

7. Trees in Agroforestry Systems in India

7.1 Introduction

Agroforestry, the inclusion of woody perennials within farming systems, has been practiced as a traditional landuse and livelihood option since time immemorial. It was being practiced on agricultural lands and other rural areas for variety of reasons like, bio-fertilizer trees to enrich soil and helping in land regeneration enabling food security, fuel-wood and fodder trees, fruit trees as cash crops, medicinal trees, trees providing non-timber forest products, trees providing timber, shelters etc. It has been observed that farmers usually prefer multipurpose tree species. Generally, agroforestry is considered as a concept for rural areas, but many of the small towns of India, particularly in those having population less than 50,000, exhibits similar trends of agroforestry as in rural areas. FSI has been estimating the number of stems along with wood volume of TOF at state and national level and has been reporting the same since SFR 2003. Although the agroforestry systems constitute an important component of TOF, yet the information on available tree resources in agroforestry system has not been separated and reported. Considering its importance, it was thought appropriate to include one additional chapter on information of tree resources in agroforestry systems in India.

7.2 Agroforestry in India

Indian economy has been experiencing many challenges due to growing population pressure, increasing food, fodder, fuel needs, natural resources degradation and climate change which are affecting agriculture and allied agriculture systems. The traditional knowledge of agroforestry has been continuously used as a means to tackle such problems of rural livelihood in India for centuries. To supplement such efforts on scientific basis many initiatives has been taken and the country has become one of the leaders in agroforestry research and development.

The research on agroforestry started in the eighties, simultaneously, by Indian Council of Forestry Research and Education (ICFRE) and Indian Council of Agricultural Research (ICAR). The ICAR launched an All India Coordinated Research Project (AICRP) on agroforestry during that period and created National Research Centre for Agroforestry (NRCAF) at Jhansi to accelerate basic, strategic and applied research in agroforestry. The AICRP is continuing the efforts along with 37 Centres tackling the problems posed by the major agro-ecological zones of the country.

The National Forest Policy 1952, 1988 and the National Agriculture Policy 2000, Task Force on Greening India 2001, National Bamboo

Mission 2002 and National Policy on Farmers, 2007 has recognised agroforestry as an effective program for efficient nutrient cycling, enhancement of organic matter in the soil for sustainable agriculture and for improving tree cover. The National Agriculture Policy (2000) stresses that, "farmers will be encouraged to take up farm/agroforestry for higher income generation by evolving technology, extension and credit support packages and removing constraints to development of agroforestry". It also advocates practicing agroforestry in areas currently under shifting cultivation.

The Report of the Task Force on Greening India for Livelihood Security and Sustainable Development, Planning Commission, 2001, assessed that there is a potential of commercially viable agroforestry in 10 million ha irrigated lands and further 18 million ha of rain-fed area could be brought in subsistence agroforestry. The implementation of such agroforestry programme in rain-fed area will help in poverty alleviation of 30 million people of weaker sections. Further, it has recommended several measures for promoting agroforestry including commercial agroforestry in irrigated areas, promotion of agroforestry models that would complement agriculture, improved and high quality saplings, role of private sector in R&D, market information system for buyers and farmers, removal of restrictions on felling, transport and marketing of private agroforestry produce, establishing agroforestry boards and marketing federations, etc.

Though, there is a great realization of importance of agroforestry but there is no specific scheme to promote Agroforestry in

the country. There are a number of schemes of Government of India in which agroforestry is recognized as a component, namely, Integrated Watershed Management Programme, Mahatma Gandhi NREGA (MoRD), Soil Conservation in the Catchment of River Valleys and Flood Prone Rivers, National Horticulture Mission, Green India Mission (MoEF), etc. Therefore, sizable amount of money is being spent annually on tree planting / agroforestry through a number of Centrally Sponsored Schemes.

7.3 Assessment of Agroforestry

The information about area, tree resources, their volume, farmers' preferences of species etc. under agroforestry is hardly available. FSI has been carrying out inventory of TOF both in rural and urban area at national level since 2002 and the methodology has already been explained in chapter 5. However a brief account of scope of agroforestry and estimation procedure used for green cover and growing stock in agroforestry has been given in section 7.3.1 and 7.3.2.

7.3.1 Scope of Agroforestry

For the purpose of agroforestry only rural TOF inventory has been taken into consideration. High resolution satellite data has been used for stratification of Culturable Non Forest Area (CNFA) into three strata, viz., Block, Linear and Scattered. CNFA excludes all areas which do not support tree vegetation, like rivers and water bodies, riverbeds, snow covered mountains, etc. which is termed as Un-culturable Non Forest Area. Out of three strata, only blocks and scattered stratum are accounted and liner stratum and other private

forest are excluded as they do not qualify the definition of agroforestry. The information collected from the field plots of these two strata have been used for estimating the green cover and growing stock under agroforestry. During the field inventory the data on a number of parameters are recorded. The important parameters from agroforestry point of view which describe the sample plot are ownership, category of plot (hilly/plain, irrigated/unirrigated and proximity to forests) and category of plantation. The ownership is recorded in the category of (1) Private individual/organization 2) Communities, (3) Government Departments (4) Panchayat Lands, (5) Institutions and Others. It helps in identifying the agroforestry status of the plots.

The most important parameter for agroforestry is 'category of plantation/tree' and recorded as (1) Farm forestry: Trees in small patches up to 0.1 ha in area, (2) Village Woodlots: Naturally growing trees/planted trees on community land, (3) Block plantations: Patches covering an area of more than 0.1 ha and not falling in any of the above, (4) Road side plantations, (5) Pond side plantations, (6) Railway line side plantations, (7) Canal side plantations, (8) Homestead: Trees appearing in the house premises and not covered in above first three categories and (9) Others: Trees not falling in any of the above categories. This parameter is helpful in discarding the trees which do not fall in the category of agroforestry and therefore, increases the precision.

7.3.2 Estimation Procedure

The area under tree green cover for block stratum was obtained by digital interpretation of remote sensing data. To estimate the area

of tree green cover under scattered stratum, crown diameter of each tree recorded from all field plots which qualify the definition of agroforestry was used which is then converted into equivalent notional area corresponding to 70 per cent canopy density. Using tree cover area of sampled plots and corresponding CNFA of scattered stratum of the district, estimate at district level is generated. The total tree green cover in agroforestry system for the selected district is obtained by aggregating the area of tree green cover under the modified block and scattered strata. On the basis of tree green cover under agroforestry of sampled districts, the tree green cover under agroforestry in each physiographic zone is estimated. Aggregation of tree green cover of all the physiographic zones leads to tree green cover estimate under agroforestry of the country. The present estimate is based on 179 sampled districts across the country, which was inventoried during the period from 2006 to 2012. The growing stock has been estimated as per the methodology described in chapter 5.

7.4 Results

7.4.1 Physiographic Zone-wise Tree Green Cover under Agroforestry System

The estimated total tree green cover in the agroforestry system of the country is estimated as 111,554 sq km which is 3.39 per cent of country's geographical area. The estimates of tree green cover for each physiographic zone is given in Table 7.1. It is observed that the tree green cover is maximum in West Coast (13,523 sq km),

Table 7.1 : Physiographic Zone-wise Tree green Cover under Agroforestry

Physiographic Zone	Geographical Area (sq km)	Tree green Cover (sq km)	Tree green Cover % to GA
Western Himalayas	329,255	7,131	2.17
Eastern Himalayas	74,618	1,818	2.44
North East	133,990	7,513	5.61
Northern Plains	295,780	8,740	2.96
Eastern Plains	223,339	9,872	4.42
Western Plains	319,098	7,450	2.33
Central Highlands	373,675	9,168	2.45
North Deccan	355,988	6,949	1.95
East Deccan	336,289	12,450	3.70
South Deccan	292,416	7,771	2.66
Western Ghats	72,381	7,465	10.31
Eastern Ghats	191,698	5,102	2.66
West Coast	121,242	13,523	11.15
East Coast	167,494	6,602	3.94
TOTAL	3,287,263	111,554	3.39

followed by East Deccan (12,450 sq km) and Eastern Plain (9,872 sq km). Eastern Himalayas have the lowest tree green cover of 1,818 sq km, as this zone is predominantly forested. As percentage to geographical area, the maximum percentage of tree green cover was observed in West Coast (11.15 percent) followed by Western Ghats (10.31 percent) and North East (5.61 percent).

7.4.2 States/UTs-wise Tree Green Cover under Agroforestry System

The estimates of tree green cover for each States/ UTs are given in Table 7.2. The state having maximum tree green cover area in agroforestry system is Maharashtra (11,806

sq km) followed by Gujarat (11,591 sq km) and Rajasthan (8,373 sq km). As percentage to geographical area, the maximum percentage of tree green cover was observed in the Union Territory of Lakshadweep (50.00 per cent) followed by Dadra & Nagar Haveli (11.36 percent) and Kerala (9.79 percent).

7.4.3 Physiographic Zone-wise Growing and Carbon Stock Estimates under Agroforestry System

The physiographic zone wise growing and carbon stock of the trees observed in agroforestry system in respective zone, is

Table 7.2: States/UTs-wise Tree green Cover under Agroforestry

States/ UTs	Geographical Area (sq km)	Tree green Cover (sq km)	Tree green Cover % to GA
Andhra Pradesh	275,069	8,224	2.99
Arunachal Pradesh	83,743	2,610	3.12
Assam	78,438	3,922	5.00

States/ UTs	Geographical Area (sq km)	Tree green Cover (sq km)	Tree green Cover % to GA
Bihar	94,163	4,570	4.85
Chhattisgarh	135,191	4,535	3.35
Delhi	1,483	23	1.57
Goa	3,702	280	7.56
Gujarat	196,022	11,591	5.91
Haryana	44,212	1,333	3.01
Himachal Pradesh	55,673	2,303	4.14
Jammu & Kashmir	222,236	2,728	1.23
Jharkhand	79,714	3,358	4.21
Karnataka	191,791	6,090	3.18
Kerala	38,863	3,803	9.79
Madhya Pradesh	308,245	6,745	2.19
Maharashtra	307,713	11,806	3.84
Manipur	22,327	606	2.71
Meghalaya	22,429	1,876	8.36
Mizoram	21,081	464	2.20
Nagaland	16,579	1,037	6.26
Odisha	155,707	5,136	3.30
Punjab	50,362	1,635	3.25
Rajasthan	342,239	8,373	2.45
Sikkim	7,096	128	1.80
Tamil Nadu	130,058	4,590	3.53
Tripura	10,486	576	5.49
Uttar Pradesh	240,928	7,082	2.94
Uttarakhand	53,483	1,966	3.68
West Bengal	88,752	4,018	4.53
Andaman & Nicobar Islands	8,249	49	0.59
Chandigarh	114	0	0.00
Dadra & Nagar Haveli	491	56	11.36
Daman & Diu	112	9	8.19
Lakshadweep	32	16	50.00
Puducherry	480	16	3.39
TOTAL	3,287,263	111,554	3.39

estimated using the data collected from selected inventoried districts falling in that physiographic zone. The estimates given in this ISFR is based on 21,543 sample plots laid out in 179 districts during 2006 to 2012. The physiographic zone wise growing and carbon stock is presented in Table 7.3. The

total growing stock of wood in agroforestry system of the country is estimated to be 1,022.85 m. cum (m. cum). The maximum growing stock is estimated in East Deccan (177.74 m. cum) followed by South Deccan (96.01 m. cum) and West Coast (91.00 m. cum).

Table 7.3: Physiographic Zone-wise Growing and Carbon Stock Estimate under Agroforestry

Physiographic Zone	Geographical Area (sq km)	Tree green Cover (sq km)	Growing Stock Volume (m cum)	Carbon Stock in m. tonnes
Western Himalayas	329,255	7,131	55.14	15.47
Eastern Himalayas	74,618	1,818	11.30	2.98
North East	133,990	7,513	60.93	9.51
Northern Plains	295,780	8,740	74.33	22.66
Eastern Plains	223,339	9,872	77.68	19.86
Western Plains	319,098	7,450	55.65	10.42
Central Highlands	373,675	9,168	74.09	22.85
North Deccan	355,988	6,949	57.67	14.91
East Deccan	336,289	12,450	177.74	53.30
South Deccan	292,416	7,771	96.01	23.74
Western Ghats	72,381	7,465	69.21	22.57
Eastern Ghats	191,698	5,102	54.39	9.64
West Coast	121,242	13,523	91.00	33.33
East Coast	167,494	6,602	67.73	18.60
TOTAL	3,287,263	111,554	1,022.85	279.83

7.4.4 States/UTs-wise Growing and Carbon Stock Estimates under Agroforestry System

To estimate growing and carbon stock in agroforestry system in each State/UT, aggregation protocol similar to that of TOF

was followed. The maximum growing stock is observed in Maharashtra (98.95 m.cum.) followed by Andhra Pradesh (92.29 m.cum.) and Gujarat (81.98 m.cum.). The States/UTs wise growing stock estimate under agroforestry is presented in table 7.4.

Table 7.4: States/UTs-wise Growing Stock Estimate under Agroforestry

States/ UTs	Geographical Area(sq km)	Tree green Cover (sq km)	Growing Stock Volume (m cum)	Carbon Stock in m. tonnes
Andhra Pradesh	275,069	8,224	92.289	21.58
Arunachal Pradesh	83,743	2,610	16.659	3.73
Assam	78,438	3,922	31.805	6.51
Bihar	94,163	4570	37.484	9.75
Chhattisgarh	135,191	4535	64.749	19.41
Delhi	1,483	23	0.195	0.06
Goa	3,702	280	1.880	0.71
Gujarat	196,022	11,591	81.983	26.41
Haryana	44,212	1333	11.331	3.45
Himachal Pradesh	55,673	2303	15.811	5.09
Jammu & Kashmir	222,236	2,728	24.089	6.03
Jharkhand	79,714	3,358	47.935	14.37
Karnataka	191,791	6,090	69.819	18.33

States/ UTs	Geographical Area(sq km)	Tree green Cover (sq km)	Growing Stock Volume (m cum)	Carbon Stock in m. tonnes
Kerala	38,863	3,803	28.100	9.97
Madhya Pradesh	308,245	6,745	60.167	17.83
Maharashtra	307,713	11,806	98.947	29.78
Manipur	22,327	606	5.051	0.78
Meghalaya	22,429	1,876	15.662	2.42
Mizoram	21,081	464	3.831	0.59
Nagaland	16,579	1,037	8.661	1.34
Odisha	155,707	5,136	65.189	17.88
Punjab	50,362	1,635	13.726	4.03
Rajasthan	342,239	8,373	64.770	15.18
Sikkim	7,096	128	0.796	0.21
Tamil Nadu	130,058	4,590	47.389	11.76
Tripura	10,486	576	4.802	0.74
Uttar Pradesh	240,928	7,082	60.564	18.48
Uttarakhand	53,483	1,966	14.277	4.21
West Bengal	88,752	4,018	33.508	8.78
Andaman & Nicobar Islands	8,249	49	0.499	0.14
Chandigarh	114	0	0.000	0.00
Dadra & Nagar Haveli	491	56	0.517	0.17
Daman & Diu	112	9	0.062	0.02
Lakshadweep	32	16	0.040	0.01
Puducherry	480	16	0.165	0.05
TOTAL	3,287,263	111,554	1,022.852	279.83

7.4.5 Species-wise Number of Stems under Agroforestry System in India

Tree species in agroforestry is very important and vital. It reflects the choice of farmers and in some sense demand of market. Therefore, the number of top 40 most occurring tree

species has been worked out from the collected data and their dia-class distribution is given in Table 7.5. *Mangifera indica* has maximum stems (9.25 %) followed by *Areca catechu* (7.26%), *Cocos nucifera* (5.6%) and *Azadirachta indica* (5.59%).

Table 7.5 Species-wise Number of Stems under Agroforestry System in India (number in '000)

Species	Diameter class (cm)				Percentage
	10-30	30-50	50+	Total	
<i>Acacia nilotica</i> (<i>Acacia arabica</i>)	132,281	19,074	1,313	152,668	4.09
<i>Acacia catechu</i>	48,142	558	11	48,711	1.31
<i>Acacia lenticularis</i>	62,861	4,795	259	67,914	1.82
<i>Albizia spp.</i>	17,807	6,697	763	25,266	0.68

Species	Diameter class (cm)				Percentage
	10-30	30-50	50+	Total	
<i>Anacardium occidentale</i>	44,403	1,647	0	46,050	1.23
<i>Areca catechu</i>	270,636	367	0	271,002	7.26
<i>Artocarpus heterophyllus</i>	36,645	8,828	1,174	46,647	1.25
<i>Azadirachta indica</i>	176,671	27,952	3,844	208,466	5.59
<i>Bombax ceiba</i>	16,380	3,773	1,053	21,206	0.57
<i>Borassus flabelliformis</i>	18,551	74,411	1,276	94,237	2.53
<i>Butea monosperma</i>	114,359	15,977	1,640	131,976	3.54
<i>Cocos nucifera</i>	168,423	43,238	101	211,762	5.68
<i>Dalbergia sissoo</i>	46,898	6,331	600	53,829	1.44
<i>Eucalyptus sp.</i>	112,361	6,115	442	118,919	3.19
<i>Ficus bengalensis</i>	2,376	546	1,545	4,466	0.12
<i>Ficus racemosa</i>	3,915	3,119	1,241	8,274	0.22
<i>Ficus religiosa</i>	3,109	1,417	784	5,310	0.14
<i>Ficus sp.</i>	12,645	1,480	700	14,826	0.40
<i>Gmelina arborea</i>	18,027	1,375	328	19,730	0.53
<i>Grevillea robusta</i>	51,034	3,021	577	54,631	1.46
<i>Grewia optiva (Grewia oppositifolia)</i>	41,333	1,010	48	42,391	1.14
<i>Holoptelea integrifolia</i>	13,656	2,346	386	16,387	0.44
<i>Hevea brasiliensis</i>	55,786	1,334	0	57,120	1.53
<i>Madhuca longifolia</i>	6,573	6,467	11,546	24,586	0.66
<i>Mangifera indica</i>	255,815	60,917	28,323	345,054	9.25
<i>Phoenix sylvestris</i>	19,092	8,239	63	27,394	0.73
<i>Pinus kesiya (Pinus khasya)</i>	44,593	553	0	45,146	1.21
<i>Pinus roxburghii (Pinus longifolia)</i>	95,156	18,633	2,694	116,484	3.12
<i>Populus sp.</i>	44,198	1,295	1	45,495	1.22
<i>Prosopis cineraria</i>	20,560	6,835	626	28,021	0.75
<i>Quercus leucotrichophora (Quercus incana)</i>	30,409	2,897	286	33,592	0.90
<i>Shorea robusta</i>	43,171	5,180	1,711	50,062	1.34
<i>Syzygium cumini (Eugenia Jambolana)</i>	36,572	7,705	1,879	46,156	1.24
<i>Tamarindus indica</i>	9,144	3,401	1,539	14,084	0.38
<i>Tectona grandis</i>	72,761	2,277	156	75,194	2.02
<i>Terminalia arjuna</i>	9,811	2,985	455	13,252	0.36
<i>Terminalia bellerica</i>	3,101	1,105	970	5,176	0.14
<i>Terminalia crenulata</i>	16,759	1,946	333	19,038	0.51
<i>Toona ciliata (Cedrela toona)</i>	3,940	1,305	336	5,581	0.15
<i>Ziziphus mauritiana</i>	42,040	3,019	132	45,192	1.21
<i>Rest of species</i>	930,731	110,558	28,822	1,070,111	28.68
Total	3,152,724	480,727	97,958	3,731,409	100.00

7.4.6 Species-wise volume under Agroforestry System in India

The volume of top 40 species found in agroforestry in India has been estimated and

given in table 7.6. *Mangifera indica* has contributed maximum volume (13.29 %) followed by *Azadirachta indica* (6.76 %), *Borassus flabelliformis* (5.70 %) and *Madhuca latifolia* (5.6%).

Table 7.6 Species-wise Volume of Trees under Agroforestry System in India (Volume in m cum)

Species	Diameter class (cm)				Percentage
	10-30	30-50	50+	Total	
<i>Acacia nilotica (Acacia arabica)</i>	15.881	11.074	2.072	29.03	2.58
<i>Acacia catechu</i>	4.227	0.326	0.019	4.57	0.41
<i>Acacia lenticularis</i>	5.041	2.825	0.495	8.36	0.74
<i>Albizia spp.</i>	3.922	7.309	2.253	13.48	1.20
<i>Anacardium occidentale</i>	4.274	1.068	0.000	5.34	0.48
<i>Areca catechu</i>	7.182	0.140	0.000	7.32	0.65
<i>Artocarpus heterophyllus</i>	8.367	9.534	3.947	21.85	1.94
<i>Azadirachta indica</i>	32.799	28.734	14.449	75.98	6.76
<i>Bombax ceiba</i>	2.923	3.086	3.986	10.00	0.89
<i>Borassus flabelliformis</i>	5.856	55.961	2.303	64.12	5.70
<i>Butea monosperma</i>	12.095	12.016	4.380	28.49	2.53
<i>Cocos nucifera</i>	35.421	24.329	0.325	60.08	5.34
<i>Dalbergia sissoo</i>	10.942	5.672	1.394	18.01	1.60
<i>Eucalyptus sp.</i>	15.087	5.426	0.983	21.50	1.91
<i>Ficus bengalensis</i>	0.424	0.623	13.123	14.17	1.26
<i>Ficus racemosa</i>	0.595	2.700	4.659	7.95	0.71
<i>Ficus religiosa</i>	0.470	1.322	5.787	7.58	0.67
<i>Ficus sp.</i>	1.895	1.555	5.111	8.56	0.76
<i>Gmelina arborea</i>	3.584	1.119	0.603	5.31	0.47
<i>Grevillea robusta</i>	4.294	2.038	1.185	7.52	0.67
<i>Grewia optiva (Grewia oppositifolia)</i>	4.232	0.859	0.112	5.20	0.46
<i>Holoptelea integrifolia</i>	1.878	1.894	0.933	4.71	0.42
<i>Hevea brasiliensis</i>	8.093	0.972	0.000	9.06	0.81
<i>Madhuca longifolia</i>	1.145	5.752	57.046	63.94	5.69
<i>Mangifera indica</i>	18.280	35.585	95.484	149.35	13.29
<i>Phoenix sylvestris</i>	5.203	5.004	0.113	10.32	0.92
<i>Pinus kesiya (Pinus Khasya)</i>	6.684	0.458	0.000	7.14	0.64
<i>Pinus roxburghii (Pinus longifolia)</i>	11.983	14.924	7.488	34.40	3.06
<i>Populus sp.</i>	6.464	1.020	0.005	7.49	0.67
<i>Prosopis cineraria</i>	3.243	4.924	1.413	9.58	0.85
<i>Quercus leucotrichophora (Quercus incana)</i>	2.857	1.766	0.599	5.22	0.46
<i>Shorea robusta</i>	6.548	5.928	9.048	21.52	1.91
<i>Syzygium cumini (Eugenia jambolana)</i>	5.589	6.400	6.761	18.75	1.67
<i>Tamarindus indica</i>	1.551	2.887	8.799	13.24	1.18
<i>Tectona grandis</i>	8.780	1.998	0.488	11.27	1.00

Species	Diameter class (cm)				Percentage
	10-30	30-50	50+	Total	
<i>Terminalia arjuna</i>	1.606	2.755	1.633	5.99	0.53
<i>Terminalia bellerica</i>	0.580	1.145	3.508	5.23	0.47
<i>Terminalia crenulata</i>	2.256	1.781	1.369	5.41	0.48
<i>Toona ciliata (Cedrela toona)</i>	2.725	2.098	0.484	5.31	0.47
<i>Ziziphus mauritiana</i>	6.204	1.990	0.242	8.44	0.75
Rest of species	107.585	83.444	112.293	303.32	26.98
Total	388.766	360.439	374.892	1,124.097	100.00