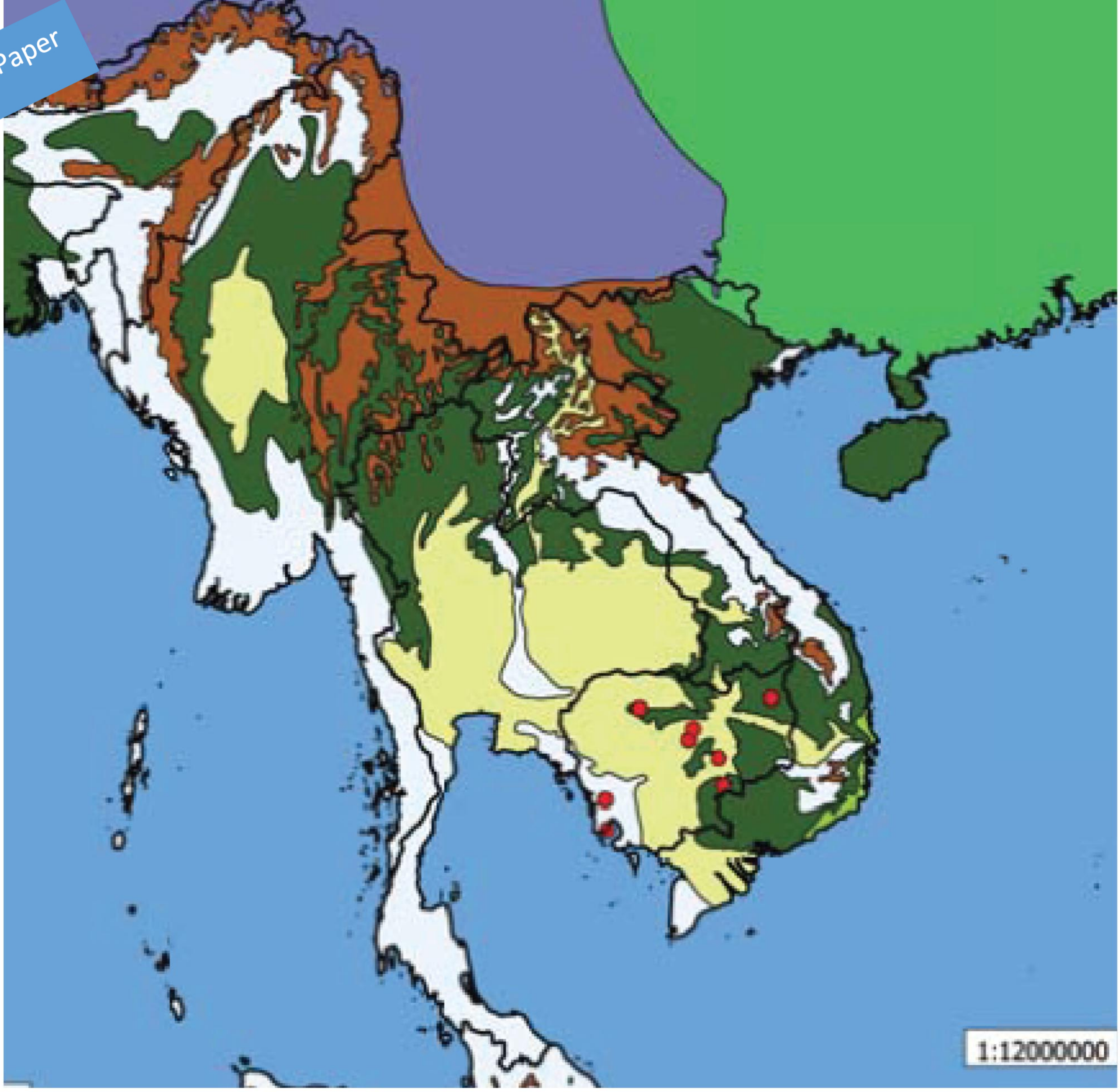
Working Paper



Tree volume and biomass allometric equations of Cambodia

Cambodia, 2012

REDD+ CAMBODIA

Disclaimer

This report prepared by Hellene Sarin, Luca Birigazzi, Samreth Vanna, Mathieu van Rijn, Matieu Henry, and does not necessarily represent the views of the Cambodia REDD+ Taskforce, the Forestry Administration, the General Department of Administration of Nature Conservation and Protection, the Fisheries Administration, and FCPF Project.

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Hellene Sarin, Luca Birigazzi, Samreth Vanna, Mathieu van Rijn, Matieu Henry.

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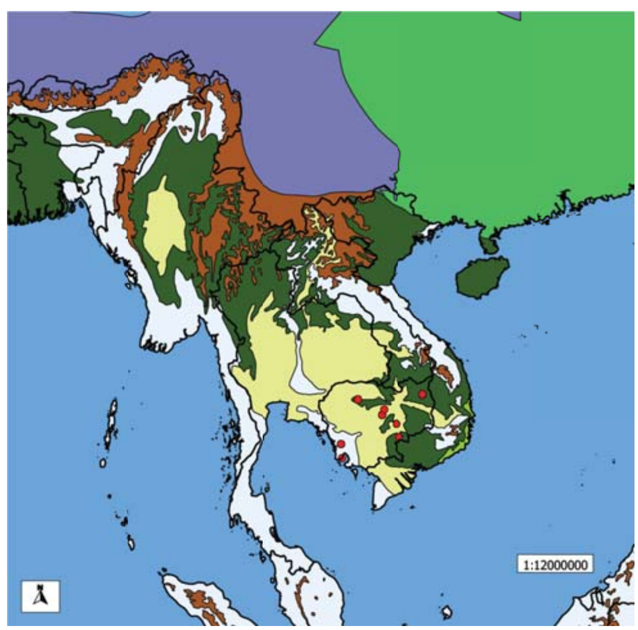

Contents

The UN-REDD Programme, implemented by FAO, UNDP and UNEP, has two components: (i) assisting developing countries prepare and implement national REDD strategies and mechanisms; (ii) supporting the development of normative solutions and standardized approaches based on sound science for a REDD instrument linked with the UNFCCC. The programme helps empower countries to manage their REDD processes and will facilitate access to financial and technical assistance tailored to the specific needs of the countries.

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.

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1. Introduction

Since 2000 the interest in forest biomass started growing (Zianis and Mencuccini,2004) In the past the estimation of above ground tree biomass has mainly been conducted for studies on the sustainable management of forest resources (Henry, et al.,2011). Before the last decade, tree volume equations were mainly developed for timber management and biomass equations for fuel wood production. But today, the need of accurately quantify the global carbon cycle and to elaborate effective climate change strategies for mitigation and adaptation, make the vegetation biomass also a crucial variable for the wellbeing of the future generations (Bombelli, et al.,2009). In particular Reducing Emissions from Deforestation and forest Degradation (REDD) may play an important role for climate change mitigation and, moreover, an accurate estimate of emission factor is also fundamental to develop and verify environmental policies and strategies. In fact, the Conference of the Parties held in Copenhagen in 2009, under the UN framework convention on climate change (UNFCCC), requests developing country Parties to establish robust and transparent monitoring systems for forest and carbon stock (UNFCCC,2009).

Forest carbon stock analysis is mainly derived from biomass estimation (Biomass is defined as the oven-dry weight of organic matter). The improvement of the accuracy of biomass estimates depends on the availability of site and species-specific allometric equations. Indeed, as tree architectures and wood gravity may considerably differ from species to species (Ketterings, et al.,2001), and from site to site, the use of generalized equations (not specific and not local) may introduce in the estimate bias and errors. In addition to this, many other factors can affect the precision of the estimate, such as, for example, the sample size of the trees used to develop the regression or the coefficient of determination of the equation (R^2). For this reason it would be important to collect not only the mere formulas but also, if available, all the related statistical regression parameters. Unfortunately tree allometric equations are rare and sometimes not readily available. During the years various tree allometric equations have been used to assess volume and biomass of Cambodian forests but no comprehensive and consistent regression compilations have been produced. The present work represents the first effort to fill this gap.

2. Objectives of the report

The objectives of this report are to (1) provide an overview of the current status of tree volume and biomass allometric equations in Cambodia, (2) identify the gaps and future needs and (3) provide recommendations for volume, biomass and carbon stock assessment, (4) provide examples of how to use the database and select the appropriate equation. The report analyses the various tree allometric equations and identify their potential when assessing national volume, biomass and carbon stocks and assess its validity and suitability for use in species that are found under the country's climatic characteristics.

3. The Compilation of the data

3.1. Review of the available allometric equations

The first phase of the work was to search and review the available literature for the allometric equations developed in Cambodia predicting Volume or Biomass for tree, stands, sprouts or tree components. The equations selected were mainly diameter-based with other possible co-variables such as height, age, etc. No other selection criteria (such as R2-values, species, ages, sizes, site conditions, or sampling methods) were used a priori.

The literature-survey was conducted through Internet and in specialized libraries. Online literature research was conducted for sources that reported biomass and volume equations. A survey of online libraries (Springerlink) and journals such as: JARQ, a database of Japan International Research Center for Agricultural Sciences (JIRCAS), Journal of Environmental Science and Management, J For Res, New Forests, Oecologia. When considering the research on internet, the following keywords were used to facilitate the research: biomass function, volume function, allometry, equation, model, timber, phytomass, aboveground biomass, belowground biomass, allometric equation.

The research was also conducted at the FAO FRA (Forest Resources Assessments) Library. The FAO FRA library comprises a collection of FAO working papers, project field documents, country reports, volume tables and forest inventories from the early 50s to the late 90s, and it was a precious source of data and information which would otherwise be difficult to obtain. Other information sources include reports and documents that are not available online or in the FRA library (mostly from the Forestry Administration). Unfortunately some articles were not in English but in Japanese and, due to the lack of an interpreter, it was not possible to enter them in the database. As soon as this problem will be addressed the database will be updated.

During the data collection, both the hard and soft copies of all the documents cited in the database were collected in order to make them available for further studies. To make the consultation of bibliography and references easier and to export them in excel database we used a RIS format reference management software. It is worth remembering that the data compilation is not exhaustive and may have not considered all the data. However, it is a first regional database that will be progressively completed.

3.2. Data classification and geo referencing

Once the documents were collected, the data were organized, georeferenced and slightly adjusted in order to make them consistent with the template database that was being elaborated. A problematic point was related to the tree compartments predicted by the equation. The equations in the literature are inconsistent in defining biomass components including fine and coarse roots, small and large branches, stump and bole, top and bole, etc. as well as there is not a standard and common definition for aboveground biomass or growing stock (it may or may not include the stump, the bark, the top etc.). Therefore in order to standardize, 11 different tree compartments have been selected (fig.1), thoroughly checking the original sources before entering the equations in the database and carefully converting their component system into ours. The figure below shows the tree components referred to in this study.

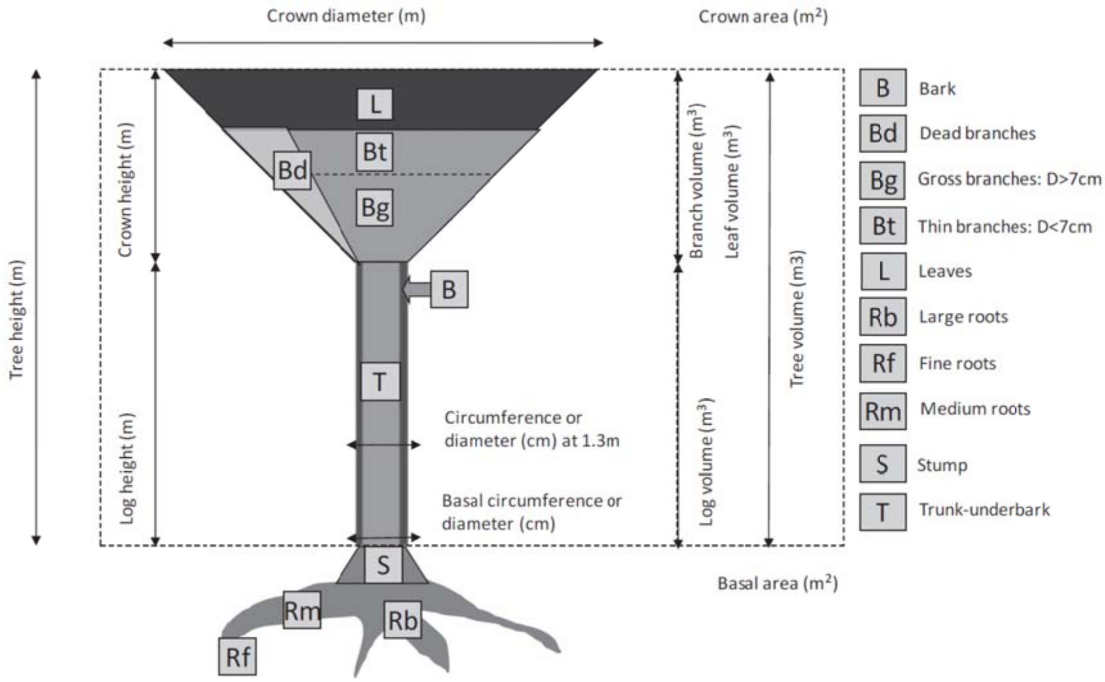

Figure 1. Tree components classification used in the present work. (Henry, et al.,2011).

The name of the locations where the equations were developed and the corresponding latitude and longitude coordinate were identified using the geographical information provided by the documents. When only the name of the location was available, the geographic coordinates were obtained using administrative maps and Google Earth. When the names of the locations were missing and only a map with the localization of the plots in the field was available, the geographic coordinates were obtained using administrative maps and the open source GIS software "Quantum GIS (FAO,2005). When it was not possible to unambiguously identify the location because the geographic position was missing or too vague, the lack was reported in the database. If the equation was developed in more than one location, all the locations were georeferenced.

Once the locations were georeferenced, they were categorized according to five ecological classifications: FAO (FAO,2001), Udvardy (Udvardy,1975), WWF (WWF,2000), Bailey (Bailey,1989), Holdridge (Holdridge,1947). Climatic parameters, such as temperature (T), precipitation (ppt) and wind (W) were obtained using the software New LocClim (FAO,2005). Additional classifications were achieved according to the ecosystem type (plantation or forest) and the level of population (Lianas, Mangroves, individual tree, sprouts and stand) considered. Where available, also some relevant regression statistics were reported, such as R^2 values (coefficient of determination of the equation), R^2 adjusted, the diameter ranges over which the equations were developed and the sample sizes of trees harvested to develop the regression.

A detailed bibliography is provided in order to allow the readers to consult the original source of the equation. The present work tried to be as comprehensive as possible but some lacks in the documentation are inevitable. To reduce the forgoing the database is designed to allow a constant updating of the data and existing gaps or inaccurate information can be addressed in the future.

3.3. Tutorial for data insertion

In order to facilitate the data insertion and the usability of the database, a specific tutorial (Baldasso and Henry,2011) was created. The tutorial provides detailed information on the database structure and about the procedures and methodology for entering the data. Additional useful information is also provided such as how to search articles, reports and documents containing allometric equations; how to manage the references using RIS format reference management software; how to geo-reference and to spatialize the data.

3.4. Database Description and Structure

The database is composed of 70 variables. These variables refer to a multiplicity of aspects of importance for correct evaluation and use of the equations. The first information showed is related to the ecology of the plants analyzed to develop the regression. The following variables describe the geographical localization. The equation parameters are moreover displayed in details: the description of the dependant and independent variables of the equations, their unit of measurement and their range of application (the minimum and maximum value within which it is possible to use the equation). The plant vegetation components considered in the equations are then illustrated both using a synthetic definition (ex. “above ground biomass”) both using a binary system of 11 columns (one for each tree component showed in fig.1) in which “0” or “1” stand for whether or not the component is considered. The botanical classification of the plant (family, genus, species), its age and the sample size used to develop the regression are also provided. Appendix 1 includes the detailed definition for each variable. Please refer to Baldasso et al. (2012) for further information. A list of the acronyms used is available in Appendix 2.

4. Tree allometric equations in Cambodia: Results and Discussion

4.1. Historical review

The first forest Inventory was conducted by FAO/UNDP between 1958 and 1962 in the East Mekong River region (Rollet,1962). Prior to this inventory no volume tables were produced for Cambodia. In this work 2640 trees of 15 species were harvested in nine different locations in order to develop volume equations. Almost at the same time (between 1960 and 1962) the United States Agency for International Development (USAID) planned a national scale inventory. Unfortunately this project was not completed and the field work was carried out only in the Cardamom range sample unit. For this inventory, however, USAID produced a practical field manual containing allometric equations and volume table for broad forest types of Cambodia (United States Agency for International Development,1962). Additional generic volume equations were produced as a result of low intensity forest sampling surveys undertaken in the Sandan district in 1998 by the Department of Forestry and Wildlife of Cambodia and FAO/UNDP (FAO,1998). The authors warned that these equations should be considered provisional, due to the time limitation of the study.

A more comprehensive forest research study was carried out by the Cambodian Department of Forestry and Wildlife in the early 2000 (FAO,2007). 1298 trees were sampled in 5 different provinces of the country and volume tables were produced for three broad forest types and for two main groups of species: dipterocarp and non dipterocarp. In the last 5 years the studies started focusing more on biomass and some biomass equations were developed in the framework of elaborating methodologies in monitoring anthropogenic greenhouse gas emissions from tropical forests (Kiyono, et al.,2011, Kiyono,2006) Furthermore, a network of permanent sampling plot for different seasonal forests types in Cambodia (Vanna et al.,2012) has been established in order to provide data to use in the near future to develop new biomass equations.

4.2 Geographical Distribution of the Equations

Overall the equations present in the database were developed in 8 different locations. The map below shows the geographical localization of the plots.

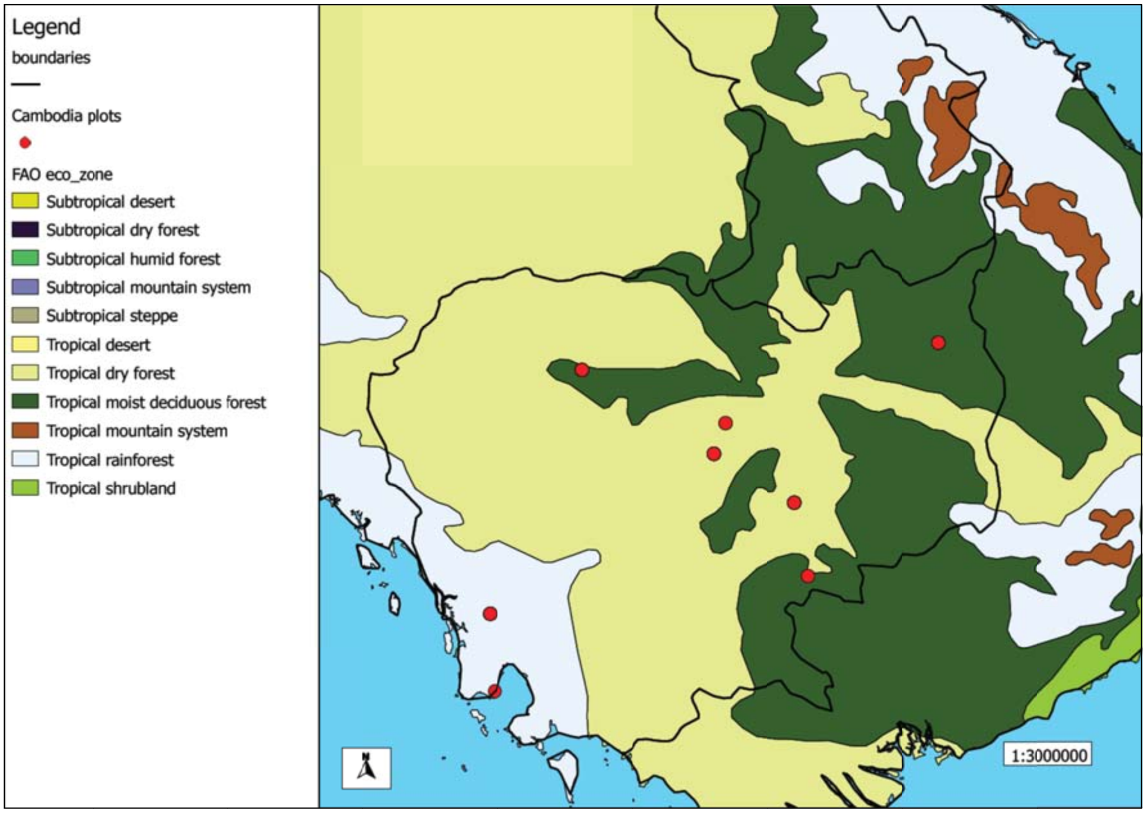

Figure 2. Geographical distribution of the sample plot in Cambodia and FAO global ecological zoning (note: the red dots represent the sites where equations were developed)

According with the FAO Global ecological zoning for the global forest resources assessment (FAO,2001), the number of equations is homogenously distribuited among the three major forest biomes of Cambodia. As we can see in figure 3, the most part of the equations were developed in the Tropical moist deciduous forest (37%), then in the Tropical rainforest (34%) and in the Tropical dry forest (29%).

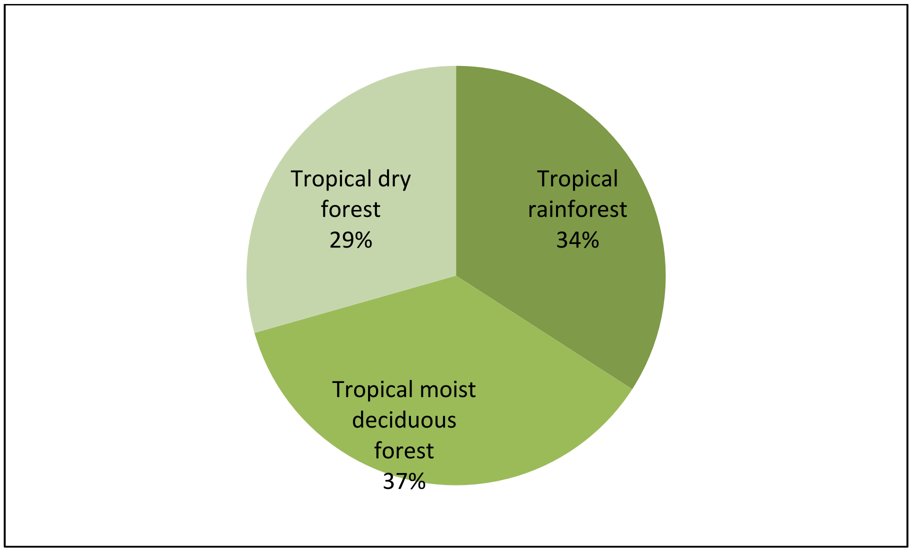

Figure 3. Percentage of equations per ecological zones (FAO, 2001)

Cambodia defines forests with the following parameters: a minimum tree crown cover of 10%, a minimum area of 0.5 ha, and a minimum tree height of 5m(MAFF,2008). The forest type classification used by the Forestry Adminstration (FA) differs from the FAO classification, and it is mainly based on forest typology. FA divides the Cambodian forest in 5 types of forest: 1.evergreen forest, 2. semi-evergreen (or mixed evergreen) forest, 3. deciduous forest, 4. other forest (including re-growth, wood and shrubland, stunted, plantations, mosaic of cropping, bamboo, and mangrove forests), and 5. non-forest(FA,2011). The main forest types in terms of forest cover area are evergreen, semi-evergreen forest, followed by deciduous forests (Table 1).

Table 1. Forests of Cambodia in 2010 by area and percentage forest type

Type	Area (ha)	Percentage (%)
Evergreen Forest	3,499,185	19.27
Semi-evergreen Forest	1,274,789	7.02
Deciduous Forest	4,481,214	24.68
Other Forest	1,108,600	6.1
Non-Forest	7,796,885	42.93
Total	18,160,674	100

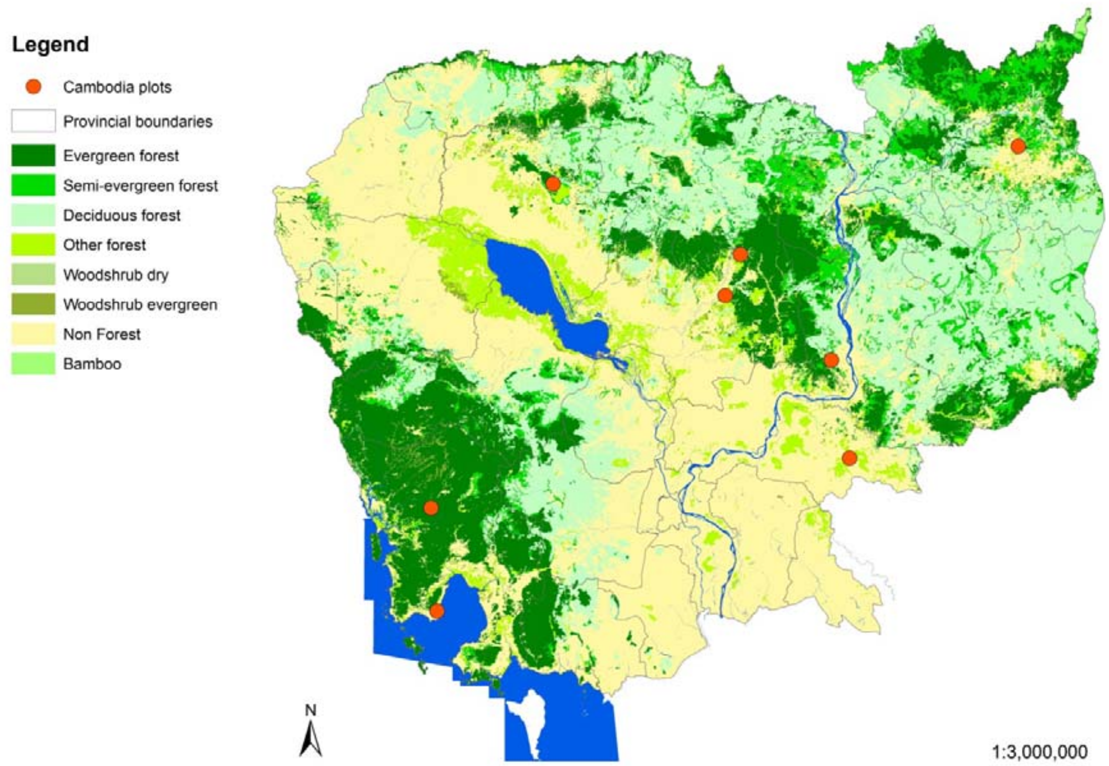

Figure 4. Geographical distribution of the permanent sample plots in Cambodia and Forestry Administration Forest cover map 2010 (FA, 2011)

The number of equations is not homogeneously distributed over the five forest types used by the Forestry Administration. Most of the plots are on locations which are under 4. other forest or area currently classified as 5. non-forest (60%). Plots to develop allometric equations are limited to two locations for 1. evergreen (19%) and 3. deciduous (19%) forest, whereas no plot is located inside the the 2. semi-evergreen forest type.

4.3 Output of the equations

The output of the equations can be volume, biomass or carbon, depending on the purpose of the study. A research more focused on timber production will tend to consider volume, whereas a study for climate change mitigation will focus more on biomass or carbon estimations. As it is shown in the graphic below (fig.4) the 88% (n=35) of the equations predict volume, while only the 12% (n=5) predict biomass.

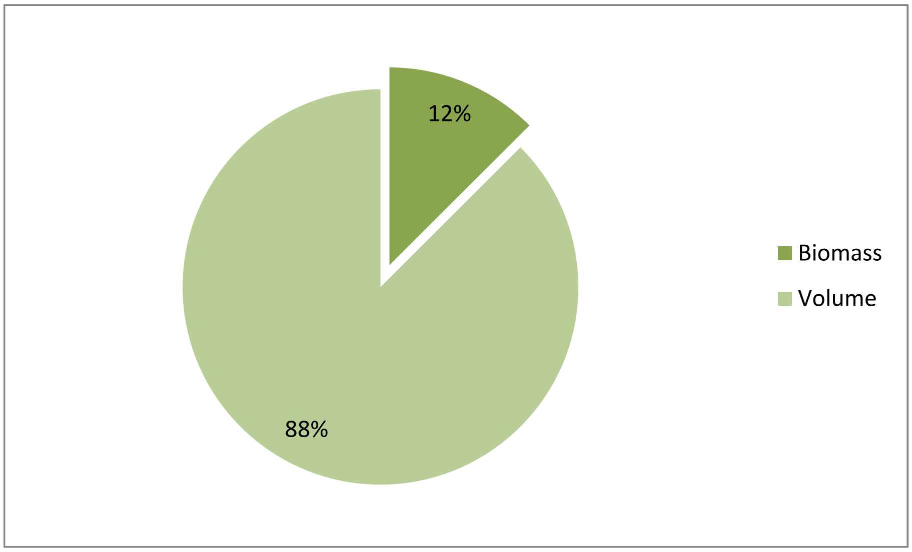

Figure 5. Outputs predicted by the available equations in Cambodia.

4.3 Tree Species to which the Equations Refer

80% of the equations (n=36) collected as far refer to groups of species (fig.5). Only four equations in the database are species-specific and refer to two species. One of these species, *Hevea brasiliensis*, is not indigenous and exclusively cultivated for rubber production. The second species, *Anisoptera glabra* (also called Mersawa in the report of the Department of Forestry and Wildlife, 2003), is indigenous and belong to the dipterocarpaceae family and is particularly sought for its timber.

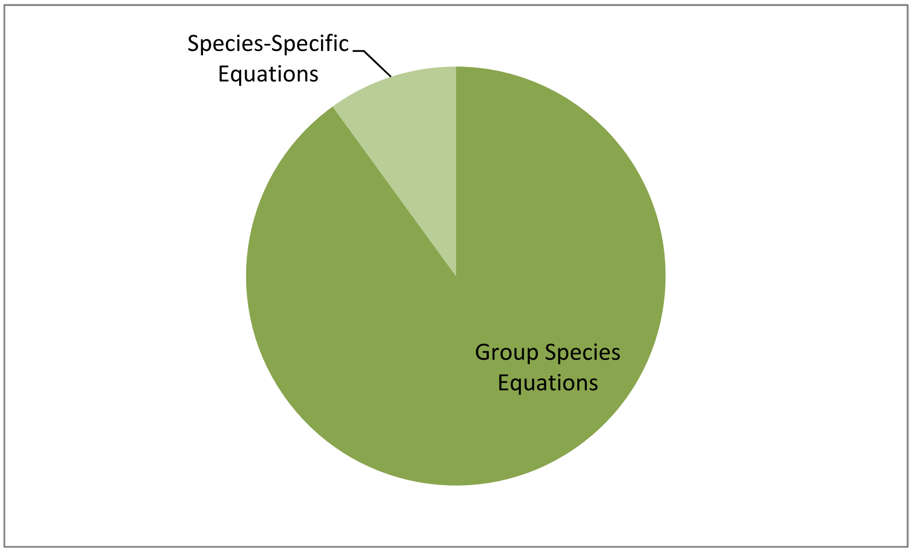

Figure 6. Percentage of species specific and species group equations

The main broad division made by the most of the authors regarding the species is between the dipterocarpaceae and others. The distribution of equations per family reflects this approach (fig.6). The very most part of the equations presenting a taxonomic indication refers to trees belonging to family of dipterocarpaceae (76%), the fabaceae represent the 6% and the other families overall no more than the 12%.

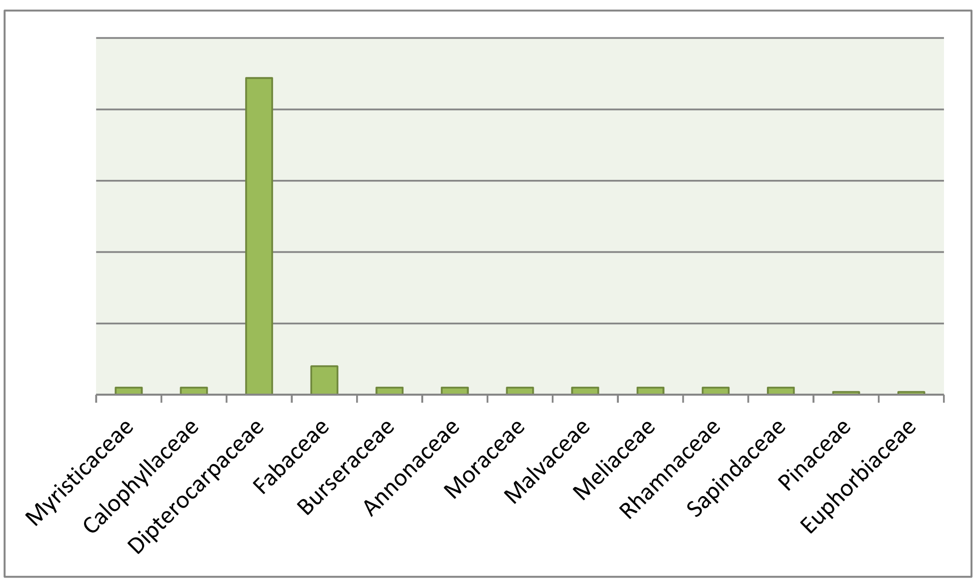

Figure 7. Distribution of equations per family

This unevenly distribution occurs also in the distribution of equations per genus(fig.7), with more than 70 % of the equation belonging to the genera Dipterocarpus, Hevea, Shorea, Vatica.

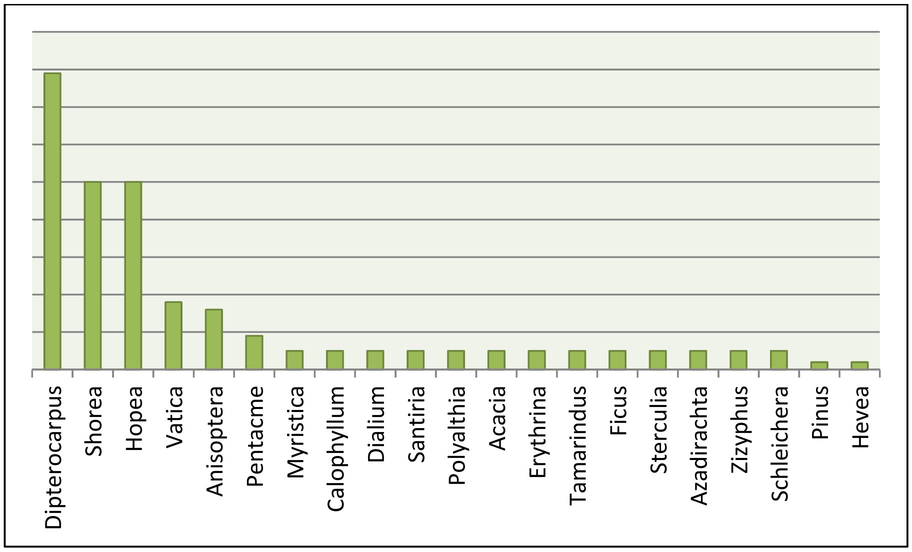

Figure 8. Distribution of equations per genus

4.4 Tree Compartments considered by the equations

Allometric equations can consider different compartments of the plant depending on to the rigor or purpose of the research. Studies more focused on merchantable wood production would tend to consider only the stem, studies for fodder production would put more attention on the foliage, whereas C stock researches would tend to be more comprehensive as possible, including also roots, branches or twigs. As it is shown in the graphic below (fig.8) the 88% (n=35) of the equations focused on the stem, while only the 12% (n=5) refers to the total tree biomass.

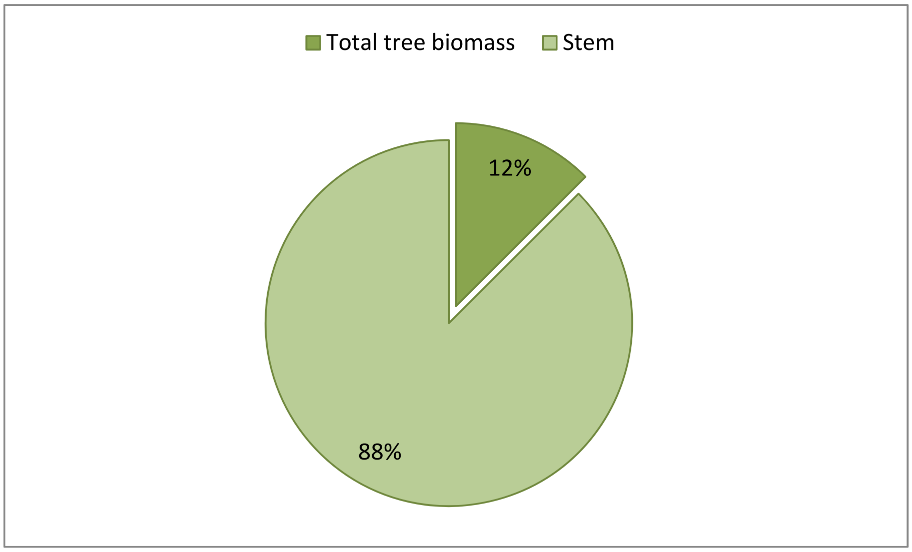

Figure 9. Tree compartment predicted by the equations

5. Gaps in assessing volume and biomass in Cambodia

According to the FAO forest classification all the forest ecological zones were covered by at least one tree allometric equation. However, very few locations were considered which limits the representativeness when considering the national forest classification. According to the forest cover classification, deciduous and evergreen forests are represented, most allometric equation however are developed in areas which are classified as other forest or areas currently classified as non-forest. Some forest types such as Bamboos were not represented. Most of the equations focused on one family while the rest of the families were not considered. Cambodia has more than 10 common families. Most of the equations focused on stem volume while only 4 equations considered tree aboveground and belowground biomass and do not represent all the forest types in Cambodia. Very few equations are species- specific and most of the equations were developed for tree families such as Dipterocarpaceae and for few broad forest types. The classification used by the authors is not consistent with the current national forest classification (MAFF,2008) and forest definition presented in the National Forest Programme (FA,2010). Besides this the national forest classification is undergoing a review as part of the REDD+ readiness process.

6. Recommendations

The forest classification must be finalized to allow the identification of the available equations and for each of the forest types. This will allow identifying the main gaps and the forest types that need to be considered for further tree allometric equation development. The development of new tree allometric equation should be made following the recommendations provided by Picard et al. (2012). Authors should provide the maximum of information identified in the national allometric equation database with particular regards to the location of the plot where the trees were harvested. In order to facilitate the assessment of the national forest biomass, the database of allometric equation should be continuously updated and subject to quality control (Henry, et al.,2011). Further studies should also go in the direction to fill the existing gaps in the allometric equations inventory: 1) to create new sample plots; taking into account also the field distribution 2) to develop equations for other tree species; 3) to increase the production of allometric equations 4) to improve the distribution of the equations per family, stimulating the production of equation also for non dipterocarpaceae trees.

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8. Appendix 1: list of variables used in the database

N.	FIELD	DESCRITPION	Notes
1	ID	Identification number of the allometric equation. Each equation has its own ID reference, two different equations cannot have the same ID.	a. c.
2	Population	Lianas: woody climbing plants mainly of tropical forests; Mangroves: evergreen trees or shrubs of tropical forests, having prop roots and stems and forming dense thickets along tidal shores; Sprout: is a shoot which grows from a bud at the base of a tree or from a shrub or from its roots; Stand: contiguous area that contains a number of trees; Tree: woody plant having a main trunk and usually a distinct crown.	a.
3	Ecosystem	Forest Plantation Hedgerow Home garden Tree outside forest	a.
4	Continent	Name of the continent where the equation was developed	a.
5	Country	Name of the country using the GAUL nomenclature (Global Administrative Unit Layers, FAO). Write "None" when the allometric equation does not refer to any country.	a.
6	ID_Location	Identification number of the location. In the same article for the same location they could be more than one equation.	a. c.

7	Group_Location	Identification number of the group locations. When an allometric equation is valid for a group of locations. Write “None” when the allometric equation does not refer to any group location. Always provide a separate list with the Group_Locations you used in the database, each one with the corresponding ID.	c.
8	Location	Location corresponds to the name of the place where the equation was developed It can be a precise location (city, village..) or a geographical area. Search a location as precisely as possible. Write “None” when the allometric equation does not refer to any location.	a.
9	Latitude	Decimal degrees Write “None” when the allometric equation does not refer to any latitude.	b.
10	Longitude	Decimal degrees Write “None” when the allometric equation does not refer to any longitude.	b.
11	Biome_FAO	Global Ecological Zones	b.
12	Biome_UDVARDY	Global Ecological Zones	b.
13	Biome_WWF	Global Ecological Zones	b.
14	Division_BAILEY	Global Ecological Zones	b.
15	Biome_HOLDRIDGE	Global Ecological Zones	b.

16	X	Independent variable (see below). e.g.: BA (basal area, the cross-sectional area of the stem at breast height), Bd (diameter at soil), Bd5 (diameter at 5 cm from soil), C (circumference at breast height), Cb (circumference at soil), Cd5 (circumference at 5 cm from soil), D10 (diameter at 10 cm of height from the soil), DBH (diameter of the stem at breast height), H (height), wd (wood density).Look at the end of the tutorial for an exhaustive list of the acronyms to be used.	a.
17	Unit_X	Unit measure (mm, cm, cm2, cm3, dm, gcm-3, m, m2...).Always keep the unit of measurement reported by the author.	a.
18	Z	Independent variable. Cannot be there a second variable. Write “None” when you have not this data.	
19	Unit_Z	Unit measure Write “None” when you have not this data.	
20	W	Independent variable. Write “None” when you have not this data.	
21	Unit_W	Unit measure. Write “None” when you have not this data.	
22	U	Independent variable. Write “None” when you have not this data.	
23	Unit_U	Unit measure Write “None” when you have not this data.	
24	V	Independent variable. Write “None” when you have not this data.	
25	Unit_V	Unit measure. Write “None” when you have not this data.	

26	Min_X	It is the minimum X value. Write "None" when you have not this data.	
27	Max_X	It is the maximum X value. Write "None" when you have not this data.	
28	Min_Z	It is the minimum Z value. Write "None" when you have not this data.	
29	Max_Z	It is the maximum Z value. Write "None" when you have not this data.	
30	Output	It is the dependent variable: Y It can express: - Biomass - Volume	a.
31	Output_TR	The output of the equation can be expressed in the Log(Y) or in the arithmetic value of Y, in which case you don't specify anything. When the result of the equation is a logarithm you have to specify if it is a natural logarithm (Log) or a logarithm to base b = 10, the common logarithm (Log10). Write "None" if "Y" does not refer to any log.	a.
32	Unit_Y	Unit measure of Y (e.g. cm3, dm3, m3, m3/ha, g, kg, Mg, kg/ha, Mg/ha...).	a.
33	Age	Age of the population considered in the experiment (years). It can be a precise number (e.g. 20) or a range (e.g. 20-40) or a definition (eg. young...). Write "None" when you have not this data.	

34	Veg_Component	They are the vegetation components of the plants considered in the equation (see below). e.g. : Branch biomass Branch biomass without twigs Biomass of roots (RC+RF+RS) Biomass of dead branches Biomass of stem bark Biomass of small roots Biomass of fine roots Crown biomass (BR+FL) Prop roots Stem volume Stem wood biomass Stump biomass Total aboveground biomass Total foliage biomass Total stem biomass (SW+SB) Total tree biomass (AB+RT) Total aboveground biomass without leaves Total aboveground woody biomass	a.
35	B	Bark Write “TRUE “if bark is considered in the output; Write “FALSE “if this component is not considered.	a.
36	Bd	Dead branches Write “TRUE “if dead branches are considered in the output; Write “FALSE “if this component is not considered.	a.
37	Bg	Gross branches: D>7 cm Write “TRUE “if gross branches are considered in the output; Write “FALSE “if this component is not considered.	a.

38	Bt	Thin branches: D<7 cm Write "TRUE" if thin branches are considered in the output; Write "FALSE" if this component is not considered.	a.
39	L	Leaves Write "TRUE" if leaves are considered in the output; Write "FALSE" if this component is not considered.	a.
40	Rb	Large roots Write "TRUE" if write are considered in the output; Write "FALSE" if this component is not considered.	a.
41	Rf	Fine roots Write "TRUE" if fine roots are considered in the output; Write "FALSE" if this component is not considered.	a.
42	Rm	Medium roots Write "TRUE" if medium roots are considered in the output; Write "FALSE" if this component is not considered.	a.
43	S	Stump Write "TRUE" if stump is considered in the output; Write "FALSE" if this component is not considered.	a.
44	T	Trunk-underbark Write "TRUE" if trunk-underbark is considered in the output; Write "FALSE" if this component is not considered.	a.
45	F	Fruits Write "TRUE" if fruits are considered in the output; Write "FALSE" if this component is not considered.	a.
46	ID_Species	Identification number of the species. Each species has its own ID, two different species cannot have the same ID. Write "1" when the allometric equation does not refer to any particular species.	a. c.
47	Genus	It is the name of the genus in the binomial literature in a Latin grammatical forms.	a.

48	Species	It is the name of the species in the binomial literature in the Latin grammatical form.	a.
49	Family	It is the name of the Taxonomic family to which belongs the species	a.
50	Group_Species	Write "1" when an allometric eq. refers to a group of species. Write "None" when the equation does not refer to any group of species. Always provide a separate list Group_Species you used in the database, each one with the corresponding ID.	a.
51	ID_Group	Identification number of the group species. Each group has its own ID, two different groups cannot have the same ID. Write "None" when the equation does not refer to any group of species.	c.
52	Equation	It is the allometric equation.	a.
53	Sample_size	Number of plants measured to obtain the equation. Write "None" where there is not this data.	
54	Top_dob	For equations that include a portion of the merchantable stem. Top d.o.b. describes the minimum diameter in cm, outside bark (d.o.b.) of the top of the merchantable stem. Write "None" where there is not this data.	-
55	Stump_height	For equations that predict the biomass of any component that includes the tree stem or the stump, this variable lists (in m.) the estimated or measured stump height. Write "None" where there is not this data.	-

56	ID_REF	Identification number of the reference. One reference can correspond to more than one equation. In the case one equation is found in more than one document, the oldest document becomes the reference	a. c.
57	Label	Identification number of the pdf/word copy of the article in your library. Hard or soft copies are identified with one label number. One label can correspond to more than one equation. The label can correspond to the ID_REF.	a. c.
58	Author	Author's surname. Write only the first two authors. If there are two authors use "**and"** between the names of the two authors. If more than two authors, write "surname of the first author et al.".	a.
59	Year	Year of publication of the document. When an author has written more than one work in the same year, use **a**, **b**, etc. to differentiate, e.g. **2000a**, **2000b**. Write "None" where there is not this data.	a.
60	Reference	Authors, year of publication, title of issue, journal, volume number, number of the issue, pages . The reference should be entered in using the Fao bibliography editorial guidelines (look at page 24 for more information).	a.
61	R^2	Coefficient of determination of the equation. Write "None" where there is not this data.	a.
62	R^2_adjusted	This is an adjustment of the R-squared that penalizes the addition of extraneous predictors to the model. Adjusted R-squared is computed using the formula $1 - ((1 - R^2)((N - 1) /(N - k - 1))$ where k is the number of predictors.	

63	Corrected for bias	A “1” value in this column means that the original author developed and reported a correction factor to compensate for the potential underestimation resulting from backtransforming logarithmic predictions to arithmetic units, as suggested by Baskerville (1972), Beauchamp and Olson (1973), and Sprugel (1983). In many cases where (7) is “yes,” item (8) will list CF, the bias correction factor to be used. In other cases, the authors embedded the correction factor into the equation parameters, or did not publish the value of CF since it can be obtained from the regression statistics. In such cases, the value of CF in the database will be zero even though the authors used the correction factor (Jennifer C. 2004). Write “None” when there is no “corrected for bias”.	
64	RMSE	Root-mean-square deviation or error of the equation. Write “None” where there is not this data.	a.
65	SEE	Standard error of the mean of the equation. Write “None” where there is not this data.	
66	Bias correction (CF)	Value of CF, to correct for potential underestimation resulting from back-transformation of logarithmic predictions to arithmetic units. Write “None” when there is no “CF”.	
67	Ratio equation	Some authors present methods for predicting the biomass of the merchantable stem to a user-defined top diameter. A “1” value in this column means that a separate ratio equation was presented by this author. Write “None” when there is no “ratio equation”.	
68	Segmented equation	Paired equations for the same species. E.g. one equation was applicable at the lower end of the diameter range and a second equation was applicable at the upper end of the range. A “1” value in this column means that the equation is one-half of a segmented equation. Write “None” when there is not this data.	

69	Contributor	Name of the institution who worked on entering data in the database.	
70	Name_operator	Name of the operator who entered the data	
71	Remarks	Any other relevant information such as silvicultural treatment, fertility class, soil description etc.	

NOTES

a. Very important data
b. Data obtained with other software (see below)

Data obtained from pre-existing database (see below

9. Appendix 2: list of acronyms using the database

Acronym	Description	Unit	Population
BA	Basal area: Stem cross-sectional area at DBH (1m30 height)	cm^2	TREE
BA0	Stem cross-sectional area at the soil	cm^2	TREE
BD	Basal diameter	cm	TREE
C	Circumference at 1.3m	cm	TREE
C10	Circumference at 10 cm height	cm	TREE
C180	Circumference at 180 cm height	cm	TREE
C20	Circumference at 20 cm height	cm	TREE
C30	Circumference at 30 cm height	cm	TREE
C50	Circumference at 50 cm height	cm	TREE
Ca	Canopy area	m^2	TREE
CA	Crown area	cm^2	TREE
Cb	Basal circumference	cm	TREE
Cb5	Circumference at 5 cm from soil	cm	TREE
CD	Crown diameter	Cm	TREE
CH	Crown height	cm	TREE
CR	Crown radius	cm	TREE
CV	Canopy volume	cm^3	TREE
D20	Diameter at 20cm height	cm	TREE
D30	Diameter at 30cm height	cm	TREE
DBH	Diameter at breast height	cm	TREE
H	Height	cm	TREE
Hd	Stand dominant height	cm	STAND
Hme	Merchantable height	cm	TREE
Ht	Height of the trunk	cm	TREE
M_DBH	Average of DBH	cm	STAND
N	Number of trees	$Tree*ha^{-1}$	STAND
R	tree ring	nr	TREE
SUMD10	Sum of the diameters at 10 cm from the soil	Cm	STAND
Yr	Year	yr	TREE/STAND
Vs	Stem volume	dm3	TREE
WD	Wood density	$g*cm^{-3}$	TREE
Age	Age of the trees	yr	STAND
V.P.	stem volume including bark	cm^3	TREE