48.66)	1,17,241 (79.12)
28.	Uttarakhand	24,305	1,59,674 (65.70)	42,893 (17.65)	3,561 (1.46)	5,194 (2.13)	1,66,847 (68.65)	3,78,159 (155.59)
29.	West Bengal	16,832	45,365 (26.95)	14,119 (8.39)	726 (0.43)	2,162 (1.28)	92,889 (55.19)	1,55,261 (92.24)

(in '000 tonnes)

S. No.	State/ UT	Area sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
30.	Andaman Nicobar Islands	6,744	47,560 (70.52)	15,450 (22.91)	1,432 (2.12)	1,808 (2.68)	43,586 (64.63)	1,09,836 (162.86)
31.	Chandigarh	23	47 (20.49)	15 (6.62)	1 (0.30)	3 (1.17)	117 (51.27)	183 (79.85)
32.	Dadra and Nagar Haveli and Daman and Diu	228	558 (24.49)	129 (5.68)	11 (0.48)	38 (1.68)	1,244 (54.60)	1,980 (86.93)
33.	Jammu & Kashmir	21,387	1,63,897 (76.63)	45,864 (21.45)	3,386 (1.58)	4,951 (2.32)	1,52,772 (71.43)	3,70,870 (173.41)
34.	Ladakh	2,272	13,293 (58.50)	3,836 (16.88)	269 (1.18)	317 (1.39)	12,987 (57.16)	30,702 (135.11)
35.	Lakshadweep	27	46 (17.12)	10 (3.77)	1 (0.25)	3 (1.15)	150 (55.34)	210 (77.63)
36.	Puducherry	53	76 (14.25)	17 (3.25)	1 (0.24)	5 (0.96)	287 (53.76)	386 (72.46)
	Total	**7,13,789**	**23,19,910 (32.50)**	**7,18,852 (10.07)**	**47,665 (0.67)**	**1,07,251 (1.50)**	**40,10,168 (56.18)**	**72,03,846 (100.92)**

The above table shows that Arunachal Pradesh has maximum carbon stock of 1,023.84 million tonnes followed by Madhya Pradesh (609.25 million tonnes), Chhattisgarh (496.44 million tonnes) and Maharashtra (451.61 million tonnes). The per hectare carbon stock among different States/UTs indicates that Jammu & Kashmir is contributing maximum per hectare carbon stock of 173.41 tonnes/ha, followed by Himachal Pradesh (167.10 tonnes/ha), Sikkim (166.24 tonnes/ha) and Andaman & Nicobar Islands (162.86 tonnes/ha). At national level 32% of carbon stock is in AGB whereas about 56% in SOC.

9.4.3 Carbon Stock in different carbon pools under different forest types and density

Carbon stock in different carbon pools under different forest types and density is given in Table 9.3. The per hectare for each forest type and pool has been given in parentheses.

Table 9.3 Forest Type and Density wise Carbon Stock in different carbon pools with per ha stock in tonnes in parentheses

(in '000 tonnes)

Forest Type Stratum	Density	Area in	AGB sq km	BGB	Dead	Litter Wood	SOC	Total
Tropical Wet Evergreen Forests	VDF	9,147	81,708 (89.33)	30,230 (33.05)	2,753 (3.01)	3,211 (3.51)	66,524 (72.73)	1,84,426 (201.63)
	MDF	7,863	54,720 (69.59)	20,248 (25.75)	1,801 (2.29)	1,989 (2.53)	51,676 (65.72)	1,30,434 (165.88)
	OF	2,562	10,250 (40.01)	3,792 (14.80)	305 (1.19)	151 (0.59)	16,256 (63.45)	30,754 (120.04)
Tropical Semi-Evergreen Forests	VDF	8,520	50,693 (59.50)	11,152 (13.09)	1,772 (2.08)	1,534 (1.80)	48,051 (56.40)	1,13,202 (132.87)
	MDF	29,997	1,28,717 (42.91)	28,317 (9.44)	2,760 (0.92)	7,079 (2.36)	1,65,103 (55.04)	3,31,976 (110.67)
	OF	30,679	62,860 (20.49)	13,836 (4.51)	460 (0.15)	4,479 (1.46)	1,59,191 (51.89)	2,40,826 (78.50)
Tropical Moist Deciduous Forests	VDF	24,796	1,13,291 (45.69)	24,920 (10.05)	1,760 (0.71)	6,372 (2.57)	1,45,624 (58.73)	2,91,967 (117.75)
	MDF	65,377	2,17,248 (33.23)	47,791 (7.31)	4,446 (0.68)	15,298 (2.34)	3,79,384 (58.03)	6,64,167 (101.59)
	OF	41,632	92,298 (22.17)	20,316 (4.88)	1,749 (0.42)	6,370 (1.53)	2,25,812 (54.24)	3,46,545 (83.24)

(in '000' tonnes)

Forest Type Stratum	Density	Area in sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
Littoral and Swamp Forests	VDF	1,558	13,644 (87.55)	5,048 (32.39)	92 (0.59)	466 (2.99)	9,764 (62.65)	29,014 (186.17)
	MDF	1,653	9,567 (57.88)	3,541 (21.42)	93 (0.56)	264 (1.60)	10,296 (62.29)	23,761 (143.75)
	OF	2,267	4,835 (21.33)	1,789 (7.89)	88 (0.39)	197 (0.87)	12,940 (57.08)	19,849 (87.56)
Tropical Dry Deciduous Forests	VDF	23,634	83,522 (35.34)	35,073 (14.84)	1,158 (0.49)	4,750 (2.01)	1,22,659 (51.90)	2,47,162 (104.58)
	MDF	1,25,840	3,56,504 (28.33)	1,49,749 (11.90)	4,279 (0.34)	12,836 (1.02)	6,11,455 (48.59)	11,34,823 (90.18)
	OF	1,31,074	1,67,119 (12.75)	70,124 (5.35)	3,670 (0.28)	11,534 (0.88)	5,42,383 (41.38)	7,94,830 (60.64)
Tropical Thorn Forests	VDF	165	412 (25.03)	172 (10.48)	30 (1.82)	18 (1.09)	750 (45.58)	1,382 (84.00)
	MDF	3,587	3,852 (10.74)	1,618 (4.51)	129 (0.36)	344 (0.96)	13,464 (37.54)	19,407 (54.11)
	OF	9,508	6,950 (7.31)	2,919 (3.07)	124 (0.13)	542 (0.57)	18,302 (19.25)	28,837 (30.33)
Tropical Dry Evergreen Forests	VDF	133	644 (48.57)	270 (20.38)	17 (1.28)	18 (1.35)	1,181 (89.02)	2,130 (160.60)
	MDF	420	1,644 (39.12)	691 (16.43)	21 (0.50)	46 (1.10)	1,524 (36.26)	3,926 (93.41)
	OF	282	475 (16.84)	200 (7.09)	2 (0.07)	25 (0.89)	991 (35.14)	1,693 (60.03)
Subtropical Broadleaved Hill Forests	VDF	7,288	49,406 (67.79)	20,749 (28.47)	794 (1.09)	1,348 (1.85)	71,089 (97.54)	1,43,386 (196.74)
	MDF	13,859	44,211 (31.90)	18,571 (13.40)	1,233 (0.89)	2,772 (2.00)	1,23,832 (89.35)	1,90,619 (137.54)
	OF	9,868	18,236 (18.48)	7,657 (7.76)	30 (0.03)	750 (0.76)	71,897 (72.86)	98,570 (99.89)
Subtropical Pine Forests	VDF	1,787	16,436 (91.98)	4,437 (24.83)	284 (1.59)	307 (1.72)	13,407 (75.03)	34,871 (195.15)
	MDF	9,077	48,516 (53.45)	13,098 (14.43)	1,253 (1.38)	1,489 (1.64)	62,848 (69.24)	1,27,204 (140.14)
	OF	6,937	22,892 (33.00)	6,181 (8.91)	333 (0.48)	992 (1.43)	46,886 (67.59)	77,284 (111.41)
Subtropical Dry Evergreen Forest	VDF	8	90 (106.25)	38 (45.00)	1 (1.25)	1 (1.25)	95 (112.50)	225 (266.25)
	MDF	60	532 (89.33)	223 (37.50)	2 (0.33)	4 (0.67)	397 (66.67)	1,158 (194.50)
	OF	105	515 (49.14)	217 (20.67)	2 (0.19)	3 (0.29)	578 (55.14)	1,315 (125.43)
Montane Wet Temperate Forests	VDF	8,599	50,614 (58.86)	13,664 (15.89)	1,789 (2.08)	1,703 (1.98)	1,11,358 (129.50)	1,79,128 (208.31)
	MDF	9,423	29,042 (30.82)	7,840 (8.32)	1,555 (1.65)	433 (0.46)	1,08,951 (115.62)	1,47,821 (156.87)
	OF	2,163	4,815 (22.26)	1,300 (6.01)	43 (0.20)	91 (0.42)	9,275 (42.88)	15,524 (71.77)
Himalayan Moist Temperate Forests	VDF	8,687	1,37,280 (158.03)	37,067 (42.67)	4,170 (4.80)	3,953 (4.55)	72,858 (83.87)	2,55,328 (293.92)
	MDF	13,534	1,37,248 (101.41)	37,056 (27.38)	2,815 (2.08)	3,262 (2.41)	1,08,637 (80.27)	2,89,018 (213.55)
	OF	6,506	43,508 (66.87)	11,744 (18.05)	768 (1.18)	1,217 (1.87)	45,135 (69.37)	1,02,372 (157.34)
Himalayan Dry Temperate Forests	VDF	1,227	20,409 (166.28)	5,919 (48.22)	242 (1.97)	1,105 (9.00)	12,968 (105.65)	40,643 (331.12)
	MDF	1,681	21,875 (130.17)	6,344 (37.75)	235 (1.40)	437 (2.60)	12,476 (74.24)	41,367 (246.16)
	OF	1,347	9,643 (71.59)	2,796 (20.76)	106 (0.79)	189 (1.40)	9,158 (67.99)	21,892 (162.53)

(In '000' tonnes)

Forest Type Stratum	Density	Area in	AGB sq km	BGB	Dead	Litter Wood	SOC	Total
Sub-Alpine Forests	VDF	2,785	32,208 (115.64)	9,339 (33.53)	443 (1.59)	735 (2.64)	32,322 (116.05)	75,047 (269.45)
	MDF	5,662	36,627 (64.69)	10,622 (18.76)	1,523 (2.69)	1,263 (2.23)	47,662 (84.18)	97,697 (172.55)
	OF	4,225	20,274 (47.99)	5,876 (13.91)	511 (1.21)	545 (1.29)	32,491 (76.91)	59,697 (141.31)
Moist Alpine Scrub	VDF	76	393 (51.45)	114 (14.87)	9 (1.18)	15 (1.97)	507 (66.32)	1,038 (135.79)
	MDF	279	781 (28.03)	227 (8.14)	10 (0.36)	23 (0.82)	1,582 (56.77)	2,623 (94.12)
	OF	297	271 (9.12)	79 (2.66)	6 (0.20)	19 (0.64)	1,598 (53.77)	1,973 (66.39)
Dry Alpine Scrub	VDF	194	1,908 (98.45)	553 (28.56)	23 (1.19)	46 (2.37)	1,171 (60.46)	3,701 (191.03)
	MDF	583	3,551 (60.87)	1,030 (17.65)	45 (0.77)	110 (1.89)	3,345 (57.34)	8,081 (138.52)
	OF	1,619	8,397 (51.88)	2,436 (15.05)	159 (0.98)	159 (0.98)	4,524 (27.95)	15,675 (96.84)
Plantation/TOF	VDF	1,174	4,749 (40.44)	1,045 (8.90)	129 (1.10)	93 (0.79)	7,278 (61.98)	13,294 (113.21)
	MDF	17,996	39,878 (22.16)	8,782 (4.88)	522 (0.29)	2,573 (1.43)	1,04,465 (58.05)	1,56,220 (86.81)
	OF	56,051	54,650 (9.75)	12,051 (2.15)	1,121 (0.20)	4,092 (0.73)	2,88,047 (51.39)	3,59,961 (64.22)
Total	**7,13,789**		**23,18,909 (32.50)**	**7,18,850 (10.07)**	**47,663 (0.67)**	**1,07,252 (1.50)**	**40,10,169 (56.18)**	**72,03,843 (100.92)**

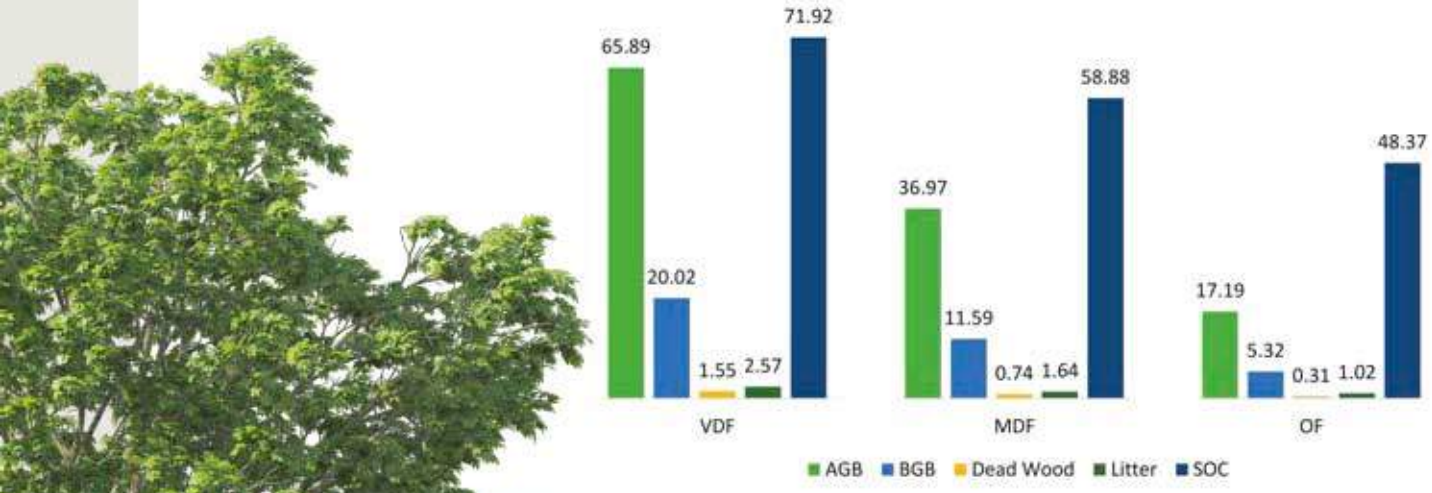


Figure 9.5
Density wise carbon stock per ha in tonnes in different pools

Carbon stock in different forest types under different pools 9.4.4

Carbon stock in different forest types under different pools is given in Table 9.4. The per hectare for each forest type and pool has been given in parentheses.

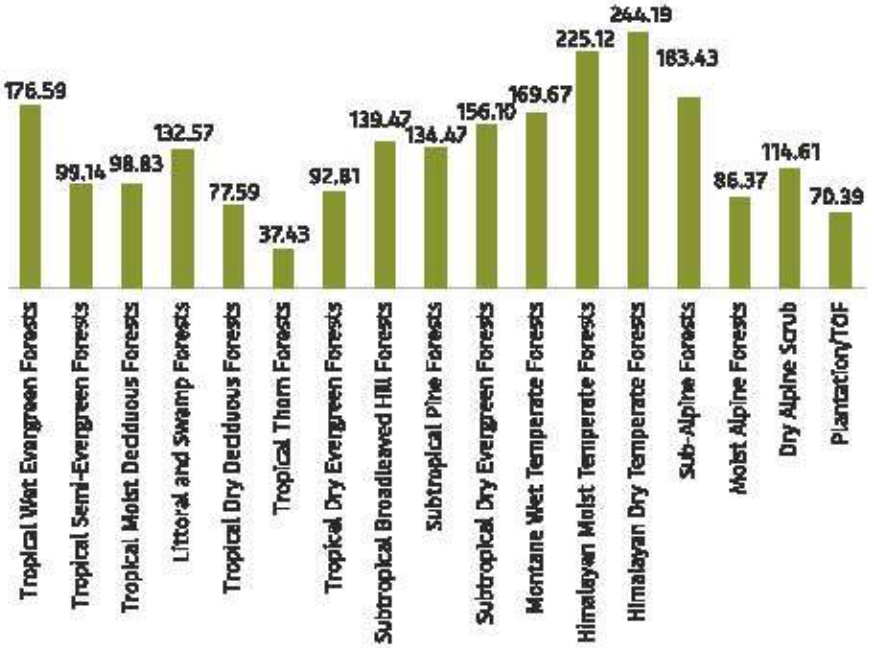
(In '000 tonnes)

Forest Type Stratum	Area in sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
Tropical Wet Evergreen Forests	19,572	1,46,678 (74.94)	54,269 (27.73)	4,859 (2.48)	5,351 (2.73)	1,34,456 (68.70)	3,45,613 (176.58)
Tropical Semi-Evergreen Forests	69,195	2,42,270 (35.01)	53,306 (7.70)	4,992 (0.72)	13,092 (1.89)	3,72,346 (53.81)	6,86,006 (99.13)
Tropical Moist Deciduous Forests	1,31,805	4,22,838 (32.08)	93,027 (7.06)	7,955 (0.60)	28,040 (2.13)	7,50,821 (56.96)	13,02,681 (98.83)
Littoral and Swamp Forests	5,478	28,046 (51.20)	10,377 (18.94)	273 (0.50)	928 (1.69)	32,999 (60.24)	72,623 (132.57)
Tropical Dry Deciduous Forests	2,80,547	6,07,145 (21.64)	2,54,946 (9.09)	9,107 (0.32)	29,121 (1.04)	12,76,497 (45.50)	21,76,816 (77.59)
Tropical Thorn Forests	13,259	11,214 (8.46)	4,709 (3.55)	283 (0.21)	904 (0.68)	32,516 (24.52)	49,626 (37.42)
Tropical Dry Evergreen Forests	835	2,763 (33.09)	1,161 (13.90)	40 (0.48)	89 (1.07)	3,696 (44.26)	7,749 (92.80)
Subtropical Broadleaved Hill Forests	31,015	1,11,853 (36.06)	46,978 (15.15)	2,057 (0.66)	4,870 (1.57)	2,66,818 (86.03)	4,32,576 (139.47)
Subtropical Pine Forests	17,801	87,843 (49.35)	23,715 (13.32)	1,870 (1.05)	2,788 (1.57)	1,23,141 (69.18)	2,39,357 (134.47)
Subtropical Dry Evergreen Forest	173	1,137 (65.77)	478 (27.66)	5 (0.29)	8 (0.47)	1,070 (61.91)	2,698 (156.10)
Montane Wet Temperate Forests	20,185	84,471 (41.85)	22,804 (11.30)	3,387 (1.68)	2,227 (1.10)	2,29,584 (113.74)	3,42,473 (169.67)
Himalayan Moist Temperate Forests	28,727	3,18,037 (110.71)	85,867 (29.89)	7,753 (2.70)	8,431 (2.93)	2,26,630 (78.89)	6,46,718 (225.12)
Himalayan Dry Temperate Forests	4,255	51,927 (122.04)	15,059 (35.39)	583 (1.37)	1,730 (4.07)	34,601 (81.32)	1,03,900 (244.19)
Sub-Alpine Forests	12,672	89,109 (70.32)	25,837 (20.39)	2,477 (1.95)	2,543 (2.01)	1,12,476 (88.76)	2,32,442 (183.43)
Moist Alpine Scrub	652	1,445 (22.16)	420 (6.43)	25 (0.38)	57 (0.87)	3,687 (56.52)	5,634 (86.36)
Dry Alpine Scrub	2,396	13,856 (57.84)	4,019 (16.78)	227 (0.95)	315 (1.31)	9,041 (37.74)	27,458 (114.62)
Plantation/TOF	75,221	99,277 (13.20)	21,878 (2.91)	1,772 (0.24)	6,758 (0.90)	3,99,790 (53.15)	5,29,475 (70.40)
Total	**7,13,789**	**23,19,909 (32.50)**	**7,18,850 (10.07)**	**47,865 (0.67)**	**1,07,252 (1.50)**	**40,10,189 (56.18)**	**72,03,845 (100.92)**

Table 9.4 Forest Type wise Carbon Stock at the National level in different carbon pools with per ha stock given in tonnes in parenthesis

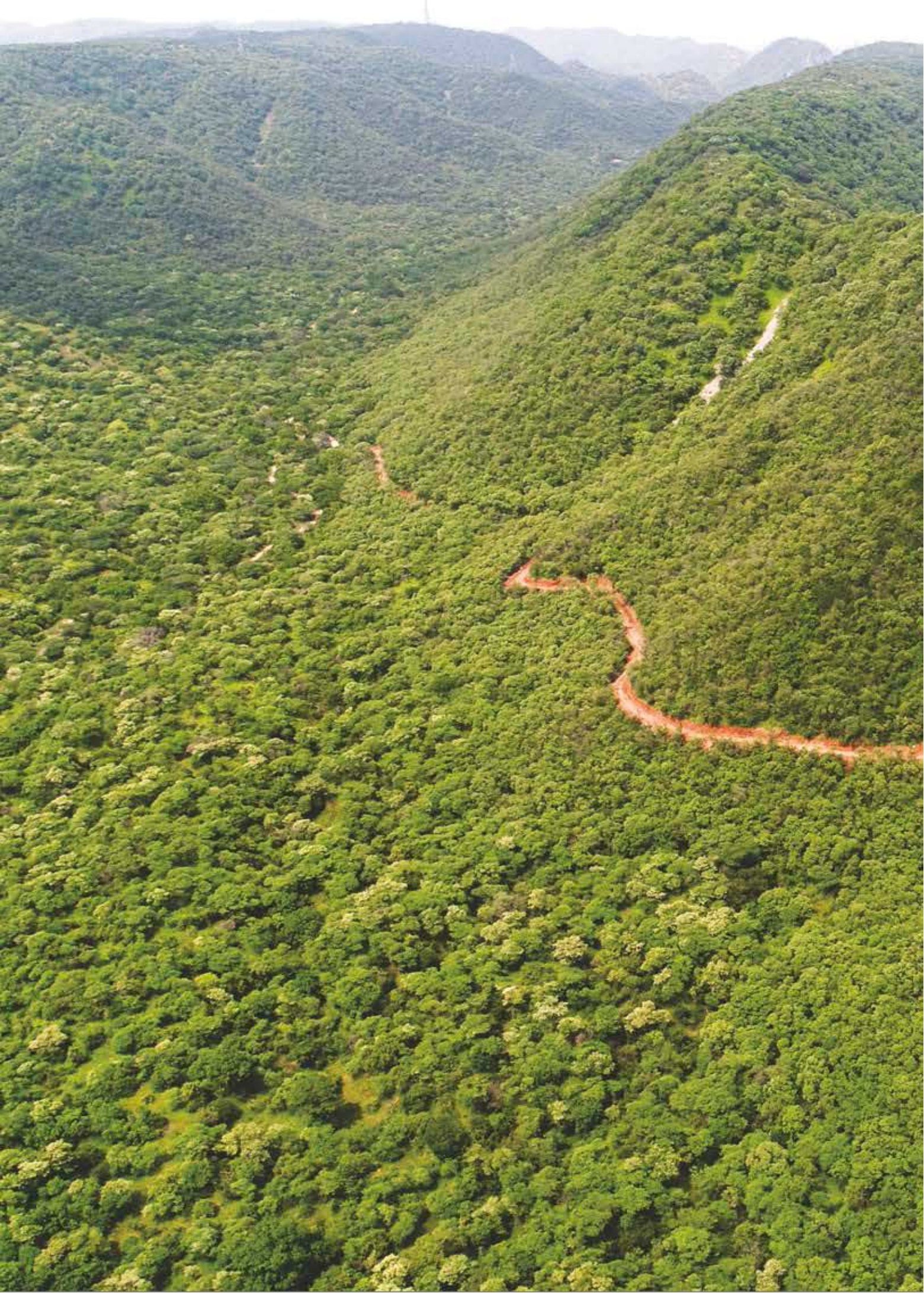
The Table 9.4 shows that the maximum carbon stock has been stored in Tropical Dry Deciduous Forest (2,177 million tonnes) followed by Tropical Moist Deciduous Forest (1,303 million tonnes) and Tropical Semi Evergreen Forest (686 million tonnes).

Figure 9.8
Forest Type wise carbon stock per ha in tonnes



9.5 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 6,663 million tonnes in the 2011 assessment to 7,204.0 million tonnes in the present assessment showing an increase of 541 million tonnes between the period 2011 to 2021.



10

ABOVE GROUND BIOMASS ESTIMATION USING SAR DATA

10.1 Introduction

Forests are important constituents of ecosystems worldwide. Forests perform a variety of ecosytem services, one of the most vital ones being absorbing Carbon dioxide from the atmosphere and converting it into biomass. Biomass refers to the mass of the living organism within a tree. Forest biomass comprises nearly 80% of the total biomass on the earth (Reichstein & Carvalhais, 2019)[1] . Estimation of forest biomass helps in enhancing our understanding about the global carbon sink, assessment of carbon stock and the commercial significance of forest through wood production. Mapping and monitoring of forest biomass provides valuable insight into health of forests, carbon stock, carbon sink and sources as well as issues related to Green House Gas (GHG) emissions.

Forest degradation has emerged as a major concern for the global community. World over, strategies are being formulated and implemented to promote sustainable development of the forest and reduction in deforestation/ degradation. Some of these programmes include Reducing Emission from Deforestation & Forest Degradation Plus sustainable forest management and enhancing forest carbon sink (REDD+), Paris Agreement, AICHI targets, Sustainable Development Goals (SDG's) etc.

Forest Survey of India (FSI) has been using field inventory techniques to assess number of trees, growing stock, bamboo estimates, soil carbon, and several other parameters that depict growth & health of forests. Such estimation is based on statistical analysis of field inventory data and provides a larger picture regarding forest biomass. However, data collection from the field is expensive, time consuming, labour intensive, and does not necessarily provide a synoptic coverage of biomass distribution. There are situations when it is not possible to collect data from remote & inaccessible areas. These limitations may be overcome by using remote sensing based tools and techniques.

Information about spatial distribution of the forest biomass and the biomass categories is important for proper management of the forest resources. In 2018 FSI, in collaboration with Space Application Centre (SAC), ISRO, Ahmedabad initiated a special study for estimation of Above Ground Biomass (AGB) at pan-India level using L- band of Synthetic Aperture Radar (SAR) data. The results for the States of Assam and Odisha (as well as AGB maps), were presented in ISFR 2019. The interim results for AGB estimates (and AGB maps) for the entire country are being presented in this chapter. The detailed report will be published on completion of the study.

[1] *M. Reichstein & N. Carvalhais, 2019, Aspects of Forest Biomass in the Earth System: Its Role and Major Unknowns, Surveys in Geophysics volume 40, pages 693-707*

10.1.1 Objectives of the Assessment

The study has been undertaken to achieve the following objectives

- Explore the potential of Synthetic Aperture Radar (SAR) data for understanding forest structure and ultimately biomass within forest.
- Generate estimates of forest biomass at state and country level.
- To prepare AGB map of the country on wall-to-wall basis.
- Synthesize National Forest Inventory data for generation of forest biomass at plot level basis.

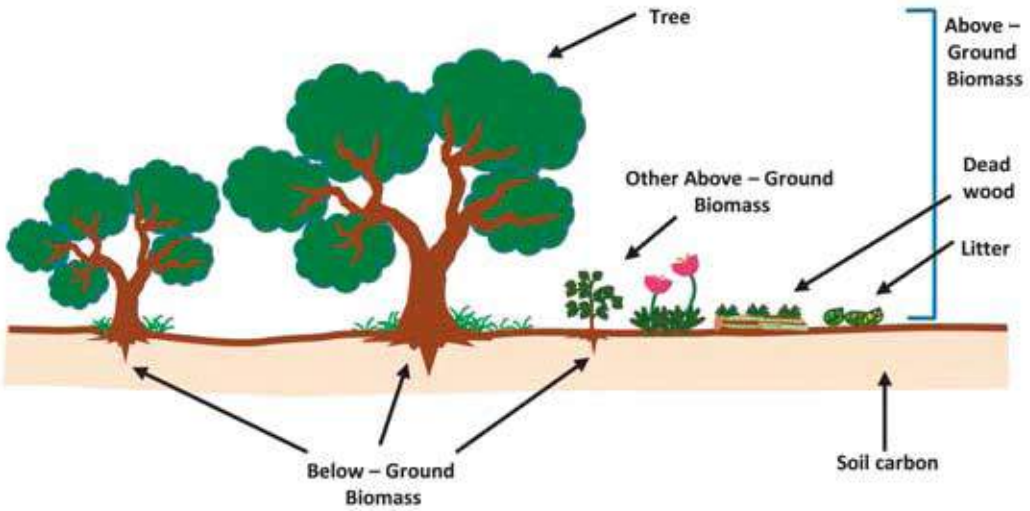
10.2 Forest Biomass

According to IPCC GPG 2003[2] , Forest biomass is an organic product of photosynthesis which is broadly divided into two components:

Above Ground Biomass (AGB) contain the part of vegetation above the ground e.g. stumps, tree, deadwood, litter and foliage.

Below Ground Biomass (BGB) which includes the parts of the tree (roots) which are situated under the ground.

Figure 10.1 Types of Forest Biomass



Source: The IPCC GPG (2003) - Five Carbon Pools

Globally, AGB is a commonly estimated parameter because of its utility in estimation of forest, atmospheric carbon and the GHGs. The present study has focused on the AGB and not ventured into the estimation of the BGB owing to limitation of sensor and non- availability of data for BGB estimates.

[2] *IPCC, 2003. Good Practice Guidance for LULUCF*

Importance of estimating Above Ground Biomass 10.2.1

- Forest biomass serves as an important variable for evaluating carbon sequestration and carbon balance capacity of forest ecosystems.
- Biomass is an important indicator of ecological and management processes in the vegetation[3].
- AGB assessment and monitoring is important for national GHG inventory and activities related to forest ecosystem.
- Provides important inputs for policy formulation related to forestry sector and environment management.
- Provides important information for forest fire risk assessment.
- AGB is the most visible of all the carbon pools, and change in AGB indicates the impact of an intervention on the carbon pool.

Different methods for Above Ground Biomass estimation 10.2.2

With the advancement of technology, techniques for assessment of biomass have changed from the traditional field measurement to the satellite based approaches. Traditionally, biomass has been measured by ground measurement through collection of information on DBH (Diameter at Breast Height), number of tree species, tree height etc. within sample plots. Weighing trees in the field is the most accurate method for estimating tree biomass. Biomass of a tree, till now has been calculated though volumetric or allometric equations in many of the countries.

Remote sensing data provides information based on spatial, spectral and temporal requirements, thereby allowing a synoptic coverage of large area. Optical remote sensing (visible to near infra-red part of the electromagnetic spectrum) is a widely used technology for mapping and monitoring forest resources. These systems use variable spectral response pattern from the visible and near-infrared spectral regions. The optical remote sensing data has been used by researchers to estimate forest biomass. However, due to data saturation beyond 30-50 tonnes/ ha, the estimates for higher biomass regions are not precise enough. Moreover, poor penetration capabilities of this part of the spectrum through forest canopy & cloud, functionality during day light hours only, and its dependence on weather conditions limits its usage for biomass estimation studies.

LIDAR (Light Detection and Ranging) is a laser scanning technique, which works in the near infra-red part of the electromagnetic spectrum (0.75 µm to 1.5 µm). It is a widely used technology for biomass estimation through 3D point cloud data. 3D point cloud data provides detailed information regarding structure and height of trees. However, LIDAR data is limited to small scale studies, as it is not freely available and is expensive when used for estimating biomass. With the advancement in space technology in terms of sensor resolution, data capture and synoptic coverage, Microwave Remote Sensing is currently the preferred technology for biomass estimation. Microwave Remote Sensing offers certain advantages like:

- Deep penetration capability within tree canopy thus allowing more information on tree structure and under the canopy.
- As an active sensor, it can capture data during day and night without any adverse effect due to atmospheric distortions.

[3] *Principles of Vegetation Measurement & Assessment and Ecological Monitoring & Analysis University of Idaho.* https://www.webpages.uidaho.edu/veg_measure/Modules/Lessons/7.BiomassUtilization.htm

- Microwave data is weather independent.
- Provides information on surface granularity, dielectric properties and moisture content.
- Imaging the earth surface from different type of polarizations (J.R. Jensen, 2007*) serves as a means for better feature extraction.

Of all the available Microwave bands, L-band is widely used for forest biomass estimation due to their longer wavelengths and deep penetration from tree canopy and better interaction in the form of backscatter from branches and tree trunk as illustrated below:

Table 10.1 Different bands of Microwave Data

RADAR Bands	Wavelength (cm)	Frequency (GHz)
Ka	0.75-1.13	26.5-40.0
K	1.13-1.67	18.0-26.5
Ku	1.67-2.4	12.5-18.0
X	2.4-3.75	8.0-12.5
C	3.75-7.5	4.0-8.0
S	7.5-15	2.0-4.0
L	15-30	1.2-2.0
P	30-100	0.3-1.0

Figure 10.2 Penetration capability of RADAR (Microwave) Data

10.3 Data Used

Following data have been used for estimation of AGB for pan-India.

* John R. Jensen (2007). Remote sensing of the environment: An earth Resource Perspective

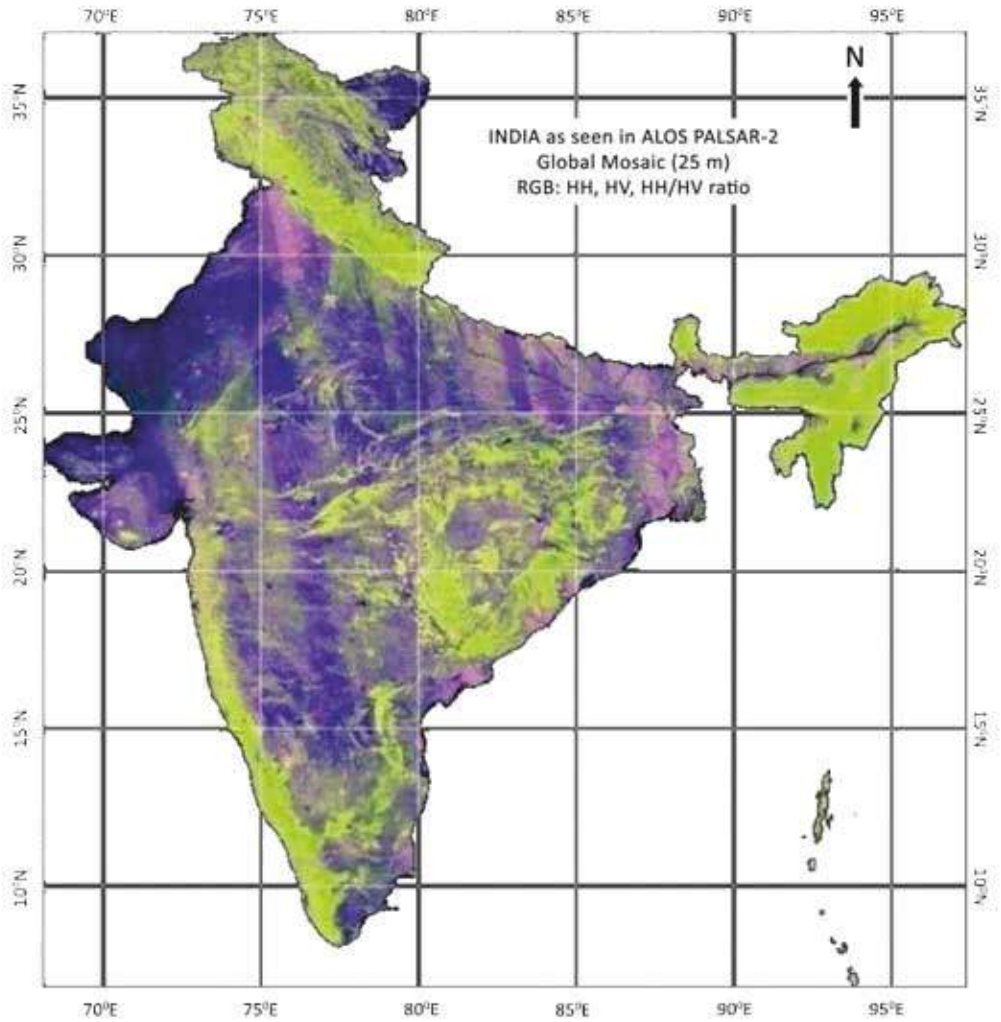
ALOS PALSAR-2 Data 10.3.1

In this study, Phased Array type L-band Synthetic Aperture Radar (PALSAR-2) on -board Advanced Land Observing Satellite (ALOS) Global Mosaic with resolution of 25 m data from Japan Aerospace Exploration Agency (JAXA)[3] has been used. The detailed specification of ALOS PALSAR-2 is given in Table 10.2 and the synoptic coverage is shown in Figure 10.3.

Satellite	ALOS PALSAR - 2
Calibration Factor	-83
Band	L-band
Resolution	25 m
Level	2
Polarization	HH+HV

Source: Japan Aerospace Exploration Agency (JAXA)

Table 10.2 Detailed specification of ALOS PALSAR-2



Source: Space Application Centre (SAC)

Figure 10.3 ALOS PALSAR-2 False Colour Composite of pan-India

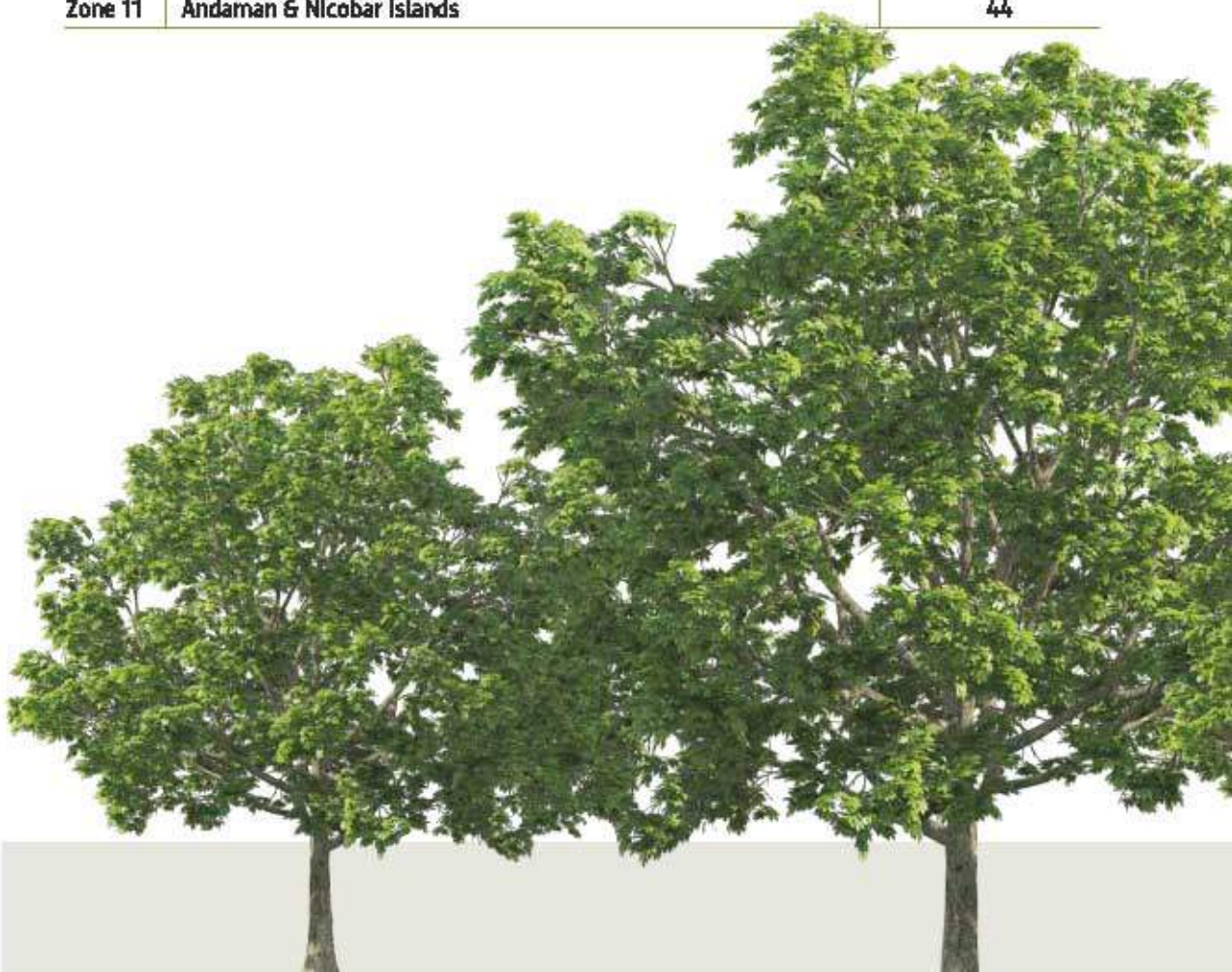
[3] (http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm)

10.3.2 Field Inventory Data

Forest inventory data collected by field parties of FSI has been synthesized to generate plot-level forest biomass data. This data has been further used to train the biomass models for generation of pan-India biomass estimates. A total of 7,835 plot level data have been used. Prior to processing the information from inventory plots, they have been verified using high resolution Google Earth imagery. Inventoried sample plots with undulating terrain and heterogeneous species have been removed from analysis to minimise errors. Finally, 6,763 plots have been selected for analysis. The zone-wise distribution of sample plots has been carried out on the basis of distribution of inventory data and physiographic zones of India as illustrated in Table 10.3 and Figure 10.4.

Table 10.3 Zone-wise distribution of inventory data

Zones	States/Union Territories	No. of plots
Zone 1	Jammu & Kashmir, Ladakh, Uttarakhand and Himachal Pradesh	814
Zone 2	Punjab, Haryana, Delhi, Chandigarh and Uttar Pradesh	346
Zone 3	Rajasthan, Gujarat and Daman & Diu	559
Zone 4	Madhya Pradesh	823
Zone 5	Jharkhand, West Bengal and Bihar	548
Zone 6	North-Eastern states and Darjeeling(West Bengal)	1,056
Zone 7	Chhattisgarh and Odisha	1,032
Zone 8	Maharashtra, Dadra & Nagar Haveli and Telangana	904
Zone 9	Goa, Karnataka and Andhra Pradesh	1,030
Zone 10	Kerala, Lakshadweep, Tamil Nadu and Puducherry	671
Zone 11	Andaman & Nicobar Islands	44



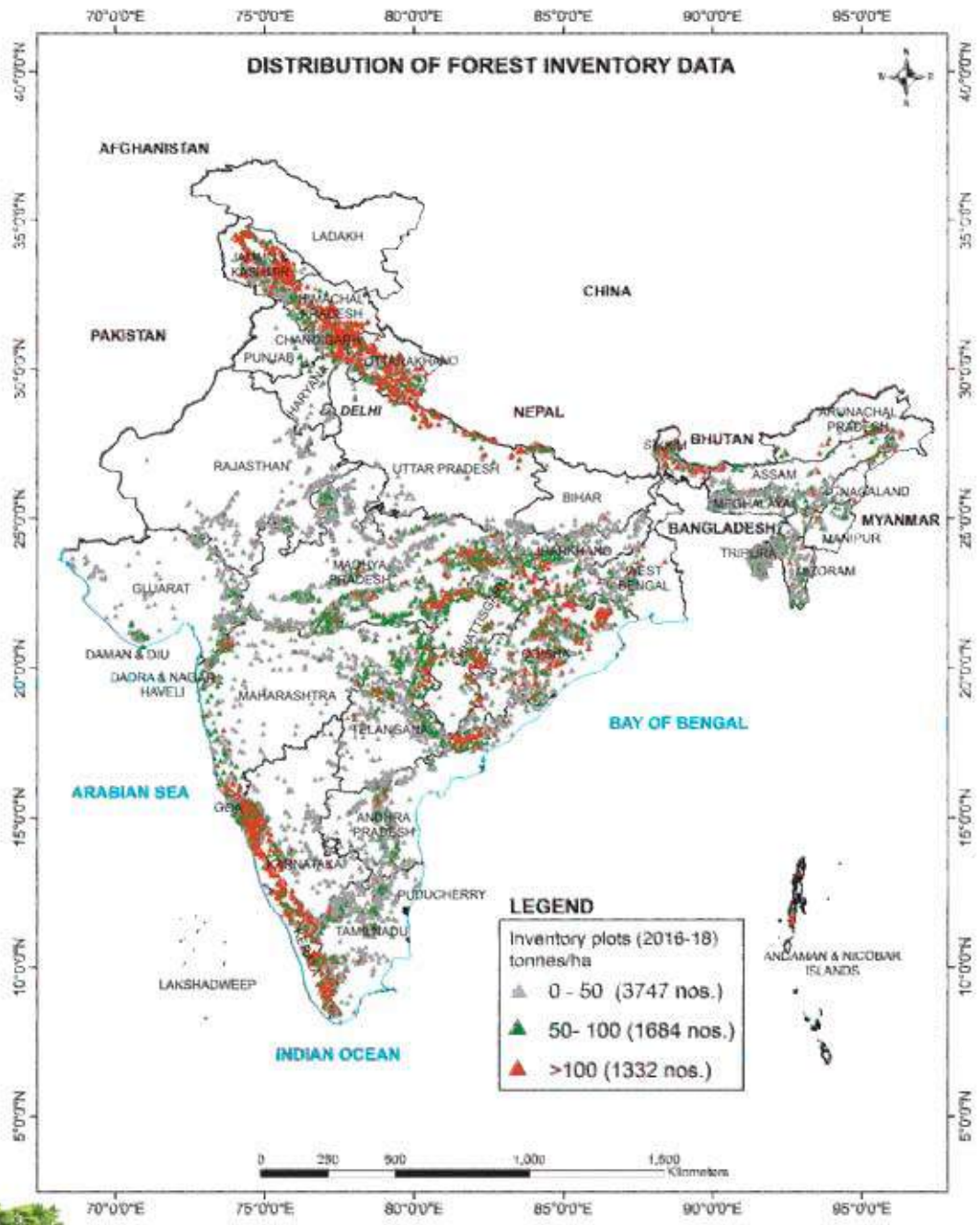


Figure 10.4
Distribution of Inventory Data in India

Forest Cover Map, 2019 10.3.3

Forest Cover map of ISFR 2019 assessment has been used in the study to mask out forest cover for estimation of AGB.

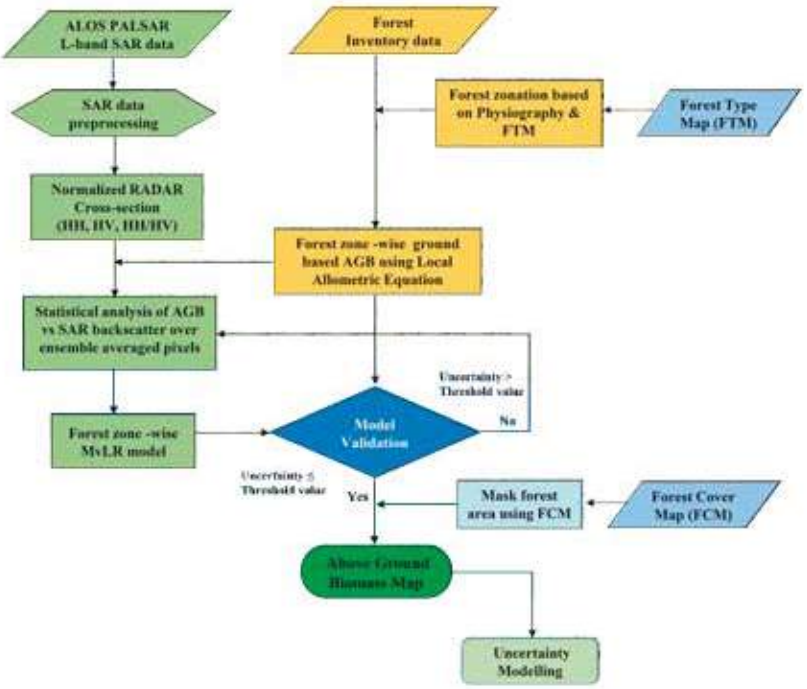
10.3.4 Forest Type Map, 2020

Forest type information has been used from Atlas Forest Types of India 2020 for analysis and validation of AGB maps. Preliminary validation of the generated biomass has been carried out using Forest Type maps. Backscatter (dependent on dielectric constant and surface granularity of the feature) has been found to have a good correlation with the different Forest Type Groups.

10.4 Methodology

The flowchart of the methodology used in the estimation is given in Figure 10.5. National Inventory Data at one hectare plot level have been used for calculation of biomass value in the individual plots.

Figure 10.5 Flowchart of the methodology used for AGB Estimation



10.4.1 Pre-processing of data

The sample biomass plots have been converted as geospatial vector layers to be further overlaid on SAR data to retrieve mean value by averaging of 3 X 3 pixels. ALOS PALSAR-2 data is ortho-rectified using SRTM data. The by-product of Shuttle Radar Topography Mission - Digital Elevation Model [SRTM (DEM)] data, slope and aspect map has been helpful to identify very steep slope areas and shadow region according to the sensor look angle and for topographic correction.

ALOS PALSAR-2 global mosaic data has been radiometrically calibrated to convert the DN value to sigma naught (σ^o) in decibel unit (dB) in order to generate backscatter image in different

polarization levels (HH, HV, and HH/HV). The calibrated Synthetic Aperture Radar (SAR) data is helpful for information extraction through statistical methods. The following equation has been used for conversion of DN image into backscatter:

$$\sigma^{\circ}(dB) = 10 * \log_{10}(DN^2) + CF \quad \ldots (1)$$

Where,

$\sigma^{\circ}(dB)$ = Backscattering coefficient (Sigma Naught) [unit: dB]

DN = Digital number (or raw pixel value)

CF = Calibration factor

Zonal analysis of biomass has been carried out on the basis of physiographic division of India and distribution of Field Inventory Data.

Source: Japan Aerospace Exploration Agency (JAXA)

Statistical Analysis 10.4.2

Correlation analysis helps to understand the relationship between two or more different variables. Coefficient of correlation (r) shows whether the relation is positive or negative which ranges from -1 to +1 between the variables. The relationship between the reference AGB obtained from field inventory plots (ground measured) and backscatter values of SAR data (HH, HV and HH/HV) has been analysed using scatterplot. The result shows HH and HV have good agreement with ground measured AGB values.

Multi-Linear Regression (MLR) technique 10.4.3

This technique has been used to model the best fitted variables (HH, HV) based on correlation analysis between ground measured AGB and SAR Data. Backscatter values of HH and HV polarised SAR data have been used as an independent variable values and ground measured AGB as dependent variables in the study to generate model coefficient which have been further used to estimate AGB for pan-India.

The biomass equation used in the present study is given below:

$$Y_{\text{Biomass (tonnes/ha)}} = A + (B * \sigma^{\circ}a_1) + (C * \sigma^{\circ}a_2) \quad \ldots (2)$$

Where,

Y = Predicted Biomass

A, B, C = Model coefficient

a1, a2, .. = Selected Parameters (HH, HV, HH/HV etc.)

Masking of Forest Cover Areas 10.4.4

The Forest Cover map (ISFR, 2019) has been used to mask out the forest and non-forest area from the estimated AGB data. Finally, AGB map has been produced.

10.5 Results & Analysis

The preliminary results of AGB estimation for the country are presented in Table 10.4 and pan-India map (MMU 1 ha) is shown in Figure 10.7. Based on the analysis, the AGB estimates have been divided into six classes (from greater than 0 tonnes/ ha to above 150 tonnes/ ha) with an interval of 30 tonnes/ ha.

Table 10.4 Class-wise distribution of Above Ground Biomass in India

Colour	AGB (tonnes/ ha)	Area (sq.km)	AGB (within forest cover in %)	Total Geographical Area (%)
	< 30	2,06,651.61	27.24	6.28
	30-60	98,525.22	12.99	3.00
	60-90	1,23,014.57	16.22	3.74
	90-120	1,33,226.30	17.56	4.05
	120-150	1,02,894.01	13.57	3.13
	>150	94,234.19	12.42	2.87

The above classification has been adopted due to sensitivity of SAR backscatter to the soil moisture, terrain properties and sensor parameters which affects SAR backscatter values, although there may be minimum difference in the forest canopy and tree structure. Class-wise distribution of AGB for the entire country has been shown in a pie-chart in Figure 10.6. Based on the analysis of the AGB estimates, it has emerged that the highest percentage of forest cover falls under the class of <30 tonnes/ha, whereas the lowest percentage of forest cover falls under the class of >150 tonnes/ha. The status of AGB estimates in State/UTs of India is presented in Table 10.5.

Figure 10.6 Pie-chart showing Class-wise distribution of AGB in India

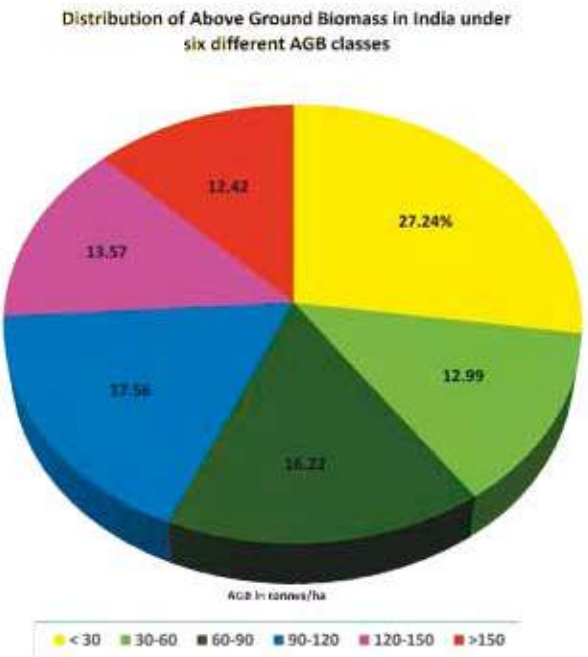
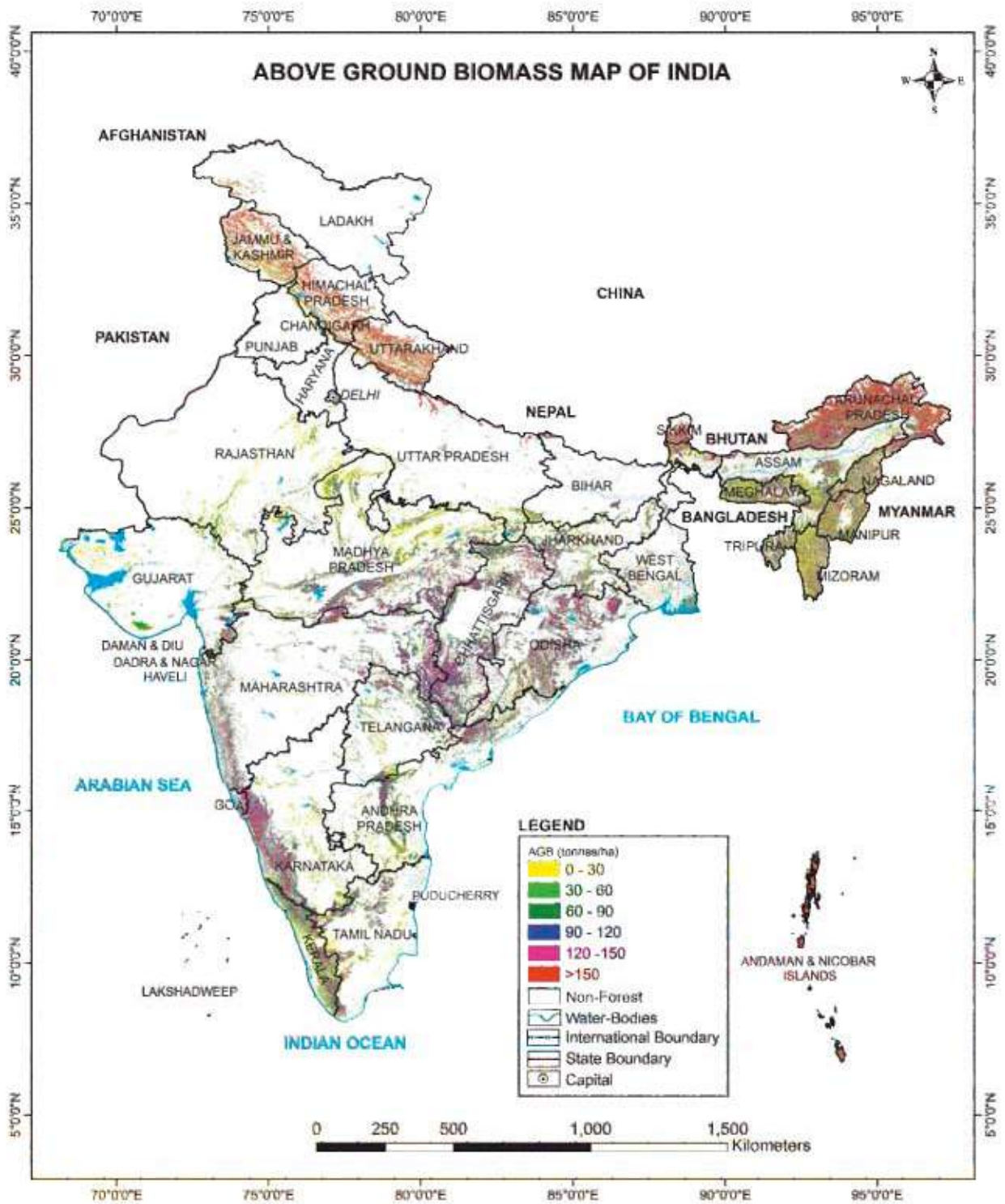
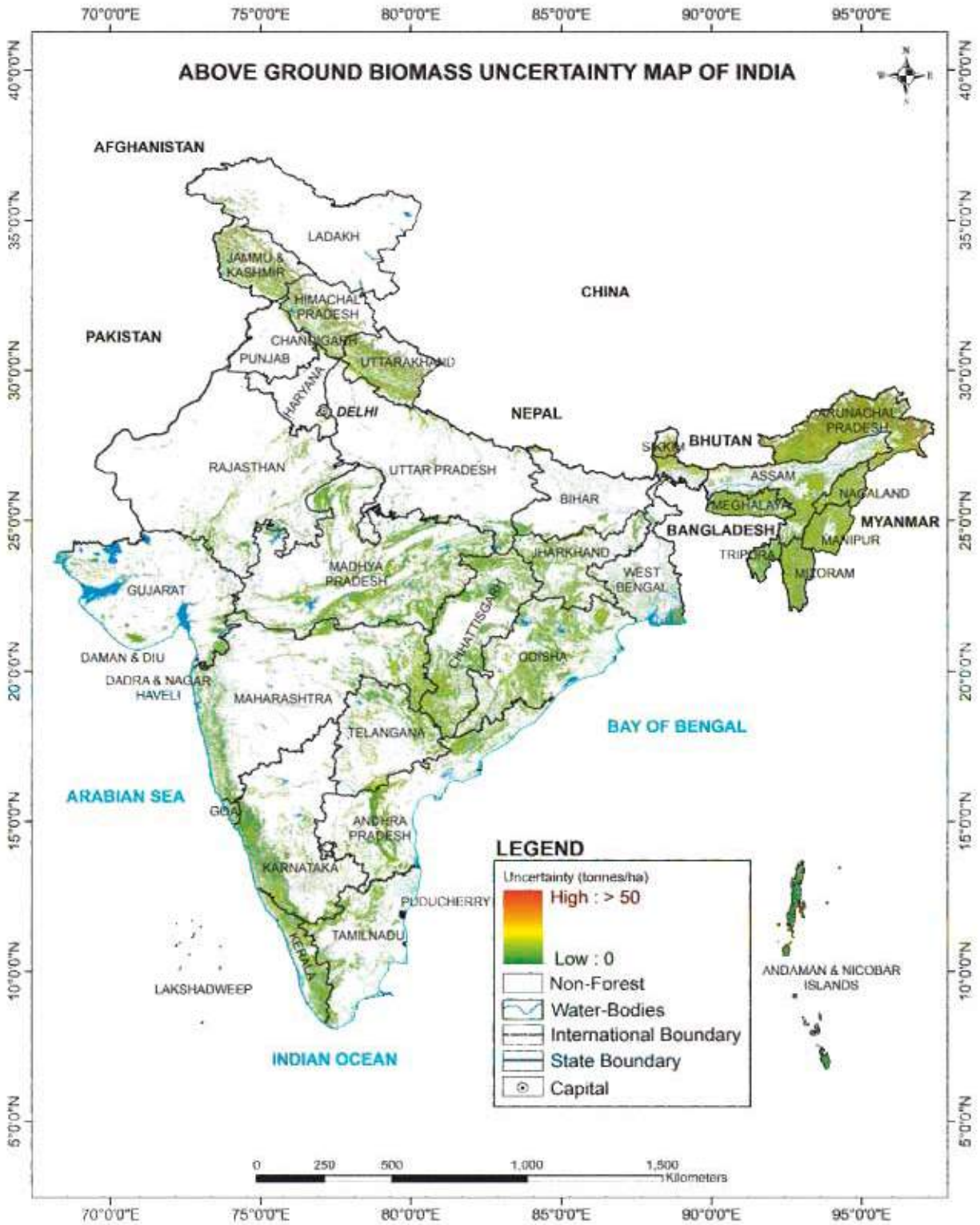


Figure 10.7
Above Ground Biomass Map of India



** Based on the above method Country level wall to wall Above Ground Biomass map is prepared. However, the detailed observations and the State/UT-wise assessment will be provided in a separate report*

Figure 10.8
Above Ground Biomass Uncertainty Map of India



State wise Area of Above Ground Biomass of India 10.5.1

Table 10.5 Above Ground Biomass in the State/UTs in India (in sq km)

Sl. No	State/UTs		Geographical Area	AGB Classes					
				<30	30-60	60-90	90-120	120-150	>150
1	Andhra Pradesh		1,62,968	11,045.73	6,533.36	7,665.03	6,782.30	3,845.89	1,519.93
2	Arunachal Pradesh		83,743	7,907.54	5,000.40	7,519.47	10,591.51	12,661.69	23,236.64
3	Assam		78,438	10,161.22	4,362.87	4,705.78	4,282.09	3,145.10	1,842.89
4	Bihar		94,163	3,174.26	1,144.08	1,278.21	1,033.61	507.69	418.02
5	Chhattisgarh		1,35,192	8,446.90	6,450.63	11,302.38	15,473.99	11,306.16	3,240.03
6	Delhi		1,483	79.93	83.73	30.62	1.35	0.08	0.03
7	Goa		3,702	167.50	176.47	354.31	551.46	588.81	398.94
8	Gujarat		1,96,244	9,442.12	3,478.48	2,304.38	1,275.47	894.08	456.91
9	Haryana		44,212	1,063.07	276.13	124.53	81.31	64.63	147.05
10	Himachal Pradesh		55,673	3,772.31	1,285.04	1,550.04	1,651.19	1,751.97	5,738.25
11	Jharkhand		79,716	7,921.57	3,670.34	4,508.85	4,355.58	2,823.64	1,019.48
12	Karnataka		1,91,791	9,905.73	5,252.02	7,318.63	9,022.70	7,617.19	3,943.28
13	Kerala		38,852	5,573.32	3,559.87	4,318.11	3,852.45	2,432.63	1,421.29
14	Madhya Pradesh		3,08,252	29,160.26	11,281.86	14,299.41	15,174.22	10,076.77	3,491.88
15	Maharashtra		3,07,713	10,108.10	6,468.74	9,935.12	13,321.43	11,110.95	4,089.71
16	Manipur		22,327	4,983.90	2,798.43	3,176.27	2,956.12	2,149.02	1,964.63
17	Meghalaya		22,429	5,518.72	2,847.36	3,234.68	2,924.61	1,915.56	1,277.69
18	Mizoram		21,081	6,482.97	2,858.25	2,922.33	2,429.45	1,585.20	1,728.21
19	Nagaland		16,579	3,146.40	1,977.08	2,326.78	2,271.34	1,766.55	1,633.74
20	Odisha		1,55,707	8,979.89	7,345.60	11,016.77	13,256.78	10,357.34	4,989.04
21	Punjab		50,362	931.02	219.62	202.72	176.62	137.12	214.46
22	Rajasthan		3,42,239	1,30,31.24	4,270.36	2,369.88	1,121.92	448.90	147.26
23	Sikkim		7,096	393.21	267.16	398.56	551.52	672.51	1,366.18
24	Tamil Nadu		1,30,060	10,400.43	3,715.77	4,509.31	4,207.45	2,857.57	1,388.20
25	Telangana		1,12,077	6,788.74	3,741.18	4,976.14	5,105.80	2,855.77	729.72
26	Tripura		10,486	2,010.01	1,198.77	1,497.10	1,460.24	1,028.16	560.10
27	Uttar Pradesh		2,40,928	6,968.66	1,947.14	1,775.99	1,282.40	676.71	2,741.27
28	Uttarakhand		53,483	5,021.05	1,908.31	2,440.50	2,922.21	3,281.89	9,112.25
29	West Bengal		88,752	6,409.53	2,321.73	2,686.36	2,724.62	1,889.04	1,016.34
30	A & N Islands		8,249	41.80	54.06	64.70	74.12	80.79	6,428.43
31	Chandigarh		114	9.17	2.45	2.83	2.56	1.89	3.23
32	Dadra & Nagar Haveli and Daman & Diu		602	76.71	51.40	49.35	34.62	15.59	5.10
33	Jammu & Kashmir	UT of J&K	53,258*	6,169.31	1,693.72	1,875.92	2,024.70	2,135.37	7,473.12
		UT of Ladakh	1,69,421*	1,305.59	269.20	265.06	245.76	211.05	490.63
		Total	2,22,236	7,474.90	1,962.92	2,140.98	2,270.46	2,346.42	7,963.75
34	Lakshadweep		30	15.95	6.62	3.48	0.95	0.10	0.00
35	Puducherry		490	37.76	7.00	4.98	1.84	0.58	0.25

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

The generated AGB map shows good correlation with Forest Type Map and Forest Cover Map. The higher values of AGB (>150 tonnes/ha) indicate healthy and Very Dense Forest which is mainly found in hilly areas of Arunachal Pradesh, Uttarakhand and Himachal Pradesh some parts of Western Ghats, part of Central India and Andaman & Nicobar Islands. Most part of Western India contains low biomass values (<60 tonnes/ha) owing to forest density and tree structure.

10.5.2 Comparison of AGB with Forest Cover Map

Comparative analysis has been carried out between predicted AGB (extracted value of AGB using 1,835 random points distributed across the forest cover of the country) for pan-India and Forest Cover Map (ISFR 2019) using line graph shown in Figure 10.9 and Figure 10.10. The line graphs illustrate the trend of forest density classes over each AGB Classes. It can be inferred that the density of forest cover has positive correlation with the increasing biomass.

Figure 10.9 Comparison between Above Ground Biomass and Forest Cover Map

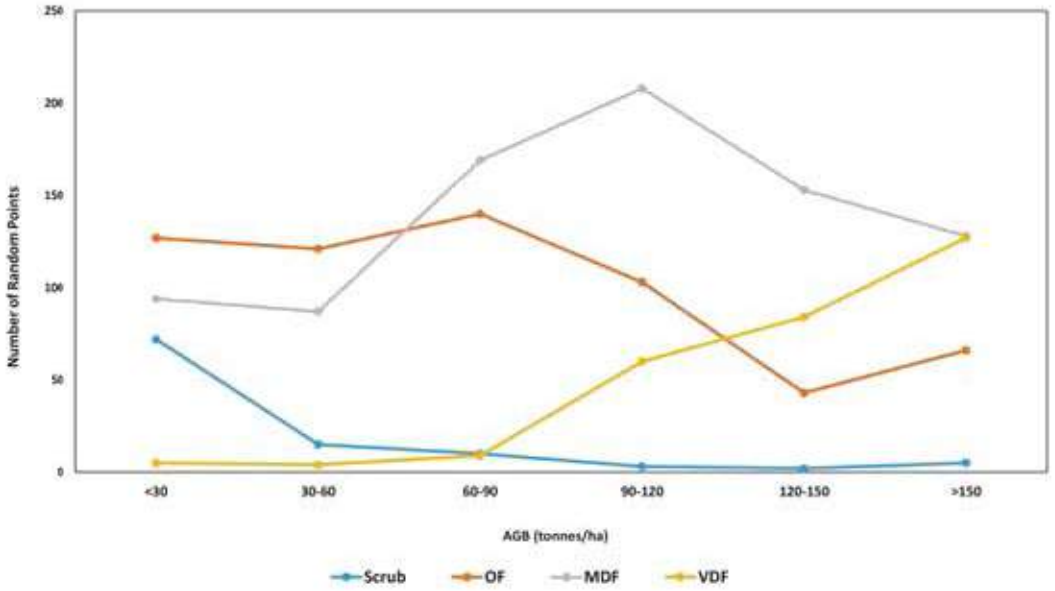
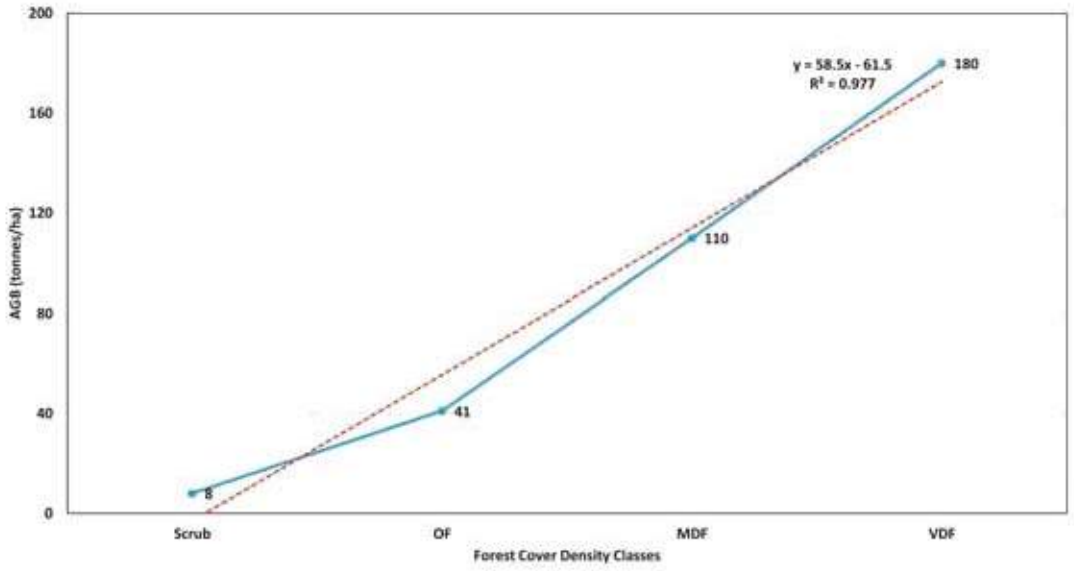


Figure 10.10 Trend of average AGB over each forest cover density classes



The key points are highlighted as given below:

- Average AGB increases with increasing forest density.
- Average AGB for VDF is 180 tonnes/ha, MDF is 110 tonnes/ha, OF is 41 tonnes/ha and Scrub is 8 tonnes/ha.
- AGB estimates have shown good agreement (r^2= 0.977) with forest cover map (ISFR, 2019).

The comparison between reference AGB and estimated AGB under each AGB range is shown in Figure 10.11. From the figure it can be inferred that:

- The estimated biomass is generally higher than the reference AGB under the AGB range of 60-90 tonnes/ha; 90-120 tonnes/ha; and 120-150 tonnes/ha respectively.
- Furthermore, number of observation in reference AGB are higher in rest of the classes under each biomass range (<30 tonnes/ha, 30-60 tonnes/ha, and >150 tonnes/ha) as compared to estimated AGB.

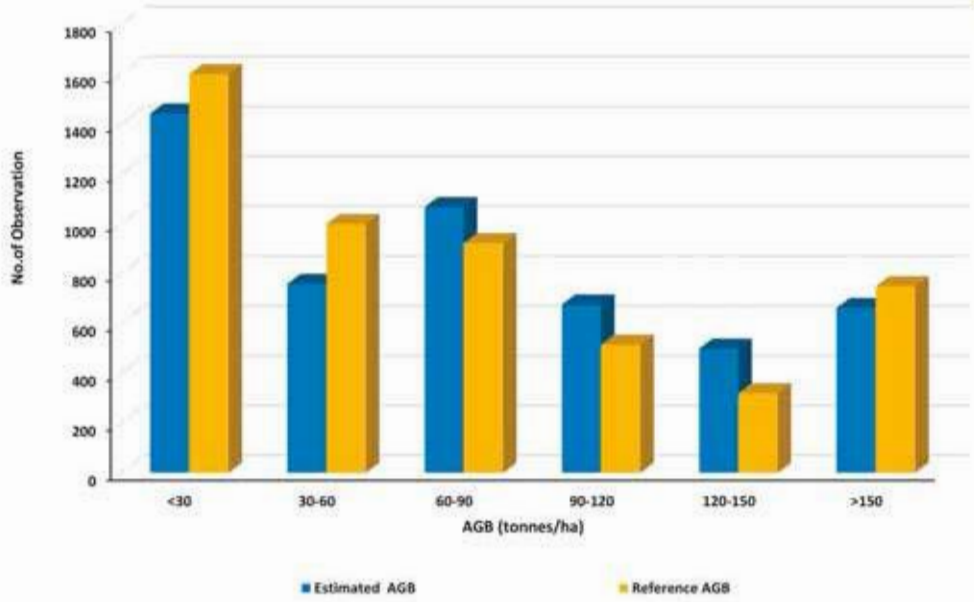


Figure 10.11 Comparison between Reference AGB and Estimated AGB per AGB classes

Key findings of the study 10.5.3

- There is a positive correlation between forest density classes and AGB estimated classes.
- Average biomass values increase with the increase in forest density.
- The highest percentage of forest cover comes under the class of <30 tonnes/ha, whereas the lowest percentage of forest cover comes under the class of >150 tonnes/ha.
- Highest AGB class is observed in the areas having least anthropogenic activity e.g. Andaman & Nicobar Islands, Arunachal Pradesh, Uttarakhand and Himachal Pradesh.
- In the Western part of the country, the majority part of forest cover area shows low biomass values e.g. Rajasthan and Gujarat.
- AGB classes vary with the change in Forest Type Group.
- SAR data has shown promise for biomass estimation at country level.

10.6 Limitations

RADAR data has certain inherent limitations such as data saturation and difficulty in distinguishing forest type, speckle noise, topography effects in undulating terrain such as Speckle, Geometric Distortion (Layover, Foreshortening & Shadow).

Use of other data such as Landsat-8 OLI, Canopy Height Data, FTM and others is being explored for overcoming limitations due to topographical errors of SAR data.

10.7 Conclusion

The correlation analysis between the AGB and the HV, HH, and HV/HH polarised backscatter reveals that the HH, HV polarized backscatter has better correlation as compared to HH/HV polarization. HH, HV polarized backscatter and field biomass values have been used to develop MLR model which have been further used to generate model coefficient for estimation of AGB map. The result suggests that the use of MLR model is quite effective for AGB estimation at country level. The use of ancillary data in combination with SAR data have been effective in improving coefficient of correlation (r) using MLR model. It has been found that biomass estimation have significant constraint over the mountainous areas.

11

MAPPING OF CLIMATE CHANGE HOTSPOTS IN INDIAN FORESTS

Introduction 11.1

The planet earth, at various points of time in its history, has witnessed catastrophic changes in its climate and these changes have impacted the geology, geography and evolution of life on earth. In the present time and age, the planet is again being subjected to deleterious changes in climate but this time, it is primarily engined by anthropogenic factors and is way faster than natural events of the past. Climate Change is the outcome of a complex set of processes that include emission of green-house gases (GHGs) from industrial and farm based processes, burning of fossil fuels and biological matter and industrial and anthropogenic effluents that impact water bodies, including the oceans.

Increase in levels of GHG including Carbon dioxide (CO_2) in the atmosphere is leading to a steady increase in mean global atmospheric temperatures. Such rise in temperature is affecting natural phenomena such as precipitation and also impact ecosystems and essential biological processes, which are germane to survival of life on earth. Increase in temperature also leads to faster melting of polar and mountain snow caps and glaciers and contribute to sea level rise which threatens pelagic and coastal biodiversity, impacts livelihoods and even threatens coastal and island dwelling human populations. Climate change negatively impacts weather patterns and thus has a cascading effect on farming and public health.

The levels of atmospheric CO_2 has been steadily increasing since pre-industrial times (middle of 18th century AD). The mean global temperatures have already risen by a little more than 1°C as compared to pre-industrial times (IPCC, 2021[1]). The IPCC AR6 report of 2021 also shows a steady rise in Global Surface Temperature since 1900 to 2020 (Figure 11.1). IPCC in October 2018, released a special report on 'Global Warming of 1.5°C' and highlighted the impacts of the same. The report goes on to state that an increase in temperature by 2°C shall have catastrophic impact on life on earth. To cite an example, the global population exposed to severe heat will be 37% at 2°C as compared to 14% at 1.5°C (IPCC, 2018[2]).

Forests play a vital role in climate change mitigation. Forests are a sink of carbon dioxide and they are the biggest terrestrial reservoir of carbon on the planet. They become source of CO_2 and other GHGs if they are cut, burnt or destroyed.

[1] *IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.*

[2] *IPCC Special Report (2018). Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments.*

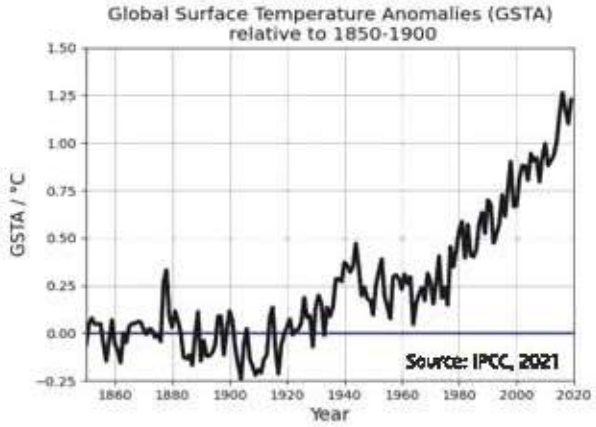


Figure 11.1
Global Surface Temperature Anomalies

Countries across the globe have committed to create a new international climate agreement by the conclusion of the U.N. Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015. India too has submitted its Nationally Determined Contribution (NDC) to the UNFCCC in October 2015[3], which outlines the post-2020 climate actions the country intends to take under a new international agreement. As per the fifth and sixth commitment by India in NDC:

- India should create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030,
- India also should better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, fisheries, health and disaster management and in regions like coastal region and Himalayan region.

In the recent COP 26 at Glasgow (2021), India is committed to reduce carbon emissions by 1 billion tonnes by the year 2030.

Moreover, by 2030, India also quoted that it will bring down carbon intensity of its economy by more than 45 per cent, whereas, the previous goal was 35%.

Forest Survey of India, in harmony with its mandate of assessing and monitoring forests of the country, has undertaken a collaborative study with Birla Institute of Technology & Science, Pilani (BITS - Goa Campus) to map climate hot spots in the forest areas of the country. The study makes use of the computer model based projections of temperature and rainfall in three time horizons i.e. 2030, 2050 and 2085 (Ashutosh & Chaturvedi *et al.*, 2020[4]) . A climate hotspot refers to an area, which is likely to face severe impacts of climatic change. Enhanced understanding about climate change hotspot areas due to adverse climatic impacts in the forests of India would help in planning and strategizing mitigation of climate change impacts and devising appropriate adaptation measures.

11.2 Importance of the Study under Indian scenario

In 2020, India Meteorological Department (IMD) has reported an increasing trend of 0.61°C/ 100 years in annual mean temperature over India during 1901 to 2019 period (IMD, 2020[5]). While Indian forests are contributing to the greening in India many forested areas are already showing shift in

[3] *India's Intended Nationally Determined Contribution: Working Towards Climate Justice (2015), MoEF&CC, GoI*

[4] *Ashutosh S, Sharma S, Lakhchaura P, Joshi M, Ghosh Sourav, Rao V (FSI, Dehradun); and Chaturvedi R (BITS Pilani, GOA); (2020). Mapping Climate Change Hotspots in Indian Forests Based on Observed Climate Change and High Resolution Climate Model Projections. FSI Technical Information Series, Vol 2 (5): 1-62.*

[5] *IMD (2020). Statement on Climate of India during 2019, Press Release, 6th January 2020, India Meteorological Department, Ministry of Earth Sciences, New Delhi*

vegetation types. Telwala *et al.* (2013[6]) has estimated shift in vegetation patterns for 124 endemic species in the Eastern Himalayan state of Sikkim, over the period 1849-1850 to 2007-2010. The study concludes that the "...present-day plant assemblages and community structure in the Himalaya is substantially different from the last century and is, therefore, in a state of flux under the impact of warming...". It further cautions that the continued warming is likely to result in ongoing elevation range contractions, and eventually species extinctions, particularly at the mountaintops.

Objective of the Study 11.3

The collaborative study was carried out with the objective to map the climatic hotspots over the forest cover in India (FSI, 2019[7]), using computer model based projection of temperature and rainfall data, for the three future time periods i.e. year 2030, 2050 and 2085.

In this chapter 2030 represents near-term timeline that coincides with global short-term climate action horizon. India's NDC also refers to the 2030 period and sixth version of NDC aims to better adapt to climate change in vulnerable sectors. On the other hand, 2050 represents our mid-term timeline and it coincides with global long-term climate action goals. We chose 2085 to represent our long term time horizon, as beyond this time-slice, climate change projections are not available.

Methodology 11.4

Model Selection 11.4.1

Climate projections have been developed by different research groups working on climate data modelling around the world, based on the Representative Concentration Pathway (RCP) scenarios. The RCPs describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use. RCP based climate projections are available from a number of climate models under the Coupled Model Inter-comparison Project (CMIP5) experiment (fifth version), as proposed by World Climate Research Programme (WCRP). WCRP under World Meteorological Organization (WMO) in Geneva, Switzerland, co-ordinates and facilitates international climate research to develop, share and apply climate knowledge.

Greenhouse gases (GHGs) are the key drivers of climate change. Depending on varying levels of socio-economic and technological developments, different GHG patterns are possible in future which are represented through four RCP scenarios: RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 (IPCC 2014[8]).

Amongst the four, RCP 8.5 represents the highest emission scenario, while RCP 6.0 and RCP 4.5 are moderate emission scenarios. RCP 2.6 is the 'best case' emission scenario that leads the world to limiting warming below 2°C towards the end of the 21st century.

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[6] *Telwala Y, Brook BW, Manish K, Pandit MK (2013). Climate-Induced Elevational Range Shifts and Increase in Plant Species Richness in a Himalayan Biodiversity Epicentre. PLoS ONE 8(2): e57103.*

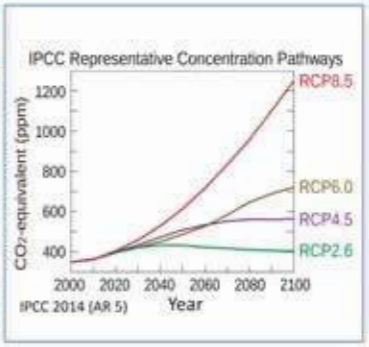
[7] *FSI (2019). India State of Forest Report. ISBN: 978-81-941018-0-2.*

[8] *IPCC (2014) Summary for policymakers, in: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*

In order to adequately represent the risks associated with future projections of climate change, RCP 4.5 and RCP 8.5 scenarios were selected for this study.

Representative Concentration Pathways (RCPs) :- The RCPs describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use. The four RCP emission scenarios: RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 (IPCC, 2014).

RCPs (Considered for Study)	Description	Developed by
RCP 2.6	RCP 2.6 is a "best case" or "peak" scenario, leading to very low greenhouse gas concentration levels . According to the IPCC, RCP 2.6 requires that carbon dioxide (CO_2) emissions start declining by 2020 and go to zero by 2100. RCP 2.6 is likely to keep global temperature rise below 2°C by 2100. Its radiative forcing level first reaches a value around 3.1 W/m2 mid-century, returning to 2.6 W/m2 by 2100	The RCP 2.6 is developed by the IMAGE modeling team of the Netherlands Environmental Assessment Agency, Van Vuuren *et al.* (2007).
RCP 4.5	It is a stabilization scenario where total * radiative forcing is stabilized well before 2100 by employing a range of technologies and strategies for reducing greenhouse gas emissions. The GHG emission reaches its peak in the year 2040.	MiniCAM modelling team at the Pacific Northwest National Laboratory's Joint Global Change Research Institute (JGCRI), Maryland, USA, (Wise *et al.* 2009).
RCP 6.0	In RCP 6, emissions peak around 2070 to 2080, then decline. The RCP 6.0 scenario uses a high greenhouse gas emission rate and having a stabilization scenario where total radiative forcing is stabilized after 2100 after reaching radiative forcing at 6.0 W/m² without overshoot by employment of a range of technologies and strategies for reducing greenhouse gas.	The RCP 6.0 is developed by the AIM modeling team at the National Institute for Environmental Studies (NIES), Japan. (Masui et. al. 2011)
RCP 8.5	The RCP 8.5 is characterized by increasing greenhouse gas emissions over time representative for scenarios in the literature leading to high greenhouse gas concentration levels. This is the worst case scenario, where GHG emission will remain in increasing trend even in the year 2100	MESSAGE modeling team and the Integrated Assessment Framework at the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria (Riahi *et al.* 2007)



* Radiative forcing, a measure, as defined by the Intergovernmental Panel on Climate Change (IPCC), of the influence a given climatic factor has on the amount of downward-directed radiant energy impinging upon Earth's surface

11.4.2 Data Acquisition

Observed gridded climate data for temperature and precipitation (Pal *et al.* 2014[9]) was obtained from India Meteorological Department (IMD).

IMD provides gridded temperature data at a resolution of 1° X 1° for the time period 1951 to 2019. Between, 1980-2019, IMD has also introduced a new temperature data product at 0.5° X 0.5° resolution, which roughly translates into 50 km in length and 50 km in width (Srivastava *et al.* 2009[10]). To fill in the data gaps, observed gridded temperature climatology for the period 1951-2019 (consistent) at 0.5° X 0.5° resolution was used from Harris *et al.* 2014[11]. The resolution of the observed precipitation dataset from IMD is further improved with the help of a Convolutional Neural Network model (CNN).

This model aims to learn from the spatial distribution of the high-resolution gridded satellite based precipitation data very high resolution gridded precipitation product from GPM (Global Precipitation Monitoring Programme) to fill the gaps in the gridded precipitation dataset.

Temperature dataset (1951-2019) from Harris *et al.* 2014 (as referred earlier) is available at a coarse resolution of 0.5° X 0.5°. The resolution of this data is improved with the help of a Convolutional Neural Network model (CNN) by using the high-resolution gridded satellite based temperature data (Land Surface Temperature - LST from the Moderate Resolution Imaging Spectro-radiometer- MODIS platform). Performance of these models is duly validated.

[9] *Pal DS, Sridhar L, Badwaik MR, Rajeevan M (2014). Analysis of the daily rainfall events over India using a new long period (1901–2010) high resolution (0.25°× 0.25°) gridded rainfall data set. Climate Dynamics, 45:755–776.*

[10] *Srivastava AK, Rajeevan M, Kshirsagar SR (2009). Development of a high resolution daily gridded temperature data set (1969–2005) for the Indian region. Atmospheric Science Letters, 10 (4): 249-254.*

[11] *Harris I, Jones PD, Osborn TJ, Lister DH (2014). Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset, International Journal of Climatology, 34(3):623-642.*

The gridded precipitation dataset from IMD is available at a much finer spatial resolution i.e. 0.25° X 0.25°. Thus, due to difference in resolution of the precipitation and temperature datasets, the respective datasets were downscaled to a resolution of about 10km X 10km (0.1° X 0.1°) grid by using a newly developed CNN (Convolutional Neural Network) based model.

This model uses high resolution satellite data products (Land Surface Temperature (LST) (1 km X 1 km) for temperature and Global Precipitation Measurement (GPM) (1 km X 1 km)) and coarse resolution observed gridded data with great accuracies (Ghosh 2010[2], Khan *et al.* 2006[3])

Selection of Climatic Hotspots 11.4.3

A temperature hotspot for this study has been defined as any forested grid that is projected to experience a temperature rise over 1.5°C compared to 1860-1900 scenario. On the other hand a precipitation hotspot refers to the change of rainfall greater or less than 20% with respect to the 1960-1990 scenario. The severity of the hotspots has been scaled on the basis of magnitude of increase in temperature over 1.5°C, and change in precipitation greater/less than +/- 20%. Hotspot maps are particularly useful for climate change adaptation planning by identifying forest areas likely to be impacted by climate change and showing them in maps.

Further, hotspot maps hold the promise of transparent and defensible priority setting to address critical issues in a scientific manner.

Categorization of Climatic Hotspots 11.4.4

Temperature change (ΔT in degree C) in 2030/2050/2080 compared to 1860-1900 base spatial distribution over 1.5°C is classified into following:

1. High - Increase of 1.5 to 2.1°C
2. Very High - Increase of 2.1 to 3.3 °C
3. Extremely High - Increase of 3.3 to 5.1 °C
4. Critical - Increase of 5.1 to 6.6 °C

Precipitation change (change in precipitation greater/less than +/- 20% i.e. ΔP in %) in 2030/2050/2080 compared to 1960-1990 base is classified into following:

1. High - 20% to 26 %
2. Very High - 26% to 32%
3. Extremely High - 32% to 38%
4. Critical - 38% to 41%

Thereafter, a composite score combining the temperature and precipitation variables were computed assigning 75% weightage to temperature and 25% to precipitation and classified into following:

1. High - 0.75 to 3
2. Very High - 3 to 4.25
3. Extremely High - 4.25 to 6.75
4. Critical - 6.75 to 8.75

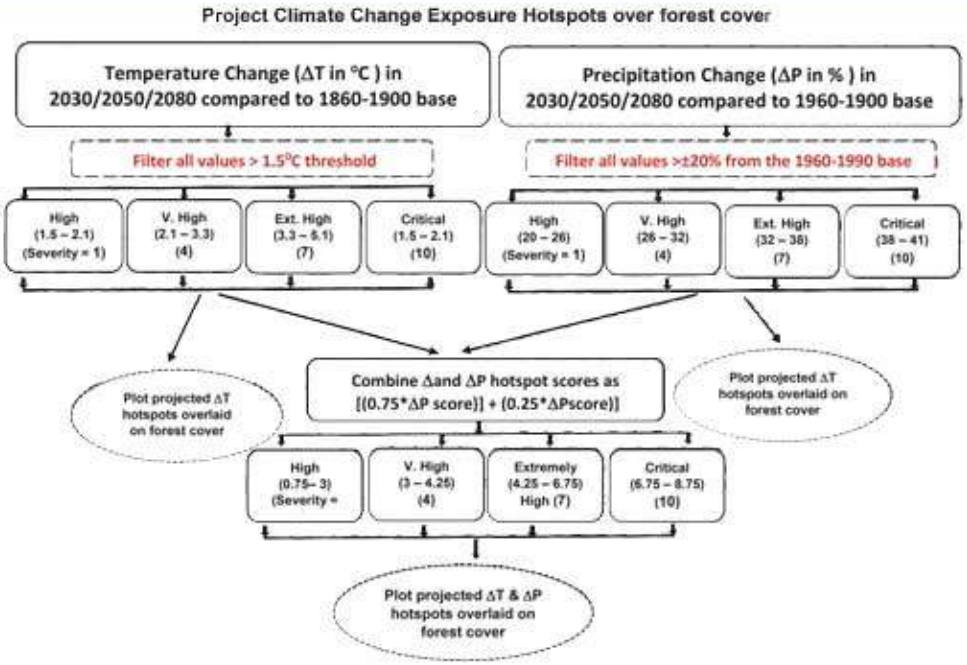
[2]*Ghosh Subimal (2010) SVM-PGSL Coupled Approach for Statistical Downscaling to Predict Rainfall from GCM Output. Journal of Geophysical Research, 115:D22102*

[3]*Khan M, Coulibaly P, Dibike Y (2006) Uncertainty Analysis of Statistical Downscaling Methods. Journal of Hydrology 319(1):357-382.*

11.4.5 Mapping of Hotspot

The identified climatic hotspots categories, such as, 'High', 'Very High', 'Extremely High' and 'Critical' based on temperature and rainfall change parameters; have been further sub-divided into 10 classes depending on their severity. The 'High' category is having 3 severity classes (1, 2, and 3) and are colour coded within the shades ranging from blue to green. The 'Very High' category is further segregated in 3 severity classes (4, 5 and 6) having the colour shades ranging from green to yellow. The hotspot category 'Extremely High' is again sub-divided into 3 severity classes (7, 8 and 9) having the colours varying from yellow to orange.

Figure 11.2 Schema adopted to classify climate change hotspots



The 'Critical' hotspot category is kept as severity class 10, with red as its colour of notification. The 'Critical' hotspot class are expected to lead to the catastrophic impact in the forest environment.

The above 10 sub-categorization with the colour coding has been done to generate self-explanatory thematic maps. These thematic maps at a glance could guide to set respective locational priority, for any future planning activities, to mitigate and adapt adverse projected climate impacts.

11.5 Results and Discussion

The computer model based projection analysis over scaled down (1° X 1°) gridded temperature and rainfall data was carried out to generate National level hotspots database over forest grids based on Forest cover layer of ISFR 2019.

Both RCP 4.5 and RCP 8.5 based model were run using computation based platform to predict the future climatic hotspot. The models predicted climatic hotspots for the year 2030, 2050 and 2085. Accordingly, the thematic maps were generated over the forest cover. The climate change maps show the degree of severity to be faced by Indian forests in different time periods i.e. 2030, 2050, 2085.

Forest cover area in the country under different hotspots classes in different time periods with RCP 4.5 and RCP 8.5 scenarios using combined temperature and precipitation data is given in Table 11.1.

(In sq km)

Hotspot Classes	Year 2030		Year 2050		Year 2085	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
High	314969	448367	367334	260883	11804	0
Very High	698	1552	330602	343726	656094	0
Extremely High	0	0	6899	100569	37196	566442
Critical	0	0	0	0	0	138736
TOTAL	315667	449919	704835	705178	705094	705178

Table 11.1 Forest cover area (sq km) under hotspots in 2030/ 2050/2085 with RCP 4.5 and RCP 8.5 models

It is clearly observed that time period transitions from 2030 to 2050 and 2085; the area under hot spots within forest cover increases. Moreover, the concept of Models RCP 4.5 and RCP 8.5 tells us that RCP 8.5 is the more extreme scenario between these two i.e. the areas under forest hot spot always show higher values in RCP 8.5 scenarios than RCP 4.5 for all the three future projected years i.e. 2030, 2050 and 2085.

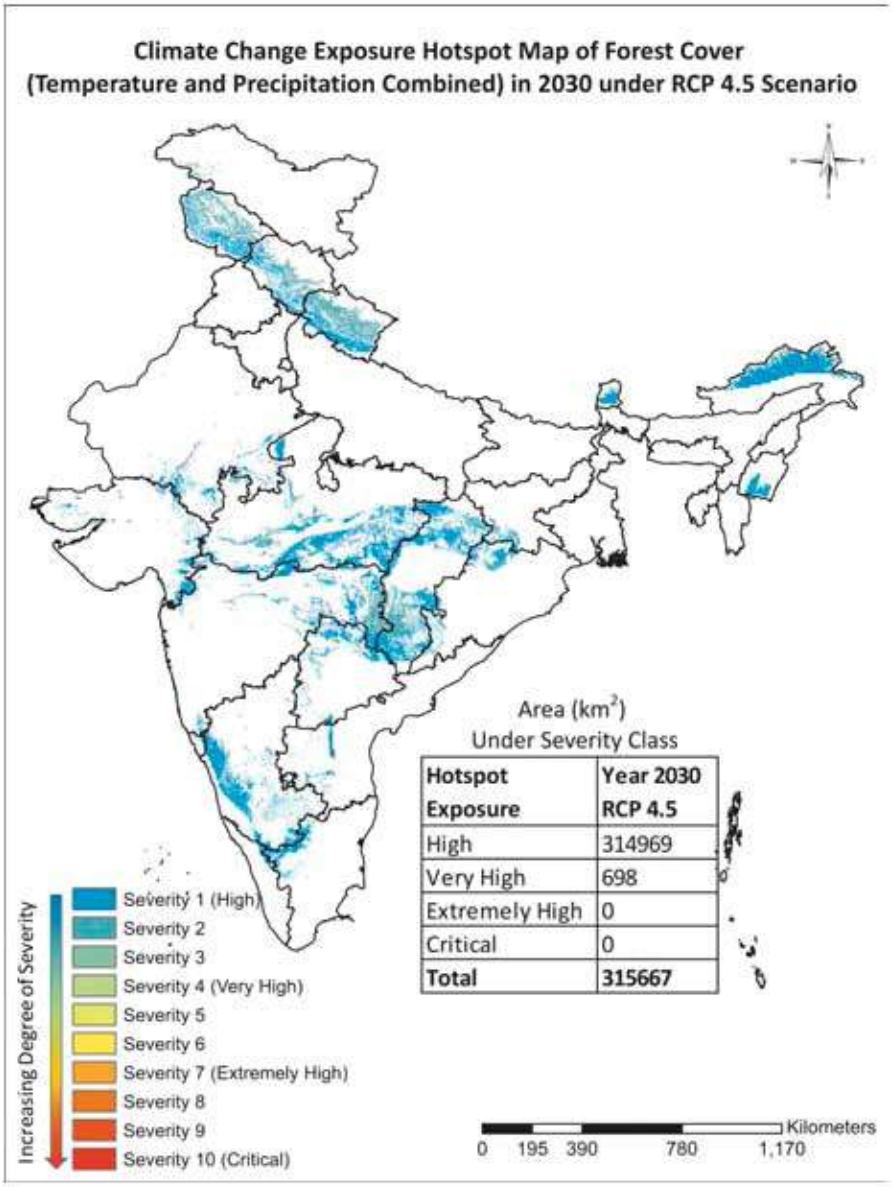


Figure 11.3 Climate change hotspot in 2030 in terms of combined temperature rise and precipitation change for RCP 4.5 (Resolution: 1km X 1km)

Figure 11.4
Climate change hotspot in 2030 in terms of combined temperature rise and precipitation change for RCP 8.5 (Resolution: 1km X 1km)

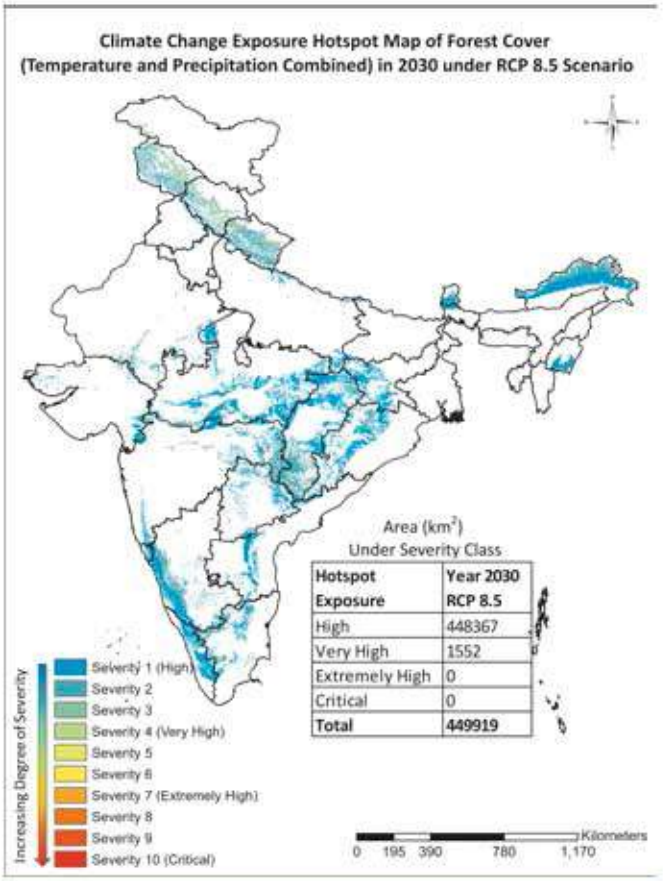
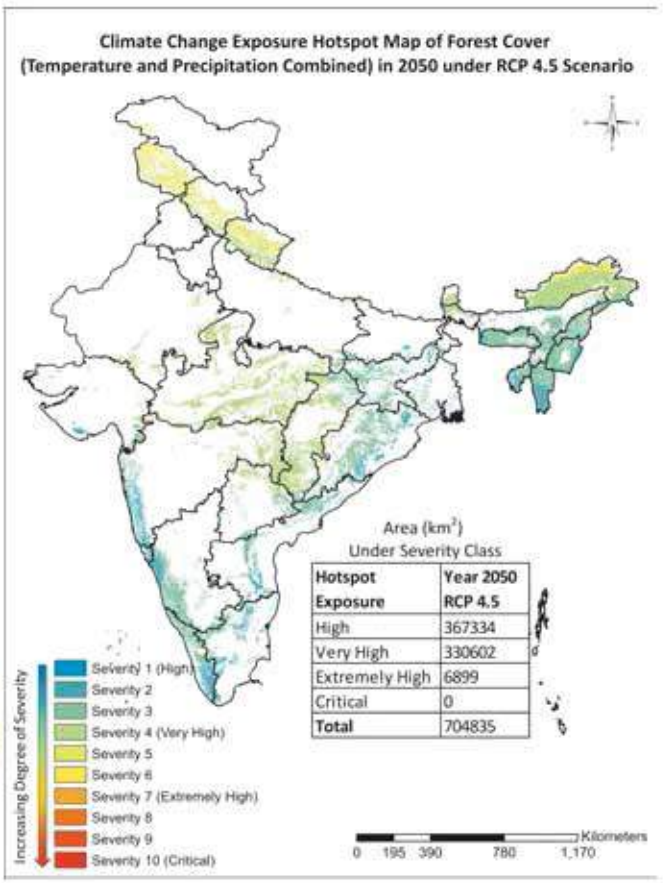
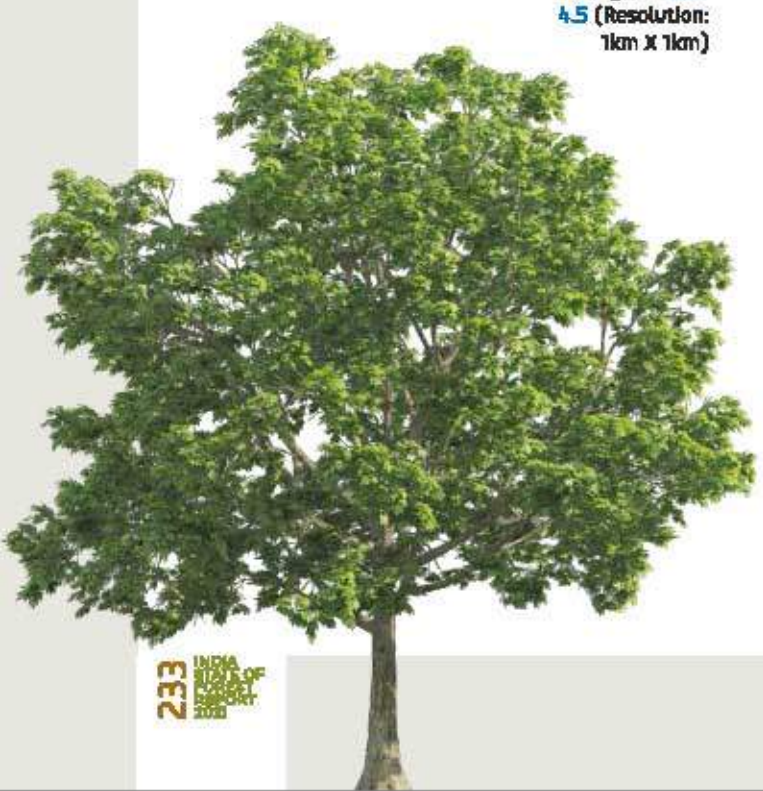


Figure 11.5
Climate change hotspot in 2050 in terms of combined temperature rise and precipitation change for RCP 4.5 (Resolution: 1km X 1km)





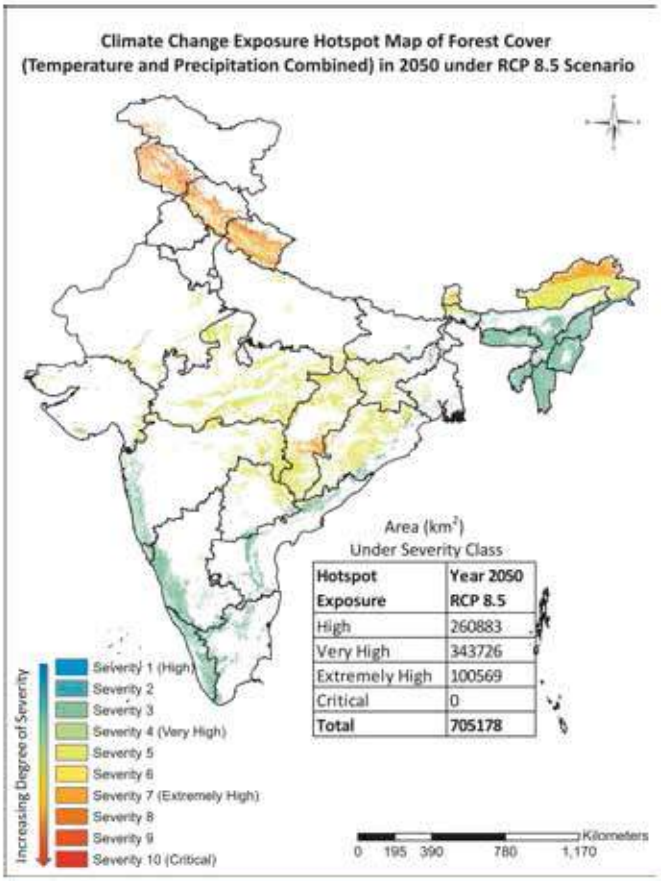


Figure TL6
Climate change hotspot in 2050 in terms of combined temperature rise and precipitation change for RCP 8.5 (Resolution: 1km X 1km)

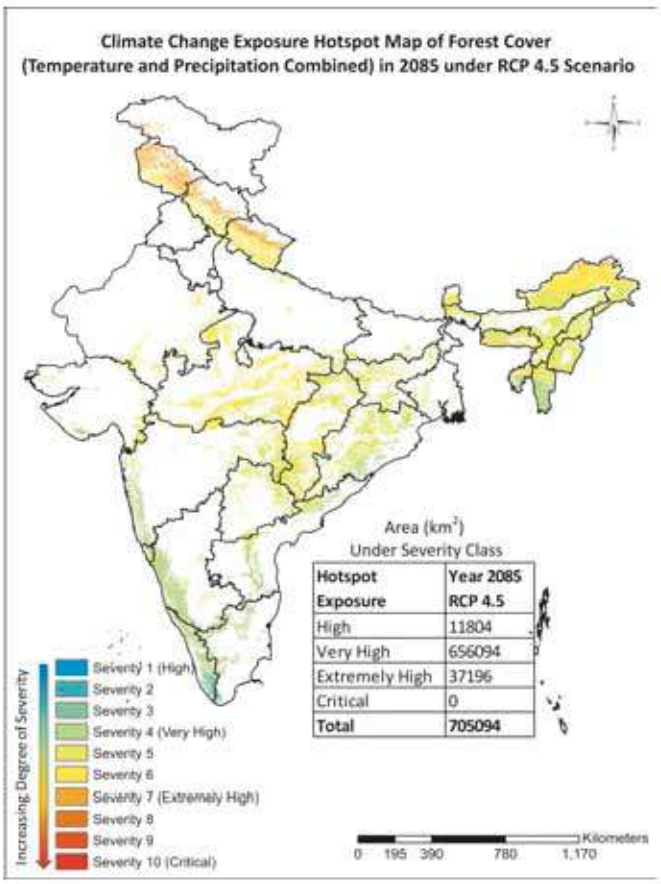


Figure TL7
Climate change hotspot in 2085 in terms of combined temperature rise and precipitation change for RCP 4.5 (Resolution: 1km X 1km)

Figure 11.8 Climate change hotspot in 2085 in terms of combined temperature rise and precipitation change for RCP 8.5 (Resolution: 1km X 1km)

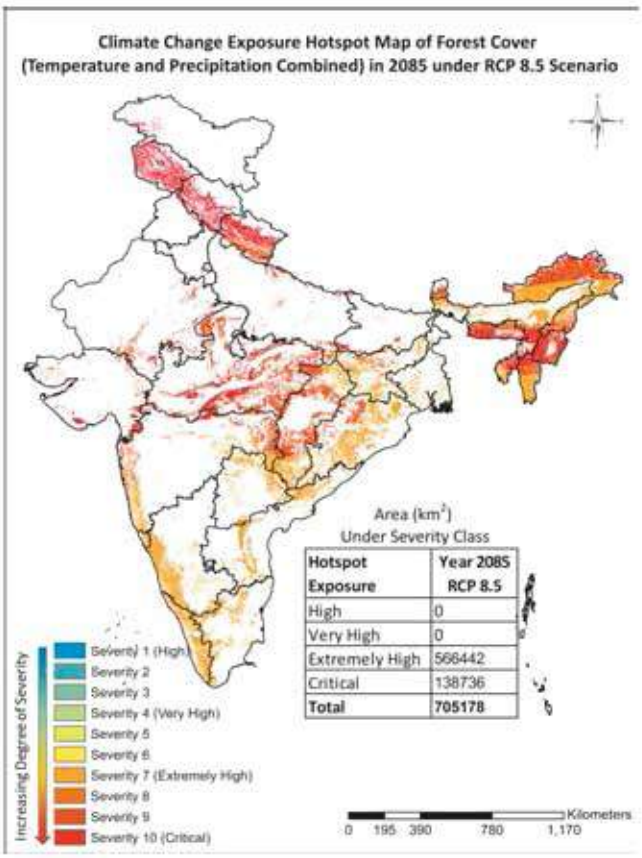


Table 11.2 Projected climate change (temperature and precipitation combined) exposure hotspot area in forest ecosystems in India

Forest Type	Total Area (in 2019), sq km	2030 RCP 4.5	
1 Tropical Wet Evergreen Forests	20054	4448	
2 Tropical Semi-evergreen Forests	71171	28519	
3 Tropical Moist Deciduous Forests	135492	63940	
4 Littoral & Swamp Forests	5596	542	
5 Tropical Dry Deciduous Forests	313617	172719	
6 Tropical Thorn Forests	20877	9738	
7 Tropical Dry Evergreen Forests	937	6	
8 Subtropical Broad leaved Hill Forests	32706	4934	
9 Subtropical Pine Forests	18102	16955	
10 Subtropical Dry Evergreen Forests	180	180	
11 Montane Wet Temperate Forests	20435	1039	
12 Himalayan Moist Temperate Forests	25743	25743	
13 Himalayan Dry Temperate Forests	5627	5627	
14 Sub-alpine Forests	14995	14866	
15 Moist Alpine Scrub	959	959	
16 Dry Alpine Scrub	2922	2922	

Table 11.2 indicates that 'Tropical Dry Deciduous Forests', 'Tropical Moist Deciduous Forests' and 'Tropical Semi-evergreen Forests'; the three top most dominant forest type groups of the country, covering 313617 sq km, 135492 sq km and 71171 sq km area respectively shall be highly vulnerable to climate change. Results from both the models i.e. RCP 4.5 and RCP 8.5, depict that almost the entire area under these dominant forest type groups will be falling within climate hot spots in the coming years from 2050 onwards.

Climate Change hotspot area under projected temperature and precipitation combined (sq km)				
2030 RCP 8.5	2050 RCP 4.5	2050 RCP 8.5	2085 RCP 4.5	2085 RCP 8.5
10077	16343	19717	19717	19717
43046	71171	71171	71171	71171
85122	135492	135492	135492	135492
2003	3808	5596	5596	5596
245501	313617	313617	313617	313617
12931	16020	16026	16026	16026
311	896	896	896	896
7080	21116	21116	21116	21116
18054	18059	18100	18100	18100
180	180	180	180	180
1641	5333	5333	5333	5333
25743	25743	25743	25743	25743
5627	5627	5627	5627	5627
14995	14995	14995	14995	14995
959	959	959	959	959
2922	2922	2922	2922	2922

Table TL3 State wise Distribution of hotspots (sq km) in 2030 under RCP 4.5 and RCP 8.5 scenarios

States / UTs	Forest Cover (sq km) ISFR 2019	Projected Area (in sq km) of Hotspots				
		RCP 4.5				
		(Hot Spots with Increasing Degree of Severity from High to Critical)				
		High	Very High	Extremely High	Critical	Total
Andhra Pradesh	29137	3977	0	0	0	3977
Arunachal Pradesh	66688	26360	0	0	0	26360
Assam	28327	0	0	0	0	0
Bihar	7306	0	0	0	0	0
Chhattisgarh	55611	46937	0	0	0	46937
Delhi	195	0	0	0	0	0
Goa	2237	671	0	0	0	671
Gujarat	14857	10549	0	0	0	10549
Haryana	1602	293	0	0	0	293
Himachal Pradesh	15434	13846	0	0	0	13846
Jammu & Kashmir	21122	20741	0	0	0	20741
Jharkhand	23612	3165	0	0	0	3165
Karnataka	38575	28534	0	0	0	28534
Kerala	21144	1522	0	0	0	1522
Ladakh	2490	1694	698	0	0	2392
Maharashtra	50778	34170	0	0	0	34170
Manipur	16847	3937	0	0	0	3937
Meghalaya	17119	0	0	0	0	0
Mizoram	18006	92	0	0	0	92
Madhya Pradesh	77482	50159	0	0	0	50159
Nagaland	12486	0	0	0	0	0
Odisha	51619	8895	0	0	0	8895
Punjab	1849	259	0	0	0	259
Rajasthan	16630	12613	0	0	0	12613
Sikkim	3342	2460	0	0	0	2460
Telangana	20582	12341	0	0	0	12341
Tamil Nadu	26364	7826	0	0	0	7826
Tripura	7726	0	0	0	0	0
Uttar Pradesh	14806	890	0	0	0	890
Uttarakhand	24303	23038	0	0	0	23038
West Bengal	16902	0	0	0	0	0
Total	**705178**	**314969**	**698**	**0**	**0**	**315667**
% Hotspot severity classes existing in Forest Present in the above mentioned States/UTs (ISFR 2019)		**45**	**0.1**	**0**	**0**	**45**

Note: Although the total Forest Cover in India is 7,12,249 sq km (as per ISFR 2019) but in this study the forest cover areas of UTs like; Andaman & Nicobar Islands, Chandigarh, Dadra & Nagar Haveli, Daman & Diu, Lakshadweep, Puducherry are not considered due to in adequate number of Grids for future climate projection.

over Indian Forests with various Degree of Severity for the year 2030

RCP 8.5

(Hot Spots with Increasing Degree of Severity from High to Critical)

% of Forest Cover	High	Very High	Extremely High	Critical	Total	% of Forest Cover
14	14653	0	0	0	14653	50
40	38099	0	0	0	38099	57
0	0	0	0	0	0	0
0	1218	0	0	0	1218	17
84	55139	0	0	0	55139	99
0	118	0	0	0	118	61
30	1800	0	0	0	1800	80
71	10752	0	0	0	10752	72
18	1163	0	0	0	1163	73
90	15431	3	0	0	15434	100
98	20736	5	0	0	20741	98
13	15694	0	0	0	15694	66
74	36800	0	0	0	36800	95
7	15018	0	0	0	15018	71
96	847	1544	0	0	2392	96
67	36227	0	0	0	36227	71
23	4640	0	0	0	4640	28
0	0	0	0	0	0	0
1	23	0	0	0	23	0
65	56131	0	0	0	56131	72
0	0	0	0	0	0	0
17	30205	0	0	0	30205	59
14	1843	0	0	0	1843	100
76	13833	0	0	0	13833	83
74	3131	0	0	0	3131	94
60	19632	0	0	0	19632	95
30	21594	0	0	0	21594	82
0	0	0	0	0	0	0
6	8526	0	0	0	8526	58
95	23561	0	0	0	23561	97
0	1552	0	0	0	1552	9
45	**448367**	**1552**	**0**	**0**	**449919**	**64**
	64	**0.2**	**0**	**0**	**64**	

Table 11.4 State wise Distribution of hotspots (sq km) in 2050 under RCP 4.5 and RCP 8.5 scenarios

States / UTs	Forest Cover (sq km) ISFR 2019	Projected Area (in sq km) of Hotspots				
		RCP 4.5				
		(Hot Spots with Increasing Degree of Severity from High to Critical)				
		High	Very High	Extremely High	Critical	Total
Andhra Pradesh	29137	29137	0	0	0	29137
Arunachal Pradesh	66688	9313	57240	0	0	66553
Assam	28327	26623	1644	0	0	28267
Bihar	7306	6460	846	0	0	7306
Chhattisgarh	55611	12723	42888	0	0	55611
Delhi	195	0	195	0	0	195
Goa	2237	2237	0	0	0	2237
Gujarat	14857	7024	7684	0	0	14708
Haryana	1602	0	1602	0	0	1602
Himachal Pradesh	15434	95	15005	334	0	15434
Jammu & Kashmir	21122	100	17110	3912	0	21122
Jharkhand	23612	23612	0	0	0	23612
Karnataka	38575	38110	465	0	0	38575
Kerala	21144	21144	0	0	0	21144
Ladakh	2490	0	0	2490	0	2490
Maharashtra	50778	19191	31587	0	0	50778
Manipur	16847	16847	0	0	0	16847
Meghalaya	17119	17119	0	0	0	17119
Mizoram	18006	18006	0	0	0	18006
Madhya Pradesh	77482	85	77397	0	0	77482
Nagaland	12486	12486	0	0	0	12486
Odisha	51619	46477	5142	0	0	51619
Punjab	1849	0	1849	0	0	1849
Rajasthan	16630	0	16630	0	0	16630
Sikkim	3342	0	3342	0	0	3342
Telangana	20582	9610	10972	0	0	20582
Tamil Nadu	26364	26364	0	0	0	26364
Tripura	7726	7726	0	0	0	7726
Uttar Pradesh	14806	3677	11129	0	0	14806
Uttarakhand	24303	0	24140	163	0	24303
West Bengal	16902	13168	3734	0	0	16902
Total	**705178**	**367334**	**330602**	**6899**	**0**	**704835**
% Hotspot severity classes existing in Forest Present in the above mentioned States/UTs (ISFR 2019)		**52**	**47**	**1**	**0**	**100**

Note: Although the total Forest Cover in India is 7,12,249 sq km (as per ISFR 2019) but in this study the forest cover areas of UTs like; Andaman & Nicobar Islands, Chandigarh, Dadra & Nagar Haveli, Daman & Diu, Lakshadweep, Puducherry are not considered due to in adequate number of Grids for future climate projection.

over Indian Forests with various Degree of Severity for the year 2030

RCP 8.5

(Hot Spots with Increasing Degree of Severity from High to Critical)

% of Forest Cover	High	Very High	Extremely High	Critical	Total	% of Forest Cover
100.0	27672	1465	0	0	29137	100.0
99.8	4777	42879	19032	0	66688	100.0
99.8	23995	4332	0	0	28327	100.0
100.0	2282	5024	0	0	7306	100.0
100.0	0	47877	7734	0	55611	100.0
100.0	0	195	0	0	195	100.0
100.0	2237	0	0	0	2237	100.0
99.0	1725	13069	63	0	14857	100.0
100.0	0	1032	570	0	1602	100.0
100.0	0	0	15434	0	15434	100.0
100.0	0	0	21122	0	21122	100.0
100.0	1958	21654	0	0	23612	100.0
100.0	36710	1865	0	0	38575	100.0
100.0	21144	0	0	0	21144	100.0
100.0	0	0	2490	0	2490	100.0
100.0	17251	33527	0	0	50778	100.0
100.0	16847	0	0	0	16847	100.0
100.0	16975	144	0	0	17119	100.0
100.0	18006	0	0	0	18006	100.0
100.0	0	77482	0	0	77482	100.0
100.0	12486	0	0	0	12486	100.0
100.0	8681	40960	1978	0	51619	100.0
100.0	0	259	1590	0	1849	100.0
100.0	0	12436	4194	0	16630	100.0
100.0	0	2252	1090	0	3342	100.0
100.0	5014	15568	0	0	20582	100.0
100.0	26364	0	0	0	26364	100.0
100.0	7726	0	0	0	7726	100.0
100.0	0	13751	1055	0	14806	100.0
100.0	0	86	24217	0	24303	100.0
100.0	9034	7868	0	0	16902	100.0
100.0	**260883**	**343726**	**100569**	**0**	**705178**	**100.0**
	37	**49**	**14**	**0**	**100**	

Table 11.5 State wise Distribution of hotspots (sq km) in 2085 under RCP 4.5 and RCP 8.5 scenarios

States / UTs	Forest Cover (sq km) ISFR 2019	Projected Area (in sq km) of Hotspots				
		RCP 4.5				
		(Hot Spots with Increasing Degree of Severity from High to Critical)				
		High	Very High	Extremely High	Critical	Total
Andhra Pradesh	29137	1759	27378	0	0	29137
Arunachal Pradesh	66688	0	63475	3177	0	66653
Assam	28327	0	28327	0	0	28327
Bihar	7306	0	7306	0	0	7306
Chhattisgarh	55611	0	55611	0	0	55611
Delhi	195	0	195	0	0	195
Goa	2237	0	2237	0	0	2237
Gujarat	14857	0	14808	0	0	14808
Haryana	1602	0	1602	0	0	1602
Himachal Pradesh	15434	0	7373	8061	0	15434
Jammu & Kashmir	21122	0	5277	15845	0	21122
Jharkhand	23612	0	23612	0	0	23612
Karnataka	38575	0	38575	0	0	38575
Kerala	21144	5855	15289	0	0	21144
Ladakh	2490	0	0	2490	0	2490
Maharashtra	50778	1	50777	0	0	50778
Manipur	16847	0	16847	0	0	16847
Meghalaya	17119	0	17119	0	0	17119
Mizoram	18006	0	18006	0	0	18006
Madhya Pradesh	77482	0	77482	0	0	77482
Nagaland	12486	0	12486	0	0	12486
Odisha	51619	315	51304	0	0	51619
Punjab	1849	0	1727	122	0	1849
Rajasthan	16630	0	16630	0	0	16630
Sikkim	3342	0	3326	16	0	3342
Telangana	20582	0	20582	0	0	20582
Tamil Nadu	26364	3672	22692	0	0	26364
Tripura	7726	0	7726	0	0	7726
Uttar Pradesh	14806	0	14806	0	0	14806
Uttarakhand	24303	0	16818	7485	0	24303
West Bengal	16902	202	16700	0	0	16902
Total	**705178**	**11804**	**656094**	**37196**	**0**	**705094**
% Hotspot severity classes existing in Forest Present in the above mentioned States/UTs (ISFR 2019)		**2**	**93**	**5**	**0**	**100**

Note: Although the total Forest Cover in India is 7,12,249 sq km (as per ISFR 2019) but in this study the forest cover areas of UTs like; Andaman & Nicobar Islands, Chandigarh, Dadra & Nagar Haveli, Daman & Diu, Lakshadweep, Puducherry are not considered due to in adequate number of Grids for future climate projection.

over Indian Forests with various Degree of Severity for the year 2030

RCP 8.5

(Hot Spots with Increasing Degree of Severity from High to Critical)

% of Forest Cover	High	Very High	Extremely High	Critical	Total	% of Forest Cover
100	0	0	29137	0	29137	100
100	0	0	63159	3529	66688	100
100	0	0	22091	6236	28327	100
100	0	0	6364	942	7306	100
100	0	0	55611	0	55611	100
100	0	0	195	0	195	100
100	0	0	2237	0	2237	100
100	0	0	7933	6924	14857	100
100	0	0	1595	7	1602	100
100	0	0	1146	14288	15434	100
100	0	0	0	21122	21122	100
100	0	0	23612	0	23612	100
100	0	0	38575	0	38575	100
100	0	0	21144	0	21144	100
100	0	0	0	2490	2490	100
100	0	0	45693	5085	50778	100
100	0	0	5002	11845	16847	100
100	0	0	8010	9109	17119	100
100	0	0	14592	3414	18006	100
100	0	0	50822	26660	77482	100
100	0	0	12025	461	12486	100
100	0	0	51619	0	51619	100
100	0	0	1342	507	1849	100
100	0	0	13891	2739	16630	100
100	0	0	3338	4	3342	100
100	0	0	20582	0	20582	100
100	0	0	26364	0	26364	100
100	0	0	4819	2907	7726	100
100	0	0	10012	4794	14806	100
100	0	0	8629	15674	24303	100
100	0	0	16902	0	16902	100
100	**0**	**0**	**566442**	**138736**	**705178**	**100**
	0	**0**	**80**	**20**	**100**	

11.5.1 Salient Findings

2030 Scenario

- By the year 2030, under RCP 4.5 scenario, about 3,15,667 sq km of forest cover will fall under climate hotspots while under RCP 8.5 scenario, about 4,49,919 sq km of forest cover will fall under the same. These occupy almost 45% and 64% of India's forest cover respectively, as reported in ISFR 2019.
- By 2030, under both RCP 4.5 and RCP 8.5 scenarios, almost all the States of India (except: Assam, Meghalaya, Nagaland and Tripura) are coming under 'High' category.
- Part of Ladakh (0.1 to 0.2 % of forest cover) is coming under 'Very High' category of climate hotspot.
- In the climate hotspot maps for 2030 (Figure 11.2 and Figure 11.3), the forest cover area under climate hotspot categories are shown by shades of blue, indicating less severity.

2050 Scenario

- By the year 2050, under RCP 4.5 scenario, about 3,67,334 sq km, 330602 sq km and 6899 sq km of forest cover will fall under 'High', 'Very High' and 'Extremely High' severity classes of climate hotspots respectively, thereby covering 52%, 47% and 1% area of the same.
- Under RCP 8.5 scenario, about 2,60,883 sq km, 3,43,726 sq km and 1,00,569 sq km of forest cover will fall under 'High', 'Very High' and 'Extremely High' severity classes of climate hotspots respectively, thereby covering 37%, 49% and 14% area of the same.
- By 2050, entire forest cover of the country is projected to be under climate change hotspots with varying severity classes.
- Under RCP 8.5 scenario, 14% of India's forests come under 'Extremely High' severity class. No climate hotspots are falling under 'Critical' hotspot severity class in the year 2050.
- The States/UT of Himachal Pradesh, Jammu & Kashmir and Ladakh will be under 'Extremely High' severity class even under moderate scenario of RCP 4.5.
- In the climate hotspot maps for 2050 (Figure 11.4 and Figure 11.5), the forest cover area under climate hotspot categories range from yellow to orange. This implies that severity of the hotspots are projected to be increased in the 20 years of time-period from 2030 to 2050.

2085 Scenario

- By the year 2085, under RCP 4.5 scenario, about 11,804 sq km, 6,56,094 sq km and 37,196 sq km are falling under 'High', 'Very High' and 'Extremely High' severity classes of climate hotspots respectively, thereby covering 2%, 93% and 5% area of the same. Over a period of 35 years, between 2050 to 2085, there is a rise of 4% (from 1 % to 5%) in 'Extremely High' severity class.
- Under RCP 8.5 scenario, about 5,66,442 sq km (80%) and 1,38,736 sq km (20%) of forest cover will fall under 'Extremely High' and 'Critical' severity classes respectively. This implies that by 2085 the RCP 8.5 model shows that 20 % of Indian forests may experience catastrophic changes due to adverse impact of climate change.
- The 'Critical' hotspots, i.e. those likely to experience catastrophic effect have been observed mainly in the Western Himalayas and Karakoram ranges across the Union Territories of Jammu-Kashmir, Himachal Pradesh and Uttarakhand. Some 'Critical' hotspots are also identified in north-eastern States like Assam, Manipur, Mizoram, Meghalaya, Tripura, and in few grids of central India and Gujarat.
- In the climate hotspot maps for 2085 (Figure 11.7 and Figure 11.8), the forest cover area under climate hotspot categories range from orange to red, there by indicating extremely high to critical severity in almost entire country under scenario 8.5.

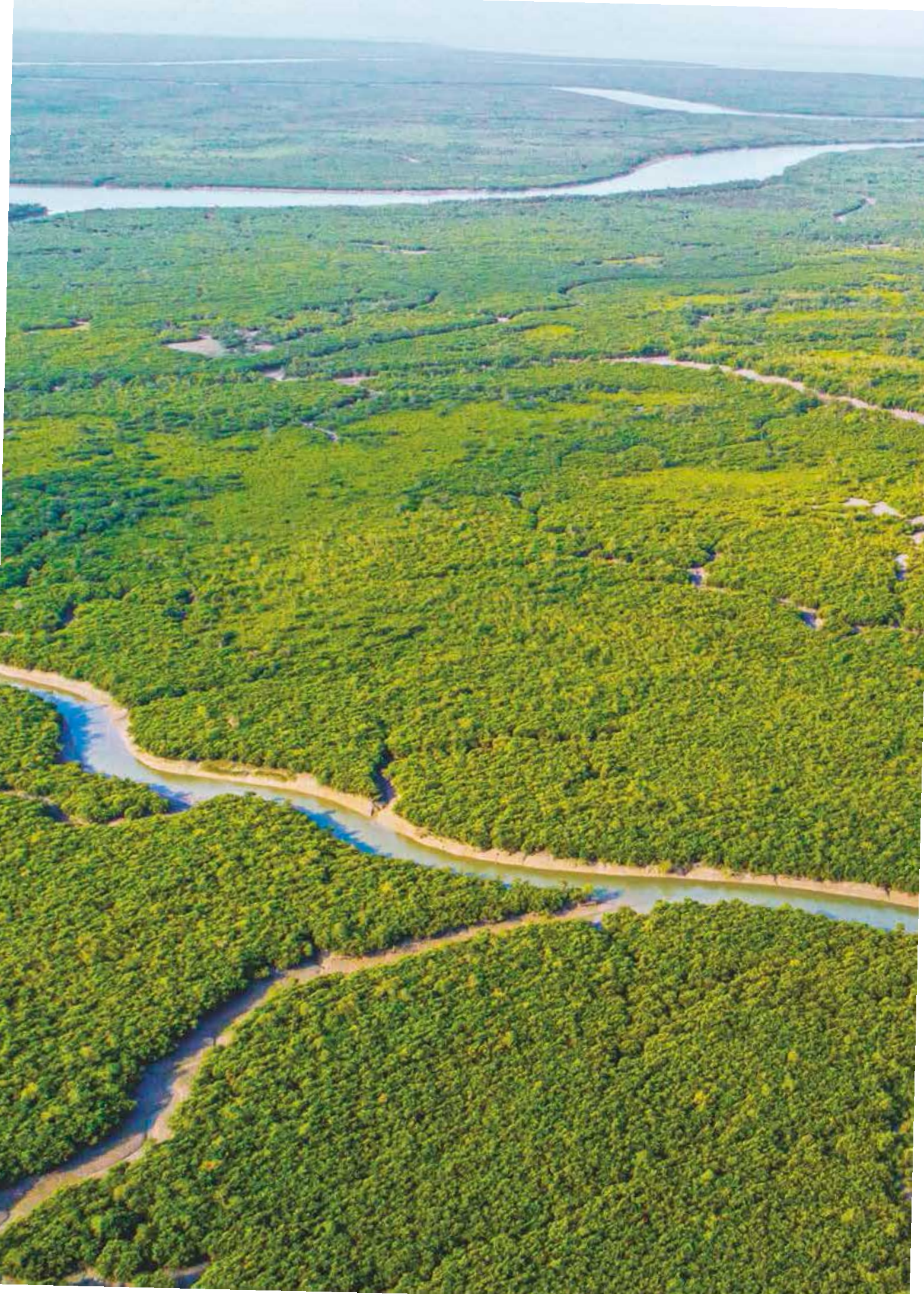
Affected Forest Type Groups

- Forested grids in western Himalayan region and from the north-eastern States are consistently appearing as climate change hotspots across various climate scenarios in three selected time-horizons.
- Himalayan ecosystems and forest types especially Himalayan dry temperate forests, Himalayan moist temperate forests, Sub-Alpine forests, Moist Alpine scrub and Dry Alpine scrub are most exposed throughout the projections of 2030, 2050 and 2085. A large exposure for Subtropical pine forests and Subtropical dry evergreen forests is also identified for 2030 and beyond.
- Tropical thorn forests, Tropical dry evergreen forests, Montane wet temperate forests, Littoral and Swamp forests and Subtropical broad leaved hill forests have relatively lesser exposure to temperature projections
- 'Tropical Dry Deciduous Forests', 'Tropical Moist Deciduous Forests' and 'Tropical Semi-evergreen Forests', which are most dominant in the central India covering major part of the States of Madhya Pradesh, Chhattisgarh, Northern part of Odisha and western part of Jharkhand will be impacted by adverse climate change from 2050 onwards.

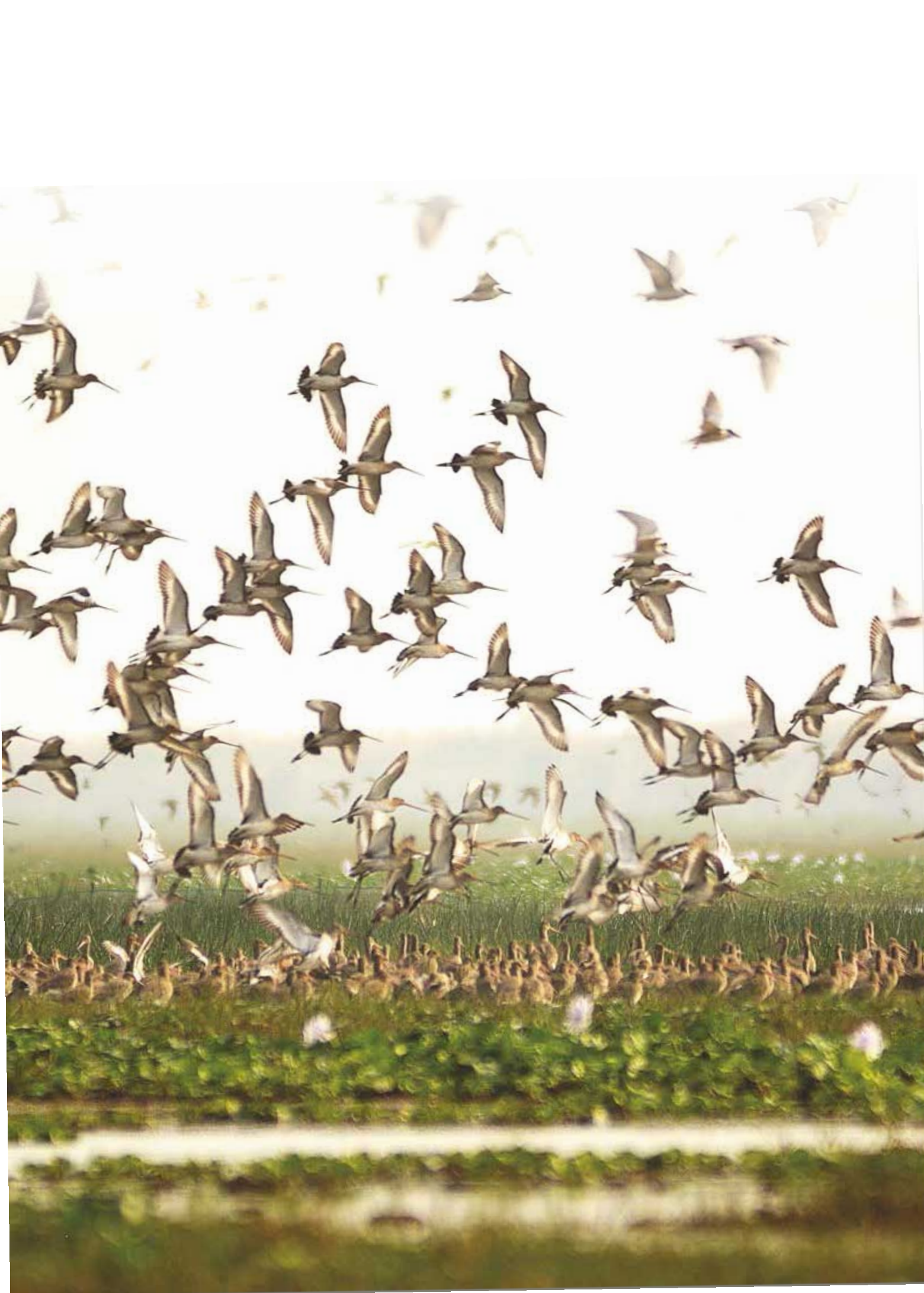
Conclusion 11.6

By analysing all the scenarios in the studied periods i.e. 2030, 2050 and 2085; it has been observed that Ladakh, Jammu-Kashmir, Himachal Pradesh and Uttarakhand are projected to witness highest temperature increase while Andaman & Nicobar Islands, West Bengal, Goa, Tamil Nadu and Andhra Pradesh are projected to witness the least temperature rise over these periods. The North-Eastern States and Upper Malabar Coast of India are projected to experience highest increase in rainfall; whereas, part of North-Eastern States like Arunachal Pradesh, Sikkim; North-Western parts of the country namely Ladakh, Jammu & Kashmir and Himachal Pradesh are projected to experience least increase and sometimes even decline in rainfall.

Climate change will affect forests in multiple ways, both directly and indirectly. Keeping in view the projected impact of climate change in forest areas of the country, suitable studies need to be conducted to ascertain the impact on forest, species composition and related biodiversity. Suitable mitigation and adaptation strategies have to be devised as well as implemented.




12
NEW INITIATIVES



Introduction 12.1

There is continuous endeavor at FSI to keep pace with technological advancements to meet the information needs of the forestry sector. From time to time new initiatives are taken, which contribute significantly in updating methodologies, generate new information and eventually leading to greater precision and enhancement of knowledge. Information about some of the important initiatives undertaken in the last two years and published as Technical Information Series of FSI are being presented in this chapter.

Trees Outside Forest Resources in India[1] 12.2

Trees Outside Forest (TOF) resources play a vital role in the socio-economic life of rural India and generate valuable ecosystem services in urban and rural parts of the country. These are found in diverse formations in the rural and urban landscapes in the country like small woodlots, block plantations, trees along linear features such as roads, canals, bunds, etc. and scattered trees on farmlands, agricultural lands, homesteads, community lands and urban areas. Timber and panel products of TOF origin have emerged as the major alternative to timber from forests and thus TOF have significantly obviated pressure from forests. It also acts as an important source for timber and fuel wood and contributes to carbon sequestration and conservation of biodiversity, provides habitat for wildlife and help in microclimate stabilization. Thus TOF resources contribute significantly to sustainable agriculture, food security and rural household economies.

Considering the ecological and economic importance of TOF resources, the Technical Information series focused on TOF resources in India, evolution of assessment methodology and important outcomes. The TOF methodology that was followed from 1991 to 2001, was confined to State or group of districts only. The study area was stratified according to agro-ecological zones (AEZ) and village was taken as sampling unit for the inventory in rural areas. For urban TOF, the Urban Frame Survey (UFS) block maps of National Sample Survey Organization (NSSO) were taken as sampling unit. This was modified in 2001 and was continued till 2016. Under this methodology, the country was stratified into 14 physiographic zones based on the similar vegetation type, climate, soil etc. Thereafter, 60 districts spread over the entire country representing all the physiographic zones were selected for the detailed inventory of TOF in a cycle of 2 years. For inventory of TOF (Rural), high-resolution satellite data was used to stratify TOF resources of the selected districts into three strata, namely block, linear and scattered. The methodology of TOF assessment was further improved in 2016 and the cycle of the new design for TOF was fixed at 10 years. All TOF grids are marked with numbers 1 to 10 in a sequential manner. Grids of a particular number are taken for

[1] *FSI Technical Information Series Volume 2, No. 1, 2020*

inventory in a particular year. Both TOF (Rural) and TOF (Urban) inventory are carried out in the selected grids.

In this Technical information series, for the first time, the extent of TOF in the country has been assessed at 29.38 m ha which is 8.94% of the total geographical area of the country. TOF form nearly 38% of the carbon sink in forest and tree cover of the country. The scattered and block plantations contribute more than 90% of the TOF volume of the entire country. *Mangifera indica, Azadirachta indica, Acacia arabica* and *Cocos nucifera* are the major species found in TOF in rural areas which are contributing most to the total growing stock, whereas, *Cocos nucifera, Areca catechu, Mangifera indica and Azadirachta indica* are the major TOF species in the urban areas of the country.

The potential annual yield of timber from TOF using the inventory data has been generated on the basis of dominant species. For calculation of potential annual yield, only timber species were considered. The rotation period of different timber species available with FSI from State Forest Departments and other sources was used. Using the estimates of growing stock and rotation period of the species, annual potential yield was calculated for each State by applying Von Mantel's formula. The potential annual yield of timber from TOF has been assessed at 85.16 MCUM.

12.3 India's Nationally Determined Contribution of creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 eq through additional forest & tree cover: Possibilities, scale and costs for formulating strategy[2]

Under the United Nation Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in December 2015, countries made post 2020 climatic action commitments called Nationally Determined Contributions (NDC). The NDCs will largely determine whether the world will achieve an ambitious 2015 agreement and is put on a path towards a low-carbon, climate-resilient future 'by keeping global temperature rise in this century well below 2° Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5° Celsius[3] (UNFCCC, 2015)'.

India has submitted its NDC to the UNFCCC in October 2015, which outlines the post 2020 climate actions the country intends to take under a new international agreement. There are three quantified targets in India's NDC; the first one related to emission intensity of GDP, second about the contribution of renewable energy to the overall installed power and the third about achieving additional carbon sink of 2.5 billion to 3.0 billion tonnes through additional forest and tree cover by 2030. This Technical Information series focusses on the third target related to forestry sector.

Achieving this ambitious target requires a well-planned strategy taking into consideration all possible interventions within the forests and all other available lands. With an objective to provide important inputs in formulating a strategy to achieve the NDC target, FSI had undertaken a detailed exercise for exploring the possibilities. The implications of above NDC target in terms of actions on the ground, associated cost and carbon sequestration levels etc were analyzed in this exercise. A bottom-up approach was followed wherein computations for each State has been done according to the States' circumstances and available lands and using State, forest type and physiographic zone specific emission/removal factors and cost norms.

An attempt has been made first to understand the magnitude and scale of actions required to achieve the target and then the possibilities of implementation, while looking at the availability of

[2] *FSI Technical Information Series Volume I, No. 3, 2019*

[3] *Paris agreement, UNFCCC, 2015*

land for different activities. The study is based on calculations on time series data on forest cover, its past and projected changes i.e flux, stratification of changes (activity data) in terms of forest types, emission and removal factors for each forest type and land use and land cover area figures. The figures used in the study are largely from the primary data reported by FSI in ISFRs. Data on land availability under different categories has been taken from different credible sources.

Analysis of trend of carbon in India's forest & tree cover vis-à-vis NDC target helps in understanding implication of increasing carbon sink through forest & tree cover. The study presents different scenarios and magnitude of actions required for achieving the NDC target for creating additional carbon sink through additional forest and tree cover in the country. The information may be found useful in providing inputs for drawing a comprehensive strategy to achieve the NDC target in terms of possible interventions, potential carbon sink in respect of each intervention and cost involved in implementation.

Trend of carbon sink through forest & tree cover analyzed in the study, provides an understanding of the implications of the NDC target vis-a-vis creation of additional carbon sink by different activities of restoration of forests and tree plantations. The study, reveals that if the NDC target is not above the 'Business As Usual (BAU)' level, then the increase in carbon sink by 2030 to the target level may be achieved by just sustaining the existing policies and programmes of conservation and afforestation.

12.4 Variability in forests and optimum sample size for estimation of Growing Stock in different districts of the country: a ready reckoner for working plan preparation or any other forest resource assessment exercise[4]

Information on forestry parameters such as distribution of timber species, volume, biomass, carbon stock, regeneration status, population etc is vital for Forest managers, planners and policy makers for strategic planning and management of forest resources. On the basis of forest resources assessment, the past growth and productivity of a forest area is evaluated for sustainable forest management.

Encompassing the ecological, economic and social dimensions of the National Forest Policy, it is necessary to carry out monitoring and assessment of forest resources (with regard to biodiversity, climate change and carbon emission/sequestration) on the basis of sound, statistically robust sampling design, especially in the present changing scenario of forest resources management. The scientific management of the forests is essentially required at all levels, for planning and management of forests.

Working plan is one such important tool which helps in evaluating the status of forest resources, assessing the impacts of past management practices and deciding about suitable management interventions for the future. In Working Plans, growing stock has traditionally been used for calculation of sustainable yield of timber from forests. Growing stock is an important indicator of forest productivity which has gained importance due to the significant role of forest in climate change mitigation. The growing stock data forms the basis for calculation of biomass and carbon stock in the forest. Further, the United Nations Framework Convention on Climate Change (UNFCCC) guidelines for implementation of REDD+ requires that every country should have a National Forest Monitoring System (NFMS) consisting of satellite based forest monitoring system and National Forest Inventory.

[4] *FSI Technical Information Series Volume 2, No. 3, 2020*

Forest inventories are primarily aimed at assessing the growing stock and other quantitative and qualitative parameters of the forests. Forest inventory is mostly a sampling based exercise. Determination of sample size is an important step in constructing a sample design. This document provides optimum sample size for different districts of the country for conducting inventory to estimate growing stock. It gives district wise information on coefficient of variation (CV) and sampling intensity of growing stock at different allowable errors. The optimum sample size i.e. optimum number of plots to be included in the sample, which may provide the estimates of population parameters within the prescribed limit of error, is of great importance. Thus instead of prescribing sampling intensity, the allowable level of error in the estimates at division/range level say 5% to 10% at the 95% confidence level is fixed.

As any sample survey involves cost, time and manpower, it is necessary to have optimum sample size for timely completion of the survey within the prescribed budgets. The sample size depends mainly on the variability of the attribute (parameter) under assessment and permissible error. The surveyor can decide the sample size at different allowable errors depending upon availability of man power, time and cost. Both variability and allowable errors will have bearing on the sample size. More the variability of main characteristic means larger the sample size. Similarly, lesser the allowable error means larger the sample size.

12.5 A new grid-based algorithm for detecting locations of change in forest vegetation in a pin-pointed manner over large landscapes[5]

Forests are facing increasing pressure due to rapid growth in population, industrialization, urban sprawl, infrastructure projects, spreading of agricultural land use and adverse climate change. In this scenario, close monitoring of forest resources has become an essential requirement for managing the forest ecosystems for ensuring environmental benefits to the society. With the growing pressures on the country's forest, now there is an emerging need of detecting the changes occurring in the forests at an early stage, in an accurate manner with reduced cycle of revisit.

In India, Forest Survey of India (FSI) is engaged in regular monitoring of forest resources in the biennial cycle using remote sensing technique and forest inventory.

In this regard, a new index called 'Grid Vegetation Change Index' (GVCI) has been used to detect changes in forests through grid based approach in a rapid manner for operational use. Four study areas, each of size approximately 400 sq km have been taken from different regions of the country namely East, West, South and North as test sites. The results of the study consistently show that the values of GVCI above a threshold, highlights change in forest vegetation with high accuracy, wherever significant change in forest vegetation has taken place. The smallest area of detecting change in this study has been kept at 1.44ha (i.e a grid size of 120m by 120m) which corresponds to area of 16 pixels of Landsat 8 data. The positive GVCI value corresponds to vegetation gain and on the other hand the negative GVCI values correspond to vegetation loss.

This, being a ratio based index, it minimizes the atmospheric effect and radiometric differences among the multi-temporal satellite images. The Vector Grid based approach used to calculate GVCI, also minimizes the errors of geo-registration.

The algorithm can be used to generate SMS alerts to notify the forest vegetation loss to the concerned officials who have registered their mobile numbers for the areas of their interest.

GVCI can be used as an operational application in detecting change in vegetation over an area of interest between two time-periods. GVCI numerical value provides quantified assessment of the degree of change. By applying the GVCI on a pair of remotely sensed images of two dates of an

[5] *FSI Technical Information Series Volume 2, No. 4, 2020*

area, one can know degree of vegetation change in every unit area (grid) of the large landscape. Based on the GVCI values, one can select those grids which show significant changes. Such 'candidate grids with significant changes' may be shortlisted for ground verification and studying the causes of change. Since the change identification is based on the index value, it is free from human subjectivity or bias.

12.6 Rapid assessment of fire affected forest areas in the country based on MODIS-detections following a sampling approach[6]

Assessment of burnt forest area provides an important input for understanding the ecological, social as well as economic impacts of forest fires. This study was carried out with the objective of developing a methodology for rapid assessment of burnt forest areas at the country-wide scale based on a statistical sampling approach. Forest Survey of India issues alerts of forest fires based on near-real time detections of forest fires by MODIS sensor. Detected forest fires in the country based on MODIS data during the fire season of 2019-2020 has been used as population for assessing the burnt forest areas in the country. The total burnt forest area in India for the fire season 2019-2020 (i.e. from 01st November, 2019 to 30th June, 2020) has been assessed 11,094 sq km with 95% confidence level, which is 1.56% of the total forest cover area of the country. Among the different physiographic zones, the maximum forest burnt area has been found in Deccan (5626 sq km) followed by Central Highlands (2160 sq km). These two physiographic zones together has contributed to 70% of the total forest burnt areas. In contrast, north-east region with maximum number of MODIS detected forest fire points in the last fire season, has only 12.50% of the total forest burnt areas.

The methodology developed is a simple and reliable procedure to estimate the forest burnt areas in a cost-effective and time-efficient manner. The burnt area estimation would be a useful data for damage assessment and planning of restoration activities in fire affected forest areas.

12.7 Hand Book of Index Maps of India for Indian Remote Sensing (IRS2) Satellite LISS-III and SOI Topographic sheets

FSI is engaged in Forest Cover Mapping of the Country since 1987 using satellite data. Wall-to-wall Forest Cover maps are prepared on 1:50,000 scale at biennial interval. The primary source of satellite data is from Indian Remote sensing series (IRS) of satellite, which is procured from National Remote sensing Centre (NRSC), Hyderabad. Survey of India (SoI) Topographic sheets i.e. 1:2,50,000 and 1:50,000 are also used in mapping exercise.

Forest Cover mapping is carried out using a standardized methodology with sequence of steps to be followed by the analysts. The first step in the mapping exercise is to acquire the satellite data of appropriate season of the required area. For this, it is essential that information about the area of interest and its coverage of satellite image is known to assist the analyst in accessing above information. The "Hand book of Index map for Indian Remote Sensing (IRS2) satellite LISS-III and SoI Topographic Sheets" has been prepared with the objective of serving an important purpose of being a ready reckoner to correctly know the number of topographic sheets and satellite imagery required for image analysis and mapping of different States and districts. This document will be very useful for State Forest Department, scientists & analysts involved in Natural Resource mapping.

[6] *FSI Technical Information Series Volume 2, No. 2, 2020*

13

FOREST & TREE RESOURCES IN STATES AND UNION TERRITORIES

Introduction 13

This chapter gives information on the forest and tree cover of different States and Union Territories as per the present assessment and changes with respect to the previous assessment.

It also gives statistics about total population, urban, rural, tribal, livestock population and average population density. Forest cover within and outside recorded forest areas for 24 states and within and outside green wash boundaries for 11 States/UTs have also been given. Altitude and slope wise forest cover under different density classes and forest cover information in different forest types has also been given for each States and UTs. In addition statistics on tree cover, growing stock in recorded forest and TOF are separately given. Apart from the regular features of ISFR like forest carbon, bamboo resource, map and forest cover under different categories of fire proneness, major NTFPs, major invasive species and dia-class distribution of dominant forest species are also being presented.

District wise forest cover has been given for all the States/UTs. Change in the forest cover is based on the satellite data of the years 2019-20. The change in the different categories of forest cover and dynamics of the changes are sown for each of the States/UTs.

13.1 ANDHRA PRADESH

Geographical Area
1,62,968 sq km

Geographical Coordinates
Latitude- 12°37' N to 19°55' N
Longitude-76° 45' E to 84° 46' E

Population (as per Census 2011)
49.39 million
Urban 14.61 million (29.58 %)
Rural 34.78 million (70.42 %)
Tribal 2.63 million (5.32 %)

Average Population Density
308 per sq km

Livestock population
(as per 19th Live Stock Census)
56.10 million

No. of Districts
13

No. of Hill Districts
0

No. of Tribal Districts
5

Table 13.1.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	16,297	
Reporting area for land utilization	16,297	100.00
Forests	3,688	22.63
Not available for land cultivation	3,400	20.86
Permanent pastures and other grazing lands	209	1.28
Land under misc. tree crops and groves	155	0.95
Culturable wasteland	414	2.54
Fallow land other than current fallows	940	5.77
Current fallows	1,443	8.86
Net area sown	6,048	37.11

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.1.1 Forest Cover

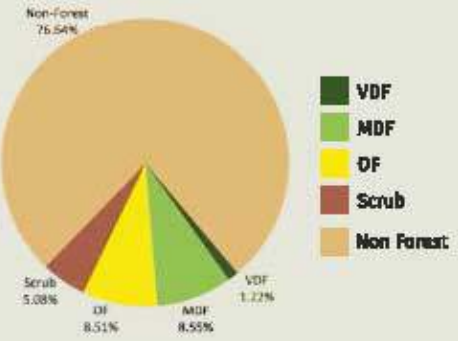


Figure 13.1.1
Forest Cover of Andhra Pradesh

Table 13.1.2
Forest Cover of Andhra Pradesh (In sq km)

Class	Area	% of GA
VDF	1,994.28	1.22
MDF	13,928.75	8.55
OF	13,861.27	8.51
Total	**29,784.30**	**18.28**
Scrub	8,276.09	5.08

Table 13.1.3 District- wise Forest Cover in Andhra Pradesh (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				% of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Anantapur	19,130	0.00	212.22	785.78	998.00	5.22	11.17	1,100.38
Chittoor	15,152	0.00	1,245.35	2,028.33	3,273.68	21.61	73.25	1,240.83
East Godavari[T]	12,805	1,103.32	2,586.75	1,431.13	5,121.20	39.99	127.10	143.59
Guntur	11,391	1.00	290.33	601.59	892.92	7.84	4.92	456.87
Krishna	8,727	38.00	138.95	486.81	663.76	7.61	13.58	25.27
Kurnool	17,658	87.00	1,509.88	582.62	2,179.50	12.34	6.93	682.02
Prakasam	17,626	254.61	1,802.59	1,276.48	3,333.68	18.91	29.84	1,217.30
Sri Potti Sriramulu Nellore	13,076	27.00	629.90	812.03	1,468.93	11.23	127.27	787.18
Srikakulam[T]	5,837	0.00	154.12	706.71	860.83	14.75	41.52	389.64
Visakhapatnam[T]	11,161	67.31	1,875.27	1,831.30	3,773.88	33.81	17.45	853.86
Vizianagaram[T]	6,539	0.00	231.00	882.58	1,113.58	17.03	61.59	352.43
West Godavari[T]	8,507	376.04	544.15	808.12	1,728.31	20.32	123.91	3.60
YSR Kadapa/ Cuddapah	15,359	40.00	2,708.24	1,627.79	4,376.03	28.49	8.37	1,023.12
Grand Total	**1,82,968**	**1,994.28**	**13,928.75**	**13,861.27**	**29,784.30**	**18.28**	**645.90**	**8,276.09**

13.1.1.1 Forest Cover inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

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Table 13.1.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Andhra Pradesh (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
1,965	12,814	9,460	24,239	29	1,115	4,401	5,545
8.10%	52.87%	39.03%		0.52%	20.11%	79.37%	

**In case of Andhra Pradesh, RFA boundaries have been used.*

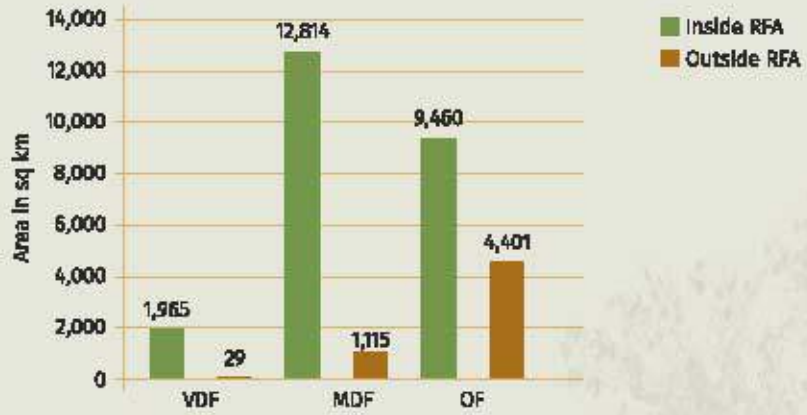

Figure 13.1.2
Forest Cover Inside and Outside of RFA in Andhra Pradesh

Table 13.1.5 Forest Cover Change Matrix for Andhra Pradesh (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	1,993	0	0	0	1	1,994
Moderately Dense Forest	1	13,913	4	3	17	13,938
Open Forest	0	11	13,066	10	118	13,205
Scrub	0	2	141	8,033	79	8,255
Non Forest	0	3	650	230	1,24,693	1,25,576
Total ISFR 2021	**1,994**	**13,929**	**13,861**	**8,276**	**1,24,908**	**1,62,968**
Net Change	0	-9	656	21	-668	

Table 13.1.6 Altitude-wise Forest Cover in Andhra Pradesh (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	1,35,122	1,082	8,549	10,683	20,314	6,313
500-1000	25,747	840	5,222	3,019	9,081	1,666
1000-2000	2,099	72	158	159	389	297
Total	**1,62,968**	**1,994**	**13,929**	**13,861**	**29,784**	**8,276**

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

Table 13.1.7 Forest Cover in different slope classes in Andhra Pradesh (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,31,263	525	4,201	6,539	11,265	4,311
5-10	10,695	376	2,318	1,874	4,568	1,312
10-15	6,738	324	2,069	1,566	3,959	915
15-20	5,500	288	1,899	1,405	3,592	721
20-25	4,285	239	1,606	1,164	3,009	532
25-30	2,718	154	1,079	788	2,021	315
>30	1,769	88	757	525	1,370	170
Total	**1,62,968**	**1,994**	**13,929**	**13,861**	**29,784**	**8,276**

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

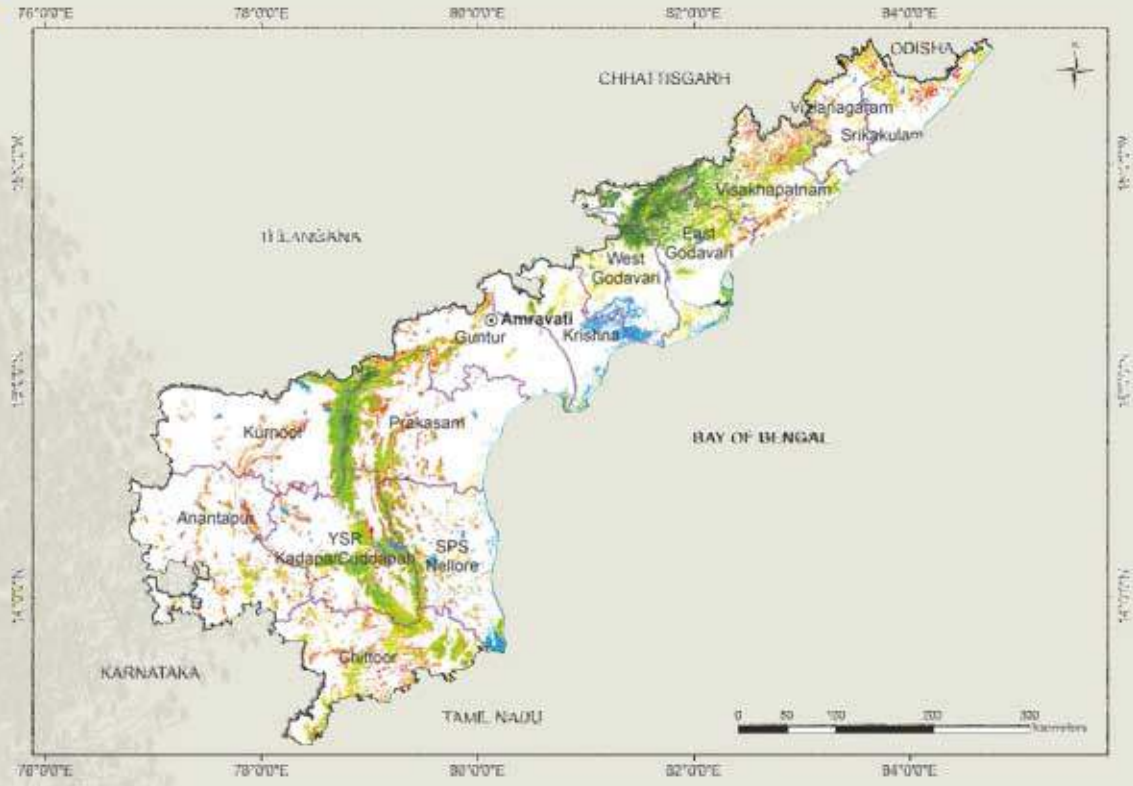

Figure 13.1.3 Forest Cover Map of Andhra Pradesh

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.1.2 Forest Types

The area under different forest types of Andhra Pradesh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

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Table 13.1.8 Area statistics of the Forest Types found in Andhra Pradesh (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3B/C2 Southern moist mixed deciduous forest	1,752.05	4.64
2.	4A/L1 Littoral forest	51.93	0.14
3.	4B/TS2 Mangrove forest	404.14	1.07
4.	5A/C1b Dry teak forest	551.72	1.46
5.	5A/C2 Dry red sanders-bearing forest	1,085.99	2.88
6.	5A/C3 Southern dry mixed deciduous forest	14,970.34	39.66
7.	5B/C1c Dry peninsular sal forest	0.62	0.00
8.	5B/C2 Northern dry mixed deciduous forest	0.68	0.00
9.	5/DS1 Dry deciduous scrub	12,892.22	34.16
10.	5/DS2 Dry savannah forest	35.98	0.10
11.	5/E4 *Hardwickia* forest	8.73	0.02
12.	5/E9 Dry bamboo brakes	297.85	0.79
13.	5/2S1 Secondary dry deciduous forest	724.19	1.92
14.	6A/C1 Southern thorn forest	1,659.27	4.40
15.	6A/C2 Carnatic umbrella thorn forest	21.75	0.06
16.	6A/DS1 Southern thorn scrub	12.80	0.03
17.	6A/DS2 Southern *Euphorbia* scrub	0.26	0.00
18.	7/C1 Tropical dry evergreen forest	434.95	1.15
19.	7/DS1 Tropical dry evergreen scrub	17.60	0.05
	Sub Total	**34,923.07**	**92.53**
20.	TOF/Plantation	2,469.17	6.54
	Total (Forest Cover & Scrub)	**37,392.24**	
	Grassland forest type (outside forest cover)		
21.	5/DS4 Dry grassland	352.08	0.93
	Grand Total	**37,744.32**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

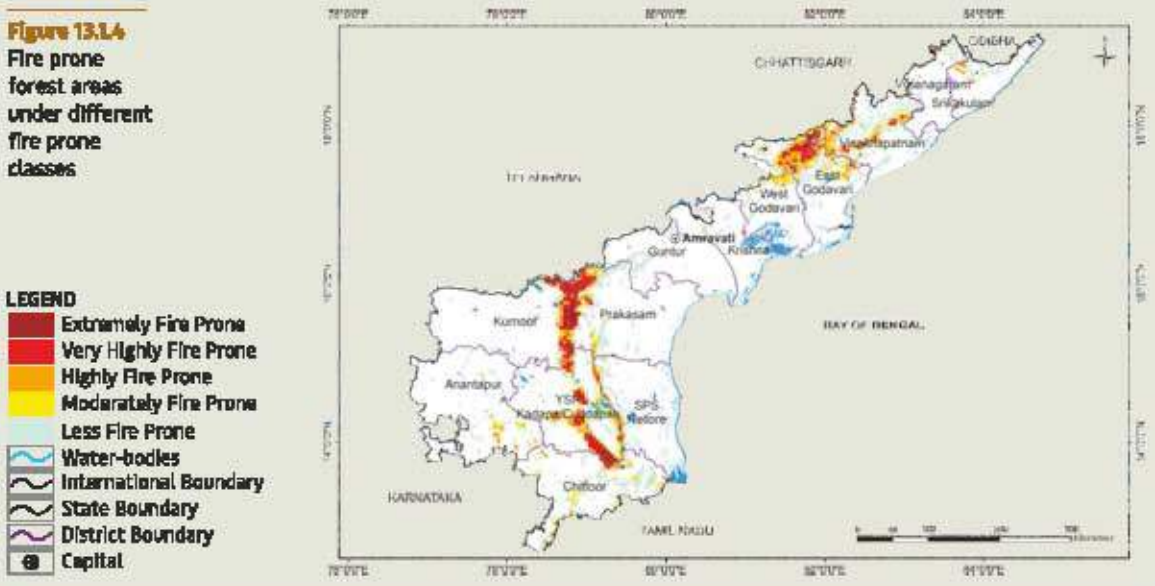
Table 13.1.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	1,150.13	3.86
2.	Very highly fire prone	3,832.50	12.87
3.	Highly fire prone	4,915.11	16.50
4.	Moderately fire prone	4,153.69	13.95
5.	Less fire prone	15,732.57	52.95
	Total	**29,784.00**	**100.00**

13.1.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Figure 13.1.4
Fire prone forest areas under different fire prone classes



13.1.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Andhra Pradesh has been estimated as given in following table.

Table 13.1.10 Tree Cover in Andhra Pradesh (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
3,914	4,679	765

13.1.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.1.11 Extent of TOF in Andhra Pradesh (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
5,545	4,679	10,224

13.1.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Andhra Pradesh is given in the Table 13.1.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.1.13

Table 13.1.12 Growing Stock in Andhra Pradesh (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	119.02	115.71	-3.31	2.64
2.	Growing Stock in TOF	67.68	73.16	5.48	4.11

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Table 13.1.13 Diameter class distribution of top five tree species inside RFA in Andhra Pradesh (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Anogeissus latifolia*	62,213	1,972	169
2.	*Xylia xylocarpa*	36,842	6,785	503
3.	*Lannea coramandelica*	21,499	2,486	42
4.	*Terminalia tomentosa*	16,112	2,016	169
5.	*Hardwickia binata*	14,453	1,642	85

13.1.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Andhra Pradesh in Rural and Urban areas are given in the Table 13.1.14 and Table 13.1.15 respectively

Table 13.1.14 Top five tree species in TOF (Rural) in Andhra Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	28.83
2.	*Borassus flabelliformis*	9.61
3.	*Azadirachta indica*	9.25
4.	*Cocos nucifera*	8.47
5.	*Anacardium occidentale*	6.03

Table 13.1.15 Top five tree species in TOF (Urban) in Andhra Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	15.87
2.	*Azadirachta indica*	12.49
3.	*Pongamia pinnata*	7.36
4.	*Mangifera indica*	7.13
5.	*Tectona grandis*	6.54

13.1.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 230.22 million tonnes (844.14 million tonnes of CO_2 equivalent) which is 3.20 % of total forest carbon of the country. Pool wise forest carbon in Andhra Pradesh is given in the following table.

Table 13.1.16 Forest Carbon in Andhra Pradesh in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	63,951
2.	BGB	25,064
3.	Dead wood	979
4.	Litter	3,171
5.	SOC	1,37,057
	Total	**2,30,222**

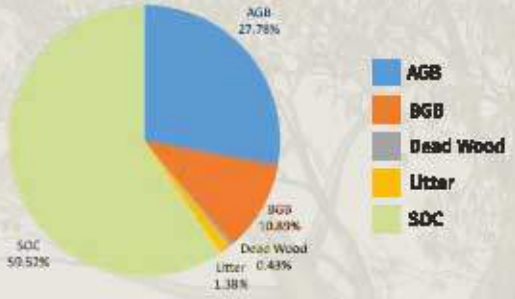

Figure 13.1.5 Forest Carbon in Andhra Pradesh

13.1.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.1.17 Growing Stock of Bamboo in Andhra Pradesh

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	6,104	4.08
Total number of culms (in millions)	2,244	4.21
Total equivalent green weight (in '000 tonnes)	27,219	6.77

13.1.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.1.18 and Table 13.1.19 respectively.

Table 13.1.18 Major NTFP species in Andhra Pradesh

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Solanum nigrum*	Herbs	84.55
2.	*Hemidesmus indicus*	Climber	8.81
3.	*Cardiospermum helicabum*	Climber	6.63

Table 13.1.19 Major invasive species in the State inside the RFA/Green Wash in Andhra Pradesh (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	253
2.	*Ageratum conyzoides*	183
3.	*Chromolaena odorata*	99
4.	*Cuscuta* spp.	49
5.	*Prosopis juliflora*	46

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.2 ARUNACHAL PRADESH

Geographical Area
83,743 sq km

Geographical Coordinates
Latitude 26° 28' N to 29° 30' N
Longitude 91° 30' E to 97° 30' E

Population (as per Census 2011)
1.38 million
Urban 0.32 million (22.94 %)
Rural 1.06 million (77.06 %)
Tribal 0.95 million (68.79 %)

Average Population Density
17 per sq km

Livestock population
(as per 19th Live Stock Census)
1.41 million

No. of Districts
16

No. of Hill Districts
16

No. of Tribal Districts
16

Table 13.2.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	8,374	
Reporting area for land utilization	7,172	100.00
Forests	6,669	92.99
Not available for land cultivation	62	0.86
Permanent pastures and other grazing lands	18	0.25
Land under misc. tree crops and groves	34	0.47
Culturable wasteland	61	0.85
Fallow land other than current fallows	61	0.86
Current fallows	34	0.47
Net area sown	233	3.25

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.2.1 Forest Cover

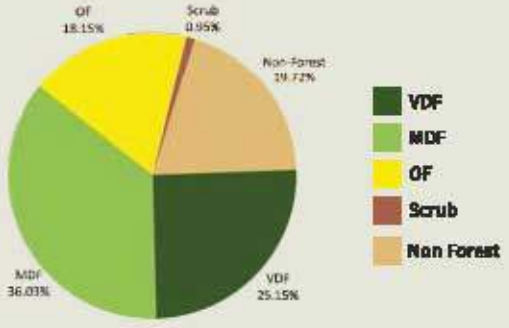

Figure 13.2.1
Forest Cover of Arunachal Pradesh

Table 13.2.2 Forest Cover of Arunachal Pradesh (in sq km)

Class	Area	% of GA
VDF	21,058.37	25.15
MDF	30,175.56	36.03
OF	15,196.74	18.15
Total	**66,430.67**	**79.33**
Scrub	796.98	0.95

Table 13.2.3 District- wise Forest Cover in Arunachal Pradesh (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Changlang[T]	4,662	1,809.08	1,327.54	844.39	3,981.01	85.39	-5.75	10.68
Dibang Valley[H] & Lower Dibang Valley[H]	13,029	1,688.91	4,805.97	2,583.83	9,079.71	69.69	-128.19	83.24
East Kameng[H] & West Kameng[H]	11,556	3,504.95	4,478.14	2,241.25	10,224.34	88.48	-9.78	166.20
East Siang[H]	3,603	876.18	1,261.58	773.91	2,911.67	80.81	42.57	12.98
Kurung Kumey[H] & Lower Subansiri[H]	9,548	3,120.32	3,821.11	1,439.86	8,381.29	87.78	11.17	67.19
Lohit[H] & Anjaw[H]	11,402	2,016.68	3,805.80	1,547.55	7,370.03	64.64	-217.57	83.45
Papum Pare[H]	3,462	981.00	1,473.11	741.92	3,196.03	92.32	11.12	7.60
Tawang[H]	2,172	325.81	410.82	412.64	1,149.27	52.91	-24.88	106.79
Tirap[H]	2,362	736.80	646.96	469.67	1,853.43	78.47	-7.56	76.03
Upper Siang[H]	6,590	1,551.83	2,479.31	1,329.12	5,360.26	81.34	-0.47	111.98
Upper Subansiri[H]	7,032	1,813.33	2,567.30	1,180.36	5,560.99	79.08	7.99	45.09
West Siang[H]	6,325	2,633.48	3,096.92	1,632.24	7,362.64	88.44	64.24	25.75
Grand Total	**83,743**	**21,058.37**	**30,175.56**	**15,196.74**	**66,430.67**	**79.33**	**-257.11**	**796.98**

13.2.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.2.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Arunachal Pradesh (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
19,637	27,171	11,872	58,680	1,421	3,005	3,325	7,751
33.46%	46.31%	20.23%		18.33%	38.77%	42.90%	

 # In case of Arunachal Pradesh, Green Wash boundaries have been used

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Figure 13.2.2 Forest Cover Inside and Outside of Green Wash in Arunachal Pradesh

Table 13.2.5 Forest Cover Change Matrix for Arunachal Pradesh (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	20,918	64	76	14	23	21,095
Moderately Dense Forest	124	29,790	386	128	129	30,557
Open Forest	7	267	14,109	111	542	15,036
Scrub	0	0	18	188	23	229
Non Forest	9	55	608	356	15,798	16,826
Total ISFR 2021	**21,058**	**30,176**	**15,197**	**797**	**16,515**	**83,743**
Net Change	-37	-381	161	568	-311	

Table 13.2.6 Altitude-wise Forest Cover in Arunachal Pradesh (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	11,136	1,509	3,313	2,320	7,142	70
500-1000	11,082	2,843	4,151	3,156	10,150	47
1000-2000	23,752	7,977	9,831	4,601	22,409	59
2000-3000	17,965	6,676	8,864	1,707	17,247	29
3000-4000	13,370	2,032	3,900	3,096	9,028	358
>4000	6,438	21	117	317	455	234
Total	**83,743**	**21,058**	**30,176**	**15,197**	**66,431**	**797**

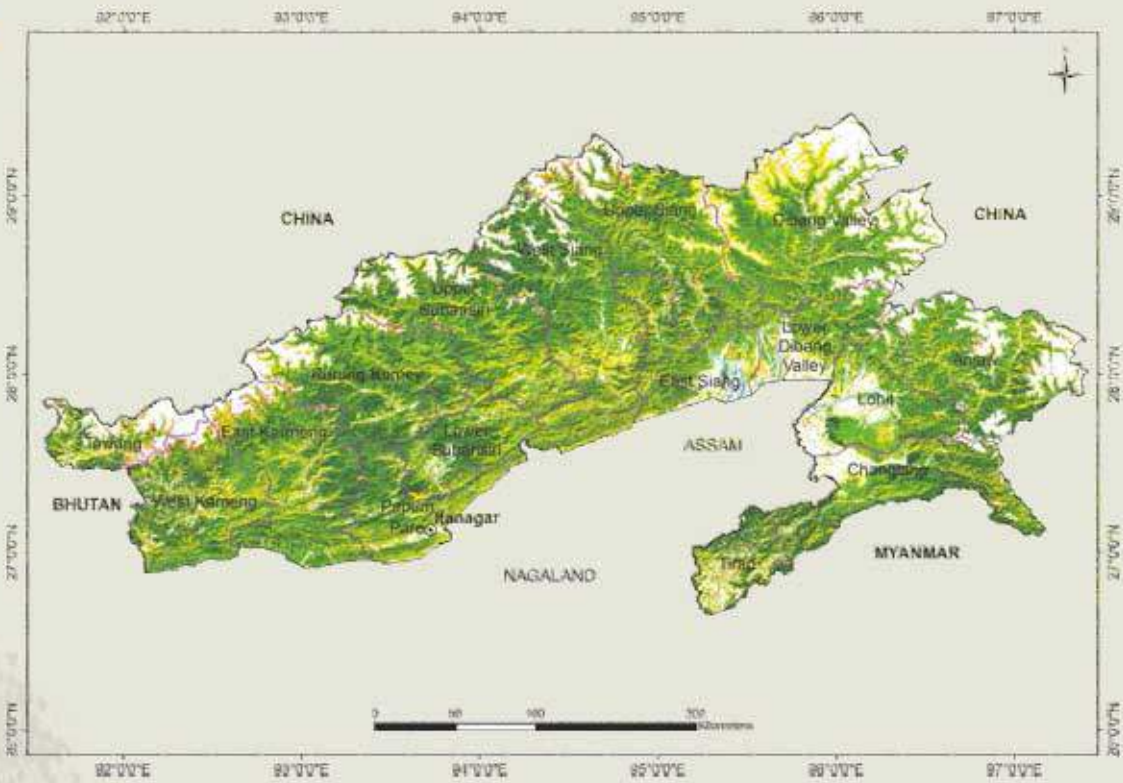
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.2.7 Forest Cover in different slope classes in Arunachal Pradesh (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	7,629	701	1,804	1,217	3,722	77
5-10	5,608	1,435	1,961	911	4,307	52
10-15	8,588	2,508	2,998	1,449	6,955	78
15-20	11,278	3,355	3,964	1,960	9,279	102
20-25	12,494	3,649	4,456	2,209	10,314	115
25-30	12,172	3,431	4,474	2,213	10,118	115
>30	25,974	5,979	10,519	5,238	21,736	258
Total	**83,743**	**21,058**	**30,176**	**15,197**	**66,431**	**797**

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

Figure 13.2.3 Forest Cover Map of Arunachal Pradesh



LEGEND

- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.2.2 Forest Types

The area under different forest types of Arunachal Pradesh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.2.8 Area statistics of the Forest Types found in Arunachal Pradesh (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1B/C1 Assam Valley tropical wet evergreen forest *(Dipterocarpus)*	1,505.16	2.07
2.	1B/C2a Kayea forest	745.68	1.03
3.	1/2S1 Pioneer Euphorbiaceous scrub	103.86	0.14
4.	2B/ C1a Assam alluvial plains semi-evergreen forest	3,961.00	5.44
5.	2B/C1b Eastern sub-montane semi-evergreen forest	2,330.86	3.20
6.	2B/C1/1S1 Sub-Himalayan light alluvial semi-evergreen forest	4,077.78	5.60
7.	2B/C1/2S2 Eastern alluvial secondary semi-evergreen forest	3,777.01	5.19
8.	2/2S1 Secondary moist bamboo brakes	1,133.65	1.56
9.	3C/C3/2S2 Secondary Euphorbiaceous scrub	0.26	0.00

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(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
10.	3/1S2b *Terminalia-Duabanga*	854.57	1.17
11.	8B/C1 East Himalayan subtropical wet hill forest	15,667.69	21.53
12.	8B/C2 *Khasi* subtropical wet hill forest	1,253.62	1.72
13.	9/C2 Assam subtropical pine forest	718.82	0.99
14.	11B/C1 East Himalayan wet temperate forest	16,531.13	22.72
15.	12/C1f Low-level blue pine forest *(P. wallichiana)*	211.82	0.29
16.	12/C3a East Himalayan mixed coniferous forest	4,333.74	5.96
17.	12/D51 Montane bamboo brakes	66.17	0.09
18.	13/C6 East Himalayan dry temperate coniferous forest	540.45	0.74
19.	14/C2 East Himalayan sub-alpine birch/fir forest	7,810.33	10.73
20.	15/C1 Birch/*Rhododendron* scrub forest	159.22	0.22
21.	16/C1 Dry alpine scrub	481.74	0.66
	Sub Total	**66,264.56**	**91.05**
22.	TOF/ Plantation	652.68	0.90
	Total (Forest Cover & Scrub)	**66,917.24**	
	Grassland forest types (outside forest cover)		
23.	9/C2/D51 Assam subtropical pine savannah	36.07	0.05
24.	12/D53 Himalayan temperate pastures	375.10	0.52
25.	15/C3 Alpine pastures	5,446.34	7.48
	Sub Total	**5,857.51**	**8.05**
	Grand Total	**72,774.75**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.2.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.2.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	35.16	0.06
2.	Very highly fire prone	959.77	1.44
3.	Highly fire prone	2,744.50	4.13
4.	Moderately fire prone	4,459.72	6.71
5.	Less fire prone	58,231.85	87.66
	Total	**66,431.00**	**100.00**

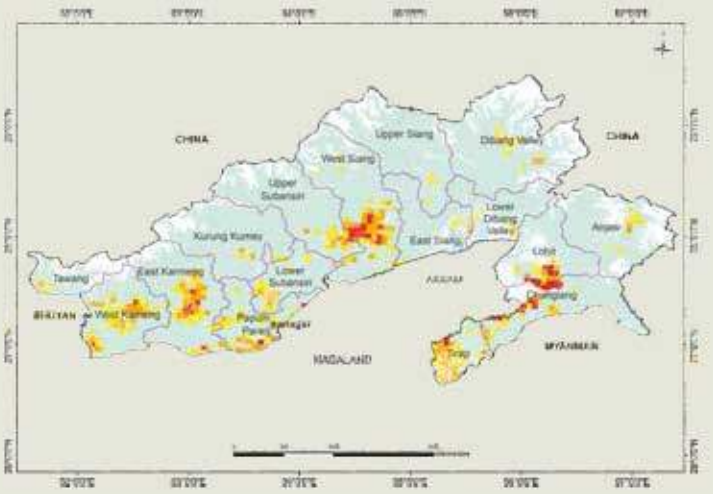


Figure 13.2.4
Fire prone forest areas under different fire prone classes

LEGEND
- Extremely Fire Prone
- Very Highly Fire Prone
- Highly Fire Prone
- Moderately Fire Prone
- Less Fire Prone
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.2.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Arunachal Pradesh has been estimated as given in following table.

Table 13.2.10 Tree Cover in Arunachal Pradesh (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
848	1,001	153

13.2.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.2.11 Extent of TOF in Arunachal Pradesh (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
7,751	1,001	8,752

13.2.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Arunachal Pradesh is given in the Table 13.2.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.2.13

Table 13.2.12 Growing Stock in Arunachal Pradesh (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	458.00	418.99	-39.01	9.55
2.	Growing Stock in TOF	75.08	73.48	-1.60	4.13

ARUNACHAL PRADESH

Table 13.2.13 Diameter class distribution of top five tree species inside RFA in Arunachal Pradesh (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Castanopsis spp.*	67,024	15,779	4,717
2.	*Terminalia myriocarpa*	18,087	11,137	1,782
3.	*Shorea assamica*	17,733	5,082	891
4.	*Ficus spp.*	15,005	2,055	1,782
5.	*Duabanga grandiflora*	10,170	4,197	1,164

13.2.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Arunachal Pradesh in Rural and Urban areas are given in the Table 13.2.14 and Table 13.2.15 respectively

Table 13.2.14 Top five tree species in TOF (Rural) in Arunachal Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Castanopsis spp.*	17.46
2.	*Pinus excelsa*	12.67
3.	*Citrus spp.*	4.45
4.	*Terminalia myriocarpa*	4.43
5.	*Macaranga spp.*	2.60

Table 13.2.15 Top five tree species in TOF (Urban) in Arunachal Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Gmelina arborea*	6.39
2.	*Areca catechu*	6.06
3.	*Mangifera indica*	5.10
4.	*Grevillea robusta*	4.04
5.	*Artocarpus heterophyllus*	3.90

13.2.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 1,023.84 million tonnes (3,754.08 million tonnes of CO_2 equivalent) which is 14.21% of total forest carbon of the country. Pool wise forest carbon in Arunachal Pradesh is given in the following table.

Table 13.2.16 Forest Carbon in Arunachal Pradesh in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	3,40,351
2.	BGB	1,02,229
3.	Dead wood	9,163
4.	Litter	11,802
5.	SOC	5,60,298
	Total	**10,23,843**

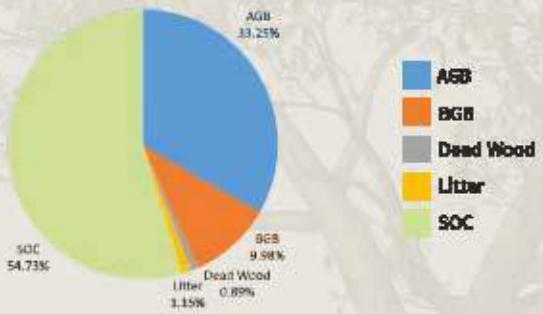


Figure 13.2.5 Forest Carbon in Arunachal Pradesh

13.2.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.2.17 Growing Stock of Bamboo in Arunachal Pradesh

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	15,739	10.53
Total number of culms (in millions)	8,824	16.54
Total equivalent green weight (in '000 tonnes)	46,546	11.58

13.2.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.2.18 and Table 13.2.19 respectively.

Table 13.2.18 Major NTFP species in Arunachal Pradesh

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Piper spp./Piper longum/ Piper mullesua*	Climber	46.27
2.	*Swertia chiraita*	Herbs	24.38
3.	*Thysanolaena maxima*	Herbs	12.94
4.	*Acorus calamus*	Herbs	5.97
5.	*Oroxylum indicum*	Tree	4.48

Table 13.2.19 Major invasive species in the State inside the RFA/Green Wash in Arunachal Pradesh (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	295
2.	*Mikania micrantha*	277
3.	*Ageratum conyzoides*	73
4.	*Lantana camara*	63
5.	*Acacia farnesiana*	53

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.3 ASSAM

Geographical Area
78,438 sq km

Geographical Coordinates
Latitude 24° 07' N to 28° 00' N
Longitude 89° 42' E to 96° 02' E

Population (as per Census 2011)
31.21 million
Urban 4.40 million (14.10 %)
Rural 26.81 million (85.90 %)
Tribal 3.88 million (12.45 %)

Average Population Density
398 per sq km

Livestock population
(as per 19th Live Stock Census)
17.23 million

No. of Districts
27

No. of Hill Districts
3

No. of Tribal Districts
19

Table 13.3.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	7,844	
Reporting area for land utilization	7,844	100.00
Forests	1,853	23.62
Not available for land cultivation	2,509	31.99
Permanent pastures and other grazing lands	180	2.29
Land under misc. tree crops and groves	221	2.82
Culturable wasteland	160	2.04
Fallow land other than current fallows	92	1.18
Current fallows	106	1.35
Net area sown	2,723	34.71

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.3.1 Forest Cover

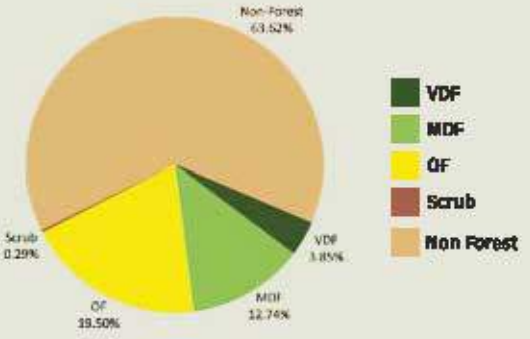


Figure 13.3.1
Forest Cover of Assam

Table 13.3.2
Forest Cover of Assam (in sq km)

Class	Area	% of GA
VDF	3,016.67	3.85
MDF	9,991.02	12.74
OF	15,303.82	19.50
Total	**28,311.51**	**36.09**
Scrub	227.94	0.29

Table 13.3.3 District- wise Forest Cover in Assam (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Baksa[T]	2,457	154.50	130.56	277.83	562.89	22.91	3.22	7.23
Barpeta[T]	2,282	0.00	33.42	84.28	117.70	5.16	2.52	1.09
Bongaigaon	1,093	0.00	62.32	188.37	250.69	22.94	0.56	0.11
Cachar[T]	3,786	183.15	985.06	1,059.34	2,227.55	58.84	5.21	17.43
Chirang	1,923	395.58	107.87	198.78	702.23	36.52	2.39	5.34
Darrang[T]	1,585	0.00	14.10	79.98	94.08	5.94	4.65	1.15
Dhemaji[T]	3,237	68.65	123.20	164.83	356.68	11.02	11.88	5.56
Dhubri[T]	2,176	0.98	22.65	83.02	106.65	4.90	8.19	3.84
Dibrugarh[T]	3,381	105.78	68.70	584.04	758.52	22.43	3.29	7.30
Dima Hasao[H]	4,888	268.66	1,455.08	2,428.18	4,151.92	84.94	-55.01	8.59
Goalpara[T]	1,824	13.73	139.14	251.74	404.61	22.18	8.87	2.18
Golaghat	3,502	22.95	118.12	533.13	674.20	19.25	4.29	6.74
Hailakandi	1,327	15.97	360.97	391.15	768.09	57.88	-6.25	1.49
Jorhat[T]	2,851	12.00	104.70	449.12	565.82	19.85	5.72	7.87
Kamrup[T]	3,105	50.00	454.06	462.64	966.70	31.13	3.23	3.25
Kamrup Metropolitan[T]	955	0.00	224.32	238.51	462.83	48.46	2.78	0.75
Karbi-Anglong[H]	10,434	662.07	3,657.48	3,514.36	7,833.91	75.08	-55.27	83.66
Karimganj	1,809	3.00	299.88	553.58	856.46	47.34	5.03	1.05
Kokrajhar[T]	3,296	437.60	270.40	460.86	1,168.86	35.46	2.29	4.08
Lakhimpur[T]	2,277	28.40	85.47	196.68	310.55	13.64	3.98	1.87
Morigaon[T]	1,551	10.00	42.15	124.26	176.41	11.37	2.30	4.05
Nagaon[T]	3,973	50.28	360.29	503.86	914.43	23.02	3.17	11.37
Nalbari[T]	1,052	0.00	30.93	81.07	112.00	10.65	4.89	0.01
Sivasagar[T]	2,668	8.97	150.50	540.52	699.99	26.24	10.03	5.25
Sonitpur[T]	5,204	108.88	255.79	706.69	1,071.36	20.59	1.75	15.33
Tinsukia[T]	3,790	407.83	350.49	825.06	1,583.38	41.78	0.81	15.58
Udalguri[T]	2,012	7.69	83.37	321.94	413.00	20.53	0.48	5.77
Grand Total	**78,438**	**3,016.67**	**9,991.02**	**15,303.82**	**28,311.51**	**36.09**	**-15.00**	**227.94**

ASSAM

13.3.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.3.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Assam (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
2,748	8,566	8,689	20,003	269	1,425	6,615	8,309
13.74%	42.82%	43.44%		3.24%	17.15%	79.61%	

*In case of Assam, GW boundaries have been used.

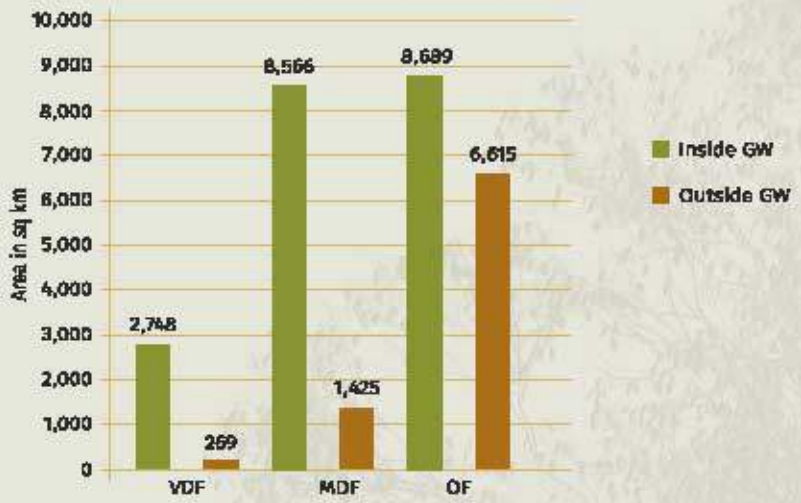


Figure 13.3.2 Forest Cover Inside and Outside of GW in Assam

Table 13.3.5 Forest Cover Change Matrix for Assam (in sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	2,770	12	2	0	11	2,795
Moderately Dense Forest	247	9,948	14	1	69	10,279
Open Forest	0	8	14,869	32	344	15,253
Scrub	0	0	7	160	6	173
Non Forest	0	23	412	35	49,468	49,938
Total ISFR 2021	**3,017**	**9,991**	**15,304**	**228**	**49,898**	**78,438**
Net Change	222	-288	51	55	-40	

Table 13.3.6 Altitude-wise Forest Cover in Assam (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	72,348	2,344	7,761	12,899	23,004	191
500-1000	5,315	388	2,082	2,146	4,616	36
1000-2000	775	285	148	259	692	1
Total	**78,438**	**3,017**	**9,991**	**15,304**	**28,312**	**228**

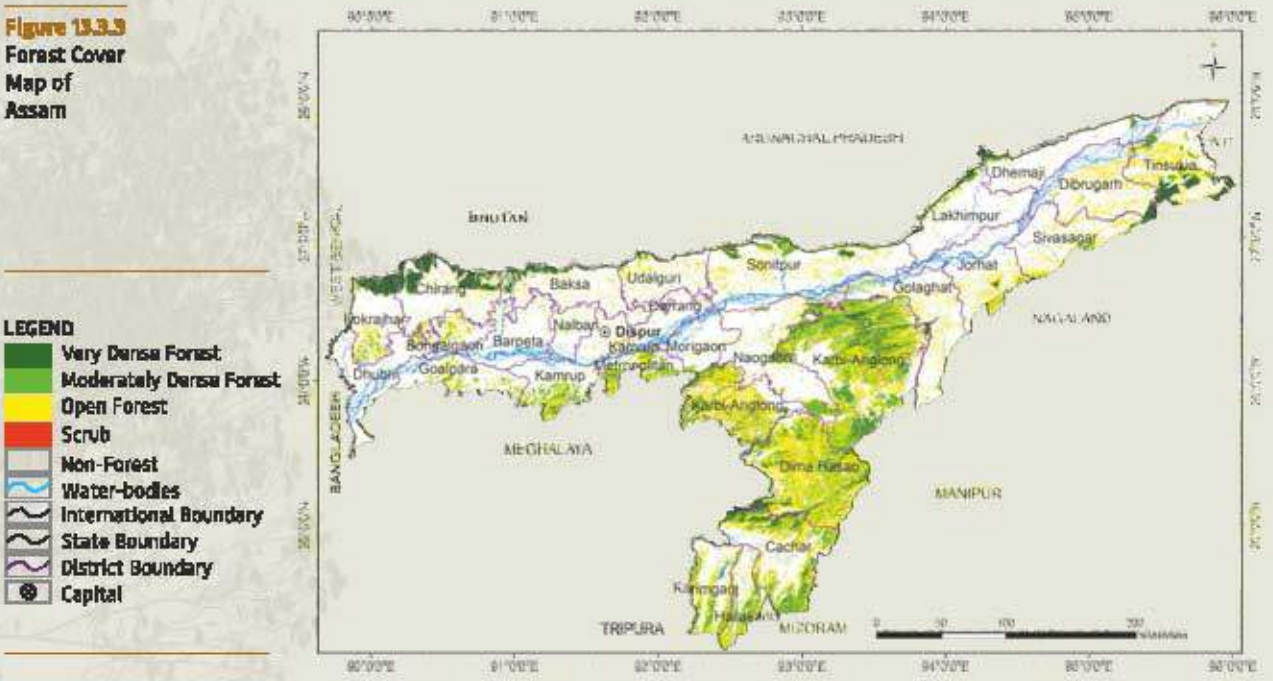
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.3.7 Forest Cover in different slope classes in Assam (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	61,901	1,777	3,842	8,707	14,326	160
5-10	6,929	395	2,277	2,504	5,176	31
10-15	4,156	265	1,643	1,788	3,696	17
15-20	2,643	216	1,074	1,158	2,448	11
20-25	1,511	162	615	647	1,424	6
25-30	759	104	308	312	724	2
>30	539	98	232	188	518	1
Total	**78,438**	**3,017**	**9,991**	**15,304**	**28,312**	**228**

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

Figure 13.3.9
Forest Cover Map of Assam



ASSAM

13.3.2 Forest Types

The area under different forest types of Assam as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.3.2 Area statistics of the Forest Types found in Assam (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1B/C1 Assam Valley tropical wet evergreen forest *(Dipterocarpus)*	1,006.79	3.51
2.	1B/C2a *Kayea* forest	216.12	0.75
3.	1B/C2b *Mesua* forest	5.53	0.02
4.	1B/C3 Cachar tropical evergreen forest	886.92	3.1
5.	2B/ C1a Assam alluvial plains semi-evergreen forest	453.68	1.58
6.	2B/C1/1S1 Sub-Himalayan light alluvial saml-evargreen forest	356.00	1.24
7.	2B/C1/1S2 *Syzygium* parkland	19.43	0.07
8.	2B/C1/2S1 Pioneer Euphorbiaceous scrub	84.52	0.29
9.	2B/C1/2S2 Eastern alluvial secondary semi-evergreen forest	348.87	1.22
10.	2B/C2 Cachar semi-evergreen forest	10,719.16	37.41
11.	2/2S1 Secondary moist bamboo brakes	857.76	2.99
12.	3C/C1a(II) *Khasi* hill sal	40.39	0.14
13.	3C/C1b(I) East Himalayan upper *bhabar* sal	670.56	2.34
14.	3C/C2d (iv) App. Kamrup sal	759.57	2.65
15.	3C/C3b East Himalayan moist mixed deciduous forest	5,095.46	17.78
16.	3C/C3/2S1 Northern secondary moist mixed deciduous forest	505.65	1.76
17.	3C/1S1 Low alluvial savannah woodland *(Solmalia-Albizia)*	13.69	0.05
18.	3/1S2(a) *Terminalia-Lagerstroemia*	2.83	0.01
19.	4C/FS3 Creeper swamp forest	0.09	0.00
20.	4D/SS1 Eastern seasonal swamp forest	0.88	0.00
21.	5/1S2 *Khair-sissv* forest	24.19	0.08
22.	8B/DS1 Assam subtropical hill savannah woodland	9.79	0.03
23.	9/C2 Assam subtropical pine forest	119.72	0.42
	Sub Total	**22,197.60**	**77.44**
24.	TOF/Plantation	6,302.34	21.99
	Total (Forest Cover & Scrub)	**28,499.94**	
	Grassland forest types (outside forest cover)		
25.	4D/2S1 Syzygium parkland	0.65	0.00
26.	4D/2S2 Eastern wet alluvial grassland	153.18	0.57
	Sub Total	**153.83**	**0.57**
	Grand Total	**28,653.77**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

Table 13.3.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	3,166.11	11.18
2.	Very highly fire prone	4,871.05	17.20
3.	Highly fire prone	3,400.46	12.01
4.	Moderately fire prone	2,653.93	9.37
5.	Less fire prone	14,220.45	50.24
	Total	**28,312.00**	**100.00**

13.3.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

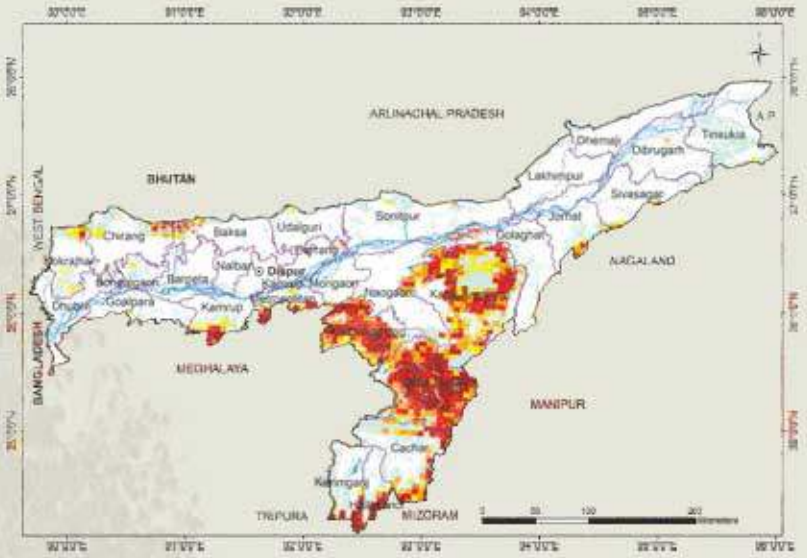


Figure 13.3.4 Fire prone forest areas under different fire prone classes

13.3.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Assam has been estimated as given in following table.

Table 13.3.10 Tree Cover in Assam (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
1,408	1,630	222

11.3.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

ASSAM

Table 13.3.11 Extent of TOF in Assam (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
8,309	1,630	9,939

13.3.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Assam is given in the Table 13.3.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.3.13

Table 13.3.12 Growing Stock in Assam (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	115.40	112.68	-2.72	2.57
2.	Growing Stock in TOF	22.96	23.94	0.98	1.35

Table 13.3.13 Diameter class distribution of top five tree species inside RFA in Assam (In '000)

		Dia class (cm)		
Sl. No.	Species	10-30	30-60	>60
1.	*Schima wallichii*	15,948	2,714	75
2.	*Tectona grandis*	11,449	2,520	59
3.	*Albizia* spp.	9,119	2,717	144
4.	*Bombax ceiba*	2,554	2,692	443
5.	*Stereospermum personatum/ colais/chelonoides*	1,625	1,639	449

13.3.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Assam in Rural and Urban areas are given in the Table 13.3.14 and Table 13.3.15 respectively.

Table 13.3.14 Top five tree species in TOF (Rural) in Assam

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	33.68
2.	*Tectona grandis*	4.26
3.	*Gmelina arborea*	3.70
4.	*Albizia* spp.	3.55
5.	*Mangifera indica*	3.23

Table 13.3.15 Top five tree species in TOF (Urban) in Assam

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	42.07
2.	*Cocos nucifera*	11.11
3.	*Mangifera indica*	8.90
4.	*Artocarpus heterophyllus*	3.62
5.	*Anthocephalus cadamba*	3.23

13.3.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size is 271.37 million tonnes (995.02 million tonnes of CO_2 equivalent) which is 3.77 % of total forest carbon of the country. Pool wise forest carbon in Assam is given in the following table.

Table 13.3.16 Forest Carbon in Assam in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	87,070
2.	BGB	21,495
3.	Dead wood	1,875
4.	Litter	4,890
5.	SOC	1,56,042
	Total	**2,71,372**

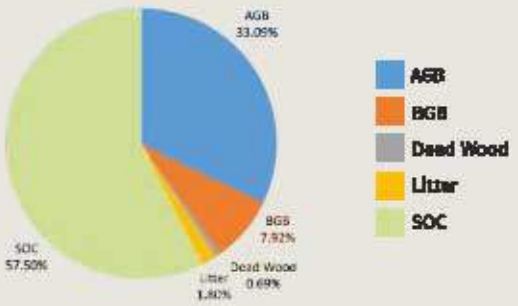


Figure 13.3.5 Forest Carbon in Assam

13.3.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.3.17 Growing Stock of Bamboo in Assam

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	10,659	7.13
Total number of culms (in millions)	5,656	10.60
Total equivalent green weight (in '000 tonnes)	38,600	9.60

13.3.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.3.18 and Table 13.3.19 respectively.

Table 13.3.18 Major NTFP species in Assam

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Shorea robusta*	Tree	41.64
2.	*Bombax spp. / Bombax ceiba*	Tree	13.83
3.	*Terminalia belerica*	Tree	11.10
4.	*Piper spp./ Piper longum/ Piper mullesua*	Climber	8.65
5.	*Smilax china*	Climber	6.92

Table 13.3.19 Major invasive species in the State inside the RFA/Green Wash in Assam (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	457
2.	*Mikania micrantha*	242
3.	*Lantana camara*	175
4.	*Microcystis aeruginosa*	22
5.	*Imperata cylindrica*	21

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.4 BIHAR

Geographical Area
94,163 sq km

Geographical Coordinates
Latitude 24° 16' N to 27° 45' N
Longitude 83° 16' E to 88° 30' E

Population (as per Census 2011)
104.10 million
Urban 11.76 million (11.29 %)
Rural 92.34 million (88.71 %)
Tribal 1.34 million (1.28 %)

Average Population Density
1,106 per sq km

Livestock population
(as per 19th Live Stock Census)
32.93 million

No. of Districts
38

No. of Hill Districts
0

No. of Tribal Districts
0

Table 13.4.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	9,416	
Reporting area for land utilization	9,360	100.00
Forests	622	6.65
Not available for land cultivation	2,150	22.97
Permanent pastures and other grazing lands	15	0.16
Land under misc. tree crops and groves	248	2.65
Culturable wasteland	44	0.47
Fallow land other than current fallows	120	1.28
Current fallows	919	9.82
Net area sown	5,242	56.00

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.4.1 Forest Cover

Figure 13.4.1
Forest Cover
of Bihar

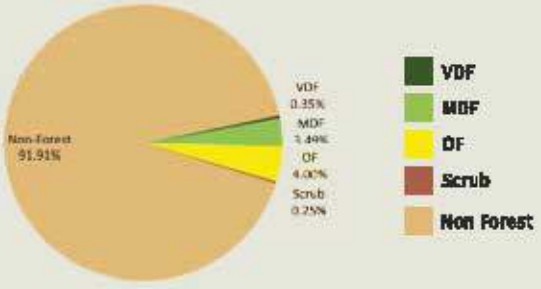


Table 13.4.2
Forest Cover of Bihar (In sq km)

Class	Area	% of GA
VDF	333.42	0.35
MDF	3,285.83	3.49
OF	3,761.54	4.00
Total	**7,380.79**	**7.84**
Scrub	235.89	0.25

Table 13.4.3 District- wise Forest Cover in Bihar (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Araria	2,830	0.00	8.10	142.78	150.88	5.33	-0.13	0.38
Arwal	638	0.00	1.63	2.51	4.14	0.65	0.14	0.39
Aurangabad	3,305	0.00	62.44	97.41	159.85	4.84	3.09	16.85
Banka	3,020	0.00	99.96	177.06	277.02	9.17	16.29	21.59
Begusarai	1,918	0.00	28.93	53.65	82.58	4.31	0.63	0.00
Bhagalpur	2,569	0.00	46.41	23.52	69.93	2.72	0.20	0.00
Bhojpur	2,395	0.00	19.44	12.55	31.99	1.34	-0.26	1.25
Buxar	1,703	0.00	2.94	2.95	5.89	0.35	0.00	0.00
Darbhanga	2,279	0.00	43.54	94.44	137.98	6.05	0.32	0.00
East Champaran	3,968	0.00	64.61	101.19	165.80	4.18	1.94	0.00
Gaya	4,976	0.00	132.03	470.52	602.55	12.11	12.24	66.50
Gopalganj	2,033	0.00	2.64	5.92	8.56	0.42	3.65	0.00
Jamui	3,098	28.97	352.76	279.44	661.17	21.34	13.22	3.21
Jehanabad	931	0.00	0.00	4.43	4.43	0.48	4.43	5.13
Kaimur	3,332	0.00	519.83	531.73	1,051.56	31.56	-4.83	25.65
Katihar	3,057	0.00	6.22	55.76	61.98	2.03	0.00	0.00
Khagaria	1,486	0.00	3.18	15.27	18.45	1.24	0.00	0.00
Kishanganj	1,884	0.00	16.32	87.23	103.55	5.50	-0.15	0.00
Lakhisarai	1,228	17.00	143.5	22.91	183.41	14.94	3.00	4.80
Madhepura	1,788	0.00	0.93	51.91	52.84	2.96	-0.04	0.40
Madhubani	3,501	0.00	40.39	164.98	205.37	5.87	1.30	0.00
Munger	1,419	37.97	223.61	24.43	286.01	20.16	2.41	9.43
Muzaffarpur	3,172	0.00	52.17	114.12	166.29	5.24	4.47	0.00
Nalanda	2,355	0.00	6.86	31.71	38.57	1.64	6.72	10.59
Nawada	2,494	0.00	214.68	302.20	516.88	20.72	3.38	18.13
Patna	3,202	0.00	19.55	8.48	28.03	0.88	4.49	0.54
Purnia	3,229	0.00	5.00	50.67	55.67	1.72	0.00	0.00

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(in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Rohtas	3,881	0.14	351.25	318.52	669.91	17.26	-2.32	40.92
Saharsa	1,687	0.00	4.17	30.22	34.39	2.04	-0.23	0.00
Samastipur	2,904	0.00	105.39	48.83	154.22	5.31	0.86	0.00
Saran	2,641	0.00	26.28	33.04	59.32	2.25	0.19	0.00
Sheikhpura	689	0.00	1.00	0.19	1.19	0.17	0.19	0.00
Sheohar	349	0.00	2.00	19.57	21.57	6.18	0.99	0.00
Sitamarhi	2,294	0.00	37.41	110.38	147.79	6.44	0.01	0.00
Siwan	2,219	0.00	2.11	5.55	7.66	0.35	0.50	0.00
Supaul	2,425	0.00	3.89	130.43	134.32	5.54	-4.46	0.00
Vaishali	2,036	0.00	86.19	29.51	115.70	5.68	3.88	0.00
West Champaran	5,228	249.34	548.47	105.53	903.34	17.28	-1.32	10.13
Grand Total	**94,163**	**333.42**	**3,285.83**	**3,761.54**	**7,380.79**	**7.84**	**74.80**	**235.89**

13.4.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.4.4 Forest Cover Inside and outside Recorded Forest Area (or Green Wash) in Bihar (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
314	2,457	2,060	4,831	19	829	1,702	2,550
6.50%	50.86%	42.64%		0.74%	32.51%	66.75%	

*In case of Bihar, RFA boundaries have been used.

Figure 13.4.2 Forest Cover Inside and Outside of RFA in Bihar

Table 13.4.5 Forest Cover Change Matrix for Bihar (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	333	0	0	0	0	333
Moderately Dense Forest	0	3,244	27	7	2	3,280
Open Forest	0	33	3,612	17	31	3,693
Scrub	0	0	62	172	16	250
Non Forest	0	9	61	40	86,497	86,607
Total ISFR 2021	**333**	**3,286**	**3,762**	**236**	**86,546**	**94,163**
Net Change	0	6	69	-14	-61	

Table 13.4.6 Altitude-wise Forest Cover in Bihar (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	93,821	330	3,145	3,637	7,112	232
500-1000	342	3	141	125	269	4
Total	**94,163**	**333**	**3,286**	**3,762**	**7,381**	**236**

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

Table 13.4.7 Forest Cover in different slope classes in Bihar (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	91,177	172	2,132	2,942	5,246	150
5-10	1,576	72	487	372	931	32
10-15	594	38	277	177	492	19
15-20	363	25	176	116	317	13
20-25	222	15	105	72	192	10
25-30	122	7	57	43	107	7
>30	109	4	52	40	96	5
Total	**94,163**	**333**	**3,286**	**3,762**	**7,381**	**236**

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

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Figure 13.4.3
Forest Cover Map of Bihar

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.4.2 Forest Types

The area under different forest types of Bihar as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.4.8 Area statistics of the Forest Types found in Bihar (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2/E1 Cane brakes	2.61	0.03
2.	3B/C1b Moist teak forest	4.16	0.06
3.	3C/C2b(1) *Bhabar-dun* sal	278.11	3.68
4.	3C/C3a West Gangetic moist mixed deciduous forest	176.39	2.33
5.	4D/SS2 *Barringtonia* swamp forest	1.63	0.02
6.	4D/2S2 Eastern wet alluvial grassland	11.36	0.15
7.	5B/C1a Dry Siwalik sal forest	392.89	5.20

(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
9.	5B/C2 Northern dry mixed deciduous forest	2,266.39	29.97
10.	5/DS1 Dry deciduous scrub	246.39	3.26
11.	5/E2 *Boswellia* forest	327.59	4.33
12.	5/E9 Dry bamboo brakes	69.34	0.92
13.	5/1S2 *Khair-sissu* forest	2.61	0.03
	Sub Total	**5,360.85**	**70.89**
14.	TOF/Plantation	2,195.82	29.04
	Total (Forest Cover & Scrub)	**7,555.87**	
	Grassland forest type (outside forest cover)		
15.	4D/2S2 Eastern wet alluvial grassland	5.28	0.07
	Grand Total	**7,561.15**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.4.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

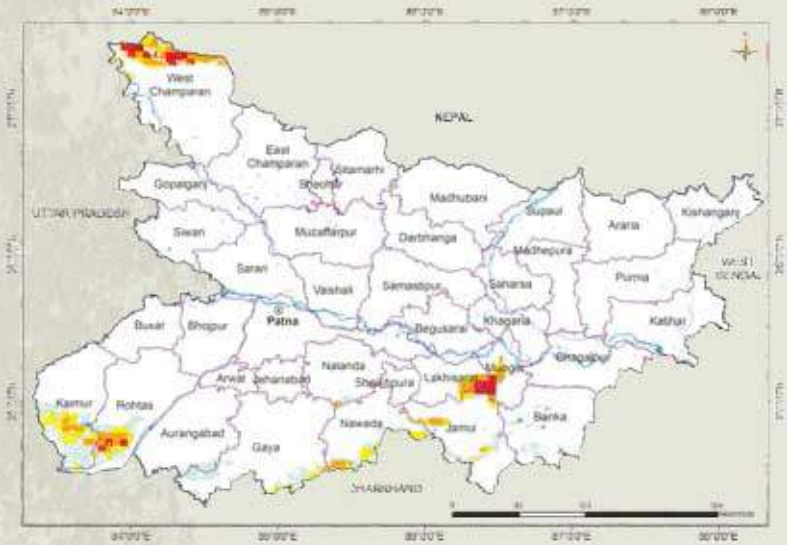

Figure 13.4.4 Fire prone forest areas under different fire prone classes

Table 13.4.9 Forest Fire Prone Classes

(In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	24.38	0.33
2.	Very highly fire prone	471.89	6.39
3.	Highly fire prone	984.48	13.34
4.	Moderately fire prone	1,173.58	15.90
5.	Less fire prone	4,726.67	64.04
	Total	**7,381.00**	**100.00**

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13.4.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Bihar has been estimated as given in following table.

Table 13.4.10 Tree Cover in Bihar (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
2,003	2,341	338

13.4.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.14.11 Extent of TOF in Bihar (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
2,550	2,341	4,891

13.4.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Bihar is given in the Table 13.4.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.4.13

Table 13.4.12 Growing Stock in Bihar (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	26.73	30.52	3.79	0.70
2.	Growing Stock in TOF	40.46	41.04	0.58	2.31

Table 13.4.13 Diameter class distribution of top five tree species inside RFA in Bihar (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Shorea robusta*	20,756	4,788	514
2.	*Lannea coromandelica*	11,323	434	67
3.	*Madhuca latifolia*	7,377	654	139
4.	*Terminalia tomentosa*	7,058	708	137
5.	*Anogeissus latifolia*	6,266	482	0

13.4.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Bihar in Rural and Urban areas are given in the Table 13.4.14 and Table 13.4.15 respectively.

Table 13.4.14 Top five tree species in TOF (Rural) in Bihar

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	34.16
2.	*Dalbergia sissoo*	11.52
3.	*Borassus flabellifermis*	7.86
4.	*Litchi senensis*	3.66
5.	*Syzygium cumini*	3.39

Table 13.4.15 Top five tree species in TOF (Urban) in Bihar

Sl. No.	Species	Relative Abundance (%)
1.	*Litchi senensis*	13.87
2.	*Mangifera indica*	13.80
3.	*Bombax ceiba*	8.82
4.	*Dalbergia sissoo*	5.73
5.	*Psidium guajava*	4.53

13.4.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size is 56.88 million tonnes (208.56 million tonnes of CO_2 equivalent) which is 0.79% of total forest carbon of the country. Pool wise forest carbon in Bihar is given in the following table.

Table 13.4.16 Forest Carbon in Bihar in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	14,743
2.	BGB	5,249
3.	Dead wood	231
4.	Litter	785
5.	SOC	35,873
	Total	**56,881**

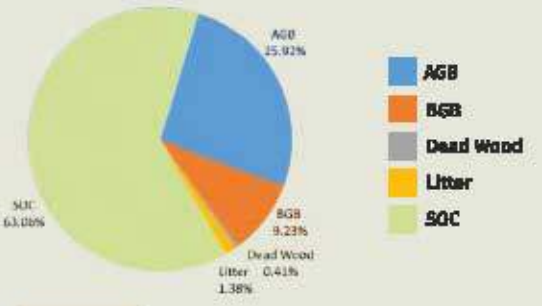

Figure 13.4.5 Forest Carbon in Bihar

13.4.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

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Table 13.4.17 Growing Stock of Bamboo in Bihar

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	1,103	0.74
Total number of culms (in millions)	235	0.44
Total equivalent green weight (in '000 tonnes)	1,672	0.42

13.4.10 Major Invasive Species

Major invasive species as assessed from forest inventory data are presented in the Table 13.4.18.

Table 13.4.18 Major invasive species in the State inside the RFA/Green Wash in Bihar

(In sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	261
2.	*Chromolaena odorata*	47
3.	*Argemone mexicana*	17
4.	*Cassia tora*	15
5.	*Senna occidentalis*	14

Major invasive species are given in terms of their estimated extent.

13.5
CHHATTISGARH

Geographical Area
1,35,192 sq km

Geographical Coordinates
Latitude 17°47' N to 24°06' N
Longitude 80°15' E to 84°24' E

Population (as per Census 2011)
25.55 million
Urban 5.94 million (23.24 %)
Rural 19.61 million (76.76 %)
Tribal 7.82 million (30.62 %)

Average Population Density
189 per sq km

Livestock population
(as per 19th Live Stock Census)
15.04 million

No. of Districts
18

No. of Hill Districts
0

No. of Tribal Districts
11

Table 13.5.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	13,519	
Reporting area for land utilization	13,790	100.00
Forests	6,314	45.79
Not available for land cultivation	1,031	7.48
Permanent pastures and other grazing lands	883	6.40
Land under misc. tree crops and groves	1	0.01
Culturable wasteland	365	2.65
Fallow land other than current fallows	253	1.83
Current fallows	290	2.10
Net area sown	4,653	33.74

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.5.1 Forest Cover

Figure 13.5.1 Forest Cover of Chhattisgarh

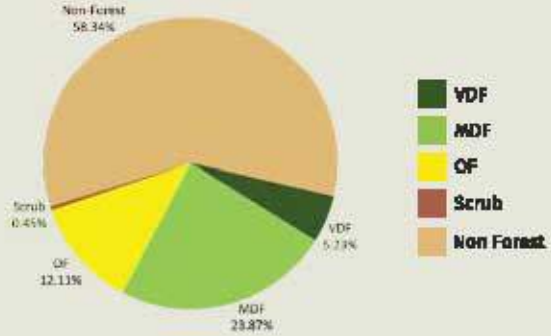

Table 13.5.2 Forest Cover of Chhattisgarh (In sq km)

Class	Area	% of GA
VDF	7,068.21	5.23
MDF	32,278.59	23.87
OF	16,369.80	12.11
Total	55,716.60	41.21
Scrub	615.26	0.45

Table 13.5.3 District- wise Forest Cover in Chhattisgarh (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Bastar*	10,470	937.72	2,104.39	1,190.24	4,232.35	40.42	-0.51	41.52
Bijapur*	8,530	2,047.13	2,991.56	1,499.57	6,538.26	76.65	26.11	4.47
Bilaspur*	8,272	399.22	1,569.99	491.59	2,460.80	29.75	3.91	46.12
Dantewada*	8,298	250.57	2,325.76	1,896.47	4,472.80	53.90	9.65	39.28
Dhamtari	4,084	49.00	1,384.66	426.29	1,859.95	45.54	0.83	10.66
Durg*	8,535	44.00	511.74	221.41	777.15	9.11	0.76	20.86
Janjgir-Champa	3,853	2.00	22.25	127.17	151.42	3.93	1.53	13.93
Jashpur*	5,838	225.31	1,316.76	576.56	2,118.63	36.29	2.86	21.52
Kabeerdham	4,235	80.61	1,077.87	389.40	1,547.88	36.55	-0.84	12.58
Korba	6,598	203.00	2,313.03	884.90	3,400.93	51.54	7.23	91.02
Koriya	6,604	80.88	2,580.69	1,443.80	4,105.37	62.16	8.76	60.20
Mahasamund	4,790	4.00	515.34	428.90	948.24	19.80	3.27	29.75
Narayanpur*	4,653	1,126.69	1,688.70	982.04	3,797.43	81.61	1.13	19.64
Raigarh*	7,086	237.96	1,590.95	794.54	2,623.45	37.02	3.12	27.70
Raipur	12,383	146.00	2,402.93	1,086.92	3,635.85	29.36	5.93	53.83
Rajnandgaon*	8,070	31.00	1,755.64	752.81	2,539.45	31.47	4.27	46.81
Surguja*	15,732	714.29	3,923.54	2,471.93	7,109.76	45.19	27.15	67.27
Uttar Bastar Kanker*	7,161	488.83	2,202.79	705.26	3,396.88	47.44	0.87	8.10
Grand Total	1,35,192	7,068.21	32,278.59	16,369.80	55,716.60	41.21	106.03	615.26

13.5.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

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Table 13.5.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Chhattisgarh (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
5,358	26,478	10,631	42,467	1,710	5,801	5,739	13,250
12.62%	62.35%	25.03%		12.91%	43.78%	43.31%	

**In case of Chhattisgarh, RFA boundaries has been used*

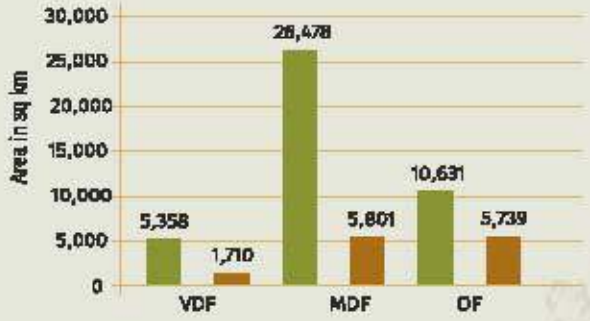

Figure 13.5.2 Forest Cover Inside and Outside of RFA in Chhattisgarh

Table 13.5.5 Forest Cover Change Matrix for Chhattisgarh (in sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	7,048	2	11	0	7	7,068
Moderately Dense Forest	20	32,108	35	6	29	32,198
Open Forest	0	156	16,141	14	34	16,345
Scrub	0	0	32	566	12	610
Non Forest	0	13	151	29	78,778	78,971
Total ISFR 2021	**7,068**	**32,279**	**16,370**	**615**	**78,860**	**1,35,192**
Net Change	0	81	25	5	-111	

Table 13.5.6 Altitude-wise Forest Cover in Chhattisgarh (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	88,516	3,430	16,045	9,634	29,109	420
500-1000	45,491	3,583	15,888	6,500	25,971	182
1000-2000	1,185	55	346	236	637	13
Total	**1,35,192**	**7,068**	**32,279**	**16,370**	**55,717**	**615**

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

Table 13.5.7 Forest Cover in different slope classes in Chhattisgarh (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,06,433	4,051	17,624	11,007	32,682	354
5-10	16,248	1,503	7,062	2,744	11,309	130
10-15	6,477	829	3,822	1,252	5,903	72
15-20	3,345	413	2,081	710	3,204	36
20-25	1,638	177	1,024	393	1,594	15
25-30	696	67	433	180	680	6
>30	355	28	233	84	345	2
Total	**1,35,192**	**7,068**	**32,279**	**16,370**	**55,717**	**615**

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

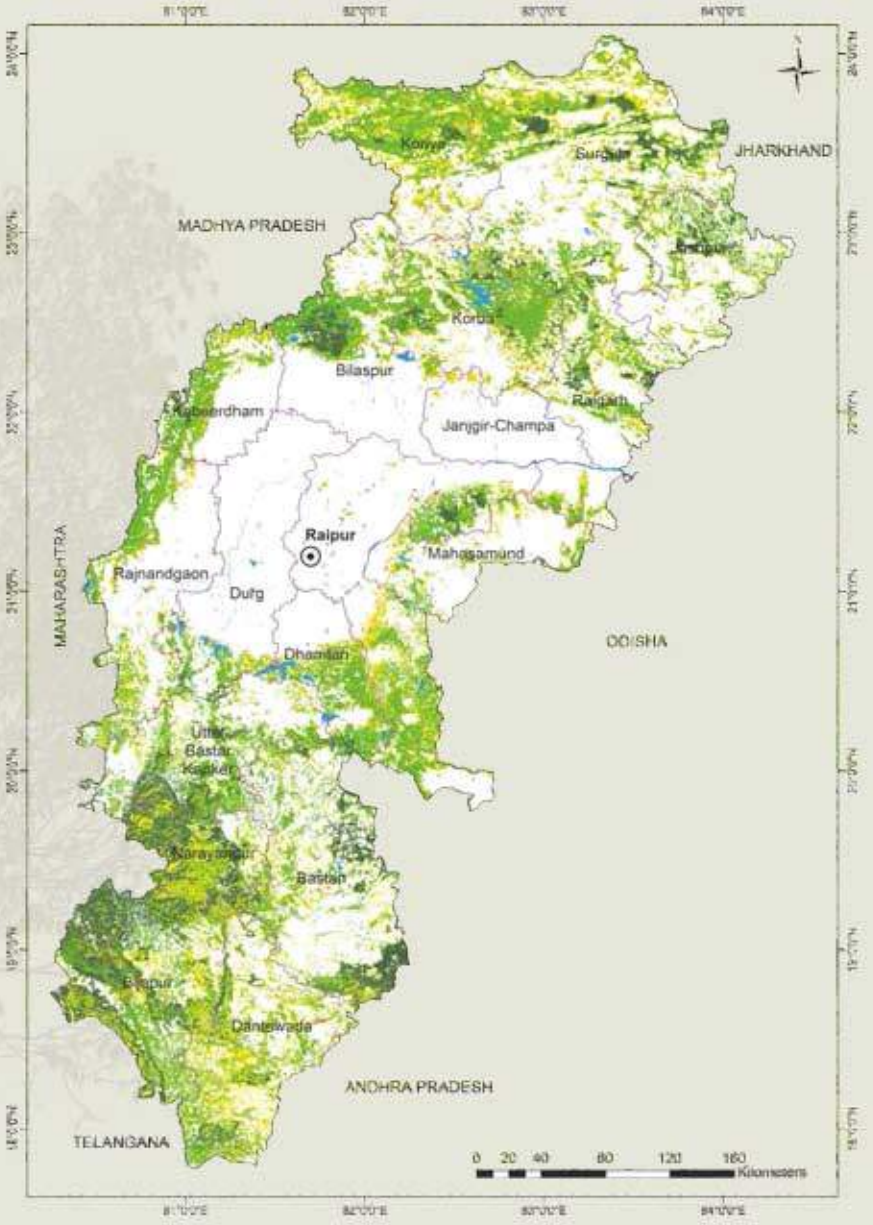

Figure 13.5.3 Forest Cover Map of Chhattisgarh

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

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13.5.2 Forest Types

The area under different forest types of Chhattisgarh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.5.8 Area statistics of the Forest Types found in Chhattisgarh (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3B/C1c Slightly moist teak forest	3,619.06	6.44
2.	3B/C2 Southern moist mixed deciduous forest	8,778.21	15.61
3.	3C/C2e (I) Moist peninsular high level sal	843.59	1.50
4.	3C/C2e (II) Moist peninsular low level sal	9,350.91	16.63
5.	3/E1 *Terminalia tomentosa* forest	11.92	0.02
6.	3/2S1 Dry bamboo brakes	0.76	0.00
7.	5A/C1b Dry teak forest	242.52	0.43
8.	5A/C3 Southern dry mixed deciduous forest	15,315.84	27.24
9.	5B/C1c Dry peninsular sal forest	8,591.22	15.28
10.	5B/C2 Northern dry mixed deciduous forest	7,388.21	13.14
11.	5/DS1 Dry deciduous scrub	627.82	1.12
12.	5/E9 Dry bamboo brakes	840.04	1.50
	Sub Total	**55,610.10**	**98.91**
13.	TOF/Plantation	609.99	1.09
	Total (Forest Cover & Scrub)	**56,220.09**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub*

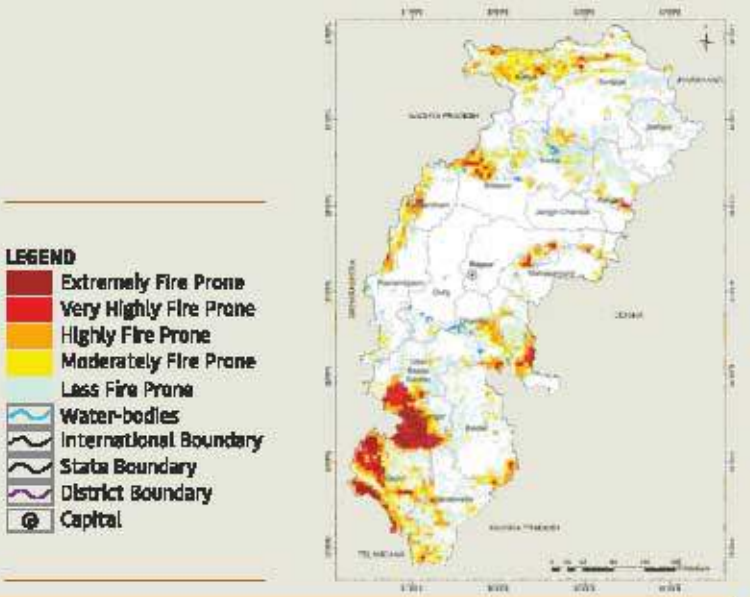
13.5.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.5.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	1,935.04	3.47
2.	Very highly fire prone	3,655.58	6.56
3.	Highly fire prone	8,159.70	14.64
4.	Moderately fire prone	11,275.57	20.24
5.	Less fire prone	30,691.11	55.09
	Total	**55,717.00**	**100.00**

Figure 13.5.4
Fire prone forest areas under different fire prone classes



13.5.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Chhattisgarh has been estimated as given in following table.

Table 13.5.10 Tree Cover in Chhattisgarh (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
4,248	5,355	1,107

13.5.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.5.11 Extent of TOF in Chhattisgarh (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
13,250	5,355	18,605

13.5.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Chhattisgarh is given in the Table 13.5.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.5.13.

Table 13.5.12 Growing Stock in Chhattisgarh (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	358.96	389.64	30.68	8.88
2.	Growing Stock in TOF	99.92	117.30	17.38	6.59

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Table 13.5.13 Diameter class distribution of top five tree species inside RFA in Chhattisgarh (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Shorea robusta*	2,87,993	77,599	4,445
2.	*Terminalia tomentosa*	73,428	17,772	893
3.	*Diospyros melanoxylon*	63,521	9,934	565
4.	*Anogeissus latifolia*	58,889	7,922	165
5.	*Lannea coromandelica*	58,490	8,362	85

13.5.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Chhattisgarh in Rural and Urban areas are given in the Table 13.5.14 and Table 13.5.15 respectively.

Table 13.5.14 Top five tree species in TOF (Rural) in Chhattisgarh

Sl. No.	Species	Relative Abundance (%)
1.	*Shorea robusta*	23.33
2.	*Mangifera indica*	7.18
3.	*Butea monosperma*	6.49
4.	*Acacia arabica*	5.90
5.	*Madhuca latifolia*	5.86

Table 13.5.15 Top five tree species in TOF (Urban) in Chhattisgarh

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	14.67
2.	*Moringa spp.*	9.64
3.	*Azadirachta indica*	7.23
4.	*Tectona grandis*	6.00
5.	*Psidium guajava*	5.30

13.5.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size is 496.44 million tonnes (1,820.28 million tonnes of CO_2 equivalent) which is 6.89% of total forest carbon of the country. Pool wise forest carbon in Chhattisgarh is given in the following table.

Table 13.5.16 Forest Carbon in Chhattisgarh in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,52,714
2.	BGB	48,947
3.	Dead wood	2,520
4.	Litter	8,487
5.	SOC	2,83,769
	Total	**4,96,437**

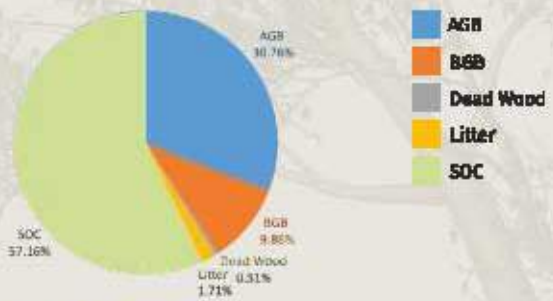


Figure 13.5.5 Forest Carbon in Chhattisgarh

13.5.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.5.17 Growing Stock of Bamboo in Chhattisgarh

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	10,467	7.00
Total number of culms (in millions)	2,800	5.25
Total equivalent green weight (in '000 tonnes)	16,780	4.17

13.5.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.5.18 and Table 13.5.19 respectively.

Table 13.5.18 Major NTFP species in Chhattisgarh

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Shorea robusta*	Tree	42.88
2.	*Ocimum spp. (Ocimum gratissimum/ Ocimum sanctum/Ocimum tenuiflorum/ Ocimum americanum)*	Herbs	11.76
3.	*Buchanania lanzan*	Tree	8.69
4.	*Diospyros melanoxylon*	Tree	8.48
5.	*Anogeissus latifolia*	Tree	7.67

Table 13.5.19 Major invasive species in the state inside the RFA/Green Wash in Chhattisgarh

(In sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	728
2.	*Ageratum conyzoides*	495
3.	*Cassia tora*	333
4.	*Triumfetta rhomboidea*	200
5.	*Chromolaena odorata*	183

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.6 DELHI

Geographical Area
1,483 sq km

Geographical Coordinates
Latitude 28°22' N to 28°54' N
Longitude 76°48' E to 77°23'E

Population (as per Census 2011)
16.79 million
Urban 16.37 million (97.50 %)
Rural 0.42 million (2.50 %)
Tribal Nil

Average Population Density
11,320 per sq km

Livestock population
(as per 19th Live Stock Census)
0.36 million

No. of Districts
9

No. of Hill Districts
0

No. of Tribal Districts
0

Table 13.6.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	148	
Reporting area for land utilization	147	100.00
Forests	1	0.68
Not available for land cultivation	93	63.27
Permanent pastures and other grazing lands	0	0.00
Land under misc. tree crops and groves	1	0.68
Culturable wasteland	10	6.80
Fallow land other than current fallows	8	5.44
Current fallows	12	8.16
Net area sown	22	14.97

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.6.1 Forest Cover

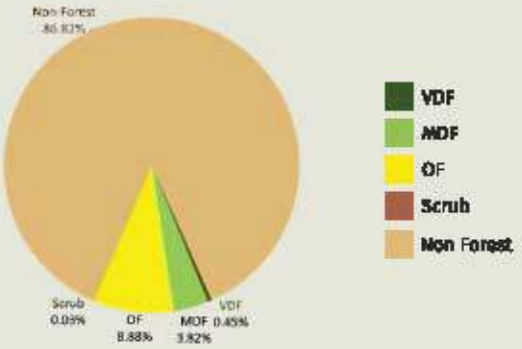


Figure 13.6.1
Forest Cover
of Delhi

Table 13.6.2 Forest Cover of Delhi (In sq km)

Class	Area	% of GA
VDF	6.72	0.45
MDF	56.60	3.82
OF	131.68	8.88
Total	**195.00**	**13.15**
Scrub	0.38	0.03

Table 13.6.3 District-wise Forest Cover in Delhi (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Central Delhi	21	0.00	2.08	2.93	5.01	23.86	0.07	0.00
East Delhi	63	0.00	1.05	2.79	3.84	6.10	0.09	0.00
New Delhi	35	1.69	5.47	9.31	16.47	47.06	0.00	0.00
North Delhi	61	0.00	2.82	1.89	4.71	7.72	0.13	0.00
North-East Delhi	62	0.00	0.99	3.15	4.14	6.68	0.15	0.00
North-West Delhi	443	0.09	8.93	8.51	17.53	3.96	-0.51	0.07
South Delhi	247	2.59	17.75	64.30	84.64	34.27	0.01	0.23
South-West Delhi	421	2.35	14.93	34.53	51.81	12.31	-0.38	0.08
West Delhi	130	0.00	2.58	4.27	6.85	5.27	0.00	0.00
Grand Total	**1,483**	**6.72**	**56.60**	**131.68**	**195.00**	**13.15**	**-0.44**	**0.38**

13.6.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.6.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Delhi (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
3.19	16.05	39.93	59.17	3.53	40.55	91.75	135.83
5.39%	27.13%	67.48%		2.60%	29.85%	67.55%	

**In case of Delhi, RFA boundaries have been used.*

DELHI

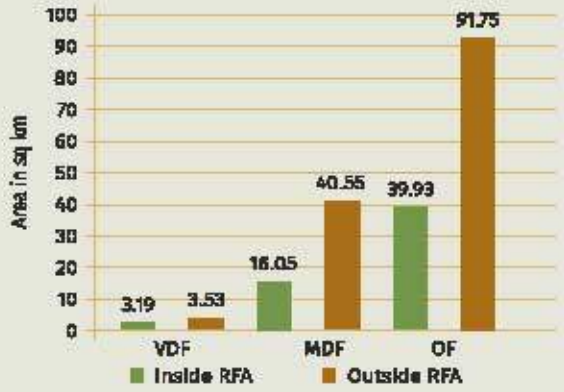


Figure 13.6.2
Forest Cover Inside and Outside of RFA in Delhi

Table 13.6.5 Forest Cover Change Matrix for Delhi (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	6.72	0.00	0.00	0.00	0.00	6.72
Moderately Dense Forest	0.00	56.33	0.00	0.00	0.09	56.42
Open Forest	0.00	0.08	130.64	0.08	1.50	132.30
Scrub	0.00	0.00	0.00	0.30	0.00	0.30
Non Forest	0.00	0.19	1.04	0.00	1,286.03	1,287.26
Total ISFR 2021	**6.72**	**56.60**	**131.68**	**0.38**	**1,287.62**	**1,483.00**
Net Change	0.00	0.18	-0.62	0.08	0.36	

Table 13.6.6 Altitude-wise Forest Cover in Delhi (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	1,483	6.72	56.60	131.68	195.00	0.38
Total	**1,483**	**6.72**	**56.60**	**131.68**	**195.00**	**0.38**

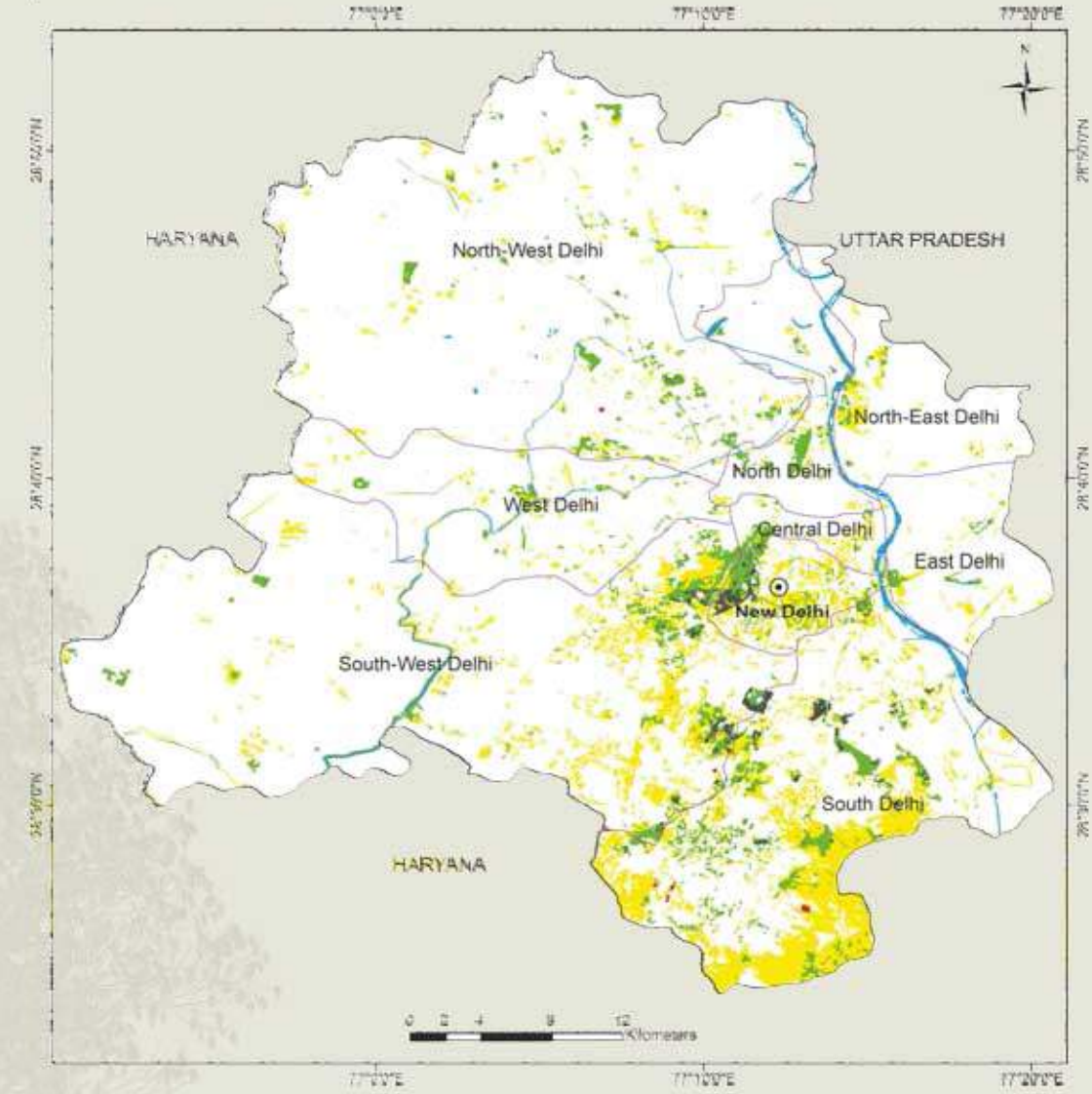
(based on SRTM, Digital Elevation Model, 30 m, 2015)

Table 13.6.7 Forest Cover in different slope classes in Delhi (In sq km)

Slope(in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,407	6.72	52.57	121.44	180.73	0.37
5-10	70	0.00	4.03	9.30	13.33	0.00
10-15	5	0.00	0.00	0.94	0.94	0.01
15-20	1	0.00	0.00	0.00	0.00	0.00
Total	**1,483**	**6.72**	**56.60**	**131.68**	**195.00**	**0.38**

(based on SRTM, Digital Elevation Model, 30 m, 2015)

Figure 13.6.3
Forest Cover Map of Delhi



LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.6.2 Forest Types

The area under different forest types of Delhi as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

DELHI

Table 13.6.8 Area statistics of the Forest Types found in Delhi (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	5B/C2 Northern dry mixed deciduous forest	20.51	10.48
2.	6B/C2 Ravine thorn forest	62.95	32.16
	Sub Total	**83.46**	**42.64**
3.	TOF/Plantation	112.28	57.36
	Total (Forest Cover & Scrub)	**195.74**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

13.6.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

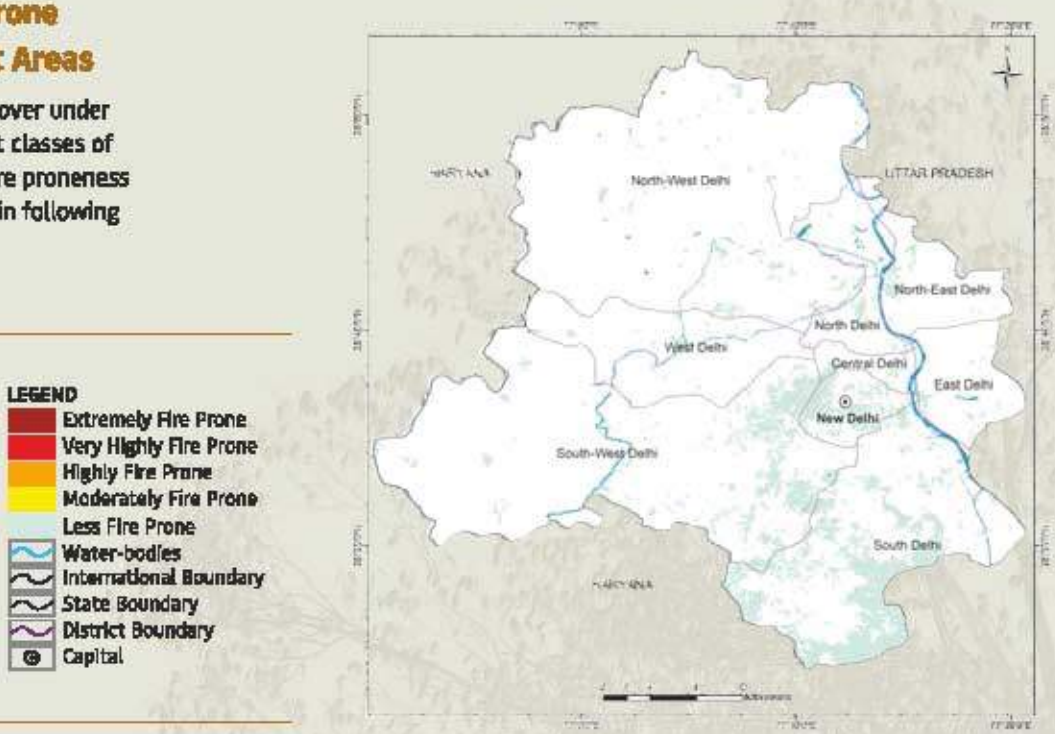


Figure 13.6.A Fire prone forest areas under different fire prone classes

Table 13.6.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	0.00	0.00
5.	Less fire prone	195.00	100.00
	Total	**195.00**	**100.00**

13.6.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Delhi has been estimated as given in following table.

Table 13.6.10 Tree Cover in Delhi (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 assessment
129	147	18

13.6.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.6.11 Extent of TOF in Delhi (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
136	147	283

13.6.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Delhi is given in the Table 13.6.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.6.13.

Table 13.6.12 Growing Stock in Delhi (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	0.54	0.51	-0.03	0.01
2.	Growing Stock in TOF	1.69	1.75	0.06	0.10

DELHI

Table 13.6.13 Diameter class distribution of top five tree species inside RFA in Delhi (In sq km)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Prosopis juliflora*	475	25	6
2.	*Acacia lenticularis*	172	8	0
3.	*Azadirachta indica*	45	18	0
4.	*Holoptelea integrifolia*	33	4	0
5.	*Ficus virens*	6	8	0

13.6.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Delhi in Rural and Urban areas are given in the Table 13.6.14 and Table 13.6.15 respectively

Table 13.6.14 Top five tree species in TOF (Rural) in Delhi

Sl. No.	Species	Relative Abundance (%)
1.	*Prosopis juliflora*	29.52
2.	*Azadirachta indica*	13.06
3.	*Eucalyptus spp.*	8.07
4.	*Leucaena leucocephala*	7.72
5.	*Ficus spp.*	5.29

Table 13.6.15 Top five tree species in TOF (Urban) in Delhi

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	10.77
2.	*Prosopis juliflora*	8.11
3.	*Polyalthia longifolia*	6.20
4.	*Morus spp.*	6.03
5.	*Ficus religiosa*	5.80

13.6.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size is 1.20 million tonnes (4.40 million tonnes of CO_2 equivalent) which is 0.02% of total forest carbon of the country. Pool wise forest carbon in Delhi is given in the following table.

Table 13.6.16 Forest Carbon in Delhi in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	263
2.	BGB	78
3.	Dead wood	5
4.	Litter	17
5.	SOC	839
	Total	1,202

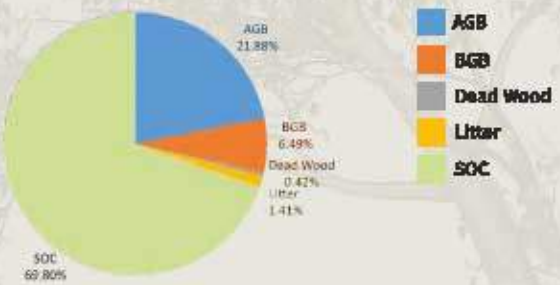


Figure 13.6.5 Forest Carbon in Delhi

13.6.9 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.6.17 and Table 13.6.18 respectively.

Table 13.6.17 Major NTFP species in Delhi

Sl. No.	Species	Plant type	Relative Abundance (%)
1.	*Lantana camara*	Shrub	37.74
2.	*Cassia tora*	Herbs	24.53
3.	*Carissa opaca*	Shrub	20.75
4.	*Parthenium hysterophorus*	Herbs	9.43
5.	*Flacourtia indica*	Tree	5.66

Table 13.6.18 Major invasive species in the State inside the RFA/Green Wash in Delhi

(In sq km)

Sl. No.	Species	Estimated Extent
1.	*Prosopis juliflora*	3.00
2.	*Lantana camara*	0.27
3.	*Cassia tora*	0.12
4.	*Achyranthes aspera*	0.12
5.	*Ageratina adenophora*	0.12

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.7 GOA

Geographical Area
3,702 sq km

Geographical Coordinates
Latitude- 14° 53'N to 15° 40' N
Longitude-73° 40' E to 74° 21' E

Population (as per Census 2011)
1.46 million
Urban 0.91 million (62.17 %)
Rural 0.55 million (37.83 %)
Tribal 0.15 million (10.23 %)

Average Population Density
394 per sq km

Livestock population
(as per 19th Live Stock Census)
0.18 million

No. of Districts
2

No. of Hill Districts
0

No. of Tribal Districts
0

Table 13.7.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	370	
Reporting area for land utilization	361	100.00
Forests	125	34.63
Not available for land cultivation	37	10.25
Permanent pastures and other grazing lands	1	0.28
Land under misc. tree crops and groves	1	0.28
Culturable wasteland	53	14.68
Fallow land other than current fallows	-	-
Current fallows	15	4.15
Net area sown	129	35.73

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.7.1 Forest Cover

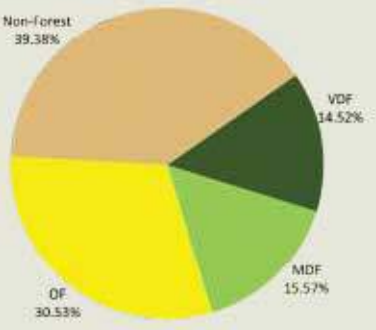


Figure 13.7.1
Forest Cover of Goa

Table 13.7.2 Forest Cover of Goa (In sq km)

Class	Area	% of GA
VDF	537.53	14.52
MDF	576.49	15.57
OF	1,130.19	30.53
Total	**2,244.21**	**60.62**
Scrub	0.00	0.00

Table 13.7.3 District-wise Forest Cover in Goa (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 Assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
North Goa	1,736	127.00	229.77	578.95	935.72	53.90	2.81	0.00
South Goa	1,966	410.53	346.72	551.24	1,308.49	66.56	3.91	0.00
Grand Total	**3,702**	**537.53**	**576.49**	**1,130.19**	**2,244.21**	**60.62**	**6.72**	**0.00**

13.7.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.7.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Goa (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
516	329	375	1,220	22	247	755	1,024
42.30%	26.97%	30.73%		2.15%	24.12%	73.73%	

**In case of Goa, RFA boundaries have been used.*

GOA

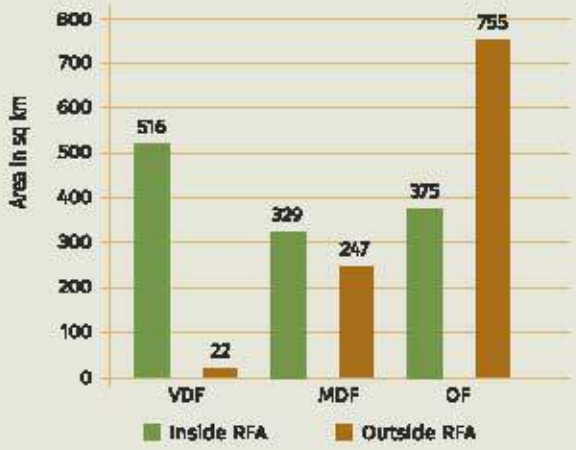


Figure 13.7.2 Forest Cover Inside and Outside of RFA in Goa

Table 13.7.5 Forest Cover Change Matrix for Goa (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	538	0	0	0	0	538
Moderately Dense Forest	0	576	0	0	0	576
Open Forest	0	0	1123	0	0	1,123
Scrub	0	0	0	0	0	0
Non Forest	0	0	7	0	1,458	1,465
Total ISFR 2021	**538**	**576**	**1,130**	**0**	**1,458**	**3,702**
Net Change	0	0	7	0	-7	

Table 13.7.6 Altitude-wise Forest Cover in Goa (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	3,549	442	557	1,102	2,101	0
500-1000	153	96	19	28	143	0
Total	**3,702**	**538**	**576**	**1,130**	**2,244**	**0**

(based on SRTM, Digital Elevation Model, 30 m, 2015)

Table 13.7.7 Forest Cover in different slope classes in Goa (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,918	99	212	507	818	0
5-10	795	122	148	284	554	0
10-15	463	118	104	162	384	0
15-20	273	93	64	89	246	0
20-25	136	55	29	45	129	0
25-30	64	28	12	22	62	0
>30	53	23	7	21	51	0
Total	**3,702**	**538**	**576**	**1,130**	**2,244**	**0**

(based on SRTM, Digital Elevation Model, 30 m, 2015)

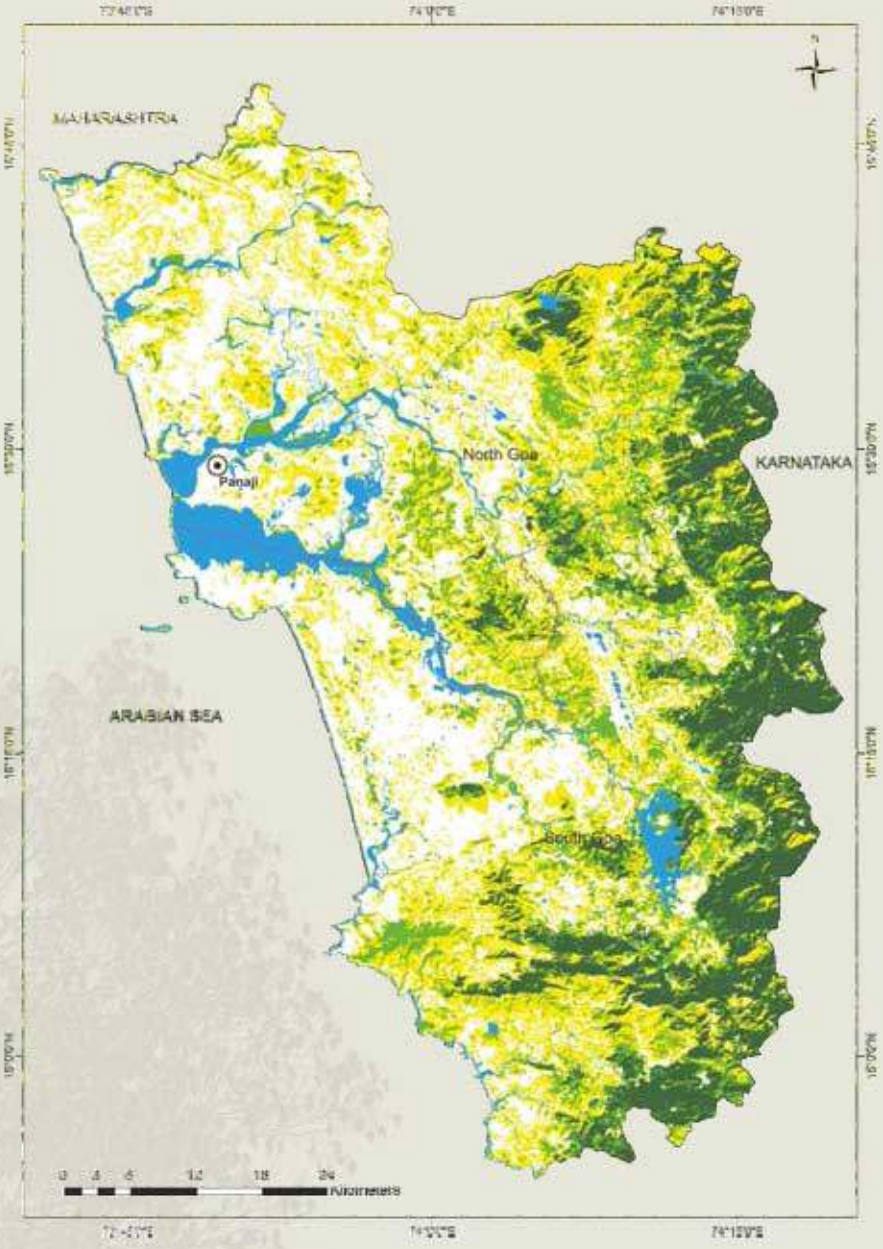


Figure 13.7.3
Forest Cover Map of Goa

13.7.2 Forest Types

The area under different forest types of Goa as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

GOA

Table 13.7.2 Area statistics of the Forest Types found in Goa (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1A/C4 West Coast tropical evergreen forest	506.33	22.63
2.	2A/C2 West Coast semi-evergreen forest	483.38	21.60
3.	3B/C2 Southern moist mixed deciduous forest	906.80	40.53
4.	4B/TS2 Mangrove forest	26.00	1.16
5.	5/E7 Laterite thorn forest	0.50	0.02
	Sub Total	**1,923.01**	**85.94**
6.	TOF/Plantation	314.48	14.06
	Total (Forest Cover & Scrub)	**2,237.49**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

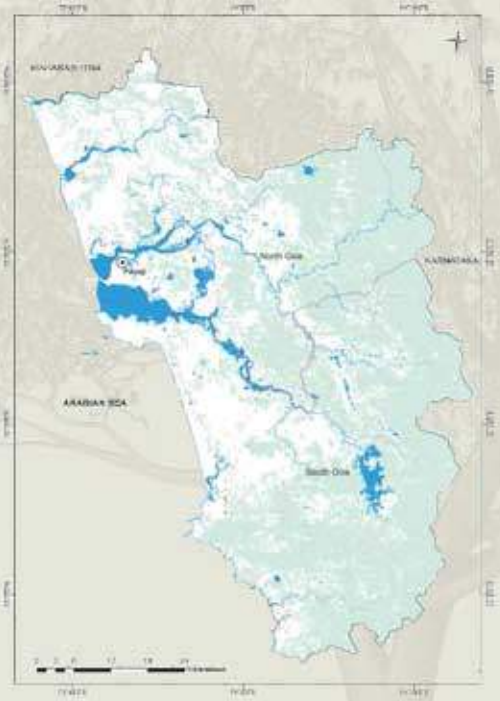
Table 13.7.3 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	0.00	0.00
5.	Less fire prone	2,244.00	100.00
	Total	**2,244.00**	**100.00**

13.7.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Figure 13.7.4 Fire prone forest areas under different fire prone classes



13.7.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Goa has been estimated as given in following table.

Table 13.7.10 Tree Cover in Goa (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
272	244	-28

13.7.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.7.11 Extent of TOF in Goa (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
1,024	244	1,268

13.7.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Goa is given in the Table 13.7.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.7.13

Table 13.7.12 Growing Stock in Goa (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	11.16	12.87	1.71	0.29
2.	Growing Stock in TOF	4.03	4.15	0.12	0.23

Table 13.7.13 Diameter class distribution of top five tree species inside RFA in Goa (In '000)

		Dia class (cm)		
Sl. No.	Species	10-30	30-60	>60
1.	*Terminalia paniculata*	7,178	1,675	174
2.	*Anacardium occidentale*	3,993	201	0
3.	*Xylia xylocarpa*	3,323	563	27
4.	*Terminalia Tamentosa*	2,925	616	67
5.	*Lagerstroemia lanceolata/ tricocarpa*	536	281	107

GOA

13.7.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Goa in rural and urban areas are given in the Table 13.7.14 and Table 13.7.15 respectively.

Table 13.7.14 Top five tree species in TOF (Rural) in Goa

Sl. No.	Species	Relative Abundance (%)
1.	*Areca triandra*	26.63
2.	*Cocos nucifera*	17.41
3.	*Anacardium occidentale*	10.68
4.	*Acacia auriculiformis*	6.53
5.	*Terminalia paniculata*	3.49

Table 13.7.15 Top five tree species in TOF (Urban) in Goa

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	39.4
2.	*Mangifera indica*	9.62
3.	*Tectona grandis*	3.99
4.	*Artocarpus heterophyllus*	3.75
5.	*Areca triandra*	3.34

13.7.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size 25.24 million tonnes (92.55 million tonnes of CO_2 equivalent) which is 0.35 % of total forest carbon of the country. Pool wise forest carbon in Goa is given in the following table.

Table 13.7.16 Forest Carbon in Goa in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	8,863
2.	BGB	2,606
3.	Dead wood	232
4.	Litter	448
5.	SOC	13,095
	Total	25,244

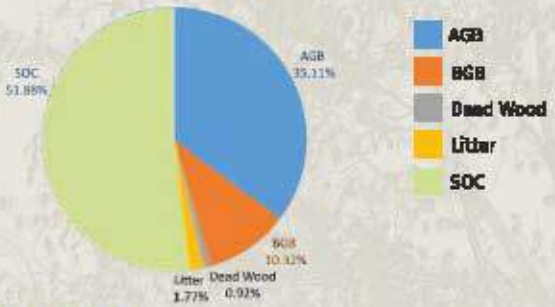


Figure 13.7.5 Forest Carbon in Goa

13.7.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.7.17 Growing Stock of Bamboo in Goa

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	288	0.19
Total number of culms (in millions)	30	0.06
Total equivalent green weight (in '000 tonnes)	257	0.06

13.7.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.7.18 and Table 13.7.19 respectively.

Table 13.7.18 Major NTFP species in Goa

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Terminalia paniculata*	Tree	45.58
2.	*Terminalia tomentosa*	Tree	21.22
3.	*Xylia xylocarpa*	Tree	18.43
4.	*Syzigium cumini*	Tree	4.65
5.	*Terminalia belerica*	Tree	3.26

Table 13.7.19 Major invasive species in the State inside the RFA/Green wash in Goa

(In sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	37
2.	*Cassia tora*	8
3.	*Ageratina adenophora*	1
4.	*Triumfetta rhomboidea*	0.86
5.	*Acacia farnesiana*	0.45

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.8 GUJARAT

Geographical Area
1,96,244 sq km

Geographical Coordinates
Latitude- 20° 07'N to 24° 43' N
Longitude-68° 10' E to 74° 28' E

Population (as per Census 2011)
60.44 million
Urban 25.74 million (42.60 %)
Rural 34.70 million (57.40 %)
Tribal 8.92 million (14.75 %)

Average Population Density
308 per sq km

Livestock population
(as per 19th Live Stock Census)
27.12 million

No. of Districts
26

No. of Hill Districts
0

No. of Tribal Districts
9

Table 13.8.1 Land Use Pattern

Land Use Types	Area (in '000ha)	Percentage
Geographical Area	19,602	
Reporting area for land utilization	19,069	100.00
Forests	1,834	9.63
Not available for land cultivation	3,723	19.52
Permanent pastures and other grazing lands	851	4.46
Land under misc. tree crops and groves	4	0.02
Culturable wasteland	1,960	10.28
Fallow land other than current fallows	16	0.08
Current fallows	379	1.99
Net area sown	10,302	54.02

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.8.1 Forest Cover

Figure 13.8.1 Forest Cover of Gujarat

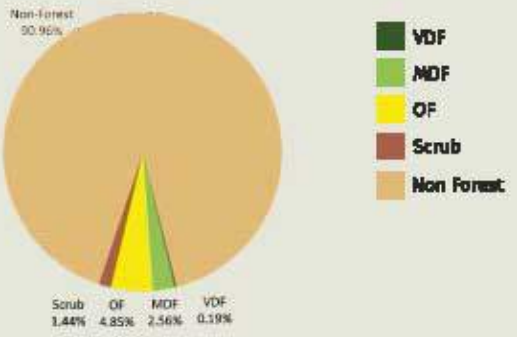


Table 13.8.2 Forest Cover of Gujarat (In sq km)

Class	Area	% of GA
VDF	377.68	0.19
MDF	5,032.19	2.56
OF	9,516.00	4.85
Total	**14,925.87**	**7.60**
Scrub	2,828.20	1.44

Table 13.8.3 District- wise Forest Cover in Gujarat (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				% of GA	Change wrt 2019 Assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Ahmedabad	8,107	0.00	10.56	103.05	113.61	1.40	-17.60	31.16
Amreli	7,397	0.00	64.69	200.49	265.18	3.58	4.78	90.15
Anand	3,204	0.00	6.17	27.81	33.98	1.06	-16.50	14.27
Banas Kantha[T]	10,743	0.00	354.78	461.93	816.71	7.60	-5.79	116.50
Bharuch[T]	6,509	0.00	56.02	216.93	272.95	4.19	-4.57	7.22
Bhavnagar	10,034	0.00	47.28	245.27	292.55	2.92	-0.66	79.12
Dahod	3,642	1.00	115.06	405.98	522.04	14.33	-7.78	29.35
Gandhinagar	2,140	0.00	9.40	90.69	100.09	4.68	8.04	37.84
Jamnagar	14,184	0.00	53.70	423.55	477.25	3.36	6.14	158.94
Junagadh	8,831	15.00	938.10	785.73	1,738.83	19.69	45.52	85.74
Kachchh/Kutch	45,674	0.00	282.89	2156.59	2,439.48	5.34	94.19	1,506.26
Kheda	3,953	0.00	15.04	72.95	87.99	2.23	-6.45	31.56
Mehsana	4,401	0.00	10.72	153.61	164.33	3.73	5.71	30.48
Narmada	2,817	20.00	442.80	464.43	927.23	32.92	-20.77	23.17
Navsari	2,246	18.00	121.95	222.13	362.08	16.12	-0.35	7.66
Panch Mahals[T]	5,231	0.00	201.71	531.08	732.79	14.01	22.73	50.80
Patan	5,792	0.00	0.89	97.46	98.35	1.70	-4.16	93.04
Porbandar	2,316	0.00	16.15	110.12	126.27	5.45	-0.41	40.74
Rajkot	11,198	0.00	2.64	153.64	156.28	1.40	1.96	98.84
Sabarkantha[T]	7,394	29.00	298.61	483.97	811.58	10.98	-3.69	101.78
Surat[T]	4,549	5.00	285.08	209.05	499.13	10.97	-0.93	77.92
Surendranagar	10,423	0.00	5.78	157.06	162.84	1.56	-11.15	48.10
Tapi[T]	3,139	79.68	469.28	236.38	785.34	25.02	-7.07	5.84
The Dangs[T]	1,766	210.00	739.82	404.26	1,354.08	76.67	-8.54	3.00
Vadodara[T]	7,546	0.00	139.50	452.71	592.21	7.85	-11.00	37.91
Valsad[T]	3,008	0.00	343.57	649.13	992.70	33.00	6.89	20.81
Grand Total	**1,96,244**	**377.68**	**5,032.19**	**9,516.00**	**14,925.87**	**7.61**	**68.54**	**2,828.20**

GUJARAT

13.8.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.8.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Gujarat (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
356	4,016	5,463	9,835	22	1,016	4,053	5,091
3.62%	40.83%	55.55%		0.43%	19.96%	79.61%	

*In case of Gujarat RFA boundaries have been used.

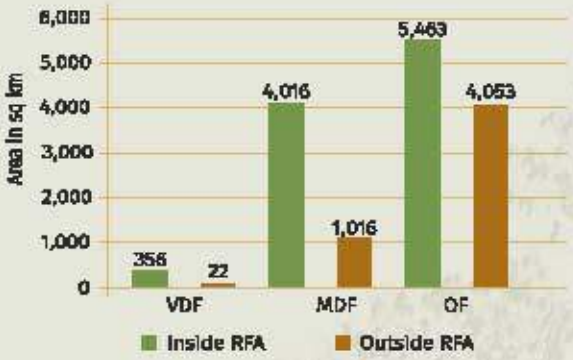


Figure 13.8.2 Forest Cover Inside and Outside of RFA in Gujarat

Table 13.8.5 Forest Cover Change Matrix for Gujarat (in sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	378	0	0	0	0	378
Moderately Dense Forest	0	5,022	5	1	64	5,092
Open Forest	0	5	8,966	49	367	9,387
Scrub	0	0	254	2,548	192	2,994
Non Forest	0	5	291	230	1,77,867	178,393
Total ISFR 2021	**378**	**5,032**	**9,516**	**2,828**	**1,78,490**	**196,244**
Net Change	0	-60	129	-166	97	

Table 13.8.6 Altitude-wise Forest Cover in Gujarat (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	1,95,407	329	4,693	9,305	14,327	2,823
500-1000	830	49	338	210	597	4
1000-2000	7	0	1	1	2	1
Total	**1,96,244**	**378**	**5,032**	**9,516**	**14,926**	**2,828**

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

Table 13.8.7 Forest Cover in different slope classes in Gujarat (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,85,312	121	2,265	6,466	8,852	2,431
5-10	6,265	73	1,060	1,399	2,532	250
10-15	2,322	67	736	799	1,602	82
15-20	1,257	56	489	460	1,005	40
20-25	659	37	282	244	563	16
25-30	291	17	133	105	255	6
>30	138	7	67	43	117	3
Total	**1,96,244**	**378**	**5,032**	**9,516**	**14,926**	**2,828**

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

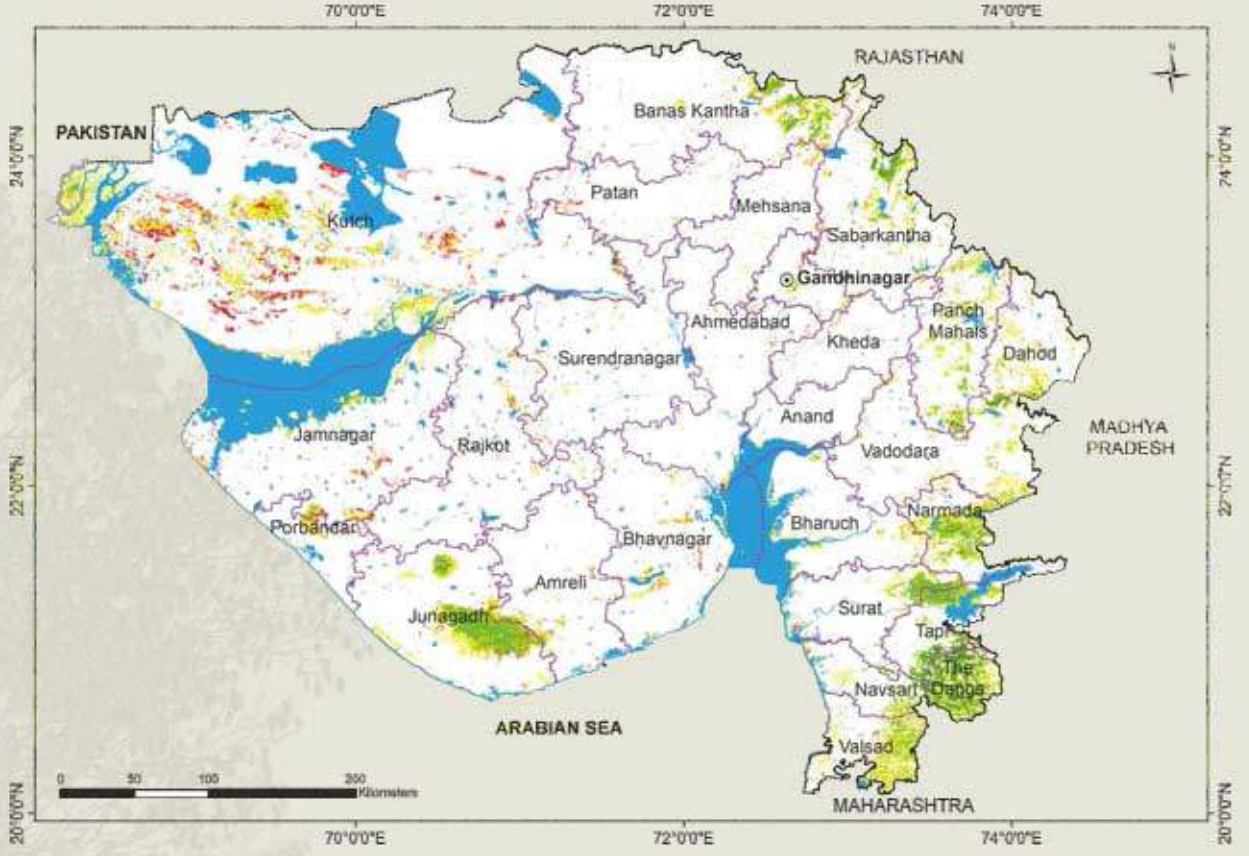


Figure 13.8.3
Forest Cover Map of Gujarat

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

GUJARAT

13.8.2 Forest Types

The area under different forest types of Gujarat as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.8.2 Area statistics of the Forest Types found in Gujarat (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3B/C1b Moist teak forest	800.31	4.48
2.	3B/C1c Slightly moist teak forest	689.16	3.86
3.	3B/C2 Southern moist mixed deciduous forest	1,204.97	6.75
4.	4B/TS1 Mangrove scrub	618.70	3.47
5.	4B/TS2 Mangrove forest	558.57	3.13
6.	5A/C1a Very dry teak forest	770.57	4.32
7.	5A/C1b Dry teak forest	2,041.02	11.43
8.	5A/C3 Southern dry mixed deciduous forest	2,254.66	12.63
9.	5B/C2 Northern dry mixed deciduous forest	944.55	0.21
10.	5/DS1 Dry deciduous scrub	756.74	5.29
11.	5/DS4 Dry grass land	372.49	4.24
12.	5/E1 *Anogeissus pendula* Forest	65.76	2.09
13.	5/E2 *Boswellia* forest	2.07	0.37
14.	5/E3 *Babul* forest	59.48	0.01
15.	5/E5 *Butea* forest	98.30	0.33
16.	5/E8c *Salvadora - Tamarix* scrub	153.83	0.55
17.	5/E9 Dry bamboo brake	121.51	0.86
18.	5/1S1 Dry tropical riverain forest	2.08	0.68
19.	5/2S1 Secondary dry deciduous forest	36.67	0.01
20.	6A/C1 Southern thorn forest	49.43	0.28
21.	6B/C1 Desert thorn forest	1,333.94	7.47
22.	6B/DS2 Tropical *Euphorbia* scrub	964.40	5.40
23.	6/E2 *Acacia senegal* forest	944.04	5.29
24.	6/E3 *Rann* saline thorn forest	590.37	3.31
25.	6/E4 *Salvadora* scrub	22.23	0.12
	Sub Total	**15,455.85**	**86.58**
26.	TOF/Plantation	2,395.59	13.42
	Total (Forest Cover & Scrub)	**17,851.44**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

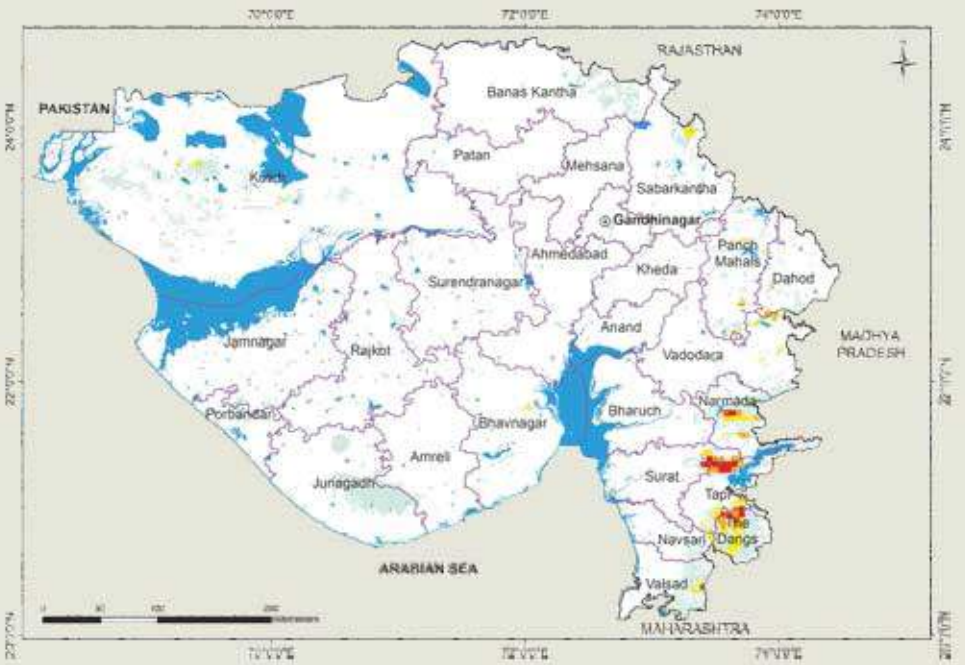


Figure 13.8.4 Fire prone forest areas under different fire prone classes

13.8.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.8.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	8.08	0.05
2.	Very highly fire prone	384.42	2.58
3.	Highly fire prone	523.32	3.51
4.	Moderately fire prone	975.10	6.53
5.	Less fire prone	13,035.08	87.33
	Total	**14,926.00**	**100.00**

13.8.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Gujrat has been estimated as given in following table.

Table 13.8.10 Tree Cover in Gujarat (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
6,912	5,489	-1,423

13.8.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

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Table 13.8.11 Extent of TOF in Gujarat (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
5,091	5,489	10,580

13.8.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Gujarat is given in the Table 13.8.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.8.13

Table 13.8.12 Growing Stock in Gujarat (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	48.31	51.22	2.91	1.17
2.	Growing Stock in TOF	82.60	78.74	-3.86	4.43

Table 13.8.13 Diameter class distribution of top five tree species inside RFA in Gujarat (In '000)

		Dia class (cm)		
Sl. No.	Species	10-30	30-60	>60
1.	*Tectona grandis*	52,619	2,911	200
2.	*Butea monosperma*	18,199	1,086	38
3.	*Terminalia tomentosa*	12,000	1,525	0
4.	*Lannea coromandelica*	8,894	1,581	105
5.	*Anogeissus latifolia*	8,822	750	0

13.8.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Gujarat in Rural and Urban areas are given in the Table 13.8.14 and Table 13.8.15 respectively

Table 13.8.14 Top five tree species in TOF (Rural) in Gujarat

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	27.81
2.	*Mangifera indica*	9.71
3.	*Prosopis juliflora*	6.34
4.	*Acacia arabica*	6.29
5.	*Tectona grandis*	3.76

Table 13.8.15 Top five tree species in TOF (Urban) in Gujarat

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	23.81
2.	*Pittosprorum ferrugineum*	5.89
3.	*Polyalthia spp.*	5.72
4.	*Mangifera indica*	5.53
5.	*Jonesia asoca*	3.84

13.8.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size 107.77 million tonnes (395.16 million tonnes of CO_2 equivalent) which is 1.50 % of total forest carbon of the country. Pool wise forest carbon in Gujarat is given in the following table.

Table 13.8.16 Forest Carbon in Gujarat in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	28,602
2.	BGB	9,814
3.	Dead wood	502
4.	Litter	1,634
5.	SOC	67,214
	Total	**1,07,766**

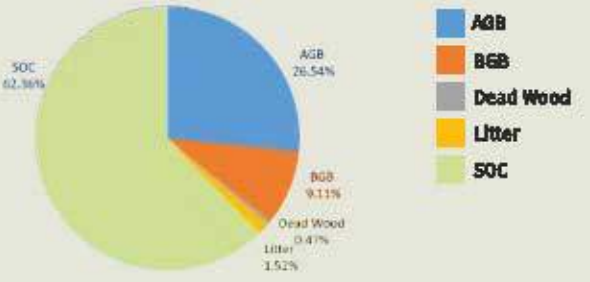


Figure 13.8.5 Forest Carbon in Gujarat

13.8.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.7.17 Growing Stock of Bamboo in Goa

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	3,547	2.37
Total number of culms (in millions)	878	1.65
Total equivalent green weight (in '000 tonnes)	10,560	2.63

13.8.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.8.18 and Table 13.8.19 respectively.

Table 13.8.18 Major NTFP species in Gujarat

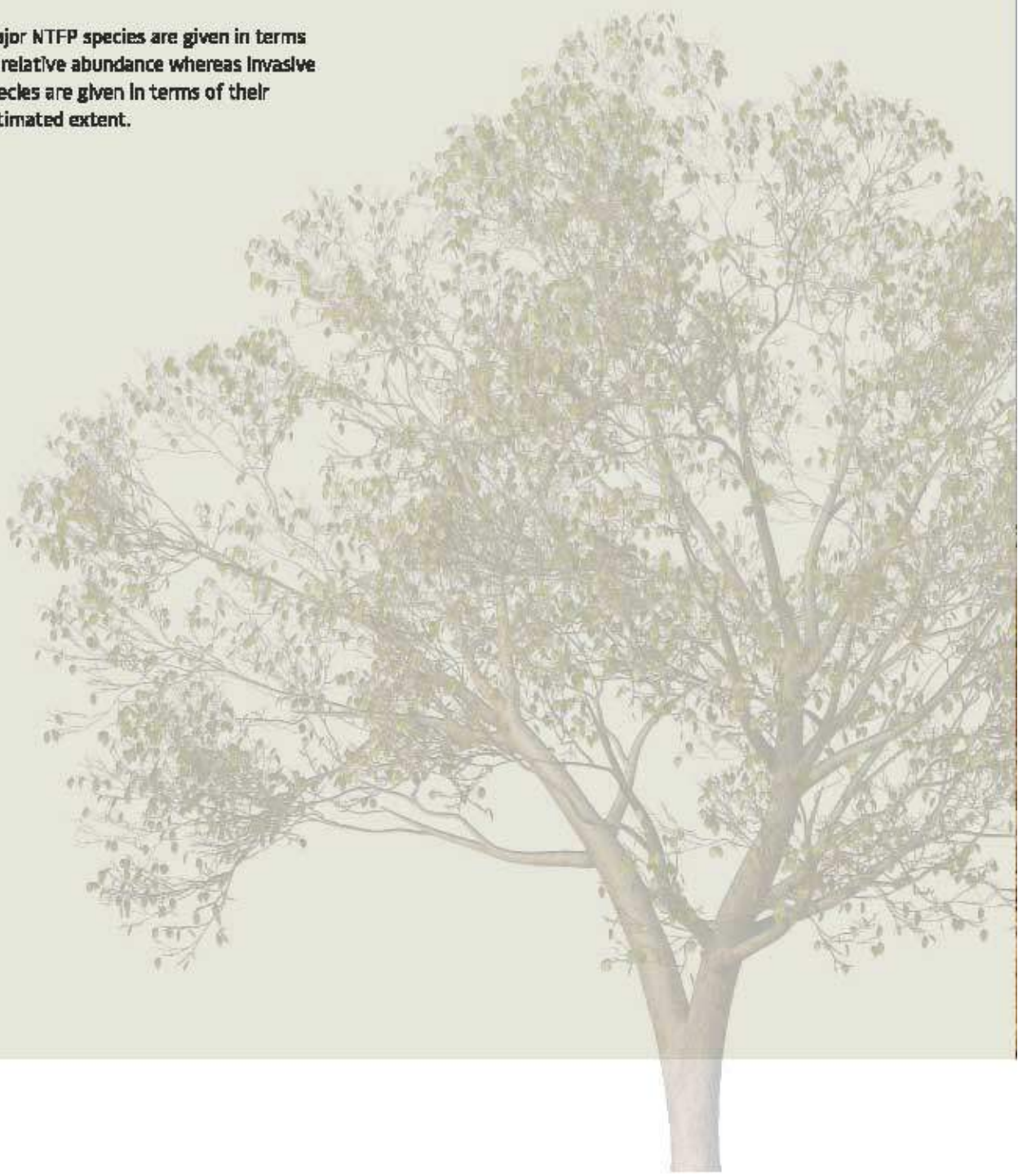
Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Ocimum spp. (Ocimum gratissimum/ Ocimum sanctum/Ocimum tenuiflorum/ Ocimum americanum)*	Herbs	41.24
2.	*Butea monosperma*	Tree	10.76
3.	*Cassia tora*	Shrub	9.96
4.	*Prosopis juliflora*	Tree	9.07
5.	*Diospyros melanoxylon*	Tree	7.61

GUJARAT

Table 13.8.19 Major invasive species in the State inside the RFA/Green Wash in Gujarat (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Prosopis juliflora*	143
2.	*Cassia tora*	132
3.	*Ageratum conyzoides*	74
4.	*Lantana camara*	69
5.	*Senna occidentalis*	36

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.



Gujarat

13.9 HARYANA

Geographical Area
44,212 sq km

Geographical Coordinates
Latitude- 27°39' N to 30°55' N
Longitude-74°27' E to 77° 36' E

Population (as per Census 2011)
25.35 million
Urban 8.84 million (34.87 %)
Rural 16.51 million (65.13 %)
Tribal NIL

Average Population Density
573 per sq km

Livestock population
(as per 19th Live Stock Census)
8.82 million

No. of Districts
21

No. of Hill Districts
0

No. of Tribal Districts
0

Table 13.9.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	4,421	
Reporting area for land utilization	4,371	100.00
Forests	36	0.82
Not available for land cultivation	553	12.65
Permanent pastures and other grazing lands	24	0.55
Land under misc. tree crops and groves	6	0.14
Culturable wasteland	49	1.12
Fallow land other than current fallows	75	1.72
Current fallows	111	2.54
Net area sown	3,517	80.46

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.9.1 Forest Cover

Figure 13.9.1
Forest Cover of Haryana

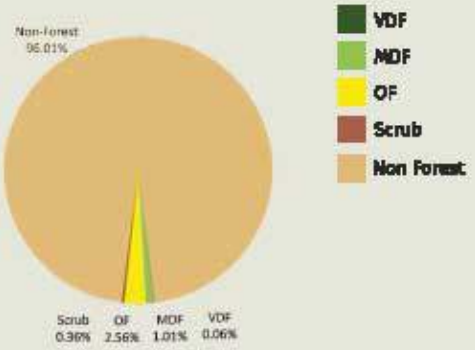


Table 13.9.2 Forest Cover of Haryana (In sq km)

Class	Area	% of GA
VDF	28.00	0.06
MDF	445.38	1.01
OF	1,130.10	2.56
Total	**1,603.48**	**3.63**
Scrub	158.93	0.36

Table 13.9.3 District- wise Forest Cover in Haryana (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Ambala	1,574	0.00	16.94	35.33	52.27	3.32	0.92	0.83
Bhiwani	4,778	0.00	8.12	103.30	111.42	2.33	-2.39	14.18
Faridabad	741	0.00	26.37	52.86	79.23	10.69	-0.71	17.72
Fatehabad	2,538	0.00	3.23	15.26	18.49	0.73	0.49	0.91
Gurgaon	1,258	0.00	32.65	81.06	113.71	9.04	-2.47	17.51
Hisar	3,983	0.00	11.12	46.24	57.36	1.44	-0.28	5.39
Jhajjar	1,834	0.00	0.00	25.41	25.41	1.39	-0.52	4.27
Jind	2,702	0.00	4.98	17.36	22.34	0.83	1.34	0.02
Kaithal	2,317	0.00	23.48	35.34	58.82	2.54	1.75	0.09
Karnal	2,520	0.00	3.45	28.19	31.64	1.26	-0.60	1.02
Kurukshetra	1,530	0.00	16.40	23.72	40.12	2.62	0.37	2.08
Mahendragarh	1,899	0.00	20.82	82.56	103.38	5.44	0.09	34.29
Mewat	1,507	0.00	13.76	96.65	110.41	7.33	-0.77	25.81
Palwal	1,359	0.00	1.94	11.62	13.56	1.00	-0.41	0.00
Panchkula	898	6.00	150.67	235.43	392.10	43.66	1.40	22.59
Panipat	1,268	0.00	3.14	13.31	16.45	1.30	0.57	1.23
Rewari	1,594	0.00	11.46	51.64	63.10	3.96	0.65	8.67
Rohtak	1,745	0.00	2.44	17.95	20.39	1.17	-0.74	0.46
Sirsa	4,277	0.00	2.95	55.30	58.25	1.36	1.65	0.06
Sonipat	2,122	0.00	2.83	19.21	22.04	1.04	1.07	0.87
Yamunanagar	1,768	22.00	88.63	82.36	192.99	10.92	-0.37	0.93
Grand Total	**44,212**	**28.00**	**445.38**	**1,130.10**	**1,603.48**	**3.63**	**1.04**	**158.93**

HARYANA

13.9.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.9.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Haryana (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
22	155	197	374	6	290	933	1,229
5.88%	41.44%	52.68%		0.49%	23.60%	75.91%	

**In case of Haryana, RFA boundaries have been used.*

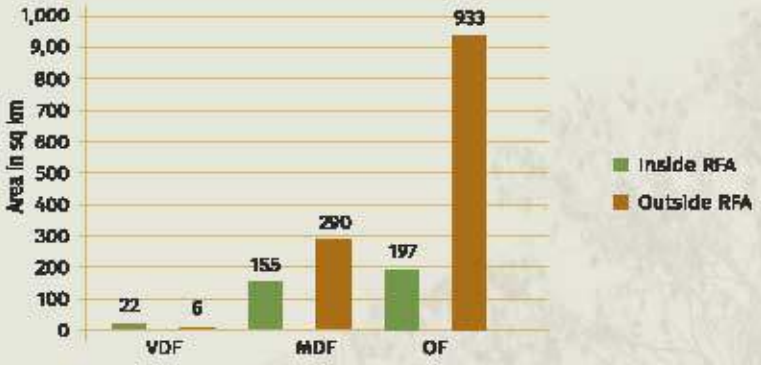


Figure 13.9.2 Forest Cover Inside and Outside of RFA in Haryana

Table 13.9.5 Forest Cover Change Matrix for Haryana (In sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	28	0	0	0	0	28
Moderately Dense Forest	0	436	6	1	8	451
Open Forest	0	6	1,048	8	61	1,123
Scrub	0	0	10	141	3	154
Non Forest	0	3	66	9	42,378	42,456
Total ISFR 2021	**28**	**445**	**1,130**	**159**	**42,450**	**44,212**
Net Change	0	-6	7	5	-6	

Table 13.9.6 Altitude-wise Forest Cover in Haryana (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	43,838	16	330	975	1,321	149
500-1000	330	12	94	135	241	9
1000-2000	44	0	21	20	41	1
Total	**44,212**	**28**	**445**	**1,130**	**1,603**	**159**

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

Table 13.9.7 Forest Cover in different slope classes in Haryana (in sq km)

Slope (in Degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	42,615	14	238	789	1,041	100
5-10	1,104	7	75	130	212	23
10-15	228	4	55	85	144	14
15-20	126	2	37	55	94	10
20-25	74	1	22	37	60	6
25-30	41	0	12	21	33	4
>30	24	0	6	13	19	2
Total	**44,212**	**28**	**445**	**1,130**	**1,603**	**159**

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

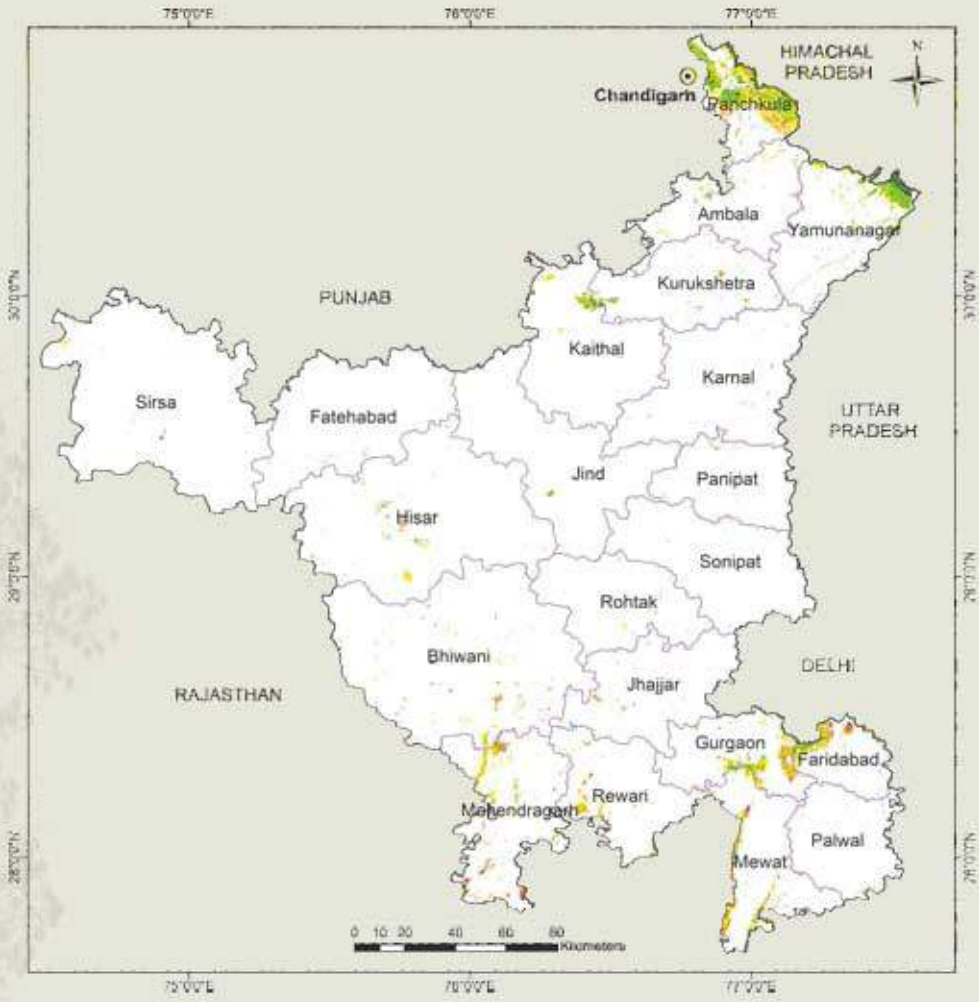


Figure 13.9.3 Forest Cover Map of Haryana

13.9.2 Forest Types

The area under different forest types of Haryana as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

HARYANA

Table 13.9.2 Area statistics of the Forest Types found in Haryana (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	5B/C1a Dry Siwalik sal forest	46.15	2.63
2.	5B/C2 Northern dry mixed deciduous forest	518.73	29.53
3.	5/DS1 Dry deciduous scrub	32.07	1.82
4.	5/E1 *Anogeissus pendula* forest	97.71	5.56
5.	5/E1/DS1 *Anogeissus pendula* scrub	21.46	1.22
6.	5/E9 Dry bamboo brakes	7.11	0.40
7.	6B/C1 Desert thorn forest	86.71	4.94
8.	6B/C2 Ravine thorn forest	258.61	14.72
9.	6/1S1 Desert dune scrub	102.76	5.85
10.	9/C1a Lower or Siwalik chir pine forest	12.94	0.74
	Sub Total	**1,184.25**	**67.41**
11.	TOF/Plantation	572.48	32.59
	Total (Forest Cover & Scrub)	**1,756.73**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

13.9.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

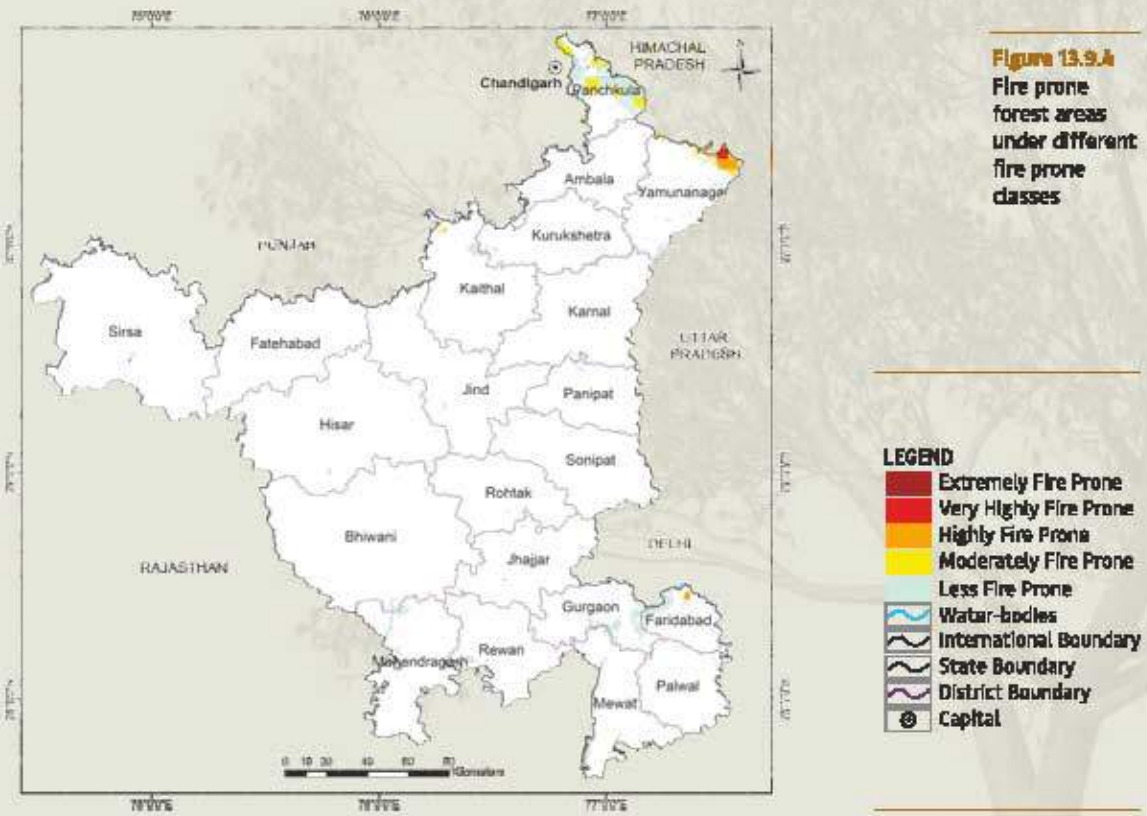


Figure 13.9.A Fire prone forest areas under different fire prone classes

Table 13.9.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	20.40	1.27
3.	Highly fire prone	66.81	4.17
4.	Moderately fire prone	154.50	9.64
5.	Less fire prone	1,361.29	84.92
	Total	**1,603.00**	**100.00**

13.9.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Haryana has been estimated as given in following table.

Table 13.9.10 Tree Cover in Haryana (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 assessment
1,565	1,425	-140

13.9.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.9.11 Extent of TOF in Haryana (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
1,229	1,425	2,654

13.9.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Haryana is given in the Table 13.9.12, Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.9.13

Table 13.9.12 Growing Stock in Haryana (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	4.22	4.31	0.09	0.10
2.	Growing Stock in TOF	17.56	19.26	1.70	1.08

HARYANA

Table 13.9.13 Diameter class distribution of top five tree species inside RFA in Haryana (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Acacia tortalis*	3,083	71	0
2.	*Eucalyptus* spp.	2,446	533	34
3.	*Acacia catechu*	2,550	69	0
4.	*Prosopis juliflora*	2,250	105	0
5.	*Dalbergia sissoo*	1,459	344	0

13.9.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Haryana in Rural and Urban areas are given in the Table 13.9.14 and Table 13.9.15 respectively.

Table 13.9.14 Top five tree species in TOF (Rural) in Haryana

Sl. No.	Species	Relative Abundance (%)
1.	*Eucalyptus* spp.	29.23
2.	*Dalbergia sissoo*	11.04
3.	*Prosopis cineraria*	9.03
4.	*Azadirachta indica*	6.65
5.	*Populus* spp.	5.79

Table 13.9.15 Top five tree species in TOF (Urban) in Gujarat

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	12.69
2.	*Eucalyptus* spp.	11.69
3.	*Melia azadirachta*	7.43
4.	*Morus* spp.	6.82
5.	*Prosopis juliflora*	6.30

13.9.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size is 10.23 million tonnes (37.51 million tonnes of CO_2 equivalent) which is 0.14 % of total forest carbon of the country. Pool wise forest carbon in Haryana is given in the following table.

Table 13.9.16 Forest Carbon in Haryana in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	2,326
2.	BGB	836
3.	Dead wood	41
4.	Litter	139
5.	SOC	6,890
	Total	10,232

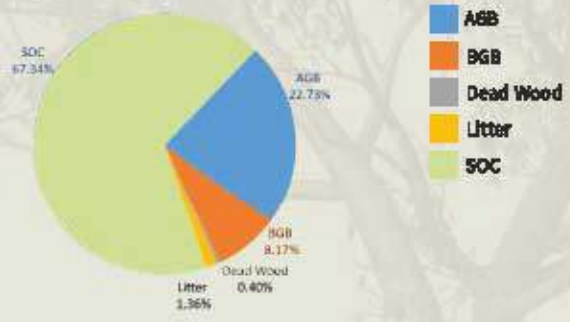


Figure 13.9.5 Forest Carbon in Haryana

13.9.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.9.17 Growing Stock of Bamboo in Haryana

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	39	0.03
Total number of culms (in millions)	15	0.03
Total equivalent green weight (in '000 tonnes)	33	0.01

13.9.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.9.18 and Table 13.9.19 respectively

Table 13.9.18 Major NTFP Species in Haryana

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Adhatoda vasica*	Shrub	47.06
2.	*Achyranthes aspera*	Herbs	33.33
3.	*Abrus precatorius*	Climber	9.80
4.	*Cucumis pubescens*	Climber	7.84
5.	*Asparagus adscendens*	Shrub	1.96

Table 13.9.19 Major invasive species in the State inside the RFA/Green Wash in Haryana (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	41
2.	*Prosopis juliflora*	29
3.	*Saccharum spontanem*	29
4.	*Ageratum houstonianum*	14
5.	*Leucanea leucocephala*	8

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.10 HIMACHAL PRADESH

Geographical Area
55,673 sq km

Geographical Coordinates
Latitude- 30°22' N to 33°12' N
Longitude- 75°45' E to 79°04' E

Population (as per Census 2011)
6.86 million
Urban 0.69 million (10.03 %)
Rural 6.17 million (89.97 %)
Tribal 0.39 million (5.71%)

Average Population Density
123 per sq km

Livestock population
(as per 19th Live Stock Census)
4.84 million

No. of Districts
12

No. of Hill Districts
12

No. of Tribal Districts
3

Table 13.10.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	5,567	
Reporting area for land utilization	4,577	100.00
Forests	1,124	24.56
Not available for land cultivation	1,136	24.82
Permanent pastures and other grazing lands	1,501	32.79
Land under misc. tree crops and groves	68	1.49
Culturable wasteland	120	2.62
Fallow land other than current fallows	20	0.44
Current fallows	65	1.42
Net area sown	543	11.86

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.10.1 Forest Cover

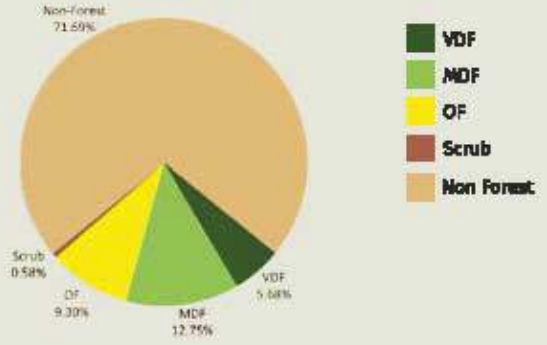


Figure 13.10.1
Forest Cover of Himachal Pradesh

Table 13.10.2 Forest Cover of Himachal Pradesh (in sq km)

Class	Area	% of GA
VDF	3,162.99	5.68
MDF	7,100.13	12.75
OF	5,179.83	9.30
Total	**15,442.95**	**27.73**
Scrub	321.78	0.58

Table 13.10.3 District- wise Forest Cover in Himachal Pradesh (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Bilaspur[H]	1,167	21.25	192.03	168.30	381.58	32.70	0.88	1.93
Chamba[TH]	6,522	767.89	1,011.92	673.51	2,453.32	37.62	-1.84	21.49
Hamirpur[H]	1,118	37.85	115.40	203.17	356.42	31.85	1.52	12.20
Kangra[H]	5,739	297.56	1,289.74	769.97	2,357.27	41.08	3.08	16.42
Kinnaur[TH]	6,401	79.81	329.28	236.22	645.31	10.08	-0.68	61.94
Kullu[H]	5,503	567.59	677.60	510.38	1,975.57	35.90	-0.72	25.10
Lahaul & Spiti[TH]	13,841	15.00	30.67	113.18	158.85	1.15	-1.50	14.59
Mandi[H]	3,950	371.74	757.03	646.60	1,775.37	44.95	2.35	20.25
Shimla[H]	5,131	764.89	1,073.52	584.10	2,422.51	47.21	3.10	31.28
Sirmaur[H]	2,825	156.98	669.54	567.04	1,393.56	49.33	2.69	55.52
Solan[H]	1,936	43.78	443.56	403.52	890.86	46.02	0.57	52.33
Una[H]	1,540	18.65	309.84	303.84	632.33	41.06	-0.02	8.73
Grand Total	**55,673**	**3,162.99**	**7,100.13**	**5,179.83**	**15,442.95**	**27.73**	**9.43**	**321.78**

13.10.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

HIMACHAL PRADESH

Table 13.10.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Himachal Pradesh

(In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
2,820	4,923	2,901	10,644	343	2,177	2,279	4,799
26.49%	46.25%	27.26%		7.15%	45.36%	47.49%	

**In case of Himachal Pradesh, Green Wash boundaries have been used.*

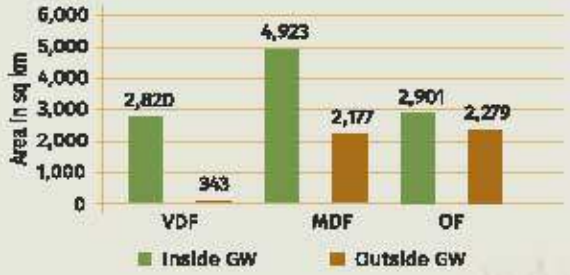


Fig 13.10.2 Forest Cover Inside and Outside of Green Wash in Himachal Pradesh

Table 13.10.5 Forest Cover Change Matrix for Himachal Pradesh

(In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	3,110	3	0	0	0	3,113
Moderately Dense Forest	51	7,068	5	1	1	7,126
Open Forest	2	29	5,150	1	13	5,195
Scrub	0	0	2	312	1	315
Non Forest	0	0	23	8	39,893	39,924
Total ISFR 2021	**3,163**	**7,100**	**5,180**	**322**	**39,908**	**55,673**
Net Change	50	-26	-15	7	-16	

Table 13.10.6 Altitude-wise Forest Cover in Himachal Pradesh

(In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	2,925	25	448	358	831	16
500-1000	7,625	234	1,917	1,577	3,728	63
1000-2000	9,628	696	1,677	1,562	3,935	125
2000-3000	8,101	1,836	2,207	1,057	5,100	30
3000-4000	6,848	372	847	617	1,836	71
>4000	20,546	0	4	9	13	17
Total	**55,673**	**3,163**	**7,100**	**5,180**	**15,443**	**322**

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

Table 13.10.7 Forest Cover in different slope classes in Himachal Pradesh (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	6,362	90	427	545	1,062	28
5-10	5,614	153	804	707	1,664	27
10-15	6,424	284	979	726	1,989	36
15-20	7,274	425	1,072	730	2,227	45
20-25	7,570	503	1,076	693	2,272	49
25-30	7,224	521	999	613	2,133	46
>30	15,205	1,187	1,743	1,166	4,096	91
Total	**55,673**	**3,163**	**7,100**	**5,180**	**15,443**	**322**

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

LEGEND

- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

Figure 13.10.3 Forest Cover Map of Himachal Pradesh

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13.10.2 Forest Types

The area under different forest types of Himachal Pradesh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.10.6 Area statistics of the Forest Types found in Himachal Pradesh (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3C/C2b(i) *Bhabar-dun* sal	208.63	1.02
2.	5B/C1a Dry Siwalik sal forest	94.50	0.46
3.	5B/C2 Northern dry mixed deciduous forest	2,516.36	12.29
4.	5/DS1 Dry deciduous scrub	150.51	0.73
5.	5/DS3 *Euphorbia* scrub	5.15	0.03
6.	5/E9 Dry bamboo brakes	80.63	0.39
7.	5/1S2 *Khair-sissu* forest	1.27	0.01
8.	9/C1a Lower or Siwalik chir pine forest	1,434.74	7.01
9.	9/C1b Upper or Himalayan chir pine forest	1,324.88	6.47
10.	9/C1/DS1 Himalayan subtropical scrub	81.49	0.40
11.	12/C1a *Ban* oak forest (*Q. incana*)	813.58	3.97
12.	12/C1b *Moru* oak forest (*Q. dilatata*)	11.58	0.06
13.	12/C1c Moist deodar forest (*Cedrus*)	2,117.65	10.34
14.	12/C1d Western mixed coniferous forest (spruce, blue pine, silver fir)	2,875.96	14.05
15.	12/C1e Moist temperate deciduous forest	109.80	0.54
16.	12/C1f Low-level blue pine forest (*P. wallichiana*)	467.73	2.28
17.	12/C1/DS1 Oak scrub	235.36	1.15
18.	12/C1/DS2 Himalayan temperate secondary scrub	128.51	0.63
19.	12/C2a *Kharsu* oak forest (*Q. semecarpifolia*)	153.51	0.75
20.	12/C2b West Himalayan upper oak/fir forest	141.84	0.69
21.	12/DS1 Montane bamboo brakes	12.00	0.06
22.	12/E1 Cypress forest	8.64	0.04
23.	12/1S1 Alder forest	3.58	0.02
24.	13/C1 Dry broadleaved and coniferous forest (*Q. ilex-P. gerardiana*)	7.43	0.04
25.	13/C2a *Neoza* pine forest (*P. gerardiana*)	129.54	0.63
26.	13/C2b Dry deodar forest (*Cedrus*)	228.73	1.12
27.	13/C3 West Himalayan dry temperate deciduous forest	0.11	0.00
28.	13/C4 West Himalayan high level dry blue pine forest (*P. wallichiana*)	69.56	0.34
29.	13/C5 West Himalayan dry juniper forest (*J. macropoda*)	62.56	0.30
30.	13/1S2 *Populus/Salix* forest	4.58	0.02
31.	14/C1a West Himalayan sub-alpine fir forest	119.77	0.58
32.	14/C1b West Himalayan sub-alpine birch/fir forest	541.70	2.65
33.	15/C1 Birch/*Rhododendron* scrub forest	45.62	0.22
34.	15/C2 Deciduous alpine scrub	9.78	0.05
35.	15/E1 Dwarf *Rhododendron* scrub	2.65	0.01
36.	16/C1 Dry alpine scrub	148.12	0.72

(in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
37.	16/E1 Dwarf Juniper scrub	187.58	0.92
	Sub Total	**14,535.63**	**70.99**
38.	TOF/Plantation	1,213.17	5.92
	Total (Forest Cover & Scrub)	**15,748.80**	
	Grassland Forest Types (outside forest cover)		
39.	12/DS3 Himalayan temperate pastures	1,004.58	4.91
40.	15/C3 Alpine pastures	3,721.73	18.18
	Sub Total	**4,726.31**	**23.09**
	Grand Total	**20,475.11**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total Map Area, therefore, is some of forest cover, scrub and grassland forest types(found in non-forest)*

13.10.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.10.3 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	6.81	0.04
3.	Highly fire prone	305.56	1.98
4.	Moderately fire prone	999.03	6.47
5.	Less fire prone	14,131.60	91.51
	Total	**15,443.00**	**100.00**

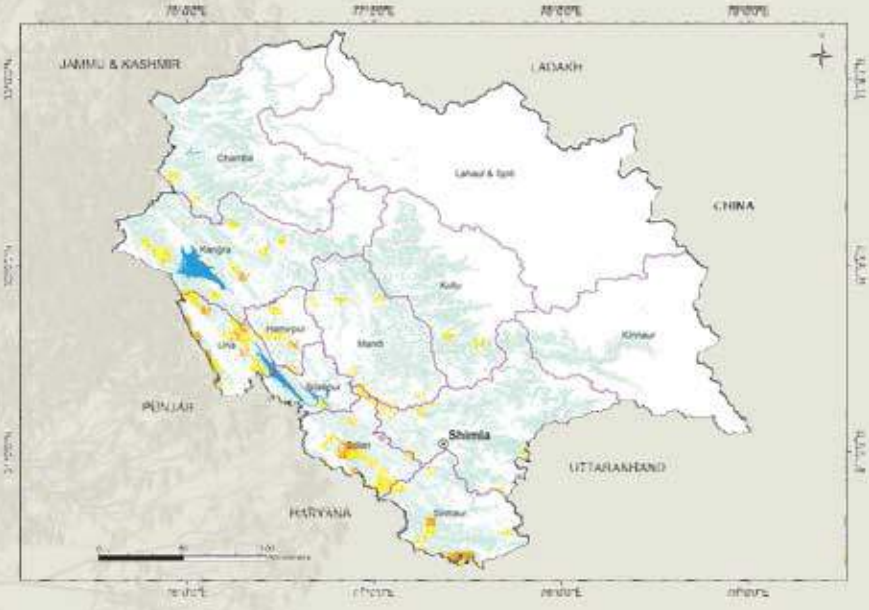

Figure 13.10.4 Fire prone forest areas under different fire prone classes

13.10.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Himachal Pradesh has been estimated as given in following table.

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Table 13.10.10 Tree Cover in Himachal Pradesh (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
829	675	-154

13.10.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.10.11 Extent of TOF in Himachal Pradesh (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
4,799	675	5,474

13.10.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Himachal Pradesh is given in the Table 13.10.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.10.13.

Table 13.10.12 Growing Stock in Himachal Pradesh (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	347.07	345.62	-1.45	7.88
2.	Growing Stock in TOF	25.19	28.30	3.11	1.59

Table 13.10.13 Diameter class distribution of top five tree species inside RFA in Himachal Pradesh (in '000)

		Dia class (cm)		
Sl. No.	Species	10-30	30-60	>60
1.	*Pinus roxburghii*	52,131	20,874	1,766
2.	*Cedrus deodara*	35,634	13,880	3,805
3.	*Pinus excelsa*	30,638	12,142	3,643
4.	*Abies pindrow*	11,169	9,017	3,043
5.	*Abies smithiana*	13,471	5,459	4,260

13.10.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Himachal Pradesh in Rural and Urban areas are given in the Table 13.10.14 and Table 13.10.15 respectively

Table 13.10.14 Top five tree species in TOF (Rural) in Himachal Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Pinus roxburghii*	23.05
2.	*Cedrus deodara*	7.95
3.	*Acacia catechu*	5.68
4.	*Grewia oppositifolia*	5.61
5.	*Quercus leucotrichophora*	4.93

Table 13.10.15 Top five tree species in TOF (Urban) in Himachal Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Pinus roxburghii*	11.46
2.	*Grewia oppositifolia*	7.27
3.	*Mangifera indica*	5.97
4.	*Morus spp.*	5.87
5.	*Cedrus deodara*	4.27

13.10.8 Carbon Stock in Forest

The total Carbon stock of forests in the State including the TOF patches which are more than 1 ha in size is 258.07 million tonnes (946.26 million tonnes of CO_2 equivalent) which is 3.58 % of total forest carbon of the country. Pool wise forest carbon in Himachal Pradesh is given in the following table.

Table 13.10.16 Forest Carbon in Himachal Pradesh in different pools

(In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,14,269
2.	BGB	31,880
3.	Dead wood	2,657
4.	Litter	3,328
5.	SOC	1,05,937
	Total	**2,58,071**

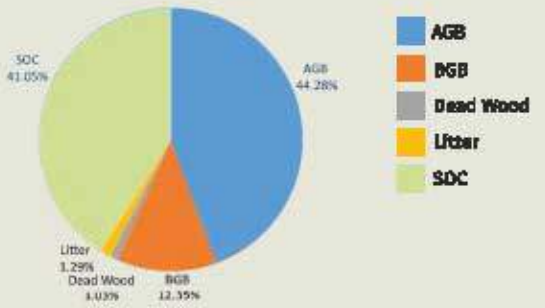

Figure 13.10.5 Forest Carbon in Himachal Pradesh

13.10.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.10.17 Growing Stock of Bamboo in Himachal Pradesh

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	1,027	0.69
Total number of culms (in millions)	671	1.26
Total equivalent green weight (in '000 tonnes)	2,876	0.72

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13.10.10 Major NTFP and Invasive Species

Major NTFP and Invasive species as assessed from forest inventory data are presented in the Table 13.10.18 and Table 13.10.19 respectively.

Table 13.10.18 Major NTFP species in Himachal Pradesh

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Berberis aristata*	Shrub	71.19
2.	*Skimmia laureola*	Shrub	10.22
3.	*Trillidium govanianum*	Herbs	5.02
4.	*Bauhinia vahlii*	Climber	4.83
5.	*Zanthoxylum armatum*	Shrub	4.09

Table 13.10.19 Major invasive species in the State inside the RFA/Green Wash in Himachal Pradesh (in sq km)

Sl. No.	Species	Estimated Extent
1	*Lantana camara*	321
2	*Ageratina adenophora*	19
3	*Ageratum conyzoides*	18
4	*Melochia corchorifolia*	15
5	*Dioscorea deltoidea*	14

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.11 JHARKHAND

Geographical Area
79,716 sq km

Geographical Coordinates
Latitude- 22° 00' N to 24°37' N
Longitude- 83° 15' E to 87° 01' E

Population (as per Census 2011)
32.99 million
Urban 7.93 million (24.05 %)
Rural 25.06 million (75.95 %)
Tribal 8.65 million (26.21%)

Average Population Density
414 per sq km

Livestock population
(as per 19th Live Stock Census)
18.05 million

No. of Districts
24

No. of Hill Districts
0

No. of Tribal Districts
17

Table 13.11.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	7,972	
Reporting area for land utilization	7,970	100.00
Forests	2,239	28.09
Not available for land cultivation	1,281	16.07
Permanent pastures and other grazing lands	127	1.59
Land under misc. tree crops and groves	121	1.52
Culturable wasteland	368	4.62
Fallow land other than current fallows	1,105	13.86
Current fallows	1,285	16.13
Net area sown	1,444	18.12

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.11.1 Forest Cover

Figure 13.11.1
Forest Cover of Jharkhand

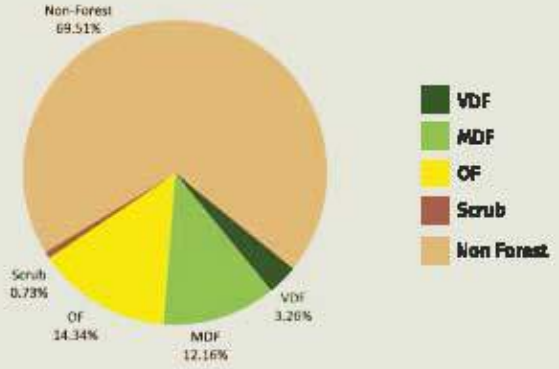


Table 13.11.2 Forest Cover of Jharkhand (In sq km)

Class	Area	% of GA
VDF	2,601.05	a3.26
MDF	9,688.91	12.16
OF	11,431.18	14.34
Total	**23,721.14**	**29.76**
Scrub	584.20	0.73

Table 13.11.3 District- wise Forest Cover in Jharkhand (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Bokaro	2,883	60.99	231.94	283.07	576.00	19.98	2.45	37.95
Chatra	3,718	244.28	871.73	666.08	1,782.09	47.93	4.74	23.57
Deoghar[T]	2,477	0.00	14.30	191.50	205.80	8.31	2.09	14.04
Dhanbad	2,040	0.00	44.00	174.18	218.18	10.70	4.67	16.05
Dumka[T]	3,761	0.00	259.40	318.23	577.63	15.36	0.32	44.55
East Singhbhum[T]	3,562	54.81	591.69	434.19	1,080.69	30.34	1.31	20.91
Garhwa[T]	4,093	125.14	415.60	890.98	1,431.72	34.98	40.13	44.32
Giridih	4,962	77.16	338.56	490.19	905.91	18.26	4.67	28.92
Godda[T]	2,266	12.81	271.88	138.66	423.35	18.68	0.00	14.27
Gumla[T]	5,360	304.69	585.81	552.65	1,443.15	26.92	0.89	8.25
Hazaribagh	3,555	230.11	348.54	784.54	1,363.19	38.35	10.42	15.99
Jamtara[T]	1,811	0.00	20.84	85.18	106.02	5.85	5.38	5.32
Khunti[T]	2,535	72.97	344.59	496.18	913.74	36.04	8.25	3.11
Koderma	2,540	80.80	494.43	447.82	1,023.05	40.28	-0.42	6.37
Latehar[T]	4,291	480.36	1,308.93	613.75	2,403.04	56.00	-3.30	9.30
Lohardaga[T]	1,502	174.03	218.40	111.99	504.42	33.58	-0.20	7.66
Pakur[T]	1,811	2.96	172.40	111.64	287.00	15.85	-0.13	20.06
Palamu[T]	4,393	62.82	512.73	640.18	1,215.73	27.67	14.95	84.23
Ramgarh	1,341	30.96	109.32	190.98	331.26	24.70	2.26	14.49
Ranchi[T]	5,097	62.89	363.91	741.98	1,168.78	22.93	4.29	27.98
Sahibganj[T]	2,063	17.74	258.73	297.48	573.95	27.82	1.60	47.53
Seraikela-Kharsawan[T]	2,657	22.03	213.84	338.73	574.60	21.63	0.56	21.87
Simdega[T]	3,774	21.97	343.54	877.89	1,243.40	32.95	2.48	20.28
West Singhbhum[T]	7,224	461.53	1,353.80	1,553.11	3,368.44	46.63	2.32	47.18
Grand Total	**79,716**	**2,601.05**	**9,688.91**	**11,431.18**	**23,721.14**	**29.76**	**109.73**	**584.20**

JHARKHAND

13.11.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.11.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Jharkhand (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
1,414	5,186	5,682	12,282	1,187	4,503	5,749	11,439
11.51%	42.23%	46.26%		10.37%	39.37%	50.26%	

**In case of Jharkhand, RFA boundaries have been used.*

Figure 13.11.2 Forest Cover Inside and Outside of RFA in Jharkhand

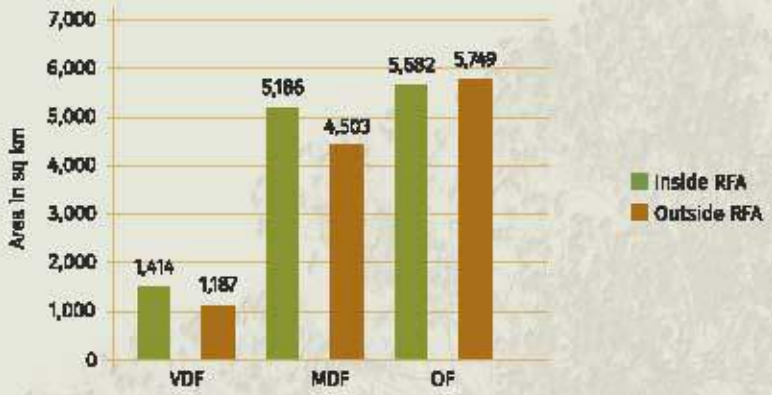


Table 13.11.5 Forest Cover Change Matrix for Jharkhand (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	2,586	13	3	0	1	2,603
Moderately Dense Forest	11	9,615	34	1	26	9,687
Open Forest	3	37	11,164	3	114	11,321
Scrub	0	1	61	567	59	688
Non Forest	1	23	169	13	55,211	55,417
Total ISFR 2021	**2,601**	**9,689**	**11,431**	**584**	**55,411**	**79,716**
Net Change	-2	2	110	-104	-6	

Table 13.11.6 Altitude-wise Forest Cover in Jharkhand (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	61,272	1,041	6,726	8,385	16,152	552
500-1000	18,051	1,493	2,839	3,006	7,337	32
1000-2000	393	67	124	40	232	0
Total	**79,716**	**2,601**	**9,689**	**11,431**	**23,721**	**584**

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

Table13.11.7 Forest Cover in different slope classes in Jharkhand (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	65,120	1,211	4,737	6,886	12,834	337
5-10	8,083	676	2,257	2,235	5,168	111
10-15	3,260	384	1,284	1,104	2,772	61
15-20	1,790	203	764	641	1,608	38
20-25	915	87	399	351	837	22
25-30	390	30	172	157	359	11
>30	158	10	76	57	143	4
Total	**79,716**	**2,601**	**9,689**	**11,431**	**23,721**	**584**

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

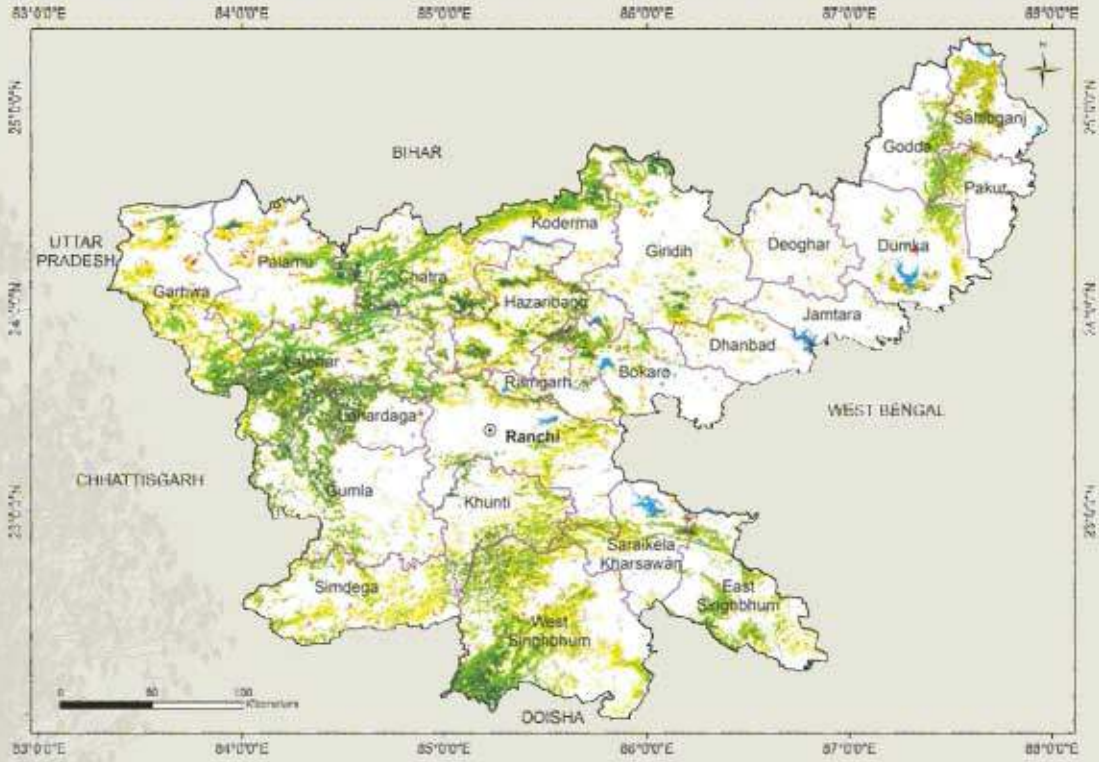


Figure 13.11.3 Forest Cover Map of Jharkhand

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.11.2 Forest Types

The Area under different forest types of Jharkhand as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

JHARKHAND

Table 13.11.8 Area statistics of the Forest Types found in Jharkhand (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3C/C2a (ii) Moist peninsular low level sal	566.05	2.33
2.	3C/C2e (iii) Moist peninsular valley sal	64.47	0.27
3.	5B/C1c Dry peninsular sal forest	12,969.73	53.37
4.	5B/C2 Northern dry mixed deciduous forest	8,283.65	34.09
5.	5/DS1 Dry deciduous scrub	815.38	3.36
6.	5/E2 *Boswellia* forest	11.06	0.05
7.	5/E5 *Butea* forest	1.03	0.00
8.	5/E9 Dry bamboo brakes	131.64	0.54
	Sub Total	**22,843.21**	**94.01**
9.	TOF/Plantation	1,456.25	5.99
	Total (Forest Cover & Scrub)	**24,299.46**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

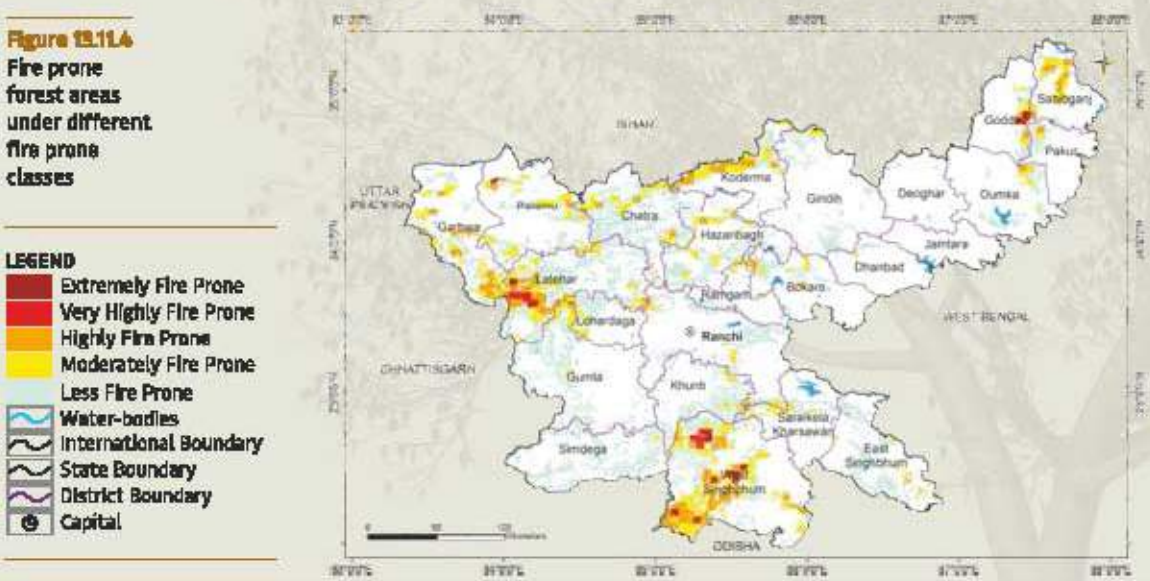
Table 13.11.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	47.36	0.20
2.	Very highly fire prone	480.45	2.03
3.	Highly fire prone	2,159.16	9.10
4.	Moderately fire prone	4,227.02	17.82
5.	Less fire prone	16,807.01	70.85
	Total	**23,721.00**	**100.00**

13.11.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Figure 13.11.4 Fire prone forest areas under different fire prone classes



13.11.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Jharkhand has been estimated as given in following table.

Table 13.11.10 Tree Cover in Jharkhand (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
2,657	2,867	210

13.11.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.1.11 Extent of TOF in Jharkhand (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
11,439	2,867	14,306

13.11.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Jharkhand is given in the Table 13.11.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.11.13.

Table 13.11.12 Growing Stock in Jharkhand (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	96.22	100.80	4.58	2.30
2.	Growing Stock in TOF	71.93	74.35	2.42	4.18

JHARKHAND

Table 13.11.13 Diameter class distribution of top five tree species inside RFA in Jharkhand (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Shorea robusta*	1,81,819	12,537	834
2.	*Terminalia tomentosa*	21,830	2,778	128
3.	*Madhuca latifolia*	16,832	3,596	422
4.	*Anogeissus latifolia*	16,487	1,375	0
5.	*Lagerstroemia parviflora*	18,217	1,559	0

13.11.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Jharkhand in Rural and Urban areas are given in the Table 13.11.14 and Table 13.11.15 respectively.

Table 13.11.14 Top five tree species in TOF (Rural) in Jharkhand

Sl. No.	Species	Relative Abundance (%)
1.	*Shorea robusta*	12.37
2.	*Butea monosperma*	10.28
3.	*Acacia auriculiformis*	8.25
4.	*Mangifera indica*	7.41
5.	*Phoenix sylvestris*	6.26

Table 13.11.15 Top five tree species in TOF (Urban) in Jharkhand

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	11.71
2.	*Azadirachta indica*	7.75
3.	*Moringa spp.*	7.53
4.	*Cassia siamea*	7.08
5.	*Artocarpus heterophyllus*	4.90

13.11.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 184.81 million tonnes (677.64 million tonnes of CO_2 equivalent) which is 2.57 % of total forest carbon of the country. Pool wise forest carbon in Jharkhand is given in the following table.

Table 13.1.16 Forest Carbon in Andhra Pradesh in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	51,017
2.	BGB	20,189
3.	Dead wood	774
4.	Litter	2,536
5.	SOC	1,09,665
	Total	**1,84,811**

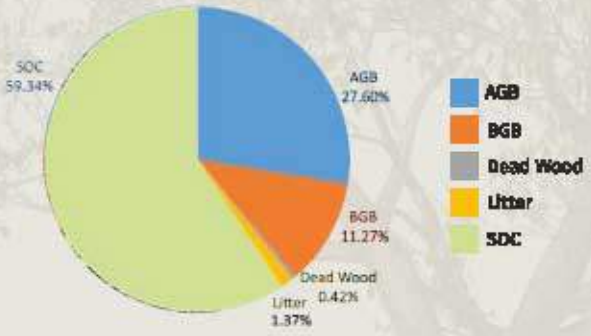


Figure 13.11.5 Forest Carbon in Jharkhand

13.11.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.11.17 Growing Stock of Bamboo in Jharkhand

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	3,717	2.49
Total number of culms (in millions)	996	1.87
Total equivalent green weight (in '000 tonnes)	6,147	1.53

13.11.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.11.18 and Table 13.11.19 respectively.

Table 13.11.18 Major NTFP species in Jharkhand

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Shorea robusta*	Tree	66.89
2.	*Buchanania lanzan*	Tree	7.63
3.	*Madhuca indica*	Tree	7.25
4.	*Diospyros melanoxylon*	Tree	5.14
5.	*Butea monosperma*	Tree	4.15

Table 13.11.19 Major invasive species in the State inside the RFA/Green Wash in Jharkhand (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	342
2.	*Chromolaena odorata*	85
3.	*Ageratum houstonianum*	18
4.	*Acacia farnesiana*	14
5.	*Imperata cylindrica*	3

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.12 KARNATAKA

Geographical Area
1,91,791 sq km

Geographical Coordinates
Latitude- 11° 30' N to 18° 30' N
Longitude- 74° 00' E to 78° 30' E

Population (as per Census 2011)
61.10 million
Urban 23.63 million (38.67%)
Rural 37.47 million (61.33%)
Tribal 4.25 million (6.96%)

Average Population Density
319 per sq km

Livestock population
(as per 19th Live Stock Census)
27.70 million

No. of Districts
30

No. of Hill Districts
6

No. of Tribal Districts
5

Table 13.12.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	19,179	
Reporting area for land utilization	19,050	100.00
Forests	3,073	16.13
Not available for land cultivation	2,294	12.04
Permanent pastures and other grazing lands	905	4.75
Land under misc. tree crops and groves	274	1.44
Culturable wasteland	400	2.10
Fallow land other than current fallows	688	3.61
Current fallows	1,521	7.99
Net area sown	9,895	51.94

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.12.1 Forest Cover

Figure 13.12.1
Forest Cover
of Karnataka

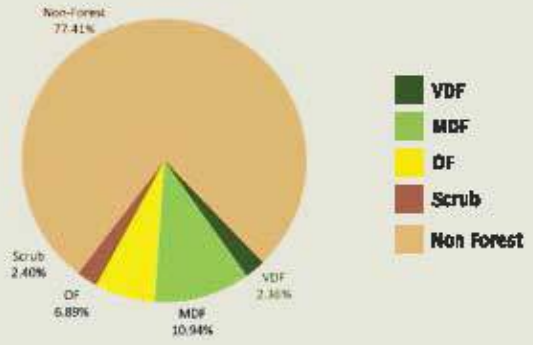


Table 13.12.2 Forest Cover of Karnataka (in sq km)

Class	Area	% of GA
VDF	4,532.94	2.36
MDF	20,984.85	10.94
OF	13,212.20	6.89
Total	**38,729.99**	**20.19**
Scrub	4,610.76	2.40

Table 13.12.3 District- wise Forest Cover in Karnataka (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Bagalkot	6,552	0.00	18.99	238.24	257.23	3.93	4.26	393.02
Ballari	8,461	0.00	110.19	627.30	737.49	8.72	-1.73	485.08
Belagavi[H]	13,433	35.99	736.99	392.68	1,165.66	8.68	24.06	671.67
Bengaluru	2,196	0.00	24.88	263.60	288.48	13.14	1.05	7.45
Bengaluru Rural	2,298	0.00	24.04	133.98	158.02	6.88	-4.73	27.00
Bidar	5,448	0.00	21.46	76.10	97.58	1.79	9.16	46.28
Chamarajanagar	5,648	93.19	1,525.16	1,112.85	2,731.20	48.36	7.01	125.82
Chikkamagaluru[TH]	7,202	901.63	2,584.95	478.92	3,965.50	55.06	13.72	77.10
Chikkaballapura	4,244	0.00	19.73	255.59	275.32	6.49	5.62	184.37
Chitradurga	8,436	0.00	47.06	559.94	607.00	7.20	30.39	618.33
Dakshina Kannada[TH]	4,861	557.88	1,471.73	1,035.37	3,064.98	63.05	0.32	2.85
Davanagere	5,924	11.00	167.02	535.56	713.58	12.05	4.01	323.80
Dharwad	4,260	0.00	223.71	151.20	374.91	8.80	0.49	3.52
Gadag	4,657	0.00	0.23	140.82	141.05	3.03	-0.57	117.63
Hassan	6,814	147.67	771.51	565.63	1,484.81	21.79	6.37	73.39
Haveri	4,823	0.00	144.76	202.37	347.13	7.20	3.88	102.29
Kalaburagi	10,954	0.00	91.93	102.96	194.89	1.78	-0.16	40.89
Kodagu[TH]	4,102	794.32	1,886.30	577.29	3,257.91	79.42	-5.47	2.16
Kolar	3,979	0.00	58.05	325.67	383.72	9.64	2.33	67.95
Koppal	5,570	0.00	0.00	35.96	35.96	0.65	2.64	168.95
Mandya	4,962	0.00	114.15	394.18	508.33	10.24	9.01	103.68
Mysuru[T]	6,307	124.96	586.74	351.35	1,063.05	16.86	10.22	36.02
Raichur	8,442	0.00	0.94	43.29	44.23	0.52	0.00	184.91
Ramanagara	3,516	0.00	196.71	477.30	674.01	19.17	9.32	176.23
Shivamogga[H]	8,478	481.89	2,827.90	963.39	4,273.18	50.40	2.40	22.33
Tumakuru	10,597	0.00	72.34	1,250.73	1,323.07	12.49	39.03	402.96
Udupi[T]	3,582	216.53	1,383.74	656.46	2,256.73	63.00	-26.65	0.00
Uttara Kannada[H]	10,277	1,167.88	5,856.60	1,106.46	8,130.94	79.12	7.19	3.49
Vijayapura	10,498	0.00	0.00	27.12	27.12	0.26	2.07	8.71
Yadgir	5,270	0.00	17.02	129.89	146.91	2.79	-0.73	132.88
Grand Total	**1,91,791**	**4,532.94**	**20,984.85**	**13,212.20**	**38,729.99**	**20.19**	**154.51**	**4,610.76**

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13.12.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.12.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Karnataka (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
3,679	12,721	6,148	22,548	854	8,264	7,064	16,182
16.32%	56.41%	27.27%		5.28%	51.07%	43.65%	

*In case of Karnataka, RFA boundaries have been used.

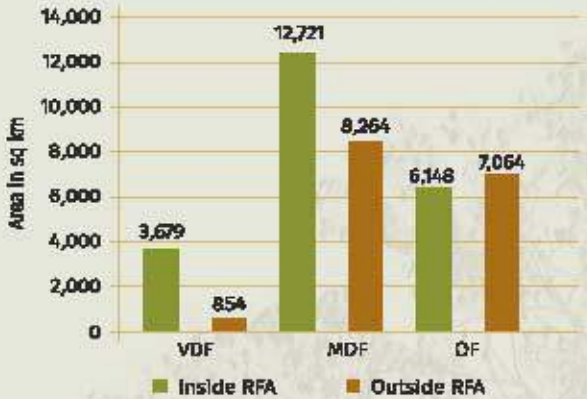

Figure 13.12.2 Forest Cover Inside and Outside of RFA in Karnataka

Table 13.12.5 Forest Cover Change Matrix for Karnataka (In sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	4,499	0	0	0	2	4,501
Moderately Dense Forest	34	20,954	2	0	58	21,048
Open Forest	0	12	12,898	19	97	13,026
Scrub	0	1	71	4,381	31	4,484
Non Forest	0	18	241	211	1,48,262	1,48,732
Total ISFR 2021	**4,533**	**20,985**	**13,212**	**4,611**	**1,48,450**	**1,91,791**
Net Change	32	-63	186	127	-282	

Table 13.12.6 Altitude-wise Forest Cover in Karnataka (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	41,511	1,457	5,755	2,917	10,129	318
500-1000	1,46,593	2,618	13,490	9,789	25,897	4,213
1000-2000	3,687	458	1,740	506	2,704	80
Total	**1,91,791**	**4,533**	**20,985**	**13,212**	**38,730**	**4,611**

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

Table 13.12.7 Forest Cover in different slope classes in Karnataka (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,61,569	949	9,552	8,576	19,077	2,686
5-10	15,763	978	5,364	2,408	8,750	1,004
10-15	6,715	905	2,890	900	4,695	387
15-20	3,796	721	1,640	618	2,979	275
20-25	2,122	482	848	370	1,700	158
25-30	1,085	259	450	203	912	73
>30	741	239	241	137	617	28
Total	**1,91,791**	**4,533**	**20,985**	**13,212**	**38,730**	**4,611**

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

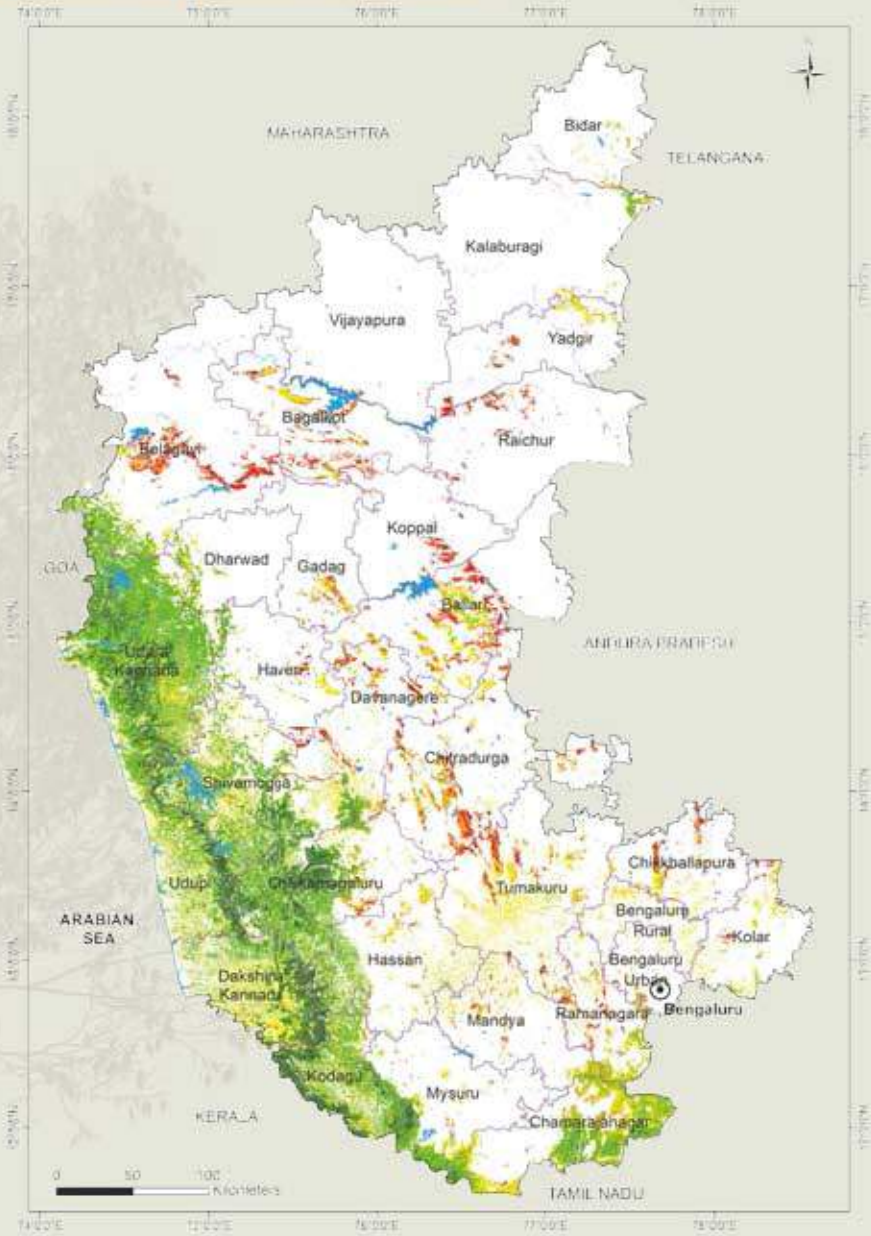

Figure 13.12.3 Forest Cover Map of Karnataka

13.12.2 Forest Types

The Area under different forest types of Karnataka as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

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Table 13.12.8 Area statistics of the Forest Types found in Karnataka (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1A/C4 West Coast tropical evergreen forest	5,143.60	11.91
2.	2A/C2 West Coast semi-evergreen forest	4,366.52	10.11
3.	2A/2S1 West Coast secondary evergreen Dipterocarp forest	326.31	0.76
4.	2/E3 Moist bamboo brakes	1.79	0.00
5.	2/E4 Lateritic semi-evergreen forest	155.60	0.36
6.	3B/C1a Very moist teak forest	84.59	0.20
7.	3B/C1b Moist teak forest	1,771.05	4.10
8.	3B/C1c Slightly moist teak forest	942.15	2.18
9.	3B/C2 Southern moist mixed deciduous forest	4,718.62	10.93
10.	3B/C2/2S1 Southern secondary moist mixed deciduous forest	657.51	1.52
11.	4B/TS1 Mangrove scrub	10.04	0.02
12.	5A/C1a Very dry teak forest	20.47	0.05
13.	5A/C1b Dry teak forest	2,427.23	5.62
14.	5A/C3 Southern dry mixed deciduous forest	3,093.68	7.17
15.	5/DS1 Dry deciduous scrub	2,950.85	6.83
16.	5/E4 *Hardwickia* forest	409.55	0.95
17.	5/E7 Laterite thorn forest	122.34	0.28
18.	5/2S1 Secondary dry deciduous forest	37.43	0.09
19.	6A/C1 Southern thorn forest	1,891.25	4.39
20.	6A/DS1 Southern thorn scrub	3,220.54	7.46
21.	8A/C1 Nilgiri subtropical hill forest	364.46	0.84
	Sub Total	**32,715.58**	**75.77**
22.	TOF/Plantation	10,343.97	23.96
	Total (Forest Cover & Scrub)	**43,059.55**	
	Grassland forest types (outside forest cover)		
23.	5/DS4 Dry grassland	51.11	0.12
24.	8A/C1/DS1 South Indian sub-tropical hill savannah (woodland)	66.82	0.15
	Sub Total	**117.93**	**0.27**
	Grand Total	**43,177.48**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

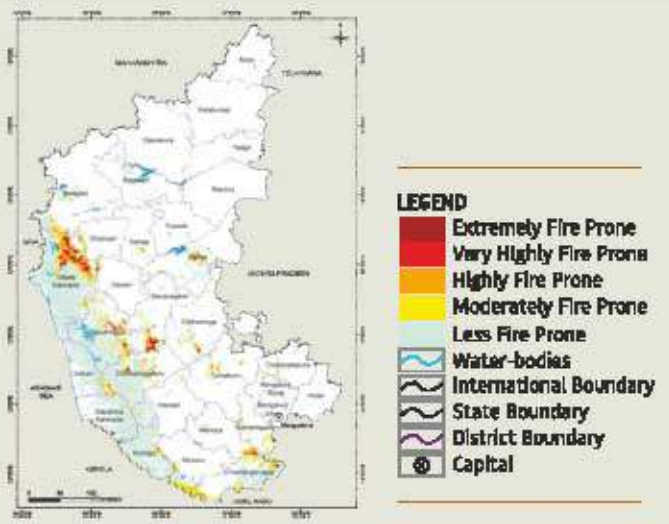
Table 13.12.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	71.58	0.18
2.	Very highly fire prone	930.93	2.40
3.	Highly fire prone	2,506.25	6.47
4.	Moderately fire prone	2,989.30	7.72
5.	Less fire prone	32,231.94	83.23
	Total	**38,730.00**	**100.00**

13.12.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Figure 13.12.4
Fire prone forest areas under different fire prone classes



13.12.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Karnataka has been estimated as given in following table.

Table 13.12.10 Tree Cover in Karnataka (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
6,257	7,494	1,237

13.12.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.12.11 Extent of TOF in Karnataka (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
16,182	7,494	23,676

13.12.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Karnataka is given in the Table 13.12.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.12.13.

Table 13.12.12 Growing Stock in Karnataka (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	334.08	302.14	-31.94	6.89
2.	Growing Stock in TOF	103.03	121.72	18.69	6.84

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Table 13.12.13 Diameter class distribution of top five tree species inside RFA in Karnataka (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Terminalia paniculata*	44,233	12,727	2,690
2.	*Tectona grandis*	36,695	8,889	796
3.	*Xylia xylocarpa*	29,607	8,914	700
4.	*Terminalia tomentosa*	28,690	8,335	1,446
5.	*Lagerstroemia lanceolata*	10,310	5,209	1,008

13.12.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Karnataka in Rural and Urban areas are given in the Table 13.12.14 and Table 13.12.15 respectively.

Table 13.12.14 Top five tree species in TOF (Rural) in Karnataka

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	22.99
2.	*Cocos nucifera*	12.81
3.	*Azadirachta indica*	11.66
4.	*Mangifera indica*	6.11
5.	*Acacia auriculiformis*	3.74

Table 13.12.15 Top five tree species in TOF (Urban) in Karnataka

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	24.80
2.	*Areca catechu*	21.01
3.	*Acacia auriculiformis*	4.93
4.	*Mangifera indica*	4.61
5.	*Tectona grandis*	3.55

13.12.7 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 376.40 million tonnes (1,380.13 million tonnes of CO_2 equivalent) which is 5.22 % of total forest carbon of the country. Pool wise forest carbon in Karnataka is given in the following table.

Table 13.12.16 Forest Carbon in Karnataka in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,22,741
2.	BGB	36,716
3.	Dead wood	2,890
4.	Litter	6,380
5.	SOC	2,07,668
	Total	**3,76,395**

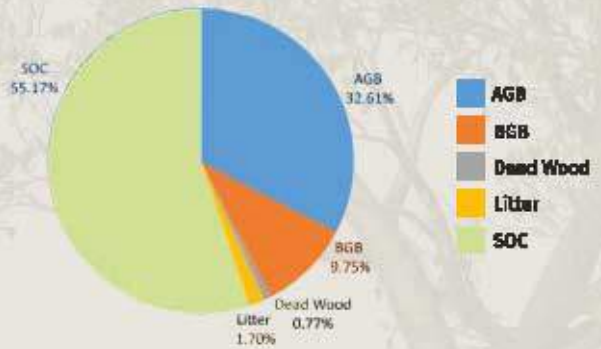

Figure 13.12.5 Forest Carbon in Karnataka

13.12.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.12.17 Growing Stock of Bamboo in Karnataka

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	8,624	5.77
Total number of culms (in millions)	2,653	4.97
Total equivalent green weight (in '000 tonnes)	35,008	8.71

13.12.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.12.18 and Table 13.12.19 respectively.

Table 13.12.18 Major NTFP species in Karnataka

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Cymbopogan citrates*	Herbs	45.51
2.	*Piper spp./Piper longum/ Piper mullesua*	Climber	19.55
3.	*Asparagus racemosa*	Climber	13.78
4.	*Curcuma aromatica*	Herbs	7.69
5.	*Ocimum spp. (Ocimum gratissimum/Ocimum sanctum /Ocimum tenuiflorum/ Ocimum americanum)*	Herbs	6.41

Table 13.12.19 Major invasive species in the State inside the RFA/Green Wash in Karnataka (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	1,432
2.	*Chromolaena odorata*	1,243
3.	*Ageratum conyzoides*	70
4.	*Acacia farnesiana*	61
5.	*Cassia tora*	54

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.13 KERALA

Geographical Area
38,852 sq km

Geographical Coordinates
Latitude- 8° 17' N to 12° 47' N
Longitude- 74° 52' E to 77° 24' E

Population (as per Census 2011)
33.41 million
Urban 15.94 million (47.70%)
Rural 17.47 million (52.30%)
Tribal 0.48 million (1.45%)

Average Population Density
860 per sq km

Livestock population
(as per 19th Live Stock Census)
2.73 million

No. of Districts
14

No. of Hill Districts
10

No. of Tribal Districts
9

Table 13.13.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	3,886	
Reporting area for land utilization	3,886	100.00
Forests	1,082	27.84
Not available for land cultivation	559	14.38
Permanent pastures and other grazing lands	-	-
Land under misc. tree crops and groves	2	0.05
Culturable wasteland	96	2.47
Fallow land other than current fallows	49	1.27
Current fallows	58	1.49
Net area sown	2,040	52.50

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.13.1 Forest Cover

Figure 13.13.1
Forest Cover of Kerala

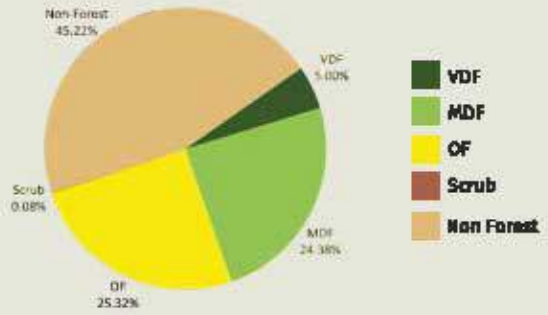

Table 13.13.2 Forest Cover of Kerala (In sq km)

Class	Area	% of GA
VDF	1,944.32	5.00
MDF	9,472.00	24.38
OF	9,837.17	25.32
Total	**21,253.49**	**54.70**
Scrub	29.90	0.08

Table 13.13.3 District-wise Forest Cover in Kerala (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				% of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Alappuzha	1,415	0.00	27.00	53.54	80.54	5.69	0.64	0.00
Ernakulam[TR]	3,063	165.52	614.40	604.56	1,384.48	45.20	18.77	5.60
Idukki[TR]	4,356	355.72	1,783.33	1,016.27	3,155.32	72.44	4.67	2.51
Kannur[TR]	2,961	58.00	489.63	1,121.23	1,668.86	56.36	14.89	0.18
Kasaragod[TR]	1,989	1.90	288.70	692.97	983.57	49.45	17.09	0.00
Kollam[TR]	2,483	104.40	656.88	572.50	1,333.78	53.72	11.27	0.00
Kottayam	2,206	11.31	525.73	562.01	1,099.05	49.82	-5.24	0.00
Kozhikode[TR]	2,345	70.77	409.94	967.11	1,447.82	61.74	10.85	0.80
Malappuram[TR]	3,554	142.67	424.68	1,416.32	1,983.67	55.82	2.34	6.47
Palakkad[TR]	4,482	402.14	637.77	1,063.77	2,103.68	46.94	20.09	12.71
Pathanamthitta	2,652	164.92	1,229.12	554.88	1,948.92	73.49	-6.60	0.51
Thiruvananthapuram[TR]	2,189	59.12	702.42	555.50	1,317.04	60.17	13.11	0.07
Thrissur	3,027	218.86	477.79	469.60	1,166.25	38.53	7.03	0.62
Wayanad[TR]	2,130	188.99	1,204.61	186.91	1,580.51	74.20	0.29	0.43
Grand Total	**38,852**	**1,944.32**	**9,472.00**	**9,837.17**	**21,253.49**	**54.70**	**109.20**	**29.90**

13.13.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

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Table 13.13.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Kerala (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
1,804	5,299	2,576	9,679	140	4,173	7,261	11,574
18.64%	54.75%	26.61%		1.21%	36.05%	62.74%	

**In case of Kerala, RFA boundaries have been used*

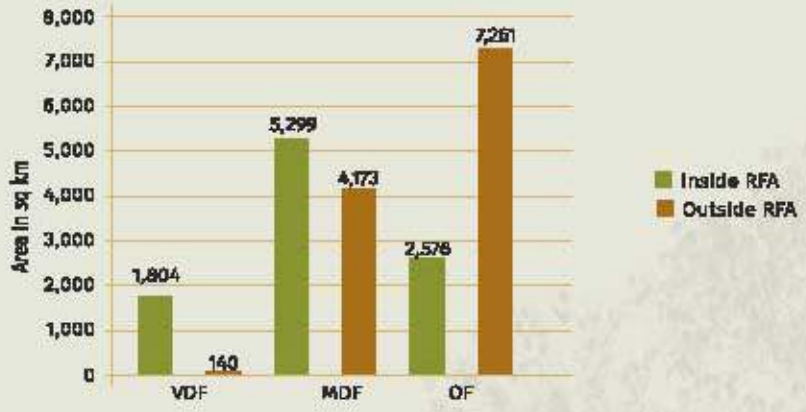

Figure 13.13.2 Forest Cover Inside and Outside of RFA in Kerala

Table 13.13.5 Forest Cover Change Matrix for Kerala (in sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	1,928	5	1	0	1	1,935
Moderately Dense Forest	15	9,423	35	0	35	9,508
Open Forest	0	1	9,604	1	95	9,701
Scrub	0	0	0	13	0	13
Non Forest	1	43	197	16	17,438	17,695
Total ISFR 2021	**1,944**	**9,472**	**9,837**	**30**	**17,569**	**38,852**
Net Change	9	-36	136	17	-126	

Table 13.13.6 Altitude-wise Forest Cover in Kerala (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	28,678	178	5,193	7,985	13,356	13
500-1000	6,478	837	2,889	1,167	4,893	8
1000-2000	3,441	750	1,343	650	2,743	4
2000-3000	255	179	47	35	261	5
Total	**38,852**	**1,944**	**9,472**	**9,837**	**21,253**	**30**

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

Table 13.13.7 Forest Cover in different slope classes in Kerala (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	17,923	169	2,206	3,913	6,288	7
5-10	8,347	271	2,268	2,623	5,162	5
10-15	4,607	322	1,713	1,432	3,467	4
15-20	3,051	335	1,271	866	2,472	4
20-25	2,137	305	932	544	1,781	4
25-30	1,402	236	616	319	1,171	4
>30	1,385	306	466	140	912	2
Total	**38,852**	**1,944**	**9,472**	**9,837**	**21,253**	**30**

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

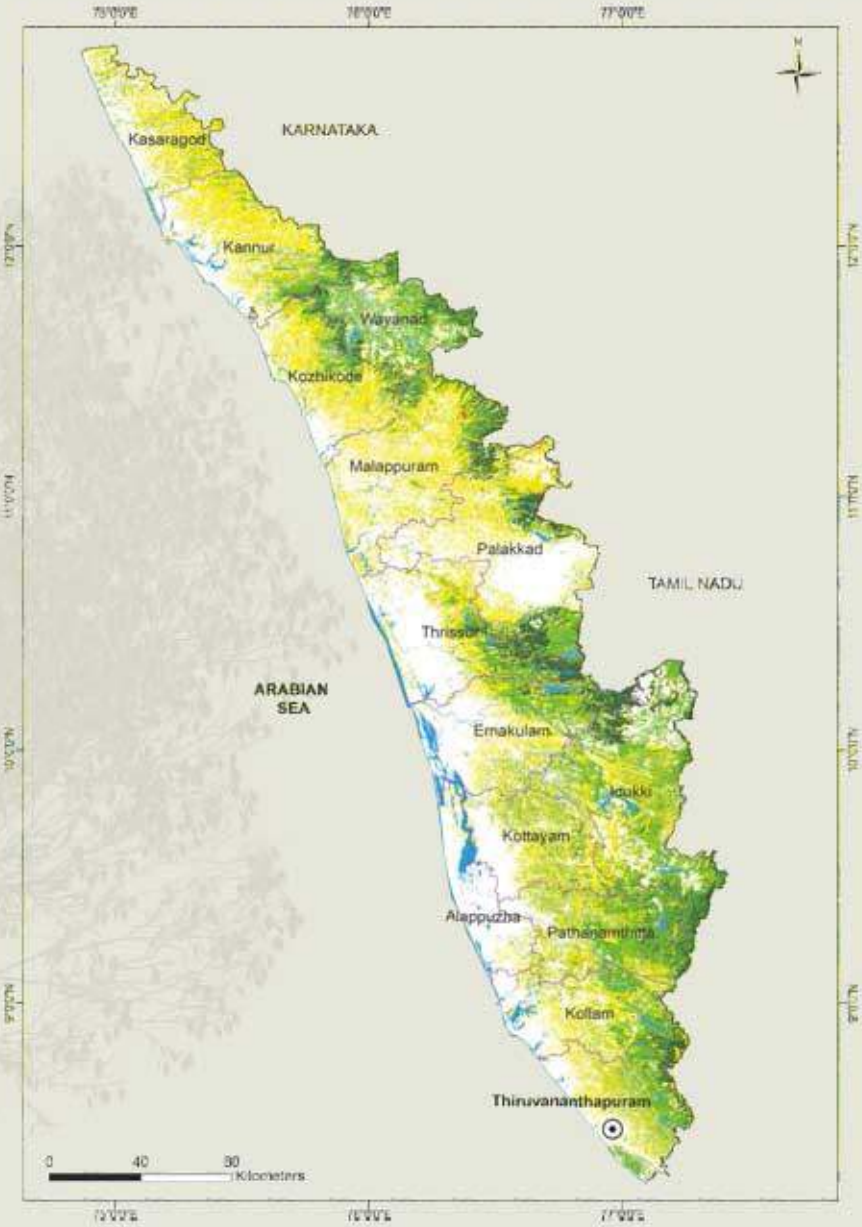

Figure 13.13.3
Forest Cover Map of Kerala

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.13.2 Forest Types

The Area under different forest types of Kerala as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

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Table 13.13.8 Area statistics of the Forest Types found in Kerala (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1A/C3 Southern hilltop tropical evergreen forest	294.34	1.38
2.	1A/C4 West Coast tropical evergreen forest	3,005.85	14.10
3.	1/E2 Wet bamboo brakes	25.04	0.12
4.	1/2S1 Pioneer Euphorbiaceous scrub	18.60	0.09
5.	2A/C2 West Coast semi-evergreen forest	2,664.21	12.50
6.	3B/C1a Very moist teak forest	162.58	0.76
7.	3B/C1b Moist teak forest	130.69	0.61
8.	3B/C1c Slightly moist teak forest	442.38	2.07
9.	3B/C2 Southern moist mixed deciduous forest	1,704.93	8.00
10.	4B/TS2 Mangrove forest	8.90	0.04
11.	4C/FS1 *Myristica* swamp forest	1.56	0.01
12.	5A/C3 Southern dry mixed deciduous forest	331.95	1.56
13.	6A/C1 Southern thorn forest	1.03	0.00
14.	11A/C1 Southern montane wet temperate forest	303.98	1.43
	Sub Total	**9,096.04**	**42.67**
15.	TOF/Plantation	12,061.62	56.58
	Total (Forest Cover & Scrub)	**21,157.66**	
	Grassland forest types (outside forest cover)		
16.	5/DS4 Dry grassland	11.41	0.05
17.	11A/C1/DS2 Southern montane wet grassland	149.12	0.70
	Sub Total	**160.53**	**0.75**
	Grand Total	**21,318.19**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

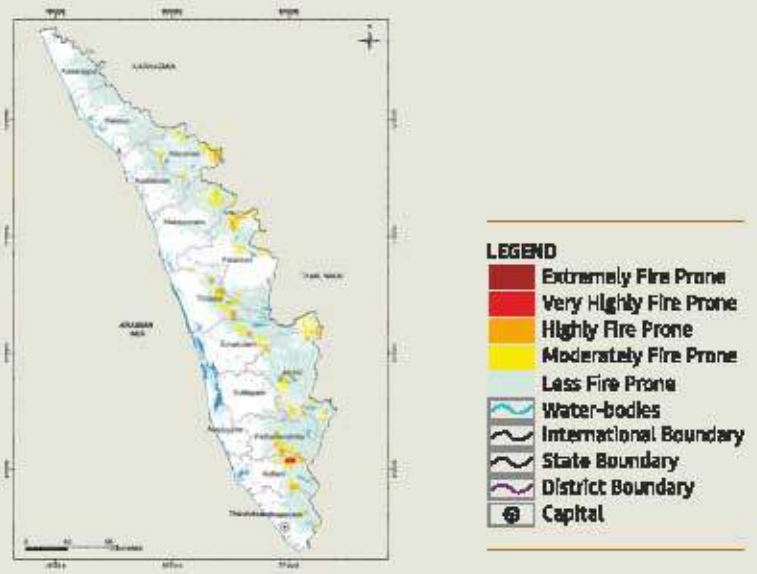
13.13.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.13.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	54.79	0.26
3.	Highly fire prone	461.06	2.17
4.	Moderately fire prone	1,266.42	5.96
5.	Less fire prone	19,470.73	91.61
	Total	**21,253.00**	**100.00**

Figure 13.13.4
Fire prone forest areas under different fire prone classes



13.13.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Kerala has been estimated as given in following table.

Table 13.13.10 Tree Cover in Kerala (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
2,936	2,820	-116

13.13.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.13.11 Extent of TOF in Kerala (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
11,574	2,820	14,394

13.13.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Kerala is given in the Table 13.13.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.13.13.

Table 13.13.12 Growing Stock in Kerala (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	147.10	160.53	13.43	3.66
2.	Growing Stock in TOF	55.26	61.04	5.78	3.43

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Table 13.13.13 Diameter class distribution of top five tree species inside RFA in Kerala (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Tectona grandis*	12,882	5,220	391
2.	*Terminalia paniculata*	9,523	4,809	1,455
3.	*Xylia xylocarpa*	10,490	3,941	498
4.	*Syzygium cumini/ jambolanum(Old)/ Eugenia jambolana*	4,159	1,677	546
5.	*Lagerstroemia lanceolata/ Indica*	1,455	1,323	601

13.13.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Kerala in Rural and Urban areas are given in the Table 13.13.14 and Table 13.13.15 respectively.

Table 13.13.14 Top five tree species in TOF (Rural) in Kerala

Sl. No.	Species	Relative Abundance (%)
1.	*Hevea brasiliensis*	36.01
2.	*Areca catechu*	17.83
3.	*Cocos nucifera*	12.21
4.	*Artocarpus heterophyllus*	4.09
5.	*Swietenia mahagoni*	3.09

Table 13.13.15 Top five tree species in TOF (Urban) in Kerala

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	33.84
2.	*Areca catechu*	13.42
3.	*Hevea brasiliensis*	8.39
4.	*Mangifera indica*	6.67
5.	*Artocarpus heterophyllus*	6.37

13.13.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 205.52 million tonnes (753.57 million tonnes of CO_2 equivalent) which is 2.85 % of total forest carbon of the country. Pool wise forest carbon in Kerala is given in the following table.

Table 13.13.16 Forest Carbon in Kerala in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	61,802
2.	BGB	17,440
3.	Dead wood	1,534
4.	Litter	3,198
5.	SOC	1,21,549
	Total	**2,05,523**

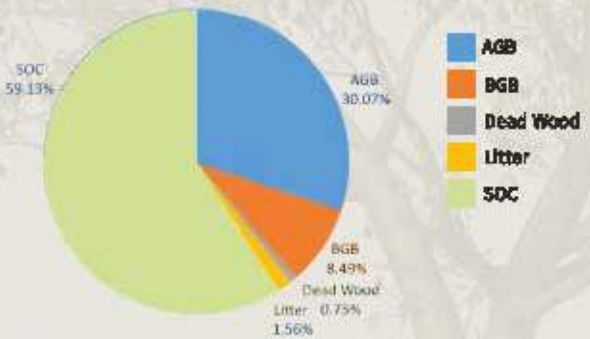

Figure 13.13.5 Forest Carbon in Kerala

13.13.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.13.17 Growing Stock of Bamboo in Kerala

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	2,404	1.61
Total number of culms (in millions)	1,087	2.04
Total equivalent green weight (in '000 tonnes)	14,681	3.65

13.13.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.13.18 and Table 13.13.19 respectively.

Table 13.13.18 Major NTFP Species in Kerala

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Hydrocotyle asiatica*	Herbs	52.01
2.	*Piper spp./Piper longum/Piper mullesua*	Climber	29.93
3.	*Curcuma zedoaria*	Herbs	3.68
4.	*Rubia cordifolia*	Climber	3.01
5.	*Phyllanthus amarus*	Herbs	2.68

Table 13.13.19 Major invasive species in the State inside the RFA/Green wash in Kerala (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	362
2.	*Lantana camara*	87
3.	*Ageratum conyzoides*	29
4.	*Ageratina adenophora*	9
5.	*Mikania micrantha*	3

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.14 MADHYA PRADESH

Geographical Area
3,08,252 sq km

Geographical Coordinates
Latitude- 21° 17' N to 26° 52' N
Longitude- 74° 08' E to 82°49' E

Population (as per Census 2011)
72.63 million
Urban 20.07 million (27.63 %)
Rural 52.56 million (72.37 %)
Tribal 15.32 million (21.09 %)

Average Population Density
236 per sq km

Livestock population
(as per 19th Live Stock Census)
36.33 million

No. of Districts
50

No. of Hill Districts
0

No. of Tribal Districts
24

Table 13.14.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	30,825	
Reporting area for land utilization	30,756	100.00
Forests	8,708	28.31
Not available for land cultivation	3,504	11.39
Permanent pastures and other grazing lands	1,337	4.35
Land under misc. tree crops and groves	20	0.07
Culturable wasteland	967	3.14
Fallow land other than current fallows	486	1.58
Current fallows	543	1.77
Net area sown	15,191	49.39

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.14.1 Forest Cover

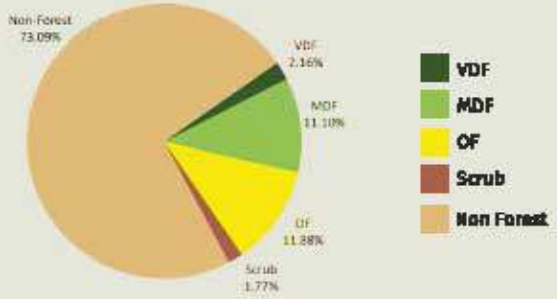

Figure 13.14.1 Forest Cover of Madhya Pradesh

Table 13.14.2 Forest Cover of Madhya Pradesh (In sq km)

Class	Area	% of GA
VDF	6,664.95	2.16
MDF	34,209.02	11.10
OF	36,618.63	11.88
Total	**77,492.60**	**25.14**
Scrub	5,456.55	1.77

Table 13.14.3 District- wise Forest Cover in Madhya Pradesh (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				% of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Alirajpur[T]	3,182	0.00	207.29	474.06	681.35	21.41	-3.07	29.72
Anuppur[T]	3,747	108.31	337.50	411.66	857.47	22.88	-11.21	46.23
Ashoknagar	4,674	0.00	265.93	421.32	687.25	14.70	-1.79	123.91
Balaghat[T]	9,229	1,407.64	2,630.88	884.26	4,922.78	53.34	-9.28	28.06
Barwani[T]	5,427	0.00	186.79	717.57	904.36	16.66	-23.63	33.67
Betul[T]	10,043	230.11	1,922.32	1,510.36	3,662.79	36.47	-0.91	157.62
Bhind	4,459	0.00	28.08	198.48	226.56	5.08	119.81	283.24
Bhopal	2,772	0.00	120.77	207.79	328.56	11.85	-0.11	70.31
Burhanpur	3,427	57.92	625.89	603.75	1,287.56	37.57	-7.00	37.74
Chhatarpur	8,687	184.01	817.24	755.89	1,757.14	20.23	-1.41	282.18
Chhindwara[T]	11,815	575.68	2,021.61	2,010.84	4,608.13	39.00	20.12	284.14
Damoh	7,306	2.00	844.92	1,739.79	2,586.71	35.41	-0.47	126.22
Datia	2,902	0.00	91.13	121.65	212.78	7.33	10.50	68.07
Dewas[T]	7,020	12.00	935.21	1,000.06	1,947.27	27.74	-8.60	43.44
Dhar[T]	8,153	0.00	115.64	528.62	644.26	7.90	-6.99	81.95
Dindori[T]	7,470	1,084.98	1,271.24	666.21	3,022.43	40.46	-9.53	123.13
East Nimar[T]	7,352	147.80	1,153.11	784.48	2,085.39	28.36	-3.73	21.94
Guna	6,390	2.00	414.00	911.50	1,327.50	20.77	-2.24	156.80
Gwalior	4,560	1.00	323.69	902.14	1,226.83	26.90	5.65	132.71
Harda[T]	3,334	19.00	523.70	396.61	939.31	28.17	-16.95	3.06
Hoshangabad[T]	6,703	271.64	1,366.15	783.41	2,421.20	36.12	-1.45	9.34
Indore	3,898	0.00	348.10	326.51	674.61	17.31	-4.12	21.69
Jabalpur[T]	5,211	40.26	501.04	560.53	1,101.83	21.14	-12.10	106.51
Jhabua[T]	3,600	0.00	30.69	189.52	220.21	6.12	-1.46	160.07
Katni	4,950	93.90	607.87	654.85	1,356.62	27.41	-4.68	36.16
Mandla[T]	5,800	691.78	1,092.55	792.65	2,576.98	44.43	-0.53	36.93
Mandsaur	5,535	0.00	42.01	198.67	240.68	4.35	-0.91	108.31
Morena[T]	4,989	0.00	96.12	665.55	761.67	15.27	21.50	367.86

MADHYA PRADESH

(In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Narsinghpur	5,133	61.00	655.81	623.97	1,340.78	26.12	-1.98	90.26
Neemuch	4,256	0.04	119.22	669.74	789.00	18.54	-6.69	387.01
Panna	7,135	82.95	1476.06	1,189.59	2,748.60	38.52	5.89	190.67
Raisen	8,466	22.55	1,302.18	1,346.59	2,671.32	31.55	-4.94	142.75
Rajgarh	6,153	0.00	37.86	133.94	171.80	2.79	-0.29	78.14
Ratlam[T]	4,861	0.00	2.53	72.63	75.16	1.55	15.31	111.54
Rewa	6,314	60.91	377.18	363.11	801.20	12.69	20.05	97.12
Sagar	10,252	1.00	1,138.81	1,645.43	2,785.24	27.17	-9.30	186.83
Satna	7,502	12.00	904.19	835.33	1,751.52	23.35	-1.38	165.39
Sehore	6,578	20.70	614.84	714.61	1,350.15	20.53	-7.75	53.85
Seoni[T]	8,758	237.07	1,787.12	1,038.84	3,063.03	34.97	-6.56	70.51
Shahdol[T]	6,205	122.03	818.26	1,014.41	1,954.70	31.50	-16.01	44.25
Shajapur	6,195	0.00	2.44	59.47	61.91	1.00	-1.44	64.90
Sheopur[T]	6,606	6.00	1,394.25	2,043.66	3,443.91	52.13	-16.09	130.51
Shivpuri	10,066	18.00	779.39	1,749.14	2,546.53	25.30	6.61	209.74
Sidhi[T]	4,851	315.96	881.29	805.27	2,002.52	41.28	33.36	47.02
Singrauli[T]	5,675	393.73	992.29	776.84	2,162.86	38.11	-17.27	54.41
Tikamgarh	5,048	1.00	89.73	295.58	386.31	7.65	-0.33	135.96
Ujjain	6,091	0.00	2.60	34.10	36.70	0.60	0.48	55.83
Umaria[T]	4,076	377.98	1,092.66	530.60	2,001.24	49.10	-21.34	22.90
Vidisha	7,371	1.00	344.52	431.24	776.76	10.54	-0.70	89.85
West Nimar[T]	8,025	1.00	474.32	825.81	1,301.13	16.21	-4.93	46.10
Grand Total	**3,08,252**	**6,664.85**	**34,209.02**	**36,618.63**	**77,492.60**	**25.14**	**10.11**	**5,456.55**

13.13.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.14.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Madhya Pradesh (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
6,251	30,195	28,326	64,772	414	4,014	8,293	12,721
9.65%	46.62%	43.73%		3.25%	31.56%	65.19%	

**In case of Madhya Pradesh, RFA boundaries have been used.*

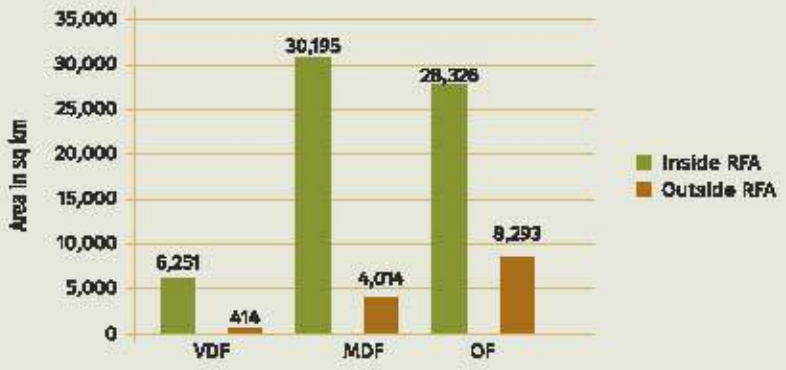

Figure 13.14.2 Forest Cover Inside and Outside of RFA in Madhya Pradesh

Table 13.14.5 Forest Cover Change Matrix for Madhya Pradesh (in sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	6,660	9	3	0	4	6,676
Moderately Dense Forest	5	34,165	51	4	116	34,341
Open Forest	0	24	35,875	71	495	36,465
Scrub	0	0	510	5,289	203	6,002
Non Forest	0	11	180	93	2,24,484	2,24,768
Total ISFR 2021	**6,665**	**34,209**	**36,619**	**5,457**	**2,25,302**	**3,08,252**
Net Change	-11	-132	154	-545	534	

Table 13.14.6 Altitude-wise Forest Cover in Madhya Pradesh (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	2,31,982	2,092	20,996	25,805	48,893	4,423
500-1000	75,712	4,461	13,063	10,726	28,250	1,027
1000-2000	558	112	150	88	350	7
Total	**3,08,252**	**6,665**	**34,209**	**36,619**	**77,493**	**5,457**

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

Table 13.14.7 Forest Cover in different slope classes in Madhya Pradesh (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	2,65,973	3,339	21,040	25,224	49,603	4,403
5-10	25,674	1,604	7,038	5,931	14,573	707
10-15	9,369	905	3,372	2,826	7,103	224
15-20	4,283	470	1,626	1,498	3,594	80
20-25	1,884	219	719	719	1,657	29
25-30	708	86	271	277	634	9
>30	361	42	143	144	329	5
Total	**3,08,252**	**6,665**	**34,209**	**36,619**	**77,493**	**5,457**

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

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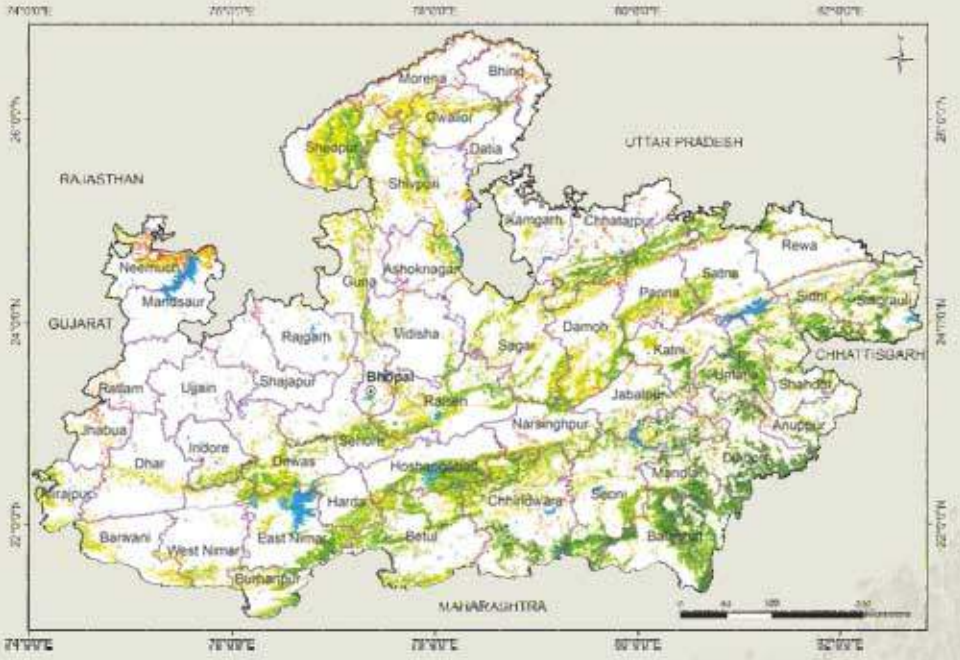

Figure 13.14.3
Forest Cover Map of Madhya Pradesh

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.14.2 Forest Types

The Area under different forest types of Madhya Pradesh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.14.8 Area statistics of the Forest Types found in Madhya Pradesh (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3B/C1c Slightly moist teak forest	1,889.89	2.26
2.	3B/C2 Southern moist mixed deciduous forest	1,909.35	2.28
3.	3C/C2e (I) Moist peninsular high level sal	2,746.69	3.29
4.	4E/RS1 Riparian fringing forest	15.07	0.02
5.	5A/C1a Very dry teak forest	712.34	0.85
6.	5A/C1b Dry teak forest	22,283.27	26.68
7.	5A/C3 Southern dry mixed deciduous forest	20,147.88	24.12
8.	5B/C1c Dry peninsular sal forest	4,152.12	4.97
9.	5B/C2 Northern dry mixed deciduous forest	15,752.36	18.86
10.	5/DS1 Dry deciduous scrub	5,468.47	6.55
11.	5/DS2 Dry savannah forest	1.15	0.00
12.	5/E1 *Anogeissus pendula* forest	2,813.01	3.37
13.	5/E1/DS1 *Anogeissus pendula* scrub	368.80	0.44
14.	5/E2 *Boswellia* forest	388.48	0.46
15.	5/E5 *Butea* forest	194.38	0.23
16.	5/E9 Dry bamboo brakes	734.60	0.88
17.	5/1S2 *Khair-sissu* forest	1,370.77	1.64
18.	6B/C2 Ravine thorn forest	882.97	1.06

(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
19.	8A/C3 Central Indian subtropical hill forest	1.35	0.00
	Sub Total	**81,892.95**	**97.98**
20.	TOF/Plantation	1,651.45	1.98
	Total (Forest Cover & Scrub)	**83,484.40**	
	Grassland forest types (outside forest cover)		
21.	3C/C2/DS1 Moist sal savannah	40.41	0.05
22.	5/DS4 Dry grassland	6.83	0.01
	Total	**47.24**	**0.06**
	Grand Total	**83,531.64**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019).Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.14.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Figure 13.14.4
Fire prone forest areas under different fire prone classes

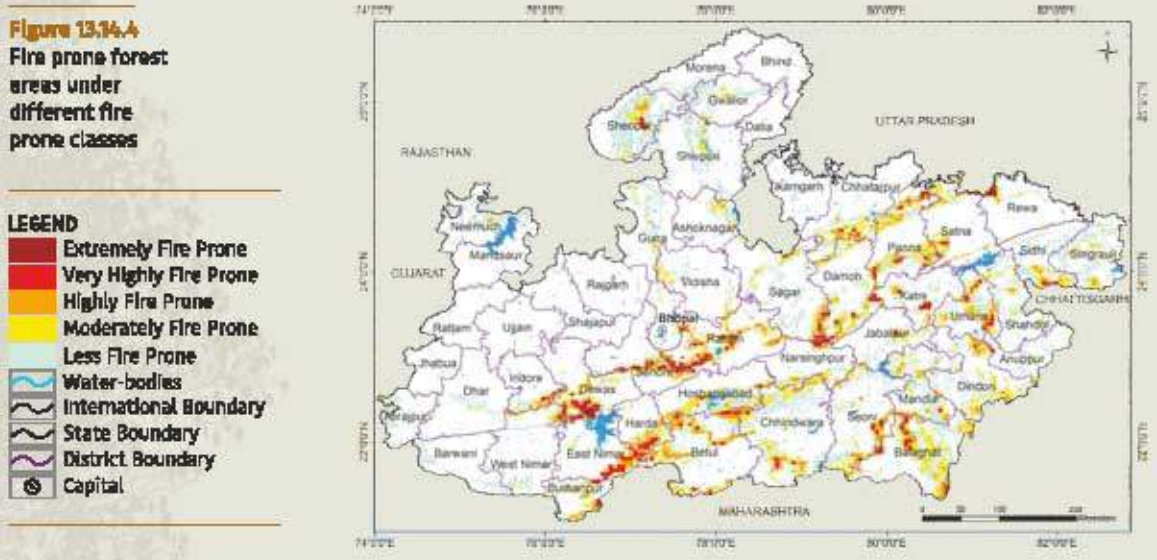

Table 13.14.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	336.52	0.43
2.	Very highly fire prone	4,730.92	6.11
3.	Highly fire prone	10,889.70	14.05
4.	Moderately fire prone	15,231.85	19.66
5.	Less fire prone	46,304.01	59.75
	Total	**77,493.00**	**100.00**

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13.14.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Madhya Pradesh has been estimated as given in following table.

Table 13.14.10 Tree Cover in Madhya Pradesh (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
8,339	8,054	-285

13.14.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.14.11 Extent of TOF in Madhya Pradesh (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
12,721	8,054	20,775

13.14.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Madhya Pradesh is given in the Table 13.14.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.14.13

Table 13.14.12 Growing Stock in Madhya Pradesh (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	342.62	374.44	31.82	8.53
2.	Growing Stock in TOF	106.39	118.05	11.66	6.63

Table 13.14.13 Diameter class distribution of top five tree species inside RFA in Madhya Pradesh (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Tectona grandis*	3,00,466	34,156	0
2.	*Shorea robusta*	1,03,481	31,613	987
3.	*Anogeissus latifolia*	79,178	9,423	313
4.	*Lannea coromandelica*	69,528	13,578	126
5.	*Terminalia tomentosa*	57,431	18,915	383

13.14.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Madhya Pradesh in Rural and Urban areas are given in the Table 13.14.14 and Table 13.14.15 respectively.

Table 13.14.14 Top five tree species in TOF (Rural) in Madhya Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Butea monosperma*	19.34
2.	*Acacia arabica*	13.15
3.	*Azadirachta indica*	7.10
4.	*Zizyphus mauritiana*	6.40
5.	*Tectona grandis*	6.37

Table 13.14.15 Top five tree species in TOF (Urban) Madhya Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	13.85
2.	*Mangifera indica*	11.09
3.	*Leucaena leucocephala*	7.12
4.	*Psidium guajava*	6.89
5.	*Zizyphus mauritiana*	3.84

13.14.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 609.25 million tonnes (2,233.92 million tonnes of CO_2 equivalent) which is 8.46 % of total forest carbon of the country. Pool wise forest carbon in Madhya Pradesh is given in the following table.

Table 13.14.16 Forest Carbon in Madhya Pradesh in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,71,587
2.	BGB	67,160
3.	Dead wood	2,676
4.	Litter	8,356
5.	SOC	3,59,174
	Total	**6,09,250**

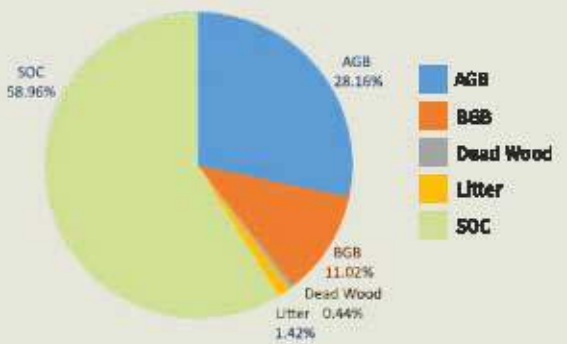

Figure 13.14.5 Forest Carbon in Madhya Pradesh

13.14.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

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Table 13.14.17 Growing Stock of Bamboo in Madhya Pradesh

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	18,394	12.31
Total number of culms (in millions)	4,762	8.93
Total equivalent green weight (in '000 tonnes)	22,284	5.54

13.14.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.14.18 and Table 13.14.19 respectively.

Table 13.14.18 Major NTFP species in Madhya Pradesh

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Helicteres isora*	Shrub	43.71
2.	*Buchanania Lanzan*	Tree	28.62
3.	*Boswellia serrata*	Tree	12.44
4.	*Emblica officinalis/Phyllanthus*	Tree	7.49
5.	*Terminalia belerica*	Tree	2.71

Table 13.14.19 Major invasive species in the State inside the RFA/Green wash in Madhya Pradesh (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	2,852
2.	*Cassia tora*	1,324
3.	*Ageratina adenophora*	547
4.	*Ageratum conyzoides*	439
5.	*Senna occidentalis*	229

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.15
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Geographical Area
307,713 sq km

Geographical Coordinates
Latitude- 15° 35' N to 22° 02' N
Longitude- 72° 36' E to 80° 54' E

Population (as per Census 2011)
112.37 million
Urban 50.82 million (45.22 %)
Rural 61.55 million (54.78%)
Tribal 10.51 million (9.35 %)

Average Population Density
365 per sq km

Livestock population
(as per 19th Live Stock Census)
32.48 million

No. of Districts
35

No. of Hill Districts
7

No. of Tribal Districts
12

Table 13.15.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	30,771	
Reporting area for land utilization	30,742	100.00
Forests	5,220	16.98
Not available for land cultivation	3,485	11.34
Permanent pastures and other grazing lands	1,287	4.19
Land under misc. tree crops and groves	256	0.83
Culturable wasteland	924	3.01
Fallow land other than current fallows	1,261	4.10
Current fallows	1,366	4.44
Net area sown	16,943	55.11

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.15.1 Forest Cover

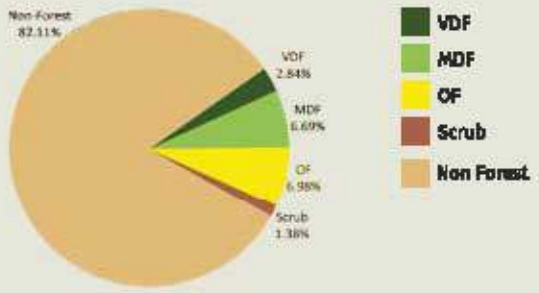

Figure 13.15.1
Forest Cover of Maharashtra

Table 13.15.2 Forest Cover of Maharashtra (in sq km)

Class	Area	% of GA
VDF	8,733.75	2.84
MDF	20,589.00	6.69
OF	21,475.01	6.98
Total	**50,797.76**	**16.51**
Scrub	4,247.39	1.38

Table 13.15.3 District- wise Forest Cover in Maharashtra (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Ahmednagar[T]	17,048	0.00	68.79	210.10	278.89	1.64	12.00	556.55
Akola	5,673	11.00	108.12	222.41	341.53	6.02	1.16	15.29
Amravati[T]	12,210	618.47	1,458.36	1,091.28	3,168.11	25.95	0.34	112.82
Aurangabad	10,131	20.00	105.70	444.52	570.22	5.63	2.29	168.98
Beed	10,693	0.00	12.32	149.23	161.55	1.51	-2.48	359.10
Bhandara	4,087	170.86	561.52	265.37	997.75	24.41	-1.17	18.57
Buldhana	9,661	25.00	143.11	426.57	594.68	6.16	3.08	161.20
Chandrapur[T]	11,443	1,320.89	1,555.39	1,173.99	4,050.27	35.40	-4.19	44.06
Dhule[T]	7,195	0.00	68.57	233.09	301.66	4.19	0.39	112.54
Gadchiroli[T]	14,412	4,705.05	3,288.46	1,909.31	9,902.82	68.71	-14.12	17.35
Gondia	5,234	895.40	739.26	310.95	1,945.61	37.17	7.02	27.18
Hingoli	4,827	0.00	9.09	102.91	112.00	2.32	1.99	48.88
Jalgaon[T]	11,765	51.00	347.31	754.44	1,152.75	9.80	5.91	97.55
Jalna	7,694	0.00	8.22	26.31	34.53	0.45	-1.95	50.11
Kolhapur[#]	7,685	64.00	1,019.47	702.11	1,785.58	23.23	-0.74	102.35
Latur	7,157	0.00	0.04	13.08	13.12	0.18	0.10	19.04
Mumbai City	157	0.00	0.00	3.20	3.20	2.04	0.20	0.00
Mumbai Suburban	446	0.00	67.05	71.92	138.97	31.16	-0.89	0.04
Nagpur[T]	9,892	400.25	902.15	696.39	1,998.79	20.21	-1.59	73.90
Nanded	10,528	58.00	442.07	438.72	938.79	8.92	2.03	122.06
Nandurbar[T]	5,955	0.00	403.68	791.61	1,195.29	20.07	-0.70	30.23
Nashik[M]	15,530	0.00	346.45	733.31	1,079.76	6.95	3.21	348.82
Osmanabad	7,569	0.00	2.03	47.50	49.53	0.65	-0.13	45.93
Parbhani	6,214	0.00	3.51	36.31	39.82	0.64	-0.61	47.44
Pune[M]	15,643	0.00	760.99	955.50	1,716.49	10.97	5.63	510.33

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(In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Raigad*	7,152	13.00	1,254.21	1,683.80	2,951.01	41.26	11.55	86.23
Ratnagiri*	8,208	34.94	1,889.14	2,287.86	4,211.94	51.32	-0.96	3.28
Sangli	8,572	0.00	94.90	55.67	150.57	1.76	0.44	169.22
Satara*	10,480	117.00	569.68	591.51	1,278.19	12.20	-0.18	366.20
Sindhudurg*	5,207	90.93	1,383.88	1,348.87	2,823.68	54.23	-4.30	29.04
Solapur	14,895	0.00	4.98	41.88	46.86	0.31	-2.81	64.54
Thane*	9,558	0.00	1,293.03	1,699.91	2,992.94	31.31	-5.15	259.03
Wardha	6,309	9.97	409.91	444.41	864.29	13.70	2.34	56.21
Washim	4,901	5.00	101.51	189.88	296.39	6.05	-0.37	30.60
Yavatmal*	13,582	122.99	1,166.10	1,321.09	2,610.18	19.22	2.86	92.72
Grand Total	**3,07,713**	**8,753.75**	**20,589.00**	**21,475.01**	**50,797.76**	**16.51**	**20.20**	**4,247.39**

13.15.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.15.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Maharashtra (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
8,476	15,068	12,496	36,040	258	5,521	8,979	14,758
23.52%	41.81%	34.67%		1.75%	37.41%	60.84%	

In case of Maharashtra, RFA boundaries have been used.

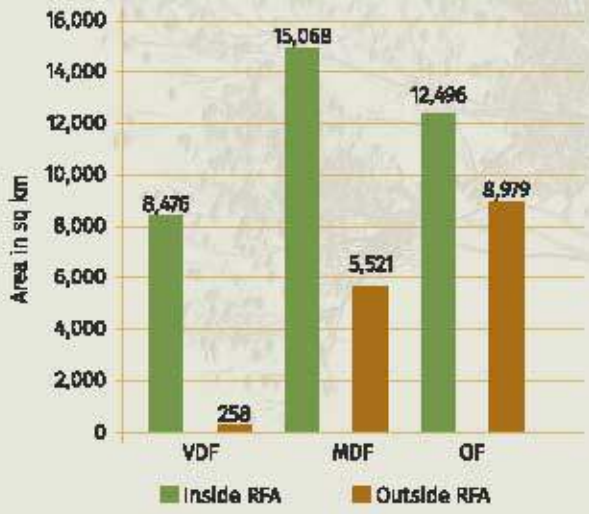

Figure 13.15.2 Forest Cover Inside and Outside of RFA in Maharashtra

Table 13.15.5 Forest Cover Change Matrix for Maharashtra (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	8,704	6	2	0	9	8,721
Moderately Dense Forest	29	20,491	8	0	44	20,572
Open Forest	0	86	21,301	3	95	21,485
Scrub	0	0	38	4,189	29	4,256
Non Forest	1	6	126	55	2,52,491	2,52,679
Total ISFR 2019	**8,734**	**20,589**	**21,475**	**4,247**	**2,52,668**	**3,07,713**
Net Change	13	17	-10	-9	-11	

Table 13.15.6 Altitude-wise Forest Cover in Maharashtra (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	2,37,017	7,604	15,453	16,110	39,167	1,336
500-1000	66,142	1,082	4,753	5,060	10,895	2,806
1000-2000	4,554	48	383	305	736	105
Total	**3,07,713**	**8,734**	**20,589**	**21,475**	**50,798**	**4,247**

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

Table 13.15.7 Forest Cover in different slope classes in Maharashtra (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	2,58,652	6,162	9,348	10,334	25,844	1,533
5-10	23,811	1,217	3,928	4,383	9,528	1,039
10-15	11,555	667	2,970	2,928	6,565	721
15-20	6,633	379	2,044	1,818	4,241	468
20-25	3,707	188	1,219	1,065	2,472	275
25-30	1,896	78	637	549	1,264	139
>30	1,459	43	443	398	884	72
Total	**3,07,713**	**8,734**	**20,589**	**21,475**	**50,798**	**4,247**

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

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Figure 13.15.3 Forest Cover Map of Maharashtra

13.15.2 Forest Types

The area under different forest types of Maharashtra as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.15.8 Area statistics of the Forest Types found in Maharashtra (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2A/C2 West coast semi-evergreen forest	6,659.15	12.10
2.	3B/C1b Moist teak forest	5,715.15	10.38
3.	3B/C2 Southern moist mixed deciduous forest	11,353.06	20.63
4.	4A/L1 Littoral forest	1.11	0.00
5.	4B/TS1 Mangrove scrub	28.33	0.05
6.	4B/TS2 Mangrove forest	291.94	0.53
7.	4E/RS1 Riparian fringing forest	1.18	0.00
8.	5A/C1b Dry teak forest	9,536.93	17.34
9.	5A/C3 Southern dry mixed deciduous forest	14,390.79	26.15
10.	5/DS1 Dry deciduous scrub	4,354.34	7.91
11.	5/E2 *Boswellia* forest	45.02	0.08
12.	5/E3 *Babul* forest	9.30	0.02
13.	5/E4 *Hardwickia* forest	61.28	0.11

(in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
14.	5/E5 *Butea* forest	10.01	0.02
15.	5/E9 Dry bamboo brakes	254.70	0.46
16.	6A/C1 Southern thorn forest	219.22	0.40
17.	8A/C2 Western subtropical hill forest	661.19	1.20
	Sub Total	**53,592.70**	**97.38**
18.	TOF/ Plantation	1,441.35	2.62
	Total (Forest Cover & Scrub)	**55,034.05**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

Table 13.15.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	470.68	0.93
2.	Very highly fire prone	3,585.37	7.06
3.	Highly fire prone	8,540.70	16.81
4.	Moderately fire prone	9,377.92	18.46
5.	Less fire prone	28,823.33	56.74
	Total	**50,798.00**	**100.00**

13.15.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Figure 13.15.4 Fire prone forest areas under different fire prone classes

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13.15.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Maharashtra has been estimated as given in following table.

Table 13.15.10 Tree Cover in Maharashtra (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
10,806	12,108	1,302

13.15.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.15.11 Extent of TOF in Maharashtra (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
14,758	12,108	26,866

13.15.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Maharashtra is given in the Table 13.15.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.15.13.

Table 13.15.12 Growing Stock in Maharashtra (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	231.76	235.50	3.74	5.37
2.	Growing Stock in TOF	177.12	187.69	10.57	10.55

Table 13.15.13 Diameter class distribution of top five tree species inside RFA in Maharashtra (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Tectona grandis*	2,28,206	22,210	369
2.	*Terminalia tomentosa*	1,02,049	13,564	427
3.	*Anogeissus latifolia*	56,588	6,184	131
4.	*Lannea coromandelica*	34,533	5,763	59
5.	*Madhuca latifolia*	11,486	5,404	563

13.15.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Maharashtra in Rural and Urban areas are given in the Table 13.15.14 and Table 13.15.15 respectively.

Table 13.15.14 Top five tree species in TOF (Rural) in Maharashtra

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	15.37
2.	*Mangifera indica*	9.69
3.	*Acacia arabica*	6.53
4.	*Tectona grandis*	6.47
5.	*Terminalia crenulata*	5.44

Table 13.15.15 Top five tree species in TOF (Urban) in Maharashtra

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	11.80
2.	*Mangifera indica*	10.48
3.	*Azadirachta indica*	6.47
4.	*Moringa spp.*	3.53
5.	*Areca triandra*	3.31

13.15.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 451.61 million tonnes (1,655.90 million tonnes of CO_2 equivalent) which is 6.27 % of total forest carbon of the country. Pool wise forest carbon in Maharashtra is given in the following table.

Table 13.15.16 Forest Carbon in Maharashtra in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,37,831
2.	BGB	42,353
3.	Dead wood	2,316
4.	Litter	7,928
5.	SOC	2,61,178
	Total	**4,51,606**

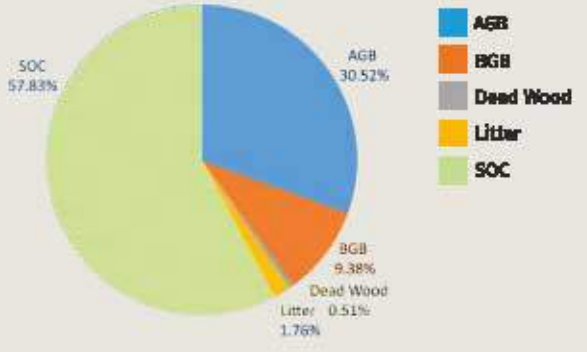


Figure 13.15.5 Forest Carbon in Maharashtra

MAHARASHTRA

13.15.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.15.17 Growing Stock of Bamboo in Maharashtra

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	13,526	9.05
Total number of culms (in millions)	4,117	7.72
Total equivalent green weight (in '000 tonnes)	29,112	7.24

13.15.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.15.18 and Table 13.15.19 respectively.

Table 13.15.18 Major NTFP species in Maharashtra

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Ocimum spp. (Ocimum gratissimum/ Ocimum sanctum/Ocimum tenuiflorum/ Ocimum americanum)*	Herbs	68.86
2.	*Butea monosperma*	Tree	7.51
3.	*Helicteres isora*	Shrub	5.85
4.	*Acacia catechu*	Tree	3.43
5.	*Syzigium cumini*	Tree	3.20

Table 13.15.19 Major invasive species in the State inside the RFA/Green Wash in Maharashtra (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	702
2.	*Cassia tora*	528
3.	*Cyperus rotundus*	170
4.	*Triumfetta rhomboidea*	153
5.	*Ageratum conyzoides*	87

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.16 MANIPUR

Geographical Area
22,327 sq km

Geographical Coordinates
Latitude- 23° 50' N to 25°42' N
Longitude- 92° 59' E to 94°46' E

Population (as per Census 2011)
2.86 million
Urban 0.84 million (29.21 %)
Rural 2.02 million (70.79 %)
Tribal 1.17 million (40.88 %)

Average Population Density
115 per sq km

Livestock population
(as per 19th Live Stock Census)
0.70 million

No. of Districts
9

No. of Hill Districts
9

No. of Tribal Districts
9

Table 13.16.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	2,233	
Reporting area for land utilization	2,166	100.00
Forests	1,685	77.79
Not available for land cultivation	27	1.24
Permanent pastures and other grazing lands	1	0.05
Land under misc. tree crops and groves	6	0.28
Culturable wasteland	1	0.05
Fallow land other than current fallows	0	0.00
Current fallows	0	0.00
Net area sown	446	20.59

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.16.1 Forest Cover

Figure 13.16.1 Forest Cover of Manipur

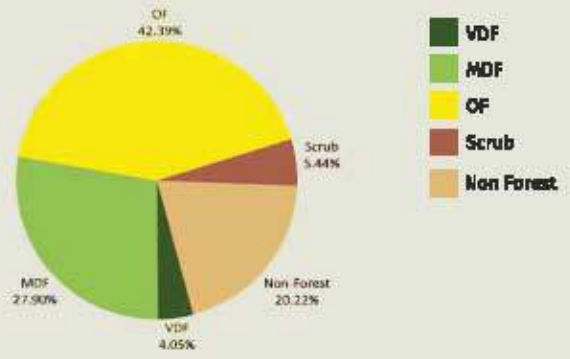


Table 13.16.2 Forest Cover of Manipur (In sq km)

Class	Area	% of GA
VDF	904.99	4.05
MDF	6,228.49	27.90
OF	9,464.79	42.39
Total	**16,598.27**	**74.34**
Scrub	1,214.98	5.44

Table 13.16.3 District- wise Forest Cover in Manipur (In sq km)

District	Geo-grapical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Bishnupur[H]	496	0.00	0.78	21.50	22.28	4.49	0.78	2.14
Chandel[TR]	3,313	11.30	929.21	1,870.56	2,811.07	84.85	-52.28	145.71
Churachandpur[H]	4,570	42.19	1,593.15	2,243.70	3,879.04	84.88	-40.47	163.69
Imphal East[H]	709	0.00	56.62	207.80	264.42	37.29	-9.84	13.51
Imphal West[H]	519	0.00	14.68	37.27	51.95	10.01	0.20	9.40
Senapati[H]	3,271	264.74	695.58	1,131.47	2,091.79	63.95	-44.79	317.65
Tamenglong[H]	4,391	392.15	1,696.10	1,706.37	3,794.62	86.42	-49.82	194.72
Thoubal[H]	514	0.00	1.15	58.20	59.35	11.55	-11.41	11.90
Ukhrul[H]	4,544	194.61	1,241.22	2,187.92	3,623.75	79.75	-41.00	356.26
Grand Total	**22,327**	**904.99**	**6,228.49**	**9,464.79**	**16,598.27**	**74.34**	**-248.63**	**1,214.98**

13.16.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.16.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Manipur (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
895	5,743	8,195	14,833	10	485	1,270	1,765
6.03%	38.72%	55.25%		0.57%	27.48%	71.95%	

**In case of Manipur, Green Wash boundaries have been used.*

MANIPUR

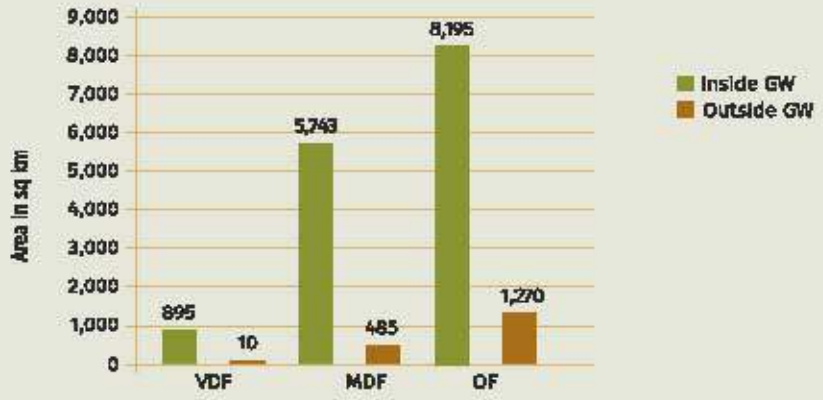


Figure 13.16.2 Forest Cover Inside and Outside of Green Wash in Manipur

Table 13.16.5 Forest Cover Change Matrix for Manipur (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	899	0	0	0	6	905
Moderately Dense Forest	6	6,177	57	15	131	6,386
Open Forest	0	51	9,221	61	223	9,556
Scrub	0	0	81	1,030	70	1,181
Non Forest	0	0	106	109	4,084	4,299
Total ISFR 2021	**905**	**6,228**	**9,465**	**1,215**	**4,514**	**22,327**
Net Change	0	-158	-91	34	215	

Table 13.16.6 Altitude-wise Forest Cover in Manipur (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	3,303	11	999	2,011	3,021	60
500-1000	9,066	28	2,079	3,639	5,746	447
1000-2000	9,342	517	3,037	3,741	7,295	655
2000-3000	616	349	113	74	536	53
Total	**22,327**	**905**	**6,228**	**9,465**	**16,598**	**1,215**

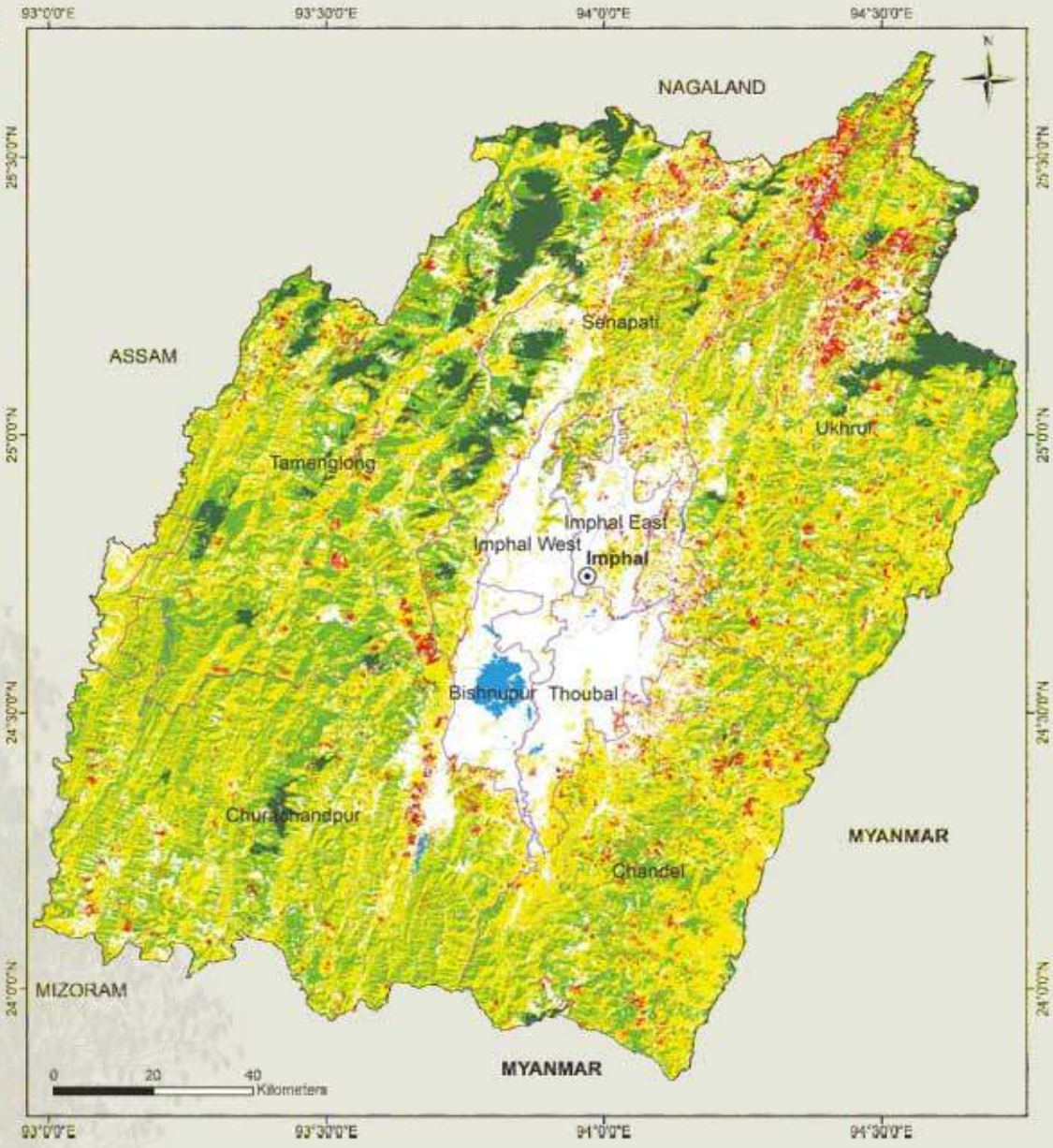
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.16.7 Forest Cover in different slope classes in Manipur (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	2,934	28	225	501	754	47
5-10	2,361	87	547	1,097	1,731	137
10-15	3,630	147	955	1,753	2,855	239
15-20	4,275	172	1,237	2,078	3,487	280
20-25	3,902	158	1,246	1,860	3,264	240
25-30	2,753	126	974	1,246	2,346	158
>30	2,472	187	1,044	930	2,161	114
Total	**22,327**	**905**	**6,228**	**9,465**	**16,598**	**1,215**

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

Figure 13.16.3
Forest Cover Map of Manipur



LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.16.2 Forest Types

The area under different forest types of Manipur as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

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Table 13.16.8 Area statistics of the Forest Types found in Manipur (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2B/C1/2S1 Pioneer Euphorbiaceous scrub	1,263.20	6.93
2.	2B/C2 Cachar semi-evergreen forest	2,852.67	15.65
3.	2/2S1 Secondary moist bamboo brakes	1,324.51	7.27
4.	3C/C3b East Himalayan moist mixed deciduous forest	4,413.95	24.22
5.	8B/C1 East Himalayan subtropical wet hill forest	6,199.75	34.02
6.	8B/C2 *Khasi* subtropical wet hill forest	423.94	2.33
7.	9/C2 Assam subtropical pine forest	632.86	3.47
8.	11B/C1b *Bulu* oak forest	530.44	2.91
9.	11B/C2 Naga hills wet temperate forest	243.92	1.34
10.	12/DS1 Montane bamboo brakes	13.49	0.07
	Sub Total	**17,898.73**	**98.21**
11.	TOF/Plantation	129.64	0.71
	Total (Forest Cover & Scrub)	**18,028.37**	
	Grassland forest types (outside forest cover)		
12.	4D/2S2 Eastern wet alluvial grassland	135.48	0.74
13.	9/C2/DS1 Assam subtropical pine savannah	60.15	0.34
	Sub Total	**195.63**	**1.08**
	Grand Total	**18,224.00**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.16.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.16.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	1,636.46	9.86
2.	Very highly fire prone	6,167.06	37.16
3.	Highly fire prone	5,423.48	32.68
4.	Moderately fire prone	2,096.16	12.62
5.	Less fire prone	1,274.84	7.68
	Total	**16,598.00**	**100.00**

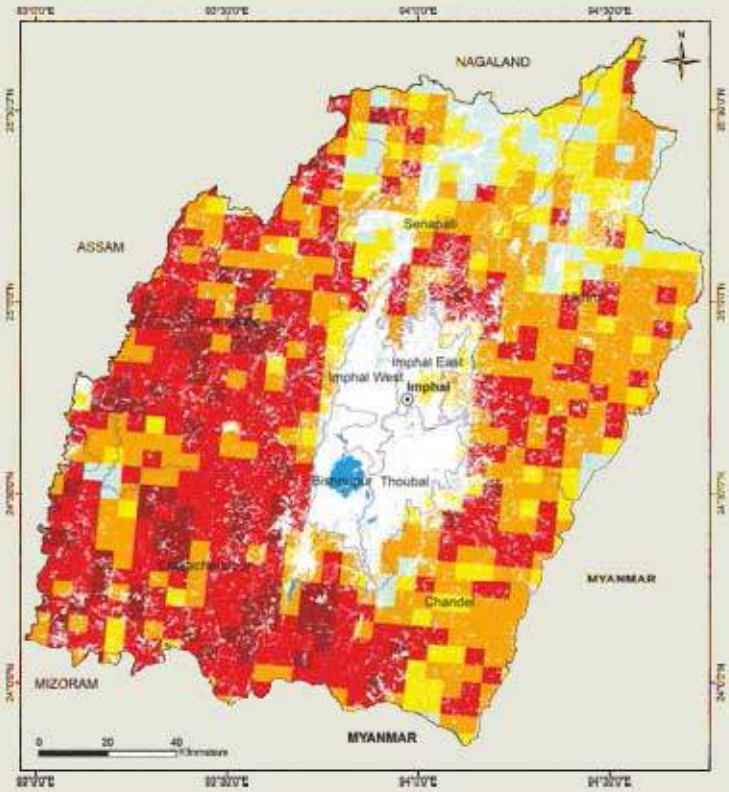

Figure 13.16.4 Fire prone forest areas under different fire prone classes

13.16.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Manipur has been estimated as given in following table.

Table 13.12.10 Tree Cover in Manipur (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
173	169	-4

13.16.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.16.11 Extent of TOF Manipur (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
1,765	169	1,934

13.16.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Manipur is given in the Table 13.16.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.16.13.

MANIPUR

Table 13.16.12 Growing Stock in Manipur (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	42.03	54.99	12.96	1.25
2.	Growing Stock in TOF	6.07	5.10	-0.97	0.29

Table 13.16.13 Diameter class distribution of top five tree species inside RFA in Manipur (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Schima wallichii*	30,022	3,002	1,201
2.	*Quercus spp.*	14,969	1,201	0
3.	*Castanopsis spp.*	12,609	0	0
4.	*Duabanga grandiflora/sonneratioides*	4,804	600	600
5.	*Pinus kesiya/insulanis*	3,575	1,072	0

13.16.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Manipur in Rural and Urban areas are given in the Table 13.16.14 and Table 13.16.15 respectively.

Table 13.16.14 Top five tree species in TOF (Rural) in Manipur

Sl. No.	Species	Relative Abundance (%)
1.	*Quercus spp.*	15.45
2.	*Castanopsis spp.*	12.25
3.	*Pinus kesiya*	10.89
4.	*Schima wallichii*	10.25
5.	*Albizia spp.*	3.09

Table 13.16.15 Top five tree species in TOF (Urban) in Manipur

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	12.25
2.	*Eucalyptus spp.*	7.78
3.	*Areca catechu*	5.92
4.	*Cedrela toona*	5.82
5.	*Syzygium cumini*	5.46

13.16.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 176.93 million tonnes (648.74 million tonnes of CO_2 equivalent) which is 2.46% of total forest carbon of the country. Pool wise forest carbon in Manipur is given in the following table.

Table 13.16.16 Forest Carbon in Manipur in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	47,590
2.	BGB	14,101
3.	Dead wood	880
4.	Litter	2,652
5.	SOC	1,11,708
	Total	1,76,931

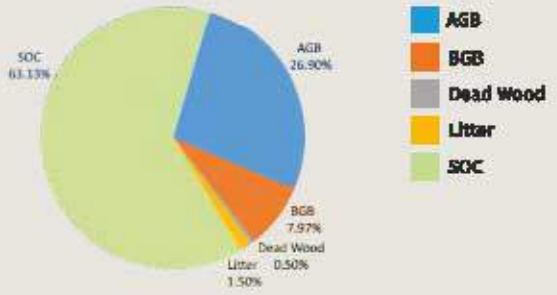

Figure 13.16.5 Forest Carbon in Manipur

13.16.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table

Table 13.16.17 Growing Stock of Bamboo in Manipur

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	8,377	5.61
Total number of culms (in millions)	1,568	2.94
Total equivalent green weight (in '000 tonnes)	11,321	2.82

13.16.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.16.18 and Table 13.16.19 respectively.

Table 13.16.18 Major NTFP species in Manipur

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Emblica officinalis/Phyllanthus*	Tree	37.14
2.	*Parkia javanica/timoriana*	Tree	20.00
3.	*Bombax* spp./*Bombax ceiba*	Tree	20.00
4.	*Thysanolaena maxima*	Herbs	17.14
5.	*Acquilaria malaccensis/Aquilaria agallocha*	Tree	5.71

Table 13.16.19 Major invasive species in the State inside the RFA/Green Wash in Manipur (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	49
2.	*Mikania micrantha*	43
3.	*Microcystis aeruginosa*	8

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.17 MEGHALAYA

Geographical Area
22,429 sq km

Geographical Coordinates
Latitude- 24° 58' N to 26° 07' N
Longitude-89° 48' E to 92° 51' E

Population (as per Census 2011)
2.96 million
Urban 0.59 million (20.07 %)
Rural 2.37 million (79.93 %)
Tribal 2.56 million (21.09 %)

Average Population Density
132 per sq km

Livestock population
(as per 19th Live Stock Census)
1.95 million

No. of Districts
7

No. of Hill Districts
7

No. of Tribal Districts
7

Table 13.17.1 Land Use Pattern

Land Use Types	Area (In '000 ha)	Percentage
Geographical Area	2,243	
Reporting area for land utilization	2,196	100.00
Forests	929	42.30
Not available for land cultivation	254	11.57
Permanent pastures and other grazing lands	-	-
Land under misc. tree crops and groves	165	7.51
Culturable wasteland	384	17.49
Fallow land other than current fallows	153	6.97
Current fallows	58	2.64
Net area sown	253	11.52

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.17.1 Forest Cover

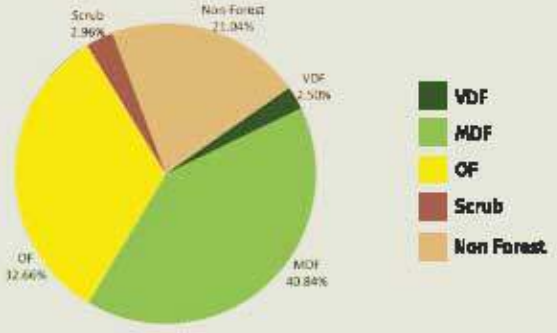

Figure 13.17.1
Forest Cover
of Meghalaya

Table 13.17.2 Forest Cover of Meghalaya (In sq km)

Class	Area	% of GA
VDF	560.16	2.50
MDF	9,159.89	40.84
OF	7,326.02	32.66
Total	**17046.07**	**76.00**
Scrub	662.89	2.96

Table 13.17.3 District- wise Forest Cover in Meghalaya (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
East Garo Hills*	2,603	62.81	1,072.48	1,120.63	2,255.92	86.67	-32.04	90.31
East Khasi Hills*	2,748	21.85	965.82	728.54	1,716.21	62.45	4.02	110.88
Jaintia Hills*	3,819	126.36	1,424.63	980.01	2,531.00	66.27	-6.89	106.86
Ribhoi*	2,448	127.38	1,095.66	915.27	2,138.31	87.35	0.97	59.25
South Garo Hills*	1,887	74.50	977.40	640.02	1,691.92	89.66	-10.28	21.41
West Garo Hills*	3,677	0.00	1,251.83	1,580.62	2,832.45	77.03	-27.77	76.33
West Khasi Hills*	5,247	147.26	2,372.07	1,360.93	3,880.26	73.95	-0.73	197.85
Grand Total	**22,429**	**560.16**	**9,159.89**	**7,326.02**	**17,046.07**	**76.00**	**-72.72**	**662.89**

13.17.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.17.4 Forest Cover Inside and Outside Recorded Forest Area or (Green Wash) in Meghalaya (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
512	7,652	6,634	14,798	48	1,508	692	2,248
3.46%	51.71%	44.83%		2.14%	67.08%	30.78%	

*In case of Meghalaya, GW boundaries have been used.

MEGHALAYA

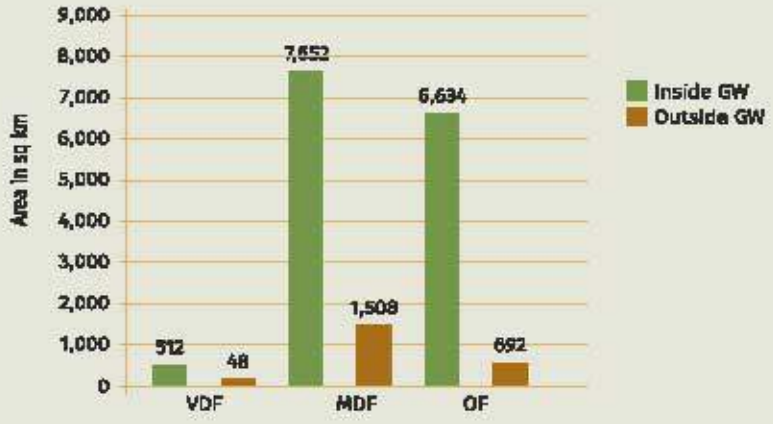

Figure 13.17.2 Forest Cover Inside and Outside of GW in Meghalaya

Table 13.17.5 Forest Cover Change Matrix for Meghalaya (In sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	487	2	0	0	0	489
Moderately Dense Forest	73	9,112	37	6	39	9,267
Open Forest	0	33	7,244	27	59	7,363
Scrub	0	1	18	576	5	600
Non Forest	0	12	27	54	4,617	4,710
Total ISFR 2021	**560**	**9,160**	**7,326**	**663**	**4,720**	**22,429**
Net Change	71	-107	-37	63	10	

Table 13.17.6 Altitude-wise Forest Cover in Meghalaya (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	10,152	269	4,241	4,070	8,580	229
500-1000	6,239	236	2,622	2,289	5,147	316
1000-2000	6,038	55	2,297	967	3,319	118
Total	**22,429**	**560**	**9,160**	**7,326**	**17,046**	**663**

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

Table 13.17.7 Forest Cover in different slope classes in Meghalaya (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	6,169	120	1,896	1,622	3,638	154
5-10	6,115	120	2,459	2,095	4,674	180
10-15	4,403	101	1,965	1,602	3,668	137
15-20	2,670	83	1,278	964	2,325	89
20-25	1,488	61	751	517	1,329	57
25-30	806	38	416	272	726	39
>30	778	37	395	254	686	7
Total	**22,429**	**560**	**9,160**	**7,326**	**17,046**	**663**

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

Figure 13.17.3 Forest Cover Map of Meghalaya

13.17.2 Forest Types

The area under different forest types of Meghalaya as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.17.8 Area statistics of the Forest Types found in Meghalaya (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1B/C3 Cachar tropical evergreen forest	1,515.18	8.22
2.	1/2S1 Pioneer Euphorbiaceous scrub	485.43	2.63
3.	2B/C1a Assam alluvial plains semi-evergreen forest	129.03	0.70
4.	2/2S1 Secondary moist bamboo brakes	375.66	2.04
5.	3C/C1a(II) *Khasi* hill sal	1,176.82	6.38
6.	3C/C3b East Himalayan moist mixed deciduous forest	8,692.38	47.14
7.	8B/C2 *Khasi* subtropical wet hill forest	3,593.38	19.49
8.	9/C2 Assam subtropical pine forest	1,169.30	6.34
	Sub Total	**17,137.18**	**92.94**
9.	TOF/Plantation	581.44	3.15
	Total (Forest Cover & Scrub)	**17,718.62**	

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(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
	Grassland forest type (outside forest cover)		
10.	9/C2/DS1 Assam subtropical pine savannah	719.70	3.91
	Sub Total	**719.70**	**3.91**
	Grand Total	**18,438.32**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

Table 13.17.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	1,588.24	9.32
2.	Very highly fire prone	3,505.49	20.56
3.	Highly fire prone	3,716.73	21.80
4.	Moderately fire prone	2,900.24	17.02
5.	Less fire prone	5,335.30	31.30
	Total	**17,046.00**	**100.00**

13.17.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

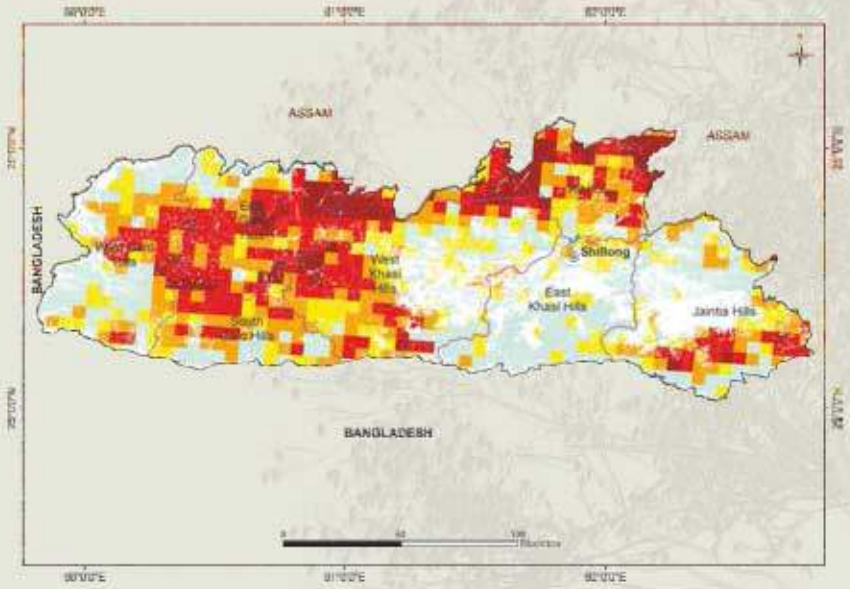

Figure 13.17.4 Fire prone forest areas under diffarent fire prone classes

13.17.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Meghalaya has been estimated as given in following table.

Table 13.17.10 Tree Cover in Meghalaya (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
710	698	-12

11.17.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.17.11 Extent of TOF in Meghalaya (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
2,248	698	2,946

13.17.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Meghalaya is given in the Table 13.17.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.17.13.

Table 13.17.12 Growing Stock in Meghalaya (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	31.28	35.54	4.26	0.81
2.	Growing Stock in TOF	18.84	20.82	1.98	1.17

Table 13.17.13 Diameter class distribution of top five tree species inside RFA in Meghalaya (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Schima wallichii*	16,460	1,701	73
2.	*Pinus kesiya*	6,802	1,511	121
3.	*Shorea robusta*	2,894	429	0
4.	*Ficus* spp.	1,935	143	70
5.	*Artocarpus heterophyllus*	855	400	32

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13.17.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Meghalaya in Rural and Urban areas are given in the Table 13.17.14 and Table 13.17.15 respectively.

Table 13.17.14 Top five tree species in TOF (Rural) in Meghalaya

Sl. No.	Species	Relative Abundance (%)
1.	*Pinus kesiya*	23.45
2.	*Pinus roxburghii*	17.09
3.	*Schima wallichii*	11.59
4.	*Areca catechu*	6.79
5.	*Pinus pectula*	5.71

Table 11.17.15 Top five tree species in TOF (Urban) in Meghalaya

Sl. No.	Species	Relative Abundance (%)
1.	*Pinus kesiya*	37.98
2.	*Pinus pectula*	14.16
3.	*Pinus roxburghii*	8.15
4.	*Areca catechu*	4.47
5.	*Schima khasiana*	3.99

13.17.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 183.39 million tonnes (672.43 million tonnes of CO_2 equivalent) which is 2.55 % of total forest carbon of the country. Pool wise forest carbon in Meghalaya is given in the following table.

Table 13.17.16 Forest Carbon in Meghalaya in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	55,241
2.	BGB	15,820
3.	Dead wood	1,238
4.	Litter	3,075
5.	SOC	1,08,014
	Total	**1,83,388**

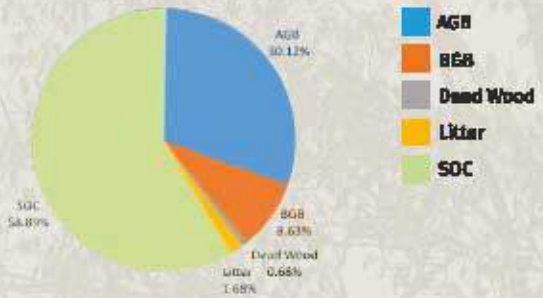

Figure 13.17.5 Forest Carbon in Meghalaya

13.17.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.17.17 Growing Stock of Bamboo in Meghalaya

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	5,007	3.35
Total number of culms (in millions)	2,199	4.12
Total equivalent green weight (in '000 tonnes)	24,745	6.16

13.17.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.17.18 and Table 13.17.19 respectively.

Table 13.17.18 Major NTFP species in Meghalaya

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	Thatch Grass	Herbs	25.99
2.	*Careya arborea*	Tree	19.49
3.	*Terminalia belerica*	Tree	15.52
4.	*Bauhinia variegate/Phanera varigeta*	Tree	11.91
5.	*Embilica officinalis/Phyllanthus*	Tree	10.11

Table 13.17.19 Major invasive species in the State inside the RFA/Green Wash in Meghalaya

(in sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	73
2.	*Lantana camara*	21
3.	*Mikania micrantha*	21
4.	*Microcystis aeruginosa*	1

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.18 MIZORAM

Geographical Area
21,081 sq km

Geographical Coordinates
Latitude- 21° 56' N to 24° 31' N
Longitude- 92° 16' E to 93° 26' E

Population (as per Census 2011)
1.09 million
Urban 0.57 million (52.11 %)
Rural 0.52 million (47.89 %)
Tribal 1.03 million (94.43 %)

Average Population Density
52 per sq km

Livestock population
(as per 19th Live Stock Census)
0.31 million

No. of Districts
8

No. of Hill Districts
8

No. of Tribal Districts
8

Table 13.18.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	2,108	
Reporting area for land utilization	2,040	100.00
Forests	1,585	77.70
Not available for land cultivation	75	3.68
Permanent pastures and other grazing lands	11	0.54
Land under misc. tree crops and groves	41	2.01
Culturable wasteland	7	0.34
Fallow land other than current fallows	128	6.27
Current fallows	47	2.30
Net area sown	146	7.16

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.18.1 Forest Cover

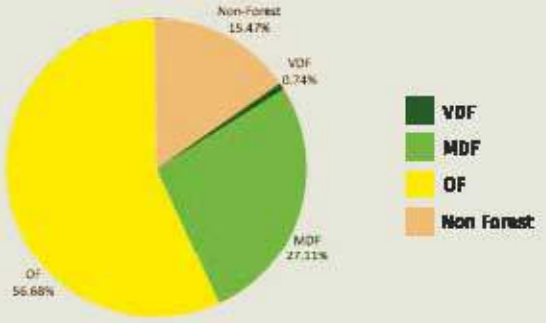

Figure 13.18.1
Forest Cover of Mizoram

Table 13.18.2 Forest Cover of Mizoram (In sq km)

Class	Area	% of GA
VDF	156.79	0.74
MDF	5,715.24	27.11
OF	11,947.97	56.68
Total	**17,820.00**	**84.53**
Scrub	0.90	0.00

Table 13.18.3 District-wise Forest Cover in Mizoram (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Aizawl*	3,576	30.30	1,062.67	1,971.90	3,064.87	85.71	-14.04	0.03
Champhai*	3,185	55.36	942.90	1,375.63	2,373.89	74.53	-113.9	0.11
Kolasib*	1,382	1.24	166.28	983.88	1,151.40	83.31	-1.15	0.00
Lawngtlai*	2,557	0.00	700.93	1,479.99	2,180.92	85.29	-19.16	0.07
Lunglei*	4,536	0.99	1,187.08	2,825.85	4,013.92	88.49	-8.25	0.69
Mamit*	3,025	52.02	756.74	1,909.94	2,718.70	89.87	1.83	0.00
Saiha*	1,399	0.00	543.88	628.98	1,172.86	83.84	-12.63	0.00
Serchhip*	1,421	16.88	354.76	771.80	1,143.44	80.47	-18.21	0.00
Grand Total	**21,081**	**156.79**	**5,715.24**	**11,947.97**	**17,820.00**	**84.53**	**-185.51**	**0.90**

13.18.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.18.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Mizoram (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
156	5,624	11,776	17,556	1	91	172	264
0.89%	32.03%	67.08%		0.38%	34.47%	65.15%	

*In case of Mizoram, Green Wash boundaries have been used.

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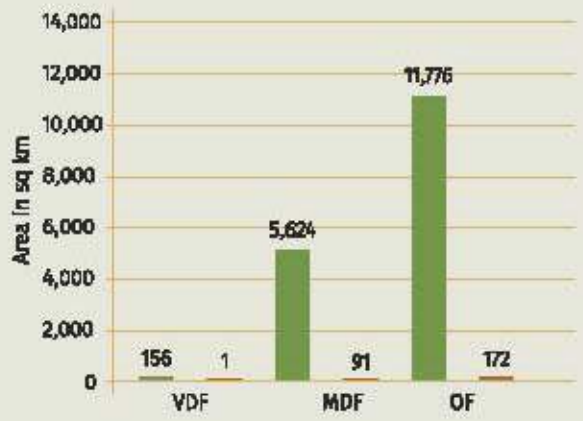

Figure 13.18.2 Forest Cover Inside and Outside of Green Wash in Mizoram

Table 13.18.5 Forest Cover Change Matrix for Mizoram (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	157	0	0	0	0	157
Moderately Dense Forest	0	5,713	1	0	87	5,801
Open Forest	0	0	11,881	0	167	12,048
Scrub	0	0	0	1	0	1
Non Forest	0	2	66	0	3,006	3,074
Total ISFR 2021	**157**	**5,715**	**11,948**	**1**	**3,260**	**21,081**
Net Change	0	-86	-100	0	186	

Table 13.18.6 Altitude-wise Forest Cover in Mizoram (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	9,163	8	1,816	6,186	8,010	0
500-1000	8,205	55	2,641	4,246	6,942	1
1000-2000	3,710	93	1,257	1,516	2,866	0
2000-3000	3	1	1	0	2	0
Total	**21,081**	**157**	**5,715**	**11,948**	**17,820**	**1**

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

Table 13.18.7 Forest Cover in different slope classes in Mizoram (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,565	7	234	894	1,135	0
5-10	2,668	22	558	1,582	2,162	0
10-15	3,625	34	875	2,119	3,028	0
15-20	4,058	31	1,089	2,339	3,459	1
20-25	3,713	23	1,095	2,096	3,214	0
25-30	2,745	16	876	1,517	2,409	0
>30	2,707	24	988	1,401	2,413	0
Total	**21,081**	**157**	**5,715**	**11,948**	**17,820**	**1**

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

Figure 13.18.3
Forest Cover
Map of Mizoram

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.18.2 Forest Types

The area under different forest types of Mizoram as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.18.8 Area statistics of the Forest Types found in Mizoram (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2B/C1/2S1 Pioneer Euphorbiaceous scrub	74.10	0.41
2.	2B/C2 Cachar semi-evergreen forest	5,580.26	30.99
3.	2/2S1 Secondary moist bamboo brakes	6,600.03	36.65
4.	3C/C3b East Himalayan moist mixed deciduous forest	5,648.50	31.37
5.	8B/C1 East Himalayan subtropical wet hill forest	7.94	0.04
6.	9/C2 Assam subtropical pine forest	92.75	0.52
	Sub Total	**18,003.58**	**99.98**
7.	TOF/Plantation	2.83	0.02
	Total (Forest Cover & Scrub)	**18,006.41**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

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13.18.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.18.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	4,683.50	26.28
2.	Very highly fire prone	8,862.58	49.73
3.	Highly fire prone	3,369.82	18.92
4.	Moderately fire prone	543.28	3.05
5.	Less fire prone	360.82	2.02
	Total	**17,820.00**	**100.00**

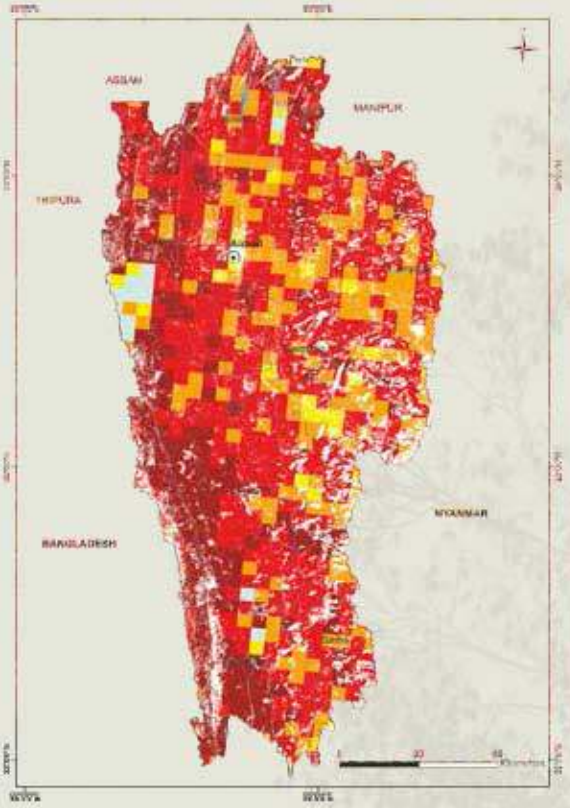


Figure 13.18.4 Fire prone forest areas under different fire prone classes

13.18.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Mizoram has been estimated as given in following table.

Table 13.1.10 Tree Cover in Mizoram (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
441	444	3

13.18.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.18.11 Extent of TOF in Mizoram (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
264	444	708

13.18.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Mizoram is given in the Table 13.18.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.18.13.

Table 13.18.12 Growing Stock in Mizoram (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	21.30	28.87	7.57	0.66
2.	Growing Stock in TOF	44.11	46.05	1.94	2.59

Table 13.18.13 Diameter class distribution of top five species inside RFA in Mizoram (in '000)

		Dia class (cm)		
Sl. No.	Species	10-30	30-60	>60
1.	*Macaranga* spp.	15,552	173	0
2.	*Schima wallichii*	11,628	1,281	46
3.	*Albizia* spp.	6,050	782	46
4.	*Tectona grandis*	5,687	792	0
5.	*Dysoxylum binectariferum*	573	34	92

MIZORAM

13.18.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Mizoram in Rural and Urban areas are given in the Table 13.18.14 and Table 13.18.15 respectively.

Table 13.18.14 Top five tree species in TOF (Rural) Mizoram

Sl. No.	Species	Relative Abundance (%)
1.	*Schima wallichii*	9.95
2.	Castanopsis spp.	9.57
3.	Quercus spp.	6.59
4.	*Macaranga* spp.	6.04
5.	*Tectona grandis*	4.48

Table 13.18.15 Top five tree species in TOF (Urban) in Mizoram

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	14.72
2.	*Mangifera indica*	12.97
3.	*Schima wallichii*	6.30
4.	*Artocarpus heterophyllus*	5.74
5.	*Albizia* spp.	4.35

13.18.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 158.64 million tonnes (581.68 million tonnes of CO_2 equivalent) which is 2.20% of total forest carbon of the country. Pool wise forest carbon in Mizoram is given in the following table.

Table 13.18.16 Forest Carbon in Mizoram in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	48,519
2.	BGB	10,700
3.	Dead wood	998
4.	Litter	1,849
5.	SOC	95,961
	Total	**1,58,027**

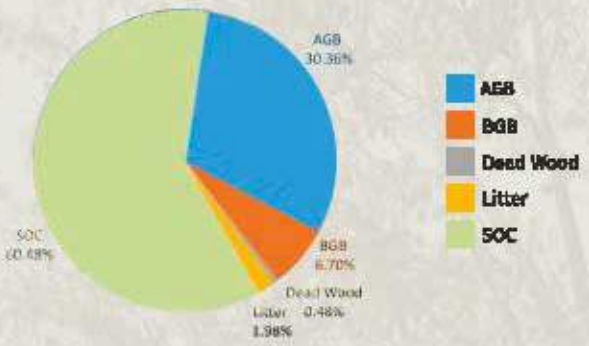


Figure 13.18.5 Forest Carbon in Mizoram

13.18.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.18.17 Growing Stock of Bamboo in Mizoram

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	4,561	3.05
Total number of culms (in millions)	1,490	2.79
Total equivalent green weight (in '000 tonnes)	12,585	3.13

13.18.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.18.18 and Table 13.18.19 respectively.

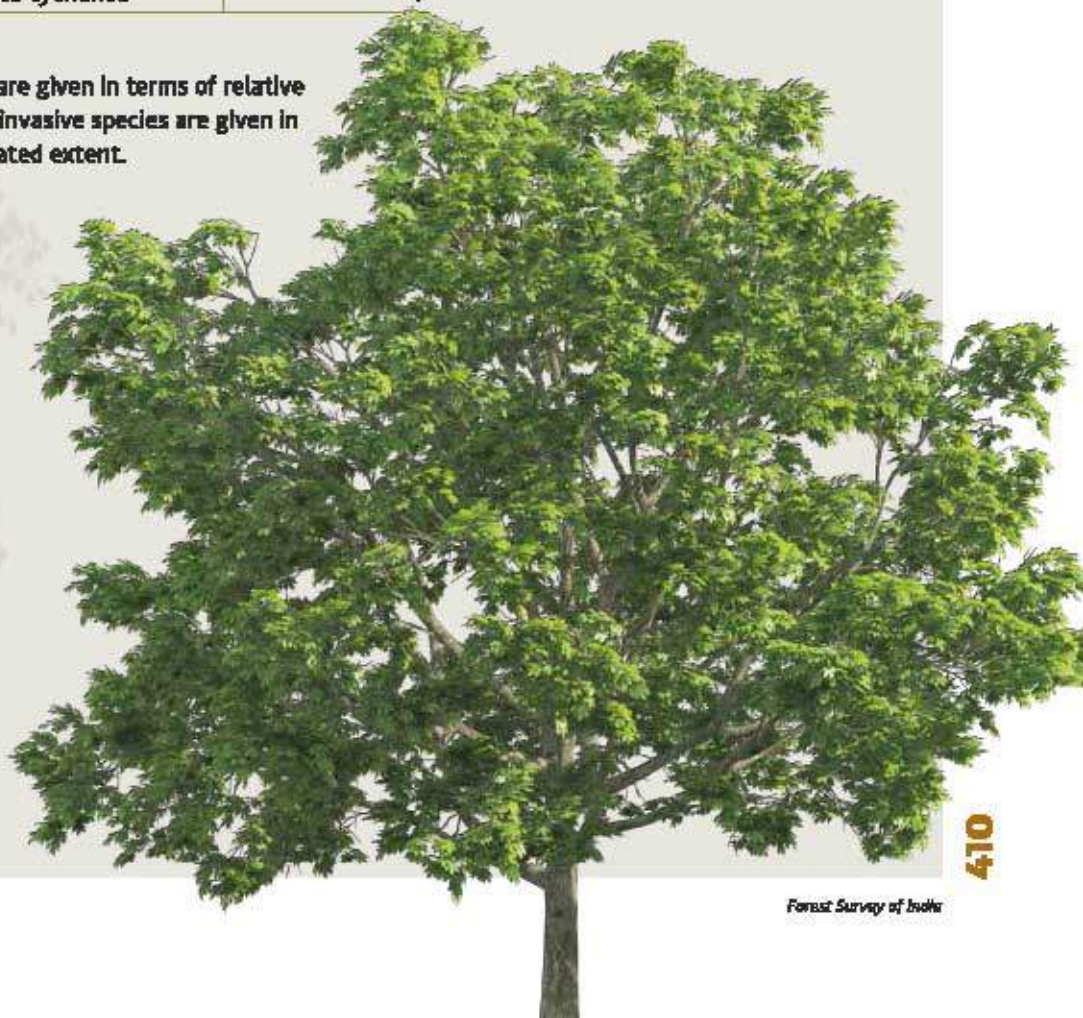
Table 13.18.18 Major NTFP species in Mizoram

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Thysanolaena maxima*	Herbs	61.75
2.	*Imperata cylindrica*	Herbs	10.76
3.	*Hedyotes scandens*	Shrub	7.17
4.	*Parkia javanica/timoriana*	Tree	3.59
5.	*Embilica officinalis/Phyllanthus*	Tree	3.19

Table 13.18.19 Major invasive species in the State inside the RFA/Green Wash in Mizoram (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	23
2.	*Mikania micrantha*	9
3.	*Imperata cylindrica*	4

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.



13.19 NAGALAND

Geographical Area
16,579 sq km

Geographical Coordinates
Latitude- 25° 10' N to 27° 4' N
Longitude- 93° 15' E to 95° 6' E

Population (as per Census 2011)
1.98 million
Urban 0.57 million (28.86%)
Rural 1.41 million (71.14%)
Tribal 1.71 million (86.48 %)

Average Population Density
119 per sq km

Livestock population
(as per 19th Live Stock Census)
0.91 million

No. of Districts
11

No. of Hill Districts
11

No. of Tribal Districts
11

Table 13.19.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	1,658	
Reporting area for land utilization	1,653	100.00
Forests	863	52.21
Not available for land cultivation	96	5.81
Permanent pastures and other grazing lands	-	-
Land under misc. tree crops and groves	90	5.44
Culturable wasteland	66	3.99
Fallow land other than current fallows	109	6.60
Current fallows	44	2.66
Net area sown	385	23.29

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.19.1 Forest Cover

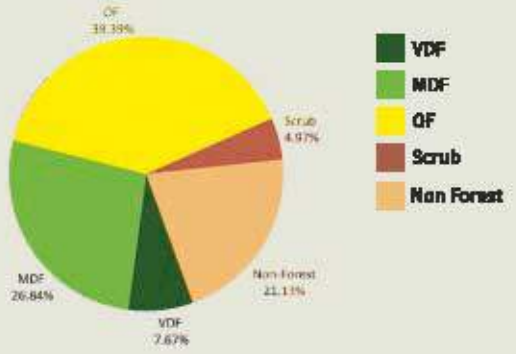


Figure 13.19.1
Forest Cover of Nagaland

Table 13.19.2 Forest Cover of Nagaland (In sq km)

Class	Area	% of GA
VDF	1,272.04	7.67
MDF	4,449.07	26.84
OF	6,530.03	39.39
Total	**12,251.14**	**73.90**
Scrub	824.30	4.97

Table 13.19.3 District-wise Forest Cover in Nagaland (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Dimapur[TH]	927	23.69	153.56	412.44	589.69	63.61	-2.40	9.23
Kiphire[TH]	1,130	150.26	266.76	376.46	793.48	70.22	-41.10	72.43
Kohima[TH]	1,463	134.19	376.40	683.89	1,194.48	81.65	11.82	57.83
Longleng[TH]	562	0.00	124.13	245.85	369.98	65.83	-2.42	44.05
Mokokchung[TH]	1,615	1.70	499.69	825.74	1,327.13	82.18	-0.48	68.27
Mon[TH]	1,786	31.50	418.97	694.07	1,144.54	64.08	-58.28	98.80
Peren[TH]	1,651	140.05	640.23	627.96	1,408.24	85.30	-6.58	89.39
Phek[TH]	2,026	272.17	625.46	696.06	1,593.69	78.66	-22.12	101.62
Tuensang[TH]	2,536	435.15	529.72	638.67	1,603.54	63.23	-96.12	166.64
Wokha[TH]	1,628	0.76	458.45	858.78	1,317.99	80.96	12.18	50.98
Zunheboto[TH]	1,255	82.57	355.70	470.11	908.38	72.38	-29.76	65.06
Grand Total	**16,579**	**1,272.04**	**4,449.07**	**6,530.03**	**12,251.14**	**73.90**	**-235.26**	**824.30**

13.19.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.19.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Nagaland (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
1,169	3,203	4,256	8,628	103	1,246	2,274	3,623
13.55%	37.12%	49.33%		2.84%	34.39%	62.77%	

**In case of Nagaland, Green Wash boundaries have been used*

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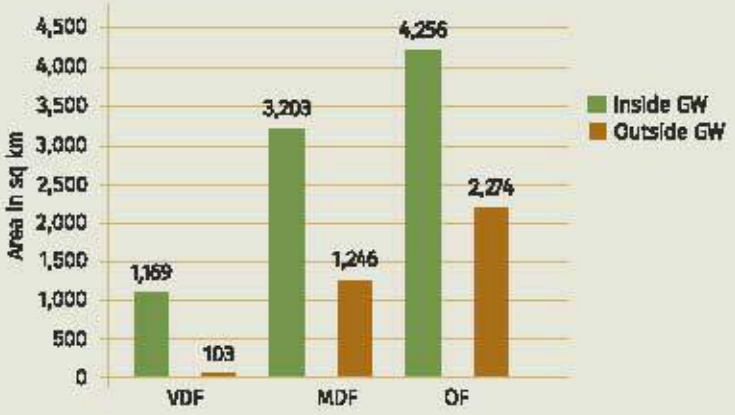

Figure 13.19.2 Forest Cover Inside and Outside of Green Wash in Nagaland

Table 13.19.5 Forest Cover Change Metrix for Nagaland (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	1,267	0	0	0	6	1,273
Moderately Dense Forest	5	4,432	0	0	97	4,534
Open Forest	0	17	6,368	45	249	6,679
Scrub	0	0	42	582	11	635
Non Forest	0	0	120	197	3,141	3,458
Total ISFR 2021	**1,272**	**4,449**	**6,530**	**824**	**3,504**	**16,579**
Net Change	-1	-85	-149	189	46	

Table 13.19.6 Altitude-wise Forest Cover in Nagaland (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	3,910	0	989	2,069	3,058	80
500-1000	5,051	8	1,256	2,293	3,557	313
1000-2000	6,520	558	1,969	2,076	4,603	421
2000-3000	1,075	692	228	90	1,010	10
3000-4000	23	14	7	2	23	0
Total	**16,579**	**1,272**	**4,449**	**6,530**	**12,251**	**824**

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

Table 13.19.7 Forest Cover in different slope classes in Nagaland (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,704	23	318	667	1,008	38
5-10	2,006	78	509	917	1,504	86
10-15	2,804	154	725	1,213	2,092	145
15-20	3,098	219	831	1,260	2,310	176
20-25	2,809	246	784	1,073	2,103	166
25-30	2,115	223	618	757	1,598	121
>30	2,043	329	664	643	1,636	92
Total	**16,579**	**1,272**	**4,449**	**6,530**	**12,251**	**824**

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

Figure 13.19.3
Forest Cover
Map of Nagaland

13.19.2 Forest Types

The area under different forest types of Nagaland as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.19.8 Area statistics of the Forest Types found in Nagaland (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1B/C1 Assam Valley tropical wet evergreen forest (*Dipterocarpus*)	82.82	0.63
2.	1/2S1 Pioneer Euphorbiaceous scrub	639.37	4.86
3.	2B/C1/2S2 Eastern alluvial secondary semi-evergreen forest	2,353.38	17.90
4.	2/2S1 Secondary moist bamboo brakes	546.69	4.16
5.	3C/C3b East Himalayan moist mixed deciduous forest	5,030.79	38.26
6.	8B/C2 *Khasi* subtropical wet hill forest	2,148.80	16.34
7.	9/C2 Assam subtropical pine forest	735.33	5.59
8.	11B/C2 Naga hill wet temperate forest	1,446.16	11.00
9.	12/D51 Montane bamboo brakes	9.16	0.08
	Sub Total	**12,992.50**	**98.82**
10.	TOF/Plantation	129.39	0.98
	Total (Forest Cover & Scrub)	**13,121.89**	

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(in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
	Grassland forest type (outside forest cover)		
11.	9/C2/DS1 Assam subtropical pine savannah	26.17	0.20
	Grand Total	**3,148.06**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.19.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.19.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	352.24	2.88
2.	Very highly fire prone	3,129.20	25.54
3.	Highly fire prone	4,849.90	39.59
4.	Moderately fire prone	2,477.96	20.23
5.	Less fire prone	1,441.70	11.76
	Total	**12,251.00**	**100.00**

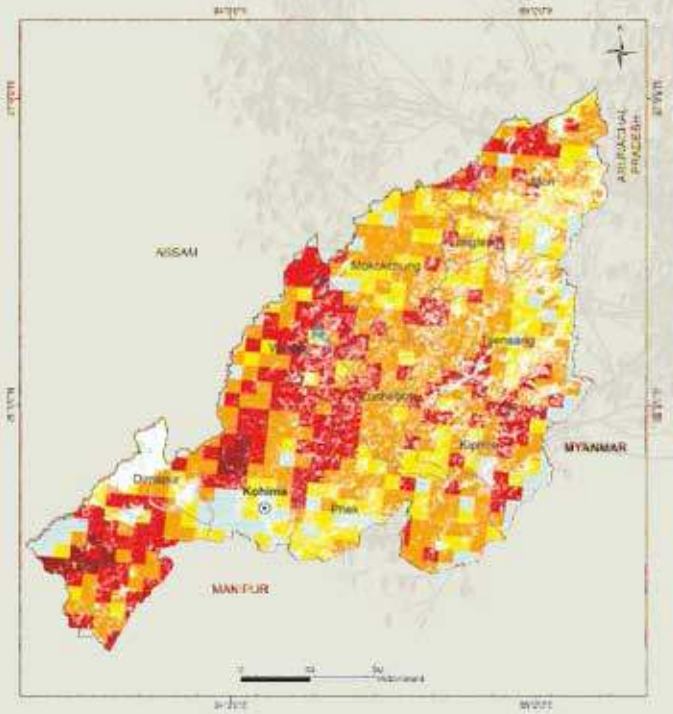

Figure 13.19.4 Fire prone forest areas under different fire prone classes

13.19.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Nagaland has been estimated as given in following table.

Table 13.19.10 Tree Cover in Nagaland (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
362	365	3

13.19.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outskie the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.19.11 Extent of TOF in Nagaland (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
3,623	365	3,988

13.19.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Nagaland is given in the Table 13.19.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.19.13.

Table13.19.12 Growing Stock in Nagaland (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	29.52	30.28	0.76	0.69
2.	Growing Stock in TOF	13.72	15.60	1.88	0.88

Table 13.19.13 Diameter class distribution of top five tree species inside RFA in Nagaland (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Schima wallichii*	9,748	1,826	0
2.	*Macaranga* spp.	9,936	228	0

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Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
3.	*Quercus* spp.	7,707	1,598	0
4.	*Ficus* spp.	5,897	456	456
5.	*Alnus* spp.	1,826	913	0

13.19.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Nagaland in Rural and Urban areas are given in the Table 13.19.14 and Table 13.19.15 respectively.

Table 13.19.14 Top five tree species in TOF (Rural) in Nagaland

Sl. No.	Species	Relative Abundance (%)
1.	*Schima wallichii*	8.46
2.	*Alnus nepalensis*	5.71
3.	*Duabanga grandiflora*	5.69
4.	*Macaranga* spp.	4.37
5.	*Livistona jenkinsiana*	4.27

Table 13.19.15 Top five tree species in TOF (Urban) in Nagaland

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	12.53
2.	*Mangifera indica*	11.22
3.	*Tectona grandis*	5.72
4.	*Artocarpus heterophyllus*	3.22
5.	*Cocos nucifera*	2.67

13.19.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 134.93 million tonnes (494.74 million tonnes of CO_2 equivalent) which is 1.87 % of total forest carbon of the country. Pool wise forest carbon in Nagaland is given in the following table.

Table 13.19.16 Forest Carbon in Nagaland in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	39,339
2.	BGB	10,618
3.	Dead wood	854
4.	Litter	2,006
5.	SOC	82,115
	Total	**1,34,932**

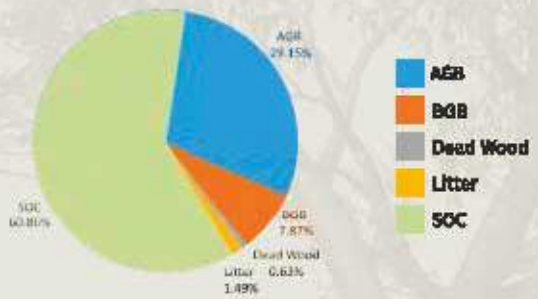

Figure 13.19.5 Forest Carbon in Nagaland

13.19.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.19.17 Growing Stock of Bamboo in Nagaland

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	3,947	2.64
Total number of culms (in millions)	2,705	5.07
Total equivalent green weight (in '000 tonnes)	32,402	8.06

13.19.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.19.18 and Table 13.19.19 respectively.

Table 13.19.18 Major NTFP species in Nagaland

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Thysanolaena maxima*	Herbs	79.17
2.	*Emblica officinalis/Phyllanthus*	Tree	8.33
3.	*Rhus semialata*	Tree	6.25
4.	*Oroxylum indicum*	Tree	4.17
5.	*Litsea citara*	Tree	2.08

Table 13.19.19 Major invasive species in the State inside the RFA/Green Wash in Nagaland (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	43
2.	*Mikania micrantha*	43
3.	*Ageratum conyzoides*	3
4.	*Parthenium hysterophorus*	1

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.20 ODISHA

Geographical Area
1,55,707 sq km

Geographical Coordinates
Latitude- 17° 47' N to 22° 34' N
Longitude- 81° 22' E to 87° 29' E

Population (as per Census 2011)
41.97 million
Urban 7.00 million (16.68 %)
Rural 34.97 million (83.32 %)
Tribal 9.59 million (22.85 %)

Average Population Density
270 per sq km

Livestock population
(as per 19th Live Stock Census)
20.73 million

No. of Districts
30

No. of Hill Districts
0

No. of Tribal Districts
12

Table 13.20.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	15,571	
Reporting area for land utilization	15,424	100.00
Forests	5,814	37.69
Not available for land cultivation	2,353	15.26
Permanent pastures and other grazing lands	512	3.32
Land under misc. tree crops and groves	276	1.79
Culturable wasteland	613	3.97
Fallow land other than current fallows	777	5.04
Current fallows	1,216	7.88
Net area sown	3,863	25.05

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.20.1 Forest Cover

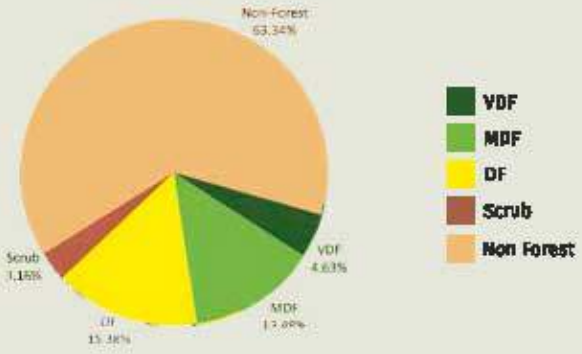

Figure 13.20.1
Forest Cover of Odisha

Table 13.20.2 Forest Cover of Odisha (In sq km)

Class	Area	% of GA
VDF	7,212.80	4.63
MDF	20,994.90	13.49
OF	23,946.25	15.38
Total	**52,155.85**	**33.50**
Scrub	4,923.70	3.16

Table 13.20.3 District- wise Forest Cover in Odisha (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Angul	6,375	370.53	1,381.34	1,031.51	2,783.38	43.66	0.75	83.30
Balangir	6,575	70.13	223.25	846.73	1,140.11	17.34	4.85	138.72
Baleshwar[T]	3,806	22.98	133.47	228.78	385.23	10.12	2.67	46.65
Bargarh	5,837	175.03	374.33	523.95	1,073.31	18.39	22.85	23.3
Baudh	3,098	262.87	562.45	467.85	1,293.17	41.74	2.23	57.73
Bhadrak	2,505	0.00	8.70	69.10	77.80	3.11	-0.20	0.00
Cuttack	3,932	52.93	235.88	539.48	828.29	21.07	23.91	59.84
Deogarh	2,940	191.14	667.59	618.28	1,477.01	50.24	-0.15	13.9
Dhenkanal	4,452	173.92	419.50	842.10	1,435.52	32.24	-10.09	82.29
Gajapati[T]	4,325	333.48	776.54	1,513.46	2,623.48	60.65	102.11	239.42
Ganjam	8,206	164.45	1,072.39	938.77	2,175.61	26.51	70.21	918.26
Jagatsinghpur	1,668	0.00	4.62	132.18	136.80	8.20	0.52	0.00
Jajapur	2,899	6.00	71.85	231.83	309.68	10.68	3.60	47.00
Jharsuguda	2,114	2.95	174.14	158.28	335.37	15.86	2.73	25.69
Kalahandi[T]	7,920	358.88	732.04	1,348.04	2,438.96	30.79	19.16	442.88
Kandhamal[T]	8,021	661.73	2,607.29	2,134.78	5,403.8	67.37	6.09	552.36
Kendrapara	2,644	83.46	88.43	163.21	335.10	12.67	23.8	1.73
Kendujhar[T]	8,303	289.23	1,418.47	1,511.22	3,218.92	38.77	-3.24	51.62
Khordha	2,813	20.98	186.13	301.05	508.16	18.06	41.07	130.65
Koraput[T]	8,807	57.76	584.52	1,516.69	2,158.97	24.51	60.7	1,141.91
Malkangiri[T]	5,791	158.24	709.97	1,456.25	2,324.46	40.14	-11.71	48.02
Mayurbhanj[T]	10,418	1,335.21	1,717.71	1,046.19	4,099.11	39.35	4.94	32.94
Nabarangpur[T]	5,291	172.35	445.85	540.52	1,158.72	21.9	11.97	47.76
Nayagarh	3,890	188.99	965.56	560.26	1,714.81	44.08	1.06	170.39
Nuapada	3,852	86.26	481.40	721.17	1,288.83	33.46	14.37	96.66
Puri	3,479	0.00	54.13	231.59	285.72	8.21	60.63	3.68

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(in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Rayagada*	7,073	373.37	1,145.05	1,622.91	3,141.33	44.41	-5.18	357.91
Sambalpur*	6,624	535.74	1,710.22	1,093.97	3,339.93	50.42	47.64	12.84
Subarnapur	2,337	43.46	185.62	167.12	396.20	16.95	45.35	8.98
Sundargarh*	9,712	1,020.73	1,856.46	1,390.98	4,268.17	43.95	-5.20	87.27
Grand Total	**1,55,707**	**7,212.80**	**20,994.90**	**23,948.25**	**52,155.95**	**33.50**	**537.44**	**4,923.70**

13.20.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.20.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Odisha (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
5,649	14,636	12,401	32,686	1,564	6,359	11,547	19,470
17.28%	44.78%	37.94%		8.03%	32.66%	59.31%	

*In case of Odisha, GW boundaries have been used.

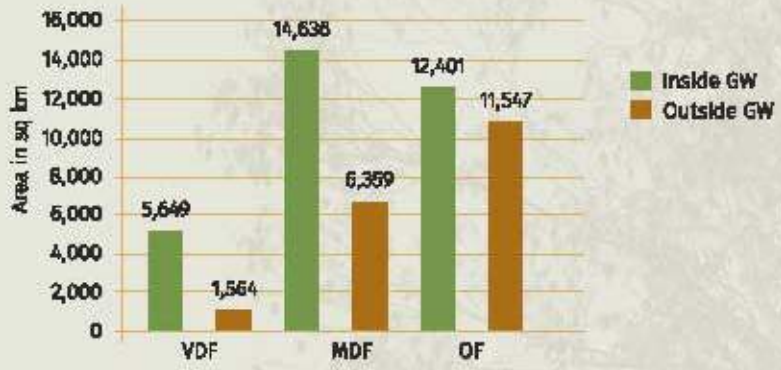


Figure 13.20.2 Forest Cover Inside and Outside of GW in Odisha

Table 13.20.5 Forest Cover Change Matrix for Odisha (in sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	5,984	736	219	12	19	6,970
Moderately Dense Forest	955	18,368	1,847	144	218	21,552
Open Forest	220	1,422	19,906	676	873	23,097
Scrub	31	233	730	2,808	525	4,327
Non Forest	23	216	1,246	1,284	96,992	99,761
Total ISFR 2021	**7,213**	**20,995**	**23,948**	**4,924**	**98,627**	**1,55,707**
Net Change	243	-557	851	597	-1,134	

Table 13.20.6 Altitude-wise Forest Cover in Odisha (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	1,19,476	3,609	13,434	16,549	33,592	2,719
500-1000	34,706	3,490	7,323	7,104	17,917	1,897
1000-2000	1,525	114	238	295	647	308
Total	**1,55,707**	**7,213**	**20,995**	**23,948**	**52,156**	**4,924**

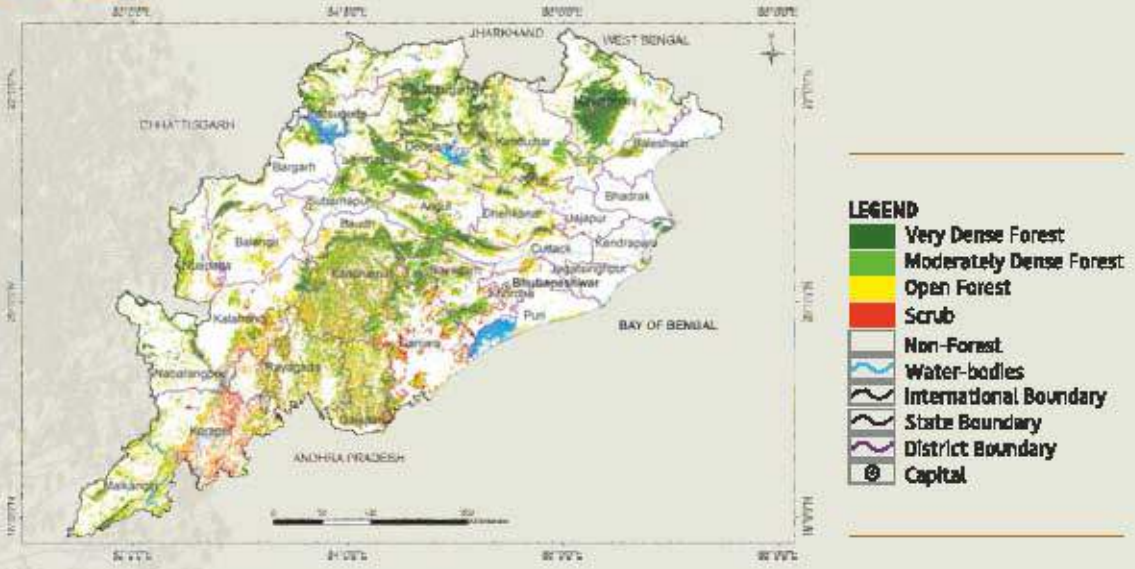
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.20.7 Forest Cover in different slope classes in Odisha (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,09,048	1,643	6,504	10,928	19,075	1,754
5-10	15,890	1,538	4,383	3,939	9,860	818
10-15	10,209	1,375	3,689	3,075	8,139	727
15-20	9,130	1,070	2,854	2,531	6,455	654
20-25	6,509	767	1,929	1,836	4,532	500
25-30	3,005	465	1,040	1,041	2,546	297
>30	1,816	355	596	598	1,549	174
Total	**1,55,707**	**7,213**	**20,995**	**23,948**	**52,156**	**4,924**

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

Figure 13.20.3 Forest Cover Map of Odisha



13.20.2 Forest Types

The area under different forest types of Odisha as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

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Table 13.20.8 Area statistics of the Forest Types found in Odisha (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2B/C3 Odisha semi-evergreen forest	79.51	0.14
2.	2/2S1 Secondary moist bamboo brakes	197.10	0.35
3.	3B/C2 Southern moist mixed deciduous forest	1,157.79	2.07
4.	3B/C2/2S1 Southern Secondary moist mixed deciduous forest	400.35	0.72
5.	3C/C1d Peninsular (coastal) sal forest	4.42	0.01
6.	3C/C2e (I) Moist peninsular high level sal	2,425.43	4.33
7.	3C/C2e (II) Moist peninsular low level sal	11,902.97	21.27
8.	3C/C2e (III) Moist peninsular valley sal	911.33	1.63
9.	3C/C3/2S1 Northern secondary moist mixed deciduous forest	4,571.39	8.17
10.	4A/L1 Littoral forest	135.02	0.24
11.	4B/TS2 Mangrove forest	250.64	0.45
12.	5A/C1b Dry teak forest	154.86	0.28
13.	5A/C3 Southern dry mixed deciduous forest	5,386.95	9.63
14.	5B/C1c Dry peninsular sal forest	9,469.29	16.92
15.	5B/C2 Northern dry mixed deciduous forest	11,327.16	20.24
16.	5/DS1 Dry deciduous scrub	2,887.03	5.16
17.	5/E2 *Boswellia* forest	30.97	0.06
18.	5/E9 Dry bamboo brakes	861.00	1.54
	Sub Total	**52,153.21**	**93.21**
19.	TOF/ Plantation	3,792.21	6.77
	Total (Forest Cover & Scrub)	**55,945.42**	
	Grassland forest type (outside forest cover)		
20.	3C/C2/DS1 Moist sal savannah	9.66	0.02
	Grand Total	**55,955.08**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

3.20.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.20.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	1,226.66	2.35
2.	Very highly fire prone	3,930.36	7.54
3.	Highly fire prone	7,634.76	14.64
4.	Moderately fire prone	10,086.77	19.34
5.	Less fire prone	29,277.45	56.13
	Total	**52,156.00**	**100.00**

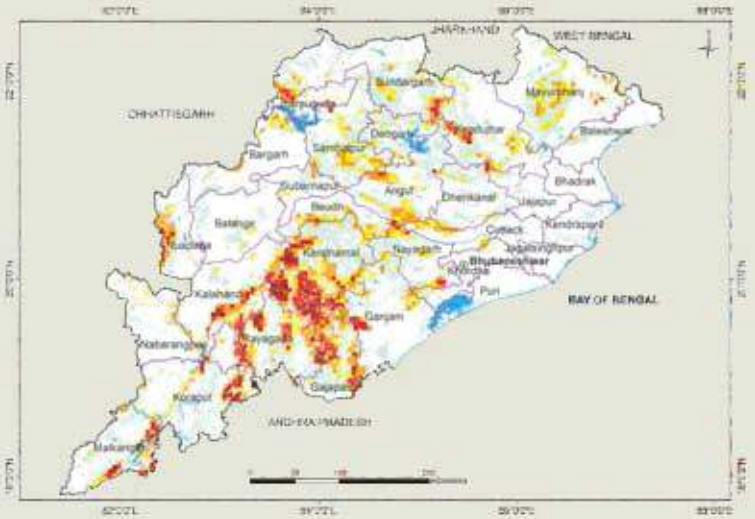


Figure 13.20.4 Fire prone forest areas under different fire prone classes

13.19.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Odisha has been estimated as given in following table.

Table 13.20.10 Tree Cover in Odisha (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
4,648	5,004	356

13.20.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.20.11 Extent of TOF in Odisha (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
19,470	5,004	24,474

13.19.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Odisha is given in the Table 13.20.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.20.13.

ODISHA

Table 13.20.12 Growing Stock in Odisha (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	299.04	276.78	-22.26	6.31
2.	Growing Stock in TOF	95.02	106.87	11.85	6.01

Table 13.20.13 Diameter class distribution of top five tree species inside RFA in Odisha (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Shorea robusta*	2,10,944	34,744	3,088
2.	*Anogeissus latifolia*	48,064	7,941	820
3.	*Terminalia tomentosa*	47,458	8,197	355
4.	*Madhuca latifolia*	19,269	7,791	888
5.	*Schleichera trijuga*	10,133	4,817	678

13.20.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Odisha in Rural and Urban areas are given in the Table 13.20.14 and Table 13.20.15 respectively.

Table 13.20.14 Top five tree species in TOF (Rural) in Odisha

Sl. No.	Species	Relative Abundance (%)
1.	*Shorea robusta*	9.49
2.	*Mangifera indica*	7.63
3.	*Butea monosperma*	5.39
4.	*Azadirachta indica*	5.29
5.	*Madhuca latifolia*	5.25

Table 13.20.15 Top five tree species in TOF (Urban) in Odisha

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	10.63
2.	*Cocos nucifera*	8.73
3.	*Azadirachta indica*	6.59
4.	*Moringa species*	5.80
5.	*Tectona grandis*	5.70

13.20.8 Carbon Stock in Forest in Odisha

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 444.83 million tonnes (1,631.04 million tonnes of CO_2 equivalent) which is 6.17 % of total forest carbon of the country. Pool wise forest carbon in Odisha is given in the following table.

Table 13.20.16 Forest Carbon in Odisha in different pools

(In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,31,015
2.	BGB	40,441
3.	Dead wood	2,252
4.	Litter	7,671
5.	SOC	2,63,451
	Total	4,44,830

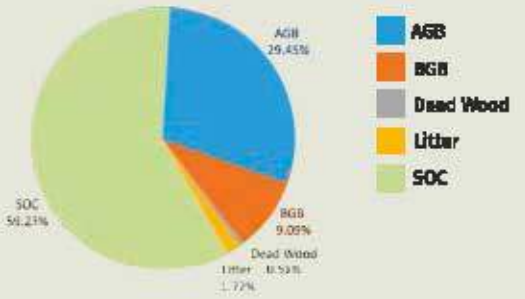


Figure 13.20.5 Forest Carbon in Odisha

13.19.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.20.17 Growing Stock of Bamboo in Odisha

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	11,199	7.49
Total number of culms (in millions)	3,973	7.45
Total equivalent green weight (in '000 tonnes)	23,716	5.90

13.20.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.20.18 and Table 13.20.19 respectively.

Table 13.20.18 Major NTFP species in Odisha

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Shorea robusta*	Tree	58.39
2.	*Madhuca indica*	Tree	15.52
3.	*Buchanania Lanzan*	Tree	12.11
4.	*Schleichera oleosa*	Tree	3.43
5.	*Semecarpus anacardium*	Tree	2.23

Table 13.20.19 Major invasive species inside the State of Odisha with RFA/Green Wash in Odisha

(In sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	389
2.	*Lantana camara*	137
3.	*Ageratum conyzoides*	124
4.	*Acacia farnesiana*	62
5.	*Dioscorea pentaphylla*	9

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.21 PUNJAB

Geographical Area
50,362 sq km

Geographical Coordinates
Latitude- 29° 33' N to 32° 32' N
Longitude- 73° 53' E to 76° 56' E

Population (as per Census 2011)
27.74 million
Urban 10.40 million (37.48 %)
Rural 17.34 million (62.52 %)
Tribal NIL

Average Population Density
551 per sq km

Livestock population
(as per 19th Live Stock Census)
8.12 million

No. of Districts
20

No. of Hill Districts
0

No. of Tribal Districts
0

Table 13.21.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	5,036	
Reporting area for land utilization	5,033	100.00
Forests	253	5.03
Not available for land cultivation	540	10.73
Permanent pastures and other grazing lands	5	0.10
Land under misc. tree crops and groves	8	0.16
Culturable wasteland	12	0.24
Fallow land other than current fallows	6	0.12
Current fallows	85	1.69
Net area sown	4,124	81.93

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.21.1 Forest Cover

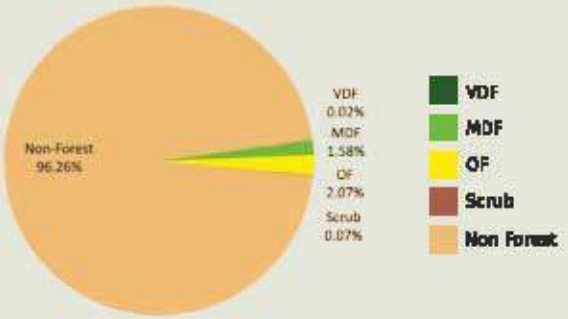


Figure 13.21.1
Forest Cover
of Punjab

Table 13.21.2 Forest Cover of Punjab

(In sq km)

Class	Area	% of GA
VDF	10.58	0.02
MDF	793.11	1.58
OF	1,042.96	2.07
Total	**1,846.65**	**3.67**
Scrub	33.89	0.07

Table 13.21.3 District- wise Forest Cover in Punjab

(In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Amritsar	2,683	1.00	10.47	14.11	25.58	0.95	-1.20	1.22
Barnala	1,482	0.00	1.00	7.22	8.22	0.55	-0.11	0.00
Bathinda	3,353	0.00	18.85	37.59	56.44	1.68	1.01	9.10
Faridkot	1,458	0.00	3.94	14.43	18.37	1.26	-0.11	1.00
Fatehgarh Sahib	1,180	0.00	3.74	0.00	3.74	0.32	0.00	0.00
Firozpur	5,305	0.00	5.65	48.99	54.64	1.03	20.98	2.50
Gurdaspur	3,551	0.00	103.39	107.3	210.69	5.93	-1.63	0.97
Hoshiarpur	3,386	0.00	369.57	347.53	717.10	21.18	-7.10	7.00
Jalandhar	2,624	0.00	1.68	8.20	10.08	0.38	-0.53	1.00
Kapurthala	1,633	0.00	1.93	8.05	9.98	0.61	0.13	1.00
Ludhiana	3,578	0.00	22.86	29.86	52.72	1.47	-6.20	1.21
Mansa	2,198	0.00	0.98	8.94	9.92	0.45	-0.06	0.52
Moga	2,242	0.00	0.00	8.45	8.45	0.38	-0.44	0.00
Muktsar	2,593	0.00	5.97	13.97	19.94	0.77	1.62	0.00
Patiala	3,325	8.13	27.78	38.81	74.72	2.25	-0.09	2.34
Rupnagar	1,356	0.00	105.07	153.99	259.06	19.10	-2.40	3.03
Sahibzada Ajit Singh Nagar	1,094	0.00	74.35	66.04	140.39	12.83	-0.34	3.00
Sangrur	3,625	0.00	6.00	17.34	23.34	0.64	0.51	0.00
Shahid Bhagat Singh Nagar	1,282	0.00	25.45	99.92	125.37	9.78	-6.39	0.00
Tarn Taran	2,414	1.45	4.23	12.22	17.90	0.74	0.37	0.00
Grand Total	**50,362**	**10.58**	**793.11**	**1,042.96**	**1,846.65**	**3.67**	**-1.98**	**33.89**

PUNJAB

13.21.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.21.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Punjab (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
10	451	327	788	1	342	716	1,059
1.27%	57.23%	41.50%		0.09%	32.30%	67.71%	

**In case of Punjab, Green Wash boundaries have been used.*

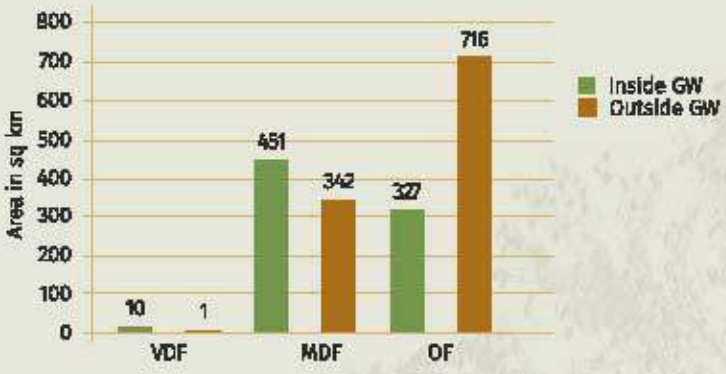


Figure 13.21.2 Forest Cover Inside and Outside of Green Wash in Punjab

Table 13.21.5 Forest Cover Change Matrix for Punjab (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	8	0	0	0	0	8
Moderately Dense Forest	3	792	0	0	6	801
Open Forest	0	1	1,009	0	30	1,040
Scrub	0	0	1	31	1	33
Non Forest	0	0	33	3	48,444	48,480
Total ISFR 2021	**11**	**793**	**1,043**	**34**	**48,481**	**50,362**
Net Change	3	-8	3	1	1	

Table 13.21.6 Altitude-wise Forest Cover in Punjab (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	49,882	11	573	888	1,472	34
500-1000	480	0	220	155	375	0
Total	**50,362**	**11**	**793**	**1,043**	**1,847**	**34**

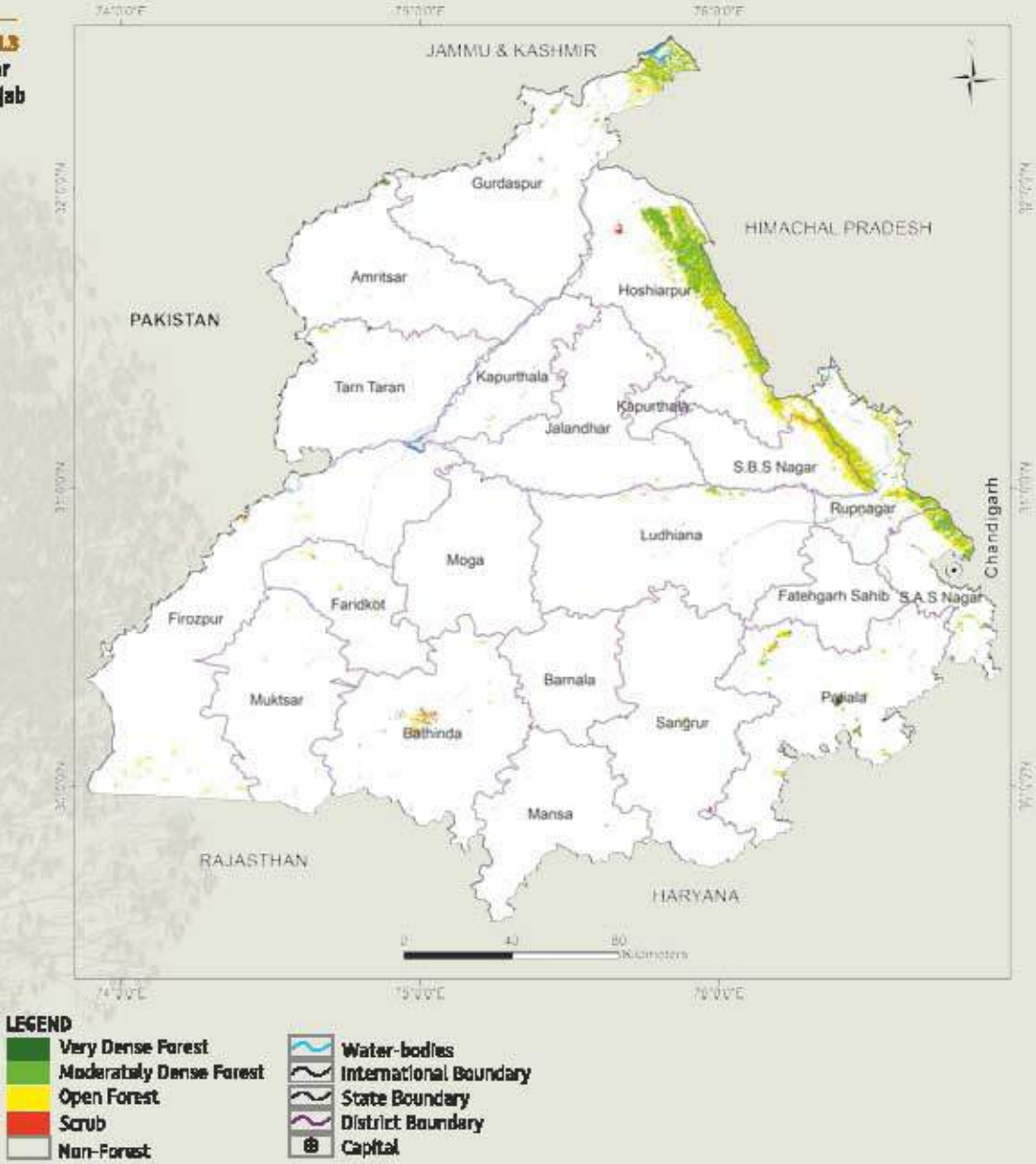
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.21.7 Forest Cover in different slope classes Punjab (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	48,329	10	371	666	1,047	33
5-10	1,582	1	229	220	450	1
10-15	316	0	126	107	233	0
15-20	99	0	48	37	85	0
20-25	26	0	14	9	23	0
25-30	7	0	4	3	7	0
>30	3	0	1	1	2	0
Total	**50,362**	**11**	**793**	**1,043**	**1,847**	**34**

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

Figure 13.21.3
Forest Cover Map of Punjab



PUNJAB

13.21.2 Forest Types

The area under different forest types of Punjab as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.21.8 Area statistics of the Forest Types found in Punjab (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	5B/C2 Northern dry mixed deciduous forest	1,241.19	65.97
2.	5/DS1 Dry deciduous scrub	10.31	0.55
3.	5/E9 Dry bamboo brakes	31.10	1.65
4.	5/1S2 *Khair-sissu* forest	0.49	0.03
5.	6B/C2 Ravine thorn forest	76.94	4.09
6.	6/1S1 Desert dune scrub	10.26	0.54
7.	9/C1a Lower or Shwalik chir pine forest	27.76	1.47
	Sub Total	**1,398.05**	**74.30**
8.	TOF/Plantation	483.52	25.70
	Total (Forest Cover & Scrub)	**1,881.57**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

13.21.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.21.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	53.86	2.92
3.	Highly fire prone	254.95	13.80
4.	Moderately fire prone	375.30	20.32
5.	Less fire prone	1,162.89	62.96
	Total	**1,847.00**	**100.00**

Figure 13.21.4 Fire prone forest areas under different fire prone classes

13.21.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Punjab has been estimated as given in following table.

Table 13.21.10 Tree Cover in Punjab (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
1,592	1,138	-454

13.21.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.21.11 Extent of TOF in Punjab (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
1,059	1,138	2,197

PUNJAB

13.21.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Punjab is given in the Table 13.21.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.21.13.

Table 13.21.12 Growing Stock in Punjab (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	11.12	12.61	1.49	0.29
2.	Growing Stock in TOF	18.56	20.31	1.75	1.14

Table 13.21.13 Diameter class distribution of top five tree species inside RFA in Punjab (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Prosopis juliflora*	14,136	835	56
2.	*Acacia catechu*	11,241	111	0
3.	*Eucalyptus* spp.	3,720	1,184	0
4.	*Lannea coromandelica*	3,367	323	56
5.	*Holoptelea integrifolia*	2,205	607	0

13.21.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Punjab in Rural and Urban areas are given in the Table 13.21.14 and Table 13.21.15 respectively.

Table 13.21.14 Top five tree species in TOF (Rural) in Punjab

Sl. No.	Species	Relative Abundance (%)
1.	*Eucalyptus* spp.	28.16
2.	*Melia azadirachta*	19.51
3.	*Dalbergia sissoo*	8.20
4.	*Populus* spp.	8.19
5.	*Morus* spp.	3.72

Table 13.21.15 Top five tree species in TOF (Urban) in Punjab

Sl. No.	Species	Relative Abundance (%)
1.	*Eucalyptus* spp.	20.48
2.	*Melia azadirachta*	19.95
3.	*Morus* spp.	6.92
4.	*Dalbergia sissoo*	4.13
5.	*Azadirachta indica*	3.80

13.21.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 13.56 million tonnes (49.72 million tonnes of CO_2 equivalent) which is 0.19 % of total forest carbon of the country. Pool wise forest carbon in Punjab is given in the following table.

Table 13.21.16 Forest Carbon in Punjab in different pools

(In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	3,420
2.	BGB	1,284
3.	Dead wood	56
4.	Litter	175
5.	SOC	8,623
	Total	13,558

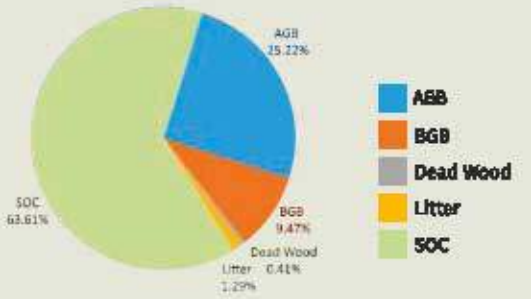


Figure 13.21.5 Forest Carbon in Punjab

13.21.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.21.17 Growing Stock of Bamboo in Punjab

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	280	0.19
Total number of culms (in millions)	28	0.05
Total equivalent green weight (in '000 tonnes)	113	0.03

13.21.10 Major Invasive Species

Major invasive species as assessed from forest inventory data are presented in the Table 13.21.18.

Table 13.21.18 Major invasive species in the State inside the RFA/Green Wash in Punjab

(in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	217
2.	*Ageratum houstonianum*	35
3.	*Leucanea leucocephala*	28
4.	*Senna occidentalis*	13
5.	*Imperata cylindrica*	13

Major invasive species are given in terms of their estimated extent.

13.22
RAJASTHAN

Geographical Area
3,42,239 sq km

Geographical Coordinates
Latitude- 23°4' N to 30° 11' N
Longitude- 69° 29' E to 78° 17' E

Population (as per Census 2011)
68.55 million
Urban 17.05 million (24.87%)
Rural 51.50 million (75.13%)
Tribal 9.24 million (13.48%)

Average Population Density
200 per sq km

Livestock population
(as per 19th Live Stock Census)
57.73 million

No. of Districts
33

No. of Hill Districts
0

No. of Tribal Districts
5

Table 13.22.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	34,224	
Reporting area for land utilization	34,287	100.00
Forests	2,756	8.04
Not available for land cultivation	4,366	12.73
Permanent pastures and other grazing lands	1,673	4.88
Land under misc. tree crops and groves	24	0.07
Culturable wasteland	3,831	11.17
Fallow land other than current fallows	1,992	5.81
Current fallows	1,742	5.08
Net area sown	17,903	52.22

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.22.1 Forest Cover

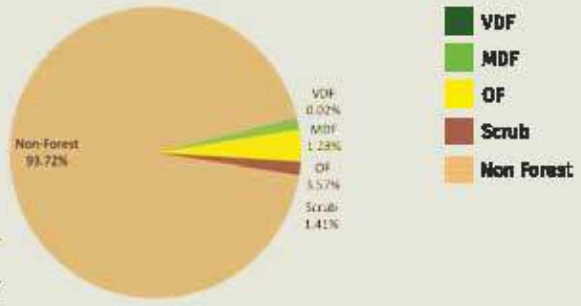


Figure 13.22.1
Forest Cover of Rajasthan

Table 13.22.2 Forest Cover of Rajasthan (in sq km)

Class	Area	% of GA
VDF	78.15	0.02
MDF	4,368.65	1.28
OF	12,208.16	3.57
Total	**16,654.96**	**4.87**
Scrub	4,808.51	1.41

Table 13.22.3 District- wise Forest Cover in Rajasthan (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Ajmer	8,481	0.00	46.49	285.07	331.56	3.91	26.45	175.72
Alwar	8,380	59.70	334.65	801.56	1,195.91	14.27	-0.75	243.08
Banswara[7]	4,522	0.00	38.52	230.09	268.61	5.94	0.19	60.17
Baran	6,992	0.00	153.66	856.39	1,010.05	14.45	-0.94	98.93
Barmer	28,387	0.00	4.79	284.43	289.22	1.02	-0.57	223.18
Bharatpur	5,066	0.00	26.33	194.73	221.06	4.36	-9.21	77.15
Bhilwara	10,455	0.00	33.31	191.00	224.31	2.15	0.12	189.76
Bikaner	30,239	0.88	28.06	250.77	279.71	0.92	24.10	49.86
Bundi	5,776	1.00	138.98	424.37	564.35	9.77	7.17	172.67
Chittaurgarh	7,822	0.00	222.01	768.04	990.05	12.66	1.25	107.42
Churu	13,835	0.00	2.44	75.25	77.69	0.56	-4.31	27.48
Dausa	3,432	0.00	11.15	105.45	116.60	3.40	-0.40	94.66
Dholpur	3,033	0.00	79.75	339.32	419.07	13.82	0.07	76.07
Dungarpur[7]	3,770	0.00	42.53	262.01	304.54	8.08	2.24	83.37
Ganganagar	10,978	0.00	9.87	105.22	115.09	1.05	2.17	15.78
Hanumangarh	9,656	1.01	6.80	85.16	92.97	0.96	3.01	6.71
Jaipur	11,143	12.00	97.20	445.66	554.86	4.98	2.10	272.85
Jaisalmer	38,401	3.56	48.64	270.19	322.39	0.84	-3.38	206.14
Jalor	10,640	0.00	22.67	212.94	235.61	2.21	-32.46	221.89
Jhalawar	6,219	0.00	83.39	353.28	436.67	7.02	1.09	102.57
Jhunjhunun	5,928	0.00	20.79	180.17	200.96	3.39	0.19	179.54
Jodhpur	22,850	0.00	4.26	104.99	109.25	0.48	1.47	163.53
Karauli	5,524	0.00	96.04	747.80	843.84	15.28	-26.16	300.54
Kota	5,217	0.00	153.28	391.55	544.83	10.44	-1.90	135.83
Nagaur	17,718	0.00	14.11	155.65	169.76	0.96	22.72	87.71

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(In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Pali	12,387	0.00	211.60	489.26	700.86	5.66	26.01	357.60
Pratapgarh*	4,449	0.00	562.97	470.80	1,033.77	23.24	-4.14	59.05
Rajsamand	4,655	0.00	129.94	386.93	516.87	11.10	-4.92	126.06
Sawai Madhopur	4,498	0.00	171.30	293.31	464.61	10.33	1.92	138.52
Sikar	7,732	0.00	31.51	170.67	202.18	2.61	9.12	198.68
Sirohi*	5,136	0.00	300.96	597.46	898.42	17.49	-13.49	247.50
Tonk	7,194	0.00	27.72	138.18	165.90	2.31	0.84	68.96
Udaipur*	11,724	0.00	1,212.93	1,540.46	2,753.39	23.49	-4.15	239.53
Grand Total	**3,42,239**	**78.15**	**4,368.85**	**12,208.16**	**16,654.96**	**4.87**	**25.45**	**4,808.51**

13.22.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.22.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Rajasthan (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
74	3,999	8,487	12,560	4	370	3,721	4,095
0.59%	31.84%	67.57%		0.10%	9.03%	90.87%	

*In case of Rajasthan, RFA boundaries have been used.

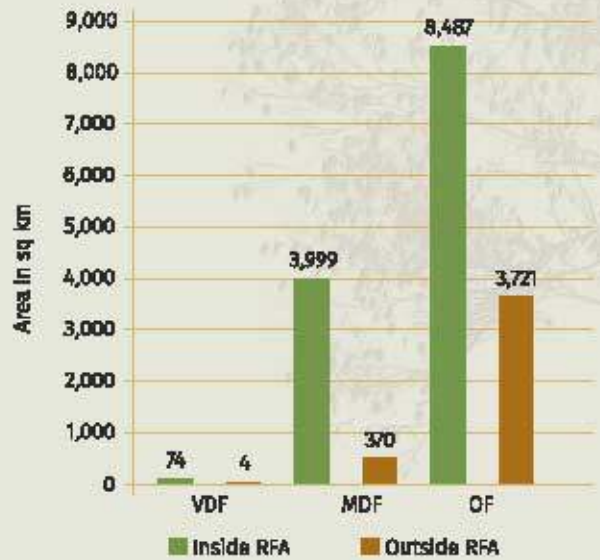

Figure 13.22.2
Forest Cover Inside and Outside of RFA in Rajasthan

Table 13.22.5 Forest Cover Change Matrix for Rajasthan (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	77	1	0	0	0	78
Moderately Dense Forest	1	4,272	36	3	30	4,342
Open Forest	0	88	11,478	253	391	12,210
Scrub	0	1	258	4,064	437	4,760
Non Forest	0	7	436	489	3,19,917	3,20,849
Total ISFR 2021	**78**	**4,369**	**12,208**	**4,809**	**3,20,775**	**3,42,239**
Net Change	0	27	-2	49	-74	

Table 13.22.6 Altitude-wise Forest Cover in Rajasthan (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	3,24,954	27	2567	9,384	11,978	4,065
500-1000	17,070	51	1,688	2,776	4,515	739
1000-2000	215	0	114	48	162	5
Total	**3,42,239**	**78**	**4,369**	**12,208**	**16,655**	**4,809**

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

Table 13.22.7 Forest Cover in different slope classes in Rajasthan (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	3,15,978	21	1,569	7,215	8,805	3,471
5-10	15,796	15	849	1,922	2,786	597
10-15	4,729	12	673	1,175	1,860	294
15-20	2,656	11	542	822	1,375	196
20-25	1,650	9	382	565	956	129
25-30	901	6	219	324	549	78
>30	529	4	135	185	324	44
Total	**3,42,239**	**78**	**4,369**	**12,208**	**16,655**	**4,809**

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

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Figure 13.22.3 Forest Cover Map of Rajasthan

LEGEND

- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.22.2 Forest Types

The area under different forest types of Rajasthan as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.22.8 Area statistics of the Forest Types found in Rajasthan (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	5A/C1a Very dry teak forest	1,052.53	4.92
2.	5A/C1b Dry teak forest	45.03	0.22
3.	5B/C2 Northern dry mixed deciduous forest	8,294.34	38.78
4.	5/DS1 Dry deciduous scrub	2,335.13	10.92
5.	5/DS2 Dry savannah forest	2.87	0.01
6.	5/E1 *Anogeissus pendula* forest	3,162.27	14.78
7.	5/E1/DS1 *Anogeissus pendula* scrub	523.55	2.45
8.	5/E2 *Boswellia* forest	151.04	0.71
9.	5/E5 *Butea* forest	54.34	0.25
10.	5/E6 *Aegle* forest	1.69	0.01
11.	5/E8a *Phoenix* savannah	2.03	0.01
12.	5/1S1 Dry tropical riverain forest	49.86	0.23
13.	5/1S2 *Khair-sissu* forest	304.35	1.42
14.	6B/C1 Desert thorn forest	813.43	3.80
15.	6B/C2 Ravine thorn forest	329.48	1.54
16.	6B/DS1 *Ziziphus* scrub	164.31	0.77
17.	6B/DS2 Tropical *Euphorbia* scrub	2.92	0.01
18.	6/E1 *Euphorbia* scrub	133.47	0.62
19.	6/E2 *Acacia senegal* forest	46.44	0.22
20.	6/1S1 Desert dune scrub	969.52	4.53
	Sub Total	**18,438.60**	**86.20**
21.	TOF/Plantation	2,950.95	13.80
	Total (Forest Cover & Scrub)	**21,389.55**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

Table 13.22.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	197.33	1.18
3.	Highly fire prone	366.57	2.20
4.	Moderately fire prone	705.56	4.24
5.	Less fire prone	15,385.54	92.38
	Total	**16,655.00**	**100.00**

13.22.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

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Figure 13.22.4 Fire prone forest areas under different fire prone classes

LEGEND
- Extremely Fire Prone
- Very Highly Fire Prone
- Highly Fire Prone
- Moderately Fire Prone
- Less Fire Prone
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.22.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Rajasthan has been estimated as given in following table.

Table 13.22.10 Tree Cover in Rajasthan (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
8,112	8,733	621

13.22.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.22.11 Extent of TOF in Rajasthan (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
4,095	8,733	12,828

13.22.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Rajasthan is given in the Table 13.22.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.22.13.

Table 13.22.12 Growing Stock in Rajasthan (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	24.39	26.56	2.17	0.61
2.	Growing Stock in TOF	89.07	90.63	1.56	5.09

Table 13.22.13 Diameter class distribution of top five tree species inside RFA in Rajasthan (in '000)

		Dia class (cm)		
Sl. No.	Species	10-30	30-60	>60
1.	*Anogeissus pendula*	51,228	606	27
2.	*Butea monosperma*	18,945	2,121	53
3.	*Boswellia serrata*	7,808	3,212	0
4.	*Acacia catechu*	9,382	122	0
5.	*Lannea coromandelica*	7,340	1,958	52

13.22.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Rajasthan in Rural and Urban areas are given in the Table 13.2214 and Table 13.22.15 respectively

Table 13.22.14 Top five tree species in TOF (Rural) in Rajasthan

Sl. No.	Species	Relative Abundance (%)
1.	*Prosopis cineraria*	22.45
2.	*Prosopis juliflora*	10.13
3.	*Acacia arabica*	8.78
4.	*Azadirachta indica*	8.33
5.	*Acacia tortolis*	7.40

Table 13.22.15 Top five tree species in TOF (Urban) in Rajasthan

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	23.42
2.	*Prosopis juliflora*	14.89
3.	*Acacia arabica*	7.95
4.	*Prosopis cineraria*	5.92
5.	*Ziziphus mauritiana*	4.00

13.22.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 110.77 million tonnes (406.16 million tonnes of CO_2 equivalent) which is 1.54 % of total forest carbon of the country. Pool wise forest carbon in Rajasthan is given in the following table.

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Table 13.22.16 Forest Carbon in Rajasthan in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	26,714
2.	BGB	10,803
3.	Dead wood	462
4.	Litter	1,476
5.	SOC	71,319
	Total	1,10,774

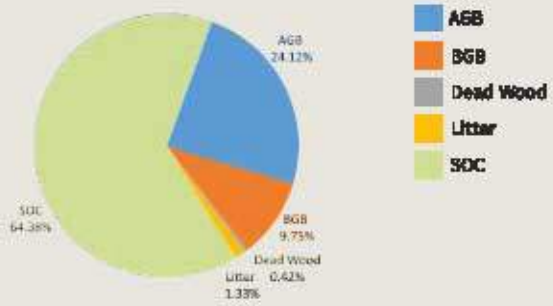


Figure 13.22.5 Forest Carbon in Rajasthan

13.22.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.22.17 Growing Stock of Bamboo in Rajasthan

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	1,555	1.04
Total number of culms (in millions)	382	0.72
Total equivalent green weight (in '000 tonnes)	2,640	0.66

13.22.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.22.18 and Table 13.22.19 respectively.

Table 13.22.18 Major NTFP species in Rajasthan

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Butea monosperma*	Tree	48.33
2.	*Boswellia serrata*	Tree	23.15
3.	*Diospyros melanoxylon*	Tree	10.48
4.	*Wrightia arborea/ Wrightia tomentosa*	Tree	7.30
5.	*Aegle Marmelos*	Tree	6.36

Table 13.22.19 Major invasive species in the State inside the RFA/Green Wash in Rajasthan (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Cassia tora*	192
2.	*Lantana camara*	108
3.	*Senna occidentalis*	100
4.	*Prosopis juliflora*	83
5.	*Triumfetta rhomboidea*	28

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

Rajasthan

13.23 SIKKIM

Geographical Area
7,096 sq km

Geographical Coordinates
Latitude- 27° 04' N to 28° 07' N
Longitude-88° 00' E to 88° 55' E

Population (as per Census 2011)
0.61 million
Urban 0.153 million (25.15 %)
Rural 0.457 million (74.85 %)
Tribal 0.206 million (33.72 %)

Average Population Density
86 per sq km

Livestock population
(as per 19th Live Stock Census)
0.29 million

No. of Districts
4

No. of Hill Districts
4

No. of Tribal Districts
4

Table 13.23.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	710	
Reporting area for land utilization	441	100.00
Forests	334	75.74
Not available for land cultivation	10	2.27
Permanent pastures and other grazing lands	-	-
Land under misc. tree crops and groves	4	0.91
Culturable wasteland	4	0.91
Fallow land other than current fallows	5	1.13
Current fallows	7	1.58
Net area sown	77	17.46

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.23.1 Forest Cover

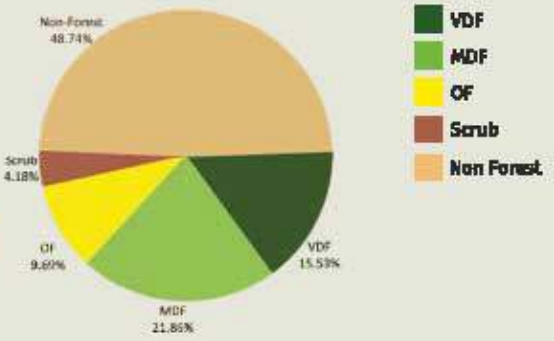


Figure 13.23.1
Forest Cover of Sikkim

Table 13.23.2 Forest Cover of Sikkim (In sq km)

Class	Area	% of GA
VDF	1,101.82	15.53
MDF	1,551.06	21.86
OF	688.15	9.69
Total	**3,341.03**	**47.08**
Scrub	296.44	4.18

Table 13.23.3 District- wise Forest Cover in Sikkim (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				% of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
East Sikkim[TH]	954	271.67	313.00	128.60	713.27	74.77	0.55	54.19
North Sikkim[TH]	4,226	410.36	586.04	285.91	1,282.31	30.34	-1.74	197.17
South Sikkim[TH]	750	173.39	288.99	108.76	571.14	76.15	-0.68	3.71
West Sikkim[TH]	1,166	246.40	363.03	164.88	774.31	66.41	0.41	41.37
Grand Total	**7,096**	**1,101.82**	**1,551.06**	**688.15**	**3,341.03**	**47.08**	**-1.46**	**296.44**

13.23.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.23.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Sikkim (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
832	879	343	2,054	270	672	345	1,287
40.51%	42.79%	16.70%		20.98%	52.21%	26.81%	

**In case of Sikkim, RFA boundaries have been used.*

SIKKIM

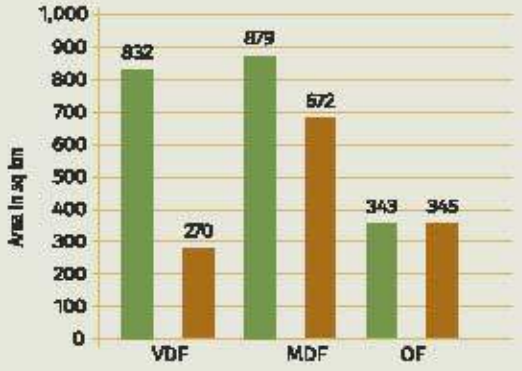


Figure 13.23.2
Forest Cover Inside and Outside of RFA in Sikkim

Table 13.23.5 Forest Cover Change Matrix for Sikkim (in sq km)

Class	2021 Assessment					Total
	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	1,101	1	0	0	0	1,102
Moderately Dense Forest	1	1,550	1	0	0	1,552
Open Forest	0	0	685	1	2	688
Scrub	0	0	1	291	15	307
Non Forest	0	0	1	4	3,442	3,447
Total ISFR 2021	**1,102**	**1,551**	**688**	**296**	**3,459**	**7,096**
Net Change	0	-1	0	-11	12	

Table 13.23.6 Altitude-wise Forest Cover in Sikkim (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	50	0	20	16	36	1
500-1000	375	12	154	95	261	12
1000-2000	1,306	277	572	246	1,095	15
2000-3000	1,155	577	404	91	1,072	7
3000-4000	1,103	230	368	172	770	105
>4000	3,107	6	33	68	107	156
Total	**7,096**	**1,102**	**1,551**	**688**	**3,341**	**296**

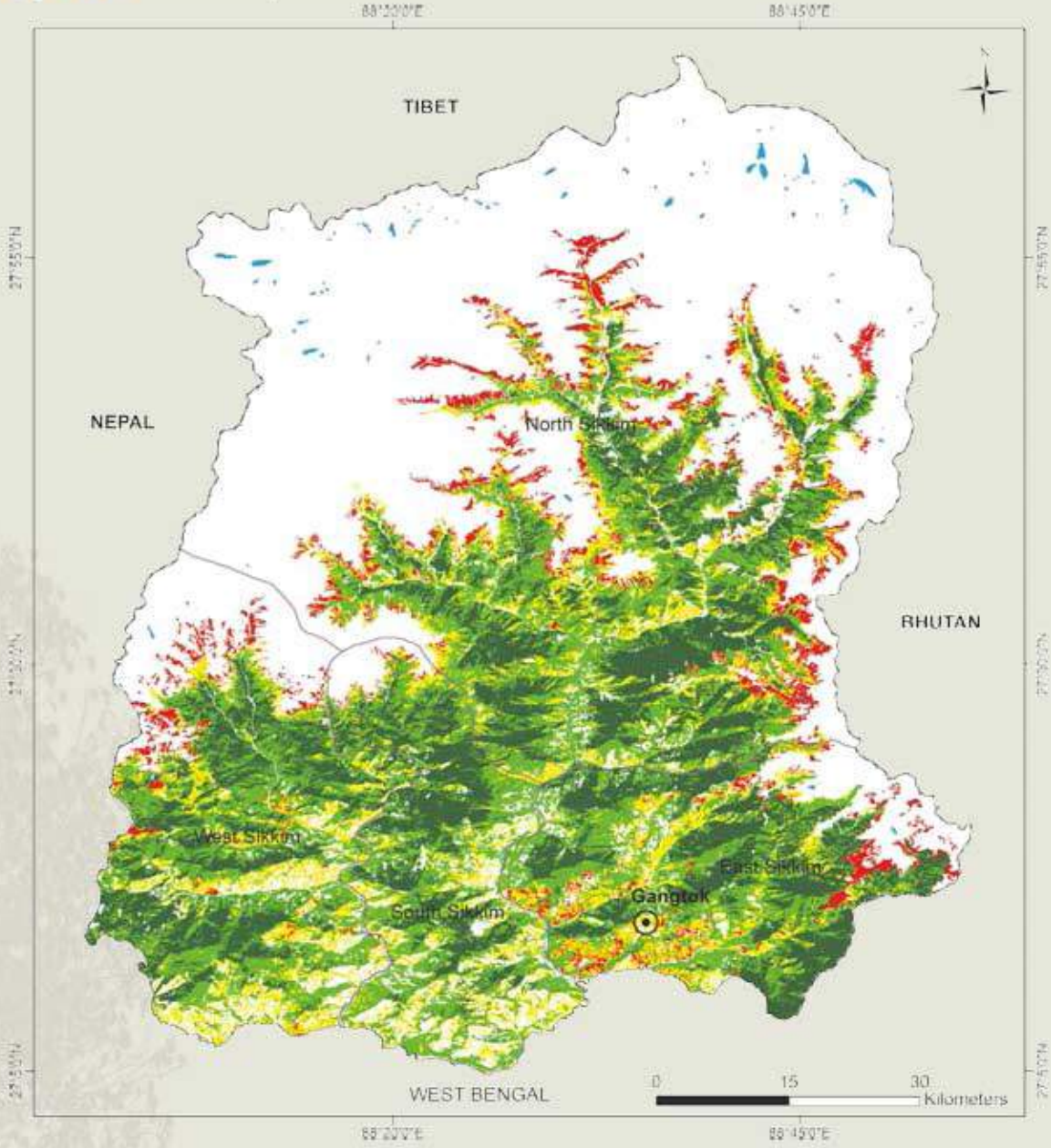
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.23.7 Forest Cover in different slope classes in Sikkim (in sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	351	13	16	7	36	8
5-10	554	48	57	25	130	20
10-15	767	109	130	54	293	34
15-20	969	167	211	89	467	45
20-25	1,062	199	266	111	576	50
25-30	1,034	198	275	116	589	18
>30	2,359	368	596	286	1,250	121
Total	**7,096**	**1,102**	**1,551**	**688**	**3,341**	**296**

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

Figure 13.23.3 Forest Cover Map of Sikkim



LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.23.2 Forest Types

The area under different forest types of Sikkim as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

SIKKIM

Table 13.23.8 Area statistics of the Forest Types found in Sikkim (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3C/C1a(i) East Himalayan sal	69.47	1.84
2.	3C/C3b East Himalayan moist mixed deciduous forest	194.86	5.15
3.	8B/C1 East Himalayan sub-tropical wet hill forest	905.73	23.93
4.	11B/C1b *Bulk* oak forest	874.93	23.11
5.	12/C3a East Himalayan mixed coniferous forest	224.16	5.92
6.	12/D51 Montane bamboo brakes	7.04	0.19
7.	14/C2 East Himalayan sub-alpine birch/fir forest	912.14	24.09
8.	15/C1 Birch/*Rhododendron* scrub forest	128.19	3.39
9.	15/E1 Dwarf *Rhododendron* scrub	11.44	0.30
10.	15/E2 Dwarf juniper scrub	187.94	4.96
	Sub Total	**3,515.90**	**92.88**
11.	TOF/Plantation	133.24	3.52
	Total (Forest Cover & Scrub)	**3,649.14**	
	Grassland forest type (outside forest cover)		
12.	15/C3 Alpine pastures	136.28	3.60
	Grand Total	**3,785.42**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

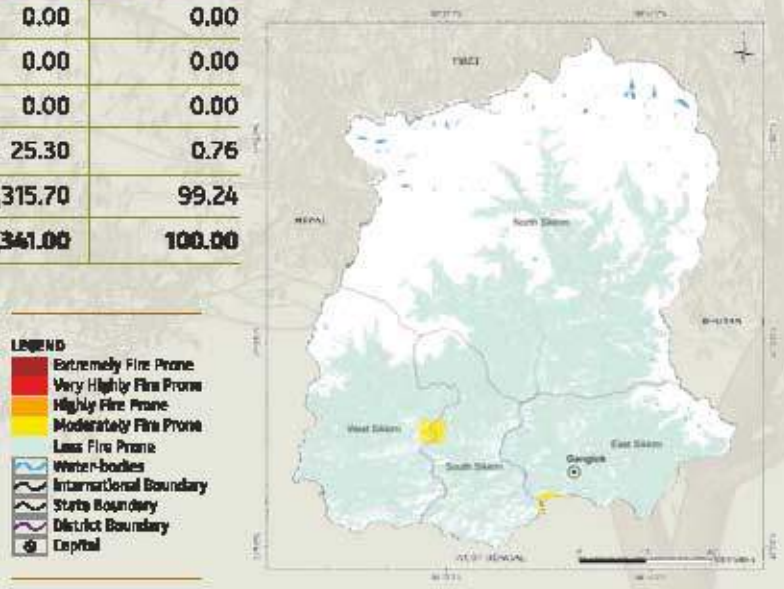
13.23.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.23.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	25.30	0.76
5.	Less fire prone	3,315.70	99.24
	Total	**3,341.00**	**100.00**

Figure 13.23.4 Fire prone forest areas under different fire prone classes



13.23.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Sikkim has been estimated as given in following table.

Table 13.23.10 Tree Cover in Sikkim (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
36	39	3

13.23.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.23.11 Extent of TOF in Sikkim (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
1,287	39	1,326

13.23.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Sikkim is given in the Table 13.23.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.23.13.

Table 13.23.12 Growing Stock in Sikkim (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	35.32	33.91	-1.41	0.77
2.	Growing Stock in TOF	1.94	1.73	-0.21	0.10

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Table 13.23.13 Diameter class distribution of top five tree species inside RFA in Sikkim (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Schima wallichii*	4,073	1,284	97
2.	*Castanopsis* spp.	2,617	1,720	700
3.	*Shorea robusta*	2,869	1,127	216
4.	*Machilus* spp.	620	679	401
5.	*Alnus* spp.	475	852	100

13.23.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Sikkim in Rural and Urban areas are given in the Table 13.23.14 and Table 13.23.15 respectively.

Table 13.23.14 Top five tree species in TOF (Rural) in Sikkim

Sl. No.	Species	Relative Abundance (%)
1.	*Schima wallichii*	19.50
2.	*Alnus* spp.	8.80
3.	*Ficus* spp.	6.45
4.	*Macaranga* spp.	5.22
5.	*Castanopsis* spp.	4.13

Table 13.23.15 Top five tree species in TOF (Urban) in Sikkim

Sl. No.	Species	Relative Abundance (%)
1.	*Cryptomeria japonica*	11.96
2.	*Schima wallichii*	11.77
3.	*Macaranga* spp.	9.00
4.	*Ficus* spp.	7.87
5.	*Prunus cornuta*	5.41

13.23.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 55.54 million tonnes (203.65 million tonnes of CO_2 equivalent) which is 0.77 % of total forest carbon of the country. Pool wise forest carbon in Sikkim is given in the following table.

Table 13.23.16 Forest Carbon in Sikkim in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	18,024
2.	BGB	5,466
3.	Dead wood	498
4.	Litter	607
5.	SOC	30,944
	Total	**55,539**

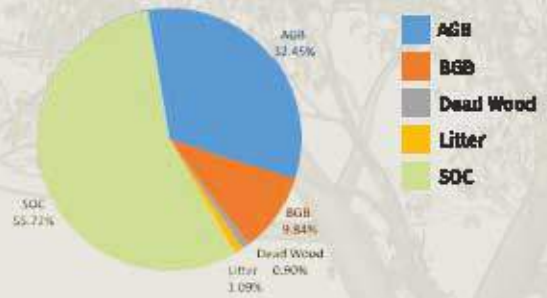

Figure 13.23.5 Forest Carbon in Sikkim

13.23.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.23.17 Growing Stock of Bamboo in Sikkim

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	994	0.67
Total number of culms (in millions)	326	0.61
Total equivalent green weight (in '000 tonnes)	624	0.16

13.23.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.23.18 and Table 13.23.19 respectively.

Table 13.23.18 Major NTFP Species in Sikkim

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Nephrolepis* spp.	Herbs	81.31
2.	*Spondias axillaris*	Tree	4.67
3.	*Diplazium* spp.	Herbs	4.67
4.	*Thysanolaena latifolia*	Shrub	4.67
5.	*Polygonum* spp.	Shrub	2.80

Table 13.23.19 Major invasive species in the State inside the RFA/Green Wash in Sikkim

(in sq km)

Sl. No.	Species	Estimated Extent
1.	*Glinsoga parviflora*	10
2.	*Acacia farnesiana*	7
3.	*Parthenium hysterophorus*	2
4.	*Solanum viarum*	1
5.	*Lantana camara*	0.44

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.24 TAMIL NADU

Geographical Area
1,30,060 sq km

Geographical Coordinates
Latitude- 8° 05' N to 13° 35' N
Longitude-76° 15' E to 80° 20' E

Population (as per Census 2011)
72.15 million
Urban 34.92 million (48.40 %)
Rural 37.23 million (51.60 %)
Tribal 0.79 million (1.10%)

Average Population Density
555 per sq km

Livestock population
(as per 19th Live Stock Census)
22.72 million

No. of Districts
32

No. of Hill Districts
5

No. of Tribal Districts
6

Table 13.24.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	13,006	
Reporting area for land utilization	13,033	100.00
Forests	2,157	16.55
Not available for land cultivation	2,659	20.40
Permanent pastures and other grazing lands	108	0.83
Land under misc. tree crops and groves	226	1.73
Culturable wasteland	320	2.46
Fallow land other than current fallows	1,932	14.82
Current fallows	992	7.61
Net area sown	4,639	35.60

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.24.1 Forest Cover

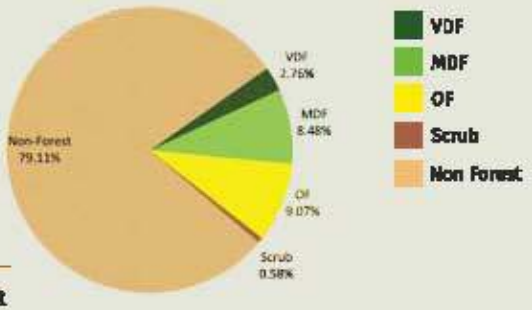

Figure 13.24.1 Forest Cover of Tamil Nadu

Table 13.24.2 Forest Cover of Tamil Nadu (In sq km)

Class	Area	% of GA
VDF	3,593.01	2.76
MDF	11,034.03	8.48
OF	11,792.19	9.07
Total	**26,419.23**	**20.31**
Scrub	757.84	0.58

Table 13.24.3 District-wise Forest Cover in Tamil Nadu (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				% of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Ariyalur	1,940	0.00	40.38	364.22	404.60	20.86	11.46	6.56
Chennai	175	0.00	6.17	6.50	12.67	7.24	-0.17	0.00
Coimbatore*	4,732	360.8	679.98	944.26	1,985.04	41.95	0.40	7.31
Cuddalore	3,703	0.00	47.56	342.68	390.24	10.54	-0.72	17.52
Dharmapuri*	4,497	261.85	835.75	605.11	1,702.71	37.86	1.57	15.06
Dindigul	6,036	251.99	762.12	843.86	1,877.97	31.11	3.57	31.9
Erode	5,760	402.17	1,128.56	765.00	2,295.73	39.86	1.27	37.50
Kancheepuram	4,483	0.00	71.79	253.52	325.31	7.26	17.53	40.29
Kanniyakumari*	1,684	136.08	570.22	297.30	1,003.60	59.60	0.06	0.58
Karur	2,904	2.24	42.58	73.82	118.64	4.09	0.18	7.48
Krishnagiri	5,129	94.87	827.61	695.47	1,617.95	31.55	0.54	32.76
Madurai*	3,710	38.87	232.76	281.59	553.22	14.91	-1.90	33.05
Nagapattinam	2,569	0.00	23.48	133.20	156.68	6.10	-2.51	0.00
Namakkal*	3,420	83.41	283.97	213.51	580.89	16.99	1.84	24.25
Perambalur*	1,756	10.03	64.81	67.33	142.17	8.10	0.91	18.79
Pudukkottai	4,644	0.77	106.51	269.85	377.13	8.12	12.34	7.30
Ramanathapuram	4,104	0.00	23.84	227.65	251.49	6.13	-5.46	6.25
Salem*	5,237	197.62	757.20	516.30	1,471.12	28.09	1.28	33.83
Sivaganga	4,233	0.00	37.60	293.49	331.09	7.82	1.43	5.34
Thanjavur	3,411	0.00	265.02	85.32	350.34	10.27	4.15	0.64
The Nilgiris*	2,565	460.67	629.51	641.20	1,731.38	67.50	0.37	8.71
Theni	2,868	183.17	471.06	529.66	1,183.89	41.28	8.60	29.42
Thiruvallur	3,394	11.00	46.10	238.42	295.52	8.71	9.85	51.41
Thiruvarur	2,274	0.46	35.65	33.96	70.07	3.08	2.60	0.00
Tirunelveli*	6,693	442.48	566.56	293.46	1,302.50	19.46	2.26	26.08
Tiruppur	5,187	48.28	237.66	560.25	846.19	16.31	1.76	8.81
Tiruvannamalai*	6,188	233.64	596.61	482.1	1,312.35	21.21	3.99	71.22

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(in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Trichirappalli*	4,509	53.53	228.35	193.94	475.82	10.55	4.46	33.61
Tuticorin	4,745	0	25.72	226.25	251.97	5.31	-4.71	69.75
Vellore	6,075	200.98	939.55	684.45	1,824.98	30.04	6.39	76.47
Villuppuram	7,194	79.36	299.05	455.94	834.35	11.60	-23.21	47.01
Virudhunagar	4,241	38.74	130.30	172.58	341.62	8.06	-4.92	8.94
Grand Total	1,30,060	3,593.01	11,034.03	11,792.19	26,419.23	20.31	55.21	757.84

13.24.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.24.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Tamil Nadu (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
3,320	8,580	5,631	17,531	273	2,454	6,161	8,888
18.94%	48.94%	32.12%		3.07%	27.61%	69.32%	

*In case of Tamil Nadu, RFA boundaries have been used.

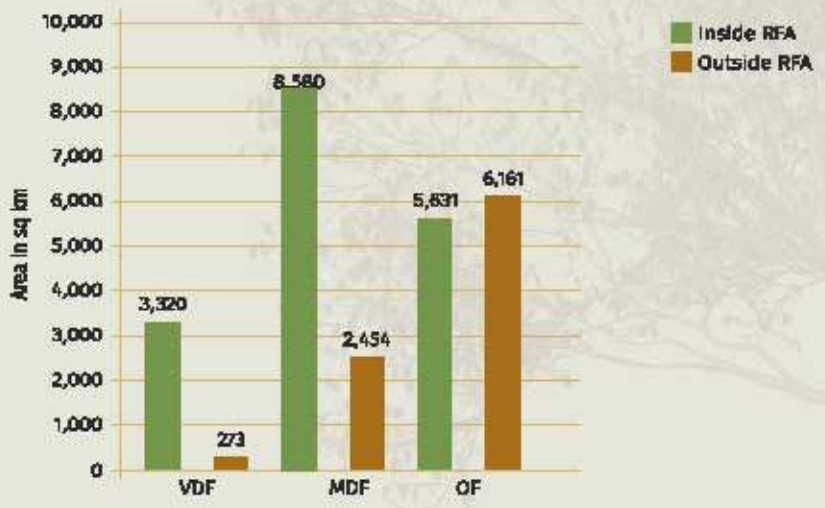


Figure 13.24.2 Forest Cover Inside and Outside of RFA in Tamil Nadu

Table 13.24.5 Forest Cover Change Matrix for Tamil Nadu (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	3,593	8	3	0	1	3,605
Moderately Dense Forest	0	11,017	4	3	6	11,030
Open Forest	0	0	11,563	12	154	11,729
Scrub	0	0	2	711	2	715
Non Forest	0	9	220	32	1,02,720	1,02,981
Total ISFR 2021	**3,593**	**11,034**	**11,792**	**758**	**1,02,883**	**1,30,060**
Net Change	-12	4	63	43	-98	

Table 13.24.6 Altitude-wise Forest Cover in Tamil Nadu (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	1,11,060	364	5,112	8,631	14,107	598
500-100	13,688	1,810	4,402	2,420	8,632	22
1000-2000	4,437	1,087	1,399	700	3,186	6
2000-3000	875	332	121	41	494	132
Total	**1,30,060**	**3,593**	**11,034**	**11,792**	**26,419**	**758**

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

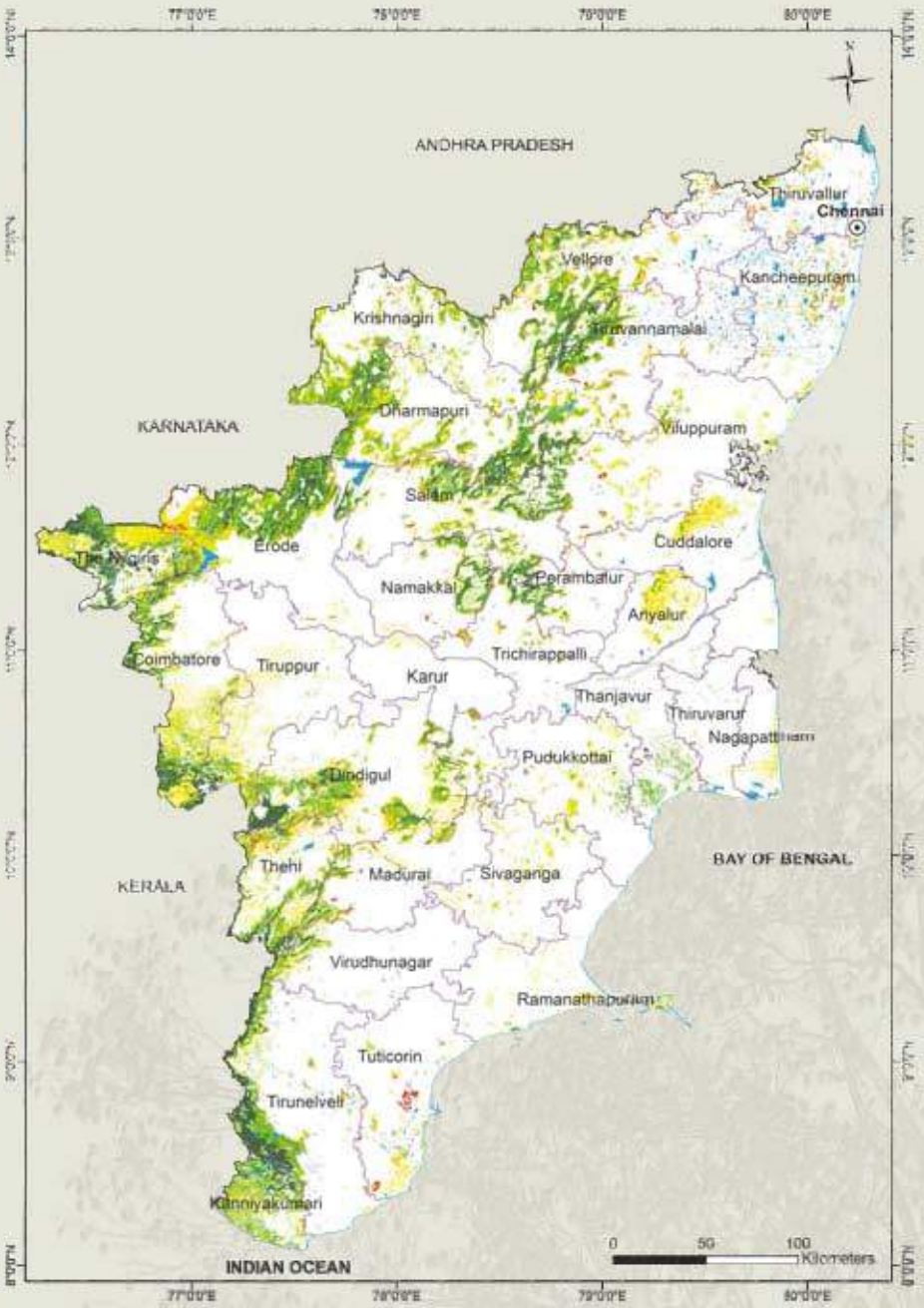
Table 13.24.7 Forest Cover in different slope classes in Tamil Nadu (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,09,583	334	3,454	7,634	11,422	386
5-10	5,911	529	1,762	1,358	3,649	102
10-15	3,943	584	1,506	876	2,966	55
15-20	3,364	586	1,387	743	2,716	66
20-25	2,856	558	1,229	623	2,410	60
25-30	2,208	484	940	475	1,899	49
>30	2,195	518	756	83	1,357	40
Total	**1,30,060**	**3,593**	**11,034**	**11,792**	**26,419**	**758**

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

TAMIL NADU

Figure 13.24.3
Forest Cover Map of Tamil Nadu



13.24.2 Forest Types

The area under different forest types of Tamil Nadu as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.24.3 Area statistics of the Forest Types found in Tamil Nadu (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1A/C3 Southern hilltop tropical evergreen forest	108.55	0.39
2.	1A/C4 West Coast tropical evergreen forest	679.02	2.46
3.	2A/C2 West Coast semi-evergreen forest	410.10	1.49
4.	2A/C3 Tirunelvali saml-evergreen forest	119.82	0.43
5.	2/E3 Moist bamboo brakes	322.88	1.17
6.	3B/C1a Very moist teak forest	58.65	0.21
7.	3B/C1b Moist teak forest	173.79	0.63
8.	3B/C1c Slightly moist teak forest	51.22	0.19
9.	3B/C2 Southern moist mixed deciduous forest	1,249.80	4.53
10.	3B/C2/2S1 Southern secondary moist mixed deciduous forest	260.86	0.94
11.	4A/L1 Littoral forest	7.96	0.03
12.	4B/TS1 Mangrove scrub	27.33	0.10
13.	4B/TS2 Mangrove forest	17.50	0.06
14.	4C/FS2 Submontane hill valley swamp forest	2.12	0.01
15.	4E/RS1 Riparian fringing forest	37.15	0.13
16.	5A/C1a Very dry teak forest	0.90	0.00
17.	5A/C1b Dry teak forest	157.01	0.57
18.	5A/C2 Dry red sanders-bearing forest	10.40	0.04
19.	5A/C3 Southern dry mixed deciduous forest	6,193.06	22.43
20.	5/DS1 Dry deciduous scrub	941.05	3.41
21.	5/DS2 Dry savannah forest	258.73	0.94
22.	5/DS3 *Euphorbia* scrub	3.28	0.01
23.	5/DS4 Dry grassland	51.21	0.19
24.	5/E4 *Hardwickia* forest	438.74	1.59
25.	5/E9 Dry bamboo brakes	150.98	0.55
26.	5/1S1 Dry tropical rivarain forest	112.74	0.41
27.	5/2S1 Secondary dry deciduous forest	2,734.24	9.90
28.	6A/C1 Southern thorn forest	1,858.24	6.73
29.	6A/C2 Carnatic umbrella thorn forest	1,469.21	5.32
30.	6A/DS1 Southern thorn scrub	514.59	1.86
31.	6A/DS2 Southern *Euphorbia* scrub	43.50	0.16
32.	7/C1 Tropical dry evergreen forest	309.75	1.12
33.	7/DS1 Tropical dry evergreen scrub	75.99	0.27
34.	8A/C1 Nilgiri sub tropical hill forest	173.08	0.63
35.	8A/C1/DS1 South Indian sub-tropical hill savannah (woodland)	19.07	0.07
36.	8A/E1 Reed brakes *(Ochlandra)*	3.47	0.01
37.	11A/C1 Southern montane wet temperate forest	186.31	0.67
38.	11A/C1/DS1 Southern montane wet scrub	4.16	0.01

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(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
39.	11A/C1/DS2 Southern montane wet grassland	17.08	0.06
	Sub Total	**19,253.54**	**69.72**
40.	TOF/Plantation	7,825.20	28.34
	Total (Forest Cover & Scrub)	**27,078.74**	
	Grassland forest types (outside forest cover)		
41.	5/DS2 Dry savannah forest	107.68	0.39
42.	5/DS4 Dry grassland	232.84	0.84
43.	11A/C1/DS2 Southern montane wet grassland	194.44	0.71
	Sub Total	**534.96**	**1.94**
	Grand Total	**27,613.70**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

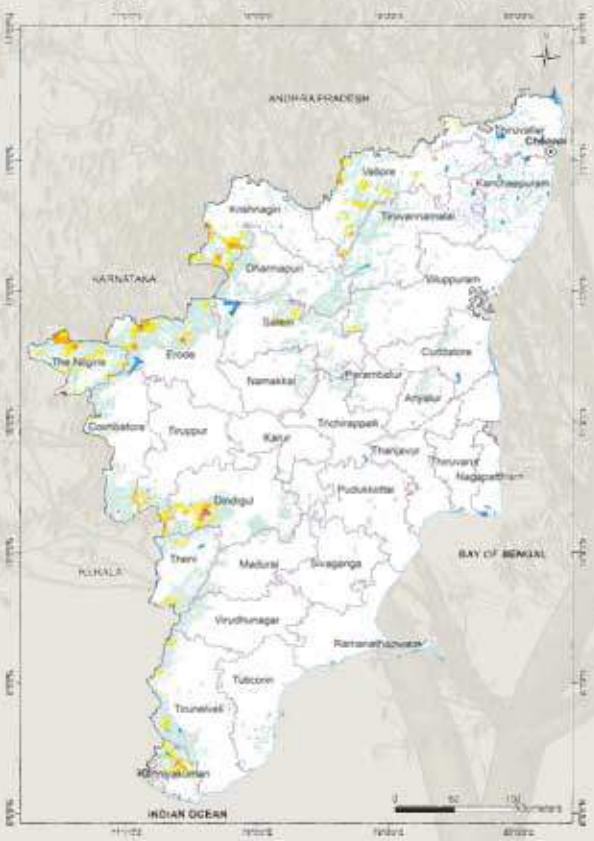
13.24.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.24.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	38.78	0.15
3.	Highly fire prone	470.00	1.78
4.	Moderately fire prone	1,910.94	7.23
5.	Less fire prone	23,999.28	90.84
	Total	**26,419.00**	**100.00**

Figure. 13.24.4 Fire prone forest areas under different fire prone classes



13.24.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Tamil Nadu has been estimated as given in following table.

Table 13.24.10 Tree Cover in Tamil Nadu (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
4,830	4,424	-406

13.24.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.24.11 Extent of TOF in Tamil Nadu (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
8,888	4,424	13,312

13.24.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Tamil Nadu is given in the Table 13.24.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.24.13

Table 13.24.12 Growing Stock in Tamil Nadu (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	96.97	92.27	-4.70	2.10
2.	Growing Stock in TOF	76.30	82.21	5.91	4.62

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Table 13.24.13 Diameter class distribution of top five tree species inside RFA in Tamil Nadu (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Albizzia amara*	73,482	2,814	68
2.	*Anogeissus latifolia*	27,875	2,687	34
3.	*Commiphora ostdets*	18,806	1,218	34
4.	*Tectona grandis*	8,096	970	317
5.	*Ficus spp.*	5,110	640	237

13.24.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Tamil Nadu in Rural and Urban areas are given in the Table 13.24.14 and Table 13.24.15 respectively.

Table 13.24.14 Top five tree species in TOF (Rural) in Tamil Nadu

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	29.47
2.	*Azadirachta indica*	11.25
3.	*Borassus flabelliformis*	10.41
4.	*Mangifera indica*	5.93
5.	*Areca catechu*	4.49

Table 13.24.15 Top five tree species in TOF (Urban) in Tamil Nadu

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	32.32
2.	*Azadirachta indica*	13.32
3.	*Morinda oleifera*	5.25
4.	*Mangifera indica*	4.16
5.	*Borassus flabelliformis*	3.66

13.24.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 214.61 million tonnes (786.90 million tonnes of CO_2 equivalent) which is 2.98 % of total forest carbon of the country. Pool wise forest carbon in Tamil Nadu is given in the following table.

Table 13.24.16 Forest Carbon in Tamil Nadu in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	60,459
2.	BGB	20,671
3.	Dead wood	1,198
4.	Litter	3,102
5.	SOC	1,29,183
	Total	**2,14,613**

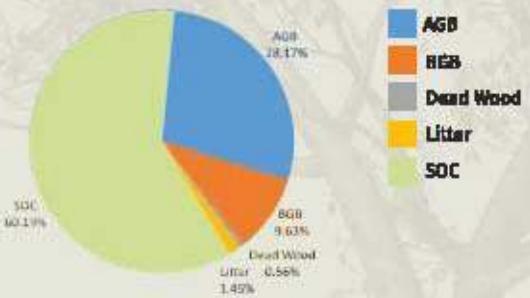


Figure 13.24.5 Forest Carbon in Tamil Nadu

13.24.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.24.17 Growing Stock of Bamboo in Tamil Nadu

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	4,001	2.68
Total number of culms (in millions)	1,021	1.91
Total equivalent green weight (in '000 tonnes)	9,215	2.29

13.24.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.24.18 and Table 13.24.19 respectively.

Table 13.24.18 Major NTFP Species in Tamil Nadu

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Albizia amara*	Tree	73.46
2.	*Cymbopogan citrates*	Herbs	9.02
3.	*Anacardium occidentale*	Tree	3.97
4.	*Embilica officinalis*	Tree	3.08
5.	*Tamarindus indica*	Tree	2.96

Table 13.24.19 Major invasive species in the State inside the RFA/Green Wash in Tamil Nadu (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	1,154
2.	*Chromolaena odorata*	220
3.	*Solanum elaegnifolium*	66
4.	*Ageratum conyzoides*	44
5.	*Cuscuta* spp.	31

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.25 TELANGANA

Geographical Area
1,12,077 sq km

Geographical Coordinates
Latitude-15° 50' N to 19° 55' N
Longitude-77° 14' E to 81° 19' E

Population (as per Census 2011)
35.19 million
Urban 13.61 million (38.88 %)
Rural 21.58 million (61.12 %)
Tribal 3.29 million (9.35 %)

Average Population Density
306 Per Sq km

Livestock population
(as per 19th Live Stock Census)
56.10 million

No. of Districts
10

No. of Hill Districts
0

No. of Tribal Districts
3

Table 13.25.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	11,210	
Reporting area for land utilization	11,208	100.00
Forests	2,698	24.07
Not available for land cultivation	1,441	12.86
Permanent pastures and other grazing lands	299	2.67
Land under misc. tree crops and groves	112	1.00
Culturable wasteland	182	1.62
Fallow land other than current fallows	662	5.91
Current fallows	916	8.17
Net area sown	4,898	43.70

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.25.1 Forest Cover

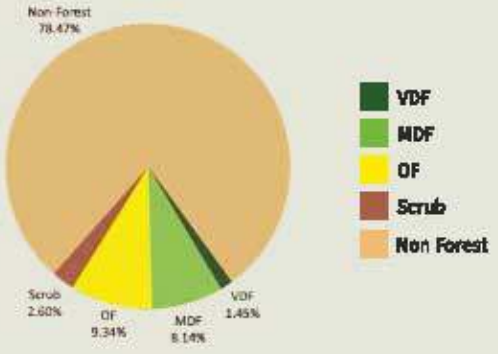


Figure 13.25.1 Forest Cover of Telangana

Table 13.25.2 Forest Cover of Telangana (In sq km)

Class	Area	% of GA
VDF	1,623.90	1.45
MDF	9,118.68	8.14
OF	10,471.40	9.34
Total	**21,213.98**	**18.93**
Scrub	2,911.37	2.60

Table 13.25.3 District- wise Forest Cover in Telangana (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Adilabad*	16,105	150.25	3,244.05	2,349.12	5,743.42	35.66	22.10	94.56
Hyderabad	217	0.00	4.91	13.09	18.00	8.29	-0.68	2.12
Karimnagar	11,823	74.50	854.59	1,276.93	2,206.02	18.66	217.81	275.42
Khammam*	13,266	730.06	2,292.84	1,485.81	4,508.71	33.99	29.57	51.69
Mahbubnagar	18,432	336.32	633.51	1,340.46	2,310.29	12.53	9.24	658.17
Medak	9,699	0.00	120.11	652.19	772.30	7.96	32.99	271.85
Nalgonda	14,240	0.15	23.11	494.93	518.19	3.64	103.75	708.64
Nizamabad	7,956	0.09	253.80	977.98	1,231.87	15.48	35.58	276.32
Rangareddy	7,493	0.02	146.10	659.99	806.11	10.76	35.69	428.24
Warangal*	12,846	332.51	1,545.66	1,220.90	3,099.07	24.12	145.62	142.17
Grand Total	**1,12,077**	**1,623.90**	**9,118.68**	**10,471.40**	**21,213.98**	**18.93**	**631.67**	**2,911.37**

13.25.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.25.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Telangana (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
1,551	8,651	8,494	18,696	73	468	1,977	2,518
8.30%	46.27%	45.43%		2.90%	18.59%	78.51%	

**In case of Telangana, RFA boundaries have been used.*

TELANGANA

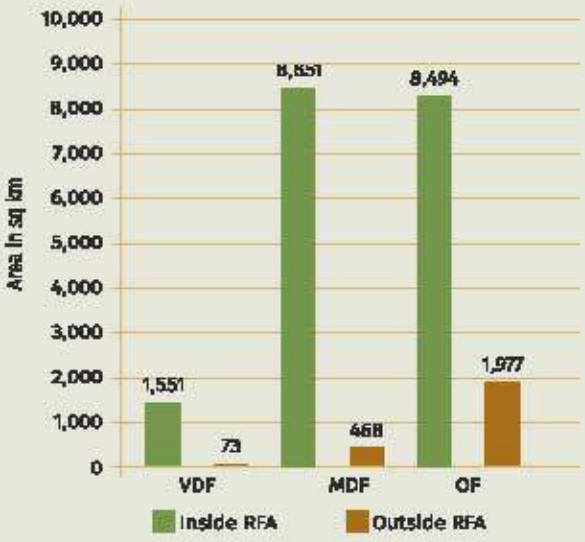


Figure 13.25.2
Forest Cover Inside and Outside of RFA in Telangana

Table 13.25.5 Forest Cover Change Matrix for Telangana (In sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	1,607	1	0	0	0	1,608
Moderately Dense Forest	17	8,748	2	2	18	8,787
Open Forest	0	365	9,706	11	105	10,187
Scrub	0	1	623	2,765	226	3,615
Non Forest	0	4	140	133	87,603	87,880
Total ISFR 2021	**1,624**	**9,119**	**10,471**	**2,911**	**87,952**	**1,12,077**
Net Change	16	332	284	-704	72	

Table 13.25.6 Altitude-wise Forest Cover in Telangana (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	88,743	1,295	7,837	7,758	16,890	2,095
500-1000	23,334	329	1,282	2,713	4,324	816
Total	**1,12,077**	**1,624**	**9,119**	**10,471**	**21,214**	**2,911**

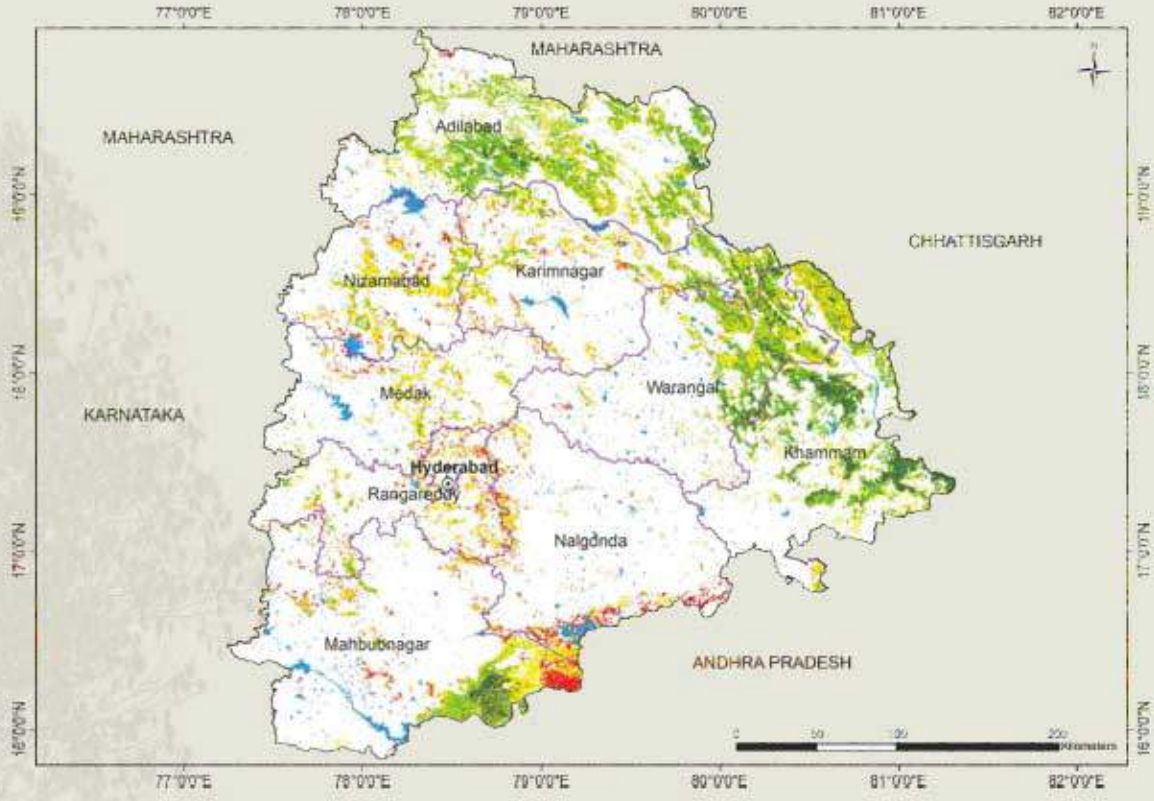
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.25.7 Forest Cover in different slope classes in Telangana (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	1,01,773	927	5,875	7,292	14,094	2,263
5-10	5,542	287	1,429	1,538	3,254	352
10-15	2,243	166	820	760	1,746	142
15-20	1,260	108	506	435	1,049	77
20-25	719	72	289	252	613	44
25-30	357	41	137	128	306	23
>30	183	23	63	66	152	10
Total	**1,12,077**	**1,624**	**9,119**	**10,471**	**21,214**	**2,911**

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

Figure 13.25.3 Forest Cover Map of Telangana



LEGEND

- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

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13.25.2 Forest Types

The area under different forest types of Telangana as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.25.8 Area statistics of the Forest Types found in Telangana (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3B/C2 Southern moist mixed deciduous forest	49.23	0.20
2.	5A/C1b Dry teak forest	3,371.64	13.87
3.	5A/C3 Southern dry mixed deciduous forest	14,383.62	59.18
4.	5/DS1 Dry deciduous scrub	5,037.40	20.72
5.	5/DS2 Dry savannah forest	5.04	0.02
6.	5/E2 *Boswellia* forest	0.77	0.00
7.	5/E4 *Hardwickia* forest	0.47	0.00
8.	5/E9 Dry bamboo brakes	16.30	0.07
9.	5/Z51 Secondary dry deciduous forest	151.94	0.63
10.	6A/C1 Southern thorn forest	320.41	1.32
11.	6A/DS1 Southern thorn scrub	0.80	0.00
	Sub Total	**23,337.62**	**96.01**
12.	TOF/Plantation	859.73	3.54
	Total (Forest Cover & Scrub)	**24,197.35**	
	Grassland forest type (outside forest cover)		
13.	5/DS4 Dry grassland	108.96	0.45
	Grand Total	**24,306.31**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

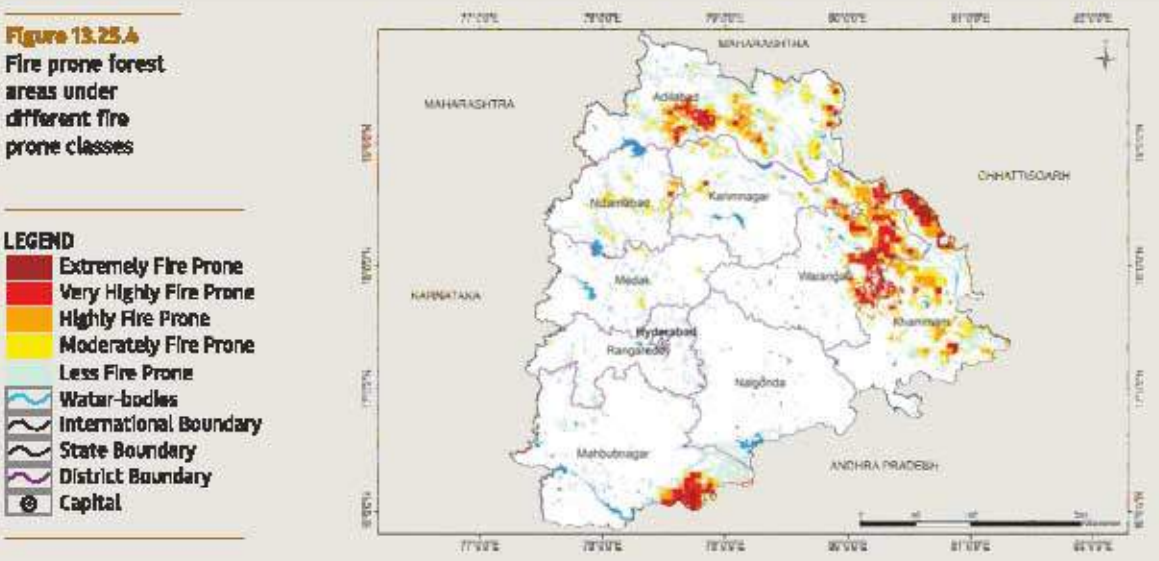
13.25.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.25.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	571.87	2.70
2.	Very highly fire prone	2,970.26	14.00
3.	Highly fire prone	3,920.18	18.48
4.	Moderately fire prone	3,522.07	16.60
5.	Less fire prone	10,229.62	48.22
	Total	**21,214.00**	**100.00**

Figure 13.25.4
Fire prone forest areas under different fire prone classes



13.25.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Telangana has been estimated as given in following table.

Table 13.25.10 Tree Cover in Telangana (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
2,514	2,848	334

13.25.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.25.11 Extent of TOF in Telangana (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
2,518	2,848	5,366

13.25.6 Growing Stock in Telangana

Growing stock in the recorded forest areas (RFA) in Telangana is given in the Table 15.25.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 15.25.13

Table 13.25.12 Growing Stock in Telangana (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	80.96	80.20	-0.76	1.83
2.	Growing Stock in TOF	41.45	43.76	2.31	2.46

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Table 13.25.13 Diameter class distribution of top five tree species inside RFA in Telangana (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Tectona grandis*	72,112	4,460	166
2.	*Anogeissus latifolia*	23,921	2,434	42
3.	*Terminalia tomentosa*	20,245	3,358	87
4.	*Lannea coromandelica*	15,285	3,940	83
5.	*Madhuca latifolia*	3,859	3,113	428

13.25.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Telangana in Rural and Urban areas are given in the Table 13.25.14 and Table 13.25.15 respectively.

Table 13.25.14 Top five tree species in TOF (Rural) in Telangana

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	38.93
2.	*Azadirachta indica*	13.66
3.	*Butea monosperma*	5.06
4.	*Borassus flabelliformis*	4.26
5.	*Tectona grandis*	3.99

Table 13.25.15 Top five tree species in TOF (Urban) in Telangana

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	19.35
2.	*Mangifera indica*	8.86
3.	*Pongamia pinnata*	6.84
4.	*Tectona grandis*	5.32
5.	*Cocos nucifera*	5.28

13.25.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 161.99 million tonnes (593.96 million tonnes of CO_2 equivalent) which is 2.25 % of total forest carbon of the country. Pool wise forest carbon in Telangana is given in the following table.

Table 13.25.16 Forest Carbon in Telangana in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	44,413
2.	BGB	18,415
3.	Dead wood	675
4.	Litter	2,169
5.	SOC	96,314
	Total	**1,61,986**

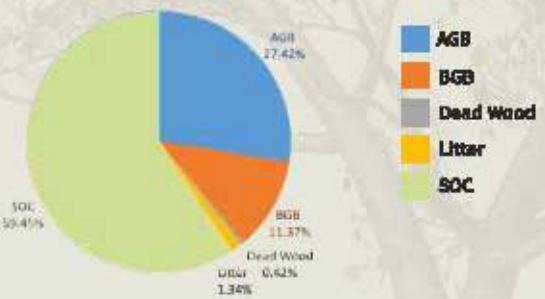


Figure 13.25.5 Forest Carbon in Telangana

13.25.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.25.17 Growing Stock of Bamboo in Telangana

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	4,535	3.03
Total number of culms (in millions)	2,008	3.76
Total equivalent green weight (in '000 tonnes)	12,516	3.11

13.24.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.24.18 and Table 13.24.19 respectively.

Table 13.25.18 Major NTFP species in Telangana

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Solanum nigrum*	Herbs	15.98
2.	*Terminalia belerica*	Tree	10.15
3.	*Desmodium gangeticum*	Shrub	9.72
4.	*Strychnos potatorum*	Tree	9.29
5.	*Strychnos nuxvomica*	Tree	9.07

Table 13.25.19 Major invasive species in the State inside the RFA/Green wash in Telangana

(in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	133
2.	*Chromolaena odorata*	128
3.	*Senna occidentalis*	78
4.	*Cassia tora*	27
5.	*Argemone mexicana*	26

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.26 TRIPURA

Geographical Area
10,486 sq km

Geographical Coordinates
Latitude- 22° 57' N to 24° 32' N
Longitude- 91° 10' E to 92° 20' E

Population (as per Census 2011)
3.67 million
Urban 0.96 million (26.17 %)
Rural 2.71 million (73.83 %)
Tribal 1.17 million (31.76 %)

Average Population Density
350 per sq km

Livestock population
(as per 19th Live Stock Census)
1.94 million

No. of Districts
4

No. of Hill Districts
4

No. of Tribal Districts
4

Table 13.26.1 Land Use Pattern

Land Use Types	Area (In '000 ha)	Percentage
Geographical Area	1,049	
Reporting area for land utilization	1,049	100.00
Forests	629	59.96
Not available for land cultivation	148	14.11
Permanent pastures and other grazing lands	1	0.10
Land under misc. tree crops and groves	10	0.95
Culturable wasteland	3	0.28
Fallow land other than current fallows	2	0.19
Current fallows	1	0.10
Net area sown	255	24.31

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.26.1 Forest Cover

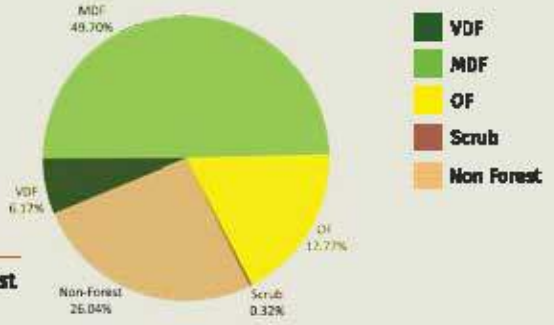


Figure 13.26.1 Forest Cover of Tripura

Table 13.26.2 Forest Cover of Tripura (In sq km)

Class	Area	% of GA
VDF	646.76	6.17
MDF	5,211.76	49.70
OF	1,863.00	17.77
Total	**7,721.52**	**73.64**
Scrub	33.22	0.32

Table 13.26.3 District- wise Forest Cover in Tripura (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Dhalai[TR]	2,400	117.71	1,453.00	406.44	1,977.15	82.38	-6.55	2.55
North Tripura[TR]	2,036	48.52	1,044.60	387.57	1,480.69	72.73	0.50	18.21
South Tripura[TR]	3,057	235.28	1,571.31	455.23	2,261.82	73.99	-10.38	0.10
West Tripura[TR]	2,993	245.25	1,142.85	613.76	2,001.86	66.88	12.36	12.36
Grand Total	**10,486**	**646.76**	**5,211.76**	**1,863.00**	**7,721.52**	**73.64**	**-4.07**	**33.22**

13.26.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.25.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Tripura (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
407	3,886	1,140	5,433	240	1,326	723	2,289
7.49%	71.53%	20.98%		10.48%	57.93%	31.59%	

**In case of Tripura, RFA boundaries have been used.*

TRIPURA

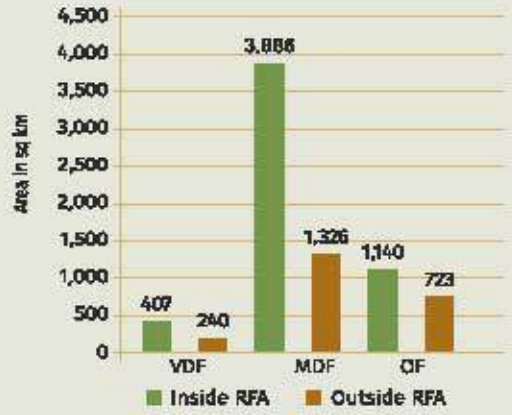


Figure 13.26.2
Forest Cover Inside and Outside of RFA in Tripura

Table 13.26.5 Forest Cover Change Matrix for Tripura (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	643	1	1	0	9	654
Moderately Dense Forest	4	5,195	14	0	23	5,236
Open Forest	0	8	1,811	3	14	1,836
Scrub	0	0	0	29	0	29
Non Forest	0	8	37	1	2,685	2,731
Total ISFR 2021	**647**	**5,212**	**1,863**	**33**	**2,731**	**10,486**
Net Change	-7	-24	27	4	0	

Table 13.26.6 Altitude-wise Forest Cover in Tripura (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	10,420	647	5,165	1,846	7,658	30
500-1000	66	0	47	17	64	3
Total	**10,486**	**647**	**5,212**	**1,863**	**7,722**	**33**

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

Table 13.26.7 Forest Cover in different slope classes in Tripura (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	6,067	428	2,422	950	3,800	13
5-10	2,630	172	1,593	466	2,231	4
10-15	1,059	35	720	235	990	3
15-20	446	8	300	123	431	4
20-25	179	2	114	56	172	4
25-30	68	1	41	22	64	3
>30	37	1	22	11	34	2
Total	**10,486**	**647**	**5,212**	**1,863**	**7,722**	**33**

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

Figure 13.26.3 Forest Cover Map of Tripura

13.26.2 Forest Types

The area under different forest types of Tripura as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

TRIPURA

Table 13.26.2 Area statistics of the Forest Types found in Tripura (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2B/C2 Cachar semi-evergreen forest	2,126.56	27.42
2.	2B/C1/2S1 Pioneer Euphorbiaceous scrub	1.15	0.02
3.	2/2S1 Secondary moist bamboo brakes	590.44	7.61
4.	3C/C1b(ii) East Himalayan lower bhaber sal	196.75	2.54
5.	3C/C3b East Himalayan moist mixed deciduous forest	3,052.68	39.37
	Sub Total	**5,967.58**	**76.96**
6.	TOF/Plantation	1,786.80	23.04
	Total (Forest Cover & Scrub)	**7,754.38**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

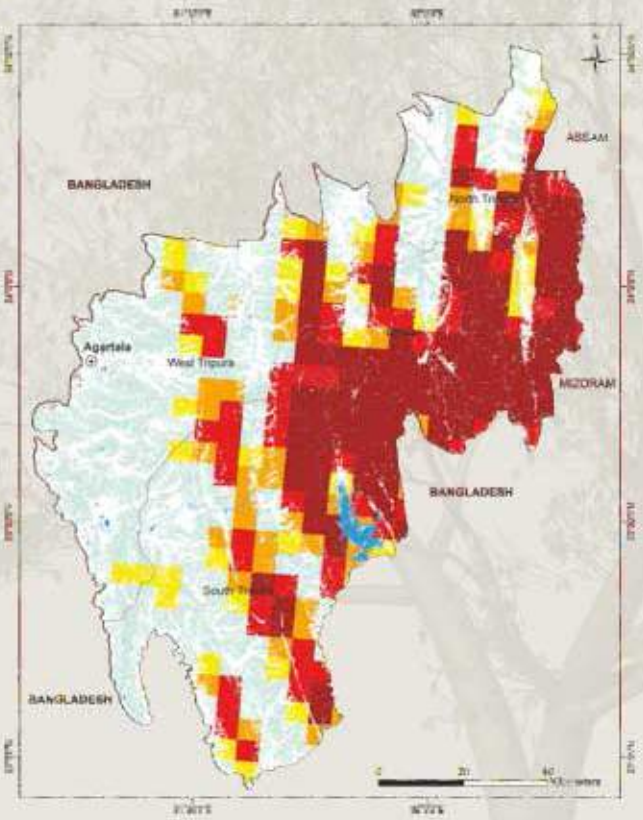
13.26.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.26.3 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	2,491.90	32.27
2.	Very highly fire prone	1,249.76	16.18
3.	Highly fire prone	812.80	10.53
4.	Moderately fire prone	641.61	8.31
5.	Less fire prone	2,525.93	32.71
	Total	**7,722.00**	**100.00**

Figure 13.26.4 Fire prone forest areas under different fire prone



13.26.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Tripura has been estimated as given in following table.

Table 13.26.10 Tree Cover in Tripura (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
231	228	-3

13.26.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.26.11 Extent of TOF in Tripura (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
2,289	228	2,517

13.26.6 Growing Stock in Tripura

Growing stock in the recorded forest areas (RFA) in Tripura is given in the Table 13.26.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.26.13.

Table 13.26.12 Growing Stock in Tripura (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	19.74	23.13	3.39	0.53
2.	Growing Stock in TOF	6.76	7.46	0.70	0.42

Table 13.26.13 Diameter class distribution of top five tree species inside RFA in Tripura (in '000)

			Dia class (cm)	
Sl. No.	Species	10-30	30-60	>60
1.	*Hevea brasiliensis*	39,996	2,963	0
2.	*Tectona grandis*	7,710	1,039	0
3.	*Albizia spp.*	6,012	1,357	93
4.	*Shorea robusta*	1,645	348	41
5.	*Pterospermum acerifolium*	1,500	444	65

TRIPURA

13.26.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Tripura in Rural and Urban areas are given in the Table 13.26.14 and Table 13.26.15 respectively.

Table 13.26.14: Top five tree species in TOF (Rural) in Tripura

Sl. No.	Species	Relative Abundance (%)
1.	*Hevea brasiliensis*	58.70
2.	*Tectona grandis*	7.76
3.	*Areca catechu*	3.95
4.	*Schima wallichii*	2.62
5.	*Syzygium cumini*	2.37

Table 13.26.15: Top five tree species in TOF (Urban) in Tripura

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	21.73
2.	*Hevea brasiliensis*	15.96
3.	*Mangifera indica*	9.30
4.	*Areca triandra*	8.93
5.	*Cocos nucifera*	6.79

13.26.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 74.97 million tonnes (274.89 million tonnes of CO_2 equivalent) which is 1.04% of total forest carbon of the country. Pool wise forest carbon in Tripura is given in the following table

Table 13.26.16 Forest Carbon in Tripura in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	24,349
2.	BGB	5,358
3.	Dead wood	477
4.	Litter	1,486
5.	SOC	43,304
	Total	**74,974**

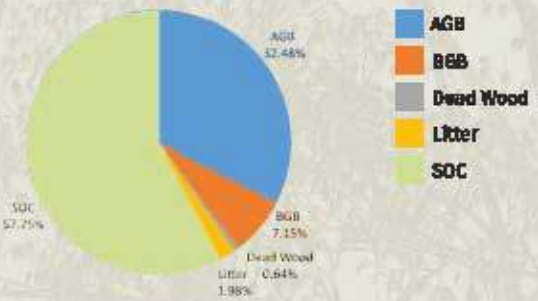


Figure 13.26.5 Forest Carbon in Tripura

13.26.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.26.17 Growing Stock of Bamboo in Tripura

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (In sq km)	4,201	2.81
Total number of culms (In millions)	1,562	2.93
Total equivalent green weight (In '000 tonnes)	12,413	3.09

13.26.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.26.18 and Table 13.26.19 respectively.

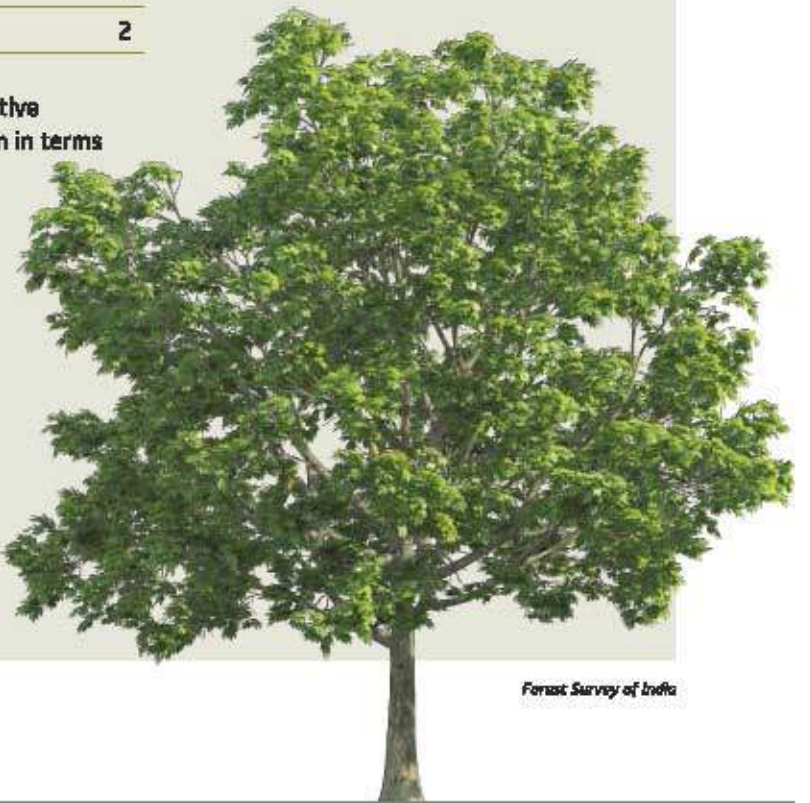
Table 13.26.18 Major NTFP species in Tripura

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Thysanolaena maxima*	Herbs	89.66
2.	*Mucuna pruriens*	Climber	10.34

Table 13.26.19 Major invasive species in the State inside the RFA/Green wash in Tripura (In sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	134
2.	*Mikania micrantha*	56
3.	*Imperata cylindrica*	11
4.	*Saccharum spontanem*	5
5.	*Lantana camara*	2

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.



13.27 UTTAR PRADESH

Geographical Area
2,40,928 sq km

Geographical Coordinates
Latitude- 23° 52' N to 31° 28' N
Longitude-77° 30' E to 84° 39' E

Population (as per Census 2011)
199.81 million
Urban 44.50 million (22.27 %)
Rural 155.31 million (77.73 %)
Tribal 1.13 million (0.57 %)

Average Population Density
829 per sq km

Livestock population
(as per 19th Live Stock Census)
68.71 million

No. of Districts
71

No. of Hill Districts
0

No. of Tribal Districts
1

Table 13.27.1 Land Use Pattern

Land Use Types	Area (In '000 ha)	Percentage
Geographical Area	24,093	
Reporting area for land utilization	24,170	100.00
Forests	1,671	6.91
Not available for land cultivation	3,607	14.92
Permanent pastures and other grazing lands	66	0.27
Land under misc. tree crops and groves	283	1.17
Culturable wasteland	389	1.61
Fallow land other than current fallows	551	2.28
Current fallows	1,061	4.39
Net area sown	16,542	68.45

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.27.1 Forest Cover

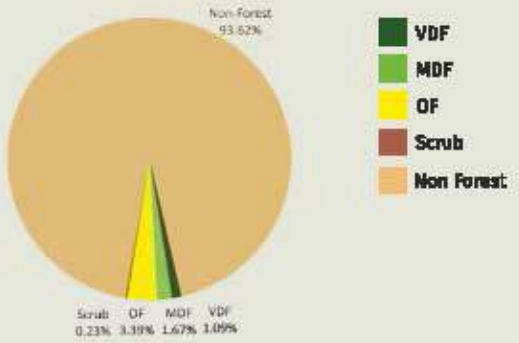


Figure 13.27.1 Forest Cover of Uttar Pradesh

Table 13.27.2 Forest Cover of Uttar Pradesh (In sq km)

Class	Area	% of GA
VDF	2,626.61	1.09
MDF	4,029.37	1.67
OF	8,161.91	3.39
Total	**14,817.89**	**6.15**
Scrub	563.36	0.23

Table 13.27.3 District- wise Forest Cover in Uttar Pradesh (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Agra	4,041	0.00	62.68	199.94	262.62	6.50	0.00	75.14
Aligarh	3,650	0.00	7.00	59.75	66.75	1.83	0.00	1.00
Ambedkar Nagar	2,350	0.00	1.00	40.16	41.16	1.75	0.04	0.08
Amroha	2,249	0.00	25.00	61.00	86.00	3.82	0.00	0.00
Auraiya	2,016	0.00	4.96	36.42	41.38	2.05	0.00	10.09
Ayodhya	2,341	6.00	9.99	73.43	89.42	3.82	0.12	0.96
Azamgarh	4,054	0.00	1.03	48.28	49.31	1.22	-0.69	0.00
Baghpat	1,321	0.00	5.00	12.06	17.06	1.29	0.00	0.00
Bahraich	5,237	240.00	156.41	159.70	556.11	10.62	6.01	6.99
Ballia	2,981	0.00	0.00	22.15	22.15	0.74	0.00	0.00
Balrampur	3,349	278.00	156.01	103.40	537.41	16.05	11.40	3.04
Banda	4,408	0.00	55.91	46.00	101.91	2.31	0.00	4.00
Bara Banki	4,402	3.00	6.14	90.29	99.43	2.26	16.36	4.33
Bareilly	4,120	0.00	7.00	38.00	45.00	1.09	0.00	0.00
Basti	2,688	1.00	5.93	24.65	31.58	1.17	2.33	0.03
Bhadohi	1,015	0.00	0.00	3.71	3.71	0.37	0.59	0.00
Bijnor	4,561	37.99	216.63	144.28	398.90	8.75	-4.71	5.52
Budaun	5,168	0.00	8.13	23.91	32.04	0.62	0.00	6.00
Bulandshahr	4,512	0.00	49.72	115.40	165.12	3.66	0.00	0.00
Chandauli	2,541	7.91	183.97	361.60	553.48	21.78	-11.78	2.50
Chitrakoot	3,216	81.30	319.19	231.20	631.69	19.64	45.29	29.84
Deoria	2,540	0.00	1.00	14.21	15.21	0.60	0.00	0.00
Etah	2,431	0.00	0.98	25.20	26.18	1.08	0.00	0.26
Etawah	2,311	0.00	62.75	188.63	251.38	10.88	0.00	45.05
Farrukhabad	2,181	0.00	14.00	33.45	47.45	2.18	0.00	2.00
Fatehpur	4,152	0.00	18.00	35.44	53.44	1.29	0.00	0.00
Firozabad	2,407	0.00	5.00	53.60	58.60	2.43	0.00	26.49

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(in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Gautam Buddha Nagar	1,282	0.00	5.00	15.00	20.00	1.56	0.00	0.00
Ghaziabad	1,179	0.00	8.67	16.55	25.22	2.14	0.00	0.00
Ghazipur	3,377	0.00	1.00	28.00	29.00	0.86	0.00	0.00
Gonda	4,003	66.64	8.92	46.28	121.84	3.04	6.98	0.23
Gorakhpur	3,321	27.86	23.10	28.10	79.06	2.38	0.06	0.00
Hamirpur	4,021	0.00	80.00	147.00	227.00	5.65	0.00	14.00
Hardoi	5,986	0.00	16.98	129.80	146.78	2.45	2.93	5.27
Hathras	1,840	0.00	1.00	22.00	23.00	1.25	0.00	0.00
Jalaun	4,565	0.00	60.58	186.73	247.31	5.42	0.00	37.97
Jaunpur	4,038	0.00	10.79	58.64	69.43	1.72	2.41	0.16
Jhansi	5,024	0.00	42.00	262.05	304.05	6.05	0.00	41.96
Kannauj	2,093	0.00	0.00	27.82	27.82	1.33	0.00	0.00
Kanpur Dehat	3,021	0.00	3.00	38.00	41.00	1.36	0.00	9.00
Kanpur Nagar	3,155	0.00	7.00	59.00	66.00	2.09	0.00	3.00
Kasganj	1,955	0.00	7.67	41.13	48.80	2.50	0.00	0.00
Kaushambi	1,779	0.00	5.00	22.83	27.83	1.56	0.00	0.00
Kheri	7,680	804.91	158.21	309.44	1,272.56	16.57	-0.50	4.39
Kushinagar	2,905	0.00	2.62	32.78	35.40	1.22	0.56	0.00
Lalitpur	5,039	0.00	128.89	452.40	581.29	11.54	0.00	33.18
Lucknow	2,528	0.00	162.28	224.92	387.20	15.32	8.33	1.13
Mahoba	3,144	0.00	21.00	149.00	170.00	5.41	0.00	62.00
Mahrajganj	2,952	261.09	94.10	72.57	427.76	14.49	-1.31	0.24
Mainpuri	2,760	0.00	1.00	12.64	13.64	0.49	0.00	0.00
Mathura	3,340	0.00	4.00	53.04	57.04	1.71	0.00	3.52
Mau	1,713	0.00	0.00	11.00	11.00	0.64	0.00	0.00
Meerut	2,559	0.00	34.00	34.41	68.41	2.67	0.00	0.00
Mirzapur	4,405	9.20	281.04	455.87	746.11	16.94	-57.62	51.14
Moradabad	3,718	0.00	5.00	23.00	28.00	0.75	0.00	0.00
Muzaffarnagar	4,008	0.00	14.00	52.03	66.03	1.65	-0.08	0.00
Pilibhit	3,686	471.00	86.52	128.21	685.73	18.60	-1.38	2.11
Pratapgarh	3,717	0.00	31.22	90.22	121.44	3.27	3.62	1.97
Prayagraj	5,482	6.16	26.19	123.92	156.27	2.85	27.06	28.32
Raebareli	4,609	0.00	4.00	89.69	93.69	2.03	0.15	1.32
Rampur	2,367	4.00	26.00	45.00	75.00	3.17	0.00	0.00
Saharanpur	3,689	0.00	174.00	319.18	493.18	13.37	49.92	0.38
Sant Kabir Nagar	1,646	0.00	0.86	13.54	14.40	0.87	0.40	1.00
Shahjahanpur	4,388	26.00	7.00	26.31	59.31	1.35	0.00	1.17
Shravasti	1,640	151.23	91.25	42.89	285.37	17.40	0.83	0.00

(In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Siddharthnagar	2,895	0.00	8.29	35.09	43.38	1.50	9.30	0.10
Sitapur	5,743	0.00	19.00	190.67	209.67	3.65	0.25	6.30
Sonbhadra	6,905	138.32	940.62	1,357.81	2,436.75	35.29	-103.54	30.18
Sultanpur	4,436	5.00	15.14	187.99	208.13	4.69	-1.90	0.02
Unnao	4,556	0.00	28.00	236.59	264.59	5.80	0.00	0.00
Varanasi	1,535	0.00	1.00	16.91	17.91	1.17	0.81	0.00
Grand Total	2,40,928	2,626.61	4029.37	8,161.91	14,817.89	6.15	12.24	583.38

13.27.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.27.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Uttar Pradesh (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
2,463	3,002	3,678	9,143	164	1,027	4,484	5,675
26.94%	32.83%	40.23%		2.89%	18.10%	79.01%	

*In case of Uttar Pradesh, Green Wash boundaries have been used.

Figure 13.27.2 Forest Cover Inside and Outside of Green Wash in Uttar Pradesh

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Table 13.27.5 Forest Cover Change Matrix for Uttar Pradesh (In sq km)

Class	2021 Assessment					Total
	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	2,612	3	1	0	1	2,617
Moderately Dense Forest	13	4,011	31	0	25	4,080
Open Forest	1	12	7,853	19	224	8,109
Scrub	0	0	31	531	25	587
Non Forest	1	3	246	13	2,25,272	2,25,535
Total ISFR 2021	**2,627**	**4,029**	**8,162**	**563**	**2,25,547**	
Net Change	10	-51	53	-24	12	

Table 13.27.6 Altitude-wise Forest Cover in Uttar Pradesh (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	2,40,458	2,627	3,844	7,955	14,426	562
500-1000	470	0	185	207	392	1
Total	**2,40,928**	**2,627**	**4,029**	**8,162**	**14,818**	**563**

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

Table 13.27.7 Forest Cover in different slope classes in Uttar Pradesh (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	2,35,259	2,397	3,103	7,136	12,636	482
5-10	4,405	159	492	629	1,280	56
10-15	730	41	216	206	463	15
15-20	300	16	115	104	235	6
20-25	143	9	61	52	122	3
25-30	60	4	28	22	54	1
>30	31	1	14	13	28	0
Total	**2,40,928**	**2,627**	**4,029**	**8,162**	**14,818**	**563**

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

Figure 13.27.3 Forest Cover Map of Uttar Pradesh

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.27.2 Forest Types

The area under different forest types of Uttar Pradesh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.27.2 Area statistics of the Forest Types found in Uttar Pradesh (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2/E1 Cane brakes	21.75	0.14
2.	3C/C2d (i) Western light alluvium plains sal	1,532.61	9.89
3.	3C/C2d (iii) Eastern heavy alluvium plains sal	638.37	4.12
4.	3C/C3a West Gangetic moist mixed deciduous forest	399.97	2.58
5.	3C/C3/2S1 Northern secondary moist mixed deciduous forest	351.41	2.27
6.	4D/SS2 *Barringtonia* swamp forest	0.29	0.00
7.	4D/SS3 *Syzygium cumini* swamp low forest	199.21	1.29

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(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
8.	5A/C1b Dry teak forest	133.70	0.86
9.	5B/C1a Dry Siwalik sal forest	109.09	0.70
10.	5B/C1b Dry plains sal forest	60.87	0.39
11.	5B/C1c Dry peninsular sal forest	345.61	2.23
12.	5B/C2 Northern dry mixed deciduous forest	5,422.03	35.00
13.	5/DS1 Dry deciduous scrub	415.43	2.68
14.	5/DS2 Dry savannah forest	1.97	0.01
15.	5/DS3 *Euphorbia* scrub	1.03	0.01
16.	5/E1 *Anogeissus pendula* forest	430.46	2.78
17.	5/E1/DS1 *Anogeissus pendula* scrub	159.90	1.03
18.	5/E2 *Boswellia* forest	113.30	0.73
19.	5/E3 *Babul* forest	40.61	0.26
20.	5/E5 *Butea* forest	7.72	0.05
21.	5/E8a *Phoenix* savannah	2.11	0.01
22.	5/E8b Babul savannah	14.46	0.09
23.	5/E9 Dry bamboo brakes	70.63	0.46
24.	5/1S1 Dry tropical riverain forest	0.26	0.00
25.	5/1S2 *Khair-sissu* forest	153.25	1.00
26.	6B/C2 Ravine thorn forest	799.27	5.16
	Sub Total	**11,425.51**	**73.74**
27.	TOF/Plantation	3,966.66	25.61
	Total (Forest Cover & Scrub)	**15,392.17**	
	Grassland Forest Types (outside forest cover)		
28.	3/1S1 Low alluvial savannah woodland *(Saimalia-Albizia)*	5.06	0.03
29.	4D/2S2 Eastern wet alluvial grassland	96.31	0.62
	Sub Total	**101.37**	**0.65**
	Grand Total	**15,493.54**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019).Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.27.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Figure. 13.27.4
Fire prone forest areas under different fire prone classes

Table 13.27.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	209.30	1.41
2.	Very highly fire prone	1,043.54	7.04
3.	Highly fire prone	1,555.38	10.50
4.	Moderately fire prone	2,070.29	13.97
5.	Less fire prone	9,939.49	67.08
	Total	**14,818.00**	**100.00**

13.27.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Uttar Pradesh has been estimated as given in following table.

Table 13.27.10 Tree Cover in Uttar Pradesh (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
7,342	7,421	79

13.27.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.27.11 Extent of TOF in Uttar Pradesh (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
5,675	7,421	13,096

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13.27.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Uttar Pradesh is given in the Table 13.27.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.27.13

Table 13.27.12 Growing Stock in Uttar Pradesh (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	96.04	104.39	8.35	2.38
2.	Growing Stock in TOF	97.62	106.75	9.13	6.00

Table 13.27.13 Diameter class distribution of top five tree species inside RFA in Uttar Pradesh (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Shorea robusta*	17,126	19,354	2,779
2.	*Tectona grandis*	13,220	5,071	181
3.	*Lannea coromandelica*	7,983	1,281	0
4.	*Syzygium cumini*	2,971	2,952	344
5.	*Terminalia tomentosa*	2,243	2,347	215

13.27.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Uttar Pradesh in Rural and Urban areas are given in the Table 13.27.14 and Table 13.27.15 respectively.

Table 13.27.14 Top five tree species in TOF (Rural) in Uttar Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	30.25
2.	*Eucalyptus spp.*	18.52
3.	*Populus spp.*	7.74
4.	*Azadirachta indica*	4.90
5.	*Dalbergia sissoo*	4.88

Table 13.27.15 Top five tree species in TOF (Urban) in Uttar Pradesh

Sl. No.	Species	Relative Abundance (%)
1.	*Azadirachta indica*	15.62
2.	*Mangifera indica*	12.03
3.	*Eucalyptus spp.*	10.64
4.	*Tectona grandis*	4.95
5.	*Prosopis juliflora*	4.12

13.27.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 117.24 million tonnes (429.88 million tonnes of CO_2 equivalent) which is 1.63 % of total forest carbon of the country. Pool wise forest carbon in Uttar Pradesh is given in the following table.

Table 13.27.16 Forest Carbon in Uttar Pradesh in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	32,543
2.	BGB	10,234
3.	Dead wood	534
4.	Litter	1,825
5.	SOC	72,105
	Total	1,17,241

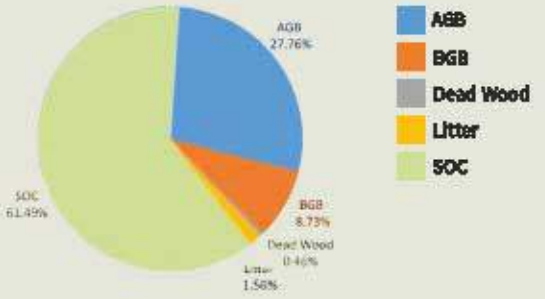


Figure 13.27.5 Forest Carbon in Uttar Pradesh

13.27.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.27.17 Growing Stock of Bamboo in Uttar Pradesh

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	1,832	1.23
Total number of culms (in millions)	310	0.58
Total equivalent green weight (in '000 tonnes)	1,534	0.38

13.27.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.27.18 and Table 13.27.19 respectively.

UTTAR PRADESH

Table 13.27.18 Major NTFP species in Uttar Pradesh

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Ocimum bassilicum*	Herbs	81.11
2.	*Dasmostachya*	Herbs	8.42
3.	*Vettveria zizanoides*	Herbs	4.62
4.	*Helicteres isora*	Shrub	2.57
5.	*Adhatoda vasica*	Shrub	1.43

Table 13.27.19 Major invasive species in the State inside the RFA/Green Wash in Uttar Pradesh

(In sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	410
2.	*Cassia tora*	99
3.	*Saccharum spontanem*	64
4.	*Dioscorea pentaphylla*	37
5.	*Ichnocarpus frutescens*	30

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.28
UTTARAKHAND

Geographical Area
53,483 sq km

Geographical Coordinates
Latitude- 28° 43' N to 31° 28' N
Longitude- 77° 34' E to 81° 03' E

Population (as per Census 2011)
10.08 million
Urban 3.05 million (30.23 %)
Rural 7.04 million (69.77 %)
Tribal 0.29 million (2.89 %)

Average Population Density
189 per sq km

Livestock population
(as per 19th Live Stock Census)
4.79 million

No. of Districts
13

No. of Hill Districts
13

No. of Tribal Districts
0

Table 13.28.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	5,348	
Reporting area for land utilization	6,005	100.00
Forests	3,812	63.48
Not available for land cultivation	435	7.24
Permanent pastures and other grazing lands	208	3.46
Land under misc. tree crops and groves	394	6.56
Culturable wasteland	324	5.40
Fallow land other than current fallows	86	1.43
Current fallows	73	1.22
Net area sown	673	11.21

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.28.1 Forest Cover

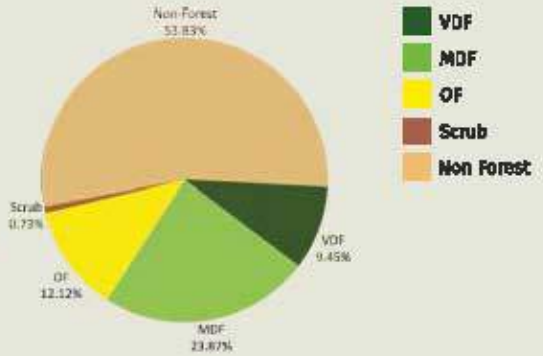


Figure 13.28.1
Forest Cover of Uttarakhand

Table 13.28.2 Forest Cover of Uttarakhand (In sq km)

Class	Area	% of GA
VDF	5,055.01	9.45
MDF	12,768.05	23.87
OF	6,482.07	12.12
Total	**24,305.13**	**45.44**
Scrub	392.37	0.73

Table 13.28.3 District- wise Forest Cover in Uttarakhand (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Almora[#]	3,144	199.09	838.28	682.43	1,719.80	54.70	0.66	6.00
Bageshwar[#]	2,241	161.56	758.66	342.45	1,262.67	56.34	-0.02	1.11
Chamoli[#]	8,030	443.08	1,573.55	693.48	2,710.11	33.75	0.68	1.00
Champawat[#]	1,766	366.88	590.37	266.91	1,224.16	69.32	-1.39	7.35
Dehradun[#]	3,088	663.25	596.85	351.48	1,611.58	52.19	2.89	86.33
Garhwal[#]	5,329	576.62	1,898.76	921.33	3,396.71	63.74	1.72	97.93
Haridwar[#]	2,360	74.47	277.35	232.12	583.94	24.74	-1.31	8.83
Nainital[#]	4,251	772.89	1,719.86	551.74	3,044.49	71.62	2.93	10.09
Pithoragarh[#]	7,090	505.54	960.17	615.04	2,080.75	29.35	0.95	42.09
Rudraprayag[#]	1,984	251.94	578.90	311.46	1,142.30	57.58	0.13	9.12
Tehri Garhwal[#]	3,642	272.89	1,084.17	707.33	2,064.39	56.68	-1.59	98.36
Udham Singh Nagar[#]	2,542	148.17	188.40	91.51	428.08	16.84	-3.71	3.14
Uttarkashi[#]	8,016	618.63	1,702.73	714.79	3,036.15	37.88	0.15	21.00
Grand total	**53,483**	**5,055.01**	**12,768.05**	**6,482.07**	**24,305.13**	**45.44**	**2.09**	**392.37**

13.28.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

UTTARAKHAND

Table 13.28.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Uttarakhand (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
4,269	9,241	3,275	16,785	786	3,527	3,207	7,520
25.43%	55.06%	19.51%		10.45%	46.90%	42.65%	

*In case of Uttarakhand, RFA boundaries have been used

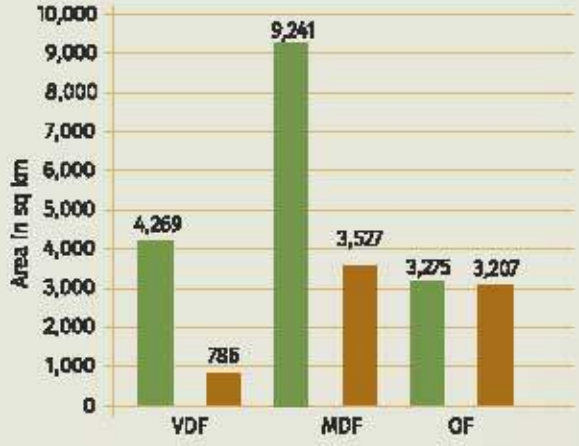


Figure 13.28.2
Forest Cover Inside and Outside of RFA in Uttarakhand

Table 13.28.5 Forest Cover Change Matrix for Uttarakhand (In sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	5,041	1	2	0	3	5,047
Moderately Dense Forest	12	12,726	34	1	32	12,805
Open Forest	1	32	6,360	11	47	6,451
Scrub	0	0	4	377	2	383
Non Forest	1	9	82	3	28,702	28,797
Total ISFR 2021	**5,055**	**12,768**	**6,482**	**392**	**28,786**	**53,483**
Net Change	8	-37	31	9	-11	

Table 13.28.6 Altitude-wise Forest Cover in Uttarakhand (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	7,937	627	1,627	626	2,880	13
500-1000	5,703	1,198	1,858	902	3,958	103
1000-2000	17,560	1,573	5,157	3,319	10,049	241
2000-3000	7,248	1,552	3,092	1,134	5,778	21
3000-4000	4,193	105	1,033	496	1,634	13
>4000	10,842	0	1	5	6	1
Total	**53,483**	**5,055**	**12,768**	**6,482**	**24,305**	**392**

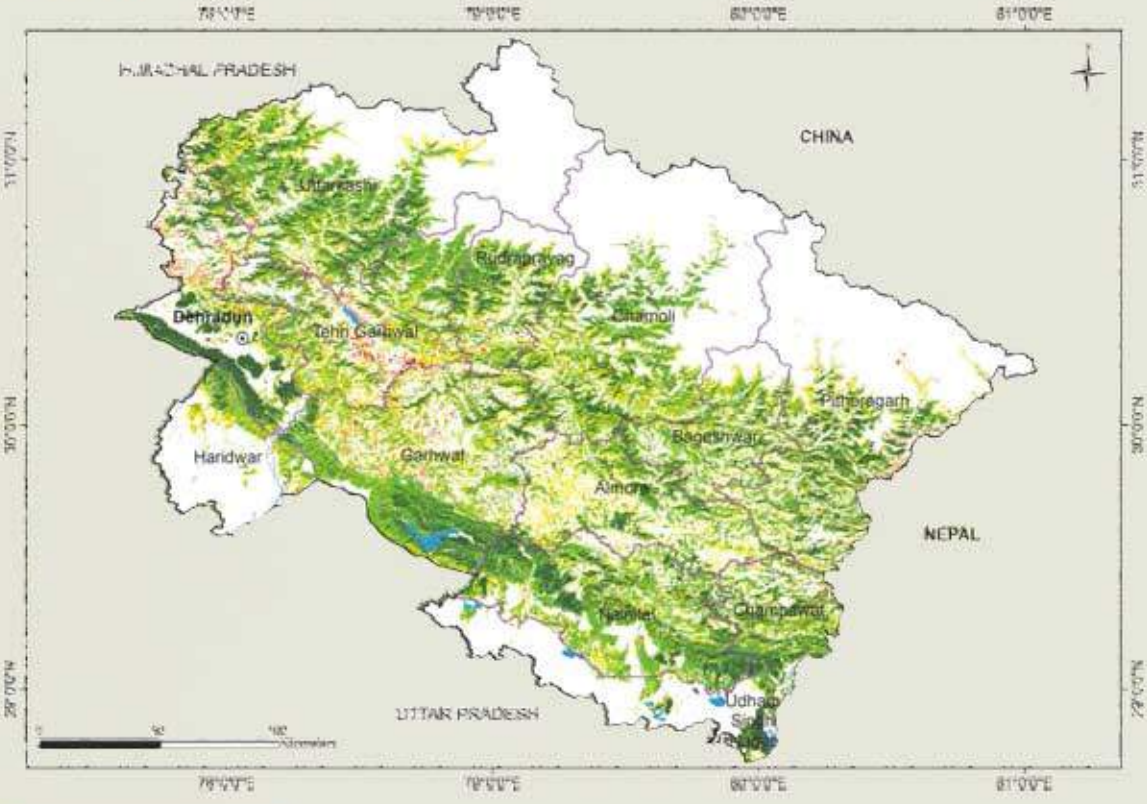
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.28.7 Forest Cover in different slope classes in Uttarakhand (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	9,446	842	1,460	646	2,948	29
5-10	4,069	487	973	348	1,808	18
10-15	5,688	615	1,503	644	2,762	38
15-20	7,028	730	1,931	925	3,586	59
20-25	7,313	730	2,046	1,053	3,829	70
25-30	6,683	650	1,870	1,026	3,546	68
>30	13,256	1,001	2,985	1,840	5,826	110
Total	**53,483**	**5,055**	**12,768**	**6,482**	**24,305**	**392**

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

Figure 13.28.3 Forest Cover Map of Uttarakhand



UTTARAKHAND

13.28.2 Forest Types

The area under different forest types of Uttarakhand as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.28.2 Area statistics of the Forest Types found in Uttarakhand (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3C/C2a Moist Siwalik sal forest	3,402.49	12.84
2.	3C/C2b(I) *Bhabar-dun* sal forest	251.06	0.95
3.	3C/C2c Moist tarai sal forest	401.60	1.51
4.	3C/C2d(I) Western light alluvium plains sal	165.52	0.62
5.	3C/C3a West Gangetic moist mixed deciduous forest	1,055.48	3.99
6.	4C/FS2 Submontane hill valley swamp forest	0.76	0.00
7.	5B/C1a Dry Siwalik sal forest	455.92	1.72
8.	5B/C1b Dry plains sal forest	8.31	0.03
9.	5B/C2 Northern dry mixed deciduous forest	903.31	3.41
10.	5/DS1 Dry deciduous scrub	39.02	0.15
11.	5/1S2 *Khair-sissu* forest	252.36	0.95
12.	9/C1a Lower or Siwalik chir pine forest	43.15	0.16
13.	9/C1b Upper or Himalayan chir pine forest	7,295.76	27.52
14.	9/C1/DS1 Himalayan subtropical scrub	379.26	1.43
15.	9/C1/DS2 Subtropical *Euphorbia* scrub	28.37	0.11
16.	12/C1a *Ban* oak forest (*Q. incana*)	3,647.31	13.75
17.	12/C1b *Moru* oak forest (*Q. dilatata*)	122.71	0.46
18.	12/C1c Moist deodar forest (*Cedrus*)	395.23	1.49
19.	12/C1d Western mixed coniferous forest (spruce, blue pine, silver fir)	1,340.10	5.05
20.	12/C1e Moist temperate deciduous forest	202.07	0.76
21.	12/C1f Low-level blue pine forest (*P. wallichiana*)	27.66	0.10
22.	12/C1/DS1 Oak scrub	29.93	0.11
23.	12/C1/DS2 Himalayan temperate secondary scrub	14.09	0.05
24.	12/C2a *Kharsu* oak forest (*Q. semecarpifolia*)	832.04	3.14
25.	12/C2b West Himalayan upper oak/fir forest	1,454.52	5.48
26.	12/C2c Moist temperate deciduous forest	201.57	0.76
27.	12/1S1 Alder forest	8.13	0.03
28.	12/2S1 Low-level blue pine forest	22.49	0.08
29.	13/C2b Dry deodar forest (*Cedrus*)	194.73	0.73
30.	13/C5 West Himalayan dry juniper forest (*J. macropoda*)	4.28	0.02
31.	13/1S1 *Hippophae/Myricaria* scrub	67.66	0.26
32.	14/C1a West Himalayan sub-alpine fir forest	184.29	0.69
33.	14/C1b West Himalayan sub-alpine birch/fir forest	542.11	2.04
34.	14/1S1 *Hippophae/Myricaria* brakes	20.23	0.08
35.	14/1S2 Deciduous sub-alpine scrub	42.77	0.16
36.	15/C1 Birch/*Rhododendron* scrub forest	117.18	0.44
37.	15/E1 Dwarf *Rhododendron* scrub	12.95	0.05

(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
38.	16/C1 Dry alpine scrub	2.78	0.01
39.	16/E1 Dwarf juniper scrub	29.92	0.11
	Sub Total	**24,199.12**	**91.24**
40.	TOF/Plantation	487.09	1.84
	Total (Forest Cover & Scrub)	**24,686.21**	
	Grassland forest types (outside forest cover)		
41.	3C/C2/DS1 Moist sal savannah	8.75	0.03
42.	3/1S1 Low alluvial savannah woodland (*Saimalia-Albizzia*)	3.30	0.01
43.	12/DS2 Himalayan temperate parkland	12.38	0.05
44.	12/DS3 Himalayan temperate pastures	84.66	0.32
45.	14/DS1 Sub-alpine pastures	212.05	0.80
46.	15/C3 Alpine pastures	1,514.99	5.71
	Sub Total	**1,836.13**	**6.92**
	Grand Total	**26,522.34**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover have also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.28.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.28.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	49.21	0.20
2.	Very highly fire prone	757.92	3.12
3.	Highly fire prone	4,070.09	16.75
4.	Moderately fire prone	5,887.70	24.22
5.	Less fire prone	13,540.08	55.71
	Total	**24,305.00**	**100.00**

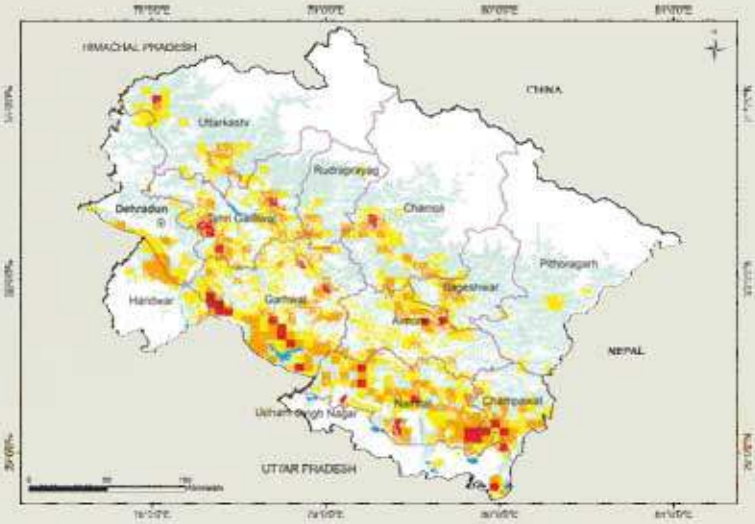


Figure. 13.28.4: Fire prone forest areas under different fire prone classes

UTTARAKHAND

13.28.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Uttarakhand has been estimated as given in following table.

Table 13.28.10 Tree Cover in Uttarakhand (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
841	1,001	160

13.28.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.28.11 Extent of TOF in Uttarakhand (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
7,520	1,001	8,521

13.28.6 Growing Stock in Uttarakhand

Growing stock in the recorded forest areas (RFA) in Uttarakhand is given in the Table 13.28.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.28.13

Table 13.28.12 Growing Stock in Forest (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	406.08	401.01	-5.07	9.14
2.	Growing Stock in TOF	19.13	18.40	-0.73	1.03

Table 13.28.13 Diameter class distribution of top five tree species inside RFA in Uttarakhand (in '000)

Sl. No.	Species	Dia class (cm) 10-30	30-60	>60
1.	*Pinus roxburghii*	1,21,913	52,699	4,755
2.	*Quercus leucotrichophora*	1,44,165	24,469	2,859
3.	*Rhododendron arboreum*	74,265	13,344	499
4.	*Shorea robusta*	45,977	30,513	4,010
5.	*Quercus semecarpifolia*	7,378	4,927	2,647

13.28.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Uttarakhand in Rural and Urban areas are given in the Table 13.28.14 and Table 13.28.15 respectively.

Table 13.28.14 Top five tree species in TOF (Rural) in Uttarakhand

Sl. No.	Species	Relative Abundance (%)
1.	*Grewia oppositifolia*	15.70
2.	*Quercus leucotrichophora*	11.77
3.	*Pinus roxburghii*	10.95
4.	*Mangifera indica*	10.22
5.	*Ficus* spp.	5.46

Table 13.28.15 Top five tree species in TOF (Urban) in Uttarakhand

Sl. No.	Species	Relative Abundance (%)
1.	*Quercus leucotrichophora*	18.61
2.	*Mangifera indica*	11.62
3.	*Cedrus deodara*	5.93
4.	*Cupressus* spp.	3.98
5.	*Pinus roxburghii*	3.72

13.28.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 378.16 million tonnes (1,386.59 million tonnes of CO_2 equivalent) which is 5.25 % of total forest carbon of the country. Pool wise forest carbon in Uttarakhand is given in the following table.

Table 13.28.16 Forest Carbon in Uttarakhand in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,59,674
2.	BGB	42,893
3.	Dead wood	3,561
4.	Litter	5,184
5.	SOC	1,66,847
	Total	**3,78,159**

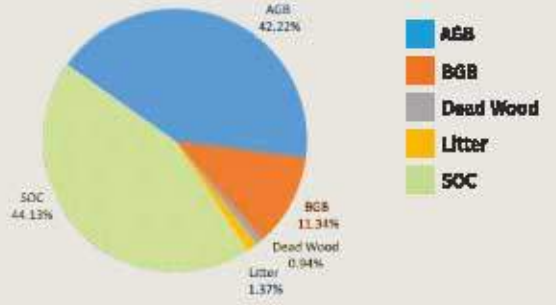


Figure 13.28.5 Forest Carbon in Uttarakhand

UTTARAKHAND

13.28.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.28.17 Growing Stock of Bamboo in Uttarakhand

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	1,201	0.80
Total number of culms (in millions)	301	0.56
Total equivalent green weight (in '000 tonnes)	2,839	0.71

13.28.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.28.18 and Table 13.28.19 respectively.

Table 13.28.18 Major NTFP species in Uttarakhand

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Rhododendron arboreum*	Tree	68.97
2.	*Myrica esculenta*	Tree	16.42
3.	*Lannea coromandelica*	Tree	5.66
4.	*Ehretia laevis*	Tree	4.06
5.	*Taxus baccata*	Tree	1.32

Table 13.28.19 Major invasive species in the State with RFA/Green Wash in Uttarakhand

(in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	323
2.	*Ageratina adenophora*	145
3.	*Saccharum spontanem*	56
4.	*Cassia tora*	22
5.	*Acacia farnesiana*	16

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.29
WEST BENGAL

Geographical Area
88,752 sq km

Geographical Coordinates
Latitude- 21° 29' N to 27° 13' N
Longitude- 85° 50' E to 89° 52' E

Population (as per Census 2011)
91.27 million
Urban 29.09 million (11.29 %)
Rural 62.18 million (88.71 %)
Tribal 5.30 million (5.80 %)

Average Population Density
1,028 per sq km

Livestock population
(as per 19th Live Stock Census)
30.35 million

No. of Districts
19

No. of Hill Districts
1

No. of Tribal Districts
12

Table 13.29.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	8,875	
Reporting area for land utilization	8,684	100.00
Forests	1,175	13.53
Not available for land cultivation	1,882	21.67
Permanent pastures and other grazing lands	2	0.02
Land under misc. tree crops and groves	48	0.56
Culturable wasteland	14	0.16
Fallow land other than current fallows	8	0.09
Current fallows	308	3.55
Net area sown	5,247	60.42

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.29.1 Forest Cover

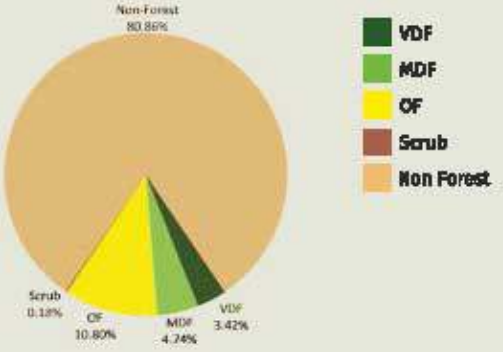


Figure 13.29.1
Forest Cover of West Bangal

Table 13.29.2 Forest Cover of West Bengal (In sq km)

Class	Area	% of GA
VDF	3,036.51	3.42
MDF	4,208.37	4.74
OF	9,586.99	10.80
Total	**16,831.87**	**18.96**
Scrub	155.72	0.18

Table 13.29.3 District- wise Forest Cover in West Bengal (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Bankura[T]	6,882	226.34	411.67	641.36	1,279.37	18.59	-6.21	34.50
Bardhaman[T]	7,024	61.17	89.76	189.75	340.68	4.85	1.37	6.67
Birbhum[T]	4,545	1.00	34.13	148.42	183.55	4.04	-1.25	7.20
Cooch Behar	3,387	0.00	27.00	322.06	349.06	10.31	0.00	0.00
Dakshin Dinajpur[T]	2,219	0.00	5.86	81.68	87.54	3.95	0.42	0.00
Darjeeling[TH]	3,149	721.05	682.05	946.78	2,349.88	74.62	-17.92	8.75
Hooghly	3,149	0.00	14.00	145.80	159.80	5.07	-0.20	0.00
Howrah	1,467	0.00	50.00	253.77	303.77	20.71	0.00	0.00
Jalpaiguri[T]	6,227	734.95	433.83	1,666.59	2,835.37	45.53	-27.03	39.35
Kolkata	185	0.00	0.00	1.00	1.00	0.54	0.00	0.00
Malda[T]	3,733	0.00	208.10	280.80	488.90	13.10	-2.79	0.00
Murshidabad[T]	5,324	0.00	52.33	291.15	343.48	6.45	-1.41	0.12
Nadia	3,927	1.00	160.13	318.84	479.97	12.22	-0.03	0.00
North 24 Parganas	4,094	13.02	184.98	524.98	722.98	17.66	0.00	0.00
Paschim Medinipur[T]	9,368	256.64	600.40	1,284.97	2,142.01	22.87	-19.53	27.03
Purba Medinipur[T]	4,713	1.99	198.01	619.89	819.89	17.40	-0.16	2.50
Purulia[T]	6,259	37.38	307.36	574.50	919.24	14.69	3.36	28.60
South 24 Parganas[T]	9,960	981.97	744.77	1,063.97	2,790.71	28.02	2.00	1.00
Uttar Dinajpur	3,140	0.00	3.99	230.68	234.67	7.47	-0.26	0.00
Grand Total	**88,752**	**3,036.51**	**4,208.37**	**9,586.99**	**16,831.87**	**18.96**	**-69.64**	**155.72**

13.29.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

WEST BENGAL

Table 13.29.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in West Bengal (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
2,624	2,391	2,097	7,112	413	1,817	7,490	9,720
36.90%	33.62%	29.48%		4.25%	18.69%	77.06%	

**In case of West Bengal, RFA boundaries have been used.*

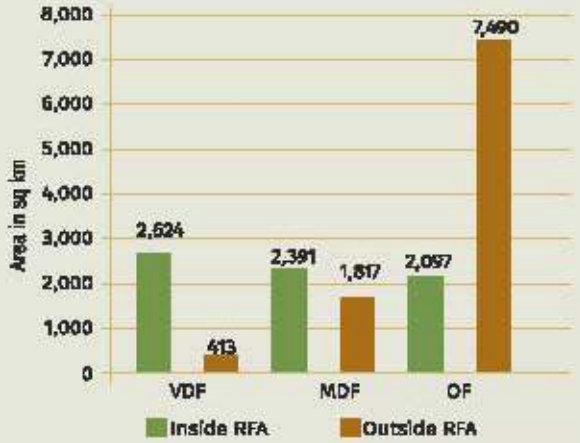


Figure 13.29.2
Forest Cover Inside and Outside of RFA in West Bengal

Table 13.29.5 Forest Cover Change Matrix for West Bengal (in sq km)

	2021 Assessment					Total
Class	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	2,988	12	15	2	2	3,019
Moderately Dense Forest	46	4,087	12	4	11	4,160
Open Forest	3	105	9,492	20	103	9,723
Scrub	0	0	13	125	8	146
Non Forest	0	4	55	5	71,640	71,704
Total ISFR 2021	**3,037**	**4,208**	**9,587**	**156**	**71,764**	**88,752**
Net Change	18	48	-136	10	60	

Table 13.29.6 Altitude-wise Forest Cover in West Bengal (in sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	86,650	2,406	3,634	8,929	14,969	156
500-1000	807	142	281	253	676	0
1000-2000	970	267	244	364	875	0
2000-3000	292	196	45	39	280	0
>3000	33	26	4	2	32	0
Total	**88,752**	**3,037**	**4,208**	**9,587**	**16,832**	**156**

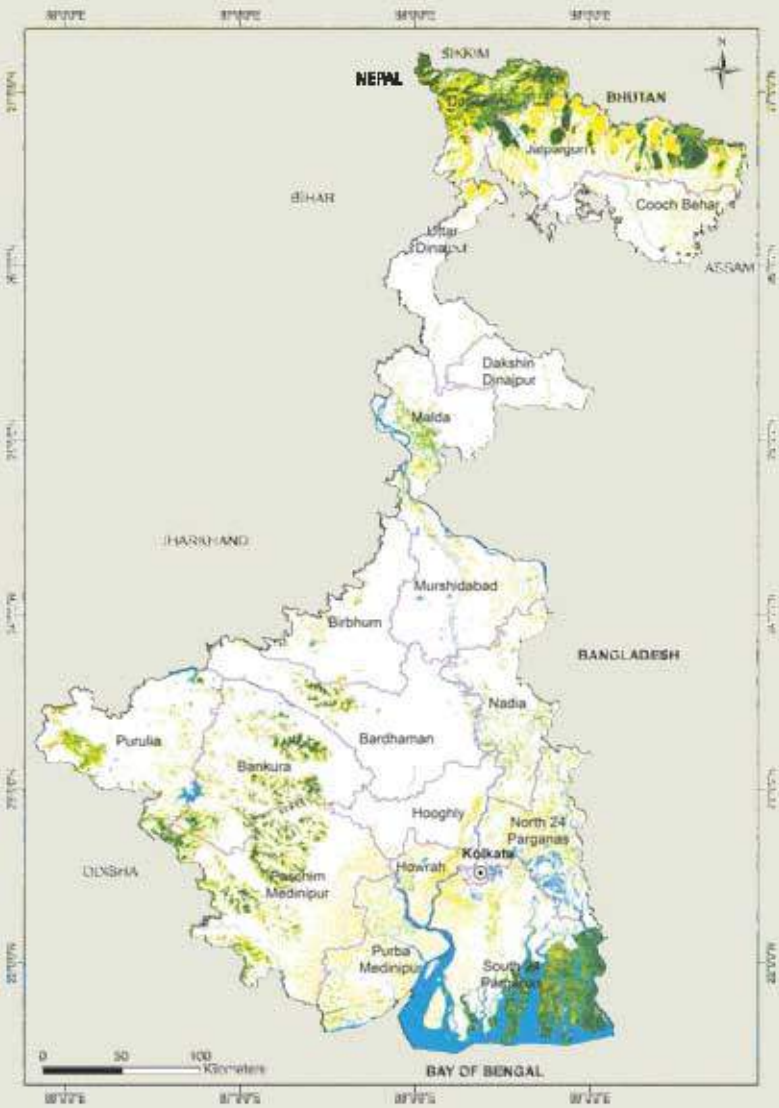
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.29.7 Forest Cover in different slope classes in West Bengal (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	85,130	2,226	3,262	8,621	14,109	140
5-10	1,227	141	219	226	586	7
10-15	508	119	153	149	421	3
15-20	539	147	162	167	476	2
20-25	514	150	154	162	466	2
25-30	404	122	124	127	373	1
>30	430	132	134	135	401	1
Total	**88,752**	**3,037**	**4,208**	**9,587**	**16,832**	**156**

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

Figure 13.29.3
Forest Cover Map of West Bengal



WEST BENGAL

13.29.2 Forest Types

The area under different forest types of West Bengal as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.29.8 Area statistics of the Forest Types found in West Bengal (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	2B/C1/2S3 Sub Himalayan secondary wet mixed forest	357.90	2.09
2.	3C/C1a(i) East Himalayan sal	399.41	2.34
3.	3C/C1b(i) East Himalayan upper *bhabar* sal	152.67	0.89
4.	3C/C1b(ii) East Himalayan lower *bhabar* sal	114.45	0.67
5.	3C/C1c Eastern *terai* sal forest	323.34	1.89
6.	3C/C2d (III) Eastern heavy alluvium plains sal	3.31	0.02
7.	3C/C2/DS1 Moist sal savannah	11.18	0.07
8.	3C/C3a West Gangetic moist mixed deciduous forest	11.74	0.07
9.	3C/C3b East Himalayan moist mixed deciduous forest	409.74	2.4
10.	3C/C3/2S2 Secondary Euphorbiaceous scrub	5.19	0.03
11.	3/1S1 Low alluvial savannah woodland (*Solmalia - Albizzia*)	31.53	0.18
12.	4B/TS1 Mangrove scrub	142.84	0.84
13.	4B/TS2 Mangrove forest	1031.1	6.03
14.	4B/TS3 Saltwater mixed forest (*Heritiera*)	472.79	2.77
15.	4B/TS4 Brackish water mixed forest (*Heritiera*)	309.38	1.81
16.	4B/TS4/E1 Palm swamp	156	0.91
17.	4C/FS2 Submontane hill valley swamp forest	7.21	0.04
18.	4D/SS2 *Barringtonia* swamp Forest	3.27	0.02
19.	5B/C1c Dry peninsular sal forest	2,766.39	16.19
20.	5B/C2 Northern dry mixed deciduous forest	250.03	1.46
21.	5/DS1 Dry deciduous scrub	29.08	0.17
22.	5/ES *Butea* forest	22.02	0.13
23.	5/1S2 *Khair-sissu* Forest	212.56	1.24
24.	8B/C1 East Himalayan subtropical wet hill forest	469.6	2.75
25.	11B/C1a Lauraceous forest	122.32	0.72
26.	11B/C1b *Buk* oak forest	52.93	0.31
27.	11B/C1c High-level oak forest	20.03	0.12
28.	12/C3a East Himalayan mixed coniferous forest	319	1.87
29.	12/DS1 Montane bamboo brakes	8.25	0.05
30.	14/C2 East Himalayan sub-alpine birch/fir forest	12.63	0.07
	Sub Total	**8227.89**	**48.15**
31.	TOF/Plantation	8819.74	51.61
	Total (Forest Cover & Scrub)	**17047.63**	
	Grassland forest types (outside forest cover)		

(in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
32.	4D/2S2 Eastern wet alluvial grassland	35.1	0.21
33.	12/D53 Himalayan temperate pastures	5.81	0.03
	Sub Total	**40.91**	**0.24**
	Grand Total	**17,088.54**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.29.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.29.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	20.05	0.12
2.	Very highly fire prone	120.03	0.71
3.	Highly fire prone	425.63	2.53
4.	Moderately fire prone	1,050.42	6.24
5.	Less fire prone	15,215.87	90.40
	Total	**16,832.00**	**100.00**

Figure. 13.29.4 Fire prone forest areas under different fire prone classes

13.29.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in West Bengal has been estimated as given in following table.

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Table 13.29.10 Tree Cover in West Bengal (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
2,006	2,349	343

13.29.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.29.11 Extent of TOF in West Bengal (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
9,720	2,349	12,069

13.29.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in West Bengal is given in the Table 13.29.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.29.13.

Table 13.29.12 Growing Stock in West Bengal (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	54.87	61.19	6.32	1.39
2.	Growing Stock in TOF	32.63	38.70	6.07	2.17

Table 13.29.13 Diameter class distribution of top five tree species inside RFA in West Bengal (In '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Shorea robusta*	83,267	2,819	713
2.	*Acacia auriculiformis*	20,057	97	0
3.	*Lagerstroemia speciosa*	6,412	1,509	31
4.	*Tectona grandis*	5,713	1,958	206
5.	*Schima wallichii*	5,826	1,136	385

13.29.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in West bengal in Rural and Urban areas are given in the Table 13.29.14 and Table 13.29.15 respectively.

Table 13.29.14 Top five tree species in TOF (Rural) in West Bengal

Sl. No.	Species	Relative Abundance (%)
1.	*Acacia auriculiformis*	14.05
2.	*Mangifera indica*	8.45
3.	*Areca catechu*	6.41
4.	*Eucalyptus spp.*	5.68
5.	*Borassus flabelliformis*	4.68

Table 13.29.15 Top five tree species in TOF (Urban) in West Bengal

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	24.27
2.	*Cocos nucifera*	10.62
3.	*Mangifera indica*	10.14
4.	*Artocarpus heterophyllus*	4.90
5.	*Azadirachta indica*	3.83

13.29.8 Carbon Stock in Forest

The total Carbon stock of forest in the State including the TOF patches which are more than 1ha in size is 155.26 million tonnes (569.29 million tonnes of CO_2 equivalent) which is 2.16 % of total forest carbon of the country. Pool wise forest carbon in West Bengal is given in the following table.

Table 13.29.16 Forest Carbon in West Bengal in different pools (in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	45,365
2.	BGB	14,119
3.	Dead wood	726
4.	Litter	2,162
5.	SOC	92,889
	Total	**1,55,261**

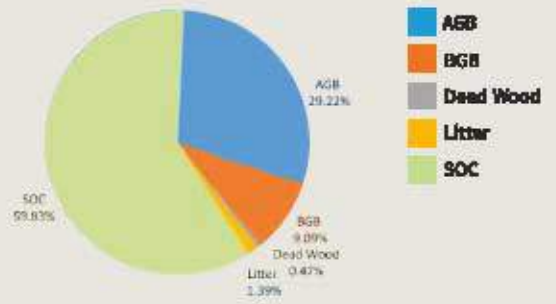

Figure 13.29.5 Forest Carbon in West Bengal

13.29.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

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Table 13.29.17 Growing Stock of Bamboo in West Bengal

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	702	0.47
Total number of culms (in millions)	280	0.52
Total equivalent green weight (in '000 tonnes)	1,471	0.37

13.29.10 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.29.18 and Table 13.29.19 respectively.

Table 13.29.18 Major NTFP Species in West Bengal

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Shorea robusta*	Tree	78.80
2.	*Madhuca indica*	Tree	7.22
3.	*Butea monosperma*	Tree	5.20
4.	*Piper spp./ Piper longum/ Piper mullesua*	Climber	2.12
5.	*Terminilia belerica*	Tree	1.59

Table 13.29.19 Major invasive species in the State inside the RFA/Green Wash in West Bengal (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Chromolaena odorata*	115
2.	*Ageratum conyzoides*	36
3.	*Mikania micrantha*	27
4.	*Lantana camara*	25
5.	*Xanthium strumarium*	7

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.30

ANDAMAN & NICOBAR ISLANDS

Geographical Area
8,249 sq km

Geographical Coordinates
Latitude- 06° N to 14° N
Longitude- 92° E to 94° E

Population (as per Census 2011)
0.38 million
Urban 0.14 million (37.70 %)
Rural 0.24 million (62.30 %)
Tribal 0.03 million (7.50 %)

Average Population Density
46 per sq km

Livestock population
(as per 19th Live Stock Census)
0.15 million

No. of Districts
3

No. of Hill Districts
0

No. of Tribal Districts
3

Table 13.30.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	825	
Reporting area for land utilization	757	100.00
Forests	717	94.72
Not available for land cultivation	9	1.19
Permanent pastures and other grazing lands	4	0.53
Land under misc. tree crops and groves	4	0.53
Culturable wasteland	3	0.40
Fallow land other than current fallows	2	0.25
Current fallows	3	0.40
Net area sown	15	1.98

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.30.1 Forest Cover

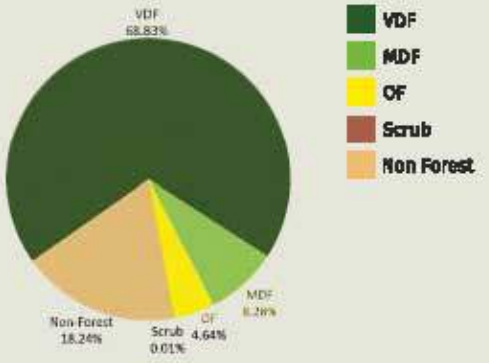

Figure 13.30.1 Forest Cover of Andaman & Nicobar Islands

Table 13.30.2 Forest Cover of Andaman & Nicobar Islands (In sq km)

Class	Area	% of GA
VDF	5,677.98	68.83
MDF	683.07	8.28
OF	382.97	4.64
Total	**6,744.02**	**81.75**
Scrub	1.13	0.01

Table 13.30.3 District- wise Forest Cover in Andaman & Nicobar Islands (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				% of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Nicobars[T]	1,841	1,148.10	105.03	154.40	1,407.53	76.45	1.36	1.00
North & Middle Andaman[T]	3,736	2,670.96	326.37	73.67	3,071.00	82.20	0.47	0.00
South Andaman[T]	2,672	1,858.92	251.67	154.90	2,265.49	84.79	-0.59	0.13
Grand Total	**8,249**	**5,677.98**	**683.07**	**382.97**	**6,744.02**	**81.75**	**1.24**	**1.13**

13.30.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.30.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Andaman & Nicobar Islands (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
5,409	546	253	6,208	269	137	130	536
87.13%	8.80%	4.07%		50.19%	25.56%	24.25%	

*In case of A&N Islands, RFA boundaries have been used

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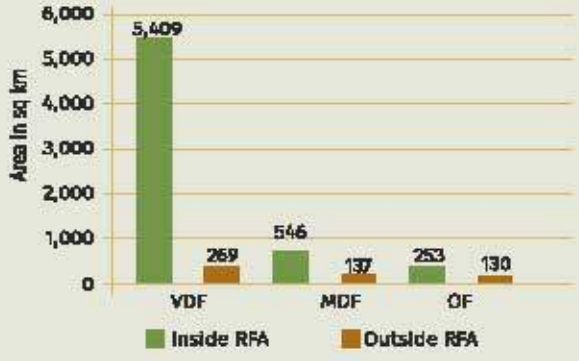


Figure 13.30.2
Forest Cover Inside and Outside of RFA in Andaman & Nicobar Islands

Table 13.30.5 Forest Cover Change Matrix for Andaman & Nicobar Islands (In sq km)

Class	2021 Assessment					Total
	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	5,678	0	0	0	0	5,678
Moderately Dense Forest	0	683	0	0	1	684
Open Forest	0	0	380	0	1	381
Scrub	0	0	0	1	0	1
Non Forest	0	0	3	0	1502	1,505
Total ISFR 2021	**5,678**	**683**	**383**	**1**	**1,504**	**8,249**
Net Change	0	-1	2	0	-1	

Table 13.30.6 Altitude-wise Forest Cover in Andaman & Nicobar Islands (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	8,238	5,667	683	383	6,733	1
500-1000	11	11	0	0	11	0
Total	**8,249**	**5,678**	**683**	**383**	**6,744**	**1**

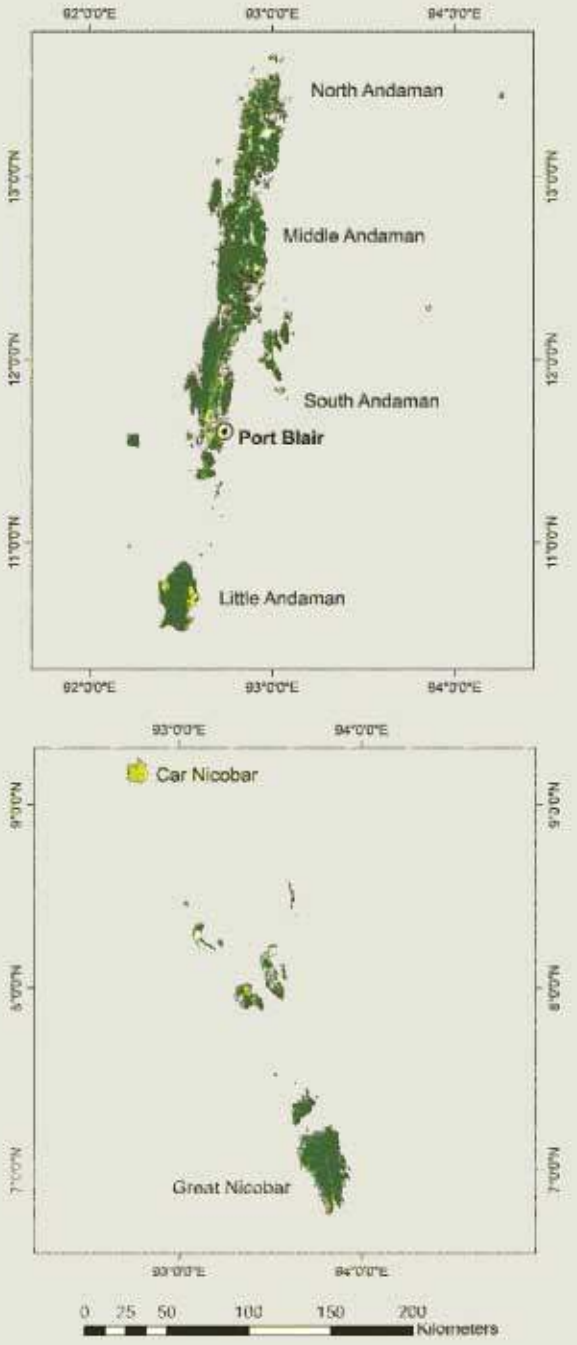
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.30.7 Forest Cover in different slope classes in Andaman & Nicobar Islands (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	3,983	2,338	391	264	2,993	1
5-10	1,999	1,461	187	76	1,724	0
10-15	1,185	949	74	28	1,051	0
15-20	651	555	22	10	587	0
20-25	299	262	6	3	271	0
25-30	101	88	2	1	91	0
>30	31	25	1	1	27	0
Total	**8,249**	**5,678**	**683**	**383**	**6,744**	**1**

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

Figure 13.30.3
Forest Cover Map of Andaman & Nicobar Islands



13.30.2 Forest Types

The area under different forest types of Andaman & Nicobar Islands as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

ANDAMAN & NICOBAR ISLANDS

Table 13.30.8 Area statistics of the Forest Types found in Andaman & Nicobar Islands (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	1A/C1 Giant evergreen forest	38.47	0.57
2.	1A/C2 Andamans tropical evergreen forest	2,961.96	43.92
3.	1A/C2/E1 Andamans moist deciduous forest	160.79	2.38
4.	1A/C3 Southern hilltop tropical evergreen forest	80.95	1.20
5.	1/E1 Cane brakes	0.26	0.00
6.	1/E2 Wet bamboo brakes	22.44	0.33
7.	1/2S1 Pioneer Euphorbiaceous scrub	3.76	0.06
8.	2A/C1 Andamans semi-evergreen forest	2,049.34	30.39
9.	2/E2 Wet bamboo brakes	12.58	0.19
10.	3A/C1 Andamans moist deciduous forest	562.02	8.33
11.	3A/C1/2S1 Andamans secondary moist deciduous forest	8.04	0.12
12.	4A/L1 Littoral forest	8.02	0.12
13.	4B/TS2 Mangrove forest	616.28	9.14
	Sub Total	**6,524.91**	**96.75**
14.	TOF/Plantation	219.00	3.25
	Total (Forest Cover & Scrub)	**6,743.91**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

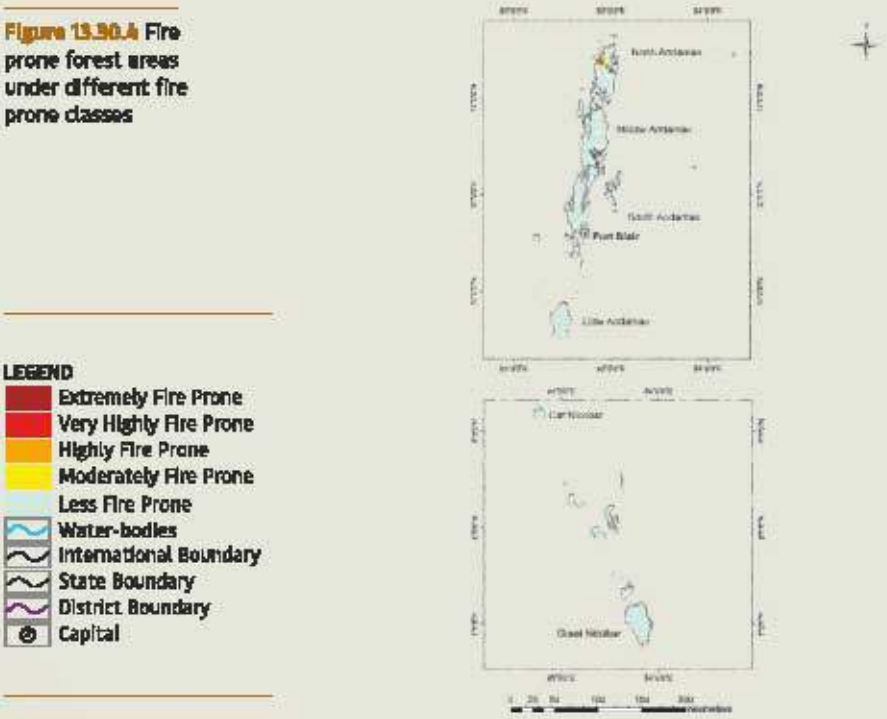
13.30.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.30.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	20.39	0.30
3.	Highly fire prone	51.38	0.76
4.	Moderately fire prone	37.49	0.56
5.	Less fire prone	6,634.74	98.38
	Total	**6,744.00**	**100.00**

Figure 13.30.4 Fire prone forest areas under different fire prone classes



13.30.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Andaman & Nicobar Islands has been estimated as given in following table.

Table 13.30.10 Tree Cover in Andaman & Nicobar Islands (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
41	23	-18

13.30.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.30.11 Extent of TOF in Andaman & Nicobar Islands (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
536	23	559

ANDAMAN & NICOBAR ISLANDS

13.30.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Andaman & Nicobar Islands is given in the Table 13.30.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.30.13.

Table 13.30.12 Growing Stock in Andaman & Nicobar Islands (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	90.82	121.72	30.90	2.77
2.	Growing Stock in TOF	2.75	5.55	2.80	0.31

Table 13.30.13 Diameter class distribution of top five tree species inside RFA in Andaman & Nicobar Islands (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Dipterocarpus turbinatus*	7,787	3,644	596
2.	*Pterocarpus indicus*	1,691	1,702	945
3.	*Terminalia bialata*	3,191	596	622
4.	*Canarium euphyllum*	1,618	1,402	755
5.	*Tetrameles nudiflora*	1,618	1,079	539

13.30.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Andaman & Nicobar Islands in Rural and Urban areas are given in the Table 13.30.14 and Table 13.30.15 respectively.

Table 13.30.14: Top five tree species in TOF (Rural) in Andaman & Nicobar Islands

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	69.62
2.	*Cocos nucifera*	5.44
3.	*Ficus racemosa*	1.87
4.	*Acacia auriculiformis*	1.71
5.	*Caryota urens*	1.03

Table 13.30.15: Top five tree species in TOF (Urban) in Andaman & Nicobar Islands

Sl. No.	Species	Relative Abundance (%)
1.	*Areca catechu*	51.36
2.	*Cocos nucifera*	15.77
3.	*Mangifera indica*	3.81
4.	*Mangifera andamanica*	3.70
5.	*Artocarpus heterophyllus*	3.46

30.30.8 Carbon Stock in Forest

The total Carbon stock of forest in the UT including the TOF patches which are more than 1ha in size is 109.84 million tonnes (402.75 million tonnes of CO_2 equivalent) which is 1.52 % of total forest carbon of the country. Pool wise forest carbon in Andaman & Nicobar Islands is given in the following table.

Table 13.30.16 Forest Carbon in Andaman & Nicobar Islands in different pools

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	47,560
2.	BGB	15,450
3.	Dead wood	1,432
4.	Litter	1,808
5.	SOC	43,586
	Total	**1,09,836**

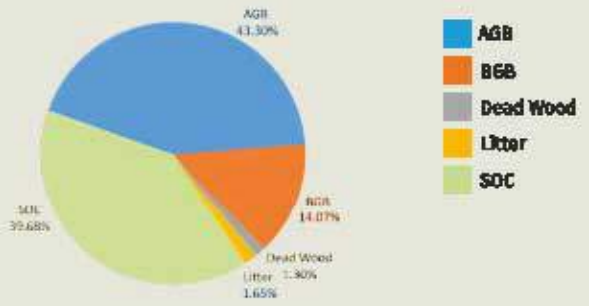


Figure 13.30.5 Forest Carbon in Andaman & Nicobar Islands

13.30.9 Growing Stock of Bamboo

Bamboo bearing area and growing stock inside the recorded forest area (RFA)/ Green Wash which include culms of 1 year age and above are given in the following table.

Table 13.30.17 Growing Stock of Bamboo in Andaman & Nicobar Islands

Growing Stock (GS)		% of Country's GS of Bamboo
Bamboo bearing area inside RFA/Green Wash (in sq km)	1,413	0.95
Total number of culms (in millions)	215	0.40
Total equivalent green weight (in '000 tonnes)	2,091	0.52

13.30.10 Major NTFP Species

Major NTFP species as assessed from forest inventory data are presented in the Table 13.30.18.

Table 13.30.18 Major NTFP species in Andaman & Nicobar Islands

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Calamus longisetus*	Shrub	63.87
2.	*Calamus palustris*	Shrub	35.60
3.	*Heritiera littoralis*	Tree	0.52

Major NTFP species are given in terms of relative abundance.

13.31 CHANDIGARH

Geographical Area
114 sq km

Geographical Coordinates
Latitude- 30° 39' N to 30° 49' N
Longitude-75° 41' E to 76° 51' E

Population (as per Census 2011)
1.06 million
Urban 1.03 million (97.25 %)
Rural 0.03 million (2.75 %)
Tribal Nil

Average Population Density
9,298 per sq km

Livestock population
(as per 19th Live Stock Census)
24,197

No. of Districts
1

No. of Hill Districts
1

No. of Tribal Districts
0

Table 13.31.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	11	
Reporting area for land utilization	7	100.00
Forests	0	0.00
Not available for land cultivation	5	71.42
Permanent pastures and other grazing lands	-	-
Land under misc. tree crops and groves	0	0.00
Culturable wasteland	-	-
Fallow land other than current fallows	1	14.29
Current fallows	0	0.00
Net area sown	1	14.29

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.31.1 Forest Cover

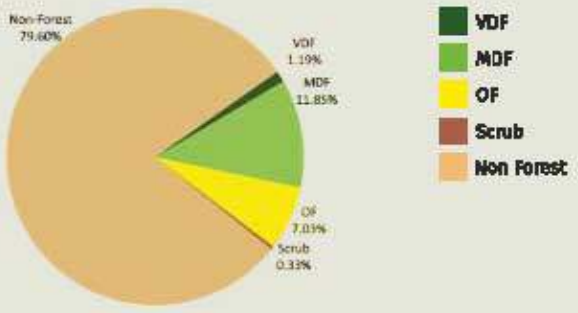


Figure 13.31.1
Forest Cover of Chandigarh

Table 13.28.2 Forest Cover of Chandigarh (in sq km)

Class	Area	% of GA
VDF	1.36	1.19
MDF	13.51	11.85
OF	8.01	7.03
Total	**22.88**	**20.07**
Scrub	0.38	0.33

Table 13.31.3 District- wise Forest Cover in Chandigarh (in sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Chandigarh	114	1.36	13.51	8.01	22.88	20.07	0.85	0.38
Grand Total	**114**	**1.36**	**13.51**	**8.01**	**22.88**	**20.07**	**0.85**	**0.38**

13.31.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.31.4 Forest Cover Inside and Outside Recorded Forest Area or (Green Wash) in Chandigarh (in sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
1.28	5.08	2.34	8.70	0.08	8.43	5.67	14.18
14.71%	58.39%	26.90%		0.56%	59.45%	39.99%	

**In case of Chandigarh, RFA boundaries have been used*

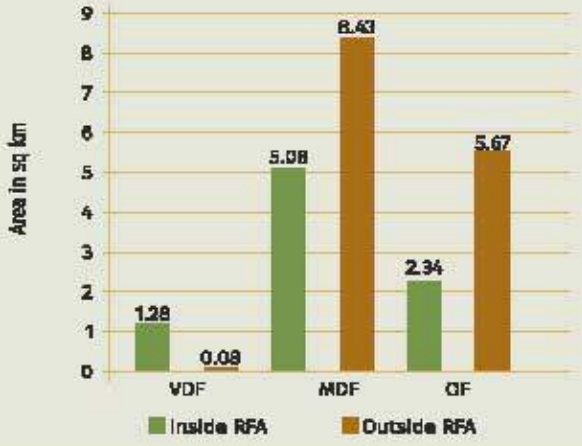


Figure 13.31.2
Forest Cover Inside and Outside of RFA in Chandigarh

CHANDIGARH

Table 13.3TL5 Forest Cover Change Matrix for Chandigarh (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	1.36	0.00	0.00	0.00	0.00	1.36
Moderately Dense Forest	0.00	12.65	0.95	0.08	0.56	14.24
Open Forest	0.00	0.29	6.11	0.00	0.03	6.43
Scrub	0.00	0.00	0.00	0.01	0.09	0.10
Non Forest	0.00	0.57	0.95	0.29	90.06	91.87
Total ISFR 2021	**1.36**	**13.51**	**8.01**	**0.38**	**90.74**	**114.00**
Net Change	0.00	-0.73	1.58	0.28	-1.13	

Table 13.3TL6 Altitude-wise Forest Cover in Chandigarh (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	114	1.36	13.51	8.01	22.88	0.38
Total	**114**	**1.36**	**13.51**	**8.01**	**22.88**	**0.38**

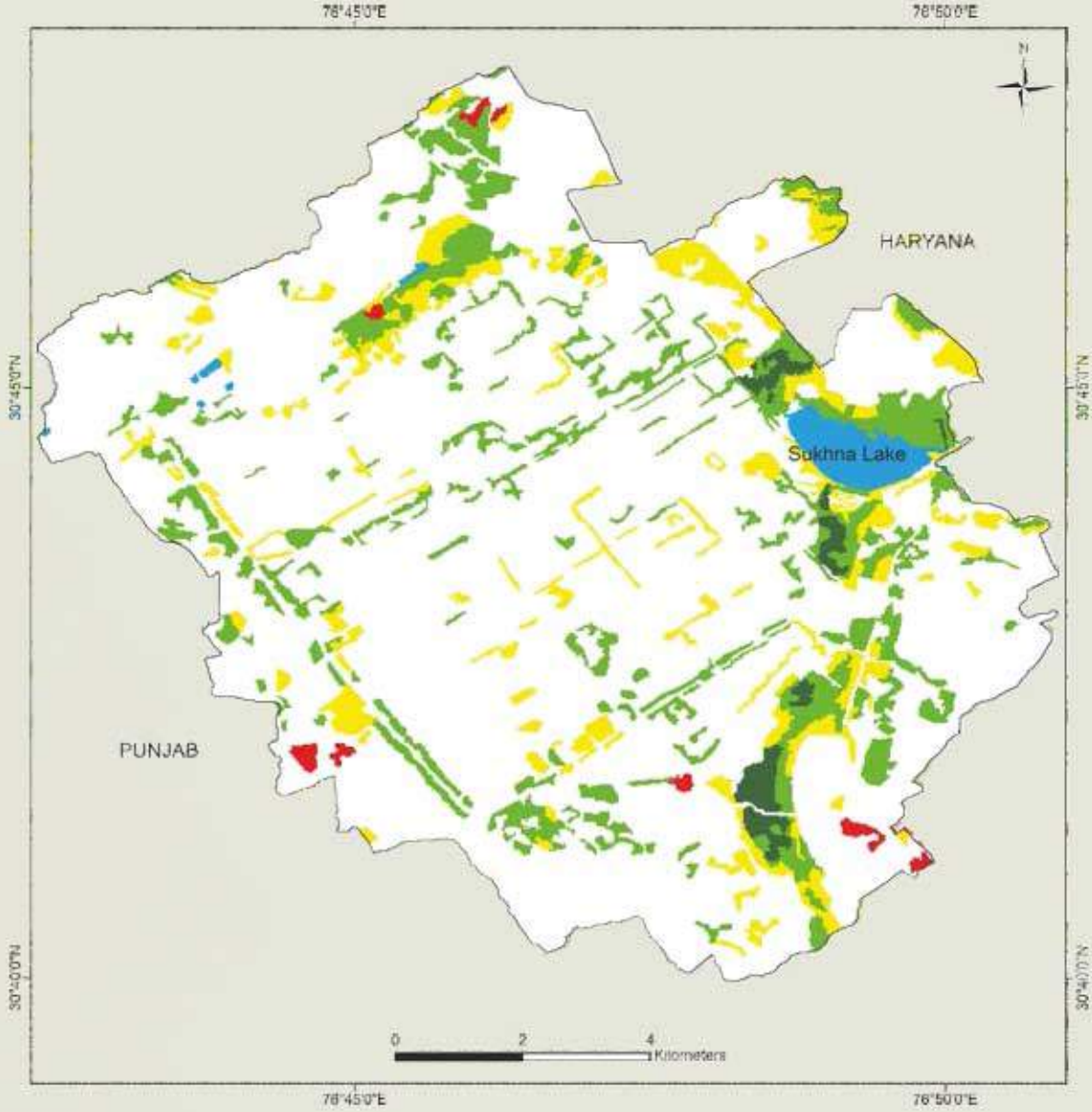
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.3TL7 Forest Cover in different slope classes in Chandigarh (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	109	1.30	12.59	7.52	21.41	0.36
5-10	5	0.06	0.92	0.49	1.47	0.02
Total	114	**1.36**	13.51	**8.01**	**22.88**	**0.38**

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

Figure 13.31.3
Forest Cover Map of Chandigarh



LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.31.2 Forest Types

The area under different forest types of Chandigarh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

CHANDIGARH

Table 13.31.8 Area statistics of the Forest Types found in Chandigarh (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	5B/C2 Northern dry mixed deciduous forest	10.20	46.09
2.	5/DS1 Dry deciduous scrub	0.05	0.23
	Sub Total	**10.25**	**46.32**
3.	TOF/Plantation	11.88	53.68
	Total (Forest Cover & Scrub)	**22.13**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

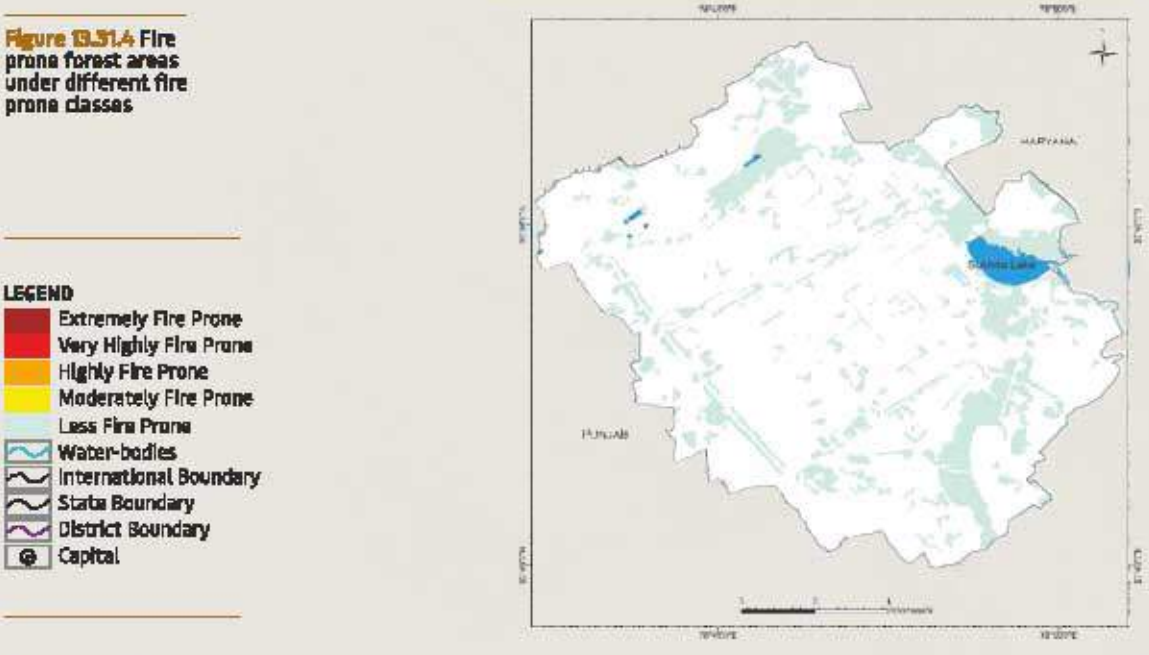
13.31.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.31.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	0.00	0.00
5.	Less fire prone	22.88	100.00
	Total	**22.88**	**100.00**

Figure 13.31.4 Fire prone forest areas under different fire prone classes



13.31.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Chandigarh has been estimated as given in following table.

Table 13.31.10 Tree Cover in Chandigarh (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
25	15	-10

13.31.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.31.11 Extent of TOF in Chandigarh (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
14	15	29

13.31.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Chandigarh is given in the Table 13.31.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.31.13.

Table 13.31.12 Growing Stock in Chandigarh (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	0.29	0.21	-0.08	0.00
2.	Growing Stock in TOF	0.50	0.29	-0.21	0.02

Table 13.31.13 Diameter class distribution of top five tree species inside RFA in Chandigarh (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Acacia catechu*	202	7	0
2.	*Leucaena leucocephala*	196	9	0
3.	*Dalbergia sissoo*	96	14	0
4.	*Melia azadirachta*	64	11	0
5.	*Eucalyptus spp.*	16	5	0

CHANDIGARH

13.31.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Chandigarh in Rural and Urban areas are given in the Table 13.31.14 and Table 13.31.15 respectively.

Table 13.31.14 Top five tree species in TOF (Rural) in Chandigarh

Sl. No.	Species	Relative Abundance (%)
1.	*Eucalyptus spp.*	38.16
2.	*Mangifera indica*	12.52
3.	*Prosopis juliflora*	8.17
4.	*Morus spp.*	7.47
5.	*Dalbergia sissoo*	4.89

Table 13.31.15 Top five tree species in TOF (Urban) in Chandigarh

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	12.32
2.	*Polyalthia longifolia*	7.13
3.	*Morus spp.*	6.28
4.	*Alstonia scholaris*	4.18
5.	*Melia azadirachta*	3.64

13.31.8 Carbon Stock in Forest

The total Carbon stock of forest in the UT including the TOF patches which are more than 1ha in size is 0.18 million tonnes (0.66 million tonnes of CO_2 equivalent) which is 0.002 % of total forest carbon of the country. Pool wise forest carbon in Changdigarh is given in the following table.

Table 13.31.16 Forest Carbon in Chandigarh in different pools

(In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	47
2.	BGB	15
3.	Dead wood	1
4.	Litter	3
5.	SOC	117
	Total	**183**

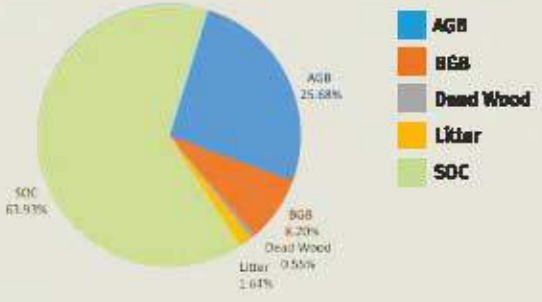


Figure 13.31.5 Forest Carbon in Chandigarh

13.31.9 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.31.17 and Table 13.31.18 respectively.

Table 13.31.17 Major NTFP species in Chandigarh

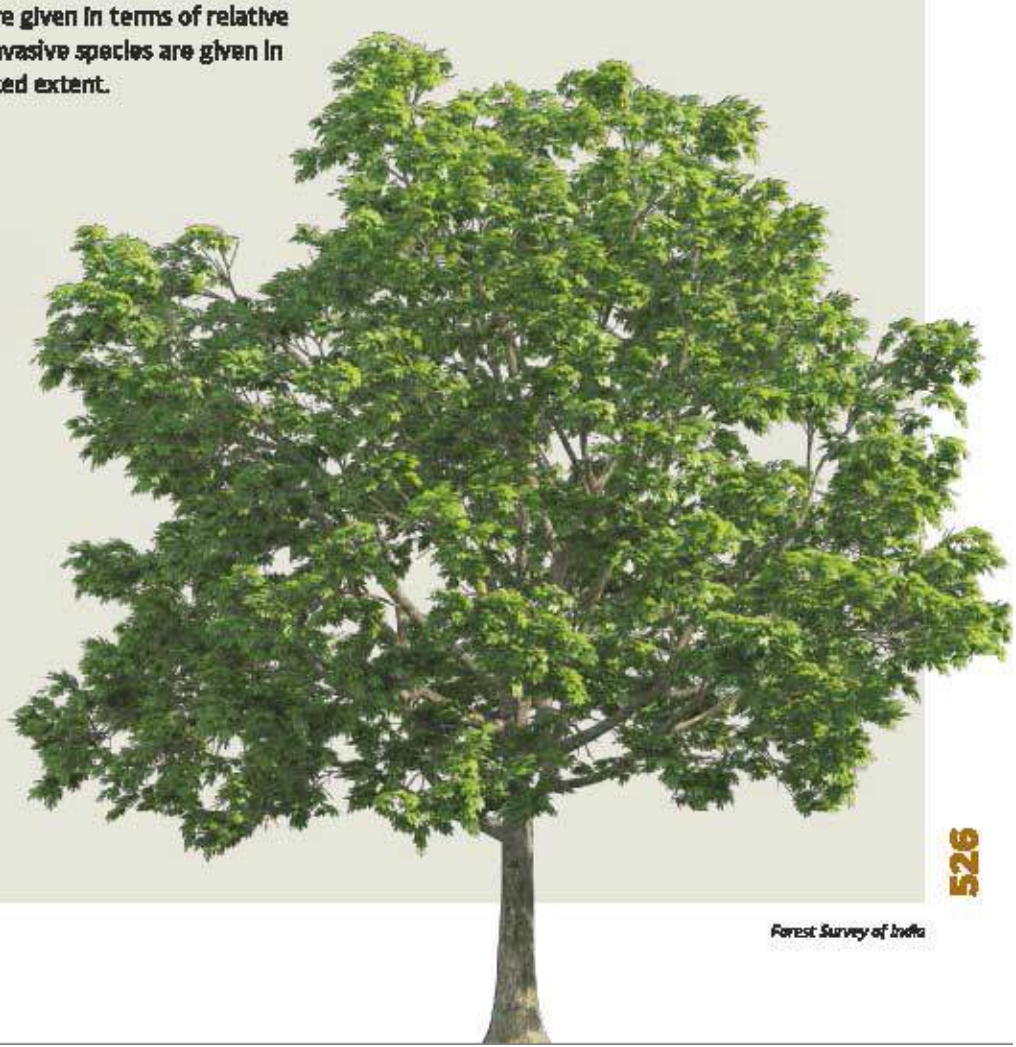
Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Emblica officinalis/Phyllanthus*	Tree	43.45
2.	Mulberry	Tree	32.41
3.	*Ficus virens*	Tree	5.52
4.	*Syzigium cumini*	Tree	4.83
5.	*Ziziphus mauritiana/jujuba*	Tree	4.14

Table 13.31.18 Major invasive species in the UT inside the RFA/Green Wash in Chandigarh

(In sq km)

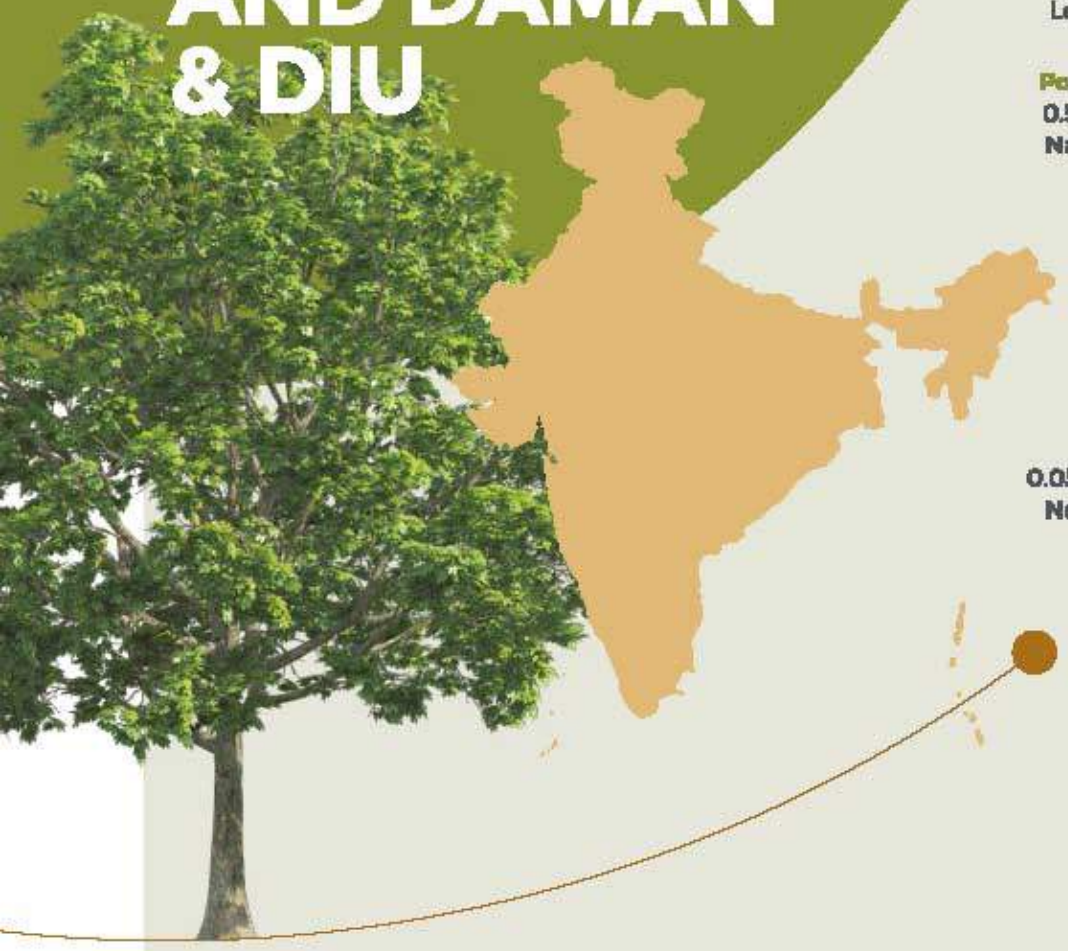
Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	1.00
2.	*Parthenium hysterophorus*	1.00
3.	*Leucanea leucocephala*	0.16
4.	*Saccharum spontanem*	0.05

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.



13.32

DADRA & NAGAR HAVELI AND DAMAN & DIU



Geographical Area
602 sq km

Geographical Coordinates
Latitude- 20° 0' N to 20° 28' N
Longitude- 70° 00' E to 73° 15' E

Population (as per Census 2011)
0.58 million (combined Dadra & Nagar Haveli and Daman & Diu)
Urban 0.34 million (58.51 %)
Rural 0.24 million (41.49 %)
Tribal 0.19 million (33.04 %)

Average Population Density
983 per sq km

Livestock population (as per 19th Live Stock Census)
0.054 million (combined Dadra & Nagar Haveli and Daman & Diu)

No. of Districts
3

No. of Hill Districts
0

No. of Tribal Districts
2

Table 13.32.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	60	
Reporting area for land utilization	52	100.00
Forests	20	38.46
Not available for land cultivation	4	7.69
Permanent pastures and other grazing lands	1	1.92
Land under misc. tree crops and groves	-	-
Culturable wasteland	0	0.00
Fallow land other than current fallows	3	5.77
Current fallows	2	3.85
Net area sown	22	42.31

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.32.1 Forest Cover

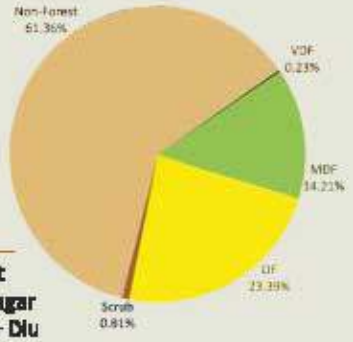


Figure 13.32.1 Forest Cover of Dadra & Nagar Haveli and Daman & Diu

Table 13.32.2 Forest Cover of Dadra & Nagar Haveli and Daman & Diu (In sq km)

Class	Area	% of GA
VDF	1.40	0.23
MDF	85.56	14.21
OF	140.79	23.39
Total	**227.75**	**37.83**
Scrub	4.85	0.81

Table 13.32.3 District- wise Forest Cover in Dadra & Nagar Haveli and Daman & Diu (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Dadra & Nagar Haveli*	491	0.00	79.87	127.44	207.31	42.22	0.15	4.66
Daman*	72	0.00	1.93	8.94	10.87	15.10	-0.04	0.19
Diu	39	1.40	3.76	4.41	9.57	24.54	-0.01	0.00
Grand Total	**602**	**1.40**	**85.56**	**140.79**	**227.75**	**37.83**	**0.10**	**4.85**

13.32.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.32.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Dadra & Nagar Haveli and Daman & Diu (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
0.00	69.38	90.64	160.02	1.40	16.18	50.15	67.73
0.00%	43.36%	56.64%		2.07%	23.89%	74.04%	

In case of Dadra & Nagar Haveli and Daman & Diu, RFA boundaries have been used.

Figure 13.32.2 Forest Cover Inside and Outside of RFA in Dadra & Nagar Haveli and Daman & Diu

DADRA & NAGAR HAVELI AND DAMAN & DIU

Table 13.32.5 Forest Cover Change Matrix for Dadra & Nagar Haveli and Daman & Diu (In sq km)

Class	2021 Assessment					Total
	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	1.40	0.00	0.00	0.00	0.00	1.40
Moderately Dense Forest	0.00	85.56	0.00	0.00	0.06	85.62
Open Forest	0.00	0.00	137.49	0.00	3.14	140.63
Scrub	0.00	0.00	0.00	4.85	0.27	5.12
Non Forest	0.00	0.00	3.30	0.00	365.93	369.23
Total ISFR 2021	**1.40**	**85.56**	**140.79**	**4.85**	**369.40**	**602.00**
Net Change	0.00	-0.06	0.16	-0.27	0.17	

Table 13.32.6 Altitude-wise Forest Cover in Dadra & Nagar Haveli and Daman & Diu (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	602	1.40	85.56	140.79	227.75	4.85
Total	**602**	**1.40**	**85.56**	**140.79**	**227.75**	**4.85**

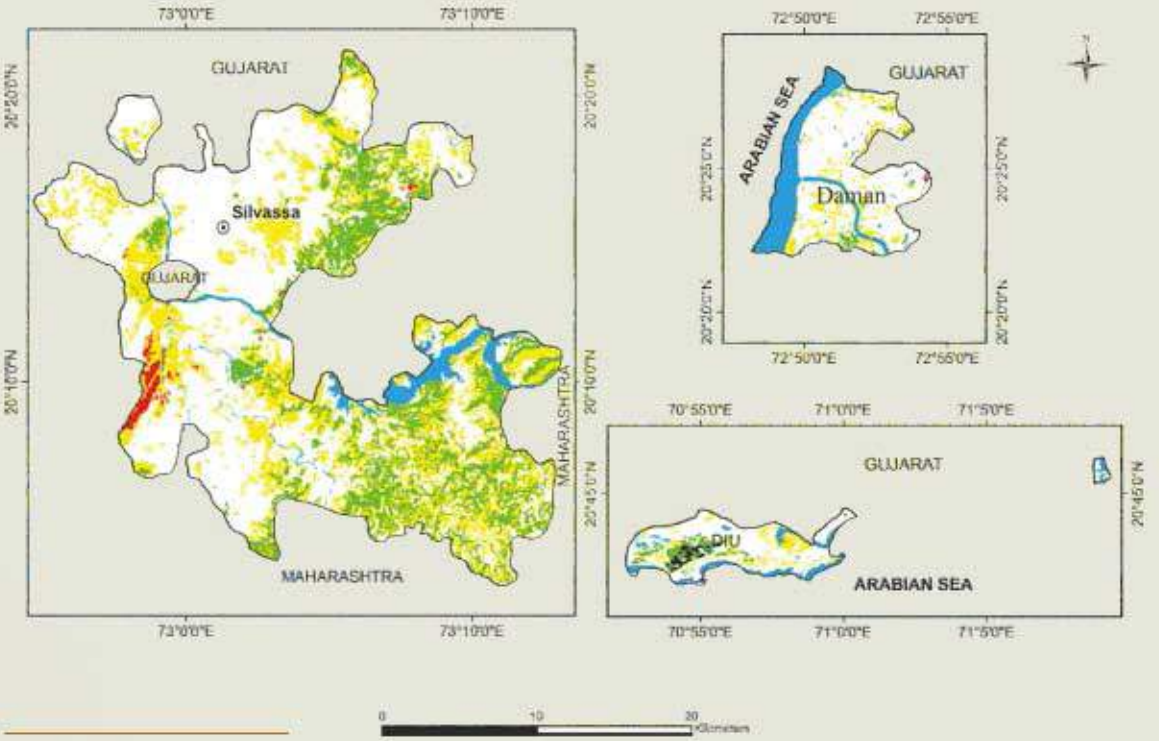
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.32.7 Forest Cover in different slope classes in Dadra & Nagar Haveli and Daman & Diu (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	432	1.39	28.54	74.03	103.96	3.11
5-10	95	0.01	24.14	35.69	59.84	1.04
10-15	45	0.00	17.81	19.04	36.85	0.69
15-20	19	0.00	9.02	8.03	17.05	0.01
20-25	7	0.00	4.05	3.00	7.05	0.00
25-30	3	0.00	2.00	1.00	3.00	0.00
>30	1	0.00	0.00	0.00	0.00	0.00
Total	**602**	**1.40**	**85.56**	**140.79**	**227.75**	**4.85**

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

Figure 13.32.3 Forest Cover Map of Dadra & Nagar Haveli and Daman & Diu



LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.32.2 Forest Types

The area under different forest types of Dadra & Nagar Haveli and Daman & Diu as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.32.8 Area statistics of the Forest Types found in Dadra & Nagar Haveli and Daman & Diu (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	3B/C1b Moist teak forest	19.89	8.54
2.	3B/C2 Southern moist mixed deciduous forest	162.75	69.92
3.	4A/L1 Littoral forest	1.35	0.58
4.	4B/T52 Mangrove forest	3.10	1.33
5.	5A/C3 Southern dry mixed deciduous forest	9.33	4.01
6.	5/DS1 Dry deciduous scrub	5.37	2.31
7.	6B/C1 Desert thorn forest	3.19	1.37

DADRA & NAGAR HAVELI AND DAMAN & DIU

Table 13.32.8 Area statistics of the Forest Types found in Dadra & Nagar Haveli and Daman & Diu (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
	Sub Total	**204.98**	**88.06**
8.	TOF/Plantation	27.79	11.94
	Total (Forest Cover & Scrub)	**232.77**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

13.32.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.32.9 Forest Fire Prone Classes (in sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	0.00	0.00
5.	Less fire prone	227.75	100.00
	Total	**227.75**	**100.00**

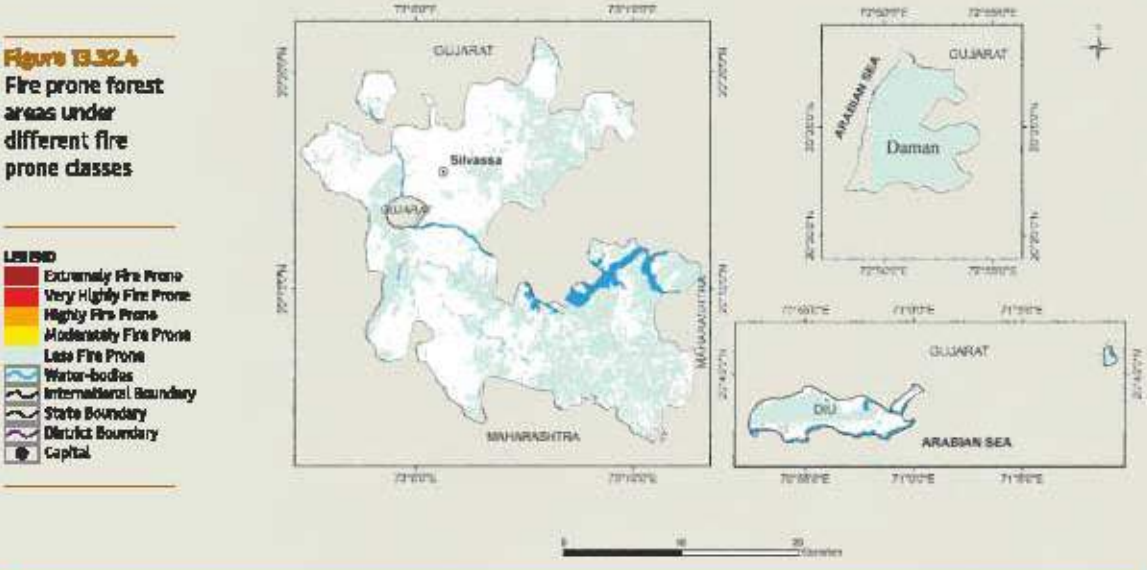


Figure 13.32.4 Fire prone forest areas under different fire prone classes

13.32.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Dadra & Nagar Haveli and Daman & Diu has been estimated as given in following table.

Table 13.32.10 Tree Cover in Dadra & Nagar Haveli and Daman & Diu (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
33	32	-1

13.32.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.32.11 Extent of TOF in Dadra & Nagar Haveli and Daman & Diu (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
68	32	100

11.32.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Dadra & Nagar Haveli and Daman & Diu is given in the Table 13.32.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.32.13

Table 13.32.12 Growing Stock in Dadra & Nagar Haveli and Daman & Diu (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	0.83	0.45	-0.38	0.01
2.	Growing Stock in TOF	1.31	0.67	-0.49	0.04

Table 13.32.13 Diameter class distribution of top five tree species inside RFA in Dadra & Nagar Haveli and Daman & Diu (in '000)

Sl. No.	Species	Dia class (cm)		
		10-30	30-60	>60
1.	*Terminalia tomentosa*	576	0	0
2.	*Lannea coromandelica*	239	30	0
3.	*Madhuca latifolia*	119	65	0
4.	*Acacia catechu*	122	0	15
5.	*Terminalia belerica*	30	15	0

DADRA & NAGAR HAVELI AND DAMAN & DIU

13.32.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Dadra & Nagar Haveli and Daman & Diu in Rural and Urban areas are given in the Table 13.32.14 and Table 13.32.15 respectively.

Table 13.32.14 Top five tree species in TOF (Rural) in Dadra & Nagar Haveli and Daman & Diu

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	34.60
2.	*Phoenix sylvestris*	12.79
3.	*Tectona grandis*	8.69
4.	*Emblica officinalis*	5.00
5.	*Terminalia crenulata*	4.88

Table 13.32.15 Top five tree species in TOF (Urban) in Dadra & Nagar Haveli and Daman & Diu

Sl. No.	Species	Relative Abundance (%)
1.	*Mangifera indica*	20.34
2.	*Cocos nucifera*	18.73
3.	*Tectona grandis*	6.91
4.	*Jonesia asoca*	6.05
5.	*Alstonia scholaris*	5.11

13.32.8 Carbon Stock in Forest

The total Carbon stock of forest in the UT including the TOF patches which are more than 1ha in size is 1.98 million tonnes (7.26 million tonnes of CO_2 equivalent) which is 0.03 % of total forest carbon of the country. Pool wise forest carbon in Dadra & Nagar Haveli and Daman & Diu is given in the following table.

Table 13.25.16 Forest Carbon in Dadra & Nagar Haveli and Daman & Diu in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	558
2.	BGB	129
3.	Dead wood	11
4.	Litter	38
5.	SOC	1,244
	Total	**1,980**

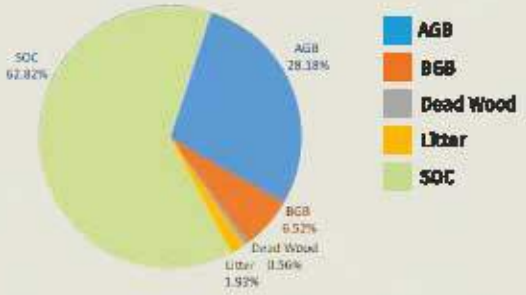


Figure 13.32.5 Forest Carbon in Dadra & Nagar Haveli and Daman & Diu

13.32.9 Major NTFP and Invasive Species

Major NTFP and invasive species as assessed from forest inventory data are presented in the Table 13.32.17 and Table 13.32.18 respectively.

Table 13.32.17 Major NTFP species in Dadra & Nagar Haveli and Daman & Diu

Sl. No.	Species	Plant Type	Relative Abundance (%)
1.	*Lannea coromandelica*	Tree	23.60
2.	*Madhuca indica*	Tree	15.73
3.	*Acacia catechu*	Tree	13.48
4.	*Anogeissus latifolia*	Tree	13.48
5.	*Acacia arabica*	Tree	7.87

Table 13.32.18 Major invasive species in the UT inside the RFA/Green Wash in Dadra & Nagar Haveli and Daman & Diu

(In sq km)

Sl. No.	Species	Estimated Extent
1.	*Cassia tora*	2.00
2.	*Glinsoga parviflora*	1.00
3.	*Lantana camara*	0.27
4.	*Chromolaena odorata*	0.16
5.	*Ageratum conyzoides*	0.16

Major NTFP species are given in terms of relative abundance whereas invasive species are given in terms of their estimated extent.

13.33 JAMMU & KASHMIR

Geographical Area
54,624 sq km#

Geographical Coordinates
Latitude- 30° 17' N to 35° 08' N
Longitude- 73° 25' E to 76° 45' E

Population (as per Census 2011)
12.54 million (including Ladakh)
Urban 3.43 million (27.38 %)
Rural 9.11 million (72.62 %)
Tribal 1.49 million (11.91%)

Average Population Density
125 per sq km (including Ladakh)

Livestock population
(as per 19th Live Stock Census)
9.20 million (including Ladakh)

No. of Districts
22

No. of Hill Districts
22

No. of Tribal Districts
0

 # Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited.

Table 13.33.1 Land Use Pattern (Combined Jammu & Kashmir and Ladakh)

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	22,224	
Reporting area for land utilization	4,120	100.00
Forests	2,361	57.31
Not available for land cultivation	570	13.84
Permanent pastures and other grazing lands	108	2.62
Land under misc. tree crops and groves	59	1.43
Culturable wasteland	139	3.37
Fallow land other than current fallows	26	0.63
Current fallows	105	2.55
Net area sown	752	18.25

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.33.1 Forest Cover

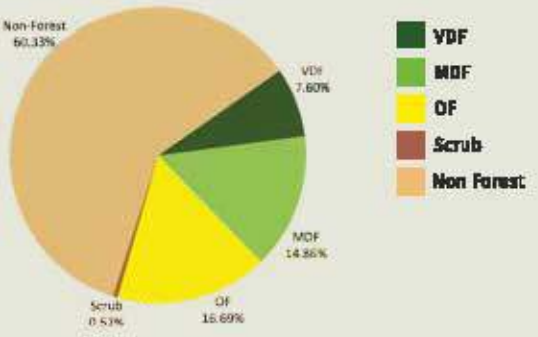


Figure 13.33.1
Forest Cover of
Jammu & Kashmir

Table 13.33.2 Forest Cover of Jammu & Kashmir (In sq km)

Class	Area	% of Shapefile Area*
VDF	4,155.11	7.60
MDF	8,116.73	14.86
OF	9,115.00	16.69
Total	**21,386.84**	**39.15**
Scrub	284.32	0.52

** Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited.*

Table 13.33.3 District- wise Forest Cover in Jammu & Kashmir (In sq km)

District	Shapefile Area*	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Anantnag*	2,727	128.34	465.56	481.16	1,075.06	39.42	0.87	0.76
Badgam*	1,250	99.38	74.70	169.22	343.30	27.46	1.46	16.71
Bandipura*	4,042	336.12	317.08	230.85	884.05	21.87	5.51	45.31
Baramula*	2,062	267.11	228.63	396.28	892.02	43.26	21.76	7.56
Doda*	2,411	328.18	713.92	444.60	1,486.70	61.66	0.77	1.29
Ganderbal*	1,620	128.24	179.80	182.62	490.66	30.29	-3.84	7.04
Jammu*	2,407	0.00	226.49	476.17	702.66	29.19	-64.97	22.01
Kathua*	2,512	108.14	628.66	594.52	1,331.32	53.00	-0.12	8.45
Kishtwar*	8,179	238.60	746.37	798.09	1,783.06	21.80	-1.99	8.74
Kulgam*	1,265	83.73	100.94	204.82	389.49	30.79	-0.75	4.98
Kupwara*	2,744	760.06	423.61	350.85	1,534.52	55.92	69.57	1.31
Nirpur*	3,759	0.00	441.75	865.14	1,306.89	34.77	69.10	25.22
Muzaffarbad*	4,663	827.06	462.07	450.94	1,740.07	37.32	131.04	54.21
Pulwama*	896	15.20	126.62	234.20	376.02	41.97	1.88	5.85
Punch*	4,244	313.63	1,044.85	690.25	2,048.73	48.27	-58.98	16.88
Rajouri*	2,635	41.12	427.67	763.60	1,232.39	46.77	-72.91	7.77
Ramban*	1,288	70.70	293.09	297.51	661.30	51.34	-4.94	1.46
Reasi*	1,932	231.63	389.48	414.59	1,035.70	53.61	-62.71	13.76
Samba*	921	0.00	136.24	195.21	331.45	35.99	-0.34	10.29
Shupiyan*	505	61.85	37.02	224.32	323.19	64.00	-0.86	1.00
Srinagar*	282	0.70	19.47	25.00	45.17	16.02	-0.07	0.00
Udhampur*	2,280	115.32	632.71	625.06	1,373.09	60.22	-0.93	23.72
Grand Total	**54,624**	**4,155.11**	**8,116.73**	**9,115.00**	**21,386.84**	**39.15**	**28.55**	**284.32**

** Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited.*

JAMMU & KASHMIR

13.33.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.33.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Jammu & Kashmir

(In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
3,036	5,432	4,708	13,176	1,119	2,685	4,407	8,211
23.04%	41.23%	35.73%		13.63%	32.70%	53.67%	

**In case of Jammu & Kashmir, RFA boundaries have been used.*

Figure 13.33.2 Forest Cover Inside and Outside of RFA in Jammu & Kashmir

Table 13.33.5 Forest Cover Change Matrix of Jammu & Kashmir

(In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	4,125	102	8	0	44	4,279
Moderately Dense Forest	21	7,864	45	0	160	8,090
Open Forest	8	127	8,284	4	566	8,989
Scrub	0	0	36	239	15	290
Non Forest	1	24	742	41	32,168	32,976
Total ISFR 2021	**4,155**	**8,117**	**9,115**	**284**	**32,953**	**54,624**
Net Change	-124	27	126	-6	-23	

Table 13.33.6 Altitude-wise forest cover in Jammu & Kashmir

(In sq km)

Altitude Zone (m)	Shapefile Area*	VDF	MDF	OF	Total	Scrub
0-500	4,992	0	222	825	1,047	63
500-1000	6,567	47	1,335	1,994	3,376	69
1000-2000	14,192	682	2,370	3,168	6,220	32
2000-3000	12,160	2,851	3,136	2,128	8,115	30
3000-4000	10,193	575	1,053	999	2,627	89
4000-Above	6,520	0	1	1	2	1
Total	**54,624**	**4,155**	**8,117**	**9,115**	**21,387**	**284**

(based on SRTM, Digital Elevation Model, 30 m, 2016)
** Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited*

Table 13.33.7 Forest Cover in different slope classes in Jammu & Kashmir (In sq km)

Slope (in degrees)	Shapefile Area*	VDF	MDF	OF	Total	Scrub
0-5	10,732	92	469	1,544	2,105	49
5-10	5,825	237	739	1,195	2,171	46
10-15	6,518	409	1,092	1,291	2,792	44
15-20	7,065	589	1,299	1,272	3,160	39
20-25	6,949	690	1,327	1,161	3,178	34
25-30	6,281	704	1,215	1,006	2,925	28
>30	11,254	1,434	1,976	1,646	5,056	44
Total	**54,624**	**4,155**	**8,117**	**9,115**	**21,387**	**284**

(based on SRTM, Digital Elevation Model, 30 m, 2016)
 # Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited

Figure 13.33.3 Forest Cover Map of Jammu & Kashmir

LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.33.2 Forest Types

The area under different forest types of Jammu & Kashmir as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

JAMMU & KASHMIR

Table 13.33.8 Area statistics of the Forest Types found in Jammu & Kashmir (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	5B/C2 Northern dry mixed deciduous forest	1,606.55	6.22
2.	5/DS1 Dry deciduous scrub	442.64	1.72
3.	5/DS3 (*Euphorbia* scrub)	0.57	0.00
4.	5/E9 Dry bamboo brake	18.45	0.07
5.	5/1S2 *Khair-sissu* forest	4.42	0.02
6.	9/C1a Lower or Siwalik chir pine forest	2,725.47	10.56
7.	9/C1b Upper or Himalayan chir pine forest	1,094.20	4.24
8.	9/C1/DS1 Himalayan subtropical scrub	287.62	1.11
9.	10/C1a *Olea cuspidata* scrub forest	153.29	0.59
10.	10/C1b *Acacia modesta* scrub forest	8.98	0.03
11.	10/DS1 *Dodonaea* scrub	7.91	0.03
12.	12/C1a *Ban* oak forest (*Q. incana*)	665.70	2.58
13.	12/C1b *Moru* oak forest (*Q. dilatata*)	37.74	0.15
14.	12/C1c Moist deodar forest (*Cedrus*)	1,589.47	6.16
15.	12/C1d Western mixed coniferous forest (spruce, blue pine, silver fir)	3,217.55	12.47
16.	12/C1e Moist temperate deciduous forest	38.21	0.15
17.	12/C1f Low-level blue pine forest (*P. wallichiana*)	2,225.13	8.62
18.	12/C1/DS1 Oak scrub	106.44	0.41
19.	12/C1/DS2 Himalayan temperate secondary scrub	122.80	0.48
20.	12/C2a *Kharsu* oak forest (*Q. semecarpifolia*)	0.60	0.00
21.	12/C2b West Himalayan upper oak/fir forest	3.35	0.01
22.	12/1S1 Alder forest	3.31	0.01
23.	12/1S2 Riverain blue pine forest	53.77	0.21
24.	12/2S1 Low level blue pine forest	50.80	0.20
25.	13/C1 Dry broadleaved and coniferous forest (*Q. ilex- P. gerardiana*)	390.71	1.51
26.	13/C2b Dry deodar forest (*Cedrus*)	639.82	2.48
27.	13/C2/DS1 Pohu scrub	60.57	0.24
28.	13/C2/DS2 Dry temperate scrub	91.06	0.35
29.	13/C3 West Himalayan dry temperate deciduous forest	236.80	0.92
30.	13/C4 West Himalayan high level dry blue pine forest (*P. wallichiana*)	1,169.22	4.53
31.	13/1S2 *Populus / Salix* forest	5.02	0.02
32.	14/C1a West Himalayan sub-alpine fir forest	358.03	1.39
33.	14/C1b West Himalayan sub-alpine birch/fir forest	1,351.11	5.23
34.	14/2S1 Sub-alpine blue pine forest (*P. wallichiana*)	84.71	0.33
35.	15/C1 Birch / *Rhododendron* scrub forest	104.32	0.40
36.	15/C2 Deciduous alpine scrub	112.37	0.44
37.	15/E1 Dwarf *Rhododendron* scrub	33.60	0.13
38.	16/C1 Dry alpine scrub	609.10	2.36
39.	16/E1 Dwarf juniper scrub	75.23	0.29
	Sub Total	**19,786.64**	**76.66**

(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
40.	TOF/ Plantation	1,585.50	6.14
	Total (Forest Cover & Scrub)	**21,372.14**	
	Grassland forest types (outside forest cover)		
41.	12/DS3 Himalayan temperate pastures	802.44	3.11
42.	14/DS1 Sub-alpine pastures	1,155.98	4.48
43.	15/C3 Alpine pastures	2,479.28	9.61
	Sub Total	**4,437.70**	**17.20**
	Grand Total	**25,809.84**	**100.00**

**Forest Types have been assigned to the natwal forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). Grassland forest types outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.33.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.33.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	17.90	0.08
3.	Highly fire prone	321.68	1.51
4.	Moderately fire prone	857.95	4.01
5.	Less fire prone	20,189.47	94.40
	Total	**21,387.00**	**100.00**

Figure 13.33.4 Fire prone forest areas under different fire prone classes

13.33.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Jammu & Kashmir has been estimated as given in following table.

JAMMU & KASHMIR

Table 13.33.10 Tree Cover in Jammu & Kashmir (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
7,944	3,511	-4,433

13.33.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.33.11 Extent of TOF in of Jammu & Kashmir (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
8,211	3,511	11,722

13.33.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Jammu & Kashmir is given in the Table 13.33.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the Table 13.33.13

Table 13.33.12 Growing Stock in Jammu & Kashmir (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	291.63	348.35	56.72	7.94
2.	Growing Stock in TOF	125.14	109.04	-16.10	6.13

Table 13.33.13 Diameter class distribution of top five tree species inside RFA in Jammu & Kashmir (In '000)

		Dia class (cm)		
Sl. No.	Species	10-30	30-60	>60
1.	*Pinus wallichiana*	32,267	35,184	7,492
2.	*Cedrus deodara*	14,364	14,559	9,094
3.	*Abies pindrow*	9,457	17,473	8,490
4.	*Pinus roxburghii*	14,140	16,376	3,763
5.	*Abies smithiana*	2,042	6,060	2,347

13.33.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Jammu & Kashmir in Rural and Urban areas are given in the Table 13.33.14 and Table 13.33.15 respectively.

Table 13.33.14 Top five tree species in TOF (Rural) in Jammu & Kashmir

Sl. No.	Species	Relative Abundance (%)
1.	*Quercus leucotrichophora*	7.49
2.	*Grewia oppositifolia*	6.14
3.	*Pyrus* spp.	5.76
4.	*Quercus dilatata floribunda*	4.70
5.	*Juglans regia*	4.33

Table 13.33.15 Top five tree species in TOF (Urban) in Jammu & Kashmir

Sl. No.	Species	Relative Abundance (%)
1.	*Grewia oppositifolia*	10.09
2.	*Leucaena leucocephala*	6.47
3.	*Pyrus* spp.	5.06
4.	*Acacia modesta*	4.25
5.	*Mangifera indica*	4.16

13.33.8 Carbon Stock in Forest

The total Carbon stock of forests in the UT including the TOF patches which are more than 1 ha in size is 370.87 million tonnes (1,359.86 million tonnes of CO_2 equivalent) which is 5.15 % of total forest carbon of the country. Pool wise forest carbon in Jammu & Kashmir is given in the following table.

Table 13.33.16 Forest Carbon in Jammu & Kashmir in different pools

(in '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	1,63,897
2.	BGB	45,864
3.	Dead wood	3,386
4.	Litter	4,951
5.	SOC	1,52,772
	Total	**3,70,870**

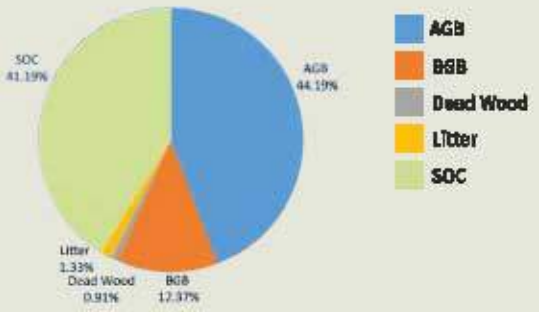


Figure 13.33.5 Forest Carbon in Jammu & Kashmir

13.33.9 Major Invasive Species

Major Invasive species as assessed from forest inventory data are presented in the Table 13.33.17.

Table 13.33.17 Major invasive species in the UT inside the RFA/Green Wash in Jammu & Kashmir (in sq km)

Sl. No.	Species	Estimated Extent
1.	*Lantana camara*	64
2.	*Parthenium hysterophorus*	24
3.	*Ageratum conyzoides*	9
4.	*Ipomoea fistulosa*	3
5.	*Solanum viarum*	2

Major invasive species are given in terms of their estimated extent.

13.34 LADAKH

Geographical Area
1,68,055 sq km#

Geographical Coordinates
Latitude- 32° 20' N to 37° 05' N
Longitude-72° 30' E to 80° 20' E

Population (as per Census 2011)
12.54 million (including J&K)
Urban 3.43 million (27.38%)
Rural 9.11 million (72.62 %)
Tribal 1.49 million (11.91 %)

Average Population Density
124 per sq km (including J&K)

Livestock population
(as per 19th Live Stock Census)
9.20 million (including J&K)

No. of Districts
2

No. of Hill Districts
2

No. of Tribal Districts
0

 # Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited.

Table 13.34.1 Land Use Pattern (Combined Jammu & Kashmir and Ladakh)

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	22,224	
Reporting area for land utilization	4,120	100.00
Forests	2,361	57.31
Not available for land cultivation	570	13.84
Permanent pastures and other grazing lands	108	2.62
Land under misc. tree crops and groves	59	1.43
Culturable wasteland	139	3.37
Fallow land other than current fallows	26	0.63
Current fallows	105	2.55
Net area sown	752	18.25

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.34.1 Forest Cover

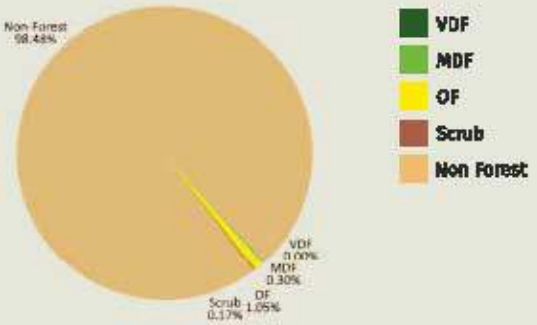


Figure 13.34.1
Forest Cover
of Ladakh

Table 13.34.2 Forest Cover of Ladakh (in sq km)

Class	Area	% of Shapefile Area*
VDF	2.27	0.00
MDF	512.10	0.30
OF	1,757.72	1.05
Total	**2,272.09**	**1.35**
Scrub	278.65	0.17

 # Area of shape file provided by Survey of India (August 2021). Notified Geographical area from SoI awaited.

Table 13.34.3 District- wise Forest Cover in Ladakh (in sq km)

District	Shapefile Area*	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Kargil#	14,202	0.00	2.24	57.30	59.54	0.42	-0.14	24.94
Leh#	1,53,853	2.27	509.86	1,700.42	2,212.55	1.44	18.63	253.71
Grand Total	**1,68,055**	**2.27**	**512.10**	**1,757.72**	**2,272.09**	**1.35**	**18.49**	**278.65**

 # Area of shape file provided by Survey of India (August 2021). Notified Geographical area from SoI awaited.

13.34.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.34.4 Forest Cover Inside and Outside Recorded Forest Area or (Green Wash) in Ladakh (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
2		179	619	800	0	333	1,1391,472
0.25%	22.37%	77.38%		0.00%	22.62%	77.38%	

**In case of Ladakh, Green Wash boundaries have been used.*

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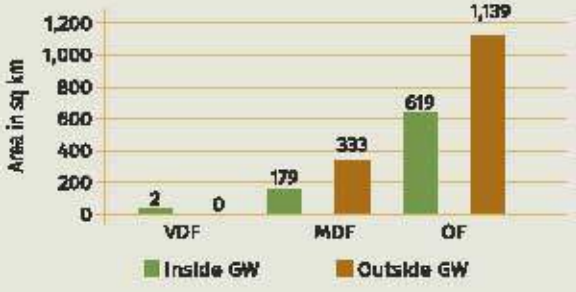


Figure 13.34.2
Forest Cover Inside and Outside Green Wash in Ladakh

Table 13.34.5 Forest Cover Change Matrix for Ladakh (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	2	0	0	0	0	2
Moderately Dense Forest	0	509	3	0	10	522
Open Forest	0	3	1,714	9	4	1,730
Scrub	0	0	2	251	5	258
Non Forest	0	0	39	19	1,65,485	1,65,543
Total ISFR 2021	**2**	**512**	**1,758**	**279**	**1,65,504**	**1,68,055**
Net Change	0	-10	28	21	-39	

Table 13.34.6 Altitude-wise forest cover in Ladakh (In sq km)

Altitude Zone (m)	Shapefile Area#	VDF	MDF	OF	Total	Scrub
0-500	0	0	0	0	0	0
500-1000	14	0	0	0	0	0
1000-2000	1,810	0	23	55	78	4
2000-3000	7,132	0	242	766	1,008	53
3000-4000	23,449	2	246	920	1,168	187
>4000	1,35,650	0	1	17	18	35
Total	**1,68,055**	**2**	**512**	**1,758**	**2,272**	**279**

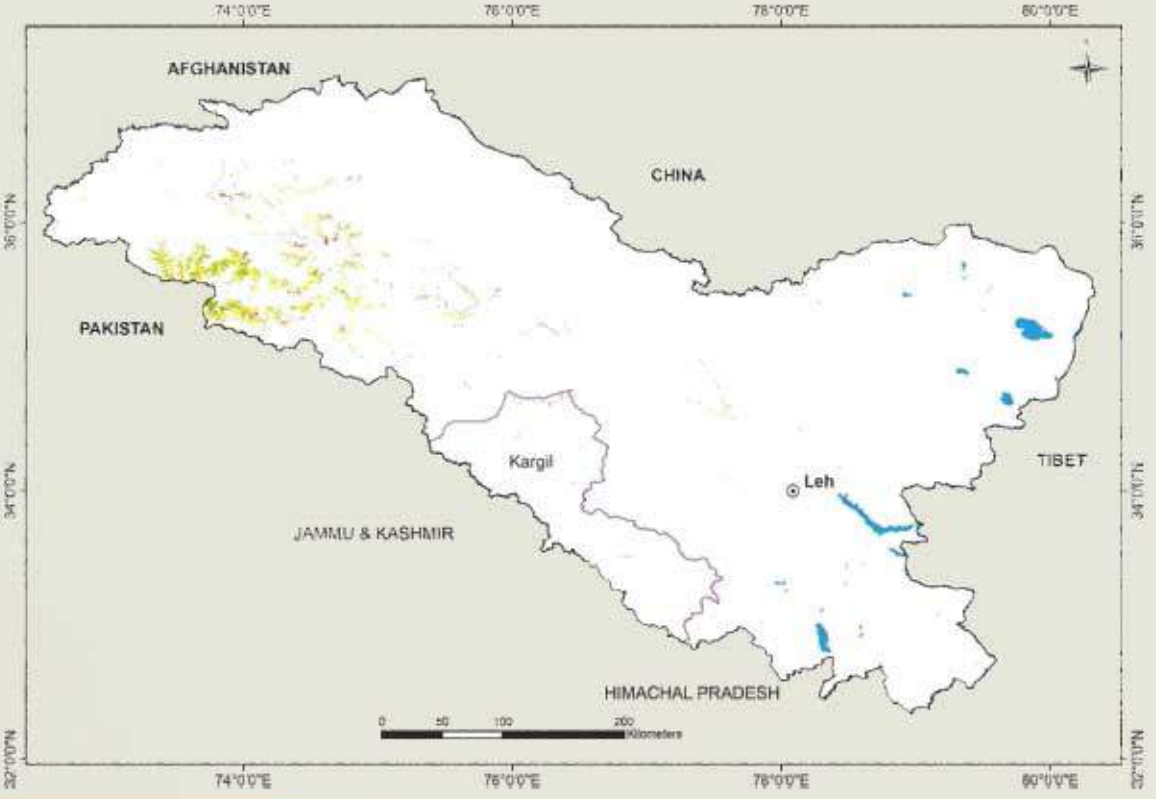
(based on SRTM, Digital Elevation Model, 30 m, 2016)
 # Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited

Table 13.34.7 Forest Cover in different slope classes in Ladakh (In sq km)

Slope (in degrees)	Shapefile Area#	VDF	MDF	OF	Total	Scrub
0-5	27,071	0	18	182	200	28
5-10	18,422	0	18	130	148	21
10-15	18,721	0	32	147	179	27
15-20	20,645	1	57	203	261	35
20-25	21,440	0	77	250	327	41
25-30	20,664	0	86	272	358	42
>30	41,092	1	224	574	799	85
Total	**1,68,055**	**2**	**512**	**1,758**	**2,272**	**279**

(based on SRTM, Digital Elevation Model, 30 m, 2016)
 # Area of shape file provided by Survey of India (August, 2021). Notified geographical area from SoI awaited

Figure 13.34.3 Forest Cover Map of Ladakh



LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.34.2 Forest Types

The area under different forest types of Ladakh as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.34.8 Area statistics of the Forest Types found in Ladakh (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	12/C1c Moist deodar forest (*Cedrus*)	3.11	0.10
2.	12/C1d Western mixed coniferous forest (spruce, blue pine, silver fir)	109.98	3.43
3.	12/C1f Low-level blue pine forest (*P. wallichiana*)	1.69	0.05
4.	12/C1/DS1 Oak scrub	0.10	0.00
5.	12/C1/DS2 Himalayan temperate secondary scrub	26.08	0.81
6.	13/C1 Dry broadleaved and coniferous forest (*Q. ilex- P. gerardiana*)	230.44	7.20

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(In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
7.	13/C2b Dry deodar forest (*Cedrus*)	2.86	0.09
8.	13/C2/DS2 Dry temperate scrub	4.02	0.13
9.	13/C4 West Himalayan high level dry blue pine forest (*P. wallichiana*)	32.21	1.01
10.	13/152 *Populus / Salix* forest	187.39	5.85
11.	14/C1a West Himalayan sub-alpine fir forest	716.97	22.39
12.	14/C1b West Himalayan sub-alpine birch/fir forest	16.62	0.52
13.	14/2S1 Sub-alpine blue pine forest (*P. wallichiana*)	168.81	5.27
14.	15/C1 Birch / *Rhododendron* scrub forest	12.28	0.38
15.	15/C2 Deciduous alpine scrub	17.65	0.55
16.	16/C1 Dry alpine scrub	543.97	16.98
17.	16/E1 Dwarf juniper scrub	670.15	20.92
	Sub Total	**2,744.33**	**85.68**
18.	TOF/Plantation	42.96	1.34
	Total (Forest Cover & Scrub)	**2,787.29**	
	Grassland forest types (outside forest cover)		
19.	14/DS1 Sub-alpine pastures	231.40	7.23
20.	15/C3 Alpine pastures	184.03	5.75
	Sub Total	**415.43**	**12.98**
	Grand Total	**3,202.72**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019).Grassland forest type outside forest cover has also been mapped. The total mapped area, therefore, is sum of forest cover, scrub and grassland forest types (found in non-forest).*

13.34.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.34.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	0.00	0.00
5.	Less fire prone	2,272.00	100.00
	Total	**2,272.00**	**100.00**

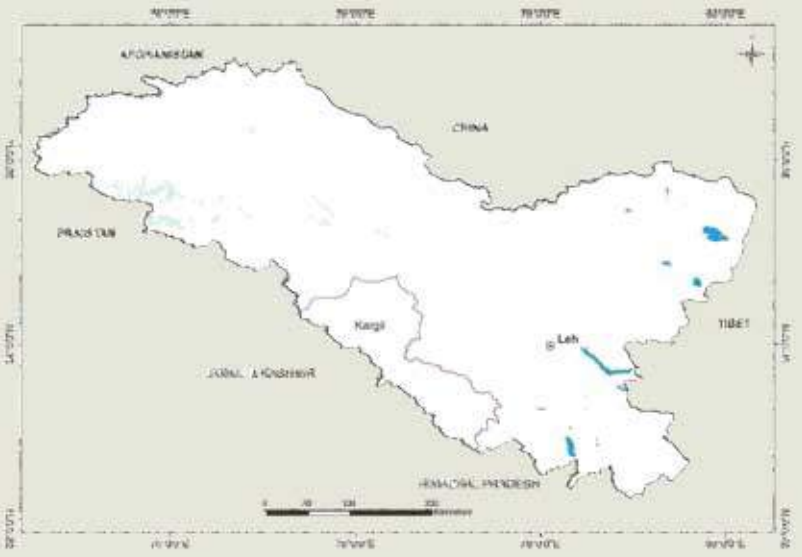

Figure 13.34.4 Fire prone forest areas under different fire prone classes

13.34.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Ladakh has been estimated as given in following table.

Table 13.34.10 Tree Cover in Ladakh (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
-	954	-

13.34.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.34.11 Extent of TOF in Ladakh (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
1,472	954	2,426

13.34.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Ladakh is given in the Table 13.34.12.

Table 13.34.12 Growing Stock in Ladakh (In m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	-	0.18	-	-
2.	Growing Stock in TOF	-	35.01	-	1.97

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13.34.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Ladakh in Rural and Urban areas are given in the Table 13.34.13 and Table 13.34.14 respectively.

Table 13.34.13 Top five tree species in TOF (Rural) in Ladakh

Sl. No.	Species	Relative Abundance (%)
1.	*Salix* spp.	62.48
2.	*Populus* spp.	28.30
3.	*Prunus* spp.	3.85
4.	*Salix tetrasperma*	2.79
5.	*Salix alba*	1.78

Table 13.34.14 Top five tree species in TOF (Urban) in Ladakh

Sl. No.	Species	Relative Abundance (%)
1.	*Populus* spp.	46.17
2.	*Salix* spp.	32.05
3.	*Salix alba*	10.53
4.	*Salix tetrasperma*	7.07
5.	*Pyrus* spp.	1.89

13.34.8 Carbon Stock in Forest

The total Carbon stock of forest in the UT including the TOF patches which are more than 1ha in size is 30.70 million tonnes (112.57 million tonnes of CO_2 equivalent) which is 0.43 % of total forest carbon of the country. Pool wise forest carbon in Ladakh is given in the following table.

Table 13.34.15 Forest Carbon in Ladakh in different pools (In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	13,293
2.	BGB	3,836
3.	Dead wood	269
4.	Litter	317
5.	SOC	12,987
	Total	**30,702**

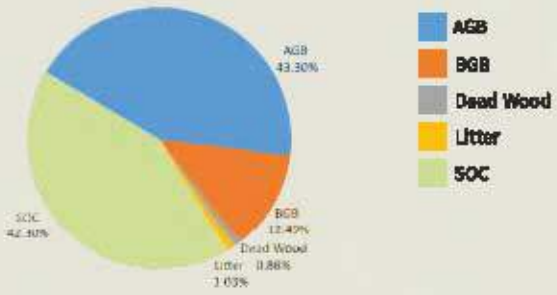


Figure 13.34.5 Forest Carbon in Ladakh

13.35
LAKSHADWEEP

Geographical Area
30 sq km

Geographical Coordinates
Latitude - 08° 15' N to 11°45' N
Longitude - 72° E to 74° E

Population (as per Census 2011)
0.064 million
Urban 0.050 million (78.07 %)
Rural 0.014 million (21.93 %)
Tribal 0.061 million (94.80%)

Average Population Density
2,015 per sq km

Livestock population
(as per 19th Live Stock Census)
0.049 million

No. of Districts
1

No. of Hill Districts
0

No. of Tribal Districts
1

Table 13.35.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	3	
Reporting area for land utilization	3	100.00
Forests	-	-
Not available for land cultivation	1	33.33
Permanent pastures and other grazing lands	-	-
Land under misc. tree crops and groves	-	-
Culturable wasteland	-	-
Fallow land other than current fallows	-	-
Current fallows	-	-
Net area sown	2	66.67

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.35.1 Forest Cover

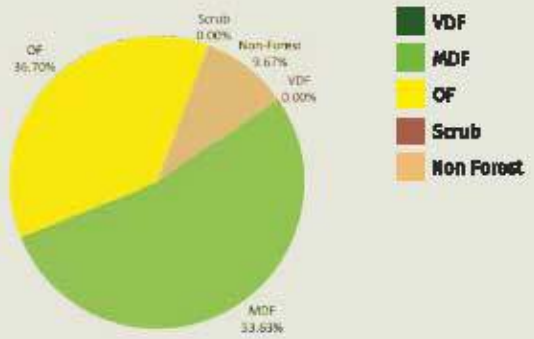


Figure 13.35.1
Forest Cover of Lakshadweep

Table 13.35.2 Forest Cover of Lakshadweep (In sq km)

Class	Area	% of GA
VDF	0.00	0.00
MDF	16.09	53.63
OF	11.01	36.70
Total	**27.10**	**90.33**
Scrub	0.00	0.00

Table 13.35.3 District- wise Forest Cover in Lakshadweep (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Lakshadweep[7]	30	0.00	16.09	11.01	27.10	90.33	0.00	0.00
Grand total	**30**	**0.00**	**16.09**	**11.01**	**27.10**	**90.33**	**0.00**	**0.00**

13.35.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.35.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Lakshadweep (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
0.00	0.00	0.00	0.00	0.00	16.09	11.01	27.10
0.00	0.00	0.00		0.00	59.37%	40.63%	

There are no Green Wash / Recorded Forest Areas in Lakshadweep (vide official letter no. F. no. 22/1/2020-E & F (Part/583)

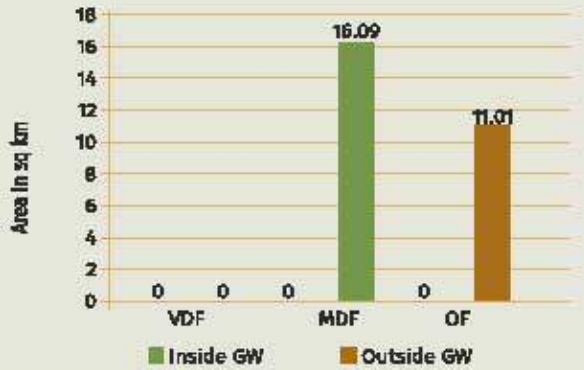


Figure 13.35.2
Forest Cover Outside of Green Wash in Lakshadweep

LAKSHADWEEP

Table 13.35.5 Forest Cover Change Matrix for Lakshadweep (In sq km)

Class	2021 Assessment					Total ISFR 2019
	VDF	MDF	OF	Scrub	NF	
Very Dense Forest	0.00	0.00	0.00	0.00	0.00	0.00
Moderately Dense Forest	0.00	16.09	0.00	0.00	0.00	16.09
Open Forest	0.00	0.00	11.01	0.00	0.00	11.01
Scrub	0.00	0.00	0.00	0.00	0.00	0.00
Non Forest	0.00	0.00	0.00	0.00	2.90	2.90
Total ISFR 2021	**0.00**	**16.09**	**11.01**	**0.00**	**2.90**	**30.00**
Net Change	0.00	0.00	0.00	0.00	0.00	

Table 13.35.6 Altitude-wise Forest Cover in Lakshadweep (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	30	0.00	16.09	11.01	27.10	0.00
Total	**30**	**0.00**	**16.09**	**11.01**	**27.10**	**0.00**

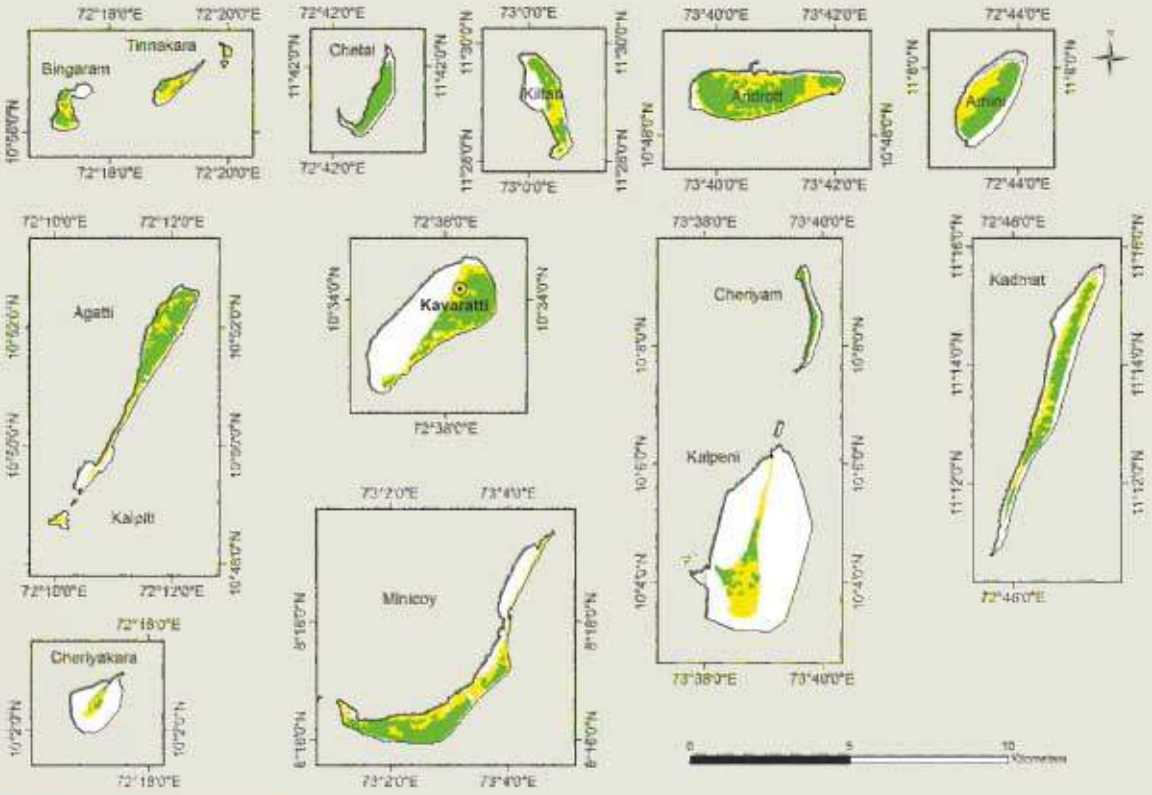
(based on SRTM, Digital Elevation Model, 30 m, 2015)

Table 13.35.7 Forest Cover in different slope classes in Lakshadweep (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	30	0.00	16.09	11.01	27.10	0.00
Total	**30**	**0.00**	**16.09**	**11.01**	**27.10**	**0.00**

(based on SRTM, Digital Elevation Model, 30 m, 2015)

Figure 13.35.3 Forest Cover Map of Lakshadweep



13.35.2 Forest Types

The area under different forest types of Lakshadweep as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.35.8 Area statistics of the Forest Types found in Lakshadweep (in sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	TOF/ Plantation	27.10	100.00
	Total	**27.10**	**100.00**

**Forest Types includes area under forest cover and scrub shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

13.35.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

LAKSHADWEEP

Table 13.35.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	0.00	0.00
5	Less fire prone	27.10	100.00
	Total	**27.10**	**100.00**

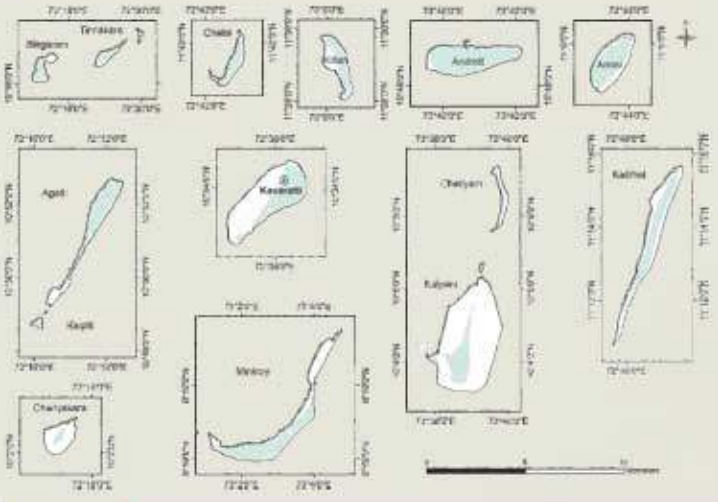


Figure 13.35.A Fire prone forest areas under different fire prone classes

13.35.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Lakshadweep has been estimated as given in following table.

Table 13.35.10 Tree Cover in Lakshadweep (In sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
0.29	0.05	-0.24

13.35.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.35.11 Extent of TOF in Lakshadweep (In sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
27	0.05	27

13.35.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Lakshadweep is given in the Table 13.35.12.

Table 13.35.12 Growing Stock in Lakshadweep (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	0.00	0.00	0.00	0.00
2.	Growing Stock in TOF	0.07	0.05	-0.02	0.00

13.35.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Lakshadweep in Rural areas are given in the Table 13.35.13.

Table 13.35.13 Top five tree species in TOF (Rural) in Lakshadweep

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	86.28
2.	*Thespesia populnea*	4.06
3.	*Artocarpus altilis*	1.19
4.	*Artocarpus hirsute*	1.13
5.	*Mallotus philippinensis*	0.60

13.35.8 Carbon Stock in Forest

The total Carbon stock of forest in the UT including the TOF patches which are more than 1ha in size is 0.21 million tonnes (0.77 million tonnes of CO_2 equivalent) which is 0.003 % of total forest carbon of the country. Pool wise forest carbon in Lakshadweep is given in the following table

Table 13.35.14 Forest Carbon in Lakshadweep in different pools (in '000 tonnes)

Sl. No.	Species	Estimated Extent
1.	AGB	46
2.	BGB	10
3.	Dead wood	1
4.	Litter	3
5.	SOC	150
	Total	**210**

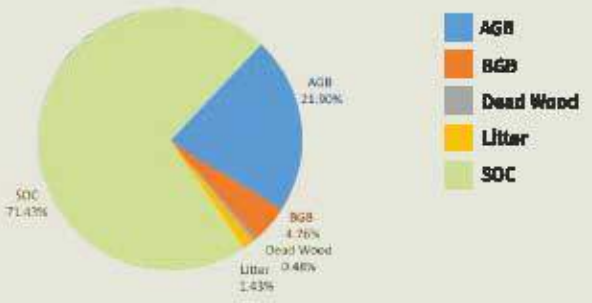


Figure 13.35.5 Forest Carbon in Lakshadweep

13.36
PUDUCHERRY

Geographical Area
480 sq km

Geographical Coordinates
Latitude- 11° 45' N to 12° 30' N
Longitude- 79° 36' E to 79° 53' E

Population (as per Census 2011)
1.25 million
Urban 0.85 million (68.33 %)
Rural 0.40 million (31.37 %)
Tribal Nil

Average Population Density
2,547 per sq km

Livestock population
(as per 19th Live Stock Census)
0.12 million

No. of Districts
4

No. of Hill Districts
0

No. of Tribal Districts
0

Table 13.36.1 Land Use Pattern

Land Use Types	Area (in '000 ha)	Percentage
Geographical Area	48	
Reporting area for land utilization	49	100.00
Forests	0	0.00
Not available for land cultivation	20	40.82
Permanent pastures and other grazing lands	-	-
Land under misc. tree crops and groves	1	2.04
Culturable wasteland	5	10.21
Fallow land other than current fallows	4	8.16
Current fallows	4	8.16
Net area sown	15	30.61

Source: Land Use Statistics, Ministry of Agriculture, GOI, (2017-18)

13.36.1 Forest Cover

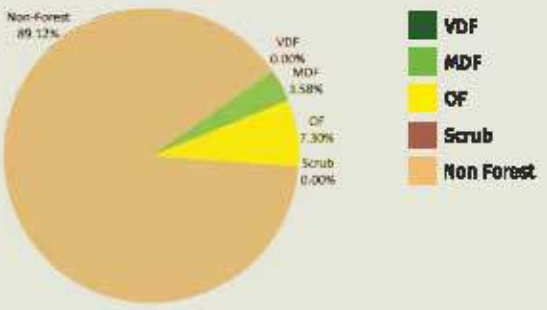


Figure 13.36.1
Forest Cover of Puducherry

Table 13.36.2 Forest Cover of Puducherry (In sq km)

Class	Area	% of GA
VDF	0.00	0.00
MDF	17.53	3.58
OF	35.77	7.30
Total	**53.30**	**10.88**
Scrub	0.00	0.00

Table 13.36.3 District- wise Forest Cover in Puducherry (In sq km)

District	Geo-graphical Area (GA)	2021 Assessment				%of GA	Change wrt 2019 assess-ment	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Karaikal	157	0.00	6.83	10.06	16.89	10.76	1.72	0.00
Mahe	9	0.00	1.04	4.54	5.58	62.00	-0.09	0.00
Puducherry	294	0.00	9.66	14.72	24.38	8.29	-0.74	0.00
Yanam	30	0.00	0.00	6.45	6.45	21.5	0.00	0.00
Grand Total	**490**	**0.00**	**17.53**	**35.77**	**53.30**	**10.88**	**0.89**	**0.00**

13.36.1.1 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash)

The Forest Cover Inside and outside Recorded Forest Area (RFA) has been analysed in different categories and presented in Table given below.

Table 13.36.4 Forest Cover Inside and Outside Recorded Forest Area (or Green Wash) in Puducherry (In sq km)

Forest Cover Inside the Recorded Forest Area (or Green Wash)				Forest Cover Outside the Recorded Forest Area (or Green Wash)			
VDF	MDF	OF	Total	VDF	MDF	OF	Total
0.00	0.00	1.00	1.00	0.00	17.53	34.77	52.30
0%	0%	100%		0%	33.52%	66.48%	

**In case of Puducherry, Green Wash boundaries have been used*

PUDUCHERRY

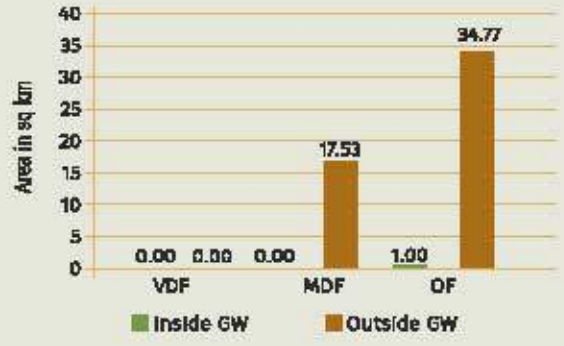


Figure 13.36.2
Forest Cover Inside and Outside of Green Wash in Puducherry

Table 13.36.5 Forest Cover Change Matrix for Puducherry (In sq km)

Class	2021 Assessment					Total
	VDF	MDF	OF	Scrub	NF	ISFR 2019
Very Dense Forest	0	0.00	0.00	0.00	0.00	0.00
Moderately Dense Forest	0	17.53	0.00	0.00	0.13	17.66
Open Forest	0	0.00	33.88	0.00	0.87	34.75
Scrub	0	0.00	0.00	0.00	0.00	0.00
Non Forest	0	0.00	1.89	0.00	435.70	437.59
Total ISFR 2021	**0**	**17.53**	**35.77**	**0.00**	**436.70**	**490.00**
Net Change	0	-0.13	1.02	0.00	-0.89	

Table 13.36.6 Altitude-wise Forest Cover in Puducherry (In sq km)

Altitude Zone (m)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-500	490	0.00	17.53	35.77	53.30	0.00
Total	**490**	**0.00**	**17.53**	**35.77**	**53.30**	**0.00**

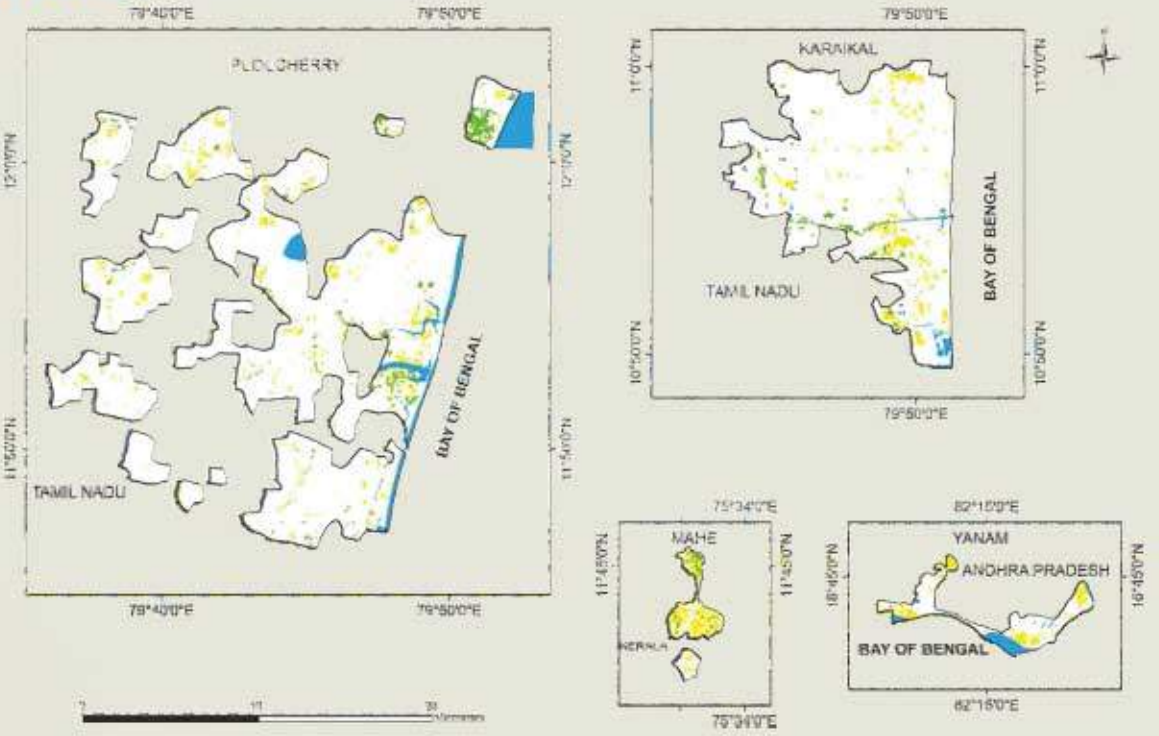
(based on SRTM, Digital Elevation Model, 30 m, 2016)

Table 13.36.7 Forest Cover in different slope classes in Puducherry (In sq km)

Slope (in degrees)	Geographical Area	VDF	MDF	OF	Total	Scrub
0-5	449	0.00	17.14	35.04	52.18	0.00
5-10	41	0.00	0.39	0.73	1.12	0.00
Total	**490**	**0.00**	**17.53**	**35.77**	**53.30**	**0.00**

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

Figure 13.36.3 Forest Cover Map of Puducherry



LEGEND
- Very Dense Forest
- Moderately Dense Forest
- Open Forest
- Scrub
- Non-Forest
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.36.2 Forest Types

The area under different forest types of Puducherry as per the Champion & Seth classification (1968), according to the Atlas Forest Types of India 2020 are presented in the following Table.

Table 13.36.8 Area statistics of the Forest Types found in Puducherry (In sq km)

Sl. No.	Forest Type	Area	% of the total mapped area*
1.	4B/TS2 Mangrove forest	1.64	3.13
2.	TOF/Plantation	50.77	96.87
	Total	**52.41**	**100.00**

**Forest Types have been assigned to the natural forest formations under forest cover and scrub categories shown in forest cover mapping (ISFR, 2019). The total mapped area, therefore, is sum of forest cover and scrub.*

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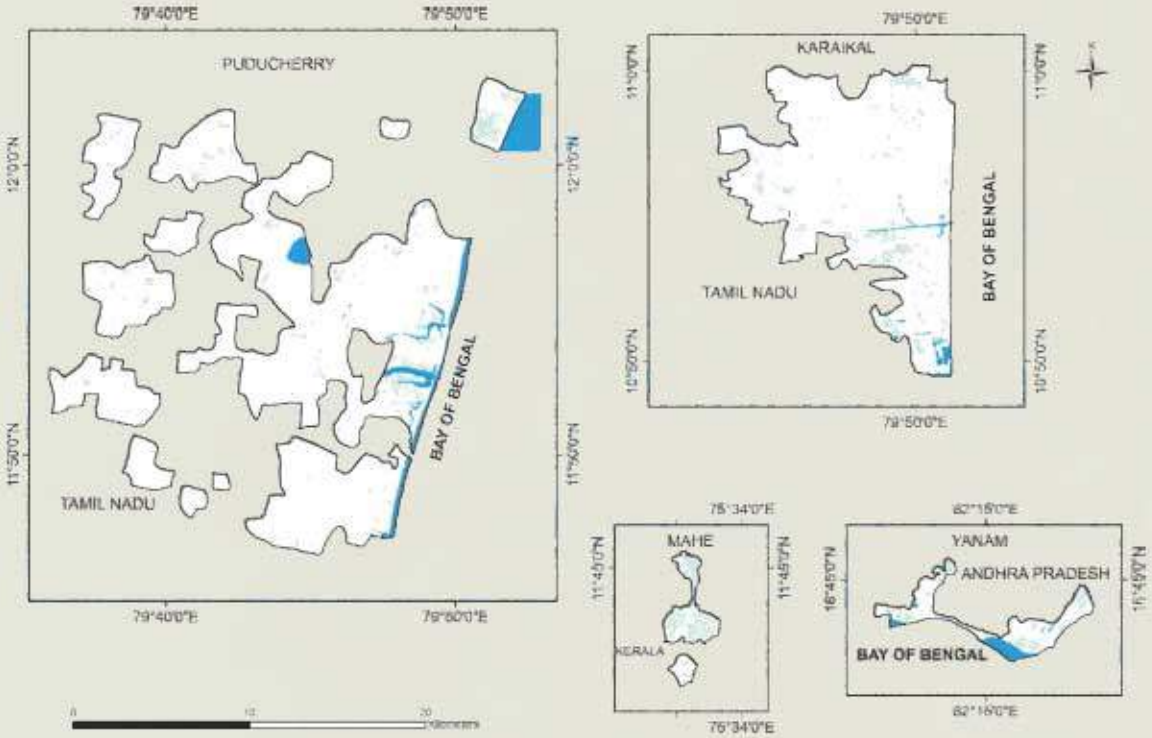
13.36.3 Fire Prone Forest Areas

Forest Cover under different classes of forest fire proneness is given in following table.

Table 13.36.9 Forest Fire Prone Classes (In sq km)

Sl. No.	Forest Fire Prone Classes	Forest Cover	% of Total Forest Cover
1.	Extremely fire prone	0.00	0.00
2.	Very highly fire prone	0.00	0.00
3.	Highly fire prone	0.00	0.00
4.	Moderately fire prone	0.00	0.00
5.	Less fire prone	53.30	100.00
	Total	**53.30**	**100.00**

Figure 13.36.4 Fire prone forest areas under different fire prone classes



LEGEND
- Extremely Fire Prone
- Very Highly Fire Prone
- Highly Fire Prone
- Moderately Fire Prone
- Less Fire Prone
- Water-bodies
- International Boundary
- State Boundary
- District Boundary
- Capital

13.36.4 Tree Cover

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. Tree cover in Puducherry has been estimated as given in following table.

Table 13.36.10 Tree Cover in Puducherry (in sq km)

2019 Assessment	2021 Assessment	Change wrt 2019 Assessment
23	23	0

13.36.5 Extent of Trees Outside Forest (TOF)

Trees outside Forests (TOF) refer to tree resources found outside the forests as defined in the Government records. Forest Cover outside the recorded forest area is derived using boundaries of RFA or Green Wash. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the recorded forest areas (RFA) and tree cover as given in following table.

Table 13.36.11 Extent of TOF in Puducherry (in sq km)

Forest Cover outside the RFA/GW	Tree Cover	Extent of TOF
52	23	75

13.36.6 Growing Stock in Forest

Growing stock in the recorded forest areas (RFA) in Puducherry is given in the Table 13.36.12. Diameter class-wise distribution of top 5 species in numbers derived from the forest inventory data is presented in the table 13.36.13

Table 13.36.12 Growing Stock in Puducherry (in m cum)

Sl. No.	Growing Stock (GS)	2019 Assessment	2021 Assessment	Change wrt 2019 Assessment	% of Country's GS
1.	Growing Stock in Recorded Forest Area	0.05	0.03	-0.02	0.00
2.	Growing Stock in TOF	0.40	0.38	-0.02	0.02

Table 13.36.13 Diameter class distribution of tree species inside RFA in Puducherry (in '000)

			Dia class (cm)	
Sl. No.	Species	10-30	30-60	>60
1.	*Rhizophora mucronata*	33	23	0

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13.36.7 Dominant tree species in Trees Outside Forests (TOF)

Top five species in numbers in Trees Outside Forests in Puducherry in Rural and Urban areas are given in the Table 13.36.14 and Table 13.36.15 respectively.

Table 13.36.14 Top five tree species in TOF (Rural) in Puducherry

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	28.69
2.	*Azadirachta indica*	9.89
3.	*Borassus flabelliformis*	8.93
4.	*Casuarina equisetifolia*	6.65
5.	*Eucalyptus* spp.	5.75

Table 13.36.15 Top five tree species in TOF (Urban) in Puducherry

Sl. No.	Species	Relative Abundance (%)
1.	*Cocos nucifera*	29.03
2.	*Azadirachta indica*	14.92
3.	*Moringa oleifera*	13.01
4.	*Mangifera indica*	6.39
5.	*Pongamia pinnata*	6.32

13.36.8 Carbon Stock in Forest in Puducherry

The total Carbon stock of forest in the UT including the TOF patches which are more than 1ha in size is 0.39 million tonnes (1.43 million tonnes of CO_2 equivalent) which is 0.01 % of total forest carbon of the country. Pool wise forest carbon in Puducherry is given in the following table

Table 13.36.16 Forest Carbon in Puducherry in different pools

(In '000 tonnes)

Sl. No.	Carbon Pools	Forest Carbon
1.	AGB	76
2.	BGB	17
3.	Dead wood	1
4.	Litter	5
5.	SOC	287
	Total	**386**

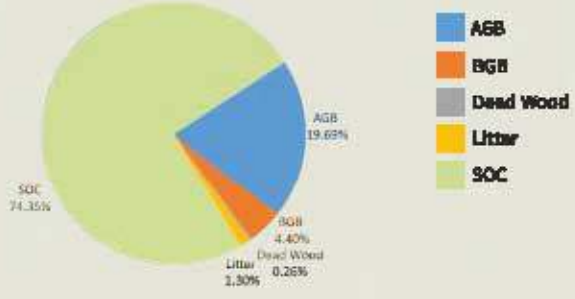

Figure 13.36.5 Forest Carbon in Puducherry

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ANNEXURE-I

Sl. No.	Name of the State/UT	Period of FCC/data used for ISFR-2021	
		From	To
1	Andhra Pradesh	November-2019	May-2020
2	Arunachal Pradesh	November-2019	April-2020
3	Assam	March-2019	September-2020
4	Bihar	November-2019	
5	Chhattisgarh	November-2019	February-2020
6	Delhi	March-2020	
7	Goa	November-2019	
8	Gujarat	October-2019	January-2020
9	Haryana	October-2019	March-2020
10	Himachal Pradesh	September-2019	December-2019
11	Jharkhand	November-2019	January-2020
12	Karnataka	November-2019	January-2020
13	Kerala	November-2019	January-2020
14	Madhya Pradesh	October-2019	January-2020
15	Maharashtra	November-2019	February-2020
16	Manipur	December-2019	March-2020
17	Meghalaya	November-2019	April-2020
18	Mizoram	November-2019	January-2020
19	Nagaland	December-2019	March-2020
20	Odisha	November-2019	January-2020
21	Punjab	October-2019	December-2019
22	Rajasthan	October-2019	January-2020
23	Sikkim	November-2019	April-2020
24	Tamil Nadu	January-2020	November-2020
25	Telangana	November-2019	April-2020
26	Tripura	November-2019	May-2020
27	Uttar Pradesh	October-2019	January-2020
28	Uttarakhand	October-2019	November-2019
29	West Bengal	November-2019	January-2020
30	A & N Islands	March-2020	April-2020
31	Chandigarh	March-2020	
32	Dadra & Nagar Haveli and Daman & Diu	November-2019	
33	Jammu & Kashmir	September-2019	May-2020
34	Ladakh	September-2019	May-2020
35	Lakshadweep	December-2019	October-2020
36	Puducherry	January-2020	October-2020

ANNEXURE-II

Volume equations to compute volume of wood in predominate trees in each State/UT are provided in the following tables:

ANDHRA PRADESH

Sl. No.	Species Name	Volume Equation
1	*Albizzia amara*	V=(0.13817-2.16947*D+11.4087*D2+1.11636*D3)
2	*Anogeissus latifolia*	V=(0.034725-0.78412*D+7.1873*D2+6.9495*D3)
3	*Dalbergia paniculata*	√V=(-0.144504+2.943115*D)
4	*Ficus species*	V=(0.088074-1.449236*D+8.760534*D2)
5	*Hardwickia binata*	V=(0.025091-0.185618*D+3.561089*D2+10.80139*D3)
6	*Lannea coromandelica*	V=(0.057424-1.153088*D+8.542648*D2)
7	*Pterocarpus marsupium*	V=(0.058424-1.233468*D+9.433633*D2)
8	*Tamarindus indica*	V=(0.088074-1.449236*D+8.760534*D2)
9	*Terminalia crenulata*	V=(0.05061-1.11994*D+8.77839*D2)
10	*Xylia xylocarpa*	V=(0.098-1.52*D+8.963*D2)

ARUNACHAL PRADESH

Sl. No.	Species Name	Volume Equation
1	*Bischofia javanica*	V=(0.00978-0.21005*D+5.62160*D2)
2	*Bombax ceiba*	V=(0.00978-0.21005*D+5.62160*D2)
3	*Castanopsis indica*	V=(0.05331-0.87098*D+6.52533*D2+1.74231*D3)
4	*Castanopsis species*	V=(0.05331-0.87098*D+6.52533*D2+1.74231*D3)
5	*Duabanga grandiflora*	√V=(0.13199+3.35856*D-0.79250*?D)
6	*Gmelina arborea*	V=0.01156+0.21230*D+5.10448*D2)
7	*Pinus roxburghii*	√V=(0.291801+6.041763*D-2.430993*?D)
8	*Pterospermum acerifolium*	V=(0.00978-0.21005*D+5.62160*D2)
9	*Sterculia villosa*	√V=(0.35895+4.99513*D-2.14135*?D)
10	*Terminalia myriocarpa*	V=(-0.096981+10.65*D2)

ASSAM

Sl. No.	Species Name	Volume Equation
1	*Albizia species*	√V=(-0.07109+2.99732*D-0.26953*?D)
2	*Bauhinia retusa*	V=(-0.04262+6.09491*D2)
3	*Bombax ceiba*	V=(0.04507-0.93461*D+5.48513*D2+9.16037*D3)
4	*Gmelina arborea*	V=(0.1156+0.21230*D+5.10448*D2)
5	*Lannea coromandelica*	√V=(-0.32985+2.21152*D+0.78769*?D)
6	*Schima wallichii*	√V=(0.28069+4.61980*D-1.65381*?D)
7	*Shorea robusta*	√V=(-0.22388+3.29474*D)
8	*Stereospermum personatum*	√V=(0.49746+5.98454*D-2.84986*?D)
9	*Tectona grandis*	√V=(-0.405890+1.98158*D+0.987373*?D)
10	*Terminalia bellirica*	√V=(-0.14325+3.07937*D)

BIHAR

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia*	√V=(-0.07738+2.592167*D)
2	*Boswellia serrata*	V=(0.03356-1.124*D+10.306*D2)
3	*Butea monosperma*	V=(0.136196-2.07674*D+10.1566*D2)
4	*Ficus racemosa*	V=(0.05396-0.82031*D+6.17975*D2)
5	*Ficus religiosa*	V=(0.05396-0.82031*D+6.17975*D2)
6	*Lannea coromandelica*	√V=(-0.32985+2.21152*D+0.78769*?D)
7	*Madhuca latifolia*	V=(-0.00092-0.55547*D+7.3446*D2)
8	*Mallotus philippinensis*	V=(0.14749-2.87503*D+19.61977*D2-19.11630*D3)
9	*Shorea robusta*	V=(0.1563-2.45104*D+11.90581*D2)
10	*Terminalia crenulata*	V=(0.08565-1.51685*D+10.24871*D2)

CHHATTISGARH

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia*	V=(-0.02958+8.05003*D2)
2	*Boswellia serrata*	V=(0.044621-1.25694*D+10.86801*D2-3.009085*D3)
3	*Cleistanthus collinus*	V=(-0.03915+0.16295*D+4.09182*D2)
4	*Diospyros melanoxylon*	V=(0.12401-2.00966*D+10.87747*D2)
5	*Lagerstroemia parviflora*	V=(0.0568-1.19611*D+9.11319*D2)
6	*Lannea coromandelica*	√V=(-0.11751+2.86874*D)
7	*Madhuca latifolia*	V=(-0.00092-0.55547*D+7.3446*D2)
8	*Pterocarpus marsupium*	V=(-0.04659+8.06901*D2)
9	*Shorea robusta*	V=(0.17279-2.54241*D+13.08048*D2-3.49087*D3)
10	*Terminalia crenulata*	V=(0.00376-0.77604*D+8.35533*D2)

DELHI

Sl. No.	Species Name	Volume Equation
1	*Acacia arabica*	V=(0.16609-2.78851*D+17.22127*D2-11.60248*D3)
2	*Acacia catechu*	V=(0.16609-2.78851*D+17.22127*D2-11.60248*D3)
3	*Acacia leucophloea*	√V=(-0.00142+2.61911*D-0.54703*?D)
4	*Azadirachta indica*	V=(-0.03510+5.32981*D2)
5	*Cassia fistula*	V=(0.05159-0.53331*D+3.46015*D2+10.18473*D3)
6	*Ehretia laevis*	V=(-0.03844+0.946490*D-5.40987*D2+33.17338*D3)
7	*Ficus virens*	√V=(0.03629+3.95389*D-0.84421*?D)
8	*Holoptelea integrifolia*	√V=(0.21569+4.329878*D-1.504977*?D)
9	*Leucaena leucocephala*	V=(0.081467-1.063661*D+6.452918*D2)
10	*Prosopis juliflora*	V=(0.081467-1.063661*D+6.452918*D2)

GOA

Sl. No.	Species Name	Volume Equation
1	*Anacardium occidentale*	V=(4.5899*D2-0.422*D+0.0148)
2	*Careya arborea*	√V=(-0.23738+2.33289*D+0.48512*?D)
3	*Dillenia pentagyna*	V=(0.070-1.295*D+9.429*D2)
4	*Lagerstroemia lanceolata*	√V=(-0.13034+2.824203*D)
5	*Lannea coromandelica*	√V=(0.404153+5.555051*D-2.545525*?D)
6	*Schleichera trijuga*	V=(0.01-0.912*D+11.396*D2)
7	*Syzygium cumini*	√V=(0.30706+5.12731*D-2.0987*?D)
8	*Terminalia crenulata*	√V=(-0.203947+3.159215*D)
9	*Terminalia paniculata*	V=(0.131-1.87132*D+9.47861*D2)
10	*Xylia xylocarpa*	V=(0.007602-0.033037*D+1.868567*D2+4.483454*D3)

GUJARAT

Sl. No.	Species Name	Volume Equation
1	*Adina cordifolia*	√V=(0.21569+4.329878*D-1.504977*?D)
2	*Anogeissus latifolia*	V=(0.030502-1.105937*D+12.261268*D2)
3	*Butea monosperma*	V=(-0.032-0.0619*D+7.208*D2)
4	*Diospyros melanoxylon*	V=(0.033867-0.975148*D+8.255412*D2)
5	*Lannea coromandelica*	√V=(0.404153+5.555051*D-2.545525*?D)
6	*Madhuca latifolia*	V=(0.074069-1.230020*D+7.726902*D2)
7	*Mitragyna parviflora*	V=(0.099768-1.744274*D+10.086934*D2)
8	*Tectona grandis*	V=(0.032011-0.995414*D+9.91129*D2)
9	*Terminalia crenulata*	V=(0.060344-1.569539*D+12.090296*D2)
10	*Wrightia tinctoria*	√V=(0.050294+3.115497*D-0.687813*?D)

HARYANA

Sl. No.	Species Name	Volume Equation
1	*Acacia arabica*	V=(0.16609-2.78851*D+17.22127*D2-11.60248*D3)
2	*Acacia catechu*	V=(0.02384-0.72161*D+7.46888*D2)
3	*Acacia tortilis*	V=(0.16609-2.78851*D+17.22127*D2-11.60248*D3)
4	*Anogeissus latifolia*	√V= (0.2122+4.947663*D-1.5929*?D)
5	*Dalbergia sissoo*	V=(0.00331+0.000636*D2*10000)
6	*Eucalyptus species*	V=(0.02894-0.89284*D+8.72416*D2)
7	*Lannea coromandelica*	V=(0.14004-2.3599*D+11.90726*D2)
8	*Phoenix sylvestris*	V=(0.0239-0.6266*D+5.4067*D2)
9	*Prosopis juliflora*	V=(0.17553-0.71434*?D+7.94663*D2)
10	*Syzygium cumini*	V=(0.08481-1.81774*D+12.63047*D2-6.69555*D3)

HIMACHAL PRADESH

SL No.	Species Name	Volume Equation
1	*Abies denso*	√V=(-0.084305+3.060072*D)
2	*Abies pindrow*	V=(7.92*D2+0.244*D-0.061)
3	*Abies smithiana*	V=(0.163269-2.232068*D+11.770869*D2+1.06041*D3)
4	*Cedrus deodara*	V=(10.03982*D2-1.28303*D+0.07367)
5	*Pinus excelso*	V=(10.44*D2-0.851*D+0.020)
6	*Pinus roxburghii*	√V=(0.05131+3.9859*D-1.0245*?D)
7	*Quercus leucotrichophora*	V=(0.0988-1.5547*D+10.1631*D2)
8	*Quercus semecarpifolia*	V=(0.098800-1.55471*D+10.16317*D2)
9	*Rhododendron arboreum*	√V=(0.306492+4.31536*D-1.749908*?D)
10	*Shorea robusta*	√V=(0.16306+4.8991*D-1.57402*?D)

JHARKHAND

SL No.	Species Name	Volume Equation
1	*Anogeissus latifolia*	√V=(-0.07738+2.592167*D)
2	*Boswellia serrata*	V=(0.03356-1.124*D+10.306*D2)
3	*Buchanania latifolia*	V=(0.031-0.64087*D+6.04066*D2)
4	*Butea monosperma*	V=(0.0417-0.47789*D+3.50714*D2+9.76048*D3)
5	*Diospyros melanoxylon*	V=(0.12401-2.00966*D+10.87747*D2)
6	*Lannea coromandelica*	√V=(-0.11751+2.86874*D)
7	*Madhuca latifolia*	V=(-0.00092-0.55547*D+7.3446*D2)
8	*Schleichera trijuga*	V=(0.010-0.912*D+11.396*D2)
9	*Shorea robusta*	V=(0.022585-0.70158*D+8.714*D2)
10	*Terminalia crenulata*	V=(0.08565-1.51685*D+10.24871*D2)

KARNATAKA

SL No.	Species Name	Volume Equation
1	*Anogeissus latifolia*	V=(0.030502-1.105937*D+12.261268*D2)
2	*Careya arborea*	√V=(0.23738+2.33289*D+0.48512*?D)
3	*Lagerstroemia lanceolata*	V=(0.066188-1.334512*D+9.403257*D2)
4	*Olea dioica*	V=(-0.03001+5.75523*D2)
5	*Poeciloneuron indicum*	√V=(-0.153973+2.724109*D)
6	*Syzygium cumini*	√V=(0.30706+5.12731*D-2.0987*?D)
7	*Tectona grandis*	√V=(-0.40589+1.98158*D+0.987373*?D)
8	*Terminalia crenulata*	√V=(-0.203947+3.159215*D)
9	*Terminalia paniculata*	V=(0.131-1.87132*D+9.47861*D2)
10	*Xylia xylocarpa*	√V=(0.01631+2.20921*D)

KERALA

Sl. No.	Species Name	Volume Equation
1	*Artocarpus hirsute*	V=(0.076-1.319*D+11.37*D2)
2	*Diospyros species*	√V=(-0.184139+2.892723*D)
3	*Lagerstroemia lanceolata*	V=(-0.06183+0.411348*D+1.84813*D2+12.43582* D3-4.26661*D4)
4	*Syzygium cumini*	√V=(0.30706+5.12731*D-2.0987*?D)
5	*Tectona grandis*	√V=(-0.40589+1.98158*D+0.987373*?D)
6	*Terminalia bellirica*	√V=(-0.153973+2.724109*D)
7	*Terminalia crenulata*	√V=(-0.203947+3.159215*D)
8	*Terminalia paniculata*	V=(0.131-1.87132*D+9.47861*D2)
9	*Vateria indica*	√V=(-0.15493+3.1119*D)
10	*Xylia xylocarpa*	√V=(0.01631+2.20921*D)

MADHYA PRADESH

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia*	V=(0.145667-2.704089*D+17.4656*D2-10.4903*D3)
2	*Boswellia serrata*	V=(0.050452-1.228748*D+9.123381*D2)
3	*Butea monosperma*	V=(0.0417-0.47789*D+3.50714*D2+9.76048*D3)
4	*Diospyros melanoxylon*	V=(0.033867-0.975148*D+8.255412*D2)
5	*Lagerstroemia parviflora*	V=(0.0568-1.19611*D+9.11319*D2)
6	*Lannea coromandelica*	√V=(-0.11751+2.86874*D)
7	*Madhuca latifolia*	V=(-0.00092-0.55547*D+7.3446*D2)
8	*Shorea robusta*	√V=(0.19994+4.57179*D-1.56823*?D)
9	*Tectona grandis*	V=(-0.003673-0.379175*D+6.368282*D2)
10	*Terminalia crenulata*	V=(0.060344-1.569539*D+12.090296*D2)

MAHARASHTRA

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia*	V=(-0.061856+7.952136*D2)
2	*Boswellia serrata*	V=(0.050452-1.228748*D+9.123381*D2)
3	*Butea monosperma*	V=(0.18573-2.85418*D+15.03576*D2)
4	*Careya arborea*	√V=(0.23738+2.33289*D+0.48512*?D)
5	*Lagerstroemia parviflora*	V=(0.06466-1.371984*D+9.629971*D2)
6	*Lannea coromandelica*	V=(0.093318-1.531417*D+9.011590*D2)
7	*Madhuca latifolia*	V=(0.074069-1.230020*D+7.726902*D2)
8	*Pterocarpus marsupium*	V=(0.028252-0.833643*D+8.033788*D2)
9	*Tectona grandis*	√V=(-0.106720+2.562418*D)
10	*Terminalia crenulata*	V=(0.048532-1.05615*D+8.204564*D2)

MANIPUR

SL No.	Species Name	Volume Equation
1	*Albizia species*	√V=(-0.07109+2.99732*D-0.26953*?D)
2	*Albizia procera*	V=(0.13817-2.16947*D+11.4087*D2+1.11636*D3)
3	*Callicarpa arborea*	V=(0.11079-1.81103*D+11.4132*D2+0.38528*D3)
4	*Castanopsis species*	V=(-0.02301+0.12721*D+2.4127*D2+8.12834*D3)
5	*Duabanga grandiflora*	√V=(-0.01217+3.3993*D-0.28981*?D)
6	*Ficus species*	√V=(0.03629+3.95389*D-0.84421*?D)
7	*Gmelina arborea*	√V=(-0.00189+2.10033*D)
8	*Pinus kesiya*	V=(-0.01523+5.65779*D2)
9	*Quercus species*	V=(0.14153-2.27358*D+12.9049*D2)
10	*Schima wallichii*	√V=(0.28069+4.61980*D-1.65381*?D)

MEGHALAYA

SL No.	Species Name	Volume Equation
1	*Albizia species*	√V=(-0.07109+2.99732*D-0.26953*?D)
2	*Areca catechu*	V=(0.0239-0.6266*D+5.4067*D2)
3	*Artocarpus chaplasha*	√V=(-0.15154+2.79983*D)
4	*Artocarpus heterophyllus*	√V=(-0.15154+2.79983*D)
5	*Callicarpa arborea*	√V=(-0.04506+2.33446*D)
6	*Careya arborea*	√V=(-0.07109+2.99732*D-0.26953*?D)
7	*Gmelina arborea*	√V=(-0.00189+2.10033*D)
8	*Hevea brasiliensis*	√V=(-0.226400+2.935870*D)
9	*Pinus kesiya*	V=(-0.01523+5.65779*D2)
10	*Schima wallichii*	√V=(0.28069+4.61980*D-1.65381*?D)

MIZORAM

SL No.	Species Name	Volume Equation
1	*Albizia species*	√V=(-0.07109+2.99732*D-0.26953*?D)
2	*Callicarpa arborea*	√V=(-0.04506+2.33446*D)
3	*Castanopsis species*	V=(0.05331-0.87098*D+6.52533*D2+1.74231*D3)
4	*Cedrela toona*	√V=(-0.05514+2.67753*D)
5	*Duabanga grandiflora*	√V=(-0.01217+3.3993*D-0.28981*?D)
6	*Dysoxylum binectariferum*	V=(-0.04752+0.50667*D+1.88433*D2+11.30632*D3)
7	*Gmelina arborea*	√V=(-0.00189+2.10033*D)
8	*Macaranga species*	V=(0.13333-2.18825*D+13.12678*D2)
9	*Schima wallichii*	√V=(0.28069+4.61980*D-1.65381*?D)
10	*Tectona grandis*	V=(0.19112-3.25372*D+17.9194*D2-1.66117*D3)

NAGALAND

Sl. No.	Species Name	Volume Equation
1	*Albizia species*	√V=(-0.07109+2.99732*D-0.26953*?D)
2	*Alnus species*	V=(0.0741-1.3603*D+10.9229*D2)
3	*Artocarpus chaplasha*	√V=(-0.226400+2.935870*D)
4	*Bauhinia retusa*	√V=(-0.226400+2.935870*D)
5	*Cedrela toona*	√V=(-0.05514+2.67753*D)
6	*Erythrina species*	V=(-0.07803+1.70258*D-9.1618*D2+33.91455*D3)
7	*Ficus species*	√V=(0.03629+3.95389*D-0.84421*?D)
8	*Quercus semiserrata*	√V=(-0.226400+2.935870*D)
9	*Schima wallichii*	√V=(0.28069+4.61980*D-1.65381*?D)
10	*Sterculia villosa*	√V=(0.35895+4.99513*D-2.14135*?D)

ODISHA

Sl. No.	Species Name	Volume Equation
1	*Anogeissus latifolia*	?V=(-0.357373+2.430449*D+0.794626*?D)
2	*Diospyros melanoxylon*	V=(-0.009124-0.494103*D+7.610416*D2)
3	*Ficus bengalensis*	V=(0.020853-0.610255*D+6.108230*D2)
4	*Lannea coromandelica*	V=(0.057424-1.153088*D+8.542648*D2)
5	*Madhuca latifolia*	V=(-0.058016+0.352354*D+2.92291*D2+3.624110*D3)
6	*Mangifera indica*	V=(0.108-1.706*D+7.559*D2)
7	*Schleichera trijuga*	?V=(-0.24358+3.58273*D)
8	*Shorea robusta*	?V=(0.19994+4.57179*D-1.56823*?D)
9	*Syzygium cumini*	LogeV=2.132776+2.479397 LogeD
10	*Terminalia crenulata*	V=(0.05061-1.11994*D+8.77839*D2)

PUNJAB

Sl. No.	Species Name	Volume Equation
1	*Acacia catechu*	V=(0.16609-2.78851*D+17.22127*D2-11.60248*D3)
2	*Albizia lebbeck*	V=(-0.0367+5.87369*D2)
3	*Butea monosperma*	√V=(-0.24276+2.95525*D)
4	*Dalbergia sissoo*	V=(0.00331+6.36*D2)
5	*Eucalyptus species*	V=0.02894-0.89284*D+8.72416*D2)
6	*Grewia oppositifolia*	V=(0.05858-1.20414*D+9.80167*D2)
7	*Holoptelea integrifolia*	V=(0.17553-0.71434*?D+7.94663*D2)
8	*Lannea coromandelica*	V=(0.14004-2.3599*D+11.90726*D2)
9	*Prosopis juliflora*	V=(0.17553-0.71434*?D+7.94663*D2)
10	*Terminalia arjuna*	√V=(-0.203947+3.159215*D)

RAJASTHAN

Sl. No.	Species Name	Volume Equation
1	*Acacia catechu*	V=(0.26949-1.61804*D+8.79495*D2+2.49489*D3)
2	*Acacia lenticularis*	V=(-0.048108+5.873169*D2)
3	*Anogeissus latifolia*	V=(-0.01662+4.4268*D2)
4	*Anogeissus pendula*	V=(0.00085-0.35165*D+4.77386*D2-0.90585*D3)
5	*Boswellia serrata*	√V=(-0.11629+2.4254*D)
6	*Butea monosperma*	V=(-0.032-0.0619*D+7.208*D2)
7	*Diospyros melanoxylon*	√V=(-0.184139+2.892723*D)
8	*Lannea coramandelica*	√V=(0.404153+5.555051*D-2.545525*?D)
9	*Madhuca latifolia*	V=(0.081467-1.063661*D+6.452918*D2)
10	*Tectona grandis*	V=(0.062108-0.927983*D+6.613031*D2)

SIKKIM

Sl. No.	Species Name	Volume Equation
1	*Abies densa*	V=(0.10774-2.09529*D+12.62008*D2-1.61065*D3)
2	*Acer species*	√V=(-0.10851+3.0425*D)
3	*Alnus species*	V=(0.0741-1.3603*D+10.9229*D2)
4	*Castanopsis species*	V=(0.05331-0.87098*D+6.52533*D2+1.74231*D3)
5	*Engelhardtia spicata*	V=(0.007602-0.033037*D+1.868567*D2+4.483454*D3)
6	*Eurya japonica*	V=(-0.01097+5.30991*D2)
7	*Machilus species*	V=(4.84009*D2-0.02402)
8	*Schima wallichii*	√V=(-0.112426+2.54133*D)
9	*Shorea robusta*	√V=(-0.22388+3.29474*D)
10	*Symplocos theaefolia*	V=(-0.03754+5.87*D2)

TAMILNADU

Sl. No.	Species Name	Volume Equation
1	*Acacia Mearnsii*	V=(0.088074-1.449236*D+8.760534*D2)
2	*Albizia amara*	√V=(-0.07109+2.99732*D-0.26953*?D)
3	*Anogeissus latifolia*	V=(0.045731-1.020606*D+9.656667*D2)
4	*Commiphora ostdets*	V=(0.088074-1.449236*D+8.760534*D2)
5	*Eucalyptus globules*	√V=(-0.115412+3.12191*D)
6	*Eucalyptus species*	V=(0.02894-0.89284*D+8.72416*D2)
7	*Ficus species*	V=(0.088074-1.449236*D+8.760534*D2)
8	*Pterocarpus marsupium*	V=(0.058424-1.233468*D+9.433633*D2)
9	*Tamarindus indica*	V=(0.131-1.87132*D+9.47861*D2)
10	*Tectona grandis*	√V=(-0.405890+1.98158*D+0.987373*?D)

TELANGANA

Sl. No.	Species Name	Volume Equation
1	Anogeissus latifolia	V=(-0.061856+7.952136*D2)
2	Boswellia serrata	V=(0.028917+7.777047*D3)
3	Cleistanthus collinus	V=(0.011617-0.309699*D+4.629527*D2)
4	Dalbergia paniculata	√V=(-0.144504+2.943115*D)
5	Lagerstroemia parviflora	V=(0.066188-1.334512*D+9.403257*D2)
6	Lannea coromandelica	V=(0.091153-1.66153*D+10.24624*D2)
7	Madhuca latifolia	V=(0.046883-0.894379*D+7.220441*D2)
8	Tectona grandis	V=(0.023613-0.531006*D+6.731036*D2)
9	Terminalia crenulata	V=(0.051812-1.076790*D+7.991280*D2)
10	Xylia xylocarpa	V=(0.05823+4.597986*D3)

TRIPURA

Sl. No.	Species Name	Volume Equation
1	Albizia species	√V=(-0.07109+2.99732*D-0.26953*?D)
2	Artocarpus chaplasha	√V=(-0.15154+2.79983*D)
3	Artocarpus heterophyllus	√V=(-0.15154+2.79983*D)
4	Gmelina arborea	√V=(-0.00189+2.10033*D)
5	Hevea brasiliensis	√V=(-0.226400+2.935870*D)
6	Lannea coromandelica	√V=(-0.21972+2.86603*D)
7	Macaranga species	V=(0.13333-2.18825*D+13.12678*D2)
8	Pterospermum acerifolium	√V=(0.21596+4.14881*D-1.38264*?D)
9	Schima wallichii	√V=(-0.11242+2.54133*D)
10	Tectona grandis	V=(0.19112-3.25372*D+17.9194*D2-1.66117*D3)

UTTAR PRADESH

Sl. No.	Species Name	Volume Equation
1	Acacia catechu	V=(0.16609-2.78851*D+17.22127*D2-11.60248*D3)
2	Anogeissus latifolia	√V=(-0.07738+2.592167*D)
3	Butea monosperma	√V=(-0.24276+2.95525*D)
4	Ficus racemosa	√V=(0.03629+3.95389*D-0.84421*?D)
5	Lannea coromandelica	V=(0.14004-2.3599*D+11.90726*D2)
6	Mallotus philippinensis	V=0.14749-2.87503*D+19.61977*D2-19.11630*D3
7	Shorea robusta	√V=(0.16306+4.8991*D-1.57402*?D)
8	Syzygium cumini	V=(0.08481-1.81774*D+12.63047*D2-6.9555*D3)
9	Tectona grandis	V=(0.08847-1.46936*D+11.98979*D2+1.970560*D3)
10	Terminalia crenulata	V=(0.18149-2.85865*D+18.60799*D2)

UTTARAKHAND

SL No.	Species Name	Volume Equation
1	*Abies smithiana*	V=(0.163269-2.232068*D+11.770869*D2+1.06041*D3)
2	*Lyonia ovalifolia*	V=(0.007602-0.033037*D+1.868567*D2+4.483454*D3)
3	*Mallotus philippinensis*	V=(0.14749-2.87503*D+19.61977*D2-19.11630*D3)
4	*Pinus roxburghii*	√V=(0.05131+3.9859*D-1.0245*?D)
5	*Quercus floribunda*	V=(0.0988-1.5547*D+10.1631*D2)
6	*Quercus leucotrichophora*	√V=(0.240157+3.820069*D-1.39452*?D)
7	*Quercus semecarpifolia*	V=(0.098800-1.55471*D+10.16317*D2)
8	*Rhododendron arboreum*	√V=(0.306492+4.31536*D-1.749908*?D)
9	*Shorea robusta*	√V=(0.16306+4.8991*D-1.57402*?D)
10	*Terminalia crenulata*	V=(0.08658-2.04096*D+13.28405*D2-3.58047*D3)

WEST BENGAL

SL No.	Species Name	Volume Equation
1	*Acacia auriculiformis*	V=(0.04235-0.74240*D+7.26875*D2)
2	*Butea monosperma*	V=(0.031-0.64087*D+6.04066*D2)
3	*Eucalyptus species*	V=(0.02894-0.89284*D+8.72416*D2)
4	*Lagerstroemia spaciosa*	V=(0.11740-1.58941*D+9.76464*D2)
5	*Madhuca latifolia*	V=(0.046883-0.894379*D+7.220441*D2)
6	*Schima wallichii*	√V=(0.28069+4.61980*D-1.65381*?D)
7	*Shorea robusta*	V=(0.16019-2.81861*D+16.19328*D2)
8	*Sterculia villosa*	V=(0.025584-0.89224*D+9.5879*D2)
9	*Tectona grandis*	V=(0.19112-3.25372*D+17.9194*D2-1.66117*D3)
10	*Trewia nudiflora*	V=(0.0549-1.31*D+10.0*D2)

ANDAMAN & NICOBAR ISLANDS

SL No.	Species Name	Volume Equation
1	*Bombax ceiba*	V=(0.136196-2.07674*D+10.1566*D2)
2	*Canarium euphyllum*	V=(0.004338-0.7315*D+11.1750*D2)
3	*Dillenia pentagyna*	V=(0.070-1.295*D+9.429*D2)
4	*Dipterocarpus species*	V=(-0.045595+8.576*D2)
5	*Dipterocarpus turbinatus*	?V=(0.06063+3.43666*D-0.75571*?D)
6	*Perishia insignis*	?V=(0.06063+3.43666*D-0.75571*?D)
7	*Pterocarpus indicus*	?V=(0.06063+3.43666*D-0.75571*?D)
8	*Pterocymbium tinctorium*	V=(0.019795-0.99448*D+10.101*D2)
9	*Terminalia procera*	V=(0.05061-1.11994*D+8.77839*D2)
10	*Tetrameles nudiflora*	?V=(0.06063+3.43666*D-0.75571*?D)

CHANDIGARH

Sl. No.	Species Name	Volume Equation
1	*Acacia arabica*	V=(0.16609-2.78851*D+17.22127*D2-11.60248*D3)
2	*Acacia catechu*	V=(0.02384-0.72161*D+7.46888*D2)
3	*Dalbergia sissoo*	V=(0.00331+6.36*D2)
4	*Eucalyptus species*	V=(0.02894-0.89284*D+8.72416*D2)
5	*Leucaena leucocephala*	V=(0.17553-0.71434*?D+7.94663*D2)
6	*Melia azadirachta*	V=(-0.03510+5.32981*D2)
7	*Morus species*	V=(-0.0351+5.32981*D2)
8	*Populus species*	?V=(-0.143393+3.040067*D)
9	*Prosopis juliflora*	V=(0.17553-0.71434*?D+7.94663*D2)
10	*Terminalia bellirica*	?V=(-0.14017+3.36423*D)

DADRA & NAGAR HAVELI AND DAMAN & DIU

Sl. No.	Species Name	Volume Equation
1	*Acacia catechu*	V=(-0.048108+5.873169*D2)
2	*Anogeissus latifolia*	V=(0.030502-1.105937*D+12.261268*D2)
3	*Bridelia retusa*	V=(-0.032-0.0619*D+7.208*D2)
4	*Butea monosperma*	V=(-0.032-0.0619*D+7.208*D2)
5	*Grewia tiliaefolia*	?V=(-0.153973+2.724109*D)
6	*Lannea coromandelica*	?V=(0.404153+5.555051*D-2.545525*?D)
7	*Madhuca latifolia*	V=(0.074069-1.230020*D+7.726902*D2)
8	*Tectona grandis*	?V=(-0.40589+1.98158*D+0.987373*?D)
9	*Terminalia belerica*	V=(0.074706-1.430082*D+10.181971*D2)
10	*Terminalia crenulata*	?V=(-0.203947+3.159215*D)

JAMMU & KASHMIR

Sl. No.	Species Name	Volume Equation
1	*Abies densa*	V=(0.10774-2.09529*D+12.62008*D2-1.61065*D3)
2	*Abies pindrow*	V=(0.10774-2.09529*D+12.62008*D2-1.61065*D3)
3	*Abies smithiana*	√V=(0.20050+4.58840*D-1.42603*?D)
4	*Cedrus deodara*	V=(10.03982*D2-1.28303*D+0.07367)
5	*Mallotus philippinensis*	V=(0.14749-2.87503*D+19.61977*D2-19.11630*D3)
6	*Pinus excelsa*	V=(0.02-0.851*D+10.44*D2)
7	*Pinus roxburghii*	V=(0.128812-2.285176*D+11.950158*D2)
8	*Quercus floribunda*	V=(0.04430-0.84266*D+6.36239*D2+2.27556*D3)
9	*Quercus leucotrichophora*	V=(0.04430-0.84266*D+6.36239*D2+2.27556*D3)
10	*Taxus baccata*	V=(0.007602-0.033037*D+1.868567*D2+4.483454*D3)

Annexure- III A

Estimated number of trees by species and diameter class in Forest at Country level (In '000)

S. No.	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1.	*Abies densa*	6,635	9,197	3,325	19,157	0.14
2.	*Abies pindrow*	22,439	28,248	12,693	63,380	0.45
3.	*Abies smithiana*	17,511	12,741	8,288	38,540	0.28
4.	*Acacia catechu*	1,69,582	5,035	242	1,74,859	1.25
5.	*Adina cordifolia*	37,944	10,747	2,521	51,212	0.37
6.	*Anogeissus latifolia*	4,60,793	50,692	2,211	5,13,696	3.67
7.	*Bombax ceiba*	27,396	14,030	4,770	46,196	0.33
8.	*Boswellia serrata*	57,114	44,927	1,372	1,03,413	0.74
9.	*Buchanania latifolia*	2,46,855	6,674	80	2,53,609	1.81
10.	*Butea monosperma*	1,80,760	17,530	410	1,98,700	1.42
11.	*Careya arborea*	47,302	4,894	216	52,412	0.37
12.	*Castanopsis species*	1,01,217	19,698	5,417	1,26,332	0.90
13.	*Cedrus deodara*	53,279	33,084	13,170	99,533	0.71
14.	*Cleistanthus collinus*	2,51,938	7,264	207	2,59,409	1.85
15.	*Dalbergia paniculata*	58,339	13,786	839	72,964	0.52
16.	*Diospyros melanoxylon*	2,70,396	30,424	1,219	3,02,039	2.16
17.	*Ficus benghalensis*	5,316	1,555	2,489	9,360	0.07
18.	*Ficus species*	59,542	8,682	4,397	72,621	0.52
19.	*Lagerstroemia lanceolata*	15,124	7,250	1,751	24,125	0.17
20.	*Lagerstroemia parviflora*	2,89,492	20,529	611	3,10,632	2.22
21.	*Lannea coromandelica*	3,50,309	57,522	1,809	4,09,640	2.92
22.	*Madhuca latifolia*	1,42,701	41,677	4,732	1,89,110	1.35
23.	*Mallotus philippinensis*	1,47,779	5,555	202	1,53,536	1.10
24.	*Pinus wallichiana*	1,01,327	53,843	11,991	1,67,161	1.19
25.	*Pinus roxburghii*	1,98,874	96,353	10,344	3,05,571	2.18
26.	*Pterocarpus marsupium*	88,887	23,645	1,869	1,14,401	0.82
27.	*Quercus dilatata*	24,730	5,956	1,761	32,447	0.23
28.	*Quercus leucotrichophora*	2,27,538	39,869	4,241	2,71,648	1.94
29.	*Quercus semecarpifolia*	20,741	10,395	4,365	35,501	0.25
30.	*Rhododendron arboreum*	1,11,116	17,939	846	1,29,901	0.93
31.	*Schima wallichii*	1,00,980	14,326	2,368	1,17,674	0.84
32.	*Schleichera trijuga*	66,949	22,181	1,832	90,962	0.65
33.	*Shorea robusta*	9,78,143	2,22,651	17,983	12,18,777	8.70
34.	*Syzygium cumini*	1,15,438	33,494	3,951	1,52,883	1.09
35.	*Tectona grandis*	8,23,427	94,170	2,769	9,20,366	6.57
36.	*Terminalia belerica*	44,992	12,232	3,727	60,951	0.44
37.	*Terminalia tomentosa*	4,03,689	85,807	5,621	4,95,117	3.53
38.	*Terminalia myriocarpa*	23,902	11,658	1,857	37,417	0.27
39.	*Terminalia paniculata*	79,805	21,253	4,449	1,05,508	0.75
40.	*Xylia xylocarpa*	1,25,985	25,021	2,050	1,53,056	1.09
41.	Rest of Species	53,38,884	6,31,021	84,225	60,54,130	43.21
	Total	**1,18,95,171**	**18,73,555**	**2,39,220**	**1,40,07,946**	**100.00**

Annexure- III B

Estimated volume by species and diameter class in Forest at Country level (In million cum)

S. No.	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1	*Abies densa*	1.60	12.56	21.68	35.84	0.82
2	*Abies pindrow*	5.90	39.92	71.48	117.30	2.67
3	*Abies smithiana*	3.28	19.18	71.61	94.07	2.15
4	*Acacia catechu*	17.82	4.18	0.78	22.78	0.52
5	*Adina cordifolia*	5.05	11.59	13.97	30.61	0.7
6	*Anogeissus latifolia*	69.55	51.87	8.26	129.68	2.96
7	*Bombax ceiba*	4.36	14.17	18.83	37.36	0.85
8	*Boswellia serrata*	10.96	41.14	4.21	56.31	1.28
9	*Buchanania latifolia*	19.51	3.65	0.21	23.37	0.53
10	*Butea monosperma*	24.04	14.90	1.69	40.63	0.93
11	*Careya arborea*	17.74	7.63	1.08	26.45	0.6
12	*Castanopsis* species	11.77	16.66	19.99	48.42	1.1
13	*Cedrus deodara*	10.61	44.80	66.99	122.40	2.79
14	*Cleistanthus collinus*	20.06	3.49	0.49	24.04	0.55
15	*Dalbergia paniculata*	8.52	13.89	3.46	25.87	0.59
16	*Diospyros melanoxylon*	26.57	27.54	4.52	58.63	1.34
17	*Ficus benghalensis*	0.60	1.52	20.17	22.29	0.51
18	*Ficus* species	7.29	8.93	39.94	56.16	1.28
19	*Lagerstroemia lanceolata*	2.27	8.73	8.44	19.44	0.44
20	*Lagerstroemia parviflora*	30.06	17.13	2.41	49.60	1.13
21	*Lannea coromandelica*	52.58	51.85	6.68	111.11	2.53
22	*Madhuca latifolia*	18.27	37.47	16.32	72.06	1.64
23	*Mallotus philippinensis*	14.78	4.32	0.74	19.84	0.45
24	*Pinus wallichiana*	21.61	76.46	59.83	157.90	3.6
25	*Pinus roxburghii*	33.33	104.01	43.51	180.85	4.12
26	*Pterocarpus marsupium*	14.42	25.05	8.51	47.98	1.09
27	*Quercus dilatata*	3.18	6.44	9.45	19.07	0.44
28	*Quercus leucotrichophora*	28.52	34.62	17.06	80.20	1.83
29	*Quercus semecarpifolia*	3.97	13.93	21.74	39.64	0.9
30	*Rhododendron arboreum*	12.71	14.62	3.22	30.55	0.7
31	*Schima wallichii*	15.66	14.28	10.08	40.02	0.91
32	*Schleichera trijuga*	11.60	26.58	8.99	47.17	1.07
33	*Shorea robusta*	136.38	251.20	89.36	476.94	10.87
34	*Syzygium cumini*	13.97	30.74	19.72	64.43	1.47
35	*Tectona grandis*	100.63	80.62	10.64	191.89	4.37
36	*Terminalia belerica*	6.62	13.85	14.80	35.27	0.8
37	*Terminalia tomentosa*	54.18	90.88	25.02	170.08	3.88
38	*Terminalia myriocarpa*	6.16	15.82	11.71	33.69	0.77
39	*Terminalia paniculata*	9.55	20.40	19.76	49.71	1.13
40	*Xylia xylocarpa*	16.50	18.76	5.20	40.46	0.92
41	Rest of Species	533.86	535.80	368.38	1,438.04	32.77
	Total	**1,406.04**	**1,831.18**	**1,150.93**	**4,388.15**	**100.00**

Annexure- III C

Estimated number of trees by species and diameter class in TOF at Country level (In '000)

S. No.	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1	*Acacia arabica*	1,83,077	44,856	1,533	2,29,466	3.29
2	*Acacia auriculiformis*	1,06,085	4,526	237	1,10,848	1.59
3	*Acacia lenticularis*	39,580	7,185	146	46,911	0.67
4	*Albizia* species	25,449	7,142	383	32,974	0.47
5	*Areca catechu*	3,61,189	152	0	3,61,341	5.18
6	*Artocarpus heterophyllus*	43,027	14,123	1,547	58,697	0.84
7	*Azadirachta indica*	3,73,956	97,243	5,630	4,76,829	6.84
8	*Bombax ceiba*	30,616	9,829	1,103	41,548	0.60
9	*Borassus flabelliformis*	16,222	91,643	909	1,08,774	1.56
10	*Butea monosperma*	1,57,770	29,945	1,216	1,88,931	2.71
11	*Castanopsis* species	54,753	6,311	505	61,569	0.88
12	*Cocos nucifera*	2,32,033	1,03,513	316	3,35,862	4.81
13	*Dalbergia sissoo*	61,190	14,034	538	75,762	1.09
14	*Elaeis guineensis*	505	6,795	9,461	16,761	0.24
15	*Eucalyptus* species	1,61,778	14,994	964	1,77,736	2.55
16	*Ficus benghalensis*	5,921	3,531	4,652	14,104	0.20
17	*Ficus racemosa*	13,345	6,296	2,020	21,661	0.31
18	*Ficus religiosa*	9,584	5,228	5,710	20,522	0.29
19	*Ficus* species	25,872	3,101	1,359	30,332	0.43
20	*Hevea brasiliensis*	1,71,486	7,832	33	1,79,351	2.57
21	*Holoptelea integrifolia*	33,143	6,804	465	40,412	0.58
22	*Madhuca latifolia*	26,009	26,879	19,861	72,749	1.04
23	*Mangifera indica*	4,95,599	1,18,445	29,285	6,43,329	9.22
24	*Phoenix sylvestris*	39,057	17,468	29	56,554	0.81
25	*Pinus roxburghii*	61,131	14,788	1,197	77,116	1.11
26	*Pinus wallichiana*	25,622	11,474	2,614	39,710	0.57
27	*Pongamia pinnata*	45,004	7,707	975	53,686	0.77
28	*Populus* species	83,990	7,710	5,153	96,853	1.39
29	*Prosopis cineraria*	58,645	37,118	1,349	97,112	1.39
30	*Prosopis juliflora*	1,29,250	3,549	320	1,33,119	1.91
31	*Prunus* species	21,782	1,842	3,706	27,330	0.39
32	*Quercus leucotrichophora*	26,750	11,399	280	38,429	0.55
33	*Schima wallichii*	45,433	5,087	320	50,840	0.73
34	*Shorea robusta*	1,28,132	24,606	4,082	1,56,820	2.25
35	*Syzygium cumini*	51,611	17,758	2,053	71,422	1.02
36	*Tamarindus indica*	26,327	21,496	8,123	55,946	0.80
37	*Tectona grandis*	2,03,459	12,846	599	2,16,904	3.11
38	*Terminalia arjuna*	34,198	14,720	1,357	50,275	0.72
39	*Terminalia tamentosa*	62,158	9,046	1,165	72,369	1.04
40	*Zizyphus mauritiana*	1,21,281	10,108	414	1,31,803	1.89
41	Rest of Species	19,33,019	2,43,278	27,129	22,03,426	31.59
	Total	**57,25,038**	**11,02,407**	**1,48,738**	**69,76,183**	**100.00**

Annexure- III D

Estimated volume by species and diameter class in TOF at Country level (In million cum)

S. No.	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1	*Acacia arabica*	19.05	26.85	3.33	49.23	2.77
2	*Acacia auriculiformis*	6.36	2.42	0.51	9.29	0.52
3	*Acacia lenticularis*	4.64	4.35	0.35	9.34	0.52
4	*Albizia* species	3.38	5.23	1.09	9.70	0.55
5	*Areca catechu*	8.97	0.06	0.00	9.03	0.51
6	*Artocarpus heterophyllus*	5.14	8.80	5.19	19.13	1.07
7	*Azadirachta indica*	41.13	64.38	15.14	120.65	6.78
8	*Bombax ceiba*	3.74	8.11	4.61	16.46	0.92
9	*Borassus flabelliformis*	3.00	47.59	1.65	52.24	2.94
10	*Butea monosperma*	17.78	21.70	4.48	43.96	2.47
11	*Castanopsis* species	6.90	5.36	2.55	14.81	0.83
12	*Cocos nucifera*	42.94	36.62	0.70	80.26	4.51
13	*Dalbergia sissoo*	11.50	12.02	1.54	25.06	1.41
14	*Elaeis guineensis*	0.05	5.61	16.07	21.73	1.22
15	*Eucalyptus* species	15.17	11.19	2.72	29.08	1.63
16	*Ficus benghalensis*	0.62	3.10	29.10	32.82	1.84
17	*Ficus racemosa*	1.38	4.64	7.52	13.54	0.76
18	*Ficus religiosa*	1.06	4.40	30.76	36.22	2.04
19	*Ficus* species	2.31	1.86	5.74	9.91	0.56
20	*Hevea brasiliensis*	15.16	3.66	0.07	18.89	1.06
21	*Holoptelea integrifolia*	3.50	4.70	1.43	9.63	0.54
22	*Madhuca latifolia*	2.90	19.23	60.57	82.70	4.65
23	*Mangifera indica*	54.40	81.96	93.97	230.33	12.94
24	*Phoenix sylvestris*	5.88	6.43	0.05	12.36	0.69
25	*Pinus roxburghii*	7.96	12.54	4.89	25.39	1.43
26	*Pinus wallichiana*	6.40	12.80	15.88	35.08	1.97
27	*Pongamia pinnata*	3.47	4.32	2.39	10.18	0.57
28	*Populus* species	7.73	3.82	12.21	23.76	1.34
29	*Prosopis cineraria*	5.90	19.00	2.71	27.61	1.55
30	*Prosopis juliflora*	7.76	2.12	1.06	10.94	0.61
31	*Prunus* species	1.08	1.25	8.20	10.53	0.59
32	*Quercus leucotrichophora*	3.93	9.34	1.07	14.34	0.81
33	*Schima wallichii*	7.52	4.94	1.47	13.93	0.78
34	*Shorea robusta*	12.33	15.65	10.17	38.15	2.14
35	*Syzygium cumini*	6.22	13.47	6.95	26.64	1.50
36	*Tamarindus indica*	2.94	13.89	22.99	39.82	2.24
37	*Tectona grandis*	21.08	8.81	3.61	33.50	1.88
38	*Terminalia arjuna*	4.43	10.22	4.47	19.12	1.07
39	*Terminalia tomentosa*	5.91	6.01	3.42	15.34	0.86
40	*Zizyphus mauritiana*	11.52	5.57	1.12	18.21	1.02
41	Rest of Species	187.66	172.00	100.79	460.44	25.89
	Total	**580.80**	**706.02**	**492.54**	**1779.35**	**100.00**

Annexure- IV

State/UTs wise Standard Error for Growing stock & Tree Cover

Sr. No.	State/Uts	SE% Forest	SE% TOF	SE% Tree Cover
1	Andhra Pradesh	4.36	4.43	2.73
2	Arunanchal Pradesh	8.46	13.36	3.77
3	Assam	7.25	5.13	5.25
4	Bihar	7.55	4.40	4.05
5	Chhattisgarh	2.69	3.84	3.43
6	Delhi	12.23	7.15	6.57
7	Goa	6.58	5.45	9.85
8	Gujarat	4.87	2.95	13.51
9	Haryana	10.34	4.46	6.22
10	Himanchal Pradesh	3.88	5.37	5.21
11	Jharkhand	3.85	4.96	3.87
12	Karnataka	3.73	4.10	4.34
13	Kerala	3.90	3.75	3.83
14	Madhya Pradesh	2.05	3.41	2.70
15	Maharashtra	3.11	2.18	2.26
16	Manipur	11.45	11.23	9.17
17	Meghalaya	7.75	7.17	10.38
18	Mizoram	10.34	10.96	8.34
19	Nagaland	13.55	9.32	4.13
20	Odisha	3.53	4.63	2.99
21	Punjab	9.22	7.03	6.39
22	Rajasthan	4.97	2.76	2.23
23	Sikkim	11.71	7.03	8.27
24	Tamil Nadu	5.67	2.27	6.78
25	Telangana	3.79	4.49	6.40
26	Tripura	6.19	7.20	8.81
27	Uttar Pradesh	4.25	1.91	2.63
28	Uttrakhand	3.77	4.30	4.42
29	West Bengal	8.72	4.97	5.27
30	A & N Island	8.96	15.60	10.50
31	Chandigarh	12.91	7.87	9.79
32	Dadar & Nagar Haveli & Daman & Diu	15.95	12.52	16.49
33	Jammu & Kashmir	4.13	4.77	5.25
34	Ladakh*	-	22.02	-
35	Lakshadweep	-	4.73	5.58
36	Puducherry*		11.60	7.24
	Total	**4.60**	**6.10**	**4.01**

Note*:- Due to Inadequate data, Standard Error (SE) is not given.

CONTRIBUTORS

Headquarters Execution, Analysis & Report Preparation
Anoop Singh, IFS, Director General

Forest Inventory & Training Division
Sushant Sharma, IFS, Joint Director
Prakash Lakhchaura, ISS, Dy. Director General
Dinesh Kumar, ISS, Ex. Dy. Director General
Kamal Pandey, ISS, Deputy Director
Girija Arora, Assistant Director
D. V. Sangolkar, Assistant Director (I/C)
H. K. Tripathi, Consultant

Forest Geoinformatics Division
Meenakshi Joshi, IFS, Joint Director
R. Arun Kumar, IFS, Ex. Deputy Director
Dr. Sunil Chandra, Deputy Director
Sanjay Kumar Agarwal, Deputy Director
Abhay Kumar Saxena, Assistant Director
Sanjay Rawat, Assistant Director
Devi Singh, Assistant Director
Neeta Goswami, Ex. Assistant Director
Savita Semwal, Assistant Director
S.K. Singh, Assistant Director

Image Interpretation
Ekta Singh, STA, Hqrs
Anita Bhunwal, STA, Hqrs
Vikas Gusain, STA, Hqrs
Imtijunghsi, STA, Hqrs
Preeti Topwal, STA, Hqrs
Dr. Rohini Ganorkar, STA, CZ
Aprajita Yadav, STA, CZ
Sapna Ghai, JTA, Hqrs
Garima Sharma, JTA, Hqrs
Prasant Kumar, JTA, Hqrs
V.P. Sharma, Dy. Ranger, Hqrs
Kusha Goyal, Dy. Ranger, Hqrs
Ashutosh Singh, Dy. Ranger, CZ
Joginder Kumar, Sr.D/man, NZ
R.K. Rajvanshi, Sr. D/man, Hqrs
Subrata Majumdar, Sr.D/man, EZ
Late. Vasantha Kumar, Sr. TA, SZ
Soma Chakraborty, Sr. TA, SZ
Felcy Cecelia, Ex. Sr. TA, SZ
Aditya Kumar Sain, Sr. TA, NZ
Anjna Kumari, Sr. TA, NZ
Savita Khadse, TA, CZ
Parikshit Agarkar, Dy. Ranger, CZ

Data Processing
Smt. Sudeshna Pal, DPA, EZ
P. Somasundaram, DPA(A), SZ
Deepak Kumar Dibansee, DPA(A), EZ
Yogesh Kumar Bansal, DPA(A), Hqrs
Suvikram Prakash, DPA(A), Hqrs
Karuna Saini, DPA(A), Hqrs
N.K Bhatia, Ex. Consultant, Hqrs
Balbir Singh Bisht, DEO(D), Hqrs
Sajjan Singh, DEO, Hqrs

Reprographic Support
Usha Goswami, Assistant Director (OL)
Anil Kumar, Jr. Hindi Translator, EZ
A.H. Ansari, Consultant, CZ
Rambha Thapa, Superintendent, Hqrs
Ashok Kumar, Dy. Ranger, Hqrs
Pratima Saini, Stenographer I, Hqrs
Rahul Chhabra, Stenographer, Hqrs
Mukesh Chauhan, Stenographer, Hqrs
Lekhraj Meena, Stenographer, Hqrs
Arun Sharma, LDC, Hqrs
Vijay Kumar Gupta, LDC, EZ
Samarjeet Kumar Suman, LDC, EZ
Saroj Mahato, DMO, EZ
Ajay Pal, AC/DC Operator, Hqrs
Bal Krishan, Electrician, Hqrs
K.C. Katheria, Stenographer, SZ
Vinod M. Lambodhari, Superintend, SZ
S. Brinda, LDC, SZ
Vinod Meena, LDC, SZ
Vinit, LDC, SZ
Krishan Saini, MTS, Hqrs
Rakesh Kumar, MTS, Hqrs
Ankuj Rana, MTS, Hqrs
Suman Bisht, Computer Operator, Hqrs
Manisha Chauhan, Computer Operator, Hqrs
Anjali Saklani, Computer Operator, Hqrs
Akhilesh Panwar, Computer Operator, Hqrs
Deepti Dogra, Computer Operator, Hqrs
Uzma Tarranum, Computer Operator, Hqrs.

Paritosh Dangwal, Computer Operator, Hqrs
Himanshi Dasila, Computer Operator, Hqrs
Mohan Negi, Computer Operator, Hqrs
Umesh Kumar, CDL, Hqrs
Sandeep Kumar, CDL, Hqrs
Hemant Bahuguna, CDL, Hqrs
Vipin Kumar, CDL, Hqrs
Ashwani Kumar Morya, CDL, Hqrs
Sunil Kumar, CDL, Hqrs
Chedda Lal, CDL, Hqrs
Rakesh Bhatt, CDL, Hqrs
Radha Krishna, CDL, Hqrs
Nirmala Rana, CDL, Hqrs
Dheeraj, CDL, Hqrs
Kunnu Lal, CDL, Hqrs
Pintu Singh, CDL, Hqrs

Zonal Offices Execution & Analysis

Sushant Sharma, IFS, Ex. Regional Director, NZ
H. Venuprasad, IFS, Sr. Dy. Director and Regional Director (I/C), SZ
Chaturbhuja Bahera, IFS, Regional Director, CZ
Satya Prakash Negi, IFS, Regional Director, NZ
Dr. Soma Das, IFS, Regional Director, EZ
S. Elamurugannan, IFS, Dy. Director, SZ
S. Sampath, Assistant Director, SZ
B.H. Naik, Assistant Director, CZ
Anil Bisla, Consultant, CZ
Sanjay S. Kumbhare, STA/Astt. Director (I/C)
Nagaraja SV, STA, SZ

Field Inventory

Rajesh Dharwade, STA, CZ
Touseef Siddique, STA, CZ
Ashwin Dhargave, STA, CZ
Pradeep Kumar Kushwaha, STA, CZ
Bahir Marzooque, STA, EZ
Durgesh Kumar Nagar I, STA, EZ
Bipab Show, STA,EZ
Ranjeet Kumar, STA, EZ
Durgesh Kumar Nagar II, STA, EZ
S.V. Pawara, JTA, CZ
P.D. Pimple, JTA, CZ
R.D. Patil, JTA, CZ
Pradeep Nagose, JTA, CZ
Devendra Gharpinde, JTA, CZ
Abhishek Singh, JTA, CZ
Rahul Chauhan, JTA,CZ
Vikash Singh, JTA, EZ
Gaurang Makwana, JDM, CZ
Fooldas Bhalavi, Dy. Ranger, CZ
Pravin Nag, Dy. Ranger, CZ
Dr. Salman Khan, Dy Ranger, CZ
Dr. Chandra Mohan, Dy. Ranger, CZ
Kartik Pramanik, Dy. Ranger, CZ
Ananta Kakade, Dy. Ranger, CZ
Bhushan Bhanarkar, Dy. Ranger, CZ
Amit Jarvekar, Dy. Ranger, CZ
Ritesh Ashtikar, Dy. Ranger, CZ
Palash Gorai, Dy. Ranger, EZ
Uttam Pal, Dy. Ranger, EZ
D.A. Modi, Dy. Ranger, EZ
Subhash Kumar Pal, Dy. Ranger, EZ
Sanjay, Dy. Ranger, EZ
Liladhar Vaidya, FM, CZ
Himalaya Putra, FM, CZ
Ashwani Kumar, STA, NZ
Ajay Kumar, STA, NZ
Raghuveer Singh Khateek, STA, NZ
Nisha Limba, STA, NZ
Rajesh Kumar, JTA, NZ
Vinay Sharma, JTA, NZ
Vikas Singla, JTA, NZ
Pooja Thakur, JTA, NZ
Prince Lal Jangid, JTA, NZ
Naresh kumar Bharti, JTA, NZ
Kuldeep Meena, JTA,NZ
Yahwant Singh Parihar, JTA, NZ
Subhash Singh, JTA, NZ
Pawan kumar, JTA, NZ
Deepti Dhiman, Dy. Ranger, NZ
Sandeep Singh, Dy. Ranger, NZ
Vijay Kumar, Dy. Ranger, NZ
Jyoti, Dy. Ranger, NZ
Chhavi Shayam, Ex. Dy. Ranger, NZ
Pawan Kumar, Dy. Ranger, NZ
Lakhwinder Singh, Dy. Ranger, NZ
Krishnamoorthi S., STA, SZ
Suresha T, STA,SZ
G.S. Thiagaraj, Jr. Draftsman, SZ
V. Rangasamy, JTA, SZ
Nandana Kumar H.V., JTA, SZ
N.U. Aruna, JTA, SZ
Anil Ramesh, JTA, SZ
Gowdappagowda N. M, JTA, SZ

Avinash karra, JTA, SZ
Aarti Das, JTA, SZ
R.D. Patil, JTA, SZ
Bidyut Nayak, JTA, SZ
B. Vijaya Kumar, JTA, SZ
Mohamad Perveez, JTA, SZ
Peeli Shekar, Dy. Ranger, SZ
Ankam Vijay, Fieldman, SZ
Vangala Sekhar, Fieldman, SZ
Sukhen Pal, Fieldman, EZ
J. Ahamed, Fieldman, EZ
Dipankar Paul, Fieldman, EZ
Manik Goral, Fieldman, EZ
Sova Pramanik, Fieldman, EZ
Abhishek Kumar, Fieldman, EZ
Sikendra Yadav, MTS, EZ
Nitesh Kumar, MTS, EZ

Project Scientist/Technical Associates

Dr. Sourav Ghosh, Project Scientist-D, Hqrs
Manoj Uniyal, Ex. Project Scientist-D, Hqrs
Sushila Tripathi, Project Scientist, Hqrs
Arun Thakur, Ex. Project Scientist, Hqrs
Santosh U, Ex. Project Scientist-B, Hqrs
Prabhbir Singh, Sr. TA, Hqrs
Neetu Verma, Sr. TA, Hqrs
Harendar Singh Negi, Sr. TA, Hqrs
Dr. Kamlesh Khanduri, Sr. TA, Hqrs
Vipin Rao, Project Associate -I, Hqrs
Dr. Sadhana Yadav, Project Associate-II, Hqrs
Nirmal Singh, Ex. Sr. TA, Hqrs
Sonia Sharma, Sr. TA, Hqrs
Deena Yadav, Sr. TA, Hqrs
Satyendra Kumar, Sr. TA, Hqrs
Chander Mohan Bisht, Sr. TA, Hqrs
Akshay Joshi, Sr. TA, Hqrs
Nitika Dangwal, Sr. TA, Hqrs
Sandeep Goel, Sr. TA, Hqrs
Ashish Sharma, Sr. TA, Hqrs
Sushil Raghunath Bhosle, Ex. Sr. TA, Hqrs
Abhishek Chaudhary, Sr. TA, Hqrs
Rashpal, Sr. TA, Hqrs
Santanu Pani, Sr. TA, Hqrs
Anupam Pal, Sr. TA, Hqrs
Tanay Das, Sr. TA, Hqrs
Anupam Ghosh, Sr. TA, EZ
Debangana Basu, Sr. TA, EZ
Tapan Dhar, Sr. TA, EZ
Dr. Anuradha Tyagi, TA, Hqrs
Dr. Srikanta Bhaya, TA, Hqrs
Jagannath Mehatari, TA, Hqrs
Kiran Gupta, TA, Hqrs
Satish Kumar, TA, Hqrs
Kanwal Preet Singh, TA, Hqrs
Manish Uniyal, TA, Hqrs
Anupama Shekhawat, TA, Hqrs
Gaurav Ramesh Arote, TA, Hqrs
Surajit Bera, TA, Hqrs
Gopal Patra, TA, Hqrs
Sabyasachi Pandit, TA, Hqrs
Pranab Khatua, TA, Hqrs
Souvik Biswas, TA, Hqrs
Biswajit Das, TA, Hqrs
Biswajit Bera, TA, Hqrs
Vishal Singh, TA, Hqrs
Kaptan Singh, TA, Hqrs
Shivam Gupta, TA, Hqrs
Shashank Kumar Anshu, TA, Hqrs
Neeraj Kumar, TA, Hqrs
Santosh Das, TA, Hqrs
Jaspreet Kaur Khaira, Ex. TA, Hqrs
Priyonath Adhikary, TA, Hqrs
Arghadyuti Banerjee, Ex. TA, Hqrs
Priyanka Kumari, TA, Hqrs
Tapan Biswas, TA, EZ
Somanath Maiti, TA, EZ