

# Rate of tree carbon accumulation increases continuously with tree size

N. L. Stephenson<sup>1</sup>, A. J. Das<sup>1</sup>, R. Condit<sup>2</sup>, S. E. Russo<sup>3</sup>, P. J. Baker<sup>4</sup>, N. G. Beckman<sup>3†</sup>, D. A. Coomes<sup>5</sup>, E. R. Lines<sup>6</sup>, W. K. Morris<sup>7</sup>, N. Rüger<sup>2,8†</sup>, E. Álvarez<sup>9</sup>, C. Blundo<sup>10</sup>, S. Bunyavejchewin<sup>11</sup>, G. Chuyong<sup>12</sup>, S. J. Davies<sup>13</sup>, Á. Duque<sup>14</sup>, C. N. Ewango<sup>15</sup>, O. Flores<sup>16</sup>, J. F. Franklin<sup>17</sup>, H. R. Grau<sup>10</sup>, Z. Hao<sup>18</sup>, M. E. Harmon<sup>19</sup>, S. P. Hubbell<sup>2,20</sup>, D. Kenfack<sup>13</sup>, Y. Lin<sup>21</sup>, J.-R. Makana<sup>15</sup>, A. Malizia<sup>10</sup>, L. R. Malizia<sup>22</sup>, R. J. Pabst<sup>19</sup>, N. Pongpattananurak<sup>23</sup>, S.-H. Su<sup>24</sup>, I.-F. Sun<sup>25</sup>, S. Tan<sup>26</sup>, D. Thomas<sup>27</sup>, P. J. van Mantgem<sup>28</sup>, X. Wang<sup>18</sup>, S. K. Wiser<sup>29</sup> & M. A. Zavala<sup>30</sup>

**Forests are major components of the global carbon cycle, providing substantial feedback to atmospheric greenhouse gas concentrations<sup>1</sup>. Our ability to understand and predict changes in the forest carbon cycle—particularly net primary productivity and carbon storage—increasingly relies on models that represent biological processes across several scales of biological organization, from tree leaves to forest stands<sup>2,3</sup>. Yet, despite advances in our understanding of productivity at the scales of leaves and stands, no consensus exists about the nature of productivity at the scale of the individual tree<sup>4–7</sup>, in part because we lack a broad empirical assessment of whether rates of absolute tree mass growth (and thus carbon accumulation) decrease, remain constant, or increase as trees increase in size and age. Here we present a global analysis of 403 tropical and temperate tree species, showing that for most species mass growth rate increases continuously with tree size. Thus, large, old trees do not act simply as senescent carbon reservoirs but actively fix large amounts of carbon compared to smaller trees; at the extreme, a single big tree can add the same amount of carbon to the forest within a year as is contained in an entire mid-sized tree. The apparent paradoxes of individual tree growth increasing with tree size despite declining leaf-level<sup>8–10</sup> and stand-level<sup>10</sup> productivity can be explained, respectively, by increases in a tree's total leaf area that outpace declines in productivity per unit of leaf area and, among other factors, age-related reductions in population density. Our results resolve conflicting assumptions about the nature of tree growth, inform efforts to understand and model forest carbon dynamics, and have additional implications for theories of resource allocation<sup>11</sup> and plant senescence<sup>12</sup>.**

A widely held assumption is that after an initial period of increasing growth, the mass growth rate of individual trees declines with increasing tree size<sup>4,5,13–16</sup>. Although the results of a few single-species studies have been consistent with this assumption<sup>15</sup>, the bulk of evidence cited in support of declining growth is not based on measurements of individual tree mass growth. Instead, much of the cited evidence documents either the well-known age-related decline in net primary productivity (hereafter 'productivity') of even-aged forest stands<sup>10</sup> (in which the trees are all of a similar age) or size-related declines in the rate of mass gain per

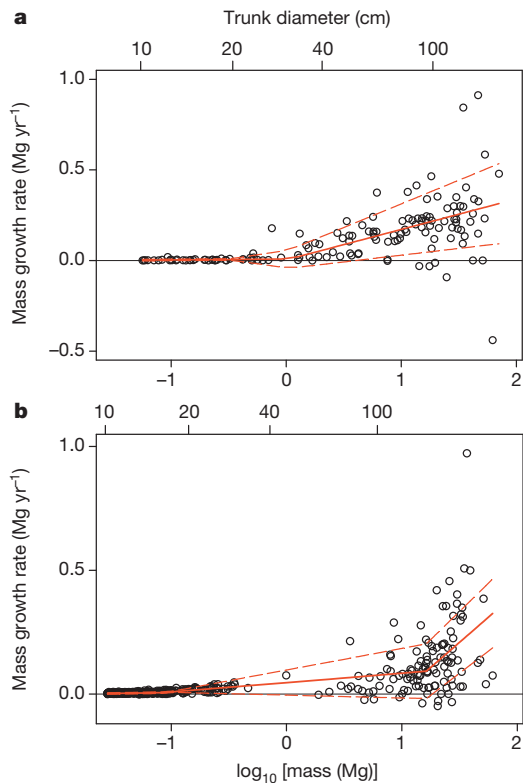
unit leaf area (or unit leaf mass)<sup>8–10</sup>, with the implicit assumption that declines at these scales must also apply at the scale of the individual tree. Declining tree growth is also sometimes inferred from life-history theory to be a necessary corollary of increasing resource allocation to reproduction<sup>11,16</sup>. On the other hand, metabolic scaling theory predicts that mass growth rate should increase continuously with tree size<sup>6</sup>, and this prediction has also received empirical support from a few site-specific studies<sup>6,7</sup>. Thus, we are confronted with two conflicting generalizations about the fundamental nature of tree growth, but lack a global assessment that would allow us to distinguish clearly between them.

To fill this gap, we conducted a global analysis in which we directly estimated mass growth rates from repeated measurements of 673,046 trees belonging to 403 tropical, subtropical and temperate tree species, spanning every forested continent. Tree growth rate was modelled as a function of log(tree mass) using piecewise regression, where the independent variable was divided into one to four bins. Conjoined line segments were fitted across the bins (Fig. 1).

For all continents, aboveground tree mass growth rates (and, hence, rates of carbon gain) for most species increased continuously with tree mass (size) (Fig. 2). The rate of mass gain increased with tree mass in each model bin for 87% of species, and increased in the bin that included the largest trees for 97% of species; the majority of increases were statistically significant (Table 1, Extended Data Fig. 1 and Supplementary Table 1). Even when we restricted our analysis to species achieving the largest sizes (maximum trunk diameter > 100 cm; 33% of species), 94% had increasing mass growth rates in the bin that included the largest trees. We found no clear taxonomic or geographic patterns among the 3% of species with declining growth rates in their largest trees, although the small number of these species (thirteen) hampers inference. Declining species included both angiosperms and gymnosperms in seven of the 76 families in our study; most of the seven families had only one or two declining species and no family was dominated by declining species (Supplementary Table 1).

When we log-transformed mass growth rate in addition to tree mass, the resulting model fits were generally linear, as predicted by metabolic scaling theory<sup>6</sup> (Extended Data Fig. 2). Similar to the results of our main

<sup>1</sup>US Geological Survey, Western Ecological Research Center, Three Rivers, California 93271, USA. <sup>2</sup>Smithsonian Tropical Research Institute, Apartado 0843-03092, Balboa, Republic of Panama. <sup>3</sup>School of Biological Sciences, University of Nebraska, Lincoln, Nebraska 68588, USA. <sup>4</sup>Department of Forest and Ecosystem Science, University of Melbourne, Victoria 3121, Australia. <sup>5</sup>Department of Plant Sciences, University of Cambridge, Cambridge CB2 3EA, UK. <sup>6</sup>Department of Geography, University College London, London WC1E 6BT, UK. <sup>7</sup>School of Botany, University of Melbourne, Victoria 3010, Australia. <sup>8</sup>Spezielle Botanik und Funktionelle Biodiversität, Universität Leipzig, 04103 Leipzig, Germany. <sup>9</sup>Jardín Botánico de Medellín, Calle 73, No. 51D-14, Medellín, Colombia. <sup>10</sup>Instituto de Ecología Regional, Universidad Nacional de Tucumán, 4107 Yerba Buena, Tucumán, Argentina. <sup>11</sup>Research Office, Department of National Parks, Wildlife and Plant Conservation, Bangkok 10900, Thailand. <sup>12</sup>Department of Botany and Plant Physiology, Buea, Southwest Province, Cameroon. <sup>13</sup>Smithsonian Institution Global Earth Observatory—Center for Tropical Forest Science, Smithsonian Institution, PO Box 37012, Washington, DC 20013, USA. <sup>14</sup>Universidad Nacional de Colombia, Departamento de Ciencias Forestales, Medellín, Colombia. <sup>15</sup>Wildlife Conservation Society, Kinshasa/Gombe, Democratic Republic of the Congo. <sup>16</sup>Unité Mixte de Recherche—Peuplements Végétaux et Bioagresseurs en Milieu Tropical, Université de la Réunion/CIRAD, 97410 Saint Pierre, France. <sup>17</sup>School of Environmental and Forest Sciences, University of Washington, Seattle, Washington 98195, USA. <sup>18</sup>State Key Laboratory of Forest and Soil Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110164, China. <sup>19</sup>Department of Forest Ecosystems and Society, Oregon State University, Corvallis, Oregon 97331, USA. <sup>20</sup>Department of Ecology and Evolutionary Biology, University of California, Los Angeles, California 90095, USA. <sup>21</sup>Department of Life Science, Tunghai University, Taichung City 40704, Taiwan. <sup>22</sup>Facultad de Ciencias Agrarias, Universidad Nacional de Jujuy, 4600 San Salvador de Jujuy, Argentina. <sup>23</sup>Faculty of Forestry, Kasetsart University, ChatuChak Bangkok 10900, Thailand. <sup>24</sup>Taiwan Forestry Research Institute, Taipei 10066, Taiwan. <sup>25</sup>Department of Natural Resources and Environmental Studies, National Dong Hwa University, Hualien 97401, Taiwan. <sup>26</sup>Sarawak Forestry Department, Kuching, Sarawak 93660, Malaysia. <sup>27</sup>Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon 97331, USA. <sup>28</sup>US Geological Survey, Western Ecological Research Center, Arcata, California 95521, USA. <sup>29</sup>Landcare Research, PO Box 40, Lincoln 7640, New Zealand. <sup>30</sup>Forest Ecology and Restoration Group, Department of Life Sciences, University of Alcalá, Alcalá de Henares, 28805 Madrid, Spain. †Present addresses: Mathematical Biosciences Institute, Ohio State University, Columbus, Ohio 43210, USA (N.G.B.); German Centre for Integrative Biodiversity Research (iDiv), Halle-Jena-Leipzig, 04103 Leipzig, Germany (N.R.).



**Figure 1 | Example model fits for tree mass growth rates.** The species shown are the angiosperm species (*Lecomtedoxa klaineana*, Cameroon, 142 trees) (a) and gymnosperm species (*Picea sitchensis*, USA, 409 trees) (b) in our data set that had the most massive trees (defined as those with the greatest cumulative aboveground dry mass in their five most massive trees). Each point represents a single tree; the solid red lines represent best fits selected by our model; and the dashed red lines indicate one standard deviation around the predicted values.

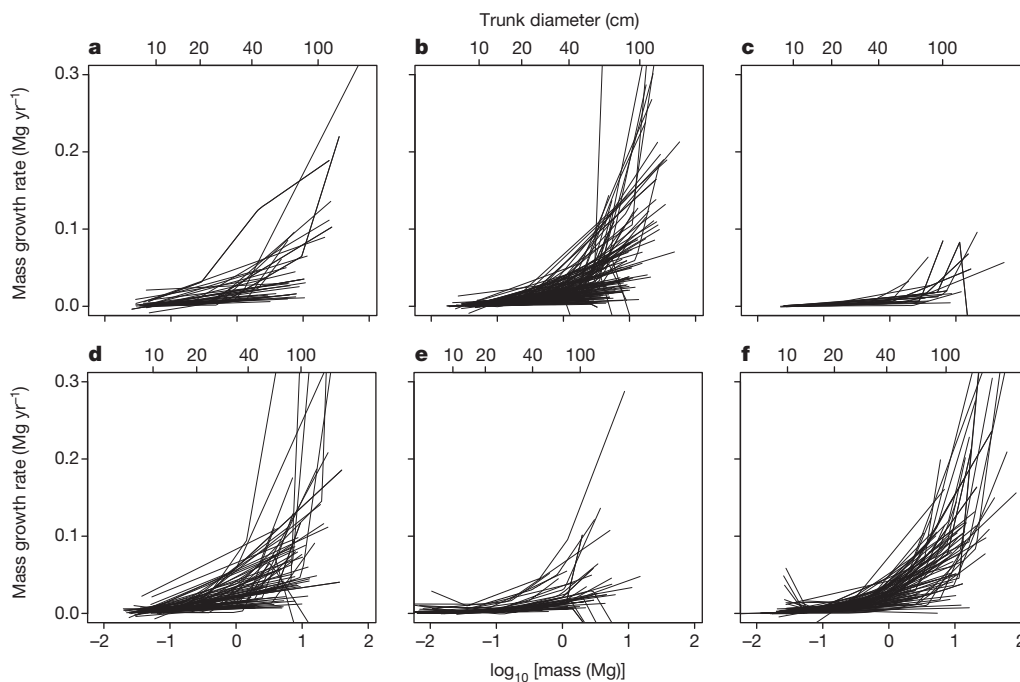
analysis using untransformed growth, of the 381 log-transformed species analysed (see Methods), the log-transformed growth rate increased in the bin containing the largest trees for 96% of species.

In absolute terms, trees 100 cm in trunk diameter typically add from 10 kg to 200 kg of aboveground dry mass each year (depending on species), averaging 103 kg per year. This is nearly three times the rate for trees of the same species at 50 cm in diameter, and is the mass equivalent to adding an entirely new tree of 10–20 cm in diameter to the forest each year. Our findings further indicate that the extraordinary growth recently reported in an intensive study of large *Eucalyptus regnans* and *Sequoia sempervirens*<sup>7</sup>, which included some of the world's most massive individual trees, is not a phenomenon limited to a few unusual species. Rather, rapid growth in giant trees is the global norm, and can exceed 600 kg per year in the largest individuals (Fig. 3).

Our data set included many natural and unmanaged forests in which the growth of smaller trees was probably reduced by asymmetric competition with larger trees. To explore the effects of competition, we calculated mass growth rates for 41 North American and European species that had published equations for diameter growth rate in the absence of competition. We found that, even in the absence of competition, 85% of the species had mass growth rates that increased continuously with tree size (Extended Data Fig. 3), with growth curves closely resembling those in Fig. 2. Thus, our finding of increasing growth not only has broad generality across species, continents and forest biomes (tropical, subtropical and temperate), it appears to hold regardless of competitive environment.

Importantly, our finding of continuously increasing growth is compatible with the two classes of observations most often cited as evidence of declining, rather than increasing, individual tree growth: with increasing tree size and age, productivity usually declines at the scales of both tree organs (leaves) and tree populations (even-aged forest stands).

First, although growth efficiency (tree mass growth per unit leaf area or leaf mass) often declines with increasing tree size<sup>8–10</sup>, empirical observations and metabolic scaling theory both indicate that, on average, total tree leaf mass increases as the square of trunk diameter<sup>17,18</sup>. A typical tree that experiences a tenfold increase in diameter will therefore undergo a roughly 100-fold increase in total leaf mass and a 50–100-fold



**Figure 2 | Aboveground mass growth rates for the 403 tree species, by continent.** a, Africa (Cameroon, Democratic Republic of the Congo); b, Asia (China, Malaysia, Taiwan, Thailand); c, Australasia (New Zealand); d, Central and South America (Argentina, Colombia, Panama); e, Europe (Spain); and

f, North America (USA). Numbers of trees, numbers of species and percentages with increasing growth are given in Table 1. Trunk diameters are approximate values for reference, based on the average diameters of trees of a given mass.

**Table 1 | Sample sizes and tree growth trends by continent**

Continent	Number of trees	Number of species	Percentage of species with increasing mass growth rate in the largest trees (percentage significant at $P \leq 0.05$ )
Africa	15,366	37	100.0 (86.5)
Asia	43,690	136	96.3 (89.0)
Australasia	45,418	22	95.5 (95.5)
Central and South America	18,530	77	97.4 (92.2)
Europe	439,889	42	90.5 (78.6)
North America	110,153	89	98.9 (94.4)
Total	673,046	403	96.8 (89.8)

The largest trees are those in the last bin fitted by the model. Countries are listed in the legend for Fig. 2.

increase in total leaf area (depending on size-related increases in leaf mass per unit leaf area<sup>19,20</sup>). Parallel changes in growth efficiency can range from a modest increase (such as in stands where small trees are suppressed by large trees)<sup>21</sup> to as much as a tenfold decline<sup>22</sup>, with most changes falling in between<sup>8,9,19,22</sup>. At one extreme, the net effect of a low (50-fold) increase in leaf area combined with a large (tenfold) decline in growth efficiency would still yield a fivefold increase in individual tree mass growth rate; the opposite extreme would yield roughly a 100-fold increase. Our calculated 52-fold greater average mass growth rate of trees 100 cm in diameter compared to those 10 cm in diameter falls within this range. Thus, although growth efficiency often declines with increasing tree size, increases in a tree's total leaf area are sufficient to overcome this decline and cause whole-tree carbon accumulation rate to increase.

Second, our findings are similarly compatible with the well-known age-related decline in productivity at the scale of even-aged forest stands. Although a review of mechanisms is beyond the scope of this paper<sup>10,23</sup>, several factors (including the interplay of changing growth efficiency and tree dominance hierarchies<sup>24</sup>) can contribute to declining productivity at the stand scale. We highlight the fact that increasing individual tree growth rate does not automatically result in increasing stand productivity because tree mortality can drive orders-of-magnitude reductions in population density<sup>25,26</sup>. That is, even though the large trees in older, even-aged stands may be growing more rapidly, such stands have fewer trees. Tree population dynamics, especially mortality, can thus be a significant contributor to declining productivity at the scale of the forest stand<sup>23</sup>.

For a large majority of species, our findings support metabolic scaling theory's qualitative prediction of continuously increasing growth

at the scale of individual trees<sup>6</sup>, with several implications. For example, life-history theory often assumes that tradeoffs between plant growth and reproduction are substantial<sup>11</sup>. Contrary to some expectations<sup>11,16</sup>, our results indicate that for most tree species size-related changes in reproductive allocation are insufficient to drive long-term declines in growth rates<sup>6</sup>. Additionally, declining growth is sometimes considered to be a defining feature of plant senescence<sup>12</sup>. Our findings are thus relevant to understanding the nature and prevalence of senescence in the life history of perennial plants<sup>27</sup>.

Finally, our results are relevant to understanding and predicting forest feedbacks to the terrestrial carbon cycle and global climate system<sup>1-3</sup>. These feedbacks will be influenced by the effects of climatic, land-use and other environmental changes on the size-specific growth rates and size structure of tree populations—effects that are already being observed in forests<sup>28,29</sup>. The rapid growth of large trees indicates that, relative to their numbers, they could play a disproportionately important role in these feedbacks<sup>30</sup>. For example, in our western USA old-growth forest plots, trees >100 cm in diameter comprised 6% of trees, yet contributed 33% of the annual forest mass growth. Mechanistic models of the forest carbon cycle will depend on accurate representation of productivity across several scales of biological organization, including calibration and validation against continuously increasing carbon accumulation rates at the scale of individual trees.

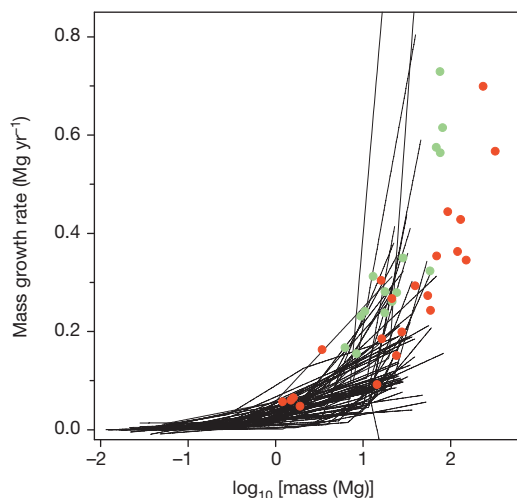
## METHODS SUMMARY

We estimated aboveground dry mass growth rates from consecutive diameter measurements of tree trunks—typically measured every five to ten years—from long-term monitoring plots. Analyses were restricted to trees with trunk diameter  $\geq 10$  cm, and to species having  $\geq 40$  trees in total and  $\geq 15$  trees with trunk diameter  $\geq 30$  cm. Maximum trunk diameters ranged from 38 cm to 270 cm among species, averaging 92 cm. We converted each diameter measurement (plus an accompanying height measurement for 16% of species) to aboveground dry mass,  $M$ , using published allometric equations. We estimated tree growth rate as  $G = \Delta M / \Delta t$  and modelled  $G$  as a function of  $\log(M)$  for each species using piecewise regression. The independent variable  $\log(M)$  was divided into bins and a separate line segment was fitted to  $G$  versus  $\log(M)$  in each bin so that the line segments met at the bin divisions. Bin divisions were not assigned a priori, but were fitted by the model separately for each species. We fitted models with 1, 2, 3 and 4 bins, and selected the model receiving the most support by Akaike's Information Criterion for each species. Our approach thus makes no assumptions about the shape of the relationship between  $G$  and  $\log(M)$ , and can accommodate increasing, decreasing or hump-shaped relationships. Parameters were fitted with a Gibbs sampler based on Metropolis updates, producing credible intervals for model parameters and growth rates at any diameter; uninformative priors were used for all parameters. We tested extensively for bias, and found no evidence that our results were influenced by model fits failing to detect a final growth decline in the largest trees, possible biases introduced by the 47% of species for which we combined data from several plots, or possible biases introduced by allometric equations (Extended Data Figs 4 and 5).

**Online Content** Any additional Methods, Extended Data display items and Source Data are available in the online version of the paper; references unique to these sections appear only in the online paper.

Received 5 August; accepted 27 November 2013.

Published online 15 January 2014.



**Figure 3 | Aboveground mass growth rates of species in our data set compared with *E. regnans* and *S. sempervirens*.** For clarity, only the 58 species in our data set having at least one tree exceeding 20 Mg are shown (lines). Data for *E. regnans* (green dots, 15 trees) and *S. sempervirens* (red dots, 21 trees) are from an intensive study that included some of the most massive individual trees on Earth<sup>7</sup>. Both axes are expanded relative to those of Fig. 2.

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**Supplementary Information** is available in the online version of the paper.

**Acknowledgements** We thank the hundreds of people who have established and maintained the forest plots and their associated databases; M. G. Ryan for comments on the manuscript; C. D. Canham and T. Hart for supplying data; C. D. Canham for discussions and feedback; J. S. Baron for hosting our workshops; and Spain’s Ministerio de Agricultura, Alimentación y Medio Ambiente (MAGRAMA) for granting access to the Spanish Forest Inventory Data. Our analyses were supported by the United States Geological Survey (USGS) John Wesley Powell Center for Analysis and Synthesis, the USGS Ecosystems and Climate and Land Use Change mission areas, the Smithsonian Institution Global Earth Observatory—Center for Tropical Forest Science (CTFS), and a University of Nebraska-Lincoln Program of Excellence in Population Biology Postdoctoral Fellowship (to N.G.B.). In addition, X.W. was supported by National Natural Science Foundation of China (31370444) and State Key Laboratory of Forest and Soil Ecology (LFSE2013-11). Data collection was funded by a broad range of organizations including the USGS, the CTFS, the US National Science Foundation, the Andrews LTER (NSF-LTER DEB-0823380), the US National Park Service, the US Forest Service (USFS), the USFS Forest Inventory and Analysis Program, the John D. and Catherine T. MacArthur Foundation, the Andrew W. Mellon Foundation, MAGRAMA, the Council of Agriculture of Taiwan, the National Science Council of Taiwan, the National Natural Science Foundation of China, the Knowledge Innovation Program of the Chinese Academy of Sciences, Landcare Research and the National Vegetation Survey Database (NVS) of New Zealand, the French Fund for the Global Environment and Fundación ProYungas. This paper is a contribution from the Western Mountain Initiative, a USGS global change research project. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USA government.

**Author Contributions** N.L.S. and A.J.D. conceived the study with feedback from R.C. and D.A.C., N.L.S., A.J.D., R.C. and S.E.R. wrote the manuscript. R.C. devised the main analytical approach and wrote the computer code. N.L.S., A.J.D., R.C., S.E.R., P.J.B., N.G.B., D.A.C., E.R.L., W.K.M. and N.R. performed analyses. N.L.S., A.J.D., R.C., S.E.R., P.J.B., D.A.C., E.R.L., W.K.M., E.A., C.B., S.B., G.C., S.J.D., A.D., C.N.E., O.F., J.F.F., H.R.G., Z.H., M.E.H., S.P.H., D.K., Y.L., J.-R.M., A.M., L.R.M., R.J.P., N.P., S.-H.S., I.-F.S., S.T., D.T., P.J.v.M., X.W., S.K.W. and M.A.Z. supplied data and sources of allometric equations appropriate to their data.

**Author Information** Fitted model parameters for each species have been deposited in USGS’s ScienceBase at <http://dx.doi.org/10.5066/F7JS9NFM>. Reprints and permissions information is available at [www.nature.com/reprints](http://www.nature.com/reprints). The authors declare no competing financial interests. Readers are welcome to comment on the online version of the paper. Correspondence and requests for materials should be addressed to N.L.S. (nstephenson@usgs.gov).

## METHODS

**Data.** We required that forest monitoring plots provided unbiased samples of all living trees within the plot boundaries, and that the trees had undergone two trunk diameter measurements separated by at least one year. Some plots sampled minimally disturbed old (all-aged) forest, whereas others, particularly those associated with national inventories, sampled forest stands regardless of past management history. Plots are described in the references cited in Supplementary Table 1.

Our raw data were consecutive measurements of trunk diameter,  $D$ , with most measurements taken 5 to 10 years apart (range, 1–29 years).  $D$  was measured at a standard height on the trunk (usually 1.3–1.4 m above ground level), consistent across measurements for a tree. Allometric equations for 16% of species required, in addition to consecutive measurements of  $D$ , consecutive measurements of tree height.

We excluded trees exhibiting extreme diameter growth, defined as trunks where  $D$  increased by  $\geq 40 \text{ mm yr}^{-1}$  or that shrank by  $\geq 12s$ , where  $s$  is the standard deviation of the  $D$  measurement error,  $s = 0.9036 + 0.006214D$  (refs 31, 32); outliers of these magnitudes were almost certainly due to error. By being so liberal in allowing negative growth anomalies, we erred on the side of reducing our ability to detect increases in tree mass growth rate. Using other exclusion values yielded similar results, as did a second approach to handling error in which we reanalysed a subset of our models using a Bayesian method that estimates growth rates after accounting for error, based on independent plot-specific data quantifying measurement error<sup>33</sup>.

To standardize minimum  $D$  among data sets, we analysed only trees with  $D \geq 10 \text{ cm}$  at the first census. To ensure adequate samples of trees spanning a broad range of sizes, we restricted analyses to species having both  $\geq 40$  trees in total and also  $\geq 15$  trees with  $D \geq 30 \text{ cm}$  at the first census. This left us with 673,046 trees belonging to 403 tropical and temperate species in 76 families, spanning twelve countries and all forested continents (Supplementary Table 1). Maximum trunk diameters ranged from 38 cm to 270 cm among species, and averaged 92 cm.

**Estimating tree mass.** To estimate each tree's aboveground dry mass,  $M$ , we used published allometric equations relating  $M$  to  $D$  (or for 16% of species, relating  $M$  to  $D$  and tree height). Some equations were species-specific and others were specific to higher taxonomic levels or forest types, described in the references in Supplementary Table 1. The single tropical moist forest equation of ref. 34 was applied to most tropical species, whereas most temperate species had unique species-specific equations. Most allometric equations are broadly similar, relating  $\log(M)$  to  $\log(D)$  linearly, or nearly linearly—a familiar relationship in allometric scaling of both animals and plants<sup>35</sup>. Equations can show a variety of differences in detail, however, with some adding  $\log(D)$  squared and cubed terms. All equations make use of the wood density of individual species, but when wood density was not available for a given species we used mean wood density for a genus or family<sup>36</sup>.

Using a single, average allometry for most tropical species, and mean wood density for a genus or family for several species, limits the accuracy of our estimates of  $M$ . However, because we treat each species separately, it makes no difference whether our absolute  $M$  estimates are more accurate in some species than in others, only that they are consistent within a species and therefore accurately reveal whether mass growth rates increase or decrease with tree size.

For two regions—Spain and the western USA—allometric equations estimated mass only for a tree's main stem rather than all aboveground parts, including branches and leaves. But because leaf and stem masses are positively correlated and their growth rates are expected to scale isometrically both within and among species<sup>18,37,38</sup>, results from these two regions should not alter our qualitative conclusions. Confirming this, the percentage of species with increasing stem mass growth rate in the last bin for Spain and the western USA (93.4% of 61 species) was similar to that from the remainder of regions (97.4% of 342 species) ( $P = 0.12$ , Fisher's exact test).

**Modelling mass growth rate.** We sought a modelling approach that made no assumptions about the shape of the relationship between aboveground dry mass growth rate,  $G$ , and aboveground dry mass,  $M$ , and that could accommodate monotonically increasing, monotonically decreasing, or hump-shaped relationships. We therefore chose to model  $G$  as a function of  $\log(M)$  using piecewise linear regression. The range of the  $x$  axis,  $X = \log(M)$ , is divided into a series of bins, and within each bin  $G$  is fitted as a function of  $X$  by linear regression. The position of the bins is adaptive: it is fitted along with the regression terms. Regression lines are required to meet at the boundary between bins. For a single model-fitting run the number of bins,  $B$ , is fixed. For example, if  $B = 2$ , there are four parameters to be fitted for a single species: the location of the boundary between bins,  $X_1$ ; the slope of the regression in the first bin,  $S_1$ ; the slope in the second bin,  $S_2$ ; and an intercept term. Those four parameters completely define the model. In general, there are  $2B$  parameters for  $B$  bins.

Growth rates, while approximately normally distributed, were heteroskedastic, with the variance increasing with mass (Fig. 1), so an additional model was needed for the standard deviation of  $G$ ,  $\sigma_G$ , as a function of  $\log(M)$ . The increase of  $\sigma_G$

with  $\log(M)$  was clearly not linear, so we used a three-parameter model:

$$\sigma_G = k \quad (\text{for } \log(M) < d)$$

$$\sigma_G = a + b \log(M) \quad (\text{for } \log(M) \geq d)$$

where the intercept  $a$  is determined by the values of  $k$ ,  $d$  and  $b$ . Thus  $\sigma_G$  was constant for smaller values of  $\log(M)$  (below the cutoff  $d$ ), then increased linearly for larger  $\log(M)$  (Fig. 1). The parameters  $k$ ,  $d$  and  $b$  were estimated along with the parameters of the growth model.

Parameters of both the growth and standard deviation models were estimated in a Bayesian framework using the likelihood of observing growth rates given model predictions and the estimated standard deviation of the Gaussian error function. A Markov chain Monte Carlo chain of parameter estimates was created using a Gibbs sampler with a Metropolis update<sup>39,40</sup> written in the programming language R (ref. 41) (a tutorial and the computer code are available through <http://ctfs.arnarb.harvard.edu/Public/CTFSRPackage/files/tutorials/growthfitAnalysis>). The sampler works by updating each of the parameters in sequence, holding other parameters fixed while the relevant likelihood function is used to locate the target parameter's next value. The step size used in the updates was adjusted adaptively through the runs, allowing more rapid convergence<sup>40</sup>. The final Markov chain Monte Carlo chain describes the posterior distribution for each model parameter, the error, and was then used to estimate the posterior distribution of growth rates as estimated from the model. Priors on model parameters were uniform over an unlimited range, whereas the parameters describing the standard deviation were restricted to  $>0$ . Bin boundaries,  $X_b$ , were constrained as follows: (1) boundaries could only fall within the range of  $X$ , (2) each bin contained at least five trees, and (3) no bin spanned less than 10% of the range of  $X$ . The last two restrictions prevented the bins from collapsing to very narrow ranges of  $X$  in which the fitted slope might take absurd extremes.

We chose piecewise regression over other alternatives for modelling  $G$  as a function of  $M$  for two main reasons. First, the linear regression slopes within each bin provide precise statistical tests of whether  $G$  increases or decreases with  $X$ , based on credible intervals of the slope parameters. Second, with adaptive bin positions, the function is completely flexible in allowing changes in slope at any point in the  $X$  range, with no influence of any one bin on the others. In contrast, in parametric models where a single function defines the relationship across all  $X$ , the shape of the curve at low  $X$  can (and indeed must) influence the shape at high  $X$ , hindering statistical inference about changes in tree growth at large size.

We used  $\log(M)$  as our predictor because within a species  $M$  has a highly non-Gaussian distribution, with many small trees and only a few very large trees, including some large outliers. In contrast, we did not log-transform our dependent variable  $G$  so that we could retain values of  $G \leq 0$  that are often recorded in very slowly growing trees, for which diameter change over a short measurement interval can be on a par with diameter measurement error.

For each species, models with 1, 2, 3 and 4 bins were fitted. Of these four models, the model receiving the greatest weight of evidence by Akaike Information Criterion (AIC) was selected. AIC is defined as the log-likelihood of the best-fitting model, penalized by twice the number of parameters. Given that adding one more bin to a model meant two more parameters, the model with an extra bin had to improve the log-likelihood by 4 to be considered a better model<sup>42</sup>.

**Assessing model fits.** To determine whether our approach might have failed to reveal a final growth decline within the few largest trees of the various species, we calculated mass growth rate residuals for the single most massive individual tree of each species. For 52% of the 403 species, growth of the most massive tree was underestimated by our model fits (for example, Fig. 1a); for 48% it was overestimated (for example, Fig. 1b). These proportions were indistinguishable from 50% ( $P = 0.55$ , binomial test), as would be expected for unbiased model fits. Furthermore, the mean residual (observed minus predicted) mass growth rate of these most massive trees,  $+0.006 \text{ Mg yr}^{-1}$ , was statistically indistinguishable from zero ( $P = 0.29$ , two-tailed  $t$ -test). We conclude that our model fits accurately represent growth trends up through, and including, the most massive trees.

**Effects of combined data.** To achieve sample sizes adequate for analysis, for some species we combined data from several different forest plots, potentially introducing a source of bias: if the largest trees of a species disproportionately occur on productive sites, the increase in mass growth rate with tree size could be exaggerated. This might occur because trees on less-productive sites—presumably the sites having the slowest-growing trees within any given size class—could be under-represented in the largest size classes. We assessed this possibility in two ways.

First, our conclusions remained unchanged when we compared results for the 53% of species that came uniquely from single large plots with those of the 47% of species whose data were combined across several plots. Proportions of species with increasing mass growth rates in the last bin were indistinguishable between the two groups (97.6% and 95.8%, respectively;  $P = 0.40$ , Fisher's exact test). Additionally,

the shapes and magnitudes of the growth curves for Africa and Asia, where data for each species came uniquely from single large plots, were similar to those of Australasia, Europe and North America, where data for each species were combined across several plots (Table 1, Fig. 2 and Extended Data Fig. 2). (Data from Central and South America were from both single and combined plots, depending on species.)

Second, for a subset of combined-data species we compared two sets of model fits: (1) using all available plots (that is, the analyses we present in the main text), and (2) using only plots that contained massive trees—those in the top 5% of mass for a species. To maximize our ability to detect differences, we limited these analyses to species with large numbers of trees found in a large number of plots, dispersed widely across a broad geographic region. We therefore analysed the twelve Spanish species that each had more than 10,000 individual trees (Supplementary Table 1), found in 34,580 plots distributed across Spain. Massive trees occurred in 6,588 (19%) of the 34,580 plots. We found no substantial differences between the two analyses. When all 34,580 plots were analysed, ten of the twelve species showed increasing growth in the last bin, and seven showed increasing growth across all bins; when only the 6,588 plots containing the most massive trees were analysed, the corresponding numbers were eleven and nine. Model fits for the two groups were nearly indistinguishable in shape and magnitude across the range of tree masses. We thus found no evidence that the potential for growth differences among plots influenced our conclusions.

**Effects of possible allometric biases.** For some species, the maximum trunk diameter  $D$  in our data sets exceeded the maximum used to calibrate the species' allometric equation. In such cases our estimates of  $M$  extrapolate beyond the fitted allometry and could therefore be subject to bias. For 336 of our 403 species we were able to determine  $D$  of the largest tree that had been used in calibrating the associated allometric equations. Of those 336 species, 74% (dominated by tropical species) had no trees in our data set with  $D$  exceeding that used in calibrating the allometric equations, with the remaining 26% (dominated by temperate species) having at least one tree with  $D$  exceeding that used in calibration. The percentage of species with increasing  $G$  in the last bin for the first group (98.0%) was indistinguishable from that of the second group (96.6%) ( $P = 0.44$ , Fisher's exact test). Thus, our finding of increasing  $G$  with tree size is not affected by the minority of species that have at least one tree exceeding the maximum value of  $D$  used to calibrate their associated allometric equations.

A bias that could inflate the rate at which  $G$  increases with tree size could arise if allometric equations systematically underestimate  $M$  for small trees or overestimate  $M$  for large trees<sup>43</sup>. For a subset of our study species we obtained the raw data—consisting of measured values of  $D$  and  $M$  for individual trees—needed to calibrate allometric equations, allowing us to determine whether the particular form of those species' allometric equations was prone to bias, and if so, the potential consequences of that bias.

To assess the potential for allometric bias for the majority (58%) of species in our data set—those that used the empirical moist tropical forest equation of ref. 34—we reanalysed the data provided by ref. 34. The data were from 1,504 harvested trees representing 60 families and 184 genera, with  $D$  ranging from 5 cm to 156 cm; the associated allometric equation relates  $\log(M)$  to a third-order polynomial of  $\log(D)$ . Because the regression of  $M$  on  $D$  was fitted on a log–log scale, this and subsequent equations include a correction of  $\exp[(\text{RSE})^2/2]$  for the error in back-transformation, where RSE is the residual standard error from the statistical model<sup>44</sup>. Residuals of  $M$  for the equation revealed no evident biases (Extended Data Fig. 4a), suggesting that we should expect little (if any) systematic size-related biases in our estimates of  $G$  for the 58% of our species that used this equation.

Our simplest form of allometric equation—applied to 22% of our species—was  $\log(M) = a + b \log(D)$ , where  $a$  and  $b$  are taxon-specific constants. For nine of our species that used equations of this form (all from the temperate western USA: *Abies amabilis*, *A. concolor*, *A. procera*, *Pinus lambertiana*, *Pinus ponderosa*, *Picea sitchensis*, *Pseudotsuga menziesii*, *Tsuga heterophylla* and *T. mertensiana*) we had values of both  $D$  and  $M$  for a total of 1,358 individual trees, allowing us to fit species-specific allometric equations of the form  $\log(M) = a + b \log(D)$  and then assess them for bias. Residual plots showed a tendency to overestimate  $M$  for the largest trees (Extended Data Fig. 4b), with the possible consequence of inflating estimates of  $G$  for the largest relative to the smallest trees of these species.

To determine whether this bias was likely to alter our qualitative conclusion that  $G$  increases with tree size, we created a new set of allometric relations between  $D$  and  $M$ —one for each of the nine species—using the same piecewise linear regression approach we used to model  $G$  as a function of  $M$ . However, because our goal was to eliminate bias rather than seek the most parsimonious model, we fixed the number of bins at four, with the locations of boundaries between the bins being fitted by the model. Our new allometry using piecewise regressions led to predictions of  $M$  with no apparent bias relative to  $D$  (Extended Data Fig. 4c). This new, unbiased allometry gave the same qualitative results as our original, simple allometry

regarding the relationship between  $G$  and  $M$ : for all nine species,  $G$  increased in the bin containing the largest trees, regardless of the allometry used (Extended Data Fig. 5). We conclude that any bias associated with the minority of our species that used the simple allometric equation form was unlikely to affect our broad conclusion that  $G$  increases with tree size in a majority of tree species.

As a final assessment, we compared our results to those of a recent study of *E. regnans* and *S. sempervirens*, in which  $M$  and  $G$  had been calculated from intensive measurements of aboveground portions of trees without the use of standard allometric equations<sup>7</sup>. Specifically, in two consecutive years 36 trees of different sizes and ages were climbed, trunk diameters were systematically measured at several heights, branch diameters and lengths were measured (with subsets of foliage and branches destructively sampled to determine mass relationships), wood densities were determined and ring widths from increment cores were used to supplement measured diameter growth increments. The authors used these measurements to calculate  $M$  for each of the trees in each of the two consecutive years, and  $G$  as the difference in  $M$  between the two years<sup>7</sup>. *E. regnans* and *S. sempervirens* are the world's tallest angiosperm and gymnosperm species, respectively, so the data set was dominated by exceptionally large trees; most had  $M \geq 20$  Mg, and  $M$  of some individuals exceeded that of the most massive trees in our own data set (which lacked *E. regnans* and *S. sempervirens*). We therefore compared *E. regnans* and *S. sempervirens* to the 58 species in our data set that had at least one individual with  $M \geq 20$  Mg. Sample sizes for *E. regnans* and *S. sempervirens*—15 and 21 trees, respectively—fell below our required  $\geq 40$  trees for fitting piecewise linear regressions, so we simply plotted data points for individual *E. regnans* and *S. sempervirens* along with the piecewise regressions that we had already fitted for our 58 comparison species (Fig. 3).

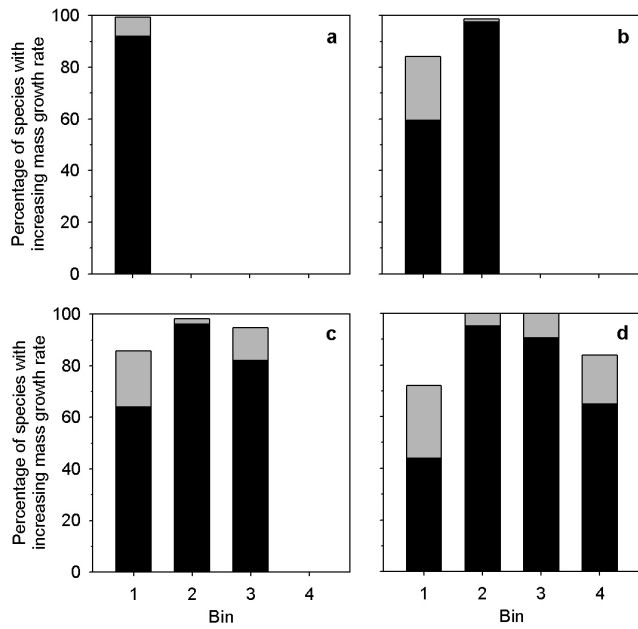
As reported by ref. 7,  $G$  increased with  $M$  for both *E. regnans* and *S. sempervirens*, up to and including some of the most massive individual trees on the Earth (Fig. 3). Within the zone of overlapping  $M$  between the two data sets,  $G$  values for individual *E. regnans* and *S. sempervirens* trees fell almost entirely within the ranges of the piecewise regressions we had fitted for our 58 comparison species. We take these observations as a further indication that our results, produced using standard allometric equations, accurately reflect broad relationships between  $M$  and  $G$ .

**Fitting log–log models.** To model  $\log(G)$  as a function of  $\log(M)$ , we used the binning approach that we used in our primary analysis of mass growth rate (described earlier). However, in log-transforming growth we dropped trees with  $G \leq 0$ . Because negative growth rates become more extreme with increasing tree size, dropping them could introduce a bias towards increasing growth rates. Log-transformation additionally resulted in skewed growth rate residuals. Dropping trees with  $G \leq 0$  caused several species to fall below our threshold sample size, reducing the total number of species analysed to 381 (Extended Data Fig. 2).

**Growth in the absence of competition.** We obtained published equations for 41 North American and European species, in 46 species-site combinations, relating species-specific tree diameter growth rates to trunk diameter  $D$  and to neighbourhood competition<sup>45–49</sup>. Setting neighbourhood competition to zero gave us equations describing estimated annual  $D$  growth as a function of  $D$  in the absence of competition. Starting at  $D_0 = 10$  cm, we sequentially (1) calculated annual  $D$  growth for a tree of size  $D_0$ , (2) added this amount to  $D_0$  to determine  $D_1$ , (3) used an appropriate taxon-specific allometric equation to calculate the associated tree masses  $M_0$  and  $M_1$ , and (iv) calculated tree mass growth rate  $G_0$  of a tree of mass  $M_0$  in the absence of competition as  $M_1 - M_0$ . For each of the five species that had separate growth analyses available from two different sites, we required that mass growth rate increased continuously with tree size at both sites for the species to be considered to have a continuously increasing mass growth rate. North American and European allometries were taken from refs 17 and 50, respectively, with preference given to allometric equations based on power functions of tree diameter, large numbers of sampled trees, and trees spanning a broad range of diameters. For the 47% of European species for which ref. 50 had no equations meeting our criteria, we used the best-matched (by species or genus) equations from ref. 17.

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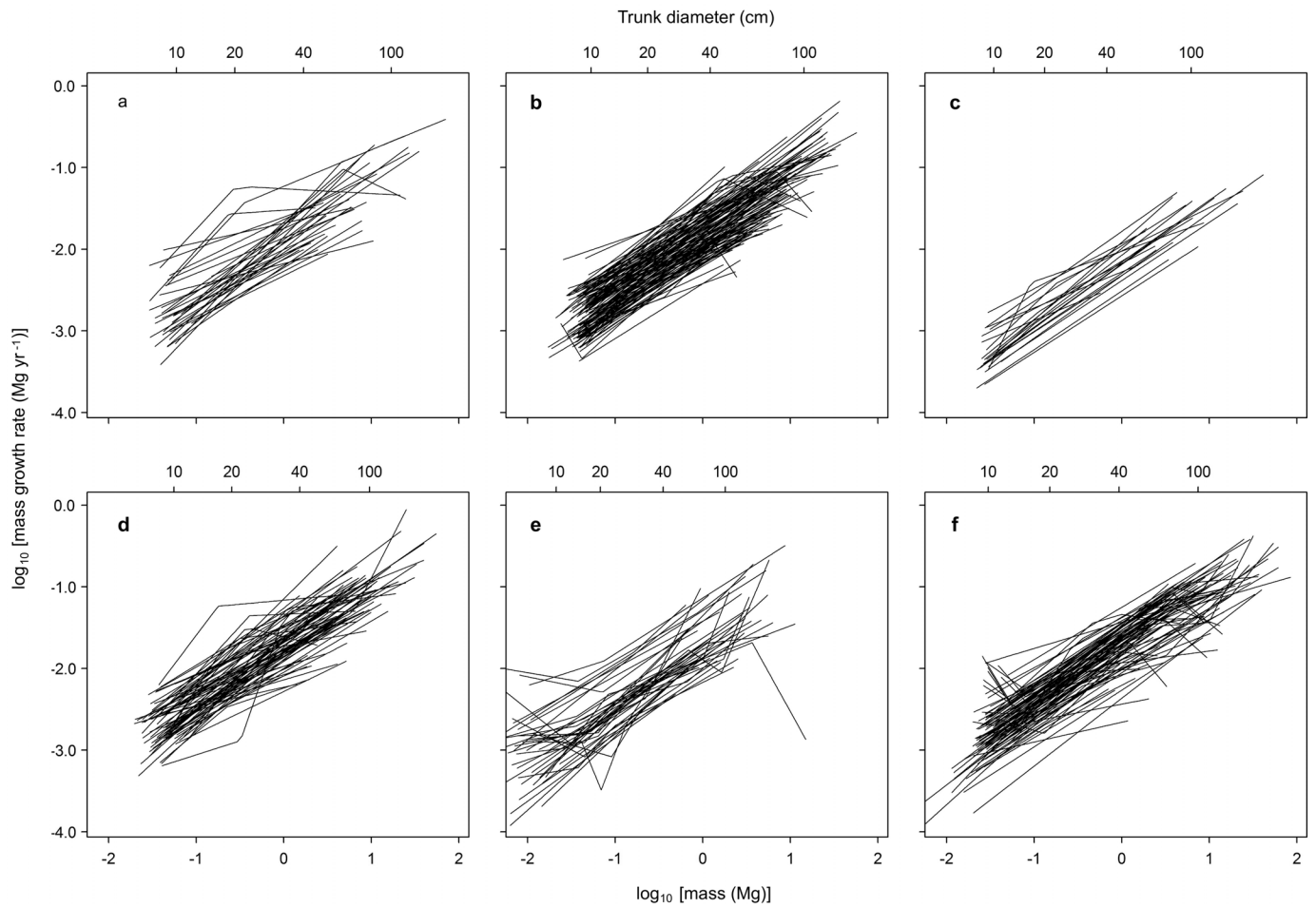
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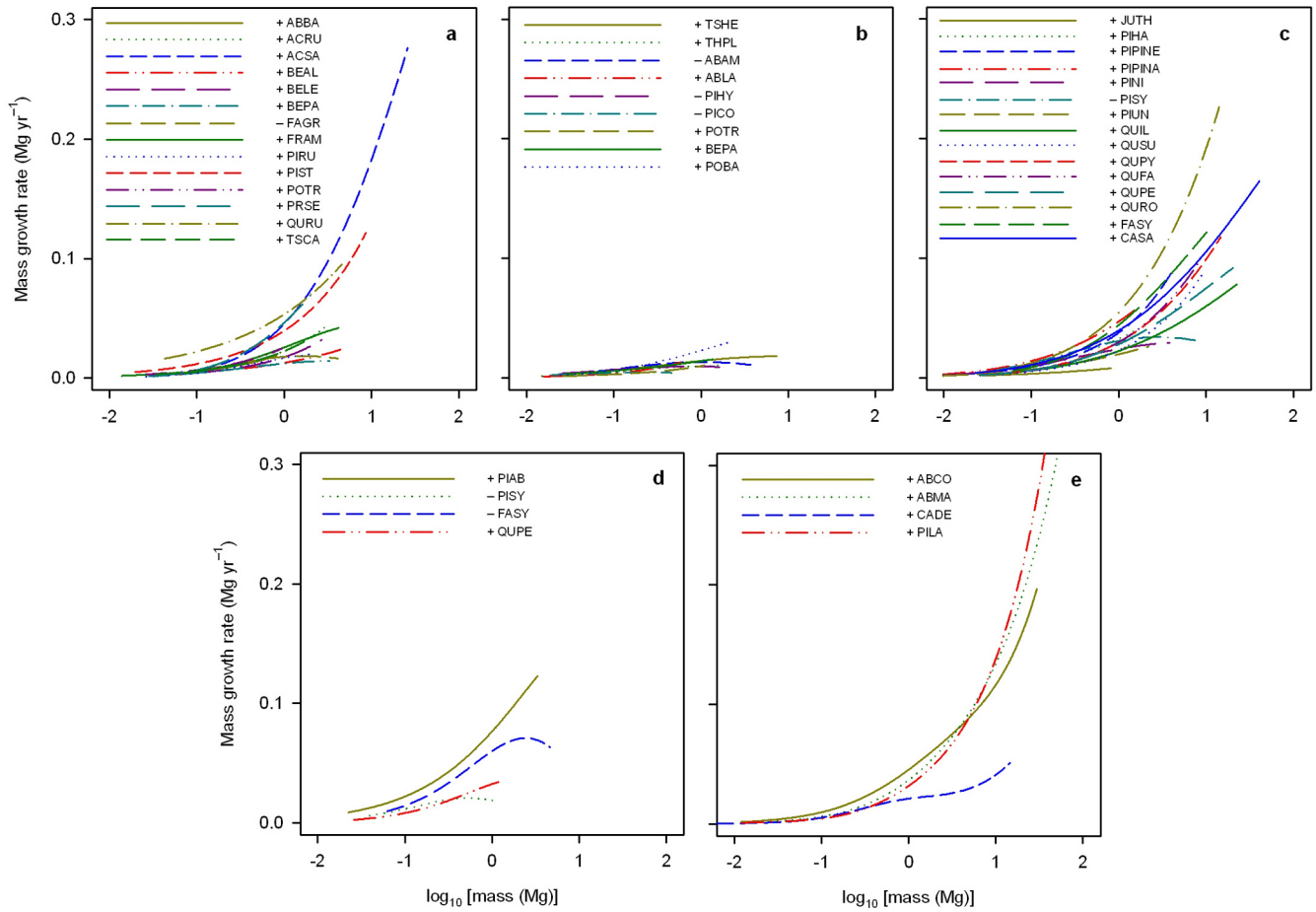
**Extended Data Figure 1 | Summary of model fits for tree mass growth rates.**

Bars show the percentage of species with mass growth rates that increase with tree mass for each bin; black shading indicates percentage significant at  $P \leq 0.05$ . Tree masses increase with bin number. **a**, Species fitted with one bin (165 species); **b**, Species fitted with two bins (139 species); **c**, Species fitted with three bins (56 species); and **d**, Species fitted with four bins (43 species).



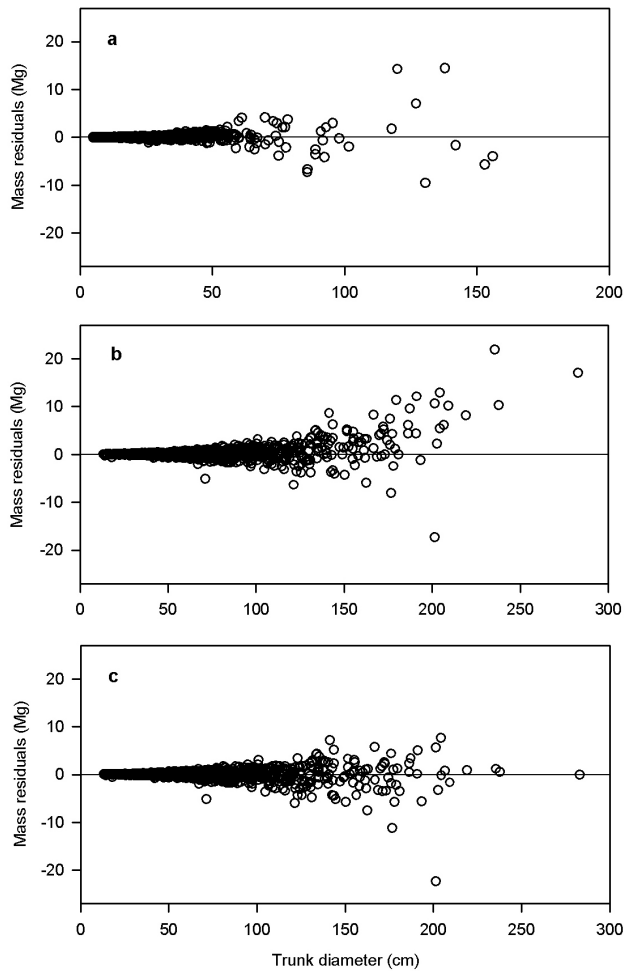


**Extended Data Figure 2 | Log-log model fits of mass growth rates for 381 tree species, by continent.** Trees with growth rates  $\leq 0$  were dropped from the analysis, reducing the number of species meeting our threshold sample size for analysis. **a**, Africa (33 species); **b**, Asia (123 species); **c**, Australasia (22 species); **d**, Central and South America (73 species); **e**, Europe (41 species); and **f**, North America (89 species). Trunk diameters are approximate values for reference, based on the average diameters of trees of a given mass.



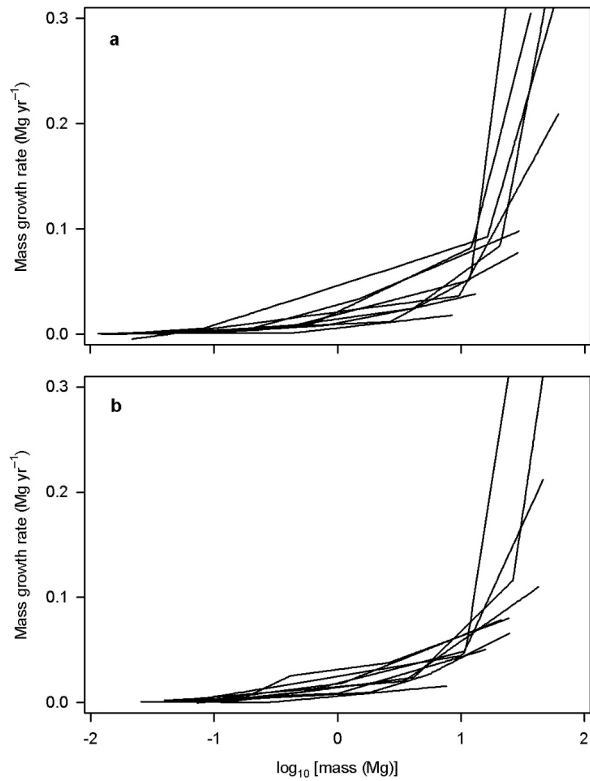
**Extended Data Figure 3 | Aboveground mass growth rates for 41 tree species in the absence of competition.** The '+' or '-' symbol preceding each species code indicates, respectively, species with mass growth rates that increased continuously with tree size or species with mass growth rates that declined in the largest trees. Sources of the diameter growth equations used to calculate mass growth were: **a**, ref. 45; **b**, ref. 46; **c**, ref. 48; **d**, ref. 47; and **e**, ref. 49. ABAM, *Abies amabilis*; ABBA, *Abies balsamea*; ABCO, *Abies concolor*; ABLA, *Abies lasiocarpa*; ABMA, *Abies magnifica*; ACRU, *Acer rubrum*; ACSA, *Acer saccharum*; BEAL, *Betula alleghaniensis*; BELE, *Betula lenta*; BEPA, *Betula papyrifera*; CADE, *Calocedrus decurrens*; CASA, *Castanea sativa*; FAGR, *Fagus grandifolia*; FASY, *Fagus sylvatica*; FRAM, *Fraxinus americana*; JUTH,

*Juniperus thurifera*; PIAB, *Picea abies*; PICO, *Pinus contorta*; PIHA, *Pinus halepensis*; PIHY, *Picea* hybrid (a complex of *Picea glauca*, *P. sitchensis* and *P. engelmannii*); PILA, *Pinus lambertiana*; PINI, *Pinus nigra*; PIPINA, *Pinus pinaster*; PIPINE, *Pinus pinea*; PIRU, *Picea rubens*; PIST, *Pinus strobus*; PISY, *Pinus sylvestris*; PIUN, *Pinus uncinata*; POBA, *Populus balsamifera* ssp. *trichocarpa*; POTR, *Populus tremuloides*; PRSE, *Prunus serotina*; QUFA, *Quercus faginea*; QUIL, *Quercus ilex*; QUPE, *Quercus petraea*; QUPY, *Quercus pyrenaica*; QURO, *Quercus robur*; QURU, *Quercus rubra*; QUSU, *Quercus suber*; THPL, *Thuja plicata*; TSCA, *Tsuga canadensis*; and TSHE, *Tsuga heterophylla*.



**Extended Data Figure 4 | Residuals of predicted minus observed tree mass.**

**a**, The allometric equation for moist tropical forests<sup>34</sup>—used for the majority of tree species—shows no evident systematic bias in predicted aboveground dry mass,  $M$ , relative to trunk diameter ( $n = 1,504$  trees). **b**, In contrast, our simplest form of allometric equation—used for 22% of our species and here applied to nine temperate species—shows an apparent bias towards overestimating  $M$  for large trees ( $n = 1,358$  trees). **c**, New allometries that we created for the nine temperate species removed the apparent bias in predicted  $M$ .



**Extended Data Figure 5 | Estimated mass growth rates of the nine temperate species of Extended Data Fig. 4.** Growth was estimated using the simplest form of allometric model [ $\log(M) = a + b\log(D)$ ] (a) and our allometric models fitted with piecewise linear regression (b). Regardless of the allometric model form, all nine species show increasing  $G$  in the largest trees.

**Supplementary Table 1 | Results by species.**

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
Cameroon	51	Achariaceae	Scottellia klaineana	153	70.6	34	+	+		
Cameroon	51	Annonaceae	Annickia chlorantha	106	51.2	34	+			
Cameroon	51	Annonaceae	Xylopia aethiopica	71	53.3	34	+			
Cameroon	51	Combretaceae	Strephonema pseudocola	55	130.7	34	(+)	+		
Cameroon	51	Dichapetalaceae	Tapura africana	57	74.9	34	+			
Cameroon	51	Ebenaceae	Diospyros gabunensis	744	50.4	34	(+)	+	+	
Cameroon	51	Erythrolaceae	Strombosia pustulata	684	46.5	34	+	+		
Cameroon	51	Erythrolaceae	Strombosia scheffleri	119	69.9	34	+			
Cameroon	51	Erythrolaceae	Strombosiopsis tetrandra	230	68.9	34	+			
Cameroon	51	Euphorbiaceae	Dichostemma glaucescens	1771	44.5	34	+			
Cameroon	51	Euphorbiaceae	Discoglyprena caloneura	43	64.9	34	+			
Cameroon	51	Euphorbiaceae	Klaineanthus gaboniae	355	55.7	34	+			
Cameroon	51	Fabaceae	Hymenostegia afzelii	476	44.3	34	+			
Cameroon	51	Fabaceae	Talbotiella eketensis	132	51.2	34	+			
Cameroon	51	Lamiaceae	Vitex grandifolia	80	46.6	34	+			
Cameroon	51	Lamiaceae	Vitex sp.1	48	126.5	34	+			
Cameroon	51	Lauraceae	Hypodaphnis zenkeri	129	91.8	34	+			
Cameroon	51	Lecythidaceae	Oubanguia alata	2639	73.8	34	+	+		
Cameroon	51	Lecythidaceae	Scytopetalum klaineanum	45	76.0	34	+			
Cameroon	51	Phyllanthaceae	Protomegabaria stapfiana	384	58.4	34	+			
Cameroon	51	Phyllanthaceae	Uapaca staudtii	90	69.0	34	(+)			
Cameroon	51	Rubiaceae	Pausinystalia macroceras	49	58.5	34	+			
Cameroon	51	Rutaceae	Zanthoxylum gillettii	120	87.4	34	+			
Cameroon	51	Salicaceae	Homalium longistylum	51	63.2	34	+			
Cameroon	51	Sapotaceae	Lecomtedoxa klaineana	142	185.0	34	(+)	+		
Cameroon	51	Vochysiaceae	Erismadelphus exsul	58	85.0	34	+			
Dem. Rep. Congo	52	Apocynaceae	Alstonia boonei	42	116.3	34	+			
Dem. Rep. Congo	52	Fabaceae	Anthonotha macrophylla	41	60.1	34	(+)			
Dem. Rep. Congo	52	Fabaceae	Cynometra alexandri	1311	123.3	34	+	+		
Dem. Rep. Congo	52	Fabaceae	Erythrophleum suaveolens	101	112.9	34	(-)	+		
Dem. Rep. Congo	52	Fabaceae	Gilbertiodendron dewevrei	3492	142.3	34	+	+	+	
Dem. Rep. Congo	52	Fabaceae	Julbernardia seretii	988	122.3	34	+	+		

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
Dem. Rep. Congo	52	Malvaceae	<i>Cola lateritia</i>	186	67.7	34	+	+		
Dem. Rep. Congo	52	Phyllanthaceae	<i>Cleistanthus michelsonii</i>	197	88.0	34	+	+		
Dem. Rep. Congo	52	Rhizophoraceae	<i>Comiphyton gabonense</i>	44	75.2	34	+			
Dem. Rep. Congo	52	Rubiaceae	<i>Hallea stipulosa</i>	88	84.0	34	(+)	+		
Dem. Rep. Congo	52	Rubiaceae	<i>Sarcocephalus pobeginii</i>	47	76.8	34	+			
China	53	Betulaceae	<i>Betula platyphylla</i>	90	46.4	54,55	+	+		
China	53	Fagaceae	<i>Quercus mongolica</i>	770	104.2	54,55	+	+		
China	53	Malvaceae	<i>Tilia amurensis</i>	2185	104.4	54,55	+	+		
China	53	Malvaceae	<i>Tilia mandshurica</i>	142	76.5	54,55	(+)			
China	53	Oleaceae	<i>Fraxinus mandshurica</i>	648	100.3	54,55	(+)	+	+	(-)
China	53	Pinaceae	<i>Pinus koraiensis</i>	2387	98.5	54,55	(-)	+	+	(-)
China	53	Rosaceae	<i>Malus baccata</i>	50	48.3	54,55	(+)			
China	53	Sapindaceae	<i>Acer mono</i>	1625	61.0	54,55	(+)	+		
China	53	Ulmaceae	<i>Ulmus japonica</i>	395	100.1	54,55	+	+	+	
Malaysia	56	Anacardiaceae	<i>Gluta laxiflora</i>	458	50.9	34	+			
Malaysia	56	Anacardiaceae	<i>Gluta macrocarpa</i>	168	80.5	34	+	+		
Malaysia	56	Anacardiaceae	<i>Gluta wallichii</i>	72	97.4	34	+	+	(+)	
Malaysia	56	Anacardiaceae	<i>Gluta woodsiana</i>	78	80.2	34	+			
Malaysia	56	Anacardiaceae	<i>Mangifera foetida</i>	81	62.0	34	+			
Malaysia	56	Anacardiaceae	<i>Mangifera parvifolia</i>	293	50.8	34	(+)	+		
Malaysia	56	Anacardiaceae	<i>Swintonia foxworthyi</i>	62	66.5	34	+			
Malaysia	56	Anacardiaceae	<i>Swintonia schwenkii</i>	211	86.1	34	(+)	+		
Malaysia	56	Burseraceae	<i>Canarium pseudopatienti-nervium</i>	54	69.9	34	(+)			
Malaysia	56	Burseraceae	<i>Dacryodes aff. incurvata</i>	161	54.7	34	+			
Malaysia	56	Burseraceae	<i>Dacryodes expansa</i>	507	49.6	34	+			
Malaysia	56	Burseraceae	<i>Dacryodes incurvata</i>	90	64.2	34	+			
Malaysia	56	Burseraceae	<i>Dacryodes rostrata</i>	403	51.6	34	+			
Malaysia	56	Burseraceae	<i>Santiria grandiflora</i>	51	68.0	34	+	+		
Malaysia	56	Burseraceae	<i>Santiria laevigata</i>	263	64.5	34	+	+		
Malaysia	56	Burseraceae	<i>Santiria mollis</i>	81	65.8	34	+			
Malaysia	56	Burseraceae	<i>Santiria rubiginosa</i>	44	89.6	34	+			
Malaysia	56	Burseraceae	<i>Santiria tomentosa</i>	128	62.8	34	(+)	(+)	(+)	(+)
Malaysia	56	Clusiaceae	<i>Calophyllum soulattri</i>	40	95.4	34	(+)	+		
Malaysia	56	Clusiaceae	<i>Garcinia caudiculata</i>	54	58.9	34	+			
Malaysia	56	Clusiaceae	<i>Kayea macrantha</i>	80	46.8	34	+			
Malaysia	56	Crypteroniaceae	<i>Crypteronia macrophylla</i>	105	48.2	34	(+)			
Malaysia	56	Ctenolophonaceae	<i>Ctenolophon parvifolius</i>	74	82.6	34	(+)	+		
Malaysia	56	Dipterocarpaceae	<i>Cotylelobium melanoxylon</i>	48	85.1	34	(+)	+		

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
Malaysia	56	Dipterocarpaceae	Dipterocarpus confertus	47	137.0	34	+	+		
Malaysia	56	Dipterocarpaceae	Dipterocarpus crinitus	51	125.5	34	(+)	+	+	
Malaysia	56	Dipterocarpaceae	Dipterocarpus geniculatus	62	118.2	34	+	+		
Malaysia	56	Dipterocarpaceae	Dipterocarpus globosus	624	118.1	34	+	+		
Malaysia	56	Dipterocarpaceae	Dipterocarpus palembanicus subsp. borneensis	47	116.7	34	+			
Malaysia	56	Dipterocarpaceae	Dipterocarpus palembanicus subsp. palembanicus	43	93.2	34	(-)	+		
Malaysia	56	Dipterocarpaceae	Dryobalanops aromatica	705	144.4	34	+	+		
Malaysia	56	Dipterocarpaceae	Dryobalanops lanceolata	43	123.4	34	+	+		
Malaysia	56	Dipterocarpaceae	Parashorea parvifolia	58	124.5	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea acuta	361	79.5	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea amplexicaulis	146	87.4	34	+			
Malaysia	56	Dipterocarpaceae	Shorea beccariana	218	110.2	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea curtisii	67	136.7	34	+			
Malaysia	56	Dipterocarpaceae	Shorea falciferoides	70	141.4	34	+	+	+	
Malaysia	56	Dipterocarpaceae	Shorea kunstleri	104	127.8	34	(+)	+		
Malaysia	56	Dipterocarpaceae	Shorea laxa	375	114.1	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea macroptera subsp. baillonii	136	97.3	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea macroptera subsp. macropterifolia	131	74.0	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea ovata	57	81.1	34	+			
Malaysia	56	Dipterocarpaceae	Shorea parvifolia	126	126.3	34	+			
Malaysia	56	Dipterocarpaceae	Shorea quadrinervis	110	69.2	34	+			
Malaysia	56	Dipterocarpaceae	Shorea rubella	53	125.7	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea scaberrima	56	125.5	34	+	+		
Malaysia	56	Dipterocarpaceae	Shorea scrobiculata	76	97.6	34	+	+	(+)	
Malaysia	56	Dipterocarpaceae	Shorea smithiana	129	130.0	34	+	+	+	
Malaysia	56	Dipterocarpaceae	Vatica badiifolia	80	81.1	34	(+)	+		
Malaysia	56	Ebenaceae	Diospyros diepenhorstii	132	58.7	34	+			
Malaysia	56	Euphorbiaceae	Chaetocarpus castanocarpus	174	48.0	34	+			
Malaysia	56	Euphorbiaceae	Elatiospermum tapos	449	51.0	34	+			
Malaysia	56	Fabaceae	Dialium indum	98	72.0	34	+			
Malaysia	56	Fabaceae	Koompassia malaccensis	68	103.0	34	+			
Malaysia	56	Fabaceae	Millettia vasta	44	79.1	34	+			
Malaysia	56	Ixonanthaceae	Allantospermum borneense	714	58.0	34	+	+		
Malaysia	56	Kiggelariaceae	Hydnocarpus pinguis	87	46.6	34	(-)	+		

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
Malaysia	56	Kiggelariaceae	Hydnocarpus woodii	62	71.0	34	+			
Malaysia	56	Lauraceae	Alseodaphne bancana	110	85.0	34	+			
Malaysia	56	Lauraceae	Alseodaphne insignis	115	98.0	34	(-)	(+)	(+)	
Malaysia	56	Malvaceae	Durio acutifolius	71	71.0	34	+			
Malaysia	56	Malvaceae	Durio crassipes	66	104.3	34	+			
Malaysia	56	Malvaceae	Pentace adenophora	82	88.1	34	(+)	+		
Malaysia	56	Moraceae	Artocarpus anisophyllus	116	52.5	34	+			
Malaysia	56	Moraceae	Artocarpus nitidus	89	46.0	34	+			
Malaysia	56	Myristicaceae	Myristica villosa	77	45.8	34	+			
Malaysia	56	Myrtaceae	Cleistocalyx cf. barringtonioides	70	67.2	34	+			
Malaysia	56	Myrtaceae	Syzygium cf. attenuatum	62	65.0	34	+			
Malaysia	56	Myrtaceae	Syzygium cf. grande	221	62.0	34	+			
Malaysia	56	Myrtaceae	Syzygium sp. incert. c	41	75.4	34	(-)	+		
Malaysia	56	Myrtaceae	Whiteodendron moultonianum	576	70.7	34	+			
Malaysia	56	Oxalidaceae	Sarcotheca diversifolia	47	50.9	34	+			
Malaysia	56	Rutaceae	Melicope glabra	58	54.2	34	+			
Malaysia	56	Sapotaceae	Palaquium microphyllum	91	62.7	34	+			
Malaysia	56	Verbenaceae	Teijsmanniodendron simplicifolium	281	60.2	34	+			
Taiwan	57	Anacardiaceae	Rhus succedanea	61	54.0	34	+			
Taiwan	57	Araliaceae	Schefflera octophylla	472	84.1	34	+			
Taiwan	57	Ebenaceae	Diospyros morrisiana	492	60.9	34	+	+		
Taiwan	57	Elaeocarpaceae	Elaeocarpus japonicus	375	72.4	34	(+)	+	+	
Taiwan	57	Fagaceae	Castanopsis cuspidata	1311	99.0	34	+	+	-	
Taiwan	57	Fagaceae	Cyclobalanopsis gilva	118	88.4	34	+			
Taiwan	57	Fagaceae	Cyclobalanopsis longinux	246	52.9	34	+			
Taiwan	57	Fagaceae	Limlia uraiana	1108	171.5	34	(+)	+		
Taiwan	57	Fagaceae	Lithocarpus harlandii	49	59.2	34	+			
Taiwan	57	Juglandaceae	Engelhardia roxburghiana	561	93.3	34	+	+	+	
Taiwan	57	Lauraceae	Cinnamomum micranthum	204	90.6	34	+			
Taiwan	57	Lauraceae	Litsea acuminata	986	67.5	34	+	+	(+)	
Taiwan	57	Lauraceae	Machilus thunbergii	1223	90.0	34	(+)	+		
Taiwan	57	Lauraceae	Machilus zuihoensis	613	79.5	34	+	-		
Taiwan	57	Lythraceae	Lagerstroemia subcostata	83	48.0	34	(+)			
Taiwan	57	Phyllanthaceae	Glochidion acuminatum	394	39.6	34	+			
Taiwan	57	Sabiaceae	Meliosma squamulata	1814	74.8	34	+	+		



Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
Taiwan	57	Theaceae	Pyrenaria shinkoensis	1679	43.3	34	+	+	+	
Thailand	58	Anacardiaceae	Gluta obovata	172	90.8	34	+	+		
Thailand	58	Annonaceae	Alphonsea ventricosa	566	71.7	34	+			
Thailand	58	Annonaceae	Polyalthia viridis	2207	46.4	34	+			
Thailand	58	Annonaceae	Saccopetalum lineatum	999	114.6	34	+	+	+	
Thailand	58	Burseraceae	Garuga pinnata	53	87.4	34	+			
Thailand	58	Clusiaceae	Garcinia speciosa	454	68.9	34	+			
Thailand	58	Datisceae	Tetrameles nudiflora	205	219.4	34	(+)	+		
Thailand	58	Dipterocarpaceae	Anisoptera costata	75	138.1	34	+	+		
Thailand	58	Dipterocarpaceae	Dipterocarpus alatus	195	149.2	34	(+)	+		
Thailand	58	Dipterocarpaceae	Hopea odorata	182	189.9	34	+	+		
Thailand	58	Dipterocarpaceae	Vatica harmandiana	692	126.8	34	+	+		
Thailand	58	Ebenaceae	Diospyros variegata	381	74.8	34	+	+		
Thailand	58	Ebenaceae	Diospyros winitii	786	45.0	34	+			
Thailand	58	Euphorbiaceae	Macaranga siamensis	90	52.0	34	+			
Thailand	58	Euphorbiaceae	Mallotus philippensis	121	51.4	34	+			
Thailand	58	Euphorbiaceae	Trewia nudiflora	159	61.7	34	+			
Thailand	58	Irvingiaceae	Irvingia malayana	95	113.0	34	+	+		
Thailand	58	Lamiaceae	Vitex peduncularis	54	71.8	34	+			
Thailand	58	Lauraceae	Neolitsea obtusifolia	500	66.6	34	+	+		
Thailand	58	Lauraceae	Persea sp.	138	63.9	34	+			
Thailand	58	Lythraceae	Lagerstroemia tomentosa	188	137.6	34	+	+		
Thailand	58	Malvaceae	Pterospermum grandiflorum	118	65.1	34	+			
Thailand	58	Meliaceae	Aglaia spectabilis	110	67.2	34	(-)	+	+	
Thailand	58	Meliaceae	Aphanamixis polystachya	71	76.9	34	+			
Thailand	58	Meliaceae	Chukrassia tabularis	96	87.0	34	(+)	+		
Thailand	58	Meliaceae	Dysoxylum grande	72	39.3	34	+			
Thailand	58	Myrtaceae	Syzygium syzgioides	75	68.0	34	+			
Thailand	58	Phyllanthaceae	Baccaurea ramiflora	907	41.4	34	+			
Thailand	58	Polygalaceae	Xanthophyllum flavescens	88	56.7	34	+			
Thailand	58	Sapindaceae	Acer oblongum	175	131.4	34	(+)	+		
Thailand	58	Sapindaceae	Arytera littoralis	818	42.5	34	(-)	+		
Thailand	58	Sapindaceae	Dimocarpus longan	999	92.2	34	+	+		
Thailand	58	Sapindaceae	Harpullia arborea	186	48.6	34	+	-		
New Zealand	59	Cunoniaceae	Weinmannia racemosa	9277	173.8	60	+	+	+	
New Zealand	59	Cupressaceae	Libocedrus bidwillii	56	83.2	60	+			
New Zealand	59	Elaeocarpaceae	Elaeocarpus dentatus	56	85.4	60	+			
New Zealand	59	Elaeocarpaceae	Elaeocarpus hookerianus	91	95.0	60	(-)	+		

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New Zealand	59	Escalloniaceae	<i>Carpodetus serratus</i>	628	48.3	60	+			
New Zealand	59	Escalloniaceae	<i>Ixerba excelsa</i>	98	58.8	60	+			
New Zealand	59	Escalloniaceae	<i>Quintinia acutifolia</i>	368	39.8	60	+			
New Zealand	59	Fagaceae	<i>Nothofagus fusca</i>	2381	203.5	60	+	+	+	-
New Zealand	59	Fagaceae	<i>Nothofagus menziesii</i>	6855	158.0	60	+	+	+	+
New Zealand	59	Fagaceae	<i>Nothofagus solandri</i>	17595	121.0	60	+	+	+	+
New Zealand	59	Fagaceae	<i>Nothofagus truncata</i>	89	124.5	60	+			
New Zealand	59	Griselinaceae	<i>Griselinia littoralis</i>	1636	106.3	60	+	+		
New Zealand	59	Lauraceae	<i>Beilschmiedia tawa</i>	304	95.0	60	+			
New Zealand	59	Myrtaceae	<i>Kunzea ericoides</i>	599	78.4	60	(+)	+	+	
New Zealand	59	Myrtaceae	<i>Metrosideros umbellata</i>	1196	267.5	60	+	+		
New Zealand	59	Onagraceae	<i>Fuchsia excorticata</i>	241	66.5	60	+	+		
New Zealand	59	Podocarpaceae	<i>Dacrydium cupressinum</i>	860	193.0	60	+	+	+	
New Zealand	59	Podocarpaceae	<i>Podocarpus hallii</i>	1277	147.7	60	(+)	+		
New Zealand	59	Podocarpaceae	<i>Prumnopitys ferruginea</i>	444	90.5	60	+			
New Zealand	59	Podocarpaceae	<i>Prumnopitys taxifolia</i>	72	65.7	60	+			
New Zealand	59	Proteaceae	<i>Knightia excelsa</i>	175	90.5	60	+	+		
New Zealand	59	Violaceae	<i>Melicytus ramiflorus</i>	1120	138	60	+			
Argentina	61	Anacardiaceae	<i>Astronium urundeuva</i>	212	90.0	34	+	+		
Argentina	61	Betulaceae	<i>Alnus acuminata</i>	145	66.2	34	+			
Argentina	61	Bignoniaceae	<i>Tabebuia impetiginosa</i>	107	62.3	34	+	+		
Argentina	61	Boraginaceae	<i>Cordia trichotoma</i>	100	54.6	34	+			
Argentina	61	Boraginaceae	<i>Patagonula americana</i>	277	77.5	34	+	+		
Argentina	61	Caprifoliaceae	<i>Sambucus nigra</i>	102	50.6	34	(+)			
Argentina	61	Combretaceae	<i>Terminalia triflora</i>	371	85.4	34	+			
Argentina	61	Elaeocarpaceae	<i>Crinodendron tucumanum</i>	175	113.4	34	+	+	(-)	
Argentina	61	Fabaceae	<i>Anadenanthera colubrina</i>	616	127.0	34	+	+		
Argentina	61	Fabaceae	<i>Gleditsia amorphoides</i>	181	45.0	34	+			
Argentina	61	Fabaceae	<i>Myroxylon peruiferum</i>	68	64.0	34	+			
Argentina	61	Fabaceae	<i>Parapiptadenia excelsa</i>	499	89.2	34	(-)	+		
Argentina	61	Fabaceae	<i>Tipuana tipu</i>	46	152.2	34	+	+		
Argentina	61	Juglandaceae	<i>Juglans australis</i>	98	56.7	34	+			
Argentina	61	Lauraceae	<i>Cinnamomum porphyrium</i>	627	174.5	34	+			
Argentina	61	Lauraceae	<i>Ocotea puberula</i>	318	82.5	34	+			
Argentina	61	Malvaceae	<i>Ceiba insignis</i>	78	95.5	34	(+)			

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Argentina	61	Malvaceae	<i>Heliocarpus popayanensis</i>	56	55.7	34	+			
Argentina	61	Meliaceae	<i>Cedrela balansae</i>	69	100.5	34	+			
Argentina	61	Meliaceae	<i>Cedrela lilloi</i>	75	82.8	34	(-)	+		
Argentina	61	Moraceae	<i>Morus alba</i>	179	76.1	34	(+)	+	(+)	(+)
Argentina	61	Myrtaceae	<i>Blepharocalyx salicifolius</i>	174	132.5	34	(+)	+	+	
Argentina	61	Myrtaceae	<i>Myrcianthes pungens</i>	516	72.6	34	+			
Argentina	61	Nyctaginaceae	<i>Pisonia zapallo</i>	365	84.7	34	+			
Argentina	61	Podocarpaceae	<i>Podocarpus parlatorei</i>	299	151.9	34	+	+		
Argentina	61	Polygonaceae	<i>Ruprechtia laxiflora</i>	93	104.8	34	+	+		
Argentina	61	Primulaceae	<i>Myrsine laetevirens</i>	149	134.4	34	+			
Argentina	61	Rhamnaceae	<i>Phyllostylon rhamnoides</i>	441	88.2	34	+	+		
Argentina	61	Rubiaceae	<i>Callycophyllum multiflorum</i>	287	83.7	34	(-)	+		
Argentina	61	Sapindaceae	<i>Cupanea vernalis</i>	128	57.5	34	+			
Argentina	61	Sapindaceae	<i>Diatenopterix sorbifolia</i>	291	54.9	34	(+)	+		
Argentina	61	Sapotaceae	<i>Chrysophyllum gonocarpum</i>	172	75.0	34	+	+		
Colombia	62	Anacardiaceae	<i>Astronium graveolens</i>	290	50.2	63	(+)	+		
Colombia	62	Burseraceae	<i>Bursera simaruba</i>	186	64.9	63	+			
Colombia	62	Dipterocarpaceae	<i>Pseudomonotes tropenbosii</i>	58	72.9	63	+			
Colombia	62	Euphorbiaceae	<i>Croton magdalenensis</i>	52	52.0	63	+			
Colombia	62	Fagaceae	<i>Quercus humboldtii</i>	509	92.5	63	+	+	-	
Colombia	62	Lecythidaceae	<i>Eschweilera punctata</i>	115	69.7	63	+			
Colombia	62	Moraceae	<i>Brosimum utile</i>	115	97.1	63	+			
Panama	64	Anacardiaceae	<i>Spondias radlkoferi</i>	57	93.9	34	(+)	+		
Panama	64	Annonaceae	<i>Guatteria dumetorum</i>	160	67.3	34	(-)	+		
Panama	64	Apocynaceae	<i>Aspidosperma spruceanum</i>	50	111.2	34	+	+		
Panama	64	Apocynaceae	<i>Tabernaemontana arborea</i>	292	82.7	34	+			
Panama	64	Araliaceae	<i>Dendropanax arboreus</i>	64	66.9	34	+	+		
Panama	64	Bignoniaceae	<i>Jacaranda copaia</i>	205	91.6	34	+			
Panama	64	Bignoniaceae	<i>Tabebuia rosea</i>	55	82.5	34	+			
Panama	64	Boraginaceae	<i>Cordia alliodora</i>	49	64.2	34	+			
Panama	64	Boraginaceae	<i>Cordia bicolor</i>	289	45.8	34	+			
Panama	64	Burseraceae	<i>Protium tenuifolium</i>	331	46.3	34	+			
Panama	64	Burseraceae	<i>Tetragastris panamensis</i>	356	74.2	34	+			
Panama	64	Chrysobalanaceae	<i>Hirtella triandra</i>	646	41.0	34	+			
Panama	64	Erythralaceae	<i>Heisteria concinna</i>	255	38.0	34	+			
Panama	64	Euphorbiaceae	<i>Alchornea costaricensis</i>	87	60.3	34	(+)			
Panama	64	Euphorbiaceae	<i>Hura crepitans</i>	87	246.8	34	(-)	+	+	
Panama	64	Fabaceae	<i>Lonchocarpus heptaphyllus</i>	86	55.7	34	+			
Panama	64	Fabaceae	<i>Prioria copaifera</i>	319	136.9	34	+	+		

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
Panama	64	Fabaceae	Tachigali versicolor	78	63.2	34	(+)	+	+	
Panama	64	Lauraceae	Beilschmiedia pendula	228	79.2	34	+	+		
Panama	64	Lauraceae	Ocotea whitei	97	82.7	34	+			
Panama	64	Lecythidaceae	Gustavia superba	547	44.8	34	+			
Panama	64	Malvaceae	Apeiba membranacea	174	114.3	34	+			
Panama	64	Malvaceae	Luehea seemannii	62	113.9	34	+			
Panama	64	Malvaceae	Quararibea asterolepis	525	92.5	34	+			
Panama	64	Meliaceae	Guarea guidonia	296	44.5	34	+			
Panama	64	Meliaceae	Trichilia tuberculata	1306	64.3	34	+	+		
Panama	64	Moraceae	Brosimum alicastrum	162	129.5	34	(-)	+		
Panama	64	Moraceae	Poulsenia armata	480	80.0	34	+			
Panama	64	Myristicaceae	Virola sebifera	495	42.3	34	+			
Panama	64	Myristicaceae	Virola surinamensis	107	88.5	34	(-)	+		
Panama	64	Nyctaginaceae	Guapira standleyana	78	108.7	34	+			
Panama	64	Putranjivaceae	Drypetes standleyi	276	60.6	34	+	+		
Panama	64	Rubiaceae	Alseis blackiana	881	89.2	34	(+)	+	+	
Panama	64	Rutaceae	Zanthoxylum ekmanii	111	67.4	34	+			
Panama	64	Salicaceae	Casearia arborea	69	54.7	34	+			
Panama	64	Sapotaceae	Pouteria reticulata	169	85.0	34	(+)	+		
Panama	64	Simaroubaceae	Simarouba amara	207	76.7	34	+	+		
Panama	64	Urticaceae	Cecropia insignis	155	56.2	34	+			
Spain	65,66	Aquifoliaceae	Ilex aquifolium	295	51.6	65,66	+			
Spain	65,66	Aquifoliaceae	Ilex canariensis	272	71.6	65,66	+			
Spain	65,66	Betulaceae	Alnus glutinosa	1177	118.4	65,66	+	+	+	
Spain	65,66	Betulaceae	Betula spp.	2343	79.6	65,66	+	+		
Spain	65,66	Cupressaceae	Chamaecyparis lawsoniana	724	50.4	65,66	+	+	+	
Spain	65,66	Cupressaceae	Juniperus communis	684	75.8	65,66	+	+		
Spain	65,66	Cupressaceae	Juniperus thurifera	5900	127.3	65,66	+	+	+	
Spain	65,66	Fagaceae	Castanea sativa	4775	240.6	65,66	(+)	+	+	-
Spain	65,66	Fagaceae	Fagus sylvatica	20676	164.9	65,66	+	+	+	(+)
Spain	65,66	Fagaceae	Quercus ilex	40451	141.6	65,66	+	+	+	-
Spain	65,66	Fagaceae	Quercus petraea	5145	187.8	65,66	(-)	+	+	
Spain	65,66	Fagaceae	Quercus pyrenaica	20466	172.4	65,66	(+)	+	+	(+)
Spain	65,66	Fagaceae	Quercus robur	8866	146.4	65,66	(-)	+	+	-
Spain	65,66	Fagaceae	Quercus suber	10907	146.5	65,66	-	+	+	+
Spain	65,66	Juglandaceae	Juglans regia	68	77.0	65,66	(+)			
Spain	65,66	Lauraceae	Persea indica	201	105.0	65,66	+			
Spain	65,66	Malvaceae	Tilia spp.	97	79.9	65,66	+			
Spain	65,66	Myricaceae	Myrica faya	786	108.2	65,66	+	+	+	
Spain	65,66	Myrtaceae	Eucalyptus camaldulensis	1189	89.1	65,66	-	+	+	+
Spain	65,66	Myrtaceae	Eucalyptus globulus	3465	117.8	65,66	-	+	+	+
Spain	65,66	Myrtaceae	Eucalyptus nitens	189	101.2	65,66	(+)	+		
Spain	65,66	Oleaceae	Olea europaea	389	81.2	65,66	(+)	-	+	
Spain	65,66	Pinaceae	Abies alba	2276	140.1	65,66	(+)	+		
Spain	65,66	Pinaceae	Larix spp.	794	47.9	65,66	(-)	(+)	+	+
Spain	65,66	Pinaceae	Picea abies	94	75.4	65,66	(-)	+		
Spain	65,66	Pinaceae	Pinus canariensis	16044	174.0	65,66	+	+	+	

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
Spain	65,66	Pinaceae	Pinus halepensis	43615	102.8	65,66	(+)	+	+	+
Spain	65,66	Pinaceae	Pinus nigra	44291	95.5	65,66	+	+	+	+
Spain	65,66	Pinaceae	Pinus pinaster	76024	96.4	65,66	+	+	+	+
Spain	65,66	Pinaceae	Pinus pinea	14112	130.5	65,66	+	+	+	-
Spain	65,66	Pinaceae	Pinus radiata	11331	90.7	65,66	(-)	+	+	+
Spain	65,66	Pinaceae	Pinus sylvestris	87225	128.3	65,66	+	+	+	+
Spain	65,66	Pinaceae	Pinus uncinata	10735	127.3	65,66	-	+		
Spain	65,66	Rosaceae	Prunus spp.	223	49.3	65,66	(+)	+		
Spain	65,66	Rosaceae	Sorbus spp.	327	65.3	65,66	(-)	(+)		
Spain	65,66	Salicaceae	Populus alba	209	91.7	65,66	(-)	+		
Spain	65,66	Salicaceae	Populus nigra	1189	101.9	65,66	(-)	+		
Spain	65,66	Salicaceae	Populus tremula	454	90.5	65,66	+			
Spain	65,66	Salicaceae	Salix spp.	636	105.0	65,66	(-)	+	(+)	
Spain	65,66	Sapindaceae	Acer campestre	1091	89.1	65,66	(+)	+		
Spain	65,66	Taxaceae	Taxus baccata	40	107.6	65,66	(-)	+		
Spain	65,66	Ulmaceae	Ulmus minor	114	111.4	65,66	+			
United States (east)	67	Betulaceae	Betula alleghaniensis	1245	102.4	17	(+)	+		
United States (east)	67	Betulaceae	Betula lenta	244	60.2	17	+			
United States (east)	67	Betulaceae	Betula nigra	212	81.0	17	+	+		
United States (east)	67	Betulaceae	Betula papyrifera	1506	63.0	17	+	+	+	
United States (east)	67	Cornaceae	Nyssa aquatica	53	101.1	17	-			
United States (east)	67	Cornaceae	Nyssa sylvatica	682	75.7	17	+			
United States (east)	67	Cupressaceae	Juniperus virginiana	800	60.7	17	(-)	+		
United States (east)	67	Cupressaceae	Thuja occidentalis	4337	80.8	17	+	+		
United States (east)	67	Fabaceae	Gleditsia triacanthos	304	103.9	17	+	+		
United States (east)	67	Fabaceae	Robinia psuedoacacia	443	64.8	17	+	+		
United States (east)	67	Fagaceae	Fagus grandifolia	2130	109.5	17	+	+	+	
United States (east)	67	Fagaceae	Quercus alba	6583	127.8	17	(+)	+	+	+
United States (east)	67	Fagaceae	Quercus bicolor	210	100.6	17	+	+		
United States (east)	67	Fagaceae	Quercus coccinea	878	68.1	17	-	+	+	+
United States (east)	67	Fagaceae	Quercus ellipsoidalis	226	76.7	17	+	+	+	

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
United States (east)	67	Fagaceae	<i>Quercus falcata</i> var. <i>falcata</i>	249	100.1	17	+	+		
United States (east)	67	Fagaceae	<i>Quercus falcata</i> var. <i>pagodaefolia</i>	60	80.8	17	(-)	+		
United States (east)	67	Fagaceae	<i>Quercus imbricaria</i>	310	72.1	17	-	+	+	
United States (east)	67	Fagaceae	<i>Quercus macrocarpa</i>	224	116.8	17	+	+		
United States (east)	67	Fagaceae	<i>Quercus michauxii</i>	45	107.7	17	+	+		
United States (east)	67	Fagaceae	<i>Quercus muehlenbergii</i>	439	94.5	17	(+)	+	+	+
United States (east)	67	Fagaceae	<i>Quercus palustris</i>	584	138.7	17	(+)	+	+	
United States (east)	67	Fagaceae	<i>Quercus prinus</i>	1900	93.7	17	+	+	+	+
United States (east)	67	Fagaceae	<i>Quercus rubra</i>	4477	157.7	17	+	+	+	
United States (east)	67	Fagaceae	<i>Quercus shumardii</i>	62	104.9	17	+			
United States (east)	67	Fagaceae	<i>Quercus stellata</i>	711	74.4	17	+	+	+	
United States (east)	67	Fagaceae	<i>Quercus velutina</i>	3867	104.4	17	+	+	+	+
United States (east)	67	Hamamelidaceae	<i>Liquidambar styraciflua</i>	777	72.6	17	(+)	+		
United States (east)	67	Juglandaceae	<i>Carya cordiformis</i>	774	81.0	17	+	+		
United States (east)	67	Juglandaceae	<i>Carya glabra</i>	2060	95.8	17	(+)	+	+	
United States (east)	67	Juglandaceae	<i>Carya laciniosa</i>	74	68.3	17	+			
United States (east)	67	Juglandaceae	<i>Carya ovata</i>	1602	82.6	17	(-)	+	+	
United States (east)	67	Juglandaceae	<i>Carya tomentosa</i>	975	93.5	17	+	+		
United States (east)	67	Juglandaceae	<i>Juglans nigra</i>	1108	82.6	17	-	+	+	+
United States (east)	67	Lauraceae	<i>Sassafras albidum</i>	895	75.7	17	+	+	+	(+)
United States (east)	67	Magnoliaceae	<i>Liriodendron tulipifera</i>	3239	117.1	17	-	+	+	+

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
United States (east)	67	Magnoliaceae	<i>Magnolia acuminata</i>	98	55.1	17	+			
United States (east)	67	Malvaceae	<i>Tilia americana</i>	1571	122.7	17	+	+	+	
United States (east)	67	Moraceae	<i>Maclura pomifera</i>	174	61.7	17	+	+		
United States (east)	67	Oleaceae	<i>Fraxinus americana</i>	2354	137.2	17	-	+	+	+
United States (east)	67	Oleaceae	<i>Fraxinus nigra</i>	712	58.2	17	+	+		
United States (east)	67	Oleaceae	<i>Fraxinus pennsylvanica</i>	906	115.6	17	+	+		
United States (east)	67	Pinaceae	<i>Abies balsamea</i>	1227	40.1	17	+			
United States (east)	67	Pinaceae	<i>Larix laricina</i>	646	57.2	17	+	+		
United States (east)	67	Pinaceae	<i>Picea glauca</i>	759	73.9	17	(+)	+		
United States (east)	67	Pinaceae	<i>Picea mariana</i>	1124	49.8	17	+	+		
United States (east)	67	Pinaceae	<i>Picea rubens</i>	412	46.5	17	+			
United States (east)	67	Pinaceae	<i>Pinus banksiana</i>	1245	47.5	17	+	+		
United States (east)	67	Pinaceae	<i>Pinus echinata</i>	596	71.4	17	(-)	+		
United States (east)	67	Pinaceae	<i>Pinus resinosa</i>	2173	65.5	17	(-)	+	+	+
United States (east)	67	Pinaceae	<i>Pinus rigida</i>	299	46.2	17	+	+		
United States (east)	67	Pinaceae	<i>Pinus strobus</i>	2728	108.0	17	+	+		
United States (east)	67	Pinaceae	<i>Pinus taeda</i>	597	58.2	17	(+)	+		
United States (east)	67	Pinaceae	<i>Pinus virginiana</i>	921	55.4	17	+	+		
United States (east)	67	Pinaceae	<i>Tsuga canadensis</i>	2071	100.1	17	+	+	+	
United States (east)	67	Platanaceae	<i>Platanus occidentalis</i>	1073	133.9	17	-	+	+	
United States (east)	67	Rosaceae	<i>Prunus serotina</i>	1532	88.9	17	+	+	+	

Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
United States (east)	67	Salicaceae	<i>Populus balsamifera</i>	381	82.8	17	+	+	+	
United States (east)	67	Salicaceae	<i>Populus deltoides</i>	648	147.1	17	-	+		
United States (east)	67	Salicaceae	<i>Populus grandidentata</i>	1242	66.5	17	+	+		
United States (east)	67	Salicaceae	<i>Populus tremuloides</i>	2270	62.5	17	+	+	+	
United States (east)	67	Salicaceae	<i>Salix nigra</i>	164	88.4	17	+			
United States (east)	67	Sapindaceae	<i>Acer negundo</i>	417	100.8	17	+	+		
United States (east)	67	Sapindaceae	<i>Acer rubrum</i>	7448	124.0	17	+	+	+	+
United States (east)	67	Sapindaceae	<i>Acer saccharinum</i>	1386	121.2	17	(+)	+	+	+
United States (east)	67	Sapindaceae	<i>Acer saccharum</i>	8681	113.3	17	+	+	+	
United States (east)	67	Sapindaceae	<i>Aesculus glabra</i>	85	61.7	17	(+)	+		
United States (east)	67	Ulmaceae	<i>Celtis occidentalis</i>	552	130.6	17	(+)	+	+	(+)
United States (east)	67	Ulmaceae	<i>Ulmus americana</i>	884	72.4	17	+	+		
United States (east)	67	Ulmaceae	<i>Ulmus rubra</i>	415	72.9	17	(+)	+	+	
United States (west)	68,69	Cupressaceae	<i>Calocedrus decurrens</i>	1587	176.0	17	(+)	+	+	+
United States (west)	68,69	Cupressaceae	<i>Chamaecyparis nootkatensis</i>	572	210.0	17	+	+	+	
United States (west)	68,69	Cupressaceae	<i>Thuja plicata</i>	284	240.7	17	+	+		
United States (west)	68,69	Fagaceae	<i>Quercus kelloggii</i>	422	97.8	17	(+)	+		
United States (west)	68,69	Pinaceae	<i>Abies amabilis</i>	2595	124.7	17	+	+	+	(+)
United States (west)	68,69	Pinaceae	<i>Abies concolor</i>	3248	166.8	17	+	+	+	
United States (west)	68,69	Pinaceae	<i>Abies magnifica</i>	1644	249.7	17	+	+	+	+
United States (west)	68,69	Pinaceae	<i>Abies procera</i>	205	230.2	17	+	+		



Country	Data ref.	Family	Species	# of trees	Max. tree diam. (cm)	Allom. ref.	Bin 1	Bin 2	Bin 3	Bin 4
United States (west)	68,69	Pinaceae	<i>Picea sitchensis</i>	409	270.5	17	+	+	(+)	+
United States (west)	68,69	Pinaceae	<i>Pinus albicaulis</i>	550	41.8	17	+			
United States (west)	68,69	Pinaceae	<i>Pinus balfouriana</i>	152	153.0	17	(+)			
United States (west)	68,69	Pinaceae	<i>Pinus contorta</i>	155	70.0	17	(+)	+		
United States (west)	68,69	Pinaceae	<i>Pinus jeffreyi</i>	99	136.6	17	+			
United States (west)	68,69	Pinaceae	<i>Pinus lambertiana</i>	564	196.9	17	+	+	+	+
United States (west)	68,69	Pinaceae	<i>Pinus monticola</i>	215	234.2	17	+	+	+	
United States (west)	68,69	Pinaceae	<i>Pinus ponderosa</i>	2191	175.5	17	+	+	+	
United States (west)	68,69	Pinaceae	<i>Pseudotsuga menziesii</i>	744	225.6	17	(+)	+	+	+
United States (west)	68,69	Pinaceae	<i>Tsuga heterophylla</i>	2253	190.8	17	+	+	+	+
United States (west)	68,69	Pinaceae	<i>Tsuga mertensiana</i>	188	115.1	17	(+)	+		

**Data ref.** = publication(s) describing our data source for each species; **Allom. ref.** = publication(s) from which we obtained allometric equations for each species. A “+” or “-” symbol in a numbered **Bin** column indicates that the model receiving the greatest weight of evidence by AIC included that bin (line segment); for example, a species having a symbol under **Bin 1** and **Bin 2** but not under **Bin 3** and **Bin 4** was fit with two line segments. “+” indicates that the line segment had a positive slope (mass growth rate increased with tree size within the bin); “-” indicates a negative slope. Symbols without parentheses indicate that the slope for that bin for that particular species was significant at  $P \leq 0.05$ .

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