





01

INTRODUCTION



Introduction

1.1

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

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

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



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

1.2 Technology Trends in Forest Resource Assessment

Since the publication of first report in 1987, FSI has kept pace with the technological and methodological improvements associated with forest cover mapping owing to availability of better satellite data, higher scale of mapping and improvement in methods of interpretation. Table 1.1 provides an overview of the technological and methodological improvements in Forest cover mapping over the years. The first report of 1987 used LANDSAT-MSS satellite data with a spatial resolution of 80 meters, the scale of mapping was 1:1 million and interpretation was in visual mode with a Minimum Mappable Unit (MMU) of 400 hectares. Subsequently there were continuous improvements in the spatial resolution of satellite data and also scale of mapping and MMU. With the availability of indigenous satellite data from 1995 onwards, FSI started using the IRS-1B satellite data and in 2001 completely switched over to LISS III data with a spatial resolution of 23.5 m at 1:50,000 scale with MMU of 1 ha. The mode of interpretation also changed to digital mode.

Table 1.1 Forest Cover Mapping over the Years

| Cycle of Assessment | Year | Data Period | Sensor | Spatial Resolution | Scale | Minimum Mappable Unit (ha) | Mode of Interpretation |
|---------------------|------|-------------|--|--------------------|-------------|----------------------------|------------------------|
| I | 1987 | 1981-83 | LANDSAT-MSS | 80 m | 1:1 million | 400 | Visual |
| II | 1989 | 1985-87 | LANDSAT-TM | 30 m | 1:250,000 | 25 | Visual |
| III | 1991 | 1987-89 | LANDSAT-TM | 30 m | 1:250,000 | 25 | Visual |
| IV | 1993 | 1989-91 | LANDSAT-TM | 30 m | 1:250,000 | 25 | Visual |
| V | 1995 | 1991-93 | IRS-1B LISSII | 36.25 m | 1:250,000 | 25 | Visual & Digital |
| VI | 1997 | 1993-95 | IRS-1B LISSII | 36.25 m | 1:250,000 | 25 | Visual & Digital |
| VII | 1999 | 1996-98 | IRS-1C/1D LISS III | 23.5 m | 1:250,000 | 25 | Visual & Digital |
| VIII | 2001 | 2000 | IRS-1C/1D LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| IX | 2003 | 2002 | IRS-1D LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| X | 2005 | 2004 | IRS-1D LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| XI | 2009 | 2006 | IRS-P6-LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| XII | 2011 | 2008-09 | IRS-P6-LISS III & IRS-P6 AWiFS | 23.5 m 56 m | 1:50,000 | 1 | Digital |
| XIII | 2013 | 2010-11 | IRS P6-LISS-III IRS-Resourcesat 2- LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| XIV | 2015 | 2013-14 | IRS P6-LISS-III IRS-Resourcesat 2- LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| XV | 2017 | 2015-16 | IRS P6-LISS-III IRS-Resourcesat 2- LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| XVI | 2019 | 2017-18 | IRS P6-LISS-III IRS-Resourcesat 2- LISS III | 23.5 m | 1:50,000 | 1 | Digital |
| XVII | 2021 | 2019-20 | IRS-Resourcesat 2- LISS III | 23.5 m | 1:50,000 | 1 | Digital |



Forest Cover and Recorded Forest Area 1.3

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

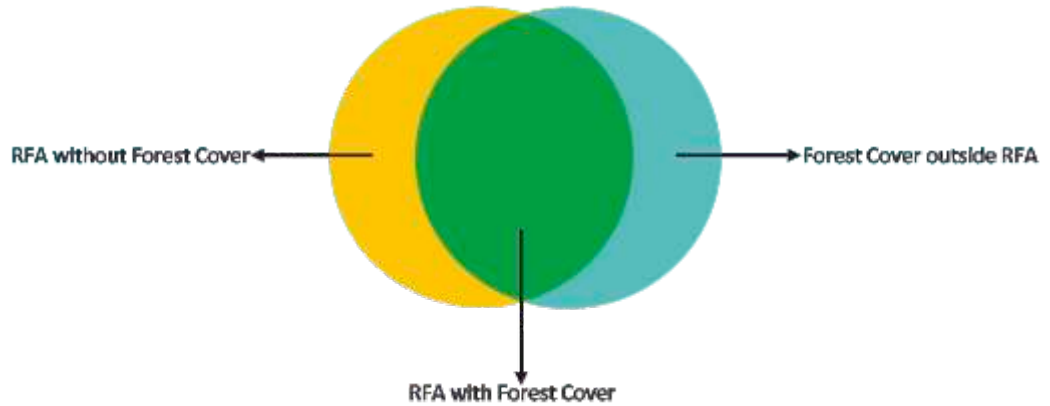
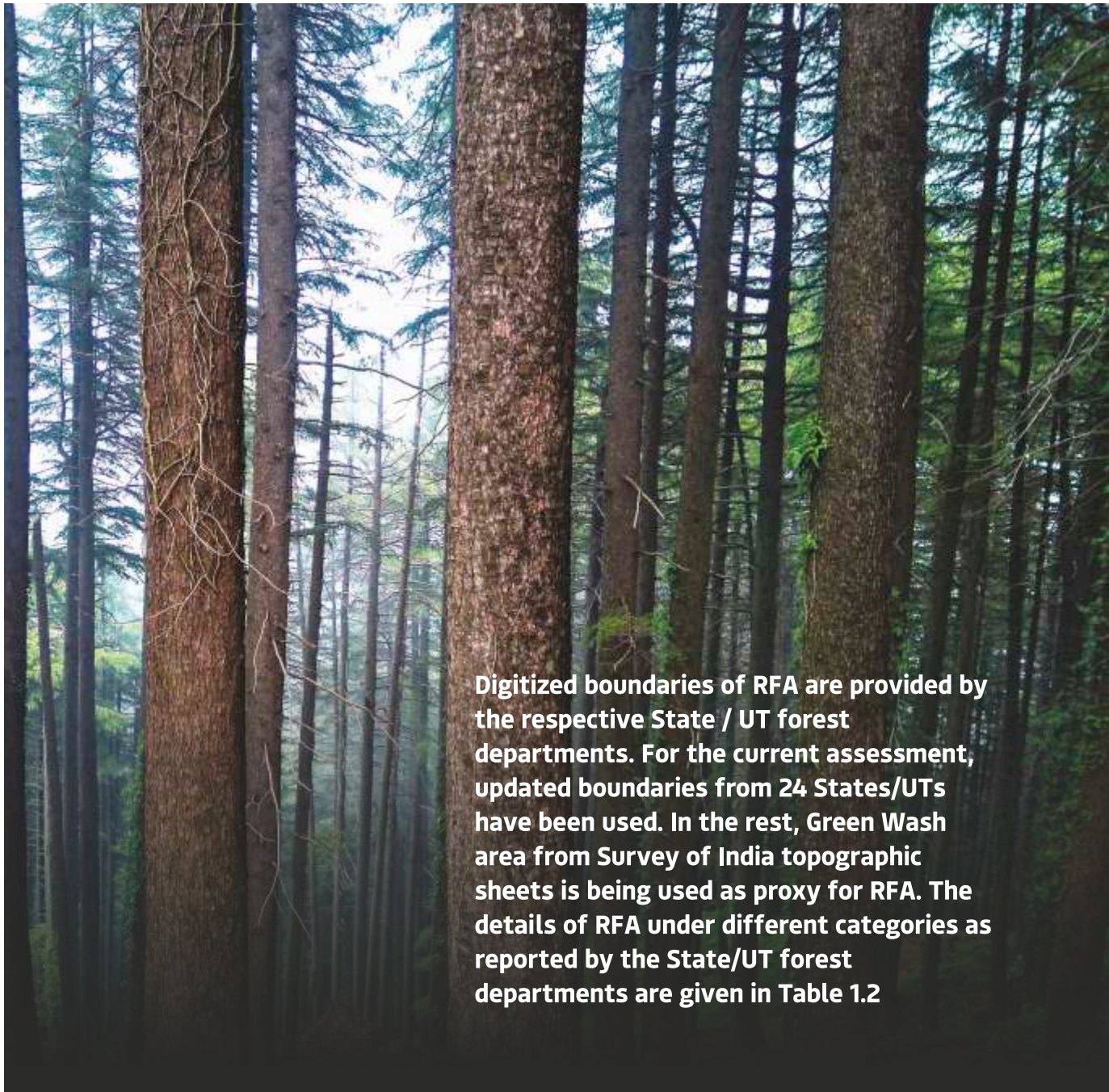


Figure 1.1
Forest Cover
and Recorded
Forest Area



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

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

(in sq km)

| Sl. No. | State/ UT | Geographical Area | RFA (in different catageries) | | | Total RFA (2021) | % of GA |
|---------|--|-------------------|-------------------------------|-----------------|-----------------|------------------|--------------|
| | | | RF | PF Forests* | Unclassed | | |
| 1. | Andhra Pradesh | 1,62,968 | 31,959 | 5,069 | 230 | 37,258 | 22.86 |
| 2. | Arunachal Pradesh | 83,743 | 12,371 | 11,857 | 27,312 | 51,540 | 61.55 |
| 3. | Assam | 78,438 | 17,864 | 0 | 8,972 | 26,836 | 34.21 |
| 4. | Bihar | 94,163 | 693 | 6,183 | 566 | 7,442 | 7.90 |
| 5. | Chhattisgarh | 1,35,192 | 25,897 | 24,036 | 9,883 | 59,816 | 44.25 |
| 6. | Delhi | 1,483 | 78 | 25 | 0 | 103 | 6.95 |
| 7. | Goa | 3,702 | 119 | 755 | 397 | 1,271 | 34.33 |
| 8. | Gujarat | 1,96,244 | 14,574 | 2,898 | 4,398 | 21,870 | 11.14 |
| 9. | Haryana | 44,212 | 249 | 1,158 | 152 | 1,559 | 3.53 |
| 10. | Himachal Pradesh | 55,673 | 1,883 | 28,887 | 7,178 | 37,948 | 68.16 |
| 11. | Jharkhand | 79,716 | 4,500 | 18,922 | 1,696 | 25,118 | 31.51 |
| 12. | Karnataka | 191,791 | 28,690 | 3,931 | 5,663 | 38,284 | 19.96 |
| 13. | Kerala | 38,852 | 11,522 | 0 | 0 | 11,522 | 29.66 |
| 14. | Madhya Pradesh | 3,08,252 | 61,886 | 31,098 | 1,705 | 94,689 | 30.72 |
| 15. | Maharashtra | 3,07,713 | 50,865 | 6,433 | 4,654 | 61,952 | 20.13 |
| 16. | Manipur | 22,327 | 984 | 3,254 | 13,180 | 17,418 | 78.01 |
| 17. | Meghalaya | 22,429 | 1,113 | 12 | 8,371 | 9,496 | 42.34 |
| 18. | Mizoram | 21,081 | 4,499 | 1,823 | 1,157 | 7,479 | 35.48 |
| 19. | Nagaland | 16,579 | 234 | 0 | 8,389 | 8,623 | 52.01 |
| 20. | Odisha | 1,55,707 | 36,049 | 25,133 | 22 | 61,204 | 39.31 |
| 21. | Punjab | 50,362 | 44 | 1,137 | 1,903 | 3,084 | 6.12 |
| 22. | Rajasthan | 3,42,239 | 12,176 | 18,543 | 2,144 | 32,863 | 9.60 |
| 23. | Sikkim | 7,096 | 5,452 | 389 | 0 | 5,841 | 82.31 |
| 24. | Tamil Nadu | 1,30,060 | 20,523 | 1,053 | 1,612 | 23,188 | 17.83 |
| 25. | Telangana | 1,12,077 | 25,800 | 1,592 | 296 | 27,688 | 24.70 |
| 26. | Tripura | 10,486 | 3,588 | 2 | 2,704 | 6,294 | 60.02 |
| 27. | Uttar Pradesh** | 2,40,928 | 11,560 | 296 | 5,528 | 17,384 | 7.22 |
| 28. | Uttarakhand | 53,483 | 26,547 | 9,885 | 1,568 | 38,000 | 71.05 |
| 29. | West Bengal | 88,752 | 7,054 | 3,772 | 1,053 | 11,879 | 13.38 |
| 30. | A & N Islands | 8,249 | 5,613 | 1,558 | 0 | 7,171 | 86.93 |
| 31. | Chandigarh | 114 | 32 | 0 | 3 | 35 | 30.70 |
| 32. | Dadra & Nagar Haveli and Daman & Diu | 602 | 203 | 5 | 6 | 214 | 35.55 |
| 33. | Jammu & Kashmir Shapefile Area*** (54,624) | 2,22,236 | 17,648 | 2,551 | 0 | 20,199 | 36.98 |
| 34. | Ladakh Shapefile Area*** (1,68,055) | | 7 | 0 | 0 | 7 | 0.00 |
| 35. | Lakshadweep | 30 | 0 | 0 | 0 | 0 | 0.00 |
| 36. | Puducherry | 490 | 0 | 2 | 11 | 13 | 2.65 |
| | Total | 32,87,469 | 4,42,276 | 2,12,259 | 1,20,753 | 7,75,288 | 23.58 |

Source: State/UTs Forest Departments

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

**In case of Uttar Pradesh, the RFA excludes 9,662.764 km of linear plantations along Road, Railway line and Canal.

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

1.4 National Forest Inventory (NFI)

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

A new grid-based NFI design has been adopted in 2016, in which approximately 6,000 sample plots are laid annually in forest areas and about 10,000 plots are laid in Trees Outside Forest areas (TOF). In addition to Growing stock assessment, the NFI inputs are also used to assess bamboo resources, soil carbon, occurrence of Non-Timber Forest Product (NTFP) and invasive species and several other parameters depicting the general health of forests. TOF inventory provides information on 'tree cover', which includes patches of trees occurring outside RFA, less than 1 hectare, both in rural and urban areas. 'Forest cover' and 'tree cover' put together constitutes 'Forest & Tree Cover' which is the key parameter for monitoring progress as per the National Forest Policy¹ goal of achieving 33% of the country's geographical area under green cover. TOF inventory also provides estimates of the annual potential production of timber from outside the RFA. The design and methodology of the NFI has been described in detailed in the Chapter 6 of this report.

1.5 Special Features in ISFR 2021 Assessment of Forest Cover in Tiger Reserves and Lion Conservation Areas of India

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

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



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

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

The objectives of this study were as follows:

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

Generate estimates of forest biomass at state and country level.

To prepare AGB map of the country.

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

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

Mapping of Climate Change Hotspots in Indian Forests

Life on earth is facing new challenges because of changing climate. Extreme climatic events such as more frequent and intense drought, storms, heat waves, rising sea levels, melting glaciers and warming of oceans are posing serious threats to habitats and livelihoods, world over.

Intergovernmental Panel on Climate Change (IPCC) reports have been continuously highlighting the impacts of climate change.

The importance of forests in mitigation of climate change has been understood in recent years. Forests act as a sink of atmospheric carbon dioxide, they are the biggest terrestrial reservoir of carbon on the planet but become a source of CO₂ and other Green House Gases (GHGs) if they are cut, burnt or destroyed. Forestry interventions, especially afforestation and eco-restoration activities, play a significant role in mitigating negative effects of climate change and offer low cost opportunities to adapt to climate change outcomes. It is imperative to appreciate the likely impacts of climate change on forests using all available tools and techniques. FSI in tune with its mandate of monitoring and assessment of forests of the country has undertaken a collaborative study with BITS Pilani (Goa Campus) to map climate hotspots in the forest areas of the country. A climate hotspot refers to an area, which is prone to adverse climatic change. This study is based on the computer model projections of temperature and rainfall in three time horizons i.e. 2030, 2050 and 2085. The enhanced understanding about the climate change hotspot areas in Indian forests would assist in planning and strategizing preventive and adaptive measures against changing climate. The significant outcomes of the study on climate change hotspots in Indian forests have been presented in Chapter 11 of this report.

1.6 Recent Initiatives of FSI

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

- **Trees Outside Forest Resources in India**

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

- **India's Nationally Determined Contribution of creating an additional carbon sink of 2.5 to 3 billion tonnes of CO₂ eq through additional forest & tree cover: Possibilities, scale and costs for formulating strategy**

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

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


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

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

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

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

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



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

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

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

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

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

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

| Sl. No. | Country | Annual Forest Area Gain | |
|---------|-----------|-------------------------|--------------------------|
| | | Area (000 ha) | % of 2010 forest area |
| 1. | China | 1,937 | 0.93 |
| 2. | Australia | 446 | 0.34 |
| 3. | India | 266 | 0.38 |
| 4. | Chile | 149 | 0.85 |
| 5. | Vietnam | 126 | 0.90 |
| 6. | Turkey | 114 | 0.53 |
| 7. | USA | 108 | 0.03 |
| 8. | France | 83 | 0.50 |
| 9. | Italy | 54 | 0.58 |
| 10. | Romania | 41 | 0.62 |



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

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

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

