9.2. Volume

The tree volumes have been divided into "Commercial volume" and "Gross volume" according to measured commercial height and total height of the trees (see Annex XII). However, since the pressure on the natural resources in Bangladesh is very high, it is plausible that not only the "commercial volume", but also the total gross volume will be of significant value to the people of Bangladesh.

The Gross Tree stem Volume has been calculated as : $D_{bh}^2 / 4 * \pi * H_{tot} * \pi * f_{gross}$

Where

D_{bh} = Tree Diameter at breast height
H_{tot} = Tree Total Heigth
π = 3.1416
f_{gross} = 0.5

The Commercial Tree stem Volume has been calculated as : $D_{bh}^2 / 4 * \pi * H_{comm} * f_{comm}$

Where

D_{bh} = Tree Diameter at breast height
H_{comm} = Tree Commercial Heigth
π = 3.1416
f_{gross} = 0.7

The Bamboo Culm Woody Volume has been calculated as : $D_{bh}^2 - (D_{bh}*0.7)^2 / 4 * \pi * H_{length} * f_{bamboo}$

Where

D_{bh} = Bamboo Culm Diameter at breast height
$D_{bh}*0.7$ = Bamboo Culm inner hollow Diameter at breast height
H_{lenght} = Bamboo Culm Total Length
π = 3.1416
f_{bamboo} = 0.8

9.2.1. Tree volumes by major National Land Use Class

In Bangladesh the average gross volume per hectare is 14 m^3 per ha and the average commercial volume is 10 m^3 per ha. "Forest" is the LUC with the highest gross volume per ha, followed by "Villages". However, the commercial volume per ha is about the same for "Forest" and "Villages". "Cultivated land" and "Inland water" have low volumes per ha.

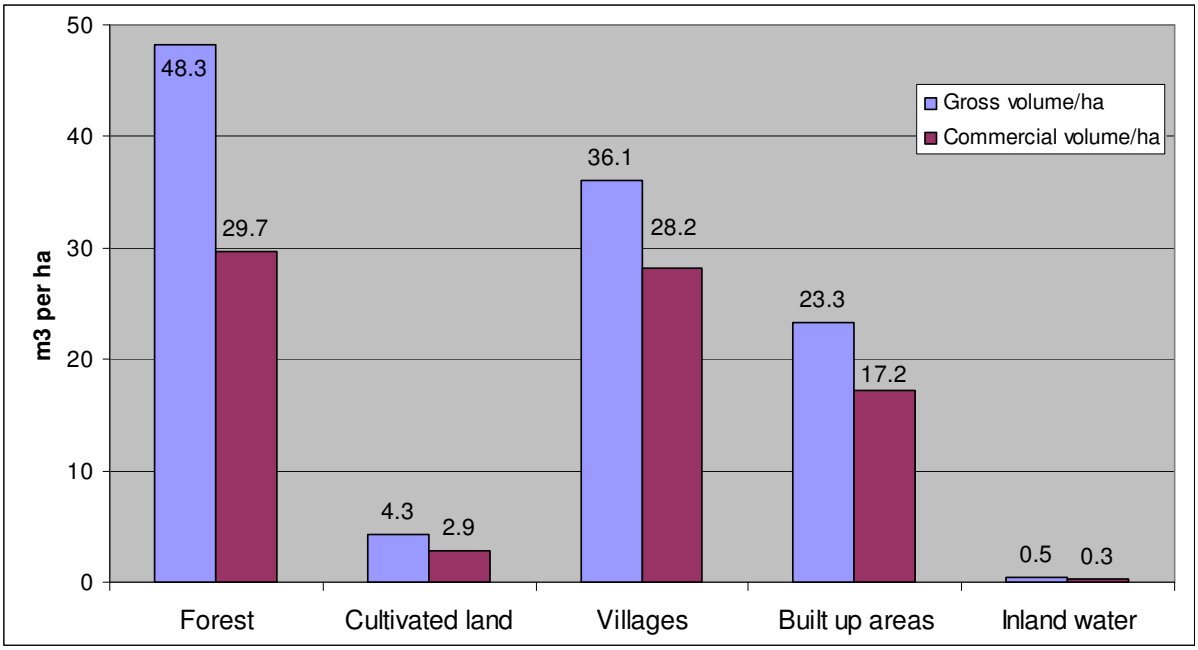

Figure 34: Average gross and commercial volume per hectare for major National LUCs

9.2.2. The total gross and commercial volume for the major National LUCs

In Bangladesh the total gross volume is 212 million m^3 and the total commercial volume is 150 million m^3 as shown in Table 36. Almost 50% of the total gross volume, and more than 50% of the total commercial volume, can be found in "Villages" (Figure 35 and Figure 36). Approximately 1/3 of the gross volume, and less than 30% of the commercial volume, is found in "Forest". "Cultivated land" contains about 17% of the total gross and 16% of the total commercial volume. "Built up areas" and "Inland water" contain low volumes.

Table 36: Total gross and commercial value for major National LUCs (million m^3)

	Forest	Cultivated land	Villages	Built up area	Inland water	Total
Gross volume	70	36	103	2.4	1.0	**212**
Commercial volume	43	24	81	1.8	0.6	**150**

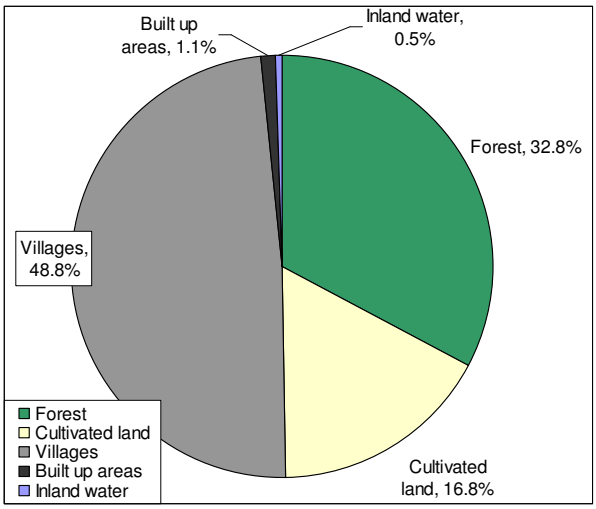

Figure 35: Percentage of total gross volume by major National LUC

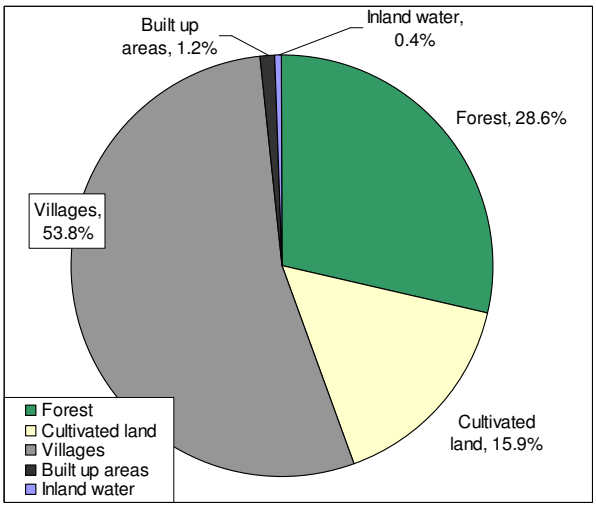

Figure 36: Percentage of total commercial volume by major National LUC

9.2.3. The total gross and commercial volume for the different forest types

Out of the total gross volume in "Forest" about 1/3 can be found in the Hill forest, 1/3 in the Bamboo forest and almost 1/3 in the Mangrove forest. The volume in plantations is representing less than 3% of the total gross volume in "Forest".

Out of the commercial volume almost 30% will be found in Hill forest, almost 30% on Bamboo forest and almost 40% in Mangrove forest. The volume in plantations constitutes less than 3% of the total commercial volume in "Forest".

Table 37: Total gross and commercial volume by forest type (million m3)

	Hill Forest	Mangrove Forest	Bamboo Forest	Long Rot. Plantation	Short Rot. Plantation
Gross volume	23	21	23	1.4	0.5
Commercial volume	12	16	13	0.8	0.3

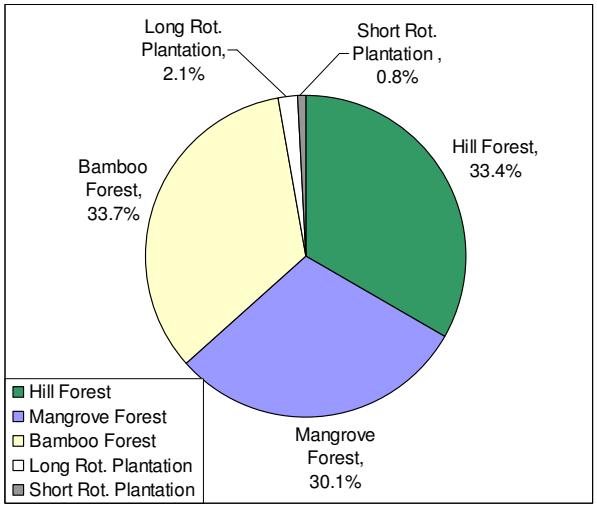

Figure 37: Total gross volume by forest type (%)

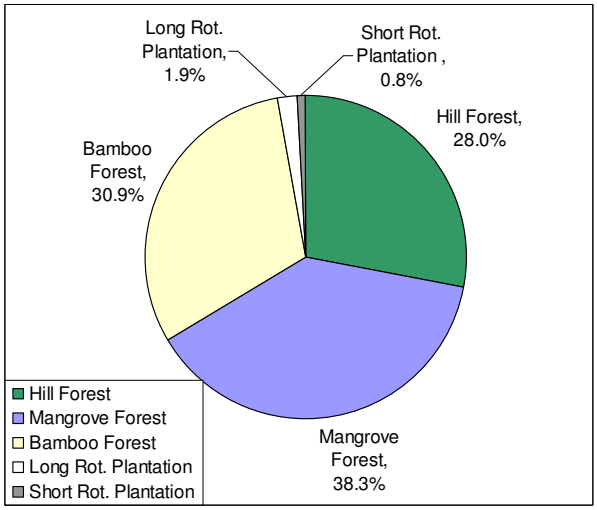

Figure 38: Total commercial volume by forest type (%)

9.2.4. The gross and commercial volume per hectare for the different forest types

Bamboo forest has the highest gross and commercial volumes per hectare. Mangrove forest and Hill forest have significantly lower gross and commercial volumes per hectare. The plantations in general have low tree volumes.

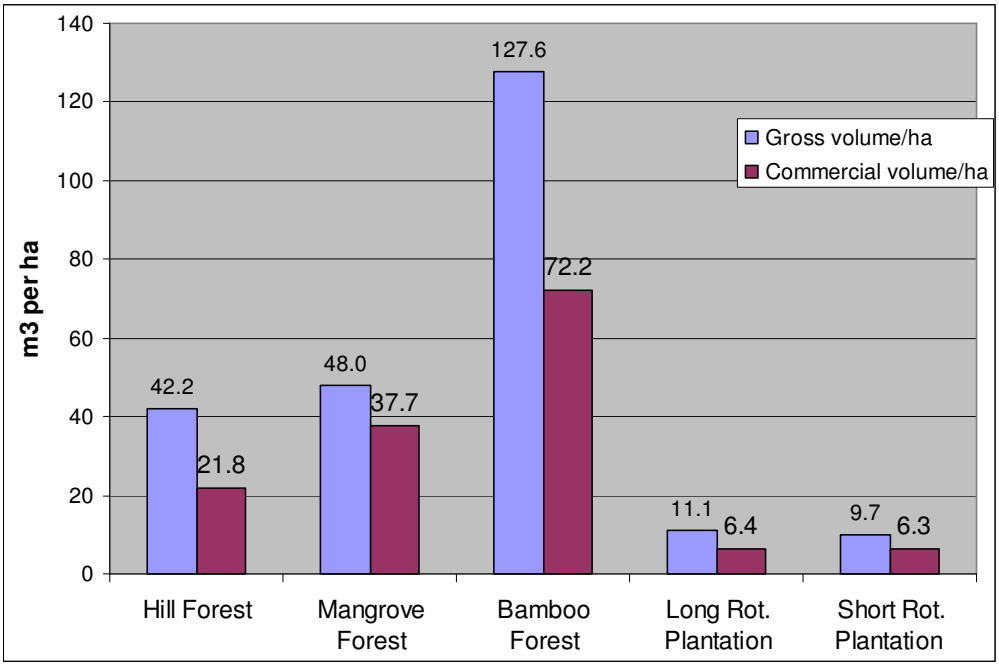

Figure 39: Average gross and commercial volume per hectare by forest type

9.2.5. The total gross volume of Bamboo in the major National LUCs

The total gross volume of bamboo in Bangladesh is 22,8 million m3. From this volume about 66% can be found in “Villages”, 16% in “Forest” and 17% in “Cultivated land”. The average number of culms per clump is 41.

Table 38: Bamboo Culm Volume ('000 m^3) in Major Land Use Class

	Forest	Cultivated Area	Villages	Built-up Area	Inland Water	Total
Number of culms (M)	2,043	2,215	3,074	2	22	7,200
Volume per hectare	1,417	266	1,074	22	11	488
Volume* ('000m^3)	**3,716**	**3,831**	**15,125**	**2**	**156**	**22,829**
% of Total Volume	16%	17%	66%	0.01%	0.7%	100%

*Total Bamboo Culm Volume = $(D_{bh}^2-D_{bh}*(d/D)^2)*pi*H_{avg}*f_{form}*n_{culms}/4000$

9.2.6. Tree volumes for the most common tree species

The 20 tree species presented in Figure 40 represent more than 75% of the total gross volume in Bangladesh. The most common species (according to volume) are *Cocos nucifera*, *Samanea saman* and *Mangifera indica*.

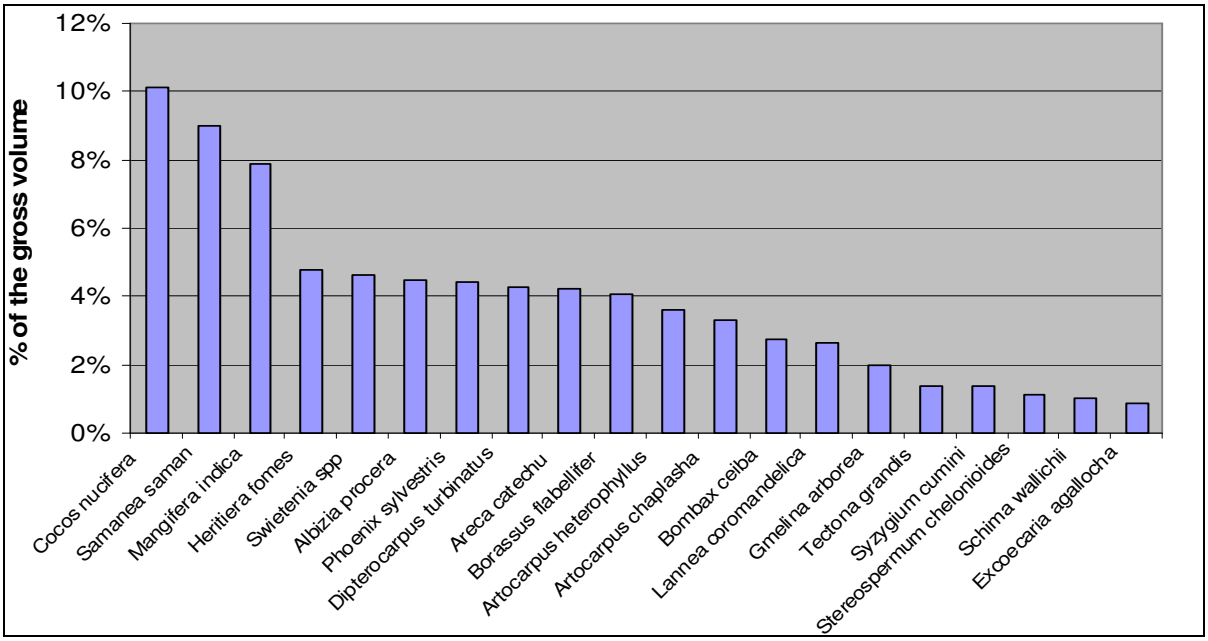

Figure 40: Percentage of total gross volume per species

9.2.7. Volume proportions of the total gross volume by tree species in "Forest"

The 15 species listed in Figure 41 represent 70% of the total tree volume in "Forest". The most common species in "Forest" are *Heritiera fomes* and *Dipterocarpus turbinatus*, representing together 25% of the total gross volume in Forest. Other important species are *Gmelina arborea, Albizia procera* and *Lannea coromandelica.*

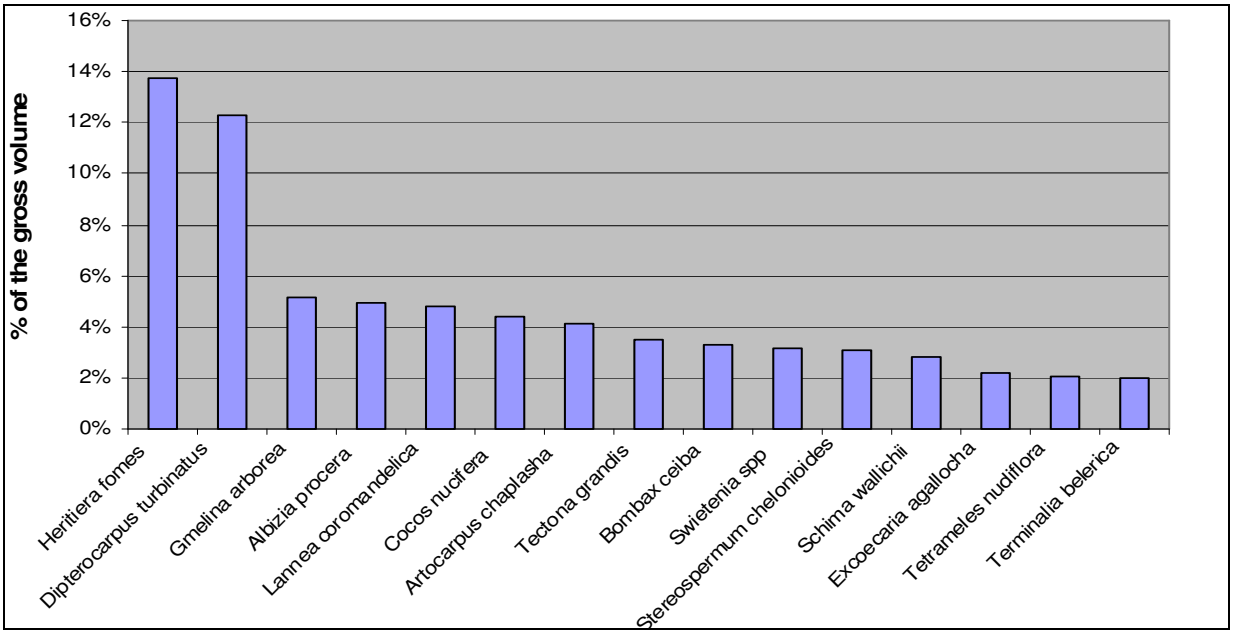

Figure 41: Percentage of total gross volume in "Forest" per species

9.2.8. Volume proportions of the total gross volume by tree species in "Cultivated land"

The 15 species listed in Figure 42 represent over 80% of the total tree volume in "Cultivated land". The four most common species (*Phoenix sylvestris, Samanea saman, Borassus flabellifer* and *Mangifera indica*) represent 50% of the gross volume in the "Cultivated land".

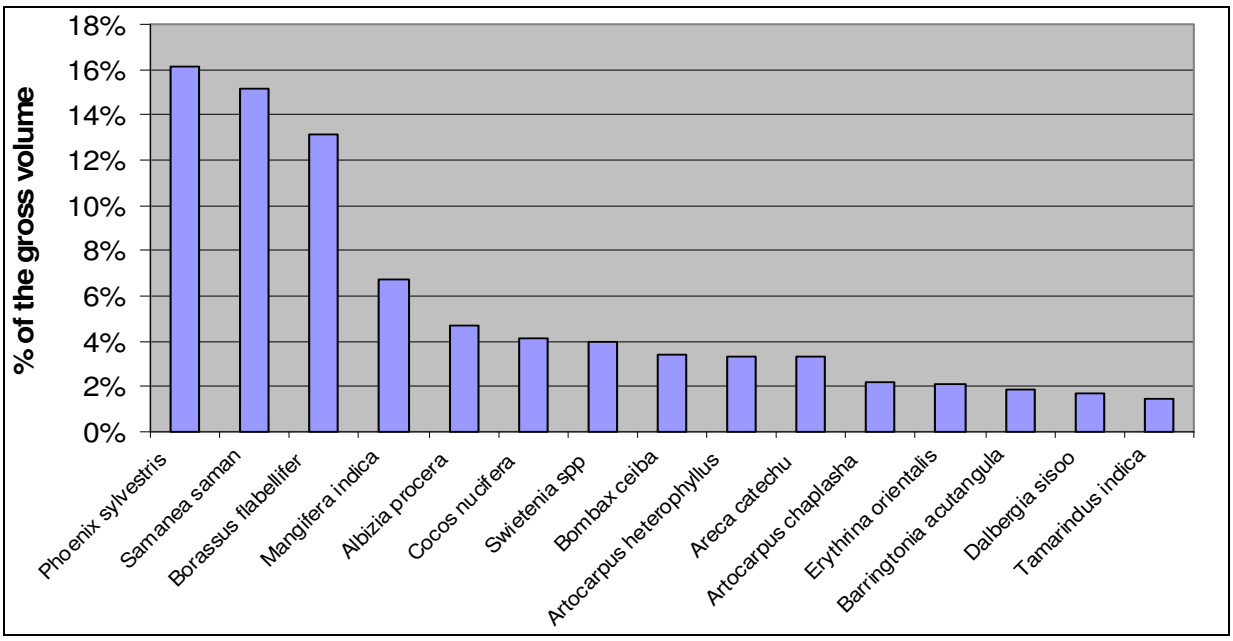

Figure 42: Percentage of total gross volume in "Cultivated land" per species

9.2.9. Volume proportions of the total gross volume by tree species in "Villages"

The 15 species listed in Figure 43 represent over 80% of the total tree volume in "Villages". The 4 most common species (*Cocos nucifera, Samanea saman, Mangifera indica* and *Areca catechu*) represent almost 50% of the gross volume in "Villages".

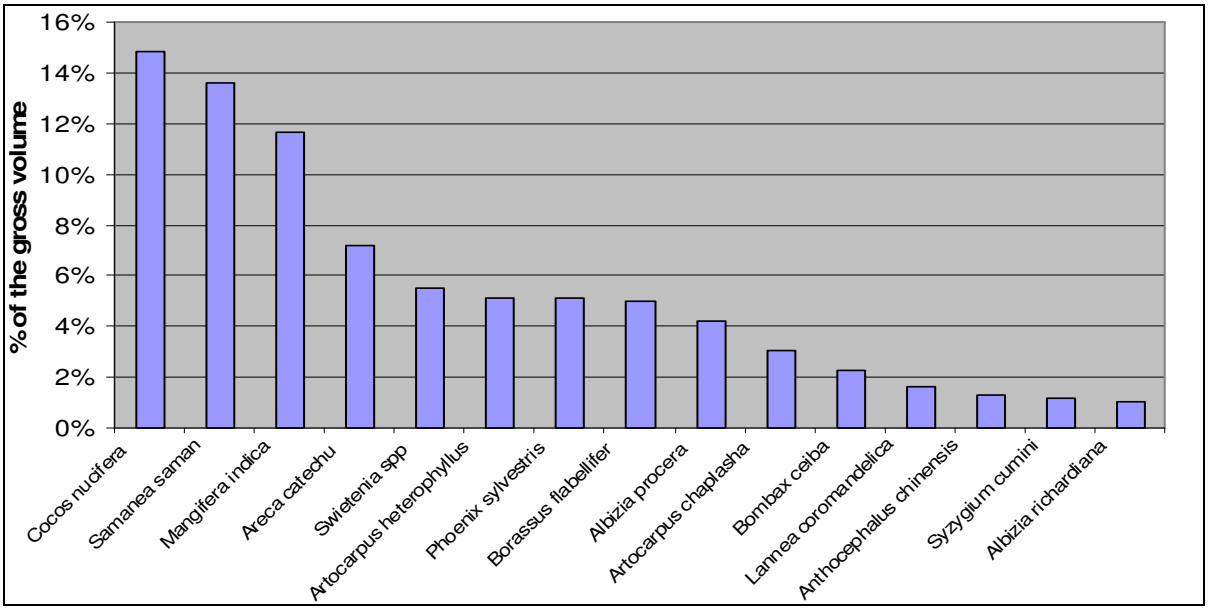

Figure 43: Percentage of total gross volume in "Villages" per species

9.2.10. Volume proportions of the total gross volume by tree species in "Built up areas"

The most common tree in "Built up areas" is *Swietenia spp*. with almost 25% of total volume. Other species contributing to total volume in "Built up areas" area are *Cocos nucifera* and Mangifera indica).

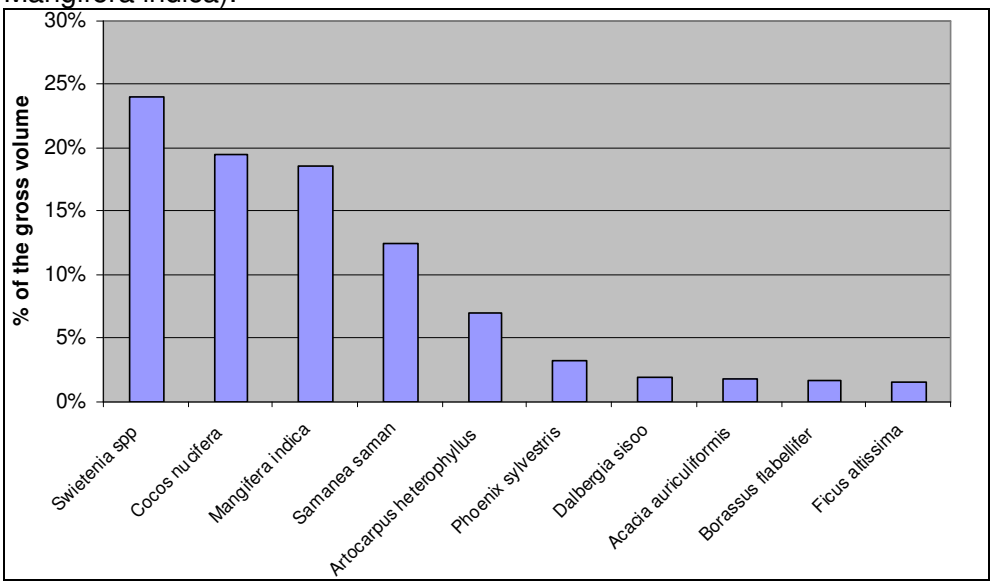

Figure 44: Percentage of total gross volume in "Built up areas" per species

9.2.11. Volume proportions of the total gross volume by tree species in "Inland water"

The most common species in "Inland water" is *Mangifera indica* representing over 18% of total volume in Inland water area.

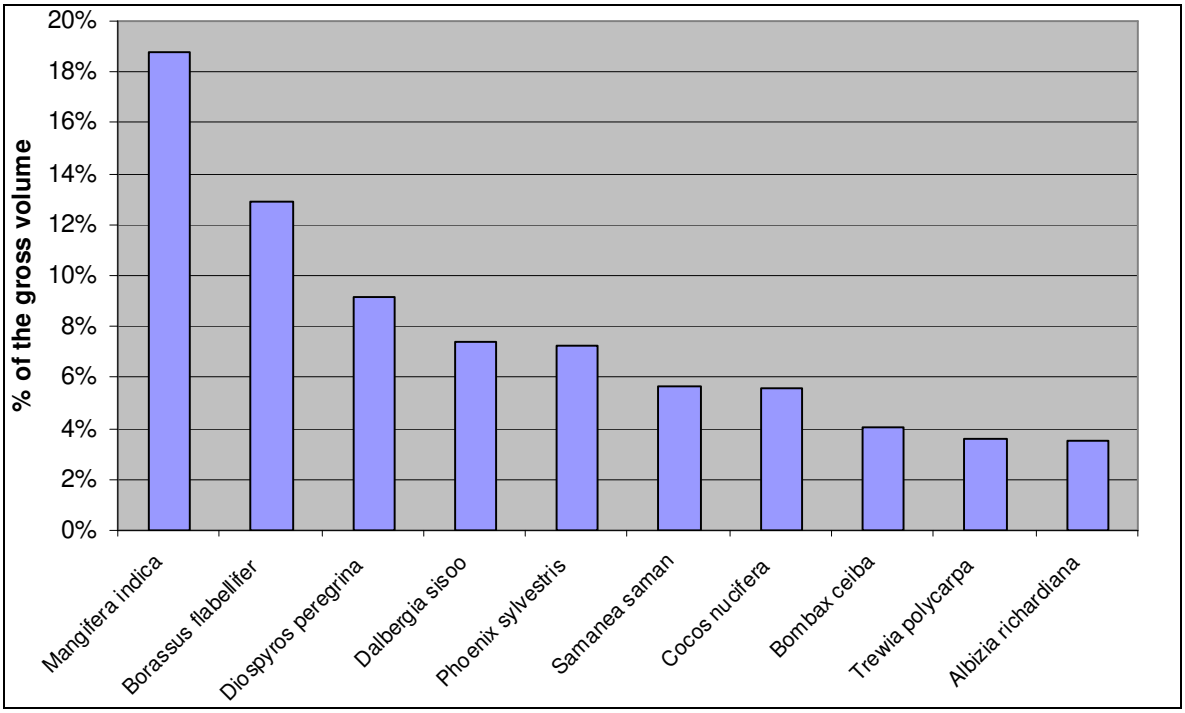

Figure 45: Percentage of total gross volume in "Inland water" per species

9.2.12. Tree volumes per Global-ecological zones (GEZs)

The volume per hectare in Tar is higher for all the different major National Land Use Classes (except "Inland water"). The average gross volume for the geo-ecological zone TAR is almost 20 m^3 per hectare. For Tawa the average volume is less than 12 m^3 per hectare.

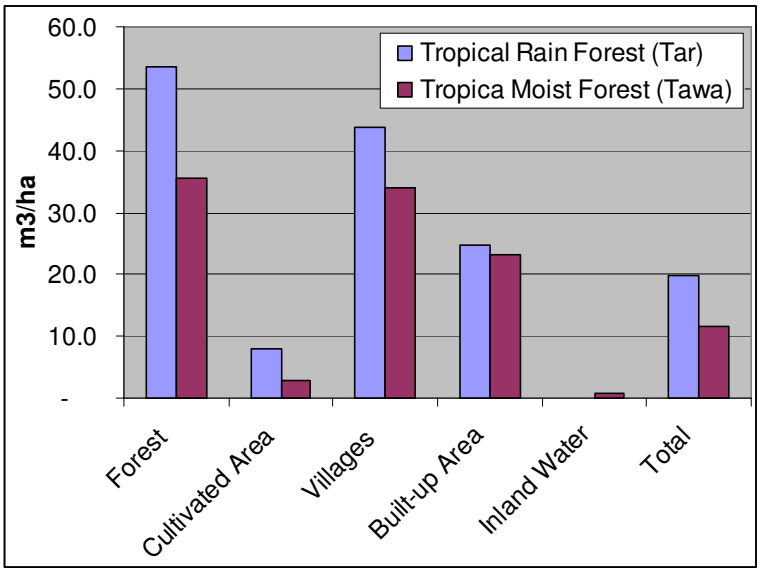

Figure 46: Gross volume per hectare for the Geo-ecological zones by major National LUC

9.2.13. Volume and stems per hectare by Dbh-class

For the total area of Bangladesh the average tree volume per hectare is 14 m^3. More than 75% of this volume can be found in trees with a Dbh smaller than 50 cm, and almost 50% of the tree volume in trees with a Dbh 20-40 cm.

The total area of Bangladesh has on average 68 stems per hectare (>10 cm). 85% of these stems have a Dbh 10-30 cm and only 5% of these stems have a Dbh >40 cm.

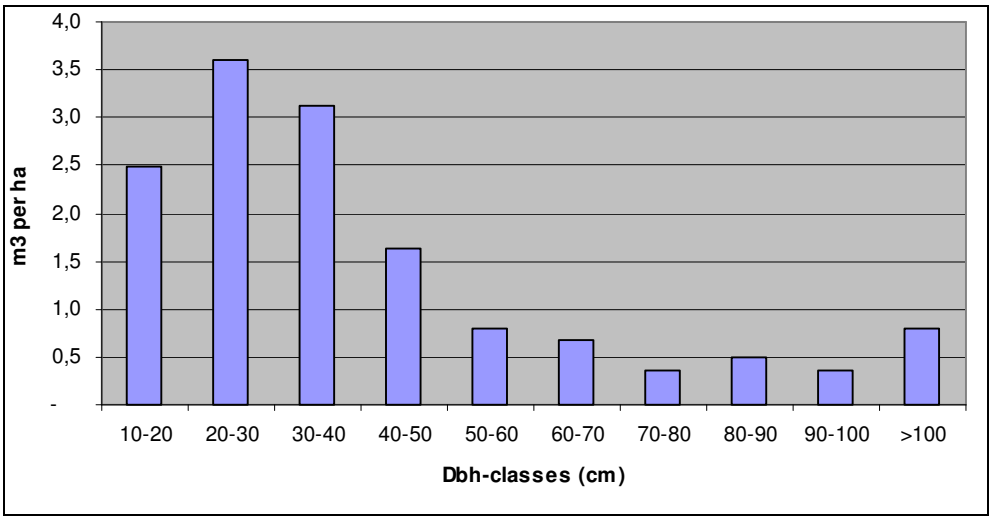

Figure 47: Gross volume per hectare by Dbh class over total area of Bangladesh

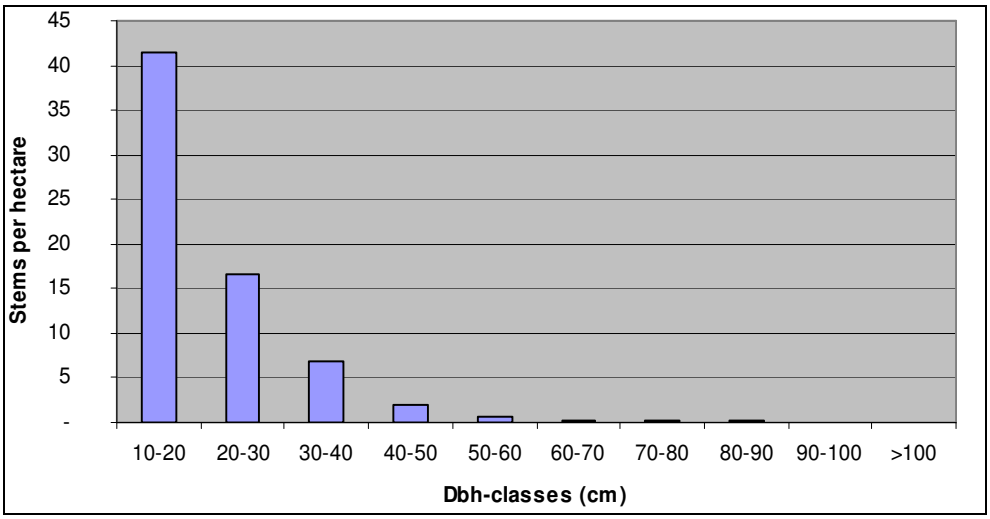

Figure 48: Stems per hectare by Dbh class over total area of Bangladesh

9.2.14. Gross volume and stems per hectare per Dbh-class for the major National Land Use Classes

The tree volume in “Villages” is concentrated to the lower Dbh-classes and more than 50 percent of the volume is found in the Dbh-classes10-30 cm. In “Cultivated land” and “Forest” the volume is more evenly distributed in relation to Dbh-class. The same applies to “Built-up areas” and “Inland Water” but in these land uses the higher Dbh-classes (>80 cm) do not contain significant tree volumes.

The average number of stems per hectare in "Forest" is 184 and almost 90% of these stems have a Dbh 10-30 cm. In "Villages" the average number of stems per hectare is over 210 and over 90% of these stems have a Dbh 10-30 cm. In "Cultivated land" the average number of stems per hectare is only 15. In "Built up areas" the average number of stems per hectare is 130 and almost entirely concentrated in the Dbh-classes 10-40 cm. In "Inland water" the average number of stems per hectare is less than 3.

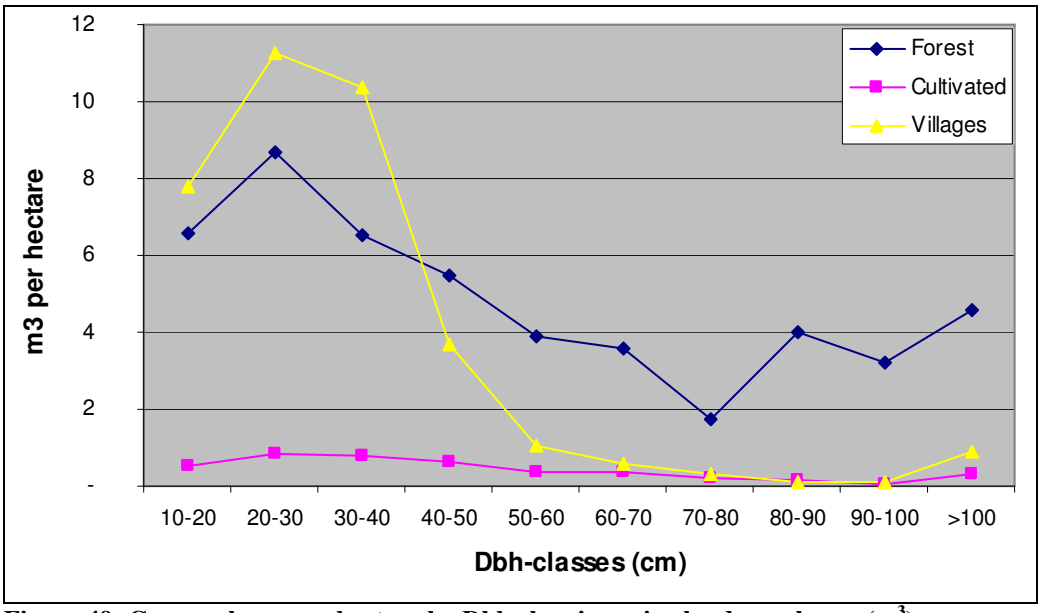

Figure 49: Gross volume per hectare by Dbh class in major land use classes (m^3)

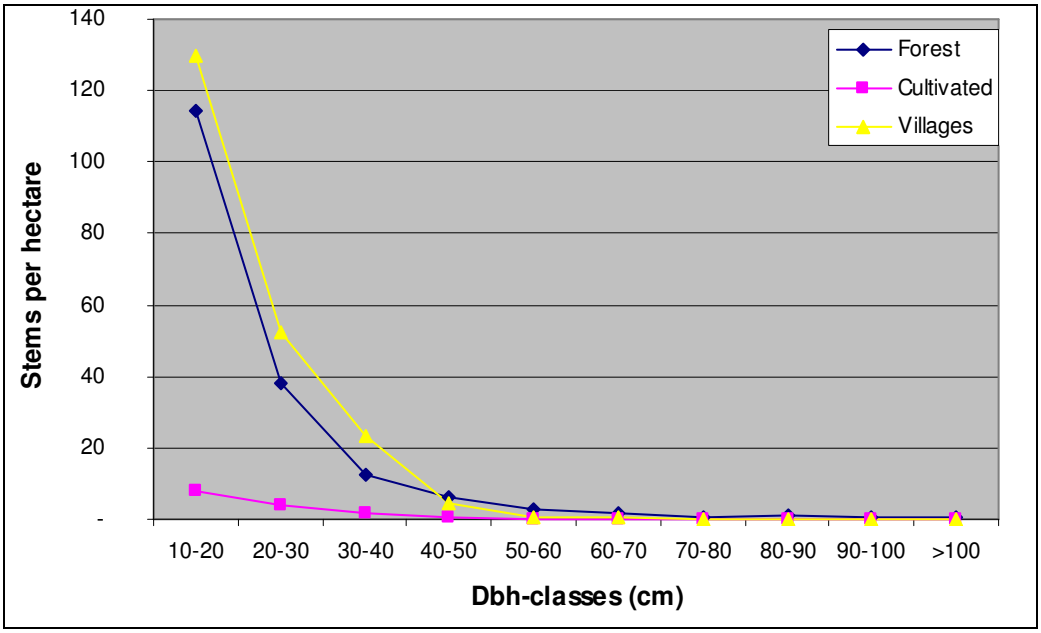

Figure 50: Stems per hectare by Dbh class in major land use classes

9.2.15. Gross volume and stems per hectare per Dbh-class for the different forest types

In Mangrove forest the volume is concentrated to the Dbh-classes 10-40 cm. In Hill forest the volume is more evenly distributed among the Dbh-classes. However, the Dbh-classes 20-50 cm have the highest volume per hectare. For Broad-leaved/Bamboo forest the tree volume

per hectare is primarily concentrated in the lower Dbh classes and tends to decrease with increasing Dbh. The same applies to Plantations, with hardly any volume in the high Dbh classes.

Mangrove forest have nearly 400 stems per hectare with a Dbh >10 cm. Almost all the stems can be found in the Dbh-classes 10-30 cm. Mixed Broadleaved/Bamboo forest have slightly over 100 tree stems per hectare and Hill Forest less than 100 stems per hectare. For Mixed Broadleaved/Bamboo forest more than 75 percent of the tree stems have a Dbh smaller than 40 cm, however it is the forest type with most even tree distribution among the diameter classes. In Hill forest 73% of the trees have a Dbh of <30 cm. In the plantations the majority of the stems can be found in the lower Dbh-classes.

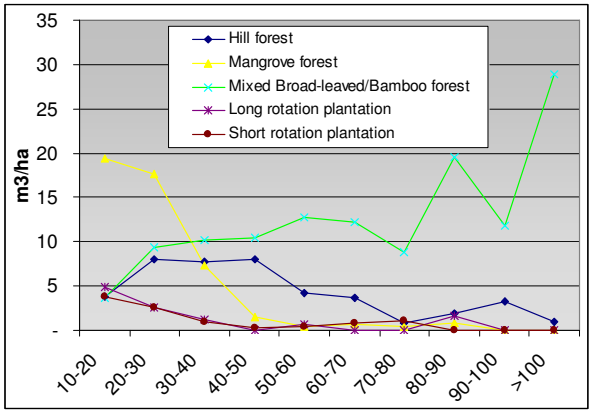

Figure 51: Gross tree volume per hectare by Diameter class in different forest types

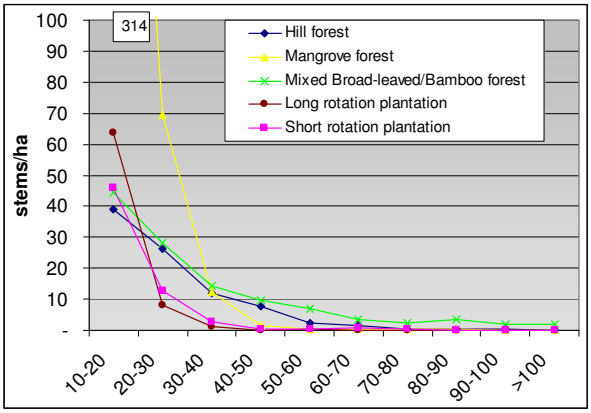

Figure 52: Stems per hectare by Diameter class in different forest types

9.2.16. Volume by stem quality class by major LUC

For all LUCs the majority (over 90%) of the Gross volume belongs to the High stem quality class as indicated in Table 39.

Table 39: Gross volume (1000 m^3) by stem quality class and major National LUC

Land Use	Stem Quality class			
	Total vol.	Low	Medium	High
Forest	69,563	1,026	2,478	66,060
Cultivated land	35,611	717	671	34,224
Villages	103,390	1,092	2,100	100,197
Built-up area	2,417	-	132	2,285
Inland water	1,038	71	64	903
Tot	***212,019***	***2,905***	***5,445***	***203,669***

* Represented by inventoried land uses

9.2.17. Gross volume by stem quality class per forest type

In all forest types, the majority of the volume belongs to the high stem quality class with percentages over 90%. For Mangroves the percentage of high stem quality volume is 80%.

Table 40: Gross volume (1000 m^3) by stem quality class and Forest Type

Land Use	Stem Quality class			
	Total vol.	Low	Medium	High
Hill forests	**23,232**	15	298	22,920
Sal forest	**-**	-	-	-
Mangrove forests	**20,911**	618	3,511	16,783
Bamboo forests	**23,447**	741	164	22,542
Long rotation	**1,445**	4	71	1,371
Short rotation	***527***	*2*	*26*	*499*

9.2.18. Commercial volume for the most important timber species for the major National Land Use Classes in Bangladesh

The commercial tree volume for the 25 most common species in each major land use class is presented in the following five tables beginning with Table 41.

In the whole of Bangladesh ten species make up almost 50 percent of the total commercial tree stem volume. Ordered by volume contribution they are: *Cocos nucifera, Samanea saman, Mangifera indica, Dipterocarpus turbinatus, Swietenia spp, Albizia procera, Areca catechu, Heritiera fomes*.

Between 8 and 15 species make up more than 50 percent of the commercial volume in each major land use class. In villages, Built-up areas and Inland water LUCs more than 25 percent of the commercial volume is made up by 2 to 3 tree species, while in Forest and Cultivated areas 4 to 6 tree species make up more than 25 percent of the commercial volume.

For more detailed and complete information on commercial tree volume by tree species and major land use class, please refer to Annex VIII.

Table 41, 42 and 43: Commercial volume of the 25 most important species in the LUC Forest, Cultivated land and Villages

Forests			
Species	**Total (1000 m^3)**	**(m^3/ha)**	**% of tot. comm. vol.**
Heritiera fomes	8,296	5.8	19.2
Dipterocarpus turbinatus	4,895	3.4	11.3
Gmelina arborea	2,432	1.7	5.6
Albizia procera	2,074	1.4	4.8
Lannea coromandelica	2,047	1.4	4.7
Cocos nucifera	1,961	1.4	4.5
Bombax ceiba	1,751	1.2	4.0
Tectona grandis	1,671	1.2	3.9
Artocarpus chaplasha	1,657	1.1	3.8
Swietenia spp	1,331	0.9	3.1
Excoecaria agallocha	1,270	0.9	2.9
Stereospermum chelonioides	1,227	0.9	2.8
Schima wallichii	1,216	0.8	2.8
Tetrameles nudiflora	952	0.7	2.2
Mangifera indica	846	0.6	2.0
Terminalia belerica	710	0.5	1.6
Duabanga grandiflora	658	0.5	1.5
Avicennia officinalis	655	0.5	1.5
Syzygium cumini	624	0.4	1.4
Xylocarpus mekengensis	483	0.3	1.1
Syzygium grandis	470	0.3	1.1
Amaranthus tricolor	448	0.3	1.0
Artocarpus heterophyllus	428	0.3	1.0
Lagerstroemia speciosa	425	0.3	1.0
Michelia champca	352	0.2	0.8

Cultivated land			
Species	**Total (1000 m^3)**	**(m^3/ha)**	**% of tot. comm. vol.**
Borassus flabellifer	2,316	0.3	10.1
Samanea saman	2,063	0.2	9.0
Dipterocarpus turbinatus	2,046	0.2	9.0
Phoenix sylvestris	1,897	0.2	8.3
Artocarpus chaplasha	1,234	0.1	5.4
Albizia procera	1,082	0.1	4.7
Cocos nucifera	771	0.1	3.4
Areca catechu	733	0.1	3.2
Swietenia spp	687	0.1	3.0
Gomphrena globosa	646	0.1	2.8
Mangifera indica	577	0.1	2.5
Bombax ceiba	524	0.1	2.3
Barringtonia acutangula	439	0.1	1.9
Syzygium cumini	410	0.05	1.8
Others	402	0.05	1.8
Lannea coromandelica	398	0.05	1.7
Artocarpus heterophyllus	349	0.04	1.5
Gmelina arborea	319	0.04	1.4
Dalbergia sisoo	258	0.03	1.1
Bouea oppositifolia	254	0.03	1.1
Terminalia belerica	253	0.03	1.1
Erythrina orientalis	234	0.03	1.0
Drimycarpus racemosus	233	0.03	1.0
Tectona grandis	219	0.03	1.0
Lagerstroemia speciosa	205	0.02	0.9

Villages			
Species	**Total (1000 m^3)**	**(m^3/ha)**	**% of tot. comm. vol**
Cocos nucifera	14,700	5.1	18.2
Samanea saman	9,961	3.5	12.4
Areca catechu	8,144	2.8	10.1
Mangifera indica	7,026	2.5	8.7
Borassus flabellifer	5,104	1.8	6.3
Phoenix sylvestris	4,898	1.7	6.1
Swietenia spp	4,059	1.4	5.0
Artocarpus heterophyllus	3,180	1.1	3.9
Albizia procera	2,502	0.9	3.1
Artocarpus chaplasha	2,380	0.8	3.0
Bombax ceiba	2,045	0.7	2.5
Anthocephalus chinensis	1,207	0.4	1.5
Lannea coromandelica	1,162	0.4	1.4
Albizia richardiana	903	0.3	1.1
Syzygium cumini	839	0.3	1.0
Eucalyptus camaldulensis	622	0.2	0.8
Terminalia catappa	604	0.2	0.7
Diospyros peregrina	540	0.2	0.7
Zizyphus mauritiana	539	0.2	0.7
Trewia polycarpa	531	0.2	0.7
Ficus benjamin	530	0.2	0.7
Dalbergia sisoo	478	0.2	0.6
Erythrina orientalis	453	0.2	0.6
Tamarindus indica	436	0.2	0.5
Azadirachta indica	383	0.1	0.5

Table 44 and 45: Commercial volume of the 25 most important species in the LUC Built up areas and Inland water

Built-up			
Species	**Total (1000 m^3)**	**(m^3/ha)**	**% of tot. comm. vol.**
Cocos nucifera	435	4.2	24.0
Swietenia spp	412	4.0	22.7
Mangifera indica	352	3.4	19.4
Samanea saman	183	1.8	10.1
Artocarpus heterophyllus	104	1.0	5.8
Phoenix sylvestris	79.4	0.8	4.4
Borassus flabellifer	47.3	0.5	2.6
Dalbergia sisoo	32.8	0.3	1.8
Acacia auriculiformis	31.1	0.3	1.7
Zizyphus mauritiana	29.3	0.3	1.6
Syzygium cumini	21.2	0.2	1.2
Acacia nilotica	15.2	0.1	0.8
Trewia polycarpa	13.9	0.1	0.8
Moringa oleifera	9.9	0.1	0.5
Ficus altissima	7.5	0.1	0.4
Erythrina orientalis	6.5	0.1	0.4
Annona squamosa	6.2	0.1	0.3
Gmelina arborea	4.9	0.05	0.3
Syzygium samarangense	3.5	0.03	0.2
Psidium guajava	3.1	0.03	0.2
Eucalyptus camaldulensis	3.1	0.03	0.2
Diospyros peregrina	2.8	0.03	0.2
Ficus hispida	2.3	0.02	0.1
Melia sempervirens	2.0	0.02	0.1
Azadirachta indica	1.5	0.01	0.1

Inland Water			
Species	**Total (1000 m^3)**	**(m^3/ha)**	**% of tot. comm. vol.**
Mangifera indica	99.0	0.05	15.1
Borassus flabellifer	96.3	0.05	14.7
Phoenix sylvestris	58.1	0.03	8.9
Cocos nucifera	57.2	0.03	8.7
Diospyros peregrina	53.4	0.03	8.2
Dalbergia sisoo	51.5	0.03	7.9
Samanea saman	42.8	0.02	6.5
Albizia richardiana	23.9	0.01	3.6
Bombax ceiba	23.3	0.01	3.6
Trewia polycarpa	21.8	0.01	3.3
Tectona grandis	19.8	0.01	3.0
Albizia procera	18.3	0.01	2.8
Artocarpus heterophyllus	14.7	0.01	2.3
Ochna squarrosa	10.5	0.01	1.6
Swietenia spp	8.9	0.004	1.4
Moringa oleifera	7.0	0.003	1.1
Syzygium cumini	6.2	0.003	1.0
Acacia nilotica	5.9	0.003	0.9
Zizyphus mauritiana	5.8	0.003	0.9
Lannea coromandelica	5.4	0.003	0.8
Azadirachta indica	4.9	0.002	0.8
Others	4.2	0.002	0.6
Tamarindus indica	3.4	0.002	0.5
Erythrina orientalis	3.2	0.002	0.5
Alstonia scholaris	2.3	0.001	0.3

9.2.19. Commercial volume per Dbh-class for the most important timber species for the total area of Bangladesh

Table 46: Commercial volume per diameter class in Bangladesh (1000 m^3)

Tree species	Total	DBH 15	DBH 25	DBH 35	DBH 45	DBH 55	DBH 65	DBH 75	DBH 85	DBH 95	DBH ≥100
Cocos nucifera	17,925	165	6,312	8,973	827	400	331	162	254	360	143
Samanea saman	12,276	1,205	3,406	3,782	2,253	773	414	65	-	-	378
Mangifera indica	8,899	1,209	2,724	2,535	1,131	509	548	172	72	-	-
Areca catechu	8,882	8,558	177	136	11	-	-	-	-	-	-
Heritiera fomes	8,301	2,910	3,760	1,528	103	-	-	-	-	-	-
Borassus flabellifer	7,571	19	253	2,738	3,734	805	23	-	-	-	-
Dipterocarpus turbinatus	6,978	17	63	106	219	546	1,081	686	1,172	757	2,330
Phoenix sylvestris	6,942	124	3,002	3,167	337	221	25	65	-	-	-
Swietenia spp	6,498	1,784	2,232	1,094	421	245	62	41	163	353	102
Albizia procera	5,676	589	1,905	1,479	583	419	317	285	98	-	-
Artocarpus chaplasha	5,272	330	1,611	1,116	246	198	247	394	383	191	556
Bombax ceiba	4,343	332	764	939	568	384	356	25	264	119	593
Artocarpus heterophyllus	4,077	1,010	1,536	1,030	367	84	19	-	30	-	-
Lannea coromandelica	3,612	813	828	434	417	216	41	199	115	300	250
Gmelina arborea	2,969	352	605	411	72	95	115	106	249	-	963
Tectona grandis	2,078	457	494	229	206	178	146	115	254	-	-
Syzygium cumini	1,901	326	535	367	500	162	10	-	-	-	-
Anthocephalus chinensis	1,453	388	631	197	69	16	86	66	-	-	-
Stereospermum chelonioides	1,442	83	319	300	216	294	159	-	71	-	-
Excoecaria agallocha	1,383	1,096	178	76	33	-	-	-	-	-	-
Schima wallichii	1,242	110	276	283	322	17	-	234	-	-	-
Albizia richardiana	1,131	225	363	443	80	21	-	-	-	-	-
Trewia polycarpa	987	98	192	315	167	104	-	-	-	-	111
Terminalia belerica	977	30	31	133	13	100	223	-	355	-	93
Tetrameles nudiflora	959	3	3	10	153	182	326	40	153	88	-

9.2.20. Commercial volume per stem quality class for the most important timber species for the total area of Bangladesh

Table 47: Commercial volume per stem quality class in Bangladesh (1000 m^3)

Tree species	Total	Low	Medium	High
Cocos nucifera	17,925	63	114	17,747
Samanea saman	12,276	7	68	12,201
Mangifera indica	8,899	19	148	8,732
Areca catechu	8,882	13	26	8,843
Heritiera fomes	8,301	110	1,335	6,855
Borassus flabellifer	7,571	4	85	7,482
Dipterocarpus turbinatus	6,978	181	-	6,797
Phoenix sylvestris	6,942	34	94	6,815
Swietenia spp	6,498	7	29	6,462
Albizia procera	5,676	12	41	5,623
Artocarpus chaplasha	5,272	9	11	5,252
Bombax ceiba	4,343	2	17	4,324
Artocarpus heterophyllus	4,077	27	120	3,930
Lannea coromandelica	3,612	28	45	3,539
Gmelina arborea	2,969	3	5	2,960
Tectona grandis	2,078	0	31	2,048
Syzygium cumini	1,901	4	14	1,882
Anthocephalus chinensis	1,453	-	2	1,451
Stereospermum chelonioides	1,442	-	6	1,436
Excoecaria agallocha	1,383	19	63	1,301
Schima wallichii	1,242	2	2	1,237
Albizia richardiana	1,131	3	16	1,112
Trewia polycarpa	987	10	18	959
Terminalia belerica	977	1	-	977
Tetrameles nudiflora	959	40	-	919

9.2.21. Gross volume in Major LUCs by health class

As shown in Table 48, 95 % of total gross volume is healthy in all LUCs. Forest and Villages contain patches of slightly affected trees in small percentages of the total as shown also in Figure 53 on a per hectare basis.

Table 48: Gross volume in major LUCs by health class (1000 m^3)

Land Use	Healthy	Slightly affected	Severely affected	Dead standing	Dead lying	Total
Total	**203,296**	**6,355**	**1,089**	**1,202**	**78**	**212,019**
Forest	65,185	3,036	411	875	56	**69,563**
Cultivated	34,698	743	37	132	1	**35,611**
Villages	100,173	2,428	576	193	21	**103,390**
Built-up areas	2,280	133	4	-	-	**2,417**
Inland Water	960	15	62	2	-	**1,038**

* Represented by inventoried land uses

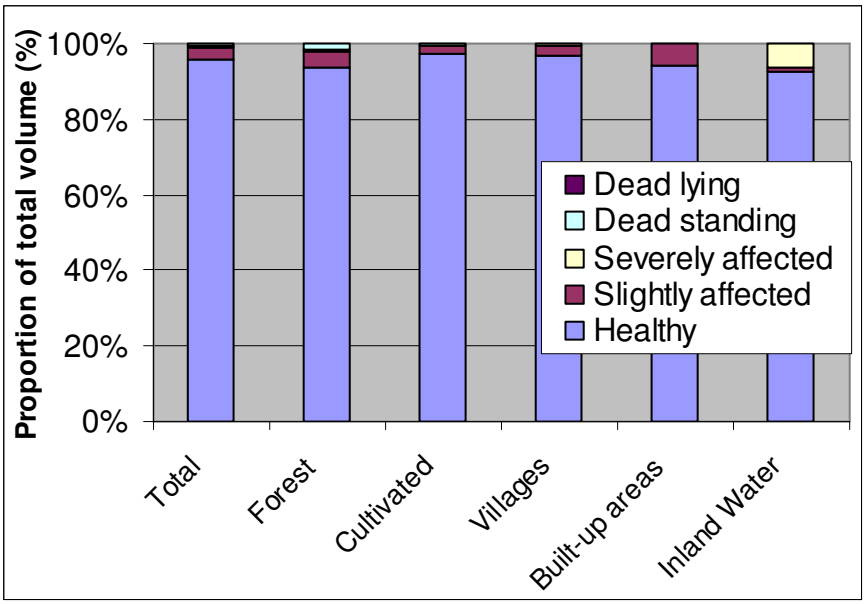

Figure 53: Gross volume per hectare in major LUCs by health class

9.2.22. Gross volume in major LUCs by Health affecting agents

Over all LUCs, about 30% of the total affected volume is due to disease and fungi. Insects, Climate and Humans are the causative agents of slightly over 20% each. Proportions are shown in Figure 54 while total volume in Table 49: Gross volume (1000 m^3) in Major LUCs by health affecting agent.

Table 49: Gross volume (1000 m^3) in Major LUCs by health affecting agent

Land Use	Insects	Disease/ Fungi	Fire	Animals	Climate	Humans	Total
Total	**2,016**	**3,545**	**769**	**44**	**1,052**	**1,065**	**8,491**
Forest	1,157	2,333	688	-	49	37	**4,264**
Cultivated	55	478	50	-	195	58	**836**
Villages	804	659	32	35	778	904	**3,211**
Built-up areas	-	67	-	10	23	-	**100**
Inland Water	-	7	-	-	8	66	**80**

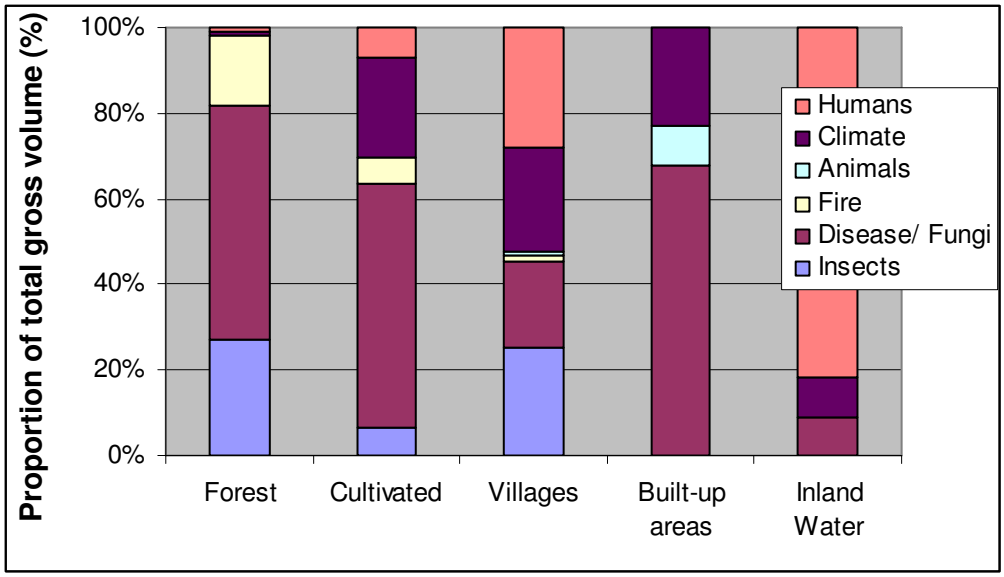

Figure 54: Proportion of gross volume in major LUCs by Health affecting agents (%)

9.2.23. Gross volume in each forest type by health class

Among all forest types, about 94% of total volume is healthy and only 4% is slightly affected. About 2/3 of the 'slightly affected' volume is within Mangrove forests which is also the only forest type with severely affected volume. Bamboo is the only class containing dead standing volume. Total volumes and proportions are presented in Table 50 and Figure 55.

Table 50: Gross volume (1000 m^3) in Forest types by health class

Forest Type	Healthy	Slightly affected	Severely affected	Dead standing	Dead lying	Total
FH	23,133	99	0	0	0	**23,232**
FM	17,634	2,681	399	141	56	**20,911**
FB	22,548	164	11	724	0	**23,447**
PL	1,371	67	0	8	0	**1,445**
PS	499	26	0	2	0	**527**
PM	0	0	0	0	0	**0**
Sum	**65,185**	**3,036**	**411**	**875**	**56**	**69,563**

* Represented by inventoried forest types

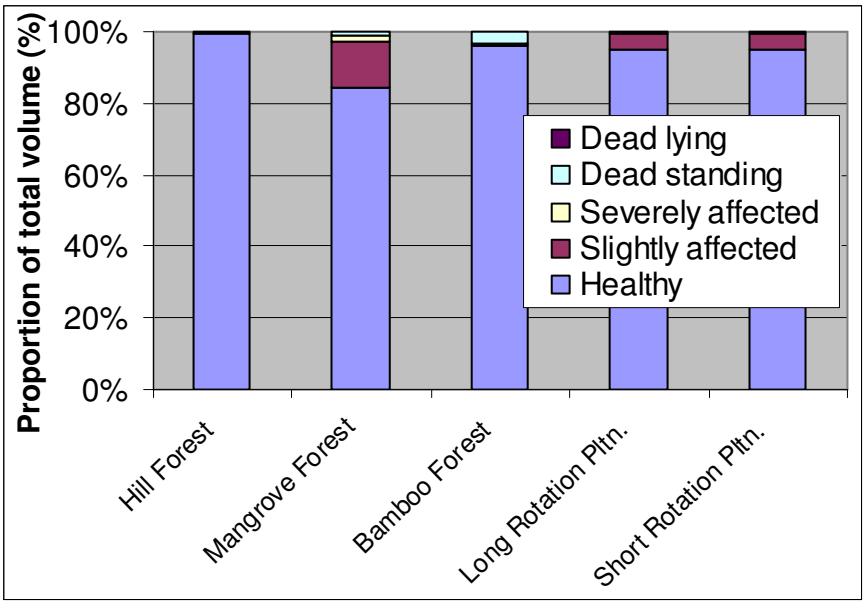

Figure 55: Gross volume per hectare in forest types by health class

9.2.24. Gross volume in major forest types by Health affecting agents

Diseases and fungi constitute 55% of the causing agents affecting tree health over the total forest volume. Insects (27%) and Fire (16%) are the other most relevant affecting agents. Mangrove forest in particular, but also bamboo appear as the forest type most affected by insects and disease / fungi, while animals do not seem to play any role as health affecting agent.

Table 51: Gross volume (1000 m^3) in forest types by health affecting agent

Forest Type	Insects	Disease/ Fungi	Fire	Animals	Climate	Humans	Total
FH	-	82	-	-	17	-	**99**
FM	1,096	1,986	24	-	21	37	**3,164**
FB	62	172	664	-	1	-	**899**
PL	-	67	-	-	8	-	**75**
PS	-	26	-	-	2	-	**28**
Sum	**1,157**	**2,333**	**688**	**-**	**49**	**37**	**4,264**

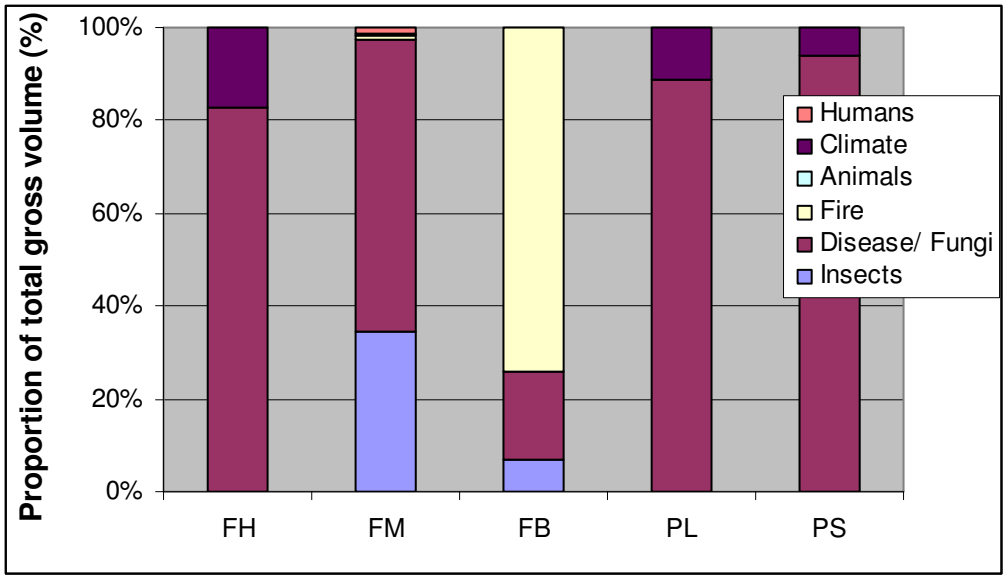

Figure 56: Proportion of gross volume in forest types by Health affecting agents

9.2.25. Number of stumps per hectare by Diameter class and stump age per major National LUC

Table 52: Total number of Stumps (1000) in Major Land Use Class, by DBH

Land Use	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100	Total
Total	**4,298**	**4,336**	**2,396**	**1,823**	**981**	**478**	**143**	**309**	**141**	**190**	**15,095**
<1 year	1,559	1,988	1,081	685	310	122	25	25	-	-	5,794
1-5 years	2,616	2,251	1,143	1,113	647	356	118	260	141	190	8,836
5-10 years	98	72	48	-	23	-	-	-	-	-	242
>10 years	25	25	49	25	-	-	-	25	-	-	148
Forest	**3,450**	**3,588**	**1,742**	**1,285**	**687**	**332**	**93**	**212**	**117**	**165**	**11,670**
<1 year	1,026	1,407	572	266	139	23	-	-	-	-	3,434
1-5 years	2,325	2,107	1,022	993	525	308	93	187	117	165	7,843
5-10 years	98	48	48	-	23	-	-	-	-	-	218
>10 years	-	25	25	25	-	-	-	25	-	-	100
Cultivated	**468**	**320**	**369**	**443**	**246**	**98**	**49**	**74**	**25**	**25**	**2,116**
<1 year	271	271	295	418	148	98	25	25	-	-	1,550
1-5 years	172	49	74	25	98	-	25	49	25	25	541
5-10 years	-	-	-	-	-	-	-	-	-	-	-
>10 years	25	-	-	-	-	-	-	-	-	-	25
Villages	**381**	**428**	**286**	**95**	**48**	**48**	**-**	**24**	**-**	**-**	**1,309**
<1 year	262	309	214	-	24	-	-	-	-	-	809
1-5 years	119	95	48	95	24	48	-	24	-	-	452
5-10 years	-	24	-	-	-	-	-	-	-	-	24
>10 years	-	-	24	-	-	-	-	-	-	-	24

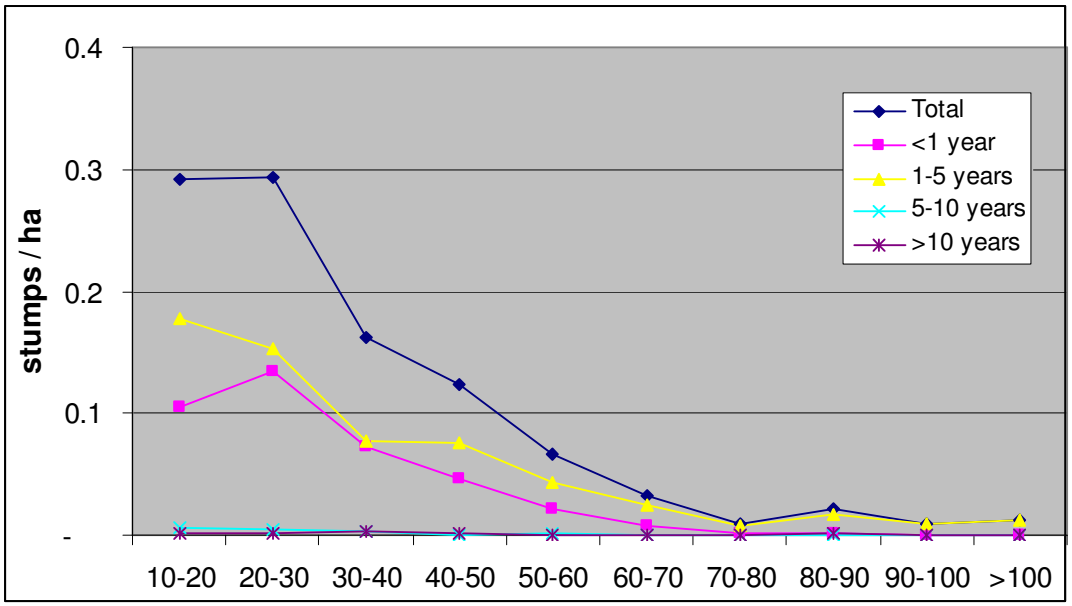

Figure 57: total number of stumps / ha in Bangladesh

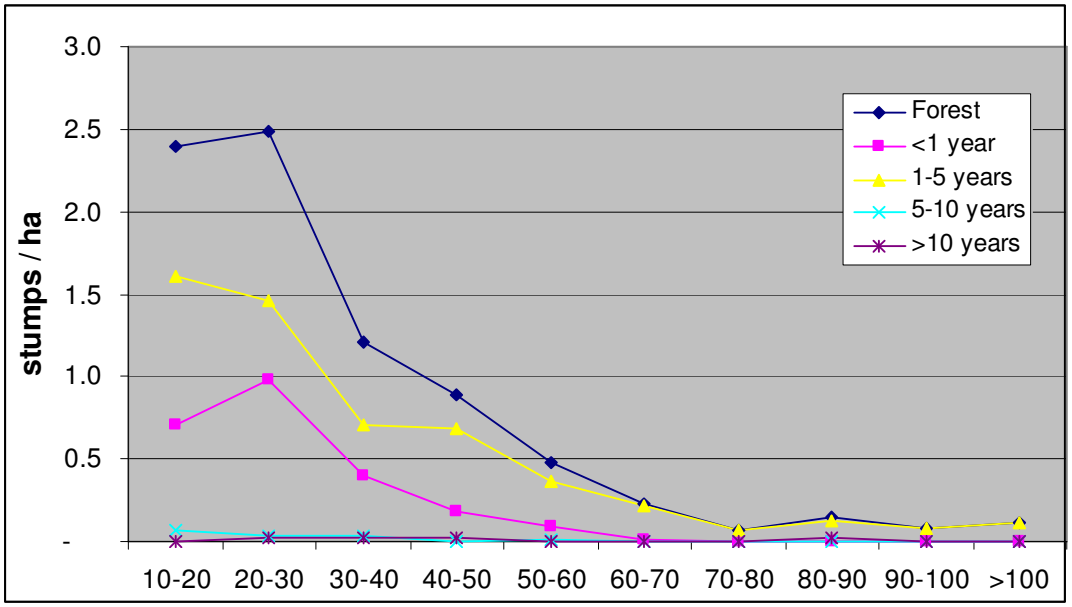

Figure 58: total number of stumps / ha in Forest

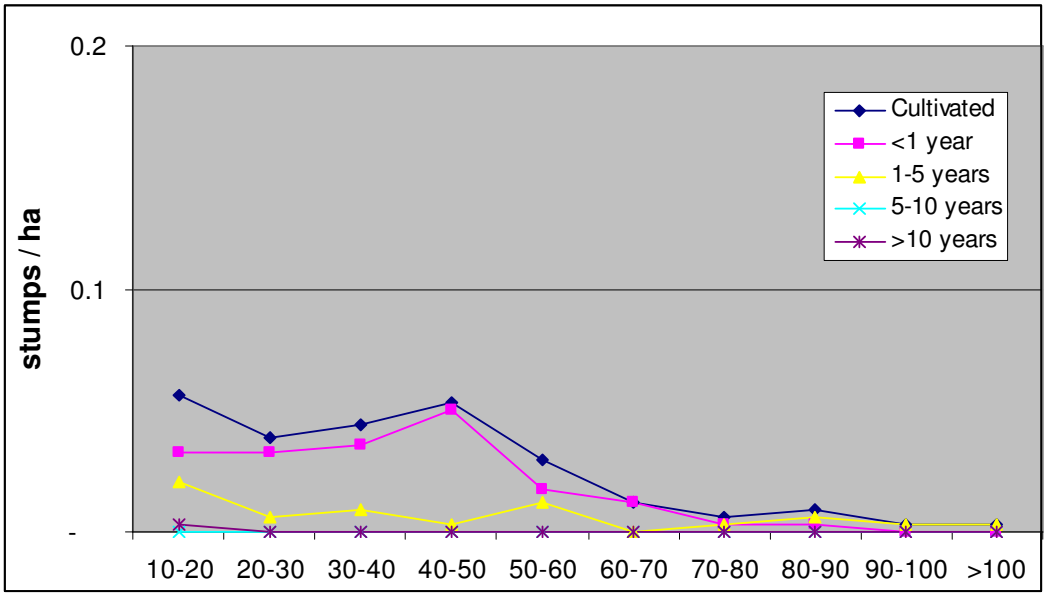

Figure 59: total number of stumps / ha in Cultivated land

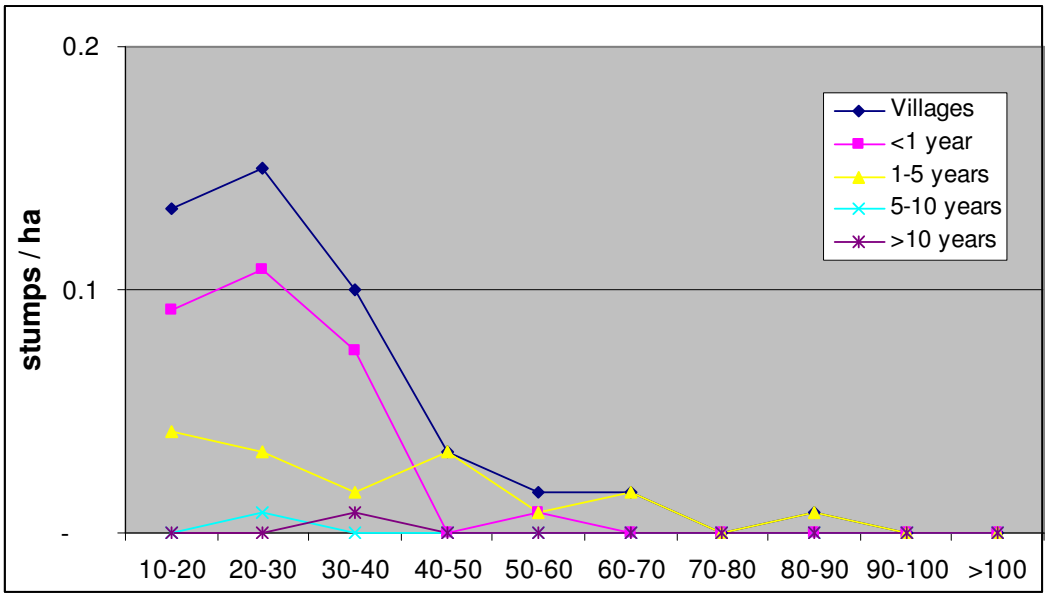

Figure 60: total number of stumps / ha in Villages

9.3. Biodiversity and regeneration

The total number of tree species (or genus) that were measured and identified in Bangladesh was 258 (see Table 53 and Annex VIII). Of these, 198 species are found in Villages, 129 species are found in Forest, 137 species are found in Cultivated Land, 33 species are found in Inland water and 28 species are found in Urban areas.

The species representing the highest volume in general are *Cocos nucifiera*, *Samanea Saman* and *Mangifera indica* (as shown previously in Table 41 through Table 47). These three species are also the most common in the major National LUC Villages. In Forest the two species with highest volume are *Dipterocarpus turbinatus* and *Heritiera fomes*, followed by *Albizia procera*, *Gmelina arborea* and *Lannea coromandelica*. The total list of tree species in the different major National LUC:s and their volumes can be viewed in Annex VII.

9.3.1. Biodiversity

Biodiversity index is a mathematical measure of species diversity in a community. It provides information on the number of species present in the community (species richness) and also the relative abundance of the different species.

To characterize the species diversity in the major land use classes, the *Shannon's Diversity Index* was employed. The *Shannon index* accounts for both abundance and evenness of the species present. The Shannon Index ranges from 0.0 to approximately 4.6. A value near 0.0 means that every tree in the sample is of the same species and a value near 4.6 would indicate that the numbers of individuals are evenly distributed among the different species.

9.3.2. Biodiversity index for the major National LUC

It can be seen in Table 53 that diversity and equitability are higher in Cultivated Land and Inland Water than in Forest. Although there are more tree species in Forest (129 species) as compared to Cultivated Land (137 species) and Inland Water (33 species), about 46% of the total number of individuals in Forest belong to only two tree species: *Heritiera fomes* and *Excoecaria agallocha*.

Table 53: Diversity Index and Equitability

	Total	Forest	Cultivated Land	Villages	Urban Areas	Inland Water
No. of species	258	129	137	198	28	33
Diversity	3.57	3.03	3.31	3.23	2.22	3.08
Equitability	0.64	0.61	0.72	0.61	0.67	0.87

9.3.3. Regeneration

In the Forest LUC, tree regeneration is of 2,361 stems per hectare on average. This is almost 20 times the average number of stems per hectare for all trees with D_{bh} >10 cm, which is 127 stems per hectare.

Results show 121 species identified as tree regeneration in the Forest. Of these, *Ceriops roxburghiana, Excoecaria agallocha and Heritiera fomes* are the most abundant tree species; their relative proportion to the total number of individuals within the Forest is approximately 49%. Table 54 shows the top 15 most abundant tree regeneration species in Forest.

Table 54: Number of regeneration stems,(Dbh <10 cm) per hectare of the most important species in major National LUC "Forest"

No.	Scientific Species Name	Total Count (NPL2)	Proportion to the total number of species(pi)	Average No. of stems per ha
1	Ceriops roxburghiana	785	18%	420
2	Excoecaria agallocha	742	17%	397
3	Heritiera fomes	635	14%	340
4	Ficus hispida	292	7%	156
5	Amoora cucullata	162	4%	87
6	Malocanna baccifera	126	3%	67
7	Tectona grandis	113	3%	60
8	Macaranga denticulate	101	2%	54
9	Grewia microcosm	83	2%	44
10	Callicarpa arborea	73	2%	39
11	Others	70	2%	37
12	Schima wallichii	68	2%	36
13	Stereospermum chelonioides	65	1%	35
14	Lannea coromandelica	59	1%	32
15	Albizia procera	57	1%	30

9.3.4. Number of stems per hectare of Dbh 1-10 cm (regeneration) in the different forest types

The number of regeneration stems per hectare in Forest is on average 2,361 stems/ha. Figure 61 shows that the Mangrove forest has more than 8,000 regeneration stems per hectare. Hill forest, Bamboo forest and Long rotation plantations have slightly over 1,000 regeneration stems per hectare and Short rotation and Mangrove plantations have around 500 such stems per hectare.

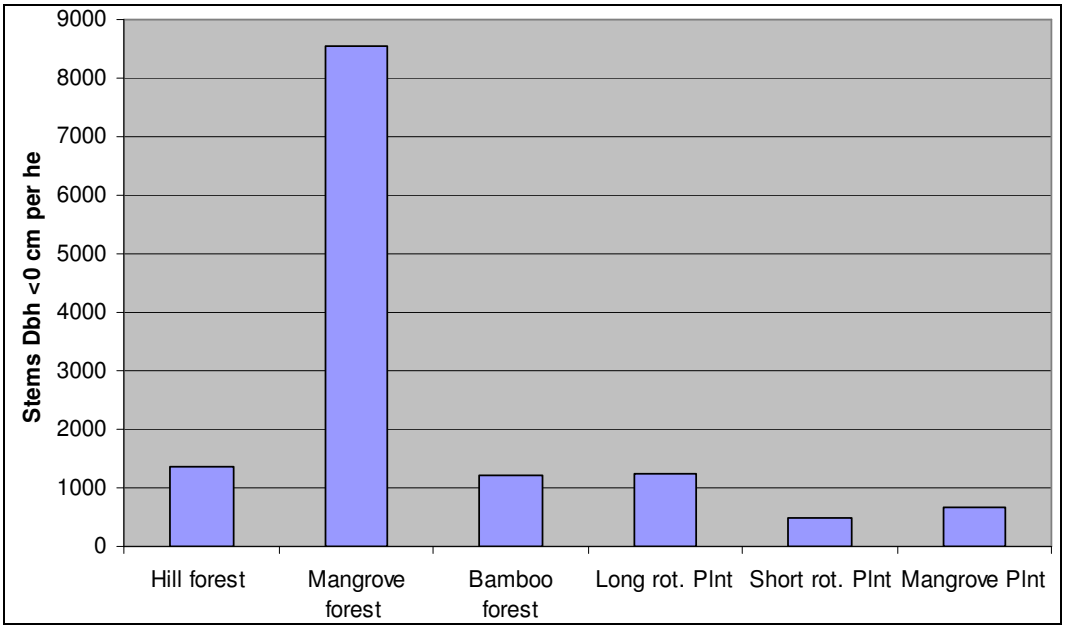

Figure 61: Number of regeneration stems (Dbh < 10 cm) per hectare for different forest types

9.4. Social and economical

The products/services for the LUCs "Built up" area and "Inland Water" will not be presented in the following (although data has been collected). This is due to low utilization of products/services in these LUCs.

9.4.1. Estimated population for tracts with high forest content and for tracts without (or low) forest content

The average population density of Bangladesh is about 1,000 persons per km^2. For tracts with low forest content (<25%) the density is slightly higher than 1,000 persons per km^2. For tracts with high forest content (>25%) the population density is significantly lower: 235 persons per km^2, as shown in Figure 62.

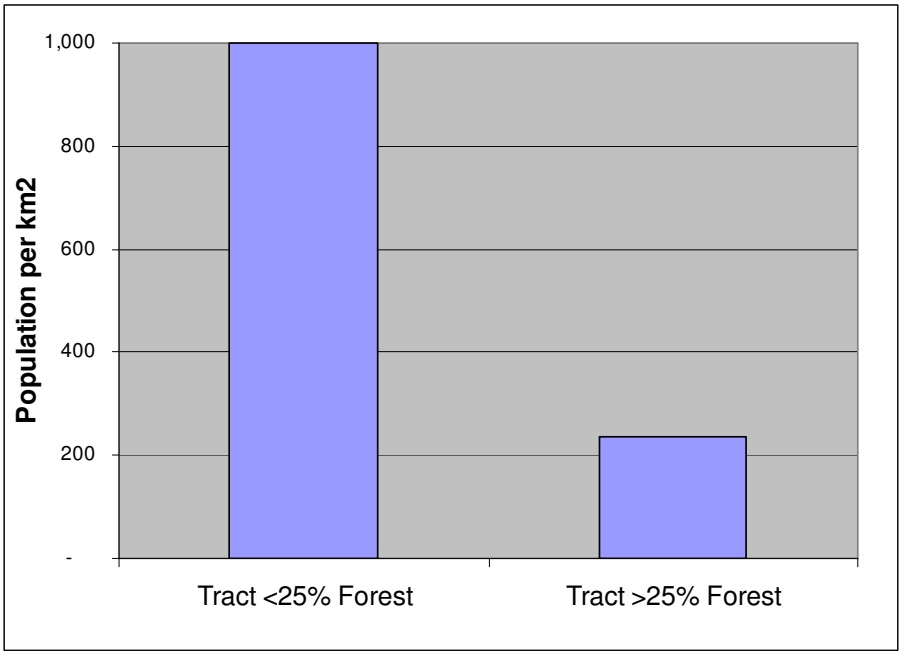

Figure 62: Estimated population per Km^2 for areas with high (>25%) and low (<25%) forest content

9.4.2. Number of years since populated for tracts with high forest content and for tracts without (or low) forest content

Almost 1/5 of the areas with high forest content were populated less than 25 years ago. In areas with low forest content only 3% were populated during the last 25 years. More then 80% of the area, both in high and low forest content, were populated more then 25 years ago.

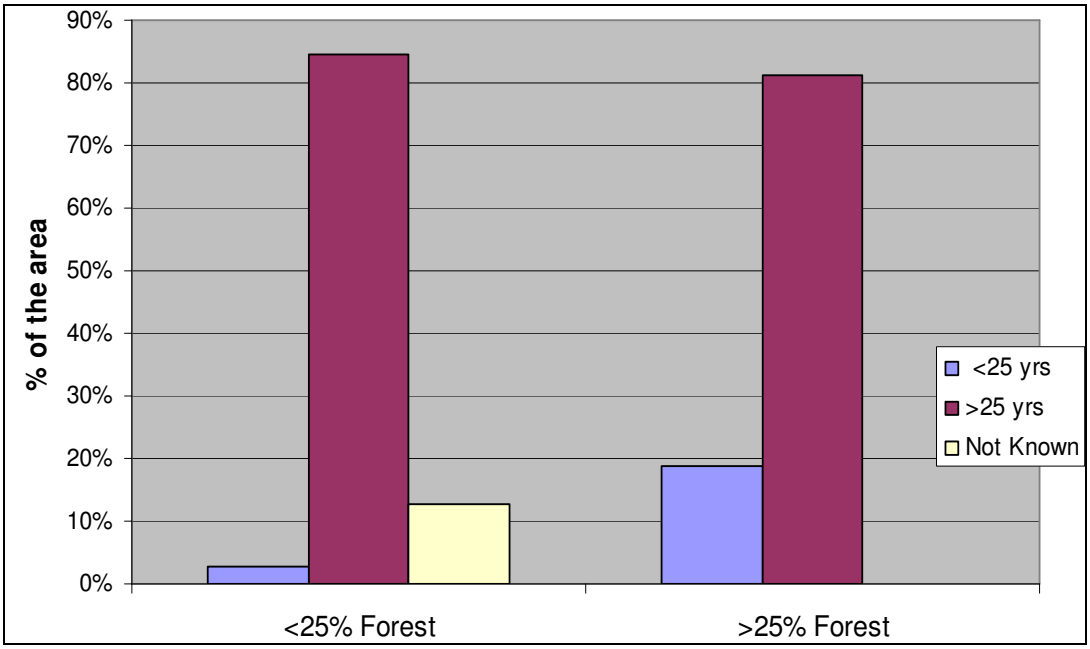

Figure 63: Number of years since populated by area with high and low forest content

9.4.3. Trend of population for tracts with high forest content and for tracts without (or low) forest content

Figure 64 shows that the population is increasing in over 85% of the areas, both in areas with high and with low forest content.

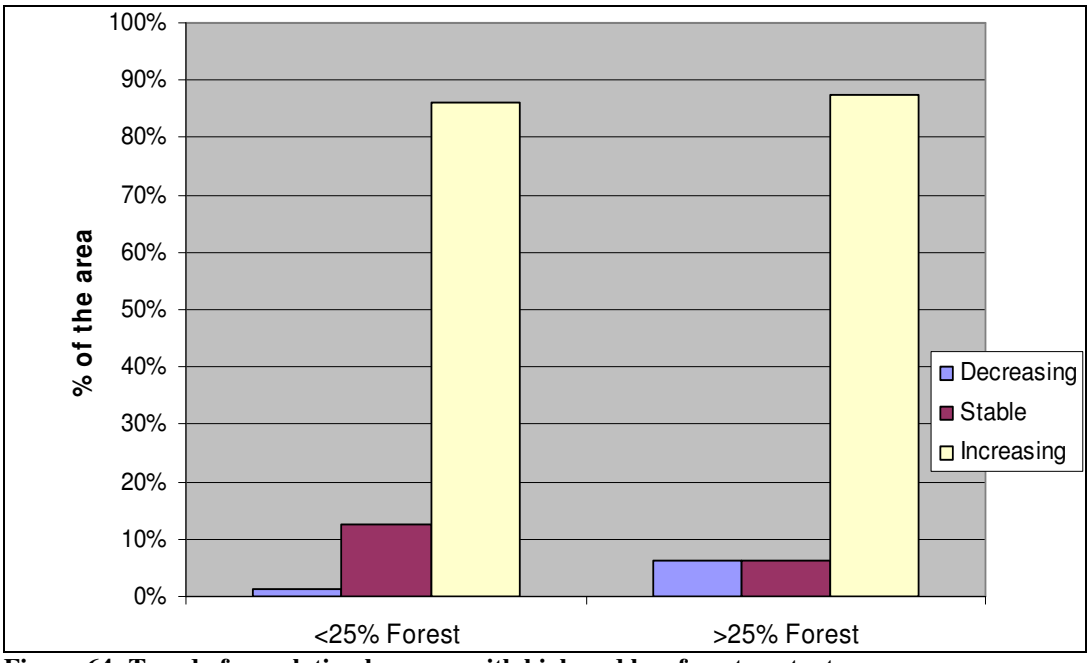

Figure 64: Trend of population by areas with high and low forest content

9.4.4. Main activity of the permanent population for tracts with high forest content and for tracts without (or low) forest content

The most important activity of the permanent population is crop production. However, in areas with high forest approximately ¼ of the population has forestry as main activity.

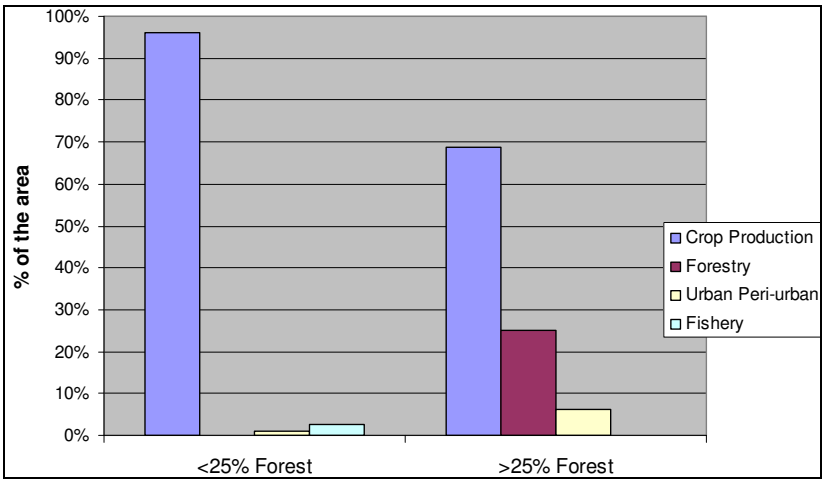

Figure 65: Main activity of permanent population by areas with high and low forest content

9.4.5. Products and services - general

The range of Forestry Products and Services included in the NFA is presented in Table 55. The findings on forestry products and services that are harvested/used are presented as area in which they are harvested/used.

Table 55 : Area in which forestry products and services are harvested/used (1000 ha)

Product/service type	TOT area
Timber	6,237
Fuelwood	6,354
Charcoal	25
Wood carvings	335
Poles	1,085
Plant Food	4,910
Fodder	148
Plant medicines	220
Soap/cosmetics	38
Dying/tannins	51
Herbs & spices	3
Exudates	79
Utensils/Handicrafts	92
Construction materials	2,472
Ornamentals	27
Other plant products	434
Living animals	7
Employment	57
Protection	295
Windbreaks	12
Shade	27

9.4.6. The area where each of product/service is used, in three classes of importance – for the total area of Bangladesh

Figure 66 shows the area where each product and service is used/harvested (based on the total area of Bangladesh). It is confirmed that the most important products are: timber, fuelwood, poles, plant food and construction material. Below, these products will be analyzed in more detail.

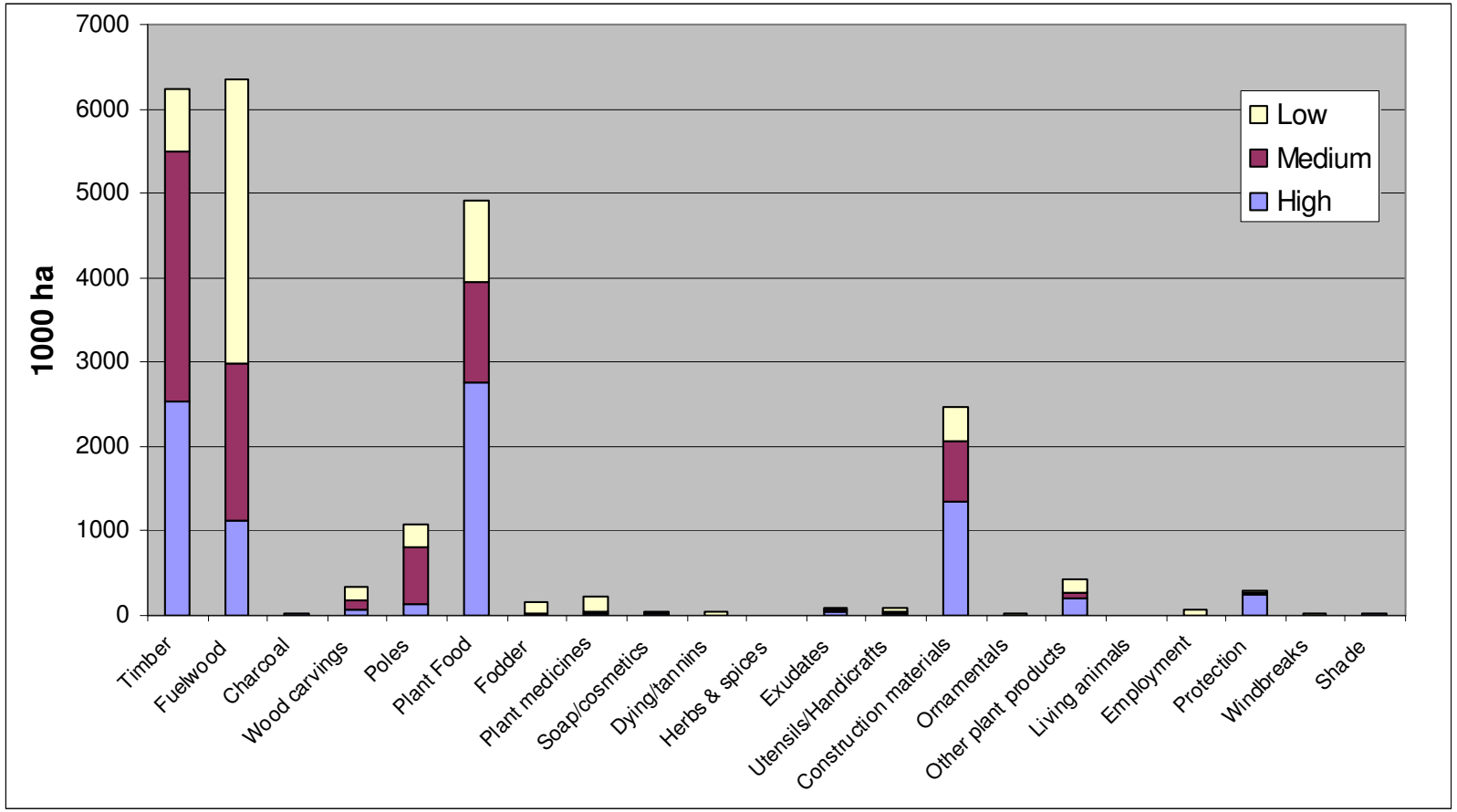

Figure 66: Importance (low/medium/high) of forestry products/services that are harvested/used in Bangladesh, presented as area in which the they are harvested/used

9.4.7. Products and services - conflicts

From Figure 67 to Figure 69 it can be seen that user conflicts are most common in the LUC "Forest". The products/services with most conflicts are timber, fuelwood and poles.

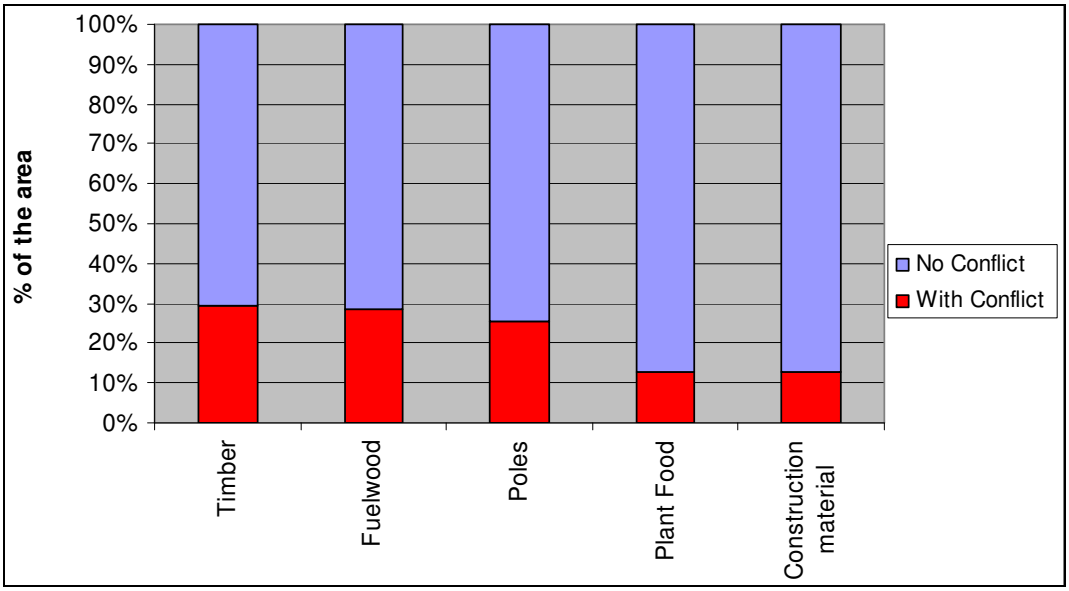

Figure 67: Proportion of forest area with user conflicts by product type

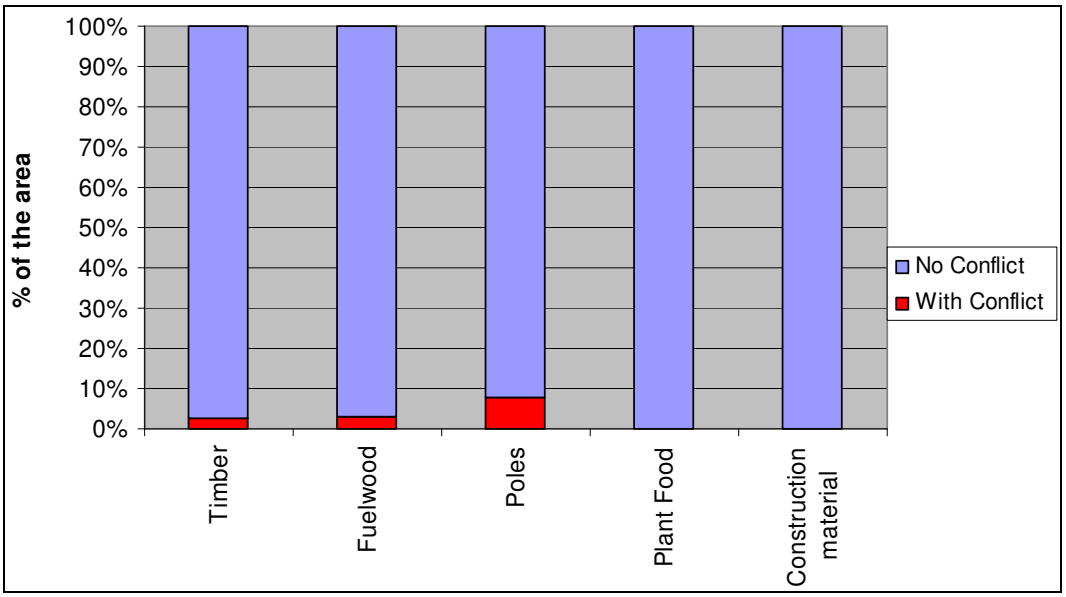

Figure 68: Proportion of cultivated land area with user conflicts by product type

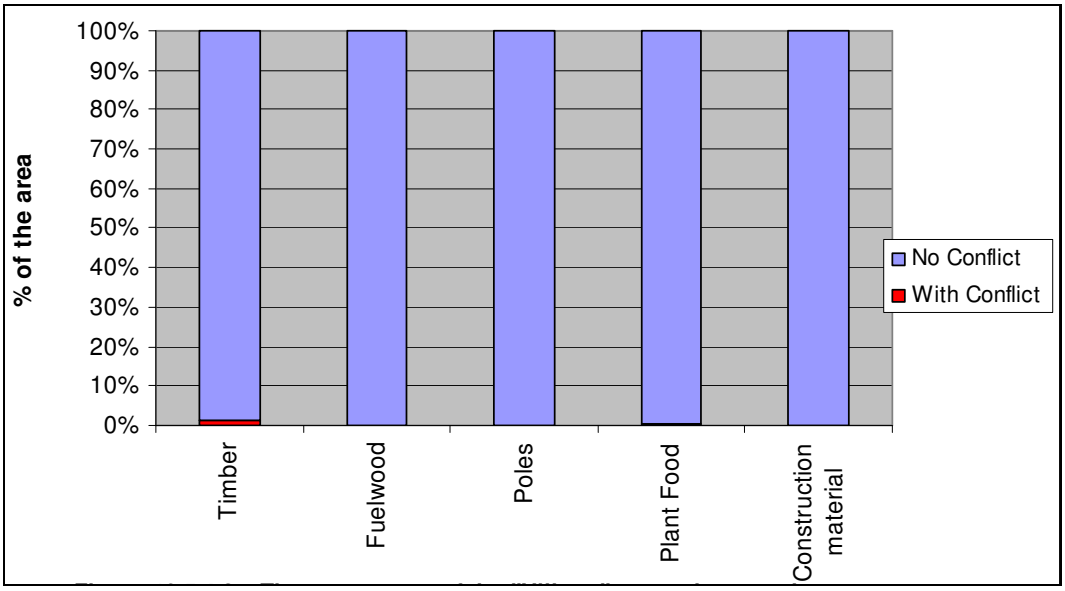

Figure 69: Proportion of village area with user conflicts by product type

9.4.8. Products and services – demand and supply

Figure 70 to Figure 72 show that the demand for timber, fuelwood, poles, construction material and plant food is increasing in all LUC:s, which creates a general shortage of the mentioned products/services.

In Forest the supply trend of fuelwood, poles and construction material is decreasing, creating a strong shortage of these products. For plant food the supply is increasing in the majority of the area, which altogether gives a nearly balanced situation. In Cultivated land the supply trend for timber, fuelwood, poles, construction material and plant food services is neutral, but the increasing demand gives altogether a shortage. In Villages the supply trend is increasing for all the mentioned products and services. But a very strongly increasing demand gives us altogether a situation of shortage.

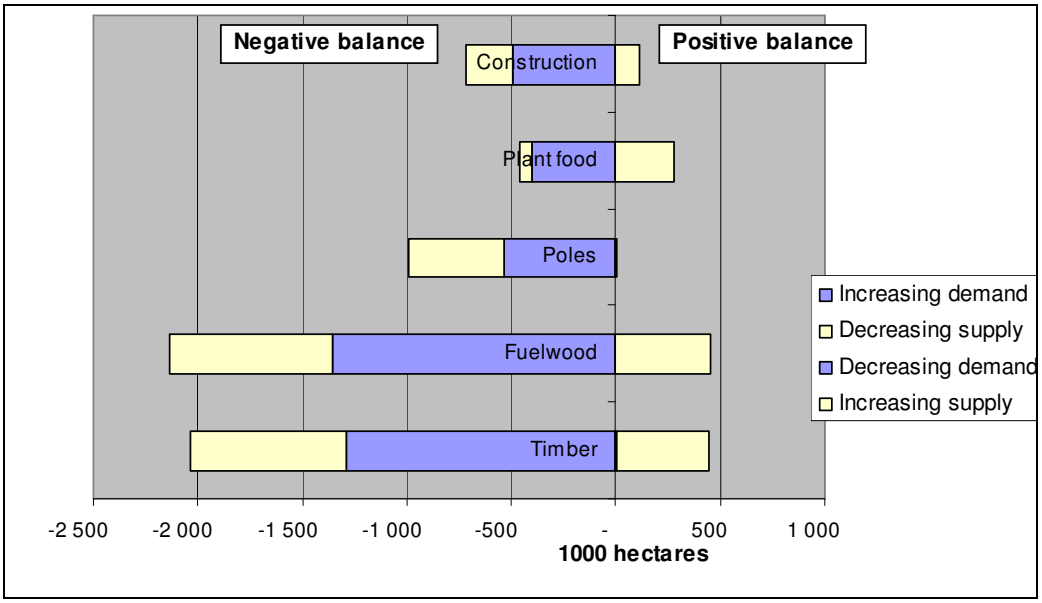

Figure 70: Supply / Demand balance for products and services in "Forest" area

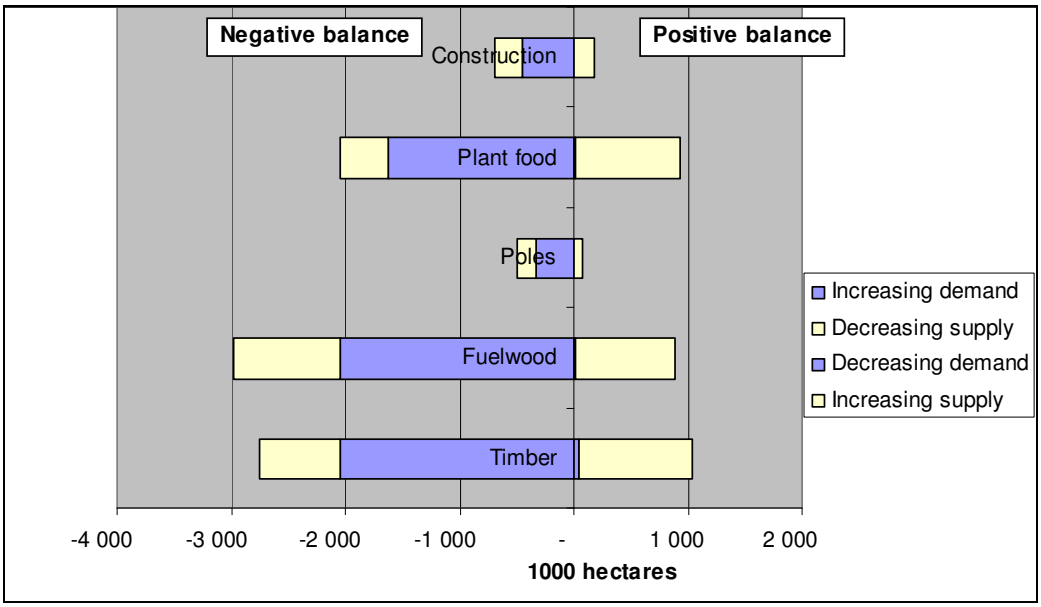

Figure 71: Supply / Demand balance for products and services in "Cultivated land" area

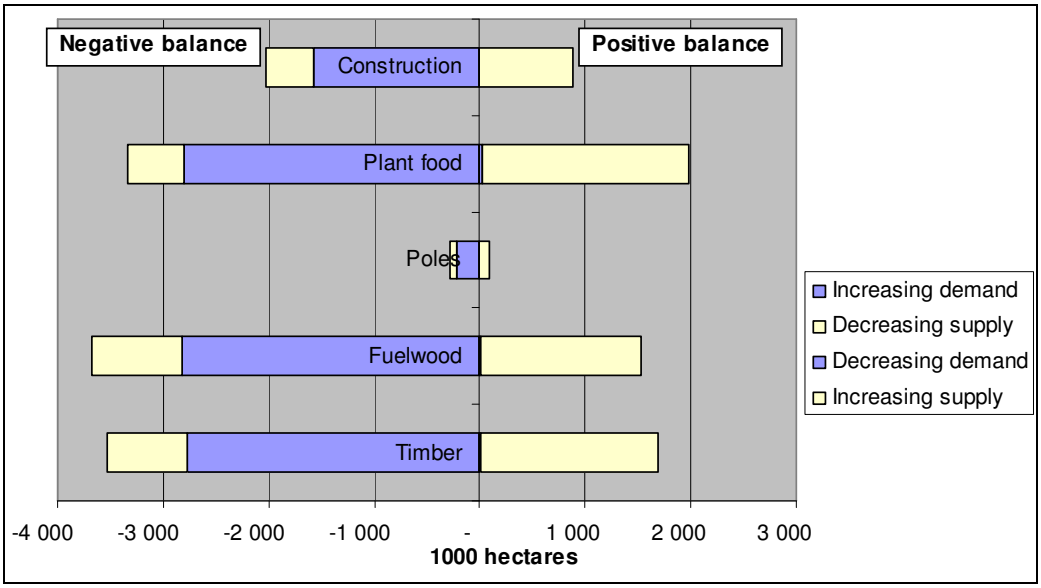

Figure 72: Supply / Demand balance for products and services in "Village" area

9.4.9. Products and services – important species

Table 56: The most important tree species for products and services in "Forest" (tree count in the NFA)

ScientificName	**Wood products**	Timber	Fuelwood	Poles	ScientificName	**NWFP-PP**	Plant Food	Constr. mtrl
Ochna squarrosa	**49**	1	34	14	Terminalia belerica	**9**	5	0
Stereospermum chelonioides	**20**	2	13	5	Syzygium cumini	**7**	7	0
Ficus hispida	**18**	1	17	0	Dillenia indica	**5**	5	0
Gmelina arborea	**17**	11	5	1	Ficus hispida	**4**	4	0
Syzygium cumini	**17**	12	4	1	Artocarpus lacucha	**2**	2	0
Lannea coromandelica	**15**	6	4	5	Swietenia spp	**2**	0	1
Albizia procera	**12**	8	3	1	Protium serratum	**1**	1	0
Toona ciliata	**12**	5	3	4	Bouea oppositifolia	**1**	0	0
Castanopsis indica	**11**	8	2	0	Bombax ceiba	**1**	0	0
Mitragyna parvifolia	**10**	3	7	0	Ficus bengalensis	**1**	0	0
Protium serratum	**10**	6	4	0	Artocarpus heterophyllus	**1**	1	0
Vitex glabrata	**10**	2	5	1	Oroxylum indicum	**1**	0	0
Microcos paniculata	**9**	0	9	0	Phoenix sylvestris	**1**	1	0
Artocarpus chaplasha	**8**	8	0	0	Xylocarpus mekengensis	**1**	1	0
Cassia fistula	**8**	1	7	0	Ceriops roxburghiana	**1**	0	1
Tectona grandis	**7**	5	1	1	Terminalia chebula	**1**	0	0
Dipterocarpus turbinatus	**6**	6	0	0				
Macaranga denticulata	**6**	3	3	0				
Schima wallichii	**6**	1	4	1				

Table 57: The most important tree species for products and services in "Cultivated land" (tree count in the NFA)

ScientificName	**Wood products**	Timber	Fuelwood	Poles	ScientificName	**NWFP-PP**	Plant Food	Constr. mtrl
Samanea saman	**47**	21	26	0	Phoenix sylvestris	**31**	24	0
Mangifera indica	**45**	20	25	0	Mangifera indica	**29**	28	1
Phoenix sylvestris	**24**	6	17	1	Borassus flabellifer	**17**	17	0
Albizia procera	**23**	11	9	2	Artocarpus heterophyllus	**8**	7	0
Lannea coromandelica	**21**	6	14	1	Cocos nucifera	**8**	8	0
Bombax ceiba	**18**	8	9	0	Syzygium cumini	**8**	8	0
Acacia nilotica	**15**	6	4	1	Moringa oleifera	**7**	7	0
Syzygium cumini	**14**	9	5	0	Areca catechu	**6**	6	0
Borassus flabellifer	**11**	4	4	3	Diospyros peregrina	**4**	4	0
Cassia fistula	**11**	4	6	1	Spondias pinnata	**4**	4	0
Azadirachta indica	**10**	8	1	0	Zizyphus mauritiana	**4**	4	0
Erythrina orientalis	**9**	1	8	0	Swietenia spp	**3**	0	3
Melia sempervirens	**9**	4	5	0	Azadirachta indica	**2**	0	2
Aphanamixis polystachya	**8**	3	4	1	Bombax ceiba	**2**	0	1
Artocarpus heterophyllus	**8**	5	3	0	Citrus grandis	**2**	2	0

Table 58: The most important tree species for products and services in "Villages" (tree count in the NFA)

ScientificName	**Wood products**	Timber	Fuelwood	Poles	ScientificName	NWFP-PP	Plant Food	Constr. mtrl
Samanea saman	**92**	48	44	0	Mangifera indica	**102**	101	0
Mangifera indica	**80**	39	41	0	Syzygium cumini	**35**	34	0
Albizia procera	**65**	40	21	2	Spondias pinnata	**33**	33	0
Lannea coromandelica	**50**	17	31	2	Zizyphus mauritiana	**32**	32	0
Syzygium cumini	**43**	34	7	2	Borassus flabellifer	**31**	30	0
Bombax ceiba	**37**	12	25	0	Phoenix sylvestris	**31**	31	0
Artocarpus heterophyllus	**32**	24	8	0	Cocos nucifera	**30**	30	0
Cassia fistula	**32**	16	14	2	Areca catechu	**28**	28	0
Phoenix sylvestris	**32**	6	25	0	Artocarpus heterophyllus	**20**	19	0
Azadirachta indica	**26**	23	3	0	Moringa oleifera	**14**	14	0
Borassus flabellifer	**26**	14	11	1	Artocarpus lacucha	**10**	10	0
Acacia auriculiformis	**22**	8	14	0	Citrus grandis	**10**	10	0
Albizia richardiana	**21**	13	7	1	Psidium guajava	**10**	10	0
Aphanamixis polystachya	**18**	11	6	1	Ficus hispida	**9**	8	0
Cocos nucifera	**18**	7	11	0	Tamarindus indica	**9**	9	0

9.4.10. Products and services – users of forestry products/services

Figure 73 to Figure 75 show that most of the important products and services are harvested or used by individuals. The only exception is construction material in the Forest area, which to 50% is harvested by companies.

In the Forest area 20-35% of these products and services are used without any rights. In the villages and in the Cultivated land almost non of the products or services is used without rights.

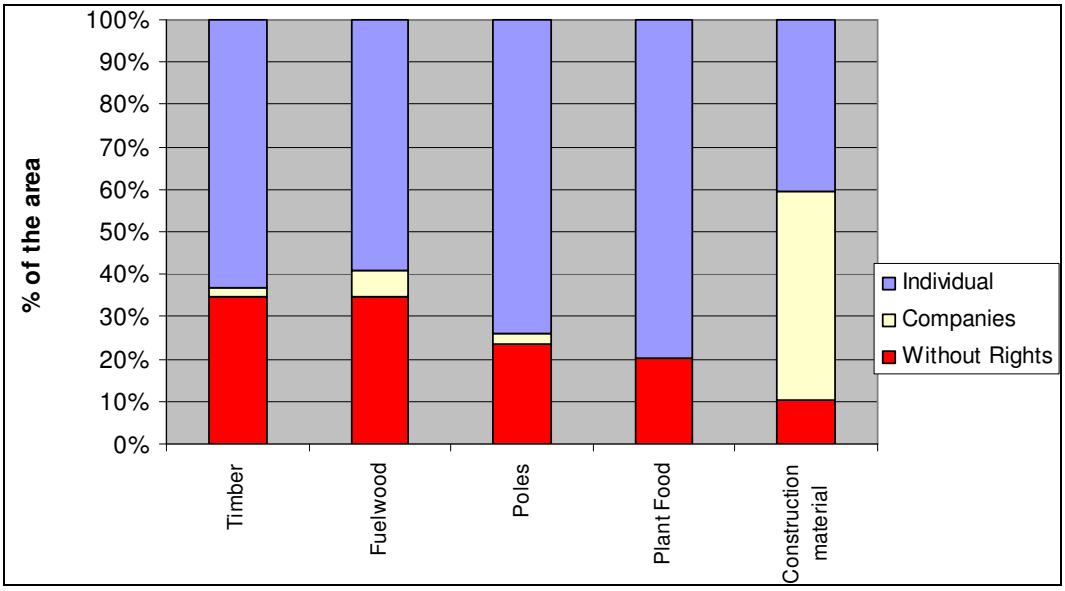

Figure 73: Users of most important products and services in "Forest" area

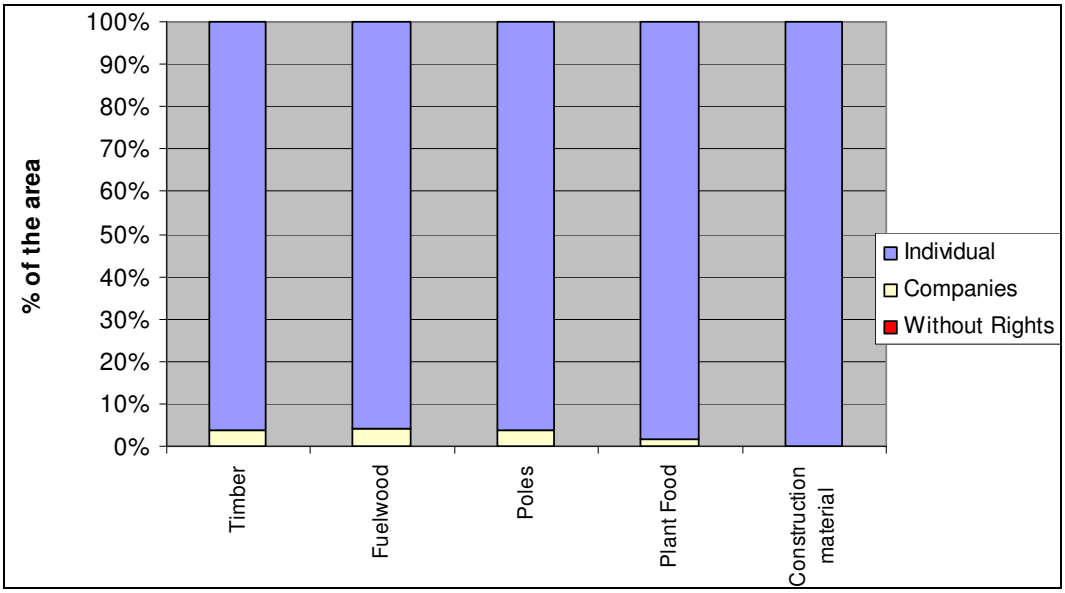

Figure 74: Users of most important products and services in "Cultivated land" area

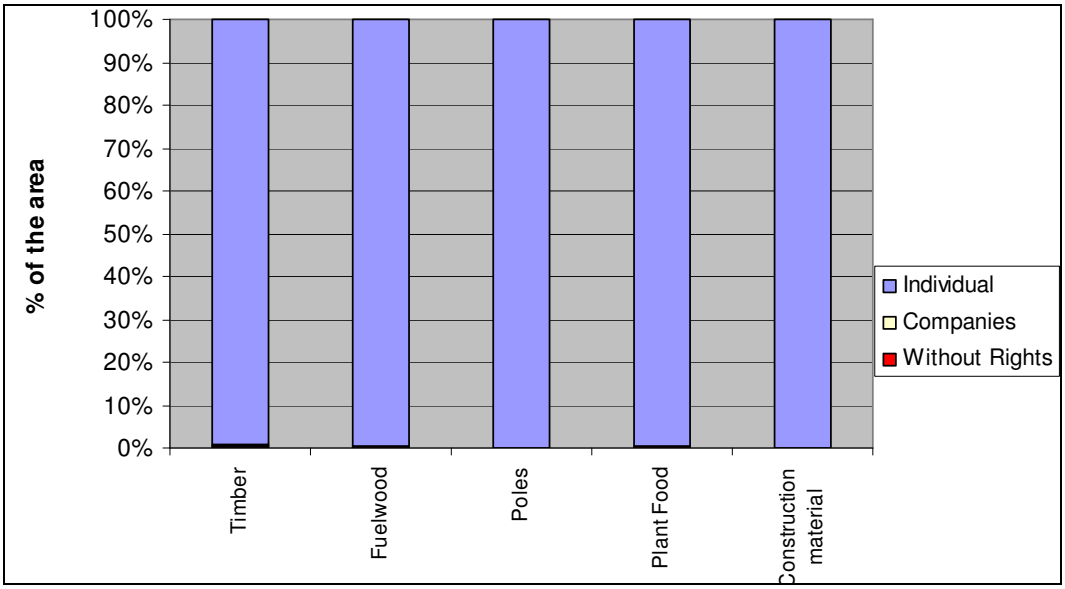

Figure 75: Users of most important products and services in "Inland water" area

9.4.11. Products and services – User rights to forestry products / services

In the Villages and in the Cultivated land the use of products and services is based on property rights. In the Forest about 50% of the use is based on property rights but approximately 30% of the use is not based on any rights at all. Some of the use in Forest is also based on customary rights or open access.

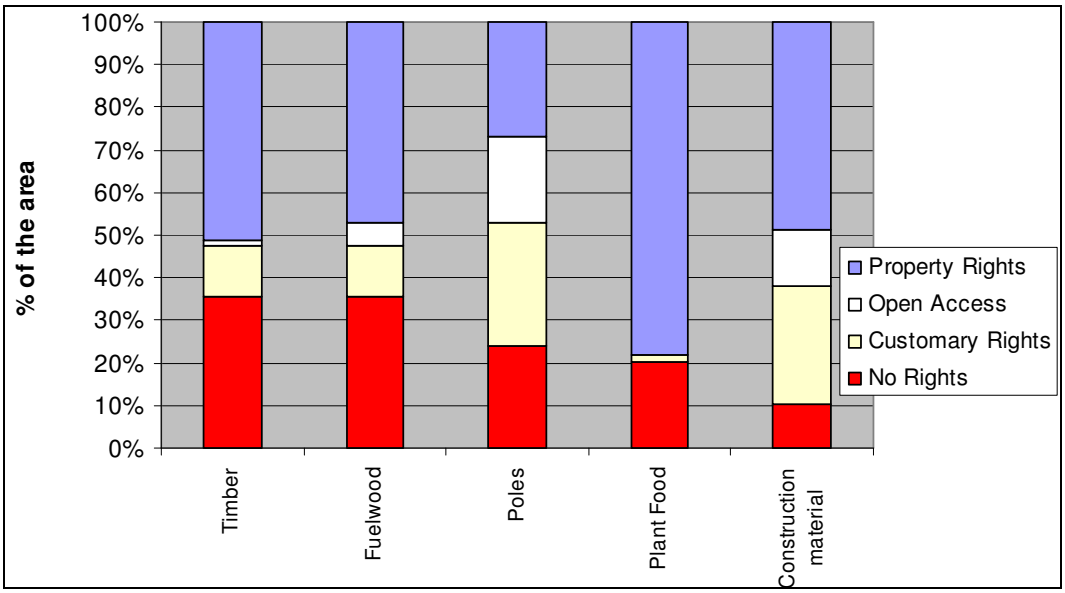

Figure 76: User right for the most important products / services in "Forest" area

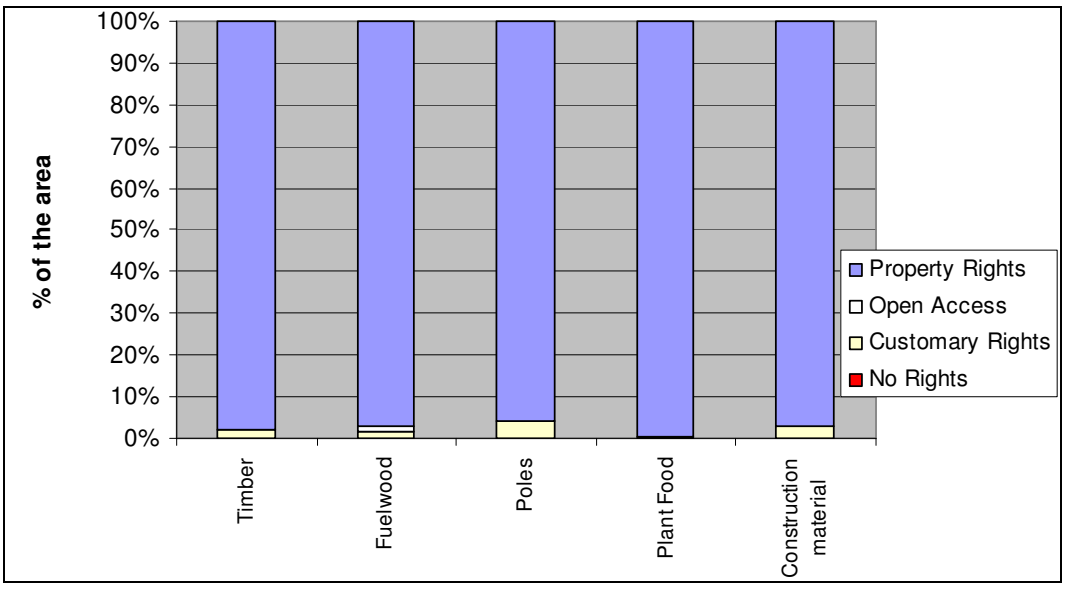

Figure 77: User right for the most important products / services in "Cultivated land" area

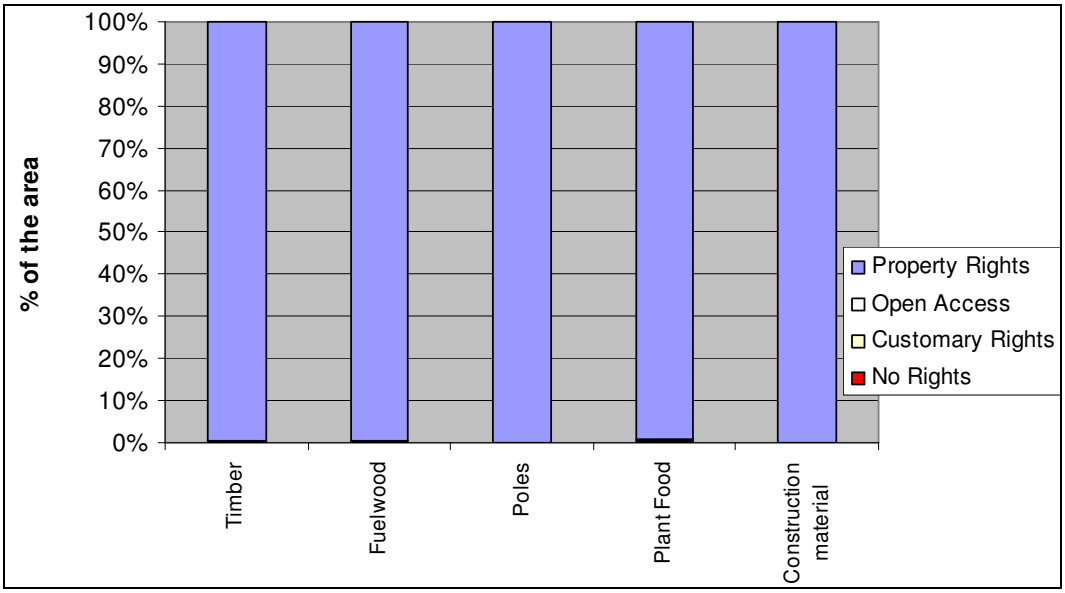

Figure 78: User right for the most important products / services in "Village" area

9.4.12. Products and services – organizational level and gender balance

Figure 79 to Figure 81 show that the harvest or use of the most important products and services in general is spontaneous. In the Villages and in the cultivated area the use is slightly more organized than in the Forest.

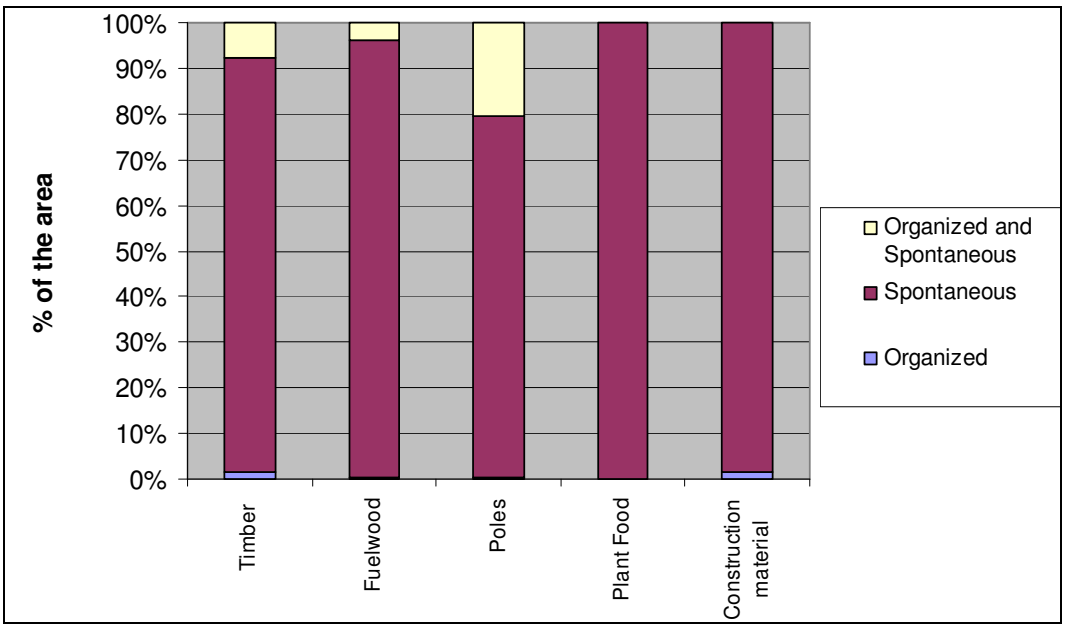

Figure 79: Organization level for the most important products/services in "Forest" area

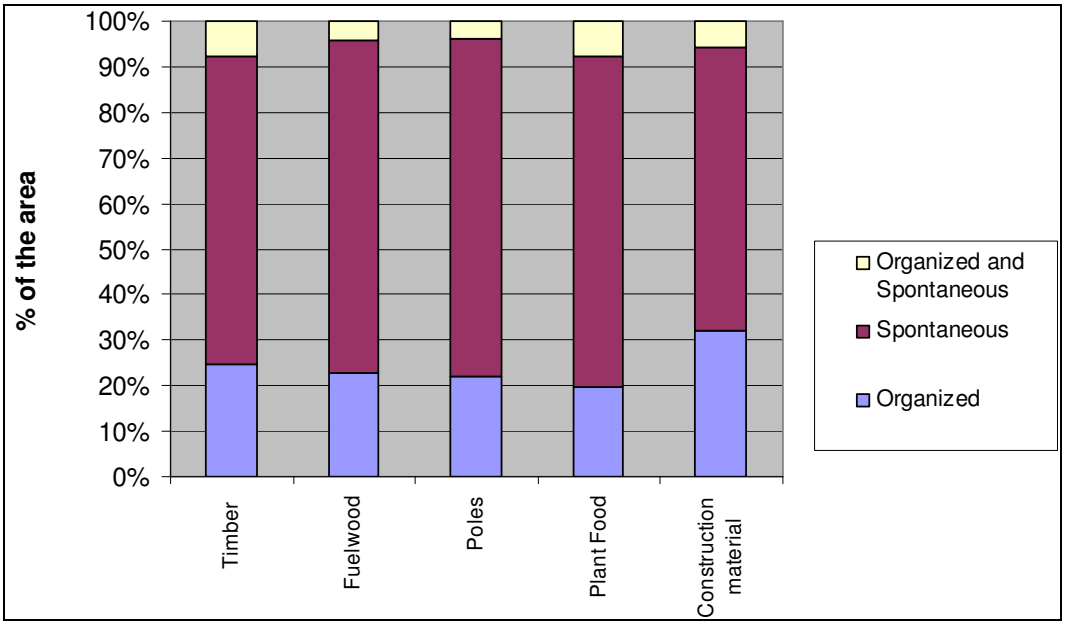

Figure 80: Organization level for the most important products/services in "Cultivated land" area

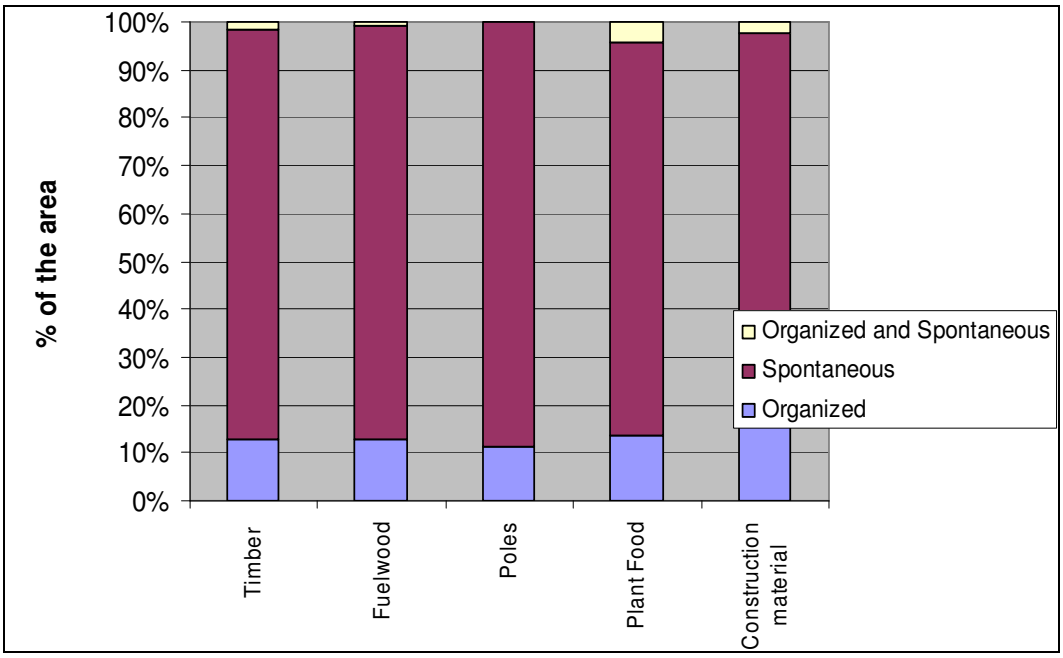

Figure 81: Organization level for the most important products/services in "Village" area

9.4.13. Products and services – Gender balance among harvesters/users of forestry products/services

Figure 85 to Figure 87 show that all the products – timber, fuelwood, poles, construction material and plant food - are mainly harvested by men.

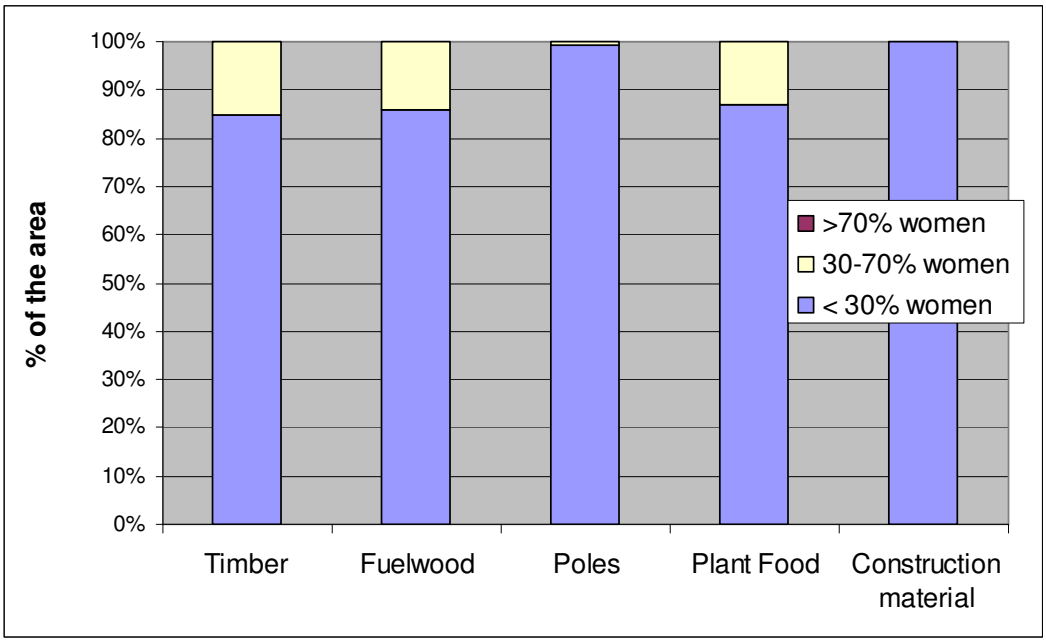

Figure 82: Gender balance among harvesters/users of products / services in "Forest" area

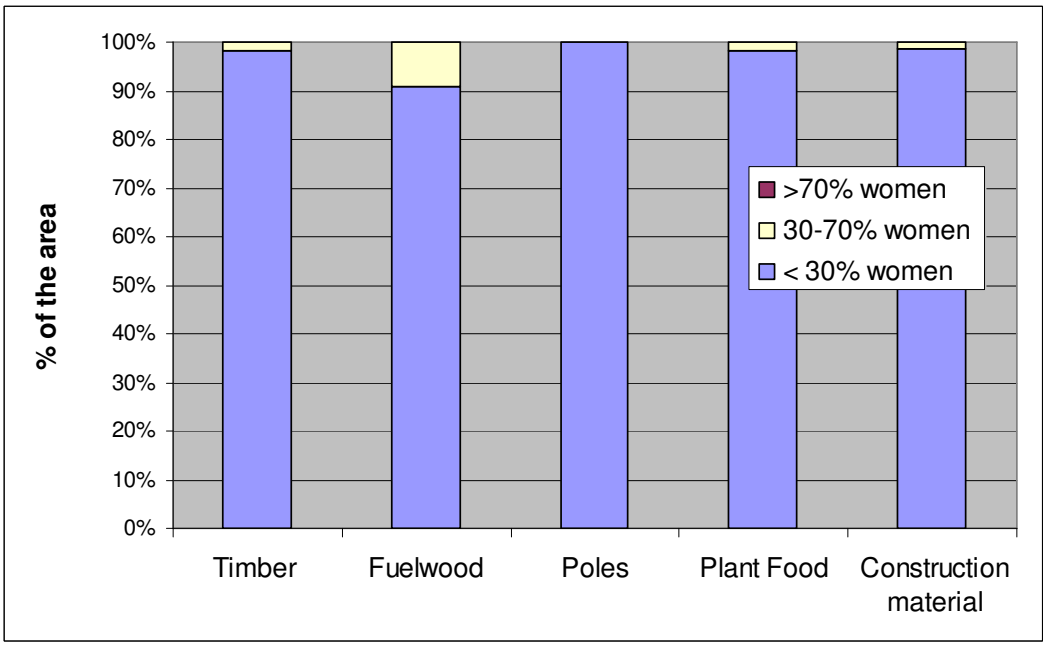

Figure 83: Gender balance among harvesters/users of products / services in "Cultivated area"

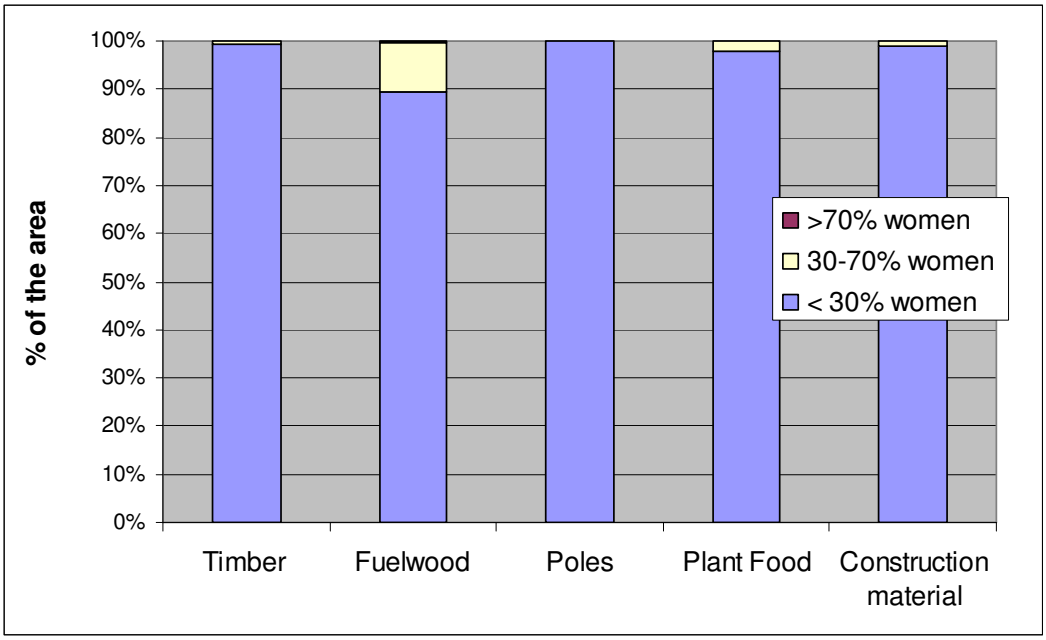

Figure 84: Gender balance among harvesters/users of products / services in "Villages"

Photo 10 : Wood locally transported on a rickshaw in the Madhupur Forest Reserve area

9.4.14. Products and services – end-use

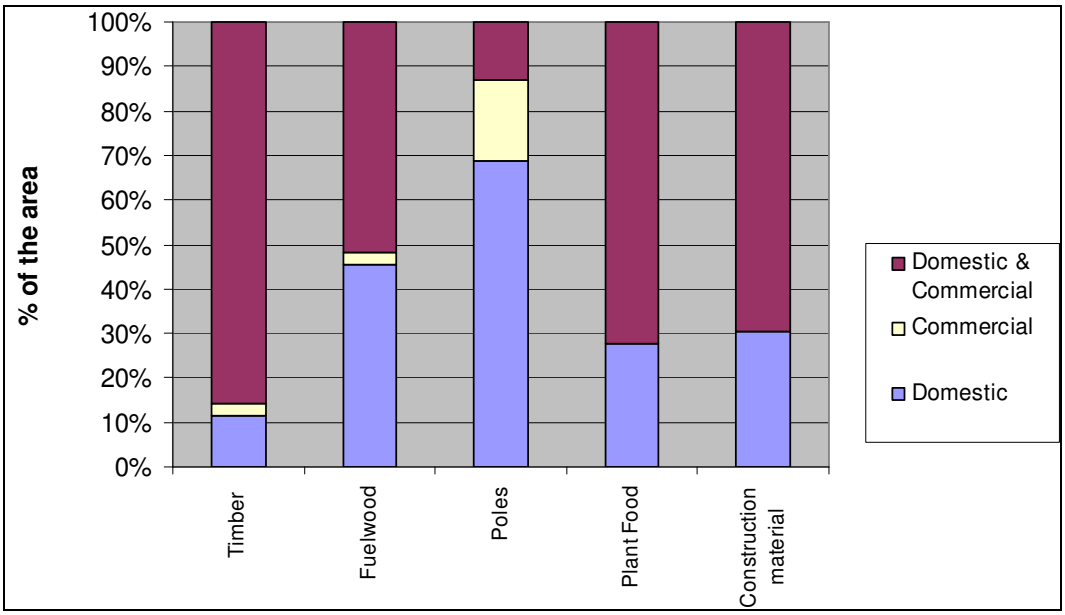

Figure 85: End use of most important products / services in "Forest" area

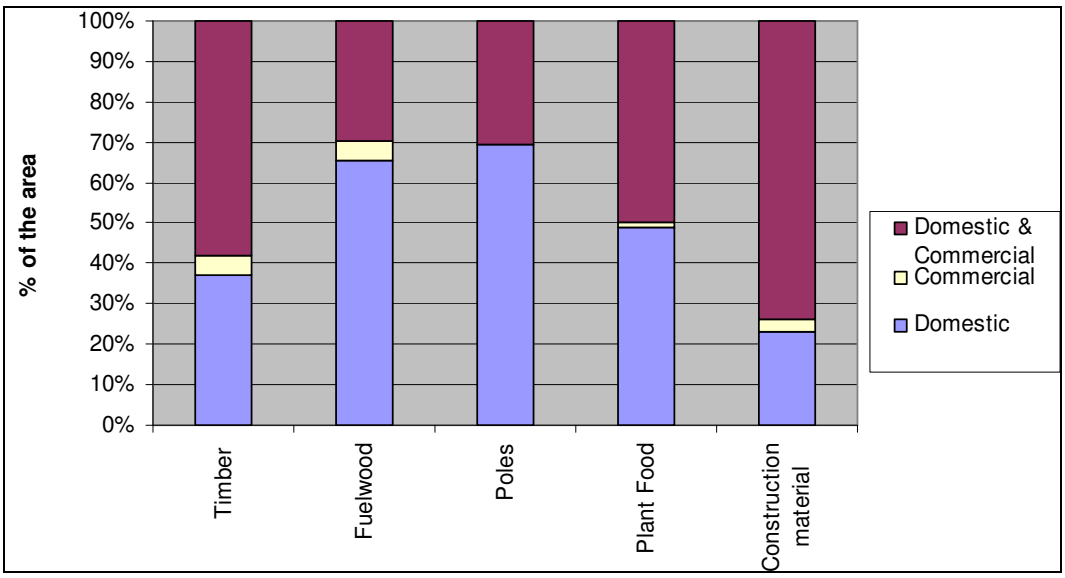

Figure 86: Organization level for the most important products/services in "Cultivated land" area

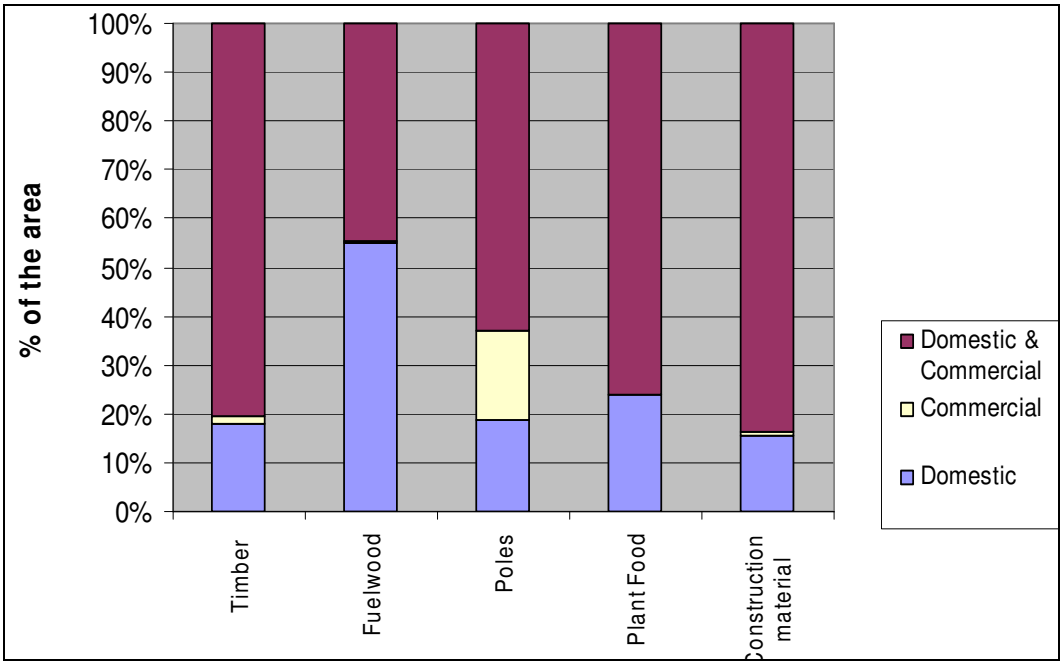

Figure 87: Organization level for the most important products/services in "Village" area

9.4.15. Products and services – frequency of harvesting/usage

Figure 88 to Figure 90 show that the frequency of harvesting/use of the different products/services is almost the same in the Forest, in the Villages and in the Cultivated land. Timber and poles are mainly harvested in intervals >1 year or seasonally. Fuelwood is mainly harvested seasonally or weekly/daily. Construction materials and also plant food are mainly harvested seasonally.

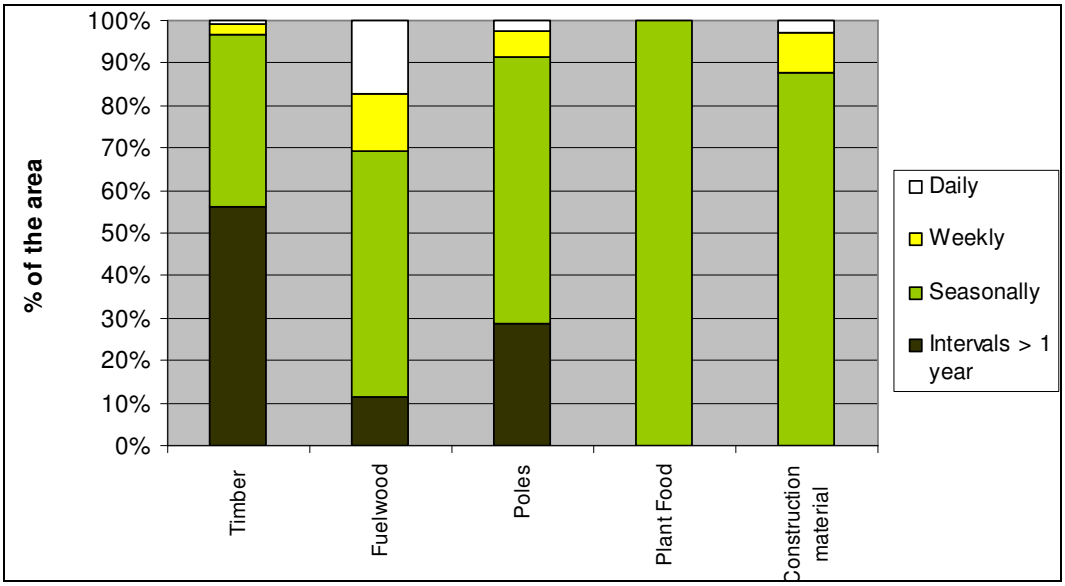

Figure 88: Frequency of harvest / use of most important products and services in "Forest" area

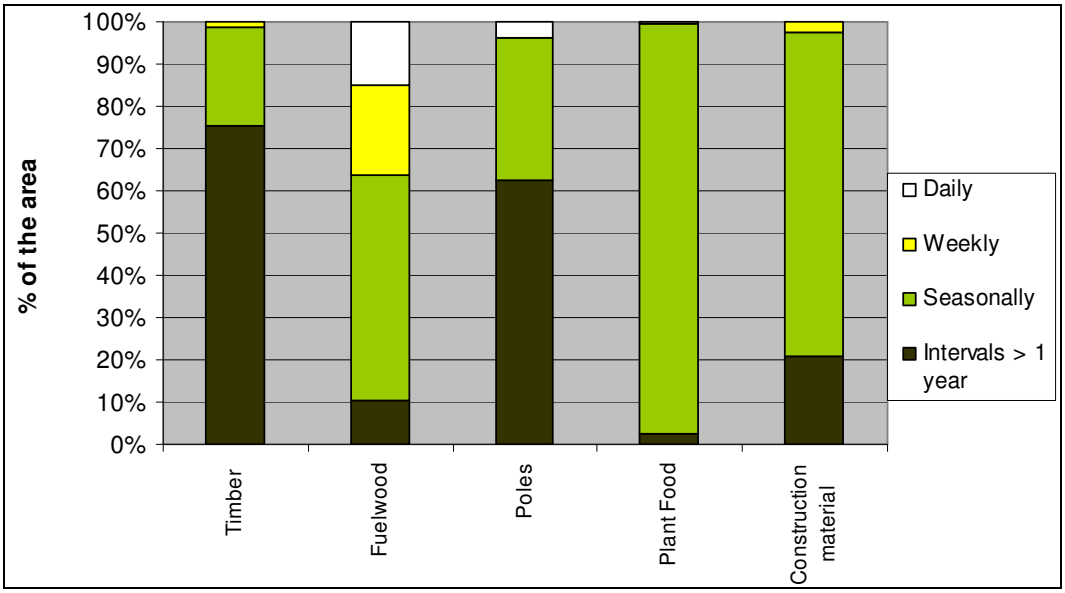

Figure 89: Frequency of harvest / use of most important products and services in "Cultivated land" area

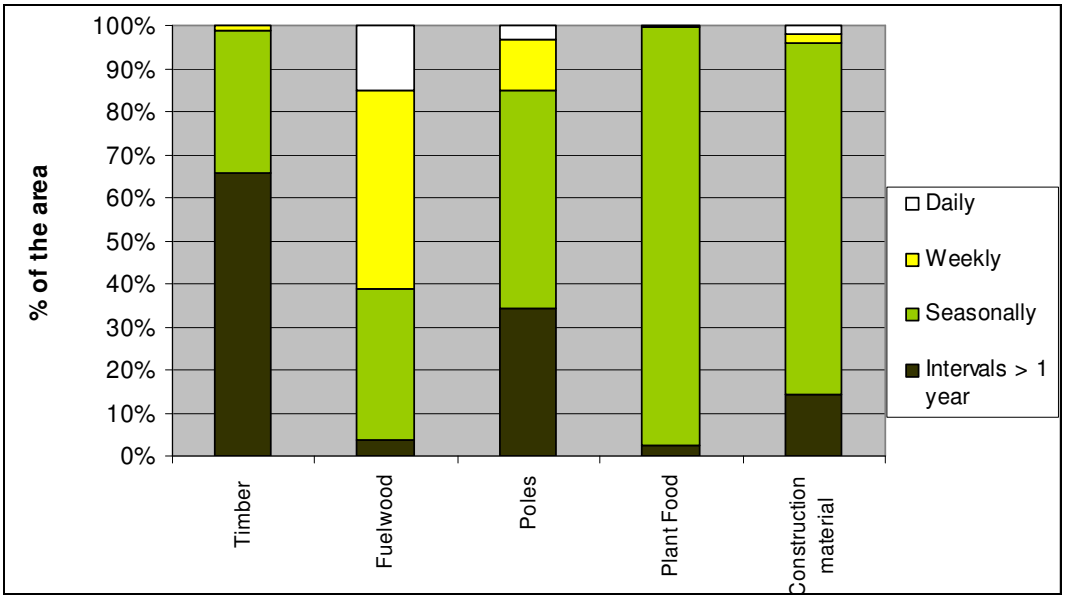

Figure 90: Frequency of harvest / use of most important products and services in "Village" area

9.4.16. Products and services – trend of harvesting/usage

Figure 91 to Figure 93 show that in the Villages the harvesting of timber, fuelwood, poles, construction materials (and also plant food) shows strongly increasing trends. In the Forest the harvesting of timber and fuelwood is increasing in the majority of the areas, but in about 30% of the area it is decreasing. Poles and construction materials are increasing in some areas, but decreasing in other areas. In the Forest, Plant food shows a strongly increasing trend. In the Cultivated land timber, fuelwood, plant food and construction materials shows weakly increasing trends, while the harvest trend for poles is stable.

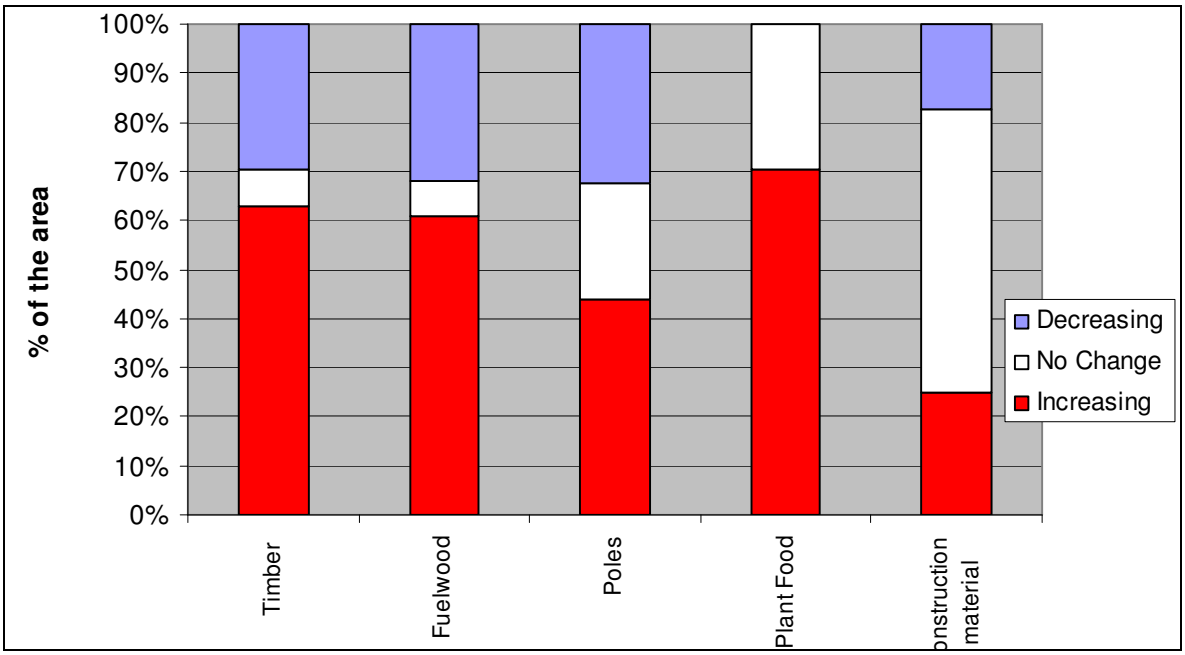

Figure 91: Trend of harvest/usage of the most common/important products/services in the "Forest" area

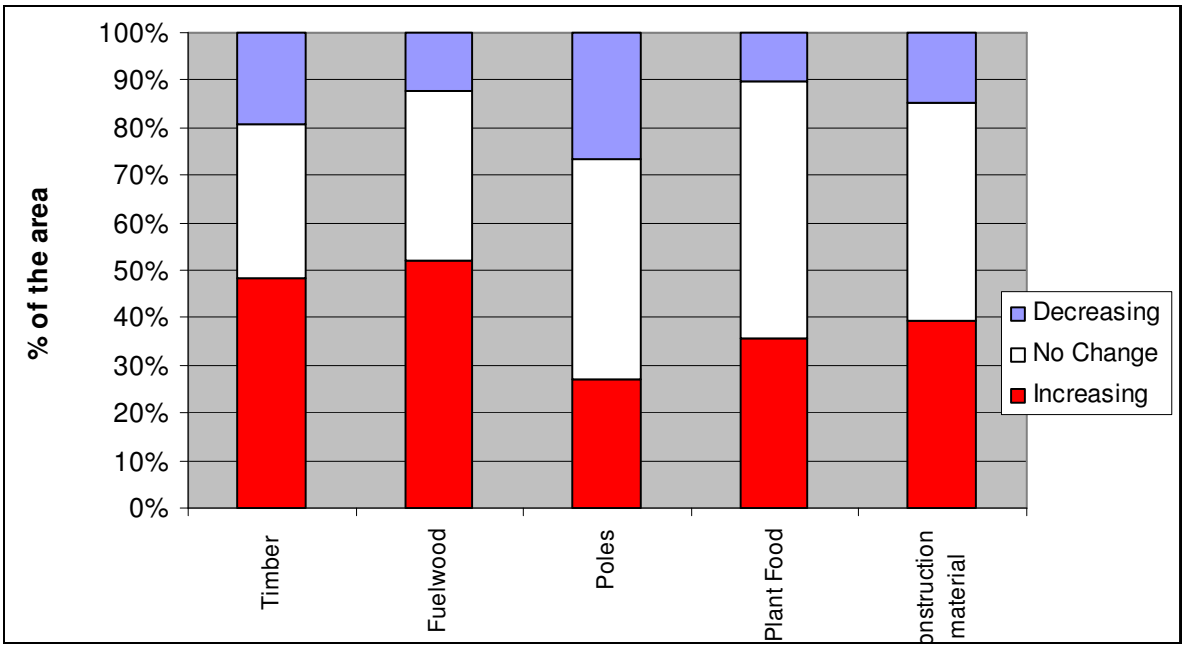

Figure 92: Trend of harvest/usage of the most common/important products/services in the "Cultivated land" area

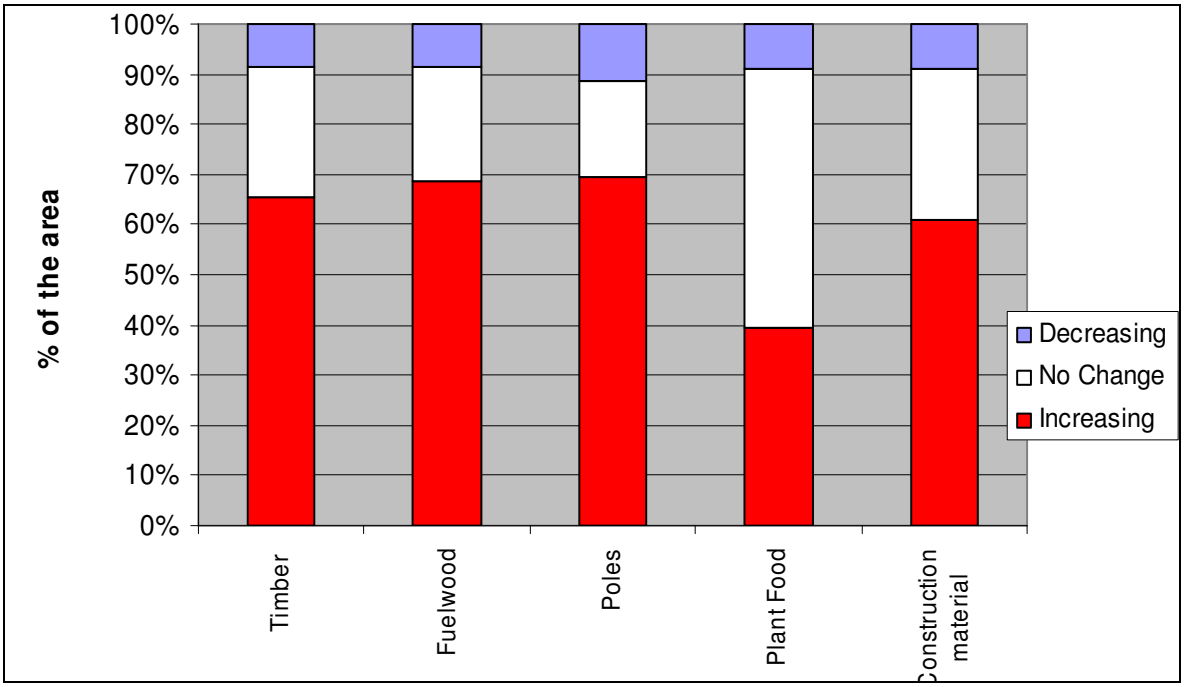

Figure 93: Trend of harvest/usage of the most common/important products/services in the "Village" area

9.5. Biomass and carbon

The primary data used to calculate the biomass and carbon is the inventoried volume over bark (VOB) of all trees with DBH/DAB 10 cm and larger. The inventoried volume is measured from stump to top of bole and excludes branches (FRA 2000).

In the case of NFA-Bangladesh, the inventoried volume refers to the total volume, which is based on the total height of the tree. The total height of a tree is the linear distance along the axis of the bole from the base of the tree to the tip of the crown.

The biomass density for each major land use class was calculated from the inventoried volume over bark per hectare (VOB/ha) by first estimating the biomass of the inventoried volume and then "expanding" this value to take into account the biomass of the other aboveground components, calculating the “aboveground biomass” (Brown and Lugo 1992):

Aboveground biomass (tons) = VOB * WD * BEF

where:

WOB = volume over bark
WD = volume-weighted average wood density (oven-dry biomass per green volume)
BEF = biomass expansion factor

The arithmetic mean and most common wood density value (tons/m^3) for tropical tree species in tropical Asia is 0.57 tons/m^3 with a common range within 0.40 – 0.69 tons/m^3 (FAO 2001). The wood density of 0.57 tons/m^3 is therefore applied in the biomass calculations.

The arithmetic mean and most common biomass expansion factor (BEF) to convert growing stock into above ground biomass is 3.4 for tropical broad-leaved forests in Asia, ranging from 2.0 – 9.0, where the higher values are related to lower biomass densities. In Bangladesh the average biomass density (tons/ha) is relatively low and the value of 6 is therefore applied to the BEF.

9.5.1. The total biomass and the biomass per hectare for the total area of Bangladesh and for the major National LUC

Table 59 shows the (aboveground) biomass per hectare and the total (aboveground) biomass in each major land use class. It can be seen that "Forest" and "Villages" have the highest aboveground biomass density whereas "Inland Water" had the lowest. In terms of the total aboveground biomass, "Villages" has a higher aboveground biomass than "Cultivated Land" despite the fact that the size of "Villages" is only approximately 34% of the area of "Cultivated Land".

Table 59: Total above ground biomass and biomass density in the major land use classes

Land use	Biomass density (tons/ha)	Total Above Ground Biomass (1000 tons)
Forest	193	278,000
Cultivated Land	17	142,000
Villages	144	413,000
Urban Areas	93	10,000
Inland Water	2	4,000
Total	**57**	**846,000**

9.5.2. The total (above ground) carbon and the (above ground) carbon per hectare for the total area of Bangladesh and for the major National LUCs

The result on total carbon and carbon per hectare was derived from the conversion of the aboveground biomass to carbon, based on the assumption that 50% of the tree biomass is comprised of carbon (Gifford 2000).

Table 60 shows the carbon per hectare and the total carbon in each major land use class. Inasmuch as the data used in calculating carbon was based on the aboveground biomass, the results are similar, whereby "Forest" and "Villages" have the highest carbon per hectare and "Inland Water" had the lowest.

Table 60: Total carbon and carbon per hectare in the major land use classes

Land use	Carbon (tons/ha)	Total Carbon (1000 tons)
Forest	96	139,000
Cultivated Land	9	71,000
Villages	72	206,000
Urban Areas	46	5,000
Inland Water	1	2,000
Total	**29**	**423,000**

10. Comparison of NFA-results earlier national statistics

10.1. Area comparisons

The following will give a comparison of area obtained through NFA and that reported by Bangladesh Bureau of Statistics (BSS) 2004.

Table 61 : Comparison of Nfa Findings with BBS 2004 Reported Data on Areas

Land Use Category	Area in Million Hectares			
	NFA 2005-2006	BSS 2004	Bangladpedia	BFD
Forest	**1.44**	2.19**	1.96	2.52
Cultivated Land	**8.33**	8.03		
Village	**2.86**			
Built-Up Area	**0.10**	0.09		
Inland Water	**2.02***			

* NFA estimate for inland water area comprises Rivers, Lakes, Haor & Baor and Ponds

** BSS statistics for forest area comprises WAPDA & Khashland, Reserve-, Acquired-, Vested-, Protected- and Unclassified State Forest, as well as nurseries and garden areas

The finding of the NFA for **'Cultivated land'** coincides well with that of the BSS 2004 (see Table 61). In case of "Forest" Bureau of Statistics (BSS 2004) reported that in 1992 the area was 1.9 Million Hectares while it was reported to be 2.6 Million Hectares in 2000. In 2004 their reported number for 'Forest' is 2.5 Million Hectares. In all the cases their reported number is higher than that what has been obtained in NFA. The area shown in BSS report is mostly legal forest area, while the legal forest area may or may not be forested and it also comprises garden areas. It is therefore logical that forest area of 1.44 Million hectares assessed by the NFA represent the most reliable estimate for the land use **'Forest'**.

BSS 2004 has reported that the urban area in Bangladesh is 0.08 Million Hectares. According to this report the total road length of various types of roads is 20,800 Km, whereof 9,200 are major roads (GIS data BFD). Using an average width of 20m for major roads and 5 m for minor roads we have found that the area under road will be about 0.02 Million Hectares. Since our major land use category **'Built-up areas'** (BUA) includes roads also this manipulation was done to have better comparable number. Thus according to the BSS 2004 the BUA equivalent area is 0.10 Million Hectares which corresponds very well with the figure presented by the NFA, 0.10 Million Hectares.

The NFA estimate of **'Inland Water'** is adopting SPARRSO's official area estimate of inland water 1.74 Million Hectares, which includes water bodies of lakes Rivers and Haor & Baor, and adding to that the 0.29 Million Hectares of Ponds assessed through the NFA field sample survey.

Discussion

According to earlier estimates of Bangladesh Forest Department a total of 2.52 million hectares, nearly 17.4% of Bangladesh, was regarded as forest, of which:

- 1.52 Million Hectares was under the direct control of Forest Department (FD), Government of Bangladesh

- 0.73 Million Hectares was Unclassed State Forest (USF) under the control of district administration and
- 0.27 Million Hectares was privately owned Village Forest (VF).

Banglapedia presents the area of forest land as 1.96 Million Hectares.

BSS 2004 presents the forest area in Bangladesh as follows.

State Forest	1.64 Million Hectares
USF	0.55 Million Hectares
Total	**2.19 Million Hectares.**

The NFA data analyses show that the total area of the land use 'Forest' in Bangladesh is 1.44 Million Hectares. No estimates of the errors for of these statistics are available, except for that of NFA. The sampling error for the estimated forest area as 1.44 Million Hectares by NFA 2005 is 18% and it was reduced further through the employment of full cover mapping.

10.2. Volume comparisons

10.2.1. Comparison of Village Forest Inventory: Gross Tree Volume with NFA Gross Volume

In 1981 a village forest inventory was conducted (Hammermaster 1981). This inventory divided the whole of Bangladesh, excluding Chittagong Hill Tracts, into six strata. This inventory focused on per capita wood volume. However, this report has the stratum wise volume of wood on pages 12 to 17 of the report. This inventory estimated volume for trees with breast height diameter (D_{bh}) 8 inches and above and did not present the volumes by the strata that were used for the purpose.

From this report, using their map and a GIS program the area of each of the stratum that were used in the said village forest inventory was computed and converted the gross volume given in thousand ft^3 (cubic feet) to m^3. (cubic meter) and calculated the gross volume per hectare.

A map was generated (By superimposing the NFA tract locations, on this map of village forest inventory we identified stratum wise NFA tracts (tract numbers). Since the village forest inventory computed the volume of trees that were 8 inches and above at their D_{bh}, the gross volumes from trees with D_{bh} ≥20cm were calculated for the land use classes presented in Table 62.

Table 62 : Land use classes, with corresponding alphanumeric and numeric codes, for which gross volume including trees with D_{bh} ≥20cm was calculated

Land Use Class	Abbreviation	DB Code
Barren/Grass Land	BG	312000
Annual Crops Without trees	CA0	321001
Annual Crops With trees 0,1 – 0,5 ha	CA1	321002
Annual Crops With trees >0,5 ha	CA2	321003
Perennial Crops Without trees	CP0	322001
Perennial Crops With trees 0,1 – 0,5 ha	CP1	322002
Perennial Crops With trees > 0,5 ha	CP2	322003
Range Land/Pasture	RL	323000
Wooded land with shifting cultivation	Fa	324000
Rural settlement without trees	SR0	332001
Rural settlement With trees 0,1 – 0,5 ha	SR1	332002
Rural settlement With trees > 0,5 ha	SR2	332003
Urban settlements	SU	331000
Highways and other artificial areas	HA	333000
Lake	WL	400010
River	WR	400020
Pond	WP	400030
Haor & Baor	WHB	400040

Only the above said land use categories were considered, as the 'Village Forest Inventory' collected only from the village and not from the Forest. It needs to be mentioned herein that our D_{bh} measurements in the NFA data are in 10cm diameter classes and not in inches. The gross volume of trees with D_{bh} ≥20cm was generated stratum (of village forest inventory)

wise. Since we have already calculated the area of each of these strata we use those and generated the following table.

Table 63 and Figure 94 give a comparison of the gross volume per hectare estimated through Village Forest Inventory 1981 with the estimated average gross volume (in Other Land & Inland Water LU) per hectare of NFA 2006, stratum (used in the Village Forest Inventory) wise. This clearly conveys that the wood (gross) volume has increased in every stratum.

Table 63 : Comparison of Gross Volume as per VFI 1981 with average Gross Volume in grouped "Other Land & Inland Water" as per NFA 2005-2006

Village Forest Inventory 1981					NFA Inventory 2005-2006	Percent Increase
Strata	Gross Volume (OB) $D_{bh} \geq 8cm$		Area	Gross Volume per hectare	Gross Volume per hectare	
	('000 ft^3)	(Mm^3)	(Mha)	(Mm^3/ha)	(Mm^3/ha)	
1 (Rajshahi)	463	13.1	3.40	3.85	**5.93**	**54%**
2 (Dhaka)	300	8.5	2.26	3.76	**6.48**	**72%**
3 (Jesore)	356	10.1	2.09	4.82	**17.03**	**252%**
4 (Barisal)	321	9.1	1.64	5.55	**24.03**	**333%**
5 (Chittagong)	372	10.5	1.50	7.00	**16.14**	**131%**
6 (Sylhet)	124	3.5	1.72	2.04	**4.90**	**141%**

In the above analysis the gross volume was computed including volumes from all Land Use categories except "Forest". It was decided to undertake another analysis to compare the gross volume of 'Rural Area' only and compare that with the Village Forest Inventory data since the Village Forest Inventory concentrated in Village Area only. Thus the gross volume in Rural Settlement i.e. in SR0, SR1 and SR2 was computed (see Table 64 and Figure 95). This is probably more realistic since the Village Forest Inventory looked for trees only in the village areas which is more or less the 'Rural Settlement' areas of NFA.

Table 64 : Comparison of Volume per hectare in VFI 1981 with Volume per hectare in SR0, SR1 and SR2 of NFA 2005-2006

Village Forest Inventory 1981					NFA Inventory 2005-2006	Percent Increase
Strata	Gross Volume (OB) $D_{bh} \geq 8cm$		Area	Gross Volume per hectare	Gross Volume per hectare	
	('000 ft^3)	(Mm^3)	(Mha)	(Mm^3/ha)	(Mm^3/ha)	
1 (Rajshahi)	463	13.1	3.40	3.85	**4.36**	**13%**
2 (Dhaka)	300	8.5	2.26	3.76	**4.43**	**18%**
3 (Jesore)	356	10.1	2.09	4.82	**12.24**	**153%**
4 (Barisal)	321	9.1	1.64	5.55	**17.26**	**211%**
5 (Chittagong)	372	10.5	1.50	7.00	**12.03**	**72%**
6 (Sylhet)	124	3.5	1.72	2.04	**3.86**	**89%**

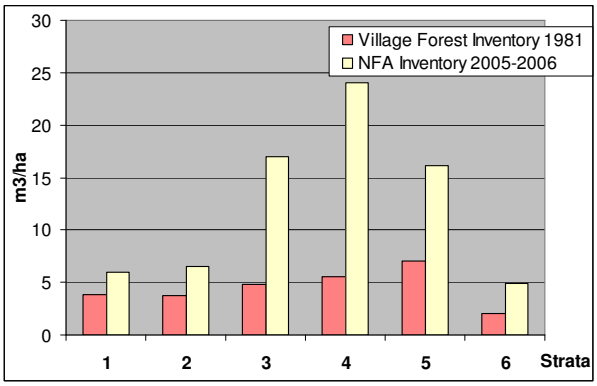

Figure 94 : Volume per hectare in VFI 1981 and average volume per hectare in grouped "Other Land & Inland Water" as per NFA 2005-2006, presented by VFI 1981 strata

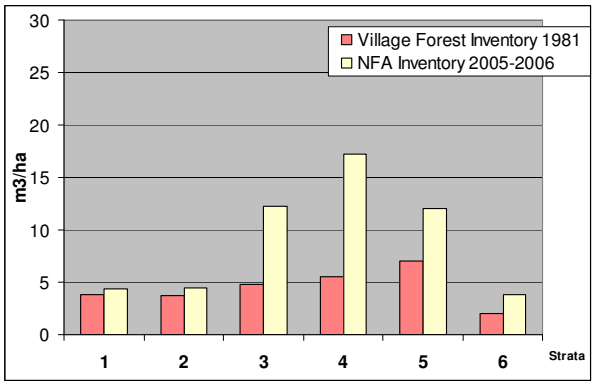

Figure 95 : Volume per hectare in VFI 1981 and average volume per hectare in "Villages" as per NFA 2005-2006, presented by VFI 1981 strata

Both analyses clearly indicate that in each stratum there has been a definite increase in the wood volume per hectare. In 1981 the total population in Bangladesh was 87.1 Million and in 2006 the estimated population was slightly more than 140 Million. Thus the population increase has been more than 60%. Under such a population growth it is likely that the forestry resources will be under heavy pressure, and therefore the rural communities need to plant more trees to sustain their increasing consumption. The increase in tree volume in village areas presented above shows the positive impact of the Community Oriented Forestry Programs launched by the Forest Department Government of Bangladesh.

The increase in tree wood volume however varies in different areas (strata). The maximum increase is seen in Barisal area. The second highest growth is in Jessore area. Barisal and Jessore are the two areas in Bangladesh that produce most of the seedlings that are planted in the country focusing on the species that are preferred by the rural communities. Good accessibility to seedlings and the promotion program of FD, Government of Bangladesh have probably lead to this increase of the wood volumes at these two given sites.

11. Conclusions

The National Forest and Tree Resources Assessment 2005-2007 is the first exercise of its kind in Bangladesh. The assessment was supported by FAO technical assistance and implemented under the entire managerial responsibility of Bangladesh Forest Department. Such model of implementation gave national ownership and responsibility to ensure the long term sustainability of the NFA findings.

Biophysical and socio-economic data about forests and trees outside forest were collected from a national grid of systematic field sampling and wall-to-wall land use mapping. The field data and maps were based on harmonised land use classification system and forest related terms and definition. Current resources assessment has covered a wide range of forest and tree attributes including the productive, social, economic and environmental functions of forests and trees, resulting in the assessment richest in information compared to any other inventory work carried out in Bangladesh.

Beside the rich baseline information developed in Bangladesh, the NFA process contributed largely to build the capacity within the Forestry Department and SPARRSO: -information framework harmonisation, -national forest and tree inventory and monitoring, -data collection for systematic field sampling, -mapping using remote sensing techniques, -database development, -data processing and reporting.

The statistics on land use areas were generated using two main sources: from the mapping on Landsat TM imagery and from the field sampling following a harmonised land use/forest type classification system. Each of these two approaches has different level of spatial resolution. The visual interpretation of 30x30m Landsat images does not recognise the small size (<25mm^2 at interpretation scale) features on the ground such small patches of forests or small land use units as defined in the classification system. This leads to mapping results generally coarse and of lower accuracy compared to field sampling when done at national level with an adequate sampling intensity. In the case of the NFA of Bangladesh, the mapping and field sampling results are used to generate the estimates of forest types and land use classes. The project findings of area and related parameters are based more on the field sampling with limited adjustment using the mapping results.

The NFA process has set up a monitoring system for future assessments of the forest and tree resources. A network of permanent sample plots has been materialised on the ground and well referenced in the records of Bangladesh Forest Department for easy re-localisation in future opportunities. This project should therefore be seen as the foundation of long term monitoring. But this remains dependent of the priorities and willingness of Bangladesh Forest Department to maintain the built capacity, the developed database, and the set up network of permanent sample plots. It will depend on the action of Bangladesh Forest Department to institutionalise the NFA and ensure continuous financing from the Government budget. Moreover, it will depend on how the results will be disseminated and used by the decision makers and these decision makers will value the NFA results.

The NFA has followed a harmonised approach to forestry resources monitoring and assessment putting Bangladesh at same level in scope, quality and format of information as other countries collaborating with FAO. The NFA followed a cost-effective approach designed and promoted by FAO for long term forestry resources and land use change monitoring. With repeated measurements, the NFA will capture information related to the change in the extent, the state and use of forest and trees outside forest resources. Additional parameters can be included in future measurements if deemed relevant. The value of the NFA will therefore increase with every re-measurement.

12. Recommendations

12.1. Future monitoring

The Forestry Department of Bangladesh collaborated with FAO in setting up a long term monitoring system of the country's forest and tree resources. The NFA and the monitoring system were a Government request that reflected the country's need for updated and sound information to feed into the national decision making process when needed. It is of utmost importance that the results of the project are valued and the monitoring system becomes a lasting activity of the Forestry Department. To guarantee continuity of the monitoring system, it is recommended that Bangladesh Forest Department:

- Institutionalise the NFA, improve the managerial capacity of the NFA team, continue strengthening the NFA unit by additional training of the national personnel, maintain the personnel assigned to the project in their position and allocate means and resources for implementation of the forestry resources monitoring related activities.
- Maintain the NFA database, introduce new technologies of information management and continue updating the baseline information to increase its relevance to the national policy processes and the international reporting.
- The NFA should be carried out on a continuous basis to enable maintenance and development of competence and limit the annual needs of resources.
- The cycle for re-measurement in the NFA permanent plots should be around 5 years. A shorter cycle would not be cost efficient and a longer cycle would not meet the needs of updated information.
- A mix of permanent and temporary plots is recommended. Information from new temporary plots during year 1-2 of the NFA could be used to increase the precision in some specific area.
- Maintain the network of the permanent sample plots by safeguarding the records and undertaking periodic visits to the plot location.
- Develop an advisory board involving experts from stakeholders e.g. FD, the regional offices of forests, Survey of Bangladesh, SPARRSO, Agriculture, Environment, etc. to provide guidance on the forestry monitoring system, facilitate inter-institutional collaboration and ensure generalised benefit of it.
- Recognise that Forest Management Inventories and the National Forest Assessment have totally different objectives and that they should not be integrated.

12.2. Additional information needs

Decision-makers have continuous changing demand of information. It is recommended that:

- the NFA and the monitoring system be continually adapted to the shifting needs of information by timely identification and inclusion of the new variables.
- the information framework be widened to cover issues of management and uses of the resources, biodiversity, climate change (biomass and carbon accounting), livelihoods and in relation with the national poverty reduction strategy.
- Bangladesh Forest Department work to count on its own technical capacity to plan and implement future surveys based on the new identified information needs and generate the required knowledge.

- Bangladesh Forest Department work to assign dedicated personnel who ensure that the interest of the forestry sector and interest of Bangladesh in general prevail by optimising the available resources and ensuring high quality delivery.

12.3. Actions for resources development

- The country-wide presence of Bangladesh Forest Department consist a great potential for undertaking future systematic monitoring of the resources. Technical personnel in the Districts require a close follow-up and training to ensure enhanced quality of data collection and timely implementation of the entire NFA process.

- The value of the NFA data will increase with every re-measurement of the permanent sample sites in order to capture information on changes. The data and the permanent sampling grid is potentially useful to many other institutions. Collaboration concerning the fieldwork and the sharing of data between relevant institutional stakeholders should therefore be promoted. It could also help spreading the workload related to conducting periodic fieldwork.

- The NFA findings will help identify priority areas and will be of use for the development of the forestry sector (national forest programme) and an evaluation of forestry policy/strategies in order to ensure a coherent legislation. The NFA is part of a continual process and not the end product in itself.

- The diversity of ownership of the forestry resources in Bangladesh and the high density of population lead to the recommendation of developing wise policies and management plans for forests and TOF to include a participatory approach with the private stakeholders.

12.4. International reporting

The NFA will facilitate International Reporting as it produces information required by a number of international processes according to international standards. However, the driving force behind the NFA is the extent to which data is of use at national level e.g. for policy development or for resources management.

Data related to the composition of forests, their state and the uses of forestry resources will always come from field inventories through on-the-ground measurements, being the only way to capture reliable information on the majority of the many functions of forest and trees.

The FAO support to the national forest and tree resources assessment of Bangladesh is a two-way process, building national capacity in NFA and providing continuous feedback on methodological issues to FAO. It is recommendable

- To continue improve the compatibility between the different classification systems and forest/land use related terms and definition employed nationally and in relation with the international reporting requirements.
- To add new scope of information on global benefits such as biodiversity, climate change, trends (deforestation, improvement or degradation of natural forests.
- To include any new parameters that can be of importance to the international processes.

12.5. Capacity building

To ensure the continuity of forestry resources monitoring it is necessary to build and maintain national capacities related to sampling design, field data collection, data processing and analysis, remote sensing and reporting. FD needs to formulate a “Plan of Action” to secure that the experiences gained from the NFA will be followed-up and implemented in such a way that the capacity to carry out long term NFAs is guarantied. The RIMS-unit (central tasks) and the Management Plan Divisions (field work) both need to be strengthened in order to take on the NFA task.

The RIMS-unit and the three Management Plan Divisions must maintain staff and their competences through continuous capacity building related to NFA activities. Bangladesh Forest Department must work to improve the field and map data processing and analytical capacity within the NFA team. Without such capacity and improved outcomes of the NFA and the resources monitoring process, Bangladesh Forest Department might find it difficult to justify maintaining and financing NFA Unit.

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