Response to Anonymous Referee #1 on "ChinAllomeTree 1.0: China's normalized tree biomass equation dataset" by Y. Luo et al.

Thanks a lot for the reviewer's thoughtful and constructive comments on our manuscript and dataset. According to the reviewer's comments, we have revised our manuscript and dataset, and also rechecked the grammar, spelling, punctuation and clarity carefully in the revised version. All changes made to the original manuscript are marked with RED in the revised manuscript, and are listed in the response to the reviewer's comments. Here we attached our responses and revised manuscript. Furthermore, I have contacted PANGAEA assignee (Stefanie Schumacher) of our dataset (https://doi.pangaea.de/10.1594/PANGAEA.895244), and then the revised dataset will be accessible soon.

1. MANUSCRIPT

1.1 The authors state, that allometric equations for China are missing (e.g. page 3, line1-2). However, the cited reference (Henry et al. 2015) uses data from 2014. In a quick internet search, I found the http://www.globallometree.org database containing more than 1000 allometric equations for China. Also the name of the new dataset (ChinAllomeTree) is quite near to that of the global database (GlobAllomeTree). Please explain in the manuscript and work out the differences. Will this new collection be introduced into GlobAllomeTree?

>> The state that allometric equation for China are missing has been deleted, and the GlobAllomeTree (http://www.globallometree.org) database and China's equations within the database have been briefed in Introduction (P2, L18-19; P3, L9-11). In the database GlobAllomeTree, only 1173 tree biomass equations were listed from China, and very limited in scope such as data sources (24 scientific articles), spatial coverage (39 sites) and tree species (*ca*. 50 species) (accessed on April 10, 2019). Importance of our article has been highlighted in the revised version (P3, L11-14). Our dataset showed in this manuscript is more complete, containing 5924 equations of near 200 tree species that were derived from 518 references (journals, reports and books). Our article will be reviewed by rigorous peer reviewer and published in ESSD journal, it will benefit more readers and stakeholders worldwide.

>> In order to distinguish our dataset from GlobAllomeTree, the abbreviation (ChinAllomeTree) of our dataset has been deleted in this version, and thus the title of our article has been revised as "A review of biomass equations for China's tree species".

1.2. Page 3, line 3-4. Please provide a citation.

>> A citation (Zhang, 2007) has been added in this version of our manuscript (P3, L2-3).

Zhang, X.S.: Vegetation Map of China and Its Geographic Patterns, Geological Publishing House, Beijing, China, 91-124pp., 2007 (In Chinese).

1.3. Page 9, line 3-4. "As it is often the case" – I would just skip that part of the sentence, as it is rather discussion than result.

>> Revised as suggested. "As it is often the case" has been deleted (P9, L12-13).

1.4. Table 1. (i) Stand density - Unclear to me, if it refers to the whole number of trees/ha or only those given in "Tree species (group)". (ii) Biomass component - How can a biomass component (after all it is said to be a string) be given in units of kilogram? I would say it's a unitless name.

>> In revised Table 1, (i) "Stand density" has been revised as "tree spacing" with unit of trees/ha; "biomass component" has been revised as "tree component", and its unit has also revised as unitless.

1.5. Table 3. (i) It might be sufficient to put it in the Appendix? (ii) Please make two sentences out of the first one in the caption. I further do not understand the second part of the sentence (". . ., and mixed species in Column 'Species name' does two or more tree species that equations are developed for. "). Please rephrase (iii) I would appreciate to have the authority after each species name.

>> (i) Table 3 has been put as Appendix D in the revised version. (ii) Column "species name" has been changed as "tree species (group)". Mixed species in column "Tree species (group)" refer to tree species groups (e.g., deciduous broadleaved trees, a certain diameter-class mixed species, even generalized) that biomass equations are developed for. (iii) The authority for each tree species are added.

1.6. Figure 1a. (i) The figure does not work when printed in greyscale (dots and height classes). (ii) In the colored version, red dots on green background are a potential problem for color-blind people. (iii) I do not understand how the map and the small 'overview' in the lower right belong together. What is the small rectangle in the lower right within that 'overview'? It might be helpful to provide Longitude and Latitude also for the 'overview' and to describe its function in the figure caption.

>> From the reviewer's comment, we think that the reviewer referred to Figure 3a rather than Figure 1a in the early version. (i) and (ii): To highlight the spatial distribution of study sites, the base map of elevation has been removed, and study sites have been marked with black dots in this version (Figure 2 in the revised version). (iii) The map is redesigned and geographical coordinates (longitude and latitude) have been added in the revised version.

1.7 Write rather “Tree-biomass equations” or “Tree-allometric equations” than “The tree biomass equation” or “The tree allometric equation”, as there is not only one equation, but several different ones.

>> Revised as suggested (P1, L10; P2, L7 and L10).

1.8 Replace ~ with –, as – is the usual from-to sign, while ~ is rather used for approximations

>> Revised as suggested.

1.9 Page 1, line 12 and page 2, line 4. “spatio-temporal scales” or “spatial and temporal scales”

>> Revised as suggested. “spatial-temporal scales” has been revised to “spatial and temporal scales” in this version of manuscript (P1, L11; P2, L4).

1.10 Page 7, line 13. Shift “(Fig. 2)” to the end of the sentence.

>> Revised as suggested. Considering the Question 1.12, Figure 2 has been put as Appendix C in the revised version. Thus, “(Appendix C)” has been shifted to the end of the sentence (P7, L22). The citation of Appendix C has shown at the end of the sentence.

1.11 Page 9, line 5. ranges

>> Revised as suggested (P9, L14).

1.12 Is Figure 2 really necessary? I think it is sufficient, that the values are presented in the text

>> Figure 2 showed temporal change of compiled studies during the period 1978-2013. We think that this figure can support the text. However, Figure 2 has been put as Appendix C. The rest figures and appendices have been rearranged.

1.13 Table 2, I. “For former two forms. . ..” – change to “For texts and tables. . .”

>> Revised as suggested (Table 2).

1.14 Table 3, header: “Number of biomass equations” instead of “The number. . .”

>> Revised as suggested (Appendix D in the revised version).

1.15 Table 3, caption: “column” instead of “Column”

>> Revised as suggested (Appendix D in the revised version).

2. DATASET

Please provide explanations of the dataset (like abbreviations) on Pangaea or within the Excel-file. The dataset should be understandable without having to read the paper, which is – at least at the moment – not linked on the Pangaea page.

>> Good suggestion. The sheet “Description” has been added within the Excel file, including the explanations of all variables used in the dataset.

2.1 Sheet “General”

2.1.1 In Table 1 of the manuscript, it is described how parameters like e.g. Latitude, Altitude or MAT are retrieved (from original studies or other sources). It would be helpful to add the information on data-origin within the “General” sheet as a new column to give the user the ability to rate its quality.

>> Column “Data origin” has been added within both Table 1 and sheet “Description”, which describes data origins (e.g., original studies, Google earth, author defined or estimated).

2.1.2 What is the difference between dominant species and tree species? What are MAT, MAP? I know it is described in the manuscript, but it should be clear from the dataset as well.

>> Sheet “Description” has been added within the Excel file, including the explanations of all variables used in the dataset. Dominant species indicates that the tree species play the most important roles in the investigated forest (or community, stand). Tree species is the tree species whose biomass equations were shown in original studies.

2.1.3 I am not sure about how equations were pooled or separated and stumbled over this example: ID 268, Li et al. 2013a, has a stand age from 16 to 68 years, while in the original publication, values are given separately per age class. ID 286-289, Li et al. 2010a, give different equations for different age classes. Unfortunately, the original publication is given in Chinese and I thus cannot have a look to see, if I understand the different splitting of age classes in the dataset.

>> The equations were not pooled or separated and shown the same as the original reports. In Li et al (2013a), the values of biomass for age class were given. These values were estimated based on the allometric equations that was reported in another reference (Li et al. 2014, in English). In the reference (Li et al., 2014), the allometric equations were reported for the whole age range from 16 to 68 yrs but not for each age class. So in record ID 268, the equations were shown with the stand age from 16 to 68 years. In Li et al. (2010a), different equations for different age class were shown because in the original reference equations for each age class were reported. In revised version, we add a standardized categorization of age classes used by Chinese scientists (Appendix A) for readers to best select equations from our dataset.

Li, H., Li, C.Y., Zha, T.S., Liu, J.L., Jia, X., Wang, X.P., Chen, W.J., and He, G.M.: Patterns of biomass allocation in an age-sequence of secondary *Pinus bungeana* forests in China, The Forestry Chronicle, 90(2), 169-176, 2014. https://doi.org/10.5558/tfc2014-034

2.1.4 A further question concerning stand age: ID 268, Li et al. 2013a, has a stand age from 16 to 68 years, the publication gives values for stands of 16, 35, 50 and 68 years. Your dataset states “16∼68” as stand age. In other cases, e.g. ID 508, Wang and Shi 1990, stand age is given as “6, 12, 22, 40”. What is the difference? Unfortunately, the original publication of Wang and Shi is in Chinese and I thus cannot have a look to see, if I would understand the difference.

>> For ID 268, see the explanation for Question 2.1.3. For ID 508, stand age was given as several separate ages but not an age range because the original report was give such ones. We always consistently follow the original report.

2.1.5 Replace “∼” with “to”

>> Revised as suggested.

2.1.6 Provide complete citations (Appendix B) within or together with the dataset

>> Good suggestion. Sheet “Source” has added within the dataset.

2.1.7 Please avoid formulas within the cells, as these can easily and unwittingly be changed by clicking in the cell (e.g. clicking in the first cell of the column “Equations included” gives’=Equation!B3&"∼"&Equation!B14’). This should be changed into plain text.

>> Column “Equations included” has been deleted in the revised version, largely due to the weak practicability of equation number in sheet “Equation”. Please refer to section 2.2.3.

2.2 Sheet “Equation”

2.2.1 What do the variables and coefficients (W, D, H, a, b, c, d) stand for? What are Methods and applicable ranges? Again, I know it is described in the manuscript, but it should be clear from the dataset as well.

>> Sheet “Description” has been added within the Excel file, including the explanations of all variables used in the dataset.

2.2.2 Applicable ranges Height and Diameter: Why are they sometimes “/”, sometimes “na”? What is the difference?

>> In our early version, differences between “/” and “na” were not explained clearly. They have been normalized in the revised version of manuscript and dataset, and also explained in the newly added sheet “Description”. “NA” refers to not available; “/” does not necessary or applicable.

2.2.3 It is to some part impractical to search for equations belonging to a specific ID as they are given e.g. as 5911∼5918. It would be helpful, to have the general ID as additional column in the Equation-sheet.

>> An addition column “equation number” was added that would follow original ID. The combination of ID

and equation number will label each equation. The same ID as sheet “General” has been added in sheet “Equation”, meanwhile, column “Tree species (group)” in sheet “General” has been moved into sheet “Equation”.

2.2.4 Formulas: saving the dataset as .csv or .txt to import it into other programs results in e.g. $W=a \cdot D^b$. It might be better to write W=a·Dˆb, which is accepted as power- function in a number of programming languages.

>> Change as you suggested.

2.2.5 Avoid merging cells as these might be unreadable for other programs.

>> Revised as suggested. Merged cells have been canceled in this version of dataset.

2.2.6 Would it be possible to provide the dataset as .txt or .csv file in general?

>> In order to maintain the integrity of the dataset, the dataset is still given in commonly used Excel file. Because special formats (e.g. merged cells, and superscript) have been removed or canceled in the revised version, this Excel file can be easy to save as .txt or .csv file, depending on the users’ purposes.

A review of biomass equations for China's tree species

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Abstract. Tree biomass equations, which are also called tree biomass allometric equations, are the most commonly used method to estimate tree and forest biomass at various spatial and temporal scales because of their high accuracy, efficiency and conciseness. For decades, many tree biomass equations have been reported in diverse types of literature (e.g., journals, books and reports). These scattered equations are being compiled, and tree biomass equation datasets are currently available for many geographical regions (e.g., Europe, North America and Sub-Saharan Africa) and countries (e.g., Australia, Indonesia and Mexico). However, one important country of the world is highlighted as an area where a large number of biomass equations are still not reviewed and inventoried extensively, China. Therefore, in this study, we carried out a broad survey and critical review of the literature (from 1978-2013) on biomass equations conducted in China and developed China's normalized tree biomass equation dataset. This dataset consists of 5924 biomass component equations for nearly 200 species and their associated background information (e.g., geographical location, climate and stand description), showing sound geographical, climatic and forest vegetation coverages across China. The dataset is freely available at https://doi.pangaea.de/10.1594/PANGAEA.895244 for noncommercial scientific applications, which fills an important regional gap in global biomass equations and provides key parameters for biomass estimation in forest inventory and carbon accounting in China.

1 Introduction

Forests are the dominant terrestrial ecosystem in the world, occupying 30.6% of the global land area (1.3×10^{10} hectare) (FAO, 2016). An important challenge that has been faced by ecologists and foresters for decades is how to enhance the accuracy, consistency and efficiency of forest biomass and carbon estimations at various spatial and temporal scales, which is essential to understanding forest carbon cycling and implementing forest carbon-offset activities (Bustamante et al., 2014; Chave et al., 2014). However, the current estimates still have considerable uncertainties (Pan et al., 2013) due in large part to the limited geographical coverage of the estimation methods and their related parameters. Tree biomass equations are commonly used for estimating forest biomass and carbon because of their high accuracy, efficiency and conciseness (Chave et al., 2014; Paul et al., 2016), but this method still faces a shortage of localized parameters.

Tree biomass equations, which are also called tree biomass allometric equations, refer to quantitative relationships between tree biomass (or tree components such as stem, branch, leaf and root) and one or more dendrometric variables (e.g., tree diameter and height). From the International Biological Programme (IBP) on, a large number of tree biomass equations have been developed at specific sites for tree species and forest types. These biomass equations that were scattered in various literature (e.g. journals, reports and books) have been evaluated and inventoried for geographical regions such as Europe (Zianis et al., 2005; Forrester et al., 2017), Latin America (Návar, 2009), North America (Ter-Mikaelian & Korzukhin, 1997; Jenkins et al., 2004), Southeast Asia (Yuen et al., 2016) and Sub-Saharan Africa (Henry et al., 2011), and for countries such as Australia (Eamus et al., 2000; Keith et al., 2000), Indonesia (Anitha et al., 2015) and Mexico (Rojas-García et al., 2015). As a global initiative, the international web platform GlobAllomeTree (http://www.globallometree.org/), launched in 2013, further promotes the compilation of global biomass equations (Henry et al., 2015). This work is of great significance to goals such as (1) facilitating the identification of the gaps in the coverage of the equations, (2) testing and comparing existing equations with new ones, (3) developing generalized biomass equations (Forrester et al., 2017; Jenkins et al., 2003), (4) validating and calibrating process-based models and remotely sensed biomass estimates (Rojas-García et al., 2015) and integrating these models with remotely sensed data (e.g., tree height and crown breadth) (Jucker et al., 2016), and (5) elucidating and confirming the generality of plant allometric scaling laws (Návar, 2009; Pilli et al., 2006).

China covers most of the world's terrestrial biomes and environmental gradients and has a series of forest types ranging from tropical rainforest to boreal forest (Zhang, 2007). It is said that 'if you study China, you'll know the world' (Fang et al., 2012). In the late 1970s, studies to measure tree biomass and develop biomass equations were initiated in China (Pan et al., 1978, Zhang and Feng, 1979). Subsequently, lots of studies have expanded to nearly all climatic zones and forest types in China (Luo et al., 2014). Some biomass equation datasets have been built for specific regions (e.g., northeastern China, Chen and Zhu, 1989; Xishuangbanna Forest Region and Hainan Island, Yuen et al., 2016), specific forest types (e.g., *Cunninghamia lanceolata* forest, Zhang et al., 2013; *Larix* forest, Wang et al., 2005; *Populus* forest, Liang et al., 2006) and short time periods (e.g., from 1978 to 1996, Feng et al., 1999). By now, the platform GlobAllomeTree includes 1173 tree biomass equations from China, but they are very limited in scope such as data sources (24 scientific articles), spatial coverage (39 sites) and tree species (*ca*. 50 species) (accessed on April 10, 2019). More importantly, these existing datasets employed different screening criteria for data inclusion. Therefore, trees biomass equations for China are still not reviewed and inventoried extensively. In addition, China's biomass equations are hard to benefit more stakeholders worldwide because of restricted data accessibility in writing language (Chinese) and hard copies (Cheng et al., 2014).

Here, after our *Ecology* data paper on forest biomass and its allocation (Luo et al., 2014; related dataset is freely accessible at http://www.esapubs.org/archive/ecol/E095/177/), we continued to review biomass equations for China's tree species from a broad literature survey and then developed a normalized tree biomass equation dataset. The dataset can provide a major expansion in comparison to the biomass equation datasets currently available for China, and also fill an important regional gap in global biomass equations.

2 Materials and methods

2.1 Literature retrieval

Concerning tree biomass equations in China (excluding Taiwan Province in our study), we made a great effort to collect the available literature (journals, books and reports) between 1978 and 2013. Using a series of keywords (biomass, allometry, allometric, relationship, equation, model, and function) with logical operators, studies were retrieved from national libraries (National Digital Library of China, and China Forestry Digital Library), online literature databases (Web of Science, China Knowledge Resource Integrated Database, and China Science and Technology Journal Database), and reference lists from our *Ecology* data paper (Luo et al., 2014) and existing compilations of biomass equations (Feng et al., 1999; Wang et al., 2005; Liang et al., 2006; Xiang et al., 2011; Zhang et al., 2013). During the literature survey, no a priori criteria (e.g., tree species, tree age, site condition, measurement method, and statistical technique) were applied.

2.2 Data collection

A critical review of the collected literature was conducted to obtain reliable biomass equations using the following criteria:

(1) **Scope:** Equations for inclusion were restricted to those for both forest-grown trees and open-grown trees. However, equations for mangrove trees and recently disturbed trees (e.g., coppicing, pruning, fire, and insect pests) were not included.

(2) **Measurement method:** A robust measurement method should cover the appropriate survey period (during the growing season, especially for deciduous trees), plot setting and tree biomass (the oven-dried mass) measurements (cf. Feng et al., 1999). Generally, plot areas were not less than 100 m^2 for boreal and temperate forests, 400 m^2 for subtropical forests, and 1000 m^2 for tropical forests. To develop biomass equations, at least three sample trees should be selected to determine the tree biomass and its components (e.g., stem, branch, foliage, and root) by destructive harvesting and weighing. The division of tree components can be summarized as shown in Fig. 1, although the number of tree components varied with the different purposes of the investigations.

- **Aboveground biomass:** The biomass of at least three aboveground tree components (stem, branch, leaf, or their whole subcomponents) should be determined. If any of the three components or their subcomponent biomass was not measured, the aboveground biomass and relevant biomass (e.g., tree crown and total aboveground biomass) were considered to be inadequate.

- **Belowground biomass:** The quality of total belowground biomass was evaluated from three aspects. (1) The total belowground biomass should be the total biomass of the entire root system (i.e., root crown and different root diameters), which was determined by using either the full excavation method for the entire root system or a hybrid of the full excavation method for the root system (excluding fine roots) and the soil pit method (or soil coring method) for fine roots. (2) The excavation area was larger than or equal to the average tree area covered, and the excavation depth reached the maximum depth where roots were nearly absent, which was more than at least 50 cm (Mokany et al., 2006). (3) Fine roots are usually classified as <2-5 mm in root diameter (Finér et al., 2011). Fine roots play significant roles in the water and nutrient uptake of trees but contribute little to the total belowground biomass (Mokany et al., 2006). However, if the minimum measured root diameter is >5 mm, the total belowground biomass may be significantly underestimated.

(3) **Equation building:** Biomass equations should be developed using robust regression methods (e.g., ordinary least squares, maximum likelihood and Bayesian techniques), explicit equation forms (e.g., power, exponential and linear equations) and valid equation evaluations.

- **Predictor variables:** The predictor variables for the biomass equations were limited to the tree diameter at a certain height (e.g., basal diameter and diameter at breast height (1.3 m above soil surface)), tree height, and various combinations of them. These variables were used mostly because other variables (e.g., stand density, site index, and soil type) were highly related to local conditions and thus reduced the robustness and generality of the biomass equations.
- **Equation forms:** If two or more equation forms with the same predictor variable(s) were used to build the equations, the regression results of only one equation form were selected. More specifically, if the differences (<0.05) in the coefficients of determination (R^2) or correlation coefficient (R) were small among all equation forms, the priority order of equation forms for inclusion was power, exponential, and others (e.g., polynomial and

hyperbolic); if not, the equation form with the highest R^2 (or R) was selected. Moreover, for studies that had original data rather than equations, equations were fitted using these original data and two typical allometric models: $W=a \cdot D_x^b$ and $W=a \cdot (D_x^2H)^b$, where W is the biomass (kg), D_x and H are tree diameter at x height (cm) and tree height (m), and a and b are equation coefficients.

- **Equation evaluation:** The goodness-of-fit of regression equations should be evaluated, where the statistical measures R^2 and R are commonly used in studies in China. Other goodness-of-fit measures except R^2 and R were not included in our dataset, largely because diverse forms of the error estimates were employed across studies. In addition, several correction factors are proposed to correct the systematic bias in the biomass estimates by using log-linearized equations (Clifford et al., 2013); thus, they were collected for log-linearized equations if available.

(4) **Quality checking:** Robust measurement methods and reliable equation building methods should be adopted in the original studies. Biomass equations for inclusion were checked and were even corrected using original biomass data if available. With increasing tree sizes (diameter and height), the biomass equations did not show unreasonable ranges of tree biomass or biomass allocations. Tree biomass and its allocations were regarded as acceptable if they fell within the biomass and allocation ranges of the averaged trees by forest type and age class (Luo et al., 2013). When the biomass or biomass allocation of the trees that were generated by an equation was outside the abovementioned empirical ranges, the equation was considered questionable and then rechecked to evaluate its inclusion in our dataset.

Biomass equations that met the above criteria were compiled to develop China's dataset of tree biomass equations, mainly consisting of an equation sheet and a general sheet. The former sheet includes tree species (group) whose biomass equations are developed, tree component, predictor variable, equation form, equation coefficients, goodness-of-fit statistics (e.g., correlation coefficient and coefficient of determination) and applicable ranges (i.e., determination methods, and the value ranges of predictor variables). The latter sheet stores the background information for the equations, including the geographical location (e.g., latitude, longitude and altitude), climate (mean annual temperature (MAT) and mean annual precipitation (MAP)) and stand description (e.g., forest type, dominant species, stand origin, stand age and tree spacing). The detailed variables and their descriptions in the dataset are summarized in Table 1.

2.3 Estimation of missing data

Not all original studies reported the geographical location, climate data (MAT and MAP), or applicable ranges of biomass equations. These missing data were estimated as follows:

(1) Geographical location: Google Earth was used to estimate the geographical centers of the study sites in the original studies without geographical location descriptions in the form of latitude, longitude and altitude.

(2) Climate data: The 30 arc-second (*ca*. 1 km at the Equator) resolution global climate database, WorldClim version 1.4 (http://worldclim.org/current), was generated through the interpolation of average monthly climatic records from the 1950-2000 period (Hijmans et al., 2005). This database was proved to have high accuracy in estimating climate data (MAT and MAP) of China (Luo et al., 2014). Therefore, MAT and MAP data were extracted using geographic coordinates from WorldClim version 1.4 in this study.

(3) Applicable ranges of biomass equations: Empirical biomass equations were built based on sample trees with limited ranges of tree size (diameter and height). When these equations are applied beyond the ranges for which they were developed, the reliability of the biomass estimates is often questionable (Henry et al., 2011). The size ranges of the sample trees were not always given in the original studies, and it was not possible to access the raw data used for equation building. According to the amount and reliability of the information in the original studies, five methods (Table 2) were used to obtain the applicable ranges for the biomass equations. However, some applicable ranges were finely calibrated under the rule ‘tree biomass increases with increasing tree size’.

3 Results

From 518 references during the period 1978-2013, 759 studies and 5924 biomass equations from these studies were compiled in China’s tree biomass equation dataset. Temporal changes in the number of studies showed a continuously increasing trend from 1978 to 1990, while a decreasing trend was found during the period 1991-2002 (Appendix C). Since

2002, there has been a generally increasing trend. Studies from 1978 to 1990, 1991 to 2002 and 2003 to 2013 contributed 27.4%, 34.0% and 38.6% of the total studies, respectively. These studies were carried out in 359 sites, showing sound geographical coverage (18.6-52.4 ºin latitude, 76.8-130.7 ºin longitude and 2-4588 m in altitude) across China (Fig. 2a) and broad climatic gradients (-5.6-24.6 ℃ in MAT and 39-2500 mm in MAP), representing all biomes from desert to tropical rainforest (Fig. 2b).

These compiled studies and equations varied greatly with forest type, stand origin and tree species (Fig. 3; Appendix D). The studied forests were categorized into five types: deciduous coniferous forest, evergreen coniferous forest, deciduous broadleaved forest, evergreen broadleaved forest, and coniferous and broadleaved mixed forest. Among the five forest types, evergreen coniferous forest had the most studies and equations (45.7% and 38.7% of the total studies and equations), followed by deciduous broadleaved forest (22.9% and 24.1%), evergreen broadleaved forest (17.5% and 21.0%), deciduous coniferous forest (10.4% and 9.5%), and coniferous-broadleaved mixed forest (3.4% and 6.7%) (Fig. 3a). For stand origins, 77.1% and 68.7% of the total studies and equations focused on planted forests (Fig. 3b). Apart from mixed species, there were 5488 equations specific to 197 species (Appendix D). However, only 63 species were in more than two studies, occupying 80.5% of the total species-specific equations. The five most commonly studied species were *Cunninghamia lanceolata* (*n*=130), *Pinus massoniana* (*n*=60), *Pinus tabuliformis* (*n*=46), *Pinus koraiensis* (*n*=32) and *Larix principis-rupprechtii* (*n*=30), which had 706, 365, 395, 218 and 235 equations, respectively.

Compared with the aboveground sector, the belowground sector was not always measured. Many studies (*n*=177) did not (properly) address the belowground sector, accounting for 23.3% of the total studies. Equations for stem biomass and its subcomponents contributed 27.1% to the total 5924 equations, while branch biomass and its subcomponents contributed 20.1%, leaf biomass and its subcomponents contributed 19.3%, aboveground biomass contributed 6.1%, belowground biomass and its subcomponents contributed 18.3%, and total tree biomass 7.8% (Appendix D). However, only 1.2% of the equations were for other biomass components, such as flower and fruit biomass and tree crown biomass.

Of the 5924 equations, 43.5% were based on a single predictor (diameter or height), and 56.5% were based on two predictors (diameter and height) or their combinations (Fig. 4a). The diameter at breast height was the most frequently used predictor in the biomass equations (96.8%), whereas tree diameter at other heights rather than breast height was used in 185 equations (3.1%). Moreover, only 9 equations (0.2%) employed tree height as a single predictor. In total, 29 equation forms were applied to develop the quantitative relationships of tree biomass with tree diameter and/or height, which were categorized into five types: power equation, log-linear equation, linear/polynomial equation, exponential equation and hyperbolic equation (Appendix E). The power equation was the most frequently used type (3948 equations, accounting for 66.6% of equations), followed by the log-linear equation (1438, 24.3%), linear/polynomial equation (432, 7.3%), exponential equation (85, 1.4%) and hyperbolic equation (21, 0.4%) (Fig. 4b).

A considerable proportion (20.1%) of the total 5924 equations did not specify the sample size (i.e., the number of trees harvested to develop the equations) (Fig. 5a). The sample size varied from 3 and 420 trees, where the most common sample sizes were between 6 and 25 trees, accounting for 74.5% of the 4,734 equations with specific sample sizes. For the applicable ranges of equations, 2790 out of the 5924 equations had clear applicable ranges in the original studies. There was a great bias towards the smaller diameter classes (Fig. 5b) and height classes (Fig. 5c). From the 5856 equations with available diameter ranges, the maximums and ranges (max-min) of tree diameter varied between 1.6 cm and 150.0 cm and between 1.0 cm and 130.0 cm, where 74.4% and 86.2% of the equations had maximums and ranges less than 30 cm, respectively. From the 3336 equations with available height ranges, the maximums and ranges of the height ranged from 1.2 m to 66.8 m and 0.6 m to 51.5 m, and most of them (73.7% and 94.1%) were less than 20 m.

4 Data availability

This version of China's tree biomass equation dataset was developed from studies that were published from 1978-2013. Data collection is ongoing, and the dataset will be updated as additional data are collected and verified. The dataset is freely available at https://doi.pangaea.de/10.1594/PANGAEA.895244 for noncommercial scientific applications, but the free availability of the dataset does not constitute permission to reproduce or publish it.

5 Conclusion and outlook

In this study, we developed a normalized tree biomass equation dataset based on an extensive literature survey, which covered broad geographical, climatic and forest vegetation gradients across China. Our dataset provides a major expansion in comparison to the biomass equation datasets currently available for China (Chen and Zhu, 1989; Feng et al., 1999; Liang et al., 2006; Wang et al., 2005; Yuen et al., 2016; Zhang et al., 2013) and thus fills an important regional gap relevant to global datasets (Henry et al., 2015). Our dataset also lays a solid data foundation for the estimation of forest biomass and carbon as well as general laws for plant allometric scaling. Moreover, this work highlights five limitations and identifies the potential for future biomass equation research in China, as follows:

(1) There are still important gaps, and new equations, particularly for natural forests and most noncommercial tree species, are needed.

(2) To some extent, transparent and consistent protocols for tree biomass measurements, especially for the belowground sector, were lacking among studies. Moreover, belowground biomass was not measured or was measured inadequately in many studies.

(3) Component-wise biomass equations were always fitted without paying much attention to the additivity of biomass component equations in practice. To date, various model specification and parameter estimation methods have been proposed to ensure additivity, for example, seemly unrelated regression (Dong et al., 2015).

(4) The complete reports on biomass equations should cover the regression method, sample size, equation evaluation (e.g., R^2, error estimates of equations, standard errors of equation coefficients, and correction factors for log-linearized equations) and applicable ranges. However, these reports are often incomplete in current studies, largely due to the lack of uniform report standards.

(5) Limited sample trees with relatively narrow ranges of tree diameter and height were selected from small biotic (e.g., stand age and tree species) and abiotic (e.g., climate and soil) gradients. Additionally, large trees were often ignored in sampling campaigns. These limitations limit the applicability of the biomass equations. To overcome these drawbacks,

further research is required to evaluate the quality and performance of these equations and develop generic biomass equations over broader ranges of abiotic and biotic conditions.

Author contribution

XW, ZO and YL originated, conceived and designed the work; YL, XW and FL developed and analyzed the equation dataset; all authors contributed to the writing of the manuscript.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgments

This study was supported by National Natural Science Foundation of China (31500388), National Key R&D Program of China (2018YFC0507303), Open Foundation of State Key Laboratory of Urban and Regional Ecology of China (SKLURE 2016-2-3), and China Postdoctoral Science Foundation (2016M601144 and 2017T100112).

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Tables

Table 1: Summary of variable information in the dataset, which is available at https://doi.pangaea.de/10.1594/PANGAEA.895244.

Variable	Description	Data origin	Unit	Type
1. General sheet				
ID	Identification number of each study.	Author defined	Unitless	Integer
Province	Province location of study site.	Original studies	Unitless	String
Study site	Locality name of study site.	Original studies	Unitless	String
Latitude	Latitudes of study sites are either directly from original studies, or are extracted from Google Earth.	Original studies or Google Earth	°	Float
Longitude	Longitudes of study sites are either directly from original studies, or are extracted from Google Earth.	Original studies or Google Earth	°	Float
Altitude	Altitudes of study sites are either directly from original studies, or are extracted from Google Earth.	Original studies or Google Earth	m	Integer
MAT	Mean annual temperatures of study sites are either directly from original studies, or are extracted from a 30 arc-seconds resolution global climate database WorldClim version 1.4.	Original studies or WorldClim	℃	Float
MAP	Mean annual precipitations of study sites are either directly from original studies, or are extracted from WorldClim version 1.4.	Original studies or WorldClim	mm	Float
Forest type	Forest community characterized by the same tree genera, or if not genera, by ecological similarities (e.g. life form and biotope).	Original studies	Unitless	String
Dominant species	Dominant tree species of a forest type. In some forest types, there are two or more co-dominant tree species, and then the first four co-dominant species are listed at most.	Original studies	Unitless	String
Stand origin	Forests are classified by stand origin into natural and planted forests.	Original studies	Unitless	String
Stand age	The age of a natural forest is defined as age since germination, and the age of a planted forest is done as age since planting. Whether discrete ages, age ranges or age classes can be entered into our dataset is determined by the original studies. Discrete ages or age ranges are entered when equations were specific to ages or age ranges in original	Original studies	year	Float

Variable	Description	Data origin	Unit	Type
	studies, otherwise age classes (young, middle-aged, premature, mature and overmature) are given according to stand descriptions. The categorization of age classes is listed in Appendix A.			
Tree spacing	The number of trees per unit area. Tree spacings are given as mean values or ranges.	Original studies	trees/ha	Integer
Miscellaneous	Other information not mentioned in front columns such as site index and human disturbances (e.g. fertilization and selective logging), if available.	Original studies	Unitless	String
Sources	Source of the data.	Original studies	Unitless	String
2. Equation sheet				
ID	Identification number of each study, the same as ID in General sheet. The same ID indicates that the equations come from the same study.	Author defined	Unitless	Integer
Equation number	Identification number of each equation within a study.	Author defined	Unitless	Integer
Tree species (group)	Tree species that biomass equations are developed for. Species names are checked with online Flora of China (http://frps.iplant.cn/). When equations are developed for mixed species, species name is specified as either a particular tree group (e.g., deciduous broadleaved trees, and a certain diameter-class mixed species) or 'generalized' according to the descriptions in original studies.	Original studies	Unitless	String
Tree component	A tree component divided in a certain way. Φ, *s* and *d* denote root diameter, excavation area and excavation depth, respectively.	Original studies	Unitless	String
Predictor variable	One or more dendrometric variables, i.e., tree diameter in cm and height in m. D and H are diameter at breast height (1.3 m above soil surface) and tree height, and Dc is tree diameter at other heights (e.g., 0 m, 0.2 m, or 0.3 m) rather than breast height.	Original studies	cm; m	String
Equation form	It is used to develop a quantitative relationship between a biomass component (W in kg) and one or more predictor variables. When multiple arithmetic operators are combined	Original studies	Unitless	String

Variable	Description	Data origin	Unit	Type
	in an equation, the order of operator precedence from highest level to lowest level is as follows: parentheses; exponentiation; multiplication and division; addition and subtraction. Within each precedence level, operators have equal precedence and are evaluated from left to right. In addition, *ln* denotes natural logarithm, and *lg* does 10-based logarithm.			
Equation coefficients	Equation coefficients consist of values of parameters Coeff. *a*, Coeff. *b*, Coeff. *c* and Coeff. *d*, but not all four parameters are used in equations.	Original studies	Unitless	Float
Goodness-of-fit statistics	Goodness-of-fit statistics consist of *n*, R^2, *R* and *CF*:			
	(1) *n*: The number of harvested trees for developing biomass equations, although it is not always available in studies.	Original studies	Unitless	Integer
	(2) R^2: Coefficient of determination, a measure of goodness-of-fit.	Original studies	Unitless	Float
	(3) *R*: Correlation coefficient, another measure of goodness-of-fit.	Original studies	Unitless	Float
	(4) *CF*: Correction factor, it is for a log-linearized equation to correct the systematic bias in biomass estimates introduced by log-transformation, if available. Baskerville's CF (Baskerville, 1972) and Snowdon's CF (Snowdon, 1991) were employed by original studies, where the latter is marked with 'λ' in our dataset.	Original studies	Unitless	Float
Applicable ranges	Applicable ranges of equations consist of three parts:			
	(1) Method: Method for determining value ranges (minimum, maximum) of predictor variables, whose descriptions are given in Table 2.	Author defined	Unitless	String
	(2) Diameter: Diameter ranges (minimum, maximum) from original studies or estimated by using determination methods in Table 2.	Original studies or author estimated	cm	Float
	(3) Height: If height is used as a predictor variable, height ranges (minimum, maximum) from original studies or estimated by using determination methods in Table 2.	Original studies or author estimated	m	Float

Table 2: Methods for determining applicable ranges of biomass equations *

Method	Description
I	Original studies presented tree diameter and height ranges (minimum, maximum) of harvested trees in the form of text, tables or figures. For texts and tables, applicable ranges (diameter and height ranges) of biomass equations are determined directly, while for figures (e.g. biomass-diameter relationship and height-diameter relationship), they are extracted by using software GetData Graph Digitizer v.2.24.
II	When stand structures (or ranges) of diameter and height are available in original studies, they are considered as applicable ranges, although they may exceed actual ranges for equation building.
III	When mean and standard deviation (SD) of tree diameter and height are available, applicable ranges are estimated as (mean-2SD, mean+2SD), nearly covering 95% of normal stand distributions of tree diameter and height.
IV	When only mean values of tree diameter were provided without other statistics (e.g. SD), a rule of thumb is that diameter ranges are roughly estimated as (mean $\times 0.5$, mean $\times 1.5$).
V	When the above situations do not occur, applicable ranges of biomass equations are roughly estimated by using ones under similar phylogeny, age and growing environments. However, applicable ranges of some equations are not still obtained because of limited data.

* According to the amount and reliability of information in original studies, five methods are employed in priority order: I > II > III > IV > V. Concerning those biomass equations with diameter and height as predictor variables, when only diameter ranges are determined, height ranges are estimated from: (1) biomass ranges, which are from original studies or could be calculated by using diameter-based equations if equations based on both diameter and height are available; or (2) height-diameter relationships (height-diameter curves or height/diameter ratios), which are from original studies, or are developed by using raw data of diameter and height within original studies or by using mean diameter and height data from Luo et al. (2013) (Appendix B).

Figures

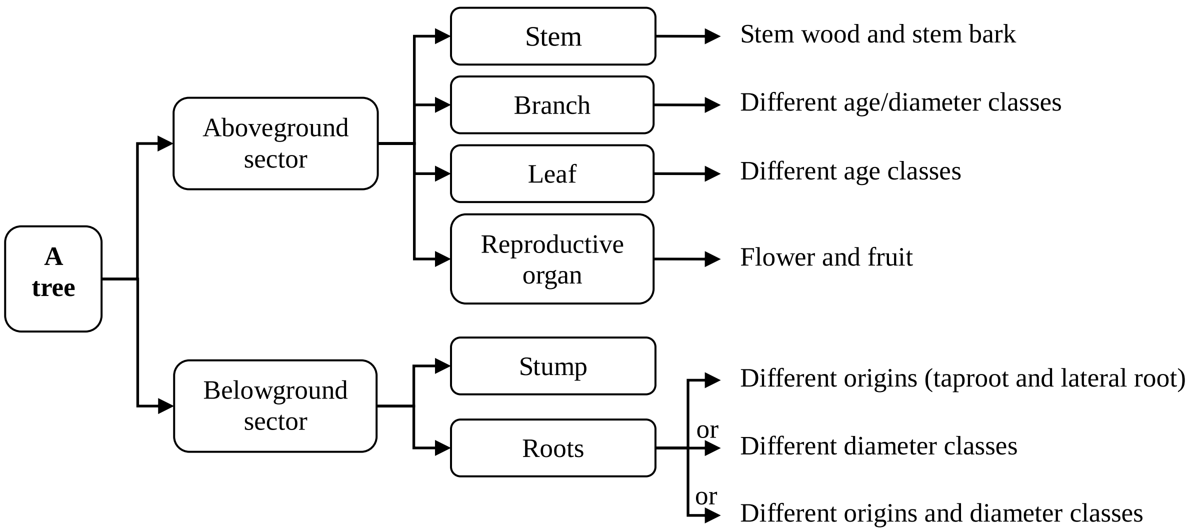


Figure 1: The division of tree components. A tree can be divided into (1) aboveground sector above the soil surface and (2) belowground sector, which are often subdivided into finer components.

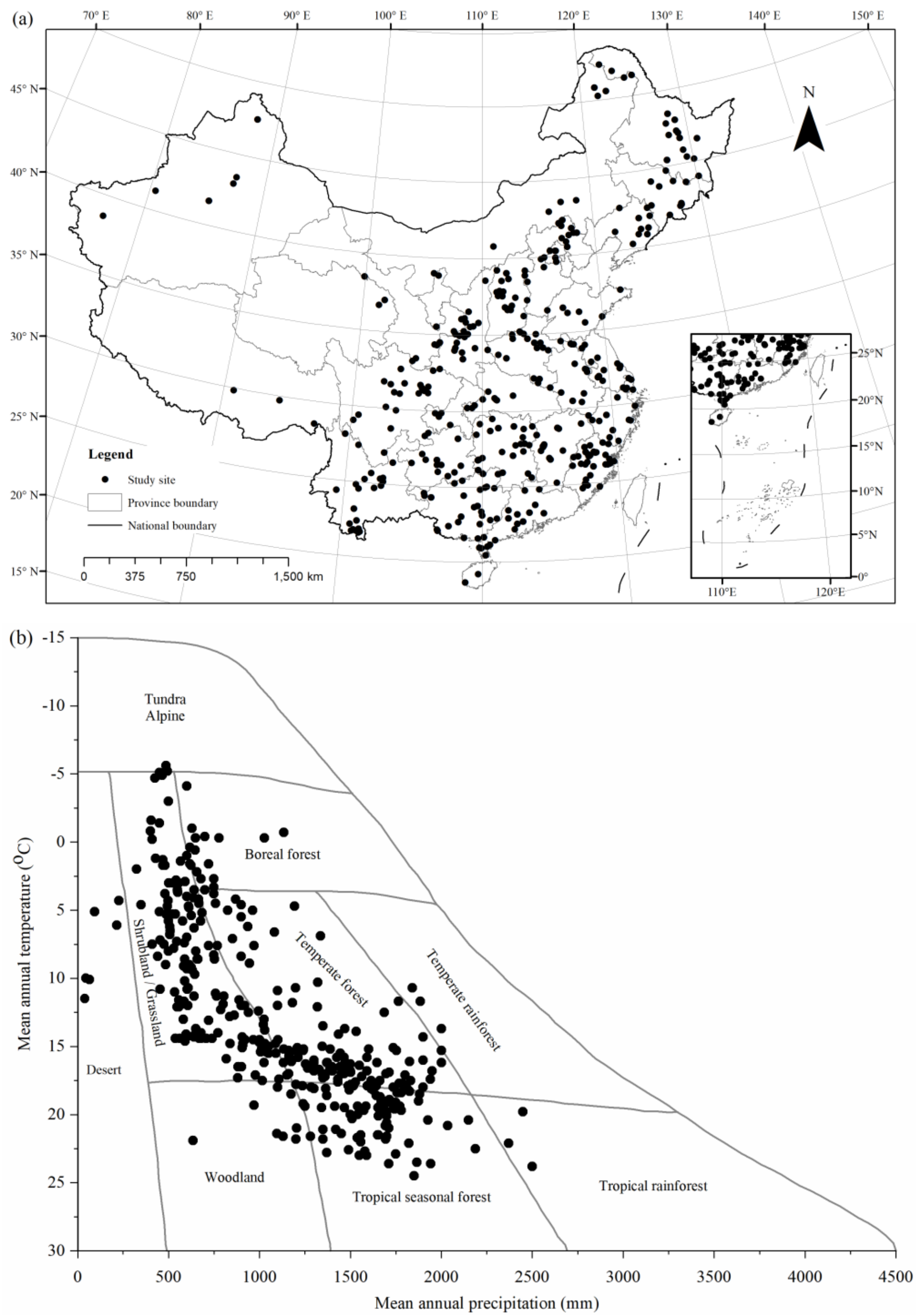


Figure 2: Spatial distribution of study sites: (a) geographical coverage and (b) climate space. Mean annual temperature and precipitation of sites are superimposed upon Whittaker's climate-biome diagram (Whittaker, 1975).

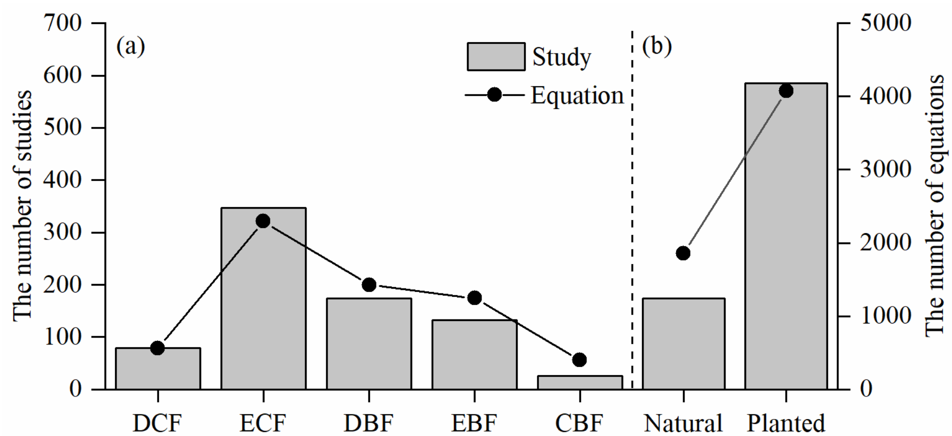


Figure 3: Distribution of compiled studies and biomass equations by (a) forest type and (b) stand origin. Forests are categorized by forest type into deciduous coniferous forest (DCF), evergreen coniferous forest (ECF), deciduous broadleaved forest (DBF), evergreen broadleaved forest (EBF), and coniferous and broadleaved mixed forest (CBF). and by stand origin into natural forest and planted forest.

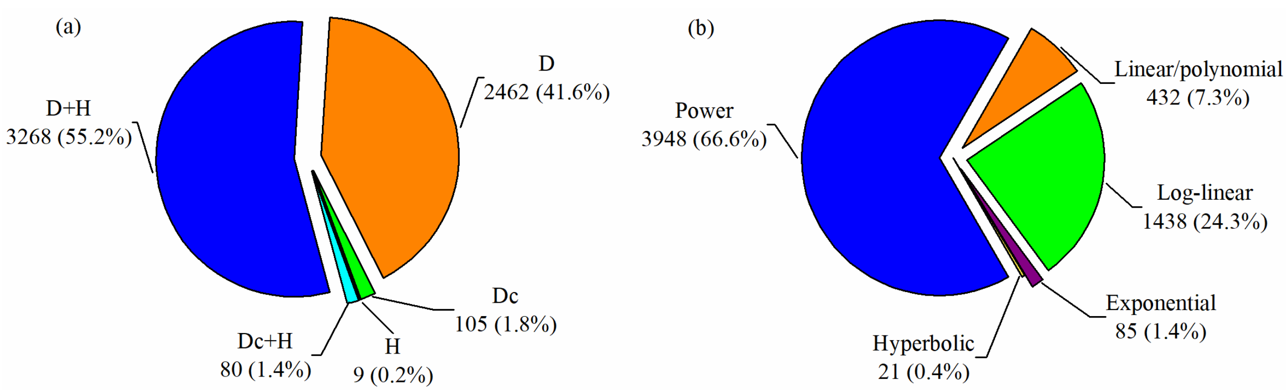


Figure 4: Distribution of biomass equations by (a) predictor variable and (b) equation form. D and H are diameter at breast height (1.3 m) and height, and Dc is tree diameter at other heights (e.g. 0 m, 0.2 m, and 0.3 m) rather than breast height. Equation forms used in original studies are categorized into power equation, log-linear equation, linear/polynomial equation, exponential equation and hyperbolic equation (Appendix E).

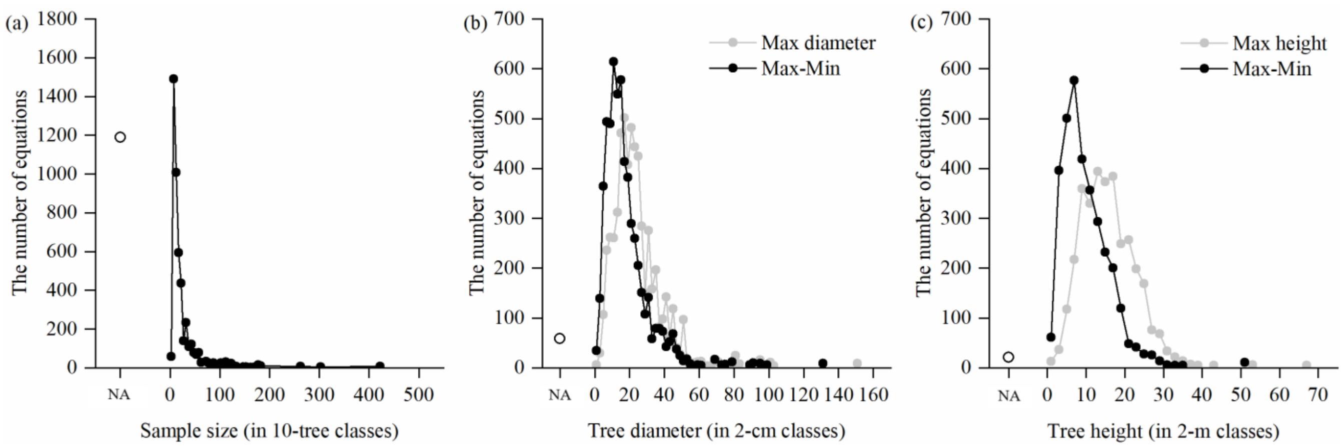


Figure 5: Distribution of sample size and applicable range of biomass equations: (a) sample size, (b) tree diameter and (c) tree height. The dots represent the number of equations within each class. If sample sizes and applicable ranges are not available, they are indicated by 'NA'.

Appendix A: Categorization of age class by dominant tree species, growing region and stand origin *

Dominant tree species	Region †	Origin ‡	Age class (year)				
			Young	Middle-aged	Premature	Mature	Overmature
Picea sp., *Pinus koraiensis*, *Taxus* sp., *Tsuga* sp.	N	NF	≤60	61-100	101-120	121-160	≥161
	N	PF	≤40	41-60	61-80	81-120	≥121
	S	NF	≤40	41-60	61-80	81-120	≥121
	S	PF	≤30	31-50	51-60	61-80	≥81
Cupressus sp.	N	NF	≤60	61-100	101-120	121-160	≥161
	N	PF	≤30	31-50	51-60	61-80	≥81
	S	NF	≤40	41-60	61-80	81-120	≥121
	S	PF	≤30	31-50	51-60	61-80	≥81
Abies sp., *Larix* sp., *Pinus densiflora*, *P. sylvestris* var. *mongolica*, *P. thunbergii*	N	NF	≤40	41-80	81-100	101-140	≥141
	N	PF	≤20	21-30	31-40	41-60	≥61
	S	NF	≤40	41-60	61-80	81-120	≥121
	S	PF	≤20	21-30	31-40	41-60	≥61
Pinus armandii, *P. densata*, *P. kesiya* var. *langbianensis*, *P. massoniana*, *P. tabuliformis*, *P. yunnanensis*	N	NF	≤30	31-50	51-60	61-80	≥81
	N	PF	≤20	21-30	31-40	41-60	≥61
	S	NF	≤20	21-30	31-40	41-60	≥61
	S	PF	≤10	11-20	21-30	31-50	≥51
Cryptomeria sp., *Cunninghamia* sp., *Metasequoia* sp.	S	PF	≤10	11-20	21-25	26-35	≥36
Populus sp., *Pterocarya* sp., *Salix* sp., *Sassafras* sp., *Paulownia* sp.	N	NF	≤20	21-30	31-40	41-60	≥61
	N	PF	≤10	11-15	16-20	21-30	≥31
	S	PF	≤5	6-10	11-15	16-25	≥26
Melia sp.	S	NF	≤20	21-30	31-40	41-60	≥61
	S	PF	≤5	6-10	11-15	16-25	≥26
Robinia pseudoacacia	N	NF & PF	≤10	11-15	16-20	21-30	≥31
	S	NF & PF	≤5	6-10	11-15	16-25	≥26
Acacia sp., *Casuarina* sp., *Eucalyptus* sp., etc.	S	PF	≤5	6-10	11-15	16-25	≥26
Betula sp. (excluding *Betula dahurica*), *Davidia* sp., *Liquidambar* sp., *Schima*	N	NF	≤30	31-50	51-60	61-80	≥81
	N	PF	≤20	21-30	31-40	41-60	≥61
	S	NF	≤20	21-40	41-50	51-70	≥71

Dominant tree species	Region †	Origin ‡	Age class (year)				
			Young	Middle-aged	Premature	Mature	Overmature
sp., *Ulmus* sp.	S	PF	≤10	11-20	21-30	31-50	≥51
Acer sp., *Betula dahurica*, *Castanopsis* sp., *Cinnamomum* sp., *Fraxinus* sp., *Juglans* sp., *Machilus* sp., *Phellodendron* sp., *Phoebe* sp., *Quercus* sp., *Tilia* sp., etc.	N	NF	≤40	41-60	61-80	81-120	≥121
	S	PF	≤20	21-40	41-50	51-70	≥71

* National Forestry and Grassland Administration of China: Regulations for Age-class and Age-group Division of Main Tree Species (LY/T 2908-2017), National Forestry and Grassland Administration of China, Beijing, China, 10pp., 2017.

† Mainland China is categorized by a demarcation line (Qinling Mountains-Huaihe River Line) into two regions: the North (N, the north of the Line, including cold- and warm-temperate zones) and the South (S, the south of the Line, including subtropical and tropical zones).

‡ Forests are categorized by stand origin into natural forest (NF) and planted forest (PF).

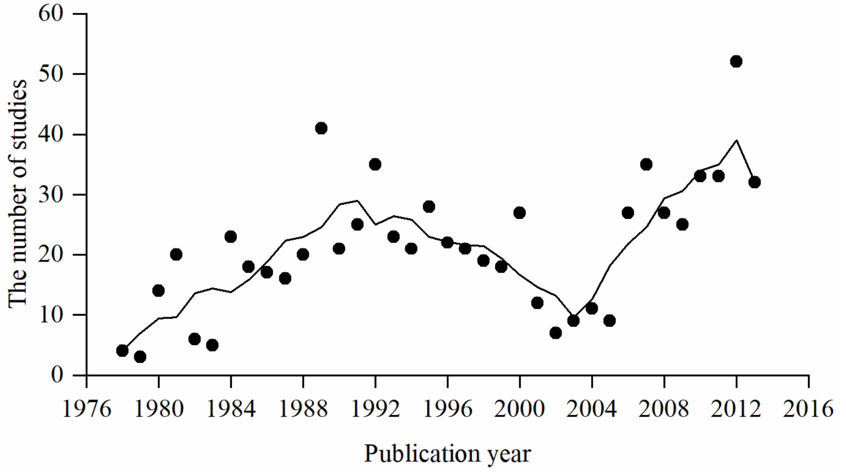
Appendix B: Height-diameter curves for tree species (group) *

Tree species (group) †	*a* (S.E.)	*b* (S.E.)	*n*	R^2
Abies, *Picea*	1.1457 (0.1626)	0.9093 (0.0517)	30	0.917
Cunninghamia lanceolata	0.7226 (0.0286)	1.0492 (0.0160)	236	0.948
Cupressus	0.9808 (0.3725)	0.8966 (0.1420)	18	0.714
Larix	1.8234 (0.1739)	0.7541 (0.0422)	85	0.794
Pinus massoniana, *P. taiwanensis*	0.8895 (0.0726)	0.9910 (0.0325)	85	0.918
P. tabuliformis	1.0951 (0.1066)	0.8184 (0.0428)	106	0.778
Other temperate conifers	1.2506 (0.1743)	0.7810 (0.0546)	75	0.737
Other subtropical conifers	0.7682 (0.2594)	0.9740 (0.1307)	50	0.536
Populus	2.0623 (0.4852)	0.6679 (0.0881)	32	0.657
Temperate deciduous broadleaved trees	1.8784 (0.3111)	0.7087 (0.0689)	51	0.683
Subtropical deciduous broadleaved trees	1.5194 (0.3618)	0.8057 (0.0978)	20	0.790
Fast-growing evergreen broadleaved trees	2.3643 (0.3310)	0.6932 (0.0555)	87	0.647
Other evergreen broadleaved trees	1.8980 (0.2141)	0.7106 (0.0443)	87	0.751

* Data of mean diameter at breast height (D, cm) and height (H, m) are from Luo et al. (2013). H-D curves are depicted by using model $H=a \cdot D^b$, where *a* and *b* are equation coefficients. S.E., standard error; *n*, sample size; and R^2, coefficient of determination.

† To categorize tree species (group), the following factors are considered in decreasing order of significance: adequate sample size (generally >20), similar phylogenetic relationship, similar ecophysiological characteristics, and similar growth conditions.

Appendix C: **Temporal change of compiled studies during the period 1978-2013. Trend line is smoothed by using an adjacent 5-point averaging method.**



Appendix D: Number of retained biomass equations by tree species and biomass component. "–" denotes no equations for a tree biomass component (group). Species names are checked with online Flora of China (http://frps.iplant.cn/). Mixed species in column "Tree species (group)" refer to tree species groups (e.g., deciduous broadleaved trees, a certain diameter-class mixed species, even generalized) that biomass equations are developed for. Abbreviations: SBs, stem biomass subcomponents (stem wood and bark); SB, stem biomass; BBs, branch biomass subcomponents (e.g. different aged branches); BB, branch biomass; LBs, leaf biomass subcomponents (different aged leaves); LB, leaf biomass; FF, flower and fruit biomass; CB, tree crown biomass (BB+LB); AW, aboveground woody biomass (SB+BB); AG, aboveground biomass (SB+BB+LB+FF); BGs, belowground biomass subcomponents (e.g. different diameter roots); BG, belowground biomass; TB, tree biomass (AG+BG).

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
1	*Abies fabri* (Mast.) Craib	3	4	2	–	4	–	4	–	–	–	3	–	4	2	23
2	*Abies georgei* Orr	1	2	–	–	1	–	1	–	–	–	–	2	–	–	6
3	*Abies georgei* Orr var. *smithii* (Viguie et Gaussen) Cheng et L.	1	4	–	–	2	–	2	–	–	–	2	–	2	2	14
4	*Abies nephrolepis* (Trautv. ex Maxim.) Maxim.	1	4	–	–	2	–	2	–	–	–	–	–	2	2	12
5	*Acacia auriculiformis* A. Cunningham ex Bentham	5	6	3	–	6	–	6	–	–	–	3	–	5	2	31
6	*Acacia confuse* Merrill	1	–	1	–	1	–	1	–	–	–	1	–	–	–	4
7	*Acacia dealbata* Link	3	2	3	–	4	–	4	1	–	–	1	–	4	4	23
8	*Acacia mangium* Willd.	6	6	5	–	8	–	8	–	–	–	4	–	3	–	34
9	*Acacia mearnsii* De Wildeman	1	1	1	–	1	–	1	–	–	–	1	–	–	–	5
10	*Acer mandshuricum* Maxim.	1	–	1	2	–	–	1	–	–	–	–	–	–	–	4
11	*Acer mono* Maxim.	7	–	9	10	5	–	9	–	–	–	3	2	5	3	46
12	*Acer truncatum* Bunge	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
13	*Ailanthus altissima* (Mill.) Swingle	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
14	*Alniphyllum fortunei* (Hemsl.) Makino	2	–	2	–	2	–	2	–	–	–	–	–	2	–	8

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
15	*Alnus cremastogyne* Burk.	4	2	4	–	5	–	5	–	–	–	3	–	3	3	25
16	*Alnus sibirica* Fisch. ex Turcz	4	8	1	–	5	–	5	–	–	–	–	–	5	4	28
17	*Amygdalus persica* L.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
18	*Aporosa yunnanensis* (Pax et Hoffm.) Metc.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
19	*Azadirachta indica* A. Juss.	1	–	2	–	2	–	2	–	–	–	2	–	2	2	12
20	*Betula albosinensis* Burk.	1	2	–	–	1	–	1	1	–	–	–	–	1	–	6
21	*Betula alnoides* Buch.-Ham. ex D. Don	4	2	6	–	7	–	7	–	–	–	–	–	7	6	35
22	*Betula costata* Trautv.	2	2	1	2	1	–	2	–	–	–	1	–	–	–	9
23	*Betula dahurica* Pall.	2	–	2	–	2	–	2	–	–	–	1	2	1	1	11
24	*Betula luminifera* H. Winkl.	3	2	3	–	4	–	4	–	–	–	2	–	2	1	18
25	*Betula platyphylla* Suk.	18	26	8	8	19	–	21	–	–	–	4	2	16	11	115
26	*Camellia oleifera* Abel.	1	2	–	2	–	–	1	–	–	–	–	3	–	1	9
27	*Caryota ochlandra* Hance	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
28	*Castanopsis echidnocarpa* J. D. Hooker et Thomson ex Miquel	2	–	2	–	2	–	2	–	–	–	–	–	2	–	8
29	*Castanopsis eyrei* (Champ.) Tutch.	1	4	–	4	–	–	2	–	–	–	2	–	–	–	12
30	*Castanopsis fargesii* Franch.	4	2	2	2	2	–	3	–	–	–	2	–	2	–	15
31	*Castanopsis fissa* (Champ. ex Benth.) Rehd. et Wils.	2	2	1	–	2	–	2	–	–	–	–	–	2	1	10
32	*Castanopsis hystrix* Miq.	2	2	1	–	2	–	2	–	–	–	–	2	1	–	10
33	*Castanopsis kawakamii* Hayata	1	–	1	–	1	–	1	–	–	–	–	–	–	–	3
34	*Castanopsis orthacantha*	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
	Franch.															
35	*Castanopsis rufescens* (Hook. f. et Thoms.) Huang et Y. T. Chang	1	–	1	–	1	–	1	–	–	–	1	–	–	–	4
36	*Castanopsis sclerophylla* (Lindl.) Schott.	1	–	–	–	–	–	–	–	–	–	–	–	2	–	2
37	*Casuarina equisetifolia* Forst.	5	8	2	–	6	–	6	–	–	–	–	–	3	–	25
38	*Celtis philippensis* Blanco	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
39	*Cercidiphyllum japonicum* Sieb. et Zucc.	1	4	–	–	2	–	2	–	–	–	2	4	2	2	18
40	Choerospondias axillaris (Roxb.) Burtt et Hill.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
41	*Cinnamomum bodinieri* Levl.	2	–	2	–	2	–	2	–	–	–	–	–	2	2	10
42	*Cinnamomum camphora* (L.) Presl	6	10	3	–	8	–	8	–	–	–	2	6	8	6	51
43	*Citrus reticulata* Blanco	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
44	*Cleidion brevipetiolatum* Pax et Hoffm.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
45	*Cleistanthus sumatranus* (Miq.) Müll. Arg.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
46	*Cryptocarya chinensis* (Hance) Hemsl.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
47	*Cryptocarya concinna* Hance	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
48	*Cryptomeria fortunei* Hooibrenk ex Otto et Dietr.	4	6	4	–	5	–	5	–	2	–	4	–	7	5	38
49	*Cryptomeria japonica* (Thunb. ex L.f.) D. Don	2	4	–	2	–	–	2	–	–	–	–	–	2	2	12

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
50	*Cunninghamia lanceolata* (Lamb.) Hook.	130	152	70	2	140	1	141	4	4	–	31	25	106	30	706
51	*Cupressus funebris* Endl.	4	2	3	–	4	–	4	–	–	–	2	–	4	3	22
52	*Cupressus lusitanica* Mill.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
53	*Cyclobalanopsis delavayi* (Franch.) Schott.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
54	*Cyclobalanopsis glauca* (Thunb.) Oerst.	8	6	9	6	9	–	12	3	–	–	11	11	6	6	79
55	*Elaeocarpus decipiens* Hemsl.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
56	*Elaeocarpus sylvestris* (Lour.) Poir.	2	4	–	–	2	–	2	–	–	–	–	–	2	1	11
57	*Engelhardtia roxburghiana* Lindl.	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
58	*Erythrophleum fordii* Oliv.	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
59	*Eucalyptus camaldulensis* Dehnh.	2	–	2	–	2	–	2	–	–	–	2	–	2	–	10
60	*Eucalyptus citriodora* Hook.f.	1	4	–	–	2	–	2	–	–	–	2	4	2	2	18
61	*Eucalyptus exserta* F. V. Muell.	2	2	1	–	2	–	2	1	–	–	–	–	2	–	10
62	*Eucalyptus globulus* Labill.	1	2	–	–	1	–	1	–	–	–	–	–	3	–	7
63	*Eucalyptus grandis* Hill ex Maiden ×*urophylla* S.T. Blake	4	8	–	–	4	–	4	3	–	–	–	–	1	–	20
64	*Eucalyptus leizhouensis* No.1	2	8	–	–	4	–	4	–	–	–	4	4	4	4	32
65	*Eucalyptus urophylla* S.T. Blake	8	24	–	–	12	–	12	–	–	–	8	–	4	–	60
66	*Eucalyptus urophylla* S.T.	7	16	–	–	8	–	8	–	–	–	2	4	7	2	47

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
	Blake ×*grandis* Hill ex Maiden															
67	*Eucommia ulmoides* Oliver	6	12	1	–	7	–	7	–	–	–	2	–	7	5	41
68	*Fagus engleriana* Seemen	1	–	2	–	2	–	2	–	–	–	–	–	2	–	8
69	*Ficus microcarpa* L.f.	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
70	*Fokienia hodginsii* (Dunn) Henry et Thomas	3	6	2	–	5	–	5	–	2	–	–	–	3	3	26
71	*Fraxinus mandshurica* Rupr.	7	–	9	10	5	–	9	–	–	–	3	2	3	3	44
72	*Fraxinus rhynchophylla* Hance	1	–	2	–	2	–	2	–	–	–	–	–	2	–	8
73	*Ginkgo biloba* L.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
74	*Gordonia acuminata* Chang	2	–	2	–	2	–	2	–	–	–	–	–	2	–	8
75	*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.	8	–	12	–	12	–	12	–	–	–	7	4	7	7	61
76	*Idesia polycarpa* Maxim.	1	–	2	–	–	–	–	–	2	–	2	–	–	–	6
77	*Juglans mandshurica* Maxim.	3	2	3	2	4	–	4	–	–	–	1	2	2	1	21
78	*Keteleeria davidiana* (Bertr.) Beissn.	1	–	2	–	2	–	2	–	–	–	2	–	2	2	12
79	*Koelreuteria bipinnata* Franch. var. *integrifoliola* (Merr.) T. Chen	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
80	*Koelreuteria paniculata* Laxm.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
81	*Larix chinensis* Beissn.	2	–	2	–	2	–	2	–	–	–	–	–	1	1	8
82	*Larix gmelinii* (Rupr.) Kuzen.	27	30	17	–	32	2	32	–	–	–	10	2	22	10	157
83	*Larix kaempferi* (Lamb.)	7	10	6	–	11	–	11	–	–	–	3	–	11	9	61

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
	Carr.															
84	*Larix mastersiana* Rehd. et Wils.	1	4	–	–	2	–	2	–	–	–	–	–	2	2	12
85	*Larix olgensis* Henry	8	10	6	–	10	–	10	–	1	–	5	–	8	6	56
86	*Larix principis-rupprechtii* Mayr.	30	32	27	6	41	–	43	–	–	–	20	–	38	28	235
87	*Lasiococca comberi* Haines	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
88	*Ligustrum lucidum* Ait.	2	–	2	–	2	–	2	–	–	–	–	–	2	2	10
89	*Liquidambar formosana* Hance	3	2	2	–	3	–	3	–	–	–	–	–	3	–	13
90	*Liriodendron chinense* (Hemsl.) Sargent.	2	4	1	–	3	–	3	–	–	–	3	–	2	2	18
91	*Lithocarpus craibianus* Barn.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
92	*Lithocarpus glaber* (Thunb.) Nakai	2	4	2	4	2	–	4	2	–	–	4	4	2	2	30
93	*Lithocarpus xylocarpus* (Kurz) Markgr.	1	–	1	–	1	–	1	–	–	–	1	–	–	–	4
94	*Litsea cubeba* (Lour.) Pers.	1	–	1	–	1	–	1	1	–	–	–	–	1	1	6
95	*Litsea pungens* Hemsl.	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
96	*Macaranga denticulata* (Bl.) Müll. Arg.	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
97	*Machilus pauhoi* Kaneh.	1	2	–	–	1	–	1	–	–	–	1	–	–	–	5
98	*Machilus viridis* Hand.-Mazz.	1	–	1	–	1	–	1	–	–	–	1	–	–	–	4
99	*Magnolia officinalis* Rehd. et Wils.	2	6	–	–	3	–	3	–	–	–	3	2	1	1	19
100	*Magnolia officinalis* Rehd. et Wils. subsp. *biloba* (Rehd. et Wils.) Law	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
101	*Mallotus paniculatus* (Lam.) Müll. Arg.	3	–	3	–	3	–	3	–	–	–	–	–	3	–	12
102	*Malus pumila* Mill.	1	–	1	–	1	–	1	1	–	–	–	–	1	–	5
103	*Manglietia glauca* Blume	1	2	–	–	1	–	1	–	–	–	–	4	–	–	8
104	*Manglietia hainanensis* Dandy	1	4	–	–	2	–	2	–	–	–	2	–	–	–	10
105	*Manglietia insignis* (Wall.) Blume	1	–	1	–	1	–	1	–	–	–	1	–	–	–	4
106	*Metasequoia glyptostroboides* Hu et Cheng	9	4	11	–	13	–	13	–	–	–	8	–	8	8	65
107	*Michelia hedyosperma* Law	1	2	–	–	1	–	1	–	–	–	1	–	1	1	7
108	*Michelia macclurei* Dandy	3	2	2	–	3	–	3	–	–	–	–	–	3	1	14
109	*Millettia laptobotrya* Wight et Arn.	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
110	*Mytilaria laosensis* Lecomte	3	6	1	–	4	–	4	–	–	–	–	4	2	2	23
111	*Ormosia hosiei* Hemsl. et Wils.	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
112	*Ormosia xylocarpa* Chun ex L. Chen	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
113	*Paramichelia baillonii* (Pierre) Hu	1	2	–	–	1	–	1	–	–	–	1	–	1	1	7
114	*Parashorea chinensis* Wang Hsie	1	2	–	–	1	–	1	–	–	–	1	4	1	1	11
115	*Paulownia elongata* S.Y. Hu	7	2	10	–	11	–	11	3	8	–	9	–	11	10	75
116	*Paulownia tomentosa* (Thunb.) Steud. × *fortunei* (Seem.) Hemsl.	1	–	1	–	1	–	1	–	–	–	1	–	–	–	4

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
117	*Phellodendron amurense* Rupr.	2	–	3	2	3	–	3	–	–	–	1	2	1	1	16
118	*Phellodendron chinense* Schneid.	3	4	1	2	2	–	3	–	–	–	–	2	2	3	19
119	*Phoebe bournei* (Hemsl.) Yen C. Yang	1	2	–	–	1	–	1	–	–	–	1	5	1	–	11
120	*Phoebe zhennan* S. Lee	2	–	2	–	2	–	2	–	–	–	1	–	2	2	11
121	*Picea asperata* Mast.	2	2	2	–	3	–	3	–	–	–	2	–	3	2	17
122	*Picea brachytyla* (Franch.) Pritz. var. *complanata* (Mast.) W.C. Cheng ex Rehder	1	2	–	–	1	–	1	–	–	–	–	2	–	–	6
123	*Picea crassifolia* Kom.	3	6	2	–	5	–	5	2	–	–	4	–	3	2	29
124	*Picea koraiensis* Nakai	2	2	1	–	2	–	2	–	–	–	2	–	2	1	12
125	*Picea likiangensis* var. *balfouriana* (Rehd. et Wils.) Hillier ex Slsvin	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
126	*Picea purpurea* Mast.	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
127	*Picea schrenkiana* Fisch. et Mey.	2	6	1	–	3	–	3	–	1	–	3	–	–	–	17
128	*Pinus armandii* Franch.	8	18	–	–	9	9	9	–	–	–	–	–	9	2	56
129	*Pinus bungeana* Zucc. ex Endl.	1	4	2	–	2	–	2	–	–	–	2	4	2	2	20
130	*Pinus densata* Mast.	2	2	2	–	3	–	3	–	–	–	2	2	–	–	14
131	*Pinus elliottii* Engelm.	13	14	9	2	15	–	16	–	–	–	7	3	7	3	76
132	*Pinus fenzeliana* Hand.-Mazz.	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
133	*Pinus henryi* Mast.	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
134	*Pinus kesiya* Royle ex Gordon var. *langbianensis* (A. Chev.) Gaussen ex Bui	4	8	–	–	4	–	4	1	–	–	–	8	–	–	25

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
135	*Pinus koraiensis* Sieb. et Zucc.	32	8	40	8	44	14	41	–	3	–	6	20	19	15	218
136	*Pinus massoniana* Lamb.	60	56	46	2	73	–	75	1	1	1	19	3	56	32	365
137	*Pinus sylvestris* L. var. *mongolica* Litv.	4	–	5	–	5	–	5	–	–	–	3	–	1	–	19
138	*Pinus sylvestris* L. var. *sylvestriformis* (Takenouchi) Cheng et C.D. Chu	3	2	2	–	3	–	3	–	–	–	2	–	1	1	14
139	*Pinus tabuliformis* Carr.	46	73	40	–	63	4	63	6	2	–	32	42	51	19	395
140	*Pinus taeda* L.	6	4	8	–	8	–	9	–	–	1	7	–	6	6	49
141	*Pinus taiwanensis* Hayata	9	2	11	–	12	–	12	–	–	–	5	4	13	7	66
142	*Pinus thunbergii* Parl.	2	2	2	–	3	–	3	–	–	–	1	–	3	3	17
143	*Pinus yunnanensis* Franch.	8	6	5	–	8	–	8	–	–	–	1	–	8	2	38
144	*Platycladus orientalis* (L.) Franco	10	–	11	–	11	–	11	–	–	–	3	–	7	1	44
145	*Podocarpus imbricatus* Bl.	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
146	*Populus alba* L.	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
147	*Populus alba* var. *pyramidalis* Bge.	2	4	–	2	1	–	2	–	–	–	–	2	1	2	14
148	*Populus canadensis* Moench cv. ‘I-214’	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
149	*Populus canadensis* Moench cv. ‘I-69'	4	4	5	4	5	–	5	–	–	–	3	4	5	3	38
150	*Populus canadensis* Moench cv. ‘I-72'	9	10	7	4	10	–	12	–	–	–	6	4	7	6	66
151	*Populus canadensis* Moench cv. ‘Neva'	1	–	1	–	1	–	1	–	–	–	–	–	–	–	3
152	*Populus canadensis* Moench cv. ‘Robusta'	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
153	*Populus canadensis*	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
	Moench cv. 'Sacrau-79'															
154	*Populus canadensis* Moench cv. 'Zhonglin-46'	1	–	2	–	2	–	2	–	–	–	–	–	2	2	10
155	*Populus dakuanensis* Hsu	1	–	2	–	2	–	2	–	–	–	–	–	2	2	10
156	*Populus davidiana* Dode	8	8	5	2	9	–	9	–	–	–	4	2	7	5	51
157	*Populus deltoides* Bartr. ex Marsh.	2	4	–	–	2	–	2	–	–	–	–	–	2	–	10
158	*Populus deltoides* Bartr. ex Marsh. cv. '35'	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
159	*Populus euphratica* Oliv.	4	–	4	–	4	–	4	–	–	–	1	–	4	1	18
160	*Populus hopeiensis* Hu et Chow	1	–	2	–	2	–	2	–	–	–	2	–	2	2	12
161	*Populus jrtyschensis* C.Y. Yang	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
162	*Populus laurifolia* Ledeb.	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
163	*Populus szechuanica* var. *tibetica* Schneid.	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
164	*Populus tomentosa* Carr.	10	26	5	–	18	–	18	–	–	–	1	–	16	16	100
165	*Populus ussuriensis* Kom.	2	–	2	–	2	–	2	–	–	–	1	–	1	1	9
166	*Populus wenxianica* Z.C. Feng et J.L. Guo ex G. Zhu	1	–	2	–	2	–	2	–	–	–	2	–	–	–	8
167	*Populus xiaohei* T.S. Hwang et Liang	4	10	–	–	5	–	5	–	–	–	–	–	5	3	28
168	*Quercus acutissima* Carruth.	4	–	4	–	4	–	4	–	–	–	2	–	2	1	17
169	*Quercus aliena* Bl. var. *acutiserrata* Maxim. ex Wenz.	7	14	2	–	9	–	9	–	–	–	–	–	8	2	44
170	*Quercus fabrei* Hance	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
171	*Quercus mongolica* Fisch. ex Ledeb.	9	4	9	8	8	–	11	–	–	–	2	2	7	3	54

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
172	*Quercus pannosa* Hand.-Mazz.	2	2	1	–	2	–	2	–	–	–	–	2	1	–	10
173	*Quercus senescens* Hand.-Mazz.	1	2	–	–	1	–	1	–	–	–	–	2	–	–	6
174	*Quercus variabilis* Bl.	5	10	2	–	7	–	7	–	–	–	2	6	7	4	45
175	*Quercus wutaishanica* Mayr	2	4	–	–	2	–	2	–	–	–	–	–	2	–	10
176	*Rhus chinensis* Mill.	1	–	1	–	1	–	1	–	–	–	1	–	1	1	6
177	*Rhus punjabensis* Stewart var. *sinica* (Diels) Rehd. et Wils.	1	–	1	–	1	–	1	–	–	–	1	–	1	1	6
178	*Robinia pseudoacacia* Linn.	16	18	11	–	20	–	20	2	–	–	–	–	16	9	96
179	*Sabina przewalskii* (Kom.) Kom.	1	–	1	–	1	–	1	1	–	–	–	–	1	1	6
180	*Salix alba* L.	1	2	–	–	1	–	1	–	–	–	–	–	1	1	6
181	*Sassafras tzumu* (Hemsl.) Hemsl.	2	–	1	–	1	–	1	–	–	–	1	–	2	–	6
182	*Schima superba* Gardn. et Champ.	6	4	4	4	4	–	7	–	–	1	4	–	4	2	34
183	*Schima wallichii* (DC.) Choisy	1	–	1	–	1	–	1	–	–	–	–	–	–	–	3
184	*Sumbaviopsis albicans* (Bl.) J.J. Sm.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
185	*Symplocos anomala* Brand	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
186	*Symplocos sumuntia* Buch.-Ham. ex D. Don	1	2	–	–	1	–	1	–	–	–	–	–	1	–	5
187	*Syzygium jambos* (L.) Alston	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
188	*Ternstroemia gymnanthera* (Wight et Arn.) Beddome	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5

No.	Tree species (group)	Number of studies	The number of biomass equations													
			SBs	SB	BBs	BB	LBs	LB	FF	CB	AW	AG	BGs	BG	TB	Total
189	*Tilia amurensis* Rupr.	7	–	9	10	5	–	9	–	–	–	5	2	5	5	50
190	*Tilia mongolica* Maxim.	1	–	2	–	2	–	2	–	–	–	–	–	2	–	8
191	*Trema tomentosa* (Roxb.) Hara	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
192	*Tsoongiodendron odorum* Chun	2	2	2	–	3	–	3	–	–	–	2	–	3	3	18
193	*Ulmus davidiana* Planch. var. *japonica* (Rehd.) Nakai	4	–	4	6	1	–	4	–	–	–	1	–	1	1	18
194	*Ulmus pumila* L.	2	–	2	–	2	–	2	–	–	–	–	2	1	1	10
195	*Vernicia fordii* (Hemsl.) Airy Shaw	1	–	2	–	2	–	2	4	–	–	–	–	2	2	14
196	*Vernicia montana* Lour.	1	–	1	–	1	–	1	–	–	–	–	–	1	1	5
197	*Zanthoxylum ailanthoides* Sieb. et Zucc.	1	–	1	–	1	–	1	–	–	–	–	–	1	–	4
198	Mixed species	69	30	75	–	88	–	88	6	–	–	21	22	73	33	436
	Total	906	910	694	116	1074	30	1116	43	26	3	364	246	837	465	5924

Appendix E: Biomass equation forms used in studies. W is the biomass (kg); X is tree diameter (cm), tree height (m) or their combinations; a, b, c, and d are equation coefficients; *log* refers to either the natural or the 10-base logarithmic transformation of arithmetic values.

Category	Equation form	Number of equations	Category	Equation form	Number of equations
Power	$W=a\cdot X^{b}$	3812	Exponential	$W=\exp(a+b\cdot X)$	4
	$W=a\cdot X^{b}+c$	7		$W=\exp(a+b/X)$	1
	$W=a\cdot(b+X)^{c}$ (c=2, 3, 4 or 5)	43		$W=a\cdot\exp(b\cdot X^{c})$ (c=1 or 2)	29
	$W=a\cdot X^{b}+c\cdot X^{d}$	1		$W=a\cdot\exp(b\cdot X)+c$	2
	$W=a\cdot X_1^{b}\cdot X_2^{c}$	85		$W=a\cdot\exp(b+c\cdot X)$	1
Linear /polynomial	$W=a+b\cdot X$	253		$W=a\cdot\exp(b/X)$	3
	$W=a+b\cdot X+c\cdot X^{2}$	90		$W=a\cdot X^{b}\cdot\exp(c\cdot X)$	31
	$W=a+b\cdot X+c\cdot X^{2}+d\cdot X^{3}$	6		$W=a\cdot b^{X}$	10
	$W=a+b\cdot X^{c}$ (c=2, 3 or 4)	82		$W=a\cdot b^{X}+c$	2
	$W=a+b\cdot X^{2}+c\cdot X^{4}$	1		$W=a\cdot\exp[b\cdot(X_1^{c}+X_2^{d})]$	2
Log-linear	$W=a+b\cdot\log(X)$	16	Hyperbolic	$W=X/(a+b\cdot X)$	17
	$\log(W)=a+b\cdot X$	2		$W=a/(b+X)$	2
	$\log(W)=a+b\cdot\log(X)$	1378		$W=1/[a+b\cdot\log(X)]$	1
	$\log(W)=a+b\cdot\log(X)+c\cdot X$	26		$W=a\cdot b^{1/X}$	1
	$\log(W)=a+b\cdot\log(X_1)+c\cdot\log(X_2)$	16			