Hyper-dominance in the Amazonian Tree Flora

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The vast extent of the Amazon Basin has historically restricted the study of its tree communities to the local and regional scales. Here we provide the first empirical data on the commonness, rarity, and richness of lowland tree species across the entire Amazon Basin and Guiana Shield (Amazonia), collected in 1170 tree plots in all major forest types. Extrapolations suggest that Amazonia harbors roughly 16,000 tree species, of which just 227 (1.4%) account for half of all trees. Most of these are habitat specialists and only dominant in 1–2 regions of the basin. We discuss some implications of the discovery that a small group of species—less diverse than the North American tree flora—accounts for half of the world's most diverse tropical forest.

Much remains unknown about the Amazonian flora, the world's richest assemblage of plant species. Here we report some unexpected results from a uniquely wide-ranging assessment of the composition and biogeography of Amazonian tree communities. Using species-abundance data for adult trees (defined as $\geq$ 10 cm in diameter-at-breast-height) collected in individual plots and the geographical distribution of those plots across Amazonia (Fig. 1, S1-3), we constructed a rank-abundance distribution (RAD) composed of estimated basin-wide population sizes of each of the 4970 valid tree species in the dataset (Fig. 2). The RAD offers four important new insights regarding Amazonian tree communities.

First, it provides the most precise estimates yet of two numbers that have been debated for decades: how many trees and how many tree species occur in the ~6 million km^2 landscape of Amazonia (1-4). Our estimate of tree density yielded a total of 3.9×10^{11} individual trees and a median tree density of 565 trees/ha (Fig. S4). Assuming that our population size estimates for the common species are reasonable (Fig. S5) and Fisher's log-series model fits our data (4), we estimate the total number of tree species in the Greater Amazon to be approximately 16,000 (Fig. 2). A second estimate based on the Fisher's alpha scores of all plots yields a similar figure: 15,182 species (Fig. S6).

Second, the RAD suggests that just 227 (1.4%) of the estimated 16,000 species account for half of all individual trees in Amazonia. We refer to these species, all of which have estimated populations of $>3.7 \times 10^8$ adults, as 'hyper-dominant' species (see a list of the 20 most abundant species in Table 1 and a full list in Appendix S1).

These hyper-dominant species form the backbone of the tree communities in individual plots as well, accounting for a median of 41% of trees (range = 0-94%, Fig. S5) and 32% of species (range = 0-78%) per plot (Fig. S7).

Third, all species ranking in abundance from 5000–16,000 are very rare. These species in the tail of the RAD have total populations of $<10^6$ individuals and together account for just 0.12% of all trees in Amazonia. While some of these species may be 'vagrants' spilling over from extra-Amazonian biomes such as the Cerrado and Andes, thousands must be Amazonian endemics that run a high risk of going extinct, and many before they can even be found and described by biologists. The rarest 5800 species have estimated population sizes of <1000, which is sufficient to classify those which are endemic as globally threatened (5). Together these rarest species account for just 0.0003% of all trees in Amazonia. Given the extreme unlikelihood of locating a fertile individual of one of these species, , whose flowers can be used for species-level identification, we believe that discovering and describing the unknown portion of Amazonian biodiversity will be a long-term struggle with steeply diminishing returns, and not an easy linear process (6). Indeed, the RAD suggests that floras of even well-collected areas may remain half-finished for decades. For example, our data predict that ~4500 tree species occur in the Guianas (Fig. S8), but centuries of collecting there have yielded just half that number (7). Some of these species may be present among the unidentified species of our plots or as undescribed specimens in herbaria (8), but the majority may yet have to be collected.

Fourth, there are strong similarities between theoretical models of tree species richness in the Amazon (4) and our distribution of species abundances based on empirical data. For example, Hubbell et al. (4) used a log-series distribution to predict that the most common species in the Amazon should account for 1.39% of all trees. This is remarkably close to our estimate for the most common species in our dataset, the palm *Euterpe precatoria* (1.32%). Our estimate of Fisher's alpha for the Amazon is also extremely close to Hubbell et al.'s modeled prediction (754 vs. 743 in (4)). Although these strong correlations between predictions and our dataset suggest that the log-series may offer useful insights on the most poorly known tree species in the Amazon (e.g., the number of undescribed taxa), they should not be interpreted as evidence for any one theory of how these tree communities are structured (9).

We examined species' geographic ranges and abundances by plots, regions, and forest types to explore how hyper-dominant species differ from other taxa, as a first step towards understanding what makes them so successful. Hyper-dominant species have larger ranges than other taxa (Fig. 3a) and reach greater maximum relative abundances in plots (Fig. 3b). Most hyper-dominant species (121 out of 227) are habitat specialists (Fig.

3c) (i.e., they show a strong preference for one of the five major Amazonian forest types: terra firme [53 spp.], várzea [26], white-sand forest [16], swamps [14], and igapó [12]). Likewise, most are only dominant within one or two forest types. When the study area was divided into six regions (Guiana Shield, NW, SW, S, E, and Central Amazonia), most hyper-dominant species (72%) were found to be dominant within only 1 or 2 regions (Table 2).

It is thus important to emphasize that while the Amazonian RAD is dominated by a small suite of species, most of those species are only dominant in certain forest types and in certain regions of the basin. Just one species qualified as dominant in all six regions (*Eschweilera coriacea*), no species were dominant in all five forest types, and only four species were dominant in four forest types (*Euterpe precatoria*, *Oenocarpus bataua*, *Licania apetala, and Euterpe oleracea*). Much more representative of the 227 hyper-dominant species are taxa like *Siparuna decipiens* (112th largest population size overall), only dominant in terra firme forests in SW Amazonia, and *Eperua falcata* (13th), only dominant in the Guiana Shield. Indeed, 59% of hyper-dominant species qualify as both dominant in 1 or 2 regions and dominant in 1 or 2 forest types.

Within each region, an even smaller number of species (72–162) typically accounts for 50% of all individual trees, and most of these regional dominants are also hyper-dominant species (Fig. 4a). For example, the data suggest that half of all individual trees in SW Amazonia belong to just 62 species, 47 of which are also hyper-dominant species. The same pattern holds for forest types, which are individually dominated by 24–196 species (Fig. 4b). Half of all individual trees in white sand forest belong to just 24 species, 15 of which are also hyper-dominant species. Because most hyper-dominant species are only dominant in 1–2 regions or forest types, however, in any single region or forest type the majority of the 227 hyper-dominant species are not locally dominant.

Given these results, it seems likely that the basin-wide patterns of dominance we describe here arise in part from regional-scale patterns of dominance described previously at various sites in upper Amazonia (*10, 11*). There is significant compositional overlap between Pitman et al.'s (*10*) 'oligarchies' in Peru and Ecuador and our hyper-dominant species, even though those authors' plots represent just 2.1% of the full ATDN dataset and only include terra firme forests. Sixty-eight 'oligarchs' of (*10*) are on the list of 227 hyper-dominant species, including 8 of the top 10 most common hyper-dominants. The 250 oligarchic species in (*10*) account for 26.9% of all trees in Amazonia, according to the RAD in Fig. 2. These results suggest that the regional-scale and Amazon-wide patterns derive from similar processes.

Hyper-dominant species occur across the angiosperm phylogeny, with no significant phylogenetic conservatism for the maximum estimated population size found within each genus (Blomberg's K (12) = 0.076, p = 0.91). Nevertheless, hyper-dominants are more frequent in some families (Appendix S2; Fig. S9). Arecaceae, Myristicaceae, and Lecythidaceae have many (~4–5x) more hyper-dominant species than expected by chance, while Myrtaceae, Melastomataceae, Lauraceae, Annonaceae, and Rubiaceae have fewer, probably because many of their species are shrubs or treelets that do not reach our 10-cm diameter cutoff. In Fabaceae, the most abundant and most diverse family in the dataset, the observed number of hyper-dominant species is not significantly different from the expected.

We observed a negative relationship between the number of species in a genus and the frequency of hyper-dominant species (Fig. S10). This pattern has been observed in several plant communities worldwide, and scientists have yet to determine whether it is ecologically informative or an artifact of rank-based taxonomy (*13, 14*). The 227 hyper-dominant species belong to 121 genera, and 68 of these contain more hyper-dominants than expected by chance (Appendix S3). The highest number of hyper-dominant species is found in moderately diverse *Eschweilera* (52 species overall; 2.4 hyper-dominant species expected vs. 14 observed), also the most abundant genus in the ATDN dataset (5.2% of all stems). Given that the families and genera mentioned here dominate Amazonian forests, it remains a key goal to determine why some achieve dominance with a large number of mostly rare species (e.g., *Inga*, Sapotaceae) while others do so with a small number of common species (palms), differences that may result from variation in speciation and extinction rates (*13-16*). And while genetics data may reveal some hyper-dominant species to be species complexes, they seem unlikely to overturn the fundamental patterns described here (*17 and references therein*).

We found no evidence that two key functional traits for trees, seed mass and wood density, vary consistently with hyper-dominance. The 227 hyper-dominant species include both shade-tolerant, typically large-seeded climax species with dense wood (e.g. *Chlorocardium rodiei*, *Clathrotropis* spp., *Eperua* spp.) and shade-intolerant, small-seeded pioneers with light wood (e.g. *Cecropia* spp., *Jacaranda copaia, Laetia procera*). Given that most hyper-dominant species attain very high local densities (>60 trees/ha) somewhere in the plot network, we predict that they will be found to be disproportionately resistant to pathogens, specialist herbivores, and other sources of frequency-dependent mortality (*18, 19*).

Widespread pre-1492 cultivation by humans is a compelling hypothesis to explain hyper-dominance (*20*). Numerous hyper-dominant species are widely used by modern indigenous groups (*Hevea brasiliensis,*

Theobroma cacao, and many palms), and some are associated with pre-Columbian settlements (*Attalea butyracea, A. phalerata, Mauritia flexuosa*) (*21-25*). On the other hand, most hyper-dominant species are not commonly cultivated, many of the most commonly used hyper-dominants (palms) belong to a family that appears to have been dominant in tropical South America since the Paleocene (*26*), and large portions of the Amazon Basin do not appear to have been heavily cultivated before 1492 (*27*).

The discovery that Amazonia is dominated by just 227 tree species has important practical implications. It suggests that roughly half of all fruits, flowers, pollen, leaves, and biomass in the world's most diverse forest belong to a very small suite of species, which must therefore account for a large proportion of Amazonian ecosystem services, including water, carbon and nutrient cycling. Our data also suggest that it may be possible to forecast a significant proportion of the tree community composition and structure of unstudied sites in Amazonia with a purely spatial model. While no one should underestimate the importance of the >10,000 rare and poorly known tree species in the Amazon (*28*), an appreciation of how thoroughly common species dominate the basin has the potential to greatly simplify research in Amazonian biogeochemistry, plant and animal ecology, and vegetation mapping.

Methods

The ATDN network (*29*) comprises 1430 tree inventory plots distributed across the Amazon Basin and Guiana Shield, hereafter Amazonia (Fig. 1). Plots were established between 1934 and 2011 by hundreds of different botanists. Analyses of tree density were performed using the 1346 plots with trees ≥10 cm dbh that remained after plots with outlying density values (<100 or >1000 ind./ha), poorly defined areas, or a different diameter cutoff level were removed.

Analyses of composition were performed with a subset of 1170 plots in which all 639,631 free-standing trees ≥10 cm dbh had been identified with a valid name at the species (86.6%), genus (96.9%), or family (98.9%) level prior to our study. We did not compare specimens or re-identify trees from these plots but resolved major nomenclatural issues (i.e., synonyms and misspellings) in the existing datasets by cross-checking all names with the TROPICOS database (*30*), via the Taxonomic Name Resolution Service (TNRS, *31*) (version October 2011). For the small proportion of names whose validity could not be determined with those tools, we used *The Plant List* (*32*). Lianas, bamboos, tree ferns, and tree-sized herbs were excluded from all analyses. Varieties and subspecies were ignored (i.e., all individuals were assigned to the species level). While some individuals may be misidentified, we assume that this error is within acceptable limits, especially for common species (see discussion in OSM).

The total number of trees ≥10 cm dbh in Amazonia was estimated as follows. First, the study area was divided into 567 1-degree-grid cells (DGCs; Fig. 1). We constructed a loess regression model for tree density (stems ha^{-1}) based on observed tree density in 1195 plots, with latitude, longitude, and their interaction as independent variables. The span was set at 0.5 to yield a relatively smooth average. The model was used to estimate average tree density in each DGC (D_{DGC}, stems ha^{-1}). The total number of trees in each DGC (N_{DGC}) was then calculated by multiplying D_{DGC} by 1,232,100 ha (the area of a DGC close to the equator - the deviation from this area is just 2.8% at 14 S and 1.1% at 8 N, our latitudinal range).

Both empirical (plot data) and interpolated tree densities are illustrated in Fig. S4.

The total number of trees belonging to each species in Amazonia was estimated as follows. Abundances of all valid species were converted to relative abundances for each plot:

$RA_i = n_i/N$, where n_i = the number of individuals of species i and N = the total number of trees in the plot (including unidentified trees).

For each of the 4970 species with a valid name we constructed a loess model for RAi, with latitude, longitude, and their interaction as independent variables, and a span of 0.2. We used only spatially independent variables, since test runs including environmental variables commonly led to predictions of species occurrences in well-sampled areas where they had never been recorded in plots. For a similar reason (i.e., to keep predictions spatially conservative), a smaller span was used than in the tree density analysis. Negative predicted abundances were set to 0. The loess model of a species predicted relative abundance in each DGC, yielding a map of its predicted variation in relative abundances across Amazonia. The total population size of each species was calculated by multiplying its relative abundance in each DGC by the total number of trees in that DGC, and then summing these products for all DGCs.

To reduce the impact of individual plots and quantify uncertainty in the above procedure, a bootstrap exercise was carried out. This involved randomly drawing 1000 plots from the 1170-plot dataset (with replacement), and calculating the population sizes of all species as described above. This was repeated 500 times, and the 500 population estimates per species were used to calculate mean estimated population size and 95% confidence intervals (i.e., mean ± 1.96 SD).

To estimate range size we used the same data and methods as (*33*), standardized with TNRS and updated with specimen records from SpeciesLink (*34*). Species not found in this database were left out of the range size analysis (n=842). Worldwide species diversity of genera was estimated by counting accepted species in (*32*). Seed mass and wood density data were obtained from sources described in (*35*).

Habitat preference was analyzed by means of Indicator Species Analysis, a permutation test that calculates indicator values for each species based on their frequency and relative abundance (*36*) in the five forest types (igapó, terra firme, swamp, várzea, and white sand forest).

To analyze regional-level dominance, we divided Amazonia into six regions and created a rank-abundance distribution (RAD) for each region by summing population sizes in the DGCs they contained. RADs were also constructed for each forest type, by summing the individuals of each species in all plots of a given forest type and calculating the average density of each species in that forest type. The forest type RADs are thus not based on population estimates in DGCs but on the raw abundance data in our plots. A species was considered dominant in a given region or forest type if it appeared in the list of species comprising the upper-50% percentile of the respective RAD.

All analyses were carried out with the R software platform (*37*). For Indicator Species Analysis we used the

package labdsv. All other permutation tests were custom written.

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Supplementary Materials

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Supplementary text

Figs. S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12

Tables S2, S2

Appendices S1, S2, S3

References (40-52)

Tables

Table 1. Mean estimated population sizes of the 20 most abundant tree species in Amazonia, and the empirical abundance and frequency data on which the estimates were based. Median values for the 207 other hyper-dominant species and for the 4743 other valid species in the dataset are provided for comparison. Data on all species can be found in Appendix S1.

Species	Mean estimated population in the Amazon	SD estimated population (%)	No. trees in dataset	% of all plots where present	Maximum abundance recorded (trees/ha)
Euterpe precatoria	5.21E+09	9.9	5903	32.7	168
Protium altissimum	5.21E+09	18.0	5889	15.6	128
Eschweilera coriacea	5.00E+09	5.6	9047	47.9	28
Pseudolmedia laevis	4.30E+09	8.9	5285	36.1	121
Iriartea deltoidea	4.07E+09	13.1	8405	18.5	169
Euterpe oleracea	3.78E+09	17.5	8572	7.4	397
Oenocarpus bataua	3.71E+09	10.7	4767	29.9	108
Trattinnickia burserifolia	2.78E+09	29.4	3023	10	125
Socratea exorrhiza	2.68E+09	10.8	863	28.6	82
Astrocaryum murumuru	2.41E+09	11.2	5748	16.7	325
Brosimum lactescens	2.28E+09	10.0	2234	28.2	106
Protium heptaphyllum	2.13E+09	32.2	1365	11.3	169
Eperua falcata	1.95E+09	15.8	1898	10.9	266
Hevea brasiliensis	1.91E+09	15.5	6031	14.8	179
Eperua leucantha	1.84E+09	32.3	1453	1.4	282
Helicostylis tomentosa	1.79E+09	25.6	1948	36.5	89

Attalea butyracea	1.78E+09	16.2	2561	5.8	73
Rinorea guianensis	1.69E+09	18.6	1243	13.7	182
Licania heteromorpha	1.57E+09	14.4	2483	35	173
Metrodorea flavida	1.55E+09	14.7	1326	7.7	128
Median of other hyper-dominant species	5.79E+08		808	11.4	60
Median of non-hyper-dominant species	1.11E+07		15	0.5	5

Table 2. The number of hyper-dominant species that are also dominant in individual forest types and regions. Note that most hyper-dominants only dominate a single forest type, and most are dominant in 1-2 regions. Colors are a visual aid to highlight the most frequent cells.

		No. forest types where dominant						
		0	**1**	**2**	**3**	**4**	**5**	**Total**
	0	2	4	0	0	0	0	6
	1	17	47	9	0	0	0	73
N. regions	**2**	9	64	15	3	0	0	91
where dominant	**3**	2	17	3	2	1	0	25
	4	0	12	2	4	1	0	19
	5	0	5	1	4	2	0	12
	6	0	0	1	0	0	0	1
	Total	30	149	31	13	4	0	227

Figure captions

Fig 1. A map of Amazonia showing the location of the 1430 ATDN plots that contributed data to this paper. The white polygon marks our delimitation of the study area at a 1-degree grid level (with sub-regions after (*38*)) and consists of 567 1-degree grid cells (area = 6.29 million km^2). Orange circles: plots on terra firme; Blue squares: plots on seasonally or permanently flooded terrain (várzea, igapó, swamps); Yellow triangles: plots on white sand podzols. Background 'Visible Earth' (*39*). More details are shown in Figs. S1-3.

Fig 2. A rank-abundance diagram (RAD) showing the estimated Amazon-wide population sizes of 4970 tree species (solid line), and an extrapolation of the distribution (dotted line) used to estimate the total number of tree species in Amazonia.

Fig 3. Characteristics of hyper-dominants. A. Hyper-dominant species (in red) have larger geographic ranges; **B.** Reach higher maximum relative abundances in individual plots (middle); **C.** and are more likely to be habitat specialists (right) than other species (in grey).

Fig 4. A. Proportions of the trees in each region belonging to species that are regionally dominant, hyper-dominant, or neither. **B.** Proportions of the trees in each forest type belonging to species that are dominant in that forest type, hyper-dominant, or neither. White integers show the number of species in each compartment.
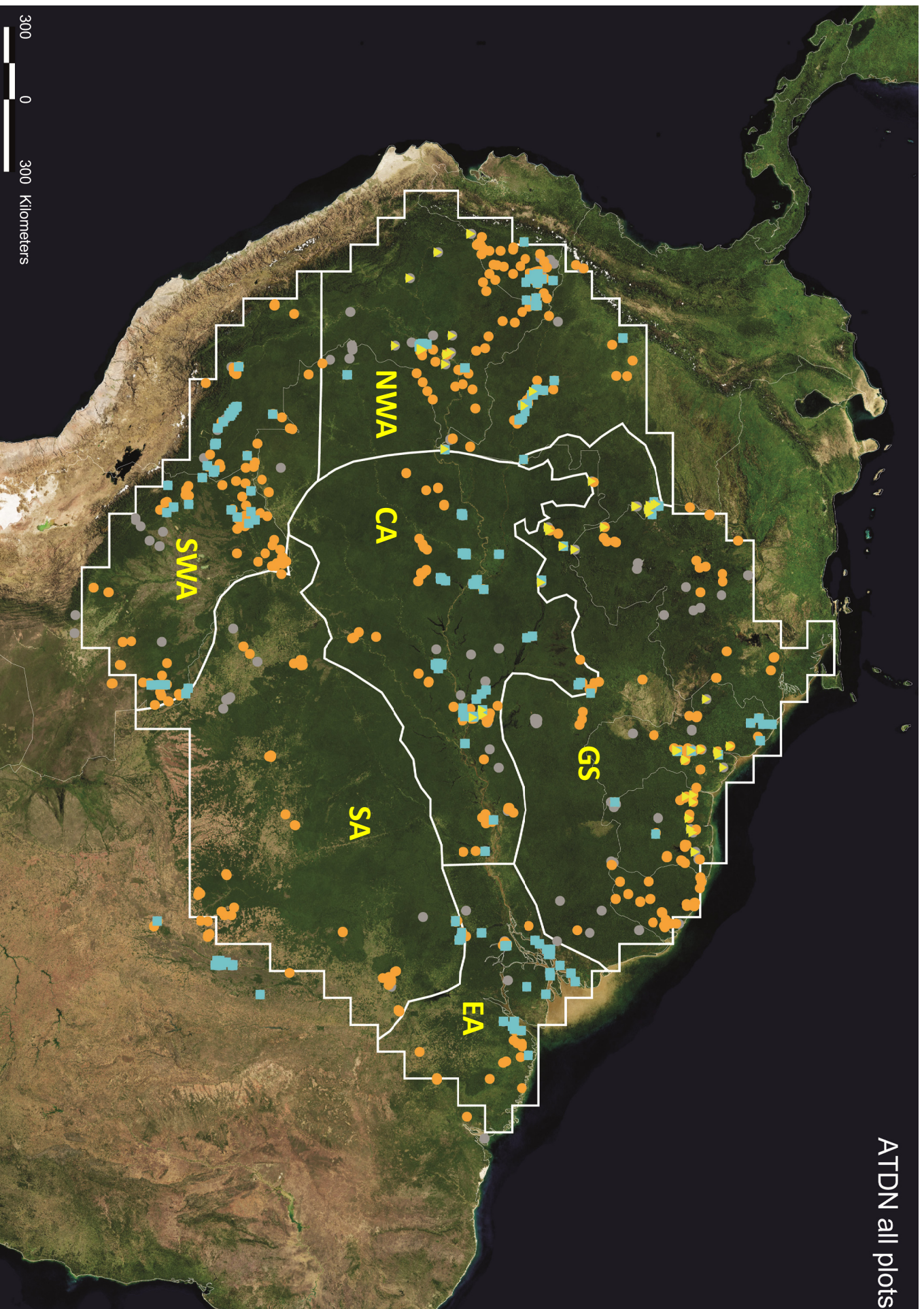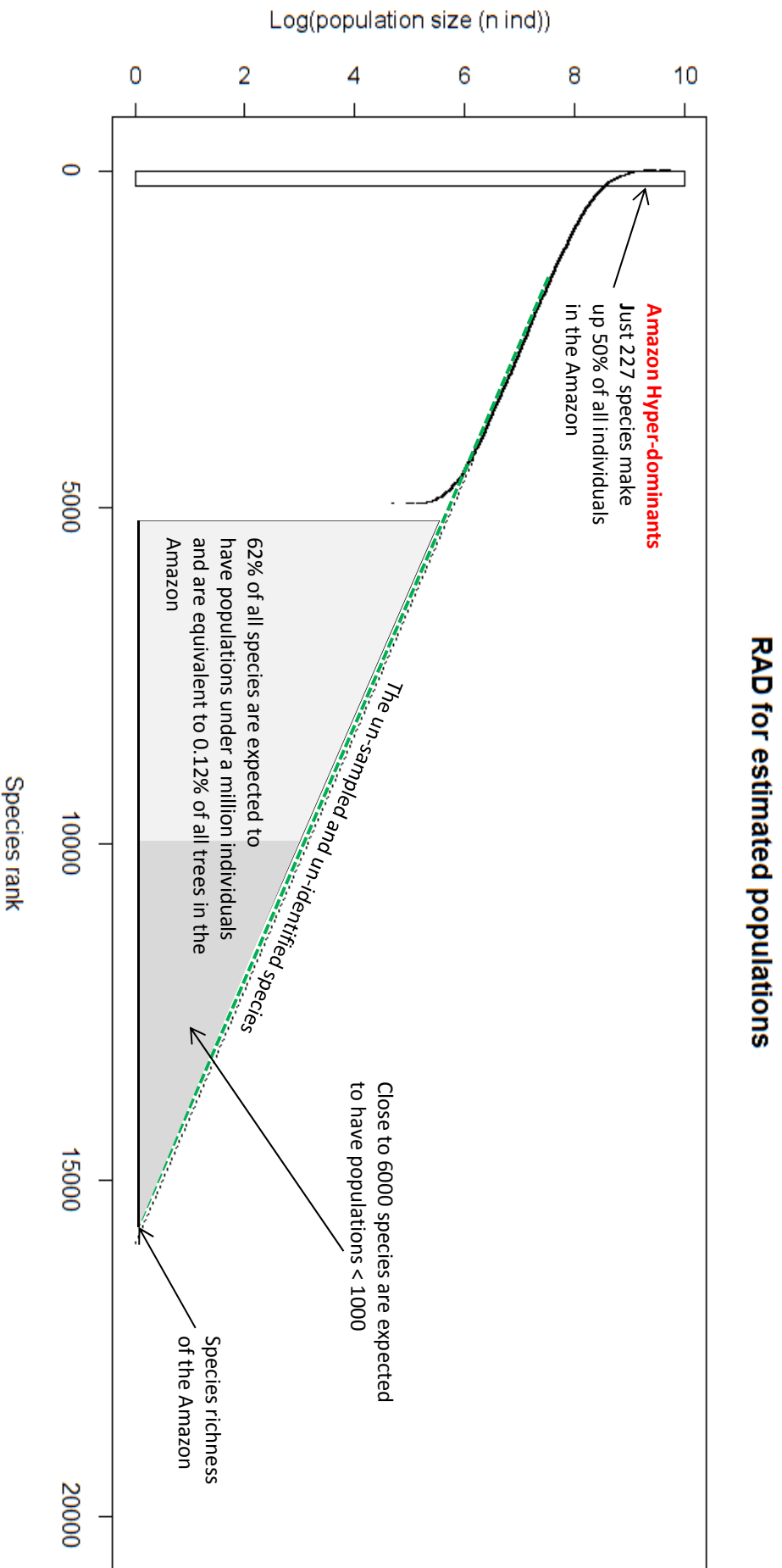
Fig 1.

ATDN all plots
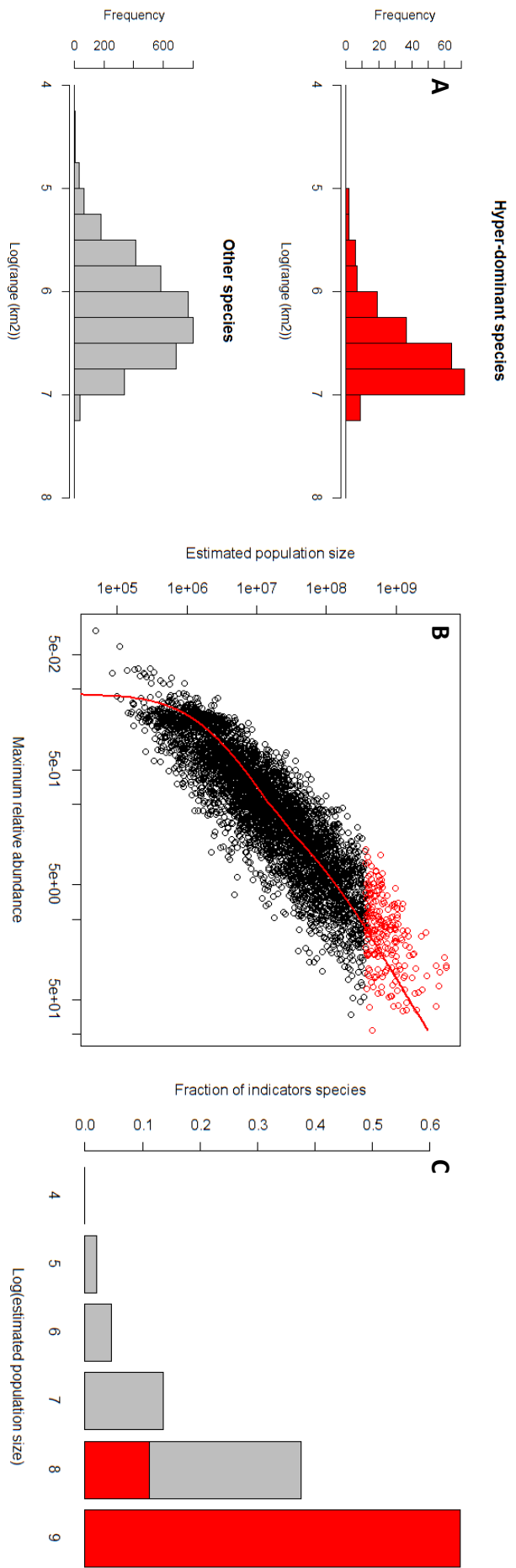
NWA

CA

SWA

SA

GS

EA

300   0   300   Kilometers

Fig 2.

RAD for estimated populations
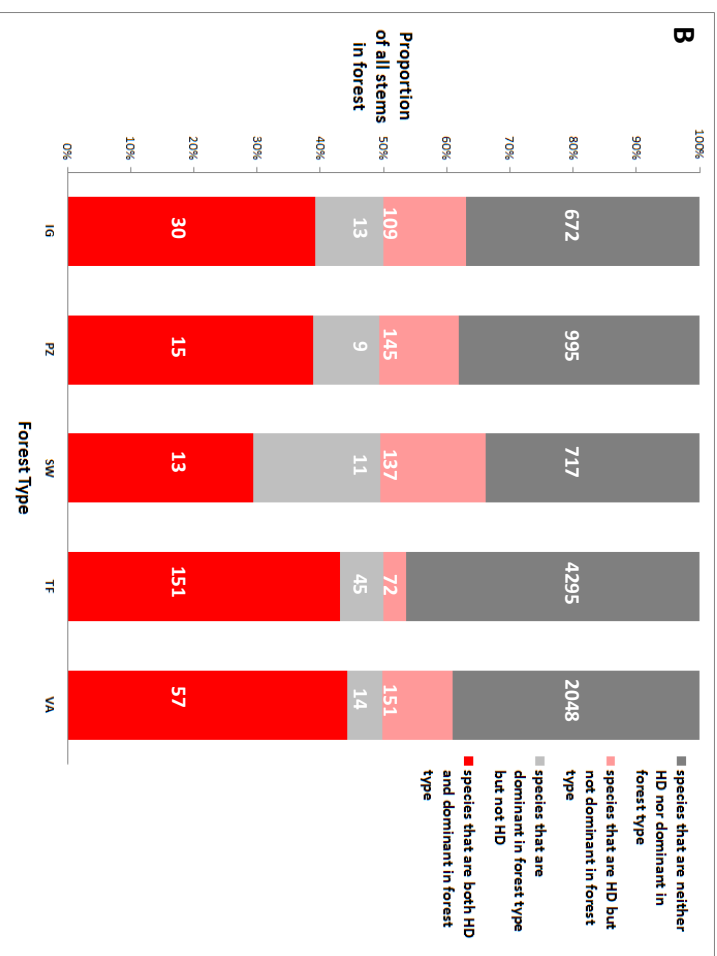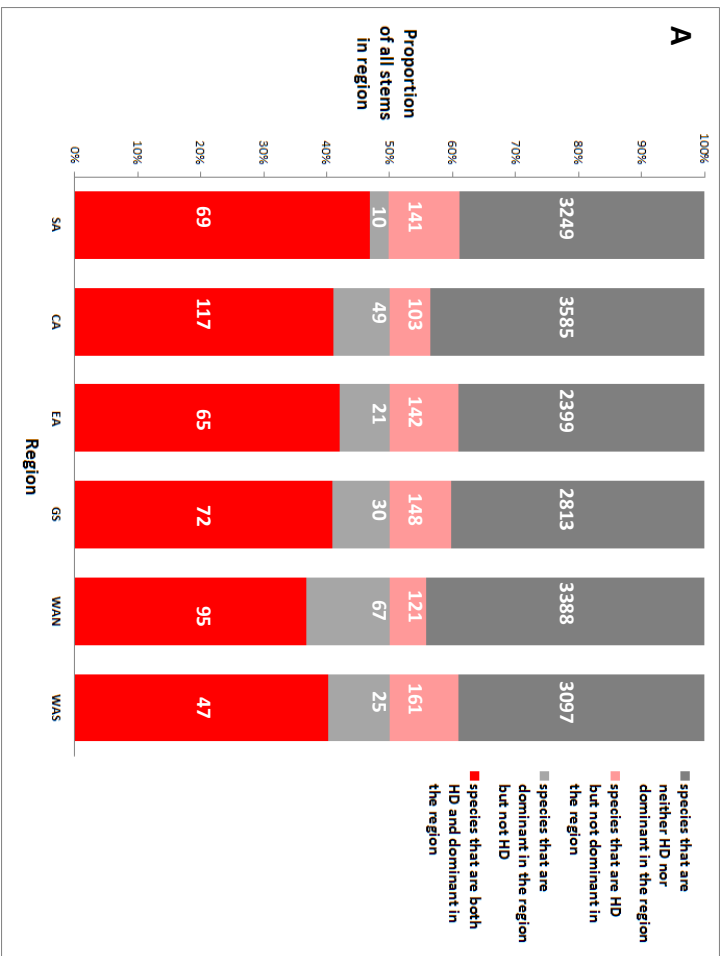
Fig 3.

Fig 4.

Online supplementary material

Hyper-dominance in the Amazonian Tree Flora

ter Steege et al. 2013

This document includes:

A short description of our data (Table S1)

Maps of plot locations (Figs. S1-3)

Estimates of tree density across Amazonia (Fig. S4)

Confidence intervals for population estimates (Fig. S5)

Estimating species richness with Fisher's alpha (Fig. S6)

Hyper-dominant species by plot (Fig. S7)

Species richness by country (Fig. S8)

Hyper-dominant species by family and in the APG tree (Table S2, Fig. S9)

Hyper-dominant species and size of genus world-wide (Fig. S10)

Testing the validity of the model predictions (Figs. S11,12)

Additional references for the online supplementary material

Appendices S1-S3 (Excel file)

A short description of our data

The 1170 tree plots used for compositional analyses were distributed among regions and forest types as shown in Figure 1 and Table S1 (see also Figs. S1-S3). Most plots (852) measured 1 ha, 253 were smaller, 61 were larger, and 4 were plotless samples (point centered quarter) for which the sampled area was unknown but the number of trees was equivalent to that typically found in 0.5-1 ha.

Table S1. The number of tree plots with compositional data in each of the five forest types and six regions used in the study.

Region	IG	PZ	SW	TF	VA	Total
CA	13	5	4	213	48	283
EA	3			71	30	104
GS	7	47	5	222	8	289
NWA	21	19	4	140	40	224
SA			2	71	18	91
SWA	3		7	133	36	179
Total	47	71	22	850	180	1170

The proportions of tree plots in the ATDN dataset that sample the five forest types are roughly equivalent to the proportions of Amazonia covered by those forest types. Várzea and igapó together cover 10% of Amazonia (*38, 40*) and account for 19% of our plots. Podzols and arenosols cover 4.6% of Amazonia (*38*) and account for 6% of our plots. Swamps account for 1.8% of our plots, and peatlands are believed to account for approximately 1.7% of the study area (*41*).

We found a total of 4970 valid species, 817 genera, and 122 families in the 1170 tree plots used for compositional analyses. Fabaceae, not surprisingly, is the most abundant family, with almost 100,000 individual trees and 119 genera, followed by Arecaceae (52,507; 25), Lecythidaceae (46,322; 10), Sapotaceae (40,429; 17), Malvaceae (29,424; 36), Burseraceae (28,762; 7), Chrysobalanaceae (28,597; 7), Moraceae (28,069; 19), Euphorbiaceae (25,955; 42), and Annonaceae (22,378; 27). Fabaceae are also the most species-rich family, with 795 species, followed by Lauraceae (311), Annonaceae (289), Rubiaceae (278), Sapotaceae (207), Chrysobalanaceae (195), Myrtaceae (176), Malvaceae (168), Melastomataceae (168), and Euphorbiaceae (143). Note that Fabaceae has more than twice as many species as the second most diverse family.

The genera with the largest numbers of individuals were *Eschweilera* (31,495), *Protium* (26,131), *Pouteria* (21,852), *Licania* (21,321), *Euterpe* (14,802), *Inga* (14,791), *Eperua* (10,951), *Virola* (10,283), *Astrocaryum* (8973), and *Lecythis* (8505).

The most species-rich genus was *Inga* with 134 species, followed by *Pouteria* (117), *Licania* (105), *Ocotea* (93), *Miconia* (92), *Guatteria* (85), *Eugenia* (76), *Protium* (69), *Swartzia* (67), *Ficus* (59), and *Eschweilera* (52).

We made two adjustments to the names given in TROPICOS (methods). *Rollinia* was merged with *Annona*, because phylogenetic analysis has revealed it to be nested inside that genus (*42*). Similarly, *Crepidospermum* and *Tetragastris* are nested in *Protium* (Fine & Daly in prep.) and were merged into that genus.
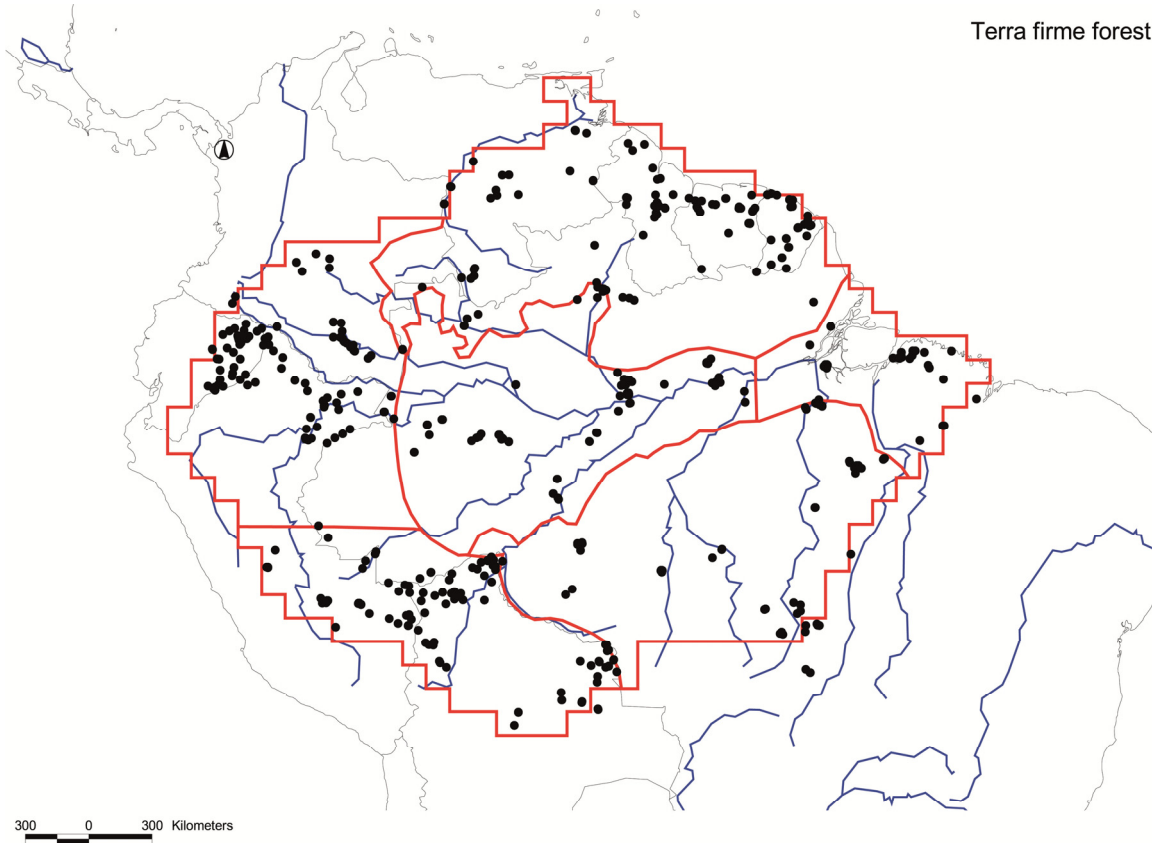
Terra firme forest plots

300   0   300 Kilometers

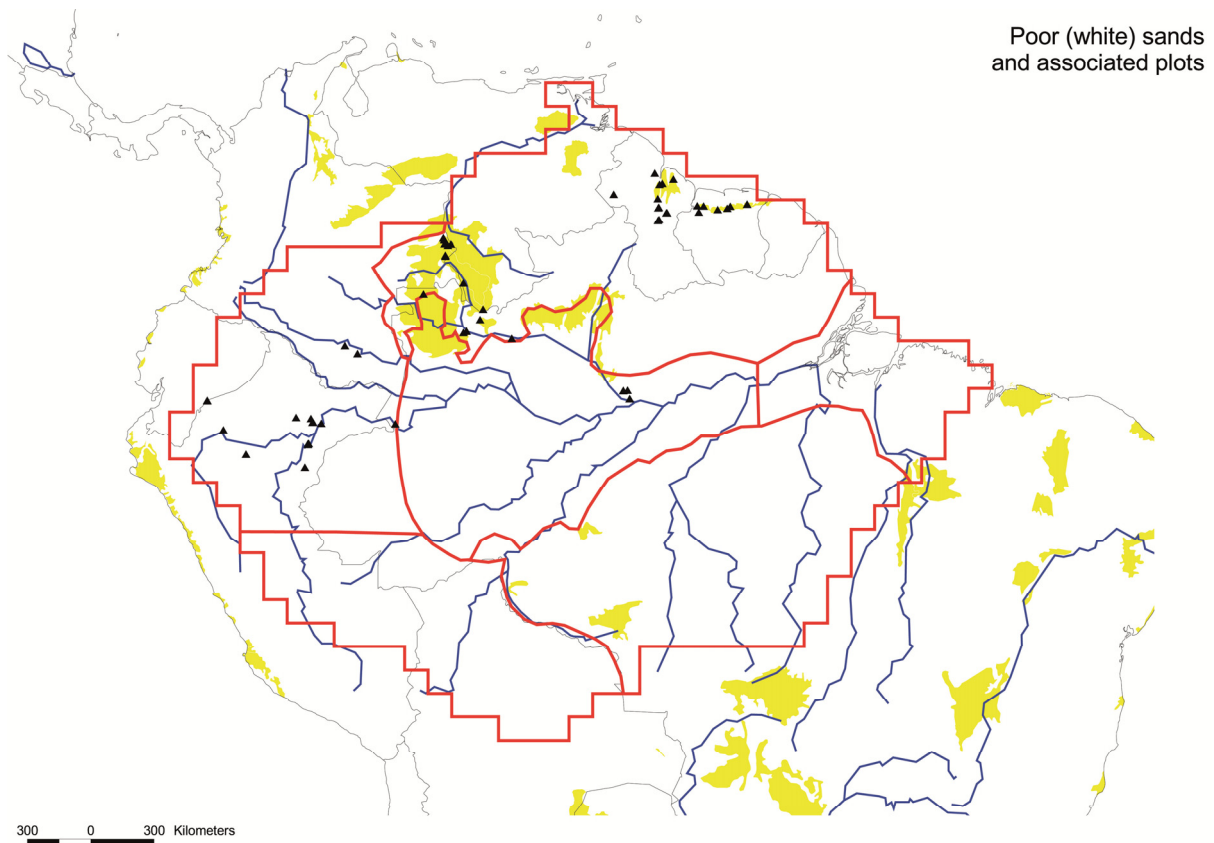**Figure S1.** Map of all plots in terra firme forest. Amazonian regions delimited in red after (after *38*).

Figure S2. Map of all plots in podzol forest, with the extent of white sand Podzol (Pz) and very poor Arenosol (Ar) soils in yellow according to (*38, 43*). Amazonian regions delimited in red after (after *38*).
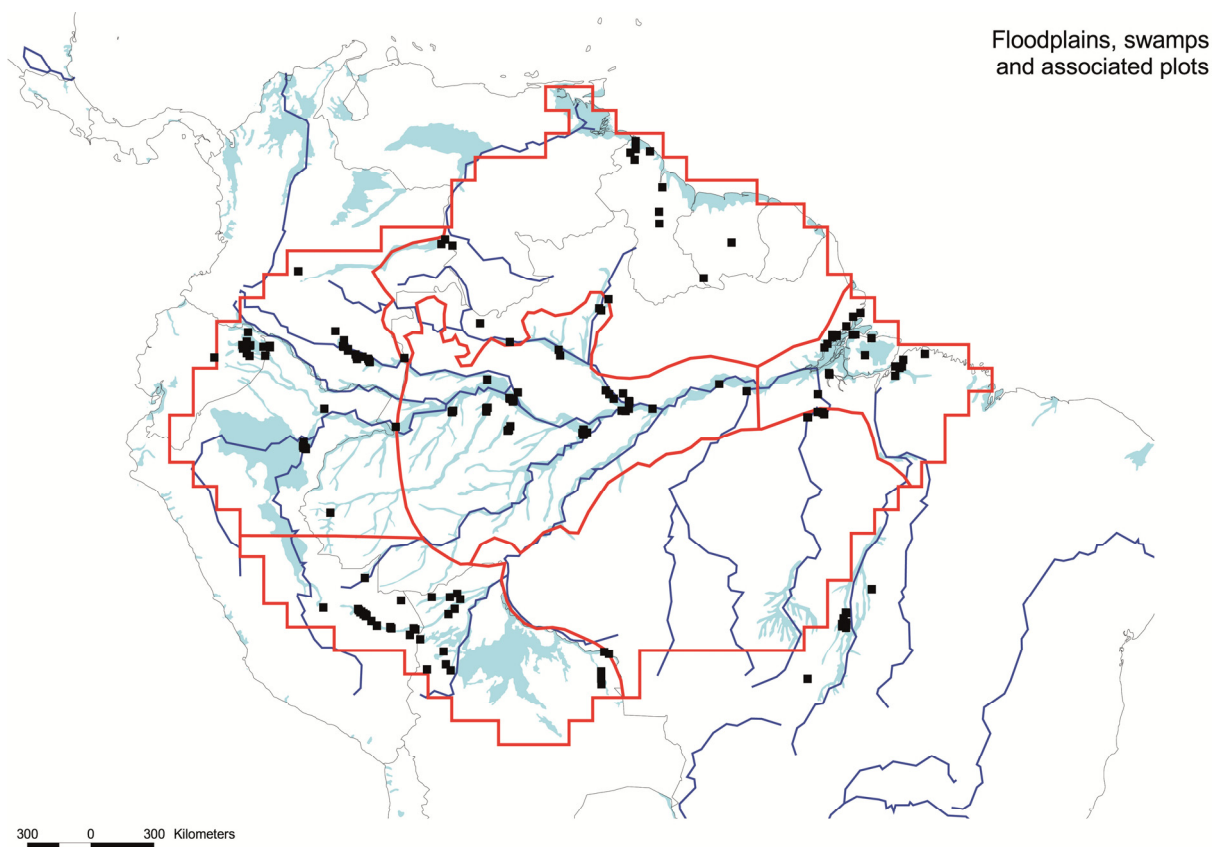

Figure S3. Map of all plots in várzea, igapó, and swamp forests, with the extent of floodplain soils (Gleysoils (Gl), Fluvisols (Fl) and Histosols (Hs)) in blue according to (*38, 43*). Amazonian regions delimited in red after (*1*).

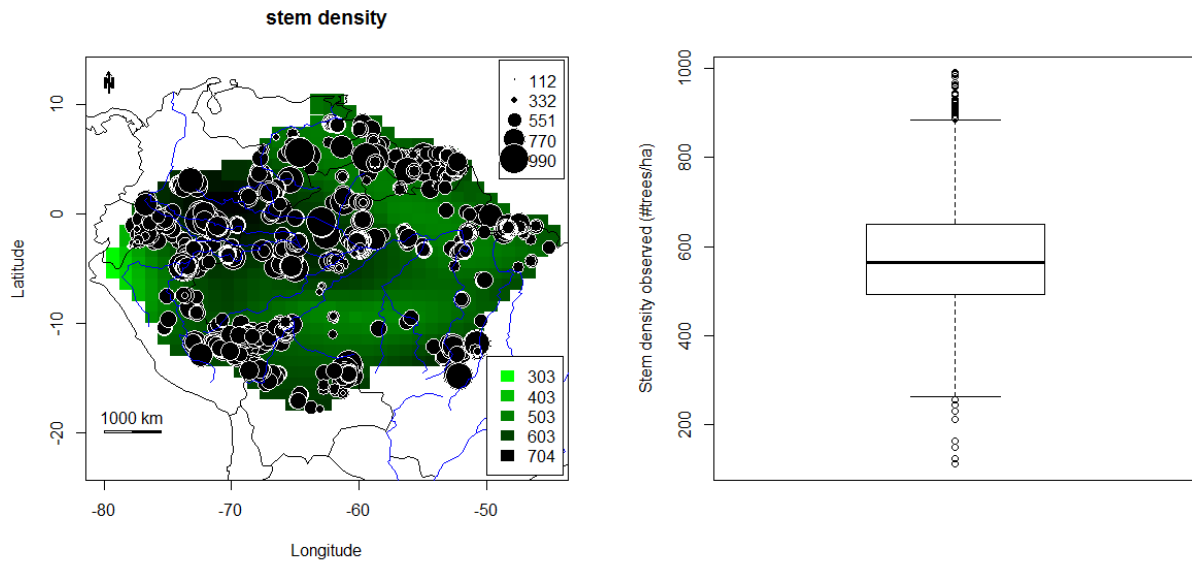# Estimates of tree density across Amazonia

stem density

Figure S4. Left. Stem density (no. of trees ≥10 cm dbh per ha) in 1195 tree plots across Amazonia. The black circles show the empirical data (range 112 – 990 trees/ha), while the green background color shows the loess interpolation of plot data for one-degree grid cells (range 303 – 705). **Right.** Boxplot of observed stem densities (n = 1195).
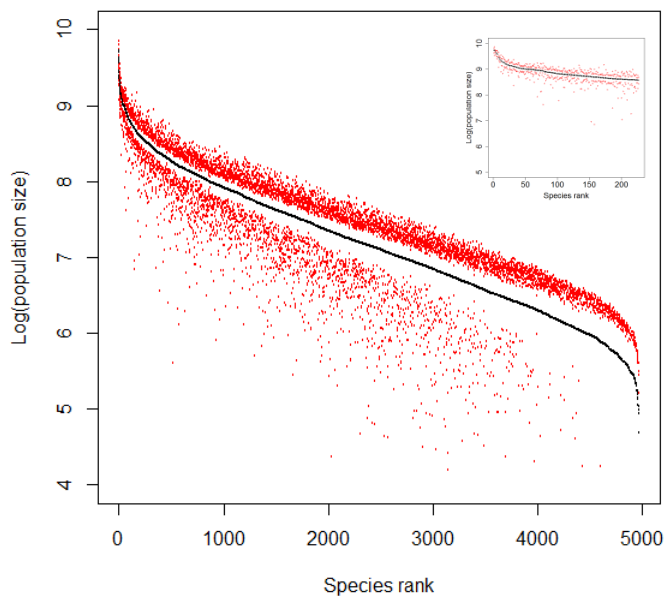
Figure S5. Rank-abundance distribution of mean estimated Amazonian population sizes (500 bootstraps of 1000 plots drawn with replacement, black dots) and 95% confidence intervals (red dots) for 4970 valid species. Population size is measured as number of trees ≥10 cm dbh. The inset shows mean estimated population sizes and 95% confidence intervals for the 227 hyper-dominants. Data for all species is provided in Appendix S1. For further information on the bootstraps see the section "Testing the validity of the model predictions". and Figure S11 below.

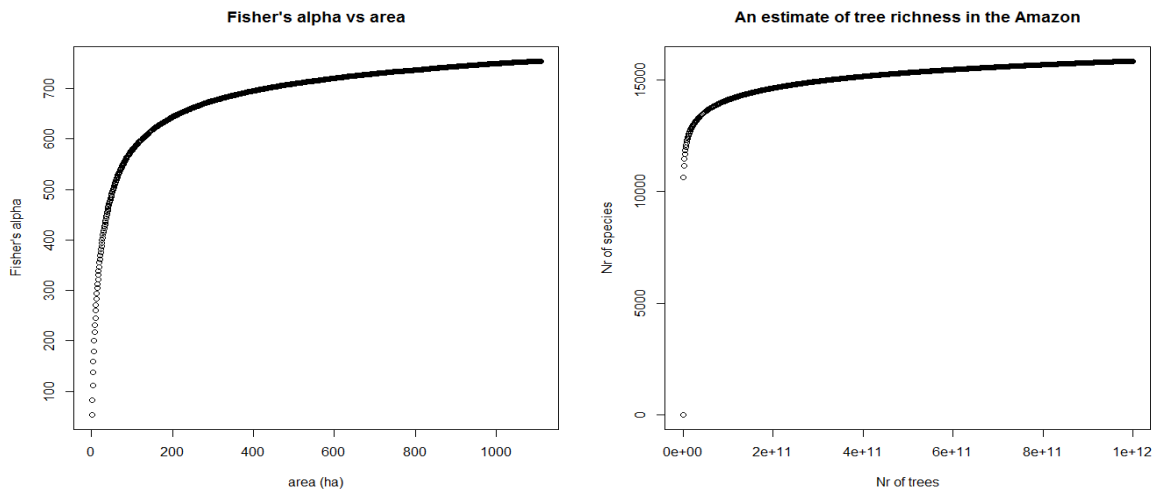# Estimating species richness with Fisher's alpha

Figure S6. If species were randomly distributed across Amazonia and we sampled at random throughout that area, our relative abundance distribution would have the same form and the same Fisher's alpha as the Amazonian RAD. Fisher's alpha would also reach an asymptote after a sufficiently large sample had been made. Because conspecific trees are clumped at various spatial scales (due to seed dispersal, preference for soil types) and our sampling was not random, our RAD differs in some respects from the true Amazon-wide RAD. Specifically, it underestimates Fisher's alpha and therefore provides an underestimate of gamma diversity. **Left.** Fisher's alpha as a function of cumulative plot area, based on 100 randomizations of the plot data. The final Fisher's alpha value is 754. **Right.** Species richness as a function of the number of trees in Amazonia, calculated as $S = FA * \ln(1 + N/FA)$; where FA = Fisher's alpha (754), and N is the number of trees. Even an error of 50% in the number of trees results causes little variation in final species richness. The final (underestimate) of the number of tree species in the greater Amazon is 15,182 ($N = 3.9*10^{11}$, FA = 754) (*44*).
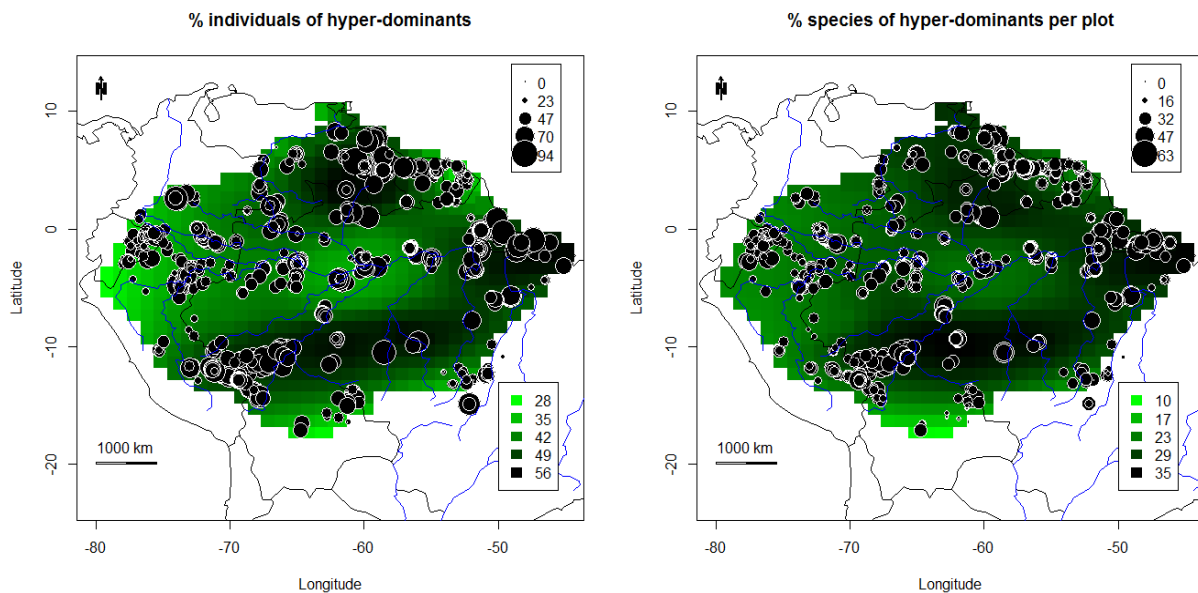
Figure S7. Left. The percentage of trees that belong to the 227 hyper-dominant species at the individual plot level. Black circles show the empirical data from individual tree plots, while the green background shows the loess interpolation of plot data for one-degree grid cells. Percentages are highest in the low-diversity areas of the Amazon (Guiana Shield and southern Amazon) but decrease towards the edges as species from neighboring biomes increase in importance. **Right.** The percentage of species in each plot that are on the list of the 227 hyper-dominant species.

Species richness by country

Our data provide estimates of the number of tree species occurring in each country in the study area (i.e., in the Amazonian portions of Bolivia, Brazil, Colombia, Ecuador, and Peru; in the three Guianan countries, which were pooled for this exercise; and in the Guianan and Amazonian portions of Venezuela; see Fig. 1) by constructing a Rank-Abundance Distribution of the estimated populations of all species predicted to occur in a country. Population sizes were estimated by summing the number of trees of each species in all the 1-degree grids cells whose centroids were in that country.
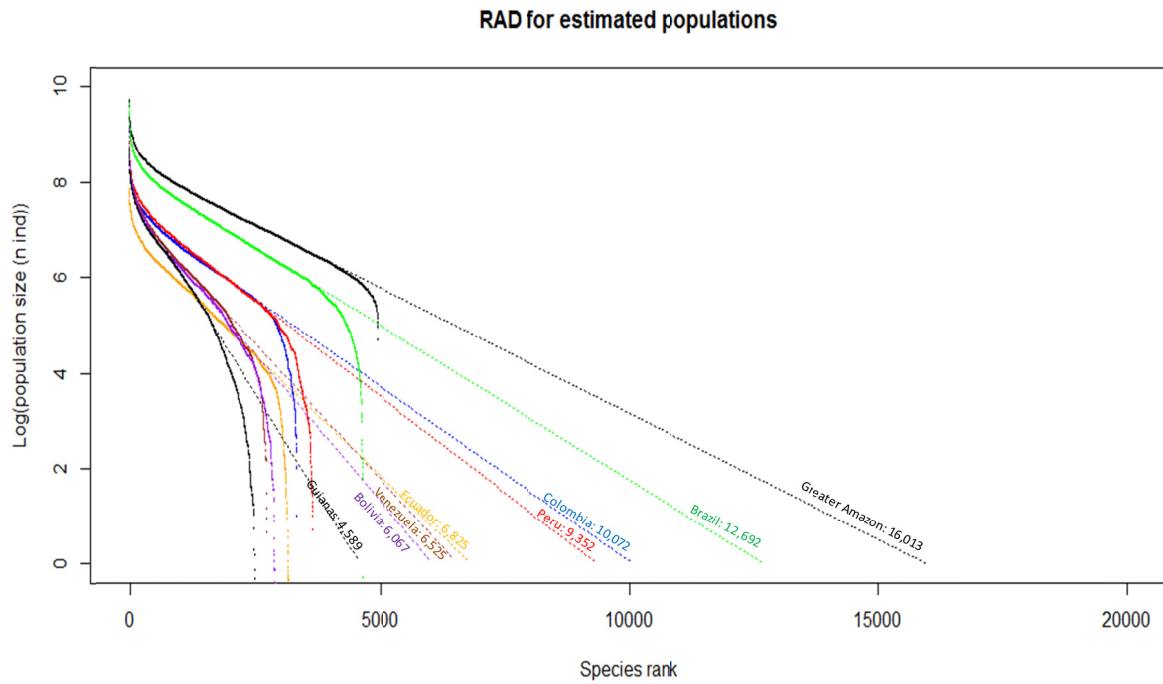

Figure S8. Rank-Abundance Distributions for countries in the greater Amazon, constructed from estimated population sizes in the Amazonian and/or Guianan portions of their territories, and linear extrapolations that yield the estimated number of tree species in each country (see text for explanation). Estimates based on one run of the full dataset for 1170 plots.

Table S2. Families with significantly more (hi) or significantly fewer (lo) hyper-dominant species than expected by chance are few. Palms (Arecaceae) have nearly five times more hyper-dominant species than expected by chance. Some very large and well-known families of the Amazon (Fabaceae, Sapotaceae and Chrysobalanaceae) have as many hyper-dominant species as expected by chance (Appendix S2). Family: name according to Tropicos (13), N ind: Number of individuals in 1170 plots used, N species: Number of species in 1170 plots used, HyperDom: Number of hyper-dominant species in family/genus observed, HypDomExp: Number of hyper-dominant species in family/genus expected (based on 1000 randomizations), ci.lo: lower 95% confidence limit for expected number of hyper-dominant species (based on 1000 randomizations), ci.hi: higher 95% confidence limit for expected number of hyper-dominant species (based on 1000 randomizations), hilo: significant deviation from expected number of hyper-dominants.

Family	N ind	N species	HyperDom	HypDomExp	ci.lo	ci.hi	hilo
Arecaceae	52507	70	15	3.196	-0.183	6.575	hi
Lecythidaceae	46332	107	19	4.846	0.698	8.994	hi
Malvaceae	29424	168	15	7.743	2.619	12.867	hi
Burseraceae	28762	94	11	4.186	0.215	8.157	hi
Moraceae	28069	135	11	6.194	1.542	10.846	hi
Euphorbiaceae	25955	143	14	6.496	1.650	11.342	hi
Myristicaceae	21648	57	11	2.564	-0.420	5.548	hi
Meliaceae	14134	71	8	3.261	-0.269	6.791	hi
Urticaceae	11869	67	7	3.205	-0.096	6.506	hi
Violaceae	10814	35	5	1.664	-0.816	4.144	hi
Goupiaceae	1670	1	1	0.037	-0.333	0.407	hi
Annonaceae	22378	289	4	13.21	6.424	19.996	lo
Lauraceae	18629	311	4	14.26	7.367	21.153	lo
Rubiaceae	11490	277	1	12.678	6.217	19.139	lo
Melastomataceae	8225	168		7.662	2.650	12.674	lo
Myrtaceae	7912	176		8.049	2.717	13.381	lo

Figure S9 (next page). An illustration of phylogenetic convergence in hyper-dominance among Amazonian tree genera. Radial phylogeny is based on two plastid markers and represents the maximum clade credibility topology from Bayesian MCMC analysis (Dexter et al., unpubl. Data (45)). Genera in red host at least one HD species. Some genera from our plot database were not available for this illustration.
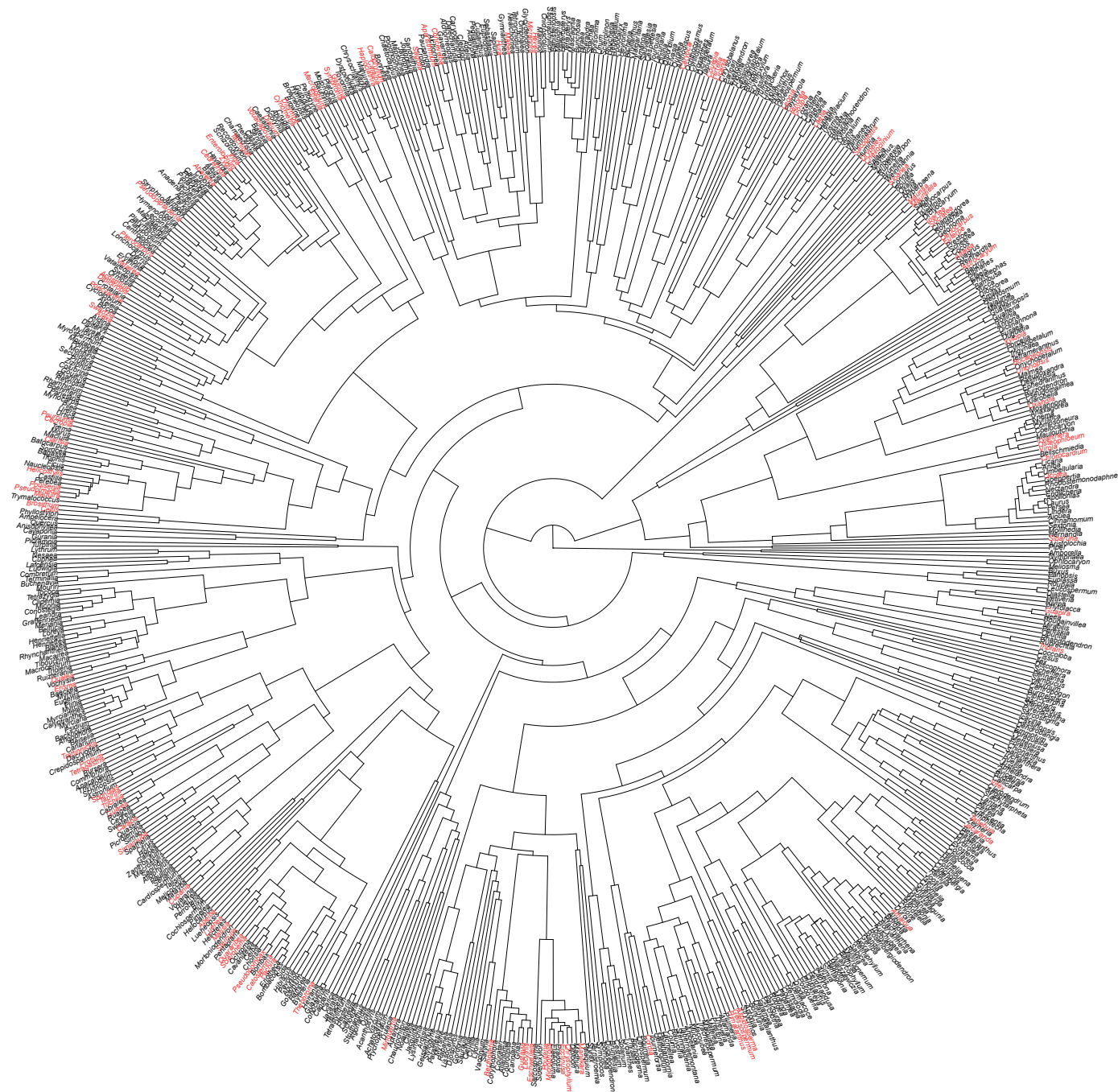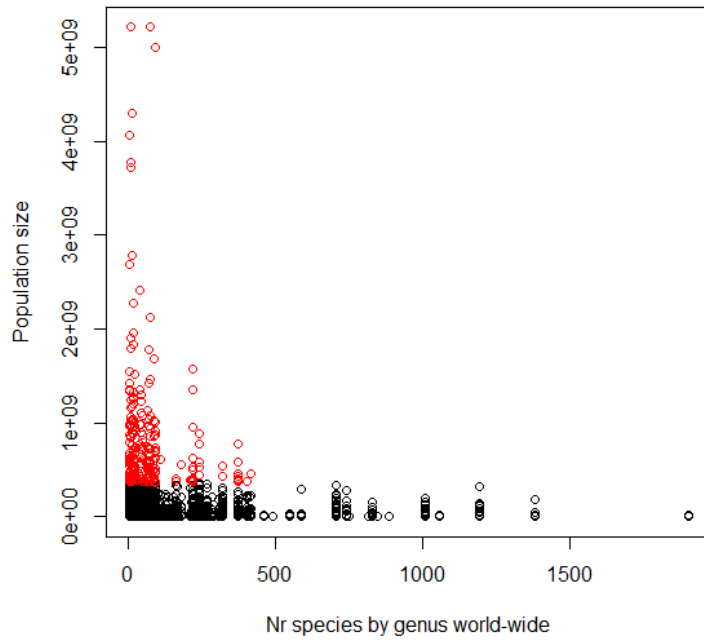
Figure S10. Hyper-dominant species are found more often (101 times) in genera that have few (20) species worldwide than expected by chance (59 times, p < 0.001). Hyper-dominants in red. NB: this figure does not correct for phylogeny nor account for the different ages of each genus.

Testing the validity of the model predictions

A fundamental assumption of our analyses is that the population size estimates generated by the loess model were reasonably accurate for the most abundant species. This assumption is disputable for a few reasons: 1) the dataset is very small compared to the community to which it was extrapolated; 2) tree plots were not distributed randomly across the study area; 3) trees were identified by many different research teams; and 4) no environmental data was used by the model, even though many species in the ATDN dataset are known to respond to environmental heterogeneity in the study area. A fifth problem makes the assumption especially difficult to test: 5) the fact that a basin-wide population size has not been empirically determined for any Amazonian tree species, which precludes a comparison between projected and observed values.

We addressed these shortcomings by quantifying the error that each could introduce into our results.

Addressing problems 1 and 2: the size of the dataset and the clumped distribution of plots

To test how sampling intensity and the geographic distribution of plots affected the estimated population sizes of hyper-dominant species, we recorded the frequency with which the 227 hyper-dominants qualified as hyper-dominant in the 500 runs of the bootstrap exercise described in the methods section. Most species (137, 60% of the total) qualified as hyper-dominants in 90-100% of runs, while 207 species (91.2%) qualified as hyper-dominants in more than half of runs (Fig. S10a). Median (Fig. S10b) and mean (Fig. S10c) ranks for the 500 runs showed high stability.
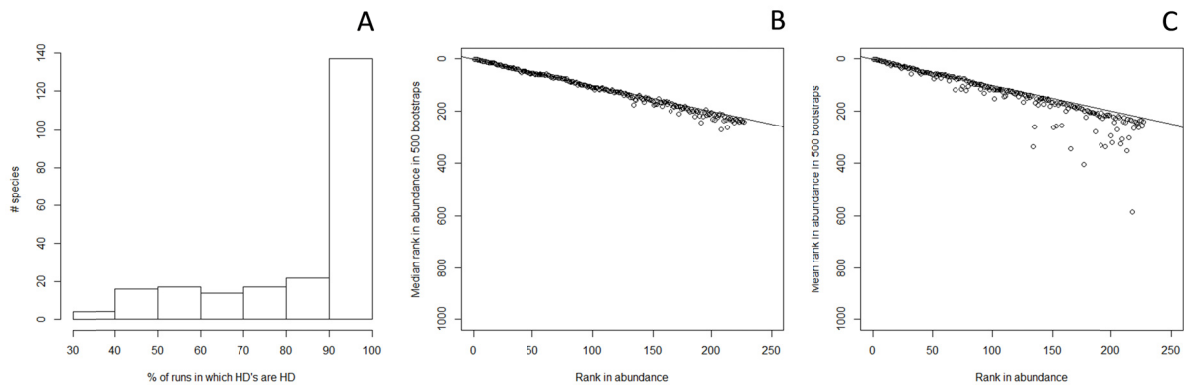

Figure S11. Most hyper-dominant species qualified as hyper-dominant species (ranks 1 - 227) in most of the 500 bootstrap runs (A). Median rank (B) and mean rank (C) were both close to the species' final rank based on mean estimated population size. B and C: straight line : y=x

In bootstrap runs for which a given hyper-dominant species did not qualify among the top 227 species, it rarely qualified as rare. The lowest median rank observed for a hyper-dominant species in the 500 bootstrap runs was 275, and hyper-dominant species never ranked lower than 1000th (i.e., ranks 1000-4790). These analyses provide strong evidence that the identities and estimated population sizes of the hyper-dominant species remain stable and predictable with varying levels of sampling intensity and geographic bias.

The median percentage of individuals that belong to hyper-dominant species within an individual plot was 40.7% (range = 0-93.9%, Fig. S7). Comparable figures for the five forest types are: igapó 32.9%, white sand forest 43.6%, swamp 35.9%, várzea 34.7%, and terra firme 30.1%. The median number of hyper-dominant species was 32 per plot (range = 0-78. The 438 plots containing fewer than 20 hyper-dominant species were evenly distributed across Amazonia but not across forest type. Only 15.1% of all terra firme plots have less than 20 hyper-dominants. For the other forest types the percentage is: igapó 76.6%, white sand forest 78.9%, swamp 50.0%, várzea 42.8%.

Addressing problem 3: taxonomic and identification problems

Taxonomic and identification problems are widespread in Amazonian tree inventories. However, two independent lines of evidence suggest that resolving these problems will not fundamentally alter the patterns described for hyper-dominant species.

First, we observed a consistent relationship in the ATDN dataset between the abundance of a species and the likelihood that it had been identified with a valid name. The percentage of identified species in individual plots was significantly higher than that of unidentified species-level taxa (87.0 vs. 13% stems/ha, $F_S = 22,774$, $p \ll 0.001$). Furthermore, very common morpho-species are very infrequent in the ATDN dataset. Only 48 of the 1170 ATDN plots contained a morpho-species that accounted for >10% of all individuals and only 10 plots contained a morpho-species that reached >20%. Given that all 227 hyper-dominants reach high local relative abundances (Fig. 3b), these numbers suggest that very few currently unidentified species will eventually qualify as hyper-dominant species.

Second, we see strong evidence that taxonomic and identification problems are less severe in hyper-dominant species than in other species, in the form of a strong positive correlation between the abundance of a species in the field, the number of specimens in herbaria, and the number of fertile specimens (i.e., specimens with flowers or fruits) collected during field work. Common species are better represented in herbaria than rare species, because individual collectors are more likely to encounter them (*46*). Common species are also more likely than rare species to be collected fertile during the establishment of tree plots. For example, in 25 ATDN plots established in eastern Ecuador (*47*), we found that hyper-dominant species were more likely than other species to be collected fertile (27.8 vs. 17.7%). Botanists trying to identify a hyper-dominant species thus have both a higher likelihood of matching their field specimens with museum specimens and a broader range of morphological features to facilitate identification.

Addressing problem 4: no use of environmental data

The model we used to estimate population sizes was a loess function, parameterized exclusively with plot location and observed species abundances in plots. This is a very different approach from the most commonly used class of species distribution modeling: maximum entropy modeling, or Maxent (*48, 49*). Maxent uses presence-only data fitted to environmental variables of confirmed locations to produce a map of habitat suitability. In a Maxent model, a species known to occur under a given set of environmental conditions is predicted to occur in all environmentally similar areas, even when those areas are outside of the species' known range. Because Amazonian tree species are known to respond strongly to environmental variation, an earlier version of our model included climatic data. That version, however, routinely predicted significant populations of species in regions of the Amazon where a large number of ATDN plots and other plant collection efforts had consistently failed to record those species (i.e., Type I errors were common). Modeling with only latitude and longitude as predictive variables is a more conservative option, because it ensures that such errors will be made at a much lower frequency and that species will never be predicted far from confirmed records. For the same reason we used a span of 0.2; at higher span values species ranges extended too far into areas with no known occurrence. Varying span values from 0.2 to 0.5 did not strongly affect population size estimates. Fig. S11 shows three examples of modeled ranges with a span value of 0.2.
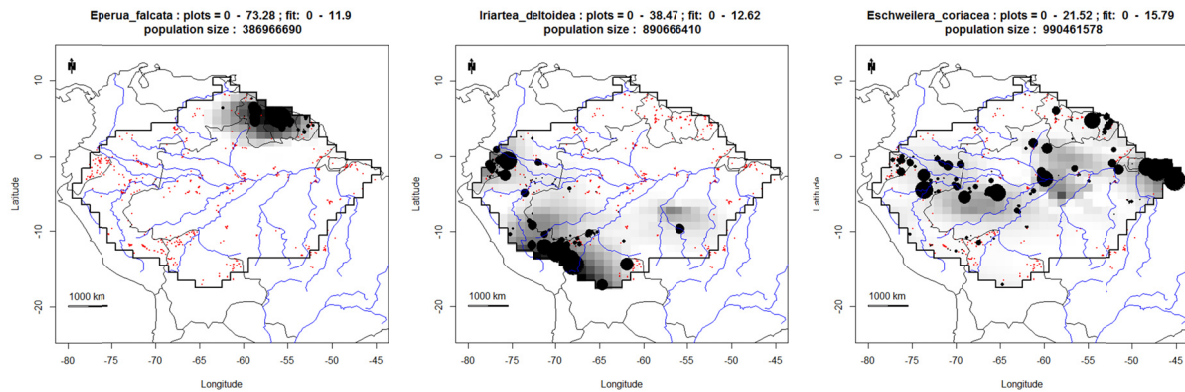
Figure S12. Distribution maps of three Amazonian hyper-dominant species as estimated by the spatial loess model: *Eperua falcata*, ranked 13th in abundance overall and with an eastern distribution, *Iriartea deltoidea*, ranked fifth overall and with a western distribution, and *Eschweilera coriacea*, ranked third overall and with a pan-Amazonian distribution. Black dots are tree plots where the species has been recorded, and dot size indicates the relative abundance of the species in the plot. Red dots are plots where the species has not been recorded. Shading in degree grid cells indicates the loess spatial average. For *E. falcata*, relative abundance in individual plots ranged from 0 to 73.28%, and the loess spatial average in individual grid cells ranged from 0 to 11.89%. Comparable numbers for *I. deltoidea* are 0-38.47% and 0-13.38%, and for *E. coriacea* 0-21.52% and 0-15.87%.

Addressing problem 5: the absence of empirically determined population sizes

It is not possible to compare estimated population sizes with measured population sizes, because the latter do not exist for any Amazonian tree species. However, it is possible to compare the population sizes estimated by the loess model with population sizes estimated using a different method based on the measured extent of Amazonian forest types. The estimated population of *Maurita flexuosa* is 1.5 billion stems. If we assume that one hectare of mono-dominant *M. flexuosa* swamp contains 500 *M. flexuosa* trees, then our 1.5 billion stem estimate suggests that there are <3 million ha of mono-dominant *M. flexuosa* swamps in the entire basin. The Pastaza Fan alone has >2 million ha of close-to-mono-dominant *M. flexuosa* stands. A similar test for white sands/podzol using *Eperua falcata* and *E. leucantha* (lumped together). Together the model estimates that 3.9 billion trees in the greater Amazon belong to these species. If we assume that one hectare of white sand/podzol forest contains on average 150 stems that belong to these species then the model suggests that there are roughly 26 million ha of white sand/podzol forest in the greater Amazon. The extent of podzols in the greater Amazon has been estimated as 17 million ha (*50*). The estimate of Podzols and Arenosols (Fig. S1.2) is 34 million ha (*38*).

We know of one study that attempted to estimate populations of trees over a large area in the Amazon Basin based on forest inventories (trees over 30cm dbh were measured) (*51*). The most abundant species in central western Amazonia (blocks: Roraima-Boa Vista, Manaus, Rio Purus – total forest area 623,139 km^2) was *Eschweilera coriacea*, with an estimated population of 193 million individuals (this compares to roughly 800 million trees > 10 cm dbh), followed by *Goupia glabra* (93 million individuals, or 370 million > 10 cm). Rollet concluded *E. coriacea* should be the most common tree species in the Brazilian Amazon. While our data suggest that two other species have higher total population size (*Euterpe precatoria* and *Protium altissimum*), a difference caused by our much larger sampled area (c. 10x) and lower diameter cut-off (four times as many trees ha^{-1}), our estimate of *E. coriacea* (c. 5,000 million) is certainly of similar order of magnitude (193*10*4 = 7,000 million). We note that in the forest inventories used by Rollet other *Eschweilera* species will have been pooled more often with *E. coriacea* than in our more acute inventories (see *35, 52 for a discussion on this*).

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Herbaria contributing tropical plant collection records for use in estimating species' range extents.

Data were accessed through the Global Biodiversity Information Facility (http://www.gbif.org/) and SpeciesLink (http://splink.cria.org.br) in March 2009.

GBIF:

1. AIMS - Bioresources Library (OBIS Australia) (http://data.gbif.org/datasets/resource/396)
2. Andes to Amazon Biodiversity Program (http://data.gbif.org/datasets/resource/56)
3. Arizona State University (http://data.gbif.org/datasets/resource/1294)
4. Arizona State University Vascular Plant Herbarium (http://data.gbif.org/datasets/resource/676)
5. Australian National Herbarium (CANB) (http://data.gbif.org/datasets/resource/47)
6. Belo Horizonte, Herbario (http://data.gbif.org/datasets/resource/1318)
7. BioCentro-UNELLEZ (http://data.gbif.org/datasets/resource/1310)
8. Biologiezentrum Linz (http://data.gbif.org/datasets/resource/1104)
9. Bishop Museum Natural History Specimen Data (http://data.gbif.org/datasets/resource/54)
10. BoGART (http://data.gbif.org/datasets/resource/1087)
11. Botanische Staatssammlung Munchen (http://data.gbif.org/datasets/resource/1289)
12. Botanischer Garten und Botanisches Museum Berlin-Dahlem, Zentraleinrichtung der Freien Universitat Berlin (http://data.gbif.org/datasets/resource/1309)
13. CABI Bioscience Genetic Resource Collection (http://data.gbif.org/datasets/resource/166)
14. California Academy of Sciences (http://data.gbif.org/datasets/resource/1352)
15. California State University, Chico (http://data.gbif.org/datasets/resource/737)
16. Canadian Museum of Nature Herbarium (http://data.gbif.org/datasets/resource/123)
17. Centre for Plant Biodiversity Research (http://data.gbif.org/datasets/resource/1340)
18. CGN-PGR (http://data.gbif.org/datasets/resource/1102)
19. CIBIO, Alicante:ABH-GBIF (http://data.gbif.org/datasets/resource/251)
20. CSIRO (http://data.gbif.org/datasets/resource/1283)
21. DAO Herbarium Type Specimens (http://data.gbif.org/datasets/resource/527)
22. Database Schema for UC Davis [Herbarium Labels] (http://data.gbif.org/datasets/resource/734)
23. Database Schema for UC Davis [TGRC] (http://data.gbif.org/datasets/resource/735)
24. Department of Botany and Microbiology, Ohio Wesleyan University, Delaware, Ohio (http://data.gbif.org/datasets/resource/1274)
25. Desmidiaceae Engels (http://data.gbif.org/datasets/resource/1089)
26. EASIANET (http://data.gbif.org/datasets/resource/206)
27. EMBRAPA (http://data.gbif.org/datasets/resource/1262)
28. Embrapa Amazonia Oriental (http://data.gbif.org/datasets/resource/1288)
29. EMBRAPA Recursos Geneticos e Biotecnologia - CENARGEN (http://data.gbif.org/datasets/resource/1279)
30. EURISCO (http://data.gbif.org/datasets/resource/1396)
31. EURISCO, The European Genetic Resources Search Catalogue (http://data.gbif.org/datasets/resource/1905)
32. Fairchild Tropical Botanic Garden Virtual Herbarium Darwin Core format (http://data.gbif.org/datasets/resource/202)
33. Field Museum of Natural History (http://data.gbif.org/datasets/resource/1190)
34. Flora of Japan Specimen Database (http://data.gbif.org/datasets/resource/586)
35. Florida Atlantic University (http://data.gbif.org/datasets/resource/1320)
36. Forschungsinstitut Senckenberg (http://data.gbif.org/datasets/resource/1130)

37. Friedrich-Schiller-Universitat Jena (http://data.gbif.org/datasets/resource/1247)

38. Fruit and seed collection database (http://data.gbif.org/datasets/resource/1093)

39. Fundacio CETEC (http://data.gbif.org/datasets/resource/1312)

40. Gent University (http://data.gbif.org/datasets/resource/1292)

41. Goteborg University (http://data.gbif.org/datasets/resource/1282)

42. Gothenburg Herbarium - Types (GBIF:IH:GB:Herbarium) (http://data.gbif.org/datasets/resource/1766)

43. Harvard University Herbaria (http://data.gbif.org/datasets/resource/1827)

44. HerbarImages (http://data.gbif.org/datasets/resource/1095)

45. Herbario (http://data.gbif.org/datasets/resource/566)

46. Herbario del Instituto de Ecolog¡a, A.C., M,xico (IE-XAL) (http://data.gbif.org/datasets/resource/1597)

47. Herbario Nacional de Bolivia (http://data.gbif.org/datasets/resource/1313)

48. Herbario Universidad de M laga: MGC-Corm¢fitos (http://data.gbif.org/datasets/resource/259)

49. Herbarium (UNA) (http://data.gbif.org/datasets/resource/775)

50. Herbarium Barroso (http://data.gbif.org/datasets/resource/1281)

51. Herbarium Descoigns (http://data.gbif.org/datasets/resource/1299)

52. Herbarium Fromm-Trinta (http://data.gbif.org/datasets/resource/1354)

53. Herbarium hermogenes (http://data.gbif.org/datasets/resource/1297)

54. Herbarium Pederson (http://data.gbif.org/datasets/resource/1270)

55. Herbarium S.C.H. Barrett (http://data.gbif.org/datasets/resource/1334)

56. Herbarium Sigrid Liede (http://data.gbif.org/datasets/resource/1277)

57. Herbarium Specimens of Museum of Nature and Human Activities, Hyogo Pref., Japan (http://data.gbif.org/datasets/resource/1798)

58. Herbarium Stace (http://data.gbif.org/datasets/resource/1302)

59. Herbarium Taylor (http://data.gbif.org/datasets/resource/1355)

60. Herbarium Universitat Ulm (http://data.gbif.org/datasets/resource/1224)

61. Herbarium Webster (http://data.gbif.org/datasets/resource/1346)

62. Herbier de la Guyane (http://data.gbif.org/datasets/resource/1436)

63. Ilha Solteira, Herbario (http://data.gbif.org/datasets/resource/1266)

64. Institut Botanic de Barcelona, BC (http://data.gbif.org/datasets/resource/299)

65. Institut de Recherche pour le Developpement (IRD) (http://data.gbif.org/datasets/resource/1265)

66. Institut fur Allgemeine Botanik (http://data.gbif.org/datasets/resource/1263)

67. Instituto de Botanica (http://data.gbif.org/datasets/resource/1252)

68. Instituto de Botanica Darwinion (http://data.gbif.org/datasets/resource/1295)

69. Instituto de Botanica del Nordeste (http://data.gbif.org/datasets/resource/1287)

70. Instituto de Pesquisas Cientificas e Tecnologicas do Estado do Amapa (http://data.gbif.org/datasets/resource/1246)

71. Instituto Nacional de Pesquisas da Amazonia (http://data.gbif.org/datasets/resource/1141)

72. Internation Botanical Collections (S) (http://data.gbif.org/datasets/resource/1983)

73. IPK Genebank (http://data.gbif.org/datasets/resource/1851)

74. Jardi Botanic de Valencia: VAL (http://data.gbif.org/datasets/resource/238)

75. Jardim Botanico do Rio de Janeiro (http://data.gbif.org/datasets/resource/1273)

76. Johannes Gutenberg-Universitat (http://data.gbif.org/datasets/resource/1301)

77. Lichen Herbarium Berlin (http://data.gbif.org/datasets/resource/1097)

78. Lichen herbarium, Oslo (O) (http://data.gbif.org/datasets/resource/1067)

79. LPT (http://data.gbif.org/datasets/resource/1306)

80. Ludwig-Maximilians-Universitat (http://data.gbif.org/datasets/resource/1291)

81. Lund Botanical Museum (LD) (http://data.gbif.org/datasets/resource/1028)

82. Manaus, Herbario da Universidade do Amazonas (http://data.gbif.org/datasets/resource/1249)

83. MEXU/Plantas Vasculares (http://data.gbif.org/datasets/resource/780)

84. Missouri Botanical Garden (http://data.gbif.org/datasets/resource/621)

85. Museo Ecuatoriano de Ciencias Naturales (http://data.gbif.org/datasets/resource/1268)

86. Museu Botanico Municipal (http://data.gbif.org/datasets/resource/1239)

87. Museu Paraense Emilio Goeldi (http://data.gbif.org/datasets/resource/1235)

88. Museum National d'Histoire Naturelle, Paris (http://data.gbif.org/datasets/resource/1146)

89. Nationaal Herbarium Nederland (http://data.gbif.org/datasets/resource/1211)

90. Nationaal Herbarium Nederland, Leiden University branch (http://data.gbif.org/datasets/resource/1275)

91. Nationaal Herbarium Nederland, Utrecht University branch (http://data.gbif.org/datasets/resource/1242)

92. National Botanic Garden Belgium - Albertian Rift Rubiaceae (ENBI wp13) (http://data.gbif.org/datasets/resource/90)

93. National Botanic Garden Belgium - Myxomycetes (http://data.gbif.org/datasets/resource/88)

94. National Museum in Prague (http://data.gbif.org/datasets/resource/1324)

95. Naturhistorisches Museum Wien (http://data.gbif.org/datasets/resource/1157)

96. NSW herbarium collection (http://data.gbif.org/datasets/resource/968)

97. Old Dominion University (http://data.gbif.org/datasets/resource/1296)

98. Online Zoological Collections of Australian Museums (http://data.gbif.org/datasets/resource/623)

99. Orchid Herbarium Collection (http://data.gbif.org/datasets/resource/1495)

100. Paleobiology Database (http://data.gbif.org/datasets/resource/563)

101. Phanerogamie (http://data.gbif.org/datasets/resource/1506)

102. Planetary Biodiversity Inventory Eumycetozoan Databank (http://data.gbif.org/datasets/resource/1515)

103. Plants of Papua New Guinea (http://data.gbif.org/datasets/resource/969)

104. Pontificia Universidad Catolica del Ecuador (http://data.gbif.org/datasets/resource/1258)

105. Pontificia Universidad Catolica Madre y Maestra (http://data.gbif.org/datasets/resource/1341)

106. Real Jardin Botanico (Madrid), Vascular Plant Herbarium (MA) (http://data.gbif.org/datasets/resource/240)

107. Royal Botanic Gardens, Kew (http://data.gbif.org/datasets/resource/629)

108. Royal Ontario Museum (http://data.gbif.org/datasets/resource/1348)

109. Ruhr-Universitat Bochum (http://data.gbif.org/datasets/resource/1317)

110. SANT herbarium vascular plant collection (http://data.gbif.org/datasets/resource/222)

111. SERNEC - University of North Carolina at Chapel Hill - Plants (http://data.gbif.org/datasets/resource/895)

112. Smithsonian Institution (http://data.gbif.org/datasets/resource/1250)

113. Species of Eastern Brazil Vascular Plant Specimens (http://data.gbif.org/datasets/resource/729)

114. SysTax (http://data.gbif.org/datasets/resource/1875)

115. Systematic Botany and Mycology Laboratory, USDA/ARS (http://data.gbif.org/datasets/resource/1264)

116. The AAU Herbarium Database (http://data.gbif.org/datasets/resource/224)

117. The Deaver Herbarium, Northern Arizona University (http://data.gbif.org/datasets/resource/678)

118. The Myxomycetes Collections at the Botanische Staatssammlung Munchen - Collection of Hermann Neubert (http://data.gbif.org/datasets/resource/1443)

119. The Natural History Museum (http://data.gbif.org/datasets/resource/1172)

120. The System-wide Information Network for Genetic Resources (SINGER) (http://data.gbif.org/datasets/resource/1430)

121. The University of Hong Kong Herbarium (http://data.gbif.org/datasets/resource/724)

122. Type herbarium, Gottingen (GOET) (http://data.gbif.org/datasets/resource/1494)

123. UCD Botanical Conservatory (http://data.gbif.org/datasets/resource/739)

124. ULNM (http://data.gbif.org/datasets/resource/1300)

125. United States National Herbarium (http://data.gbif.org/datasets/resource/1248)

126. United States National Plant Germplasm System Collection (http://data.gbif.org/datasets/resource/1429)

127. Universidad de Buenos Aires (http://data.gbif.org/datasets/resource/1345)

128. Universidad de Costa Rica (http://data.gbif.org/datasets/resource/1184)

129. Universidad de M laga: MGC-Algae (http://data.gbif.org/datasets/resource/1864)

130. Universidad de Murcia, Dpto. Biolog¡a Vegetal (Bot nica), Murcia: MUB-HEPATICAE (http://data.gbif.org/datasets/resource/1522)

131. Universidad de Oviedo. Departamento de Biolog¡a de Organismos y Sistemas: FCO (http://data.gbif.org/datasets/resource/245)

132. Universidad Nacional Autonoma de Mexico (http://data.gbif.org/datasets/resource/1322)

133. Universidad Nacional de Colombia (http://data.gbif.org/datasets/resource/1290)

134. Universidad Nacional de Loja (http://data.gbif.org/datasets/resource/1284)

135. Universidad Polit,cnica de Madrid, Dpto. Biolog¡a Vegetal, Banco de Germoplasma (http://data.gbif.org/datasets/resource/1521)

136. Universidade de Brasilia (http://data.gbif.org/datasets/resource/1272)

137. Universidade de Sao Paulo (http://data.gbif.org/datasets/resource/1311)

138. Universidade Estadual de Campinas (http://data.gbif.org/datasets/resource/1255)

139. Universidade Federal de Juiz de Fora (http://data.gbif.org/datasets/resource/1260)

140. Universidade Federal de Mato Grosso (http://data.gbif.org/datasets/resource/1254)

141. Universidade Federal de Santa Catarina (http://data.gbif.org/datasets/resource/1335)

142. Universidade Federal do Maranhao (http://data.gbif.org/datasets/resource/1305)

143. Universidade Federal do Parana (http://data.gbif.org/datasets/resource/1337)

144. Universidade Federal do Rio Grande do Sul (http://data.gbif.org/datasets/resource/1280)

145. Universitat Wien (http://data.gbif.org/datasets/resource/1286)

146. Universitat Zurich (http://data.gbif.org/datasets/resource/1276)

147. University of Aarhus (http://data.gbif.org/datasets/resource/1349)

148. University of Alabama (http://data.gbif.org/datasets/resource/1316)

149. University of Calicut (http://data.gbif.org/datasets/resource/1343)

150. University of California (http://data.gbif.org/datasets/resource/1245)

151. University of California Botanical Garden DiGIR provider (http://data.gbif.org/datasets/resource/1412)

152. University of Michigan (http://data.gbif.org/datasets/resource/1285)

153. University of Texas at Austin (http://data.gbif.org/datasets/resource/1243)

154. University of Victoria (http://data.gbif.org/datasets/resource/1261)

155. University of Wisconsin Oshkosh (http://data.gbif.org/datasets/resource/1293)

156. USDA (http://data.gbif.org/datasets/resource/1342)

157. Vanderbilt University (http://data.gbif.org/datasets/resource/1241)

158. Vascular Plant Collection - University of Washington Herbarium (WTU) (http://data.gbif.org/datasets/resource/126)

159. Vascular Plant Type Specimens (http://data.gbif.org/datasets/resource/731)

160. Wageningen University (http://data.gbif.org/datasets/resource/1267)

161. Westfalische Wilhelms-Universitat (http://data.gbif.org/datasets/resource/1271)

SpeciesLink:

1. Banco de DNA do Jardim Botânico do Rio de Janeiro Carpoteca UFP
2. Coleção de Fanerógamas do Herbário do Estado "Maria Eneyda P. Kaufmann Fidalgo"
3. Coleção de plantas medicinais e aromáticas
4. Herbário - IPA Dárdano de Andrade Lima
5. Herbário "Irina Delanova Gemtchújnicov"
6. Herbário Central da Universidade Federal do Espírito Santo VIES
7. Herbário da Escola Superior de Agricultura Luiz de Queiroz
8. Herbário da Universidade Estadual de Campinas
9. Herbário da Universidade Estadual de Londrina
10. Herbário da Universidade Estadual de Ponta Grossa
11. Herbário da Universidade Federal de Sergipe
12. Herbário Dárdano de Andrade Lima
13. Herbário de Ilha Solteira
14. Herbário de São José do Rio Preto
15. Herbário Dimitri Sucre Benjamin
16. Herbário do Departamento de Botânica, SPF-IB/USP
17. Herbário do Instituto Agronômico de Campinas
18. Herbário do Museu Botânico Municipal
19. Herbário Dom Bento Pickel
20. Herbário Dr. Roberto Miguel Klein
21. Herbário Graziela Barroso
22. Herbário Jaime Coelho de Moraes
23. Herbário Lauro Pires Xavier
24. Herbário Mogiense
25. Herbário Pe. Camille Torrand
26. Herbário Prisco Bezerra
27. Herbário Professor Vasconcelos Sobrinho
28. Herbário Rioclarense
29. Herbário Sérgio Tavares
30. Herbário UEM
31. Herbário UFP - Geraldo Mariz
32. Herbário UFRN
33. INPA - Coleção de Madeiras - Xiloteca
34. INPA-Carpoteca - Carpoteca
35. INPA-Herbario - Herbário
36. MBML-Herbario
37. SPFw - Xiloteca do Instituto de Biociências da Universidade de São Paulo
38. UPCB - Herbário do Departamento de Botânica
39. Xiloteca "Profa. Dra. Maria Aparecida Mourão Brasil"
40. Xiloteca Calvino Mainieri
41. Xiloteca do Jardim Botânico do Rio de Janeiro

Appendices

S1 species.data

Basic information for all 4970 valid species.

Accepted_family: Family according to Tropicos (*30*)

Accepted_genus: Genus according to Tropicos (*30*)

Accepted_species: Species according to Tropicos (*30*)

n.ind: Number of individuals in ATDN database for 1170 plots

n.plots: Nr of plots (of 1170) in which the species is present

maxabund: Nr of individuals per ha in the plot where the species has it highest abundance

est.ind: Population size based on 1 run with all 1170 plots

population.mean: Mean population size of 500 runs with 1000 plots (with replacement)

population.sd: SD of population size of 500 runs with 1000 plots (with replacement)

species.relmax: Fraction of individuals in the plot where the species has it highest dominance

IV.maxcls: Forest type in which species has highest IV-value (1 = igapó, 2 = podzol, 3 = swamp, 4 = terra firme, 5 = várzea)

IV.indcls: IV value

IV.pval: p value for IV value

S2/S3 Families/Genera

Family/Genus: name according to Tropicos (*30*)

N ind: Number of individuals in 1170 plots used

N species: Number of species in 1170 plots used

HyperDom: Number of hyper-dominant species in family/genus observed

HypDomExp: Number of hyper-dominant species in family/genus expected (based on 1000 randomizations)

ci.lo: lower 95% confidence limit for expected number of hyper-dominant species (based on 1000 randomizations)

ci.hi: higher 95% confidence limit for expected number of hyper-dominant species (based on 1000 randomizations)

hilo: significant deviation from expected number of hyper-dominants