Proceedings of the national consultation workshop on tree allometric equations in Bangladesh

Bangladesh Forest Department

06 March 2016

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) and the Food and Agriculture Organization of the United Nations (FAO) 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:

CONTACTS:

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

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

Suggested Citation: **Hossain, M.** 2016. Proceedings of the National Consultation Workshop on Tree Allometric Equations in Bangladesh. 06 March 2016, Dhaka, Bangladesh Forest Department, Food and Agriculture Organization of the United Nations, Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh.

Executive Summary

Measurement of forest biomass and volume are obvious for estimating forest stocking and productivity, nutrient cycling and budgeting, amount of carbon stock and prediction of future status of forest resources, which are important consideration for the sustainable management of forest. Realizing this importance, different research and academic institutions and individual researchers have developed biomass and volume allometric equations for estimation of volume stocking and biomass of a particular forest. Therefore, a database and quality control of these allometric equations have appeared as important tasks to assess the gaps and scope for the development of new allometric equations with important tree species of different forest types of Bangladesh.

Tree biomass and volume can be measured from both destructive (clear-cut) and non-destructive (allometric equation) methods. Allometric method is frequently used for estimating the biomass and volume of forest plant species, which is the most powerful tool of measurement. The use of appropriate equations for biomass and volume estimation will contribute to improve the accuracy in forest resource assessment and also guide the forest policies and its management.

Development of allometric equations for biomass and volume requires extensive planning, field work (sampling of forest within each forest strata, sampling of plots within each forest, sampling of plants within each plot; measurement of standing tree dimensions; felling of sampled plant; separating and weighing of different plant parts; sub-sampling of different plant parts for further assessment and data recording), sample analysis in the laboratory, and data compilation and analysis. Most of the cases, these activities are destructive, difficult and expensive to repeat. Measurement of some variables are mandatory for the development of allometric equations, which are linked with the national forest inventory and some other variables may consider as additional information for future forest monitoring. Therefore, development of a field measurement protocol is an important concern to maintain consistency in field measurement activities for the development of allometric equations. This protocol may guide forest technicians, professionals, and students for the development of biomass and volume allometric equations involving both the destructive and semi-destructive activities.

FAO is currently assisting Bangladesh Forest Department (BFD) to establish a national forest monitoring system. Strengthening national capacities and ownership on data management and analysis is essential to ensure the sustainability of the project. The amount of data collected on the status of forest resources is continuously increasing and improved data management tools are necessary. Such tools are fundamental to ensure the sustainability of the forest monitoring system, but also to ensure the transparency of the data analysis process and its improvement over time. Developing database and quality control of allometric equations and preparation of a field measurement protocol for the development of biomass and volume allometric equations are therefore important project activities.

Total 29 participants (23 male and 6 female) attended in the workshop.

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1. Introduction

As part of the implementation of a national system for assessing tree and forest resources, that is as much as possible accurate, the establishment and use of allometric equations that are appropriate to the conditions of the country is crucial. The overall goal is to improve the quality of estimates for a multitude of purposes including timber volume, wood energy biomass, carbon stocks etc, and to support forest policies for better management. The error related to the selection of allometric models being one of the main sources of error, improving the quality of allometric equations and the use of the equation to perform the calculations is crucial to provide estimates that are as accurate.

Theoretically, to determine the biomass or the carbon stock of tree, one must weigh all its compartments. These measurements become difficult or impossible to obtain at the forest scale for two reasons: (1) they are destructive and often prohibited on a large scale, and (2) the cost, time and labour are unrealistic. To measure the carbon content of tree roots, field work is even more tedious and is often replaced by the use of factors directly applied to the above-ground biomass.

In most of the cases, the assessment of tree volume, biomass or carbon stocks is made using tree allometic equations and dendrometric field measurements. Allometry refers to the statistical relation between two size characteristics of individuals in a population. Therefore a statistical relation can be developed between easy to measure tree characteristics (i.e. diameter, height or density) and difficult to measure variables such as biomass or volume. Consequently, costly and destructive measurements can be limited to a sample of trees and the results can be extrapolated to all trees in a given area.

The first step to understand the status of the existing tree models and forest resource estimation methods is to develop a database of tree allometric equations and related data to perform volume or biomass equations. Few countries have developed a national database for the biomass and volume allometric equations. In South Asia, the first regional database was developed in 2014. In Bangladesh, a first database was developed in 2013 (Akhter, Hossain et al. 2013) and in 2016, Khulna University, in collaboration with Forest Department and FAO, has developed a national database for our country that includes biomass and volume allometric equations, data of wood density and their related Meta data. Completion of the database and its accessibility are important national efforts that may improve the estimate of tree and forest resources. Quality selection criteria can be developed for the preparation of a database for the data analysis and to guide further improvement.

In addition, a series of capacity-building exercises have been organized to enhance national capacity among national institutions on various elements of national forest monitoring including on development of data management system, data management and analysis for the NFI inventory data and for the support of a national tree biomass estimate, management and analysis of forest data, quality assurance and control of the data.

It is certain that the current computing system can be improved and the uncertainty in estimation can be reduced by following a standard field measurement procedure. Some errors were observed in allometric equations which mostly were associated with the use of different methods of field measurement, sample processing, data compilation, statistical analysis, use of different units of measurement. Khulna University with the support of Forest Department and FAO have developed a draft field measurement protocol that can be used for development of biomass and volume allometric equations, measurement of wood density, and assessment of carbon and other nutrients

(N, P and K) in different parts of plants (e.g. Leaves, stem, branches, bark etc.). The field manual protocol aims to be multi-purpose and consider current and future needs in term of forest resource assessment.

The establishment of a monitoring system of national forests implies the commitment of the various national actors according to their mandate and expertise. The involvement of different stakeholders and consideration of their views are important from the field measurement to the prediction and the dissemination of the information.

So in order to finalize the national database of biomass and volume allometric equations and the manual for the collection of field data, this national consultation was organized on March 6th 2016. Based on the existing national forest assessment data, tree allometric equation database for Bangladesh and South Asia (Sandeep, Sivaram et al. 2013), the aims of this national consultation are to find the gaps in the developed allometric equations of Bangladesh, identify the needs for the development of new equations considering the forest type/ land uses, and finally to get feedback on field measurement protocol on tree allometric equation for estimating above-ground biomass and volume in Bangladesh.

The outputs of this national consultation will particularly contribute to support the initial efforts to implement the second national forest inventory, and implementation of the national forest monitoring system.

2. Objectives

The general objective of this national consultation was to strengthen the national capacities in developing and using of tree allometric equations and to improve the assessment of tree volume and biomass in Bangladesh.

The specific objectives were as follow:

- To present the current and up-to-date knowledge for building allometric equations including courses on the related theory, field operations, fitting and use of the allometric equations.

- To present the current status of developed allometric equations for biomass and volume.

- To propose technical exercises aiming at identifying gaps (knowledge, allometric equations and raw data) to report carbon stocks and carbon stock changes at the country level.

- To get comments and suggestion on the field measurement protocol on tree allometric equation, this will ensure the consistency in field measurement activities for the development of allometric equation in Bangladesh.

- To initiate building a network of experts on allometric equations.

3. Summary of the national workshop

3.1 Session 1: Opening session

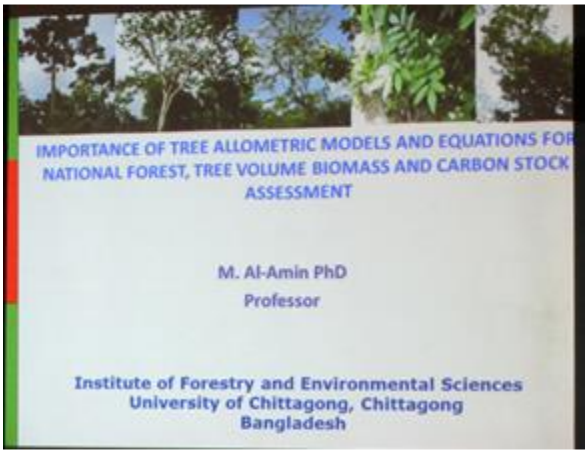
Mr. Mozaharul Islam, Conservator of Forests and National Project Coordinator delivered the welcome speech. Dr. Laskar Muksudur Rahman, FAO presented the objectives of this national consultation. Mr. Md. Farid Uddin Ahmed, Executive Director, Arannayk Foundation were present as Special Guest and Mr. Md. Yunus Ali, Chief Conservator of Forest, Forest Department was present as the Chief Guest of the national consultation workshop on tree allometric equations. Mr. Md. Yunus Ali, Chief Conservator of Forest, in his speech, highlighted important issues specific to the country and provided valuable guidelines for developing the allometric Equation. They are as followings:

- Tree grows in different region at different rate and size.
- Our instruments and methods used for forest mensuration are primitive and sometimes give gross estimation of tree dimension.
- Allometric techniques are important to assess the volume, biomass and carbon stock in any particular forest.
- Allometric equations of tree biomass and volume were developed by different organization and academic institution, but some of them have little capacity to perform it.
- Tree felling for the development of allometric equation is restricted in the natural forest.
- Use of some non-destructive methods to derive allometric equations for trees
- We should have policy that who will do what
- Science must override other philosophy.
- CCF welcome the various institutions involved in biometry and forestry were well representation in this national consultation.

Opening session of the national consultation workshop on tree allometric equations in Bangladesh

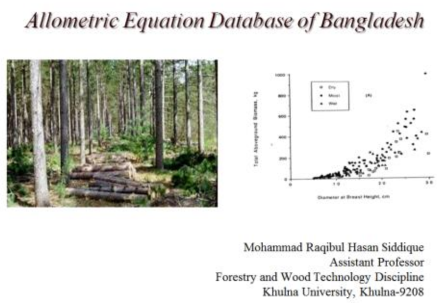
3.2 Session 2: Status of biomass and volume allometric equations in Bangladesh

Prof. Dr. Al Amin, Institute of Forestry and Environmental Sciences, University of Chittagong presented on "Importance of tree allometric models and equations for national forest, tree volume, biomass and carbon stock assessment". He mentioned the importance of site and species specific allometric equations for estimation of above-ground biomass and volume in a forest. He has presented the sources of errors in estimating forest biomass. In conclusion, he mentioned that allometric equations are the most easy and authentic way to estimate biomass or volume of trees. Furthermore, variables like yield class, species, age, site and exposure to hazard, climate regime are necessary to consider during the development of allometric equations that will allow more precise estimation of the biomass and carbon content of a particular forest and pave the way REDD+ concerns of the country.



Database on tree allometric equations, wood density, biomass expansion factors and diameter-height relationships for Bangladesh was developed by Khulna University with the support of Forest Department and FAO. As part of this activity, Mr. Mohammad Raqibul Hasan Siddique, Assistant Professor, Forestry and Wood Technology Discipline, Khulna University presented on "Allometric Equation Database of Bangladesh" to visualize the present stratus and gaps in biomass and volume allometric equations in Bangladesh. The database was developed from secondary sources (reports, Bulletins, Mamograph, Inventory report, Proceding's paper) and it was consists of 91 variables grouped into 7 different categories. A total of 515 allometric equations for 79 species were recorded of which 475 equations for trees, 31 for shrubs, 3 for palms, and 6 for bamboo. Validity of all the 515 allometric equations was tested through a quality control method following Birigazzi et al (2015) and Gamarra et al. (2016). This validation included the following areas of verification:

- **Operational verification:** Too large or too small predicted biomass or volume values
- **Conceptual verification:** Predicted biomass or volume are lower than "0" or negative values
- **Applicability:** Under which condition the model can be applied (Population ecology, environmental condition of the site where the equation was developed, tree component measured, Taxonomic reference, Range of applicability)
- **Statistical credibility:** Sample size should be at least 30 for trees and coefficient of determination should be higher than 0.85



222 allometric equations for 39 species (Table 1) under 18 families and 31 genus were valid. The results of verification in four different categories have been presented in the following table 2 and 3:

TABLE 1: LIST OF SPECIES HAVING VALID ALLOMETRIC EQUATION

Genus	Species	Local name	Volume	Green biomass	Oven-dried biomass	Carbon	Nutrients	Remark
Senna	*siamea*	Minjiri	8	23				
Sonneratia	*apetala*	Keora	12					
Avicennia	*officinalis*	Baen	2					
Albizia	*procera*	Koroi	2					
Terminalia	*arjuna*	Arjun	2					
Shorea	*robusta*	Sal	7					
Acacia	*mangium*	Mangium	12	12				
Tectona	*grandis*	Teak	2		1			
Acacia	*auriculiformis*	Akashmoni	12	5	1			
Eucalyptus	*camaldulensis*	Eucalyptus	7					
Eucalyptus	*tereticornis*	Eucalyptus	1					
Eucalyptus	*brassiana*	Eucalyptus	1					
Pinus	*caribaea*	Pine	8					
Swietenia	*macrophylla*	Mahogany	6					
Albizia	*spp*	Koroi	6					Mixed species
Dalbergia	*sissoo*	Sissoo	5					
Acacia	*nilotica*	Babla	2					
Albizia	*saman*	Rain tree	6					
Ceriops	*decandra*	Goran			5			
Aegialitis	*rotundifolia*	Nuniya			2			
Excoecaria	*agallocha*	Gewa			5	1	3	
Kandelia	*candel*	Goria			5	1	3	
Breonia	*chinensis*	Kadam	1					
Aphanamixis	*polystachya*	Pitraj	2					
Artocarpus	*chaplasha*	Chapalish	2		2			
Artocarpus	*heterophyllus*	Kathal	2					
Dipterocarpus	*turbinatus*	Telya garjan	3					
Gmelina	*arborea*	Gamar	2					
Lagerstroemia	*speciosa*	Jarul	1		1			
Albizia	*richardiana*	Rajkoroi	2					
Falcataria	*moluccana*	Moluccna	2					
Hevea	*brasiliensis*	Rubber	10					
Mangifera	*indica*	Am	2					
Melia	*azadarach*	Ghora neem	2					
Lannea	*coromandelica*	Badi	1					
Syzygium	*cumini*	Kalojam	1					
Azadirachta	*indica*	Neem	2					
Xylia	*xylocarpa*	Lohakat	1					
Aegiceras	*corniculatum*	Khulshi			4	1	3	
Mixed			1	4	1	1		Mixed species

TABLE 2THE RESULTS OF VERIFICATION OF ALLOMETRIC EQUATIONS

Category	Operational verification	Conceptual verification	Applicability	Statistical credibility	Final validation
Valid	471	394	515	283	222
Not valid	44	121	0	232	293
Total equation	515	515	515	515	515

Among the valid equation, highest (138) number of allometric equation for volume of trees followed 44 equations for green biomass of trees. But lowest (4 equations) was for carbon. The categories of valid allometric equations have been presented in Table 2.

TABLE 3 CATEGORIES OF VALID EQUATION

	Volume	Green biomass	Oven-dried biomass	Carbon	Nutrients
Tree	138	44	10	1	3
Shrub	0	0	17	3	6
Palm	0	0	0	0	0
Bamboo	0	0	0	0	0
Grand total	138	44	27	4	9

Considering the synthesis of the database of allometric equations, wood density, raw data, diameter and height relationship and biomass expansion factors, Mr. Mohammad Raqibul Hasan Siddique pointed the following gaps:

- Limited species has allometric equations
- Few equations for total above-ground biomass
- Few equations for the estimation of merchantable volume
- BEF are rare and often not adapted
- Few tree species have clear relationship between DBH and other parameters;
- Raw data are rarely accessible.

3.2.1 Group discussion: Identification of the gaps in allometric equations and need of new allometric equations considering forest types, life form

Group 1: The findings of group discussion are as follows

The following forest type have not been covered by allometric equations

- Fresh water Swamp forest
- Sal forest (for associates)
- Sundarbans (partly covered)
- Coastal afforestation (partly covered)
- Hill forest (partly covered)
- Village/ homestead forest (partly)

The following tree species need better consideration for the development of allometric equation

- *Acacia catechu*
- *Adina cordifolia*
- *Amoora cucullata*
- *Areca catechu*
- *Cassia fistula*
- *Citrus grandis*
- *Cocos nucifera*
- *Dalbergia sisoo*
- *Delonix regia*
- *Dillenia indica*
- *Ficis hispida*
- *Melocanna baccifera*
- *Michelia champca*
- *Phoenix sylvestris*
- *Samanea saman*
- *Switenia spp*
- *Syzygium grandis*
- *Tamarindus indica*
- *Terminalia belerica*
- *Terminalia catappa*
- *Toona ciliata*
- *Trewia nudiflora*

Group 2:

The findings of group discussion are as follows:

The following forest types have not been covered by allometric equations:

- Tree species outside the Forest
- Mangroves
- In deciduous forest
- In Hill forest/Nauaral forest
- In Swamp

The following tree species need better consideration for the development of allometric equation:

- Artocarpus, Guava, Mangifera, Coconut, Areca catechu, Eucalyptus etc.
- Heritiera, Avicinia, Sonneratia, Xylocarpus, Nypa etc.
- Shorea, Haldu, Sonalu,
- Bamboo, Champa, Chikrassi, Chapalish
- Barringtonia, Pongamia etc.

Group 3:

The findings of group discussion are as follows:

The following forest types have not been covered by allometric equations:

- Swamp forest
- Mango plantation
- Agor plantation
- Bamboo
- Tea garden
- Shrub land
- Sand (Inland Char land)

The following tree species need better consideration for the development of allometric equation:

- *Areca catechu*
- *Bambusa balcooa*
- *Bambusa vulgaris*
- *Cocos nucifera*
- *H. fomes*
- *Melocanna baccifera*
- *Moringa oleifera*
- *Phoenix sylvestris*
- *Psidium guajava*
- *R. apiculata*
- *Tamarindus indica*
- *Terminalia catappa*
- *X. granatum*
- *X. mekongensis*
- *Zizyphus mauritiana*

Group 4:

The findings of group discussion are as follows:

The following forest types have not been covered by allometric equations:

- Fresh Water Swamp Forest
- Tree Outside Forest

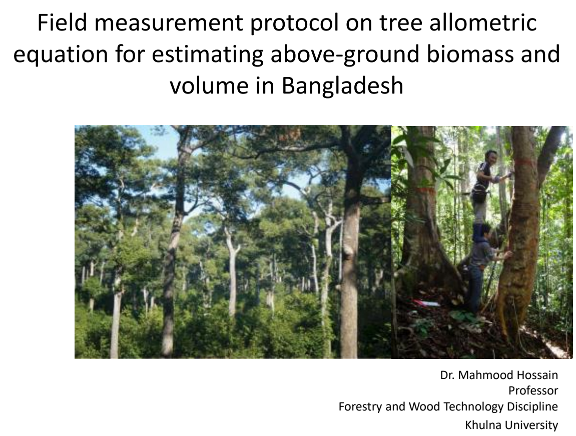
The following tree species need better consideration for the development of allometric equation:

- *Acacia catechu*
- *Amoora cucullata*
- *Anthocephalus chinensis*
- *Areca catechu*
- *Bambusa balcooa*
- *Bambusa vulgaris*
- *Borassus flabellifer*
- *Cocos nucifera*
- *Dalbergia sissoo*
- *Delonix regia*
- *Erythrina orientalis*
- *Ficus hispida*
- *Leucaena leucocephala*
- *Melocanna baccifera*
- *Oxytenanthera nigrociliata*
- *Phoenix sylvestris*
- *Samanea saman*
- *Swietenia spp*
- *Toona ciliata*
- *Zizyphus mauritiana*

3.3 Session 3: Field measurement protocol

Afternoon session initiated with the presentation from S. M. Zahirul Islam, Research Officer, Bangladesh Forest Research Institute, on “destructive field measurements for tree allometric equation development”. Starting with the meaning of tree allometry and the importance of tree allometric equations, Mr. S. M. Zahirul Islam presented the different mathematical forms used for the development of tree volume and biomass allometric equations. He also presented a list of equipment used in destructive measurement in the field. In particular, he mentioned different parameters of trees and stands to be collected for the development of growth model. In his presentation, destructive and non-destructive measurements for the development of tree volume and biomass allometric equation were also presented.

Dr. Mahmood Hossain, Professor, Forestry and Wood Technology Discipline, Khulna University presented the field measurement protocol on tree allometric equation for estimating above-ground biomass and volume in Bangladesh. In his presentation, he justified the needs and uses of this protocol for different forest types and vegetation forms. This protocol will be updated based on the participant's contribution. He presented the different steps involved in the development of allometric equation. Dr. Mahmood also presented the different tree forms and methods of assessing the tree architecture. He suggested pre and post monsoon are ideal seasons of field data collection. He presented 44 field and laboratory data forms for recording different measurement of variables and result related to the development of biomass and volume allometric equations for different plant life-form (Trees, Shrubs, Palms, Nypa palm, Liana and Bamboo). The field and laboratory analysis form contained measurements of the basic tree dendrometric measurement and laboratory measurements (fresh weight to oven-dry weight conversion ratio, wood density, carbon and nutrient content) in plant parts. He explained elaborately how semi-destructive method (Branch Cutting) can be used for the development of tree biomass allometric equations.



3.3.1 Group discussion: Improvement in field measurement protocol

Participants of the national consultation workshop discussed the different aspects of the field measurement protocol for the development of biomass and volume allometric equations for different plant life-form in Bangladesh. Participants discussed the practical applicability of the methods of measurements as suggested by this protocol. They also suggested using latest non-destructive technology like LiDAR on trial basis for future development of allometric equations and forest resource assessment. Finally, participants suggested the following to improve the field measurement protocol:

- Pictorial handbook should be prepared in In Bengali for easy understanding of the field crew
- Terminology used in the protocol need to be elaborated
- This protocol covers different life-form of plants. Therefore, the title of the protocol should be changed or improved in the context of the content
- Field testing need to include in the protocol

4. Conclusion and Recommendations

During last NFA in 2005-07, globally available equations and factors were used for the calculation of AGB for the country. The Sundarban Carbon inventory in 2009-10 also used the globally available equations for the mangrove species to calculate the carbon for the Sundarban Reserved Forest. To ensure accuracy in carbon estimation, development of Allometric equation for local species considering various factors for different forest types is essential.

The following recommendations have been identified and discussed in this national consultation workshop for the next steps:

- Share the allometric equations database with the Forest Department
- Test the field manual for some species in the felling areas (e.g. Social forestry, JUT or other felling areas)
- Provide training for the development of the allometric equation specifically in the field of data collection, laboratory analysis, statistical analysis for model development
- Validated allometric equations could be used and allometric equations for other important species could be developed
- Continuous updating of allometric equations database
- Raw data sharing agreement must be done among Forest Department and other organizations or individual researchers.

5. References

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Appendix 1. Agenda

Workshop on the development of Allometric Equation

NILG Conference Room, 2nd floor, Agargaon, Dhaka

Sunday 6 March 2016

Time	Topic	Speaker/facilitator
	Session 1: Opening session	
9.00	Registration	
9.30	Welcome remarks	Md. Mozaharul Islam, CF, NPC, FD
9:35	Objectives of the workshop	Dr. Laskar Muqsudur Rahman, FAO
10:00	Special Guest	Farid Uddin Ahmed, Executive Director, Arannayk Foundation
10:15	Chief Guest and chair	Md. Yunus Ali, Chief Conservator of Forests
10:.30	Group pictures	
	Coffee/Tea Break	
	Session 2: Status of biomass and volume allometric equations	
10.45 AM	On the importance of tree allometric equations for national forest and tree volume, biomass and carbon stock assessment	Prof. Al Amin Chittagong University
11:15	Status of biomass and volume allometric equations in Bangladesh, needs and gaps	Raqibul Hasan Siddique, Khulna University
11:45	Group session: identification of the gaps in allometric equations and need of new allometric equations considering forest types, life form	Mariam Akhter
	Group presentations	Mariam Akhter
1:00-2:00 PM	Prayer & Lunch Break	
Afternoon	**Session 3: Field measurement protocol**	
2:00 PM	Destructive field measurements for tree allometric equation development Alternative presentation: Alternative methods and options for tree allometric equation development	S. M. Zahirul Islam, BFRI
2:30	Presentation of the field measurement protocol	Dr. Mahmood Hossain, Khulna University
3:00	Group session: Improvement in the field measurement protocol	Mariam Akhter
	Session 4: Conclusion and ways to move forward	
4:15 PM	Identification of next steps: i.e. sampling design, data collection , allocation of resources, collaboration, data sharing, work plan	Matieu Henry, CTA
	Closing session	Chief Conservator of Forests

Appendix 2. Participant List

ID	Name	Gender	Organization	Designation	Phone no.	E-mail
1	Afroza Begum	F	FD	Research Officer	01711283846	b.afroza@yahoo.com
2	Akhter Hossain	M	Chittagong University	Lecturer	01827501435	akhter.hossain@cu.ac.bd
3	Baktiar Nur Siddiqui	M	FD	Divisional Forest Officer	01711819670	baktiar1971@gmail.com
4	Chameli Saha	F	KU	Student, FWT	01781689938	chamelisaha090515@yahoo.com
5	Dewan Zafrul Hassan	M	FD	PRL, DCCF, FD	01552489197	Dewanhassan82@yahoo.com
6	Lulu Rayhan Khushi	F	KU	Student, FWT	01717302717	rayhan.khushi.ku@gmail.com
7	Mahmood Hossain	M	Khulna University	Professor	01711959380	mahmoodhossain@hotmail.com
8	Mariam Akhter	F	FAO	Forestry officer	01711170697	Mariam.akhter@fao.org
9	Matieu henry	M	FAO	CTA	01745134861	Matieu.henry@fao.org
10	Md. Faruque Hossain	M	FD	PRL, DCCF, FD	017131928106	Faruque_hossain@yahoo.com
11	Md. Golam Rakkibu	M	Khulna University	Professor	01730062903	golamrakkibu@yahoo.com
12	Md. Mahmudur Rahman	M	FD	Consultant, SSO, SPARRSO	01913510107	misgis.crparp@gmail.com
13	Md. Modinul Ahsan	M	FD	ACF	01718783529	ahsanmodinul@gmail.com
14	Md. Raqibul Hasan Siddique	M	Khulna University	Assistant Professor	01716422182	raqibulhasan_fwt@yahoo.com
15	Md. Rezaul Karim Chowdhury	M	FD	ACF	01711388222	rezaulkarim91@hotmail.com
16	Mohammed Shahid Ullah	M	BFRI	Divisional Officer	01914229525	dofid@bfri.gov.bd
17	Mr. Hossain Mohammed Nishad	M	FD	Divisional Forest Officer	01715005677	hmnishad@gmail.com
18	Mr. M A Latif Fakir	M	Ex BFRI	Consultant, IUCN	01715669884	latif.fakir@yahoo.com

19	Mr. M. Abdul Kuddus	M	Arannayk Foundation	Senior Programme Officer	01715023283	quddus@arannayk.com
20	Mr. Md. Zaheer Iqbal	M	FD	Deputy Conservator of Forests	01711443750	z.iqbal60@gmail.com
21	Mr. Quazi Md. Nurul Karim	M	FD	ACF	01711395992	Quazi.karim@gmail.com
22	Mr. Ruhul Mohaimen Chowdhury	M	CREL	M&E specialist, CREL	01726892305	ruhulforester@yahoo.com
23	Mr. S. M. Rubaiot Abdullah	M	KU	Lecturer	01718096435	rubaiot@yahoo.com
24	Mr. S.M. Zahirul Islam	M	BFRI	SSO	01554314416	zahir.fid.bfri@gmail.com
25	Mr. Sourav Das	M	SUST	Assistant Professor	01711348630	souravdron@gmail.com
26	Mr. Tarik aziz	M	FD	RO	01790284328	tariqaziz9718@gmail.com
27	Mrs Raihana Siddiqui	F	FD	Conservator of Forests	01761494611	Raihana003@yahoo.com
28	Prof. M. Al-Amin	M	CU	Professor	01819820184	Prof.alamin@yahoo.com
29	Samima Begum shewly	F	FD	RO	01931407861	to.shewli99@gmail.com

Appendix 3. Background materials for the group discussion 1

Identification of the gaps in allometric equations & need of new allometric equations considering forest types, life form

1. Is there any missing document/reference to be considered for the allometric equation database?

2. Which are the forest types that have not been covered by allometric equations?

3. Which tree species need better consideration?

4. What would you use as QC criteria for the national equation database?

5. How to develop database for raw data? Which are the problems and which are the solutions?

6. What need to be done next to have a national database for the forest monitoring system?

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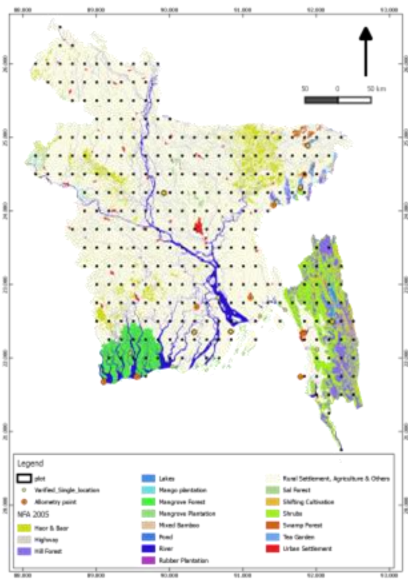
Land area Estimates in Bangladesh

NFA 2005-07 land classes	Land area estimates (1000 ha)	% of total national land area
Haor & Baor	607.38	4.27
Highway	10.16	0.07
Hill Forest	537.47	3.78
Lakes	42.44	0.30
Mango plantation	18.23	0.13
Mangrove Forest	399.36	2.81
Mangrove Plantation	43.48	0.31
Mixed Bamboo	9.21	0.06
Pond	45.24	0.32
River	878.02	6.18
Rubber Plantation	7.75	0.05
Rural Settlement, Agriculture & Others	10504.54	73.89
Sal Forest	32.93	0.23
Shifting Cultivation	97.22	0.68
Shrubs	817.07	5.75
Swamp Forest	22.35	0.16
Tea Garden	59.09	0.42
Urban Settlement	83.41	0.59
Total	14215.98	100.00

Source: NFA 2005-07



NFA classes	Volume	Biomass	Carbon	Conversio	Others	Grand Total
Hill Forest	2	5	0	6	0	13
Mangrove Forest	62	24	3	0	10	99
Rural Settlement, Agriculture & Others	4	1	28	0	0	33
Shrubs	6	0	0	6	0	12
Urban Settlement	14	1	0	10	0	25
Total	88	31	31	22	10	182

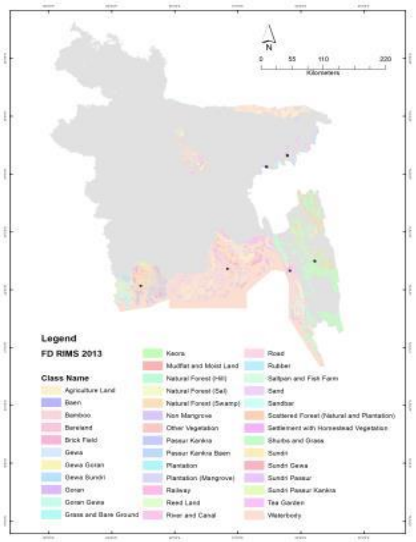
Source: Draft Tree allometric equation

FD-RIMS 2013 land classes	Land area estimates (1000 ha)	% of total national land area
Agriculture Land	924.72	6.50
Baen	1.14	0.01
Bamboo	16.82	0.12
Bareland	27.10	0.19
Brick Field	0.21	0.00
Gewa	21.45	0.15
Gewa Goran	32.57	0.23
Gewa Sundri	73.50	0.52
Goran	7.83	0.06
Goran Gewa	54.66	0.38
Grass and Bare Ground	4.86	0.03
Keora	10.60	0.07
Mudflat and Moist Land	66.27	0.47
Natural Forest (Hill)	93.28	0.66
Natural Forest (Sal)	17.49	0.12
Natural Forest (Swamp)	0.10	0.00
Non Mangrove	0.36	0.00
Other Vegetation	44.90	0.32
Passur Kankra	0.27	0.00
Passur Kankra Baen	2.52	0.02
Plantation	75.50	0.53
Plantation (Mangrove)	61.73	0.43
Railway	0.05	0.00
Reed Land	1.20	0.01
River and Canal	17.63	0.12
Road	3.93	0.03
Rubber	9.22	0.06
Saltpan and Fish Farm	36.61	0.26
Sand	7.02	0.05
Sandbar	1.22	0.01
Scattered Forest (Natural and Plantation)	164.42	1.16
Settlement with Homestead Vegetation	354.54	2.49
Shurbs and Grass	837.10	5.89
Sundri	74.26	0.52
Sundri Gewa	102.27	0.72
Sundri Passur	2.37	0.02
Sundri Passur Kankra	7.08	0.05
Tea Garden	31.57	0.22
Waterbody	1235.66	8.69
Total	4424.07	31.12

Source: FD-RIMS, 2013

Number of allometric equations according to FD-RIMS 2013

Row Labels	**Carbon in oven-dried biomass**	**Conversion**	**Green Biomass**	**Length of splited leaf**	**Nitrogen in oven-dried biomass**	**Oven-dried biomass**	**Phosphorus in oven-dried biomass**	**Potassium in oven-dried biomass**	**Volume**	**Total**
Agriculture Land									2	2
Plantation		6				2			2	10
Settlement with Homestead Vegetation		6							12	18
Sundri	3		3	1	3	24	3	3	62	102
Tea Garden						3				3
Waterbody									2	2
Total	**3**	**12**	**3**	**1**	**3**	**29**	**3**	**3**	**80**	**137**



List of tree species in the NFA and number of equations

%	Scientific Names	All Equations	Volume	Green biomass	Biomass	Carbon
0.47	Acacia auriculiformis	52	24	14		
0.04	Acacia mangium	50	18	28		
0.40	Acacia nilotica	7	2			
0.03	Albizia lebbeck	1				1
2.73	Albizia procera	8	2			
0.56	Albizia richardiana	8	2			
0.16	Alstonia scholaris	1				1
0.77	Aphanamixis polystachya	17	5			1
1.48	Artocarpus chaplasha	22	6		2	1
4.75	Artocarpus heterophyllus	8	2			1
0.20	Artocarpus lacucha	1				1
0.10	Avicennia officinalis	14	14			
0.83	Azadirachta indica	7	2			
1.35	Bambusa tulda	2		1		
1.26	Bombax ceiba	16	5			1
0.02	Dendrocalamus longispathus	2		1		
0.00	Dipterocarpus costatus	9	3			
0.00	Dipterocarpus gracilis	8	3			
0.32	Dipterocarpus turbinatus	27	13			1
0.83	Eucalyptus camaldulensis	32	17	6		
2.92	Excoecaria agallocha	21	12			
1.16	Gmelina arborea	14	7			1
5.91	Heritiera fomes	14	14			
0.00	Hopea odorata	1				1

%	Scientific Names	All Equations	Volume	Green biomass	Biomass	Carbon
0.48	Lagerstroemia speciosa	4	1		1	1
2.94	Lannea coromandelica	6	1			
7.10	Mangifera indica	7	2			
0.50	Schima wallichii	9	3			
0.24	Shorea robusta	13	11			
0.06	Sonneratia apetala	39	39			
1.36	Syzygium cumini	7	2			
1.42	Tectona grandis	16	6		1	3
0.07	Terminalia arjuna	7	2			
0.08	Tetrameles nudiflora	9	3			
0.01	Xylocarpus granatum	4	4			

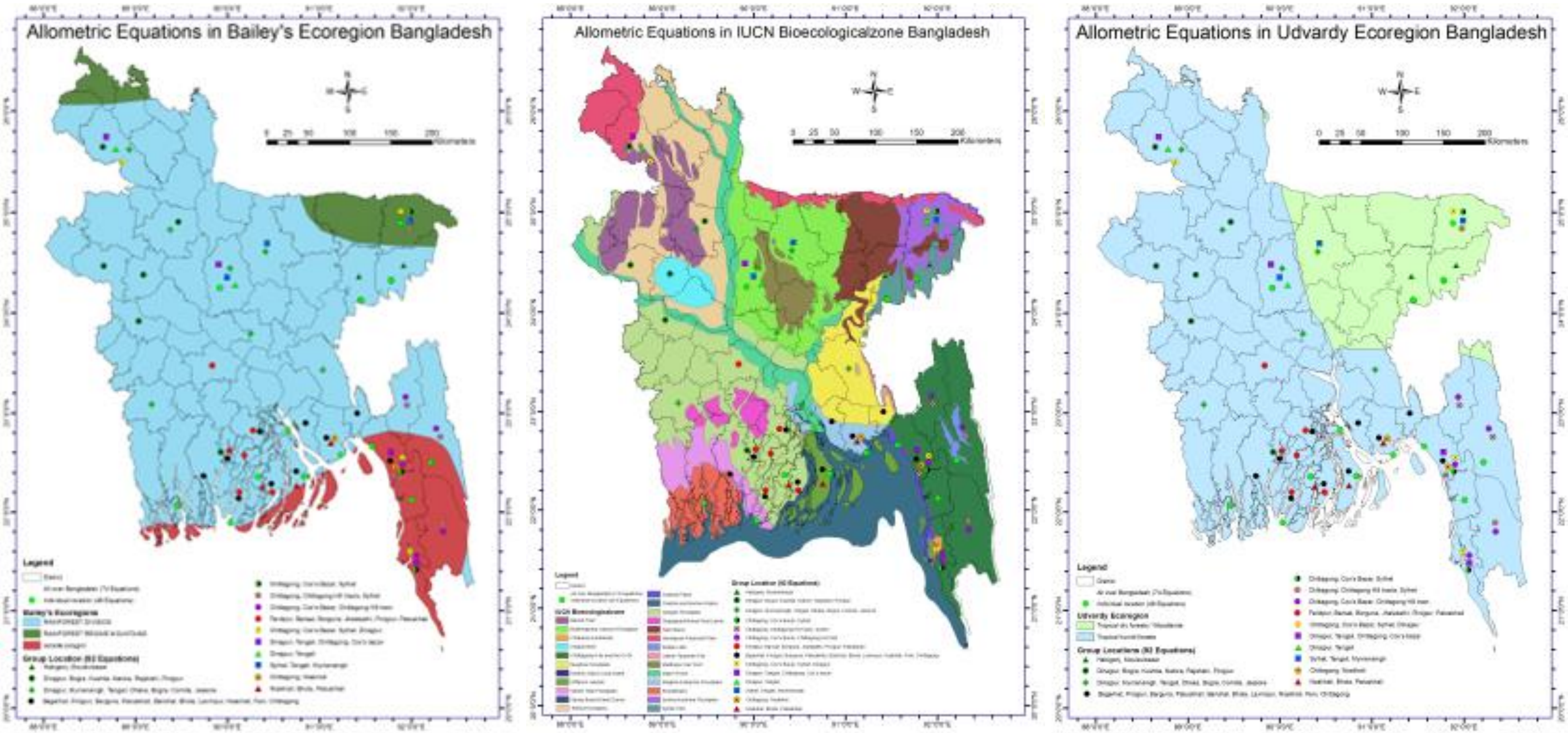
Main tree species (NFA 2005-7) without equations

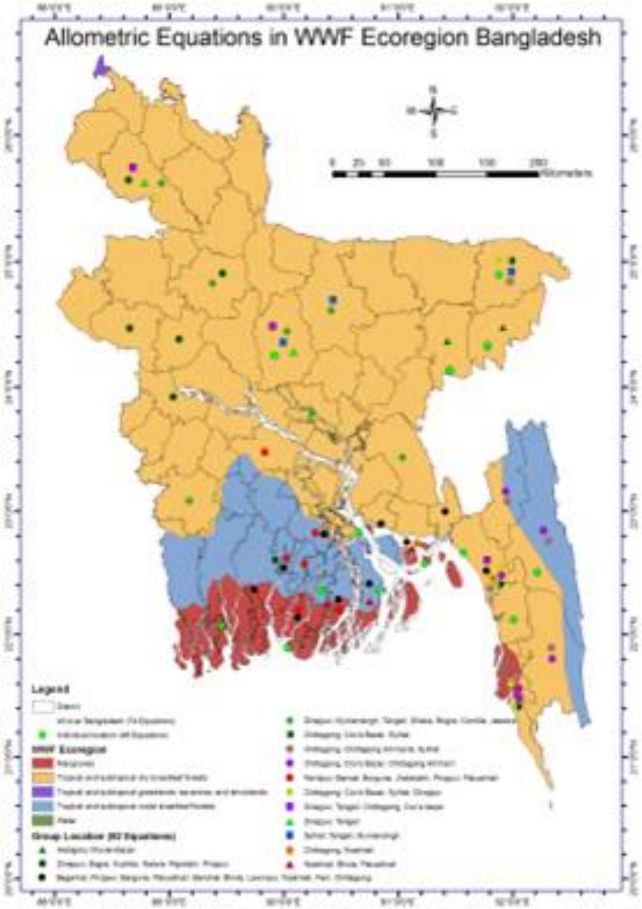
%	Scientific name	%	Scientific name	%	Scientific name
13.96	Areca catechu	0.04	Dysoxylum binectariferum	0.007	Feronia limonia
6.13	Samanea saman	0.04	Litsaea angustifolia	0.007	Mesua nagassarium
5.21	Cocos nucifera	0.04	Microcos paniculata	0.007	Quercus acuminata
4.91	Swietenia spp	0.03	Barleria lupulina	0.007	Sphaeranthus indicus
3.66	Phoenix sylvestris	0.03	Bridelia retusa	0.007	Syzygium fruticosum
2.48	Melocanna baccifera	0.03	Castanopsis indica	0.007	Terminalia citrina
1.63	Borassus flabellifer	0.03	Delonix regia	0.007	Vitex peduncularis
1.60	Bambusa balcooa	0.03	Hemarthria protensa	0.005	Amomum aromaticum
1.34	Bambusa vulgaris	0.03	Protium serratum	0.005	Aporusa aurea
1.05	Anthocephalus chinensis	0.03	Vitex glabrata	0.005	Buddleja asiatica
0.93	Erythrina orientalis	0.03	Amoora cucullata	0.005	Carica papaya
0.90	Dalbergia sisoo	0.03	Disopyros philippensis	0.005	Cerbera manghas
0.87	Ficus hispida	0.03	Elaeocarpus varunna	0.005	Cinnamomum obtusifolium
0.83	Zizyphus mauritiana	0.03	Mitragyna parvifolia	0.005	Croton tiglium
0.70	Diospyros peregrina	0.03	Amaranthus tricolor	0.005	Curcuma longa
0.63	Moringa oleifera	0.03	Derris indica	0.005	Derris trifoliata
0.59	Trewia polycarpa	0.03	Caesalpinia bonduc	0.005	Dichopsis polyantha
0.56	Stereospermum chelonioides	0.03	Calophyllum inophyllum	0.005	Ehretia serrata
0.48	Bambusa arundinacea	0.03	Elaeocarpus robustus	0.005	Elaeagnus latifolia
0.44	Melia sempervirens	0.03	Ficus lacor	0.005	Garcinia xanthochymus
0.39	Bambusa spp	0.03	Sapium indicum	0.005	Lablab purpureus
0.37	Terminalia catappa	0.02	Bambusa teres	0.005	Mallotus roxburghianus
0.35	Psidium guajava	0.02	Cassia siamea	0.005	Musa sapientum
0.34	Ochna squarrosa	0.02	Castanopsis tribuloides	0.005	Phyllanthus acidus
0.33	Spondias pinnata	0.02	Cedrela macrocarpa	0.005	Pterospermum suberifolium
0.29	Xylocarpus mekengensis	0.02	Cordia dichotoma	0.005	Randia dumetorum

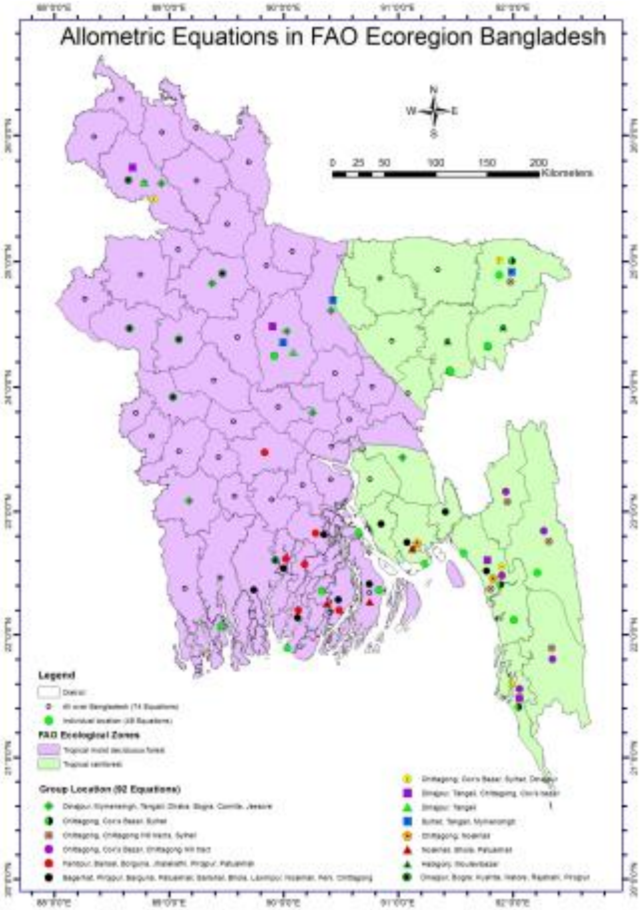
%	Scientific name	%	Scientific name	%	Scientific name
0.28	Barringtonia acutangula	0.02	Acacia catechu	0.005	Schleichera oleosa
0.28	Trema orientalis	0.02	Albizia odoratissimus	0.005	Sonneratia caseolaris
0.27	Leucaena leucocephala	0.02	Bischofia javanica	0.005	Spondias dulce
0.27	Toona ciliata	0.02	Brownlowia elata	0.005	Trapa bispinosa
0.26	Tamarindus indica	0.02	Cynometra ramiflora	0.002	Aeschynomene aspera
0.24	Olea europea	0.02	Elaeocarpus floribundas	0.002	Anispotera scaphula
0.24	Citrus grandis	0.02	Pergularia daemia	0.002	Bauhinia racemosa
0.22	Cassia fistula	0.02	Sapium baccatum	0.002	Bauhinia tomentosa
0.21	Dillenia indica	0.02	Zanthoxylum rhesta	0.002	Buettneria herbacea
0.20	Aegle marmelos	0.02	Alpinia nigra	0.002	Caesalpinia pulcherima
0.18	Oxytenanthera nigrociliata	0.02	Butea monosperma	0.002	Calotropis gigantea
0.18	Streblus asper	0.02	Dendrocalamus giganteus	0.002	Cassytha filiformis
0.17	Annona squamosa	0.02	Dillinia pentagyna	0.002	Ceriops roxburghiana
0.17	Bambusa longispiculata	0.02	Hibiscus tileiaceus	0.002	Cinnamomum cecidodaphne
0.16	Terminalia belerica	0.02	Holarrhena pubescence	0.002	Cinnamomum tamala
0.15	Bursera serrata	0.02	Lawsonia inermis	0.002	Costus speciosa
0.13	Macaranga denticulata	0.02	Baccaurea ramiflora	0.002	Curculigo orch
0.12	Pithecellobium dulce	0.02	Dendrocalamus hamiltonii	0.002	Cymbopogon cit
0.11	Trewia nudiflora	0.02	Ficus heterophylla	0.002	Desmdium gangeticum
0.11	Duabanga grandiflora	0.02	Garcinia cowa	0.002	Diospyros melanoxylon
0.10	Adina cordifolia	0.02	Hymenodictylon excelsum	0.002	Eugenia macrocarpa
0.10	Crataeva magna	0.02	Luffa cylindrica	0.002	Euphorbia nerifolia
0.10	Firmiana colorata	0.02	Phragmites karka	0.002	Ficus semicordata
0.10	Polyalthia longifolia	0.02	Terminalia chebula	0.002	Hamiltonia suaveolens
0.09	Syzygium grandis	0.01	Annona reticulata	0.002	Heterophragma adenophyllum
0.09	Aerva lanata	0.01	Ehretia acuminata	0.002	Holigarna caustica

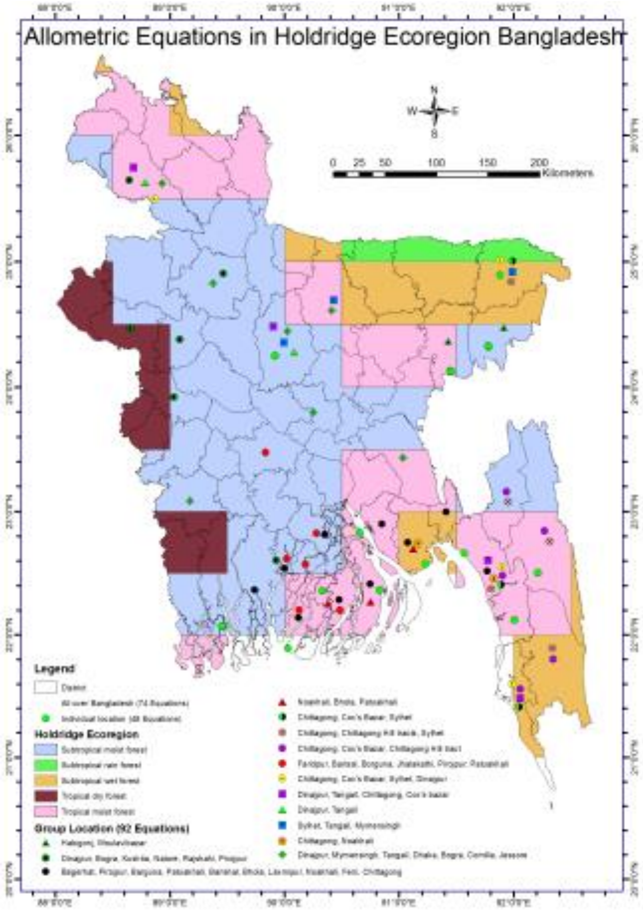
%	Scientific name	%	Scientific name	%	Scientific name
0.08	Holarrhena antidysenterica	0.01	Fimbristylis ovata	0.002	Ipomoea batatus
0.07	Ficus bengalensis	0.01	Garuga pinnata	0.002	Ixora coccinea
0.07	Elaeis guieensis	0.01	Gmelina hystrix	0.002	Justicia diffusa
0.07	Ficus altissima	0.01	Manikara achras	0.002	Leersia hexandra
0.07	Ficus religiosa	0.01	Micromelum pubescens	0.002	Manihot esculenta
0.07	Adina sessilifolia	0.01	Rourea commutta	0.002	Millingtonia hortensis
0.07	Ficus benjamin	0.01	Sarcolobus globosus	0.002	Morus indica
0.07	Litchi chinensis	0.01	Abroma augusta	0.002	Myriostachya wightiana
0.06	Anacardium occidentale	0.01	Amoora wallichii	0.002	Nerium indicum
0.06	Thespesia populnea	0.01	Careya arborea	0.002	Oldenlandia umbellata
0.06	Averrhoa carambola	0.01	Dehasia kurzii	0.002	Parkia roxburghii
0.06	Carissa carandus	0.01	Gomphrena globosa	0.002	Peucedanum sowa
0.06	Phyllanthus emblica	0.01	Mallotus repandus	0.002	Plumbago auriculata
0.05	Grewia microcos	0.01	Miliusa velutina	0.002	Premna harbaceae
0.05	Vetiveria zizanioides	0.01	Carallia brachiata	0.002	Psoralea coryllifolia
0.05	Bambusa polymorpha	0.01	Intsia bijuga	0.002	Pterospermum alata
0.05	Drimycarpus racemosus	0.01	Intsia retusa	0.002	Salix tetrasperma
0.05	Pongamia pinnata	0.01	Phaseolus vulgaris	0.002	Salmalia insignis
0.04	Michelia champca	0.01	Pothos scandens	0.002	Saussurea lappa
0.04	Neohouzeau dulloa	0.01	Rosa centifolia	0.002	Semicarpus anacardium
0.04	Syzygium samarangense	0.01	Sida cordata	0.002	Syzygium formusa
0.04	Albizia chinensis	0.01	Amaranthus spinosus	0.002	Tabernaemontana divaricata
0.04	Bouea oppositifolia	0.01	Anisoptera scaphula	0.002	Thevetia peruviana
0.04	Chickrassia tabularis	0.01	Aphania danura	0.002	Typhonium trilobatum
0.04	Mimosops elengi	0.01	Callicarpa macrophylla	0.002	Urena sinuata
0.04	Oroxylum indicum	0.01	Dellinia pentagyna	0.002	Vitex trifolia
0.04	Callicarpa arborea	0.01	Desmodium gangeticum	0.002	Webera campaniflora

Location of allometric equations in different ecological zones




Allometric Equations in WWF Ecoregion Bangladesh
Legend
WWF Ecoregion
Group Location (92 Equations)


Allometric Equations in FAO Ecoregion Bangladesh
Kilometers
Legend
FAO Ecological Zones
Group Location (92 Equations)


Allometric Equations in Holdridge Ecoregion Bangladesh
Kilometers
Legend
Holdridge Ecoregion
Group Location (92 Equations)