**Size-related scaling of tree form and function in a mixed-age forest**

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# Appendix S1 | Complete Methodology

*Dominant Species*

The stem abundance of the 15 most abundant canopy species (>0.25% of live stems) at SCBI—for which intraspecific allometries were calculated when possible—are listed in Table S1. Common understory species (>1% of live stems) include *Lindera benzoin* (L.) Blume (spicebush; 43% of live stems)*, Asimina triloba* (L.) Dunal(pawpaw; 11% of live stems)*, Carpinus caroliniana* Walter (American hornbeam; 8.8% of live stems), *Hamamelis virginiana* L.(witch hazel; 3.1% of live stems), and *Cercis canadensis* L.(eastern redbud; 1.9% of live stems)*.*

*Core Tree Census*

In 2008, a 26-ha CTFS-ForestGEO plot was established at SCBI following standardized protocol (Condit 1998); every freestanding woody stem ≥1 cm diameter at breast height (DBH) was mapped, tagged, and identified to species, and its diameter measured at breast height (1.3 m) or above stem irregularities. In 2013, as part of the first plot recensus, all stems tagged and mapped during the first inventory were revisited, their status recorded, and all new recruits were mapped and tagged following standard CTFS-ForestGEO protocols (Condit 1998).

*Tree Dimensions*

Tree heights (n=75) and crown dimensions (n=60) were measured in the summer of 2013. Previously, in the summer of 2012, tree height was measured on 158 trees randomly sampled within the SCBI plot representing three understory species (*Asimina triloba* (L.) Dunal, *Carpinus caroliniana* Walter, *Cercis occidentalis* L.) and eleven overstory species (*Ailanthus altissima* (Mill.) Swingle, *Carya* *cordiformis* (Wangenh.) K. Koch, *C. glabra* (Mill.) Sweet, *C. tomentosa* (L.) Nutt., *Juglans nigra* L., *Liriodendron tulipifera* L., *Nyssa sylvatica* Marshall, *Platanus occidentalis* L., *Prunus avium* (L.) L., *P. serotina* Ehrh., *Ulmus rubra* Muhl.). Tree height (*h*) and height to the base of the crown (*hcb*) were measured using an Impulse LR laser (Laser Technology, Inc., Norristown, PA). Crown dimensions and *h* were measured on all trees within sap flow subplots, with additional measurements on two species—*Fagus grandifolia* and *Liriodendron tulipifera*—were made on individuals randomly selected from throughout the plot to represent the range of tree sizes. Base of the crown was defined as the point below which no live branches were attached within five feet (*sensu* Forest Inventory and Analysis National Program 2005)*.* Crown depth was calculated as *h*- *hcb*. Crown diameter (*Dc*) measurements were taken in the north-south and east-west directions by stretching a measuring tape under the tree until edges of tree crowns were seen directly above when viewed perpendicularly from the length of the measuring tape. Assuming that crowns grow in the shape of an ellipsoid, crown area (*AC*) and volume (*VC*) were calculated using the formulas *AC* = π(*Dc,1* /2)×(*Dc,2* /2) and *VC*=4/3 *AC* (*ht*- *hcb*), respectively.

*Sapwood Area*

Calculation of sapwood area (*AS*), from DBH requires two measurements: (1) the sapwood radius (*rs*)—i.e., the distance from the cambium to the sapwood-heartwood boundary and (2) bark thickness (*rb*)—i.e., the average distance from the outer edge of the bark to the cambium. Scaling relationships for both variables were characterized for 15 common overstory tree species (at least 30 individuals greater than 10 cm DBH) in the 2008 census (Table S3).

To characterize scaling relationships for *rs,* 681 trees throughout the plot were cored, and “cookies” were taken from destructively harvested trees outside of the plot. Tree core sampling occurred in 2010 on the most common overstory trees species randomly distributed throughout the CTFS-ForestGEO grid. Sampled trees ranged from 5.1 cm to 136.6 cm DBH. One core was collected from each tree at 1.37 m from mid-slope. Cores were mounted on wood blocks and sanded. When a clear sapwood-heartwood boundary was visible on the core sample, sapwood radius (*rs*) was measured using digital calipers.

To characterize scaling relationships for *rb,* we measured bark thickness on 8-10 individuals of each species during fall 2013. Individuals were randomly selected to represent the entire diameter range for that species present in the plot; for each species, trees were binned into ten size classes based on 2008 census data, and one individual randomly selected from each size class. Actual sample sizes were reduced by mortality between 2008 and 2013; in particular, live individuals of *Ulmus rubra* were too rare in 2013 to sample a sizeable range. On each selected individual, three samples were taken at approximately 1.3 m height and at horizontal positions using a Haglӧf increment hammer (Haglӧf Sweden). Bark thickness was measured in the field using digital calipers.

Using the fitted scaling relationships for both *rs* and *rb* (statistical methods detailed below), we constructed equations to estimate sapwood area (*AS*), and the ratio of sapwood area to basal area (*AS*/*AB*) for each species. For each focal tree, we estimated *AS* and *AS*/*AB* using the equations and *AB* =π(DBH/2)2. In a few instances, fitted scaling relationships predicted *AS*/*AB* >1 for small trees, which is physically impossible. In these cases, we assumed that the entire tree stem consisted of sapwood (i.e., *AS*/*AB* =1.0).

*Sap Flow*

Beginning July 17, 2013, sap flow was monitored continuously using the Granier method (Granier 1985, 1987; Lu, Urban & Zhao 2004). The majority of focal trees ≥5cm DBH were instrumented with sap flow probes. Some smaller individuals were excluded when the species and size was already represented.

Sap flow probes were installed facing north, with heated probes slightly below 1.3 m height (adjusted to avoid tree irregularities and manual dendrometer bands) and unheated reference probes exactly 15 cm below. Probes came in either 1 or 2 cm lengths, with 1 cm probes installed primarily in trees with DBH <15 cm and 2 cm probes to those >15 cm DBH. In some trees, two or more pairs of probes were installed to verify that 1 and 2 cm probes gave similar readings. Probes were covered with reflective insulation to avoid potential thermal gradients (Lu *et al.* 2004).

Probes were wired to a 32-channel multiplexer (Campbell Scientific AM 16/32) connected to a datalogger (Campbell Scientific CR-1000). Differential voltage (ΔV; mV) values were scanned every minute and averaged over 15-minute intervals. The system was powered using 3-4 marine batteries (one for datalogger; 2-3 for heating probes). To guarantee a continuous record, batteries were replaced before voltage fell below 12.0 V.

Processing of sap flow data was performed in Matlab (R2012A). Data were screened for instances of probes failing to heat or giving irregular readings, and outliers removed. Afterwards, the maximum voltage difference (ΔVmax; mV) was calculated for every 24-hour period where 95% of collected data was present. To account for the fact that ΔV may not reach the true minimum values each day due to nighttime sap flow, we averaged the daily ΔVmax over 7-day moving average time period. We then calculated sap flux density (*Fd*; m3·m-2·s-1) according to the following equation (Lu *et al.* 2004):

*Fd* = 118.99 × 10-6[(ΔVmax – ΔV)/ΔV]1.231 (Equation S1)

Whole-tree transpiration (L hr-1) is often calculated simply as the product of *Fd* and sapwood area; however, given that *Fd* typically exhibits significant radial patterns as a function of depth (*d*; Phillips *et al.* 1996; Gebauer *et al.* 2008), it is more accurate to estimate transpiration by characterizing typical radial patterns in *Fd*. We used the following equation to approximate transpiration:

(Equation S2)

Here, *As(d)* is sapwood area at depth *d* (calculated as area of an annulus) and is relative sap flux density at depth *d.* Functions for were obtained from (Gebauer *et al.* 2008) and used to represent trees by size and species according to the following groupings: (1) *Fagus* (any size); (2) non-*Fagus* diffuse porous <30cm DBH; (3) non-*Fagus* diffuse porous >30 cm, and (4) all ring-porous (any size).

Total daily transpiration (*Tday*;L day-1) was calculated by summing *Fd* or *T*, respectively, for each 24-hour period. To avoid loss of data from days with small data gaps, linear interpolation was used to fill any gaps for days with <25% of data missing.

Median summer *Fd* and *Tday* were calculated for July 18-Sept. 23, 2013 (n=24 trees) and from June 1-Sept. 14, 2014 (n=31 trees). Leaf phenology observations on the same trees (unpublished data) revealed that all measured trees had fully expanded and >80% green leaves throughout both of these time periods.

*Tree Diameter Growth*

Diameter growth was measured using three different methods. First, we measured annual growth increments from tree cores collected in 2010 (See Sapwood Area for field methods). We measured annual growth increments to the nearest 0.01 mm using a uni-slide tree ring measuring device (Velmex, Inc., East Bloomfield, NY) and Wild M8 stereozoom microscope and recorded increment widths using a Quick-Chek microcomputer (Automation and Metrology, Inc., Painseville, OH) and Measure J2X software (VoorTech Consulting, Holderness, NH). We cross-dated raw ring widths by comparing shared narrow rings across cores (Yamaguchi 1991), and confirmed using the dplR package (Bunn 2008, 2010), within the R statistical software for our main species-of-interest (*Fagus grandifolia*, *Liriodendron tulipifera*, *Quercus alba*, *Q. prinus*, *Q. rubra*, *Q. velutina*). We subsequently grouped all *Quercus* spp. for further annual growth increment analysis. From the raw ring widths, we calculated mean annual growth increment for years 1999 – 2009 and a wet/dry year ratio from years 1985 and 1986. Based on growing season (April – October) Palmer Drought Severity Index (PDSI) estimates (National Climatic Data Center 2013), 1986 was the driest year within the last thirty years for Virginia (*PDSI* = -3.356) and 1985 was a near normal year (*PDSI* = -0.866). By restraining the query to the past thirty years, we were able to calculate the ratio for all trees cored. Diameter-at-breast-height for all trees was back-calculated for the years 1985 and 1986.

Second, stem diameter growth was quantified by measuring metal dendrometer bands using digital calipers at the beginning and end of the growing season. Bands were installed on trees with DBH>5cm in 2010 (n=243), 2011 (n=251), 2012 (n=18), and 2013 (n=66; in sap flow subplots), for a total of 578 bands. All dendrometer bands were prepared using stainless steel strips and installed at breast height following standard CTFS-ForestGEO protocol (Muller-Landau & Dong 2010). After exclusion of anomalous readings, mean annual diameter growth was calculated for the 2011-2014 growing seasons.

Third, for all individuals in the plot that remained alive from 2008 to 2013, five-year diameter growth increments (2008-2013) were calculated based on the difference between 2008 and 2013 diameter measurements. Data were binned as a logarithmic function of DBH with a minimum linear bin size of 0.1 cm (*sensu* White *et al.* 2012).

Because no significant growth differences in diameter growth rates were observed in the deer exclusion area (Bourg *et al.* 2013), all data were pooled for the purpose of this analysis.

*Mortality*

Annual mortality rate (*M;* % yr-1) was calculated from the core tree census data for the whole plot area from 2008 to 2013. Data were binned as a logarithmic function of DBH with a minimum linear bin size of 0.1 cm (*sensu* White *et al.* 2012). For each size bin, *M* was calculated using the following equation (Sheil, Burslem & Alder 1995):

Here, *N2008* is the number of live stems in the 2008 census, *N2013* is the number of these stems that remained alive in 2013, and *t* is the time between censuses (t=5 years).

*Stem abundance*

Stem abundance was calculated from the core tree census data as the live stem density in 2013. The following stem abundance distributions were characterized: interspecific for the whole plot; interspecific within the deer exclosure and in a reference plot of the same size (McGarvey *et al.* 2013); interspecific relationships for the whole plot.

Power function abundance distributions were fit using maximum likelihood (Muller-Landau *et al.* 2006b; White *et al.* 2008).

Size class bin width was set equal to the measurement precision of the dataset: 1 mm (any further binning essentially throws out data, which reduces the power of the test; Johnson et al. 1994.) The minimum diameter observed in the dataset was 10 mm, while the maximum was 1520 mm. Stem abundances were calculated for all 1-mm wide bins from 10.5 to 1600.5 mm. The 10-mm size class was excluded from the analysis because its definition is inconsistent with that of the other size classes: whereas stems recorded as 11 mm in diameter range in true diameter from 10.5 to 11.5 mm, stems recorded as 10 mm in diameter are supposed to range in true diameter from 10.0 to 10.5 mm, and in practice the number of stems recorded at 10 mm is usually intermediate between what would be expected under lower bounds of 9.5 and 10.0 mm.

Because the total probability must integrate to 1 over the range of the size classes used (here *Dmin*=10.5 to *Dmax*=1600.5 mm), the power function size distribution has a single free parameter – the scaling exponent itself. For *z*1, the probability density function normalized to integrate to 1 over the size class range of interest takes the form

Thus for *z*1, the total probability in size class *i* bounded by *Di,min* and *Di,min* can be calculated analytically as

For z=1, the corresponding functions are

and

The total log likelihood of size distribution data given by a vector **N** of abundances of *Ni* individuals in size class *i* under scaling exponent *z* is simply

(Muller-Landau et al. 2006b).

For each 1-mm size class between 10.5 and 1600.5 mm, we calculated the proportion of stems (out of all 10.5-1600.5 mm) expected in that size class under a candidate scaling exponent, raised this proportion to the power of the number of stems observed in that size class, and took the product over all size classes to obtain the likelihood of the full dataset.  We searched for the maximum likelihood parameter estimate using the optimize function in R version 3.0.3.  Confidence intervals were obtained by boot-strapping over 40x40 m subplots (Muller-Landau *et al.* 2006b).

For graphing only (not for fitting) and for calculation of r2 values analogous to those calculated for the other analyses, individuals were binned into approximately log-even size classes with divisions at 10.5, 11.5, 13.5, 15.5, 17.5, 19.5, 23.5, 27.5, 31.5, 35.5, 39.5, 44.5, 49.5, 59.5, 69.5, 79.5, 89.9, 99.5, 119.5, 139.5, 159.5, 179.5, 199.5, 239.5, 279.5, 319.5, 359.5, 399.5, 449.5, 499.5, 599.5, 699.5, 799.5, 899.5, 999.5, 1199.5, 1399.5, and 1600.5 mm.

*Weather*

Weather was monitored using a standardized CTFS-ForestGEO meteorological station installed adjacent to the plot. The station includes several sensors recorded automatically by a CR1000 datalogger (Campbell Scientific) at a 5-minute interval. These sensors include: 1) an aspirated and shield temperature and a relative humidity sensor plus an additional secondary temperature sensor (MetOne Instruments); 2) a 2-D sonic anemometer WS425 (Vaisala); 3) a tipping rain bucket TB4-L (Campbell Scientific); and 4) a solar radiometer CMSP2 (Kipp & Zonen), plus a secondary radiometer LI-290 (LiCOR biogeoscience).

*Global scaling exponents review*

In June 2014, we conducted a systematic review of scaling exponents for the variables measured in this study from closed canopy broadleaf forests worldwide. Specifically, we searched in Google Scholar using keywords “scaling”, “power”, “tree”, “diameter”, and a variable-specific term (i.e., “tree height”, “crown area”, “crown volume”, “sapwood area”, “sap flow”, “water use”, “growth”, “mortality”, and “size distribution”). No date limit was applied. We reviewed the list of studies (sorted by relevance) until finding >10 relevant records for interspecific scaling relationships or searching 15 papers, whichever came first. We placed primary focus on finding interspecific scaling relationships for the sake of comparison with interspecific scaling relationships observed at SCBI, but also included intraspecific relationships. Studies were only included if scaling exponents and other information necessary to determine whether they met the criteria were given in the manuscript or its supplementary information; we did not trace references to other studies. In a few instances for poorly-represented variables (sap flux density and transpiration), we extracted data from the original study and fit a scaling relationship using OLS regression. This systematic search yielded the majority of results presented here; however, to enlarge the sample size, we added results from some studies of which we had become aware through other means (these are marked in Table S8). For each scaling relationship, we recorded the scaling exponent (*z*; Eq. 1) and its 95% CI (when reported).

# Table S1 | Stem abundance of dominant canopy species at SCBI. Data are based on the 2013 core census.

|  |  |  |
| --- | --- | --- |
| Family | Species | % of all live stems |
| Sapindaceae | *Acer rubrum* L. (Red maple) | 0.8 |
| Juglandaceae | *Carya glabra* (Mill.) (Pignut hickory) | 3.9 |
|  | *Carya tomentosa* (L.) Nutt. Nutt. (Mockernut hickory) | 3.1 |
|  | *Carya ovalis* (Wangenh.) Sarg. (Red hickory) | 1.0 |
|  | *Carya cordiformis* (Wangenh.) K. Koch (bitternut hickory) | 1.0 |
| Oleaceae | *Fraxinus americana* L. (White ash) | 1.6 |
| Fagaceae | *Fagus grandifolia* Ehrh. (American beech) | 1.3 |
| Juglandaceae | *Juglans nigra* L. (Black walnut) | 0.3 |
| Magnoliaceae | *Liriodendron tulipifera* L. (Tulip poplar, yellow poplar) | 5.3 |
| Nyssaceae | *Nyssa sylvatica* Marshall (Black gum) | 3.0 |
| Fagaceae | *Quercus alba* L. (White oak) | 0.9 |
|  | *Quercus prinus* L. (Chestnut oak) | 0.6 |
|  | *Quercus rubra* L. (Northern red oak) | 0.9 |
|  | *Quercus velutina* Lam. (Black oak) | 0.6 |
| Ulmaceae | *Ulmus rubra* Muhl. (Slippery elm) | 0.9 |

# Table S2 | Scaling relationships between DBH and tree dimensions

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Trait | Species | DBH range (mm) | n | ln [*Yo*] | *z* | *p* | *R²* |
| Height (m) | All | 15.0 – 1046.8 | 301 | -0.956 ±0.199 | 0.704 ±0.039 | <0.001 | 0.851 |
|  | *Fagus grandifolia* | 29.2 – 1046.8 | 18 | -1.100 ±0.878 | 0.713 ±0.179 | <0.001 | 0.840 |
|  | *Liriodendron tulipifera* | 99.0 – 700.0 | 21 | -0.088 ±0.664 | 0.565 ±0.121 | <0.001 | 0.825 |
| Crown Area (m2) | All | 16.1 – 1046.8 | 60 | -0.872 ±0.740 | 0.853 ±0.147 | <0.001 | 0.706 |
|  | *Fagus grandifolia* | 29.2 – 1046.8 | 18 | -2.385 ±1.769 | 1.204 ±0.360 | <0.001 | 0.786 |
|  | *Liriodendron tulipifera* | 153.1 – 700.0 | 10 | -2.310 ±4.399 | 1.086 ±0.727 | 0.009 | 0.547 |
| Crown depth (m) | All | 16.1 – 1046.8 | 60 | -1.702 ±0.538 | 0.741 ±0.109 | <0.001 | 0.756 |
|  | *Fagus grandifolia* | 29.2 – 1046.8 | 18 | -2.089 ±1.126 | 0.867 ±0.229 | <0.001 | 0.825 |
|  | *Liriodendron tulipifera* | 153.1 – 700.0 | 10 | -0.193 ±2.595 | 0.466 ±0.429 | 0.036 | 0.369 |
| Crown Volume (m3) | All | 16.1 – 1046.8 | 60 | -1.920 ±1.038 | 1.528 ±0.206 | <0.001 | 0.797 |
|  | *Fagus grandifolia* | 29.2 – 1046.8 | 18 | -4.187 ±2.662 | 2.071 ±0.541 | <0.001 | 0.828 |
|  | *Liriodendron tulipifera* | 153.1 – 700.0 | 10 | -2.216 ±6.826 | 1.551 ±1.816 | 0.004 | 0.618 |

Statistically fitted equations of the form ln [Y] = ln [Y0] + z\*ln [DBH (mm)] are described. Given are the DBH range and n individuals sampled, parameters ln[*Yo*] and *z* with their 95% CIs, p, and R2.

# Table S3 | Scaling relationships between DBH and sapwood radius, bark thickness, and sapwood area

| Trait | Species | Ring porosity | DBH range (mm) | n | ln [*Yo*] | *z* | *p* | *R²* |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sapwood radius (*rs;* mm) | All diffuse-porous | Diffuse | 53.0 – 819.5 | 186 | -0.290 ±0.688 | 0.760 ±0.123 | <0.001 | 0.441 |
| *Acer rubrum* | Diffuse | 156.3 – 607.1 | 25 | -2.486 ±2.712 | 1.210 ±0.483 | <0.001 | 0.490 |
|  | *Fagus grandifolia* | Diffuse | 111.7 – 410.2 | 20 | -0.011 ±1.443 | 0.825 ±0.272 | <0.001 | 0.644 |
|  | *Liriodendron tulipifera* | Diffuse | 88.0 – 819.5 | 86 | -1.556 ±0.687 | 0.932 ±0.118 | <0.001 | 0.737 |
|  | *Nyssa sylvatica* | Diffuse | 53.0 – 575.1 | 51 | -0.525 ±1.471 | 0.813 ±0.273 | <0.001 | 0.398 |
|  | All ring-porous (including semi-ring) | Ring | 51.0 – 1366.2 | 495 | 1.430 ±0.641 | 0.327 ±0.111 | <0.001 | 0.613 |
|  | *Carya cordiformis* | Ring | 153.6 – 605.0 | 38 | 0.709 ±1.924 | 0.515 ±0.346 | >0.001 | 0.168 |
|  | *Carya glabra* | Ring | 86.0 – 606.6 | 72 | -0.060 ±1.892 | 0.661 ±0.339 | <0.001 | 0.161 |
|  | *Carya ovalis* | Ring | 159.2 – 607.1 | 48 | -0.096 ±1.888 | 0.688 ±0.331 | <0.001 | 0.249 |
|  | *Carya tomentosa* | Ring | 91.0 – 568.0 | 59 | 1.384 ±1.946 | 0.442 ±0.350 | 0.016 | 0.081 |
|  | *Fraxinus americana* | Ring | 91.0 – 851.4 | 15 | -4.092 ±2.122 | 1.413 ±0.360 | <0.001 | 0.806 |
|  | *Juglans nigra* | Semi-ring | 204.0 – 761.9 | 28 | -0.321 ±2.840 | 0.580 ±0.470 | 0.023 | 0.152 |
|  | *Quercus alba* | Ring | 159.2 – 723.0 | 30 | 1.341 ±2.161 | 0.274 ±0.365 | 0.152 | 0.039 |
|  | *Quercus prinus* | Ring | 102.2 – 845.9 | 76 | -0.983 ±0.804 | 0.700 ±0.141 | <0.001 | 0.556 |
|  | *Quercus rubra* | Ring | 87.0 – 1366.2 | 46 | -1.704 ±1.351 | 0.720 ±0.218 | <0.001 | 0.476 |
|  | *Quercus velutina* | Ring | 162.9 – 805.9 | 58 | -0.826 ±1.089 | 0.593 ±0.177 | <0.001 | 0.424 |
|  | *Ulmus rubra* | Ring | 154.9 – 370.9 | 12 | -4.607 ±4.783 | 1.480 ±0.865 | 0.007 | 0.482 |
| Bark thickness (*rb;* mm) | All | - | 50.3 – 1432.1 | 119 | -1.564 ±0.800 | 0.529 ±0.135 | <0.001 | 0.335 |
| *Acer rubrum* | Diffuse | 81.7 – 395.9 | 10 | -2.564 ±2.359 | 0.599 ±0.440 | 0.014 | 0.552 |
|  | *Fagus grandifolia* | Diffuse | - | - | - | - | - | - |
|  | *Liriodendron tulipifera* | Diffuse | 275 – 1365.2 | 9 | -0.659 ±2.910 | 0.425 ±0.444 | 0.057 | 0.423 |
|  | *Nyssa sylvatica* | Diffuse | 163.2 – 666.8 | 8 | -0.611 ±2.530 | 0.413 ±0.430 | 0.056 | 0.480 |
|  | *Carya cordiformis* | Ring | 58.9 – 681.7 | 9 | -1.917 ±4.464 | 0.503 ±0.782 | 0.172 | 0.248 |
|  | *Carya glabra* | Ring | 191.2 – 779.5 | 8 | -0.495 ±8.088 | 0.316 ±1.347 | 0.587 | 0.052 |
|  | *Carya ovalis* | Ring | 63.7 - 631 | 8 | -2.504 ±3.756 | 0.703 ±0.677 | 0.044 | 0.519 |
|  | *Carya tomentosa* | Ring | 50.3 – 572.6 | 8 | -0.945 ±3.192 | 0.396 ±0.569 | 0.139 | 0.327 |
|  | *Fraxinus americana* | Ring | 61 – 941.9 | 9 | 0.318 ±1.716 | 0.295 ±0.284 | 0.043 | 0.464 |
|  | *Juglans nigra* | Semi-ring | 136.4 - 854 | 9 | -0.293 ±2.878 | 0.385 ±0.472 | 0.095 | 0.347 |
|  | *Quercus alba* | Ring | 93 – 1017.5 | 10 | -1.231 ±2.276 | 0.526 ±0.372 | 0.011 | 0.570 |
|  | *Quercus prinus* | Ring | 57.7 – 991.2 | 8 | -0.647 ±2.520 | 0.423 ±0.422 | 0.049 | 0.501 |
|  | *Quercus rubra* | Ring | 240.8 – 1432.1 | 10 | -0.789 ±4.849 | 0.341 ±0.757 | 0.330 | 0.119 |
|  | *Quercus velutina* | Ring | 161.8 - 1107 | 8 | 1.500 ±4.192 | 0.053 ±0.661 | 0.851 | 0.006 |
|  | *Ulmus rubra* | Ring | 60.5 – 390.8 | 5 | 1.133 ±6.476 | -0.057 ±1.320 | 0.899 | 0.006 |
| Sapwood area (*As*; cm2) | All | - | 51.0 – 1432.1 | 1158 | -3.030 ±0.497 | 1.490 ±0.086 | <0.001 | 0.633 |
| All diffuse-porous | Diffuse | 53.0 – 819.5 | 182 | -4.960 ±0.545 | 1.908 ±0.097 | <0.001 | 0.891 |
|  | *Acer rubrum* | Diffuse | 156.3 – 607.1 | 25 | -6.222 ±1.762 | 2.192 ±0.314 | <0.001 | 0.886 |
|  | *Fagus grandifolia* | Diffuse | 111.7 – 410.2 | 20 | -4.652 ±0.612 | 1.945 ±0.115 | <0.001 | 0.983 |
|  | *Liriodendron tulipifera* | Diffuse | 88.0 – 819.5 | 86 | -5.937 ±0.552 | 2.039 ±0.095 | <0.001 | 0.954 |
|  | *Nyssa sylvatica* | Diffuse | 53.0 – 575.1 | 51 | -5.618 ±1.015 | 2.032 ±0.188 | <0.001 | 0.899 |
|  | All ring-porous (including semi-ring) |  | 86.0 – 1366.2 | 482 | -2.687 ±0.591 | 1.404 ±0.102 | <0.001 | 0.602 |
|  | *Carya cordiformis* | Ring | 153.6 – 605.0 | 38 | -3.628 ±1.524 | 1.629 ±0.274 | <0.001 | 0.784 |
|  | *Carya glabra* | Ring | 86.0 – 606.6 | 72 | -4.609 ±1.541 | 1.810 ±0.276 | <0.001 | 0.698 |
|  | *Carya ovalis* | Ring | 159.2 – 631.0 | 48 | -4.767 ±1.355 | 1.830 ±0.238 | <0.001 | 0.828 |
|  | *Carya tomentosa* | Ring | 91.0 – 568.0 | 59 | -3.477 ±1.444 | 1.633 ±0.260 | <0.001 | 0.723 |
|  | *Fraxinus americana* | Ring | 91.0 – 851.4 | 15 | -8.198 ±1.687 | 2.458 ±0.286 | <0.001 | 0.953 |
|  | *Juglans nigra* | Semi-ring | 204.0 – 761.9 | 28 | -4.608 ±2.645 | 1.689 ±0.438 | <0.001 | 0.675 |
|  | *Quercus alba* | Ring | 159.2 – 723.0 | 30 | -3.129 ±2.000 | 1.411 ±0.338 | <0.001 | 0.695 |
|  | *Quercus prinus* | Ring | 102.2 – 845.9 | 76 | -5.280 ±0.734 | 1.811 ±0.129 | <0.001 | 0.910 |
|  | *Quercus rubra* | Ring | 87.0 – 1366.2 | 46 | -5.364 ±1.303 | 1.744 ±0.210 | <0.001 | 0.854 |
|  | *Quercus velutina* | Ring | 162.9 – 805.9 | 58 | -4.740 ±1.040 | 1.655 ±0.169 | <0.001 | 0.865 |
|  | *Ulmus rubra* | Ring | 154.9 – 370.9 | 12 | -8.006 ±3.975 | 2.432 ±0.719 | <0.001 | 0.796 |

For *rs* and *rb*, statistically fitted equations of the form ln [*Y*] = ln [*Y0*] + *z*\*ln [DBH (mm)] are described. Given are the DBH range and n individuals sampled, parameters ln[*Yo*] and *z* with their 95% CIs, p, and R2.

# Table S4 | Scaling relationships between DBH and median growing season sap flow

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Trait | Species | Year | DBH range (mm) | n | ln [*Yo*] | | | | *z* | | | | | | *p* | | | *R²* | | |
| Peak sap flux density (*Fd,max*; m hr-1) | All | 2013 | 58-1047 | 24 | -1.657 | ± | 0.655 | 0.048 | | ± | 0.212 | | 0.661 | | | 0.01 | | |
| 2014 | 58-1047 | 31 | -1.666 | ± | 0.802 | 0.001 | | ± | | 0.251 | | 0.994 | | | 0.00 | | |
| All diffuse porous | 2013 | 58-1047 | 20 | -1.585 | ± | 0.652 | 0.031 | | ± | | 0.213 | | 0.780 | | | 0.00 | | |
| 2014 | 58-1047 | 25 | -1.820 | ± | 0.767 | 0.082 | | ± | | 0.247 | | 0.522 | | | 0.02 | | |
| *Fagus grandifolia* | 2013 | 58-1047 | 9 | -1.140 | ± | 0.708 | -0.047 | | ± | | 0.237 | | 0.711 | | | 0.02 | | |
| 2014 | 58-1047 | 12 | -0.891 | ± | 0.724 | -0.166 | | ± | | 0.249 | | 0.220 | | | 0.15 | | |
| *Liriodendron tulipifera* | 2013 | 153-700 | 6 | -1.355 | ± | 1.411 | -0.066 | | ± | | 0.380 | | 0.751 | | | 0.03 | | |
| 2014 | 153-700 | 7 | -4.007 | ± | 1.683 | 0.632 | | ± | | 0.456 | | 0.035 | | | 0.55 | | |
| All ring porous | 2013 | 182-384 | 4 | -5.960 | ± | 4.223 | 1.341 | | ± | | 1.297 | | 0.180 | | | 0.67 | | |
| 2014 | 182-600 | 6 | -1.461 | ± | 4.902 | -0.161 | | ± | | 0.703 | | 0.830 | | | 0.01 | | |
| Daily sap flux (*Fd,day*; m day-1) | All | 2013 | 58-1047 | 24 | -0.278 | ± | 0.739 | 0.230 | | ± | | 0.236 | | 0.069 | | | 0.14 | | |
| 2014 | 58-1047 | 31 | -0.321 | ± | 0.820 | 0.203 | | ± | | 0.256 | | 0.131 | | | 0.08 | | |
| All diffuse porous | 2013 | 58-1047 | 20 | -0.205 | ± | 0.748 | 0.204 | | ± | | 0.241 | | 0.114 | | | 0.13 | | |
| 2014 | 58-1047 | 25 | -0.484 | ± | 0.799 | 0.284 | | ± | | 0.257 | | 0.041 | | | 0.17 | | |
| *Fagus grandifolia* | 2013 | 58-1047 | 9 | 0.280 | ± | 0.848 | 0.085 | | ± | | 0.284 | | 0.574 | | | 0.05 | | |
| 2014 | 58-1047 | 12 | 0.425 | ± | 0.779 | 0.049 | | ± | | 0.268 | | 0.727 | | | 0.01 | | |
| *Liriodendron tulipifera* | 2013 | 153-700 | 6 | 0.517 | ± | 2.090 | 0.009 | | ± | | 0.558 | | 0.976 | | | 0.00 | | |
| 2014 | 153-700 | 7 | -2.281 | ± | 2.083 | 0.734 | | ± | | 0.564 | | 0.043 | | | 0.52 | | |
| All ring porous | 2013 | 182-384 | 4 | -4.470 | ± | 5.238 | 1.534 | | ± | | 1.609 | | 0.203 | | | 0.64 | | |
| 2014 | 182-600 | 6 | 0.446 | ± | 4.995 | -0.106 | | ± | | 1.405 | | 0.890 | | | 0.01 | | |
| Peak transpiration (*Fmax*; L hr-1) | All | 2013 | 58-1047 | 24 | -3.431 | ± | 0.965 | 1.374 | | ± | | 0.312 | | <0.001 | | | 0.77 | | |
| 2014 | 58-1047 | 31 | -3.085 | ± | 1.081 | 1.204 | | ± | | 0.338 | | <0.001 | | | 0.63 | | |
| All diffuse porous | 2013 | 58-1047 | 20 | -3.360 | ± | 1.034 | 1.347 | | ± | | 0.338 | | <0.001 | | | 0.77 | | |
| 2014 | 58-1047 | 25 | -3.349 | ± | 1.049 | 1.336 | | ± | | 0.337 | | <0.001 | | | 0.72 | | |
| *Fagus grandifolia* | 2013 | 58-1047 | 9 | -2.874 | ± | 1.207 | 1.357 | | ± | | 0.405 | | <0.001 | | | 0.86 | | |
| 2014 | 58-1047 | 12 | -2.435 | ± | 0.815 | 1.186 | | ± | | 0.280 | | <0.001 | | | 0.87 | | |
| *Liriodendron tulipifera* | 2013 | 153-700 | 6 | -3.435 | ± | 1.124 | 1.250 | | ± | | 0.303 | | 0.001 | | | 0.94 | | |
| 2014 | 153-700 | 7 | -5.897 | ± | 0.920 | 1.914 | | ± | | 0.249 | | <0.001 | | | 0.97 | | |
| All ring porous | 2013 | 182-384 | 4 | -7.197 | ± | 4.050 | 2.548 | | ± | | 1.244 | | <0.001 | | | 0.89 | | |
| 2014 | 182-600 | 6 | -2.064 | ± | 5.509 | 0.758 | | ± | | 1.549 | | 0.392 | | | 0.19 | | |
| Daily transpiration (*Fday*; L day-1) | All | 2013 | 58-1047 | 24 | -2.007 | ± | 0.980 | 1.537 | | ± | | 0.313 | | <0.001 | | | 0.80 | | |
| 2014 | 58-1047 | 31 | -1.749 | ± | 1.088 | 1.409 | | ± | | 0.340 | | <0.001 | | | 0.69 | | |
| All diffuse porous | 2013 | 58-1047 | 20 | -1.940 | ± | 1.027 | 1.501 | | ± | | 0.331 | | <0.001 | | | 0.81 | | |
| 2014 | 58-1047 | 25 | -2.012 | ± | 1.078 | 1.538 | | ± | | 0.347 | | <0.001 | | | 0.77 | | |
| *Fagus grandifolia* | 2013 | 58-1047 | 9 | -1.454 | ± | 1.306 | 1.489 | | ± | | 0.437 | | <0.001 | | | 0.86 | | |
| 2014 | 58-1047 | 12 | -1.118 | ± | 0.954 | 1.401 | | ± | | 0.328 | | <0.001 | | | 0.88 | | |
| *Liriodendron tulipifera* | 2013 | 153-700 | 6 | -1.551 | ± | 1.939 | 1.321 | | ± | | 0.517 | | 0.004 | | | 0.83 | | |
| 2014 | 153-700 | 7 | -4.171 | ± | 1.231 | 2.016 | | ± | | 0.333 | | <0.001 | | | 0.96 | | |
| All ring porous | 2013 | 182-384 | 4 | -5.707 | ± | 5.248 | 2.740 | | ± | | 1.612 | | 0.080 | | | 0.85 | | |
| 2014 | 182-600 | 6 | -0.293 | ± | 5.366 | 0.855 | | ± | | 1.509 | | 0.329 | | | 0.24 | | |

Statistically fitted equations of the form ln [*Y*] = ln [*Y0*] + *z*\*ln [DBH (mm)] are described. Given are the DBH range and n individuals sampled, parameters ln[*Yo*] and *z* with their 95% CIs, p, and *R2*.

# Table S5 | Scaling relationships between DBH and diameter growth

| Trait | Species | DBH range (mm) | N | ln [*Yo*] | *z* | p | R² |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Diameter growth from dendrometer bands (mm yr-1) | All | 56.7 – 1516.0 | 499 | -4.20 ±0.553 | 0.870 ±0.089 | <0.001 | 0.390 |
| *Acer rubrum* | 281.9 – 699.5 | 6 | -2.797 ±16.496 | 0.563 ±2.713 | 0.595 | 0.077 |
| *Fagus grandifolia* | 56.7 – 1051.6 | 15 | -0.293 ±1.944 | 0.282 ±0.367 | 0.186 | 0.175 |
| *Liriodendron tulipifera* | 97.0 – 1302.0 | 217 | -5.867 ±1.031 | 1.126 ±0.163 | <0.001 | 0.463 |
| *Nyssa sylvatica* | 94.6 – 437.8 | 6 | -1.484 ±18.802 | 0.120 ±3.587 | 0.887 | 0.002 |
| *Carya cordiformis* | 110.0 – 443.5 | 8 | -13.881 ±3.104 | 2.596 ±0.553 | <0.001 | 0.957 |
| *Carya glabra* | 69.1 – 615.0 | 24 | -6.294 ±3.475 | 1.177 ±0.621 | 0.001 | 0.413 |
| *Fraxinus americana* | 149.5 – 1075.6 | 35 | -5.271 ±2.040 | 0.989 ±0.321 | <0.001 | 0.544 |
| *Juglans nigra* | 306.0 – 885.0 | 10 | -1.532 ±11.317 | 1.020 ±1.830 | 0.869 | 0.171 |
| *Quercus alba* | 271.3 – 1030.9 | 50 | -5.500 ±3.968 | 1.001 ±0.622 | <0.001 | 0.181 |
| *Quercus prinus* | 433.0 – 704.5 | 5 | -0.386 ±40.701 | 0.170 ±6.445 | 0.935 | 0.002 |
| *Quercus rubra* | 116.7 – 1447.5 | 52 | -5.540 ±1.981 | 1.076 ±0.305 | <0.001 | 0.501 |
| *Quercus velutina* | 420.0 – 1516.0 | 27 | -0.183 ±3.994 | 0.196 ±0.605 | 0.575 | 0.017 |
| 5-year (2008-2013) diameter growth (mm yr-1) | All | 11.0 – 1520.0 | 50\* | -2.056 ±0.399 | 0.557 ±0.079 | <0.001 | 0.802 |
| *Acer rubrum* | 10.7 – 715.0 | 42\* | -2.551 ±0.754 | 0.587 ±0.162 | <0.001 | 0.573 |
| *Fagus grandifolia* | 12.5 – 1046.8 | 40\* | -2.102 ±0.812 | 0.582 ±0.174 | <0.001 | 0.548 |
| *Liriodendron tulipifera* | 13.4 – 1422.3 | 48\* | -2.666 ±0.569 | 0.663 ±0.111 | <0.001 | 0.757 |
| *Nyssa sylvatica* | 11.3 – 629.5 | 41\* | -2.444 ±0.949 | 0.559 ±0.206 | <0.001 | 0.437 |
| *Carya cordiformis* | 13.8 – 697.1 | 40\* | -1.775 ±0.485 | 0.522 ±0.102 | <0.001 | 0.738 |
| *Carya glabra* | 11.3 – 793.5 | 42\* | -3.671 ±0.645 | 0.836 ±0.138 | <0.001 | 0.789 |
| *Carya ovalis* | 13.2 – 662.2 | 38\* | -3.136 ±0.706 | 0.681 ±0.149 | <0.001 | 0.705 |
| *Carya tomentosa* | 12.9 – 693.8 | 40\* | -3.687 ±0.833 | 0.856 ±0.179 | <0.001 | 0.712 |
| *Fraxinus americana* | 13.1 – 1072.1 | 45\* | -1.911 ±0.462 | 0.518 ±0.094 | <0.001 | 0.744 |
| *Juglans nigra* | 20.7 – 903.0 | 23\* | -2.411 ±3.007 | 0.580 ±0.542 | 0.037 | 0.191 |
| *Quercus alba* | 18.9 – 1031.9 | 35\* | -2.581 ±1.077 | 0.616 ±0.202 | <0.001 | 0.538 |
| *Quercus prinus* | 14.8 – 993.4 | 34\* | -2.737 ±1.143 | 0.616 ±0.221 | <0.001 | 0.502 |
| *Quercus rubra* | 10.9 – 1483.0 | 36\* | -4.057 ±0.875 | 0.947 ±0.165 | <0.001 | 0.799 |
| *Quercus velutina* | 41.0 – 152.0 | 29\* | -3.497 ±1.277 | 0.765 ±0.224 | <0.001 | 0.645 |
| *Ulmus rubra* | 1.25 – 537.4 | 35\* | -1.897 ±1.074 | 0.566 ±0.244 | <0.001 | 0.402 |
| 10-year increment average (from cores; mm yr-1) | All | 100.5 – 1366.2 | 564 | -1.667 ±0.569 | 0.599 ±0.098 | <0.001 | 0.203 |
| *Acer rubrum* | 156.3 – 607.1 | 24 | 0.010 ±4.501 | 0.254 ±0.806 | 0.521 | 0.019 |
|  | *Fagus grandifolia* | 100.5 – 1030.4 | 87 | 1.071 ±1.079 | 0.199 ±0.207 | 0.059 | 0.041 |
|  | *Liriodendron tulipifera* | 100.5 – 819.5 | 82 | -5.100 ±1.349 | 1.174 ±0.557 | <0.001 | 0.557 |
|  | *Fraxinus americana* | 155.7 – 887.8 | 32 | -2.260 ±2.785 | 0.662 ±0.478 | 0.008 | 0.211 |
|  | *Juglans nigra* | 204.0 – 761.9 | 34 | -3.939 ±4.603 | 0.922 ±0.766 | 0.020 | 0.158 |
|  | *Quercus alba* | 158.0 – 767.3 | 66 | -4.247 ±2.259 | 0.985 ±0.376 | <0.001 | 0.300 |
|  | *Quercus prinus* | 102.2 – 845.9 | 79 | -3.944 ±1.124 | 0.954 ±0.196 | <0.001 | 0.549 |
|  | *Quercus rubra* | 160.7 – 1366.2 | 61 | -2.516 ±1.810 | 0.770 ±0.296 | <0.001 | 0.315 |
|  | *Quercus velutina* | 162.9 – 1092.1 | 69 | -2.968 ±1.932 | 0.815 ±0.312 | <0.001 | 0.288 |
| Drought year: normal year increment growth (from cores) | All | 100.5 – 1366.2 | 575 | 0.070 ±0.150 | 0.049 ±0.033 | <0.001 | 0.027 |
| *Fagus grandifolia* | 100.5 – 1030.4 | 87 | 0.321 ±0.381 | -0.091±0.104 | 0.083 | 0.083 |
|  | *Liriodendron tulipifera* | 100.5 – 819.5 | 83 | -0.119 ±0.397 | 0.049 ±0.087 | 0.263 | 0.003 |
|  | *Quercus spp.* | 102.2 – 1366.2 | 275 | 0.968 ±0.565 | 0.067 ±0.097 | 0.009 | 0.021 |

Statistically fitted equations of the form ln [*Y*] = ln [*Y0*] + *z*\*ln [DBH (mm)] are described. Given are the DBH range and n individuals or size classes (denoted with \*) sampled, parameters ln[*Yo*] and *z* with their 95% CIs, p, and R2.

# Table S6 | Scaling relationships between DBH and mortality (2008-2013; % yr-1)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Species | DBH range (mm) | n size bins | ln [*Yo*] | *Z* | *p* | *R²* |
| All | 10.0 – 1511.4 | 47 | 3.107 ±0.408 | -0.446 ±0.084 | <0.001 | 0.718 |
| *Acer rubrum* | 10.6 – 699.5 | 29 | 3.359 ±1.072 | -0.465 ±0.266 | 0.001 | 0.323 |
| *Fagus grandifolia* | 10.3 – 1030.4 | 13 | 0.550 ±3.603 | 0.126 ±0.891 | 0.760 | 0.008 |
| *Liriodendron tulipifera* | 10.4 – 1365.2 | 33 | 4.842 ±1.013 | -0.928 ±0.224 | <0.001 | 0.697 |
| *Nyssa sylvatica* | 10.0 – 666.8 | 33 | 2.050 ±1.105 | -0.328 ±0.262 | 0.016 | 0.174 |
| *Carya cordiformis* | 10.0 – 979.4 | 19 | 3.365 ±1.964 | -0.580 ±0.457 | 0.016 | 0.297 |
| *Carya glabra* | 10.0 – 779.5 | 36 | 3.144 ±1.047 | -0.652 ±0.241 | <0.001 | 0.470 |
| *Carya ovalis* | 10.5 – 631.0 | 17 | 3.174 ±1.408 | -0.543 ±0.292 | 0.001 | 0.511 |
| *Carya tomentosa* | 10.3 – 572.6 | 32 | 1.641 ±1.340 | -0.305 ±0.293 | 0.041 | 0.131 |
| *Fraxinus americana* | 10.1 – 1053.4 | 37 | 3.808 ±0.969 | -0.551 ±0.206 | <0.001 | 0.457 |
| *Juglans nigra* | 10.6 – 854.0 | 8 | 4.774 ±5.395 | -0.589 ±1.030 | 0.211 | 0.246 |
| *Quercus alba* | 11.2 – 1017.5 | 24 | 5.048 ±2.438 | -0.671 ±0.466 | 0.007 | 0.288 |
| *Quercus prinus* | 10.6 – 991.2 | 26 | 6.326 ±1.665 | -0.935 ±0.337 | <0.001 | 0.577 |
| *Quercus rubra* | 10.8 – 1432.1 | 36 | 4.590 ±1.550 | -0.583 ±0.298 | <0.001 | 0.317 |
| *Quercus velutina* | 37.8 – 1511.4 | 20 | 5.983 ±1.650 | -0.819 ±0.297 | <0.001 | 0.650 |
| *Ulmus rubra* | 10.7 – 370.8 | 35 | 0.575 ±0.173 | 0.502 ±0.173 | <0.001 | 0.513 |

Statistically fitted equations of the form ln [*Y*] = ln [*Y0*] + *z*\*ln [DBH (mm)] are described. Given are the DBH range and n diameter size bins with data, parameters ln[*Yo*] and *z* with their 95% CIs, p, and R2.

# Table S7 | Scaling relationships between DBH and stem abundance

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Species | DBH range (mm) | n | *z* (95% CI) | R² |
| All | 10.1 – 1520.0 | 44,169 | -1.787 (-1.887, -1.666) | 0.889 |
| Deer exclosure | 10.1 – 1520.0 | 8445 | -1.735 (-1.861, -1.591) | 0.934 |
| Reference area | 11.0 – 1483.0 | 2247 | -1.033 (-1.101, -0.959) | 0.860 |
| Non-exclosure | 10.1 – 1520.0 | 21,917 | -1.413 (-1.529, -1.296) | 0.862 |
| *Acer rubrum* | 10.7 – 715.0 | 337 | -1.093 (-1.176, -1.031) | 0.584 |
| *Fagus grandifolia* | 12.5 – 1046.8 | 545 | -1.117 (-1.232, -1.131) | 0.567 |
| *Liriodendron tulipifera* | 13.4 – 1046.8 | 2396 | -0.558 (-0.611, -0.532) | 0.143 |
| *Nyssa sylvatica* | 11.3 – 629.5 | 1306 | -1.233 (-1.309, -1.205) | 0.603 |
| *Carya cordiformis* | 13.8 – 697.1 | 422 | -1.098 (-1.213, -1.068) | 0.599 |
| *Carya glabra* | 11.3 – 793.5 | 1747 | -1.156 (-1.206, -1.136) | 0.427 |
| *Carya ovalis* | 13.2 – 662.2 | 448 | -0.977 (-1.082, -0.976) | 0.400 |
| *Carya tomentosa* | 12.9 – 693.8 | 1349 | -1.162 (-1.217, -1.138) | 0.363 |
| *Fraxinus americana* | 13.1 – 1072.1 | 679 | -0.949 (-1.159, -0.972) | 0.572 |
| *Juglans nigra* | 20.7 – 903.0 | 117 | -0.457 (-0.604, -0.404) | 0.233 |
| *Quercus alba* | 18.9 – 1031.9 | 421 | -0.439 (-0.522, -0.382) | 0.090 |
| *Quercus prinus* | 14.8 – 993.4 | 277 | -0.696 (-0.848, -0.656) | 0.328 |
| *Quercus rubra* | 10.9 – 1483.0 | 407 | -0.547 (-0.647, -0.502) | 0.366 |
| *Quercus velutina* | 41.0 – 1520.0 | 287 | -0.281 (-0.355, -0.212) | 0.103 |
| *Ulmus rubra* | 12.5 – 537.4 | 331 | -1.228 (-1.510, -1.264) | 0.491 |

Maximum likelihood fits for power function stem abundance distributions. Given are n individuals sampled, scaling parameter *z* and its 95% CI, and *R2*.

# Table S8 | Record of scaling exponents observed in closed-canopy forests worldwide.

| Trait | Site | Latitude | Longitude | Species | *z* ± 95% CI | Reference[[1]](#endnote-1) |
| --- | --- | --- | --- | --- | --- | --- |
| Height | Barro Colorado Island, Panama | 9.15 | -79.85 | multiple | 0.593 ± 0.003 | Muller-Landau *et al.* 2006a |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Alseis blanckiana* | 0.700 ± 0.062 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Beilschmiedia pendula* | 0.723 ± 0.048 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Faramea occidentalis* | 0.684 ± 0.115 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Ocotea whitei* | 0.640 ± 0.051 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Prioria copaifera* | 0.736 ± 0.043 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Quararibea asterolepis* | 0.703 ± 0.048 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Tetragastris panamensis* | 0.597 ± 0.053 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Trichilia tuberculata* | 0.678 ± 0.048 | O’Brien *et al.* 1995 |
|  | La Selva, Costa Rica | 10.47 | -84.00 | multiple | 0.70 | Rich *et al.* 1986 |
|  | La Selva, Costa Rica | 10.47 | -84.00 | *Pentaclethra macroloba* | 0.60 | Rich *et al.* 1986 |
|  | La Selva, Costa Rica | 10.47 | -84.00 | *Pourouma espera* | 0.81 | Rich *et al.* 1986 |
|  | Uppangala, India | 12.55 | 75.65 | multiple | 0.63 | \*Antin *et al.* 2013 |
| Crown Area | Barro Colorado Island, Panama | 9.15 | -79.85 | multiple | 1.36 ± 0.03 | Muller-Landau *et al.* 2006a |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Alseis blanckiana* | 1.92 ± 0.099 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Beilschmiedia pendula* | 1.393 ± 0.125 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Faramea occidentalis* | 1.133 ± 0.376 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Ocotea whitei* | 1.346 ± 0.196 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Prioria copaifera* | 1.368 ± 0.157 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Quararibea asterolepis* | 1.274 ± 0.137 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Tetragastris panamensis* | 1.768 ± 0.165 | O’Brien *et al.* 1995 |
|  | Barro Colorado Island, Panama | 9.15 | -79.85 | *Trichilia tuberculata* | 1.409 ± 0.124 | O’Brien *et al.* 1995 |
|  | Uppangala, India | 12.55 | 75.65 | multiple | 1.27 | \*Antin *et al.* 2013 |
|  | Los Tuxtlas research station, Mexico | 18.58 | -95.11 | group “A” | 1.78 ± 0.08 | Olson, Aguirre-Hernández & Rosell 2009 |
|  | Los Tuxtlas research station, Mexico | 18.58 | -95.11 | groups “B & C” | 1.63 ± 0.05 | Olson *et al.* 2009 |
|  | Puyhoe, Chile | -40.65 | -72.18 | *Laurelia phillipiana* | 1.17 | Lusk, Wright & Reich 2003 |
| Crown Volume | Uppangala, India | 12.55 | 75.65 | multiple | 1.84 | \*Antin *et al.* 2013 |
| Sapwood Area | Barro Colorado Island, Panama | 9.15 | -79.85 | multiple | 1.764 | Meinzer, Goldstein & Andrade 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | multiple diffuse porous | 2.071 | \*Wullschleger, Hanson & Todd 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | multiple ring porous | 1.637 | \*Wullschleger *et al.* 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Quercus prinus* | 1.751 | \*Wullschleger *et al.* 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Quercus alba* | 1.514 | \*Wullschleger *et al.* 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Nyssa sylvatica* | 1.84 | \*Wullschleger *et al.* 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Acer rubrum* | 1.654 | \*Wullschleger *et al.* 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Lirondendron tulipifera* | 2.119 | Wullschleger & King 2000; Wullschleger *et al.* 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Quercus rubra* | 1.44 | \*Wullschleger *et al.* 2001 |
|  | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Acer saccharum* | 1.859 | \*Wullschleger *et al.* 2001 |
|  | North Maroondah experimental area, Victoria, Australia | -37.57 | 145.63 | *Eucalyptus regnans* | 2.31 | Vertessy *et al.* 1995 |
|  | North Maroondah experimental area, Victoria, Australia | -37.57 | 145.63 | *Acacia dealbata* | 2.31 | Vertessy *et al.* 1995 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | multiple diffuse porous | 1.8 | Gebauer *et al.* 2008 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | *Fagus sylvatica* | 1.917 | Gebauer *et al.* 2008 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | *Tilia cordata* | 1.561 | Gebauer *et al.* 2008 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | *Carpinus betulus* | 2.149 | Gebauer *et al.* 2008 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | *Acer pseudoplatanus* | 1.967 | Gebauer *et al.* 2008 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | *Acer platanoides* | 1.706 | Gebauer *et al.* 2008 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | *Acer campestre* | 2.484 | Gebauer *et al.* 2008 |
|  | Hainich National Park, Thuringia, Germany | 51.07 | 10.5 | *Fraxinus excelsior* | 2.671 | Gebauer *et al.* 2008 |
|  | near BOREAS Northern Study Area, Manitoba, Canada | 55.88 | -98.33 | *Populus tremuloides* | 2.015 | Bond-Lamberty, Wang & Gower 2002 |
| Sap flow velocity | Barro Colorado Island, Panama | 9.15 | -79.85 | multiple | -1.038 ± 0.166 | \*Meinzer *et al.* 2001 |
|  | North Maroondah experimental area, Victoria, Australia | -37.57 | 145.63 | *Eucalyptus regnans* | 0.398 ± 0.376 | \*Vertessy *et al.* 1995 |
| Transpiration | Walker Branch Watershed, TN, USA | 35.97 | -84.28 | *Lirondendron tulipifera* | 2.266 | Wullschleger & King 2000 |
|  | Black Spur, North Maroondah experimental area, Victoria, Australia | -37.57 | 145.63 | *Eucalyptus regnans* | 2.424 | Vertessy *et al.* 1997 |
|  | 15-year-old stand, North Maroondah experimental area, Victoria, Australia | -37.57 | 145.63 | *Eucalyptus regnans* | 2.706 | Vertessy *et al.* 1995, 1997 |
| Diameter growth | Yasuni, Ecuador | -0.69 | -76.40 | multiple | 0.645 ± 0.025 | Muller-Landau *et al.* 2006a |
|  | La Planada, Colombia | 1.16 | -77.99 | multiple | 0.344 ± 0.063 | Muller-Landau *et al.* 2006a |
|  | Ituri-Edoro, Dem. Rep. of Congo | 1.44 | 28.58 | multiple | 0.751 ± 0.02 | Muller-Landau *et al.* 2006a |
|  | Ituri-Lenda, Dem. Rep. of Congo | 1.44 | 28.58 | multiple | 0.705 ± 0.022 | Muller-Landau *et al.* 2006a |
|  | Pasoh, Malaysia (1990-95) | 2.98 | 102.31 | multiple | 0.64 ± 0.017 | Muller-Landau *et al.* 2006a |
|  | Pasoh, Malaysia (1995-2000) | 2.98 | 102.31 | multiple | 0.677 ± 0.022 | Muller-Landau *et al.* 2006a |
|  | Lambir, Malaysia | 4.19 | 114.02 | multiple | 0.584 ± 0.016 | Muller-Landau *et al.* 2006a |
|  | Sinharaja, Sri Lanka | 6.40 | 80.40 | multiple | 0.679 ± 0.027 | Muller-Landau *et al.* 2006a |
|  | Barro Colorado Island, Panama (1990-95) | 9.15 | -79.85 | multiple | 0.68 ± 0.021 | Muller-Landau *et al.* 2006a |
|  | Barro Colorado Island, Panama (1995-2000) | 9.15 | -79.85 | multiple | 0.674 ± 0.018 | Muller-Landau *et al.* 2006a |
|  | Mudumalai, India (1992-96) | 11.60 | 76.53 | multiple | -0.259 ± 0.065 | Muller-Landau *et al.* 2006a |
|  | Mudumalai, India (1996-2000) | 11.60 | 76.53 | multiple | -0.032 ± 0.036 | Muller-Landau *et al.* 2006a |
|  | Huai Kha Khaeng, Thailand | 15.63 | 99.22 | multiple | 0.202 ± 0.02 | Muller-Landau *et al.* 2006a |
| Mortality | Yasuni, Ecuador | -0.69 | -76.40 | multiple | -0.024 ± 0.042 | Muller-Landau *et al.* 2006a |
|  | La Planada, Colombia | 1.16 | -77.99 | multiple | -0.4 ± 0.042 | Muller-Landau *et al.* 2006a |
|  | Ituri-Edoro, Dem. Rep. of Congo | 1.44 | 28.58 | multiple | -0.017 ± 0.046 | Muller-Landau *et al.* 2006a |
|  | Ituri-Lenda, Dem. Rep. of Congo | 1.44 | 28.58 | multiple | -0.236 ± 0.065 | Muller-Landau *et al.* 2006a |
|  | Pasoh, Malaysia (1990-95) | 2.98 | 102.31 | multiple | -0.103 ± 0.04 | Muller-Landau *et al.* 2006a |
|  | Pasoh, Malaysia (1995-2000) | 2.98 | 102.31 | multiple | -0.079 ± 0.047 | Muller-Landau *et al.* 2006a |
|  | Lambir, Malaysia | 4.19 | 114.02 | multiple | -0.213 ± 0.052 | Muller-Landau *et al.* 2006a |
|  | Sinharaja, Sri Lanka | 6.40 | 80.40 | multiple | 0.125 ± 0.05 | Muller-Landau *et al.* 2006a |
|  | Barro Colorado Island, Panama (1990-95) | 9.15 | -79.85 | multiple | -0.216 ± 0.041 | Muller-Landau *et al.* 2006a |
|  | Barro Colorado Island, Panama (1995-2000) | 9.15 | -79.85 | multiple | -0.217 ± 0.04 | Muller-Landau *et al.* 2006a |
|  | Mudumalai, India (1992-96) | 11.60 | 76.53 | multiple | -1.175 ± 0.064 | Muller-Landau *et al.* 2006a |
|  | Mudumalai, India (1996-2000) | 11.60 | 76.53 | multiple | -0.901 ± 0.108 | Muller-Landau *et al.* 2006a |
|  | Huai Kha Khaeng, Thailand | 15.63 | 99.22 | multiple | -0.591 ± 0.068 | Muller-Landau *et al.* 2006a |
| Stem abundance | Yasuni, Ecuador (1997) | -0.69 | -76.40 | multiple | -1.86 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Yasuni, Ecuador (2004) | -0.69 | -76.40 | multiple | -1.84 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | La Planada, Colombia (1997) | 1.16 | -77.99 | multiple | -1.78 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | La Planada, Colombia (2003) | 1.16 | -77.99 | multiple | -1.73 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Ituri-Edoro, Dem. Rep. of Congo (1995) | 1.44 | 28.58 | multiple | -2.07 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Ituri-Edoro, Dem. Rep. of Congo (2000) | 1.44 | 28.58 | multiple | -2.04 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Ituri-Lenda, Dem. Rep. of Congo (1995) | 1.44 | 28.58 | multiple | -2.13 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Ituri-Lenda, Dem. Rep. of Congo (2000) | 1.44 | 28.58 | multiple | -2.13 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Pasoh, Malaysia (1990) | 2.98 | 102.31 | multiple | -1.93 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Pasoh, Malaysia (1995) | 2.98 | 102.31 | multiple | -1.9 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Pasoh, Malaysia (2000) | 2.98 | 102.31 | multiple | -1.87 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Lambir, Malaysia (1992) | 4.19 | 114.02 | multiple | -1.95 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Lambir, Malaysia (1997) | 4.19 | 114.02 | multiple | -1.96 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Korup, Cameroon | 5.06 | 8.29 | multiple | -1.96 ± 0.01 | Muller-Landau *et al.* 2006b |
|  | Sinharaja, Sri Lanka (1995) | 6.40 | 80.40 | multiple | -2.05 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Sinharaja, Sri Lanka (2000) | 6.40 | 80.40 | multiple | -1.99 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Khao Chong, Thailand | 7.54 | 99.80 | multiple | -1.84 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Barro Colorado Island, Panama (1990) | 9.15 | -79.85 | multiple | -1.97 ± 0.005 | Muller-Landau *et al.* 2006b |
|  | Barro Colorado Island, Panama (1995) | 9.15 | -79.85 | multiple | -1.93 ± 0.005 | Muller-Landau *et al.* 2006b |
|  | Barro Colorado Island, Panama (2000) | 9.15 | -79.85 | multiple | -1.9 ± 0.005 | Muller-Landau *et al.* 2006b |
|  | Mudumalai, India (1992) | 11.60 | 76.53 | multiple | -1.08 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Mudumalai, India (1996) | 11.60 | 76.53 | multiple | -1.04 ± 0.015 | Muller-Landau *et al.* 2006b |
|  | Mudumalai, India (2000) | 11.60 | 76.53 | multiple | -1.16 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Huai Kha Khaeng, Thailand (1993) | 15.63 | 99.22 | multiple | -1.56 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Huai Kha Khaeng, Thailand (1999) | 15.63 | 99.22 | multiple | -1.52 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Palanan, Philippines | 17.04 | 122.39 | multiple | -1.81 ± 0.02 | Muller-Landau *et al.* 2006b |
|  | Luquillo, Puerto Rico | 18.33 | -65.82 | multiple | -1.75 ± 0.03 | Muller-Landau *et al.* 2006b |
|  | Lianhuachih, Taiwan | 23.91 | 120.88 | multiple | -1.76 ± 0.01 | \*Lai *et al.* 2013 |
|  | Gutianshan, China | 29.25 | 118.12 | multiple | -1.73 ± 0.01 | \*Lai *et al.* 2013 |
|  | Baotianman, China | 33.50 | 111.94 | multiple | -1.68 ± 0.02 | \*Lai *et al.* 2013 |
|  | Changbaishan, China | 42.38 | 128.08 | multiple | -1.65 ± 0.02 | \*Lai *et al.* 2013 |

# References

Antin, C., Pélissier, R., Vincent, G. & Couteron, P. (2013) Crown allometries are less responsive than stem allometry to tree size and habitat variations in an Indian monsoon forest. *Trees*, **27**, 1485–1495.

Bond-Lamberty, B., Wang, C. & Gower, S.T. (2002) Aboveground and belowground biomass and sapwood area allometric equations for six boreal tree species of northern Manitoba. *Canadian Journal of Forest Research*, **32**, 1441–1450.

Bourg, N.A., McShea, W.J., Thompson, J.R., McGarvey, J.C. & Shen, X. (2013) Initial census, woody seedling, seed rain, and stand structure data for the SCBI SIGEO Large Forest Dynamics Plot: *Ecological Archives* E094-195. *Ecology*, **94**, 2111–2112.

Bunn, A.G. (2008) A dendrochronology program library in R (dplR). *Dendrochronologia*, **26**, 115–124.

Bunn, A.G. (2010) Statistical and visual crossdating in R using the dplR library. *Dendrochronologia*, **28**, 251–258.

Condit, R.S. (1998) *Tropical Forest Census Plots - Methods and Results from Barro Colorado Island, Panama and a Comparison with Other Plots*. Springer-Verlag, Berlin, and R. G. Landes Company, Georgetown, TX, USA.

Forest Inventory and Analysis National Program. (2005) Crowns: Measurements and Sampling. *Forest Inventory and Analysis National Core Field Guide, Volume 1: 3.0 Phase 3 Field Guide* pp. 1–20. USDA Forest Service.

Gebauer, T., Horna, V. & Leuschner, C. (2008) Variability in radial sap flux density patterns and sapwood area among seven co-occurring temperate broad-leaved tree species. *Tree Physiology*, **28**, 1821–1830.

Granier, A. (1985) A new method of sap flow measurement in tree stems. *Annales Des Sciences Forestieres*, **42**, 193–200.

Granier, A. (1987) Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements. *Tree Physiology*, **3**, 309–320.

Lai, J., Coomes, D.A., Du, X., Hsieh, C., Sun, I.-F., Chao, W.-C., Mi, X., Ren, H., Wang, X., Hao, Z. & Ma, K. (2013) A general combined model to describe tree-diameter distributions within subtropical and temperate forest communities. *Oikos*, **122**, 1636–1642.

Lusk, C.H., Wright, I. & Reich, P.B. (2003) Photosynthetic differences contribute to competitive advantage of evergreen angiosperm trees over evergreen conifers in productive habitats. *New Phytologist*, **160**, 329–336.

Lu, P., Urban, L. & Zhao, P. (2004) Granier’s Thermal Dissipation Probe (TDP) method for measuring sap flow in trees : theory and practice. *Acta botanica sinica*, **46**, 631–646.

McGarvey, J.C., Bourg, N.A., Thompson, J.R., McShea, W.J. & Shen, X. (2013) Effects of Twenty Years of Deer Exclusion on Woody Vegetation at Three Life-History Stages in a Mid-Atlantic Temperate Deciduous Forest. *Northeastern Naturalist*, **20**, 451–468.

Meinzer, F.C., Goldstein, G. & Andrade, J.L. (2001) Regulation of water flux through tropical forest canopy trees: Do universal rules apply? *Tree Physiology*, **21**, 19–26.

Muller-Landau, H.C., Condit, R.S., Chave, J., Thomas, S.C., Bohlman, S.A., Bunyavejchewin, S., Davies, S., Foster, R., Gunatilleke, S., Gunatilleke, N., Harms, K.E., Hart, T., Hubbell, S.P., Itoh, A., Kassim, A.R., LaFrankie, J.V., Lee, H.S., Losos, E., Makana, J.-R., Ohkubo, T., Sukumar, R., Sun, I.-F., Nur Supardi, M.N., Tan, S., Thompson, J., Valencia, R., Munoz, G.V., Wills, C., Yamakura, T., Chuyong, G., Dattaraja, H.S., Esufali, S., Hall, P., Hernandez, C., Kenfack, D. & Kiratiprayoon, S. (2006a) Testing metabolic ecology theory for allometric scaling of tree size, growth and mortality in tropical forests. *Ecology Letters*, **9**, 575–588.

Muller-Landau, H.C., Condit, R.S., Harms, K.E., Marks, C.O., Thomas, S.C., Bunyavejchewin, S., Chuyong, G., Co, L., Davies, S., Foster, R., Gunatilleke, S., Gunatilleke, N., Hart, T., Hubbell, S.P., Itoh, A., Kassim, A.R., Kenfack, D., LaFrankie, J.V., Lagunzad, D., Lee, H.S., Losos, E., Makana, J.-R., Ohkubo, T., Samper, C., Sukumar, R., Sun, I.-F., Nur Supardi, M.N., Tan, S., Thomas, D., Thompson, J., Valencia, R., Vallejo, M.I., Munoz, G.V., Yamakura, T., Zimmerman, J.K. & Dattaraja, H.S. (2006b) Comparing tropical forest tree size distributions with the predictions of metabolic ecology and equilibrium models. *Ecology Letters*, **9**, 589–602.

Muller-Landau, H.C. & Dong, S.X. (2010) Metal Band Dendrometer Protocol: CTFS Global Forest Carbon Research Initiative. http://www.ctfs.si.edu/data///documents/Metal\_Band\_Dendrometer\_Protocol\_20100330.pdf.

National Climatic Data Center. (2013) *Time Bias Corrected Divisional Temperature-Precipitation-Drought Index*. National Climatic Data Center, Asheville.

O’Brien, S.T., Hubbell, S.P., Spiro, P., Condit, R. & Foster, R.B. (1995) Diameter, Height, Crown, and Age Relationship in Eight Neotropical Tree Species. *Ecology*, **76**, 1926–1939.

Olson, M.E., Aguirre-Hernández, R. & Rosell, J.A. (2009) Universal foliage-stem scaling across environments and species in dicot trees: plasticity, biomechanics and Corner’s Rules. *Ecology Letters*, **12**, 210–219.

Phillips, N., Oren, R. & Zimmermann, R. (1996) Radial patterns of xylem sap flow in non-, diffuse- and ring-porous tree species. *Plant, Cell & Environment*, **19**, 983–990.

Rich, P.M., Helenurm, K., Kearns, D., Morse, S.R., Palmer, M.W. & Short, L. (1986) Height and Stem Diameter Relationships for Dicotyledonous Trees and Arborescent Palms of Costa Rican Tropical Wet Forest. *Bulletin of the Torrey Botanical Club*, **113**, 241–246.

Sheil, D., Burslem, D.F.R.P. & Alder, D. (1995) The Interpretation and Misinterpretation of Mortality Rate Measures. *Journal of Ecology*, **83**, 331–333.

Vertessy, R.A., Benyon, R.G., O’Sullivan, S.K. & Gribben, P.R. (1995) Relationships between stem diameter, sapwood area, leaf area and transpiration in a young mountain ash forest. *Tree Physiology*, **15**, 559–567.

Vertessy, R.A., Hatton, T.J., Reece, P., O’Sullivan, S.K. & Benyon, R.G. (1997) Estimating stand water use of large mountain ash trees and validation of the sap flow measurement technique. *Tree Physiology*, **17**, 747–756.

White, E.P., Enquist, B.J. & Green, J.L. (2008) On estimating the exponent of power-law frequency distributions. *Ecology*, **89**, 905–912.

White, E.P., Xiao, X., Nick, J.B. & Sibley, R.M. (2012) Methodological Tools. *Metabolic Ecology: A Scaling Approach* (eds R.M. Sibley, J.H. Brown & A. Kodric-Brown), Wiley-Blackwell.

Wullschleger, S.D., Hanson, P.. & Todd, D.. (2001) Transpiration from a multi-species deciduous forest as estimated by xylem sap flow techniques. *Forest Ecology and Management*, **143**, 205–213.

Wullschleger, S.D. & King, A.W. (2000) Radial variation in sap velocity as a function of stem diameter and sapwood thickness in yellow-poplar trees. *Tree Physiology*, **20**, 511–518.

Yamaguchi, D.K. (1991) A simple method for cross-dating increment cores from living trees. *Can. J. For. Res.*, **21**, 414–416.

1. indicates a study identified outside of the systematic search described in Appendix A. [↑](#endnote-ref-1)