The emission factor database for the Land Use, Land-Use Change and Forestry (LULUCF) sector of Bangladesh

Bangladesh Forest Department

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UN-REDD PROGRAMME

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The application of UNDP, UNEP and FAO rights-based and participatory approaches will also help ensure the rights of indigenous and forest-dwelling people are protected and the active involvement of local communities and relevant stakeholders and institutions in the design and implementation of REDD plans.

The programme is implemented through the UN Joint Programmes modalities, enabling rapid initiation of programme implementation and channelling of funds for REDD efforts, building on the in-country presence of UN agencies as a crucial support structure for countries. The UN-REDD Programme encourage coordinated and collaborative UN support to countries, thus maximizing efficiencies and effectiveness of the organizations' collective input, consistent with the "One UN" approach advocated by UN members.

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Contents

Executive Summary

The development of the emission factor database for the Land Use, Land-Use Change and Forestry (LULUCF) sector of Bangladesh was fundamental as the country does not have long experience in data collection, archiving and documentation of activity data and emission factors to implement a GHG inventory for the LULUCF and Agriculture Forestry and Other Land use (AFOLU) sector.

The main objective of this database was the storage and archive of information on emission factors and other parameters needed to estimate greenhouse gas emissions for the national greenhouse gas inventory and for other activities under REDD+ such as the development of forest reference emission levels and/or forest reference levels. The data presented in this report were collected from i) a literature review carried out in English language peer-reviewed journals accessible on internet and ii) various forest inventories conducted in Bangladesh.

The database was composed of 1,160 emission factors. The majority (98%) of these emission factors were relevant for the forestry sector and few (2%) for cropland. Most of emission factors (81%) were suitable for tropical rainforest, some (16%) for tropical moist forest, few (2%) for tropical shrubland and 1 % of emission factors were found to belong to the tropical dry forest zone of Sri Lanka.

With regard to forestland, values have been collected for the following emission factors: average annual net increment in volume, above and belowground biomass, soil carbon stock, aboveground living biomass increment, root-to-shoot ratio, biomass expansion factor and wood density. Concerning cropland, data on aboveground biomass and soil carbon stock for perennial woody crops of *Mangifera indica* and *Cocos nucifera* have been collected.

In order to improve the coverage and completeness of the data within the database more country- specific values of emission factors from other sectors including cropland, wetland and settlements need to be considered. In addition, to maximize the usefulness of the database and make it more user friendly, the database should include more aggregated results, provide a range of values or uncertainties when available.

1. Introduction

The land use, land-use change and forestry (LULUCF) is the only sector that can act as a sink or source of greenhouse gases (GHGs) depending on the management activities. The quality of a GHG inventory for the LULUCF sector depends substantially on reliable activity data (AD) and/or emission factors (EFs). According to the United Nations Framework Convention on Climate Change (UNFCC), AD are defined as data that describe the magnitude of human activity (e.g. lime and fertilizer use) while EFs are defined as coefficients that relate the AD to the amount of a given GHG which is the source of later emissions (e.g. stock change factor for different management activities of cropland).

The compilation of a national GHG inventory for the LULUCF sector includes uncertainties which are associated with the quality and reliability of AD and/or EFs. The most common problem that a GHG inventory compiler faces during the preparation of national GHG inventory is accessible AD and/or EFs that are robust, applicable and well documented.

EFs that reflect national circumstances should be used in an inventory compilation with the aim to reduce the uncertainties and increase the accuracy and quality of a GHG inventory. However, the development of new EFs that are suitable for national conditions is difficult, costly, time-consuming and requires technical expertise.

In October 2002, the Intergovernmental Panel on Climate Change (IPCC) released a web-based database on EFs to facilitate countries on the selection of the most suitable EFs that take into consideration national conditions. The aim of the IPCC EFDB database is to serve as an updated library of well documented, evaluated and peer-reviewed EFs. The IPCC EFDB database provides information on the applicability and suitability of EFs to specific circumstances as well as the full technical references to source documents. The IPCC EFDB database allows the user to obtain information on the technologies and practices that were used to develop EFs and the parameters and conditions under which EFs were measured.

Despite the fact that the IPCC EFDB has been developed several years ago, it has the potential to be enriched with more nationally relevant EFs if more countries submit new EFs that are not included in the database. Therefore, the development of the IPCC EFDB evolves dynamically as more countries submit new data obtained from scientific papers, national inventories or non-peer reviewed papers.

1.1 The Emission Factor database of Bangladesh for the LULUCF sector

The development of the EF database of Bangladesh is fundamental as Bangladesh does not have long experience in data collection, archiving and documentation of AD and EF to implement a GHG inventory for the LULUCF and AFOLU sectors. In fact, this is the first time that a database on EFs that have been developed in Bangladesh has been prepared. Given that EFs are influenced by climate, soil, vegetation and management practices, it is important to use nationally derived EFs at a disaggregate level to improve the quality of the inventory, reduce the uncertainties and provide GHG inventory estimates that can be linked with national actions.

The EF database of Bangladesh is accompanied with an EndNote library where all the references that were used to collect EFs have been stored and archived. Each reference from the library has been labelled with a four digit numeric code that links the reference to the PDF file. Overall the EF database of Bangladesh has the same template as the one developed by the IPCC. However, there are three more parameters that have been included in the EF database of Bangladesh. These parameters are: a) the Label of the PDF document from where the EFs have been extracted. This code links the EF database to the library and the PDF document, b) the geographical coordinates in decimal degrees that indicate the site location where the EFs have been developed and c) the Global ecological zones (FAO 2012). Each EF of the database has been georeferenced and this allows the user to identify the suitability of an EF based on the ecological zones.

2. Objectives

The national EF database of Bangladesh aims to:

1. Serve as a library of well documented EFs that are suitable to be considered in the GHG compilation for the LULUCF sector and for other activities in the context of REDD+ (reduced emissions from deforestation and forest degradation)
2. To collect and validate EFs in a cost-effective way and;
3. Build the documentation and archiving of EFs that reflect national circumstances of Bangladesh

The specific objectives of this report are to:

1. Provide users with descriptive statistics of EFs that are included at current status in the national EF database of Bangladesh;
2. Identify EFs that are missing from the database and need to be developed potentially through national inventories.

3. Methodology

A literature search was carried out to collect EFs that are needed for the LULUCF sector. Searches were conducted in English language peer-reviewed journals accessible on internet. The searches were performed on Web of Science (WoS), Google scholar and Research Gate using key words (e.g. forest biomass, soil carbon, wood density, forest volume, perennial woody biomass, etc.) relevant for each EF. The literature search was focused on Bangladesh and other countries of South Asia including India, Sri Lanka, Pakistan and Nepal.

The searches were performed for the forestland and cropland. Emissions factors for grassland were not included in the database because it was assumed based on the discussions with national experts that there are no grasslands in Bangladesh due to anthropogenic pressure. Similarly, a literature search on emission factors for wetlands was not carried out because , extraction and commercial utilization of peat remains limited (Rahman 2015-2016). Therefore, this sub-category was not included in the GHG compilation.

Data extracted from studies include technical information on:

- Properties that describe the technologies and practices used to develop EFs, abatement/control technologies, parameters/conditions relevant to the study context such as soil type, land use and region/regional conditions such as country, continent, coordinates, climate etc.;
- The single value or a range of value of EF as well as the appropriate units
- The full technical reference and the source of data such as peer-reviewed journal, national inventory report etc.;
- Reference language in which the technical reference is available;
- Uncertainties expressed as 95% confidence limit, if available and;
- Type of parameter which indicates whether the parameter has been measured or modelled in the field

4. Results

4.1 Forest land

The EF database of Bangladesh consists of 1,149 EFs relevant for the forestry sector. These EFs have been collected from 21 scientific articles. The list of references is in Appendix 6.1. In total, 94% of EFs that are included in the database were developed in Bangladesh, 5% in India and 1% in Sri Lanka. The EFs concern 221 tree species that were found in various forest types such as natural Hill forest, Sal forest, plantations, Sundarbans, evergreen and semi-evergreen forest and home garden.

The database provides data on the following EFs as mentioned in the IPCC GPG 2003 (Penman, Gytarsky et al. 2003).

- Average annual net increment in volume (m^3 ha^{-1} yr^{-1})
- Aboveground living biomass (t ha^{-1})
- Aboveground living biomass carbon stock (tC ha^{-1})
- Belowground living biomass (t ha^{-1})
- Belowground living biomass carbon stock (tCha^{-1})
- Soil carbon stock (tC ha^{-1})
- Average annual aboveground living biomass increment (t ha^{-1})
- Total (above and belowground) biomass carbon stock (t ha^{-1})
- Root-to-shoot ratio (dimensionless)
- BEF for expansion of stem volume to aboveground biomass (dimensionless)
- Wood density (g cm^{-3}).

Most of EFs (81%) were found in the tropical rainforest zone while 16% of EFs were found in the tropical moist forest zone. In addition, 2% of EFs that are included in the database belong to the tropical shrubland ecological zone of India and few (1%) were found to belong to the tropical dry forest zone of Sri Lanka.

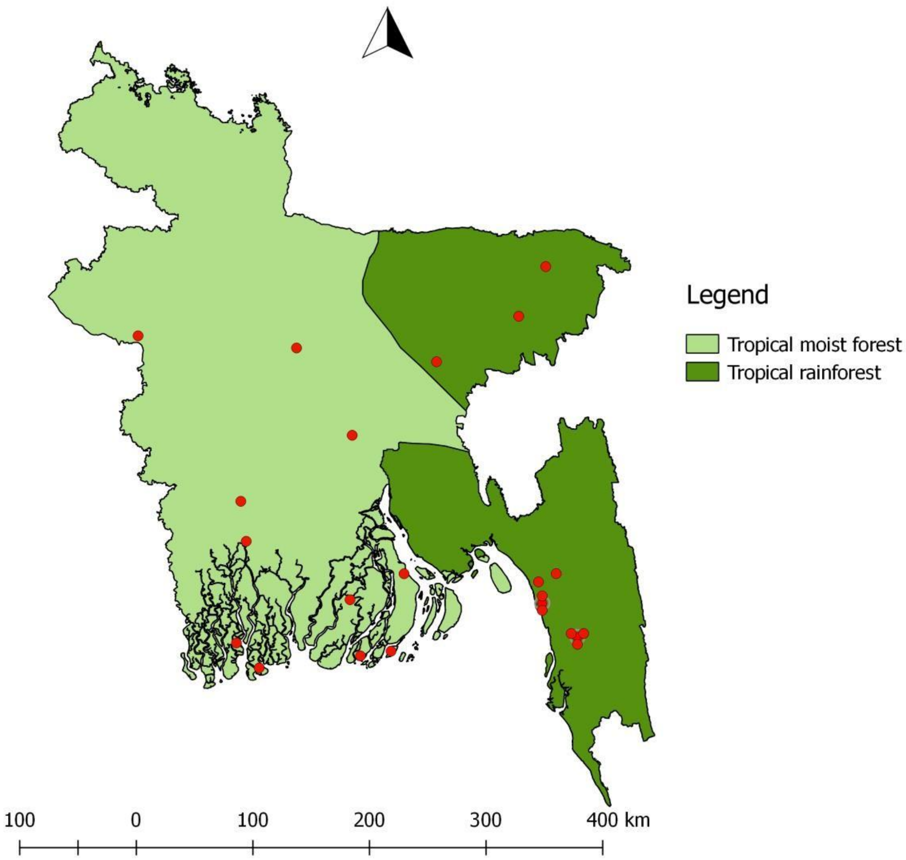

Figure 1: The FAO's ecological zones of Bangladesh and the locations (in red) where the EFs were developed.

<u>Average annual net increment in volume</u>

Compiled results on mean annual net increment in volume ($m^3ha^{-1}yr^{-1}$) for plantations of different tree species and forest types are given in table 1. The values reported in the database were developed specifically for the forests and plantations of Bangladesh, except for the values reported for plantations of *Tectona grandis* which were developed in India.

Table 1: Average annual net increment in volume by plantation tree species and forest types.

	Iv ($m^3 ha^{-1} yr^{-1}$)		
Species	**Range**	**Mean**	**Source**
Acacia mangium	0.20 – 62.73	18.06	(Latif 1995; Newaz 2004)
Avicennia officinalis	1.55 – 10.04	5.41	(Miah 2014)
Tectona grandis	1.61 - 11.31	5.63	(Jayaraman 2008)
Evergreen /semi-evergreen		10.36	(Rahman, Akter et al. 2015)
Wet deciduous (moist Sal)		9.15	(Rahman, Akter et al. 2015)
Dry deciduous (dry Sal)		8.91	(Rahman, Akter et al. 2015)
Sundarbans mangrove		8.95	(Rahman, Akter et al. 2015)
Mangrove plantations		10.15	(Rahman, Akter et al. 2015)

High variability of annual increment in volume in plantation of the same tree species was observed which is linked to differences in age of plantations (yr), site index (m), dominant height (m), stand diameter (cm), basal area (m^2ha^{-1}), and total volume ($m^3 ha^{-1}$).

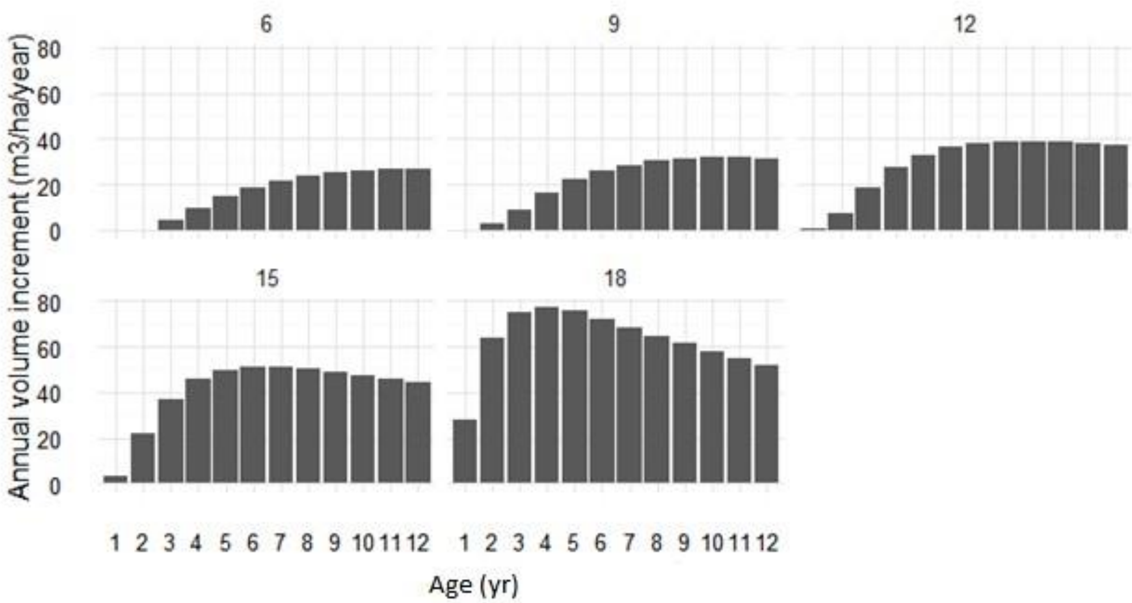

Figure 2: Variability of mean annual net increment in volume (m^3/ha/year) of plantations of *Acacia mangium* among age classes and site index (m): 6, 9, 12, 15, 18 m.

Above and belowground biomass stock

The database contains data on above-ground biomass for 82 tree species (55 genus). In the natural hill forest of Bangladesh, *Antidesma acidum* found to have the lowest (0.04 t/ha) biomass stock and *Dipterocarpus turbinatus* the highest (70.8 t/ha). Plantations of *Swietenia* *mahagoni* had the lowest (76 t/ha) aboveground stocks while the highest was found in plantations of *Shorea robusta* (388 t/ha).

Table 2: Aboveground biomass stock (t/ha) in plantations of tropical rainforest.

Species	Age class years	AGB (t/ha)	Source
Acacia auriculiformis	6 -18	156	(Yong Shin 2007)
Acacia mangium	≤ 12	99	(Latif 1995; Yong Shin 2007; Akter, Rahman et al. 2013)
Albizia sp.	-	223	(Akter, Rahman et al. 2013)
Chukrasia tabularis	≤ 17	130	(Yong Shin 2007)
Cassia sp.	-	150	(Akter, Rahman et al. 2013)
Dipterocarpus turbinatus	≤ 23	128	(Yong Shin 2007)
Eucalyptus camaldulensis	≤ 18	189	(Yong Shin 2007)
Gmelina arborea	13	103	(Yong Shin 2007)
Lagerstroemia speciosa	< 20	228	(Yong Shin 2007)
Shorea robusta		388	(Akter, Rahman et al. 2013)
Swietenia mahagoni	11-15	76	(Yong Shin 2007)
Syzygium grande	13	94	(Yong Shin 2007)

Results on aboveground biomass based on data collected from past forest inventories carried out in Bangladesh are given in Table 3.

Table 3: Aboveground biomass by FAO ecological zone and forest types of Bangladesh.

Forest types	AGB t/ha	SD	Source
TMF_plantation	43	28	(Costello 2016)
TRF_plantation	15	16	(Costello 2016)
TMF_Sal forest	57	51	(Costello 2016)
TRF_Sal forest	15	16	(Costello 2016)
TMF_Sundarbans	50	32	(Costello 2016)
TRF_Hill forest	50	61	(Costello 2016)

TMF: tropical moist forest, TRF: Tropical rainforest zone

Values of belowground biomass stocks are available for 79 tree species (57 genus). In natural hill forests, the lowest (0.01 t ha^{-1}) belowground biomass was found for *Meliosma sp.* and the highest (4.85 t ha^{-1}) for *Dipterocarpus sp. P*lantations of *Gmelina sp.* had the lowest (16.72 t ha^{-1}) belowground biomass and *Dalbargia sp* the highest (50 t ha^{-1}).

Average annual increment in aboveground biomass in plantations

Data on aboveground biomass increment (t ha^{-1} yr^{-1}) was collected from plantations of 13 tree species. The lowest (10.04 t ha^{-1} yr^{-1}) increment in aboveground biomass was reported for plantations of *Swietenia mahagoni* and the highest (26.41 t ha^{-1} yr^{-1}) for *Aphanamixis polystachya*.

Table 4: Average annual aboveground biomass increment in plantations of tropical rainforest.

Species	**Age**	**AGB increment**	**Source**
	yr	**t $ha^{-1}yr^{-1}$**	
Acacia auriculiformis	6 -18	18.60	(Yong Shin 2007)
Acacia mangium	11	20.16	(Yong Shin 2007)
Albizia procera	20	14.12	(Yong Shin 2007)
Aphanamixis polystachya	12 - 13	26.41	(Yong Shin 2007)
Chickrassia tabularis	8-17	14.27	(Yong Shin 2007)
Dipterocarpus turbinatus	6 -23	13.87	(Yong Shin 2007)
Eucalyptus camaldulensis	8 - 18	20.73	(Yong Shin 2007)
Gmelina arborea	13	13.33	(Yong Shin 2007)
Lagerstroemia speciosa	18 -20	18.60	(Yong Shin 2007)
Pinus caribaea	18	14.13	(Yong Shin 2007)
Swietenia mahagoni	11 - 15	10.04	(Yong Shin 2007)
Syzygium grande	13	11.44	(Yong Shin 2007)
Tectona grandis	20	18.94	(Yong Shin 2007)

Soil carbon stock

Data on soil carbon stocks (t ha^{-1}) are included for plantations of 15 tree species that belong to the tropical rainforest zone. The values of soil carbon stocks for plantations of different tree species and soil depths are given in Table 4. Given that all tree species belong to the same ecological zone, the differences in soil carbon are linked to the vegetation type, stand age and stand density.

In the 0-30 cm soil layer, plantations of *Pinus caribaea* found to store the lowest (83 t ha^{-1}) amount of soil carbon and the highest soil carbon in the 0-10 cm was found in plantations of *Lagerstroemia speciosa* (113 t ha^{-1}).

Table 5: Soil carbon stocks of plantations and soil depths.

Tree species	Soil carbon stock t C/ha	Soil depth cm	Source
Bambusa vulgaris	25	0-14	(Sohel 2015)
Syzygium grande	84	0-30	(Yong Shin 2007)
Swietenia Mahogany	96		(Yong Shin 2007)
Pinus caribaea	83		(Yong Shin 2007)
Lagerstroemia speciosa	113		(Yong Shin 2007)
Gmelina arborea	89		(Yong Shin 2007)
Eucalyptus camaldulensis	91		(Yong Shin 2007)
Dipterocarpus turbinatus	101		(Yong Shin 2007)
Chukrasia tabularis	93		(Yong Shin 2007)
Acacia procera	107		(Yong Shin 2007)
Acacia polystachya	107		(Yong Shin 2007)
Acacia mangium	95		(Yong Shin 2007)
Tectona grandis	89	0-100	(M.R. 2014)
Anthocephalus chinensis	83		(M.R. 2014)
Acacia auriculiformis	97		(M.R. 2014)

Biomass expansion factor (BEF) for expansion of stem volume to aboveground biomass

Data on BEF were collected from ground inventories carried out by the Forest Survey of India (FSI) for various states/union territories that took place during the period 1989 -1993. The value of BEF for tropical forests of teak, Sal, Bamboo, Dipteocarpus, evergreen and semi-evergreen forest and deciduous forest are given in table 6.

Table 6: Biomass expansion factor by tree species and forest type.

Forest type	Minimum dbh	BEF	Source
Tectona grandis	<10 cm	1.59	(Haripriya 2000; Haripriya 2002)
Sal	<10 cm	1.59	(Haripriya 2000; Haripriya 2002)
Bamboo	<10 cm	1.059	(Haripriya 2000; Haripriya 2002)
Dipteocarpus sp.	<10 cm	1.59	(Haripriya 2000; Haripriya 2002)
Miscellaneous	<10 cm	1.51	(Haripriya 2000; Haripriya 2002)
Evergreen	<10 cm	1.59	(Haripriya 2000; Haripriya 2002)
Semi-evergreen	<10 cm	1.59	(Haripriya 2000; Haripriya 2002)

Wood density

The database contains data on wood density (g cm^{-3}) for 81 species. All wood density data have been developed in Bangladesh except the wood density of *Camellia sinensis* which has been collected from a study carried out in India. All species are hardwood, except *Podocarpus nerifolia* which is the only indigenous softwood species in Bangladesh.

The species reported in the EF database have wood densities ranging from 0.22 to 0.84 g cm^{-3}. The lowest (0.22 g cm^{-3}) wood density was found for *Erythrina orientalis* while *Mesua ferrea* and *Vitex peduncularis* found to have the highest (0.84 g cm^{-3}) density.

4.2 Cropland

Data on soil carbon stocks and aboveground biomass for perennial woody crops of *Mangifera indica* and *Cocos nucifera* are given in table 6 and 7 below. Data were collected from studies carried out in India.

Table 7: Soil carbon stocks of perennial woody crops.

Orchard	**Soil carbon stock**	**Soil depth**	**Source**
	t C ha^{-1}		
Mangifera indica	25	0-30	(Selvaraj, Jayachandran et al. 2016)
Cocos nucifera	22	0-30	(Selvaraj, Jayachandran et al. 2016)

Table 8: Aboveground biomass stock of perennial woody crops.

Orchard	**AGB**	**Age**	**Source**
	t ha^{-1}	yr	
Mangifera indica	1.85 - 80.74	5-20	(Selvaraj, Jayachandran et al. 2016)
Cocos nucifera	9.14 - 285.68	5-20	(Selvaraj, Jayachandran et al. 2016)

5. Conclusion

In total, the database was composed of 1,160 EFs. The majority (98%) of these emission factors concerning forestland and few (2%) cropland. Therefore, it is important to enrich the database with country-specific values for other land categories including cropland, wetland and settlements. In addition, more data derived from grey literature and other countries with similar circumstances like Bangladesh should be considered.

6. Recommendations for Next Steps

The databases was presented at the the 13th Expert Meeting on Data (Agriculture, Forestry and Other Land Use Sector) for the IPCC Emission Factor Database (EFDB) which was held on 14-15 December 2016. The overall aim of this particular meeting was to identify, select and approve data on emission factors/parameters for estimation of emissions from Agriculture, Forestry and Other Land Use Sector (AFOLU) sector to be included in the EFDB.

The Editorial Board of the EFDB reviewed and approved six country-specific values of aboveground biomass which were developed based on data obtained from past forest inventories carried out in Bangladesh (Table 3). The following recommendations were provided by the Editorial Board of the EFDB:

- The database should include more aggregated data or provide a range of country-specific values where possible in order to maximise the usefulness of the database and make it more user friendly;
- To increase the robustness of the database, data on uncertainties should be gathered;
- As far as possible, the authors of the scientific papers considered in the EFDB database for Bangladesh should be be contacted to include the data uncertainties when available;
- The national emission factor database of Bangladesh can potentially be linked with the IPCC EFDB and with other databases such as Globallometree.

7. References

Akter, S., M. Rahman and M. Al-Amin (2013). "Chittagong university campus: Rich in forest growing stock of valuable timber tree species in Bangladesh." Journal of Forest and Environmental Science **29**(2): 157-164.

Costello, L. S., G., Aziz, T., Akhtar, M., Poultouchidou, A. (2016). Harmonization of forest inventory data in Bangladesh and calculation of emission factors for REDD+. Dhaka, Bangladesh., FAO BAngladesh. .

FAO (2012). "Global ecological zones for FAO forest reporting: 2010 Update. Retrieved from Rome: http://www.fao.org/docrep/017/ap861e/ap861e00.pdf."

Haripriya, G. S. (2000). "Estimates of biomass in Indian forests." Biomass and Bioenergy **19**(4): 245-258.

Haripriya, G. S. (2002). "Biomass carbon of truncated diameter classes in Indian forests." Forest Ecology and Management **168**(1-3): 1-13.

Jayaraman, K. R., P. (2008). "Optimizing management of even-aged teak stands using growth simulation model: A case study in Kerala." Journal of Tropical Forest Science **20**(1): 19-28.

Latif, M. A. D., S.; Rahman, M. F.; Habib, M. A. (1995). "GROWTH AND YIELD TABLES FOR ACACIA MANGIUM GROWN IN THE PLANTATIONS IN BANGLADESH." Journal of Tropical Forest Science **7**(4): 591-598.

M.R., U. (2014). "Developing Allometric Models for Carbon Stock Estimation in Eighteen Year Old Plantation Forests of Bangladesh." J J Microbiol Pathol **1(1)**(006.).

Miah, M. A. Q. I., Sk Ahiul; Habib, Md Ahsan; Moula, Md Golam (2014). "Growth performance of Avicennia officinalis L. and the effect of spacing on growth and yield of trees planted in the Western coastal belt of Bangladesh." Journal of Forestry Research **25**(4): 835-838.

Newaz, M. S. M.-E.-M., M. (2004). "Growth and yield prediction models for Acacia mangium grown in the plantations of the central region of Bangladesh." New Forests **27**(1): 81-88.

Penman, J., M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger, R. Pipatti, L. Buendia, K. Miwa, T. Ngara and K. Tanabe (2003). "Good practice guidance for land use, land-use change and forestry." Good practice guidance for land use, land-use change and forestry.

Rahman, M. (2015-2016). "Bangladesh National Conservation Stratergy: Energy and Minerals."

Rahman, M. S., S. Akter and M. Al-Amin (2015). "Forest and agro-ecosystem productivity in Bangladesh: A climate vegetation productivity approach." Forest Science and Technology **11**(3): 126-132.

Selvaraj, A., S. Jayachandran, D. P. Thirunavukkarasu, A. Jayaraman and P. Karuppan (2016). "Carbon sequestration potential, physicochemical and microbiological properties of selected trees Mangifera indica L., Manilkara zapota L., Cocos nucifera L. and Tectona grandis L."

Sohel, M. S. I. A., Mohammed; Akhter, Sayma; Rahman, Mizanur (2015). "Carbon storage in a bamboo (Bambusa vulgaris) plantation in the degraded tropical forests: Implications for policy development." Land Use Policy **49**: 142-151.

UNFCC "Toolkit: for non-Annex I Parties on establishing and maintaining institutional arrangements for preparing national communications and biennial update reports.".

Yong Shin, M. M., Danesh M.; Lee, Kyeong Hak (2007). "Potential contribution of the forestry sector in Bangladesh to carbon sequestration." Journal of environmental management **82**(2): 260-276.

8. The list of references used in the emission factor database of Bangladesh

Akter, S., Rahman, M., & Al-Amin, M. (2013). Chittagong university campus: Rich in forest growing stock of valuable timber tree species in Bangladesh. *Journal of Forest and Environmental Science, 29*(2), 157-164.

Alamgir, M., & Al-Amin, M. (2007). Organic carbon storage in trees within different Geopositions of Chittagong (South) Forest Division, Bangladesh. *Journal of Forestry Research, 18*(3), 174-180.

Azad, M. S. M., Samir; Matin, Md Abdul. (2013). Functional relationships of nodulation response and biomass production at nursery stages of two fast-growing, leguminousmultipurpose tree species in Bangladesh: Albizia saman and Leucaena leucocephala. *Forest Science and Practice, 15*(4), 274-285. doi:10.1007/s11632-013-0416-2

Barua, S., & Haque, S. (2013). Soil characteristics and carbon sequestration potentials of vegetation in degraded hills of Chittagong, Bangladesh. *Land degradation & development, 24*(1), 63-71.

Chavan, B., & Rasal, G. (2012). Total sequestered carbon stock of Mangifera indica. *Journal of Environment and Earth Science, 2*(1).

Chowdhury, M. Q., Sarker, S. K., Deb, J. C., & Sonet, S. S. (2013). Timber species grouping in Bangladesh: linking wood properties. *Wood Science and Technology, 47*(4), 797-813. doi:10.1007/s00226-013-0532-0

Costello, L. Sola, G., Aziz, T., Akhtar, M., Poultouchidou, A. (2016). Harmonization of forest inventory data in Bangladesh and calculation of emission factors for REDD+. Dhaka, Bangladesh., FAO BAngladesh.

Dey, A. I., Mahmuda; Masum, Kaji Mohammed. (2014). Above Ground Carbon Stock Through Palm Tree in the Homegarden of Sylhet City in Bangladesh. *Journal of Forest and Environmental Science, 30*(3), 293-300.

Haripriya, G. S. (2002). Biomass carbon of truncated diameter classes in Indian forests. *Forest Ecology and Management, 168*(1-3), 1-13. doi:10.1016/s0378-1127(01)00729-0

Hossain, M. S., Mohammad Raqibul Hasan; Bose, Arun; Limon, Sharif Hasan; Chowdhury, Md Rezaul Karim; Saha, Sanjoy. (2012). Allometry, above-ground biomass and nutrient distribution in Ceriops decandra (Griffith) Ding Hou dominated forest types of the Sundarbans mangrove forest, Bangladesh. *Wetlands Ecology and Management, 20*(6), 539-548. doi:10.1007/s11273-012-9274-2

http://www.nature.com/articles/srep29987#supplementary-information

Jayaraman, K. R., P. (2008). Optimizing management of even-aged teak stands using growth simulation model: A case study in Kerala. *Journal of Tropical Forest Science, 20*(1), 19-28.

Kalita, R. M. D., Ashesh Kumar; Nath, Arun Jyoti. (2015). Allometric equations for estimating above- and belowground biomass in Tea (Camellia sinensis (L.) O. Kuntze) agroforestry system of Barak Valley, Assam, northeast India. *Biomass & Bioenergy, 83*, 42-49. doi:10.1016/j.biombioe.2015.08.017

Latif, M. A. D., S.; Rahman, M. F.; Habib, M. A. (1995). GROWTH AND YIELD TABLES FOR ACACIA MANGIUM GROWN IN THE PLANTATIONS IN BANGLADESH. *Journal of Tropical Forest Science, 7*(4), 591-598.

M.R., U. (2014). Developing Allometric Models for Carbon Stock Estimation in Eighteen Year Old Plantation Forests of Bangladesh. *J J Microbiol Pathol, 1(1)*(006.).

Miah, M. A. Q. I., Sk Ahiul; Habib, Md Ahsan; Moula, Md Golam. (2014). Growth performance of Avicennia officinalis L. and the effect of spacing on growth and yield of trees planted in the Western coastal belt of Bangladesh. *Journal of Forestry Research, 25*(4), 835-838. doi:10.1007/s11676-014-0531-5

Newaz, M. S. M.-E.-M., M. (2004). Growth and yield prediction models for Acacia mangium grown in the plantations of the central region of Bangladesh. *New Forests, 27*(1), 81-88.

Rahman, M. M. K., M. N. I.; Hoque, A. K. F.; Ahmed, I. (2015). Carbon stock in the Sundarbans mangrove forest: spatial variations in vegetation types and salinity zones. *Wetlands Ecology and Management, 23*(2), 269-283. doi:10.1007/s11273-014-9379-x

Rahman, M. S., Akter, S., & Al-Amin, M. (2015). Forest and agro-ecosystem productivity in Bangladesh: A climate vegetation productivity approach. *Forest Science and Technology, 11*(3), 126-132.

Ranasinghe, D. M., G. J. (1991). DRY-MATTER CONTENT AND ITS DISTRIBUTION IN AN AGE SERIES OF EUCALYPTUS-CAMALDULENSIS (DEHN) PLANTATIONS IN SRI-LANKA. *Forest Ecology and Management, 41*(1-2), 137-142. doi:10.1016/0378-1127(91)90124-e

Selvaraj, A., Jayachandran, S., Thirunavukkarasu, D. P., Jayaraman, A., & Karuppan, P. (2016). Carbon sequestration potential, physicochemical and microbiological properties of selected trees Mangifera indica L., Manilkara zapota L., Cocos nucifera L. and Tectona grandis L.

Sohel, M. S. I. A., Mohammed; Akhter, Sayma; Rahman, Mizanur. (2015). Carbon storage in a bamboo (Bambusa vulgaris) plantation in the degraded tropical forests: Implications for policy development. *Land Use Policy, 49*, 142-151.

Thakur, S. K., B. Mohan; Kunhamu, T. K. (2015). Coarse root biomass, carbon, and nutrient stock dynamics of different stem and crown classes of silver oak (Grevillea robusta A. Cunn. ex. R. Br.) plantation in Central Kerala, India. *Agroforestry Systems, 89*(5), 869-883. doi:10.1007/s10457-015-9821-y

Ullah, M. R. A.-A., M. (2012). Above- and below-ground carbon stock estimation in a natural forest of Bangladesh. *Journal of Forest Science (Prague), 58*(8), 372-379.

Yong Shin, M. M., Danesh M.; Lee, Kyeong Hak. (2007). Potential contribution of the forestry sector in Bangladesh to carbon sequestration. *Journal of environmental management, 82*(2), 260-276. doi:10.1016/j.jenvman.2005.12.025

Zomer, R. J., Neufeldt, H., Xu, J., Ahrends, A., Bossio, D., Trabucco, A., . . . Wang, M. (2016). Global Tree Cover and Biomass Carbon on Agricultural Land: The contribution of agroforestry to global and national carbon budgets. *Scientific Reports, 6*, 29987. doi:10.1038/srep29987