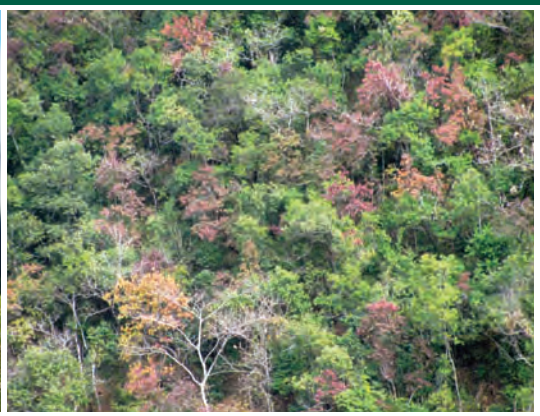
INDIA STATE OF FOREST REPORT 2019



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

Volume I

पुष्पिताः फलवन्तश्च तर्पयन्तीह मानवान्।
वृक्षदं पुत्रवत् वृक्षास्तारयन्ति परत्र च ।।

(महाभारत, अनुशासन पर्व, अध्याय, 58, श्लोक 30)

(इह पुष्पिताः फलवन्तः च मानवान् तर्पयन्ति वृक्षाः वृक्षदं पुत्रवत् परत्र च तारयन्ति।)

फलों और फूलों वाले वृक्ष मनुष्यों को तृप्त करते हैं। वृक्ष देने वाले अर्थात् समाजहित में वृक्षरोपण करने वाले व्यक्ति का परलोक में तारण भी वृक्ष करते हैं।

सत्यमेव जयते

Volume I

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सत्यमेव जयते

FOREWORD

प्रकाश जावडेकर
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पर्यावरण, वन एवं जलवायु परिवर्तन मंत्री
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In the recent years, there is a growing recognition of the vital role played by forest ecosystems in ensuring the ecological security of the world. The ecosystem services that forests provide are essential for the existence of life on the Earth. The changes in forest ecosystems are highly dynamic in nature and therefore there is a need for regular monitoring to ensure balance between conservation and development. It gives me a deep sense of pride to inform citizens of this country and world at large that India is the only country in the world which carries out nation-wide assessment of its forest resources in biennial cycle using modern techniques.

Forest Survey of India, an organisation of this Ministry, has been carrying out the gigantic task of nationwide biennial forest cover monitoring and assessment since 1987. For over three decades now, FSI has kept pace with the advancement of technologies for such assessments and created a niche for itself in this specialized field. This 16th India State of Forest Report, besides providing regular information on forest resources of the country, has also brought out findings of a few special studies which are important for the policy makers, planners, forest managers, researchers and students having interest in conservation of natural resources. It is also a pleasure to inform that FSI has been strengthening its methodology in remote sensing based forest cover mapping and national forest inventory based assessments of forest resources which is in accordance with the Hon'ble Prime Minister's vision of 'Digital India'.

It gives me satisfaction to note that despite the immense biotic pressure on the country's forests, the forest and tree cover continues to show an increasing trend over the years. This is the result of sustained conservation, protection and afforestation efforts implemented on the ground under the policies of the National Government and State Governments. It also reflects the direct impact of various Government schemes in the recent years, like "Pradhan Mantri Ujjwala Yojana" which has considerably reduced the dependence of rural households on forests for fuelwood.

It is heartening to note that FSI has also been making significant contribution towards international commitments by reporting and complying various requirements under GFRA, REDD+, UNFCCC, UNCCD etc. Recently, FSI has also carried out a comprehensive study to assess the magnitude and scale of actions required to create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 eq by 2030 through additional forest & tree cover, which is one of the commitments made in India's NDC.

I am also happy to inform the readers that since 2001, FSI has been assessing the tree cover outside the forests which is a major source of meeting the local demands of timber, fuelwood and fodder. Such assessments quantify the contribution of forestry sector to the nation's GDP.

I congratulate the Director General, FSI and his team for bringing out this highly useful and informative India State of Forest Report 2019 and wish them all the best in their endeavours towards providing qualitative and quantitative information at the national level for planning the sustainable management of the vast forest resources of the country.

(Prakash Javadekar)

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FOREWORD

बाबुल सुप्रियो
Babul Supriyo
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More than ever before, the entire world is looking at forests for providing solutions to the adverse impacts of climate change. In such a scenario, it is heartening to note that the results of the 16th biennial assessment report (ISFR 2019), published by the premier organisation of this Ministry, are indicating positive trends of forest and tree cover in the country. This clearly validates the sustainable development path charted by the government. It is not a minor achievement that despite the huge anthropogenic and other demands on natural resources, our country has been successful in achieving a balance between developmental needs and conservation. Further, the results of the Forest Fringe Village study undertaken by FSI are encouraging and show signs of the environmental benefits of the welfare schemes like Ujwala Yojana, fodder enhancement and other rural development programmes in obviating pressure on forests.

I have been informed that in keeping pace with the rapid advancements in geospatial technology, FSI has also adapted itself suitably, which is evident in improvement in 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, Drone applications and allied techniques. The use of new NFI design data in the current report for assessment of growing stock, carbon accounting and other parameters has yielded results with greater precision. I also take this opportunity to congratulate the entire FSI team for coming out with useful technical information through their publications on forest fire and strategy for achieving NDC commitment of the country on forestry.

The current ISFR provides relevant information pertaining to each State such as biodiversity assessment, slope and altitude wise forest cover etc. which the States will find very useful in formulating policies and strategies for conservation, management and enhancement of their forest and tree resources.

On the whole, the current ISFR is a treasure trove of information which I am sure will be of great relevance to the entire spectrum of stake holders from the policy makers, academicians, administrators, forest managers, and community based organizations to the citizens of the country at large.

The entire FSI team deserves congratulation for their dedicated efforts for taking out this exhaustive report on time and I look forward to many more such achievements in future also.

(Babul Supriyo)

सत्यमेव जयते

FOREWORD

सी. के. मिश्रा
C.K. Mishra
सचिव
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In today's situation, when the country is on the path of rapid all round development and the pressure on our natural resources is high, it becomes essential to keep an eye on the changes taking place in the forests of the country. Forest Survey of India (FSI), for the last three decades, has been carrying out the remote sensing based biennial forest cover assessment of the country, validated by wide spread ground truthing. FSI also implements the National Forest Inventory involving survey and enumeration on more than 16000 sample plots distributed all over the country every year. The findings of these two major activities, along with several other studies, are published in the biennial India State of Forest Report (ISFR). So far, 15 reports have been published and this is the 16th such report. These reports are widely acclaimed nationally and internationally and provide very useful information on the forest resources and on many other parameters which are relevant for nation-wide planning for the forestry sector.

It is heartening to note that as per the ISFR, 2019, the forest and tree cover of the country continues to show a rising trend despite immense pressure on our forests. The credit should go to various State/UT Forest Departments for their continuous efforts in implementing sound policies of conservation, sustainable management of forests and promotion of Trees Outside Forests. The report indicates that the positive changes in Government's policies relaxing restrictions on felling of trees from private lands and easing of transit rules, have generated the right atmosphere for planting more trees on private lands, leading to improved livelihoods and income opportunities. This strategy will also result in additional benefits in terms of enhanced carbon stock and ecosystem services.

I am happy to know that in the current ISFR, digitized forest boundaries of 23 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 the digital forest boundaries to FSI. This will help the States to plan appropriately for areas within and outside recorded forest areas.

This report, besides providing regular information on forest cover, mangroves, growing stock of timber within and outside forests, contains dedicated chapters on Bamboo Resources, Forest Fires, Carbon Stock, People and Forests and Forest Types and Bio-diversity. It is thus a storehouse of useful data for meeting the information needs of different stakeholders of the forestry sector.

I am pleased to know that the forest fire alerts provided by FSI have been found very useful by the State Forest Departments for undertaking immediate onsite control measures. Similarly, Decision Support System and e-Green watch systems operational at FSI are of immense help to the Ministry in taking objective decisions in FC matters and monitoring of CAMPA activities. The information from FSI regarding the Carbon Stock in Country's Forests is very important for formulating and finalizing the strategy for creating an additional Carbon sink of 2.5 to 3 billion tonnes of CO_2 eq by 2030 through additional forest and tree cover, which is one of the commitments made in India's NDC.

I am sure that FSI would continue to strive hard to maintain and surpass the credibility it has achieved over the last three decades. I wish the organisation would continue to evolve with the changing times for providing more comprehensive information for sustainable management of forests in the country. I wish the organisation greater success in future. Lastly, I congratulate Director General, Forest Survey of India and his competent team for this comprehensive ISFR 2019.

(C.K. Mishra)

सत्यमेव जयते

FOREWORD

सिद्धांत दास
Siddhanta Das
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Over the years, the release of the biennial India State of Forest Report (ISFR) published by Forest Survey of India is one of the most awaited events in the forestry sector in India. With the release of the 16th biennial assessment report i.e. ISFR 2019, the country has completed more than three decades of regular assessment of its forest resources.

With 2.5% of total land surface supporting 16% of human and 18% of cattle population of the world, it is not a small achievement that the country has been able to maintain a balance between conservation and development. In the current cycle, there has been an increase of over 5000 sq km of forest and tree cover as compared to the previous assessment. The impact of sustained conservation efforts over the years, agro-forestry practices, fodder improvement and renewable energy programmes have contributed in maintaining, a positive trend of forest cover.

Improvement and standardization of forest cover mapping methodology by FSI and publishing a manual for the same, nation-wide study for estimating dependence of people in forest fringe villages on forests, forest biomass mapping using SAR technology, launch of advanced Forest Fire Alert System, mapping of fire prone forest areas are indeed commendable initiatives of FSI. I have also been informed that keeping in pace with the advancement in technology and modernization, FSI has introduced a state of the art web GIS based PDA devices with specialized applications for collection and processing of inventory data on real time basis. For the first time, data from the new NFI design introduced in 2016 has been used for assessment of growing stock, forest carbon stock and several other parameters reported in the ISFR 2019. In addition to the above, inclusion of information on forest plant diversity in different forest types, impact of forestry interventions in Ganga Basin, information on invasive species and NTFPs and several other features in the ISFR 2019 have added value to its content. New information on forest cover distribution in different slope classes presented in this report will help the State Forest Departments in developing strategies for catchment area afforestation and restoration of open forests on the slopes to check soil erosion, conserve water and harness other multiple ecosystem benefits including enhanced carbon sequestration.

Assessment of dependence of people living in forest fringe villages on forests for fuel wood, fodder, small timber and bamboo will provide important insights for planning suitable measures to reduce pressure on forests. These estimates also provide an understanding of unrecorded removals from forests, which have a bearing on the lower growing stock and productivity of our forests.

In addition to contributing towards reporting for various international commitments under GFRA, REDD+, BUR and NATCOM, FSI has also come out with various technical information reports. Recently released Technical Information Series on the forestry target under the Nationally Determined Contribution (NDC) committed by India, has presented an in-depth analysis on the possibilities, scale and costs for strategy formulation for creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2eq through additional forest and tree cover.

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

(Siddhanta Das)

सत्यमेव जयते

PREFACE

डॉ0 सुभाष आशुतोष, महानिदेशक
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Forest is a dynamic natural resource because of the ecosystem cycles as well as its anthropogenic interfaces. In our country, the dynamism of forests is greatly influenced by forest-people interaction. There is a large scale demand on forests for ecosystem services, meeting needs of people living close to forests for fuel wood, fodder, timber, NTFPs etc and for development. Climate change on the other hand is causing increasing stress on the ecosystems. The significance of assessment and monitoring of forests has never been so high as in the present times. India took an early lead in remote sensing based forest cover monitoring as well as in forest inventory; these activities by FSI have completed over 30 and 50 years respectively. FSI has always endeavoured to use the latest technologies and improved methodologies in forest monitoring and assessment.

ISFR 2019 presents the results of forest cover mapping with a refined methodology, though consistent with the past assessments. A manual for forest cover mapping has been prepared for the first time. Similarly, it is the first presentation of estimates from the new grid based forest inventory design adopted by FSI in 2016 with higher sampling intensity and precision. Several new studies have been undertaken like assessment of biodiversity in the country's forests, assessment of people's dependence on forests for fuel wood, fodder, small timber and bamboo, forest cover on slopes and wetlands in forests. New set of information from forest inventory on invasive species, important NTFPs, dia-class distribution of important forest species in each State has further enriched the primary database on forests of the country for formulation of policies, strategies and sustainable management of forest resources. Improvement in forest fire alert system and the mapping of fire prone areas have equipped the States to better manage and control forest fires. Forest carbon estimates of each State & UT and the country as a whole have been calculated with higher sampling intensity and an analysis has been done for evaluating possibilities to achieve the NDC target of creating additional sink of 2.5 to 3 billion tonnes of CO_2eq through additional forest & tree cover in the country by 2030.

Forest Survey of India has enjoyed the full support and guidance from the Ministry of Environment, Forest & Climate Change, Government of India in accomplishing the tasks mandated to it. I express my heartfelt gratitude to Shri Prakash Javedkar, Hon'ble Minister, Environment, Forests & Climate Change, Government of India, Shri Babul Supriyo, Hon'ble Minister of State, Environment, Forests & Climate Change, Government of India, Shri C. K. Mishra, Secretary, MoEF&CC, Govt of India and Shri Siddhant Das, Director General of Forests & Special Secretary, MoEF&CC, Govt of India for their valuable guidance and continuous support. I am thankful to Smt Bharati, IGF (SU) and Shri Rohit Tiwari DIGF (SU) for their continued help and support to FSI. Mapping of forest cover of the country and forest inventory in a two-year cycle is a herculean task, which is made possible with the dedicated efforts of the officials of FSI at different levels, both at the headquarters and in the zones, working as a team in a professional manner. I express my appreciation for their total devotion and hard work in completing the assessments in a time bound manner for preparation of India State of Forest Report 2019.

Presenting ISFR 2019 is a matter of pride and immense satisfaction to the organization and it also motivates us to continue our endeavour to excel and serve the forest & environment sector of the country.

(Dr. Subhash Ashutosh)

ACKNOWLEDGEMENT

In the 16th cycle of biennial assessment of India's forests, Forest Survey of India has received significant assistance and contributions from various organisations and individuals. Assistance provided by Space Application Centre, Ahemdabad, National Remote Sensing Centre, Hyderabad, Indian Institute of Remote Sensing, Dehradun, Rain Forest Research Institute, Jorhat, Jammu & Kashmir Forest Department, National Sample Survey Organisation, Survey of India, Botanical Survey of India, National Botanical Research Institute and Forest Research Institute (FRI) are thankfully acknowledged.

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

Contributions of Shri Rajesh Kumar, DDG, NSSO, Dehradun, Dr. G.S. Rawat Scientist 'G' of Wildlife Institute of India, Dehradun and Dr. SAS Biswas are acknowledged with gratitude. Quality photographs provided by Dr. R.P. Saini, IFS (Retd) and Shri R.K. Dogra, Addl. PCCF, Tamil Nadu for printing in this report is thankfully acknowledged.

EXECUTIVE SUMMARY

Every two years, Forest Survey of India (FSI) undertakes assessment of country's forest resources, the results of which are presented as the 'India State of Forest Report (ISFR)'. Since 1987, 15 such assessments have been completed and the current assessment is the 16th in the series. Based on the regular nation-wide mapping of forest cover, sample plots based national forest inventory and the specific studies conducted at the national level, the information presented in the ISFR 2019 is primary information on different parameters of the forest resources of the country.

The country's forest cover includes all patches of land with a tree canopy density of more than 10% and more than 1 ha in area, irrespective of land use, ownership and species of trees. It is assessed by a wall-to-wall mapping exercise using remote sensing technique followed by intensive ground truthing. Results of the exercise is a nation-wide forest cover map of the country on 1:50,000 scale in three canopy density classes viz Very Dense Forest with a canopy density more than 70%, Moderately Dense Forest with a canopy density between 40-70% and Open Forest with a canopy density between 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.

Keeping pace with the technology and refinement in methodologies are the continuous processes in FSI. In the current assessment, ortho-rectified LISS III data of IRS Resourcesat-2 with a spatial resolution of 23.5 meters for the period October to December 2017 have been used for interpretation at a scale of interpretation 1:50,000 with the Minimum Mappable Unit of 1 ha. The procedural details of forest cover mapping have been codified into a 'Manual for Forest Cover Mapping'. For the current assessment, ground truthing has been carried out at more than 2,200 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.

FSI undertakes National Forest Inventory to assess the growing stock in forests and TOF, bamboo resource, carbon stock along with several other parameters. Field data for the same is collected from approximately 30,000 sample plots laid in 2 years period as per the standardized design. Estimate of different parameters at the State and national level. The growing stock and other assessments presented in ISFR 2019 are on the basis of a new grid based forestry inventory design adopted by FSI in 2016, which ensures higher sampling intensity with uniformly spread sample plots across the country leading to higher precision.

In the current ISFR, a new chapter 'Forest Types and Biodiversity' has been added which presents findings of the forest type mapping based on Champion & Seth classification (1968) and the results of the first ever rapid biodiversity assessment of plant species in the 16 Forest Type Groups. Since, forest and hydrology are closely associated, information on extent and types of wetlands within Recorded Forest Area (RFA) is also being presented. A new nation-wide study has been undertaken to assess the dependence of the people living in Forest Fringe Villages for fuelwood, fodder, small timber and bamboo on the forests. The results of the study will not only help in evaluating the impacts of programmes and policies but will also help in understanding the gap between the potential productivity and actual increment observed in the forests of the country. Results of the special study on fire proneness of States based on forest fire alerts generated by FSI in the last 13 years are also

being presented. This information would enable the SFDs to better manage and control forest fires in the respective States. Information on forest cover distribution in different slope classes will be useful in developing strategies for catchment area treatment programmes.

FSI under joint collaboration with ISRO Institutions has undertaken national level project for estimation of Above Ground Biomass (AGB) for the country and has completed biomass mapping for the State of Assam using Phased Array Type L-band Synthetic Aperture Radar (PALSAR) mosaic with forest inventory data at sample plots of FSI.

In view of the wealth of information generated in the current cycle, the ISFR 2019 has been structured into two volumes, Vol I pertaining to the national level assessment,and special studies. VolII is dedicated to the information about each State and Union Territories of the country as sub chapters.

Salient findings

The key findings of the ISFR 2019 are as follows:

- The total forest cover of the country is 7,12,249 sq km which is 21.67% of the geographical area of the country. The tree cover of the country is estimated as 95,027 sq km which is 2.89% of the geographical area.
- The total Forest and Tree cover of the country is 8,07,276 sq km which is 24.56% of the geographical area of the country.
- The current assessment shows an increase of 3,976 sq km (0.56%) of forest cover, 1,212 sq km (1.29%) of tree cover and 5,188 sq km (0.65%) of forest and tree cover put together, at the national level as compared to the previous assessment i.e. ISFR 2017.
- Forest cover within the RFA/GW has shown a slight decrease of 330 sq km (0.05%) whereas there is an increase of 4,306 sq km of forest cover outside the RFA/GW as compared to previous assessment of 2017.
- The top five States in terms of increase in forest cover are Karnataka (1,025 sq km), Andhra Pradesh (990 sq km), Kerala (823 sq km), Jammu & Kashmir (371 sq km) and Himachal Pradesh (334 sq km).
- Forest cover in the hill districts of the country is 2,84,006 sq km, which is 40.30% of the total geographical area of these districts. The current assessment shows an increase of 544 sq km (0.19%) in 140 hill districts of the country.
- The total forest cover in the tribal districts is 4,22,351 sq km, which is 37.54% of the geographical area of these districts. The current assessment shows a decrease of 741 sq km of forest cover within the RFA/GW in the tribal districts and an increase of 1,922 sq km outside.
- Total forest cover in the North Eastern region is 1,70,541 sq km, which is 65.05% of its geographical area. The current assessment shows a decrease of forest cover to the extent of 765 sq km (0.45%) in the region. Except Assam and Tripura, all the States in the region show decrease in forest cover.
- Mangrove cover in the country has increased by 54 sq km (1.10%) as compared to the previous assessment.
- The total growing stock of wood in the country is estimated 5,915.76 million cum comprising 4,273.47 million cum inside forest areas and 1,642.29 million cum outside recorded forest areas (TOF). The average growing stock per hectare in forest has been estimated as 55.69 cum.
- Total bamboo bearing area of the country is estimated as 1,60,037 sq km. There is an increase of 3,229 sq km in bamboo bearing area as compared to the estimate of ISFR 2017.

- In the present assessment, total carbon stock in forest is estimated as 7,124.6 million tonnes. There is an increase of 42.6 million tonnes in the carbon stock of the country as compared to the last assessment of 2017. The annual increase is 21.3 million tonnes, which is 78.1 million tonnes CO2 eq.
- Soil Organic Carbon (SOC) represents the largest pool of carbon stock in forests, which has been estimated 4,004 million tonnes. The SOC contributes 56% to the total forest carbon stock of the country.
- There are 62,466 wetlands covering 3.83% of the area within the RFA/GW of the country. The total number of wetlands located within the RFA/GW is 8.13%. Amongst the States, Gujarat has largest area of wetlands within RFA in the country followed by West Bengal.
- Dependence of fuelwood on forests is highest in the State of Maharashtra, whereas, for fodder, small timber and bamboo, dependence is highest in Madhya Pradesh. It has been assessed that the annual removal of the small timber by the people living in forest fringe villages is nearly 7% of the average annual yield of forests in the country.
- The information on area affected by five major invasive species in States/UTs based on analysis of NFI data has been given in the present ISFR.
- 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 21.40% of the forest cover of the country is highly to extremely fire prone.

TABLE 1 Forest and Tree cover of India in 2019

Class	Area (sq km)	Percentage of Geographical Area
Forest Cover		
Very Dense Forest	99,278	3.02
Moderately Dense Forest	3,08,472	9.38
Open Forest	3,04,499	9.26
Total Forest Cover*	**7,12,249**	**21.67**
Tree Cover	95,027	2.89
Total Forest and Tree Cover	**8,07,276**	**24.56**
Scrub	46,297	1.41
Non-Forest#	25,28,923	76.92
Total Geographic Area	**32,87,469**	**100.00**

* Includes 4,975 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
AWiFS	-	Advanced Wide Field Sensor
BGB	-	Below Ground Biomass
BEF	-	Biomass Expansion Factor
BUR	-	Biennial Update Reports
CBD	-	Convention on Biological Diversity
CD	-	Compact Disc
CNFA	-	Culturable Non-Forest Area
CO_2	-	Carbon Dioxide
CO_2eq	-	Carbon Dioxide Equivalent
COP	-	Conference of the Parties
DBH	-	Diameter at Breast Height
DEM	-	Digital Elevation Model
DF	-	Dense Forest
DIP	-	Digital Image Processing
DOM	-	Dead Organic Matter
FAO	-	The Food & Agriculture Organization of United Nations
FCC	-	False Colour Composite
FCS	-	Forest Carbon Stock
FDC	-	Forest Development Corporation
FFV	-	Forest Fringe Villages
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
GIS	-	Geographical Information System
GPG	-	Good Practices Guidance
GPS	-	Global Positioning System
GW	-	Green Wash
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
JFM	-	Joint Forest Management
LISS	-	Linear Imaging and Self-scanning Sensor
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
NRSC - National Remote Sensing Centre
NSO - National Statistical Office
NTFP - Non-Timber Forest Products
NWDB - National Wasteland Development Board
OF - Open Forest
PA - Protected Area
PAN - Pan-Chromatic
PF - Protected Forest
PISFR - Pre-investment Survey of Forest Resources
POP - Permanent Observation Plots
REDD+ - Reducing Emissions from Deforestation and Forest Degradation Plus
REL - National Forest Reference Emission Level
RF - Reserved Forest
RFA - Recorded Forest Area
RGI - Registrar General of India
SAC - Space Application Centre
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
TC - Tree Cover
TAC - Technical Advisory Committee
TM - Thematic Mapper
TOF - Trees Outside Forests
UFS - Urban Frame Survey
UNFCCC - United Nation Framework Convention on Climate Change
UN-REDD - United Nation 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
WMS - Web Map Service
WP - Working Plan

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 Accounting	One of the main approaches to emissions accounting by estimating the net balance of additions to and removals from, a carbon pool.
Baselines	Also called a counter-factual, the baseline scenario is a reference level that shows what would have happened in the absence of a policy or project designed to reduce emissions.
Bamboo	*Pure:* 151 and more clump/ha for clump forming bamboo or 9001 and more culms / ha for non clump forming *Dense:* 51 to 150 clump/ha for clump forming or 3001 to 9000 culms / ha for non clump forming *Scattered:* 1 to 50 clump/ha for clump forming or 1 to 3000 culms / ha for non clump forming
Below-ground biomass	The BGB carbon pool consists of the biomass contained within live roots.
Biodiversity	The variety of life found on earth (plants, animals, fungi and micro-organisms) as well as the communities that they form and habitats in which they live.
Biomass	Forest biomass is organic matter expressed as oven-dry tonnes per unit area: it can be referred to as biomass density when expressed as mass per unit area. Approximately 50% of dry forest biomass is carbon.
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 crowns 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_2eq)	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 the long term process of storage of carbon in plants, soil, geologic formations and the ocean.
Cartographic Limit	The minimum area of a feature which can be presented on a map at a given scale.
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.
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 (CNFA)	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 (DIP)	Interpretation and classification of digital satellite data using computer and a DIP software.
Drone	A drone, also known as Unmanned Aerial Vehicle (UAVs), 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.
Emissions factor	Emissions 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.
Error Matrix (Confusion matrix)	It is a means to quantitatively assess the accuracy of classification of a 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 Color 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 Fringe Villages	The villages located in the proximity of forest areas.
Forest Reference Level	FRL is 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.
Global Forest Resources Assessment (GFRA)	GFRA, led by Forestry Department of FAO of UN, is an assessment of status and trends of the global forest resources. It contains information on various thematic elements of sustainable forest management and conservation.
Geographic Information System	A computer based system for capturing, storing, manipulating, analyzing and displaying data, which are spatially referenced to the earth.

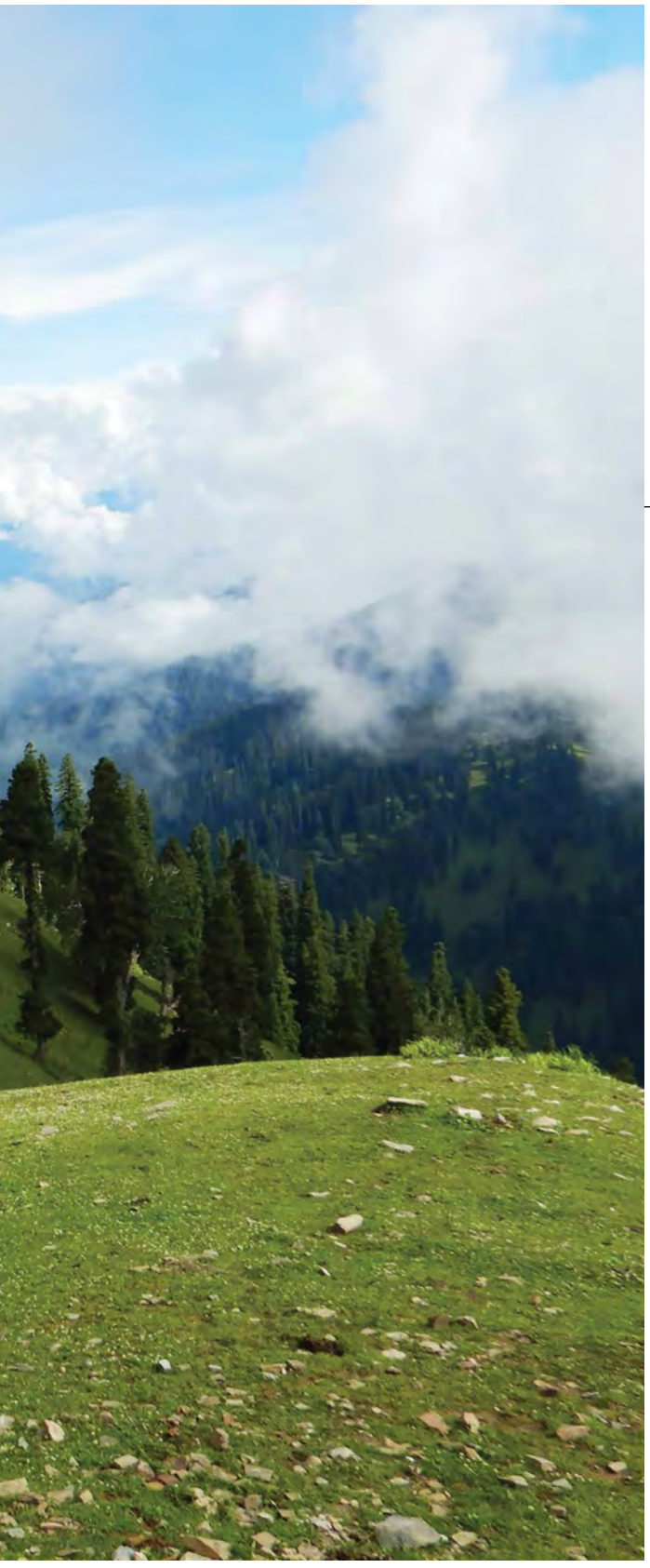
Greenhouse Gas	There are six recognized major greenhouse gases; CO_2 (carbon dioxide), CH_4 (methane), HFCs (hydro fluorocarbons), PFCs (perfluorocarbons), N_20 (nitrous oxide) and SF6 (sulphur hexafluoride). Carbon accounting often refers to the accounting of all major GHGs using a carbon dioxide equivalent (CO_2eq) that standardises these gases based on their global warming potential.
Green Wash	The extent of wooded areas generally shown in light green colour on the Survey of India toposheets.
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.
Invasive Species	The species not native to a specific location (an introduced species) and has a tendency to spread to a degree believed to cause damage to the environment, human economy or human health.
Inventory/Periodic Accounting	One of the main approaches to emissions accounting by measuring the difference in carbon stocks between two points in time.
Kyoto Protocol	In 1992, the Convention on Climate Change was agreed at the United Nations Conference on Environment and Development. In 1997, the Kyoto Protocol made this convention operational. Under the Convention Annex I (developed) countries committed to reduce GHG emissions to, on average, 5.2% of 1990 levels before 2012.
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 (LULUCF)	It is a category within UNFCCC accounting framework for greenhouse gas (GHG) emissions. LULUCF includes carbon pools of living biomass (above and below ground), dead organic matter (dead wood and litter) and organic soil carbon.
Mangroves	Salt tolerant evergreen forest ecosystem found mainly in tropical and sub-tropical 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.
Moderately Dense Forest	All lands with forest cover having a canopy density between 40 to 70 percent.
Moderate Resolution Imaging Spectro radiometer (MODIS)	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.

Non-Timber Forest Products (NTFPs)	It is defined as product or service other than timber that is produced in forests. NTFPs are useful materials or commodities obtained from forests without harvesting (logging) of trees.
Open Forest	Lands with forest cover having a canopy density between 10 to 40 percent.
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.
Physiographic Zone	A physiographic zone constitutes geographical areas that exhibit broad similarities in factors responsible for the growth of tree vegetation. Physiographic zones have been used as strata for assessing tree cover in the country.
Recorded Forest Area	Forest Area recorded as forests in Government records.
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.
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.
Shannon-Weiner Index	A measure of species richness and abundance. It is used for comparing diversity of species between various habitats.
Shuttle Radar Topography Mission (SRTM)	An international research effort that generates the most complete, high-resolution digital topographic database of the Earth.
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.
Soil Organic Matter (SOM)	It is the organic component of soil containing small plants residues, small living soil organism and decomposed organic matter.
Source	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.
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".
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.
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.
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.

Sustainable Development Goals (SDGs)	The SDGs, also known as global goals, are adopted as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. These goals are adopted by all United Nations Member States in 2015.
Thematic Maps	Maps, generally on 1:50,000 scale, showing forest types, major species composition, crown density, other land uses etc. prepared by interpretation of aerial photographs and verified by ground truthing.
Transparency	Transparency requires sufficient and clear documentation of the accounting process so that credibility and reliability of estimates can be assessed by a third party.
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 scattered trees.
Trees Outside Forests (TOF)	TOF refers to all trees growing outside recorded forest areas irrespective of patch size.
Tribal Districts	Districts identified as tribal districts under Tribal Sub-Plan (Government of India).
Uncertainty	Lack of knowledge of the true value of a variable often expressed as a probability density function.
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, normally by using magnifying glass and light table.

UNITS AND THEIR DIMENSIONS USED IN ISFR 2019

Sl. No	Name of Unit	Symbol	Value
1.	Meter	m	1 m = 100 cm
2.	Tonnes	t	1 t = 1,000 kg
3.	Hectare	ha	1 ha = 0.01 sq km 100 ha = 1 sq km
4.	Million hectare	m ha	1 m ha = 1,000,000 ha = 10^6 ha = 10,000 sq km
5.	Million cubic meter	m cum	1 m cum = 1,000,000 m^3
6.	Giga tonnes	Gt	1 Gt = 1,000,000,000 tonnes = 10^9 tonnes = 1,000 million tonnes = 1 billion tonnes
7.	CO_2 equivalent	CO_2eq	1 C = 44/12 CO_2eq = 3.67 CO_2eq



1 Chapter

Introduction

1.1 INTRODUCTION

Forest Survey of India (FSI) presents findings of its mapping and forest resource assessment activities at the national level, biennially, by publishing India State of Forest Report (ISFR). The ISFR 2019 is the 16th report in the series, the first being the report of 1987. Based on the regular nation-wide mapping of forest cover, sample plots based national forest inventory and the specific studies conducted at the national level, the information presented in the ISFR 2019 is primary information on different parameters of the forest resources of the country. Since it is a time series of biennial reports, monitoring of forest resource by comparing different parameters with the previous assessment as change, is a natural outcome.

ISFR meets the vital information needs of the forestry sector of the country and is widely used for policy formulation, planning and management of forests at the national level as well as by the States & UTs. Data presented in the ISFR are also used for various internationally mandated communications to the organisations such as FAO, UNFCCC, CBD etc.

For the sake of easy readability and presentation of large content, which has further grown in this report, in the manageable size of the document, for the first time, ISFR 2019 is being presented in two volumes. The Volume I presents chapters giving national level assessments, whereas, Volume II gives information of each State and UT of the country as separate sub-chapters. Chapters in Volume I include Forest Cover, Mangrove Cover, Forest Types & Biodiversity, Forest Fires, Tree Cover, Growing Stock, Bamboo Stock, Forest Carbon and Forest & People. In Volume II there are sub chapters, each devoted to a particular State or UT wherein district level information on forest cover is also presented.

1.2 TECHNOLOGICAL ADVANCEMENT IN THE ASSESSMENT OF FOREST COVER

Forest Survey of India has always strived to use latest satellite data, technological tools and techniques for its different mapping and forest assessment activities. The latest available satellite data suitable for nation-wide wall-to-wall forest cover mapping are procured from the National Remote Sensing Centre (NRSC) under the Indian Space Research Organisation (ISRO). Over the last three decades, FSI has regularly improved methodology for forest cover mapping. Up to the year 1999, the forest cover mapping used to be done largely by visual interpretation method. In the year 2001, a complete switch-over to the digital interpretation based approach was adopted. In the current cycle, significant improvements in methodology of satellite data interpretation for forest cover mapping have been undertaken and a Manual of Forest Cover Mapping has been published. Methodology in detail has been described in the Chapter 2.

The following table gives an overview of different satellite data, scale of mapping and minimum mappable area used in different assessments in the last 32 years of forest cover mapping.

TABLE 1.1 Satellite Data Used for 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 LISS II	36.25 m	1:250,000	25	Visual & Digital
VI	1997	1993-95	IRS-1B LISS II	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	23.5 m	1:50,000	1	Digital
XIII	2013	2010-11	IRS P6-LISS III	23.5 m	1:50,000	1	Digital
			IRS-Resourcesat-2				
			LISS III				
XIV	2015	2013-14	IRS P6-LISS III	23.5 m	1:50,000	1	Digital
			IRS-Resourcesat-2				
			LISS III				

Cycle of Assessment	Year	Data Period	Sensor	Spatial Resolution	Scale	Minimum Mappable Unit (ha)	Mode of Interpretation
XV	2017	2015-16	IRS P6-LISS III	23.5 m	1:50,000	1	Digital
			IRS-Resourcesat-2				
			LISS III				
XVI	2019	2017-18	IRS-Resourcesat-2	23.5 m	1:50,000	1	Digital
			LISS III				

1.3 FOREST COVER AND RECORDED FOREST AREA

Forest Cover and Recorded Forest Area (RFA) are the two most commonly used terms to describe extent of forest. Though apparently similar terms, forest cover and RFA denote extent of forests with different meanings. Forest cover on one hand gives information about the forest canopy area covered on the ground irrespective of the legal status of land, whereas RFA gives extent of forest in terms of legal status or definition of land as 'forest' irrespective of actual forest canopy cover on the ground.

'Forest cover' term used by FSI includes all tree patches which have canopy density more than 10% and area of 1 ha or more in size, irrespective of their legal status and species composition. On the contrary, the term 'Recorded Forest Area' is used for all such lands which have been notified as forest under any Government Act or Rules or recorded as 'forest' in the Government records. Recorded forest area may or may not have forest cover. Thus forest cover & recorded forest area overlap with each other but they are not coterminous with each other. The diagram given in Fig 1.1 depicts the relationship between the two.

FSI obtains boundaries of recorded forest areas from the State Forest Departments (SFD) as the SFDs are the custodians of the RFAs. The boundaries of RFAs from all the States have not been made available to FSI.

The following table gives extent of RFA under different categories for each State, as received from the respective States/UTs.

FIGURE 1.1 Forest Cover and Recorded Forest Area

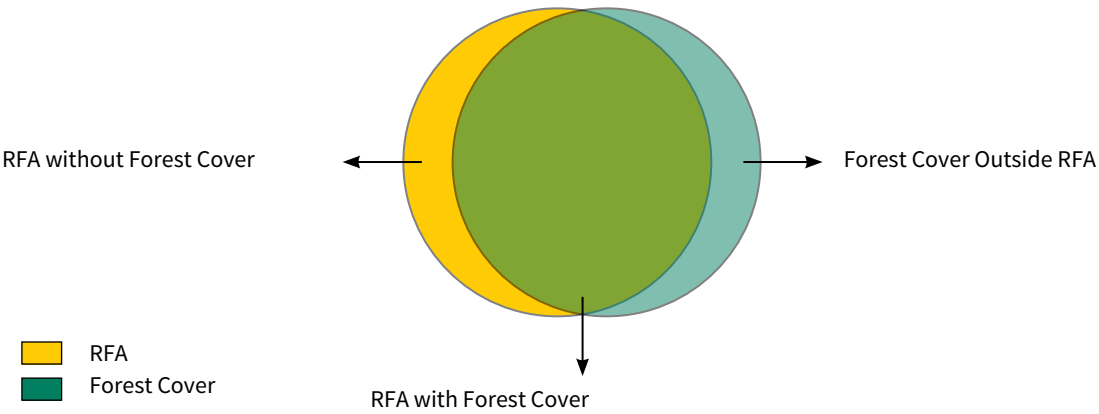


TABLE 1.2 Recorded Forest Areas (RFAs) in States and UTs

(area in sq km)

S.No.	State/ UT	Geographical Area (GA)	RFA (in different categories)			Total RFA (2019)	% of GA
			RF	PF	Unclassed Forests		
1.	Andhra Pradesh	162,968	31,959	5,069	230	37,258	22.86
2.	Arunachal Pradesh	83,743	10,589	9,779	31,039	51,407	61.39
3.	Assam	78,438	17,864	0	8,968	26,832	34.21
4.	Bihar	94,163	693	6,183	1	6,877	7.30
5.	Chhattisgarh	135,192	25,782	24,036	9,954	59,772	44.21
6.	Delhi	1,483	78	24	0	102	6.88
7.	Goa	3,702	253	0	972	1,225	33.09
8.	Gujarat	196,244	14,373	2,886	4,388	21,647	11.03
9.	Haryana	44,212	249	1,158	152	1,559	3.53
10.	Himachal Pradesh	55,673	1,898	33,130	2,005	37,033	66.52
11.	Jammu & Kashmir[#]	222,236	17,643	2,551	36	20,230	9.10
12.	Jharkhand	79,716	4,387	19,185	33	23,605	29.61
13.	Karnataka	191,791	28,690	3,931	5,663	38,284	19.96
14.	Kerala	38,852	11,309	0	0	11,309	29.11
15.	Madhya Pradesh	308,252	61,886	31,098	1,705	94,689	30.72
16.	Maharashtra	307,713	49,546	6,733	5,300	61,579	20.01
17.	Manipur	22,327	1,467	4,171	11,780	17,418	78.01
18.	Meghalaya	22,429	1,113	12	8,371	9,496	42.34
19.	Mizoram	21,081	4,483	0	1,158	5,641	26.76
20.	Nagaland	16,579	234	0	8,389	8,623	52.01
21.	Odisha	155,707	36,049	25,133	22	61,204	39.31
22.	Punjab	50,362	44	1,137	1,903	3,084	6.12
23.	Rajasthan	342,239	12,475	18,217	2,045	32,737	9.57
24.	Sikkim	7,096	5,452	389	0	5,841	82.31
25.	Tamil Nadu	130,060	20,293	1,782	802	22,877	17.59
26.	Telangana	112,077	20,353	5,939	612	26,904	24.00
27.	Tripura	10,486	4,175	2	2,117	6,294	60.02
28.	Uttar Pradesh	240,928	12,071	1,157	3,354	16,582	6.88
29.	Uttarakhand	53,483	26,547	9,885	1,568	38,000	71.05
30.	West Bengal	88,752	7,054	3,772	1,053	11,879	13.38
31.	A & N Islands	8,249	5,613	1,558	0	7,171	86.93
32.	Chandigarh	114	32	0	3	35	30.70
33.	Dadra & Nagar Haveli	491	199	5	0	204	41.55
34.	Daman & Diu	111	0	0	8	8	7.21
35.	Lakshadweep	30	0	0	0	0	0.00
36.	Puducherry	490	0	2	11	13	2.65
Total		**3,287,469**	**434,853**	**218,924**	**113,642**	**767,419**	**23.34**

Source: State Forest Departments

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

1.4 NATIONAL FOREST INVENTORY (NFI)

National Forest Inventory is another major forest resource assessment activity carried out by FSI. The primary objective of the forest inventory is to assess growing stock of trees, number of trees, bamboo, soil carbon, occurrence of NTFP and invasive species and several other parameters depicting growth & health of forest. Forest inventory is done following a standardized sampling design by which sample plots for field observations are laid across the country. FSI has adopted a new grid based NFI design since the year 2016 in which approximately 6,000 sample plots are laid in forest areas and about 10,000 plots are laid in trees outside forests including urban areas every year. The design & methodology of the National Forest Inventory has been described in the Chapter 6.

Another important information which is assessed from the data of TOF inventory is the estimate of tree cover. Tree cover includes all patches of trees occurring outside RFA which are of size less than 1 ha including the scattered trees. Tree cover forms an important part of the trees outsides forests (TOF). Forest cover and tree cover put together is called Forest & Tree Cover which is the parameter for monitoring progress against the national forest policy[1] goal of 33% of the country's geographical area under it.

1.5 SPECIAL FEATURES IN ISFR 2019

1.5.1 Quantified estimation of dependence of people living in the forest fringe villages on forests for fuelwood, fodder, small timber and bamboo.

More than 1,70,000 villages are located in the proximity of forests[2] (FSI, 2000). People living in these villages are dependent on the forests for their needs such as fuelwood, fodder, small timber, NTFPs and Bamboo to a great extent. Their removals from forests in a gradual manner go generally unrecorded and are not accounted for in any valuation process of productivity or flow of benefits. There are no reliable estimates available which provide quantification of removal of these produce in the above manner for the States & UTs or country as a whole. To bridge this information gap, FSI has carried out a study during 2018-19 to estimate the above dependence, by carrying out a country wide survey in the sampled villages. The details of the study are presented in the Chapter 10.

1.5.2 Extent of Trees outside Forest in the country

Trees outside forests (TOF) form significant part of the forest and tree cover of the country and have emerged as major source of timber in India. TOF by definition are trees found outside the recorded forest areas. As mentioned earlier, boundaries of recorded forest areas are not available for all the States & UTs. For assessment of growing stock of TOF under NFI and Tree Cover in such States & UTs, boundaries of green wash given on the Survey of India (SOI) topo sheets have been used as an alternative to the RFA boundaries. Similarly, for forest cover outside the RFA for the States where RFA boundaries are not available, green wash boundaries are used as proxy to RFA. Using the information of forest cover outside RFA/GW and tree cover, extent of TOF has been derived for the first time in the ISFR 2019 and the results are presented in the Chapter 6.

1.5.3 Assessment of plant biodiversity in forests

Forests are considered store houses of biodiversity. There are different drivers which tend to cause degradation of forests leading to loss of biodiversity & reduced ecosystem services from the forests. Biotic pressure, climate change & forest fires are known as important causes of loss of biodiversity. In this scenario, it is important to assess and monitor biodiversity in forests so that timely interventions

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

[2] State of Forest Report 1999 (2000), Forest Survey of India, Ministry of Environment and Forests, Government of India

can be taken if the loss of biodiversity is seen in any forest area. Forest Survey of India, in a first ever attempt has carried out a rapid assessment of biodiversity for all the States and UTs (except two) and for all the sixteen Forest Type Groups as per Champion & Seth Classification (1968). Apart from the number of tree, shrub and herb species as observed in the survey, Shanon Wiener Index which gives species richness along with the relative abundance, has also been calculated for each forest type groups in each State & UT. The results are presented in the Chapter 4.

1.5.4 Refined Forest Type Map of India

FSI has done mapping of forest types of India as per the Champion & Seth Classification (1968), for the first time in the year 2011 based on the base line forest cover data of 2005. A new exercise for refining and updating the forest types as per the latest baseline forest cover was initiated in the year 2016 and has been completed in 2019. Though new forest type atlas is under preparation, the latest forest type map of India along with the area figures of the forest type groups have been presented in the Chapter 4.

1.5.5 Mapping of Fire Prone Forest Areas

FSI sends forest fire alerts to the users who have registered themselves on FSI's website through sms, emails and web map service based on the detected forest fires using MODIS and SNPP VIIRS satellite data in near real time. FSI has been providing this service since 2004, which has improved over a period of time with the evolving technology and better availability of satellite data for this purpose. Using the accumulated data of forest fire detections of the last 14 years, a study has been undertaken by FSI for analyzing forest fire prone areas in the country. Fire prone forest areas of different severity classes were mapped in the grids of 5km x 5km based on the frequency of forest fires in the last 14 years. The results of the study are presented in the Chapter 5 and also for each State &UT in the respective sub chapter in Vol II.

1.5.6 Wetlands in Forest Areas

Large numbers of wetlands are found in forest areas. These wetlands are very important from the biodiversity point of view and play important role in forest-water regime and forest hydrology. Information about their spatial spread, extent and numbers within the forest areas was not available so far. FSI has undertaken a new exercise of overlaying spatial layer of wet lands obtained from Space Application Center (SAC) Ahmedabad over the boundaries of RFA or green wash where RFA boundaries were not available, to derive information about the wetlands within the forest areas. The wetland spatial layer used in the study is the same as presented in the Wetlands Atlas of India published by SAC in 2011[3]. Findings of the study are presented in the Chapter 2 and also for each State and UT in the respective sub chapter in Volume II.

1.5.7 Forest Cover on Slopes

In addition to the forest cover in different altitude zones, an additional exercise has been undertaken to assess forest cover on different slope classes for each State & UT of the country. High forest cover on steep slopes may be a good indicator of stability of mountains and this information may also be useful in catchment area treatment plans. Findings of the study are presented in the Chapter 2 and also for each State & UT in the respective sub chapter in Volume II.

1.5.8 Major Invasive Species

Invasive species pose serious threat to the sustainable management of forests. Information on important invasive species of each State & UT is collected on each sample plot in forest under NFI. Analysis of NFI data has been done for determining five major invasive species in each State & UT and

[3] National Wetland Atlas (2011), SAC, ISRO; sponsored by Ministry of Environment and Forests, Government of India

also an estimate of area affected by them. This information has been presented in the respective sub chapter of each State & UT of the country in Vol II.

1.5.9 Important NTFP Species

NTFPs are important source of livelihood for many tribal communities and villagers living in the proximity of forests. A new information has been generated from the forest inventory data about the top five NTFP species in each State & UT in terms of their availability in forests i.e. relative occurrence. The information has been presented in the respective sub chapter of each State & UT of the country in Vol II.

1.5.10 Diameter-class wise distribution of major tree species in forests

Using NFI data, dia-class distribution of five predominant species in each State &UT of the country has been determined. This information may provide an important input for the sustainable management of forests. The information has been presented in the respective sub chapter of each State & UT of the country in Vol II.

1.5.11 Major species in Trees Outside Forests (TOF)

Five predominant species found in TOF in each State & UT have been analysed from the TOF (Rural) and TOF (Urban) inventory data and the information along with their relative abundance has been presented for each State & UTs in the respective sub chapter in Vol II.

1.6 RECENT INITIATIVES OF FSI

With the objectives of addressing the emerging information needs of the forestry sector of the country and to adopt latest tools and techniques in the field of forest monitoring and assessment, FSI always endeavours to improve the systems & processes used in its activities and new studies are also undertaken. A brief overview of some of the important initiatives is presented in this section.

1.6.1 Submission of Forest Reference Level (FRL) to UNFCCC

FSI has prepared Forest Reference Level (FRL) for the country following the internationally approved methodology given in IPCC Good Practices Guidance (2003)[4]. FRL is the base line emission level from the forests and is also one of the four requirements for a country to be REDD+ ready. It is used for determining performance of the country towards REDD+ implementation and performance based financing. FRL of India was submitted by FSI to MoEF&CC in the year 2018, which after approval, has been submitted to UNFCCC. India's FRL has been uploaded on the website of UNFCCC.

1.6.2 Submission of Country Report on Global Forest Resource Assessment (FRA) 2020

FAO, at the request of its member countries, regularly monitors the world's forests and their management and uses through the GFRA. The FRA process is coordinated by Forestry Department of FAO through nodal agencies in different countries. FSI has been designated as nodal agency for India. The country report for FRA 2020 has been recently submitted by FSI to FAO. GFRA 2020 is expected to be released by March, 2020 by FAO.

1.6.3 Upgradation of Decision Support System (DSS)

FSI established a web GIS based decision support system (DSS) in 2014 for facilitating MoEF&CC in objective decision making in connection with clearances under Forest (Conservation) Act, 1980. The DSS works with inputs from 12 spatial layers in GIS framework. There are two tiers of decision rules viz

[4] Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003), Intergovernmental Panel on Climate Change, Japan

Rule 1 and Rule 2. The polygons of area of interest which pass Rule 1 are subjected to Rule 2 in which scores are assigned based on grids' overlap with the spatial layers. After four years of its operation, upgradation of DSS is under process to incorporate technological advances, add more layers and features to make it more enriched, flexible and robust.

1.6.4 Modernisation of National Forest Inventory

FSI has adopted a new improved NFI design since 2016. The new inventory design is based on grids of size 5km x 5km. The new design has led to several improvements like sampling intensity has increased leading to higher precision, the sample plots are uniformly spread across the country, the cycle of inventory has reduced, several new parameters have been added and State level estimates are possible with better precision.

FSI has taken initiatives to modernise and add further value to NFI by introducing state of the art web GIS based PDA devices with specialized applications for collection of inventory data and its transfer to central data server on real time basis. Another application has been developed for automated data processing and integration of the sample plot data with the geo-spatial layers. A command centre has been established at the FSI headquarters for day to day monitoring of NFI and analysis of data. Field crews have been equipped with gears to increase their efficiency and safety while working in the forests.

1.6.5 Permanent Observation Plots

With an objective of long term ecological monitoring of forests in the country, FSI has undertaken a new activity of establishing a network of permanent observation plots (POP) spread across the country. A design for spreading the POPs in a manner that all the forest types are represented in each State has been finalized. A draft manual has been prepared and after establishing a few POPs, on pilot basis, the first phase of laying out POPs is expected to commence from December 2019.

1.6.6 Establishing a Centre for Methodology Research & Development

FSI uses tools, techniques and methodologies for different monitoring and assessment activities. The methodologies employed by FSI are based on science of the subjects such as remote sensing, statistics, forest biometry, geodesy, forest fire, forest carbon assessment etc. To meet the requirement of regular refinement in methodologies, develop new methodologies for studies and keep pace with the advancements in science and technologies, a need for establishing a centre for research was long felt in FSI. Recently, a Centre for Methodology Research & Development has been established in FSI, Dehradun.

1.6.7 Introduction of Drones in FSI

Drones are emerging technology with several potential applications in monitoring and assessment of forests. FSI has introduced drones in its activities on pilot basis and methodology for application of drones in forest boundary demarcation is being standardized. For building capacity of SFDs in drone applications, FSI has initiated regular training programmes also.

1.6.8 Collaboration with the ISRO Institutions for Forest Biomass Mapping of the Country

FSI has recently entered into collaboration with the ISRO institutions viz Space Application Centre (SAC), Ahmedabad, National Remote Sensing Centre (NRSC), Hyderabad, North Eastern Space Application Centre (NESAC), Shillong for forest biomass mapping at the national level using Synthetic Aperture Radar Data. Under the project, forest biomass mapping of Assam and Odisha States has already been completed.

1.7 INDIA'S FORESTS VIS-À-VIS FOREST RESOURCES IN THE WORLD

Global Forest Resource Assessment (FRA) done by FAO once in five years provides information about the forest resources of almost all the countries in the world. The latest report of GFRA has been released by FAO in the year 2015. Status of the top ten to twelve countries in respect of forest area, change in forest area, growing stock and forest carbon as per the GFRA 2015 are presented in the Tables 1.3 (a) to (d).

TABLE 1.3(a) Forest area for top ten countries in 2015

S.No.	Country	Forest area (000 ha)	% of country area	% global forest area
1.	Russian Federation	8,14,931	48	20
2.	Brazil	4,93,538	58	12
3.	Canada	3,47,069	35	9
4.	USA	3,10,095	32	8
5.	China	2,08,321	22	5
6.	Democratic Republic of the Congo	1,52,578	65	4
7.	Australia	1,24,751	16	3
8.	Indonesia	91,010	50	2
9.	Peru	73,973	58	2
10.	India	70,682	22	2
Total		**26,86,948**		**67**

TABLE 1.3(b) Countries reporting the greatest annual forest area gain (2010-15)

S.No.	Country	Annual Forest area gain	
		Area (000 ha)	% of 2010 forest area
1.	China	1,542	0.8
2.	Australia	308	0.2
3.	Chile	301	1.9
4.	United State of America	275	0.1
5.	Philippines	240	3.5
6.	Gabon	200	0.9
7.	Lao People's Democratic Republic	189	1.1
8.	India	178	0.3
9.	Viet Nam	129	0.9
10.	France	113	0.7

TABLE 1.3 (c) Growing Stock in Forests of the top twelve Countries

S.No.	Country	Growing Stock (m. cum)
1.	Brazil	96,745
2.	Russian Federation	81,488
3.	USA	40,699
4.	Democratic republic of Congo	35,115
5.	China	16,002
6.	Indonesia	10,227
7.	Peru	8,891
8.	Cameron	5,802
9.	Gabon	5,405
10.	Papua New Guinea	5,195
11.	India	5,167
12.	Malaysia	5,034

TABLE 1.3 (d) Forest Carbon Stocks in the top ten Countries

S.No.	Country	Carbon Stock (m. cum)
1.	Russian Federation	1,27,900
2.	Brazil	82,229
3.	USA	41,227
4.	Democratic Republic of Congo	29,683
5.	Indonesia	12,489
6.	Colombia	8,866
7.	China	7,827
8.	India	6,754
9.	Guyana	6,715
10.	Angola	6,485

BOX 1

Sustainable Development Goals

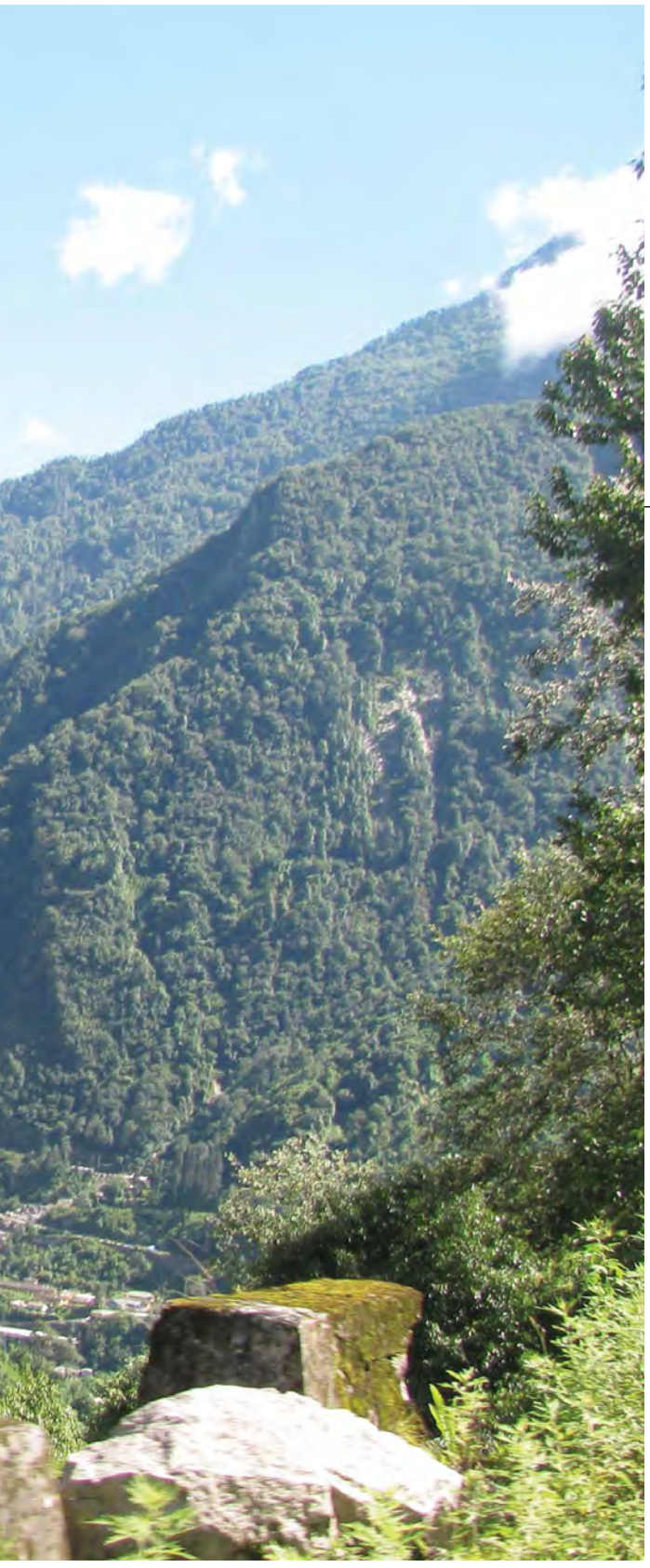
The Sustainable Development Goals (SDGs), were adopted by all the member States of United Nations in 2015 as a universal call of action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030. It consists of 17 goals and 169 targets (UNDP, 2016).

Government of India is committed to achieve the SDGs which is reflected in the integrated approach of development plans and thrust on conservation. The Country's Development paradigm of inclusive growth converges with SDG objectives of 'leaving no one behind'.

A National Indicator framework (NIF) comprising 306 statistical indicators responding to national priorities and needs has been prepared by Ministry of Statistics and Programme Implementation (MOSPI), Government of India. The indicators directly respond to the goals and targets. Most of the goals and targets in the SDGs have environmental dimension and 25 specific targets are identified for priority implementation by the Ministry of Environment, Forest and Climate Change. FSI is reporting on the following National Indicators pertaining to forestry sector.

14.2.1: Percentage change in area under mangroves (2 years)
14.5.2: Percentage change in area under Mangroves (Annual)

15.1.1: Forest area as a proportion of total land area
15.1.2: Percentage of Tree Outside Forest (TOF) in total forest cover
15.2.1: Percentage change in Forest area coverage
15.2.3: Total tree cover achieved outside forest area
15.3.2: Increasing Tree/Forest cover in degraded area
15.4.1: Increase in forest/vegetative cover in mountain areas



2 Chapter

Forest Cover

2.1 INTRODUCTION

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

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

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

2.2 OBJECTIVES OF THE NATION-WIDE FOREST COVER MAPPING

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

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

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

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

2.3 SATELLITE DATA AND PERIOD

The wall-to-wall mapping of forest cover of the country since 1999 is based on data from the indigenous LISS III sensor of IRS Resourcesat series of satellites from Indian Space Research Organization (ISRO). For the current cycle, data from the latest LISS III sensor onboard Resourcesat-2 satellite has been used. The advantage of the LISS III data from Resourcesat-2 is its higher radiometric resolution at 10 bits as compared to 8 bit data of Resourcesat-1, giving more levels of reflectance values. The details of the satellite data used in the current cycle (16th) of forest cover mapping exercise are presented in Table 2.1.

TABLE 2.1 Specifications of LISS III Data from Resourcesat-2

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

The LISS III satellite data used in the current assessment was procured from National Remote Sensing Centre (NRSC), Hyderabad in digital form. Most of the satellite data pertain to the period October to December, 2017 as better foliage conditions are observed in the forests during this period and the images are also generally cloud free. However, some parts of the country especially the North Eastern region and A&N Islands have cloud cover even during this period and in such cases additional images were obtained for the period January to March, 2018. Period of satellite data used for forest cover mapping for different States & UTs is given in the Annexure I. A total of 306 scenes of IRS Resourcesat 2 LISS III covering the whole country have been used for forest cover mapping exercise.

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

2.4 FOREST COVER

Forest cover reported in ISFR includes all lands having trees more than one hectare in area with tree canopy density of more than 10%, irrespective of ownership, legal status of the land and species composition of trees. LISS III data with the resolution 23.5m allows mapping at the maximum scale of 1:50,000, at which the minimum mappable unit (MMU) becomes 1 ha. The MMU represents the cartographic limit of the mapping scale corresponding to a discernible polygon of 2 mm X 2 mm on the map. During the interpretation of the satellite images, forest cover is mapped in canopy density classes as depicted in Table 2.2.

TABLE 2.2 Forest cover classified in terms of canopy density classes

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

2.5 FOREST COVER ASSESSMENT: BROAD APPROACH

The wall-to-wall forest cover mapping of the country is done following a set of sequential steps which involve a hybrid approach for classification of satellite data using digital image processing, visual image analysis, post classification comparison, ground truthing and validation by the State Forest Departments. The broad approach followed in forest cover assessment is depicted in the Fig 2.2 below.

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

FIGURE 2.1 Pictorial depiction of different forest cover classes and scrub

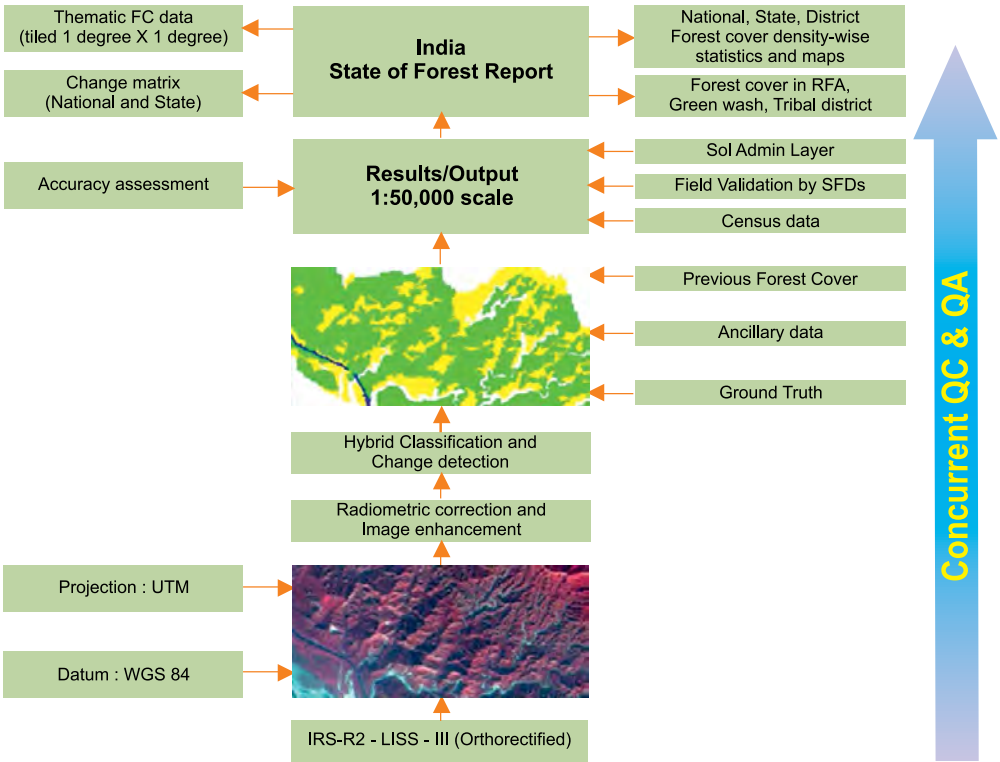
Very Dense Forest

Moderately Dense Forest

Open Forest

Scrub

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



2.6 IMPROVEMENTS IN THE METHODOLOGY OF FCM

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

2.6.1 Use of Ortho rectified LISS III imagery

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

2.6.2 Radiometric correction of ortho-rectified satellite data

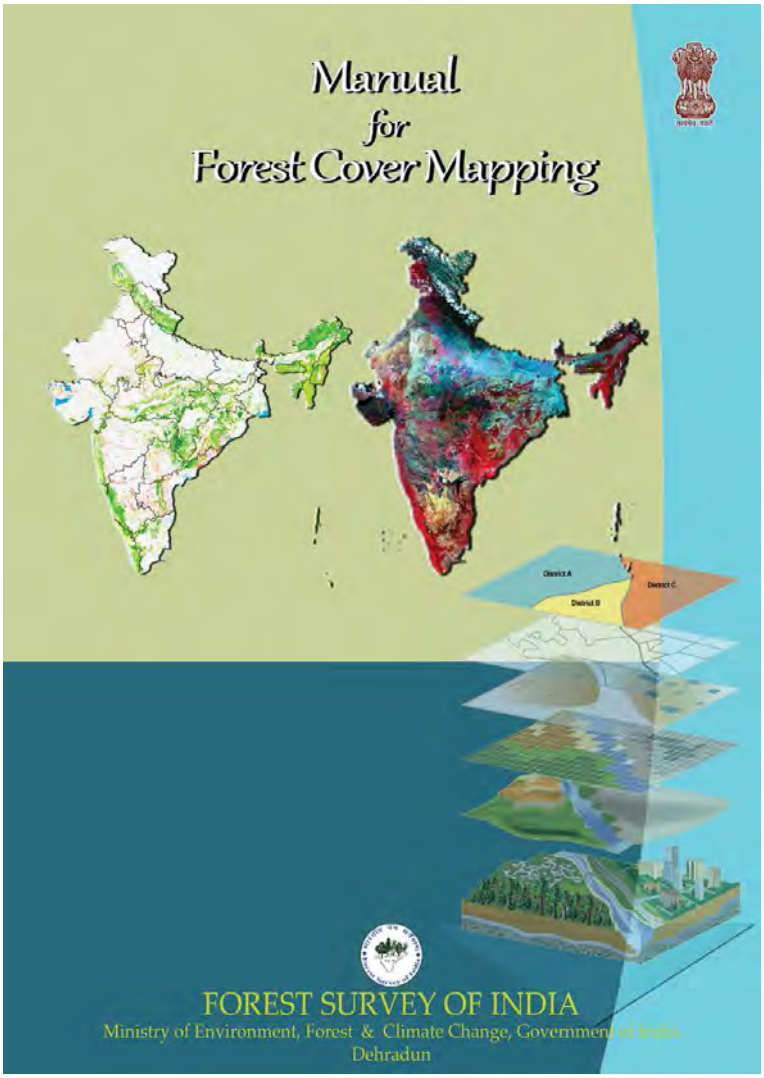
Optical sensors of the satellite record intensity of the reflected electromagnetic radiations from different features on the earth surface as digital numbers (DN) associated with each pixel in different spectral bands. Radiometric correction is carried out to reduce the radiometric distortions, which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

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

2.6.3 Refinement in FCM Methodology and publishing a Manual of FCM

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

FIGURE 2.3 Forest Cover Mapping Manual



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

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

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

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

2.6.3.2 Ground Truthing and Use of Mobile Application

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

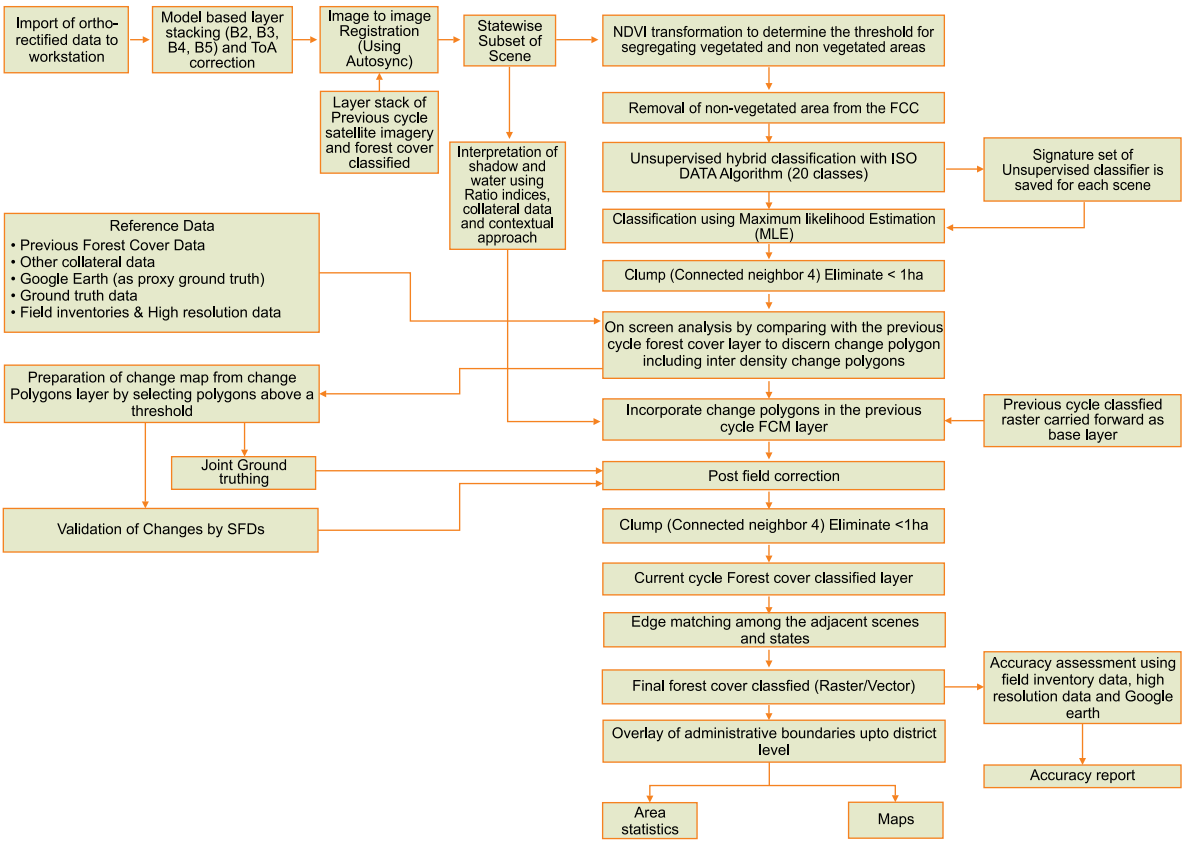
An open source Transerve Data Collector (TDC) mobile application was customized for ground truthing in the current FCM exercise for collection, storage and analysis of Ground Truth observations. The analysts captured the ground data such as geo-tagged photographs, canopy density, tree species and observations related to change and stored them on the mobile application and transmitted the same to the cloud server. The data stored in the server was retrieved and used as point GIS layer over the interpreted forest cover in order to incorporate changes observed during ground truthing.

2.7 FOREST COVER MAPPING METHODOLOGY

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

The previous FCM layer was made compatible with the current satellite data using digital image processing tools of geo-rectification. Registering the previous cycle imagery over the current cycle imagery ensures better image-to-image correspondence, comparability and minimization of errors due to shift over the corresponding forest cover maps.

FIGURE 2.4 Forest Cover Mapping Methodology



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

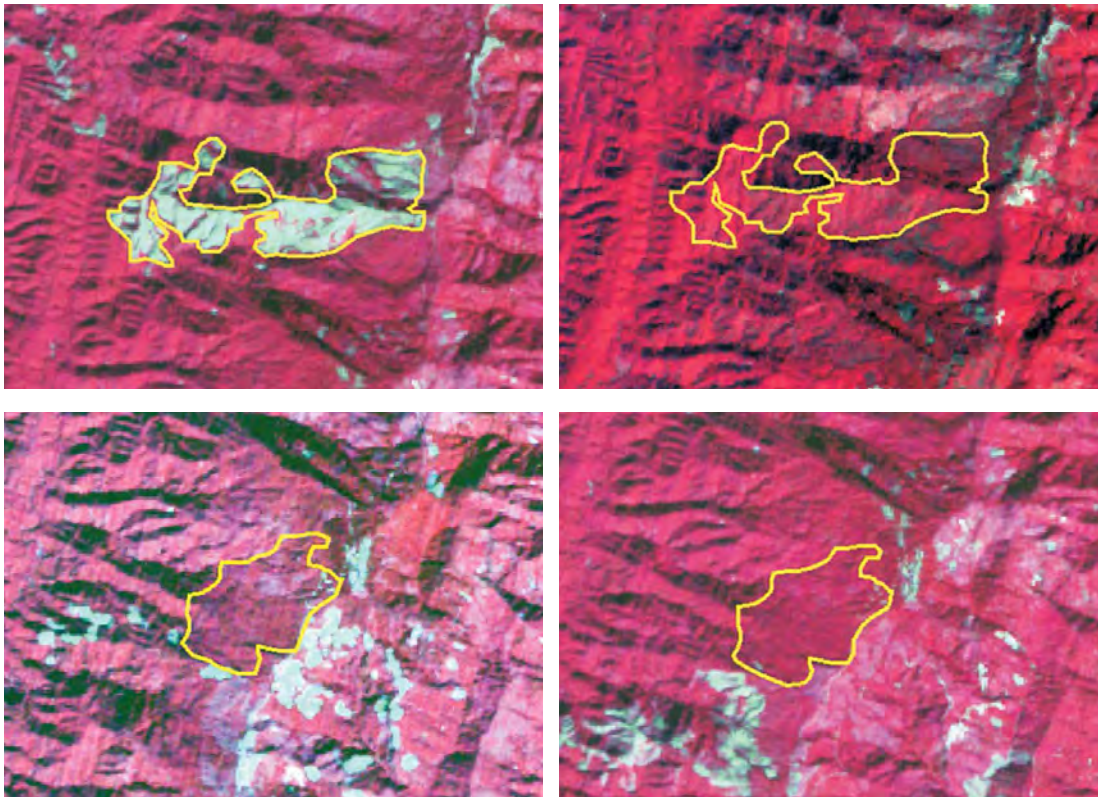
2.7.1 Use of Collateral data to aid interpretation

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

2.7.2 Validation of Change Maps

The change maps depict changes in current forest cover with respect to previous forest cover. As part of methodology the change maps showing polygons above 5 ha in size are sent to SFDs for validation. After receiving the feedback from SFDs, necessary corrections are incorporated in the final change layer. The final layer for the change is retained in both raster and vector formats. Maintaining the layer in vector format helps in incorporating additional information in the attribute table. The vector layer also facilitates compatibility to the GIS environment for further analysis.

FIGURE 2.5 Illustration of change polygons



2.7.3 Post Field Correction

Corrections are incorporated in the interpreted layers of forest cover as per the ground truth observations, ancillary data and inputs from the State Forest Departments. The classification is completed after edge matching with the adjacent scenes as well as with the adjacent States. A mosaic of the classified raster data is created for the entire State, followed by clump & elimination of the patches of area less than 1 ha for smoothening of the FCM layer.

2.8 LIMITATIONS OF THE FOREST COVER MAPPING

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

Some of the significant limitations are as follows:

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

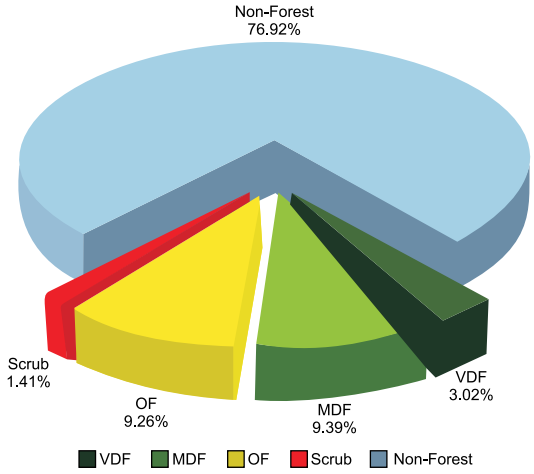
2.9 FOREST COVER: 2019 ASSESSMENT

The forest cover of the country has been mapped into three canopy density classes viz Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF). Scrub areas though not part of the forest cover, have also been mapped. The Table 2.3 presents area figures for the above classes of forest cover and scrub. The relative composition of forest cover in different classes is depicted in the pie chart (Fig 2.6)

TABLE 2.3 Forest Cover of India

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

FIGURE 2.6 Pie-chart showing Forest Cover of India



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

2.10 STATE/UT WISE FOREST COVER

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

FIGURE 2.7 Forest Cover Map of India 2019

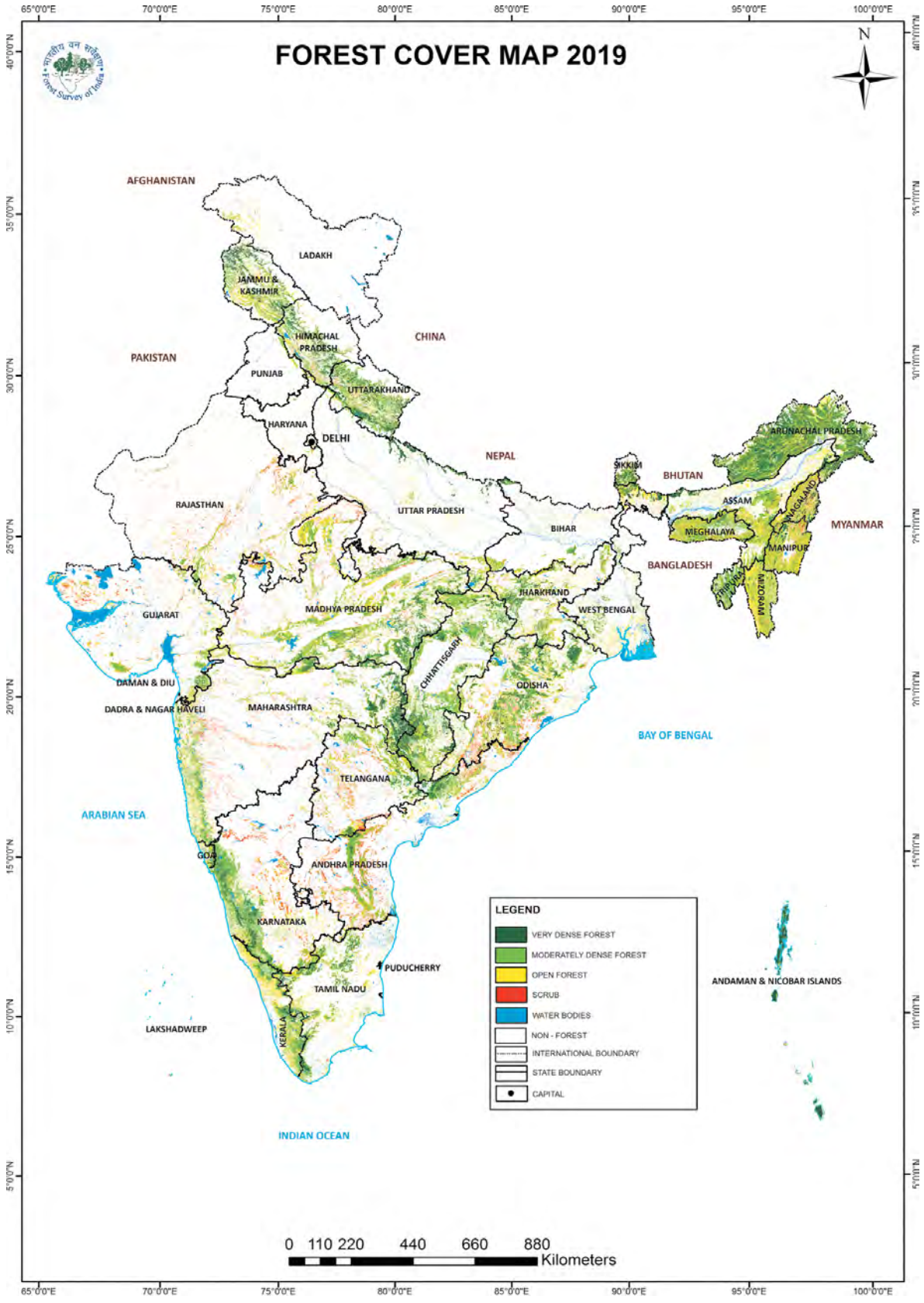


TABLE 2.4 Forest Cover in the States/UTs in India

(area in sq km)

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

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

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

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

2.11 CHANGE IN FOREST COVER

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

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

Gain in forest cover or improvement in forest canopy density may be attributed to better conservation measures, protection, afforestation activities, tree plantation drives and agroforestry whereas, loss in forest cover and impairment of forest canopy may be attributed to shifting cultivation, forest fires, felling of trees, natural calamities,anthropogenic pressure and developmental activities.

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

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

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

(area in sq km)

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

2.12 FOREST COVER INSIDE AND OUTSIDE RECORDED FOREST AREA OR GREEN WASH

Although most of the recorded forest area has vegetation cover on it, yet there are blanks and areas with density less than 10% within it. On the other hand, there are areas outside the recorded forests with tree stands of more than 10% canopy density and size 1 ha or more, such areas also constitute forest cover and are included in the forest cover assessment of FSI. Therefore, the changes taking place in the forest cover is not necessarily due to changes within the recorded forest areas (RFA) but also because of changes outside recorded forest area. The information of forest cover inside and outside RFA/ Green Wash is presented in the Table 2.6.

2.12.1 Recorded Forest Areas (RFA)

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

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

2.12.2 Green Wash

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

In order to carry out this exercise, the green wash boundaries of the country have been digitized largely on 1:50,000 scale using Open Series Maps (OSM) topo-sheets of SOI. Based on the green-wash boundary, the forest cover inside and outside green-wash for the identified States and UTs were extracted using overlay in GIS and the figures were generated separately for both the segments.

TABLE 2.6 Forest Cover inside and outside Recorded Forest Area / Green Wash Area

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

(area in sq km)

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

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

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

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

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

(area in sq km)

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

2.13 CHANGE MATRIX

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

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

(area in sq km)

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

▪ Gain ▪ Loss

2.14 FOREST COVER IN HILL DISTRICTS

Forest cover plays an important role in the mountain ecology and socio-economic life of the hill people. Forests are critical from the point of view of soil, water and environmental conservation in the hills. The forest cover in the hill districts has been given separately. The hill districts have been identified following definition given by the erstwhile Planning Commission of India. There are 140 hill districts as marked by superscript ('H') in the district-wise tables of forest cover in Chapter 11 (Vol II). Table 2.8 gives a State wise summary of forest cover in the hill districts of the country. As seen in the table, there is an increase of 544 sq km in the hill districts of the country.

TABLE 2.8 State wise summary of Forest Cover in Hill districts

(area in sq km)

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

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

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

2.15 FOREST COVER IN TRIBAL DISTRICTS

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

TABLE 2.9 Abstract of Forest Cover in tribal district

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

(area in sq km)

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

2.16 FOREST COVER IN THE NORTH EASTERN STATES

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

TABLE 2.10 Forest Cover in North Eastern States

(area in sq km)

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

2.17 FOREST COVER IN DIFFERENT ALTITUDE ZONES

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

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

(area in sq km)

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

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

2.18 FOREST COVER ON DIFFERENT SLOPE CLASSES

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

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

(area in sq km)

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

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

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

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

TABLE 2.13 Wetlands within Recorded Forest Area/Green Wash

(area in ha)

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

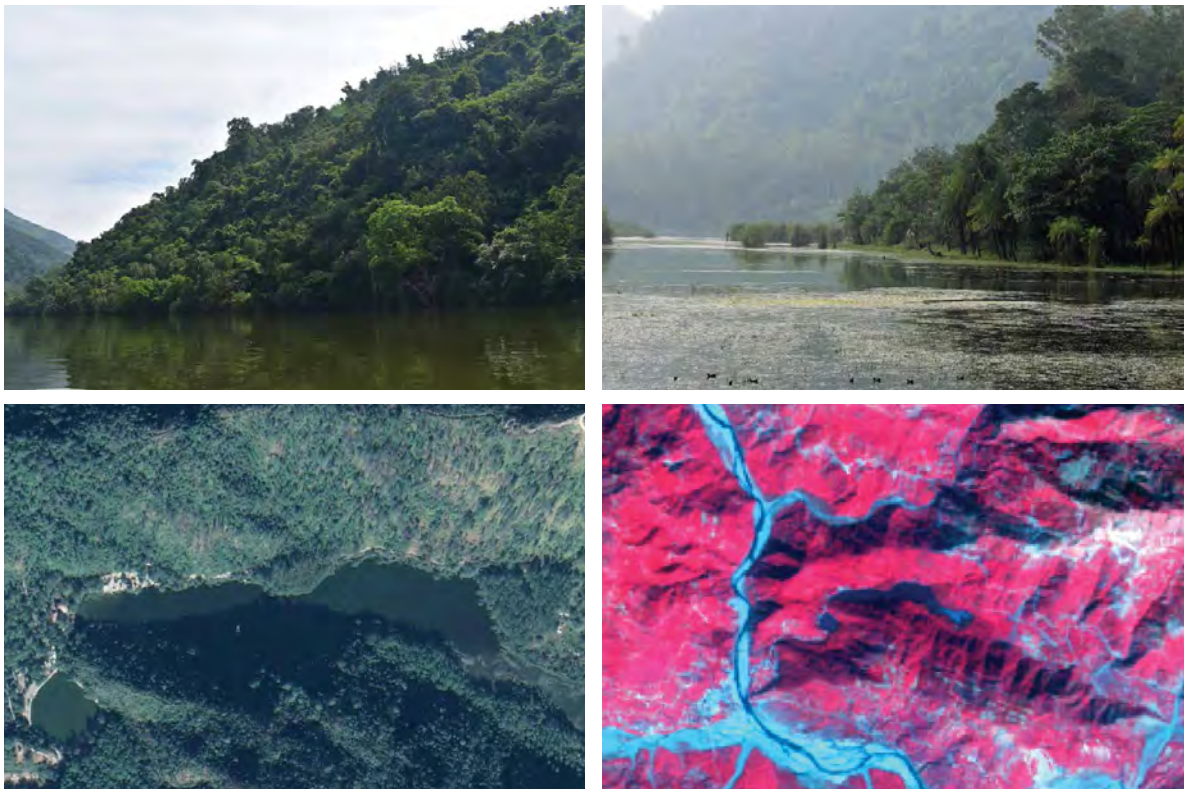
It is seen that among the big States, Gujarat has the largest area of the wetlands within RFA/GW in the country followed by West Bengal. Among the smaller States/UTs Puducherry followed by A&N Islands have large areas of wetlands within RFA/GW. In the country as a whole there are 62,466 wetlands covering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

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

Ranjit Sagar Dam Lake, Pathankot, Punjab

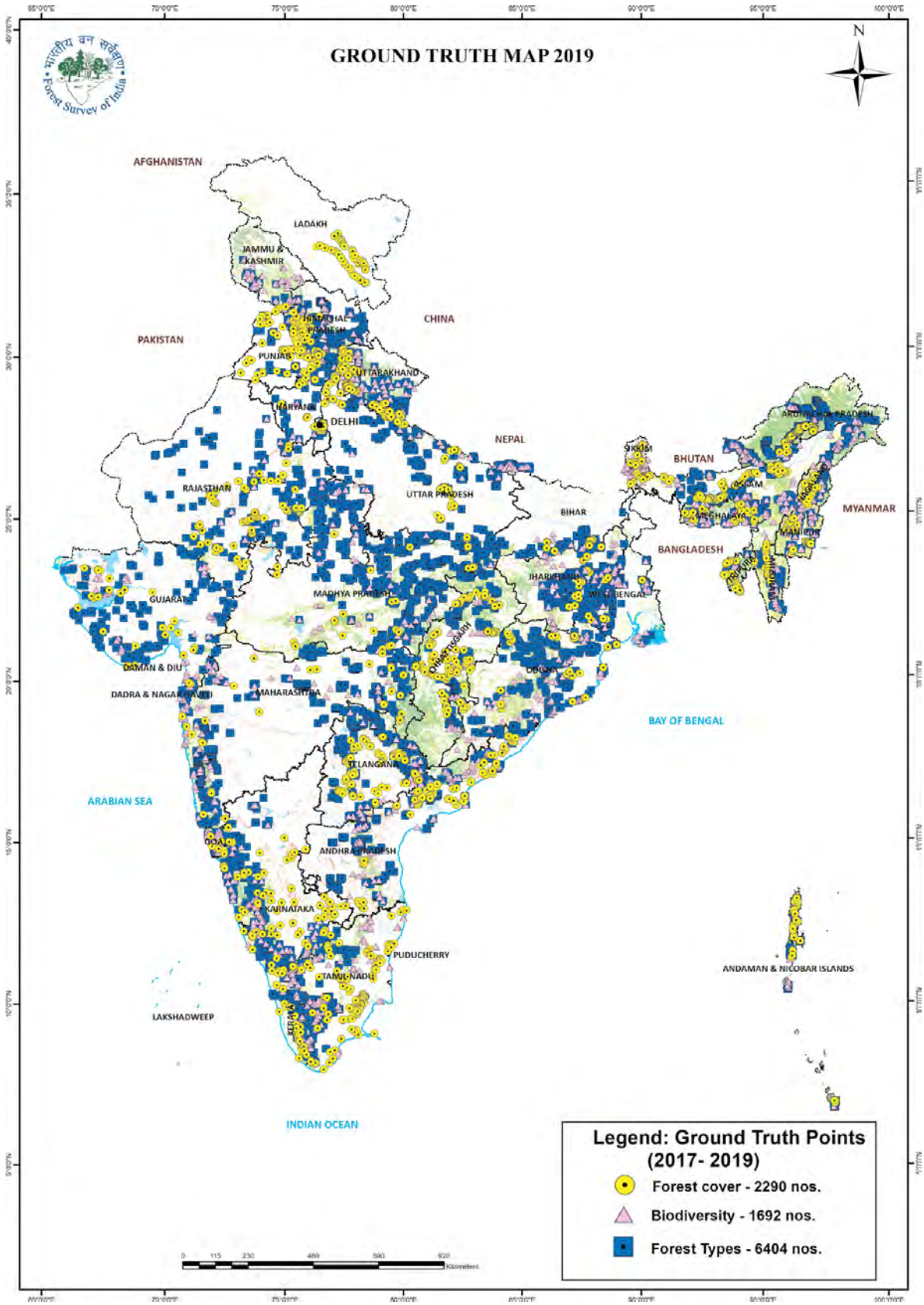
Google Earth imagery of Sep 2018 | LISS III imagery of Oct 2015

Renuka Lake, Sirmaur. Himachal Pradesh



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

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



2.20 ACCURACY ASSESSMENT OF FOREST COVER

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

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

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

2.20.1 Methodology

The sampling design used for assessing the accuracy of classification should ensure proper representation of all the classes of mapping. Similarly, the selection of appropriate sampling size is also very important. Literature suggests that if the area of assessment is large or the classification has large number of vegetation/ land use classes, then the minimum number of samples should be more than 50 sample points per class.

For the purpose of preparing error matrix, a total of 5,283 sample points spread across the country have been selected giving proportionate representation to both forests and TOF. Out of the total 5,283 sample points, 1,305 sample points have been selected from TOF. To record canopy density class at each point, a buffer of 1 ha around the point was created and canopy density on each point is recorded from inventory data. Similarly, canopy density from the classification has been determined for 1 ha buffer on each point. Comparison between the two data sets leads to error matrix.

2.20.2 Findings

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

TABLE 2.14 Error Matrix for Forest Cover Classes

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

A simplified error matrix has also been prepared by grouping the classification into two broad "forest" and "non-forest" classes. This is done by combining VDF, MDF and OF into one class i.e. "Forest". The scrub and the non-forest class have been combined into "Non-Forest". The simplified error matrix is given in Table 2.15. In the simplified error matrix, classification of 5,135 points has been found to be correct, yielding an overall accuracy of 97.20 %.

TABLE 2.15 Error Matrix for Forest and Non-Forest Classes

Classification Classes	Ground truth (based on field inventory data)			User's Accuracy (%)
	Forest	Non-Forest	Total	
Forest	3,451	50	3,501	98.57
Non-Forest	98	1,684	1,782	94.50
Total	3,549	1,734	5,283	
Producer's Accuracy (%)	97.24	97.12		
Overall Accuracy	97.20 %			
Overall Kappa Statistics	0.94			

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

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

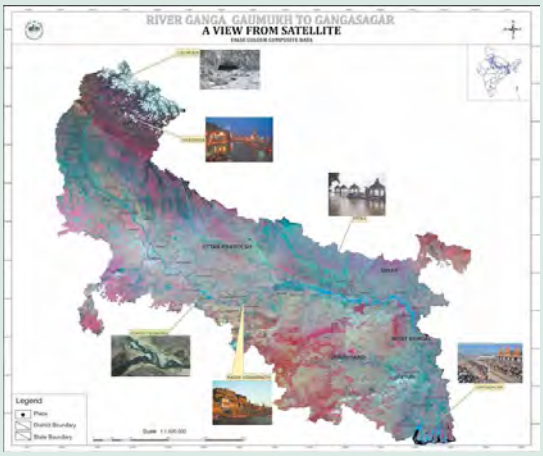
User's accuracy can be obtained by dividing the correct classified units in a class by the total number of units that were classified in that class. One class in the map can have two types of classes on the ground. The 'right' class, refers to the same land-cover-class in the map and on the ground, and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

From Table 2.14, it is found that the producer's accuracy for VDF, MDF, OF, Scrub and Non-forest classes are 97.62%, 93.59%, 88.07%, 85.88% and 97.17% respectively. Similarly, user's accuracy for these classes are 93.41%, 92.86%, 93.12%, 89.94% and 93.80% respectively. The producer's accuracy for forest and non-forest classes are found to be 97.24% and 97.12% respectively while user's accuracy for these classes are 98.57% and 94.50% respectively.

To further authenticate the results of accuracy, Kappa analysis, which is a multivariate technique, providing a statistics known as $K_{HAT.}$ This coefficient gives a measure of overall agreement of error matrix. In contrast to the overall accuracy-the ratio of the sum of diagonal values to total number of sampling points in the error matrix, the Kappa coefficient takes also non-diagonal elements into account. This statistic usually ranges between 0 and 1 and is used to indicate whether the correct values of the error matrix are due to true or chance agreement. Any classification having kappa coefficient more than 0.6 is considered as statistically sound. K_{HAT} calculated from the error matrix given at Table 2.14 is equal to 0.91, which indicates that an observed classification is 91% better than one resulting from chance. For the simplified matrix of forest and non-forest classes, the K_{HAT} value is 0.94.

BOX 2

Forest Cover along Ganga river under Namami Gange Programme



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

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

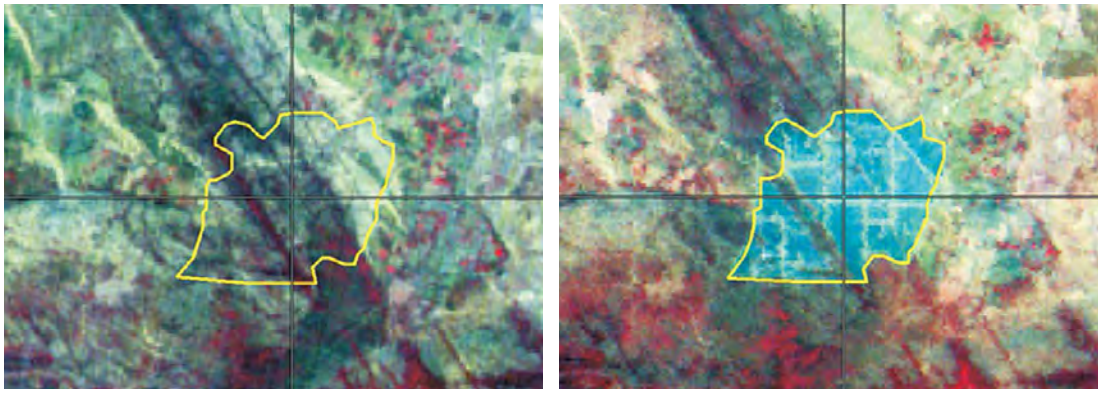
REGION	SPECIES
Himalayan Region	*Pinus wallichiana, Cedrus deodara, Betula utilis, Quercus dilatata, Shorea robusta*
Gangetic Plains	*Dalbergia sissoo, Shorea robusta, Terminalia arjuna, Acacia catechu, Terminalia alata, Tectona grandis*
Deltaic Plains	*Heritiera spp, Ceriops spp, Sonneratia spp, Avicennia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

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

area in sq km

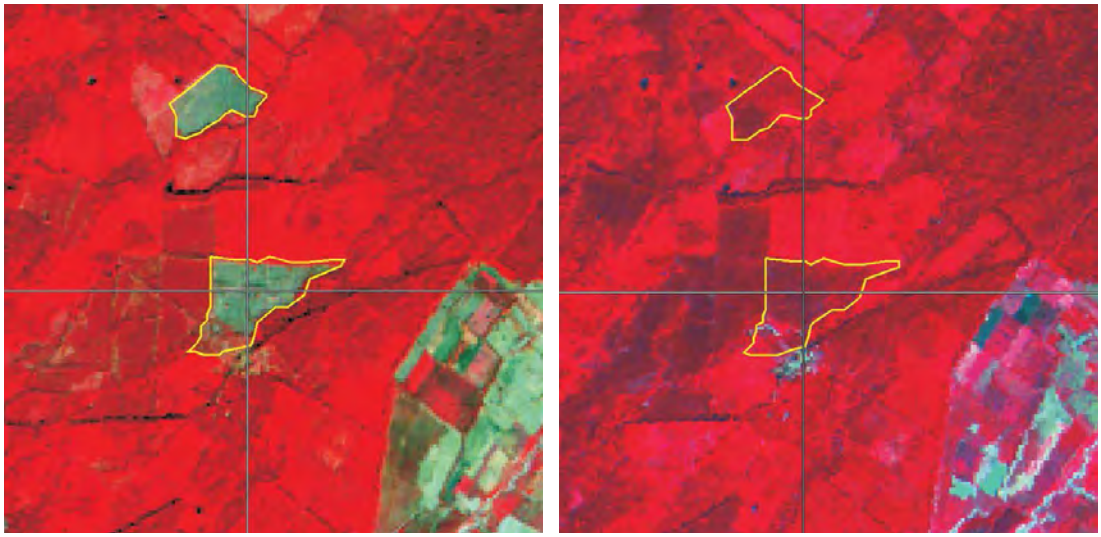
States	Area of River scape	2019 Assessment				
		VDF	MDF	OF	Total Forest Cover	Forest cover as % of River scape area
Uttarakhand	24,189.47	1,689.21	5,283.28	2,885.80	9,858.29	40.75
Uttar Pradesh	26,851.05	66.12	205.20	695.86	967.18	3.60
Bihar	13,466.91	0.00	145.86	133.43	279.29	2.07
Jharkhand	3,599.79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

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



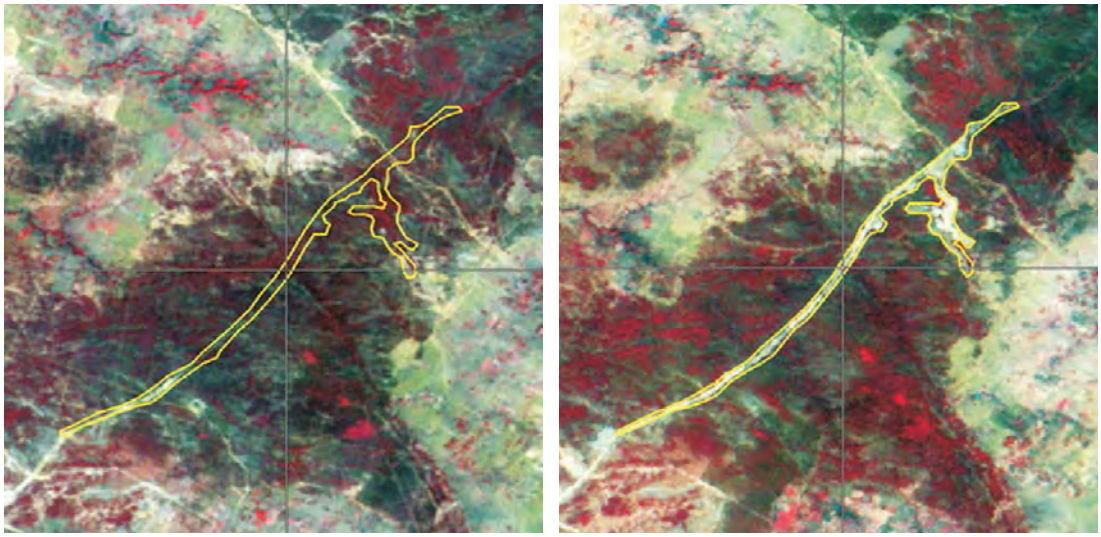
2017 2019

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



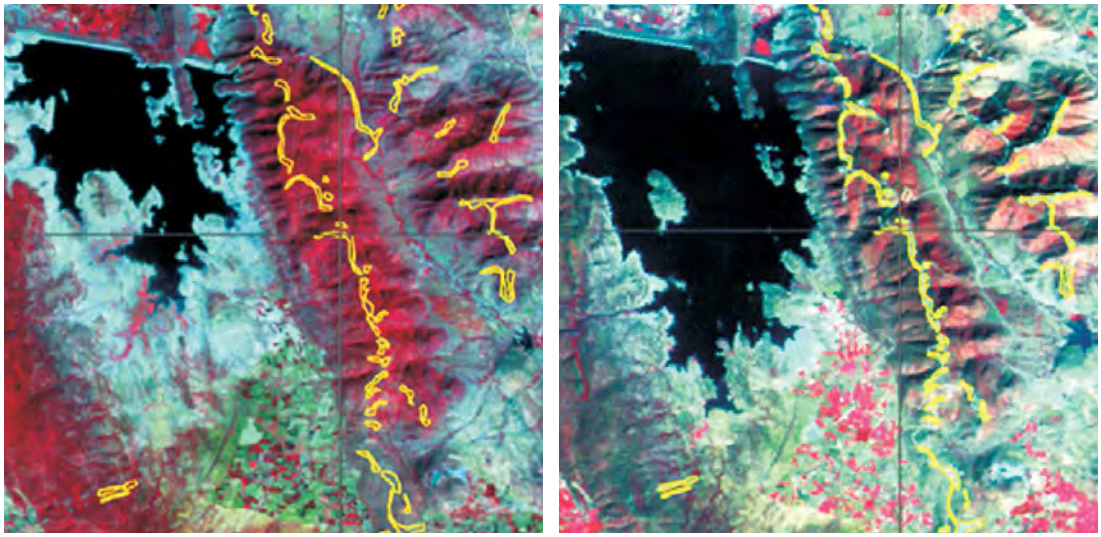
2017 2019

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

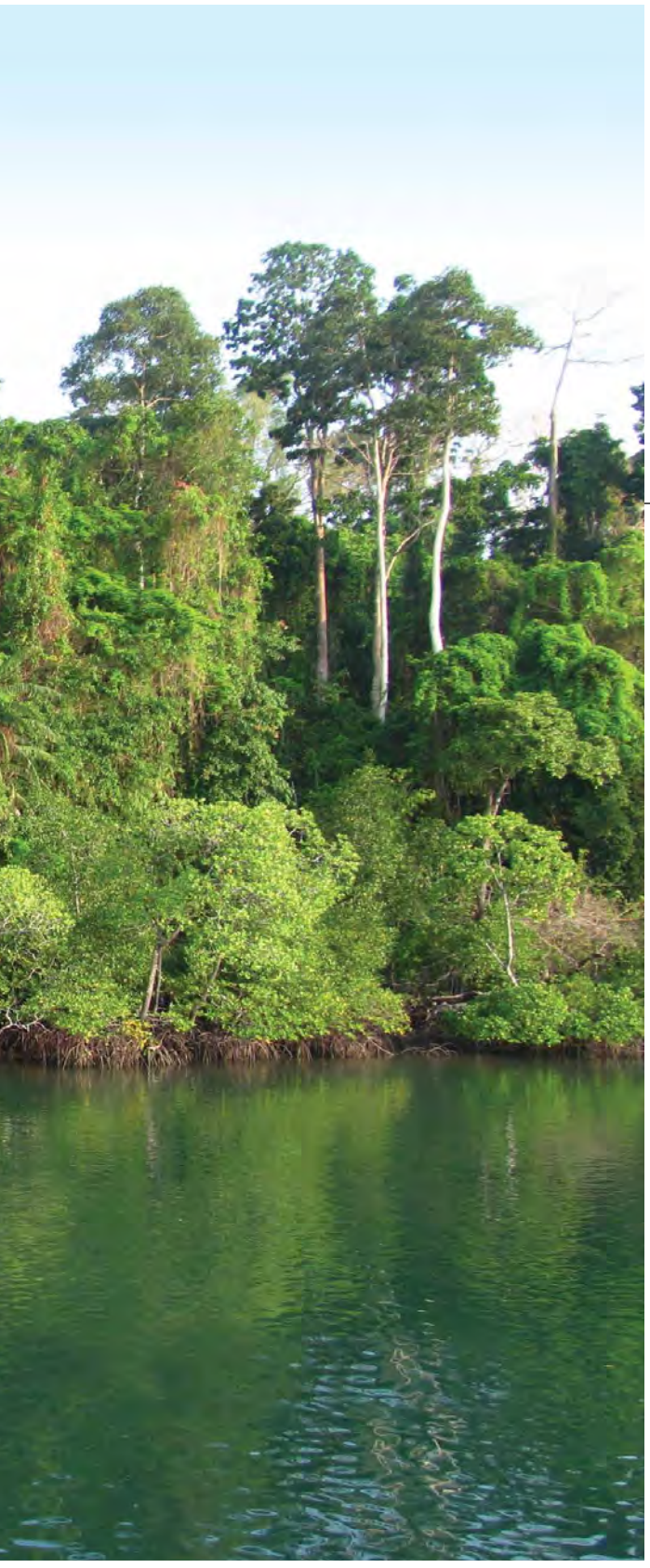


2017 2019

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



2017 2019



3 Chapter

Mangrove Cover

3.1 INTRODUCTION

Mangroves are diverse group of salt-tolerant plant community of tropical and subtropical intertidal regions of the world, occurring mainly between latitude 24^0 N and 38^0 S. They exhibit varied morphological and physiological evolutionary adaptations to survive the limiting factors imposed by lack of oxygen, high salinity and diurnal tidal inundation. Succulent leaves, sunken stomata, aerial breathing roots called 'pneumatophores', vivipary, stilt roots, buttresses etc are some of the adaptations exhibited by mangroves.

Remote sensing is an efficient method of mapping and monitoring of mangroves, because of their conspicuous signatures which are easily discernible on the satellite images. The spread of mangroves particularly those occurring in inaccessible areas can be assessed through remote sensing techniques. Satellite data analysis along with the Geographical Information System (GIS) is the most effective way of regular monitoring of mangrove ecosystems.

3.2 IMPORTANCE OF MANGROVES

a) Mangroves have a complex root system which is very efficient in dissipating the sea wave energy thus protecting the coastal areas from tsunamis, storm surge and soil erosion. Their protective role has been widely recognized especially after the devastating Tsunami of 2004.

b) Mangrove roots slow down water flows and enhance sediment deposition. Therefore, they act as a zone of land accretion due to trapping of fine sediments including heavy metal contaminants. They also arrest coastal erosion and sea water pollution.

c) They act as a fertile breeding ground for many fish species and other marine fauna.

d) They act as an important source of livelihood for the coastal communities dependent on collection of honey, tannins, wax and fishing.

e) Mangroves are important carbon sink.

3.3 GLOBAL STATUS OF MANGROVE COVER

The total Mangrove cover in the world is 15 million ha[1] which is 1% of the Tropical Forests of the World. Mangroves are mostly distributed over 123 countries and territories in the tropical and sub-tropical regions. Asia has the largest extent of the world's mangroves**.** About 40% of world's Mangrove Cover is found in South East Asia and South Asia followed by South America, North Central America and West and Central Africa. Amongst the remaining six regions (South Asia, Australia/New Zealand, East and South Africa, Pacific Ocean, East Asia, Middle East), South Asia has the highest percentage 6.8% comprising 10,344 sq km mangrove cover. India has about 3% of the total Mangrove cover in South Asia.

3.4 CONSERVATION OF MANGROVES

Mangrove ecosystems are under pressure due to increased human population in coastal areas and rising demand for small timber, fodder, fuelwood and other non-wood forest products. Appropriate management and conservation strategies are required for their conservation and sustainably generate the ecosystem benefits along with the forest products to meet the needs of local people.

Mangroves are rich in biodiversity. According to Champion & Seth Classification (1968)[2] Mangroves are included in Type Group-4 Littoral & Swamp Forests and are covered under 4A/L1 Littoral forest, 4B/TS1 Mangrove scrub, 4B/TS2 Mangrove forest, 4B/TS3 Saltwater mixed forest (*Heritiera*), and 4B/TS4 Brackish water mixed forest (*Heritiera*) types. Mangrove bearing States are implementing different measures for conservation and management of mangroves. Some important techniques adopted in Gujarat for restoration of degraded mangrove habitats are direct seed sowing, raised bed plantation and fishbone channel plantation. In Andhra Pradesh, Forest Department has formed Eco-Development Committees and Van Samrakshan Samithis for joint implementation of projects in mangrove areas. Regular, trainings are also being conducted for sustainable mangrove conservation. In Maharashtra, steps have been taken to conserve ecology and biodiversity of mangroves by protection, restoration, regeneration and maintenance. Important species of mangrove ecosystems in India include *Avicennia officinalis, Morinda citrifolia, Rhizophora mucronata, Sonneratia alba, Avicennia alba, Bruguiera cylindrica, Heritiera littoralis, Phoenix paludosa, Morinda citrifolia* & *Ceriops tagal.*

[1] The world's mangrove 1980-2005 (2007), FAO Forestry Paper 153, Food and Agricultural Organization of the UN

[2] Champion H.G. and Seth S.K. (1968). A revised survey of: The Forest Types of India. Forest Research Institute, Dehradun

3.5 MANGROVE COVER: 2019 ASSESSMENT

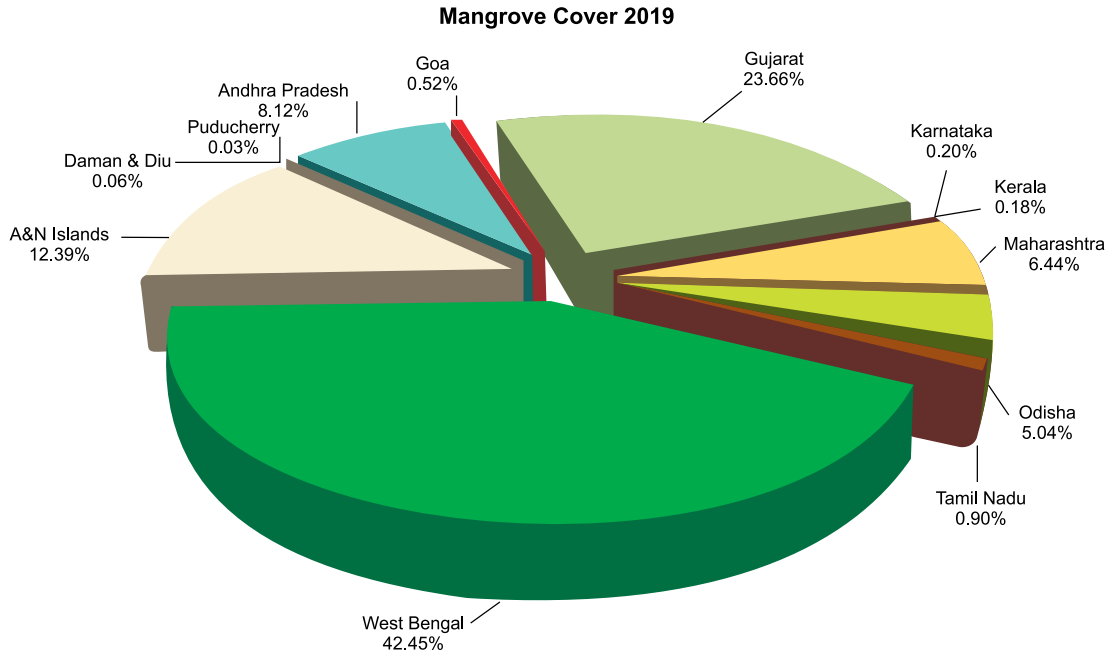
Mangrove Cover assessment is part of the country-wide forest cover mapping. Forest cover given in chapter 2 includes mangrove cover, however because of their special ecological significance, district wise mangrove cover in different States/UTs are being presented in this chapter. The current assessment shows that mangrove cover in the country is 4,975 sq km, which is 0.15% of the country's total geographical area. Very Dense mangrove comprises 1476 sq km (29.66%) of the mangrove cover, Moderately Dense mangrove is 1479 sq km (29.73%) while Open mangroves constitute an area of 2020 sq km (40.61%). There has been a net increase of 54 sq km in the mangrove cover of the country as compared to 2017 assessment. The State/UT wise extent of mangrove cover in the three canopy density classes along with the change in comparison to 2017 assessment is presented in the Table 3.1. Mangrove Cover maps of different States/UTs are shown in Fig 3.3 (a) to Fig 3.3 (l).

TABLE 3.1 Mangrove Cover Assessment 2019

(area in sq km)

S.No.	State/UT	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change with respect to ISFR 2017
1.	Andhra Pradesh	0.00	213.00	191.00	404.00	0.00
2.	Goa	0.00	20.00	6.00	26.00	0.00
3.	Gujarat	0.00	169.00	1,008.00	1,177.00	37.00
4.	Karnataka	0.00	2.00	8.00	10.00	0.00
5.	Kerala	0.00	5.00	4.00	9.00	0.00
6.	Maharashtra	0.00	88.00	232.00	320.00	16.00
7.	Odisha	81.00	94.00	76.00	251.00	8.00
8.	Tamil Nadu	1.00	27.00	17.00	45.00	-4.00
9.	West Bengal	996.00	692.00	424.00	2,112.00	-2.00
10.	A&N Islands	398.00	169.00	49.00	616.00	-1.00
11.	Daman & Diu	0.00	0.00	3.00	3.00	0.00
12.	Puducherry	0.00	0.00	2.00	2.00	0.00
Total		**1,476.00**	**1,479.00**	**2,020.00**	**4,975.00**	**54.00**

FIGURE 3.1 Pie Chart showing Mangrove Cover in different States & UTs



It may be seen that West Bengal has 42.45% of India's mangrove cover, followed by Gujarat 23.66% and A&N Islands 12.39%. Gujarat shows maximum increase of 37 sq km in mangrove cover.

3.6 DISTRICT WISE MANGROVE COVER

The district wise mangrove cover in different States/UTs is given in Table 3.2

TABLE 3.2 District wise Mangrove Cover

(area in sq km)

S. No.	State/UTs and District	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change w.r.t. 2017 Assessment
1.	**Andhra Pradesh**					
	East Godavari	0.00	126.00	62.06	188.06	0.06
	Guntur	0.00	35.00	33.00	68.00	0.00
	Krishna	0.00	50.18	86.90	137.08	0.08
	Sri Potti Sriramalu Nellore	0.00	2.00	8.00	10.00	0.00
	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**	**213.18**	**190.96**	**404.14**	**0.14**
2.	**Goa**					
	North Goa	0.00	17.00	3.00	20.00	0.00
	South Goa	0.00	3.00	3.00	6.00	0.00
	Total	**0.00**	**20.00**	**6.00**	**26.00**	**0.00**
3.	**Gujarat**					
	Ahmedabad	0.00	0.87	30.18	31.05	-0.95
	Amreli	0.00	0.00	2.37	2.37	0.37
	Anand	0.00	0.00	7.25	7.25	-0.75
	Bharuch	0.00	13.35	31.09	44.44	-0.56
	Bhavnagar	0.00	5.90	15.73	21.63	-0.37
	Jamnagar	0.00	28.06	201.44	229.50	45.50
	Junagarh	0.00	0.00	3.33	3.33	0.33
	Kuchchh	0.00	116.41	678.36	794.77	-3.23
	Navsari	0.00	0.00	12.97	12.97	-1.03
	Porbandar	0.00	0.00	1.00	1.00	0.00
	Rajkot	0.00	0.90	2.63	3.53	-0.47
	Surat	0.00	3.87	16.40	20.27	-0.73
	Vadodara	0.00	0.00	3.00	3.00	0.00
	Valsad	0.00	0.00	2.16	2.16	-0.84
	Total	**0.00**	**169.36**	**1,007.91**	**1,177.27**	**37.27**
4.	**Karnataka**					
	Uttar Kannada	0.00	0.28	8.22	8.50	0.00
	Udupi	0.00	1.54	0.00	1.54	0.00
	Total	**0.00**	**1.82**	**8.22**	**10.04**	**0.00**
5.	Kerala					
	Ernakulum	0.00	0.79	1.03	1.82	0.00
	Kannur	0.00	3.89	2.35	6.24	0.00
	Kasaragod	0.00	0.01	0.83	0.84	0.00
Total		**0.00**	**4.69**	**4.21**	**8.90**	**0.00**

S. No.	State/UTs and District	Very Dense Mangrove	Moderately Dense Mangrove	Open Mangrove	Total	Change w.r.t. 2017 Assessment
6.	**Maharashtra**					
	Mumbai city	0.00	0.00	2.00	2.00	0.00
	Mumbai Sub-urban	0.00	27.00	37.30	64.30	0.30
	Raigarh	0.00	12.00	108.97	120.97	14.97
	Ratnagiri	0.00	15.00	15.15	30.15	0.15
	Sindhudurg	0.00	5.00	7.19	12.19	0.19
	Thane	0.00	29.00	61.66	90.66	0.66
	Total	**0.00**	**88.00**	**232.27**	**320.27**	**16.27**
7.	**Odisha**					
	Baleshwar	0.00	1.00	4.07	5.07	0.07
	Bhadrak	0.00	8.76	26.11	34.87	2.87
	Jagatsinghpur	0.00	1.01	7.05	8.06	0.06
	Kendrapara	80.45	83.56	37.48	201.49	4.49
	Puri	0.00	0.00	1.15	1.15	0.15
	Total	**80.45**	**94.33**	**75.86**	**250.64**	**7.64**
8.	**Tamil Nadu**					
	Cuddalore	0.00	7.05	0.68	7.73	0.00
	Nagapattinam	0.00	1.10	1.95	3.05	-1.07
	Pudukkottai	0.67	0.46	0.77	1.90	0.00
	Ramanathapuram	0.37	0.71	1.26	2.34	0.16
	Thanjavur	0.00	8.96	3.29	12.25	0.00
	Thiruvallur	0.00	0.00	0.91	0.91	0.00
	Thiruvarur	0.00	8.11	4.74	12.85	-3.04
	Thoothukkudi	0.00	0.85	2.95	3.80	0.00
	Total	**1.04**	**27.24**	**16.55**	**44.83**	**-3.95**
9.	**West Bengal**					
	Purba Medinipur	0.00	1.00	3.00	4.00	0.00
	North 24 Parganas	12.97	10.98	1.99	25.94	-0.06
	South 24 Parganas	982.65	680.02	419.50	2082.17	-1.83
	Total	**995.62**	**692.00**	**424.49**	**2,112.11**	**-1.89**
10.	**A&N Islands**					
	North Andaman	284.76	111.90	27.86	424.52	-0.48
	South Andaman	113.65	54.88	21.20	189.73	-0.27
	Nicobar	0.00	2.00	0.03	2.03	0.03
	Total	**398.41**	**168.78**	**49.09**	**616.28**	**-0.72**
11.	**Daman & Diu**					
	Daman	0.00	0.00	1.02	1.02	0.02
	Diu	0.00	0.00	2.08	2.08	0.08
	Total	**0.00**	**0.00**	**3.10**	**3.10**	**0.10**
12	**Puducherry**					
	Karaikal	0.00	0.00	0.00	0.00	0.00
	Mahe	0.00	0.00	0.00	0.00	0.00
	Puducherry	0.00	0.00	0.00	0.00	0.00
	Yanam	0.00	0.00	1.64	1.64	0.00
	Total	**0.00**	**0.00**	**1.64**	**1.64**	**0.00**
Grand Total		**1,475.52**	**1,479.40**	**2,020.30**	**4,975.22**	**54.86**

The above table shows that South 24 Parganas district of West Bengal alone accounts for 41.85% mangrove cover of the country.

FIGURE 3.2 Photo showing Mangrove Forest Ecosystem

FIGURE 3.3a Map showing Mangrove cover in Andhra Pradesh

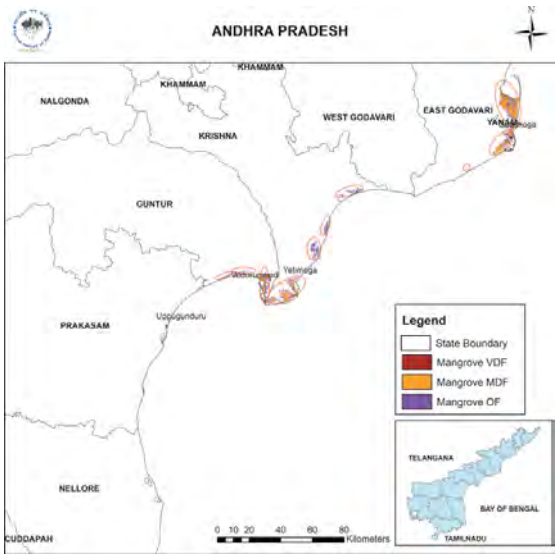


FIGURE 3.3b Map showing Mangrove cover in Goa

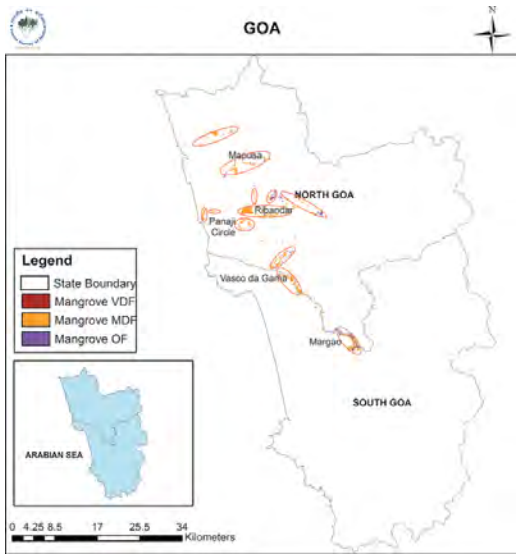


FIGURE 3.3c Map showing Mangrove cover in Gujarat

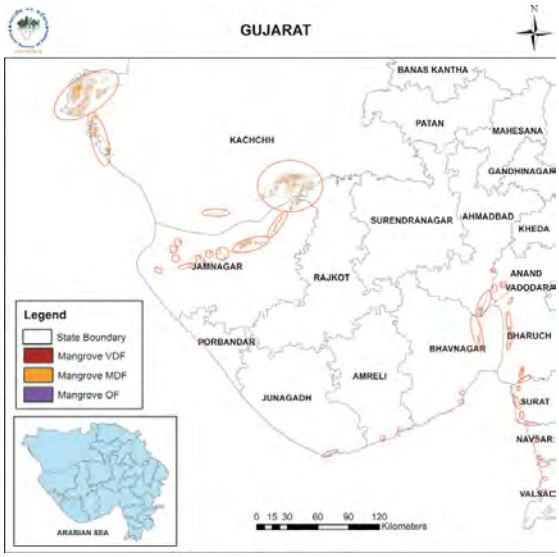


FIGURE 3.3d Map showing Mangrove cover in Karnataka

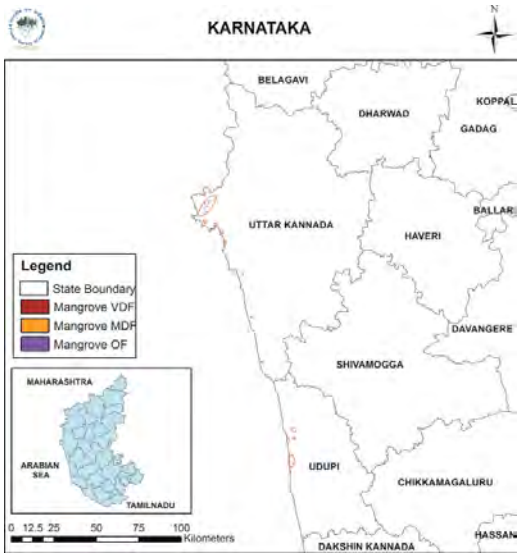


FIGURE 3.3e Map showing Mangrove cover in Kerala

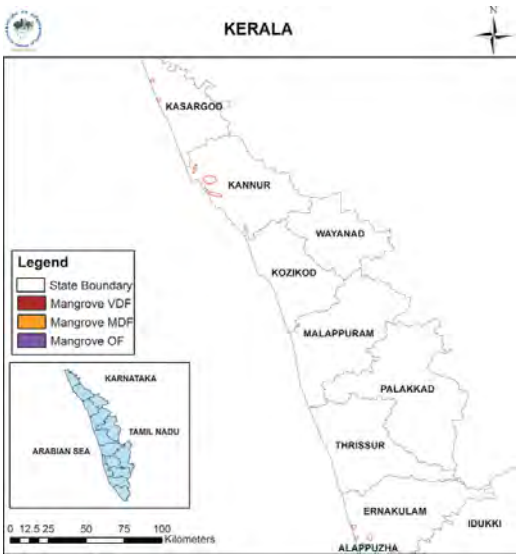


FIGURE 3.3f Map showing Mangrove cover in Maharashtra

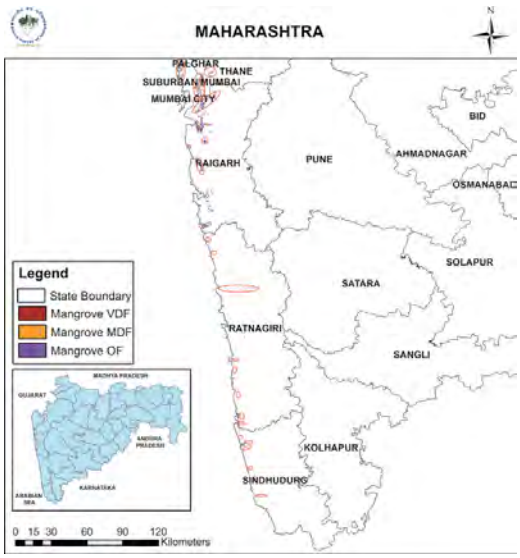


FIGURE 3.3g Map showing Mangrove cover in Odisha

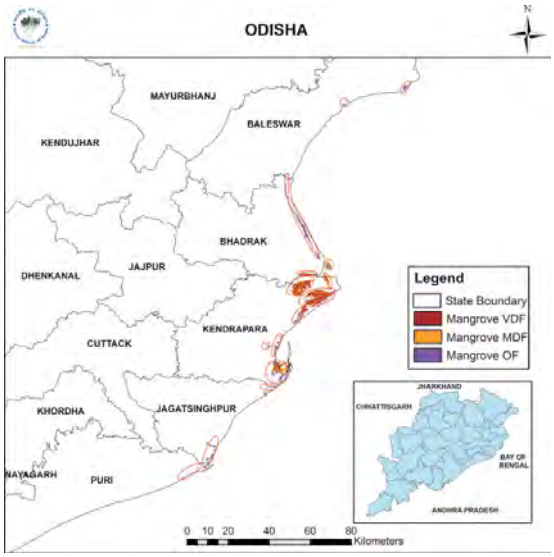


FIGURE 3.3h Map showing Mangrove cover in Tamil Nadu

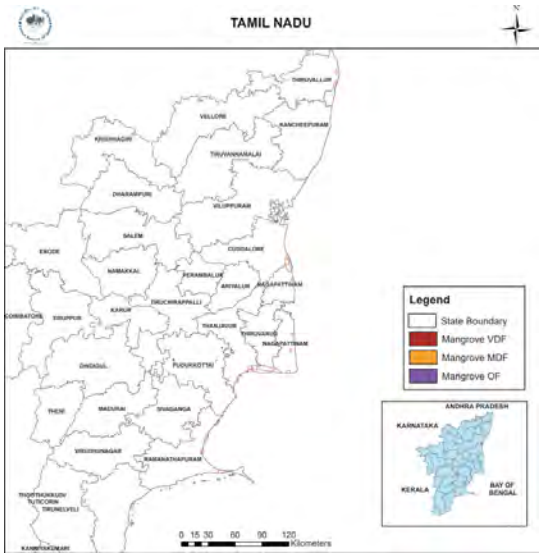


FIGURE 3.3i Map showing Mangrove cover in West Bengal

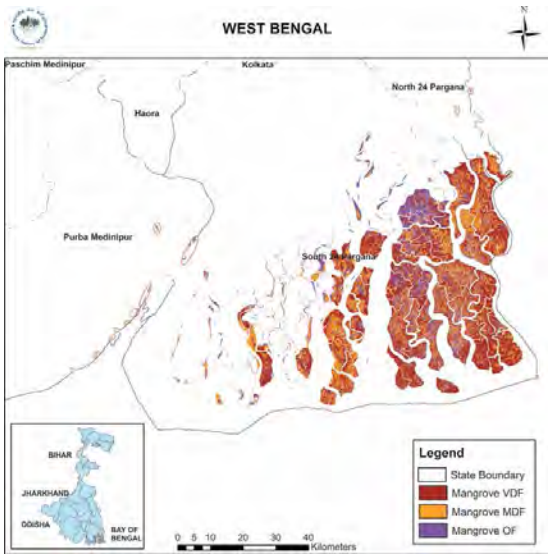


FIGURE 3.3j Map showing Mangrove cover in A & N Islands

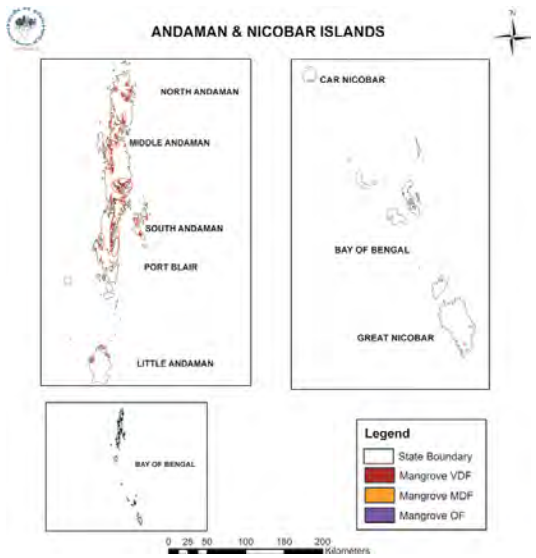


FIGURE 3.3k Map showing Mangrove cover in Daman & Diu

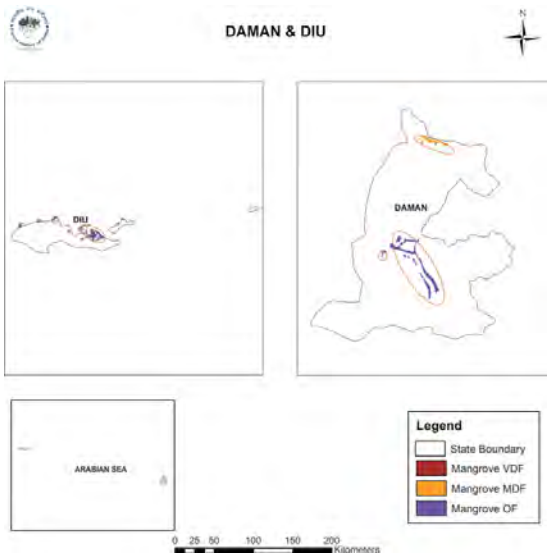


FIGURE 3.3l Map showing Mangrove cover in Puducherry

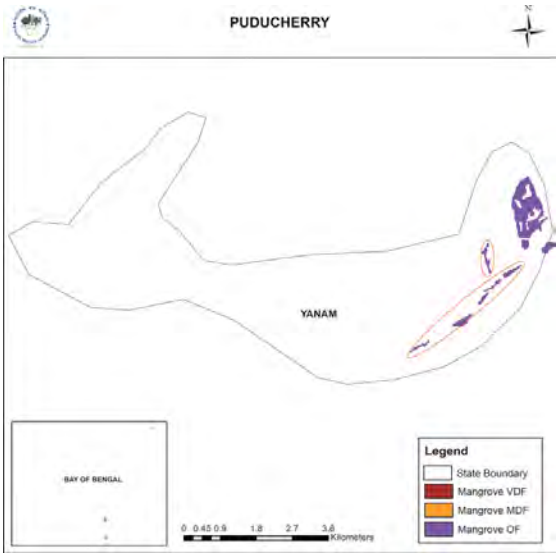
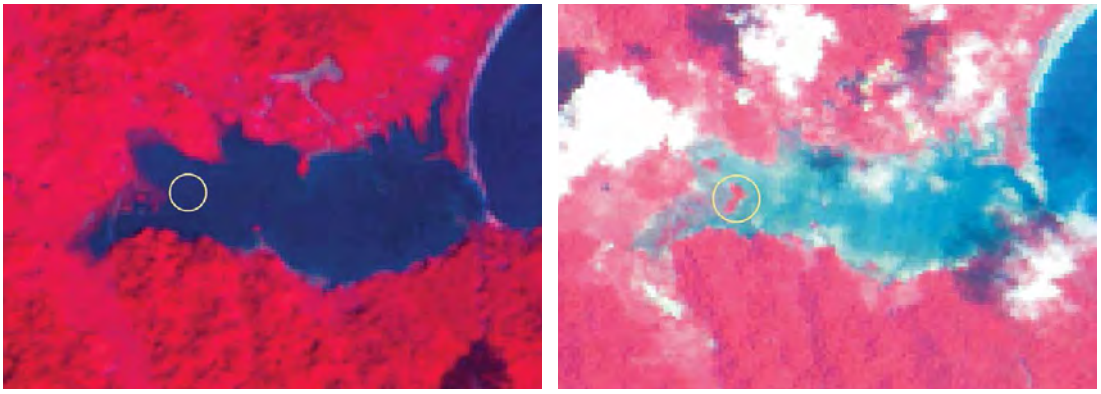


FIGURE 3.4 Photo showing Mangrove Plantation in Great Nicobar



2017 2019

4

Chapter

Forest Types and Biodiversity

4.1 INTRODUCTION

Scientific information about the forest resources like extent and distribution of forest types which signifies association of plants community and biodiversity is a prerequisite for the implementation of forest policy, planning, management and conservation efforts. The panorama of Indian forests ranges from Tropical Wet Evergreen Forests in the Andaman & Nicobar Islands, the Western Ghats, and the northeastern States, to Dry Alpine Scrub high in the Himalayas in the North. The country has Semi-Evergreen Forests, Deciduous Forests, Thorn Forests, and Subtropical Pine Forests in the lower montane zone and Temperate Montane Forests in the higher zones. On the other extreme, tropical dry deciduous and thorn forests predominate in the semi-arid areas of Rajasthan and Gujarat.

H.G. Champion first enunciated a classification system for forests of undivided India in 1935. S.K. Seth subsequently joined Champion in refining the earlier work by bringing out a monumental document 'A Revised Survey of the Forest

Types of India' in 1968. Subsequently, their system became the standard in forest type classification in the country. Champion and Seth (1968) defined Forest types as "*a unit of vegetation which possesses (broad) characteristics in physiognomy and structure sufficiently pronounced to permit its differentiation from other such units*". Their classification of forest types is based on the premise that a forest type unit could be treated as a distinct ecosystem; many preceding forest classification systems are based on climate, soil or vegetation alone. It placed greater importance on the main tree layers in view of the practical utility from the forest management perspective. It is a three-tier system of classification: six climate based major groups were sub-divided into 16 precipitation and temperature range based type groups. These type groups have been further divided into Southern and Northern forms. Ultimately, the type groups have been further sub-divided into 200 forest types based on floristic, edaphic and physiographic factors.

Classification and description of forests of any area into the Forest Types provide a scientific basis for diverse applications such as management, silvicultural research, resource assessment, environment impact assessment, growing stock assessment, working plan preparation, wildlife management, carbon stock assessment, climate change and biodiversity studies etc.

4.2 MAPPING OF FOREST TYPES OF INDIA

Forest types of India published by Champion & Seth in the year 1968 is a seminal classification system of forest types of India. However, the book provides only description of 200 forest types and its higher hierarchical levels. It does not provide maps showing distribution of forest types. In absence of remote sensing data and GIS at that point of time, it may not have been possible to produce such maps. This long standing information need was fulfilled by FSI when it undertook the nation-wide exercise during 2005 to 2010 and released first ever 'Forest Type Atlas of India' in the year 2011. After 10 years, the second exercise has been undertaken by FSI to further refine and update forest type map of India with the latest base line forest cover map. Brief outline of the two mapping exercises are given below:

4.2.1 Mapping of Forest Types of India: 2005-10

The project on Forest Type Mapping (FTM) of India was initiated by FSI in March 2005 under the National Natural Resources Management System (NNRMS) Programme sub-committee on Bio Resources of the MoEF&CC, Govt. of India. The main objectives of the project were:

a) Preparation of a detailed report on forest type mapping of the country, using Champion & Seth classification (1968) scheme.

b) Generation of forest type maps for the entire country on 1:50,000 scale in the digital and hard copy forms.

c) Publication of an Atlas depicting the forest type maps for different States/UTs of India.

To achieve the above objectives an elaborate methodology was developed with inputs from the accumulated information available at FSI, the latest tools and techniques of geo-informatics (Remote Sensing, GIS and GPS), forest inventory, working plans, thematic maps and extensive field visits for ground truthing in nearly 600 districts (82% of the total districts)of the country. The State/UTs Forest Departments (SFDs) and various central government agencies like Survey of India (SOI), National Remote Sensing Centre (NRSC), and Space Application Centre (SAC) etc contributed in the project through workshops (including expert consultations), feedback and field validation. For this project, forest cover maps of 2005 assessment of FSI were used as the base layer.

Salient findings of the mapping exercise (2005-09) were as follows:

- 178 out of 200 forest types (mentioned by Champion & Seth) could be mapped
- The final maps had an accuracy of 77.5% at the forest type level (i.e. 200 types) and 88.5% at the type group level (i.e. 16 type groups)
- Forest type maps of the country including States/UTs & districts were prepared on 1:50,000 scale
- Area figures for the sixteen type groups and all the 178 forest types of the country were generated
- Forest type wise area figures for all the States/UTs were also generated
- Area figures under different type groups and canopy density classes for each State/UT were computed
- An Atlas showing forest type maps of all the States and UTs with some relevant details especially floral composition and area statistics was published in 2011
- Twenty Two forest types could not be mapped due to various reasons including limitations of the data, definitions used in the study, lack of ground truthing and in a few cases non-discernibility of the forest types under various stages of degradation.
- Ground truthing and field observations were taken on more than 18000 locations across the country.

4.2.2 Revisiting Forest Types Map of India: 2015 onwards

FSI published an Atlas of "Forest Type Mapping of India"[1] in 2011, with overall accuracy of 77.5% at the type level. Due to its significant importance, another exercise for further refining the forest types map of India has been initiated in 2015. The exercise is also intended to update and achieve higher accuracy as compared to the previous one. Forest Cover Maps of the country pertaining to ISFR 2017 have been used as the base layer. The project has been initiated with the following objectives:

a) to identify the remaining 22 forest types which appear in Champion and Seth (1968) classification but could not be mapped in previous FTM.

b) to check the existence of 27 last remnant forest types (those types whose total area is less than 50 sq. km in the country) based on the outcome of the previous Forest Type Mapping.

c) to assign the forest types to the increased forest cover (based on the Forest Cover Maps pertaining to ISFR 2017) in comparison to previous FTM.

d) to identify and map different plantations like Mango orchards, Arecanut/ Coconut, Rubber, Tea, Eucalyptus, Poplar etc separately.

e) to delineate and assign nomenclature of forest types for grasslands.

f) to classify the plantation of forest species under corresponding forest types e.g. Teak, Bamboo, Sal etc.

g) to align the forest types of India with the prevailing International classification systems viz. UNESCO, WWF, UNEP and FAO classifications.

h) to produce forest type maps on 1:50,000 scale of every State/UT of the country along with a detailed report showing area statistics of forest types in every State/UT.

Patches of the old plantations which have naturalized over a period of time have also been included for assigning the forest types. Scrub shown in the forest cover map which represents natural forests with scanty trees have also been taken into account for assigning forest types, though area of scrub

[1] FSI (2011). Atlas Forest Types of India. Forest Survey of India, Ministry of Environment and Forests, Government of India

FIGURE 4.1 Photograph showing Biodiversity rich landscape

is not included in the forest cover. Natural grasslands and pastures, which are included in the non-forest category of the forest cover mapping are delineated afresh with the help of satellite data and are assigned the relevant forest type as per the Champion & Seth classification. The final output of this exercise i.e. forest type map would therefore, overlap with the forest cover map showing VDF, MDF,OF and Scrub class and grass lands from the non-forest categories in the forest cover map. Trees Outside Forest (TOF) and plantations have been shown as a separate class and they have not been assigned forest types. The methodology followed is shown in the flow chart given at Fig 4.2.

4.2.2.1 Findings

The exercise of revisiting the earlier forest types mapping for refinement and updation has been completed. Preparation of Atlas and final report is in progress. However, the final result in terms of area figures of the type groups are being presented in this report. Forest type map of India showing 16 type groups is shown in Fig 4.3. Salient findings of the current forest type mapping are mentioned below:

- 188 forest types have been identified.
- Grasslands have been delineated separately in forest and non forest areas and assigned the forest types.
- Plantation areas have been marked with the type of major crop and species planted
- Area figures of the sixteen type groups in the country have been shown in the Table 4.1.
- The forest types of India have been aligned with the international classification systems.
- Forest type maps of all the States/UTs have been prepared on 1:50,000 scale.
- States of Himachal Pradesh, Jammu & Kashmir, Tamil Nadu and Uttarakhand have large number of forest types i.e. more than 35.

FIGURE 4.2 Workflow for forest type mapping

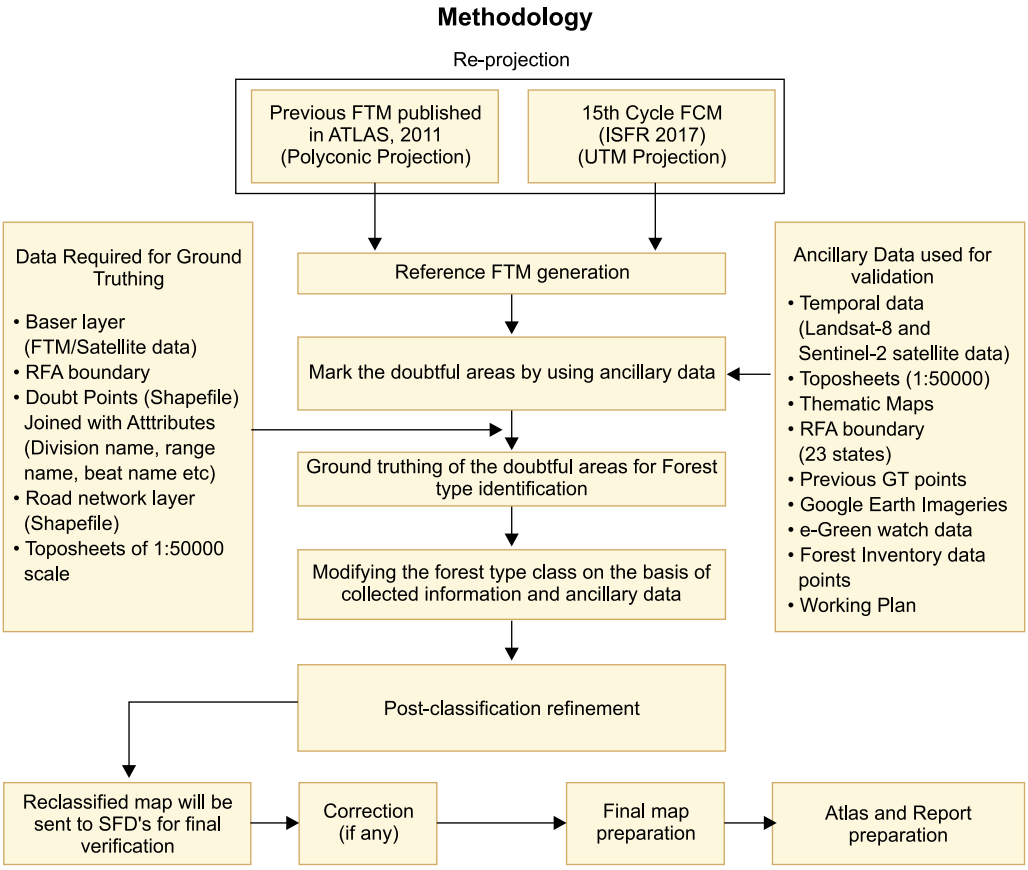
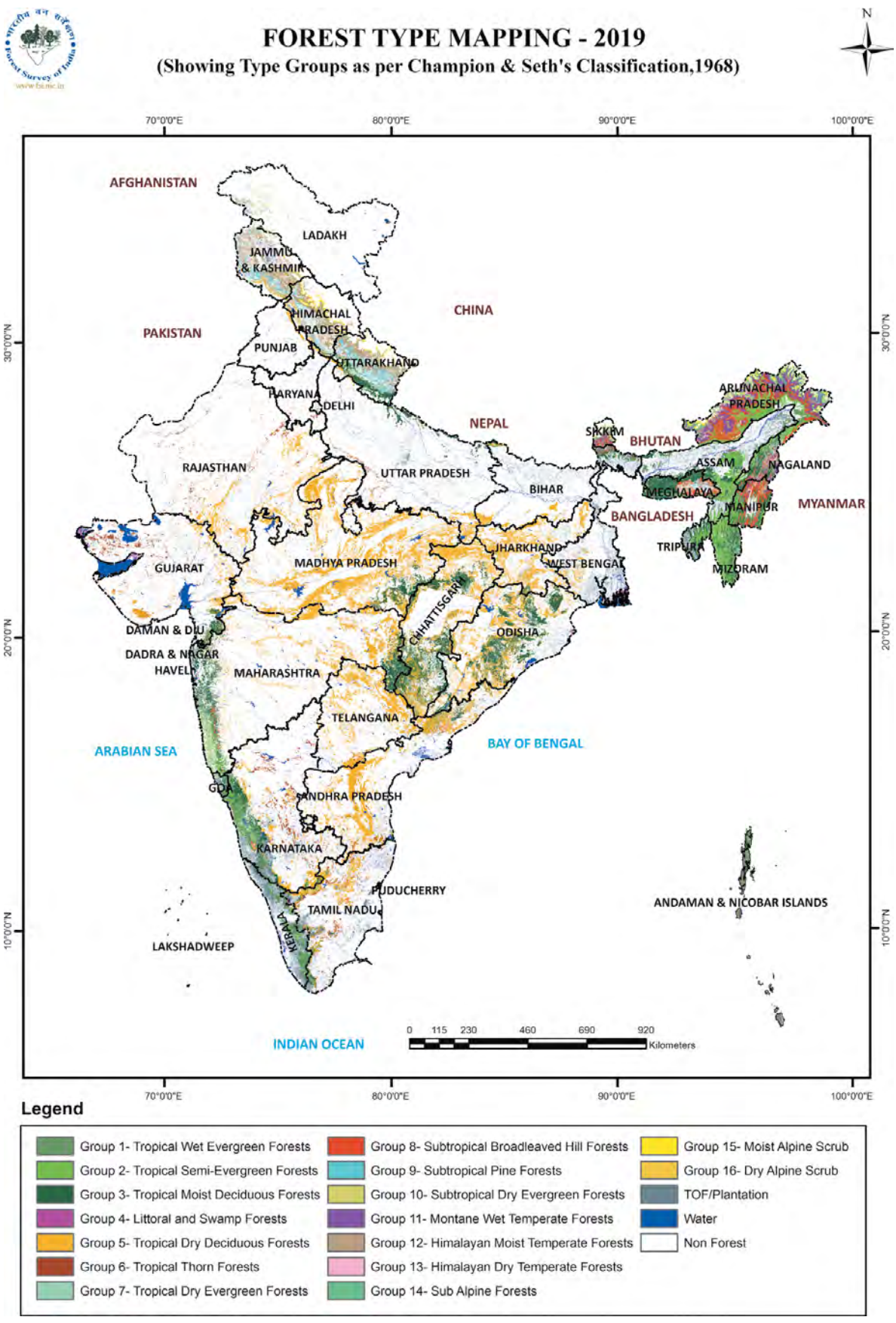


TABLE 4.1 Area under different Forest Type Groups of India

S.No	Type Group	Area in sq km	% of Grand Total*
1.	Group1 Tropical Wet Evergreen Forests	20,054	2.61
2.	Group2 Tropical Semi Evergreen Forests	71,171	9.27
3.	Group3 Tropical Moist Deciduous Forests	1,35,492	17.65
4.	Group4 Littoral & Swamp Forests	5,596	0.73
5.	Group5 Tropical Dry Deciduous Forests	3,13,617	40.86
6.	Group6 Tropical Thorn Forests	20,877	2.72
7.	Group7 Tropical Dry Evergreen Forests	937	0.12
8.	Group8 Subtropical Broadleaved Hill Forests	32,706	4.26
9.	Group9 Subtropical Pine Forests	18,102	2.36
10.	Group10 Subtropical Dry evergreen Forests	180	0.02
11.	Group11 Montane Wet Temperate Forests	20,435	2.66
12.	Group12 Himalayan Moist Temperate Forests	25,743	3.35
13.	Group13 Himalayan Dry Temperate Forests	5,627	0.73
14.	Group14 Sub Alpine Forests	14,995	1.96
15.	Group15 Moist Alpine Scrub	959	0.13
16.	Group16 Dry Alpine Scrub	2,922	0.38
17.	Plantation/TOF	64,839	8.45
Total (Forest Cover + Scrub)		**7,54,252**	**98.26**
18.	Grass land in different forest type groups (without forest cover)	13,329	1.74
Grand Total*		**7,67,581**	**100.00**

FIGURE 4.3 Forest Type Group Map of India



4.3 BIODIVERSITY ASSESSMENT IN DIFFERENT FOREST TYPE GROUPS

4.3.1 Introduction

Recognition of biodiversity as an important environmental issue emerged in 1992 during Rio de Janeiro Conference on Environment and Development. The conference opened the way towards the ratification of the Convention on Biological Diversity (CBD) in 2002, when countries agreed to reduce the rate of biodiversity loss. As an active and responsible party to the convention and being a mega biodiverse country, India is committed towards conservation of its biological resources. India, understanding the importance of the biodiversity, enacted necessary legislation i.e. The Biological Diversity Act in the year 2002 which aims to conserve biodiversity, manage its sustainable use and enable fair and equitable sharing of benefits arising out of the use of biological resources.

The Act envisages "Biological Diversity" as the variability among living organisms from all sources and the ecological complexes of which they are part and includes diversity within species or between species and their ecosystems.

Assessment of biodiversity in forests is important since it provides an indicator to represent the state of conservation of forest ecosystems and it can help to evaluate and monitor sustainability of the biological resources. It also helps in comparative evaluation of stability, productivity and ecosystem functions of forests in temporal and spatial scales. A rapid assessment of plant biodiversity in all the 16 forest type groups has been attempted by FSI as a part of the current exercise of refinement of forest types map of India. In the context of this exercise, biodiversity meant plant diversity only. In the assessment presented in this section, biodiversity of trees, shrubs and herbs in different forest type groups in natural forests of different States have been assessed through survey on the sample plots as per the standard statistical design.

4.3.2 Assessing Biodiversity

Several quantitative indices have been designed to provide information on different aspects of biodiversity viz, Margalef index, Menhinick index, Simpson index, Shannon-Weiner Index etc. The most commonly used index is the Shannon-Wiener Index which is based on information theory that provides the biodiversity values and helps to compare it between plant communities/ecosystems.

4.3.3 Shannon-Weiner Index

Shannon-Weiner Index is widely used for comparing diversity between various habitats[2]. It gives a measure of species abundance and richness to quantify diversity of the species. This index takes both species abundance and species richness into account. Shanon-Weiner index is calculated by the following formula

$$H' = -\sum p_i \ln p_i$$

Shanon-Weiner index is elaborated as "the proportion of the species is relative to the total number of species (p_i) and then multiplied by the natural logarithm of this proportion" (ln $p_{i.}$ Where, p_i is the proportion of individuals found in species 'i'. For a well-sampled community, this proportion can be estimated as $p_i = n_i/N$, where ni is the number of individuals in species i and N is the total number of individuals in the community. Since by definition the p_i will all be between zero and one, the natural log makes all of the terms of the summation negative and that is why the inverse of the sum is taken.

[2] Clarke, K.R and Warwick, R.N.(2001) Change in Marine Communities: An approach to statistical analysis and interpretation

Assessment of biodiversity is a qualitative and relative process and thus the numerical values of biodiversity assessment should be seen as a general estimate of a forest's biodiversity potential. It is not an absolute measurement. Biodiversity assessment of forest facilitates comparison of a forest over a period of time, makes comparison with other forests, provides a basis for evaluating impacts of interventions or different drivers causing pressure on forests.

4.3.4 Methodology

Distribution of sample plots for data collection has been done following Stratified Random Sampling design with the forest type groups in each State as strata. Approximately 1700 sample plots locations in the country were distributed with the help of GIS software in such a manner that every Forest Type Group in every State/UT got suitably represented. On every location, there was a cluster of five sample plots in a design which varied in inter plot distances in different type groups. The design of clusters has been depicted in Fig 4.4 (a) to 4.4 (c). Salient features of the methodology are described below:

a) Biodiversity assessment in different Forest Type Groups, present in States / Union Territories has been carried out by collecting data from statistically distributed sample plots in different Forest Type Groups.

b) Data has been collected from the sample plots for herbs, shrubs, non-clump forming bamboo (in all the Type Groups) and for Clump forming Bamboos (in few Type Groups) using a pre designed form.

c) Distribution of sample plots has been done with the help of GIS software. Latitude-Longitude at the centre of the plot has been generated.

d) Each Plot is having five sub-plots. The plot centre is named as sub-plot -1. Sub-plot nos. 2,3,4 and 5 and are located in North, East, South and West directions, respectively at different distances from the plot centre depending upon the Type Group.

e) The distances for sub-plots 2,3,4 & 5 as shown Fig 4.2 (a,b,c) differs between different Forest Type Groups.

f) In all the Type Groups and at all the five sub-plots, herb information has been collected from a circular plot of 0.6 m radius from the sub-plot centre, whereas shrub and non- clump bamboo information has been collected from a circular plot of 1.7 m radius in the prescribed field forms.

g) In few Type Groups in addition to herbs, shrubs and non-clump forming bamboo, the information of clump forming bamboo has also been collected from a circular plot of 8 m radius from the sub-plot centre in the prescribed field forms.

h) It is to be noted that all the circular plots are concentric. Circular plots of 0.6 m, 1.7 m and 8 m radius represent approximately 1 sq m, 9 sq m and 200 sq m of area respectively.

i) Shape and size of the sample plots and their variation for different forest type groups were finalized after analyzing species–area curves and variability of species from the national forest inventory sample plot data. It was observed from the pilot study that circular and square shapes of plot do not make significant difference in the species richness observations. Since the circular

plots are easily laid in the field and thus save time and therefore the same was adopted for the study.

j) The data for the trees were obtained from the National Forest Inventory by the Forest Inventory unit on a statistical design.

k) The rapid data collection for the herbs and shrubs were carried out for a single season, therefore those species which are seasonal in nature and are not present at the time of survey could not be recorded, hence the diversity values (Shannon-Weiner) could be lower than the potential maximum value.

l) Herbarium of all the herb and shrub species observed in the rapid biodiversity assessment has been made using digital photographs and physical specimen of the plants.

m) The biodiversity value (Shannon-Weiner Index) of trees will be at the lower end as only 1,200 trees could be identified in the National Forest Inventory Programme. Rest of the tree species have been categorized into a common group named Miscellaneous species.

4.3.4.1 Sample Plot Design

(a) This design is applicable to the Tropical Wet Evergreen, Tropical Semi Evergreen, Tropical Moist Deciduous and Tropical Dry Deciduous forests. All the sub-plots are laid at a distance of 50 meters in North, South, East and West directions from the plot-centre. Concentric circular plots of 0.6m and 1.7m are laid at all the five sub-plots for data collection of herbs and shrubs & non-clump forming bamboo. The data for trees are obtained from National Forest Inventory

(b) This design is applicable to the Littoral and Swamp, Tropical Thorn, Subtropical Broad Leaved Hill, Sub Tropical Pine and Himalayan Moist Temperate forests. In this design sub-plots 2 and 4 are laid at a distance of 50 meter each away from plot-centre in North and South directions whereas sub-plots 3 and 5 are laid at a distance of 75 meters each in East and West directions away from the plot-centre. Concentric circular plots of 0.6m and 1.7m are laid at all the five sub-plots for data collection of herbs and shrubs & non-clump bamboo. The data for trees are obtained from National Forest Inventory.

(c) This design is applicable to the Tropical Dry Evergreen, Subtropical Dry Evergreen, Montane Wet Temperate, Himalayan Dry Temperate, Sub Alpine, Moist Alpine Scrub and Dry Alpine Scrub forests. Sub-plots 2 & 4 are laid at a distance of 50m each in in North and South directions and sub-plots 3 and 5 at a distance of 100m each respectively in East and West directions away from the plot-centre. Concentric circular plots of 0.6m and 1.7m are laid at all the five sub-plots for data collection of herbs and shrubs & non-clump bamboo. The data for trees are obtained from National Forest Inventory.

4.3.5 Results

Biodiversity data have been collected from 8,500 sub-plots spread in all the States/UTs among sixteen type groups. Information of 2,300 herb species and 3,111 shrub species along with their photographs from all the sub-plots in the country have been collected. A digital herbarium of all the herb and shrub species has been prepared.

Number of species of trees, shrubs and herbs found in each State/UT are presented in the Table 4.2.

FIGURE 4.4a

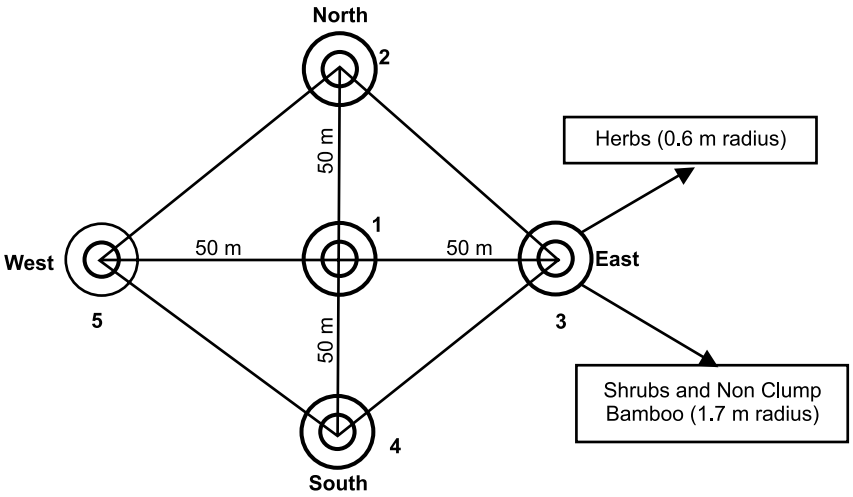


FIGURE 4.4b

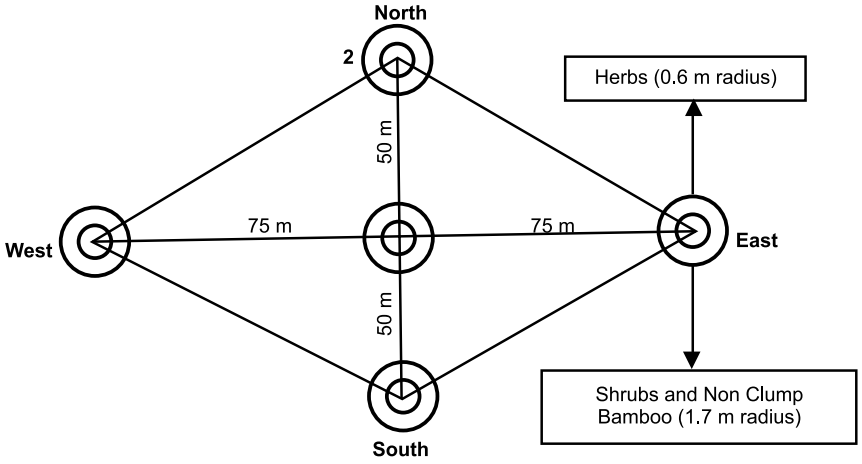


FIGURE 4.4c

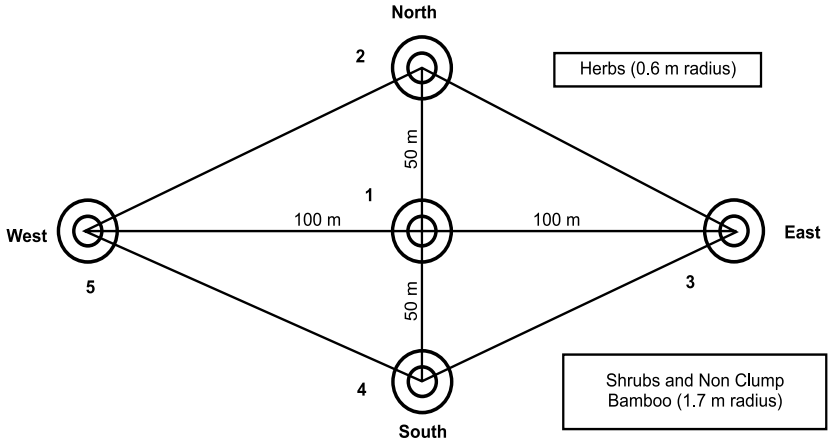


TABLE 4.2 State/ UT wise Number of species of Trees, Shrubs and Herbs

Table Showing Number of Species observed during the Rapid Assessment of Biodiversity					
S. No.	**StateName**	**Trees**	**Shrubs**	**Herbs**	**Total Number of Plant Species**
		No of Species	**No of Species**	**No of Species**	
1.	Andhra Pradesh	242	64	58	364
2.	Arunachal Pradesh	110	435	192	737
3.	Assam	143	149	153	445
4.	Bihar	113	42	52	207
5.	Chhatisgarh	129	48	50	227
6.	Delhi	16	11	36	63
7.	Goa	118	50	38	206
8.	Gujarat	102	37	73	212
9.	Haryana	45	43	50	138
10.	Himachal Pradesh	116	99	109	324
11.	Jammu And Kashmir	73	133	272	478
12.	Jharkhand	111	26	40	177
13.	Karnataka	325	140	40	505
14.	Kerala	238	158	81	477
15.	Madhya Pradesh	146	79	72	297
16.	Maharashtra	170	135	54	359
17.	Manipur	43	89	56	188
18.	Meghalaya	93	176	42	311
19.	Mizoram	87	96	56	239
20.	Nagaland	56	137	113	306
21.	Odisha	192	90	105	387
22.	Punjab	50	31	37	118
23.	Rajasthan	65	30	8	103
24.	Sikkim	59	35	29	123
25.	Tamil Nadu	252	313	87	652
26.	Telangana	167	67	33	267
27.	Tripura	89	37	22	148
28.	Uttar Pradesh	84	71	86	241
29.	Uttarakhand	112	73	94	279
30.	West Bengal	113	103	65	281
31.	Andaman Nicobar Islands	89	102	79	270
32.	Chandigarh	21	4	7	32
33.	Dadra Nagar Haveli	25	8	11	44
Total		**3,794**	**3,111**	**2,300**	**9,205**

* No samples plots fell in UT of Lakshadweep, Yanam and Mahe parts of Puducherry

TABLE 4.3 State/ UT wise and Forest type wise Shannon-Wiener Index for Trees

S. No.	State Name	1-Tropical Wet Evergreen Forests	2-Tropical Semi-Evergreen Forests	3-Tropical Moist Deciduous Forests	4-Littoral and Swamp Forests	5-Tropical Dry Deciduous Forests	6-Tropical Thorn Forests
1.	Andhra Pradesh			3.15	*	4.07	3.74
2.	Arunachal Pradesh	3.18	3.33	2.13			
3.	Assam	2.63	3.50	3.58	1.37	*	
4.	Bihar		*	3.10	*	3.42	
5.	Chhattisgarh			3.17		3.07	
6.	Delhi					1.56	0.99
7.	Goa	2.86	3.14	3.13	*	*	
8.	Gujarat			2.80	*	3.09	1.93
9.	Haryana					2.69	1.94
10.	Himachal Pradesh			1.95		2.87	
11.	Jammu and Kashmir					2.28	
12.	Jharkhand			2.18		2.70	
13.	Karnataka	4.19	4.00	3.56		3.66	3.09
14.	Kerala	3.78	3.80	3.48	*	3.10	*
15.	Madhya Pradesh			2.91	0.94	3.16	*
16.	Maharashtra		3.38	3.57	0.56	3.03	1.51
17.	Manipur		2.49	2.25			
18.	Meghalaya	2.79	1.95	3.06			
19.	Mizoram		3.08	2.78			
20.	Nagaland	*	2.15	2.94			
21.	Odisha		2.05	3.10	*	3.33	
22.	Punjab					3.06	1.78
23.	Rajasthan					2.59	1.86
24.	Sikkim			1.08			
25.	Tamil Nadu	3.25	2.77	3.39	*	3.92	3.09
26.	Telangana			2.65		3.63	2.42
27.	Tripura		2.77	3.14			
28.	Uttar Pradesh		*	2.31	1.98	3.44	1.42
29.	Uttarakhand			2.51		2.53	
30.	West Bengal		2.33	2.76	*	2.32	
31.	Andaman &Nicobar Islands	3.01	3.19	2.67	*		
32.	Chandigarh					1.60	
33.	Dadra &Nagar Haveli			2.48		*	

* adequate number of sample plots are not available

7-Tropical Dry Evergreen Forests	8-Subtropical Broad leaved Hill Forests	9-Subtropical Pine Forests	10-Subtropical Dry Evergreen Forest	11-Montane Wet Temperate Forests	12-Himalayan Moist Temperate Forests	13-Himalayan Dry Temperate Forests	14-Sub-Alpine Forests	15-Moist Alpine Scrub	16-Dry Alpine Scrub
3.28									
	1.49	*		0.93	2.06	*	*	*	
	0.50	1.56							
		*							
		2.63			2.95	2.03	1.64	0.17	0.87
		2.43	0.69		1.98	1.53	1.58	1.25	1.05
	2.53			1.88					
				1.84					
	*								
	0.78								
	2.26	1.12		1.48					
	1.76	2.01							
	2.62	1.31		1.04	*				
		*							
	2.75			2.53	*		2.09	*	
2.81	2.94			2.18					
		1.84			2.41	0.65	*	1.35	*
	1.76			1.51	1.96		1.19		

TABLE 4.4 State/ UT wise and Forest type wise Shannon-Wiener Index for Shrubs

S. No.	State Name	1-Tropical Wet Evergreen Forests	2-Tropical Semi-Evergreen Forests	3-Tropical Moist Deciduous Forests	4-Littoral and Swamp Forests	5-Tropical Dry Deciduous Forests	6-Tropical Thorn Forests
1.	Andhra Pradesh			2.13	1.43	2.92	2.37
2.	Arunachal Pradesh	3.62	4.50	3.81			
3.	Assam	2.99	3.17	2.64	2.20	2.77	
4.	Bihar		2.22	2.65	1.58	2.25	
5.	Chhattisgarh			2.62		2.89	
6.	Delhi					*	2.07
7.	Goa	2.54	2.16	2.65	0.23	1.23	
8.	Gujarat			2.40	0.86	2.14	1.44
9.	Haryana					1.88	1.96
10.	Himachal Pradesh			2.15		2.13	
11.	Jammu and Kashmir					3.00	
12.	Jharkhand			1.77		2.04	
13.	Karnataka	3.09	2.58	2.66		2.68	2.32
14.	Kerala	3.26	2.87	2.97	1.42	2.63	2.46
15.	Madhya Pradesh			2.55	*	1.21	2.11
16.	Maharashtra		2.65	2.60	0.77	2.83	2.51
17.	Manipur		1.56	2.47			
18.	Meghalaya	3.54	3.10	3.94			
19.	Mizoram		3.37	3.38			
20.	Nagaland	3.09	2.97	3.48			
21.	Odisha		2.51	2.91	2.74	3.26	
22.	Punjab					2.07	2.38
23.	Rajasthan					2.63	1.69
24.	Sikkim			1.95			
25.	Tamil Nadu	3.23	2.82	3.27	1.04	3.91	3.10
26.	Telangana			3.03		2.68	2.33
27.	Tripura		1.69	2.95			
28.	Uttar Pradesh		2.48	2.41	2.29	2.15	2.07
29.	Uttarakhand			2.08		2.19	
30.	West Bengal		2.51	1.21	1.28	2.49	
31.	A & N Islands	3.34	3.31	3.10	2.29		
32.	Chandigarh					1.23	
33.	Dadra & Nagar Haveli			0.97		*	

* adequate number of sample plots are not available

7-Tropical Dry Evergreen Forests	8-Subtropical Broadleaved Hill Forests	9-Subtropical Pine Forests	10-Subtropical Dry Evergreen Forests	11-Montane Wet Temperate Forests	12-Himalayan Moist Temperate Forests	13-Himalayan Dry Temperate Forests	14-Sub-Alpine Forests	15-Moist Alpine Scrub	16-Dry Alpine Scrub
2.55									
	3.57	3.09		*	3.11	2.80	3.16	1.60	
	2.44	2.54							
		2.62							
		2.17			3.25	2.56	1.83	*	2.34
		3.37	2.64		3.26	2.49	2.96	1.30	*
	2.55			*					
				2.20					
	2.49								
	2.40								
	3.71	2.45		2.67					
	3.66	2.36							
		2.45							
	3.40	1.55		1.17	1.16				
		1.94							
	2.62			2.41	2.57		1.87	0.64	
2.82	3.20			2.68					
		1.90			2.58	1.76	2.49	*	1.36
	2.36			2.66	2.72		2.03		

TABLE 4.5 State/ UT wise and Forest type wise Shannon-Wiener Index for Herbs

S. No.	State Name	1-Tropical Wet Evergreen Forests	2-Tropical Semi-Evergreen Forests	3-Tropical Moist Deciduous Forests	4-Littoral and Swamp Forests	5-Tropical Dry Deciduous Forests	6-Tropical Thorn Forests
1.	Andhra Pradesh			2.89	*	2.63	2.25
2.	Arunachal Pradesh	2.99	4.05	3.09			
3.	Assam	3.16	3.47	2.85	2.38	2.82	
4.	Bihar		2.85	2.02	2.72	1.21	
5.	Chhattisgarh			2.59		2.61	
6.	Delhi					*	3.38
7.	Goa	2.61	2.28	1.83	0.67	0.41	
8.	Gujarat			2.02	1.80	3.30	2.58
9.	Haryana					1.70	2.24
10.	Himachal Pradesh			1.71		1.95	
11.	Jammu and Kashmir					2.04	
12.	Jharkhand			2.43		3.04	
13.	Karnataka	2.22	1.85	2.24		1.04	1.01
14.	Kerala	2.94	2.15	2.62	0.95	2.45	1.43
15.	Madhya Pradesh			2.77	*	2.60	2.35
16.	Maharashtra		2.44	2.09	*	2.76	1.96
17.	Manipur		2.02	1.15			
18.	Meghalaya	2.17	0.59	1.19		*	
19.	Mizoram		3.15	3.26			
20.	Nagaland	2.81	2.35	3.61			
21.	Odisha		2.78	3.48	2.36	3.61	
22.	Punjab					1.65	2.28
23.	Rajasthan					2.01	*
24.	Sikkim			2.35			
25.	Tamil Nadu	2.03	2.30	2.31	1.43	2.26	1.85
26.	Telangana			1.95		2.34	1.80
27.	Tripura		3.47	2.97			
28.	Uttar Pradesh		2.49	2.26	2.63	2.97	*
29.	Uttarakhand			*		2.18	
30.	West Bengal		2.40	1.59	1.10	1.95	
31.	Andaman &Nicobar Islands	3.28	3.21	2.85	2.11		
32.	Chandigarh					1.56	
33.	Dadra &Nagar Haveli			1.33		0.69	

* adequate number of sample plots are not available

7-Tropical Dry Evergreen Forests	8-Subtropical Broadleaved Hill Forests	9-Subtropical Pine Forests	10-Subtropical Dry Evergreen Forests	11-Montane Wet Temperate Forests	12-Himalayan Moist Temperate Forests	13-Himalayan Dry Temperate Forests	14-Sub-Alpine Forests	15-Moist Alpine Scrub	16-Dry Alpine Scrub
2.07									
	2.96	2.01		*	2.41	1.76	1.88	*	
	2.25	3.07							
		2.23							
		1.89			3.48	2.51	1.87	*	2.30
		1.97	2.46		4.10	3.68	3.52	2.77	*
	1.29			*					
				2.14					
	2.09								
	1.07								
	2.88	1.58		1.75					
	1.86	2.59							
		2.19							
	2.92	2.19		1.90	*				
		2.36							
	2.19			1.90	1.66		0.83	0.69	
1.77	0.62			2.36					
		2.41			3.70	1.85	2.82	*	1.10
	2.33			1.76	2.32		1.24		

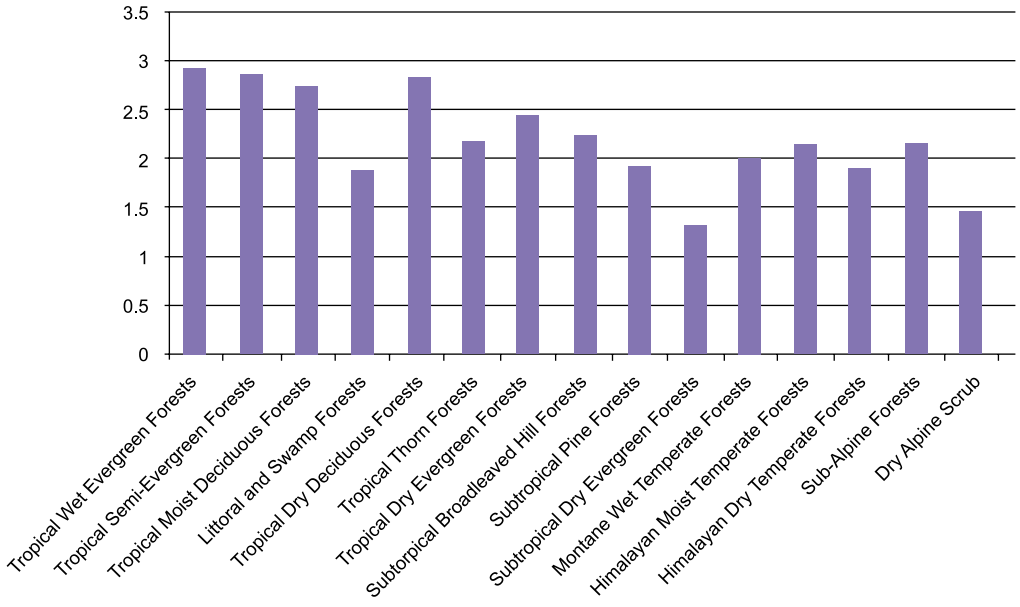
4.3.6 Analysis

The Tables 4.3 to 4.5 present the findings of rapid assessment of biodiversity in the forests of India done by FSI during 2018-19, which is the first ever attempt by FSI at the national level. The numbers presented in the Tables are at the lower end for different States/UTs or Forest Type Groups due to the limitations mentioned in the preceding section dealing with methodology. However, the values in the tables obtained through an unbiased and robust methodology involving over 8,500 sample plots provide a basis for comparative assessment of biodiversity richness in different forest type groups in different States and UTs.

4.3.6.1 Tree biodiversity

It is seen from the Table 4.3 that maximum tree diversity has been found in Tropical wet evergreen and semi evergreen forests of Western Ghats (Tamil Nadu, Kerala and Karnataka) followed by North Eastern states. Low tree diversity has been noticed in the Sub Tropical dry evergreen forests of Jammu and Kashmir and forest deficit States like Punjab, Haryana and Rajasthan. Among the States, Karnataka has the highest tree species richness followed by Tamil Nadu and Andhra Pradesh as observed in the rapid survey.

FIGURE 4.5 Biodiversity of trees in different forest type groups



4.3.6.2 Shrub biodiversity

Table 4.4 reveals that maximum shrub diversity has been observed in Tropical wet evergreen forests of Western Ghats (Tamil Nadu, Kerala and Karnataka) and North Eastern states. Low shrub diversity has been noticed in Moist alpine scrub forests of Sikkim. Among the States, Arunachal Pradesh has the highest shrub species richness followed by Tamil Nadu, Meghalaya, Kerala and Assam as observed in the rapid survey.

4.3.6.3 Herb biodiversity

It is seen from the Table 4.5 that maximum herb diversity has been observed in Tropical wet and semi evergreen forests of North East (Arunachal Pradesh and Assam). Low herb diversity has been observed in Littoral and Swamp forests. Among the States, Jammu & Kashmir has the highest herb species richness followed by Arunachal Pradesh, Assam, Nagaland and Himachal Pradesh as observed in the rapid survey.

FIGURE 4.6 Biodiversity of shrubs in different forest type groups

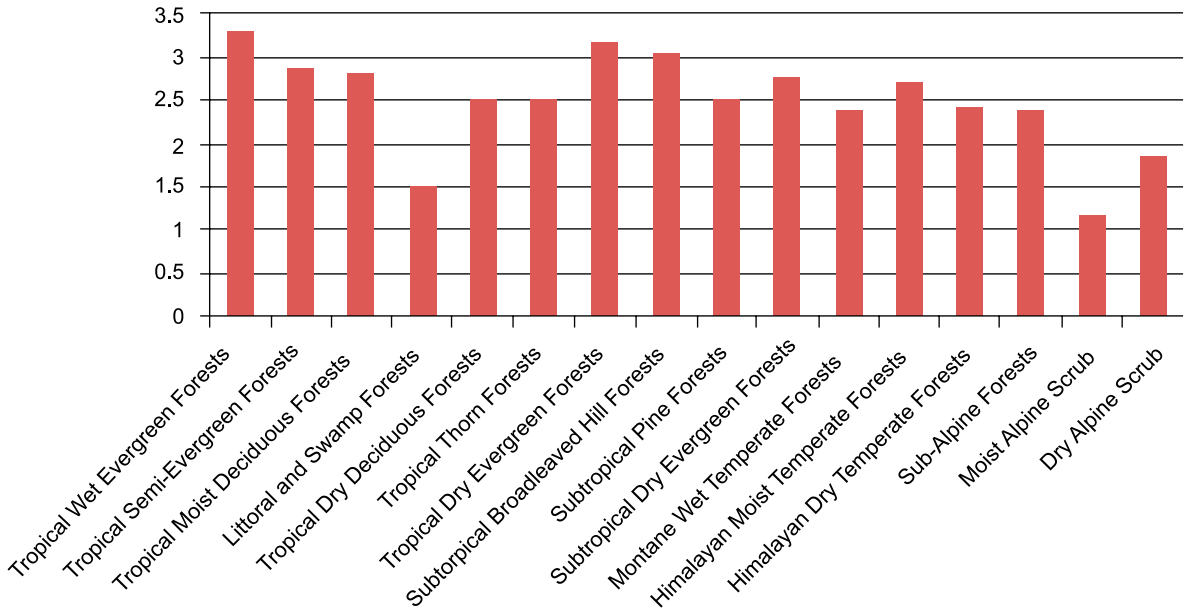
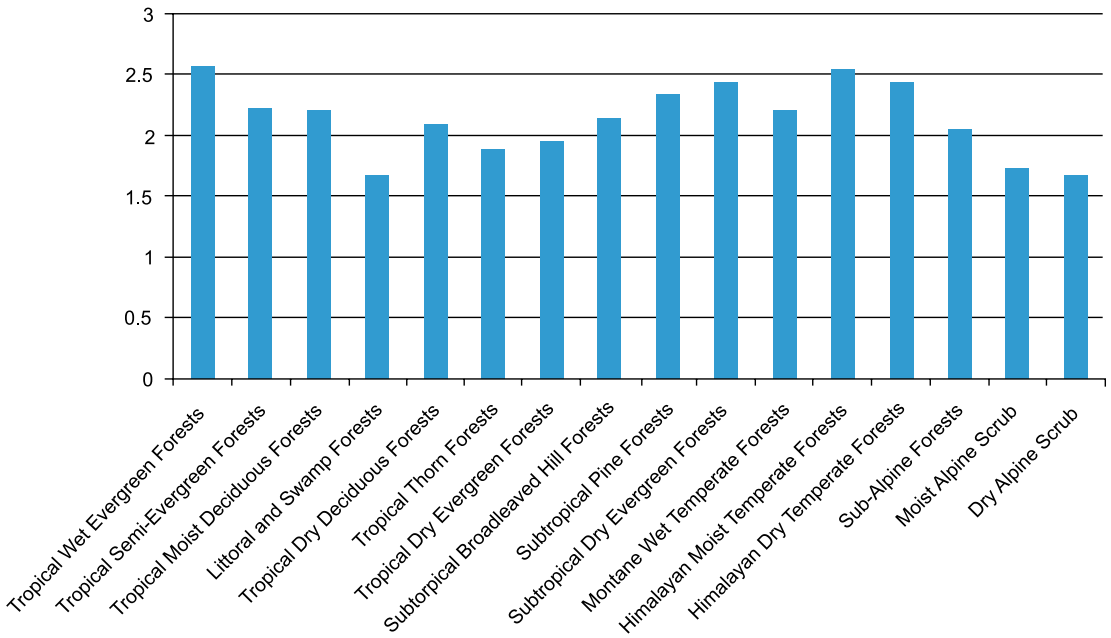


FIGURE 4.7 Biodiversity of herbs in different forest type groups



4.3.6.4 Species Richness of Top five States for Trees, Shrubs and Herbs

Species richness of top five States for trees, shrubs and herbs have been given in Fig 4.8 (a) to 4.8 (c). The State of Karnataka has maximum species richness for trees, Arunachal Pradesh has maximum species richness for shrubs and Jammu & Kashmir has maximum species richness for herbs. Fig 4.8 (d) shows the total number of plant species. The State of Arunachal Pradesh has the maximum richness of species when all the three types of plants are taken into account, followed by Tamil Nadu and Karnataka.

FIGURE 4.8a Species Richness of top five States for trees

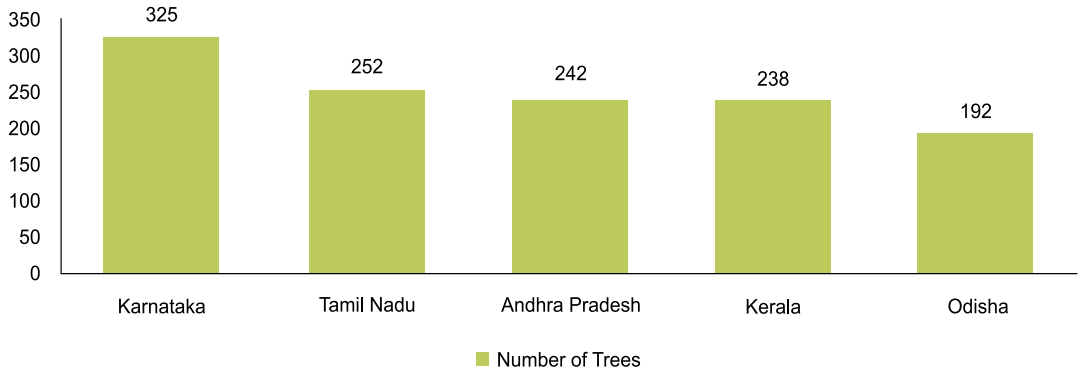


FIGURE 4.8b Species Richness of top five States for shrubs

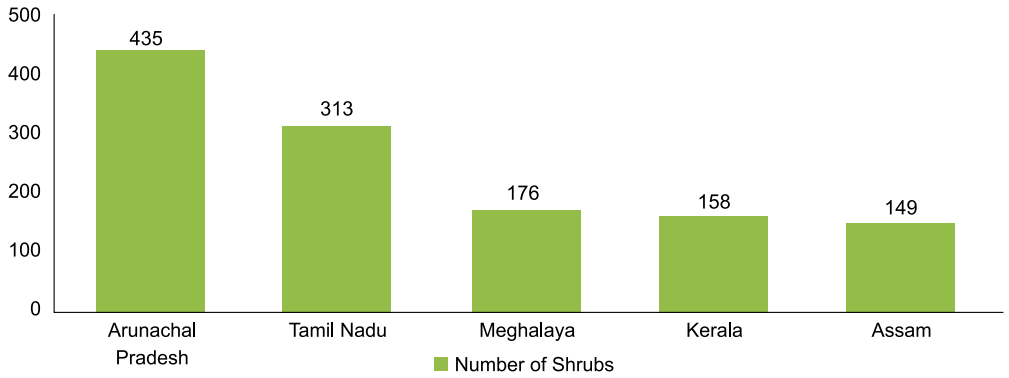


FIGURE 4.8c Species Richness of top five States for herbs

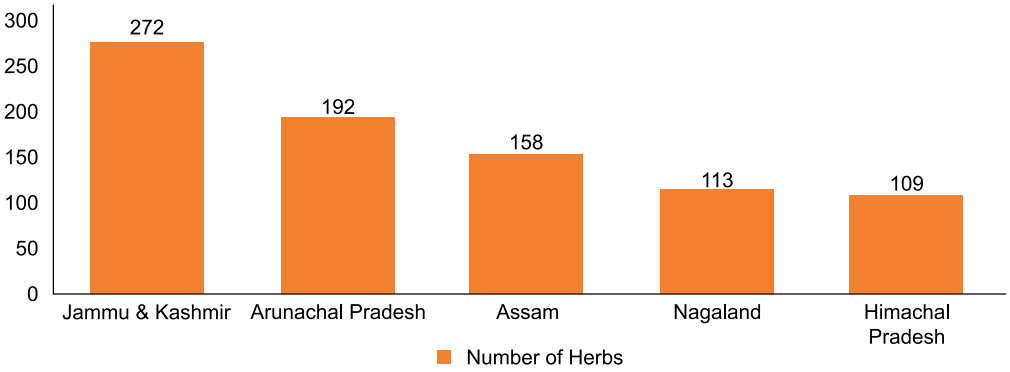
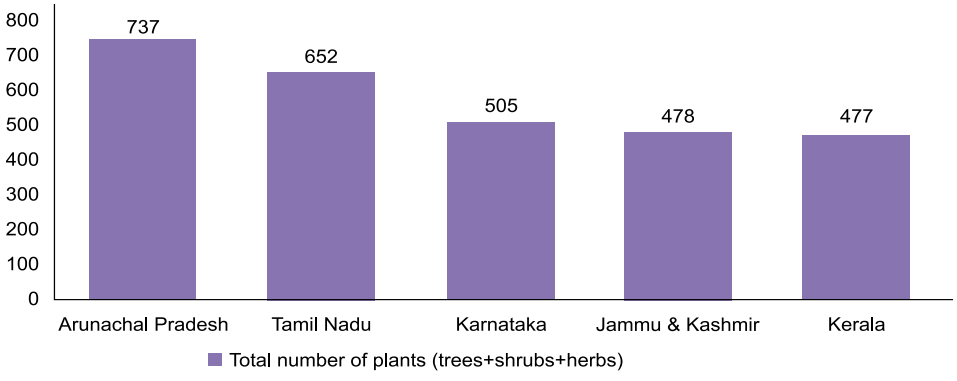


FIGURE 4.8d Species Richness of top five States for plants



5 Chapter

Forest Fire Monitoring

5.1 INTRODUCTION

Forest fires are one of the major drivers of damage caused to forests in the country. Uncontrolled forest fires can lead to significant losses of forests and ecosystem services. Studies suggest that climate change influences forest fire frequency and intensity which results in forests becoming increasingly inflammable[1]. The increasing duration of forest fire season, numbers of large fires, frequency of severe fire years may be related to climate change. Besides direct losses, foresters have to also deal with many side effects of fires such as increasing spread of weeds, soil erosion, loss of regeneration, landslides, habitat degradation, loss of forest produce etc.

Controlled fire has traditionally been used as a tool of forest management. However, uncontrolled fires of anthropogenic origin are a serious concern for sustainability of forests and their prevention poses

[1] Flannigan M., Stocks B.J., Turretsky M. and Wotton M. (2008) Impacts of climate change on fire activity and fire management in the circumboreal forest, Global Change Biology,15 (3): 549 - 560

a challenge which can be addressed only by mass awareness and participation of local people. Traditional fire fighting methods and equipments may not be sufficient to fight the growing number of large forest fires. Technology such as satellite remote sensing based forest fire detection in near real time is of critical help in controlling forest fires.

5.2 NATIONAL ACTION PLAN ON FOREST FIRES, 2018

Recognizing the need to revamp forest fire management in the country, the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India has come up with the National Action Plan on Forest Fires, 2018.

One of the main objectives of the action plan is to reduce the incidences of fires by informing, enabling and empowering forest fringe communities and incentivizing them to work in tandem with the State Forest Departments (SFDs). The plan also aims to reduce the vulnerability of forests against fire hazards across the diverse forest ecosystems in the country, enhancing the capabilities of institutions in fighting fires, and accelerating the recovery after a fire incidence. The plan proposes nine strategies to address the issue, including establishment of a **"Centre of Excellence on Forest Fire Management"**at FSI. The National Action Plan also acknowledges the role of FSI in providing timely forest fire alerts to the SFDs and Communities.

5.3 STRENGTHENING FOREST FIRE MANAGEMENT IN INDIA – A JOINT STUDY

A joint study report of MoEF&CC and World Bank titled "Strengthening Forest Fire Management in India" was released in June 2018[2]. It synthesized information from various studies, questionnaire, field visits to analyze the forest fire situation in the country and suggested measures to improve them. The study revealed that in the year 2000, 20 districts, representing 3% of India's land area and 16% of forest cover accounted for 44% of all fire detections. It also analyzed policy gaps and suggested various measures to improve forest fire management including a further study on the long-term impacts and wider economic costs of forest fires.

5.4 FOREST FIRE ALERTS SYSTEM OF FSI – A TIMELINE

Forest Fire Alerts System of FSI has undergone significant improvements in the recent years to make the system more user friendly and robust. The system started in the year 2004 has seen regular improvements in the last fifteen years leading to the complete automation of the processes involved in alert generation by FSI. The upgraded version of the Forest Fire Alert System version 3.0 (FAST 3.0) was released during the pre-fire season meeting with the Nodal Officers of the SFDs on 16th January, 2019. The evolution of the Forest Fire Alerts System is shown in Table 5.1.

TABLE 5.1 Evolution of FSI Forest Fire Alerts System

Year	Milestone
2004	Dissemination of forest fire alerts based on MODIS data started through emails/FAX
2008	Initiation of SMS alerts on number of fires in States/Districts
2012	KML alerts to Nodal Officers through email along with SMS Publication of report 'Vulnerability of India's Forests to Fires'
2015	Pilot study on Burnt Scar assessments
2016	Pilot trial of Pre warning alerts Automated email alerts to Nodal Officers using python script

[2] Strengthening Forest Fire Management in India (2018), Joint Report by the Ministry of Environment, Forest & Climate Change, Government of India and The World Bank

Year	Milestone
2017	Forest Fire Alert System 2.0 released with complete automation of the processes Use of VIIRS data started Long term Characterization study of Forest Fires in India was carried out
2018	Improved feedback system for forest fire alerts
2019	Forest Fire Alerts System version 3.0 (FAST 3.0) released

5.5 FOREST FIRE ALERTS: THE PROCESS

Forest Fire alerts disseminated by FSI is based on the inputs from two collaborative arrangements between NASA-ISRO and ISRO-FSI. The Fire hotspots detected by MODIS (1km x 1km resolution) and SNPP-VIIRS (375m X 375m resolution) sensors are received at Shadnagar Earth station of NRSC and processed using NASA's algorithm. The fire hotspots are transmitted to FSI electronically, which are then processed automatically by FSI and alerts are generated and disseminated to the registered end users.

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

a) The fire hotspots received from NRSC comprise all the hot spots detected by the sensors i.e. the features on the ground above certain threshold temperature irrespective of whether they fall within forests or outside. FSI undertakes filtering of all the fire hotspots other than forest fires using a custom filter developed for the purpose which is a combination of Recorded Forest Area boundaries as well as forest cover spatial data. Forest fire information is enriched by appending attributes like State, District, Circle, Division, Range, Beat, compartment number etc to the forest fire locations.

b) FSI has also created a filter to mask out fires from mining areas and other Industries, which could add false alarms to the forest fire alert data. After filtering, all the users who have registered their mobile numbers are notified through SMS about the fires that have been detected within their area of interest. This information is also shared with the State Nodal Officers. The information and the analysis generated in the form of Table and Maps are also uploaded online on the website and a dedicated Geo portal for the purpose.

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

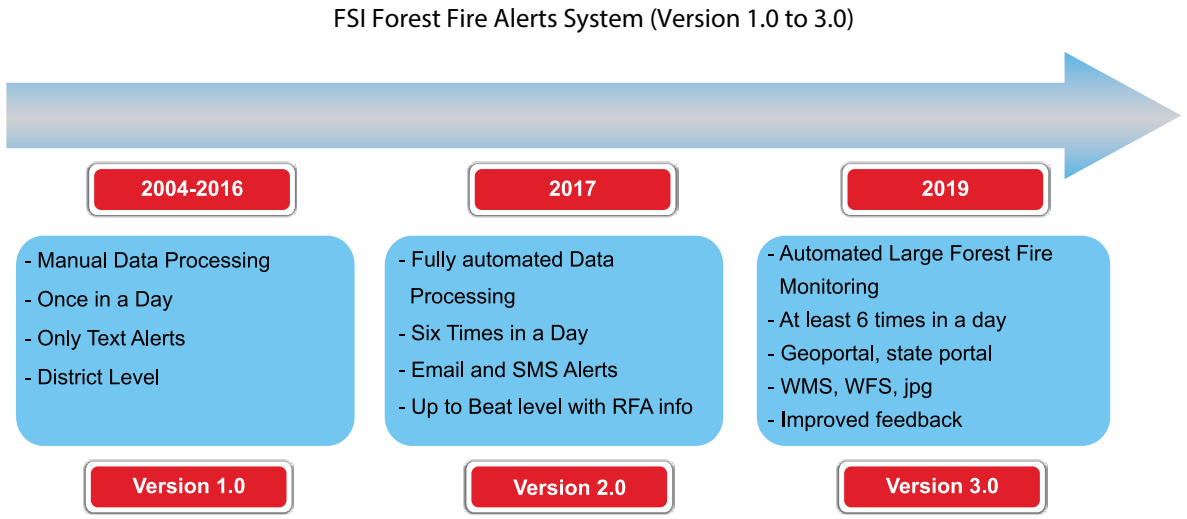
TABLE 5.2 Comparison between the two satellite systems viz. MODIS and SNPP-VIIRS

Feature	MODIS	SNPP-VIIRS
	Moderate Resolution Imaging Spectro-radiometer	Visible Infrared Imaging Radiometer Suite
Sensor	36 spectral bands (channel 21, 22,31)	5 HR Imagery channels (I-bands), 16 moderate resolution channels (M-bands), and a D/N Band (M13 and M15)
Satellite	Aqua and Terra	Suomi National Polar-orbiting Partnership (SNPP) 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 1km	375m x 375m & 750m x 750m

Work flow for alerts generation and dissemination of the information/SMS is explained in the schematic diagram given at Fig 5.1.

FIGURE 5.1 Work flow of near real time forest fire monitoring

FIGURE 5.2 Evolution of forest fire alert system



5.6 FOREST FIRE ALERTS SYSTEM (VERSION 3.0)

A new version of FSI Forest Fire Alerts System (Version 3.0) was launched in 2019 by adding several new features to the earlier Version 2.0. A major improvement over the previous version is the addition of large forest fire monitoring which identifies and tracks large fires in an automated manner. Large forest fires are those forest fires which engulf minimum three adjoining pixels of SNPP VIIRS (approximately 45 ha).

5.6.1 Features in FAST 3.0

a) Monitoring of Large Forest Fires based on satellite data (SNPP-VIIRS) to automatically identify and track large forest fires

b) FSI Forest Fire Geoportal to view forest fire related data along with other thematic layers

c) Web Map Service (WMS) has been made available for integration with web portals/geo portal of SFDs and other disaster management agencies

d) Wider coverage of customized alerts for 21 States at beat level and 3 States at Range level

e) Improved portal and feedback system for Nodal Officers (via SMS and Nodal Officer page)

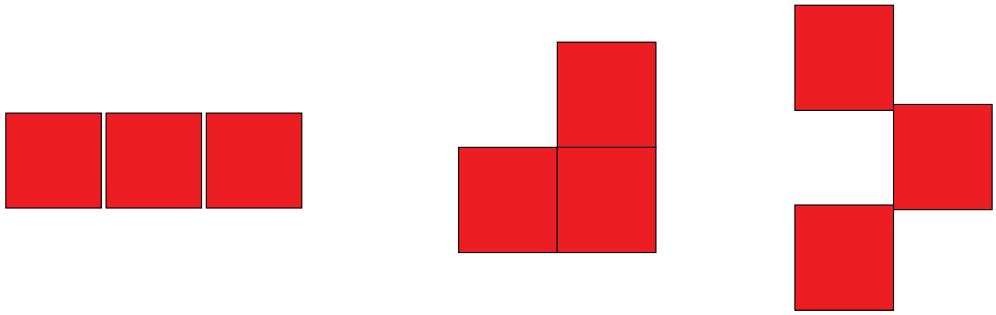
TABLE 5.3 Details of customization in forest fire alerts and number of Users

S. No.	State/UT	Alert Level	RFA details included in alerts (Yes/No)	Number of Users	Number of feedback received for MODIS & SNPP-VIIRS alerts -2018
1.	Andhra Pradesh	Beat	Yes	2,039	62
2.	Arunachal Pradesh	District	No	10	0
3.	Assam	District	No	16	0
4.	Bihar	Beat	No	71	14
5.	Chhattisgarh	Beat	Yes	2,541	310
6.	Delhi	District	No	10	0
7.	Goa	Beat	Yes	282	13
8.	Gujarat	Beat	No	1,178	2
9.	Haryana	Beat	Yes	144	4
10.	Himachal Pradesh	Beat	No	20,082	213
11.	Jammu & Kashmir	Range	Yes	1,070	2
12.	Jharkhand	Beat	No	247	2
13.	Karnataka	Beat	No	3,954	416
14.	Kerala	Range	No	2,948	95
15.	Madhya Pradesh	Beat	Yes	3,971	622
16.	Maharashtra	Beat	Yes	8,156	452
17.	Manipur	Beat	No	216	42
18.	Meghalaya	Range	No	9	0
19.	Mizoram	Beat	No	102	0
20.	Nagaland	District	No	10	0
21.	Odisha	Beat	Yes	2,612	89
22.	Punjab	Beat	No	1,218	95
23.	Rajasthan	District	No	450	12
24.	Sikkim	District	No	6	0
25.	Tamil Nadu	Beat	Yes	1,864	267
26.	Telangana	Beat	Yes	3,681	3,183
27.	Tripura	Beat	No	5	0
28.	Uttar Pradesh	Beat	No	1,879	4,102
29.	Uttarakhand	Beat	Yes	3,716	5,745
30.	West Bengal	Beat	Yes	415	0
31.	A&N Islands	District	No	63	0
32.	Chandigarh	District	No	5	0
33.	Dadra & Nagar Haveli	District	No	2	0
34.	Daman & Diu	District	No	2	0
35.	Lakshadweep	District	No	1	0
36.	Puducherry	District	No	9	0

5.7 MONITORING OF LARGE FOREST FIRES

In the latest version of Forest Fire Alert System (Version 3.0), a new and separate activity of monitoring large forest fires has been added. The input for the large forest fire detection is the same SNPP-VIIRS based feed of hotspots. This program monitors large forest fires and provides alerts to field officers in order to generate special emphasis towards control of larger fires. The software developed by FSI fire team, identifies a candidate large fire through an automated algorithm which identifies a large fire comprising at least 3 contiguous VIIRS pixels. Once the candidate large fire is detected through analysis of three connected VIIRS pixels in any geometry, it is continuously monitored using data from subsequent satellite passes as long as the fire is alive. The program also scans the area for additional 3 days after its inactivity to detect dormant fires, if any, relapsing in the same area again. 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. Field studies are also underway for testing and validation of the system.

FIGURE 5.3 Examples of pixel clusters in large forest fires



FSI disseminates Large Forest Fire alerts to help SFDs to monitor such fires so that additional assistance and resources may be mobilized to contain such fires. However, the detected large fires may not actually be a large fire on the ground as there could be multiple small fires within the area covered by the three adjacent pixels. However, even in such cases, it would be prudent to act on these smaller fires and not allow them to coalesce and develop into a large fire.

The objectives of monitoring of Large Forest Fires are enlisted below:

a) to monitor continuous, large forest fires in near-real time

b) to enable SFDs to control such fires timely

c) to escalate the alerts for timely additional support from agencies such as District Administration, SDMA, NDMA, Armed forces etc

d) to enable creation of a National Large Forest Fire Database for future planning especially in development of State Crisis Management Plans and Working Plans

e) to support rehabilitation of fire affected areas through post fire studies

5.8 OUTREACH OF FOREST FIRE ALERT SYSTEM

The user base of Forest Fire Alert System has grown significantly from around 2,000 in 2017 to more than 66,000 in 2019. The increase in number of subscriptions indicate the usefulness of the service particularly in those States where customized alerts are being disseminated to the administrative jurisdiction of the field officials.

The number of States where beat level information was available has gone from 10 to 21, in the last two years. This has made possible to send alerts right up to the forest compartment level in larger number of States.

Table 5.4 presents total number of alerts issued for each State based on MODIS and SNPP-VIIRS satellite data from November 2018 to June 2019. These alerts include repeat detections of continuing forest fires.

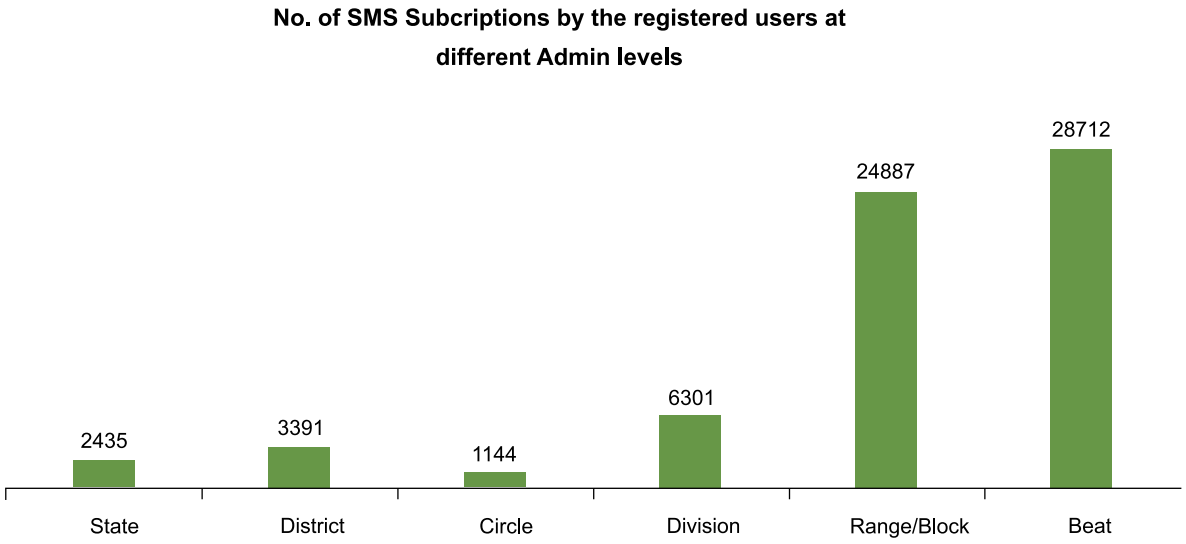
TABLE 5.4 State-wise forest fire alerts disseminated from Nov. 2018 to June 2019

S. No.	States/UTs	Number of Forest Fire Alerts issued by FSI from November 2018 to June 2019	
		MODIS	SNPP-VIIRS
1.	Andhra Pradesh	1,748	15,746
2.	Arunachal Pradesh	926	2,617
3.	Assam	1,940	5,935
4.	Bihar	203	2,450
5.	Chhattisgarh	1,608	25,750
6.	Delhi	2	20
7.	Goa	11	140
8.	Gujarat	224	2,885
9.	Haryana	24	135
10.	Himachal Pradesh	142	1,446
11.	Jammu & Kashmir	62	661
12.	Jharkhand	363	6,221
13.	Karnataka	1,228	8,078
14.	Kerala	192	1,162
15.	Madhya Pradesh	2,723	22,108
16.	Maharashtra	2,516	26,939
17.	Manipur	1,752	7,384
18.	Meghalaya	1,545	5,797
19.	Mizoram	2,795	7,597
20.	Nagaland	1,057	2,898
21.	Odisha	2,123	19,159
22.	Punjab	77	214
23.	Rajasthan	386	3,025
24.	Sikkim	11	64
25.	Tamil Nadu	752	4,402
26.	Telangana	1,246	15,262
27.	Tripura	1,195	3,083
28.	Uttar Pradesh	855	4,428
29.	Uttarakhand	1,578	12,965
30.	West Bengal	257	1,653
31.	Andaman & Nicobar Islands	6	37
32.	Chandigarh	0	0
33.	Dadra & Nagar Haveli	0	19
34.	Daman & Diu	0	2
35.	Lakshadweep	0	0
36.	Puducherry	0	4
Grand Total		**29,547**	**2,10,286**

SMS Subscriptions at Different Levels

SMS Subscription Details	State	District	Circle	Division	Range/ Block	Beat	Total
	2,435	3,391	1,144	6,301	24,887	28,712	66,870

FIGURE 5.4 Users subscriptions across different levels of administrative hierarchy



5.9 EARLY WARNING & DANGER RATING

Early Warning and Danger Rating for forest fires are the concepts which make use of weather data, forest fuel load conditions, socio-economic & infrastructure data and terrain conditions in issuing early warning for likely forest fire incidents in an area. These warnings are useful in taking timely preventive measures to avoid occurrence of forest fires and related losses.

FSI started working on the Early Warning & Danger Rating systems in 2016. The vulnerable forest areas which had conducive short term weather forecast for forest fires to occur, were overlaid on fire prone forest areas. This method was modified in 2017 wherein these parameters were quantified and overlaid on grids of 5 km x 5km. The pattern of distribution of fire incidences over the grid from past fire alert data were included as an additional input along with daily Relative Humidity and Maximum Temperature to estimate drought conditions. The short term ensemble weather prediction data from Indian Institute of Tropical Meteorology, Pune was used to estimate drought and to mask out areas where rainfall is expected. Grids to be alerted were selected based on a knowledge based decision system and these areas were communicated once in a week to the States.

FSI has recently started to work on a system similar to Fire Weather Index (FWI) of Canadian Forest Fire Danger Rating System (CFFDRS) for fire danger rating in India on a pilot basis. The FWI values from GEOS-5 daily data from NASA's GFWED database were downloaded and thresholds were customized for Western Himalayan and Central Indian region. The Fire Danger Rating was categorized into five classes which are Extreme, Very High, High, Moderate and Low.

5.10 IDENTIFYING FIRE PRONE FOREST AREAS OF INDIA

An analysis of fire prone forest areas was carried out by FSI and the results were published in the Technical Information Series (Vol I, No I)[3] report in January, 2019. Findings of the study indicate that 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. More than 36% of the country's forest cover has been estimated prone to frequent forest fires.

All the forest fire points detected by FSI based on MODIS data during the period 2004 to 2017 were analyzed in GIS by overlaying the points coverage over the grid coverage of 5km x 5km. The detected forest fire points (FFP) numbering 2,77,758 include repeat detections of continuing forest fires also. The analysis was done on the premise that a fire prone forest area will show relatively higher number of detected forest fire points over a long period of time i.e. 13 years. Frequency of forest fire points in each grid of 5 km x 5km was determined through the GIS analysis. Based on the derived frequency of FFPs per year each grid was categorized in terms of fire proneness using the following criteria.

TABLE 5.5 Fire Proneness categories and criteria

Category	Range
Extremely fire prone forest area	Average frequency of forest fires≥4 in a grid per year
Very highly fire prone forest area	Average frequency of forest fires (≥ 2 and <4) in a grid per year
Highly fire prone forest area	Average frequency of forest fires (≥ 1 and <2) in grid per year
Moderately fire prone forest area	Average frequency of forest fires (≥ 0.5 and <1) in grid per year
Less fire prone forest area	Average frequency of forest fires (< 0.5) in grid per year

Further, an analysis in GIS was done by overlaying the forest cover layer over the grids categorized into different fire prone classes to assess extent of forest cover under different intensities of fire proneness. The results at the national level are summarized in the Table 5.6 below:

TABLE 5.6 Forest cover in different fire prone classes

S. No.	Forest Fire Prone Classes	No. of Grids	Forest Cover* (in sq km)	% of Total forest cover
1.	Extremely fire prone	665	25,617	3.89
2.	Very highly fire prone	2,259	39,500	6.01
3.	Highly fire prone	3,708	75,952	11.50
4.	Moderately fire prone	5,496	96,422	14.70
5.	Less fire prone	57,489	4,20,625	63.90
Total		**69,617**	**6,58,116**	**100.00**

*Forest Cover in the above table excludes Trees Outside Forest (TOF) area.

A map showing fire prone forest areas in the country under different categories is presented as Fig. 5.5. State wise forest cover under different fire proneness categories is presented in Table 5.7. Maps showing fire prone forest areas and related statistics are presented for each State and UT in the respective sub chapters in Vol II.

It is seen that most of the fire prone forest area are found in the northeastern region and the central part of the country. The above study assumes significance from the point of view of strategizing forest fire mitigation measures by the SFDs by according priority to forest areas in terms of fire proneness. It can also be used as a basis for resource allocation for the forest control activities both at the Central and State levels.

[3] Kumar S., Chaudhary A., Biswas T., Ghosh S. and Ashutosh S. (2019). Identification of Fire Prone Forest Areas Based on GIS Analysis of Archived Forest Fire Points Detected in the Last Thirteen Years. FSI Technical Information Series. Vol **1** (1): 1-15

FIGURE 5.5 Map showing forest areas under different fire prone classes

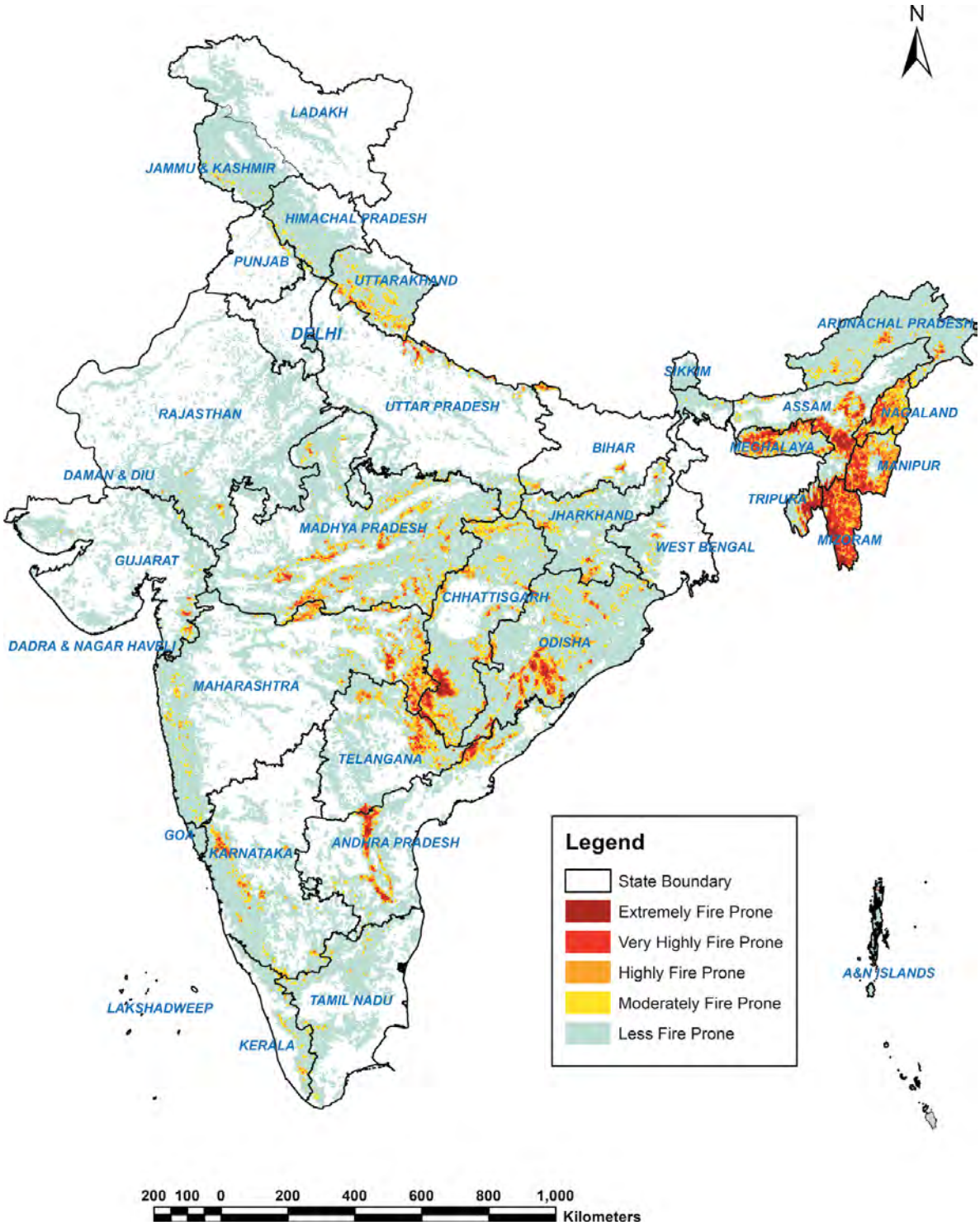


TABLE 5.7 Forest Cover# of States & UTs under different fire prone classes

(area in sq km)

S. No.	State / UT	Extremely Fire Prone		Very Highly Fire Prone		Highly Fire Prone		Moderately Fire Prone		Less Fire Prone	
		Forest cover	% of total forest cover	Forest cover	% of total forest cover	Forest cover	% of total forest cover	Forest cover	% of total forest cover	Forest cover	% of total forest cover
1.	Andhra Pradesh	1,095	4.27	3,611	13.04	4,152	15.27	5,089	18.72	13,244	48.70
2.	Arunachal Pradesh	13	0.02	648	0.97	2,334	3.49	4,598	6.87	59,371	88.65
3.	Assam	5,493	21.98	1,522	6.10	3,619	14.48	3,428	13.72	10,923	43.72
4.	Bihar	0	0	371	7.15	917	17.68	1,180	22.74	2,720	52.43
5.	Chhattisgarh	2,140	3.9	3,327	6.04	7,452	13.55	12,287	22.34	29,784	54.17
6.	Delhi	0	0	0	0	0	0	0	0	131	100.00
7.	Goa	0	0	0	0	0	0	1	0.05	1,925	99.95
8.	Gujarat	32	0.25	329	2.69	424	3.45	1,036	8.43	10,467	85.18
9.	Haryana	0	0	25	2.33	63	5.87	194	18.08	791	73.72
10.	Himachal Pradesh	0	0	4	0.03	172	1.18	670	4.59	13,748	94.20
11.	Jammu & Kashmir	0	0	18	0.08	84	0.38	584	2.65	21,355	96.89
12.	Jharkhand	47	0.21	488	2.18	2,048	9.16	4,370	19.54	15,414	68.91
13.	Karnataka	95	0.29	863	2.61	2,301	6.96	3,301	9.99	26,494	80.15
14.	Kerala	0	0	22	0.18	460	3.84	1,396	11.67	10,087	84.31
15.	Madhya Pradesh	109	0.14	2,893	3.79	9,077	11.87	14,806	19.36	49,599	64.84
16.	Maharashtra	1,677	3.40	1,966	4.01	7,667	15.60	8,181	16.65	29,642	60.34
17.	Manipur	769	4.48	5,755	33.13	6,219	35.85	2,665	15.36	1,937	11.18
18.	Meghalaya	983	5.74	3,152	18.38	3,452	20.13	3,047	17.77	6,512	37.98
19.	Mizoram	5,423	29.91	7,009	38.46	4,481	24.64	972	5.35	299	1.64
20.	Nagaland	380	3.05	2,309	18.48	4,752	38.05	3,204	25.65	1,844	14.77
21.	Odisha	1,449	2.82	3,940	7.73	6,808	13.32	10,200	19.96	28,706	56.17
22.	Punjab	0	0	8	0.56	242	17.09	414	29.24	752	53.11
23.	Rajasthan	0	0	50	0.32	384	2.48	561	3.62	14,491	93.58
24.	Sikkim	0	0	0	0	0	0	0	0	3,213	100.00
25.	Tamil Nadu	0	0	0	0	439	2.19	1,589	7.92	18,036	89.89
26.	Telangana	911	4.21	1,322	6.89	3,540	17.59	3,743	18.60	10,606	52.71
27.	Tripura	1,862	26.95	1,555	21.90	881	12.62	751	10.76	1,939	27.77
28.	Uttar Pradesh	104	0.92	805	7.10	1,344	11.86	2,002	17.66	7,079	62.46
29.	Uttarakhand	40	0.17	389	1.60	2,254	9.32	5,238	21.66	16,264	67.25
30.	West Bengal	0	0	82	0.99	360	4.33	892	10.72	6,988	83.96
31.	A & N Islands	0	0	32	0.52	26	0.42	23	0.38	6,044	98.68
32.	Chandigarh	0	0	0	0	0	0	0	0	10	100.00
33.	Dadra & Nagar Haveli	0	0	0	0	0	0	0	0	194	100.00
34.	Daman & Diu	0	0	0	0	0	0	0	0	16	100.00
35.	Puducherry	0	0	0	0	0	0	0	0	2	100.00
Total		**22,622**		**42,495**		**75,952**		**96,422**		**4,20,627**	

excludes Trees Outside Forest (TOF)

FIGURE 5.6 Burnt scars on satellite image Sentinel 2A

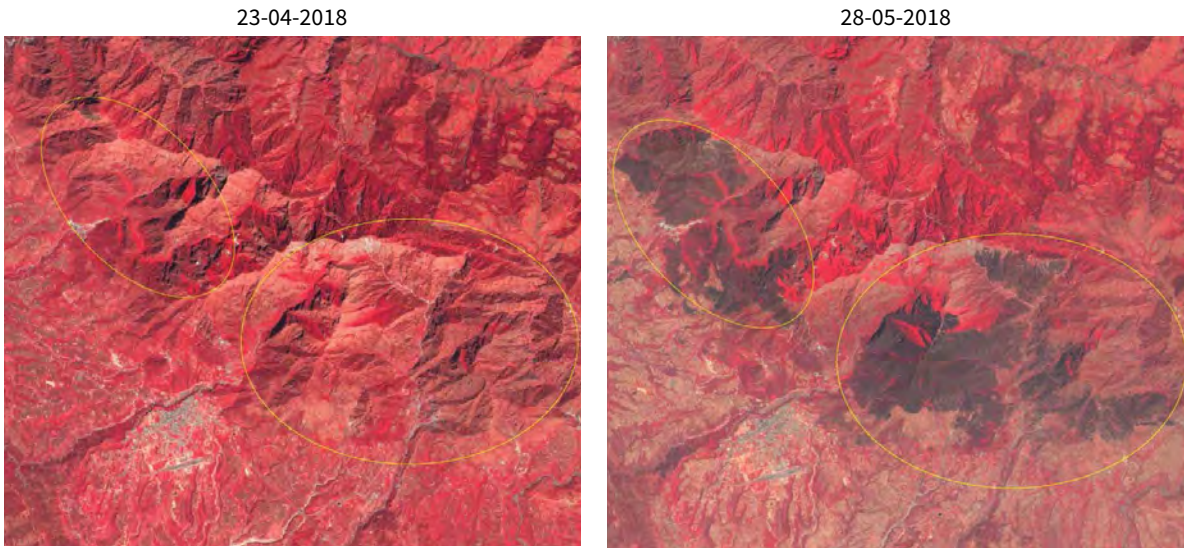


FIGURE 5.7 Forest Fire detections based on MODIS in the last five years

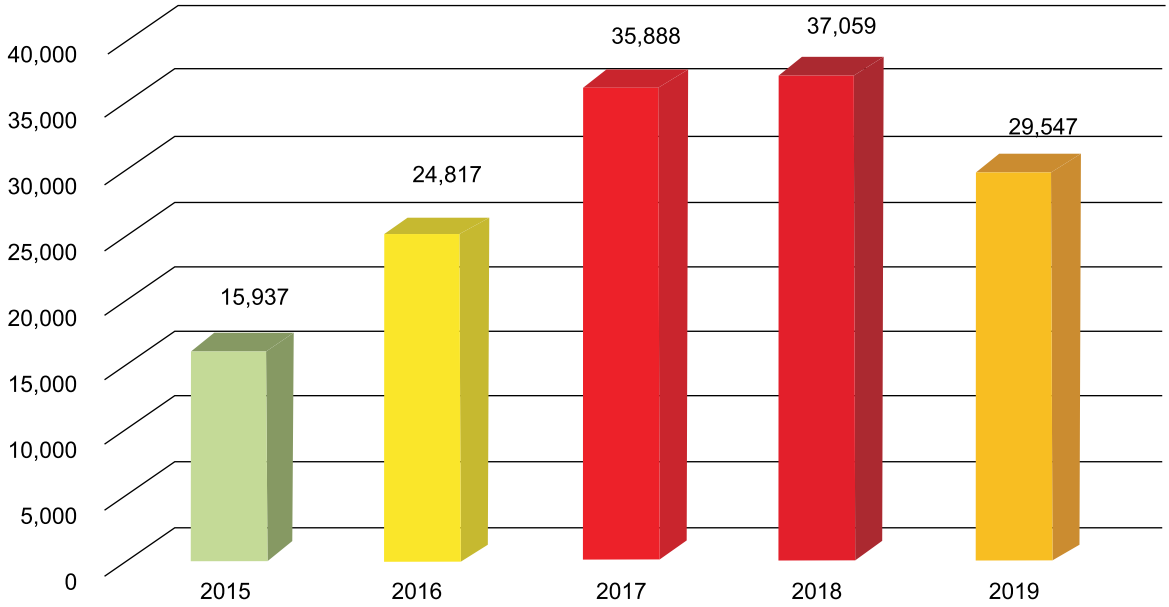
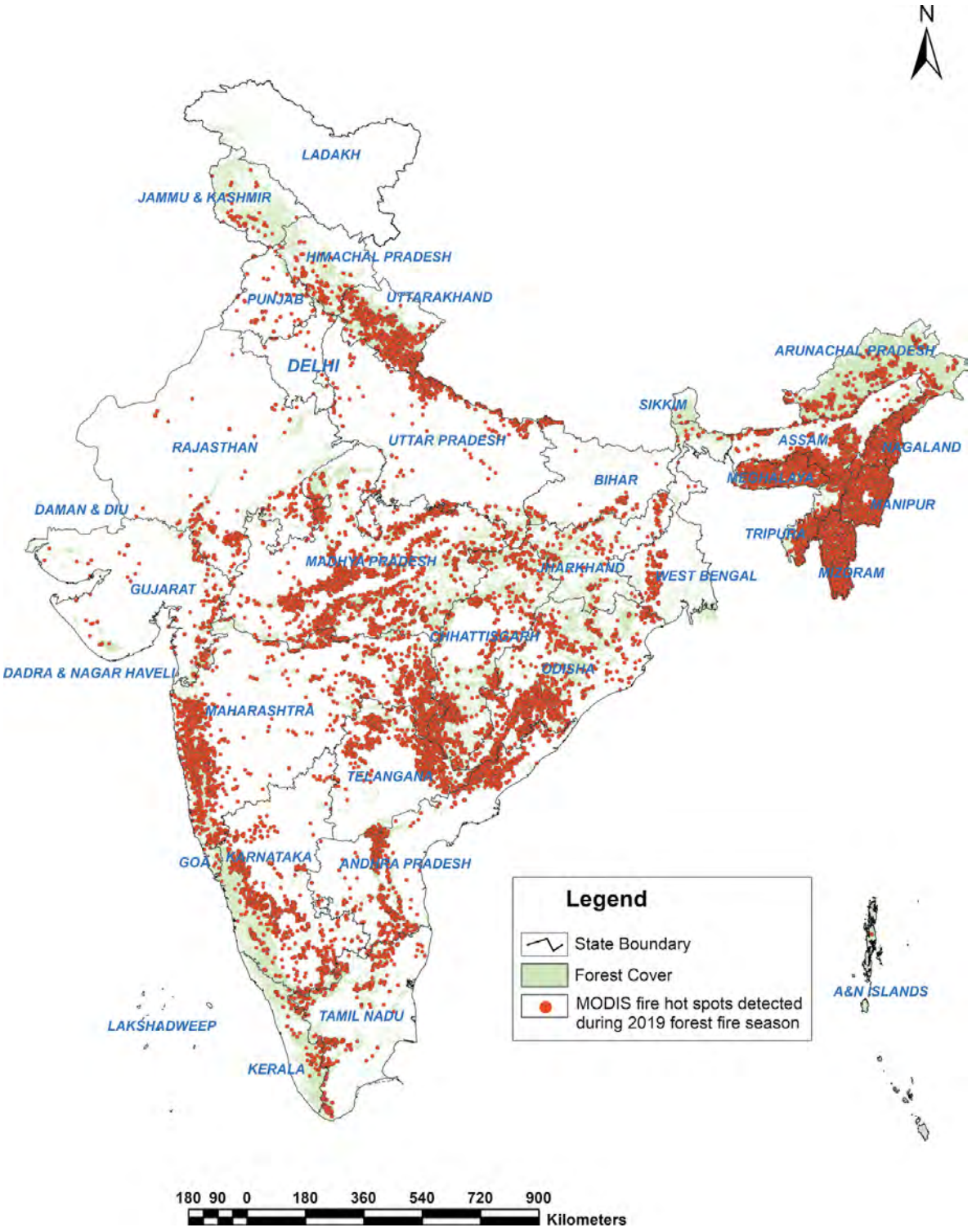
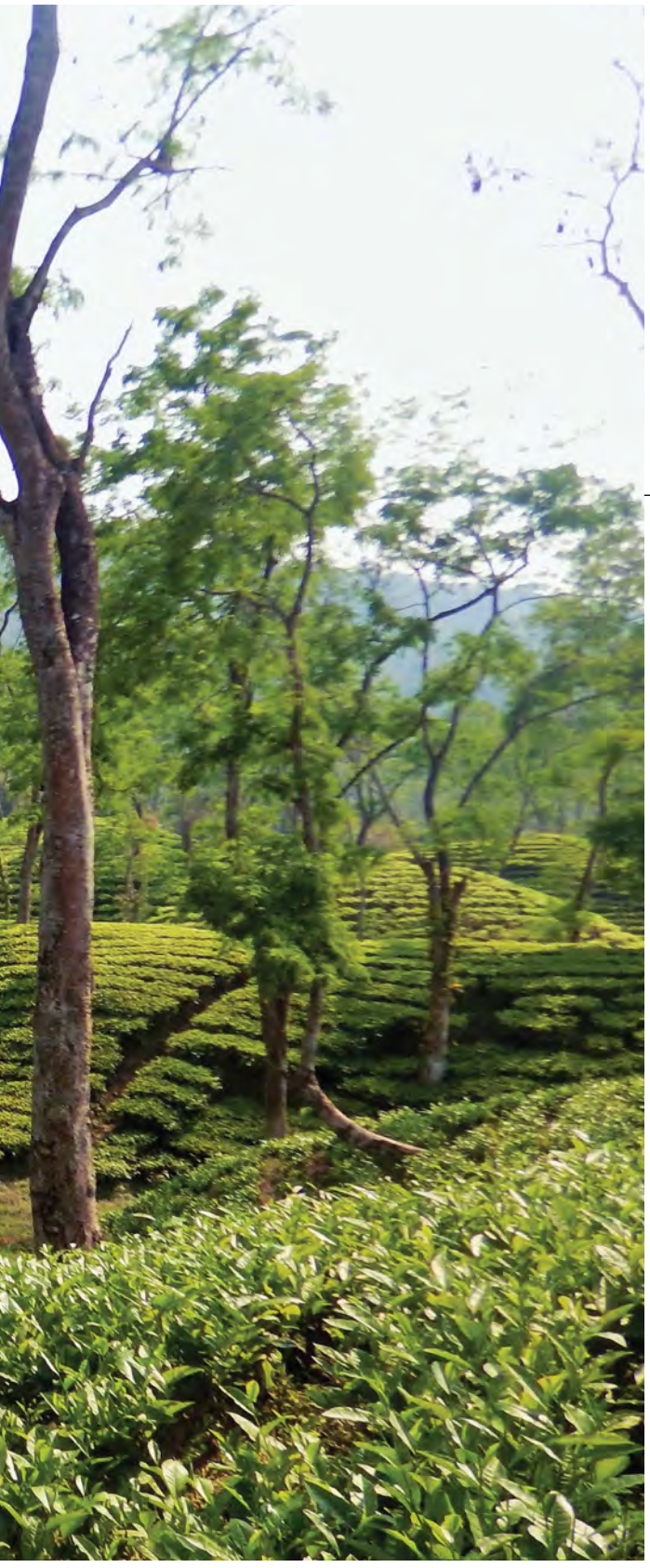


FIGURE 5.8 Map showing MODIS hot spots detected during 2018-19 forest fire season





6 Chapter

Tree cover

6.1 INTRODUCTION

The National Forest Policy 1988 aims at bringing 33% of the geographical area of the country under forest and tree cover. FSI assesses forest and tree cover of the country in biennial cycle. The forest cover assessment, which 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, is done using satellite data. However, there are many small patches of trees which are less than 1 ha in extent, such as trees in village woodlots, homesteads, trees along linear features such as roads, canals, bunds, trees in urban areas, scattered trees etc. These smaller patches of trees are not included in the forest cover due to technological limitations of spatial resolution of satellite data used for the forest cover mapping. These widely spread patches of trees in the rural and urban landscapes play significant socio-economic, cultural and ecological roles. The extent of such tree formations is assessed as tree cover using a methodology based on stratified random sampling. The methodology

involves use of high-resolution remote sensing data and field measurements on sample plots. Thus, information on tree cover along with forest cover gives a complete extent of tree resources of the country which is often termed as 'Forest & Tree Cover'.

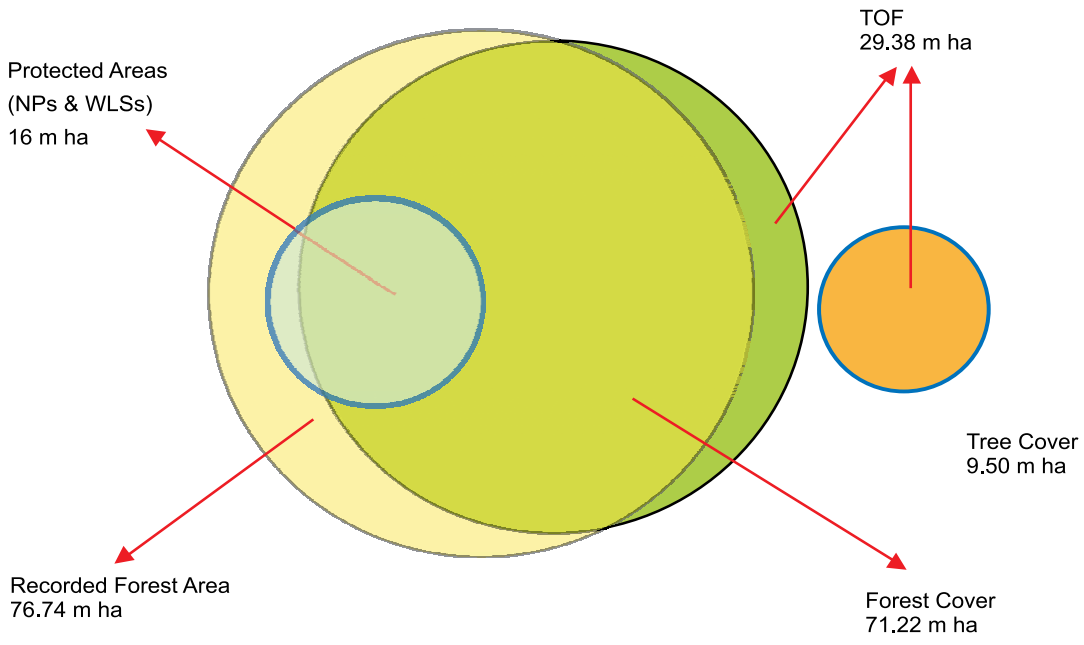
6.2 TREE COVER AND TREES OUTSIDE FOREST (TOF)

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. Though TOF and tree cover appear as similar terms but they are two different entities as defined in the FSI's assessment, though closely related to each other. TOF refers to all trees growing outside RFA irrespective of patch size which could also be larger than 1 ha. Thus tree cover becomes a subset of TOF. Tree cover is estimated using a sampling based methodology wherein high resolution satellite imagery is used for stratification. Thus, trees included in the tree cover constitute only a part of TOF Fig. 6.3 gives a diagrammatic relationship between the TOF and Tree Cover.

FIGURE 6.1 Linear plantation along Canal

FIGURE 6.2 Block plantation

FIGURE 6.3 Showing relationship between Tree Cover and TOF



6.3 METHODOLOGY FOR TREE COVER ESTIMATION

Tree cover of the country has been estimated State wise from the data collected during inventory of TOF in rural and urban areas following the grid based inventory design. The TOF inventories of rural and urban areas are carried out in the grids selected for a particular year. Though primary objective of TOF inventory is estimation of growing stock, the data collected during the inventory is used for estimation of tree cover also. Separate methodologies are followed for inventory of TOF (rural) and TOF (urban).

6.3.1 Estimation of Tree cover in Rural Areas

The tree cover of the rural area has been estimated by sampling approach using high-resolution satellite data in conjunction with the inventory data of TOF (rural). For inventory of rural areas, high-resolution satellite data is used for stratification of TOF into three strata namely block, linear and scattered. The methodology has been described briefly as follows:

The Multispectral data of Sentinel-2 with spatial resolution of 10 m and swath of 290 km has been used for classification of the selected grids. The Sentinel satellite data is downloaded and geo-rectified with the help of Survey of India (SOI) open series map topo sheets on 1: 50,000 scale. The image is then classified into settlement, water bodies, tree patches, agriculture and other land cover classes. This classification enables the interpreter to distinguish between tree patches and other classes. The classified image is visually analysed for editing and refinement. Since the minimum mappable area is 0.1 ha, pixels are clumped and cluster of pixels having area less than 0.1 ha are eliminated. After editing of the classified image, the final classified map is generated having three classes in TOF areas, namely Block, Linear and Scattered. From the classified TOF map, area under each category (stratum) is calculated. In addition, areas which do not support tree vegetation, like rivers and water bodies, riverbeds, snow covered mountains etc which are termed as Un-Culturable Non Forest Area are also calculated. The schematic chart of the methodology of TOF using remote sensing is depicted in the Fig 6.6.

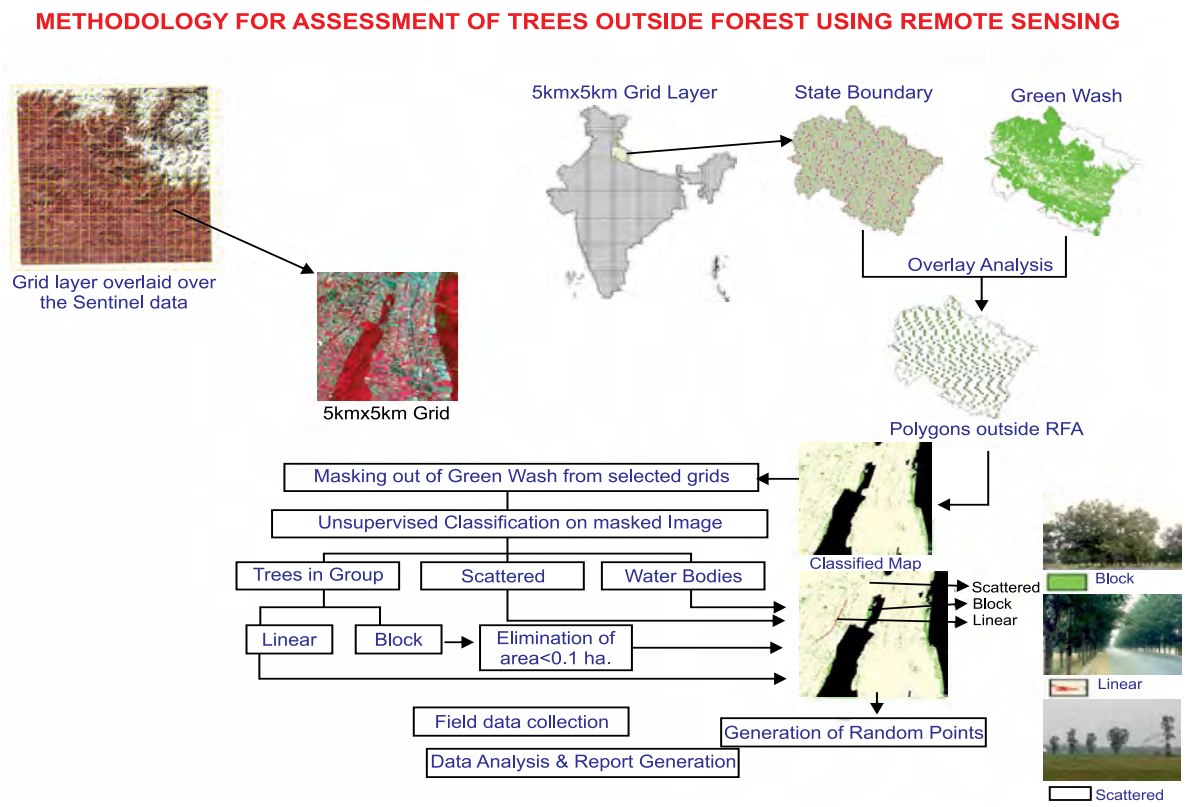
The plot size for Block and Linear strata is 0.1 ha square plot and 10 m ×125 m strip, respectively. In case of scattered stratum, the plots of size 3.0 ha square in non-hilly areas and 0.5 ha square in hilly areas are laid out.

Sample points are randomly generated within selected grids for each stratum in area proportion to size and the data on pre-decided variables like dbh, crown diameter, species and category of

FIGURE 6.4 Trees in village woodlots

FIGURE 6.5 Trees on Farm Bunds

FIGURE 6.6 Schematic diagram of the methodology of TOF



plantation etc are collected on pre-designed formats. The complete enumeration of all the trees of 5 cm and above dbh is carried out.

The tree cover of the rural area comprises area of block and linear 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 clumped and eliminated as the same has 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 are estimated at the State level with rural CNFA. 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 percent canopy density. The total tree cover of the State is obtained by adding the estimated area of block, linear and scattered tree formations.

6.3.2 Estimation of Tree Cover in Urban Areas

The tree cover of the urban area is estimated from the inventory of TOF (Urban). For urban TOF inventory, urban centers defined by the office of Registrar General of India are considered as study area. For the inventory of urban areas, high-resolution satellite data is not used due to non-availability of digital boundaries of the urban areas. Moreover, configuration of urban setting does not permit to

FIGURE 6.7 Trees along road

FIGURE 6.8 Trees in urban setting

follow the same design as used for the rural inventory. Therefore for urban areas, the sampling frame is taken from the National Sample Survey Organisation (NSSO) which has stratified the urban areas into Urban Frame Survey (UFS) Blocks. UFS blocks have well defined boundaries and they generally comprise 600 to 800 population size or 120-160 households. All the UFS blocks put together cover the whole area within the geographical boundary of a town including vacant lands.

The list of all urban towns and cities as per the census of 2011[1] 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 on pre-decided variables like dbh, crown diameter, species name and category of plantation, etc are collected on pre-designed formats. The complete enumeration of all the trees of 5 cm and above dbh is carried out in the prescribed forms. 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 block plantation of trees with area more than one hectare are eliminated, as the same has 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 percent canopy density.

The total tree cover of the State is obtained 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 95,027 sq km. There is an increase of 1,212 sq km in the extent of tree cover as compared to the 2017 assessment. The standard error of the tree cover estimate at the national level has been assessed at 6.06%. The standard error at the State level varies from 3.41% to 16.86%, which is given at annexure IV. The State wise estimates of tree cover is given in Table 6.1 which shows that the State having maximum tree cover is Maharashtra (10,806 sq km) followed by Madhya Pradesh (8,339 sq km), Rajasthan (8,112 sq km) and Jammu & Kashmir (7,944 sq km). Considering the percentage of geographical area of State/UTs, the Union Territory of Chandigarh shows highest percentage of tree cover (22.34%) followed by Delhi (8.73%), Kerala (7.56%), and Goa (7.34%).

[1] Census of India (2011). Office of Registrar General & Census Commissioner of India, Ministry of Home Affairs, Govt. of India

TABLE 6.1 State/ UT wise Tree Cover estimates

(in sq km)

S. No	State/UTs	Geographical Area (GA)	Tree Cover	Percent of GA
1.	Andhra Pradesh	162,968	3,914	2.40
2.	Arunachal Pradesh	83,743	848	1.01
3.	Assam	78,438	1,408	1.80
4.	Bihar	94,163	2,003	2.13
5.	Chhattisgarh	135,192	4,248	3.14
6.	Delhi	1,483	129	8.73
7.	Goa	3,702	272	7.34
8.	Gujarat	196,244	6,912	3.52
9.	Haryana	44,212	1,565	3.54
10.	Himachal Pradesh	55,673	829	1.49
11.	Jammu & Kashmir*	222,236	7,944	3.57
12.	Jharkhand	79,716	2,657	3.33
13.	Karnataka	191,791	6,257	3.26
14.	Kerala	38,852	2,936	7.56
15.	Madhya Pradesh	308,252	8,339	2.71
16.	Maharashtra	307,713	10,806	3.51
17.	Manipur	22,327	173	0.77
18.	Meghalaya	22,429	710	3.17
19.	Mizoram	21,081	441	2.09
20.	Nagaland	16,579	362	2.19
21.	Odisha	155,707	4,648	2.98
22.	Punjab	50,362	1,592	3.16
23.	Rajasthan	342,239	8,112	2.37
24.	Sikkim	7,096	36	0.51
25.	Tamil Nadu	130,060	4,830	3.71
26.	Telangana	112,077	2,514	2.24
27.	Tripura	10,486	231	2.20
28.	Uttar Pradesh	240,928	7,342	3.05
29.	Uttarakhand	53,483	841	1.57
30.	West Bengal	88,752	2,006	2.26
31.	A & N Islands	8,249	41	0.50
32.	Chandigarh	114	25	22.34
33.	Dadra & Nagar Haveli	491	28	5.75
34.	Daman & Diu	111	5	4.87
35.	Lakshadweep	30	0.29	0.97
36.	Puducherry	490	23	4.66
Total		**3,287,469**	**95,027**	**2.89**

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

6.5 EXTENT OF TREES OUTSIDE FORESTS

In India, requirement of wood and wood based products to a large extent is met from Trees Outside Forests. They are also important for their ecological, socio- economic and cultural significance. TOF are also seen as an important carbon sink. Extent of TOF and its dynamics is important information for policies, planning and programme formulation for its management and enhancement.

TOF refer to tree resources found outside the recorded forest areas. FSI maps forest cover using satellite data and assesses tree cover outside forests using sampling based method. Forest Cover outside the recorded forest area is derived using boundaries of RFA. There are States where RFA boundaries are not available in digital format, in such states Green Wash shown on SOI toposheets have been used as a substitute to the RFA boundaries. Extent of TOF therefore may be estimated as the sum of extent of forest cover outside the RFA / Green Wash as given in the section 2.12 of chapter 2 and tree cover as given in the section 6.3 of this chapter.

In the current assessment, the extent of TOF has been derived for the first time and is assessed 29.38 million hectares which is 36.40 % of the total forest and tree cover in 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)

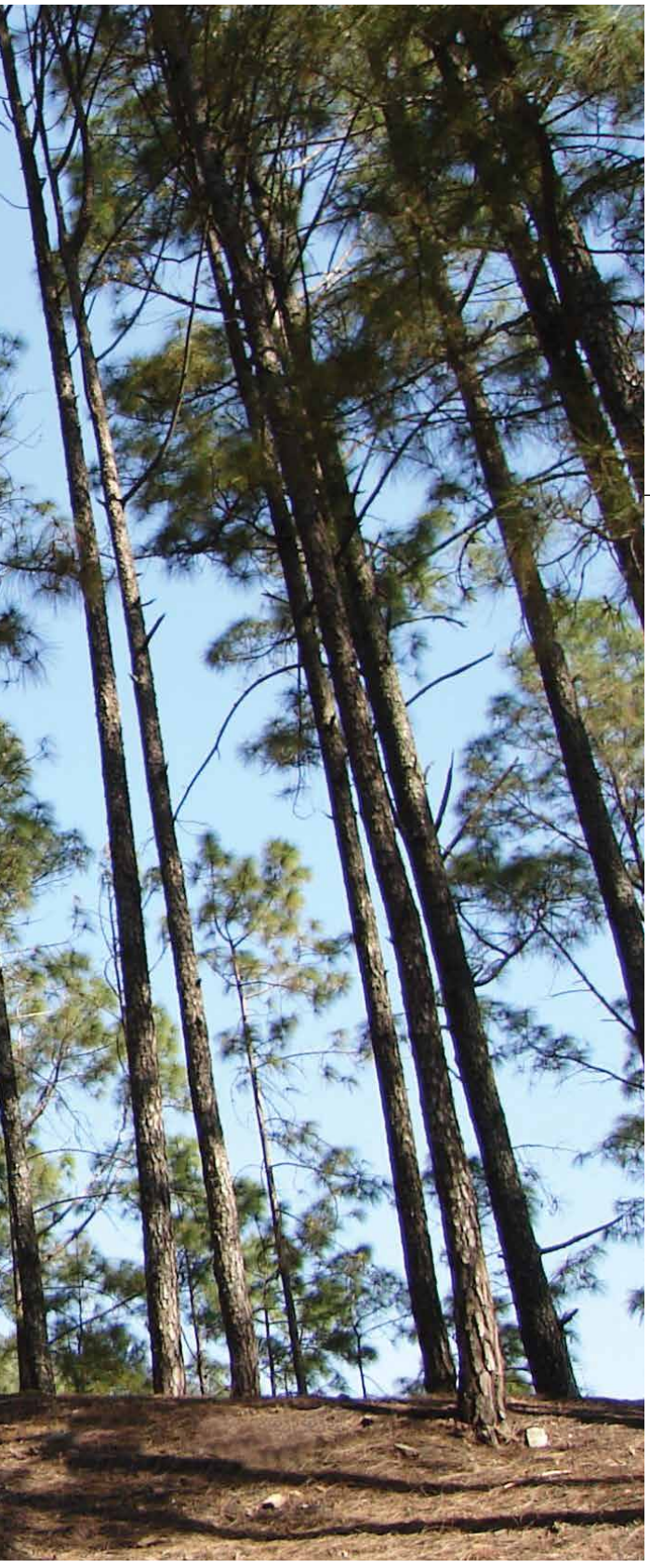
S.No	State/UTs	Geo. Area	Tree cover 2019	Forest cover outside RFA	Extent of TOF**	% of Forest & Tree Cover of the State/ UTs	% of Geographical Area of the State/UTs
1.	Andhra Pradesh	1,62,968	3,914	5,018	8,932	27.03	5.48
2.	Arunachal Pradesh	83,743	848	7,967	8,815	13.05	10.53
3.	Assam	78,438	1,408	8,183	9,591	32.25	12.23
4.	Bihar	94,163	2,003	2,537	4,540	48.77	4.82
5.	Chhattisgarh	1,35,192	4,248	13,195	17,443	29.14	12.90
6.	Delhi	1,483	129	136.37	265	81.68	17.92
7.	Goa	3,702	272	1,063	1,335	53.21	36.05
8.	Gujarat	1,96,244	6,912	5,072	11,984	55.05	6.11
9.	Haryana	44,212	1,565	1,229	2,794	88.22	6.32
10.	Himachal Pradesh	55,673	829	4,796	5,625	34.58	10.10
11.	Jammu & Kashmir*	2,22,236	7,944	11,390	19,334	61.27	8.70
12.	Jharkhand	79,716	2,657	11,402	14,059	53.52	17.64
13.	Karnataka	1,91,791	6,257	16,104	22,361	49.88	11.66
14.	Kerala	38,852	2,936	11,507	14,443	59.98	37.17
15.	Madhya Pradesh	3,08,252	8,339	12,730	21,069	24.55	6.83
16.	Maharashtra	3,07,713	10,806	16,139	26,945	43.75	8.76
17.	Manipur	22,327	173	1,829	2,002	27.03	8.96
18.	Meghalaya	22429	710	2,275	2,985	13.05	13.31
19.	Mizoram	21,081	441	270	711	32.25	3.37
20.	Nagaland	16,579	362	3,759	4,121	48.77	24.86
21.	Odisha	1,55,707	4,648	18,810	23,458	29.14	15.06
22.	Punjab	50,362	1,592	1,065	2,657	81.68	5.28
23.	Rajasthan	3,42,239	8,112	4,348	12,460	53.21	3.64

S.No	State/UTs	Geo. Area	Tree cover 2019	Forest cover outside RFA	Extent of TOF**	% of Forest & Tree Cover of the State/ UTs	% of Geographical Area of the State/UTs
24.	Sikkim	7,096	36	996	1,032	55.05	14.54
25.	Tamil Nadu	1,30,060	4,830	8,775	13,605	88.22	10.46
26.	Telangana	1,12,077	2,514	2,313	4,827	34.58	4.31
27.	Tripura	10,486	231	2,275	2,506	38.35	23.90
28.	Uttar Pradesh	2,40,928	7,342	5,611	12,953	27.03	5.38
29.	Uttarakhand	53,483	841	7,513	8,354	13.05	15.62
30.	West Bengal	88,752	2,006	9,825	11,831	32.25	13.33
31.	A & N Islands	8,249	41	521	562	48.77	6.81
32.	Chandigarh	114	25	13.76	39	29.14	34.41
33.	Dadra & Nagar Haveli	491	28	47	75	81.68	15.32
34.	Daman & Diu	111	5	20.49	25	53.21	22.52
35.	Lakshadweep	30	0.29	27.10	27	55.05	91.30
36.	Puducherry	490	23	51.41	74	88.22	15.15
Total		**32,87,469**	**95,027**	**1,98,813**	**2,93,840**	**36.40**	**8.94**

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

** extent of TOF given in the above table are approximate figures due to limitations of boundaries of RFAs and Green Wash areas

It is seen from the above table that the State of Maharashtra is having largest extent of TOF in the country, followed by Odisha and Karnataka. In terms of percentage of geographical area, the State of Kerala has highest percentage of TOF, followed by Goa and Nagaland.



7 Chapter

Growing Stock

7.1 INTRODUCTION

Forest managers, planners and policy makers often need the detailed information about different forestry parameters such as distribution of timber species, volume, biomass, carbon stock, regeneration status, population and structures etc. in different regions of the country for strategic planning and management of forest resources. Growing stock is one of the most important parameters which quantifies forest resources. It is also an indicator of forest productivity. Forest inventories are primarily aimed at assessing the growing stock and other quantitative and qualitative parameters of the forests. In Working Plans, growing stock has traditionally been used for calculation of sustainable yield of timber from forests. In the recent past, growing stock estimation has gained further 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 forests. Further, the United Nations Framework Convention on Climate Change (UNFCCC) guidelines for implementation

of REDD+ require that every country should have a National Forest Monitoring System (NFMS) consisting of satellite based forest monitoring system and National Forest Inventory.

FSI has a long experience and expertise in carrying out inventory in the forest areas. In 1965, the Pre-Investment Survey of Forest Resources (PISFR) was established as a joint project of FAO, UNDP and Govt of India, to estimate availability of wood from forest rich areas of the country for establishing wood-based industries. The forest inventory in selected parts of the country continued after creation of FSI in 1981 following a uniform sampling design. About three-fourth of the country's forests had been inventoried till 2001 with some areas inventoried twice. About 140 reports have been published by FSI on forest inventory for the selected States and districts during this period.

Forest inventories carried out by FSI during the above period were limited to the selected areas at different times and hence were not suitable for generating national level estimates of growing stock. Therefore, FSI modified its sampling design in 2002 and launched National Forest Inventory (NFI) including both forest and TOF inventory. Under the modified design, the country was stratified in different physiographic zones based on the physiography, climate, vegetation etc. The NFI was based on systematic sampling approach wherein sixty districts, spread across the county used to be selected in the first stage distributed in different physiographic zones for the inventory on the systematically laid sample plots in 1 ¼‘ X 1 ¼‘ grids. This sampling design continued till 2016 when it was again modified with the objectives of generating National and State level estimates at acceptable precision level, reduce the revisit time to 5 years for forest and 10 years for TOF and meet the requirements of information on additional parameters.

7. 2 NEW NATIONAL FOREST INVENTORY (NFI) DESIGN

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

7.2.1 Forest Inventory

FSI has switched over to a grid based sampling design from a district based design since 2016. The new design is based on country wide uniform grids of size 5 km x 5 km and each year inventory of forest and TOF is carried out in systematically selected grids from the total grids across the country as shown in Fig 7.3. The plot configuration has also been changed from a single square plot to cluster of circular plots. Before launching of the new design, extensive technical discussions were held within FSI and also involving other stake holders like SFDs. A pilot study was conducted in all the zones of FSI to ascertain the size of the circular plots and distance between central subplots and other sub-plots. Additional parameters such as NTFPs, 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 have 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/Green Wash. Grids having a specific number in the panel are covered in a single survey year.

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 Fig 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. A schematic diagram of plot design is shown in Fig 7.4

7.2.2 Trees Outside Forest (TOF)

Since the cycle for the TOF inventory in the new design has been kept at 10 years, all TOF grids are marked with numbers 1 to 10. Grids of a particular number are taken for inventory in the corresponding 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 centers defined by the Registrar General of India are considered as study area. The sampling unit for urban inventory is taken as Urban Frame Survey (UFS) from National Sample Survey Office (NSSO). The urban centers of a district are delineated into blocks called 'UFS blocks', which are shown on maps with well-defined boundaries and generally cover 600 to 800 population size or 120-160 households. These blocks put together cover the whole area within the geographical boundary of a town including vacant lands.

The list of all urban towns and cities with the names 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 latitude and longitude of centroid and area of the towns, a circular buffer zone of appropriate radius is created. At 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 5 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 NSSO. One UFS block is selected randomly from each grid for urban TOF inventory. Remaining grids are covered under TOF (Rural) inventory.

FIGURE 7.1 Measurements during forest inventory

FIGURE 7.2 Recording field observations during forest inventory

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

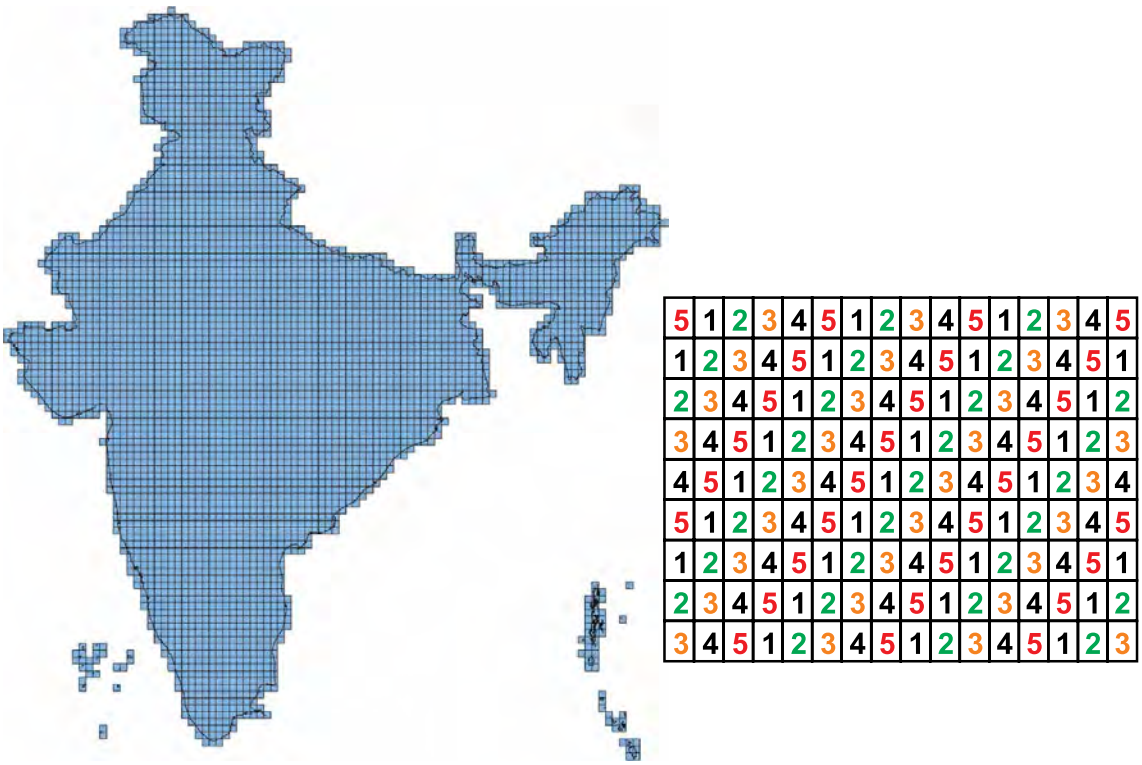
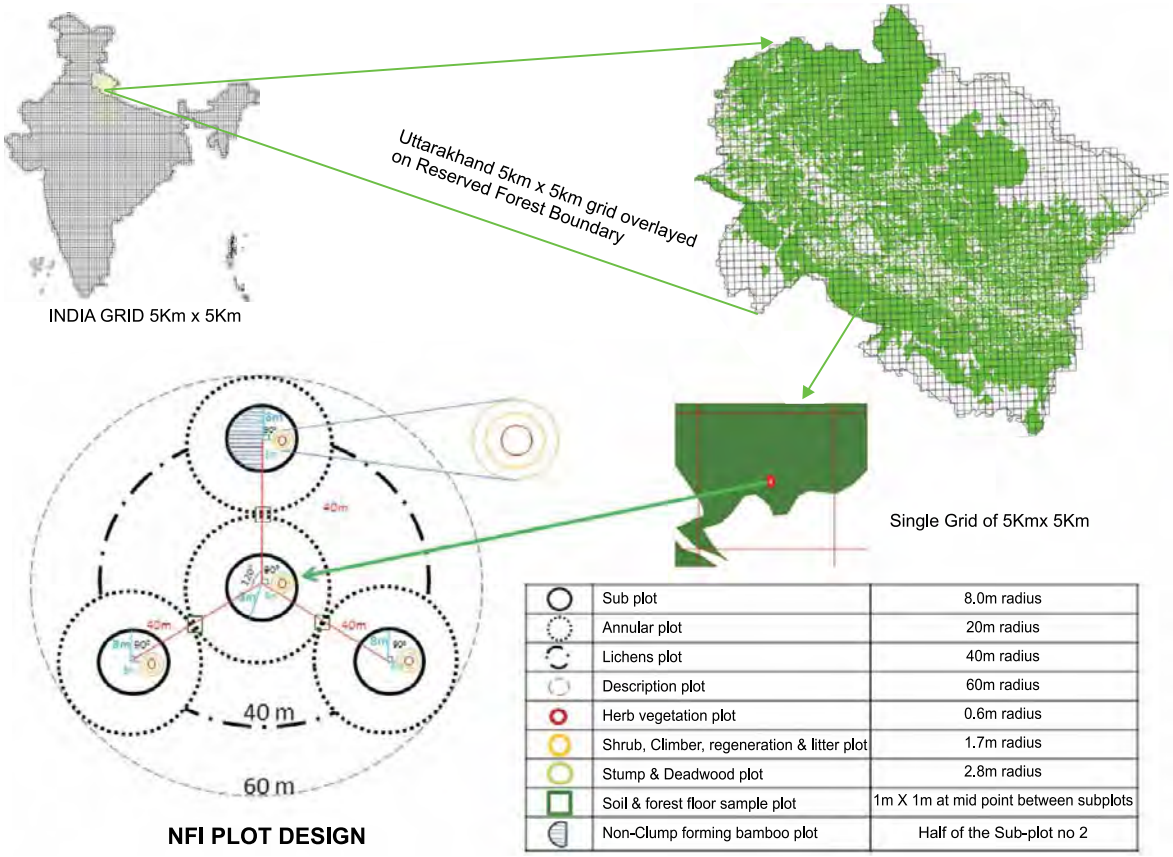


FIGURE 7.4 Plot Configuration



For 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 number of sample points are generated in the selected grids. The latitude and longitude of all the 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 schematic diagram.

The Multispectral data of Sentinel-2 with spatial resolution of 10m and swath of 290 km has been used for classification of the selected grids. The sentinel satellite data is downloaded and geo-rectified with the help of Survey of India (SOI) open series map toposheets on 1:50,000 scale. The image is then classified into settlement, water bodies, tree patches, agriculture and other land cover classes. This classification enables the interpreter to distinguish between tree patches and other classes. The classified image is visually analysed for editing and refinement. Since the minimum mappable area for stratification of block and linear strata is 0.1 ha, pixels are clumped and cluster of pixels having area less than 0.1 ha are eliminated. After editing of the classified image, the final classified map is generated having three classes in TOF areas, namely Block, Linear and Scattered. From the classified TOF map, area under each category (stratum) is calculated. In addition, areas which do not support tree vegetation, like rivers and water bodies, riverbeds, snow covered mountains etc which are termed as Un-Culturable Non Forest Area are also calculated. The schematic chart of the methodology of TOF using remote sensing is depicted in the Fig 7.7.

The optimum size of the plot for each stratum has been determined by FSI after conducting a pilot study. The optimum plot size for Block and Linear strata is 0.1 ha square plot and 10 m ×125 m strip, respectively. In case of scattered stratum, square plots of the optimum size 3.0 ha for non-hilly and 0.5 ha for hilly areas are laid out. In the new grid based design, the scattered plots are identified as hilly or non-hilly based on altitude of a particular plot in the grid and same is mentioned against each plot.

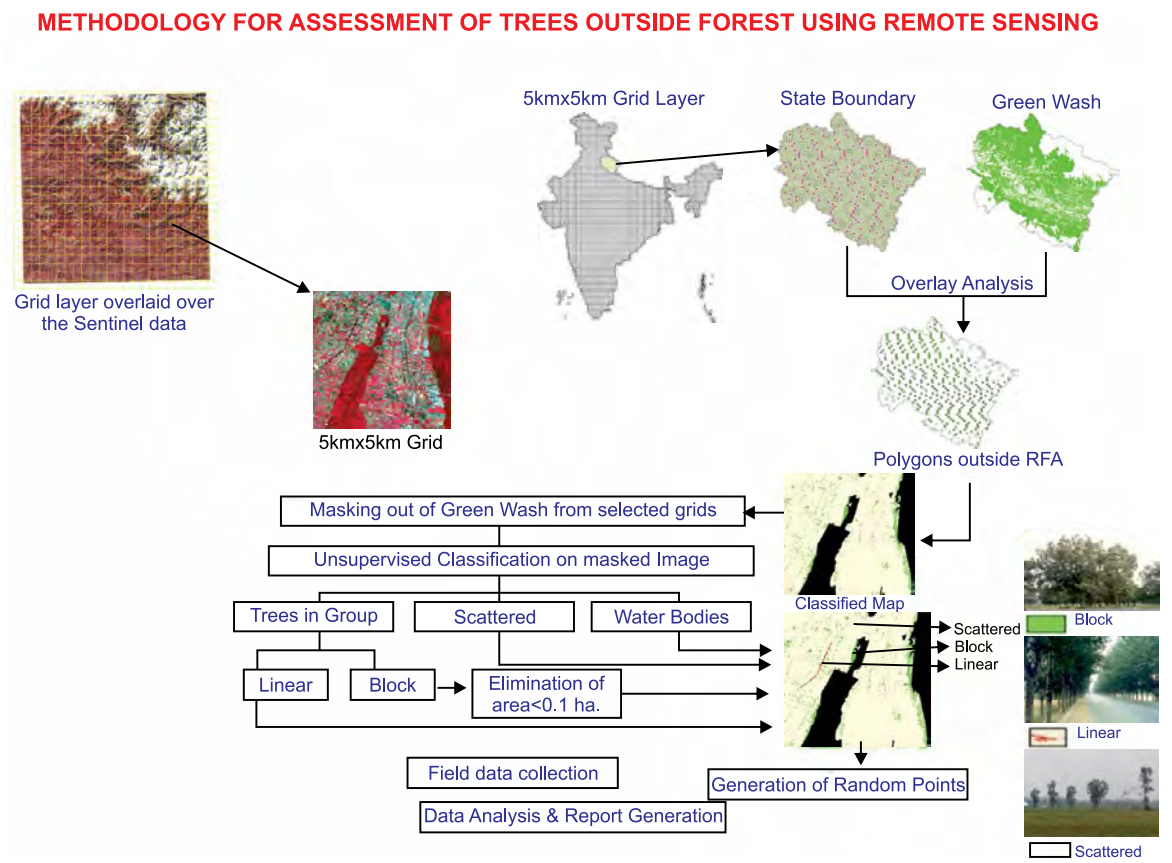
7.3 DATA PROCESSING

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) as the steps involved to them are little different.

FIGURE 7.5 Measurements for TOF inventory

FIGURE 7.6 Field observations during TOF inventory

FIGURE 7.7 Schematic diagram of the methodology of TOF



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 and per plot area (area factor) is calculated on the basis of plots in recorded forest area. These plots are further classified into different crop composition 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 are 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 the State level has been carried out separately for Block, Linear and Scattered strata. The area figures for block and linear strata have been obtained from the digital interpretation of remote sensing data, whereas the area of scattered stratum has been 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 have been used for calculating stems per ha under each stratum. The corresponding volume for each stratum has been calculated using volume equations developed by FSI. Estimates of the Growing stock in TOF of the States has been calculated using per ha figures of stems volume and respective areas of each stratum. The national growing stock estimate of TOF has been generated by adding the estimates of growing stock of all the States.

7.4 RESULTS

Data from around 30,000 plots surveyed during the last two years i.e. 2016-18 has been 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 level and State level. The estimates presented in the current report are based on 9,628 sample plots laid inside forests and 20,612 sample plots outside. As compared to the last assessment, the number of sample plots inside forest and TOF are almost double in number for the corresponding period and spread over the entire country under the new inventory design unlike previous design wherein the plots used be laid in sixty districts in two years. As a result, the precision of growing stock both at the National and State level is higher than the previous estimates. The Standard Error (SE) of estimate for Forest Inventory at the National level is 7.21%. The SE for TOF at the National level is 6.65%. At the State level, SE varies from 2.69% to 15.73% for forest. For the TOF, the SE at State level varies from 2.92% to 14.10%. The State wise SE of growing stock for forest and TOF is given at annexure IV.

The total growing stock of wood in the country is estimated 5,915.76 m cum comprising 4,273.47 m cum inside forest areas and 1,642.29 m cum outside recorded forest areas (TOF). There is a total increase of 93.38 m cum (1.6%) in the growing stock of the country as compared to the estimates reported in ISFR 2017. Out of this, the increase in growing stock inside the forest is 55.09 m cum (1.3%) and 38.30 (2.4%) outside the forest area.

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

FIGURE 7.8 Growing Stock of Forest & TOF

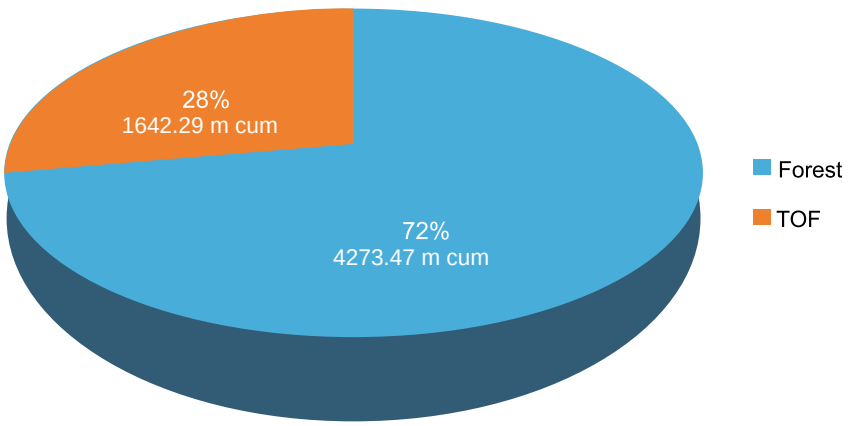


TABLE 7.1 State/UT wise Growing Stock

S.No.	State/UTs	Geographical Area (sq km)	Volume of Growing Stock (million cum)			Growing Stock in Forest (cum /ha)	Growing Stock in TOF (cum / ha)
			Forest	TOF	Total		
1.	Andhra Pradesh	162,968	119.02	67.68	186.70	31.94	5.69
2.	Arunachal Pradesh	83,743	458.00	75.08	533.08	89.09	43.01
3.	Assam	78,438	115.40	22.96	138.36	43.01	5.03
4.	Bihar	94,163	26.73	40.46	67.19	38.87	4.81
5.	Chhattisgarh	135,192	358.96	99.92	458.88	60.05	14.19
6.	Delhi	1,483	0.54	1.69	2.23	52.94	12.31
7.	Goa	3,702	11.16	4.03	15.19	91.10	20.37
8.	Gujarat	196,244	48.31	82.60	130.91	22.32	5.28
9.	Haryana	44,212	4.22	17.56	21.78	27.07	4.17
10.	Himachal Pradesh	55,673	347.07	25.19	372.26	93.72	17.27
11.	Jammu & Kashmir*	222,236	291.63	125.14	416.77	144.16	17.72
12.	Jharkhand	79,716	96.22	71.93	168.15	40.76	13.41
13.	Karnataka	191,791	334.08	103.03	437.11	87.26	7.05
14.	Kerala	38,852	147.10	55.26	202.36	130.07	20.99
15.	Madhya Pradesh	308,252	342.62	106.39	449.01	36.18	6.48
16.	Maharashtra	307,713	231.76	177.12	408.88	37.64	7.41
17.	Manipur	22,327	42.03	6.07	48.10	24.13	12.52
18.	Meghalaya	22,429	31.28	18.84	50.12	32.94	16.34
19.	Mizoram	21,081	21.30	44.11	65.41	37.76	28.94
20.	Nagaland	16,579	29.52	13.72	43.24	34.23	17.33
21.	Odisha	155,707	299.04	95.02	394.06	48.86	10.55
22.	Punjab	50,362	11.12	18.56	29.68	36.06	3.96
23.	Rajasthan	342,239	24.39	89.07	113.46	7.45	5.33
24.	Sikkim	7,096	35.32	1.94	37.26	60.47	56.28
25.	Tamil Nadu	130,060	96.97	76.30	173.27	42.39	7.18
26.	Telangana	112,077	80.96	41.45	122.41	30.09	5.02
27.	Tripura	10,486	19.74	6.76	26.50	31.36	16.67
28.	Uttar Pradesh	240,928	96.04	97.62	193.66	57.92	4.45
29.	Uttarakhand	53,483	406.08	19.13	425.21	106.86	15.31
30.	West Bengal	88,752	54.87	32.63	87.50	46.19	4.66
31.	A & N Islands	8,249	90.82	2.75	93.57	126.65	25.08
32.	Chandigarh	114	0.29	0.50	0.79	82.86	49.56
33.	Dadra & Nagar Haveli	491	0.74	1.16	1.90	36.27	32.32
34.	Daman & Diu	111	0.09	0.15	0.24	112.50	14.42
35.	Lakshadweep	30	0.00	0.07	0.07	0.00	44.61
36.	Puducherry	490	0.05	0.40	0.45	38.46	11.79
Total		**3,287,469**	**4,273.47**	**1,642.29**	**5,915.76**	**55.69**	**7.87**

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

From Table 7.1, it is observed that the growing stock per hectare at the national level has been estimated as 55.69 cum. The highest per hectare growing stock in forest has been found in J&K followed by Kerala and A & N Islands. In respect of total growing stock Arunachal Pradesh has maximum growing stock of 458.00 m cum in forests followed by Uttarakhand 406.08 m cum, Chhattisgarh 358.96 m cum and Himachal Pradesh 347.07 m cum. In TOF, Maharashtra has maximum growing stock of 177.12 m

cum followed by Jammu & Kashmir (125.14 m cum), Madhya Pradesh (106.39 m cum) and Karnataka (103.03 m cum).

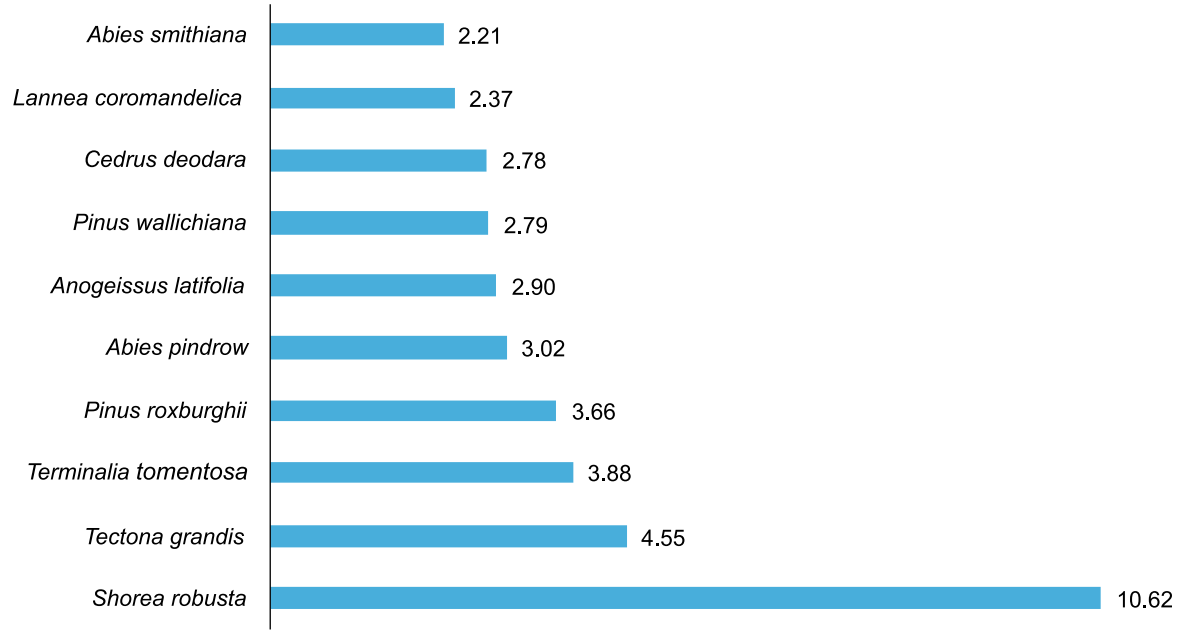
7.4.2 Growing Stock of top ten species in forests and TOF

National level estimates of number of trees and their volume for major species by diameter class in forest and TOF has been presented in Annexure III A and III B. The growing stock of top 10 species of forest & TOF and their percentage in total growing stock of the country 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*	453.81	10.62
2.	*Tectona grandis*	194.54	4.55
3.	*Terminalia tomentosa*	165.71	3.88
4.	*Pinus roxburghii*	156.52	3.66
5.	*Abies pindrow*	129.20	3.02
6.	*Anogeissus latifolia*	124.12	2.90
7.	*Pinus wallichiana*	119.27	2.79
8.	*Cedrus deodara*	118.71	2.78
9.	*Lannea coromandelica*	101.41	2.37
10.	*Abies smithiana*	94.45	2.21

FIGURE 7.9 Percentage volume of top ten species in forest



It is observed that *Shorea robusta* has the maximum contribution in total volume (10.62%) followed by *Tectona grandis* (4.55%), *Terminalia tomentosa* (3.88%) *and Pinus roxburghii* (3.66%).

TABLE 7.3 Growing stock in TOF for top ten species

S.No	Nameof the Species	Total volume (m cum)	Percentage of total volume (%)
1.	*Mangifera indica*	207.24	12.62
2.	*Azadirachta indica*	133.23	8.11
3.	*Madhuca latifolia*	81.46	4.96
4.	*Cocos nucifera*	63.93	3.89
5.	*Borassus flabelliformis*	62.42	3.80
6.	*Acacia arabica*	52.34	3.19
7.	*Butea monosperma*	45.65	2.78
8.	*Tamarindus indica*	42.50	2.59
9.	*Pinus wallichiana*	42.45	2.58
10.	*Ficus religiosa*	40.07	2.44

In TOF, *Mangifera indica* contributes maximum volume of 12.62% to total volume followed by *Azadirachta indica* (8.11%), *Madhuca latifolia* (4.96%) and *Cocos nucifera* (3.89%).

The estimates of growing stock at the State level are given in Table 7.1. As mentioned earlier also, one of the objectives of new sampling design is to generate the State level estimates at an acceptable precision level. In the new design, sample plots in both forest and TOF fall in all the States. The state wise standard error percentage both forest and TOF is given in Annexure-4.

FIGURE 7.10 Percentage volume of top ten species in TOF

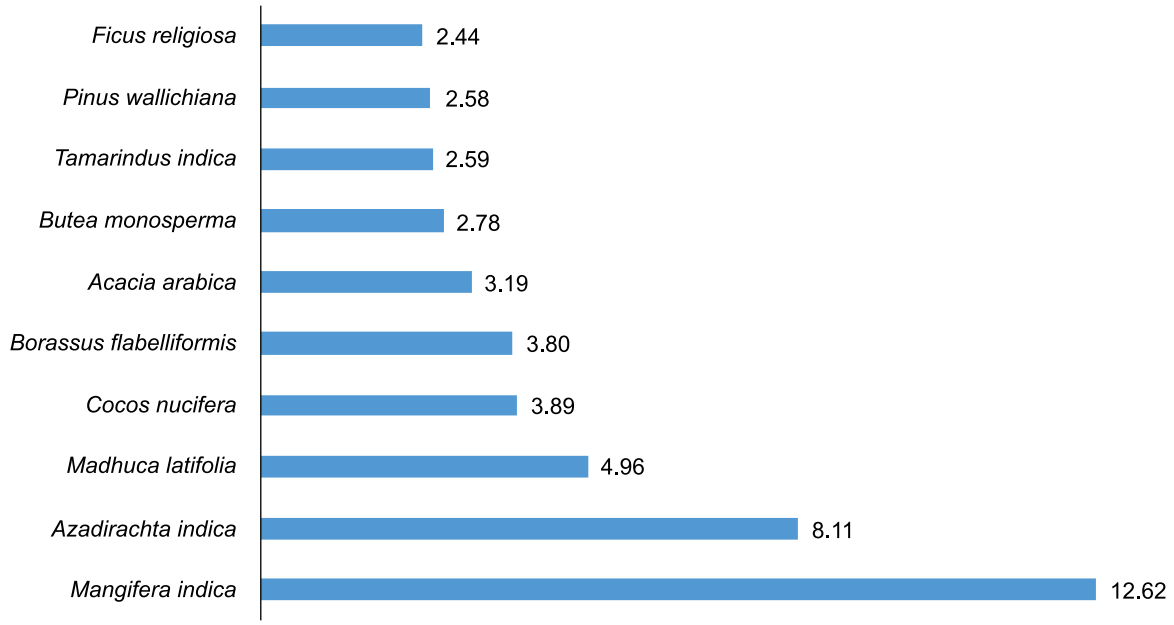


FIGURE 7.11 Map showing sample plots of NFI during 2016-2018

8 Chapter

Bamboo Resources of the Country

8.1 INTRODUCTION

Bamboos are one of the fastest growing perennial plants in the world. They belong to the family Poaceae (Graminae) and are found in the in the tropical, sub-tropical and mild temperate regions of the world. Bamboos are distributed naturally in abundance in East and Southeast Asia and Islands of Pacific & Indian oceans. As per an FAO report (2007)[1], there are about 1,200 species in 90 genera worldwide. Distribution of bamboo is uneven and 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 grows naturally almost throughout the country except in Kashmir region.

[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

Bamboo culms grow from the dense root rhizome system. There are two main types of rhizomes i.e. monopodial and sympodial. The former grows horizontally and the rhizome buds develop either upward, generating a culm, or horizontally with a new tract of the rhizomal net. Monopodial bamboos are non-clump forming with culms distant from each other and can be invasive. They are usually found in temperate regions and include the genera *Phyllostachys* and *Pleioblastus*. Sympodial rhizomes are short and thick, and the culms above 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 genus are *Arundinaria, Bambusa, Dendrocalamus*.

India is reportedly home to about 125 indigenous and 11 exotic species of bamboo from 23 genera. Bamboos occur 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.

Bamboo contributes significantly to the social, economic & ecological development of any region. It is a universally used plant and contributes to subsistence needs of more than 2.5 billion people. Bamboos are an important component of the subsistence economy in providing livelihood to the tribals, forest dwellers and other communities. It is estimated that in India there are about 2 million traditional artisans whose livelihood depends almost entirely 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 variety of products by small entrepreneurs without any major initial investment.

FIGURE 8.1 Bamboo clump

Although, bamboo occurs in almost every State of the country, its distribution and concentration varies primarily due to the climatic and edaphic conditions. *Bambusa* and *Dendrocalamus* are the species found in tropical conditions, whereas *Arundinaria* and its associates occur in the temperate region and are common on high altitudes in the Western and Eastern Himalayas. *Dendrocalamus strictus* is the 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 is capable of thriving in an extreme range of climatic and edaphic conditions. With its wide distribution, Bamboo also plays an important role in carbon sequestration, bio-diversity and soil moisture conservation. Their diversity in terms of size, being light yet strong, hard, straight and yet flexible, fast growth and abundance make them amenable to versatility of uses. The physical and environmental properties of bamboo make it an exceptional economic resource for a wide range of uses and for poverty alleviation. It is an important non-wood forest product used in making normal and fine quality paper, furniture, flooring, handicrafts, walking sticks, fishing poles etc. Young bamboo shoots are used as vegetables in many cuisines. Bamboo stems can be split up for use as pipes in channelling water. Raw leaves of many bamboo species are a source of fodder for cattle . The largest stems of bamboo are used as planks for houses and rafts, while both large and small stems are lashed together to form the scaffoldings at construction sites. Bamboo is therefore, called as green gold, poor man's timber, cradle to coffin timber etc.

The Government of India, in a landmark initiative, has promulgated the Indian Forest (Amendment) Ordinance, 2017 to exempt bamboo grown in non-forest areas from the definition of tree, by amending the Section 2 (7) of the Indian Forest Act 1927 and thereby dispensing with the requirement of felling/ transit permit for its transport and economic use. Before this amendment, the felling and transit of bamboo grown on forest as well non-forest land attracted the provisions of the Indian Forest Act, 1927. This was a major impediment for bamboo cultivation by farmers on non-forest land. Major objective of the amendment is to promote cultivation of bamboo in non-forest areas to achieve twin objectives of increasing the income of farmers and also increasing green cover of the country.

With this background and the importance of bamboo in our day-to-day life, its assessment has been an integral part of Forest Inventory and is presented as a separate chapter in ISFRs. The data on bamboo resources are collected while carrying out the inventory of forest and TOF. Further, a comparison of bamboo bearing areas and its growing stock as compared to ISFR 2017[2] has also been given in this chapter.

8.2 SAMPLING DESIGN

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 of both forest and TOF inventory 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.

[2] India State of Forest Report (2017), Forest Survey of India, Ministry of Environment, Forest and Climate Change, Government of India

For the forest inventory under the new design, 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.

8.3 DATA COLLECTION

8.3.1 Forest inventory

The information on bamboo is collected on 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 and crown width of the clump.

8.3.2 Bamboo Clump Analysis for Clump forming Bamboo

The information 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 carrying out this analysis, it is first determined whether a culm is green sound, green damaged, dry or dry damaged; these are then further classified as current year's culms, one to two-year-old culms and over two years old culms. In case of dry and decayed culms (both sound as well as damaged), however, 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 information 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 put 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 categorised 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, over two year old culms. In case of dry (both sound as well as damaged) and decayed culms, the age classification is not necessary. The culm, other than the current years and decayed culm, 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, 2cm 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.

8.4.1 Bamboo Assessment from Forest Inventory

The data collected from more than 9,628 points surveyed during 2016-17 & 2017-18 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.

8.4.2 Bamboo Assessment from TOF Inventory

The area figures for block and linear strata are obtained by digital interpretation of remote sensing data, whereas the area of scattered stratum is obtained by subtracting the area of block and linear patches from rural culturable non-forest area. Species and size class wise number of clump/ha and culms/clump is obtained for each stratum. In several States, adequate number of TOF plots having bamboo could not be found during the period of current assessment i.e. 2016 to 2018 and therefore, the estimate of State wise bamboo could not be generated. However, the number of plots having bamboo have been found sufficient to generate national level estimate which are given at the end of this chapter.

8.5 RESULTS

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

8.5.1 Bamboo Resources in Recorded Forest Areas

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

(in million)

Culm Size Class	Green Sound	Dry Sound	Decayed	Total no of culms 2019	Total culms in ISFR 2017	change with respect to ISFR 2017
Current year*	4,917	NA	NA	4,917	5,034	-117
1-2 cm**	6,280	2,176	NA	8,456	NA	NA
2-5 cm	11,842	3,416	NA	15,258	14,199	1,059
5-8 cm	4,470	939	NA	5,409	5,016	393
8 cm +	1,849	230	NA	2,079	1,836	243
			3,335	3,335	2,018	1,317
Total	**29,358**	**6,761**	**3,335**	**39,454**	**28,103**	**11,351**

* size class of culms of current year are not measured

**culms of size 1-2 cm are estimated first time for ISFR 2019

The total number of culms at the national level has been estimated 39,454 million out of which the percentage of green sound, dry sound and decayed culms has been observed as 74.41%, 17.14% and 8.45% respectively. Size class 2-5 cm has contributed maximum number of culms (38.67%). The total number of culms has increased by 11,351 million as compared to the estimates of ISFR 2017.

Table 8.1 shows that the estimated number of culms has increased in all the age classes and for all the soundness classes. On an average, there is an increase of 40.39% in number of culms at country level as compared to 2017 assessment.

TABLE 8.2 Equivalent Green Weight of Bamboo at the country level by Age and Soundness in Recorded Forest Area (in '000 tonnes)

(in '000 tonnes)

Culm Size Class	Green sound	Dry Sound	Total Green weight	Total Green weight as per ISFR 2017	Changes w.r.t. ISFR 2017
1-2 cm*	34,391	26,956	61,347	NA	NA
2 - 5 cm	63,658	38,596	1,02,254	65,947	36,307
5 - 8 cm	57,823	22,289	80,112	69,039	11,073
8 + cm	25,774	8,100	33,874	53,773	-19,899
Total	**1,81,646**	**95,941**	**2,77,587**	**1,88,759**	**88,828****

*culms of size 1-2 cm are estimated first time for ISFR 2019

** it includes 61.35 million tonnes green weight of 1-2 cm culm size

The total estimated green weight of bamboo culms at the national level is 278 million tonnes of which green sound bamboos contribute 65 % and dry sound bamboos contribute remaining 35 %. As compared to the estimate of ISFR 2017, there is an increase of about 88 million tonnes equivalent green weight of bamboo has been observed in the present assessment.

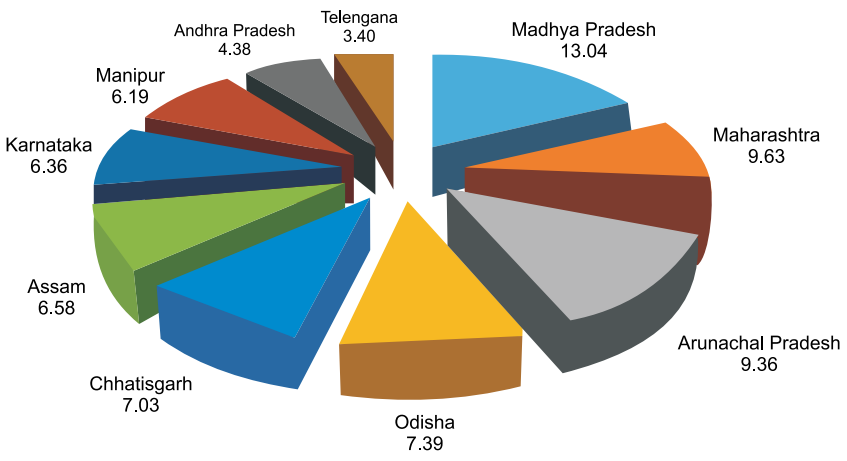
TABLE 8.3 State/UT wise Distribution of Bamboo Area in Recorded Forest Area

(in sq km)

S. No.	State/UTs	Bamboo bearing area	Bamboo bearing area as per ISFR 2017	Change in area with respect to ISFR 2017
1.	Andhra Pradesh	7,003	7,578	-575
2.	Arunachal Pradesh	14,981	15,125	-144
3.	Assam	10,525	8,955	1,570
4.	Bihar	1,136	1,004	132
5.	Chhattisgarh	11,255	11,060	195
6.	Goa	418	382	36
7.	Gujarat	3,393	3,544	-151
8.	Haryana	72	21	51
9.	Himachal Pradesh	650	540	110
10.	Jharkhand	4,123	4,470	-347
11.	Karnataka	10,181	10,442	-261
12.	Kerala	2,849	3,484	-635
13.	Madhya Pradesh	20,867	18,167	2,700
14.	Maharashtra	15,408	15,927	-519
15.	Manipur	9,903	10,687	-784
16.	Meghalaya	5,410	5,943	-533
17.	Mizoram	3,476	3,267	209
18.	Nagaland	4,284	6,025	-1,741
19.	Odisha	11,827	12,109	-282
20.	Punjab	255	44	211
21.	Rajasthan	1,874	1,976	-102
22.	Sikkim	1,176	553	623
23.	Tamil Nadu	4,357	4,154	203
24.	Telangana	5,438	4,778	660
25.	Tripura	3,783	3,617	166
26.	Uttar Pradesh	1,235	936	299
27.	Uttrakhand	1,489	1,078	411
28.	West Bengal	855	942	-87
29.	A & N Islands	1,814	0	1,814
Total		**1,60,037**	**1,56,808**	**3,229**

Note: Information of bamboo bearing area for Chandigarh, Dadra Nagar Haveli, Daman & Diu, Delhi, Lakshadweep, J & K 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 16.0 m ha. Madhya Pradesh has maximum bamboo bearing area of 2.0 m ha followed by Maharashtra (1.54 m ha), Arunachal Pradesh (1.49 m ha) and Odisha (1.18 m ha). As compared to the estimates of ISFR 2017, the total bamboo bearing area in the country has increased by 0.32 m ha. Comparing change in bamboo bearing area of assessment with ISFR 2017, it has been observed that bamboo bearing area in Madhya Pradesh has shown highest increase of 0.27 m ha followed by Assam (0.16 m ha). Similarly, Nagaland has shown highest decrease of 0.17 m ha in the bamboo bearing area followed by Kerala (0.06 m ha).

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

(area in sq km)

S. No	State/UTs	Pure Bamboo	Dense	Scattered	Bamboo present but clumps completely hacked	Regeneration crop
1.	Andhra Pradesh	424	3,180	2,975	71	353
2.	Arunachal Pradesh	417	3,389	10,904	0	271
3.	Assam	204	2,350	7,664	0	307
4.	Bihar	0	121	975	40	0
5.	Chhattisgarh	637	1,698	6,056	531	2,333
6.	Goa	0	197	112	11	98
7.	Gujarat	69	891	2,124	69	240
8.	Haryana	0	24	48	0	0
9.	Himachal Pradesh	150	200	250	0	50
10.	Jharkhand	0	103	2,601	550	869
11.	Karnataka	196	1,304	6,008	0	2,673
12.	Kerala	141	563	1,958	0	187
13.	Madhya Pradesh	700	4,358	12,539	1,167	2,103
14.	Maharashtra	810	2,543	8,261	1,762	2,032
15.	Manipur	0	1,383	6,862	995	663
16.	Meghalaya	140	467	4,803	0	0
17.	Mizoram	0	1,370	2,106	0	0
18.	Nagaland	227	1,137	2,730	75	115
19.	Odisha	56	1,351	9,788	407	225
20.	Punjab	0	113	142	0	0
21.	Rajasthan	0	215	547	550	562
22.	Sikkim	141	94	894	0	47
23.	Tamil Nadu	0	551	2,024	740	1,042
24.	Telangana	0	1,683	2,463	1,292	0
25.	Tripura	20	617	3,146	0	0
26.	Uttar Pradesh	0	309	926	0	0
27.	Uttrakhand	0	271	1,151	0	67
28.	West Bengal	0	0	816	0	39
29.	A & N Islands	0	93	1,266	0	455
Total (2019)		**4,332**	**30,575**	**1,02,139**	**8,260**	**14,731**
Total as per ISFR 2017		**638**	**40,503**	**91411**	**6,485**	**17,829**
Changes w.r.t. ISFR 2017		3,694	-9,928	10,728	1,775	-3,098

Note: Information of bamboo density for Chandigarh, Dadar Nagar Haveli, Daman & Diu, Delhi, Lakshadweep, J & K and Puducherry is not given due to inadequate data. The different classes of bamboo are defined in glossary.

Table 8.4 reveals that pure bamboo area has increased and dense bamboo area has reduced from the earlier estimates published in ISFR 2017.

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 bamboo in about 4% and scattered bamboo in about 14% of the RFA . In about 1% of the bamboo area, bamboo was present but clumps has been found completely hacked. Regeneration crop of bamboo was observed in only 2% of forest area.

Maximum occurrence of pure bamboo has been observed in Maharashtra (810 sq km) followed by Madhya Pradesh (700 sq km) and Chhattisgarh (637sq km). The area under dense bamboo has been found highest in Madhya Pradesh (4358 sq km) followed by Arunachal Pradesh (3389 sq km) and Andhra Pradesh (3180 sq km). The area with hacked bamboo clumps has been found highest in Maharashtra (1762 sq km) followed by Telangana (1292 sq km) and Madhya Pradesh (1167 sq km). Bamboo regeneration is maximum in Karnataka (2673 sq km) followed by Chhattisgarh (2333 sq km) and Madhya Pradesh (2103 sq km)

TABLE 8.5 State/UT wise number of estimated culms in Recorded Forest Area

(in million)

S. No	State/UTs	Green Culms	Dry Culms	Decayed	Total	Total as per ISFR 2017	Changes w.r.t. 2017
1.	Andhra Pradesh	1,237	424	159	1,820	1,076	744
2.	Arunachal Pradesh	4,869	512	388	5,769	4,048	1,721
3.	Assam	3,082	466	281	3,829	2,452	1,377
4.	Bihar	221	25	1	247	353	-106
5.	Chhattisgarh	1,175	660	279	2,114	1,075	1,039
6.	Goa	3	17	10	30	26	4
7.	Gujarat	513	117	47	677	485	192
8.	Himachal Pradesh	356	113	16	485	321	164
9.	Jharkhand	569	146	161	876	666	210
10.	Karnataka	1,305	454	151	1,910	1,166	744
11.	Kerala	780	207	43	1,030	834	196
12.	Madhya Pradesh	2,406	828	361	3,595	2,406	1,189
13.	Maharashtra	1,979	718	274	2,971	1,816	1,155
14.	Manipur	843	205	78	1,126	2,340	-1,214
15.	Meghalaya	1,148	188	185	1,521	1,323	198
16.	Mizoram	863	134	77	1,074	716	358
17.	Nagaland	2,289	98	157	2,544	1,301	1,243
18.	Odisha	1,563	426	302	2,291	1,585	706
19.	Punjab	9	1	1	11	6	5
20.	Rajasthan	465	60	2	527	831	-304
21.	Sikkim	197	12	9	218	135	83
22.	Tamil Nadu	575	283	88	946	777	169
23.	Telangana	615	211	100	926	651	275
24.	Tripura	963	88	59	1,110	797	313
25.	Uttar Pradesh	155	75	6	236	175	61
26.	Uttarakhand	210	115	59	384	267	117
27.	West Bengal	352	20	12	384	464	-80
28.	A & N Islands	616	158	29	803	0	803
Total		**29,358**	**6,761**	**3,335**	**39,454**	**28,092**	**11,362**

Note:1. The difference in the total number of culms from ISFR 2017 is due to that the culms of Dadar Nagar & Haveli is not included in ISFR 2019 due to inadequate area.

As per current assessment maximum number of green culms are found in Arunachal Pradesh (4869 million) followed by Assam (3082 million) and Madhya Pradesh (2406 million). Dry culms are found maximum in Madhya Pradesh (828 million) followed by Maharashtra (718 million) and Chhattisgarh (660 million). As compared to the estimates given in ISFR 2017, maximum increase in number of culms by soundness has been observed in Arunachal Pradesh (1721 million) followed by Assam (1377 million) and Nagaland (1243 million).

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

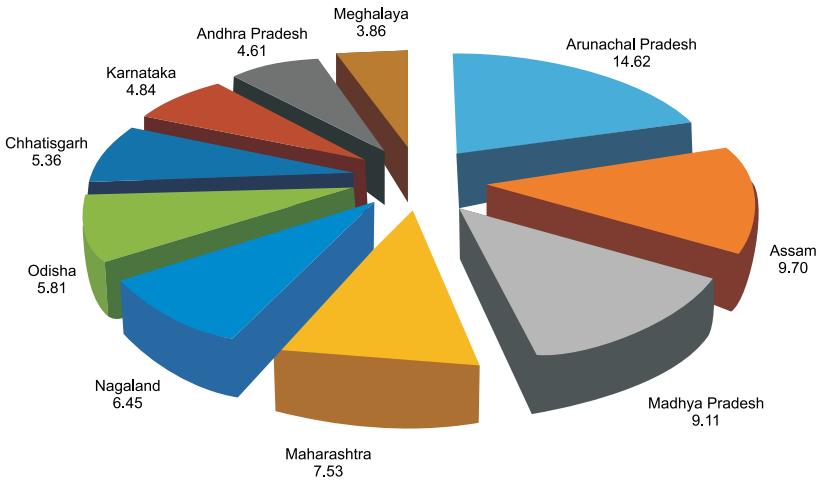


TABLE 8.6 State/UT wise Equivalent Green Weight of culms in Recorded Forest Area

(in '000 tonnes)

S. No.	State/UTs	Green Culms	Dry Culms	Total	Total as per ISFR 2017	Change w.r.t. ISFR 2017
1.	Andhra Pradesh	9,702	6,455	16,157	9,903	6,254
2.	Arunachal Pradesh	22,601	5,331	27,932	18,863	9,069
3.	Assam	17,226	6,838	24,064	14,912	9,152
4.	Bihar	1,544	278	1,822	1,692	130
5.	Chhattisgarh	5,400	6,343	11,743	5,942	5,801
6.	Goa	14	188	202	148	54
7.	Gujarat	6,008	2,869	8,877	6,035	2,842
8.	Himachal Pradesh	1,146	829	1,975	1,156	819
9.	Jharkhand	2,880	1,693	4,573	2,520	2,053
10.	Karnataka	15,423	11,033	26,456	16,538	9,918
11.	Kerala	8,718	4,374	13,092	7,220	5,872
12.	Madhya Pradesh	7,887	6,201	14,088	9,073	5,015
13.	Maharashtra	13,842	12,673	26,515	15,879	10,636
14.	Manipur	4,664	3,090	7,754	15,469	-7,715
15.	Meghalaya	8,770	3,553	12,323	11,462	861
16.	Mizoram	6,475	2,337	8,812	6,217	2,595
17.	Nagaland	18,678	1,869	20,547	11,269	9,278
18.	Odisha	9,675	6,456	16,131	9,864	6,267
19.	Punjab	34	13	47	27	20
20.	Rajasthan	1,288	1,232	2,520	3,661	-1,141
21.	Sikkim	365	64	429	305	124
22.	Tamil Nadu	3,068	4,711	7,779	6,470	1,309

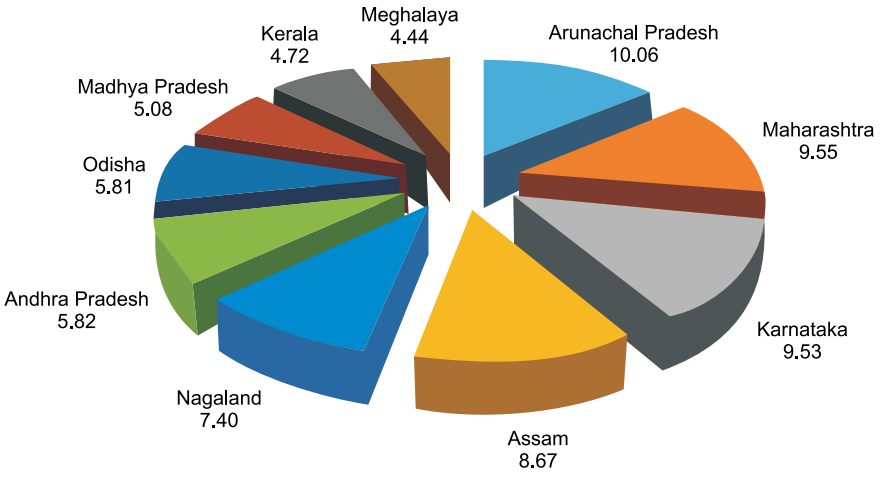
S. No.	State/UTs	Green Culms	Dry Culms	Total	Total as per ISFR 2017	Change w.r.t. ISFR 2017
23.	Telangana	4,250	2,531	6,781	5,009	1,772
24.	Tripura	5,053	1,242	6,295	6,494	-199
25.	Uttar Pradesh	483	491	974	641	333
26.	Uttarakhand	580	810	1,390	963	427
27.	West Bengal	943	167	1,110	948	162
28.	A & N Islands	4,929	2,270	7,199	0	7,199
Total		**181,646**	**95,941**	**2,77,587**	**1,88,680**	**88,907**

Note: The difference in the total equivalent green weight is due to that the weight of Dadra Nagar & Haveli is not included in ISFR 2019 due to inadequate data.

The table shows that weight of green culms is maximum in Arunachal Pradesh (22.6 m tonnes) followed by Nagaland (18.6. m tonnes) and Assam (17.2 m tonnes). The weight of dry culms is maximum in Maharashtra (12.67 m tonnes) followed by Karnataka (11.03. m tonnes) and Assam (6.8 m tonnes).

Maharashtra has shown maximum increase of 10.6 million tonnes in equivalent green weight as compared to the assessment given in ISFR 2017 followed by Karnataka (9.9 million tonnes) and Nagaland (9.2 million tonnes).

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



8.5.2 Bamboo Resources in TOF

In TOF areas, the total number of culms estimated at national level are 3,046 million with an equivalent green weight of 19.73 million tonnes. As compared to the assessment of 2017, it is observed that there is an increase of 178 million number of culms. The increase in equivalent green weight as compared to 2017 has been observed as 2.32 million tonnes. The State wise number of culms and their equivalent green weight could not be estimated due to inadequate number of sample plots with presence of bamboo in the two years period of the inventory with the new NFI design.

9 Chapter

Carbon Stock in India's Forests

9.1 INTRODUCTION

Climate change poses a serious threat to the ecosystems and the quality of human life all over the world. It is for this reason that the parties to the United Nations Framework Convention on Climate Change (UNFCCC) have undertaken wide ranging policy measures, actions and programmes to address the issues of climate change adaptation and mitigation. India as a Party to the Convention is required to periodically communicate greenhouse gas inventory for the country from all the sectors including Land Use, Land-Use Change and Forestry (LULUCF) as National Communication (NATCOM). Accordingly, India has furnished its initial National Communication in 2004, second National Communication in 2012, first Biennial Update Report (BUR-I) in 2016 and second Biennial Update Report (BUR-II) in 2018 to the UNFCCC. 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 commitment is backed with the fact that the emission intensity of India's Gross Domestic Product (GDP) has reduced by 21% over the period of 2005- 2014. This achievement has been made possible by a strong political will for climate action leading to well designed outcome-oriented policies, programmes and measures on mitigation.

As per the BUR-II of India, submitted to UNFCCC, emission from India stood at 2607.49 million tonnes CO_2 eq in 2014. Out of the total emissions, the energy sector accounted for 73%, Industrial Processes and Product Use (IPPU) 8%, agriculture 16% and waste sector 3% whereas the Land Use, Land Use Change and Forestry sector offset about 12% of India's total emissions.

Forests play an important role in mitigation and adaptation to climate change. Forests are considered as sink, reservoir and source of carbon. Healthy and growing forests sequester and store more carbon than any other terrestrial ecosystem. 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 world's forests and forest soils currently store more than one trillion tons of carbon which is nearly 1.3 times larger than the carbon stored in fossil fuel reserves (estimated at about 800 Gt) and more than the carbon already added to the atmosphere as a consequences of human activities since 1870 (about 600 Gt)[1]. It has been estimated that since 1750, forests (and other vegetation, but mainly forests) have been responsible for about half of the carbon emissions naturally sequestered from the atmosphere; the rest has been absorbed by the oceans. According to Global Forest Resource Assessment Report, 2015 of FAO[2], the worlds' forests store an estimated 296 Gt of carbon in both above and below ground biomass which contains almost half of the total carbon stored in forests, the other half being the soil organic carbon. Globally, over the last 25 years, the carbon stock in forest biomass has decreased by almost 17.4 Gt, equivalent to a reduction of 697 million tonnes per year or about 2.5 Gt of carbon dioxide equivalent. REDD+ and other initiatives have contributed to increased awareness of role of forests as terrestrial sinks of carbon.

9.1.1 General concepts and approaches in forest carbon accounting

The 'Good Practices Guidance' (GPG) 2003[3] released by Intergovernmental Panel on Climate Change (IPCC) is the universally accepted source book for concepts, definitions, various pools, methods, default values, equations etc for assessing forest carbon stocks. The GPG 2003 has categorised LULUCF sector into six land use classes viz Forest land, Cropland, Grassland, Wetlands, Settlements and Other lands for estimating greenhouse gases. The 'forest land' is divided into three sub categories namely 'forest land remaining forest land', 'land converted to forest land' and 'forest land converted to other land'.

[1] Federici S., Donna L. and Herold M. (2018). Forest Mitigation: A permanent contribution to the Paris agreement

[2] FAO (2015), Global Forest Resources Assessment, Desk Reference

[3] Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003), Intergovernmental Panel on Climate Change, Japan

Three levels of carbon assessment are given in the GPG to present the activity data (the change in area of different land categories). **Approach 1** identifies the total area for each land category; it only provides "net" area. **Approach 2** identifies the land conversions between categories by tracking and provides tabular information about land-use conversion. **Approach 3** involves, in addition, the spatially explicit land-use change.

The total carbon which is stocked in the forests is divided into five pools and the emission factors for different categories of activity data may be derived from the assessments of changes in carbon stocks in these carbon pools. The default values of emission factors for different forest biomes in the world are given in the IPCC Guidelines[4] (2006). Table 9.1 describes the three tiers of forest carbon assessment under the IPCC framework.

TABLE 9.1 Three IPCC tiers and data requirements

Tier	Data needs/examples of appropriate biomass data
Tier 1	IPCC default factors: Default MAI (for degradation) and/or forest biomass stock (for deforestation) values for broad continental forest types - default values given for all vegetation-based pools.
Tier 2	Country specific data for key factors: MAI and/or forest biomass values from existing forest inventories and/or ecological studies. Default values provided for all non-tree pools. Newly-collected forest biomass data is required.
Tier 3	Detailed national inventory of key Carbon stocks, repeated measurements of key stocks through time or modeling: Repeated measurement of trees from permanent plots and/or calibrated process models. Can use default data for other pools stratified by in-county regions and forest type, or estimates from process module.

In general, moving to higher tiers improves the accuracy of the inventory and reduces uncertainty, but the complexity and resources needed for conducting inventories also increase with higher tiers.

The Tier 1 employs the basic method and default emission factors provided in the IPCC Guidelines (Workbook). Tier 1 methodologies usually use activity data that are spatially coarse, such as nationally or globally available estimates of deforestation rates, agricultural production statistics, and global land cover maps.

The Tier 2 applies emission factors and activity data which are defined by the country and are generally available in tabular form. Tier 2 can also apply stock change methodologies based on country-specific data. Country-defined emission factors/activity data are more appropriate for the climatic regions and land use systems in that country.

At Tier 3, higher order methods including models and inventory measurement systems are used in which measurements are repeated over time and supported by high-resolution spatially explicit activity data and disaggregated at sub-national level. This tier generally involves use of Remote Sensing and GIS tools for generating activity data of land-use change over time.

In forest ecosystems, enormous carbon is stored which is divided in five pools by GPG[5], 2003. The living portion of biomass carbon is categorised in two pools: the 'above ground biomass' (AGB) and 'below ground biomass' and are stores of significant amount of carbon. The 'dead organic matter' (DOM) is also categorised in two pools: 'dead wood' and 'litter'. The fifth pool is 'Soil organic matter' (SOC) which accounts for nearly 50% of the total carbon locked in forests.

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

[5] Good Practices Guidance for Land Use, Land-Use Change and Forestry (2003), Intergovernmental Panel on Climate Change, Japan

FIGURE 9.1 Five Carbon Pools in Forests

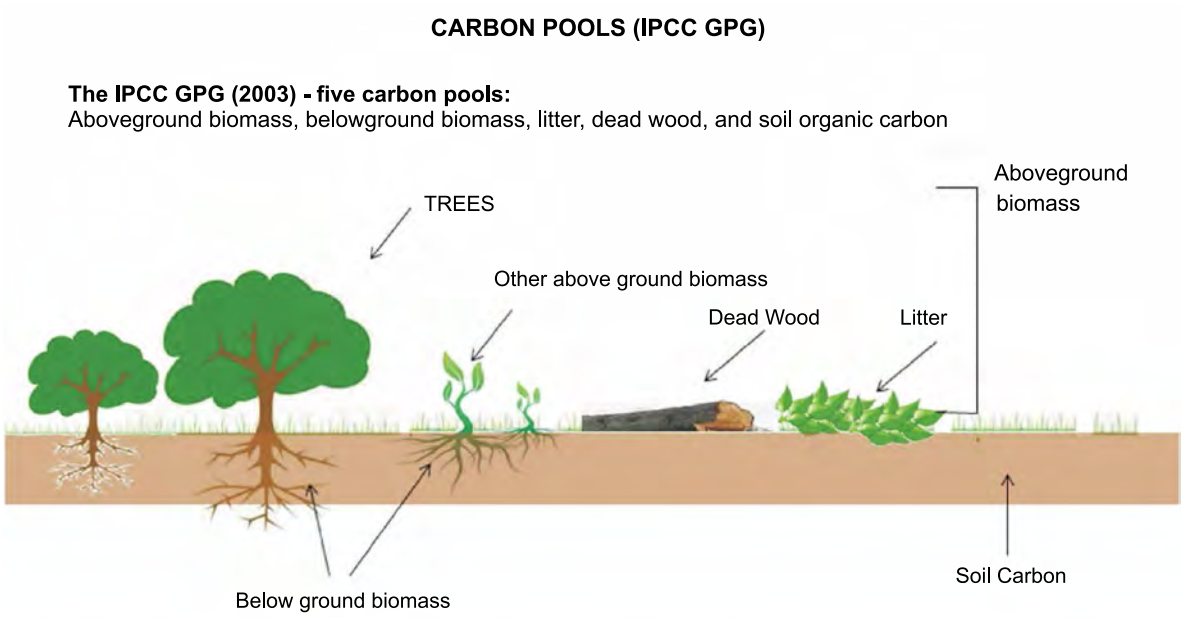
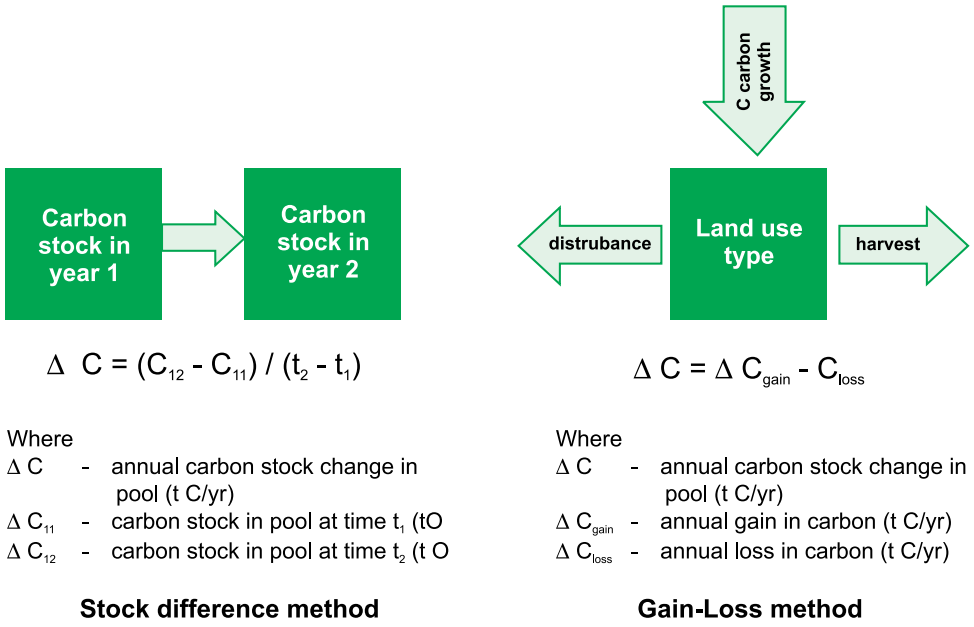


TABLE 9.2 Different forest carbon pools

Pools		Description
Living Biomass	Above ground biomass (AGB)	All living biomass above the soil including stems, stumps, branches, bark, seeds and foliage.
	Below ground biomass	All living biomass of live roots. Fine roots of less than 2mm diameter (country specific) are often excluded because these often cannot be distinguished from soil organic matter or litter.
Dead Organic Matter	Dead wood	Includes all non-living woody biomass not contained in the litter, either standing or lying on the ground. Dead wood also includes dead roots and stumps larger than or equal to 10cm in diameter or any other diameter used by the country.
	Litter	Includes all non-living biomass with a diameter less than a minimum diameter chosen by the country (for FSI 5 cm), lying dead, in various states of decomposition above the mineral or organic soil.
Soil	Soil organic matter	Includes organic carbon in mineral and organic soils (including peat) to a specific depth chosen by the country (for FSI 30 cm) and applied consistently through the time series.

There are two broad approaches of forest carbon accounting *viz* stock difference method and the gain-loss method. Figure 9.2 presents the two concepts. For stock difference method, the data required includes spatial layers of forest cover and forest types and biomass expansion factors (BEFs) for important species for each forest type. Similarly, data requirement for gain-loss method includes activity data signifying changes in forest and for each category of change the associated emission or removal factors. Stratification with the help of forest type layer helps in improving precision of the estimates of forest carbon in both the above approaches.

FIGURE 9.2 Stock difference & Gain-Loss methods for determining change in forest carbon stock



9.2 FOREST CARBON ESTIMATION OF THE COUNTRY BY FSI

The first ever country vide forest carbon estimation was done in the year 2002-03 for reporting change in forest carbon stock of the country for the period 1984-1994 to the UNFCCC as first national communication (NATCOM). Since then, FSI has periodically undertaken assessment of forest carbon of the country and now since last eight years it has become a regular chapter in the India State of Forest Report.

The basic information required for estimation of carbon stock is obtained from forest inventory. FSI has been conducting forest inventory since its inception. Initially, the forest inventories were aimed at estimation of growing stock from forest rich areas of the country. In 2002, the forest inventory was up-scaled to the entire country by launching the National Forest Inventory (NFI) after suitable modifications in the sampling design. With the launch of NFI, FSI has been estimating the national level growing stock in both forest and TOF since 2003. Subsequently suitable modifications were made in the plot design to collect necessary information required for calculation of the carbon stock in different carbon pools. The NFI design was again changed in 2016 by switching over from district based to grid based design to fulfil the data needs at the national and international levels. Due to long history of forest inventory, FSI has a huge repository of data on forest growing stock. FSI made the first tentative estimate of woody growing stock of the country's forests in 1995 using its forest inventory data collected during 1965 to 1990, thematic maps and forest cover information (SFR, 1995). This information was used by different institutions and scientists for estimating forest carbon stock.

FSI has been estimating carbon stock in the country's forests for various National Communications (NATCOMs) and providing valuable inputs to the MoEF&CC in preparation of GHG inventory of the country. FSI has estimated forest biomass and carbon stock change between 1984 and 1994 for India's Initial National Communication (INC) submitted to UNFCCC in 2004. In Initial National Communication (INC) (also referred as NATCOM -I) process, 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 to 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 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 the 'Land Use, Land-Use Change and Forestry (LULUCF)' sector. 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. Forests of India were the net sink of CO_2 in the SNC.

FSI published a separate report on 'Carbon stock in India's Forests' in 2011. A separate chapter on 'Carbon stock' was given first time in ISFR 2011. Since then, the information on total carbon stock and change with respect to previous assessment is a part of successive ISFRs. Considering the importance of carbon stock, a separate chapter has been given in the present report giving total carbon stock in 2019, change with respect to ISFR 2017 for each State and forest carbon in major forest type groups in terms of per hectare carbon stock.

9.3 METHODOLOGY FOR FOREST CARBON ESTIMATION

Estimation of forest carbon for the States and the whole country has been done by FSI 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 over laid on different strata and biomass for each pool is determined. Fig 9.3 shows the schematic diagram depicting the methodology.

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 Fig 9.2.

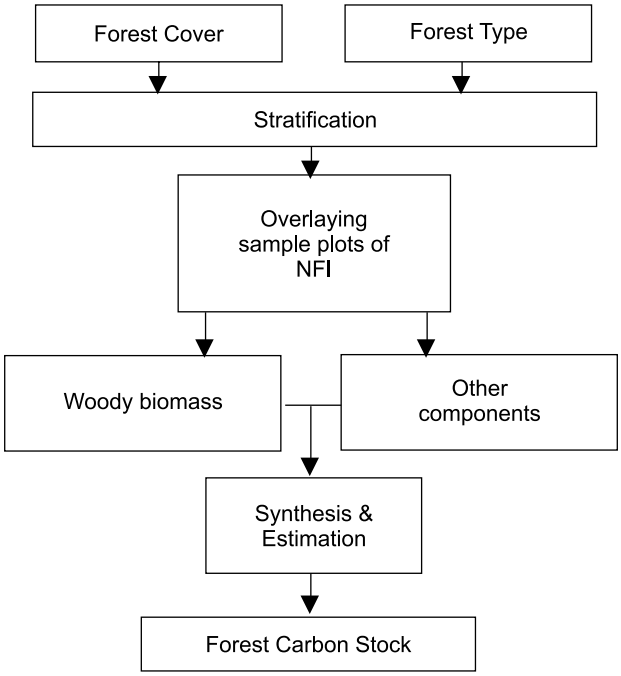
9.3.1 Stratification of Forest area

Stratification helps to improve 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 characterizes forests in terms of floristic composition and bio-physical conditions of plant growth like climate, soil, topography etc. FSI has 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 of 2019 in different forest types has been determined for the country. Forest cover map has been superimposed over the forest type map for creating the stratification. Overlay of forest cover layer with three canopy density classes and forest type with the 17 type groups including TOF & plantations has resulted into fifty one strata. Area statistics for each stratum has been generated using GIS.

FIGURE 9.3 Schematic diagram showing methodology of forest carbon assessment



9.3.3 Estimation of Biomass and Carbon in different pools

FSI has developed volume equations of 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 equation, 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)[6] have been used in estimation of forest carbon. Methods for biomass/carbon in different pools are described in short in the following sub sections.

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

Forest inventory data collected from around 9628 sample plots in the last two 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 few species, percentage carbon content was ascertained by experimentation and for remaining an average of all other species was used. Standard formulae were used to calculate biomass and carbon content.

The estimates of bamboo biomass and its carbon stock has been calculated from NFI data. 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 was calculated which is duly adjusted for 'bark void factor'. With the help of the specific gravity of bark,

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

the volume was converted into biomass. Using carbon content percent of wood, carbon stored in bark was estimated.

9.3.3.2 Above ground biomass of trees having dbh < 10 cm

This information was 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.

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 5mx5m, 3mx3m and 1mx1m were laid out at a distance of 30m away from the centre of sample point in North and South direction. In 5mx5m plot, all dead wood above 5 cm diameter were collected, weighed and recorded. In 3mx3m plot, all woody litter i.e. all branches below 5 cm diameter were collected, weighed and recorded. All shrubs & climbers in 3mx3m 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 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, Blank 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 Soil Organic Carbon (SOC) and Carbon in humus

During forest inventory, the data on forest floor (non-woody litter and humus) and soil carbon is also collected from each sample plot. For collecting data 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 was first swept and material so collected was weighed and a portion of the same was 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 the same is used for the calculation.

9.3.3.6 Below ground biomass

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

9.3.4 Synthesizing Data for National Carbon Estimation

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 has been determined for each strata. 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.

9.4 RESULTS

9.4.1 Forest Carbon Stock of States & UTs

The Forest Carbon Estimates of States and UTs and for the country as a whole as per the 2019 assessment are presented in the Table 9.3.

BOX 3

Above Ground Forest Biomass Estimation of Assam and Odisha using Synthetic Aperture Radar (SAR) Data

Global estimation of carbon and biomass is linked to environment and climate change. As one of the largest carbon sinks on land, forest ecosystems account for 80% of the terrestrial carbon stock and plays an important role in mitigating climate change. Forest biomass determination is useful in modelling ecosystem dynamics and estimate carbon stock sequestered in the forests. Traditional methods for biomass estimation do not provide its spatial distribution. Therefore, satellite data analysis is required for better estimation of forest carbon stocks and AGB at regional to national level. An appropriate combination of multisource data, such as the field measurement and the monitoring through Remote Sensing can potentially improve spatially explicit estimation of biomass over large areas. Forest biomass occurs in different stories of vegetation and Optical remote sensing data cannot penetrate the tree canopy. These limitation can be overcome by using Synthetic Aperture Radar (SAR) data. SAR due to its higher sensitivity to vegetation growth variables has emerged as the most suitable tool for retrieval of vegetation parameters specific to forests. Forest vegetation shows distinct scattering mechanism in SAR data, such as direct back scattering from crown (branch and leaves), crown-ground scattering, trunk-ground scattering and the direct scattering from the forest floor. The upcoming NASA-ISRO Synthetic Aperture Radar (NISAR) mission is a joint project between NASA and ISRO to co-develop and launch a dual-frequency Synthetic Aperture Radar on an Earth observation satellite. In this regard, an attempt has been made by FSI under joint collaboration with Space Application Centre (SAC), ISRO, Ahmedabad for estimation of AGB for Assam State. Global 25 m resolution Phased Array Type L-band Synthetic Aperture Radar (PALSAR) mosaic with forest inventory data at sample plots available with FSI has been used for AGB estimation. Forest inventory data has been used for training and validation of AGB map. A Multivariate Linear Regression Model (MLR) based on backscatter values and ratios of PALSAR global mosaic polarizations have been used to estimate AGB of Assam State.

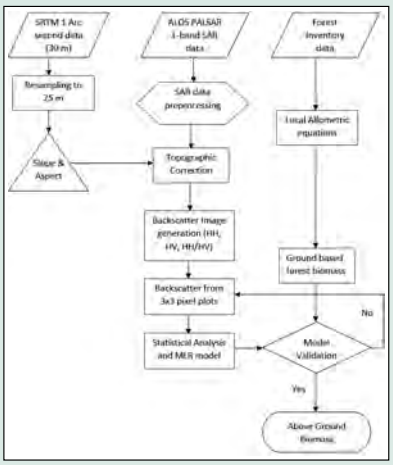


Figure 1 Methodology for estimation of AGB

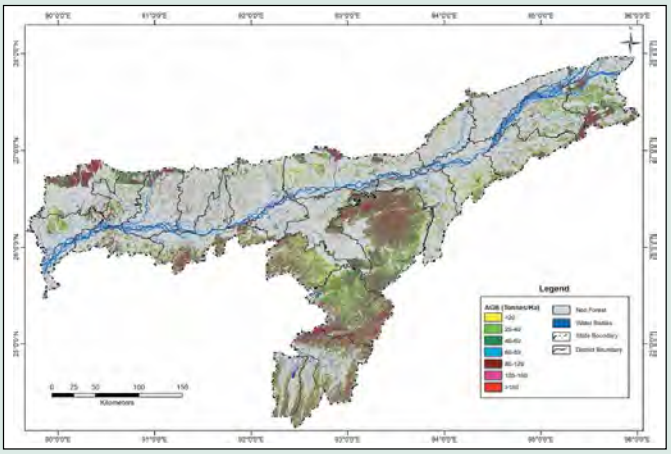


Figure 2 Biomass Map of Assam

An overview of methodology of this study is shown in Figure 1. Forest Inventory data collected from more than 200 sample plots across the forested area of the State of Assam have been used in conjunction with the dual polarised L-band data of ALOS PALSAR-2. The HV polarisation shows a better correlation with the forest biomass and this has been used along with the HH/HV ratio for the study. Approximately 70% of the inventory data was used to build the model and the remaining 30% was used to validate the model. The total biomass available in the forests of Assam has been divided into seven biomass classes. The biomass map depicting biomass classes in tonnes per hectare is shown in Figure 2. The study shows acceptable correlation between the SAR data and forest inventory data with a R^2 value 0.48. The study paves way for developing a biomass map of the country.

Similar study has also been carried for Odisha State by National Remote Sensing Centre (NRSC), ISRO, Hyderabad for spatial estimation of AGB using field inventory data collected from RS stratification based network of ~8,000, 0.1 ha plots using Microwave RS data synergistically with optical RS, bio-climatic parameters and topographic information. Spatial estimates of AGB are prepared using a K-NN approach with a random forest distance measure to relate field measure AGB. The forest cover layer generated by the Forest Survey of India (FSI) for ISFR 2017 was used to arrive at area weighted AGB for the analysis. The modelled relationship had a R^2 of 0.83 with an RMSE of 30%. The Forest Above Ground Biomass map is shown in Figure 3.

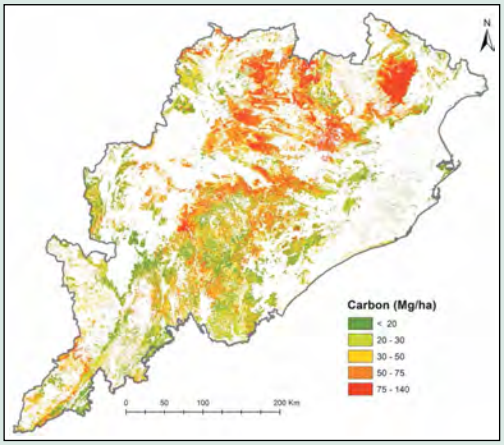


Figure 3 Biomass Map of Odisha

TABLE 9.3 Forest Carbon Stock in State/UTs in different carbon pools with per ha stock in tonnes given in parenthesis

('000 tonnes)

S. No.	State/ UTs	Area in sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
1.	Andhra Pradesh	29,137	60,972 (20.93)	24,206 (8.31)	629 (0.22)	3,074 (1.05)	1,30,647 (44.84)	2,19,528 (75.34)
2.	Arunachal Pradesh	66,688	3,30,856 (49.61)	1,00,379 (15.05)	7,816 (1.17)	15,436 (2.31)	5,96,836 (89.50)	10,51,323 (157.65)
3.	Assam	28,327	85,844 (30.30)	21,148 (7.47)	1,102 (0.39)	7,223 (2.55)	1,54,832 (54.66)	2,70,149 (95.37)
4.	Bihar	7,306	15,007 (20.54)	5,428 (7.43)	127 (0.17)	746 (1.02)	33,931 (46.44)	55,239 (75.61)
5.	Chhattisgarh	55,611	1,45,912 (26.24)	46,908 (8.43)	1,858 (0.33)	9969 (1.79)	2,75,603 (49.56)	4,80,250 (86.36)
6.	Delhi	195	277 (14.19)	98 (5.03)	2 (0.11)	21 (1.06)	838 (42.86)	1,236 (63.26)
7.	Goa	2,237	9,010 (40.27)	2,617 (11.70)	172 (0.77)	665 (2.97)	12,874 (57.54)	25,338 (113.24)
8.	Gujarat	14,857	27,737 (18.67)	9,636 (6.49)	315 (0.21)	1,556 (1.05)	68,003 (45.77)	1,07,247 (72.18)
9.	Haryana	1,602	2,455 (15.32)	929 (5.80)	18 (0.11)	137 (0.86)	6,927 (43.23)	10,466 (65.31)
10.	Himachal Pradesh	15,434	1,10,045 (71.30)	30,745 (19.92)	2,559 (1.66)	2,711 (1.76)	1,06,300 (68.87)	2,52,360 (163.51)
11.	Jammu & Kashmir	23,612	1,70,222 (72.09)	47,806 (20.25)	3,813 (1.62)	3,706 (1.57)	1,64,648 (69.73)	3,90,195 (165.25)
12.	Jharkhand	23,611	48,994 (20.75)	19,899 (8.43)	423 (0.18)	2,826 (1.20)	1,05,870 (44.84)	1,78,012 (75.39)
13.	Karnataka	38,575	1,28,882 (33.41)	38,742 (10.04)	1,993 (0.52)	8,931 (2.32)	2,05,215 (53.20)	3,83,763 (99.49)
14.	Kerala	21,144	67,979 (32.15)	19,070 (9.02)	1,017 (0.48)	5,001 (2.36)	1,19,889 (56.70)	2,12,956 (100.72)
15.	Madhya Pradesh	77,482	1,65,067 (21.30)	64,630 (8.34)	1,535 (0.20)	8,156 (1.05)	3,49,339 (45.09)	5,88,727 (75.98)
16.	Maharashtra	50,778	1,31,249 (25.85)	40,380 (7.95)	1,586 (0.31)	10,687 (2.10)	2,56,606 (50.53)	4,40,508 (86.75)
17.	Manipur	16,847	44,723 (26.55)	13,317 (7.90)	508 (0.30)	3,924 (2.33)	1,16,251 (69.00)	1,78,723 (106.08)
18.	Meghalaya	17,119	52,302 (30.55)	14,963 (8.74)	731 (0.43)	4,328 (2.53)	1,08,642 (63.46)	1,80,966 (105.71)
19.	Mizoram	18,006	44,973 (24.98)	9,925 (5.51)	451 (0.25)	4,516 (2.51)	96,689 (53.70)	1,56,554 (86.95)
20.	Nagaland	12,486	35,850 (28.71)	9,612 (7.70)	522 (0.42)	2,897 (2.32)	86,646 (69.39)	1,35,527 (108.54)
21.	Odisha	51,619	1,26,656 (24.54)	39,066 (7.57)	1,647 (0.32)	9,062 (1.76)	2,55,857 (49.57)	4,32,288 (83.75)
22.	Punjab	1,849	3,529 (19.09)	1,367 (7.40)	25 (0.14)	125 (0.67)	8,298 (44.89)	13,344 (72.18)
23.	Rajasthan	16,630	26,155 (15.73)	10,865 (6.53)	191 (0.12)	928 (0.56)	70,224 (42.23)	1,08,363 (65.17)
24.	Sikkim	3,342	17,645 (52.78)	5,372 (16.07)	505 (1.51)	664 (1.99)	32,994 (98.69)	57,180 (171.04)
25.	Tamil Nadu	26,364	62,092 (23.55)	21,433 (8.13)	776 (0.29)	4,107 (1.56)	1,28,374 (48.69)	2,16,782 (82.23)

S. No.	State/ UTs	Area in sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
26.	Telangana	20,582	41,389 (20.11)	17,227 (8.37)	333 (0.16)	2,031 (0.99)	90,862 (44.15)	1,51,842 (73.77)
27.	Tripura	7,726	25,061 (32.44)	5,513 (7.14)	297 (0.38)	2,169 (2.81)	43,017 (55.68)	76,057 (98.44)
28.	Uttar Pradesh	14,806	32,498 (21.95)	10,374 (7.01)	372 (0.25)	1,893 (1.28)	70,553 (47.65)	1,15,690 (78.14)
29.	Uttarakhand	24,303	1,52,540 (62.77)	40,975 (16.86)	2948 (1.21)	4,904 (2.02)	1,69,545 (69.76)	3,70,912 (152.62)
30.	West Bengal	16,902	40,388 (23.90)	12,193 (7.21)	447 (0.26)	2,533 (1.50)	92,144 (54.52)	1,47,705 (87.39)
31.	A & N Islands	6,743	49,468 (73.36)	15,823 (23.47)	1116 (1.66)	2,912 (4.32)	43,347 (64.29)	1,12,666 (167.09)
32.	Chandigarh	22	57 (25.91)	18 (8.10)	0.46 (0.21)	3 (1.58)	111 (50.28)	189 (86.08)
33.	Dadra & Nagar Haveli	207	500 (24.14)	113 (5.47)	7 (0.35)	47 (2.25)	1,133 (54.70)	1800 (86.91)
34.	Daman & Diu	20	35 (17.23)	10 (4.91)	0.27 (0.13)	2 (1.21)	105 (51.15)	152 (74.64)
35.	Lakshadweep	27	67 (24.73)	15 (5.42)	0.47 (0.17)	5 (1.77)	149 (54.89)	236 (86.98)
36.	Puducherry	52	97 (18.54)	22 (4.22)	0.63 (0.12)	7 (1.42)	276 (52.57)	403 (76.87)
Total		7,12,249	**22,56,533 (31.68)**	**7,00,824 (9.84)**	**35,842 (0.50)**	**1,27,902 (1.80)**	**40,03,575 (56.21)**	**71,24,676 (100.03)**

The above table reveals that Arunachal Pradesh has maximum carbon stock of 1,051.32 million tonnes followed by Madhya Pradesh (588.73 million tonnes), Chhattisgarh (480.25 million tonnes) and Maharashtra (440.51 million tonnes). The per hectare carbon stock among different states/UTs given in parenthesis in Table 9.3 shows that Sikkim has maximum per hectare carbon stock of 171.04 tonnes/ha, followed by Andaman & Nicobar Islands (167.09 tonnes/ha), Jammu & Kashmir (165.25 tonnes/ha), Himachal Pradesh (163.51 tonnes/ha) and Arunachal Pradesh (157.65 tonnes/ha). At the national level 32% of carbon stock is in AGB where as about 56% in SOC. In all the NE states it is observed that SOC is almost double the carbon in AGB.

9.4.2 Change in Forest Carbon Stock

Change in carbon stock in India's forests between 2017 and 2019 is presented in the Table 9.4.

TABLE 9.4 Change in forest carbon stock of India between 2017 and 2019

(million tonnes)

Component	Carbon Stock in forest in 2017	Carbon stock in forest in 2019	Net change in Carbon stock	Annual change in Carbon stock
Above Ground Biomass	2,237.5	2,256.5	19.0	9.5
Below Ground Biomass	698.7	700.8	2.1	1.0
Dead wood	30.1	35.8	5.7	2.9
Litter	136.2	127.9	-8.3	-4.1
Soil	3,979.5	4,003.6	24.1	12.1
Total	**7,082.0**	**7,124.6**	**42.6**	**21.3**

The carbon stock in India's forests for 2019 has been estimated 7,124.6 million tonnes. There is an increase of 42.6 million tonnes of forest carbon stock in the country as compared to the estimates of previous assessment. The annual increase of carbon stock is estimated 21.3 million tonnes which is 78.1 million tonnes of CO_2 equivalent. Soil organic carbon is the largest pool of forest carbon accounting for (56.19 %) followed by AGB (31.67 %), BGB (9.84 %), Litter (1.80 %) and dead wood (0.50 %). On comparing the changes between the present and previous assessment, the largest increase has been observed in soil organic carbon followed by AGB and dead wood.

FIGURE 9.4 Forest Carbon stock in different pools (in million tonnes)

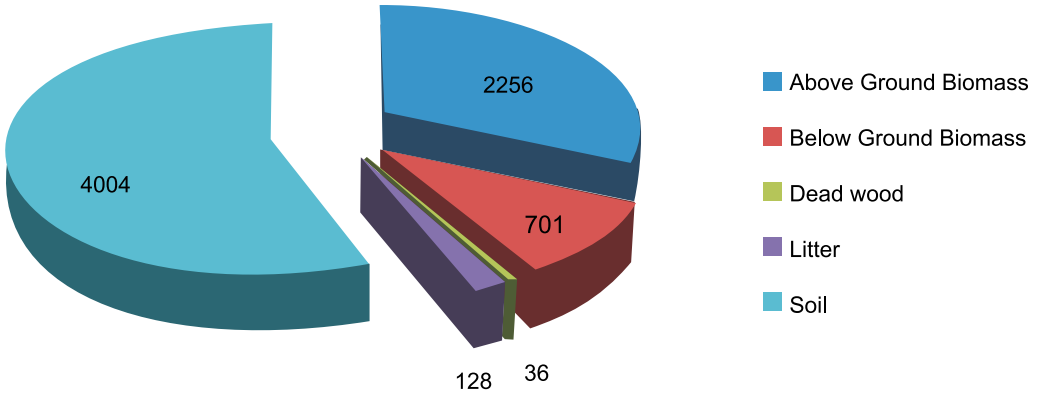
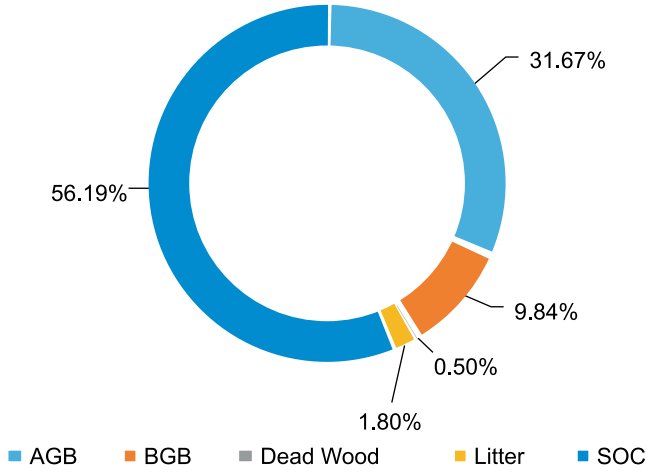


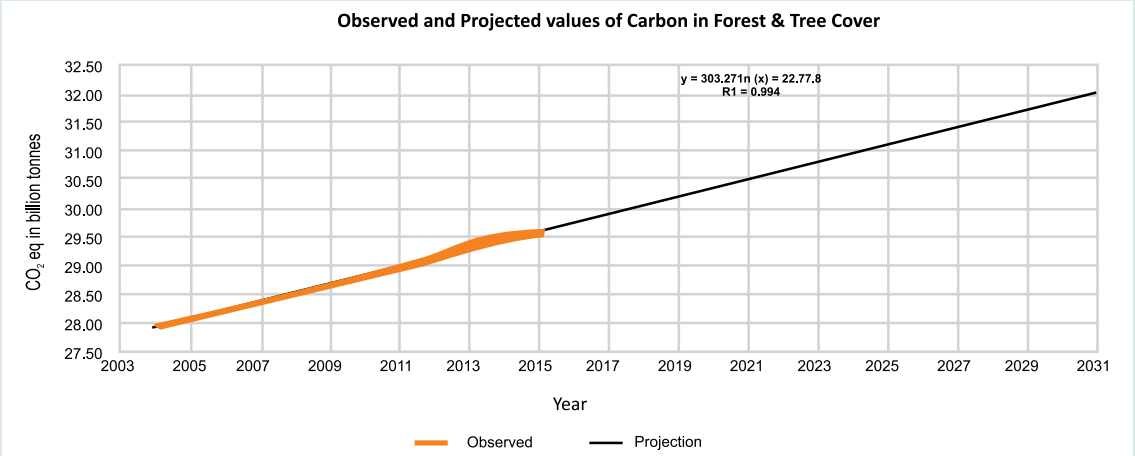
FIGURE 9.5 Forest Carbon stock in different pools (%)



BOX 4

Trend of Carbon Stock in Forest & Tree Cover in India vis-à-vis India's Nationally Determined Contribution (NDC) target of creating 'an additional carbon sink of 2.5 to 3.0 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030'

India's NDC makes a commitment to create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030. FSI has been assessing the carbon stock of India's forests on a regular basis, the same has also been reported to UNFCCC under different National Communications (NATCOM). In order to understand the magnitude and scale of actions required to achieve the target vis-à-vis trend of carbon stock in forest & tree cover in business as usual (BAU), FSI has carried out a study using time series data on forest cover, its projected changes and change matrix. The details of the study has been given in FSI Technical Information Series Volume 1 No. 3. Using estimates of forest carbon of different years in the past, projections of forest carbon upto 2030 have been made using trend line.



Based on the projection, it is observed form the following table that the carbon stock in forest & tree cover of India which was 28.12 billion tonnes CO2 eq in 2005 would rise to 31.87 billion tonne CO2 eq in 2030 showing an increase of 3.75 billion tonnes CO2 eq in 25 years in BAU.

Projection of NDC targets in different (indicative) baseline years

Year	Projection of Carbon in Forest & Tree Cover in BAU Scenario (billion tonnes CO2 eq)	Plus 2.5 billion tonnes	Plus 3.0 billion tonnes	Difference from the Projected Value in 2030	
				2.5 billion tonnes	3.0 billion tonnes
2005	28.12	30.62	31.12	-1.25	-0.75
2015	29.62	32.12	32.62	0.25	0.75
2020	30.53	33.03	33.53	1.16	1.66
2030	31.87				

It is seen form the above table that with the baseline year 2015, a comparison between the NDC target and the projection for 2030 in BAU shows a short fall of 0.25 billion tonnes and 0.75 billion tonnes of CO2 eq against the target of 2.5 - 3.0 billion tonnes respectively, which can be achieved by activities such as restoration of open forests and afforestation on different kinds of available lands like wastelands, agro-forestry, along national & State highways, railway siding, urban landscapes etc. The study further shows that restoration of open forests is the most cost effective strategy to achieve the NDC target and at the same time it holds large potential of creating additional carbon sink.

TABLE 9.5 Forest Type and Density wise Carbon Stock in different carbon pools with per ha stock in tonnes given in parentheses

('000 tonnes)

S. No.	Forest Type Stratum	Density	Area in sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
1.	Tropical Wet Evergreen Forests	VDF	8,809	82,816 (94.01)	30,639 (34.78)	2,361 (2.68)	4,880 (5.54)	58,344 (66.23)	1,79,040 (203.24)
2.	Tropical Wet Evergreen Forests	MDF	8,408	56,814 (67.57)	21,021 (25.00)	1,152 (1.37)	3,077 (3.66)	54,241 (64.51)	1,36,305 (162.11)
3.	Tropical Wet Evergreen Forests	OF	2,953	7,351 (24.89)	2,720 (9.21)	56 (0.19)	806 (2.73)	18,367 (62.19)	29,300 (99.21)
4.	Tropical Semi-Evergreen Forests	VDF	8,423	63,855 (75.81)	14,050 (16.68)	1,028 (1.22)	3,900 (4.63)	55,281 (65.63)	1,38,114 (163.97)
5.	Tropical Semi-Evergreen Forests	MDF	31,173	1,27,468 (40.89)	28,056 (9.00)	1,122 (0.36)	10,381 (3.33)	1,69,241 (54.29)	3,36,268 (107.87)
6.	Tropical Semi-Evergreen Forests	OF	32,211	57,336 (17.80)	12,627 (3.92)	354 (0.11)	7,151 (2.22)	1,67,143 (51.89)	2,44,611 (75.94)
7.	Tropical Moist Deciduous Forests	VDF	24,463	1,11,182 (45.45)	24,463 (10.00)	2,202 (0.90)	6,776 (2.77)	1,42,910 (58.42)	2,87,533 (117.54)
8.	Tropical Moist Deciduous Forests	MDF	66,936	2,12,254 (31.71)	46,721 (6.98)	3,815 (0.57)	22,490 (3.36)	3,79,593 (56.71)	6,64,873 (99.33)
9.	Tropical Moist Deciduous Forests	OF	44,435	93,224 (20.98)	20,529 (4.62)	1,111 (0.25)	7,820 (1.76)	2,44,479 (55.02)	3,67,163 (82.63)
10.	Littoral and Swamp Forests	VDF	1,575	7,118 (45.19)	2,634 (16.72)	3 (0.02)	180 (1.14)	10,766 (68.35)	20,701 (131.42)
11.	Littoral and Swamp Forests	MDF	1,655	5,082 (30.71)	1,880 (11.36)	65 (0.39)	113 (0.68)	9,927 (59.99)	17,067 (103.13)
12.	Littoral and Swamp Forests	OF	2,297	4,111 (17.90)	1,520 (6.62)	92 (0.40)	90 (0.39)	12,094 (52.66)	17,907 (77.97)
13.	Tropical Dry Deciduous Forests	VDF	23,624	74,320 (31.46)	31,207 (13.21)	992 (0.42)	14,859 (6.29)	1,19,796 (50.71)	2,41,174 (102.09)
14.	Tropical Dry Deciduous Forests	MDF	1,27,230	3,44,411 (27.07)	1,44,660 (11.37)	2,545 (0.20)	7,888 (0.62)	5,82,839 (45.81)	10,82,343 (85.07)
15.	Tropical Dry Deciduous Forests	OF	1,39,870	1,75,117 (12.52)	73,572 (5.26)	1,259 (0.09)	5,875 (0.42)	5,78,781 (41.38)	8,34,604 (59.67)
16.	Tropical Thorn Forests	VDF	171	334 (19.56)	140 (8.21)	6 (0.36)	36 (2.12)	828 (48.54)	1,344 (78.79)
17.	Tropical Thorn Forests	MDF	3,594	6,537 (18.19)	2,746 (7.64)	50 (0.14)	464 (1.29)	15,759 (43.85)	25,556 (71.11)
18.	Tropical Thorn Forests	OF	10,787	7,788 (7.22)	3,268 (3.03)	76 (0.07)	798 (0.74)	37,808 (35.05)	49,738 (46.11)
19.	Tropical Dry Evergreen Forests	VDF	138	670 (48.58)	281 (20.40)	17 (1.21)	13 (0.97)	1227 (89.01)	2208 (160.17)
20.	Tropical Dry Evergreen Forests	MDF	427	1,701 (39.88)	715 (16.75)	176 (4.13)	79 (1.86)	1,381 (32.37)	4,052 (94.99)
21.	Tropical Dry Evergreen Forests	OF	293	318 (10.83)	133 (4.55)	5 (0.16)	26 (0.89)	819 (27.92)	1,301 (44.35)
22.	Subtropical Broad leaved Hill Forests	VDF	7,481	53,102 (70.98)	22,302 (29.81)	367 (0.49)	1,421 (1.90)	66,928 (89.46)	1,44,120 (192.64)
23.	Subtropical Broad leaved Hill Forests	MDF	14,569	45,091 (30.95)	18,940 (13.00)	437 (0.30)	3,992 (2.74)	1,23,428 (84.72)	1,91,888 (131.71)
24.	Subtropical Broad leaved Hill Forests	OF	9,943	16,406 (16.50)	6,891 (6.93)	109 (0.11)	1,820 (1.83)	82,667 (83.14)	1,07,893 (108.51)
25.	Subtropical Pine Forests	VDF	1,661	14,559 (87.63)	3,931 (23.66)	111 (0.67)	238 (1.43)	14,824 (89.23)	33,663 (202.62)

S. No.	Forest Type Stratum	Density	Area in sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
26.	Subtropical Pine Forests	MDF	8,796	41,358 (47.02)	11,171 (12.70)	290 (0.33)	1143 (1.30)	66,214 (75.28)	12,0176 (136.63)
27.	Subtropical Pine Forests	OF	7,162	19,646 (27.43)	5,307 (7.41)	208 (0.29)	666 (0.93)	45,495 (63.52)	71,322 (99.58)
28.	Subtropical Dry Evergreen Forests	VDF	9	83 (93.07)	35 (39.09)	1 (1.43)	0.23 (0.26)	100 (112.86)	219.23 (246.71)
29.	Subtropical Dry Evergreen Forests	MDF	60	390 (65.41)	164 (27.47)	2 (0.33)	2 (0.41)	569 (95.41)	1127 (189.03)
30.	Subtropical Dry Evergreen Forests	OF	115	567 (49.14)	238 (20.64)	2 (0.17)	4 (0.33)	612 (53.04)	1423 (123.32)
31.	Montane Wet Temperate Forests	VDF	8,721	35,877 (41.14)	9,689 (11.11)	1,186 (1.36)	2,110 (2.42)	1,18,784 (136.21)	1,67,646 (192.24)
32.	Montane Wet Temperate Forests	MDF	9,704	29,909 (30.82)	8,074 (8.32)	1,601 (1.65)	1,873 (1.93)	1,18,162 (121.76)	1,59,619 (164.48)
33.	Montane Wet Temperate Forests	OF	2,228	3,295 (14.79)	889 (3.99)	45 (0.20)	352 (1.58)	23,904 (107.30)	28,485 (127.86)
34.	Himalayan Moist Temperate Forests	VDF	7,766	1,15,248 (148.40)	31,119 (40.07)	5,079 (6.54)	2,376 (3.06)	63,565 (81.85)	2,17,387 (279.92)
35.	Himalayan Moist Temperate Forests	MDF	12,148	1,26,715 (104.31)	34,209 (28.16)	1,604 (1.32)	3,049 (2.51)	95,410 (78.54)	2,60,987 (214.84)
36.	Himalayan Moist Temperate Forests	OF	6,270	33,722 (53.78)	9,105 (14.52)	113 (0.18)	1,235 (1.97)	45,247 (72.16)	89,422 (142.61)
37.	Himalayan Dry Temperate Forests	VDF	1,729	27,124 (156.86)	7,866 (45.49)	576 (3.33)	325 (1.88)	12,392 (71.66)	48,283 (279.22)
38.	Himalayan Dry Temperate Forests	MDF	2,348	28,339 (120.67)	8,217 (34.99)	878 (3.74)	352 (1.50)	15,429 (65.70)	53,215 (226.6)
39.	Himalayan Dry Temperate Forests	OF	1,488	8,056 (54.13)	2,336 (15.70)	280 (1.88)	131 (0.88)	8,965 (60.24)	19,768 (132.83)
40.	Sub-Alpine Forests	VDF	3,218	35,407 (110.04)	10,268 (31.91)	1,261 (3.92)	595 (1.85)	37,341 (116.05)	84,872 (263.77)
41.	Sub-Alpine Forests	MDF	6,522	56,815 (87.11)	16,475 (25.26)	2,596 (3.98)	652 (1.00)	71,940 (110.30)	1,48,478 (227.65)
42.	Sub-Alpine Forests	OF	4,444	20,782 (46.76)	6,027 (13.56)	89 (0.20)	289 (0.65)	41,800 (94.05)	68,987 (155.22)
43.	Moist Alpine Scrub	VDF	228	1,146 (50.19)	332 (14.56)	27 (1.20)	21 (0.90)	1,515 (66.34)	3,041 (133.19)
44.	Moist Alpine Scrub	MDF	691	1,937 (28.03)	562 (8.13)	25 (0.36)	58 (0.84)	4,275 (61.86)	6,857 (99.22)
45.	Moist Alpine Scrub	OF	1,056	963 (9.12)	279 (2.64)	20 (0.19)	69 (0.65)	3,961 (37.52)	5,292 (50.12)
46.	Dry Alpine Scrub	VDF	194	1,576 (81.44)	457 (23.62)	23 (1.18)	23 (1.18)	728 (37.61)	2,807 (145.03)
47.	Dry Alpine Scrub	MDF	518	3,152 (60.88)	914 (17.65)	10 (0.20)	62 (1.19)	1,635 (31.58)	5,773 (111.5)
48.	Dry Alpine Scrub	OF	1,294	7,127 (55.07)	2,067 (15.97)	16 (0.12)	127 (0.98)	3,617 (27.95)	12,954 (100.09)
49.	Plantation/TOF	VDF	1,069	4,910 (45.92)	1,080 (10.10)	5 (0.05)	214 (2.00)	7,044 (65.88)	13,253 (123.95)
50.	Plantation/TOF	MDF	13,693	48,297 (35.27)	10,585 (7.73)	397 (0.29)	3,122 (2.28)	80,600 (58.86)	1,43,001 (104.43)
51.	Plantation/TOF	OF	37,652	35,129 (9.33)	7,719 (2.05)	0 (0)	3,878 (1.03)	1,84,796 (49.08)	2,31,522 (61.49)
Total			**7,12,249**	**22,56,535 (31.68)**	**7,00,825 (9.84)**	**35,844 (0.50)**	**1,27,903 (1.80)**	**40,03,572 (56.21)**	**71,24,679 (100.03)**

Above 70% of forest cover in India falls in Tropical Semi-Evergreen, Tropical Moist Deciduous and Tropical Dry Deciduous Forest Type. More than 30% areas have this Forest Types fall in the category of Open Forest, which need to be improved in order to achieve NDC targets. Among these forest types Tropical Dry Deciduous and Tropical Moist Dry Deciduous may be taken up. This can also be seen from the above table that the per hectare carbon stock for open forest is 59.67 tonnes per hectare whereas for moderately dense forest it is 85.07 tonnes per hectare, implying significant gain in carbon sequestration rate if Dry Deciduous Open Forest is converted to Dry Deciduous Moderately Dense Forest.

FIGURE 9.6 Density wise carbon stock per ha in different pools

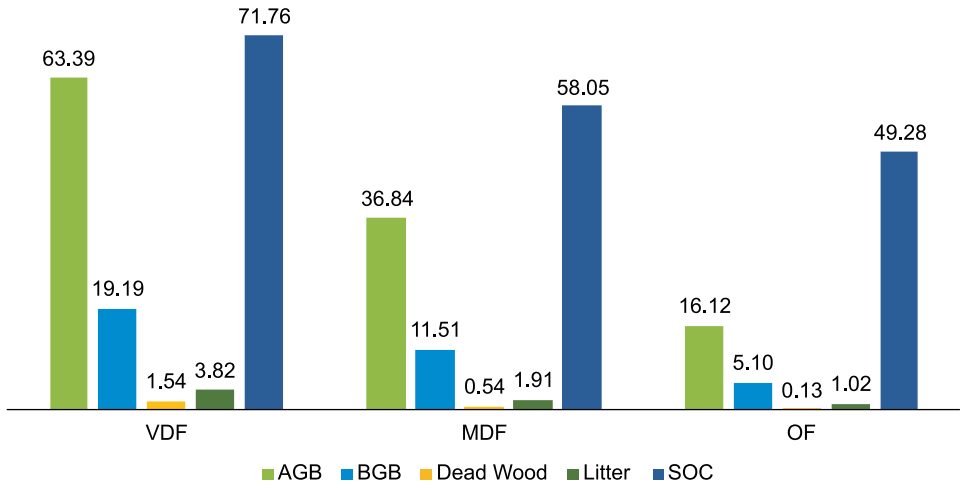


FIGURE 9.7 Forest Type wise carbon stock per ha

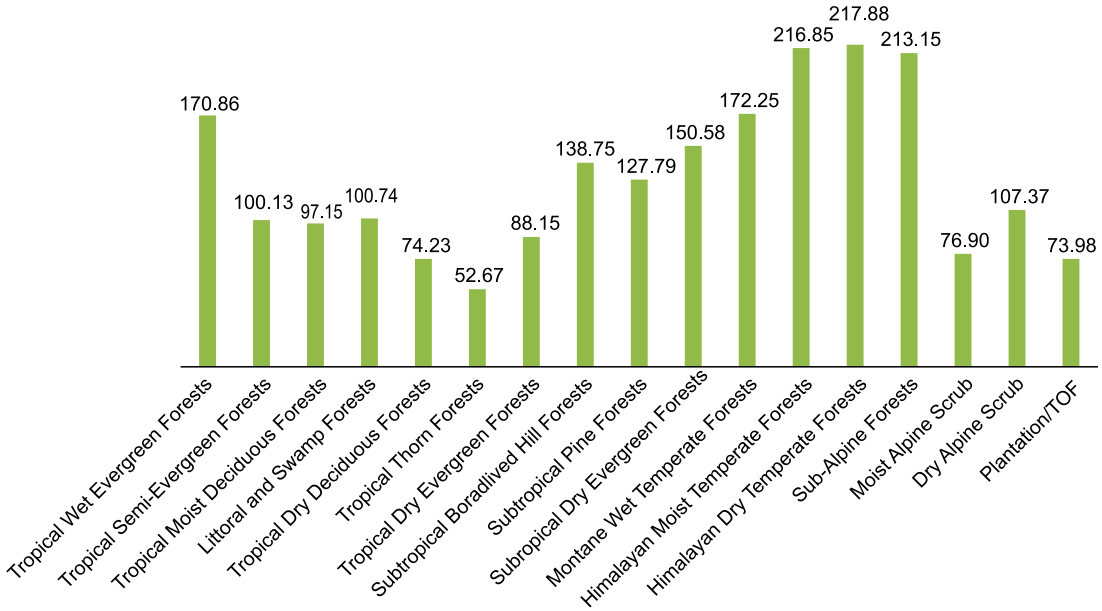


TABLE 9.6 Forest Type wise Carbon Stock at the National level in different carbon pools with per ha stock given in tonnes in parenthesis

('000 tonnes)

S. No.	Forest Type Stratum	Area in sq km	AGB	BGB	Dead Wood	Litter	SOC	Total
1.	Tropical Wet Evergreen Forests	20,170	1,46,982 (72.87)	54,379 (26.96)	3,569 (1.77)	8,764 (4.34)	1,30,952 (64.92)	**3,44,646 (170.86)**
2.	Tropical Semi-Evergreen Forests	71,807	2,48,659 (34.63)	54,733 (7.62)	2,504 (0.35)	21,432 (2.98)	3,91,665 (54.54)	**7,18,993 (100.13)**
3.	Tropical Moist Deciduous Forests	1,35,834	4,16,660 (30.67)	91,713 (6.75)	7,128 (0.52)	37,087 (2.73)	7,66,982 (56.47)	**13,19,570 (97.15)**
4.	Littoral and Swamp Forests	5,527	16,310 (29.51)	6,034 (10.92)	160 (0.29)	382 (0.69)	32,786 (59.33)	**55,672 (100.74)**
5.	Tropical Dry Deciduous Forests	2,90,724	5,93,848 (20.43)	2,49,439 (8.58)	4,796 (0.16)	28,622 (0.98)	12,81,417 (44.08)	**21,58,122 (74.23)**
6.	Tropical Thorn Forests	14,552	14,659 (10.07)	6,154 (4.23)	132 (0.09)	1,298 (0.89)	54,395 (37.38)	**76,638 (52.67)**
7.	Tropical Dry Evergreen Forests	858	2,689 (31.35)	1,129 (13.17)	198 (2.30)	119 (1.39)	3,427 (39.95)	**7,562 (88.15)**
8.	Subtropical Broad leaved Hill Forests	31,993	1,14,599 (35.82)	48,132 (15.04)	913 (0.29)	7,233 (2.26)	2,73,023 (85.34)	**4,43,900 (138.75)**
9.	Subtropical Pine Forests	17,619	75,562 (42.89)	20,409 (11.58)	609 (0.35)	2,047 (1.16)	1,26,534 (71.81)	**2,25,161 (127.79)**
10.	Subtropical Dry Evergreen Forests	184	1,040 (56.54)	437 (23.75)	5 (0.28)	6 (0.35)	1,281 (69.67)	**2,769 (150.58)**
11.	Montane Wet Temperate Forests	20,653	69,081 (33.45)	18,652 (9.03)	2,832 (1.37)	4,335 (2.10)	2,60,850 (126.30)	**3,55,750 (172.25)**
12.	Himalayan Moist Temperate Forests	26,184	2,75,685 (105.29)	74,432 (28.43)	6,795 (2.60)	6,661 (2.54)	2,04,222 (77.99)	**5,67,795 (216.85)**
13.	Himalayan Dry Temperate Forests	5,565	63,519 (114.12)	18,420 (33.09)	1,734 (3.12)	808 (1.45)	36,786 (66.09)	**1,21,267 (217.88)**
14.	Sub-Alpine Forests	14,184	1,1,3005 (79.67)	32,769 (23.10)	3,946 (2.78)	1,536 (1.08)	1,51,081 (106.51)	**3,02,337 (213.15)**
15.	Moist Alpine Scrub	1,975	4,046 (20.48)	1,173 (5.94)	72 (0.37)	147 (0.75)	9,752 (49.37)	**15,190 (76.9)**
16.	Dry Alpine Scrub	2,006	11,855 (59.12)	3,438 (17.14)	49 (0.24)	211 (1.05)	5,980 (29.82)	**21,533 (107.37)**
17.	Plantation/TOF	52,414	88,336 (16.85)	19,384 (3.70)	402 (0.08)	7,214 (1.38)	2,72,439 (51.98)	**3,87,775 (73.98)**
Total		**7,12,249**	**22,56,535 (31.68)**	**7,00,827 (9.84)**	**35,844 (0.50)**	**1,27,902 (1.80)**	**40,03,572 (56.21)**	**71,24,680 (100.03)**

The Table 9.6 reveals that the maximum carbon stock has been stored in tropical dry Deciduous forests (2,158 m tonnes) followed by Tropical Moist Deciduous Forest (1,320 m tonnes) and Tropical Semi Evergreen forests (719 m tonnes).

10 Chapter

People & Forests

Dependence of people in forest fringe villages on forests for fuelwood, fodder, small timber and bamboo

10.1 INTRODUCTION

In India, the rural population is about 68% of the country's total population[1] and a significant part of it is dependent on the forests for meeting the needs of fuelwood, fodder, small timber, bamboo and NTFPs. The livestock population in the country is one of the largest in the world. As per the Census 2011, there are about 6,50,000 villages in the country, out of which nearly 1,70,000 villages are located in the proximity of forest areas, they are often termed Forest Fringe Villages[2] (FFVs). Forests play an important role in the socio-economic and cultural lives of the people inhabiting these villages. They have been dependant on the forests for fuel wood, fodder, timber and bamboo since ages but with the manifold increase in their population in the last 60 to 70 years, pressure on forests has also increased in the likewise manner. Most of these removals from forests, which take place in a

[1] Census of India (2011), Office of Registrar General and Census Commissioner of India, Ministry of Home Affairs, Govt. of India

[2] State of Forest Report (1999), Forest Survey of India

gradual and continuous manner remain unrecorded. Thus, possibly a major driver of impairment of forest productivity remains unassessed and does not get adequate attention of policy makers and forest managers due to lack of data. Also, the information on socio-economic and ecological impact of such removals of forest produce on forests is scant. Under the circumstances, need for a study was felt to assess the dependence of communities inhabiting the forest fringe villages in quantified terms. It has been more than eight years since a study on production and consumption of forest resources in India was conducted by Forest Survey of India (FSI, 2011). The study revealed that the dependence of communities for fuelwood and fodder which is available to them free of cost from the forests is high. Moreover, it was done for the whole country including all the villages and therefore it did not reflect dependence of the people in forest fringe villages only. Therefore, a study to assess the dependence of the people living in proximity to forests on produce such as fuelwood, fodder, small timber and bamboo was undertaken by FSI during Sept 2018 to June 2019 to understand the removals in quantified terms and provide the information for policy, planning and management purposes. The study has been done using a statistical design considering forest fringe villages as the first stage sample unit and households in the sample villages as the second stage sampling units. The methodology in detail is described in the following sections.

10.2 OBJECTIVE

The main objective of the study is to estimate the dependence of people living in forest fringe villages on the nearby forests in terms of the removal of

- quantity of fuel wood
- quantity of fodder
- quantity of small timber
- quantity of bamboo

10.3 POPULATION UNDER STUDY

The scope of this study encompasses assessment of the dependence of people in FFVs on forests for fuelwood, fodder, small timber and bamboo all over the country. FFVs in this study have been defined as those villages which fall within five kilometres from the periphery of Recorded Forest Areas (RFA) or Green wash area where boundaries of RFAs are not available in digital form. Vector layer of boundaries of RFA/Green wash area in GIS has been used to select the FFVs. Since the dependence of the FFVs may vary with the distance from RFA boundary, therefore it has been decided to distribute the FFVs into four strata (buffers) as follows:

a) Villages inside the forests (Stratum 0)

b) Villages within one km (Stratum 1)

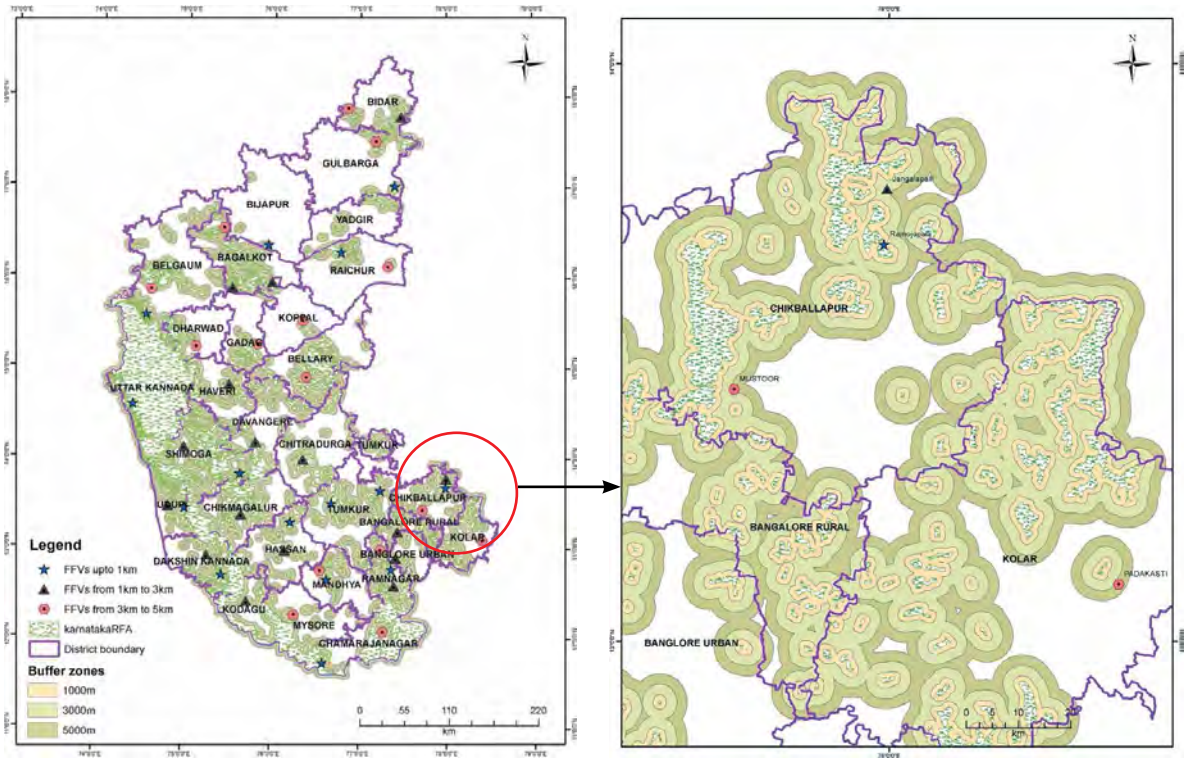
c) Villages between one to three km (Stratum 2)

d) Villages between three to five km (Stratum 3)

Vector coverage of village boundaries of all the States in the country was procured from the Survey of India (SOI). The coverage provided by SOI did not have village boundaries of a few states of North Eastern India viz Meghalaya, Arunachal Pradesh and Nagaland. For these States, point locations of the villages were digitized from the SOI toposheets and buffers around these locations were used as proxy for the village boundary. Socio economic data of the villages was collected from the Census Report (2011). The following figure illustrates selection of villages (FFVs) in different strata:

FIGURE 10.1 Selection of FFVs using buffers

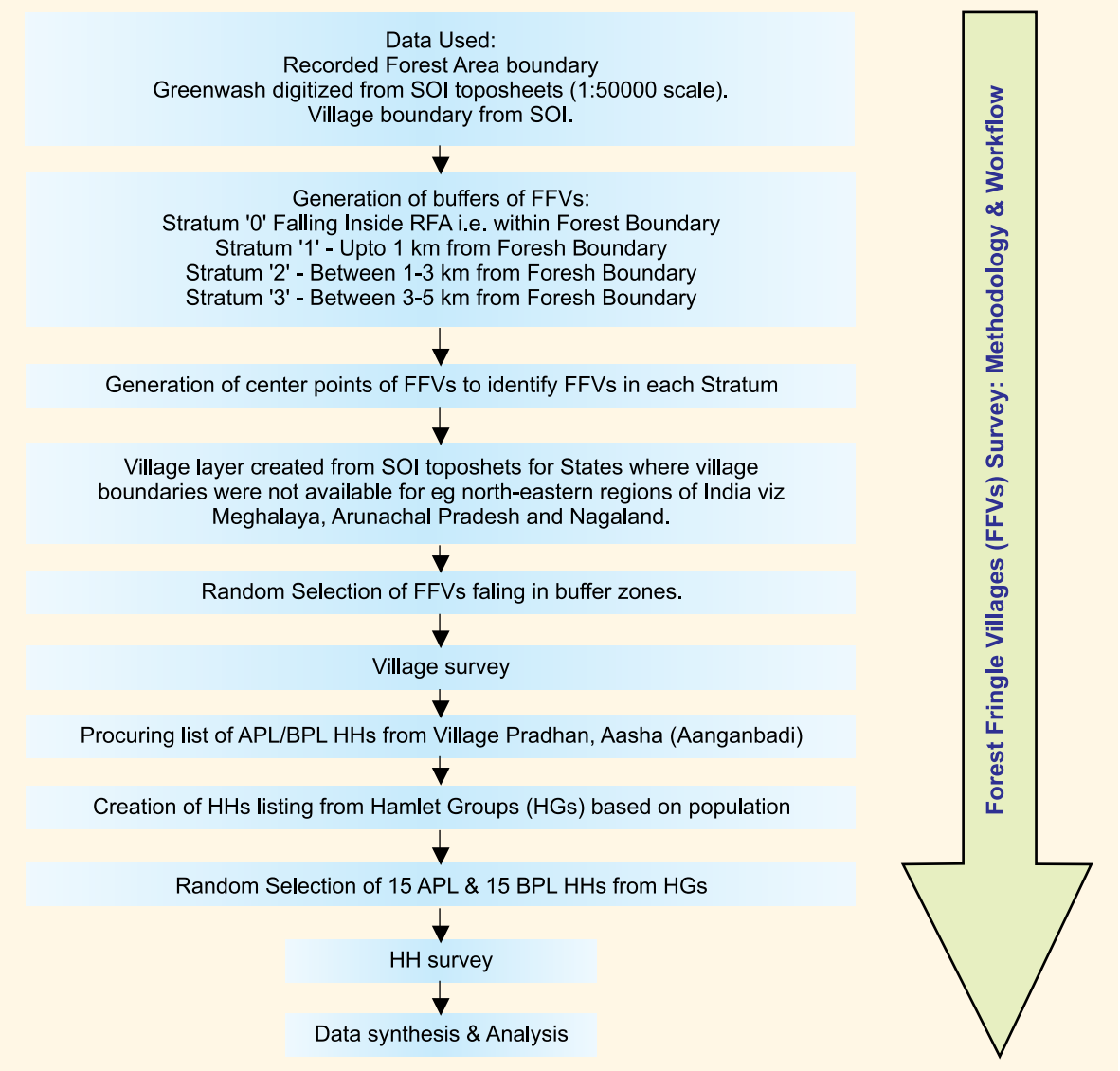
Selection of FFVs – an example from Chikballapur district of Karnataka (zoomed view)



10.4 SURVEY DESIGN & METHODOLOGY

A two stage stratified random sampling approach has been followed for the survey. The country has been stratified into 24 strata on the basis of large States or group of States/UTs. Within each stratum (State), a minimum of 40 villages were selected randomly in a stratified manner using three GIS layers at distances of 1 km, 3 kms and 5 kms from RFA/Green wash boundary, the villages were distributed equally in the four buffers. Within each selected village, 30 households including 15 households from above poverty line (APL) and 15 households from the below poverty line (BPL) have been selected randomly. Data from each selected household in the sample from a village was collected using pre designed forms. These selected households form the second stage sampling units. APL and BPL households identified through the list provided by the local administrative authorities or MNREGA website have been referred for observing their status as per the norms of Government of India. Any shortfall in one category has been compensated from another category. Further, in the villages with larger population, suitable number of hamlets-groups (HGs) based on population, have been identified in terms of physical landmarks and out of two randomly selected HGs, thirty households were selected. The following schematic diagram presents steps and work flow of the study.

FIGURE 10.2 Schematic diagram presents steps and work flow of the study



The number of villages sampled in each State and UT are given in the following table.

TABLE 10.1 State/UT wise number of villages selected for the study

S.No.	State/UTs	Stratum 0	Stratum 1	Stratum 2	Stratum 3	Total
1.	Andhra Pradesh	2	14	14	13	43
2.	Arunachal Pradesh	-	29	14	-	43
3.	Assam	-	15	13	12	40
4.	Bihar	-	12	14	14	40
5.	Chhattisgarh	5	20	20	20	65
6.	Goa	-	3	4	1	8
7.	Gujarat	5	21	18	18	62
8.	Haryana	-	12	12	16	40
9.	Himachal Pradesh	2	15	14	14	45
10.	Jammu & Kashmir	-	1	5	3	9
11.	Jharkhand	-	12	16	12	40

S.No.	State/UTs	Stratum 0	Stratum 1	Stratum 2	Stratum 3	Total
12.	Karnataka	1	15	16	15	47
13.	Kerala	-	13	14	13	40
14.	Madhya Pradesh	5	30	23	22	80
15.	Maharashtra	5	22	22	18	67
16.	Manipur	-	3	3	3	9
17.	Meghalaya	-	7	2	3	12
18.	Mizoram	-	11	1	-	12
19.	Nagaland	-	5	4	6	15
20.	Odisha	-	23	19	20	62
21.	Punjab	2	14	13	13	42
22.	Rajasthan	2	13	11	16	42
23.	Sikkim	-	10	2	-	12
24.	Tamilnadu	4	14	12	13	43
25.	Telangana	-	13	14	11	38
26.	Tripura	-	5	5	3	13
27.	Uttar Pradesh	-	14	13	15	42
28.	Uttarakhand	4	22	11	8	45
29.	West Bengal	-	17	11	12	40
30.	A & N Islands	-	11	-	-	11
31.	Dadra & Nagar Haveli	-	1	1	1	3
Total		**37**	**417**	**341**	**315**	**1110**

10.5 DATA ENTRY AND PROCESSING MODULE

A Data Entry and Processing Module has been developed by FSI for generating the estimates. The structured database is maintained in Microsoft SQL Server 2014. Estimates generated from the study are based on the population of the study villages extrapolated to 2019.

10.6 RESULTS

Results of the study are summarised in the following sub-sections.

FIGURE 10.3 (a) Collection of fuel wood by households

FIGURE 10.3 (b) Collection of fodder by households

10.6.1 State wise quantified estimation of dependence of people living in FFVs on forests for fuel wood, fodder, small timber and bamboo

Estimates of quantities of fuelwood, fodder, small timber and bamboo collected annually by the people living in the FFVs from the nearby forests is presented in Table 10.2

TABLE 10.2 State/UT wise quantities of fuelwood, fodder, small timber and bamboo collected annually by the people living in the FFVs from forests

S.No.	State/UTs	Fuelwood ('000 tonnes)	Fodder ('000 tonnes)	Small Timber (cum)	Bamboo ('000 tonnes)
1.	Andhra Pradesh	2,789	25,043	81,808	14.74
2.	Arunachal Pradesh	44	528	1,314	0.40
3.	Assam	1,411	11,712	32,972	14.44
4.	Bihar	821	4,338	13,766	11.34
5.	Chhattisgarh	3,608	82,771	852,164	392.49
6.	Goa	30	35	2,699	0.31
7.	Gujarat	4,983	119,054	1,192,475	291.75
8.	Haryana	500	6,840	16,471	0.04
9.	Himachal Pradesh	593	3,256	11,264	0.59
10.	Jammu & Kashmir	1,299	14,018	19,763	0.09
11.	Jharkhand	7,372	55,482	183,240	50.54
12.	Karnataka	6,323	21,501	41,098	0.40
13.	Kerala	3,390	3,472	100,259	0.85
14.	Madhya Pradesh	7,663	222,720	1,473,754	630.66
15.	Maharashtra	9,539	157,136	862,138	128.67
16.	Manipur	39	262	8,618	2.92
17.	Meghalaya	93	220	5,821	0.90
18.	Mizoram	18	23	849	0.42
19.	Nagaland	278	488	12,225	1.09
20.	Odisha	9,186	56,035	376,521	110.79
21.	Punjab	456	4,269	18,758	0.09
22.	Rajasthan	8,560	112,708	82,433	3.70
23.	Sikkim	82	440	1,320	0.07
24.	Tamilnadu	1,752	20,123	102,566	2.35
25.	Telangana	1,969	15,958	1,541	6.86
26.	Tripura	700	1,588	8,468	3.50
27.	Uttar Pradesh	5,141	59,335	159,587	109.51
28.	Uttarakhand	4,076	32,119	38,801	2.43
29.	West Bengal	2,519	21,209	134,946	45.47
30.	A & N Islands	22	83	2,506	3.74
31.	Dadra & Nagar Haveli	33	274	8,057	3.10
Total		**85,290**	**1053,039**	**5,848,204**	**1,834.25**

TABLE 10.3 State/UT wise quantities of fuelwood, fodder, small timber and bamboo removed from forests by the people living in FFVs in per capita per annum

S.No.	State/UTs	Population in FFVs*	Average Removal (per capita/annum)			
			Fuelwood (tonnes)	Fodder (tonnes)	Small Timber (cum)	Bamboo (tonnes)
1.	Andhra Pradesh	16,929,522	0.165	4.350	0.005	0.005
2.	Arunachal Pradesh	87,786	0.502	7.726	0.015	0.005
3.	Assam	6,469,538	0.218	3.751	0.005	0.007
4.	Bihar	2,415,714	0.340	5.956	0.006	0.009
5.	Chhattisgarh	12,772,615	0.283	6.497	0.067	0.031
6.	Goa	83,661	0.362	6.184	0.032	0.004
7.	Gujarat	21,875,737	0.228	4.928	0.055	0.013
8.	Haryana	2,425,740	0.206	5.095	0.007	0.004
9.	Himachal Pradesh	781,340	0.759	5.831	0.014	0.006
10.	Jammu & Kashmir	3,500,415	0.371	4.998	0.006	0.0005#
11.	Jharkhand	18,843,815	0.391	7.866	0.010	0.011
12.	Karnataka	16,293,496	0.388	4.113	0.003	0.005
13.	Kerala	7,296,407	0.465	3.601	0.014	0.004
14.	Madhya Pradesh	38,766,588	0.198	6.098	0.038	0.016
15.	Maharashtra	42,319,648	0.225	5.905	0.020	0.003
16.	Manipur	430,209	0.090	3.813	0.020	0.009
17.	Meghalaya	257,954	0.362	5.142	0.023	0.007
18.	Mizoram	38,675	0.461	7.972	0.022	0.016
19.	Nagaland	334,406	0.830	7.568	0.037	0.015
20.	Odisha	19,638,249	0.468	5.823	0.019	0.010
21.	Punjab	1,295,803	0.352	4.758	0.014	0.005
22.	Rajasthan	24,710,255	0.346	4.316	0.003	0.005
23.	Sikkim	139,576	0.588	5.432	0.009	0.007
24.	Tamilnadu	16,648,215	0.105	6.564	0.006	0.004
25.	Telangana	10,559,667	0.186	7.070	0.0001	0.006
26.	Tripura	980,226	0.714	6.590	0.009	0.005
27.	Uttar Pradesh	22,720,296	0.226	5.156	0.007	0.008
28.	Uttarakhand	6,189,670	0.659	5.922	0.006	0.015
29.	West Bengal	11,559,614	0.218	4.557	0.012	0.008
30.	A & N Islands	82,789	0.266	4.111	0.030	0.074
31.	Dadra & Nagar Haveli	108,638	0.299	5.139	0.074	0.029

* Population in FFVs has been projected for the year 2019.

Adequate data was not available

Based on the estimates in respect of fuelwood, fodder, small timber and bamboo presented in Table 10.2 and 10.3, analysis in respect of each of the above forest produced is briefly presented below.

10.6.2 Fuelwood

In terms of total removal of fuelwood by the people living in FFVs, the highest quantity of removal of fuelwood is estimated for Maharashtra followed by Odisha and Rajasthan.

In terms of average removal of fuelwood per capita in a year, the highest dependance is observed in Nagaland followed by Himachal Pradesh and Tripura.

A comparative analysis using the estimates of FSI's study conducted in 2011 (ISFR 2011) shows that the fuelwood consumption in terms of per capita per year at the national level has reduced from 294.28 kg/capita/year in 2011 to 278.21 kg/capita/year in 2019 which is a reduction of 5.46%. It is possible that Govt. schemes of promoting alternative fuels like LPG under Ujjawala scheme and non renewable energy have been effective in reducing fuelwood removal from forests to some extent.

10.6.3 Fodder

The quantity of removal of fodder, in terms of total removal, is estimated highest for Madhya Pradesh followed by Maharashtra and Gujarat.

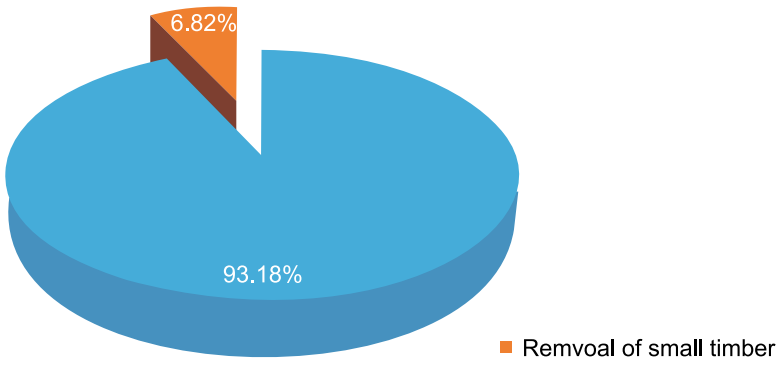
In terms of average removal of fodder per capita in a year, the highest dependence is observed in Mizoram followed by Jharkhand and Arunachal Pradesh.

10.6.4 Small Timber

As evident from the table above, the total removal of small timber is estimated highest for Madhya Pradesh followed by Gujarat and Maharashtra whereas, the average removal of small timber per capita in a year is observed highest in Dadra and Nagar Haveli followed by Chhattisgarh and Gujarat.

An analysis has been done to assess the removal of small timber from the recorded forests by the people living in FFVs against the average annual yield of timber at the national level. This has been done to get an indicative figure showing removal on this count as fraction of the total potential increment in the whole of the recorded forest areas in the country. For this, State wise annual yield has been estimated using the growing stock data of current assessment and average rotation age of the predominant species as given in the FSI Publication (1995)[3]. As per the analysis, the average annual yield at the national level is estimated 85.65 million cum, whereas, the annual removal of the small timber as given in the Table 10.2 is estimated 5.85 million cum which is 6.82% of the average annual yield at the national level. It is important to note here that the above fraction gives removal against the total yield from the whole RFAs of the country whereas, removal of small timber largely takes place from the forests close to the villages where the corresponding fraction would be several times higher.

FIGURE 10.4 Annual removal of small timber by people in FFVs against the average yield at the national level



[3] FSI (1995), Extent, Composition, Density, Growing Stock and annual increment of India's Forests, Forest Survey of India.

10.6.5 Bamboo

The total removal of bamboo from forest, by the people living in FFVs is estimated highest for Madhya Pradesh followed by Chhattisgarh and Gujarat.

In terms of average removal of bamboo per capita in a year, the highest dependence is observed in Andaman & Nicobar Islands followed by Chhattisgarh and Dadra & Nagar Haveli.

The top 10 States in terms of dependence of people on forests for fuelwood, fodder, small timber and bamboo are shown graphically in Figs 10.5 (a) to (d).

The top 10 States in terms of per capita dependence of people on forests for fuelwood, fodder, small timber and bamboo are shown graphically in Figs 10.6 (a) to (d)

FIGURE 10.5 (a) Top 10 states in terms of dependence on forests for fuelwood ('000 tonnes)

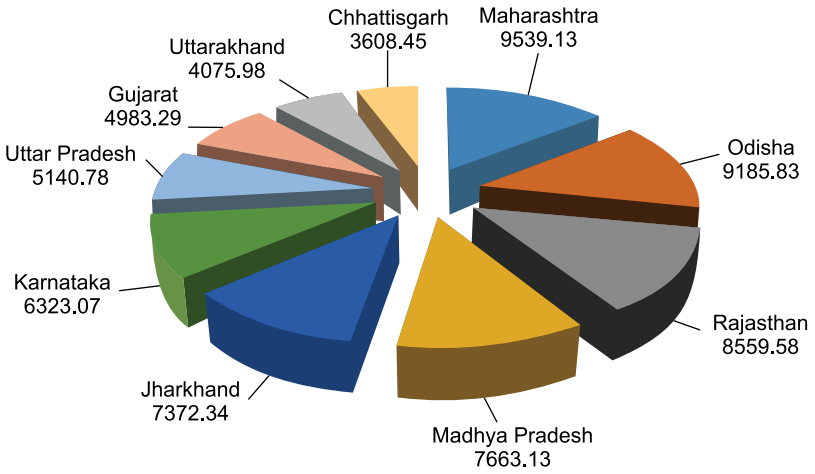


FIGURE 10.5 (b) Top 10 states in terms of dependence on forests for fodder ('000 tonnes)

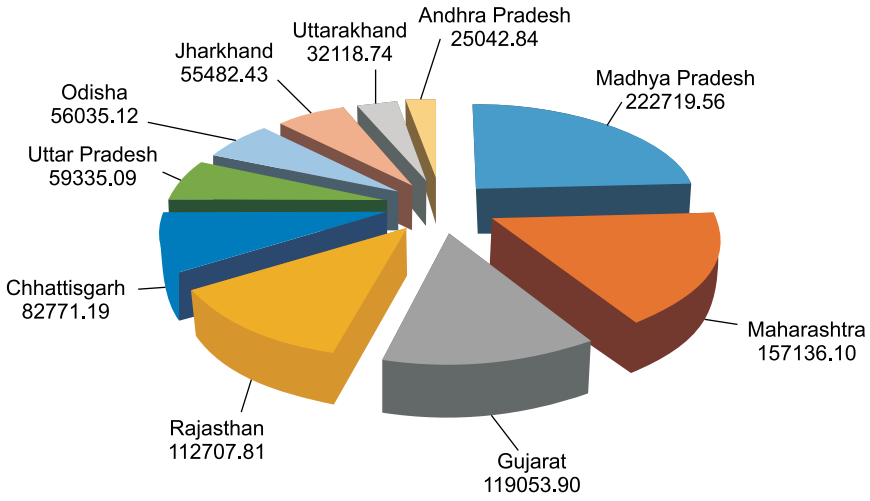


FIGURE 10.5 (c) Top 10 states in terms of dependence on forests for bamboo ('000 tonnes)

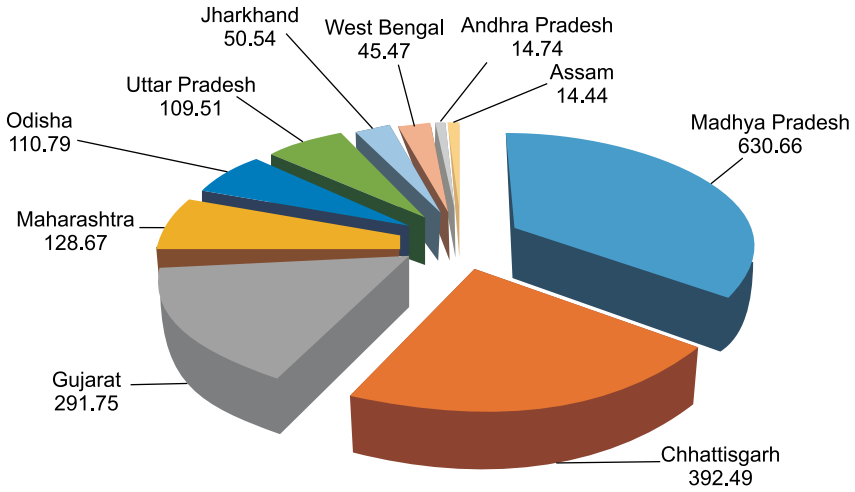


FIGURE 10.5 (d) Top 10 states in terms of dependence on forests for small timber (cum)

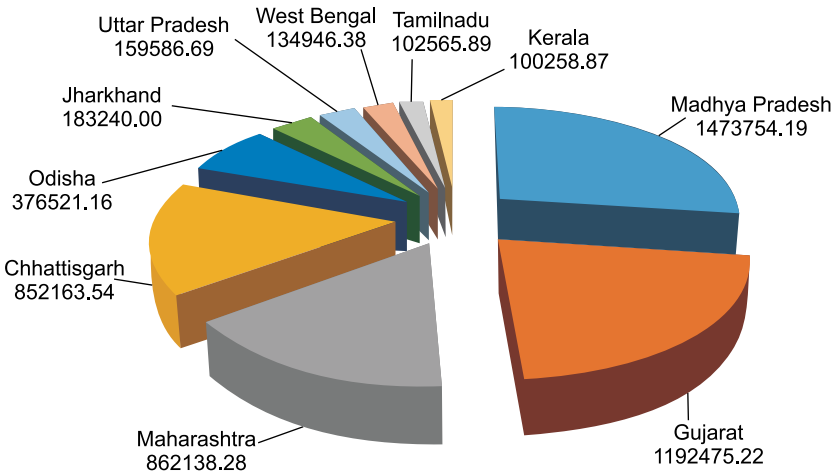


FIGURE 10.6 (a) Top 10 states in terms of per capita dependence on forests for Fuelwood (tonnes)

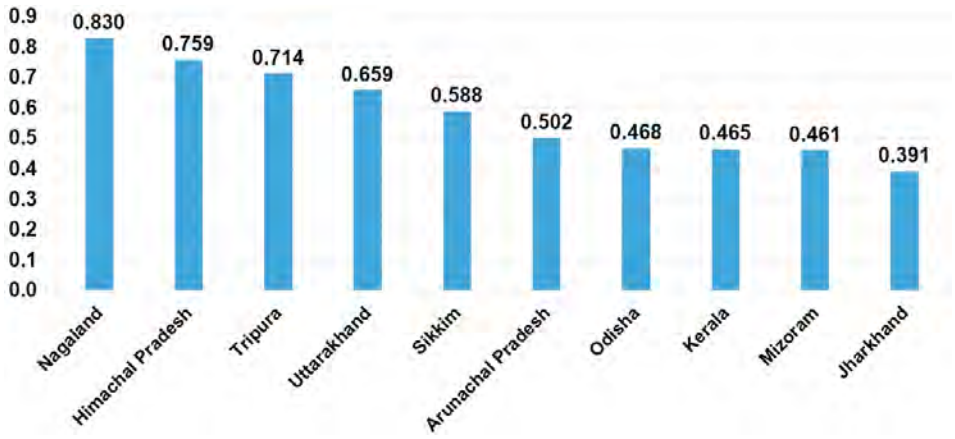


FIGURE 10.6 (b) Top 10 states in terms of per capita dependence on forests for Fodder (tonnes)

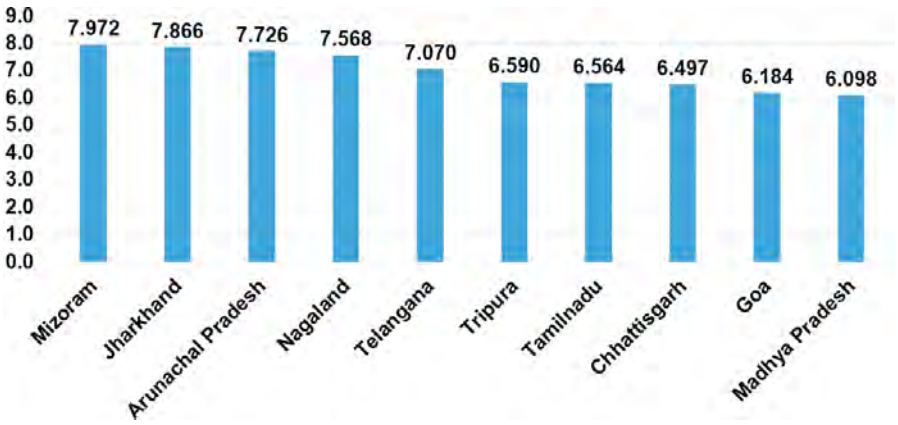


FIGURE 10.6 (c) Top 10 states in terms of per capita dependence on forests for Bamboo (tonnes)

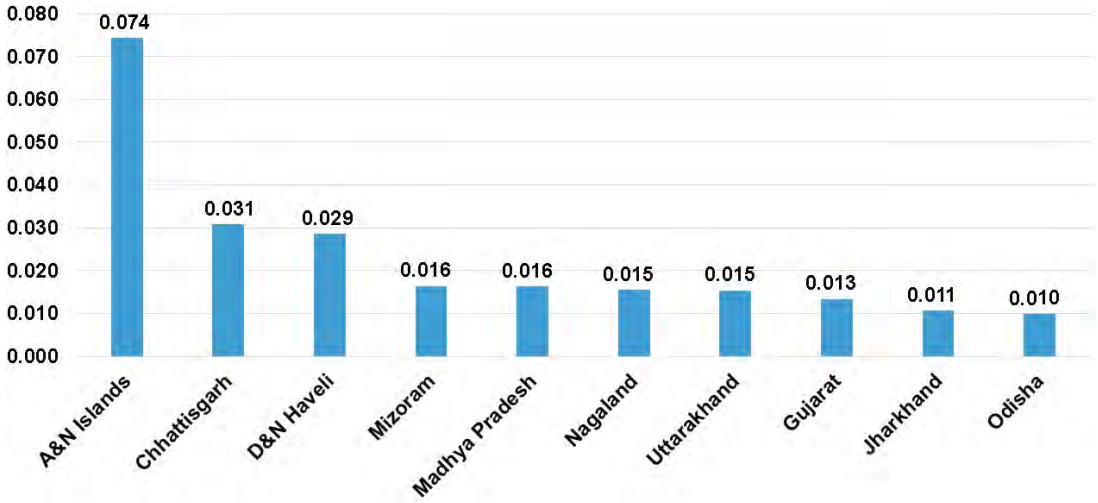


FIGURE 10.6 (d) Top 10 states in terms of per capita dependence on forests for small Timber (cum)

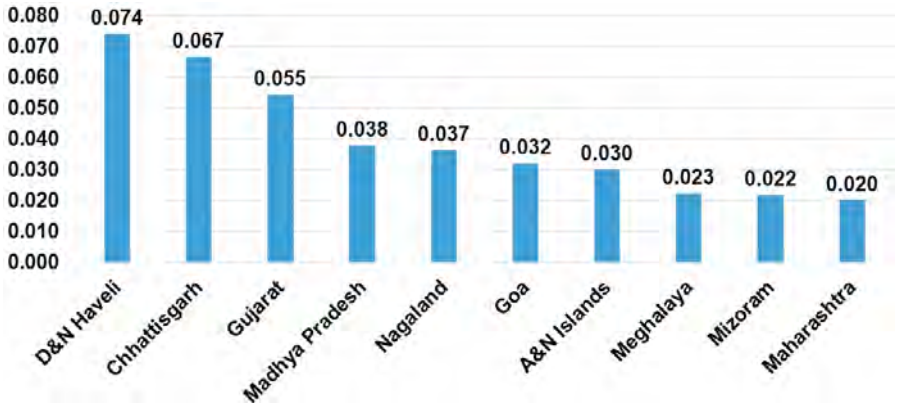
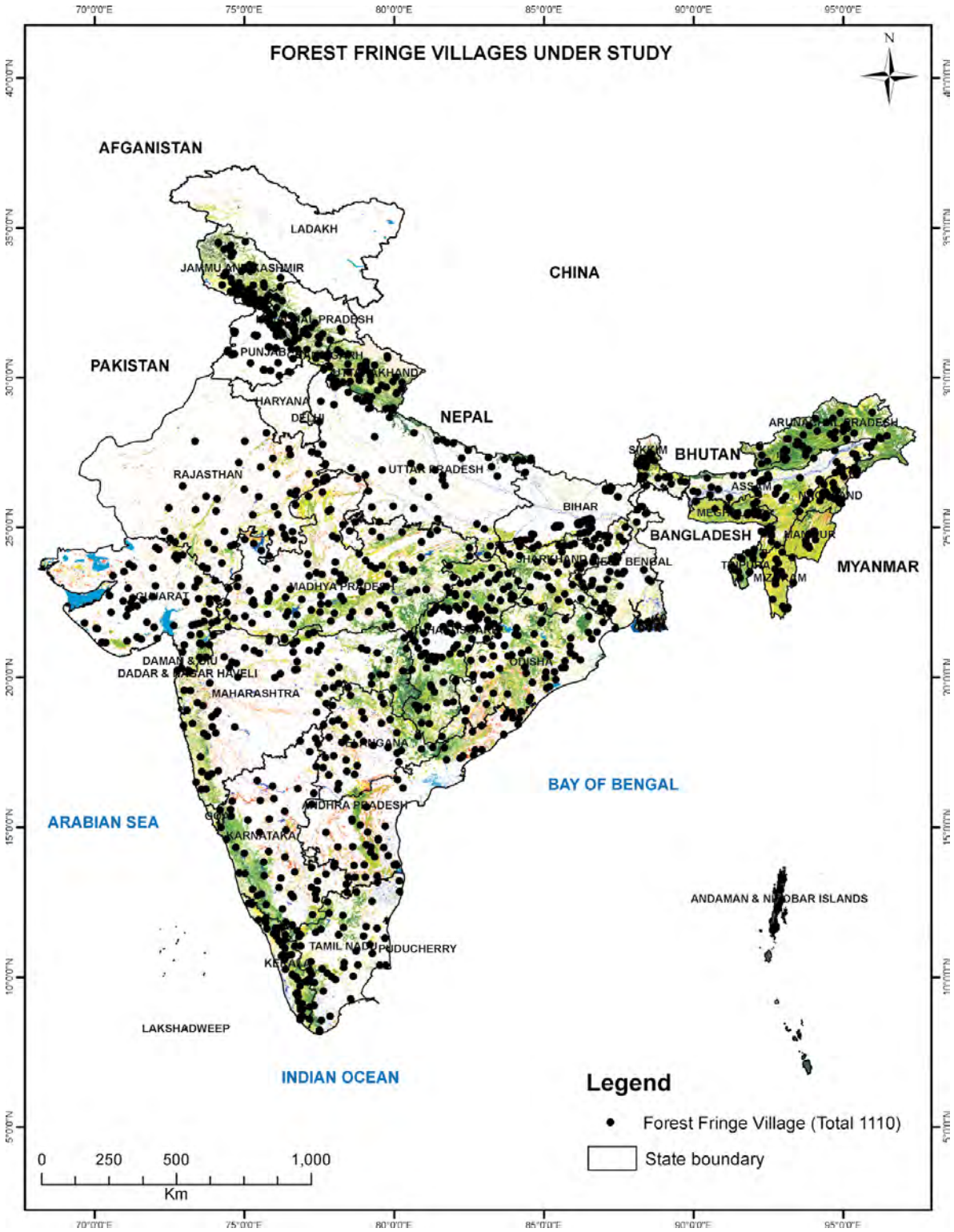


FIGURE 10.7 Map showing location of sampled forest fringe villages for the Study



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ANNEXURE-I

Period of FCC/data used for ISFR- 2019

S. No.	Name of the State/UT	Period of FCC/data used for ISFR – 2019	
		From	To
1.	Andhra Pradesh	November – 2017	October – 2018
2.	Arunachal Pradesh	October – 2017	March – 2018
3.	Assam	November – 2017	February – 2018
4.	Bihar	October – 2017	December – 2018
5.	Chhattisgarh	November – 2017	January – 2018
6.	Delhi	November – 2017	
7.	Goa	December – 2017	
8.	Gujarat	October – 2017	December – 2017
9.	Haryana	October – 2017	December – 2017
10.	Himachal Pradesh	October – 2017	October – 2017
11.	J & K	September – 2017	November – 2017
12.	Jharkhand	November – 2017	January – 2018
13.	Karnataka	November – 2017	March – 2018
14.	Kerala	December – 2017	March – 2018
15.	Madhya Pradesh	October – 2017	January – 2018
16.	Maharashtra	October – 2017	January – 2018
17.	Manipur	October – 2017	February – 2018
18.	Meghalaya	November – 2017	January – 2018
19.	Mizoram	December – 2017	February – 2018
20.	Nagaland	October – 2017	February – 2018
21.	Odisha	November – 2017	February – 2018
22.	Punjab	October – 2017	October – 2017
23.	Rajasthan	October – 2017	December – 2017
24.	Sikkim	November – 2017	November – 2017
25.	Tamil Nadu	October – 2017	August – 2018
26.	Telangana	November – 2017	January – 2018
27.	Tripura	October – 2017	December – 2017
28.	Uttar Pradesh	October – 2017	January – 2018
29.	Uttarakhand	October - 2017	October – 2018
30.	West Bengal	November – 2017	February – 2018
31.	Andaman & Nicobar Island	April – 2017	March – 2018
32.	Chandigarh	October – 2017	
33.	Dadra & Nagar Haveli	October – 2017	
34.	Daman & Diu	October – 2017	
35.	Lakshadweep	November – 2017	July – 2018
36.	Puducherry	December – 2017	August – 2018

ANNEXURE-II

Volume Equations

Volume equations to compute volume of wood in predominate trees in each States/ UTs are provided in the following tables:

Andhra Pradesh

S. No.	Species Name	Volume Equation
1.	*Albizzia amara*	$V=(0.13817-2.16947*D+11.4087*D^2+1.11636*D^3)$
2.	*Anogeissus latifolia*	$V=(0.034725-0.78412*D+7.1873*D^2+6.9495*D^3)$
3.	*Dalbergia paniculata*	$\sqrt{V}=(-0.144504+2.943115*D)$
4.	*Ficus species*	$V=(0.088074-1.449236*D+8.760534*D^2)$
5.	*Hardwickia binata*	$V=(0.025091-0.185618*D+3.561089*D^2+10.80139*D^3)$
6.	*Lannea coromandelica*	$V=(0.057424-1.153088*D+8.542648*D^2)$
7.	*Pterocarpus marsupium*	$V=(0.058424-1.233468*D+9.433633*D^2)$
8.	*Tamarindus indica*	$V=(0.088074-1.449236*D+8.760534*D^2)$
9.	*Terminalia tomentosa*	$V=(0.05061-1.11994*D+8.77839*D^2)$
10.	*Xylia xylocarpa*	$V=(0.098-1.52*D+8.963*D^2)$

Arunachal Pradesh

S. No.	Species Name	Volume Equation
1.	*Bischofia javanica*	$V=(0.00978-0.21005*D+5.62160*D^2)$
2.	*Bombax ceiba*	$V=(0.00978-0.21005*D+5.62160*D^2)$
3.	*Castanopsis indica*	$V=(0.05331-0.87098*D+6.52533*D^2+1.74231*D^3)$
4.	*Castanopsis species*	$V=(0.05331-0.87098*D+6.52533*D^2+1.74231*D^3)$
5.	*Duabanga grandiflora*	$\sqrt{V}=(0.13199+3.35856*D-0.79250*\sqrt{D})$
6.	*Gmelina arborea*	$V=(0.01156+0.21230*D+5.10448*D^2)$
7.	*Pinus roxburghii*	$\sqrt{V}=(0.291801+6.041763*D-2.430993*\sqrt{D})$
8.	*Pterospermum acerifolium*	$V=(0.00978-0.21005*D+5.62160*D^2)$
9.	*Sterculia villosa*	$\sqrt{V}=(0.35895+4.99513*D-2.14135*\sqrt{D})$
10.	*Terminalia myriocarpa*	$V=(-0.096981+10.65*D^2)$

Assam

S. No.	Species Name	Volume Equation
1.	*Albizia species*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
2.	*Bauhinia retusa*	$V=(-0.04262+6.09491*D^2)$
3.	*Bombax ceiba*	$V=(0.04507-0.93461*D+5.48513*D^2+9.16037*D^3)$
4.	*Gmelina arborea*	$V=(0.1156+0.21230*D+5.10448*D^2)$
5.	*Lannea coromandelica*	$\sqrt{V}=(-0.32985+2.21152*D+0.78769*\sqrt{D})$
6.	*Schima wallichii*	$\sqrt{V}=(0.28069+4.61980*D-1.65381*\sqrt{D})$
7.	*Shorea robusta*	$\sqrt{V}=(-0.22388+3.29474*D)$
8.	*Stereospermum personatum*	$\sqrt{V}=(0.49746+5.98454*D-2.84986*\sqrt{D})$
9.	*Tectona grandis*	$\sqrt{V}=(-0.405890+1.98158*D+0.987373*\sqrt{D})$
10.	*Terminalia belerica*	$\sqrt{V}=(-0.14325+3.07937*D)$

Bihar

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$\sqrt{V}=(-0.07738+2.592167*D)$
2.	*Boswellia serrata*	$V=(0.03356-1.124*D+10.306*D^2)$
3.	*Butea monosperma*	$V=(0.136196-2.07674*D+10.1566*D^2)$
4.	*Ficus racemosa*	$V=(0.05396-0.82031*D+6.17975*D^2)$
5.	*Ficus religiosa*	$V=(0.05396-0.82031*D+6.17975*D^2)$
6.	*Lannea coromandelica*	$\sqrt{V}=(-0.32985+2.21152*D+0.78769*\sqrt{D})$
7.	*Madhuca latifolia*	$V=(-0.00092-0.55547*D+7.3446*D^2)$
8.	*Mallotus philippinensis*	$V=(0.14749-2.87503*D+19.61977*D^2-19.11630*D^3)$
9.	*Shorea robusta*	$V=(0.1563-2.45104*D+11.90581*D^2)$
10.	*Terminalia tomentosa*	$V=(0.08565-1.51685*D+10.24871*D^2)$

Chhattisgarh

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$V=(-0.02958+8.05003*D^2)$
2.	*Boswellia serrata*	$V=(0.044621-1.25694*D+10.86801*D^2-3.009085*D^3)$
3.	*Cleistanthus collinus*	$V=(-0.03915+0.16295*D+4.09182*D^2)$
4.	*Diospyros melanoxylon*	$V=(0.12401-2.00966*D+10.87747*D^2)$
5.	*Lagerstroemia parviflora*	$V=(0.0568-1.19611*D+9.11319*D^2)$
6.	*Lannea coromandelica*	$\sqrt{V}=(-0.11751+2.86874*D)$
7.	*Madhuca latifolia*	$V=(-0.00092-0.55547*D+7.3446*D^2)$
8.	*Pterocarpus marsupium*	$V=(-0.04659+8.06901*D^2)$
9.	*Shorea robusta*	$V=(0.17279-2.54241*D+13.08048*D^2-3.49087*D^3)$
10.	*Terminalia tomentosa*	$V=(0.00376-0.77604*D+8.35533*D^2)$

Delhi

S. No.	Species Name	Volume Equation
1.	*Acacia arabica*	$V=(0.16609-2.78851*D+17.22127*D^2-11.60248*D^3)$
2.	*Acacia catechu*	$V=(0.16609-2.78851*D+17.22127*D^2-11.60248*D^3)$
3.	*Acacia lenticularis*	$\sqrt{V}=(-0.00142+2.61911*D-0.54703*\sqrt{D})$
4.	*Azadirachta indica*	$V=(-0.03510+5.32981*D^2)$
5.	*Cassia fistula*	$V=(0.05159-0.53331*D+3.46016*D^2+10.18473*D^3)$
6.	*Ehretia laevis*	$V=(-0.03844+0.946490*D-5.40987*D^2+33.17338*D^3)$
7.	*Ficus virene*	$\sqrt{V}=(0.03629+3.95389*D-0.84421*\sqrt{D})$
8.	*Holoptelea integrifolia*	$\sqrt{V}=(0.21569+4.329878*D-1.504977*\sqrt{D})$
9.	*Leucaena leucocephala*	$V=(0.081467-1.063661*D+6.452918*D^2)$
10.	*Prosopis juliflora*	$V=(0.081467-1.063661*D+6.452918*D^2)$

Goa

S. No.	Species Name	Volume Equation
1.	*Anacardium occidentale*	$V=(4.5899*D^2-0.422*D+0.0148)$
2.	*Careya arborea*	$\sqrt{V}=(-0.23738+2.33289*D+0.48512*\sqrt{D})$
3.	*Dillenia pentagyna*	$V=(0.070-1.295*D+9.429*D^2)$
4.	*Lagerstroemia lanceolata*	$\sqrt{V}=(-0.13034+2.824203*D)$

S. No.	Species Name	Volume Equation
5.	*Lannea coromandelica*	$\sqrt{V}=(0.404153+5.555051*D-2.545525*\sqrt{D})$
6.	*Schleichera trijuga*	$V=(0.01-0.912*D+11.396*D^2)$
7.	*Syzygium cumini*	$\sqrt{V}=(0.30706+5.12731*D-2.0987*\sqrt{D})$
8.	*Terminalia tomentosa*	$\sqrt{V}=(-0.203947+3.159215*D)$
9.	*Terminalia paniculata*	$V=(0.131-1.87132*D+9.47861*D^2)$
10.	*Xylia xylocarpa*	$V=(0.007602-0.033037*D+1.868567*D^2+4.483454*D^3)$

Gujarat

S. No.	Species Name	Volume Equation
1.	*Adina cordifolia*	$\sqrt{V}=(0.21569+4.329878*D-1.504977*\sqrt{D})$
2.	*Anogeissus latifolia*	$V=(0.030502-1.105937*D+12.261268*D^2)$
3.	*Butea monosperma*	$V=(-0.032-0.0619*D+7.208*D^2)$
4.	*Diospyros melanoxylon*	$V=(0.033867-0.975148*D+8.255412*D^2)$
5.	*Lannea coromandelica*	$\sqrt{V}=(0.404153+5.555051*D-2.545525*\sqrt{D})$
6.	*Madhuca latifolia*	$V=(0.074069-1.230020*D+7.726902*D^2)$
7.	*Mitragyna parviflora*	$V=(0.099768-1.744274*D+10.086934*D^2)$
8.	*Tectona grandis*	$V=(0.032011-0.995414*D+9.91129*D^2)$
9.	*Terminalia tomentosa*	$V=(0.060344-1.569539*D+12.090296*D^2)$
10.	*Wrightia tinctoria*	$\sqrt{V}=(0.050294+3.115497*D-0.687813*\sqrt{D})$

Haryana

S. No.	Species Name	Volume Equation
1.	*Acacia arabica*	$V=(0.16609-2.78851*D+17.22127*D^2-11.60248*D^3)$
2.	*Acacia catechu*	$V=(0.02384-0.72161*D+7.46888*D^2)$
3.	*Acacia tortolis*	$V=(0.16609-2.78851*D+17.22127*D^2-11.60248*D^3)$
4.	*Anogeissus latifolia*	$\sqrt{V}= (0.2122+4.947663*D-1.5929*\sqrt{D})$
5.	*Dalbergia sissoo*	$V=(0.00331+0.000636*D^2*10000)$
6.	*Eucalyptus species*	$V=(0.02894-0.89284*D+8.72416*D^2)$
7.	*Lannea coromandelica*	$V=(0.14004-2.3599*D+11.90726*D^2)$
8.	*Phoenix sylvestris*	$V=(0.0239-0.6266*D+5.4067*D^2)$
9.	*Prosopis juliflora*	$V=(0.17553-0.71434*\sqrt{D}+7.94663*D^2)$
10.	*Syzygium cumini*	$V=(0.08481-1.81774*D+12.63047*D^2-6.69555*D^3)$

Himachal Pradesh

S. No.	Species Name	Volume Equation
1.	*Abies densa*	$\sqrt{V}=(-0.084305+3.060072*D)$
2.	*Abies pindrow*	$V=(7.92*D^2+0.244*D-0.061)$
3.	*Abies smithiana*	$V=(0.163269-2.232068*D+11.770869*D^2+1.06041*D^3)$
4.	*Cedrus deodara*	$V=(10.03982*D^2-1.28303*D+0.07367)$
5.	*Pinus wallichiana*	$V=(10.44*D^2-0.851*D+0.020)$
6.	*Pinus roxburghii*	$\sqrt{V}=(0.05131+3.9859*D-1.0245*\sqrt{D})$
7.	*Quercus leucotrichophora*	$V=(0.0988-1.5547*D+10.1631*D^2)$
8.	*Quercus semecarpifolia*	$V=(0.098800-1.55471*D+10.16317*D^2)$
9.	*Rhododendron arboreum*	$\sqrt{V}=(0.306492+4.31536*D-1.749908*\sqrt{D})$
10.	*Shorea robusta*	$\sqrt{V}=(0.16306+4.8991*D-1.57402*\sqrt{D})$

Jammu & Kashmir

S. No.	Species Name	Volume Equation
1.	*Abies densa*	$V=(0.10774-2.09529*D+12.62008*D^2-1.61065*D^3)$
2.	*Abies pindrow*	$V=(0.10774-2.09529*D+12.62008*D^2-1.61065*D^3)$
3.	*Abies smithiana*	$\sqrt{V}=(0.20050+4.58840*D-1.42603*\sqrt{D})$
4.	*Cedrus deodara*	$V=(10.03982*D^2-1.28303*D+0.07367)$
5.	*Mallotus philippinensis*	$V=(0.14749-2.87503*D+19.61977*D^2-19.11630*D^3)$
6.	*Pinus wallichiana*	$V=(0.02-0.851*D+10.44*D^2)$
7.	*Pinus roxburghii*	$V=(0.128812-2.285176*D+11.950158*D^2)$
8.	*Quercus dilatata floribunda*	$V=(0.04430-0.84266*D+6.36239*D^2+2.27556*D^3)$
9.	*Quercus leucotrichophora*	$V=(0.04430-0.84266*D+6.36239*D^2+2.27556*D^3)$
10.	*Taxus baccata*	$V=(0.007602-0.033037*D+1.868567*D^2+4.483454*D^3)$

Jharkhand

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$\sqrt{V}=(-0.07738+2.592167*D)$
2.	*Boswellia serrata*	$V=(0.03356-1.124*D+10.306*D^2)$
3.	*Buchanania latifolia*	$V=(0.031-0.64087*D+6.04066*D^2)$
4.	*Butea monosperma*	$V=(0.0417-0.47789*D+3.50714*D^2+9.76048*D^3)$
5.	*Diospyros melanoxylon*	$V=(0.12401-2.00966*D+10.87747*D^2)$
6.	*Lannea coromandelica*	$\sqrt{V}=(-0.11751+2.86874*D)$
7.	*Madhuca latifolia*	$V=(-0.00092-0.55547*D+7.3446*D^2)$
8.	*Schleichera trijuga*	$V=(0.010-0.912*D+11.396*D^2)$
9.	*Shorea robusta*	$V=(0.022585-0.70158*D+8.714*D^2)$
10.	*Terminalia tomentosa*	$V=(0.08565-1.51685*D+10.24871*D^2)$

Karnataka

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$V=(0.030502-1.105937*D+12.261268*D^2)$
2.	*Careya arborea*	$\sqrt{V}=(0.23738+2.33289*D+0.48512*\sqrt{D})$
3.	*Lagerstroemia lanceolata*	$V=(0.066188-1.334512*D+9.403257*D^2)$
4.	*Olea dioica*	$V=(-0.03001+5.75523*D^2)$
5.	*Poeciloneuron indicum*	$\sqrt{V}=(-0.153973+2.724109*D)$
6.	*Syzygium cumini*	$\sqrt{V}=(0.30706+5.12731*D-2.0987*\sqrt{D})$
7.	*Tectona grandis*	$\sqrt{V}=(-0.40589+1.98158*D+0.987373*\sqrt{D})$
8.	*Terminalia tomentosa*	$\sqrt{V}=(-0.203947+3.159215*D)$
9.	*Terminalia paniculata*	$V=(0.131-1.87132*D+9.47861*D^2)$
10.	*Xylia xylocarpa*	$\sqrt{V}=(0.01631+2.20921*D)$

Kerala

S. No.	Species Name	Volume Equation
1.	*Artocarpus hirsute*	$V=(0.076-1.319*D+11.37*D^2)$
2.	*Diospyros species*	$\sqrt{V}=(-0.184139+2.892723*D)$
3.	*Lagerstroemia lanceolata*	$V=(-0.06183+0.411348*D+1.84813*D^2+12.43582*D^3-4.26661*D^4)$
4.	*Syzygium cumini*	$\sqrt{V}=(0.30706+5.12731*D-2.0987*\sqrt{D})$

S. No.	Species Name	Volume Equation
5.	*Tectona grandis*	$\sqrt{V}=(-0.40589+1.98158*D+0.987373*\sqrt{D})$
6.	*Terminalia belerica*	$\sqrt{V}=(-0.153973+2.724109*D)$
7.	*Terminalia tomentosa*	$\sqrt{V}=(-0.203947+3.159215*D)$
8.	*Terminalia paniculata*	$V=(0.131-1.87132*D+9.47861*D^2)$
9.	*Vateria indica*	$\sqrt{V}=(-0.15493+3.1119*D)$
10.	*Xylia xylocarpa*	$\sqrt{V}=(0.01631+2.20921*D)$

Madhya Pradesh

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$V=(0.145667-2.704089*D+17.4656*D^2-10.4903*D^3)$
2.	*Boswellia serrata*	$V=(0.050452-1.228748*D+9.123381*D^2)$
3.	*Butea monosperma*	$V=(0.0417-0.47789*D+3.50714*D^2+9.76048*D^3)$
4.	*Diospyros melanoxylon*	$V=(0.033867-0.975148*D+8.255412*D^2)$
5.	*Lagerstroemia parviflora*	$V=(0.0568-1.19611*D+9.11319*D^2)$
6.	*Lannea coromandelica*	$\sqrt{V}=(-0.11751+2.86874*D)$
7.	*Madhuca latifolia*	$V=(-0.00092-0.55547*D+7.3446*D^2)$
8.	*Shorea robusta*	$\sqrt{V}=(0.19994+4.57179*D-1.56823*\sqrt{D})$
9.	*Tectona grandis*	$V=(-0.003673-0.379175*D+6.368282*D^2)$
10.	*Terminalia tomentosa*	$V=(0.060344-1.569539*D+12.090296*D^2)$

Maharashtra

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$V=(-0.061856+7.952136*D^2)$
2.	*Boswellia serrata*	$V=(0.050452-1.228748*D+9.123381*D^2)$
3.	*Butea monosperma*	$V=(0.18573-2.85418*D+15.03576*D^2)$
4.	*Careya arborea*	$\sqrt{V}=(0.23738+2.33289*D+0.48512*\sqrt{D})$
5.	*Lagerstroemia parviflora*	$V=(0.06466-1.371984*D+9.629971*D^2)$
6.	*Lannea coromandelica*	$V=(0.093318-1.531417*D+9.011590*D^2)$
7.	*Madhuca latifolia*	$V=(0.074069-1.230020*D+7.726902*D^2)$
8.	*Pterocarpus marsupium*	$V=(0.028252-0.833643*D+8.033788*D^2)$
9.	*Tectona grandis*	$\sqrt{V}=(-0.106720+2.562418*D)$
10.	*Terminalia tomentosa*	$V=(0.048532-1.05615*D+8.204564*D^2)$

Manipur

S. No.	Species Name	Volume Equation
1.	*Albizia species*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
2.	*Albizzia procera*	$V=(0.13817-2.16947*D+11.4087*D^2+1.11636*D^3)$
3.	*Callicarpa arborea*	$V=(0.11079-1.81103*D+11.4132*D^2+0.38528*D^3)$
4.	*Castanopsis species*	$V=(-0.02301+0.12721*D+2.4127*D^2+8.12834*D^3)$
5.	*Duabanga grandiflora*	$\sqrt{V}=(-0.01217+3.3993*D-0.28981*\sqrt{D})$
6.	*Ficus species*	$\sqrt{V}=(0.03629+3.95389*D-0.84421*\sqrt{D})$
7.	*Gmelina arborea*	$\sqrt{V}=(-0.00189+2.10033*D)$
8.	*Pinus kesiya*	$V=(-0.01523+5.65779*D^2)$
9.	*Quercus species*	$V=(0.14153-2.27358*D+12.9049*D^2)$
10.	*Schima wallichii*	$\sqrt{V}=(0.28069+4.61980*D-1.65381*\sqrt{D})$

Meghalaya

S. No.	Species Name	Volume Equation
1.	*Albizia species*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
2.	*Areca catechu*	$V=(0.0239-0.6266*D+5.4067*D^2)$
3.	*Artocarpus chaplasha*	$\sqrt{V}=(-0.15154+2.79983*D)$
4.	*Artocarpus heterophyllus*	$\sqrt{V}=(-0.15154+2.79983*D)$
5.	*Callicarpa arborea*	$\sqrt{V}=(-0.04506+2.33446*D)$
6.	*Careya arborea*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
7.	*Gmelina arborea*	$\sqrt{V}=(-0.00189+2.10033*D)$
8.	*Hevea brasiliensis*	$\sqrt{V}=(-0.226400+2.935870*D)$
9.	*Pinus kesiya*	$V=(-0.01523+5.65779*D^2)$
10.	*Schima wallichii*	$\sqrt{V}=(0.28069+4.61980*D-1.65381*\sqrt{D})$

Mizoram

S. No.	Species Name	Volume Equation
1.	*Albizia species*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
2.	*Callicarpa arborea*	$\sqrt{V}=(-0.04506+2.33446*D)$
3.	*Castanopsis species*	$V=(0.05331-0.87098*D+6.52533*D^2+1.74231*D^3)$
4.	*Cedrela toona*	$\sqrt{V}=(-0.05514+2.67753*D)$
5.	*Duabanga grandiflora*	$\sqrt{V}=(-0.01217+3.3993*D-0.28981*\sqrt{D})$
6.	*Dysoxylum binectariferum*	$V=(-0.04752+0.50667*D+1.88433*D^2+11.30632*D^3)$
7.	*Gmelina arborea*	$\sqrt{V}=(-0.00189+2.10033*D)$
8.	*Macaranga species*	$V=(0.13333-2.18825*D+13.12678*D^2)$
9.	*Schima wallichii*	$\sqrt{V}=(0.28069+4.61980*D-1.65381*\sqrt{D})$
10.	*Tectona grandis*	$V=(0.19112-3.25372*D+17.9194*D^2-1.66117*D^3)$

Nagaland

S. No.	Species Name	Volume Equation
1.	*Albizia species*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
2.	*Alnus species*	$V=(0.0741-1.3603*D+10.9229*D^2)$
3.	*Artocarpus chaplasha*	$\sqrt{V}=(-0.226400+2.935870*D)$
4.	*Bauhinia retusa*	$\sqrt{V}=(-0.226400+2.935870*D)$
5.	*Cedrela toona*	$\sqrt{V}=(-0.05514+2.67753*D)$
6.	*Erythrina species*	$V=(-0.07803+1.70258*D-9.1618*D^2+33.91455*D^3)$
7.	*Ficus species*	$\sqrt{V}=(0.03629+3.95389*D-0.84421*\sqrt{D})$
8.	*Quercus semiserrata*	$\sqrt{V}=(-0.226400+2.935870*D)$
9.	*Schima wallichii*	$\sqrt{V}=(0.28069+4.61980*D-1.65381*\sqrt{D})$
10.	*Sterculia villosa*	$\sqrt{V}=(0.35895+4.99513*D-2.14135*\sqrt{D})$

Odisha

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$\sqrt{V}=(-0.357373+2.430449*D+0.794626*\sqrt{D})$
2.	*Diospyros melanoxylon*	$V=(-0.009124-0.494103*D+7.610416*D^2)$
3.	*Ficus bengalensis*	$V=(0.020853-0.610255*D+6.108230*D^2)$
4.	*Lannea coromandelica*	$V=(0.057424-1.153088*D+8.542648*D^2)$

5.	*Madhuca latifolia*	$V=(-0.058016+0.352354*D+2.92291*D^2+3.624110*D^3)$
6.	*Mangifera indica*	$V=(0.108-1.706*D+7.559*D^2)$
7.	*Schleichera trijuga*	$\sqrt{V}=(-0.24358+3.58273*D)$
8.	*Shorea robusta*	$\sqrt{V}=(0.19994+4.57179*D-1.56823*\sqrt{D})$
9.	*Syzygium cumini*	$Log_eV=2.132776+2.479397\ log_eD$
10.	*Terminalia tomentosa*	$V=(0.05061-1.11994*D+8.77839*D^2)$

Punjab

S. No.	Species Name	Volume Equation
1.	*Acacia catechu*	$V=(0.16609-2.78851*D+17.22127*D^2-11.60248*D^3)$
2.	*Albizzia lebbek*	$V=(-0.0367+5.87369*D^2)$
3.	*Butea monosperma*	$\sqrt{V}=(-0.24276+2.95525*D)$
4.	*Dalbergia sissoo*	$V=(0.00331+6.36*D^2)$
5.	*Eucalyptus species*	$V=0.02894-0.89284*D+8.72416*D^2)$
6.	*Grewia oppositifolia*	$V=(0.05858-1.20414*D+9.80167*D^2)$
7.	*Holoptelea integrifolia*	$V=(0.17553-0.71434*\sqrt{D}+7.94663*D^2)$
8.	*Lannea coromandelica*	$V=(0.14004-2.3599*D+11.90726*D^2)$
9.	*Prosopis juliflora*	$V=(0.17553-0.71434*\sqrt{D}+7.94663*D^2)$
10.	*Terminalia arjuna*	$\sqrt{V}=(-0.203947+3.159215*D)$

Rajasthan

S. No.	Species Name	Volume Equation
1.	*Acacia catechu*	$V=(0.26949-1.61804*D+8.79495*D^2+2.49489*D^3)$
2.	*Acacia lenticularis*	$V=(-0.048108+5.873169*D^2)$
3.	*Anogeissus latifolia*	$V=(-0.01662+4.4268*D^2)$
4.	*Anogeissus pendula*	$V=(0.00085-0.35165*D+4.77386*D^2-0.90585*D^3)$
5.	*Boswellia serrata*	$\sqrt{V}=(-0.11629+2.4254*D)$
6.	*Butea monosperma*	$V=(-0.032-0.0619*D+7.208*D^2)$
7.	*Diospyros melanoxylon*	$\sqrt{V}=(-0.184139+2.892723*D)$
8.	*Lannea coromandelica*	$\sqrt{V}=(0.404153+5.555051*D-2.545525*\sqrt{D})$
9.	*Madhuca latifolia*	$V=(0.081467-1.063661*D+6.452918*D^2)$
10.	*Tectona grandis*	$V=(0.062108-0.927983*D+6.613031*D^2)$

Sikkim

S. No.	Species Name	Volume Equation
1.	*Abies densa*	$V=(0.10774-2.09529*D+12.62008*D^2-1.61065*D^3)$
2.	*Acer species*	$\sqrt{V}=(-0.10851+3.0425*D)$
3.	*Alnus species*	$V=(0.0741-1.3603*D+10.9229*D^2)$
4.	*Castanopsis species*	$V=(0.05331-0.87098*D+6.52533*D^2+1.74231*D^3)$
5.	*Engelhardtia spicata*	$V=(0.007602-0.033037*D+1.868567*D^2+4.483454*D^3)$
6.	*Eurya japonica*	$V=(-0.01097+5.30991*D^2)$
7.	*Machilus species*	$V=(4.84009*D^2-0.02402)$
8.	*Schima wallichii*	$\sqrt{V}=(-0.112426+2.54133*D)$
9.	*Shorea robusta*	$\sqrt{V}=(-0.22388+3.29474*D)$
10.	*Symplocos theaefolia*	$V=(-0.03754+5.87*D^2)$

Tamil Nadu

S. No.	Species Name	Volume Equation
1.	*Acacia Mearnsii*	$V=(0.088074-1.449236*D+8.760534*D^2)$
2.	*Albizzia amara*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
3.	*Anogeissus latifolia*	$V=(0.045731-1.020606*D+9.656667*D^2)$
4.	*Commiphora ostdets*	$V=(0.088074-1.449236*D+8.760534*D^2)$
5.	*Eucalyptus globules*	$\sqrt{V}=(-0.115412+3.12191*D)$
6.	*Eucalyptus species*	$V=(0.02894-0.89284*D+8.72416*D^2)$
7.	*Ficus species*	$V=(0.088074-1.449236*D+8.760534*D^2)$
8.	*Pterocarpus marsupium*	$V=(0.058424-1.233468*D+9.433633*D^2)$
9.	*Tamarindus indica*	$V=(0.131-1.87132*D+9.47861*D^2)$
10.	*Tectona grandis*	$\sqrt{V}=(-0.405890+1.98158*D+0.987373*\sqrt{D})$

Telangana

S. No.	Species Name	Volume Equation
1.	*Anogeissus latifolia*	$V=(-0.061856+7.952136*D^2)$
2.	*Boswellia serrata*	$V=(0.028917+7.777047*D^3)$
3.	*Cleistanthus collinus*	$V=(0.011617-0.309699*D+4.629527*D^2)$
4.	*Dalbergia paniculata*	$\sqrt{V}=(-0.144504+2.943115*D)$
5.	*Lagerstroemia parviflora*	$V=(0.066188-1.334512*D+9.403257*D^2)$
6.	*Lannea coromandelica*	$V=(0.091153-1.66153*D+10.24624*D^2)$
7.	*Madhuca latifolia*	$V=(0.046883-0.894379*D+7.220441*D^2)$
8.	*Tectona grandis*	$V=(0.023613-0.531006*D+6.731036*D^2)$
9.	*Terminalia tomentosa*	$V=(0.051812-1.076790*D+7.991280*D^2)$
10.	*Xylia xylocarpa*	$V=(0.05823+4.597986*D^3)$

Tripura

S. No.	Species Name	Volume Equation
1.	*Albizia species*	$\sqrt{V}=(-0.07109+2.99732*D-0.26953*\sqrt{D})$
2.	*Artocarpus chaplasha*	$\sqrt{V}=(-0.15154+2.79983*D)$
3.	*Artocarpus heterophyllus*	$\sqrt{V}=(-0.15154+2.79983*D)$
4.	*Gmelina arborea*	$\sqrt{V}=(-0.00189+2.10033*D)$
5.	*Hevea brasiliensis*	$\sqrt{V}=(-0.226400+2.935870*D)$
6.	*Lannea coromandelica*	$\sqrt{V}=(-0.21972+2.86603*D)$
7.	*Macaranga species*	$V=(0.13333-2.18825*D+13.12678*D^2)$
8.	*Pterospermum acerifolium*	$\sqrt{V}=(0.21596+4.14881*D-1.38264*\sqrt{D})$
9.	*Schima wallichii*	$\sqrt{V}=(-0.11242+2.54133*D)$
10.	*Tectona grandis*	$V=(0.19112-3.25372*D+17.9194*D^2-1.66117*D^3)$

Uttar Pradesh

S. No.	Species Name	Volume Equation
1.	*Acacia catechu*	$V=(0.16609-2.78851*D+17.22127*D^2-11.60248*D^3)$
2.	*Anogeissus latifolia*	$\sqrt{V}=(-0.07738+2.592167*D)$
3.	*Butea monosperma*	$\sqrt{V}=(-0.24276+2.95525*D)$
4.	*Ficus racemosa*	$\sqrt{V}=(0.03629+3.95389*D-0.84421*\sqrt{D})$

S. No.	Species Name	Volume Equation
5.	*Lannea coromandelica*	$V=(0.14004-2.3599*D+11.90726*D^2)$
6.	*Mallotus philippinensis*	$V=(0.14749-2.87503*D+19.61977*D^2-19.11630*D^3)$
7.	*Shorea robusta*	$\sqrt{V}=(0.16306+4.8991*D-1.57402*\sqrt{D})$
8.	*Syzygium cumini*	$V=(0.08481-1.81774*D+12.63047*D^2-6.9555*D^3)$
9.	*Tectona grandis*	$V=(0.08847-1.46936*D+11.98979*D^2+1.970560*D^3)$
10.	*Terminalia tomentosa*	$V=(0.18149-2.85865*D+18.60799*D^2)$

Uttarakhand

S. No.	Species Name	Volume Equation
1.	*Abies smithiana*	$V=(0.163269-2.232068*D+11.770869*D^2+1.06041*D^3)$
2.	*Lyonia ovalifolia*	$V=(0.007602-0.033037*D+1.868567*D^2+4.483454*D^3)$
3.	*Mallotus philippinensis*	$V=(0.14749-2.87503*D+19.61977*D^2-19.11630*D^3)$
4.	*Pinus roxburghii*	$\sqrt{V}=(0.05131+3.9859*D-1.0245*\sqrt{D})$
5.	*Quercus dilatata floribunda*	$V=(0.0988-1.5547*D+10.1631*D^2)$
6.	*Quercus leucotrichophora*	$\sqrt{V}=(0.240157+3.820069*D-1.39452*\sqrt{D})$
7.	*Quercus semecarpifolia*	$V=(0.098800-1.55471*D+10.16317*D^2)$
8.	*Rhododendron arboreum*	$\sqrt{V}=(0.306492+4.31536*D-1.749908*\sqrt{D})$
9.	*Shorea robusta*	$\sqrt{V}=(0.16306+4.8991*D-1.57402*\sqrt{D})$
10.	*Terminalia tomentosa*	$V=(0.08658-2.04096*D+13.28405*D^2-3.58047*D^3)$

West Bengal

S. No.	Species Name	Volume Equation
1.	*Acacia auriculiformis*	$V=(0.04235-0.74240*D+7.26875*D^2)$
2.	*Butea monosperma*	$V=(0.031-0.64087*D+6.04066*D^2)$
3.	*Eucalyptus species*	$V=(0.02894-0.89284*D+8.72416*D^2)$
4.	*Lagerstroemia spaciosa*	$V=(0.11740-1.58941*D+9.76464*D^2)$
5.	*Madhuca latifolia*	$V=(0.046883-0.894379*D+7.220441*D^2)$
6.	*Schima wallichii*	$\sqrt{V}=(0.28069+4.61980*D-1.65381*\sqrt{D})$
7.	*Shorea robusta*	$V=(0.16019-2.81861*D+16.19328*D^2)$
8.	*Sterculia villosa*	$V=(0.025584-0.89224*D+9.5879*D^2)$
9.	*Tectona grandis*	$V=(0.19112-3.25372*D+17.9194*D^2-1.66117*D^3)$
10.	*Trewia nudiflora*	$V=(0.0549-1.31*D+10.0*D^2)$

A & N Islands

S. No.	Species Name	Volume Equation
1.	*Bombax ceiba*	$V=(0.136196-2.07674*D+10.1566*D^2)$
2.	*Canarium euphyllum*	$V=(0.004338-0.7315*D+11.1750*D^2)$
3.	*Dillenia pentagyna*	$V=(0.070-1.295*D+9.429*D^2)$
4.	*Dipterocarpus species*	$V=(-0.045595+8.576*D^2)$
5.	*Dipterocarpus turbinatus*	$\sqrt{V}=(0.06063+3.43666*D-0.75571*\sqrt{D})$
6.	*Perishia insignis*	$\sqrt{V}=(0.06063+3.43666*D-0.75571*\sqrt{D})$
7.	*Pterocarpus indicus*	$\sqrt{V}=(0.06063+3.43666*D-0.75571*\sqrt{D})$
8.	*Pterocymbium tinctorium*	$V=(0.019795-0.99448*D+10.101*D^2)$
9.	*Terminalia procera*	$V=(0.05061-1.11994*D+8.77839*D^2)$
10.	*Tetrameles nudiflora*	$\sqrt{V}=(0.06063+3.43666*D-0.75571*\sqrt{D})$

Chandigarh

S. No.	Species Name	Volume Equation
1.	*Acacia arabica*	$V=(0.16609-2.78851*D+17.22127*D^2-11.60248*D^3)$
2.	*Acacia catechu*	$V=(0.02384-0.72161*D+7.46888*D^2)$
3.	*Dalbergia sissoo*	$V=(0.00331+6.36*D^2)$
4.	*Eucalyptus species*	$V=(0.02894-0.89284*D+8.72416*D^2)$
5.	*Leucaena leucocephala*	$V=(0.17553-0.71434*\sqrt{D}+7.94663*D^2)$
6.	*Melia azadirachta*	$V=(-0.03510+5.32981*D^2)$
7.	*Morus species*	$V=(-0.0351+5.32981*D^2)$
8.	*Populus species*	$\sqrt{V}=(-0.143393+3.040067*D)$
9.	*Prosopis juliflora*	$V=(0.17553-0.71434*\sqrt{D}+7.94663*D^2)$
10.	*Terminalia belerica*	$\sqrt{V}=(-0.14017+3.36423*D)$

Dadra & Nagar Haveli

S. No.	Species Name	Volume Equation
1.	*Acacia catechu*	$V=(-0.048108+5.873169*D^2)$
2.	*Anogeissus latifolia*	$V=(0.030502-1.105937*D+12.261268*D^2)$
3.	*Bridelia retusa*	$V=(-0.032-0.0619*D+7.208*D^2)$
4.	*Butea monosperma*	$V=(-0.032-0.0619*D+7.208*D^2)$
5.	*Grewia tiliaefolia*	$\sqrt{V}=(-0.153973+2.724109*D)$
6.	*Lannea coromandelica*	$\sqrt{V}=(0.404153+5.555051*D-2.545525*\sqrt{D})$
7.	*Madhuca latifolia*	$V=(0.074069-1.230020*D+7.726902*D^2)$
8.	*Tectona grandis*	$\sqrt{V}=(-0.40589+1.98158*D+0.987373*\sqrt{D})$
9.	*Terminalia belerica*	$V=(0.074706-1.430082*D+10.181971*D^2)$
10.	*Terminalia tomentosa*	$\sqrt{V}=(-0.203947+3.159215*D)$

Daman Diu

S. No.	Species Name	Volume Equation
1.	*Acacia arabica*	$\sqrt{V}=(-0.153973+2.724109*D)$
2.	*Azadirachta indica*	$\sqrt{V}=(-0.153973+2.724109*D)$
3.	*Casuarina equisetifolia*	$\sqrt{V}=(-0.153973+2.724109*D)$
4.	*Prosopis juliflora*	$V=(0.081467-1.063661*D+6.452918*D^2)$

ANNEXURE- III A

Estimated number of stems by species and diameter class in Forest at Country level

(in '000)

Sl.No	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1.	*Abies densa*	7,747	4,970	4,905	17,622	0.13
2.	*Abies pindrow*	20,803	27,549	17,338	65,690	0.48
3.	*Abies smithiana*	21,514	12,912	9,608	44,034	0.32
4.	*Acacia catechu*	1,70,811	5,192	236	1,76,239	1.29
5.	*Adina cordifolia*	39,811	12,167	2,571	54,549	0.40
6.	*Albizia species*	71,839	15,636	548	88,023	0.64
7.	*Anogeissus latifolia*	4,41,050	47,106	2,189	4,90,345	3.59
8.	*Bombax ceiba*	24,032	15,791	3,442	43,265	0.32
9.	*Boswellia serrata*	56,781	45,021	1,143	1,02,945	0.75
10.	*Buchanania latifolia*	2,32,126	6,449	0	2,38,575	1.75
11.	*Butea monosperma*	1,69,913	15,071	383	1,85,367	1.36
12.	*Careya arborea*	50,623	4,747	314	55,684	0.41
13.	*Castanopsis species*	1,00,095	14,086	1,354	1,15,535	0.85
14.	*Cedrus deodara*	61,811	34,425	13,417	1,09,653	0.80
15.	*Cleistanthus collinus*	2,55,882	6,980	371	2,63,233	1.93
16.	*Dalbergia paniculata*	55,773	12,226	814	68,813	0.50
17.	*Diospyros melanoxylon*	2,51,493	31,031	1,294	2,83,818	2.08
18.	*Ficus species*	62,602	13,171	2,136	77,909	0.57
19.	*Gmelina arborea*	38,593	11,873	1,886	52,352	0.38
20.	*Lagerstroemia parviflora*	2,63,178	19,154	518	2,82,850	2.07
21.	*Lannea coromandelica*	3,36,866	54,306	1,583	3,92,755	2.88
22.	*Madhuca latifolia*	1,31,418	42,683	5,010	1,79,111	1.31
23.	*Pinus wallichiana*	91,879	37,351	10,267	1,39,497	1.02
24.	*Pinus roxburghii*	1,83,057	87,140	8,876	2,79,073	2.04
25.	*Pterocarpus marsupium*	88,111	23,587	1,600	1,13,298	0.83
26.	*Quercus dilatata floribunda*	19,638	6,862	2,029	28,529	0.21
27.	*Quercus leucotrichophora*	2,18,018	40,293	4,101	2,62,412	1.92
28.	*Quercus semecarpifolia*	23,982	10,248	5,339	39,569	0.29
29.	*Rhododendron arboreum*	94,318	18,274	1,061	1,13,653	0.83
30.	*Schima wallichii*	1,03,239	16,218	614	1,20,071	0.88
31.	*Schleichera trijuga*	59,934	17,582	2,180	79,696	0.58
32.	*Shorea robusta*	9,08,393	2,13,322	17,265	11,38,980	8.34
33.	*Sterculia villosa*	27,343	12,849	1,396	41,588	0.30
34.	*Syzygium cumini*	1,24,181	35,140	3,443	1,62,764	1.19
35.	*Tectona grandis*	7,46,416	98,312	3,408	8,48,136	6.21
36.	*Terminalia belerica*	43,381	12,341	4,861	60,583	0.44
37.	*Terminalia tomentosa*	4,00,545	83,205	5,932	4,89,682	3.59
38.	*Terminalia myriocarpa*	39,027	19,098	3,465	61,590	0.45
39.	*Terminalia paniculata*	76,826	21,419	4,188	1,02,433	0.75
40.	*Xylia xylocarpa*	1,31,098	25,233	2,178	1,58,509	1.16
41.	Rest of Species	53,06,676	6,29,465	86,541	60,22,682	44.12
Total		**1,15,50,823**	**18,60,485**	**2,39,804**	**1,36,51,112**	**100.00**

ANNEXURE- III B

Estimated volume by species and diameter class in Forest at Country level

(in million cum)

Sl.No	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1.	*Abies densa*	1.75	7.99	32.16	41.90	0.98
2.	*Abies pindrow*	4.56	37.68	86.96	129.20	3.02
3.	*Abies smithiana*	3.89	19.11	71.45	94.45	2.21
4.	*Acacia catechu*	18.00	4.35	0.61	22.96	0.54
5.	*Adina cordifolia*	5.45	12.78	11.56	29.79	0.70
6.	*Albizia species*	11.50	9.69	1.61	22.80	0.53
7.	*Anogeissus latifolia*	67.26	48.94	7.92	124.12	2.90
8.	*Bombax ceiba*	3.87	17.41	15.85	37.13	0.87
9.	*Boswellia serrata*	11.05	41.93	3.65	56.63	1.33
10.	*Buchanania latifolia*	18.55	3.26	0.00	21.81	0.51
11.	*Butea monosperma*	22.48	12.64	1.86	36.98	0.87
12.	*Careya arborea*	19.21	8.06	1.66	28.93	0.68
13.	*Castanopsis species*	10.79	12.53	4.79	28.11	0.66
14.	*Cedrus deodara*	12.05	44.94	61.72	118.71	2.78
15.	*Cleistanthus collinus*	20.38	3.38	0.87	24.63	0.58
16.	*Dalbergia paniculata*	8.45	12.59	3.69	24.73	0.58
17.	*Diospyros melanoxylon*	25.48	27.98	4.55	58.01	1.36
18.	*Ficus species*	8.06	14.08	11.35	33.49	0.78
19.	*Gmelina arborea*	5.88	11.70	4.27	21.85	0.51
20.	*Lagerstroemia parviflora*	26.87	16.27	1.75	44.89	1.05
21.	*Lannea coromandelica*	48.49	47.12	5.80	101.41	2.37
22.	*Madhuca latifolia*	16.72	38.48	16.96	72.16	1.69
23.	*Pinus wallichiana*	19.88	53.64	45.75	119.27	2.79
24.	*Pinus roxburghii*	30.58	92.82	33.11	156.52	3.66
25.	*Pterocarpus marsupium*	14.19	24.99	7.44	46.62	1.09
26.	*Quercus dilatata floribunda*	2.91	6.73	12.41	22.05	0.52
27.	*Quercus leucotrichophora*	28.19	35.04	15.34	78.57	1.84
28.	*Quercus semecarpifolia*	4.57	13.27	26.52	44.36	1.04
29.	*Rhododendron arboreum*	11.63	14.63	3.90	30.16	0.71
30.	*Schima wallichii*	18.00	16.26	2.45	36.71	0.86
31.	*Schleichera trijuga*	10.34	22.12	11.55	44.01	1.03
32.	*Shorea robusta*	124.68	245.82	83.31	453.81	10.62
33.	*Sterculia villosa*	3.56	11.89	8.24	23.69	0.55
34.	*Syzygium cumini*	13.97	33.10	15.94	63.01	1.47
35.	*Tectona grandis*	94.32	86.26	13.96	194.54	4.55
36.	*Terminalia belerica*	6.34	14.66	20.88	41.88	0.98
37.	*Terminalia tomentosa*	53.21	86.47	26.03	165.71	3.88
38.	*Terminalia myriocarpa*	9.07	28.21	24.58	61.86	1.45
39.	*Terminalia paniculata*	9.19	19.71	18.56	47.46	1.11
40.	*Xylia xylocarpa*	17.19	18.63	5.47	41.29	0.97
41.	Rest of Species	536.41	527.41	363.54	1427.36	33.40
Total		**1378.96**	**1804.53**	**1089.98**	**4273.47**	**100.00**

ANNEXURE- III C

Estimated number of stems by species and diameter class in TOF at Country level

(in '000)

Sl.No	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1.	*Acacia arabica*	1,84,396	47,834	1,487	2,33,717	3.83
2.	*Acacia lenticularis*	40,278	7,595	159	48,032	0.79
3.	*Albizia species*	25,150	6,699	343	32,192	0.53
4.	*Artocarpus heterophyllus*	32,289	11,479	2,014	45,782	0.75
5.	*Azadirachta indica*	3,83,927	1,00,485	5,366	4,89,778	8.02
6.	*Bombax ceiba*	28,517	8,281	826	37,624	0.62
7.	*Borassus flabelliformis*	17,079	86,261	1,002	1,04,342	1.71
8.	*Butea monosperma*	1,60,715	30,543	1,218	1,92,476	3.15
9.	*Cocos nucifera*	1,83,766	74,376	436	2,58,578	4.24
10.	*Dalbergia sissoo*	62,720	13,499	408	76,627	1.26
11.	*Eucalyptus species*	1,33,175	14,955	815	1,48,945	2.44
12.	*Ficus bengalensis*	6,484	3,389	4,592	14,465	0.24
13.	*Ficus racemosa*	12,349	6,185	1,856	20,390	0.33
14.	*Ficus religiosa*	10,299	5,257	6,852	22,408	0.37
15.	*Ficus species*	31,241	4,615	1,278	37,134	0.61
16.	*Gmelina arborea*	34,631	4,886	603	40,120	0.66
17.	*Grewia oppositifolia*	98,638	2,745	0	1,01,383	1.66
18.	*Hevea brasiliensis*	1,16,811	5,662	5	1,22,478	2.01
19.	*Holoptelea integrifolia*	31,999	6,349	321	38,669	0.63
20.	*Juglans regia*	8,311	4,066	1,073	13,450	0.22
21.	*Madhuca latifolia*	23,631	30,326	21,628	75,585	1.24
22.	*Mangifera indica*	4,47,196	99,274	26,667	5,73,137	9.39
23.	*Palm oil tree*	451	7,008	3,912	11,371	0.19
24.	*Phoenix sylvestris*	35,823	16,358	35	52,216	0.86
25.	*Pinus wallichiana*	45,212	19,800	2,052	67,064	1.10
26.	*Pinus kesia*	42,170	3,772	0	45,942	0.75
27.	*Pinus roxburghii*	33,001	8,591	429	42,021	0.69
28.	*Pongamia pinnata*	36,069	7,243	1,502	44,814	0.73
29.	*Prosopis cineraria*	50,407	34,028	1,331	85,766	1.40
30.	*Prosopis juliflora*	1,08,511	2,870	215	1,11,596	1.83
31.	*Quercus leucotrichophora*	35,900	6,226	180	42,306	0.69
32.	*Schima wallichii*	45,595	3,669	206	49,470	0.81
33.	*Shorea robusta*	48,976	12,278	2,658	63,912	1.05
34.	*Syzygium cumini*	43,901	16,558	1,620	62,079	1.02
35.	*Tamarindus indica*	23,939	19,813	7,734	51,486	0.84
36.	*Tectona grandis*	1,70,781	11,058	709	1,82,548	2.99
37.	*Terminalia arjuna*	31,225	13,760	1,236	46,221	0.76
38.	*Terminalia belerica*	10,991	4,438	877	16,306	0.27
39.	*Terminalia tomentosa*	59,661	8,466	959	69,086	1.13
40.	*Zizyphus mauritiana*	1,45,433	12,668	527	1,58,628	2.60
41.	Rest of species	19,53,186	2,00,216	21,083	21,74,485	35.62
Total		**49,94,834**	**9,83,581**	**1,26,214**	**61,04,629**	**100.00**

ANNEXURE- III D

Estimated volume by species and diameter class in TOF at Country level

(in million cum)

Sl.No	Species	Diameter Class (cm)			Total	Percent
		10-30	30-60	60+		
1.	*Acacia arabica*	20.39	28.95	3.00	52.34	3.19
2.	*Acacia lenticularis*	4.95	4.79	0.41	10.15	0.62
3.	*Albizia species*	3.73	5.68	1.04	10.45	0.64
4.	*Artocarpus heterophyllus*	4.32	7.20	4.61	16.13	0.98
5.	*Azadirachta indica*	46.03	71.07	16.13	133.23	8.11
6.	*Bombax ceiba*	4.90	7.10	3.05	15.05	0.92
7.	*Borassus flabelliformis*	3.82	56.56	2.04	62.42	3.80
8.	*Butea monosperma*	19.02	22.21	4.42	45.65	2.78
9.	*Cocos nucifera*	35.36	27.70	0.87	63.93	3.89
10.	*Dalbergia sissoo*	12.15	11.64	1.39	25.18	1.53
11.	*Eucalyptus species*	12.88	11.05	2.14	26.07	1.59
12.	*Ficus bengalensis*	0.75	3.35	25.74	29.84	1.82
13.	*Ficus racemosa*	1.39	5.22	7.75	14.36	0.87
14.	*Ficus religiosa*	1.16	4.73	34.18	40.07	2.44
15.	*Ficus species*	4.19	4.11	5.59	13.89	0.85
16.	*Gmelina arborea*	5.52	3.01	2.34	10.87	0.66
17.	*Grewia oppositifolia*	10.56	2.54	0.00	13.10	0.80
18.	*Hevea brasiliensis*	12.51	3.56	0.03	16.10	0.98
19.	*Holoptelea integrifolia*	3.42	4.28	1.12	8.82	0.54
20.	*Juglans regia*	0.92	2.64	4.87	8.43	0.51
21.	*Madhuca latifolia*	2.75	20.04	58.67	81.46	4.96
22.	*Mangifera indica*	48.68	70.35	88.21	207.24	12.62
23.	*Palm oil tree*	0.05	6.22	8.46	14.73	0.90
24.	*Phoenix sylvestris*	6.03	6.54	0.12	12.69	0.77
25.	*Pinus wallichiana*	10.70	19.47	12.28	42.45	2.58
26.	*Pinus kesia*	7.33	2.44	0.00	9.77	0.59
27.	*Pinus roxburghii*	5.63	7.49	1.87	14.99	0.91
28.	*Pongamia pinnata*	3.27	3.77	1.96	9.00	0.55
29.	*Prosopis cineraria*	4.80	16.34	2.49	23.63	1.44
30.	*Prosopis juliflora*	6.66	1.77	0.72	9.15	0.56
31.	*Quercus leucotrichophora*	5.08	4.96	0.65	10.69	0.65
32.	*Schima wallichii*	6.79	3.84	1.14	11.77	0.72
33.	*Shorea robusta*	6.05	9.47	6.35	21.87	1.33
34.	*Syzygium cumini*	5.67	12.67	5.92	24.26	1.48
35.	*Tamarindus indica*	2.99	14.44	25.07	42.50	2.59
36.	*Tectona grandis*	19.22	7.72	6.23	33.17	2.02
37.	*Terminalia arjuna*	4.36	10.18	4.48	19.02	1.16
38.	*Terminalia belerica*	1.53	3.60	3.03	8.16	0.50
39.	*Terminalia tomentosa*	6.43	6.17	2.56	15.16	0.92
40.	*Zizyphus mauritiana*	13.52	6.68	1.11	21.31	1.30
41.	Rest of species	173.65	142.07	77.47	393.19	23.94
Total		**549.16**	**663.62**	**429.51**	**1642.29**	**100.00**

ANNEXURE-IV

States/UTs wise Standard Error for Growing Stock & Tree Cover

Sl.No.	States/Uts	SE% Forest	SE% TOF	SE% Tree Cover
1.	Andhra pradesh	6.10	4.65	6.05
2.	Arunachal Pradesh	14.57	14.10	16.86
3.	Assam	8.94	9.28	7.98
4.	Bihar	12.47	6.82	8.14
5.	Chattisgarh	3.17	7.49	3.87
6.	Delhi	14.15	11.54	11.68
7.	Goa	8.37	10.13	7.35
8.	Gujarat	6.83	3.69	4.05
9.	Haryana	13.03	10.84	11.41
10.	Himachal Pradesh	5.82	7.30	8.84
11.	Jammu & Kashmir	7.26	12.68	10.59
12.	Jharkhand	5.63	9.65	7.19
13.	Karnataka	4.87	7.65	4.56
14.	Kerala	5.96	5.08	8.68
15.	Madhya Pradesh	2.69	6.75	3.71
16.	Maharashtra	4.24	4.14	3.58
17.	Manipur	9.87	11.11	11.14
18.	Meghalaya	10.05	8.76	6.22
19.	Mizoram	14.22	10.33	12.56
20.	Nagaland	14.87	12.98	9.84
21.	Odisha	4.41	7.04	4.53
22.	Punjab	11.59	9.43	12.28
23.	Rajasthan	7.87	4.01	3.41
24.	Sikkim	12.82	9.54	12.70
25.	Tamil Nadu	7.58	4.11	9.19
26.	Telengana	5.21	5.58	6.14
27.	Tripura	8.06	8.46	5.60
28.	Uttar Pradesh	6.51	2.92	9.71
29.	Uttarakhand	5.41	6.20	13.02
30.	West Bengal	9.16	10.11	10.53
31.	A & N Island	13.14	4.65	15.64
32.	Chandigarh	15.73	9.43	12.28
33.	Dadar & Nagar Haveli	13.31	3.69	4.05
34.	Daman & Dui	13.31	3.69	4.05
35.	Lakshadweep	-	4.73	5.22
36.	Puducherry	7.58	4.11	9.19
Total		**7.21**	**6.65**	**6.06**

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About FSI

Forest Survey of India (FSI) is a premier national organization under the Ministry of Environment, Forest and Climate Change, Government of India. It is responsible for assessment and monitoring of the forest resources of the country on regular basis. Established on 1st June 1981, Forest Survey of India succeeded the "Pre-investment Survey of Forest Resources" (PISFR), a project initiated in 1965 by Government of India with the sponsorship of FAO and UNDP. The main objective of PISFR was to ascertain the availability of raw material for establishment of wood based industries in selected areas of the country. In its report in 1976, the National Commission on Agriculture (NCA) recommended for the creation of a National Forest Survey Organization for a regular, periodic and comprehensive forest resources survey of the country leading to creation of FSI.

The major activities of FSI include remote sensing based nation-wide forest cover mapping in biennial cycle, National Forest Inventory based on large number of sample plots laid across the country, forest fire monitoring, forest carbon assessment, forest type mapping and several projects on emerging issues and State specific requirements. Since 1987, FSI is publishing biennial 'State of Forest Reports' on the status of the forest resources of the country. These reports are widely acclaimed nationally and as well as internationally and are treasure trove of primary information on Indian Forests.

FSI has headquarters at Dehradun and has pan India presence with four regional offices at Shimla, Kolkata, Nagpur and Bangalore. The Eastern zone has a sub center at Burnihat.

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