Proceedings of the training on data and sample analysis for the hill zone allometric equation development

Bangladesh Forest Department
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Food and Agriculture Organization of the United Nations

The Forest Department of Bangladesh leads actions to improve forest management and conservation, adopting forward thinking, innovative approaches in its management of approximately 1.55 million hectares of land across the country.

In 2015, the Forest Department began a process to establish a National Forest Inventory and Satellite Land Monitoring System for improved forest and natural resource management. The process supports national objectives related to climate change mitigation and provides information in support of the UN REDD programme aimed at Reducing Emissions from Deforestation and Forest Degradation (REDD+). The process also addresses domestic information needs and supports national policy processes related to forests and the multitude of interconnected human and environmental systems that forests support.

The activities implemented under the Bangladesh Forest Inventory process are collaboration between several national and international institutions and stakeholders. National partners from multiple government departments and agencies assist in providing a nationally coordinated approach to land management. International partners, including the United Stated Agency for International Development (USAID), the Food and Agriculture Organization of the United Nations (FAO) and SilvaCarbon are supporting the development of technical and financial resources that will assist in institutionalizing the process.

The results will allow the Forest Department to provide regular, updated information about the status of trees and forests for a multitude of purposes including for assessment of role of trees for firewood, medicines, timber and climate change mitigation.

CONTACTS:

Zaheer Iqbal
National Project Coordinator
Bangladesh Forest Department
Email: z.iqbal60@mail.com

Matieu Henry
Chief Technical Advisor
Food & Agriculture Organization of The United Nations
Email: matieu.henry@fao.org

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Executive Summary

A total of 177 individuals of 14 species of hill zone of Bangladesh were sampled for the development of a common allometric equation of this zone. These data contain log diameters of the stem and bigger branches (diameter >7 cm), base diameter of smaller branches (diameter < 7 cm), fresh biomass of trimmed smaller branches of the sampled trees. On the contrary, Bangladesh Forest Research Institute (BFRI) has shared a bulk of raw data that was previously used to develop volume table for some tree species. This training was supported under a project titled "Strengthening National Forest Inventory and Satellite Land Monitoring System in support of REDD+ in Bangladesh" of Bangladesh Forest Department. The objectives of this training was to develop stakeholder's capacity on data entry, analysis and development of common allometric equation for the Hill zone. Six participants, 2 resource persons from Khulna University and Bangladesh Forest Research Institute were involved in this training programme. Analysis of data provided the common allometric equation for biomass and carbon of Hill zone of Bangladesh are Ln (TAGB) = -6.9531 + 0.8250 Ln (D^2HW); Adjusted R^2 = 0.9334 and Ln (TAGB) = -7.7129 + 0.8268 Ln (D^2HW); Adjusted R^2 = 0.9342 respectively.

Introduction

Under the project GCP/BGD/058/USAID and in collaboration with the UN-REDD Bangladesh National Programme, capacities of Bangladesh Forest Department were strengthened along with capacities from other relevant national entities involved in the forestry sector such as universities and research institute. In particular, trainings, workshops and support were provided for the establishment of national specific allometric equations and improve national biomass estimates. Allometric equation is an important tool to estimate the standing biomass and carbon stock in trees and forest. The development of allometric equation requires extensive fieldwork and involvement of huge time and budget. Accuracy of this equation depends on the sample size, method of biomass determination (destructive or non-destructive or semi-destructive), field data receding, data entry and selection of appropriate models. Previously, three trainings were organized by the Forest Department and FAO on the fieldwork of destructive and semi-destructive method of biomass data collection to the officials of Forest Department, Bangladesh Forest Research Institute and forestry students. There are 222 verified allometric equations in Bangladesh covering only 39 tree species, shrubs and bamboos (Mahmood *et al*. 2006). But, Bangladesh Forest Inventory (BFI) already recorded more than 280 tree species. Considering this situation, Bangladesh Forest Department and FAO have initiated to derive common allometric equations for the BFI zones. Samples from 177 individuals of 14 species and data has been collected for the development of common allometrice equation for hill zone using the semi destructive method. The semi-structure method of allometric equation development requires collection of volume data from the field and collection of samples to convert the volume data into biomass. After the field data collection, next step is to entry the field data, volume calculation and sample analysis. This training programme is designed to processing the samples to record data and data entry for analysis ultimately to strengthen the capacity of national stakeholders for the development of a common allometric equation for hill zone of Bangladesh.

Objectives

The objective of this report is to document the ten days laboratory and classroom training on field data and sample analysis for the development of allometric equation of Hill Zone.

The specific objectives were as follow:

1. Data entry of the collected field data from hill zone,
2. Sample processing,

3. Data entry of supplied raw data from BFRI, and
4. Development of species specific/common allometric equation for the Hill zone

Description of the training program

Six students from Forestry and Wood Technology Discipline, Khulna University and two resource persons from Khulna University and Bangladesh Forest Research Institute were joined the training (Appendix 1).

Semi-destructive method of allometric equation development

Field data entry

Data on tree species, coordinate, administrative location, measurement of tree dimension (DBH, Total Height, Bole length), measurement of selected trimmed branches (base dia, weight of leaves, leaf containing smaller branches, woody smaller branches), base diameter of untrimmed branches, length and diameter of main bole, and length and diameter of untrimmed bigger branches were entered. The sampled species with their number has been presented in the following Table 1. The summarized data has been presented in Appendix 2.

Table 1: *Sampled species with their sample size)*

Species	Number of individual
Albizia spp	9
Aquilaria malaccensis	15
Artocarpus chaplasha	15
Dipterocarpus turbinatus	15
Eucalyptus camaldulensis	6
Hevea brasiliensis	15
Hopea odorata	3
Lagerstroemia speciose	15
Swietenia mahagoni	15
Syzygium grande	15
Tectona grandis	15
Terminalia arjuna	16
Terminalia bellirica	15
Senna siamea	6
Total	**175**

Branch allometric equations

Allometric equations for trimmed branches were developed for each species. These equations were used to estimate the biomass of leaf, leaf containing smaller branches and smaller branches of untrimmed smaller branches (diameter > 7 cm). The range of adjusted R^2 values of leaf, leaf containing

smaller branches and woody part of smaller branches were 0.2487 to 0.9767. Lower values of adjusted R^2 values were observed for leaf and leaf containing smaller branches (Table 2-4).

Table 2: *Allometric equations for leaf biomass for the sampled tree species*

Species Name	Formula	a	b	Adjusted R^2	RSE	AIC	CF
Albizia spp	Ln (Leaf) = a + b Ln (Base dia)	-4.8263	2.2000	0.6630	0.4590	30.7924	1.1111
Aquilaria malaccensis	Ln (Leaf) = a + b Ln (Base dia)	-4.3355	1.8418	0.6588	0.4913	66.2753	1.1283
Artocarpus chaplasha	Ln (Leaf) = a + b Ln (Base dia)	-4.5919	2.1181	0.4355	0.5605	77.8736	1.1701
Dipterocarpus turbinatus	Ln (Leaf) = a + b Ln (Base dia)	-3.5536	1.6613	0.6995	0.3908	41.3420	1.0794
Eucalyptus camaldulensis	Ln (Leaf) = a + b Ln (Base dia)	-3.3784	1.6193	0.8608	0.2607	6.5590	1.0346
Hevea brasiliensis	Ln (Leaf) = a + b Ln (Base dia)	-3.1346	1.4186	0.4171	0.4487	55.8321	1.1059
Hopea odorata	Ln (Leaf) = a + b Ln (Base dia)	-5.7394	2.7592	0.6825	0.3468	10.2186	1.0620
Lagerstroemia speciosa	Ln (Leaf) = a + b Ln (Base dia)	-4.3903	1.0905	0.2487	0.6780	84.3070	1.2584
Senna siamea	Ln (Leaf) = a + b Ln (Base dia)	-2.7384	0.9915	0.3660	0.4037	16.0980	1.0849
Swietenia mahagoni	Ln (Leaf) = a + b Ln (Base dia)	-5.1682	2.1500	0.8564	0.3799	41.8351	1.0748
Syzygium grande	Ln (Leaf) = a + b Ln (Base dia)	-3.2408	1.8044	0.5003	0.5647	71.7442	1.1728
Tectona grandis	Ln (Leaf) = a + b Ln (Base dia)	-3.8044	1.6906	0.5649	0.4906	66.1453	1.1279
Terminalia arjuna	Ln (Leaf) = a + b Ln (Base dia)	-4.6348	1.7160	0.6665	0.4298	107.4087	1.0968
Terminalia bellirica							

Table 3: *Allometric equations for biomass of leaf containing smaller branches of the sampled tree species*

Species Name	Formula	a	b	Adjusted R^2	RSE	AIC	CF
Albizia spp	Ln (LSB) = a + b Ln (Base dia)	-5.0858	2.2000	0.6630	0.4590	30.7924	1.1111
Aquilaria malaccensis	Ln (LSB) = a + b Ln (Base dia)	-4.6118	1.8418	0.6588	0.4913	66.2753	1.1283
Artocarpus chaplasha	Ln (LSB) = a + b Ln (Base dia)	-5.4560	2.1181	0.4355	0.5605	77.8736	1.1701
Dipterocarpus turbinatus	Ln (LSB) = a + b Ln (Base dia)	-3.8259	1.6613	0.6995	0.3908	41.3420	1.0794
Eucalyptus camaldulensis	Ln (LSB) = a + b Ln (Base dia)	-3.7565	1.6193	0.8608	0.2607	6.5590	1.0346
Hevea brasiliensis	Ln (LSB) = a + b Ln (Base dia)	-3.3129	1.4186	0.4171	0.4487	55.8321	1.1059
Hopea odorata	Ln (LSB) = a + b Ln (Base dia)	-5.6311	2.7592	0.6825	0.3468	10.2186	1.0620
Lagerstroemia speciosa	Ln (LSB) = a + b Ln (Base dia)	-3.9839	1.0905	0.2487	0.6780	84.3070	1.2584
Senna siamea	Ln (LSB) = a + b Ln (Base dia)	-2.7718	0.9915	0.3660	0.4037	16.0980	1.0849
Swietenia mahagoni	Ln (LSB) = a + b Ln (Base dia)	-4.7818	2.1500	0.8564	0.3799	41.8351	1.0748
Syzygium grande	Ln (LSB) = a + b Ln (Base dia)	-3.9056	1.8044	0.5003	0.5647	71.7442	1.1728
Tectona grandis	Ln (LSB) = a + b Ln (Base dia)	-4.9475	1.6906	0.5649	0.4906	66.1453	1.1279
Terminalia arjuna	Ln (LSB) = a + b Ln (Base dia)	-4.7956	1.7160	0.6665	0.4298	107.4087	1.0968
Terminalia bellirica	Ln (LSB) = a + b Ln (Base dia)	-4.9524	1.9584	0.6621	0.5707	79.4639	1.1769

Table 4: *Allometric equations for biomass of woody part of the sampled tree species*

Species Name	Formula	a	b	Adjusted R^2	RSE	AIC	CF
Albizia spp	Ln (Smaller branch) = a + b Ln (Base dia)	-2.6978	2.2300	0.7270	0.4013	25.1448	1.0838
Aquilaria malaccensis	Ln (Smaller branch) = a + b Ln (Base dia)	-4.4371	2.7251	0.8996	0.3390	33.6234	1.0591
Artocarpus chaplasha	Ln (Smaller branch) = a + b Ln (Base dia)	-3.9161	2.8530	0.8124	0.3225	29.2441	1.0534
Dipterocarpus turbinatus	Ln (Smaller branch) = a + b Ln (Base dia)	-2.9422	2.4435	0.9145	0.2694	12.3242	1.0370
Eucalyptus camaldulensis	Ln (Smaller branch) = a + b Ln (Base dia)	-3.1944	2.5920	0.9551	0.2259	1.4004	1.0258
Hevea brasiliensis	Ln (Smaller branch) = a + b Ln (Base dia)	-2.6717	2.3207	0.7818	0.3325	30.6521	1.0568
Hopea odorata	Ln (Smaller branch) = a + b Ln (Base dia)	-2.8822	2.2256	0.9211	0.1228	-8.4698	1.0076
Lagerstroemia speciosa	Ln (Smaller branch) = a + b Ln (Base dia)	-2.8503	2.2832	0.8707	0.3263	27.2671	1.0547
Senna siamea	Ln (Smaller branch) = a + b Ln (Base dia)	-2.3945	2.3390	0.9767	0.1202	-12.9755	1.0073
Swietenia mahagoni	Ln (Smaller branch) = a + b Ln (Base dia)	-4.4535	3.1104	0.9664	0.2506	6.8934	1.0319
Syzygium grande	Ln (Smaller branch) = a + b Ln (Base dia)	-2.6282	2.3104	0.8482	0.3092	23.5734	1.0490
Tectona grandis	Ln (Smaller branch) = a + b Ln (Base dia)	-2.9229	2.2546	0.7781	0.4003	48.2573	1.0834
Terminalia arjuna	Ln (Smaller branch) = a + b Ln (Base dia)	-3.5494	2.6620	0.8889	0.3340	61.9939	1.0574
Terminalia bellirica	Ln (Smaller branch) = a + b Ln (Base dia)	-3.2717	2.4554	0.9146	0.3076	25.0585	1.0484

Common allometric equation

Common allometric equations for the hill zone were derived from the processed data using R statistical software. The equations for above-ground biomass and carbon in above-ground biomass are presented in the following Table 5-6 (Where, TAGB= Total above-ground biomass in Kg, D= Diameter at Breast Height in cm, H = Total Height in m and W = wood density in Kg/m^3). The best fit equation was Ln (TAGB) = a + b Ln (D^2HW) both for total above-ground biomass and carbon in total above-ground biomass.

Table 5: *Common allometric biomass equation for the Hill zone of Bangladesh*

Formula	a	b	c	d	R^2_adj	RSE	AIC	CF
Ln (TAGB) = a + b Ln (D)	-1.2571	2.1771			0.8587	0.3636	146.5130	1.0683
Ln (TAGB) = a + b Ln (D) + c Ln (H)	-1.7872	1.7232	0.7739		0.8847	0.3274	111.7851	1.0554
Ln (TAGB) = a + b Ln (D) + c Ln (H) + d Ln (W)	-7.0679	1.7546	0.6657	0.8543	0.9338	0.2474	15.8159	1.0315
Ln (TAGB) = a + b Ln (D^2HW)	-6.9531	0.8250			0.9334	0.2496	14.9057	1.0317
Ln (TAGB) = a + b Ln (D)) + c Ln (W)	-6.9589	2.1430	0.9096		0.9144	0.2821	59.6342	1.0408
Ln (TAGB) = a + b Ln (D^2H) + c Ln (W)	-7.0543	0.8237	0.8426		0.9330	0.2496	16.8474	1.0318
Ln (TAGB) = a + b Ln (D^2H)	-1.8116	0.8393			0.8852	0.3277	110.0875	1.0551

Table 6*: Common allometric equation of carbon in total above-ground biomass for the Hill zone of Bangladesh*

Formula	a	b	c	d	R^2_adj	RSE	AIC	CF
Ln (TAGB) = a + b Ln (D)	-1.9985	2.1803			0.8581	0.3650	147.8675	1.0689
Ln (TAGB) = a + b Ln (D) + c Ln (H)	-2.5354	1.7204	0.7839		0.8848	0.3279	112.3985	1.0556
Ln (TAGB) = a + b Ln (D) + c Ln (H) + d Ln (W)	-7.8659	1.7521	0.6747	0.8623	0.9345	0.2464	14.4017	1.0312
Ln (TAGB) = a + b Ln (D^2HW)	-7.7129	0.8268			0.9342	0.2485	13.2847	1.0314
Ln (TAGB) = a + b Ln (D)) + c Ln (W)	-7.7554	2.1458	0.9184		0.9147	0.2821	59.6452	1.0408
Ln (TAGB) = a + b Ln (D^2H) + c Ln (W)	-7.8529	0.8251	0.8512		0.9339	0.2484	15.1720	1.0315
Ln (TAGB) = a + b Ln (D^2H)	-2.5567	0.8408			0.8853	0.3282	110.6267	1.0553

Data entry and volume calculation of bulk of raw data from BFRI

Hard copy of volume data of 11 species (Table 7) were collected from Bangladesh Forest Research Institute (BFRI). This hard copy contained volume data of 3132 individual of 11 species. These data were previously used by BFRI to develop volume table. These data contain log diameter and bark thickness of the sampled tree. Microsoft Excel was used for data entry from the hard copy, calculation of log volume, and stem volume with and without bark.

Table 7: *List of species with their sample size*

Species	Number of individual
Acacia aulicuriformis	628
Acacia mangium	314
Aquilaria malaccensis	250
Dipterocarpus turbinatus	215
Eucalyptus camaldulensis	324
Gmelina arborea	137
Hevea brasiliensis	584
Lagerstroemia speciose	311
Syzygium grande	114
Tectona grandis	56
Senna siamea	199
Total	**3,132**

Recommendation and next steps

- It is recommended to calculate species specific biomass expansion factor for the species having volume data from BFRI
- Calculation of Total Above Ground Biomass (TAGB) of trees having volume data using BEF
- Derive species specific biomass allometric equation for the 11 species having volume data

References

Mahmood, H., Siddique, M.R.H., Abdullah, S.M.R., Akhter, M., Islam, S.M.Z. 2016. Field measurement protocol on tree allometric equations for estimating above-ground biomass and volume in Bangladesh. Food & Agriculture Organization of the United Nations, Rome, Italy and Forest Department, Government of the People's Republic of Bangladesh, 101 pp.

Appendix 1: *List of participant*

ID	Name	Gender	Organization	Designation	Phone no	E-mail
1	Dr. Mahmood Hossain	M	Khulna University	Professor	01711959380	mahmoodhossain@hotmail.com
2	Md. Zahir	M	BFRI	RO	01837000010	Zahir.fid.bfri@gmail.com
3	MST Lulu Rayhan Khushi	F	Khulna University	Student		
4	Shraboni Deb	F	Khulna University	Student		Shrabonided60@gmail.com
5	Md. Naif Ahmed Chowdhydy	M	Khulna University	Student		naiffwt@gmail.com
6	Mr. Narottom Paul	M	Khulna University	Student		
7	Biskwajit Deb	M	Khulna University	Student		
8	Md. Sazzad Hossain	M	Khulna University	Student		

***Appendix 2**: Summarized Field data*

Tree no	Scientific name	Longitude	Latitude	DBH (cm)	Total Height (m)	Leaf biomass (kg)	Branch biomass (kg)	Bole without bark (kg)	Bark biomass (kg)	TAGB (kg)	Carbon in TAGB (kg)
1	*Syzygium grande*	91.9382	24.9541	31.0	17.3	28.76	201.80	640.526107	53.24721	924.34	448.4581
2	*Artocarpus chaplasha*	91.9379	24.9539	33.3	15.4	5.92	46.11	322.890403	33.67833	408.60	191.1472
3	*Artocarpus chaplasha*			17.0	13.5	6.19	67.56	80.9328286	20.57565	175.25	80.6575
4	*Terminalia arjuna*	91.9381	24.9558	19.1	14.4	1.44	31.03	200.393289	10.40498	243.26	117.4596
5	*Terminalia arjuna*	91.9381	24.9558	15.5	13.3	1.89	42.43	101.834648	11.45932	157.62	75.37023
6	*Terminalia arjuna*	91.9383	24.9557	30.2	18.7	4.13	105.25	589.715563	48.71754	747.81	359.5397
7	*Terminalia arjuna*	91.9383	24.9559	35.1	19.5	5.28	170.87	695.436057	46.73265	918.32	442.0533
8	*Terminalia arjuna*	91.9385	24.9558	25.7	15.5	5.73	140.87	370.198607	16.26276	533.07	256.8661
9	*Terminalia arjuna*	91.9384	24.9559	22.6	12.7	2.97	66.36	302.275362	15.11855	386.73	186.5979
10	*Syzygium grande*	91.9387	24.9554	23.1	15.9	18.45	115.80	287.097962	21.72664	443.08	214.6776
11	*Artocarpus chaplasha*	91.9382	24.9553	17.5	11.7	5.70	50.38	61.6061163	6.692414	124.38	57.3743
12	*Syzygium grande*	91.9382	24.9553	16.5	13.1	12.39	58.51	141.076826	15.27148	227.24	109.988
13	*Syzygium grande*	91.9381	24.9554	31.8	15	14.58	80.18	379.3844	36.37876	510.53	248.0336
14	*Syzygium grande*	91.9384	24.9554	15.7	12.2	12.13	60.74	101.627744	11.21318	185.71	89.69103
15	*Artocarpus chaplasha*	91.9383	24.9539	30.0	16	9.11	105.52	295.531457	19.9198	430.08	200.2886
16	*Tectona grandis*	91.7745	24.3127	25.7	14.3	6.01	60.65	293.937273	17.36856	377.96	183.9129
17	*Lagerstroemia speciosa*	91.7746	24.3127	30.2	14.7	2.54	264.72	309.055439	22.70369	599.02	289.4906
18	*Lagerstroemia speciosa*	91.775	24.3126	43.9	17.8	3.83	619.19	553.876148	30.69587	1207.59	583.0349
19	*Lagerstroemia speciosa*	91.775	24.3127	22.6	16	1.23	100.16	219.945138	15.9868	337.33	163.648
20	*Lagerstroemia speciosa*	91.7751	24.3124	31.0	18.2	1.41	58.00	453.237242	11.86382	524.51	256.5886
21	*Lagerstroemia speciosa*	91.7752	24.4124	15.5	8	0.58	29.29	57.18545	31.22063	118.27	56.30187
22	*Tectona grandis*	91.7753	24.3121	48.5	19.5	15.84	173.74	820.069115	106.9313	1116.58	541.0328
23	*Tectona grandis*	91.7753	24.3123	41.4	16.2	15.64	147.88	664.000283	49.73544	877.26	426.2338
24	*Dipterocarpus turbinatus*	91.7785	24.3292	31.0	18.5	18.22	142.95	360.470725	103.8917	625.53	300.947
25	*Dipterocarpus turbinatus*	91.7784	24.3292	22.9	19	30.74	239.10	200.711703	72.34191	542.89	261.4029
26	*Dipterocarpus turbinatus*	91.7784	24.3292	22.9	17.7	9.52	79.94	208.204092	64.92393	362.59	174.3339
27	*Dipterocarpus turbinatus*	91.7784	24.3292	12.4	12	10.86	73.89	35.7183979	18.19981	138.67	66.72473
28	*Dipterocarpus turbinatus*	91.7785	24.3292	14.0	11.7	7.72	59.76	44.9534243	20.04095	132.48	63.71911
29	*Aquilaria malaccensis*	91.7786	24.3293	24.1	14	0.93	35.07	136.887412	7.960717	180.85	87.67651
30	*Artocarpus chaplasha*	91.7788	24.3292	36.1	20.1	19.55	328.76	466.131421	58.06043	872.50	403.2551
31	*Artocarpus chaplasha*	91.7788	24.3293	28.4	17	7.40	72.32	242.553967	22.89795	345.17	160.8235
32	*Aquilaria malaccensis*	91.7782	24.3292	33.0	21	1.72	44.45	298.319114	20.35099	364.84	176.9194
33	*Tectona grandis*	91.7753	24.3117	34.3	18	16.12	119.51	501.594385	75.45478	712.68	344.5748
34	*Tectona grandis*	91.7754	24.3118	26.9	18.1	12.53	99.90	380.710729	58.16259	551.30	266.4127
35	*Tectona grandis*	91.7756	24.3118	22.9	17	8.95	76.30	280.011639	47.88821	413.15	199.4539
36	*Tectona grandis*	91.7755	24.3118	14.5	8	8.82	67.29	45.3975003	11.18286	132.68	63.15944
37	*Tectona grandis*	91.7755	24.3118	11.2	9.5	4.06	30.87	78.2743039	8.706393	121.92	58.87617
38	*Terminalia arjuna*	91.7752	24.3118	26.4	16.8	8.26	172.78	28.8446103	5.962117	215.85	102.2899
39	*Lagerstroemia speciosa*	91.7753	24.3123	30.5	15.3	2.81	165.42	351.024118	26.69761	545.95	264.7204
40	*Tectona grandis*	91.7754	24.3124	39.1	23	11.64	100.30	787.995941	73.55302	973.49	473.6468
41	*Aquilaria malaccensis*	91.4572	24.1265	26.4	16	0.62	24.52	160.548987	6.293861	191.98	93.22533
42	*Aquilaria malaccensis*	91.4571	24.1266	27.4	13.7	1.68	51.44	130.572021	7.271542	190.96	92.49751
43	*Aquilaria malaccensis*	91.4572	24.1267	14.5	10	0.64	21.01	38.4746542	1.476885	61.60	29.83064
44	*Aquilaria malaccensis*	91.4571	24.1266	10.9	7	0.91	11.47	2.77217481	0.436776	15.59	7.484799
45	*Aquilaria malaccensis*	91.4571	24.1265	32.3	15.3	1.51	116.21	90.8013371	5.380143	213.90	103.3273
46	*Aquilaria malaccensis*	91.4564	24.1261	38.6	20	1.44	140.93	185.842835	13.16313	341.38	165.0864
47	*Aquilaria malaccensis*	91.4567	24.1267	17.8	11.4	0.51	15.00	64.4405826	3.528437	83.48	40.47794
48	*Artocarpus chaplasha*	91.4569	24.1263	23.9	13	10.74	105.30	220.929262	15.99434	352.96	163.884
49	*Artocarpus chaplasha*	91.4565	24.1268	57.7	20	39.89	998.64	760.996395	55.59052	1855.12	852.6985
50	*Eucalyptus camaldulensis*	91.4548	24.1278	25.7	18	11.71	109.89	290.515431	84.28716	496.40	242.1867
51	*Eucalyptus camaldulensis*	91.4548	24.1274	41.4	24	31.68	412.09	1109.53082	227.2577	1780.56	872.2508
52	*Eucalyptus camaldulensis*	91.4548	24.1274	29.5	18	11.82	102.87	392.6486	79.71715	587.06	287.6828
53	*Eucalyptus camaldulensis*	91.1213	24.1274	27.7	17.1	10.90	109.81	356.294475	65.8532	542.86	266.2186
54	*Albizia spp.*	91.4548	24.1274	17.3	11.5	3.97	36.77	63.1286515	19.13704	123.00	59.51078
55	*Eucalyptus camaldulensis*	91.4548	24.7648	13.0	11.2	3.77	29.83	61.67374	12.27032	107.54	52.6264
56	*Hevea brasiliensis*	91.5035	24.1631	20.6	9	13.22	138.85	52.7968069	12.8891	217.76	104.6193
57	*Hevea brasiliensis*	91.5036	24.1631	16.5	10	8.67	88.23	39.9718784	9.845877	146.71	70.58075
58	*Hevea brasiliensis*	91.5036	24.163	24.6	9.2	21.98	206.34	10.0755312	2.30436	240.70	114.5714
59	*Hevea brasiliensis*	91.5037	24.1631	13.0	5.6	5.64	58.97	13.392066	4.062629	82.07	39.29607
60	*Hevea brasiliensis*	91.5034	24.1632	25.4	10.5	11.56	138.71	90.4347259	19.09637	259.80	125.399
61	*Hevea brasiliensis*	91.5063	24.16426	32.5	9.8	17.32	216.96	115.44731	23.70418	373.43	179.9358
62	*Hevea brasiliensis*	91.5065	24.1646	30.5	10	16.79	176.91	86.2441438	14.91928	294.86	141.9197
63	*Dipterocarpus turbinatus*	92.0637	21.9558	42.4	16.7	13.93	150.80	665.584324	99.0428	929.36	448.8695
65	*Dipterocarpus turbinatus*	92.0637	21.9556	62.0	21	21.85	459.99	1527.3899	182.3247	2191.56	1060.047
66	*Dipterocarpus turbinatus*	92.0628	21.9548	40.9	22.4	9.09	91.26	663.643592	159.2806	923.28	444.3611

Tree no	Scientific name	Longitude	Latitude	DBH (cm)	Total Height (m)	Leaf biomass (kg)	Branch biomass (kg)	Bole without bark (kg)	Bark biomass (kg)	TAGB (kg)	Carbon in TAGB (kg)
67	Dipterocarpus turbinatus	92.064	21.9563	32.5	16.4	9.49	118.88	421.675766	66.50217	616.55	297.7561
68	Dipterocarpus turbinatus	92.0619	21.9532	16.5	11.5	2.37	13.38	61.1238445	16.96636	93.84	45.11789
69	Dipterocarpus turbinatus	92.0647	21.9539	16.5	8.2	5.01	36.44	55.3410818	6.536304	103.33	49.96791
70	Lagerstroemia speciosa	92.0623	21.9637	35.6	16.1	3.59	277.72	460.110199	60.52826	801.94	387.3779
71	Lagerstroemia speciosa	92.0617	21.9637	57.7	17.2	5.18	893.18	1119.84976	125.4425	2143.66	1035.069
72	Lagerstroemia speciosa	92.06172	21.9636	35.8	14.3	1.57	147.75	343.983513	33.45611	526.76	255.3201
73	Lagerstroemia speciosa	92.06182	21.9637	26.7	14.5	1.57	71.97	241.853893	35.01836	350.42	169.6481
74	Lagerstroemia speciosa	92.0617	21.9637	24.4	13	0.94	69.83	141.203297	21.85998	233.83	112.9427
75	Syzygium grande	92.0668	21.9551	21.6	11.1	14.70	86.55	110.200671	33.24001	244.69	117.7898
76	Syzygium grande	92.0669	21.955	18.3	7.5	15.09	88.22	67.3787984	5.491082	176.19	84.68415
77	Syzygium grande	92.0668	21.9551	15.7	9.2	14.63	85.40	39.3228446	5.207662	144.57	69.24833
78	Terminalia arjuna	92.0668	21.955	19.6	9.1	3.30	54.93	116.431353	9.452556	184.12	88.26572
79	Terminalia arjuna	92.0664	21.9546	15.7	8.7	2.72	63.65	39.4380123	5.837664	111.64	53.07577
82	Artocarpus chaplasha	92.0566	21.9226	57.7	17.2	34.84	627.77	1007.67448	56.15706	1726.44	800.1849
83	Artocarpus chaplasha	92.05668	21.9224	25.9	11	8.95	97.52	171.164656	16.37734	294.01	136.2069
84	Terminalia bellirica	92.0549	21.9233	11.4	6	0.00	30.50	21.6180624	2.208881	54.33	25.5342
85	Terminalia bellirica	92.0549	21.9234	12.2	7	0.00	34.84	33.3692231	5.807405	74.01	34.96896
86	Terminalia bellirica	92.0549	21.9233	13.7	7	0.00	25.83	35.5215377	5.485055	66.83	31.80761
87	Terminalia bellirica	92.0548	21.9234	11.2	7.2	0.00	10.04	25.5192538	4.795916	40.35	19.38591
88	Terminalia bellirica	92.06005	21.9312	20.6	12.5	0.00	47.47	150.49605	22.59475	220.56	106.4058
89	Terminalia arjuna	92.05958	21.9314	55.4	18.6	16.63	831.37	1420.51374	93.14479	2361.67	1133.693
90	Terminalia arjuna	92.06005	21.9312	31.2	13.1	3.66	86.90	410.570373	38.80748	539.94	259.1189
91	Terminalia arjuna	92.05998	21.93118	31.0	16	7.49	279.51	399.044412	36.93993	722.99	345.9318
92	Syzygium grande	92.08237	21.71181	35.8	20.5	22.06	210.83	806.523184	83.9871	1123.40	545.4283
93	Syzygium grande	92.08248	21.71206	19.6	15.5	8.41	50.43	213.622713	22.81125	295.27	143.3662
94	Syzygium grande	92.0824	21.71193	33.3	22.4	17.07	134.88	862.324308	136.2802	1150.56	558.9918
95	Dipterocarpus turbinatus	92.0817	21.71321	44.7	16.5	22.01	403.64	1048.47228	88.49683	1562.62	756.8447
96	Dipterocarpus turbinatus	92.08251	21.71338	29.2	17.7	9.64	92.99	368.09229	53.13665	523.86	253.0601
97	Dipterocarpus turbinatus	92.08247	21.71307	24.6	16.3	3.85	31.40	261.355897	37.79113	334.40	161.4774
98	Dipterocarpus turbinatus	92.08245	21.71325	16.5	10.2	3.76	40.32	114.878176	13.35511	172.32	83.34101
99	Syzygium grande	92.08194	21.71326	75.9	20.2	115.81	2570.50	3144.33901	116.9517	5947.60	2872.957
100	Syzygium grande	92.08295	21.71298	31.8	21.3	18.43	116.71	589.169965	74.451	798.76	387.9694
101	Terminalia bellirica	92.0812	21.6842	29.0	11.8	0.00	138.45	334.285246	36.53485	509.27	245.0459
102	Terminalia bellirica	92.08108	21.68401	34.3	14.8	0.00	134.27	564.683973	61.26479	760.22	368.6211
103	Terminalia bellirica	92.08114	21.68424	22.1	10.5	0.00	87.85	171.611688	29.22559	288.69	138.1927
104	Terminalia bellirica	92.0812	21.68395	22.9	10.9	0.00	108.20	128.728909	17.54366	254.47	120.8129
105	Terminalia bellirica	92.08097	21.6842	23.6	12.1	0.00	100.67	242.767138	32.12786	375.57	180.5803
106	Terminalia bellirica	92.08105	21.6843	27.2	14.2	0.00	86.15	242.306262	31.46238	359.92	173.4681
107	Terminalia bellirica	92.08068	21.68441	21.8	10.3	0.00	86.98	173.774065	10.75288	271.51	130.4088
108	Terminalia bellirica	92.08124	21.68428	24.6	8.5	0.00	141.31	168.354398	12.24742	321.91	153.0113
109	Terminalia bellirica	92.08135	21.68448	38.1	12.1	0.00	249.91	361.184022	26.93716	638.03	304.4534

Tree no	Scientific name	Longitude	Latitude	DBH (cm)	Total Height (m)	Leaf biomass (kg)	Branch biomass (kg)	Bole without bark (kg)	Bark biomass (kg)	TAGB (kg)	Carbon in TAGB (kg)
110	*Terminalia bellirica*	92.08114	21.68391	26.4	11.7	0.00	100.01	200.738368	29.48777	330.24	158.2486
111	*Terminalia arjuna*	92.081233	21.68393	31.2	13.4	4.60	92.64	327.1898	34.56184	458.99	219.8343
112	*Terminalia arjuna*	92.08115	21.68401	15.5	7	2.17	50.88	75.8086818	5.428694	134.29	64.36226
113	*Terminalia arjuna*	92.08093	21.6842	23.9	14.3	3.79	95.85	267.902744	38.05485	405.60	193.4462
114	*Terminalia arjuna*	92.08083	21.68406	20.8	10.5	2.75	72.35	136.414999	12.23313	223.75	107.1662
115	*Eucalyptus camaldulensis*	92.0744	21.6654	40.1	19.4	14.34	278.81	615.814235	62.80659	971.76	478.3114
116	*Artocarpus chaplasha*	92.07421	21.6651	56.9	18.5	20.22	344.69	946.509292	53.47384	1364.89	635.9147
117	*Artocarpus chaplasha*	92.074067	21.66518	29.7	14.3	6.66	73.42	195.387786	17.55582	293.03	136.3065
118	*Artocarpus chaplasha*	92.07423	21.66513	28.4	15.8	5.89	66.26	138.509664	12.92333	223.58	103.7679
119	*Senna siamea*	92.0746	21.66497	45.0	16.1	6.28	423.53	706.360694	41.02546	1177.19	579.0569
120	*Senna siamea*	92.07477	21.66494	38.4	16.5	5.55	333.30	505.17662	29.99026	874.01	429.8117
121	*Hopea odorata*	92.19375	21.8155	36.3	11.5	16.43	115.81	331.291738	28.31924	491.85	233.9978
122	*Hopea odorata*	92.19416	21.81605	35.8	14.6	24.53	179.73	442.054569	34.20912	680.51	323.4788
123	*Albizia spp.*	92.1934	21.81551	18.5	9.8	4.63	60.83	49.9474536	5.292143	120.70	58.36715
124	*Albizia spp.*	92.19345	21.81553	20.3	10.3	8.60	81.48	84.4701249	8.670246	183.23	88.67548
125	*Albizia spp.*	92.19385	21.81341	46.5	14.7	12.26	166.25	515.100428	63.1438	756.75	367.6156
126	*Aquilaria malaccensis*	92.19175	21.8134	18.8	9.7	0.32	114.06	54.4599223	2.92311	171.77	82.90957
127	*Aquilaria malaccensis*	92.19163	21.8135	22.9	11.7	0.48	20.38	100.848489	4.224923	125.93	61.12228
128	*Aquilaria malaccensis*	92.19185	21.81345	14.0	7.3	0.28	14.76	25.6541974	1.403093	42.09	20.37364
129	*Aquilaria malaccensis*	92.19153	21.8135	14.2	6.5	0.17	12.96	13.8696183	1.519923	28.52	13.76857
130	*Aquilaria malaccensis*	92.19171	21.8134	17.3	8.8	0.47	9.73	51.4556958	4.050491	65.71	31.83565
131	*Aquilaria malaccensis*	92.19167	21.81332	16.8	10.9	0.21	26.75	32.3569927	2.595545	61.91	29.92814
132	*Swietenia mahagoni*	92.20365	21.7651	51.6	22.3	13.27	462.70	1057.53993	109.8615	1643.37	792.1835
133	*Swietenia mahagoni*	92.20376	21.76486	24.9	18.4	3.63	72.82	263.076995	29.39261	368.93	178.3262
134	*Swietenia mahagoni*	92.203674	21.76487	34.3	17.3	1.67	30.17	411.290535	52.53801	495.67	240.6689
135	*Swietenia mahagoni*	92.20384	21.76505	21.1	16.3	2.68	37.68	185.108201	20.57037	246.03	119.1187
136	*Swietenia mahagoni*	92.20395	21.765	31.8	16.3	3.68	95.76	405.134079	35.92248	540.50	261.8159
137	*Hevea brasiliensis*	92.16285	21.72575	30.5	12.8	9.02	162.32	196.773307	11.94188	380.06	184.5402
138	*Hevea brasiliensis*	92.162884	21.72568	29.0	13.5	9.33	127.73	185.584129	11.57026	334.21	162.5059
139	*Hevea brasiliensis*	92.162884	21.72568	33.3	15.6	11.57	204.80	183.29975	73.94651	473.61	229.4141
140	*Hevea brasiliensis*	92.1631	21.72608	23.6	8.9	8.80	97.68	103.075817	7.087685	216.64	104.993
141	*Hevea brasiliensis*	92.16285	21.72588	16.8	12.6	4.53	298.23	63.7525073	4.961515	371.48	177.9944
142	*Hevea brasiliensis*	92.16283	21.72607	28.4	10.8	6.72	85.64	162.249557	14.22682	268.83	131.0101
143	*Hevea brasiliensis*	92.16311	21.72595	21.6	10.8	6.01	81.00	124.176099	9.275481	220.46	107.2468
144	*Hevea brasiliensis*	92.1629	21.72593	22.9	9.6	6.97	103.70	102.077005	7.557312	220.30	106.7387
145	*Lagerstroemia speciosa*	92.19136	22.50421	49.3	18.6	3.11	317.08	656.255225	51.6106	1028.06	498.4727
146	*Lagerstroemia speciosa*	92.19183	22.5044	39.1	15.7	2.12	149.01	475.207653	35.80047	662.14	321.7841
147	*Lagerstroemia speciosa*	92.19114	22.50425	33.3	9.3	2.12	218.14	254.959227	22.97961	498.20	240.6159
148	*Lagerstroemia speciosa*	92.19135	22.50401	30.7	15.9	1.08	89.40	327.749067	33.1016	451.32	219.151
149	*Swietenia mahagoni*	92.17167	22.50038	34.3	12.9	4.10	117.78	315.624304	20.57784	458.08	221.4344
150	*Swietenia mahagoni*	92.1717	22.50061	24.9	15.3	2.98	42.85	218.97794	21.7862	286.59	138.8636

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151	*Swietenia mahagoni*	92.17148	22.5	29.7	12.3	3.77	126.12	255.097834	17.2698	402.26	193.9781
152	*Swietenia mahagoni*	92.171733	22.032	21.3	13.3	3.32	56.14	145.099121	15.56351	220.13	106.1675
153	*Swietenia mahagoni*	92.17195	22.5006	22.9	10.6	2.22	39.17	137.919941	12.60093	191.91	92.82718
154	*Swietenia mahagoni*	92.17175	22.5005	26.7	17.9	3.83	60.56	272.619861	29.29627	366.30	177.3068
155	*Swietenia mahagoni*	92.17154	22.5005	18.8	7.7	2.71	48.94	95.0148013	9.004817	155.67	74.94172
156	*Swietenia mahagoni*	92.1716	22.5007	23.9	11.2	2.67	43.82	143.614117	15.24601	205.35	99.2117
157	*Swietenia mahagoni*	92.171516	22.50043	42.9	18.3	5.07	102.50	682.022824	44.43252	834.02	405.4261
158	*Swietenia mahagoni*	92.17188	22.50053	31.2	15.6	5.20	99.88	336.082746	25.0225	466.19	225.6096
159	*Tectona grandis*	92.17248	22.50091	38.4	16.1	8.81	76.03	464.337963	31.30948	580.49	282.5999
160	*Tectona grandis*	92.17175	22.50035	30.7	12.7	10.42	106.02	239.793799	21.864	378.10	182.7169
161	*Albizia spp.*	92.0021	22.0048	83.1	32.9	60.24	1516.78	3858.26807	231.9539	5667.24	2754.519
162	*Albizia spp.*	92.2139	22.48863	41.1	19.4	15.70	191.69	754.056421	56.96359	1018.41	495.4485
163	*Tectona grandis*	92.2136	22.4885	19.3	14.1	4.87	44.36	113.556537	15.03173	177.81	85.82231
164	*Tectona grandis*	92.21361	22.48808	21.3	17	3.76	27.67	233.982967	15.95923	281.37	137.1428
165	*Tectona grandis*	92.2136	22.48831	18.0	11.3	4.76	171.25	95.2373805	15.72081	286.97	137.1225
166	*Tectona grandis*	92.21336	22.48831	24.9	16.7	6.28	44.25	279.765594	18.4001	348.69	169.7548
167	*Albizia spp.*	92.21256	22.48648	37.6	21.6	9.52	134.26	842.475951	91.60631	1077.86	524.5964
168	*Senna siamea*	92.19496	22.50101	45.2	16.7	6.41	169.70	687.06783	28.89812	892.08	439.7392
169	*Senna siamea*	92.19503	22.50116	56.1	18.7	8.47	1289.86	1034.63429	64.57475	2397.53	1177.428
170	*Senna siamea*	92.19511	22.50058	50.8	18.8	5.83	582.16	828.050615	80.32081	1496.36	735.026
171	*Senna siamea*	92.1951	22.5005	55.6	18.9	9.47	571.76	1194.19528	49.21818	1824.65	898.4523
172	*Artocarpus chaplasha*	92.14928	22.309	51.3	17.8	28.14	407.73	639.86335	79.84841	1155.58	534.5663
173	*Artocarpus chaplasha*	92.14906	22.30966	37.8	17.9	9.27	171.94	429.440094	51.1882	661.85	307.56
174	*Albizia spp.*	92.14875	22.3075	22.4	15.2	4.35	50.46	176.708106	20.96565	252.48	122.6971
175	*Albizia spp.*	92.01487	22.30738	16.3	9.5	3.38	36.06	62.4611364	6.786042	108.69	52.70829
176	*Syzygium grande*	92.149	22.30815	38.9	14.4	31.16	356.71	372.780915	67.15828	827.81	398.7256
177	*Syzygium grande*	92.15093	22.30945	51.6	17.7	41.34	553.81	1271.68408	91.39062	1958.23	949.0372
178	*Hopea odorata*	92.1506	22.3096	39.6	15.8	37.02	359.73	704.837913	72.91833	1174.50	557.0111