Forests

the Climate Protectors

Chapter 3
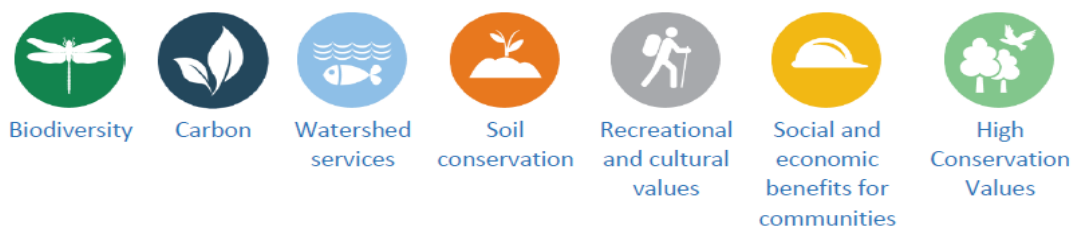# Forests - the Climate Protectors

Introduction - Forest as an ecosystem

1.   The term 'Forest', as defined in the online version of Oxford dictionary, is a large area covered chiefly with trees and undergrowth. FAO in its Forest Resources Assessment, defines forest as "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use."

2.   Forests are one of the multifunctional ecosystems which provide several services on all spatial and temporal levels. The services provided by forests cover a wide spectrum of ecological, economic, social and cultural considerations and processes providing a multitude of benefits at local, national and global levels. Without the ecosystem services emanating from forests, life on earth would not be possible. Forests are vital to the global economy and ecosystem for an ample number of reasons. Not only do they provide a production function in the form of a wealth of resources, but they also play a significant role in terms of regulatory functions such as carbon sequestration and hydrological cycling. Another critical role played by forests is that of habitat provision, an essential function for more than half of the world's species which live there.

3.   Forest ecosystems conserve soil and stabilize flows and runoff which in turn prevents land degradation and desertification, and diminishes the risks of natural disasters such as droughts, floods, and landslides. In essence, forests are important since they help in maintaining and upgrading the environmental quality which is much beyond quantification (Figure 1).

Figure 1: Ecosystem services provided by forests[1]

| Biodiversity | Carbon | Watershed services | Soil conservation | Recreational and cultural values | Social and economic benefits for communities | High Conservation Values |

---

1   Jenkins, M. and Schaap B., (2018), Forest Ecosystem Services, Background study prepared for the thirteenth session of the United Nations Forum on Forests, can be accessed at: https://www.un.org/esa/forests/wp-content/uploads/2018/05/UNFF13_ BkgdStudy_ForestsEcoServices.pdf

4.   In the "2030 Agenda for Sustainable Development" adopted by 196 countries including India, which lists the Sustainable Development Goals (SDGs), 17 goals and 169 targets to be achieved over the next 15 years have been spelled out. Owing to the importance of forests, out of these global goals and targets, 21 targets spread over 8 Goals are directly or indirectly related to forestry activities (shown in Figure 2).

Figure 2: Forest and SDGs[2]
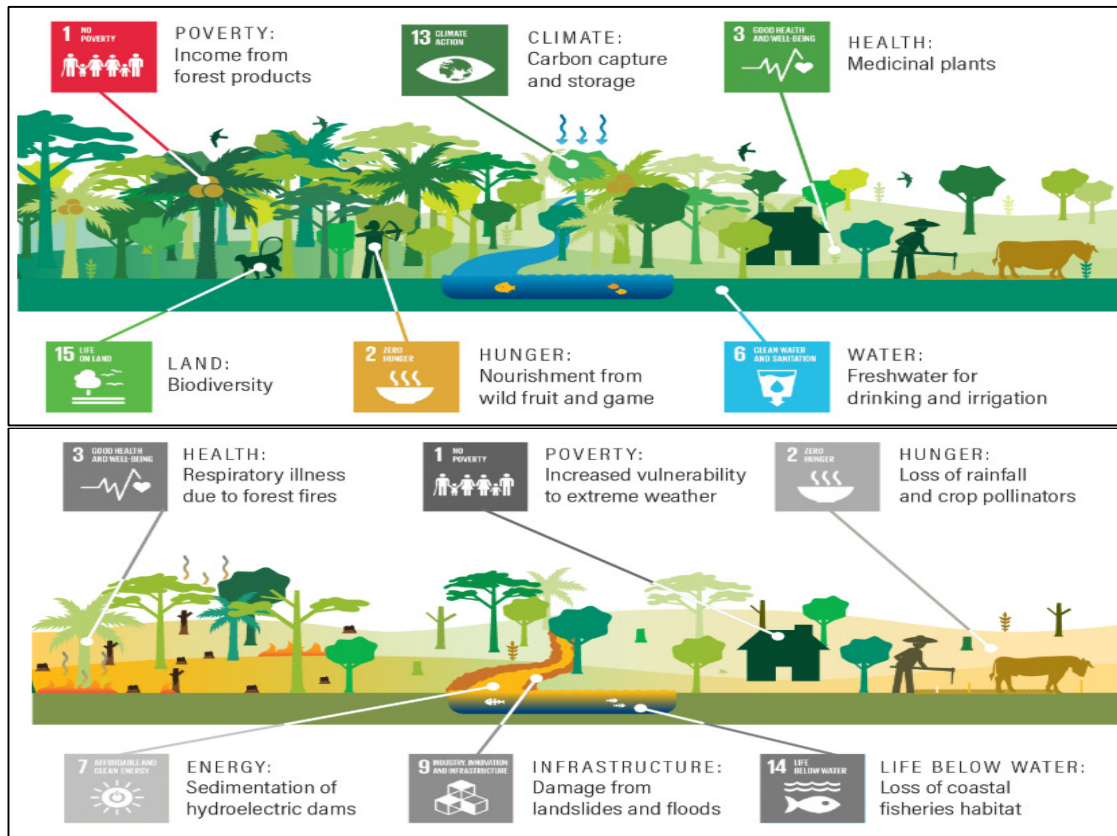
5.   Forests are linked to the other SDGs as well – forest-based ecosystem services play an underpinning role in sustainable agricultural production and food security. Forests regulate hydrological services including the quantity, quality, and timing of water available for irrigation. Forest-based bats and bees pollinate crops. Forests mitigate impacts of climate change and also extreme weather events at the landscape scale.

Forest in India

6.   In India, the term **'Forest Cover'** refers to "All lands, more than one hectare in area, with a tree canopy density of more than 10% irrespective of ownership and legal

2   https://www.wri.org/blog/2017/09/forests-and-sdgs-taking-second-look

status. Such lands may not necessarily be recorded forest area. It also includes orchards, bamboo and palm" (FSI, 2019)[3]. It is assessed through remote sensing. In addition, the term '**Recorded Forest Area' or 'Forest Area'** refers to all the geographical areas recorded as 'Forests' in government records.

7.   In the Indian context, the evaluation of forest cover is undertaken by Forest Survey of India (FSI), with national assessments starting in the year 1987 using remote sensing techniques. The assessment of forest cover mapping is a biennial cycle at the national level which is published as India State of Forest Report (ISFR). Forests play a vital role in sustainable development, especially due to their role in providing livelihood to a significant portion of the population and hence in income generation. Nearly 25% (one fourth) of India's total land area is now under forest and tree cover. As per latest India State of Forest Report (ISFR 2019) by Forest Survey of India (FSI), the total forest and tree cover is 24.56 % of the geographical area of the country. Out of this, total forest cover alone is 7,12,249 sq. km contributing to 21.67% and tree cover is estimated as 95027 sq. km which is 2.89 % of the geographical area of India[5].

8.   In India, forest cover has been classified in terms of the following tree canopy density as follows:

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

9.   As per Champion and Seth (1968)[4] classification, India's forests are classified into four major groups, namely, tropical, sub-tropical, temperate and alpine. These four groups are further classified into 16 type groups (Table 1) and map depicting different forest type groups of India is presented in Figure 3. The landscape of Indian forests ranges from Tropical Wet Evergreen Forests in the Andaman & Nicobar

---

3   India State of Forest Report 2019, Forest Survey of India.
4   Champion, H. G. and Seth, S. K. (1968). A Revised Survey of Forest Types of India, Govt. of India Press, New Delhi, p. 404.
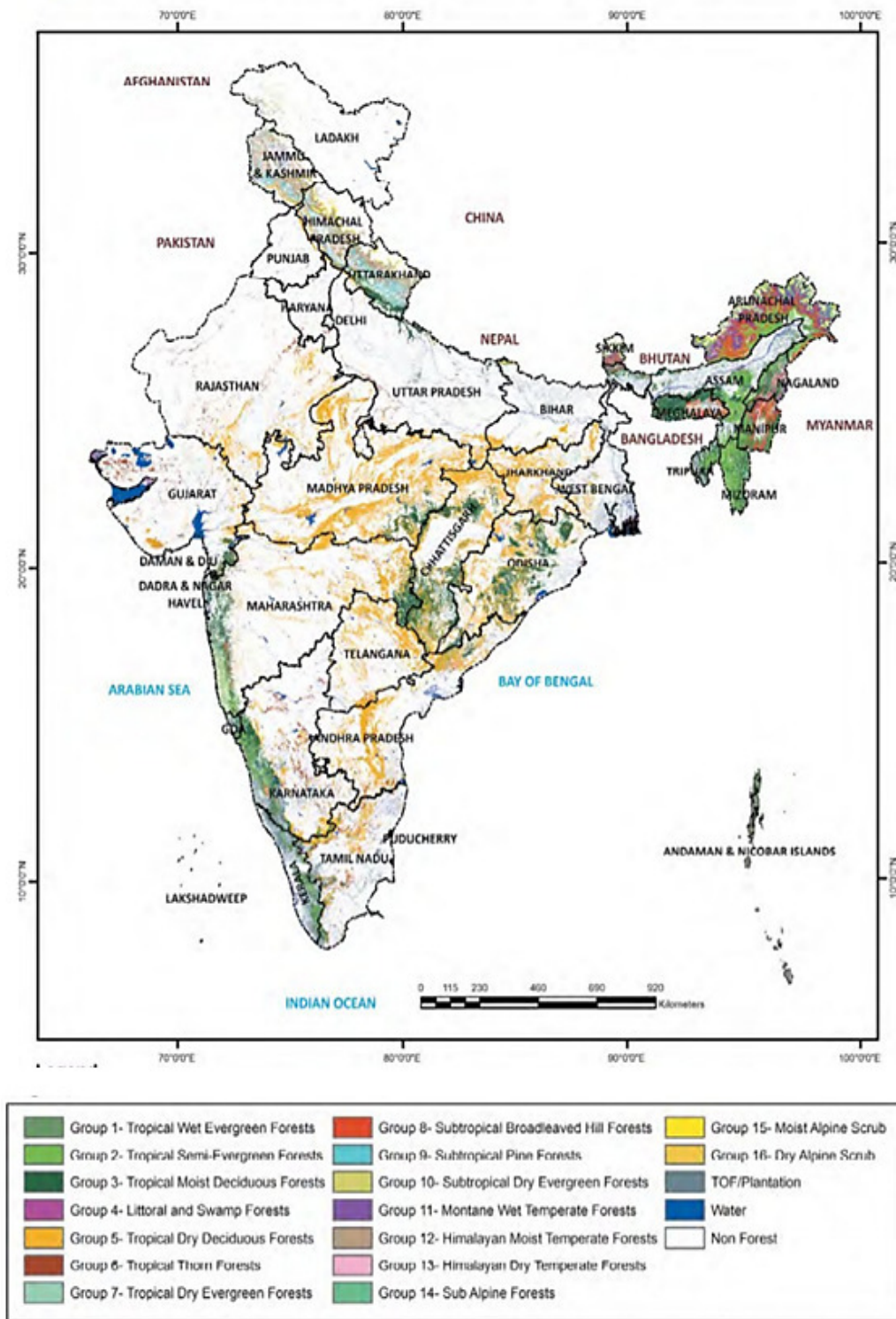
Islands, the Western Ghats, and the north-eastern States, to Dry Alpine Scrub high in the Himalayas in the north. The country has Semi-Evergreen Forests, Deciduous Forests, Thorn Forests, and Subtropical Pine Forests in the lower montane zone and Temperate Montane Forests in the higher zones. At the other extreme, tropical dry deciduous and thorn forests predominate in the semi-arid areas of Rajasthan and Gujarat.

Table 1: Area under different Forest Type Groups of India

Forest Type	Group	Area in sq. km	% of Grand Total
Tropical	Group1 Tropical Wet Evergreen Forests	20,054	2.61
	Group2 Tropical Semi Evergreen Forests	71,171	9.27
	Group3 Tropical Moist Deciduous Forests	1,35,492	17.65
	Group4 Littoral & Swamp Forests	5,596	0.73
	Group5 Tropical Dry Deciduous Forests	3,13,617	40.86
	Group6 Tropical Thorn Forests	20,877	2.72
	Group7 Tropical Dry Evergreen Forests	937	0.12
Sub-Tropical	Group8 Subtropical Broadleaved Hill Forests	32,706	4.26
	Group9 Subtropical Pine Forests	18,102	2.36
	Group10 Subtropical Dry evergreen Forests	180	0.02
Temperate	Group11 Montane Wet Temperate Forests	20,435	2.66
	Group12 Himalayan Moist Temperate Forests	25,743	3.35
	Group13 Himalayan Dry Temperate Forests	5,627	0.73
Alpine	Group14 Sub Alpine Forests	14,995	1.96
	Group15 Moist Alpine Scrub	959	0.13
	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**

Source: India State of Forest Report (ISFR), 2019, Forest Survey of India (FSI)

Figure 3: Forest Type Group Map of India
(Depicting Type Groups as per Champion & Seth's Classification, 1968[4])

Group 1- Tropical Wet Evergreen Forests	Group 8- Subtropical Broadleaved Hill Forests	Group 15- Moist Alpine Scrub
Group 2- Tropical Semi-Evergreen Forests	Group 9- Subtropical Pine Forests	Group 16- Dry Alpine Scrub
Group 3- Tropical Moist Deciduous Forests	Group 10- Subtropical Dry Evergreen Forests	TOF/Plantation
Group 4- Littoral and Swamp Forests	Group 11- Montane Wet Temperate Forests	Water
Group 5- Tropical Dry Deciduous Forests	Group 12- Himalayan Moist Temperate Forests	Non Forest
Group 6- Tropical Thorn Forests	Group 13- Himalayan Dry Temperate Forests	
Group 7- Tropical Dry Evergreen Forests	Group 14- Sub Alpine Forests	

Source: India State of Forest Report 2019, Forest Survey of India

Extent and Condition Account for Forest Ecosystem

10.   Ecosystem assets are measured in terms of ecosystem extent, ecosystem condition and ecosystem services flow. Forest provides various forms of ecosystem services. The ability of the forest to provide these services is dependent on the health or condition of the forest. In other words, the condition of forest influences the extent to which these services can be provided by the forest, although it is not necessarily the case that ecosystems with relatively lower condition will generate fewer ecosystem services. However, there is likely to be a close relationship between reductions in condition on the one hand, and the capacity of an ecosystem to generate ecosystem services sustainably on the other. Thus, the prevailing cross sectoral linkages present in the forest ecosystem and the importance of services provided by the forest highlight the importance of monitoring not just the quantity but the quality of the forest ecosystem is important.

11.   The System of Environmental Economic Accounting (SEEA) prescribes the compilation of extent and condition accounts to comprehend the quality and quantity of the forest, with 'ecosystem condition' representing both quality and biophysical state measures that are required to understand the capacity of the ecosystem to generate services.

12.   A format for ecosystem extent and condition account is given in **Table 2** which has been prepared based on a review of available datasets for selected variables in required format.

Table 2: Format for Extent and Condition Account of Forest

Indicator
Extent
Recorded Forest Area, by type of Protection – Reserved, Protected or Unclassed
Condition Accounts
Volume of Growing Stock
Carbon Stock, by type of carbon pool – Above Ground Biomass (AGB), Below Ground Biomass (BGB), Soil Organic Carbon (SOC), Dead Wood and Litter
Carbon Stock per hectare, by type of carbon pool
Number and Area of Wetlands Within RFA
Biodiversity Assessment
Total Number of species of Herbs, Shrubs and Trees
Shannon-Wiener Index of Herbs, Shrubs and Trees
Effective Number of Species (ENS) of Herbs, Shrubs and Trees
Average Patch Size, Number of patches in different patch size classes, Proportion of small patches (of less than 1 sq. km)

13.   Some of the important indicators for the extent and condition of forest ecosystem contained in the format above are the ___Carbon stock, forest fragmentation and Effective number of species (ENS) which is calculated from Shannon-Wiener Index of biodiversity___ evaluated for different forest types. These concepts are explained in the following paragraphs.

14.   ___Carbon Stock:___ Forests are both a source and sink for carbon as a growing forest captures carbon from the atmosphere whereas a mature forest is a store house of carbon. Healthy and growing forests sequester and store more carbon than any other terrestrial ecosystem and act as natural 'brakes' on climate change.

15.   Carbon stocks are classified into: geocarbon (carbon stored in the geosphere) and biocarbon (carbon stored in the biosphere, in living and dead biomass and in soils). Based on the availability of data, only the biocarbon component has been considered in this report. The total biocarbon stocked in the forests is divided into five pools by Good Practice Guidance (GPG)[5] of the Intergovernmental Panel for Climate Change (IPCC). The living portion of biomass carbon is classified as ___'above ground biomass (AGB)' and 'below ground biomass (BGB)'___ and stores significant amount of carbon. The ___'dead organic matter (DOM)'___ is classified as ___'dead wood' and 'litter'___. The fifth pool is ___'soil organic matter'___ which contains substantial amount of organic carbon. Description about the classification of different carbon pools is presented in **Table 3**.

Table 3: Classification of carbon stock in forests under different carbon pools

Pools		Description
Living Biomass	**Above ground biomass (AGB)**	All living biomass above the soil including stem, stump, branches, bark, seeds and foliage.
	Below ground biomass (BGB)	All living biomass of live roots. Fine roots of less than 2mm diameter (country specific) are often excluded because these often cannot be distinguished empirically 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.

---

5 https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/ Chp3_1_Introduction.pdf

16.   _Forest Fragmentation:_ Forest fragmentation is the breaking of a large, contiguous forested area into smaller parts of forests which are mostly separated by roads, utility corridors, agriculture, other subdivisions, or human developments. With time these patches that separate the different pieces of forest tend to multiply and expand, which affects the health, value and functioning of the forest and forest ecosystem and the ecosystems within forests. Fragmentation generally leads to loss of biodiversity, increases in invasive plants, pests, and pathogens, and reduction in water quality.

17.   _Growing Stock:_ This is the volume of all living trees more than 10 cm in diameter at breast height (or above buttress if these are higher) measured over bark from ground or stump height to a top stem diameter of 10 cm, excluding or including branches to a minimum diameter of 5 cm. The term excludes smaller branches, twigs, foliage, flowers, seeds, stump and roots.

18.   **_Biological Diversity and Shannon-Weiner Index of Biodiversity:_** Biodiversity within a forest is an essential indicator of forest ecosystem condition as 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 as well as be of high assistance in comparative evaluation of stability, productivity and ecosystem functions of forests.

19.   _Species diversity_ is defined as the number of species and abundance of each species that live in a particular location. _Species richness_ (number of different species) is a common way of measuring biodiversity. _Species abundance_ is the total number of individuals of a species in the area, community, or population. There are numerous reasons why species diversity is essential. _Species density_ considers the number of species in a sampled area. Several indices of species diversity and evenness have been conceptualized, one of which is the Shannon-Wiener index (often denoted as H').

20.   The **_Shannon-Weiner Index of Biodiversity_** is a commonly used indicator for comparing diversity between various habitats. It quantifies diversity of the species by measuring both species abundance and species richness. Shannon-Wiener index is calculated by the following formula: -

$$H' = -\Sigma \, p_i \ln p_i$$

where, p_i is the proportion of individuals found in species 'i'

21.   For a well-sampled community, this proportion can be estimated as

$$p_i = n_i/N,$$

where n_i is the number of individuals or the population of species 'i' and N is the total number of individuals or total population across species in the community. By definition, p_i will all be between zero and one, the natural log makes all the terms of the summation negative, which is why the inverse of the sum is taken.

22.   The Shannon-Wiener Index assumes that all species are represented in a sample and that they are randomly sampled. A high value of H' would be a representative of a diverse and equally distributed community and lower values represent less diverse community. A community with only one species would have an H' value of 0 because pi would equal 1 and be multiplied by ln pi which would equal zero. Values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4.

23.   The Shannon index increases as both the richness and the evenness of the community increase. That is, the more equal the proportions for each of the groups, the more homogeneous or even, they are. From the resultant Shannon index value, an *effective number of species (ENS)* can be subsequently computed using the following formula[6]:

$$\textbf{ENS} = \textbf{e}^{\textbf{H}'}$$

where H' is the Shannon Weiner Index.

24.   In India, the Forest Survey of India (FSI) is mandated with the Forest Resource Assessment, which it undertakes on a biennial basis. The report of the assessment is published as the India State of Forest Report. All the indicators explained above have been sourced from the India State of Forest Report. FSI has presented an assessment of plant biodiversity in all the forest type groups for the first time in the ISFR report for the year 2019 (assessment year 2017-18).

25.   The extent and condition accounts for the forests of India for the year 2017-18 are given in **Table 4** below. Some indicators, including those for biodiversity assessment, have not been shown in this table, as these have been compiled at the State level only.

---

6   Aguilar J, Gramig GG, Hendrickson JR, Archer DW, Forcella F, Liebig MA (2015) Crop Species Diversity Changes in the United States: 1978–2012. PLoS ONE 10(8): e0136580. doi:10.1371/journal.pone.0136580

Table 4: Forest Condition Accounts for the year 2017-18

Indicator	Unit	Value
Extent		
Recorded Forest Area (RFA)	sq km	7,67,419
Geographical Area(GA)*	sq km	32,87,469
% of GA		23.34
Type of Protection		
Reserved Forests (RF)	sq km	4,34,853
Protected Forest (PF)	sq km	2,18,924
Unclassed Forests	sq km	1,13,642
Growing Stock		
Volume of Growing Stock	million cum	4,273.47
Growing Stock in Forest	cum/ha	55.69
Carbon Stock	'000 tonnes	71,24,676
Wetlands Within RFA	Number	62,466
	Area (in ha)	27,93,141
	% of RFA	3.83
Forest Fragmentation**		
Average Patch Size	Sq km	0.95
Proportion of small patches (≥0.01sq km to ≤1 sq km)	%	97.45

* As reported in the India State of Forest Report, 2017 and 2019.

** Information on Fragmentation pertains to the year 2015-16.

Extent and condition accounts of the States of India are given in Annexure 3.1.

Forest Ecosystem Services

26.   The ***forest products*** are classified into two broad groups in the national accounts, namely,

(i)   Major products comprising ***Industrial Wood*** (timber, round wood, match and pulpwood) and ***fuel wood*** (firewood and charcoal wood), and

(ii)   ***Non Timber Forest Products*** (NTFPs) comprising a large number of wild growing forest material such as bamboo, fodder, lac, sandalwood, honey, resin, gum, tendu leaves (Diospyros Melanoxylon), cork, balsams, eelgrass, acorns, horse chestnuts, mosses, lichens etc.

27.   Apart from these, as explained in the earlier sections on the carbon, trees absorb carbon dioxide and release oxygen through the process of photosynthesis, transferring the carbon to their trunks, limbs, roots, and leaves as they grow. When leaves or branches fall and decompose, or when trees die, the stored carbon is released by

respiration and/or combustion back to the atmosphere or transferred to the soil. It is because of these processes, forests and forested landscapes are able to store considerable carbon and their growth can provide a carbon sink. This particular ecosystem service provided by the forests is referred to as the '*carbon retention service*'.

28.   The three ecosystem services- timber provisioning, non-timber forest products (NTFP) provisioning and carbon retention services from forests in India are described in the following sections.

Timber and Non-Timber Forests Products (NTFP) Provisioning Services

29.   Timber includes rose wood, teak wood, jungle wood, etc. The source of production of *timber* is either *from forests* or from *trees outside forests (TOF).* FAO has defined TOF as "*Trees on land not defined as forests and other wooded land*". In India, FSI has defined TOF as "*all trees growing outside government recorded forest areas (RFAs) irrespective of patch size*". Besides constituting a major source for production of industrial wood in India, its benefits are multidimensional.

30.   *Non-timber forest products (NTFPs)* constitute an important source of livelihood for millions of people from forest fringe communities across the world. NTFPs include plants used for food, beverages, forage, fuel, medicine, fibres and biochemicals; animals, birds and fish for food, fur and feathers; as well as their products such as honey, lac and silk. Another term, Non-wood Forest Products differs from the NTFP in that it excludes all wood (including fuelwood) while NTFP includes wood for uses other than for timber. As per FAO, there are at least 150 NTFPs that contribute substantially to international trade, including honey, gum arabic, rattan and bamboo shoots, cork, forest nuts and mushrooms, oleoresins, essential oils, and plant or animal parts for pharmaceutical products.

31.   In India, NTFPs are associated with the socio-economic and cultural life of forest dependent communities inhabiting wide variety of ecological and geo-climatic conditions throughout the country. In India, the rural population is about 68% of the country's total population and 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, and so, often termed as Forest Fringe Villages (FFVs)[3]. Populations residing in these Forest Fringe Villages are dependent on the forests for meeting the needs of fuelwood, fodder, small timber, bamboo and NTFPs (ISFR 2019). NTFP extraction has a multiplier effect in the economy by generating employment not only for the inhabitants of these Forest Fringe Villages, but also for others involved in downstream processing and trading activities.

Monetary Values of Timber and NTFP Provisioning Services

32.   The estimation of Gross Value Added from the "Forestry and Logging" sector in India is carried out by the production approach. It aims at estimating the value of output at factor cost in the first instance and then deducting the value of various inputs at purchaser's prices. The state wise estimates of value of timber provisioning service are based on these exchange values that are adopted in compilation of National Accounts Statistics[7].

33.   For the compilation of national accounts, the data on production and prices of industrial wood/timber are supplied by State Forest Departments (SFDs). Estimates of value of output at current prices are compiled by multiplying the category-wise production figures with their respective average annual prices, both of which are supplied by the SFDs. In addition to the production of industrial wood from these Government forests, there would be

(i)   authorized (but unrecorded) removals of timber from forests; and

(ii)   unrecorded production of industrial wood from private owned forests and non-traditional forest areas (e.g. trees in village common fields, ridges, canal sides, road sides, fruit trees no longer productive etc.).

34.   The value of unrecorded, but authorised, production from forest is taken as 10% of the value of recorded production. The estimates of industrial wood from trees outside forests (TOF) (i.e. private owned forests and non-traditional forest areas like village commons, field ridges, canal sides, road sides, fruit trees no longer productive etc.) are provided by Forest Survey of India. Prices for the same are also provided by the SFDs.

35.   The valuation of NTFP Provisioning Services is also based on the concept of *exchange value.* The state wise estimates of value of output of non-timber forest products, and separate estimates of fuelwood are available in India's National Accounts Statistics. The items of NTFP vary from state to state. Information is built up on the basis of royalty received (in value terms) from those authorized to extract these from the forests. Value of Fodder from forest, as estimated using the 'per animal consumption' norms, is also a component of the estimate of NTFPs, as available in the National Accounts Statistics.

36.   _**Forest Rent**_ as a percentage of GDP is taken from World Bank's databank[8]. Forest Rent as percentage of the gross value of output of Timber/NTFP can then be

---

7 State-wise and item-wise value of output from agriculture, forestry and fishing with Base Year: 2011-2012, MoSPI
8 https://databank.worldbank.org/home.aspx; Forest Rents to GDP for India, as downloaded on September 17, 2020

estimated using the ratios between GVO-Forestry, GVA-Forestry and GDP. This value can be said to be an approximation of the share of 'resource rent' and therefore, has been used to estimate the value of timber and NTFP provisioning service.

Table 5: Method of estimation of value of Timber & NTFP provisioning services

Step	Item	Method of estimation
1	Value of output of Industrial wood and Non-Timber Forest Products (NTFP)	Estimates taken from the National Accounts[12]
2	Forest rent / GVO of forestry	Estimated using the following factors: (Forest rent/GDP) * (GDP/GVA of forestry) * (GVA /GVO of forestry).
3	Value of timber and NTFP provisioning service	Value of service = (Forest rent / GVO of forestry) * Value of output of timber and NTFP

37.   The changes in values of both timber and NTFP provisioning service in India during the period 2011-12 to 2017-18 has been depicted in **Figure 4**.

Figure 4: Value of Timber and NTFP Provisioning Services in India
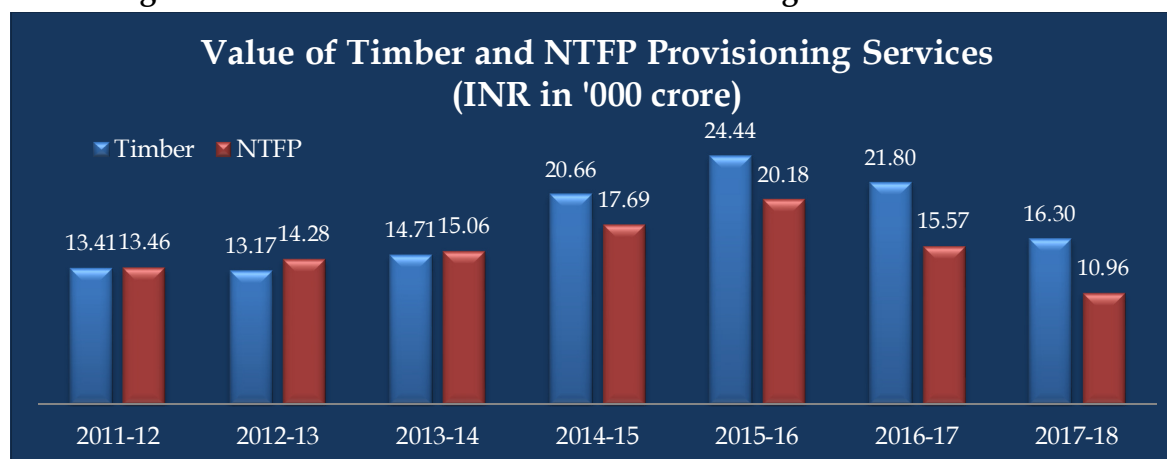
State wise estimates of value of timber and NTFP provisioning services are given Statements 3.1 and 3.2 at the end of the chapter.

Carbon Retention Service

38.   Forests play an important role in mitigation and adaptation to climate change. The diversity of forests in India makes it resilient to climate change and an efficient sink of carbon. 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). As one of the three NDCs, India has committed to create additional carbon sink of 2.5 to 3.0 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.

39. Apart from potential carbon that could sequester in forests, the existing carbon stored in forests has an economic value too as the forests lock up the carbon from getting released into the atmosphere and avoid escalation of the climate change concerns. The social cost of carbon (SCC) represents the economic cost associated with climate damage (or benefit) resulting from the emission of an additional ton of CO_2[9]. Hence the social cost of carbon is often used as a carbon price estimate.

40. With a view to understand the carbon retention service provided by the forests of India which also contribute to the global climate regulation, estimates for economic value of carbon retention during the assessment year 2015-16 and 2017-18 were compiled using the social cost of carbon (SCC) approach. The step-wise methodology used for valuation of carbon retention service is explained in **Table 6** below.

Table 6: Method of estimation of economic value of Carbon Retention Service

Steps	Method of Estimation	Data Sources/Assumptions
1	Total Carbon Stock= Above ground biomass + Below ground biomass + Dead wood + Litter + Soil Organic Carbon	India State of Forest Report, Forest Survey of India
2	Carbon stock (CO_2 eq.) = Carbon content * 3.67	Based on default IPCC conventions[10]
3	Value of carbon stock (CO_2 eq.) in US\$ = Carbon dioxide * Social Cost of tonne of CO_2	Using India's country-level social cost of carbon (CSCC) emission as mentioned in Ricke et al article[9].
4	Value of carbon stock (CO_2 eq.) in INR = Value of carbon stock in US\$ * Exchange rate	Using the exchange rate of Indian Rupee vis-à-vis the US Dollar (in Financial Year-Annual Average)[11].
5	Value of Carbon Retention service = Value of carbon stock (CO_2 eq.) (as obtained in step 4) * Rate of return	A 3% rate of return has been assumed, which is equivalent to the discount rate taken for calculating SCC[12].

41. The calculation of state wise value of Carbon Retention service during the year 2015-16 is based on estimates of carbon stock from ISFR 2017, while that for the year

---

9 Ricke, K., Drouet, L., Caldeira, K., &Tavoni, M. (2018). Country-level social cost of carbon. Nature Climate Change, 8(10), 895-900.
10 Penman, J., M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger, R. Pipatti, et al. 2003. Good practice guidance for land use, land-use change and forestry. Institute for Global Environmental Strategies, Hayama, Japan
11 Handbook of Statistics on Indian Economy, Reserve Bank of India
12 Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide (2017)

2017-18 is based on ISFR 2019. The corresponding exchange rates were 66 INR per US$ and 65 INR per US$. India's country-level social cost of a tonne of CO_2 is US$ 86 as per Nature Climate Change article for the year 2017-18. India's country-level social cost of a tonne of CO_2 for the year 2015-16 has been estimated at US$80 using the GDP deflator.

42.   The value of carbon retention service computed for the year 2017-18 is estimated as INR 438.49 thousand crore as compared to the value computed for the year 2015-16, which is estimated as INR 411.70 thousand crore.

The detailed calculations of state wise estimates of value of carbon retention service for the year 2015-16 and 2017-18 are given in Statements 3.3 and 3.4 respectively at the end of the chapter.

Summary of Forest Ecosystem Services

43.   During the year 2017-18, it is observed that value of timber provisioning services is about 0.10% of India's GDP, while that of NTFP provisioning service is 0.06% of India's GDP. The value of the carbon retention service obtained using a social cost of carbon approach during the year 2017-18 is equivalent to 2.58% of India's GDP, which is almost double the share of forestry sector in India's GDP. The national level estimates of economic value of these ecosystem services obtained have been summarised in **Table 7** below.

Table 7: Summary of selected ecosystem services from forests in India

Ecosystem services	Assessment period	Values (in '000 crore INR)	% of GDP
Timber provisioning	2017-18	16.30	0.10
Non-timber forest resources	2017-18	10.96	0.06
Carbon retention	2017-18	438.49	2.58
Total value of Forest Ecosystem services		**465.75**	**2.74**

44.   **Table 8** below gives the economic values per hectare of the three forest ecosystem services for the States of India. The highest economic value per hectare from forest ecosystem services during the year 2017-18 was observed in Andaman & Nicobar Islands, followed by Arunachal Pradesh and Nagaland.

Table 8: State-wise Value of Forest Ecosystem Services per hectare, 2017-18

S. No.	States/ Union Territories	Geographic Area (in hectare)	Timber Provisioning Service	NTFP Provisioning Service	Carbon Retention Service	Total Value of Forest Ecosystem Services
				(INR/ha/yr)		
1	Andhra Pradesh	162,96,800	232	224	8291	8746
2	Arunachal Pradesh	83,74,300	435	77	77266	77778
3	Assam	78,43,800	141	329	21197	21667
4	Bihar	94,16,300	292	704	3610	4607
5	Chhattisgarh	135,19,200	605	375	21863	22844
6	Goa	3,70,200	1223	120	42125	43467
7	Gujarat	196,24,400	927	348	3363	4639
8	Haryana	44,21,200	1130	3	1457	2591
9	Himachal Pradesh	55,67,300	771	673	27898	29341
10	Jammu & Kashmir	222,23,600	64	58	10806	10928
11	Jharkhand	79,71,600	949	346	13744	15039
12	Karnataka	191,79,100	232	347	12315	12894
13	Kerala	38,85,200	1834	1347	33735	36916
14	Madhya Pradesh	308,25,200	315	313	11755	12383
15	Maharashtra	307,71,300	792	349	8811	9951
16	Manipur	22,32,700	300	128	49266	49694
17	Meghalaya	22,42,900	576	159	49658	50393
18	Mizoram	21,08,100	1338	112	45706	47156
19	Nagaland	16,57,900	1067	232	50311	51610
20	Odisha	155,70,700	317	488	17087	17893
21	Punjab	50,36,200	1389	219	1631	3239
22	Rajasthan	342,23,900	458	377	1949	2784
23	Sikkim	7,09,600	111	37	49594	49742
24	Tamil Nadu	130,06,000	202	339	10258	10799
25	Telangana	112,07,700	166	227	8338	8732
26	Tripura	10,48,600	681	1694	44640	47015
27	Uttar Pradesh	240,92,800	584	282	2955	3821
28	Uttarakhand	53,48,300	502	279	42683	43464
29	West Bengal	88,75,200	497	458	10243	11198
30	Andaman & Nicobar Islands	8,24,900	47	40	84060	84147
31	Chandigarh	11,400	588	455	10204	11247
32	Dadra & Nagar Haveli	49,100	1102	569	22563	24234
33	Daman & Diu	11,100	1564	409	8428	10402
34	Delhi	1,48,300	991	64	5130	6184
35	Lakshadweep	3,000	788	1498	48416	50702
36	Puducherry	49,000	1030	525	5062	6617

Way Forward

45.   In this chapter, ecosystem extent and condition accounts based on the SEEA framework, as well as estimates of flows of forest ecosystem services, have been presented for India. Values of *three selected ecosystem services*: timber provisioning, non-timber forest resources and carbon retention provided by the forests of India have been compiled using data sources and appropriate valuation approaches that are conceptually valid and that produce values consistent with the System of National Accounts to facilitate the integration of environmental and economic statistics. There are still several important indicators of condition and ecosystem services provided by forests which have not been included in this assessment, but are nevertheless, very important. Proper sustainable management of forests is possible only when a holistic assessment is made to understand the real worth of the forests.

****

Statement 3.1: State wise estimates of value of timber provisioning services

(INR in lakh)

States/ Union Territories	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Andhra Pradesh	6417	5852	7503	21831	28689	58210	37729
Arunachal Pradesh	28682	28608	38910	49658	67164	52803	36469
Assam	13819	14816	20154	19513	22640	11762	11086
Bihar	28847	28010	27292	29894	35216	39767	27490
Chhattisgarh	46226	41096	69051	85039	117745	141412	81853
Goa	2199	2164	2221	3388	5383	24718	4526
Gujarat	65261	77697	55612	65388	161623	178472	181930
Haryana	77052	78165	71559	79504	95965	61661	49978
Himachal Pradesh	49379	45159	40807	63347	65373	82549	42901
Jammu & Kashmir	11352	12997	11276	13516	15654	10863	14126
Jharkhand	35542	35289	58295	225870	113797	100346	75677
Karnataka	39729	27824	31852	35274	79405	81713	44478
Kerala	32797	26138	31581	72283	168052	122242	71261
Madhya Pradesh	97596	93945	117745	151115	178614	137403	97185
Maharashtra	153564	149911	170431	213679	225546	224792	243743
Manipur	6862	6491	5775	6823	7017	7597	6708
Meghalaya	8166	6808	14933	16816	19543	19159	12915
Mizoram	6077	6045	7320	52150	62408	40832	28216
Nagaland	14291	13585	14708	19084	21558	21395	17684
Odisha	28207	30141	48359	64534	70586	70445	49422
Punjab	138425	137766	124248	171350	189030	101509	69947
Rajasthan	165377	164508	209804	253649	284586	236522	156879
Sikkim	427	387	735	567	908	1141	789
Tamil Nadu	17379	13408	13805	17476	21266	16357	26233
Telangana	8056	5012	9635	16437	18914	27002	18660
Tripura	12482	11379	11252	13474	15036	10417	7143
Uttar Pradesh	160236	162582	147033	195832	231700	194236	140659
Uttarakhand	31556	35786	43578	46107	49694	35538	26856
West Bengal	54372	55180	63891	59682	67516	64293	44100
Andaman & Nicobar Islands	480	364	410	534	599	678	385
Chandigarh	0	0	40	52	58	97	67
Dadra & Nagar Haveli	244	221	189	493	585	783	541
Daman & Diu	0	0	51	143	170	251	174
Delhi	0	0	516	1448	1525	2126	1469
Lakshadweep	0	0	26	73	87	34	24
Puducherry	174	158	145	380	451	730	505
India	1341273	1317494	1470742	2066401	2444105	2179856	1629806

Statement 3.2: State wise estimates of value of NTFP provisioning services

(INR in lakh)

State/ UT	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Andhra Pradesh	47212	45892	46697	51338	57032	46137	36449
Arunachal Pradesh	7056	8396	8913	11100	12174	9430	6426
Assam	36143	35774	40535	48427	55077	38514	25774
Bihar	61647	63479	67149	87119	105657	87891	66306
Chhattisgarh	45789	60292	60926	77071	82449	60496	50710
Goa	366	377	795	880	934	689	445
Gujarat	66738	77807	81599	102323	124747	99953	68390
Haryana	6812	8036	5291	4942	4560	1816	140
Himachal Pradesh	38777	42498	48025	59524	75235	56753	37447
Jammu & Kashmir	17698	17308	16386	20930	23621	18473	12920
Jharkhand	41724	44883	45479	54608	60253	49837	27619
Karnataka	88222	93326	93761	109033	124113	93782	66489
Kerala	45915	45955	62406	72311	95656	71993	52344
Madhya Pradesh	105073	116960	123892	147104	171515	136130	96556
Maharashtra	173245	180560	191303	196907	193643	138349	107304
Manipur	2206	2261	2198	2634	2776	2387	2850
Meghalaya	3893	4190	4491	5799	6279	5141	3567
Mizoram	2216	2144	2713	3360	3974	3625	2360
Nagaland	2895	3129	3110	4321	5254	5848	3850
Odisha	95583	95342	101584	124822	153284	113924	76062
Punjab	16115	15881	15012	18455	23884	17880	11035
Rajasthan	140571	164003	174679	218793	239691	183372	128981
Sikkim	424	438	431	492	545	410	261
Tamil Nadu	59388	54912	60450	68614	86055	65991	44125
Telangana	33377	33941	34284	37475	42129	34167	25482
Tripura	11218	12532	14977	18692	22410	23258	17758
Uttar Pradesh	109567	111008	105374	122029	134333	102494	67945
Uttarakhand	27717	27834	28490	29138	31905	24915	14898
West Bengal	56435	57669	63719	68589	76464	61358	40644
Andaman & Nicobar Islands	394	426	469	548	632	496	332
Chandigarh	63	67	69	85	98	77	52
Dadra & Nagar Haveli	361	395	405	482	551	424	279
Daman & Diu	35	42	46	60	74	62	45
Delhi	218	198	172	201	209	150	95
Lakshadweep	55	62	64	76	86	68	45
Puducherry	542	529	498	542	576	416	257
India	1345690	1428544	1506389	1768822	2017876	1556704	1095946

Statements 3.3: State wise estimates of value of carbon retention service for the year 2015-16

States/ Union Territories	Above ground biomass (AGB)	Below ground biomass (BGB)	Dead wood	Litter	Soil Organic Carbon (SOCC	Total carbon stock	CO_2 Stock	Value of CO_2 Stock*	Value of CO_2 Stock **	Value of Carbon Retention Service ***
	(in '000 tonnes)							(in '000 US$)	(INR in lakh)	(INR in lakh)
	(1)	(2)	(3)	(4)	(5)	(6)=(1)+(2)+(3)+(4)+(5)	(7)= (6) * 3.67)	(8)=(80 * (7))	(9)=66 * (8)	(10)=(9)* (3/100)
Andhra Pradesh	100539	38585	568	4527	118471	262690	964072	77125784	50903017	1527091
Arunachal Pradesh	243462	53378	4305	16231	677163	994539	3649958	291996650	192717789	5781534
Assam	47343	10824	1093	5240	112352	176852	649047	51923747	34269673	1028090
Bihar	19063	6707	138	625	28864	55397	203307	16264559	10734609	322038
Chhattisgarh	206678	68159	2588	7628	275927	560980	2058797	164703728	108704460	3261134
Goa	5153	1512	250	417	11684	19016	69789	5583098	3684844	110545
Gujarat	32668	11719	322	993	64995	110697	406258	32500639	21450422	643513
Haryana	3736	1269	20	74	7312	12411	45548	3643870	2404954	72149
Himachal Pradesh	70655	18691	739	2511	83186	175782	645120	51609595	34062333	1021870
Jammu & Kashmir	112919	30083	1004	3529	128391	275926	1012648	81011874	53467837	1604035
Jharkhand	86006	33173	438	1298	101967	222882	817977	65438155	43189182	1295675
Karnataka	128098	35045	2545	19745	289652	475085	1743562	139484956	92060071	2761802
Kerala	74166	19245	1058	7436	153976	255881	939083	75126662	49583597	1487508
Madhya Pradesh	266040	101516	1654	7741	318713	695664	2553087	204246950	134802987	4044090
Maharashtra	142651	48947	1986	9385	290052	493021	1809387	144750966	95535637	2866069
Manipur	27253	8821	530	3909	102578	143091	525144	42011518	27727602	831828
Meghalaya	25168	6835	881	5184	117772	155840	571933	45754624	30198052	905942
Mizoram	15359	3173	633	2652	73224	95041	348800	27904038	18416665	552500
Nagaland	16151	4150	666	2432	101661	125060	458970	36717616	24233627	727009

States/ Union Territories	Above ground biomass (AGB)	Below ground biomass (BGB)	Dead wood	Litter	Soil Organic Carbon (SOCC	Total carbon stock	CO_2 Stock	Value of CO_2 Stock*	Value of CO_2 Stock **	Value of Carbon Retention Service ***
	(in '000 tonnes)							(in '000 US$)	(INR in lakh)	(INR in lakh)
	(1)	(2)	(3)	(4)	(5)	(6)=(1)+(2)+ (3)+(4)+(5)	(7)= (6) * 3.67)	(8)=(80 * (7))	(9)=66 * (8)	(10)=(9)* (3/100)
Odisha	152525	50407	2108	9087	238776	452903	1662154	132972321	87761732	2632852
Punjab	5095	1883	26	63	8971	16038	58859	4708757	3107779	93233
Rajasthan	32558	12736	216	721	43429	89660	329052	26324176	17373956	521219
Sikkim	13379	3735	211	585	30624	48534	178120	14249582	9404724	282142
Tamil Nadu	84067	29252	1006	5579	109434	229338	841670	67333637	44440200	1333206
Telangana	72498	28388	333	3117	80639	184975	678858	54308660	35843716	1075311
Tripura	15674	3224	556	1613	42341	63408	232707	18616589	12286949	368608
Uttar Pradesh	47752	14264	444	1824	60850	125134	459242	36739342	24247966	727439
Uttarakhand	105173	26961	1316	5665	145549	284664	1044717	83577350	55161051	1654832
West Bengal	45382	13916	434	2585	100884	163201	598948	47915814	31624437	948733
Andaman & Nicobar Islands	39426	11901	2048	3702	57996	115073	422318	33785433	22298386	668952
Chandigarh	61	19	0	2	122	204	749	59894	39530	1186
Dadra & Nagar Haveli	447	106	10	35	827	1425	5230	418380	276131	8284
Daman & Diu	11	2	0	2	76	91	334	26718	17634	529
Delhi	230	52	2	11	653	948	3479	278333	183700	5511
Lakshadweep	55	0	1	5	100	161	591	47270	31198	936
Puducherry	108	23	1	8	311	451	1655	132414	87393	2622
India	2237549	698701	30130	136161	3979522	7082063	25991171	2079293697	1372333840	41170015

Notes: India's country-level social cost of a tCO_2 = US$ 80 in the year 2015-16 and the average annual exchange rate of US$ to INR for the year was 66. A rate of 3% return has been assumed for estimating the value of carbon retention service

Statements 3.4: State wise estimates of value of carbon retention service for the year 2017-18

States/ Union Territories	Above ground biomass (AGB)	Below ground biomass (BGB)	Dead wood	Litter	Soil Organic Carbon	Total carbon stock	CO₂ Stock	Value of CO₂ Stock*	Value of CO₂ Stock **	Value of Carbon Retention Service ***
	(in '000 tonnes)							(in '000 US$)	(INR in lakh)	(INR in lakh)
	(1)	(2)	(3)	(4)	(5)	(6)=(1)+(2)+(3)+(4)+(5)	(7)=(6)*3.67	(8)=86 *(7)	(9)=65 * (8)	(10)=(9)*(3/100)
Andhra Pradesh	60972	24206	629	3074	130647	219528	805668	69287427	45036828	1351105
Arunachal Pradesh	330856	100379	7816	15436	596836	1051323	3858355	331818565	215682067	6470462
Assam	85844	21148	1102	7223	154832	270149	991447	85264427	55421878	1662656
Bihar	15007	5428	127	746	33931	55239	202727	17434533	11332447	339973
Chhattisgarh	145912	46908	1858	9969	275603	480250	1762518	151576505	98524728	2955742
Goa	9010	2617	172	665	12874	25338	92990	7997180	5198167	155945
Gujarat	27737	9636	315	1556	68003	107247	393596	33849298	22002044	660061
Haryana	2455	929	18	137	6927	10466	38410	3303279	2147131	64414
Himachal Pradesh	110045	30745	2559	2711	106300	252360	926161	79649863	51772411	1553172
Jammu & Kashmir	170222	47806	3813	3706	164648	390195	1432016	123153346	80049675	2401490
Jharkhand	48994	19899	423	2826	105870	178012	653304	56184147	36519696	1095591
Karnataka	128882	38742	1993	8931	205215	383763	1408410	121123278	78730131	2361904
Kerala	67979	19070	1017	5001	119889	212956	781549	67213173	43688562	1310657
Madhya Pradesh	165067	64630	1535	8156	349339	588727	2160628	185814016	120779110	3623373
Maharashtra	131249	40380	1586	10687	256606	440508	1616664	139033135	90371538	2711146
Manipur	44723	13317	508	3924	116251	178723	655913	56408553	36665560	1099967
Meghalaya	52302	14963	731	4328	108642	180966	664145	57116489	37125718	1113772
Mizoram	44973	9925	451	4516	96689	156554	574553	49411573	32117523	963526
Nagaland	35850	9612	522	2897	86646	135527	497384	42775032	27803771	834113

States/ Union Territories	Above ground biomass (AGB)	Below ground biomass (BGB)	Dead wood	Litter	Soil Organic Carbon	Total carbon stock	CO$_2$ Stock	Value of CO$_2$ Stock*	Value of CO$_2$ Stock **	Value of Carbon Retention Service ***
	(in '000 tonnes)							(in '000 US$)	(INR in lakh)	(INR in lakh)
	(1)	(2)	(3)	(4)	(5)	(6)=(1)+(2)+(3)+(4)+(5)	(7)=(6)*3.67	(8)=86 *(7)	(9)=65 * (8)	(10)=(9)*(3/100)
Odisha	126656	39066	1647	9062	255857	432288	1586497	136438739	88685180	2660555
Punjab	3529	1367	25	125	8298	13344	48972	4211633	2737562	82127
Rajasthan	26155	10865	191	928	70224	108363	397692	34201530	22230995	666930
Sikkim	17645	5372	505	664	32994	57180	209851	18047152	11730649	351919
Tamil Nadu	62092	21433	776	4107	128374	216782	795590	68420735	44473478	1334204
Telangana	41389	17227	333	2031	90862	151842	557260	47924372	31150842	934525
Tripura	25061	5513	297	2169	43017	76057	279129	24005110	15603322	468100
Uttar Pradesh	32498	10374	372	1893	70553	115690	424582	36514078	23734151	712025
Uttarakhand	152540	40975	2948	4904	169545	370912	1361247	117067245	76093710	2282811
West Bengal	40388	12193	447	2533	92144	147705	542077	46618652	30302124	909064
Andaman & Nicobar Islands	49468	15823	1116	2912	43347	112666	413484	35559643	23113768	693413
Chandigarh	57	18	0	3	111	189	694	59652	38774	1163
Dadra & Nagar Haveli	500	113	7	47	1133	1800	6606	568116	369275	11078
Daman & Diu	35	10	0	2	105	152	558	47974	31183	935
Delhi	277	98	2	21	838	1236	4536	390106	253569	7607
Lakshadweep	67	15	0	5	149	236	866	74486	48416	1452
Puducherry	97	22	1	7	276	403	1479	127195	82677	2480
India	2256533	700824	35842	127902	4003575	7124676	26147561	2248690239	1461648655	43849460

Notes: India's country-level social cost of a t CO$_2$ = US$ 86 in the year 2017-18 and the average annual exchange rate of US$ to INR for the year was 65. A rate of 3% return has been assumed for estimating the value of carbon retention service.