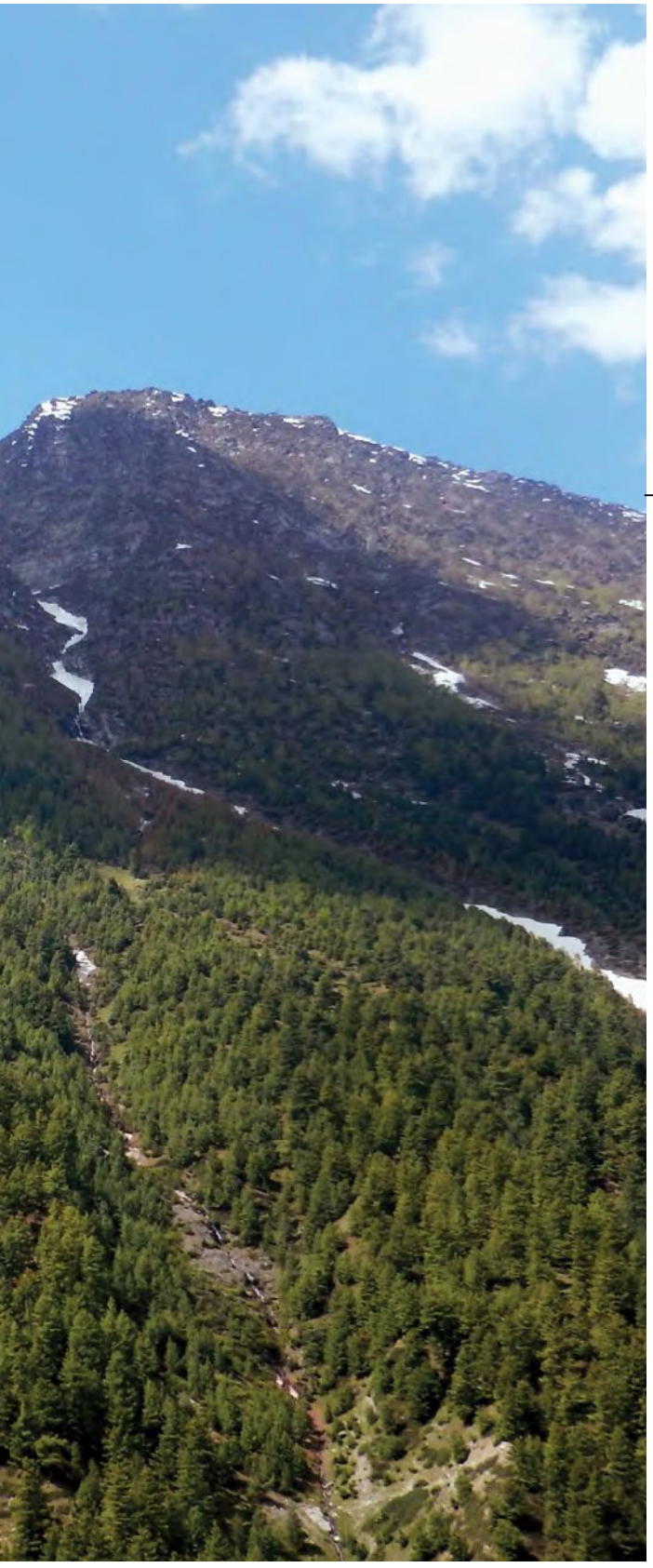


4

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

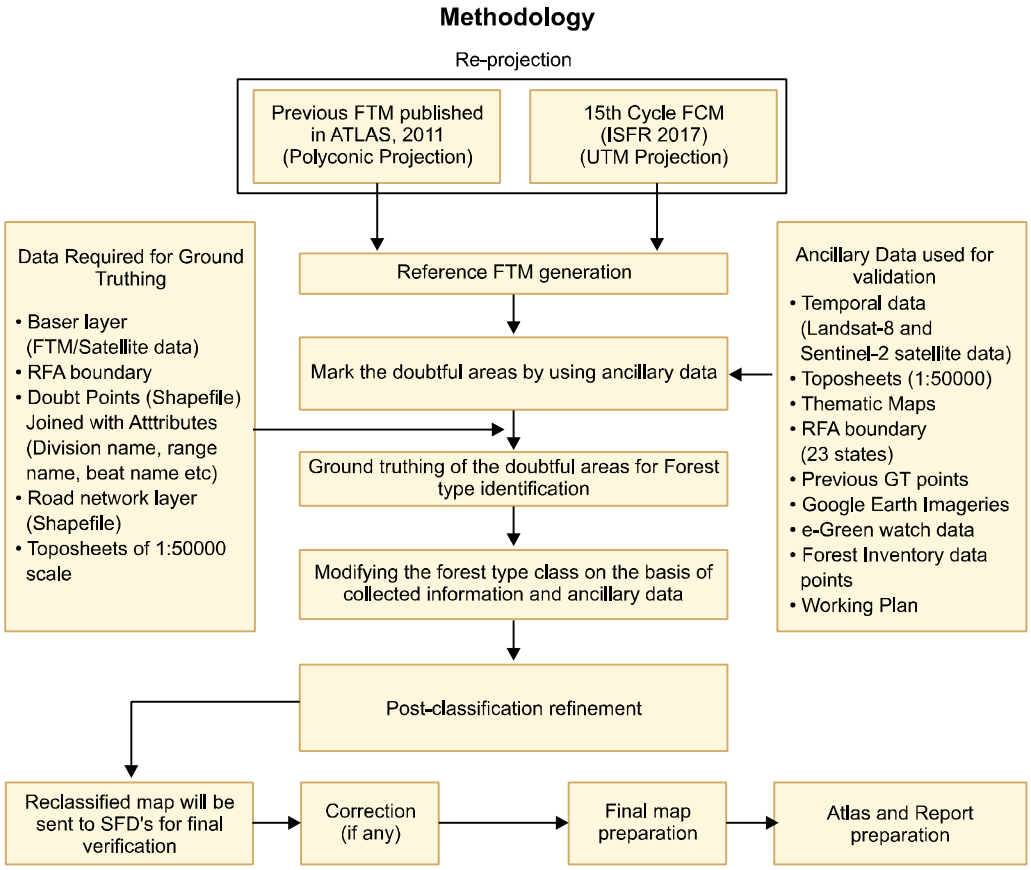
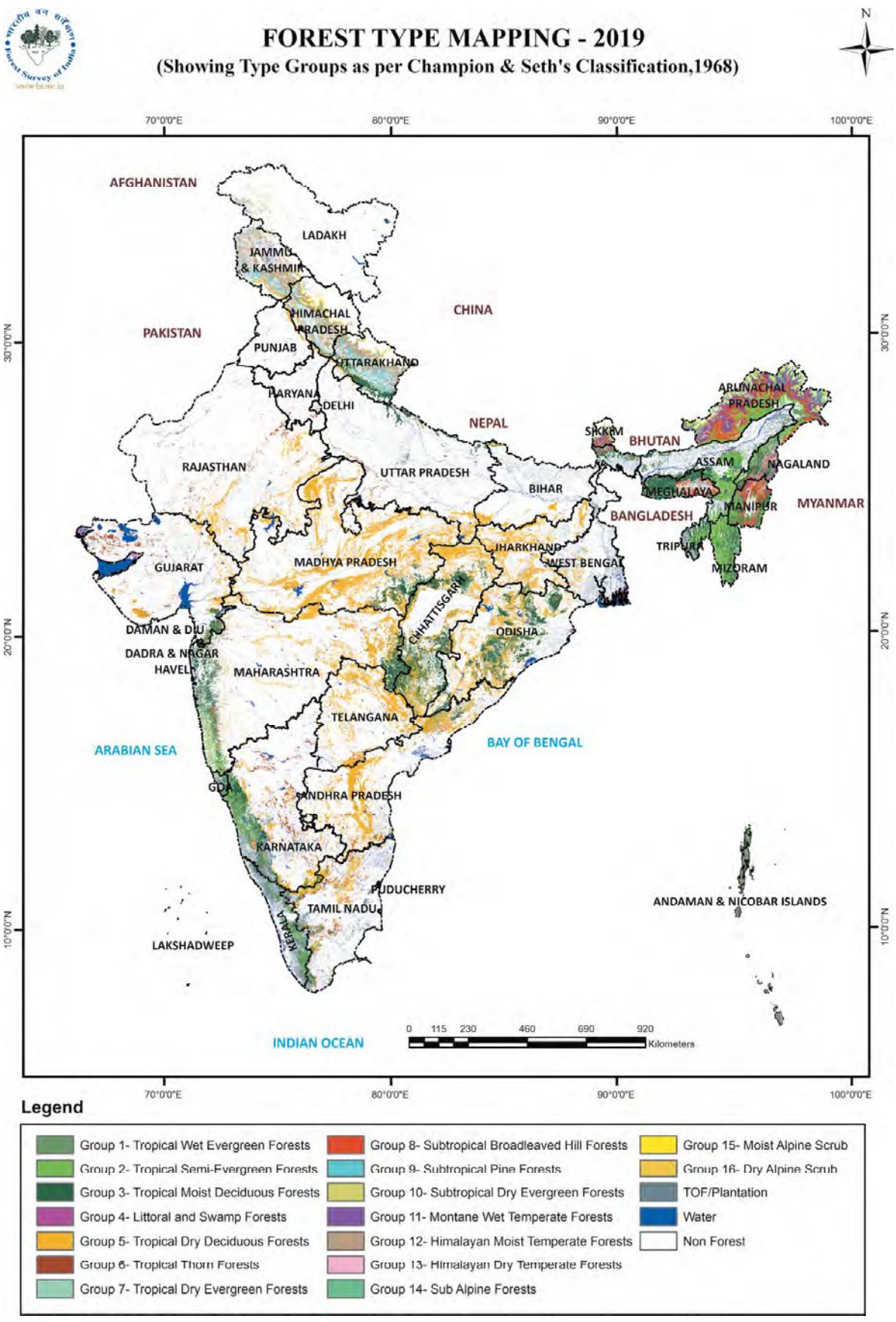


TABLE 4.1 Area under different Forest Type Groups of India

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

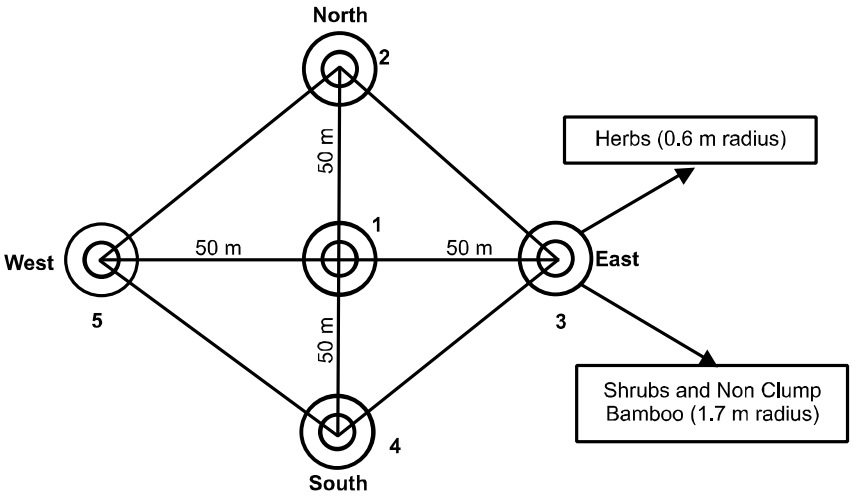


FIGURE 4.4b

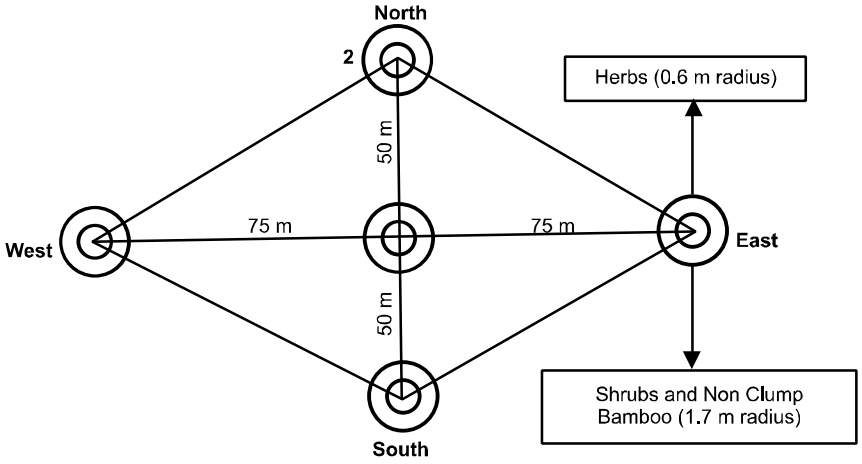


FIGURE 4.4c

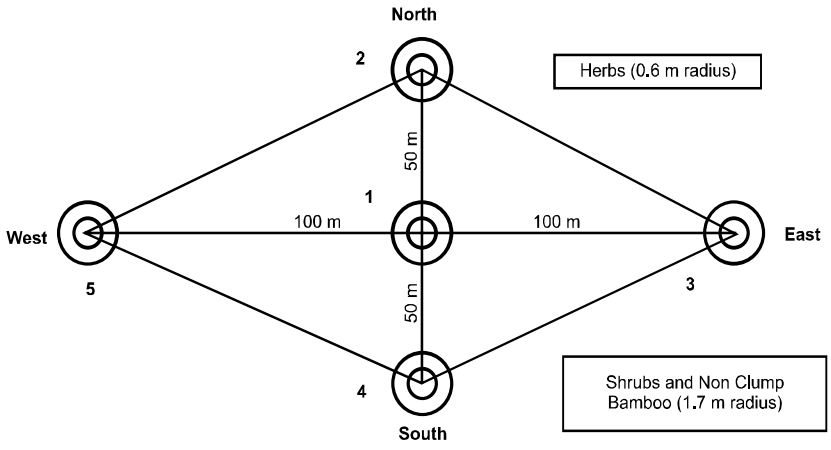


TABLE 4.2 State/ UT wise Number of species of Trees, Shrubs and Herbs

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		

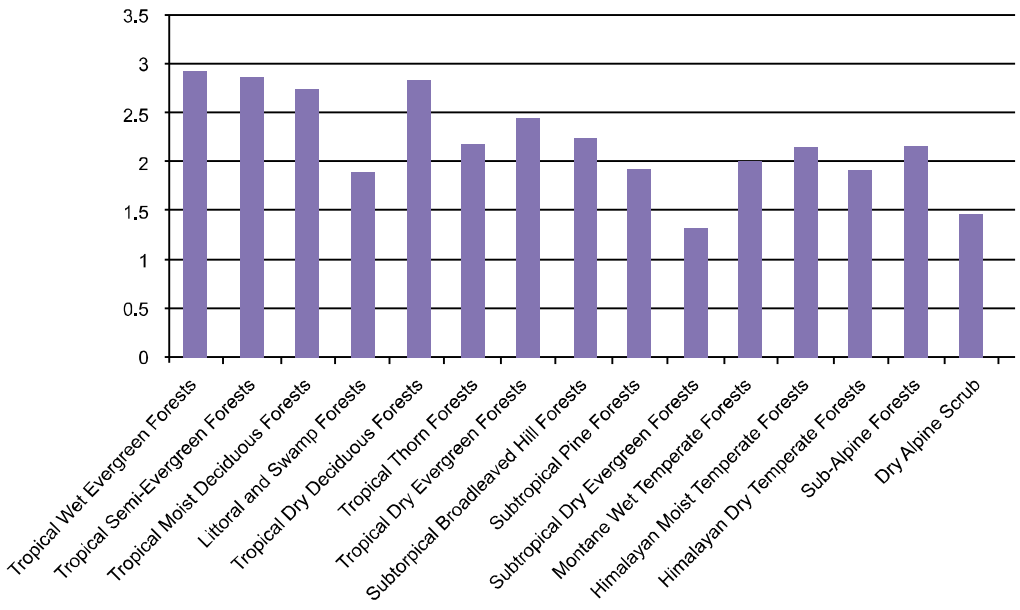
4.3.6 Analysis

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

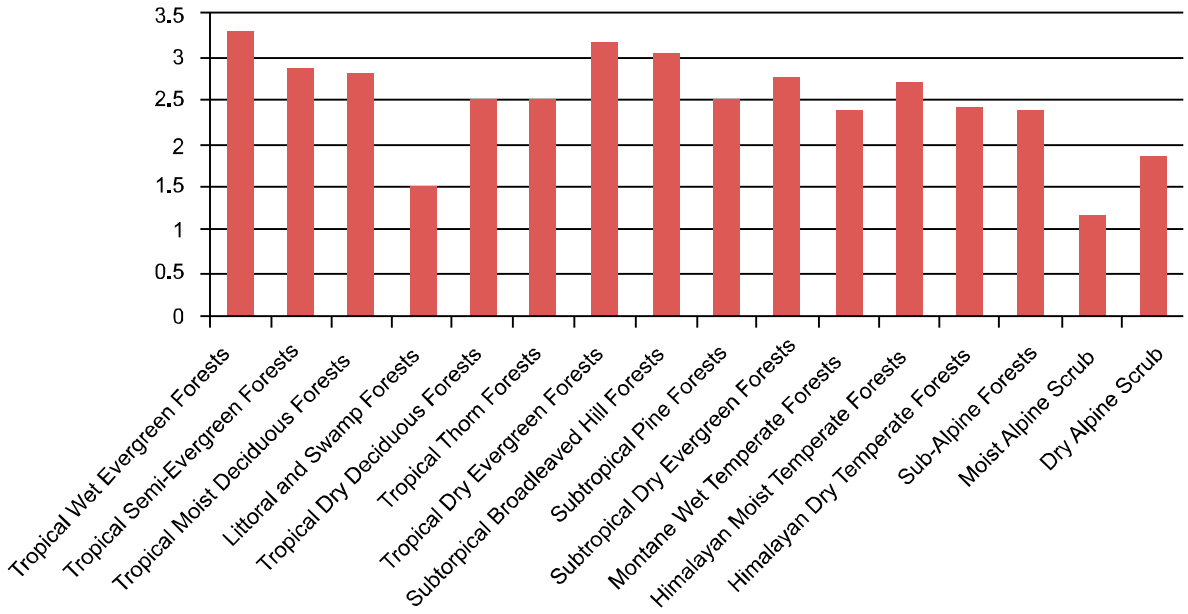
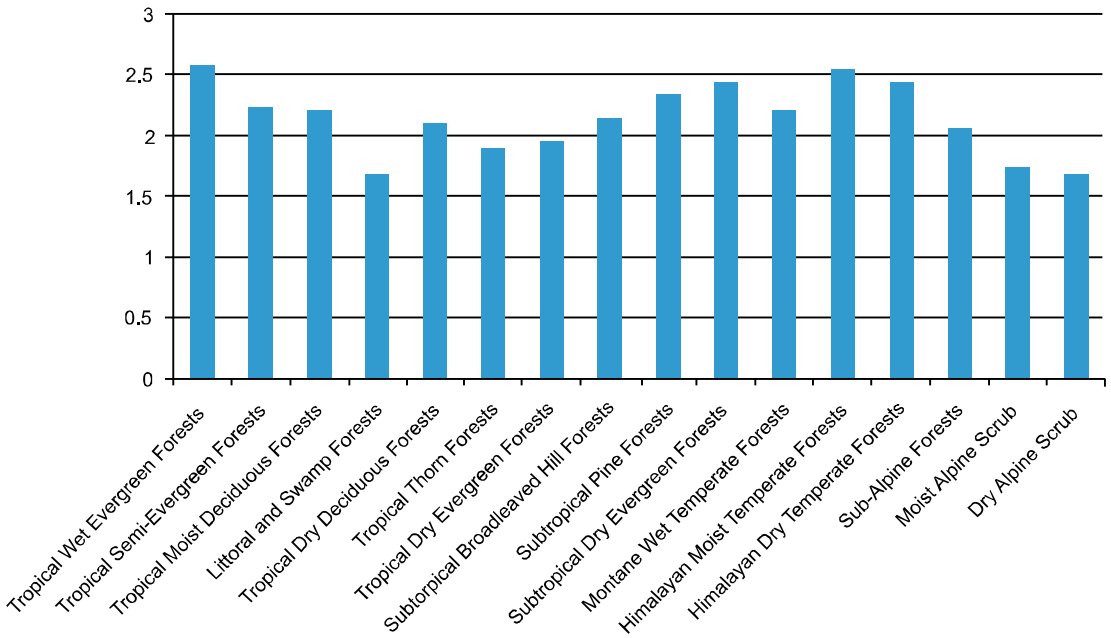


FIGURE 4.7 Biodiversity of herbs in different forest type groups



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

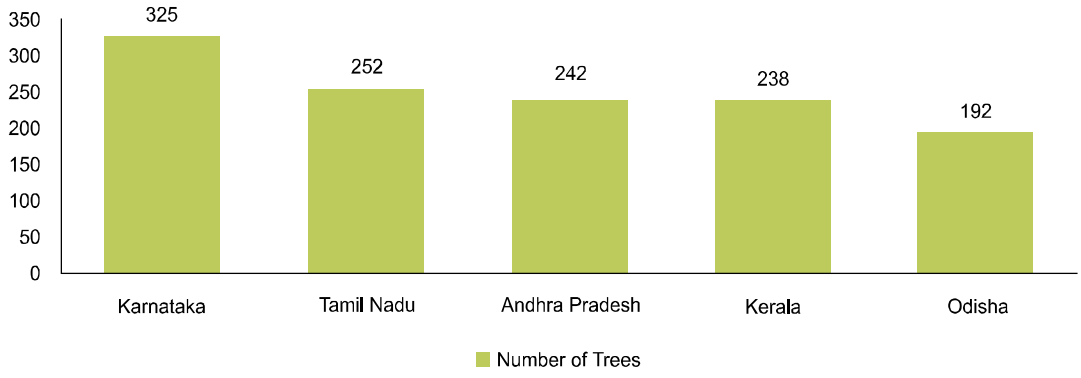


FIGURE 4.8b Species Richness of top five States for shrubs

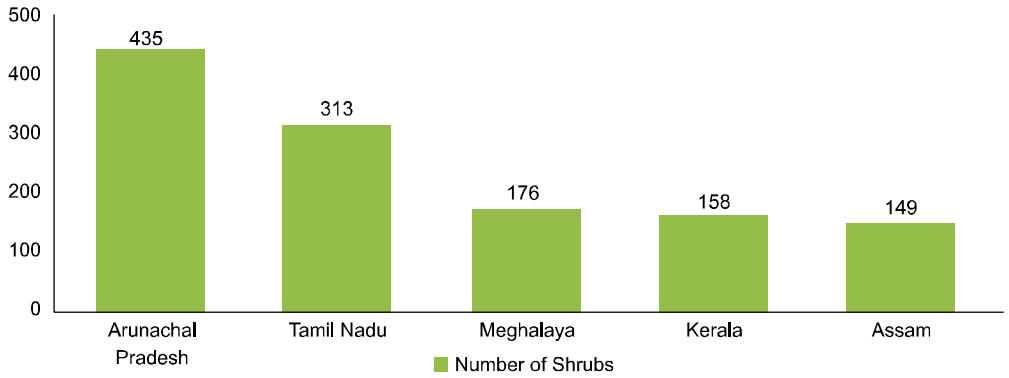


FIGURE 4.8c Species Richness of top five States for herbs

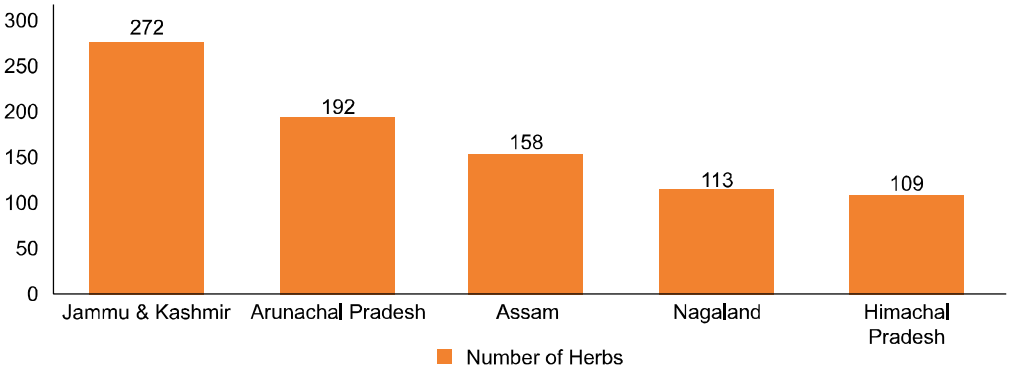


FIGURE 4.8d Species Richness of top five States for plants