

Lianas reduce tree height across the tropics

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Article

Keywords:

Posted Date: June 30th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10132764/v1>

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Additional Declarations: There is **NO** Competing Interest.

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Abstract

Lianas are a defining component of tropical forests. Yet their influence on tree architecture, particularly height—a fundamental dimension of forest structure—remains unresolved, with only fragmentary and localised evidence. In this study, we quantify the effect of liana infestation on tree height using a pantropical dataset of 50,473 individual tree height and liana occupancy observations across 66 sites, by fitting hierarchical allometric tree height models. We show that liana-hosting trees are consistently shorter than individuals of the same stem diameter that do not bear lianas. Further, tree height suppression scaled with liana occupancy, with heavily infested trees (>50% occupancy) being suppressed about twice as much as moderately infested trees. We further reveal that the magnitude of liana-induced tree height suppression increases with temperatures and rainfall seasonality. Our results indicate that liana-induced tree height suppression is likely to intensify pantropically under climate change.

Introduction

Height is a fundamental dimension of tree architecture¹, mediating trade-offs that influence individual performance², competition dynamics³, and forest structure and functioning^{4,5}. By shaping access to light, mechanical stability, and hydraulic transport, tree height influences multiple ecosystem processes, including carbon sequestration⁶, resistance to disturbance (e.g. drought, wind)^{7,8}, and reproduction². Tree height–diameter relationships vary across biogeographic¹ and environmental^{9,10} gradients as well as among species with contrasting life-history strategies^{11,12} and these variations are commonly incorporated into allometric models^{13–15}. Although recent large-scale datasets have substantially improved our ability to document variation in tree height allometry¹⁶, much less is known about the drivers of within-species variation in tree height allometry¹⁷, particularly the role of biotic interactions¹⁸.

In tropical forests, one potential powerful yet underexplored source of within-species variation in tree height allometry is competition with lianas^{19–21}. Lianas are a defining component of tropical forests²², where they play an important role in shaping stand dynamics²³ and forest biogeochemical cycles^{24,25}. Lianas compete intensely with trees for light and other resources while using host stems for structural support^{26,27} and have been associated with reduced tree growth, survival, and carbon storage capacity^{28,29}. A few pioneering studies further suggest that lianas also alter tree architecture, including height^{30–33}. These associations may arise through multiple pathways, either because lianas actively suppress tree height growth through mechanical loading³², crown shading³⁴, crown damage³⁵, or because they preferentially grow on shorter or already suppressed trees, thereby perpetuating pre-existing differences in height. Although cross-sectional observations cannot fully disentangle these mechanisms, broad-scale analyses can reveal whether consistent

liana-associated differences in tree height emerge across species, sites and environmental gradients.

We indeed expect liana-associated height differences to vary with climate and host composition because liana abundance, liana–tree competition, and host susceptibility vary with rainfall, seasonality, disturbance and temperature^{36–40}. Drier and more seasonal forests also differ in canopy structure, water limitation and tree functional composition, including traits linked to drought avoidance, deciduousness and growth strategy^{41,42}. Such differences may alter the capacity of host trees to tolerate, compensate for or recover from liana loads^{21,43}. Given projections that liana proliferation may accelerate under future climatic conditions³⁸, understanding how lianas influence tree height allometries becomes increasingly important for anticipating shifts in forest structure and carbon storage.

In this study, we assessed how liana occupancy is associated with tree height across the tropics. We addressed three questions: 1) What is the average liana-associated difference in tree height across the tropics? 2) How do liana-associated height differences vary with climate among sites? and 3) If liana effects vary with climate, how is tree height expected to shift under projected future climate scenarios? To answer these questions, we compiled the largest database to date of individual tree diameter and height measurements, each associated with a standardized liana occupancy index. By explicitly modelling variation in tree height with liana occupancy, our study provides new insights into how these often-overlooked competitors reshape tree height allometries, with implications for forest structure, function and carbon dynamics.

Results

Data overview

We compiled a total of 50,473 individual trees with coincident information on diameter at breast height (DBH, range 10-255 cm), height, and liana crown occupancy index (COI), including 18,878 trees with moderate liana occupancy (i.e., COI of 1-2 or 1-50% of tree crown covered by lianas) and 8,670 trees with heavy liana occupancy (i.e. COI of 3-4 or more than 50% of tree crown covered by lianas), see Table 1 and Figure 1. This final dataset included 66 sites (Supplementary Table S1 and Figures S1–S2), retaining only those with at least 50 trees and 10 individuals per liana occupancy level, except for the monospecific Rio Grande do Sul dataset in Brazil. Across the dataset, a total of 2,616 tree species were represented. This included 76 tree species with at least 50 tree individuals in total and at least 10 for each liana occupancy level (hereafter referred to as “*abundant*”) for a total of 13,555 individual observations.

Pantropical tree height allometric models

To estimate the effect of liana occupancy on tree height, we ranked 20 allometric model formulations spanning three common allometric functional forms and with (“liana”) or without (“null”) liana effects, based on the Watanabe-Akaike information criterion (WAIC)⁴⁴. At the pantropical level (i.e., pooling all 66 sites together), models that included liana effects consistently and substantially outperformed null models (Supplementary Table S2). Relative to the best null model, accounting for liana occupancy reduced model root mean squared error by 3.2%, mean absolute error by 3.5%, and residual variance by 6.3%, indicating that liana occupancy captured a measurable component of otherwise unexplained variation in tree height.

We quantified the liana effect through the percentage change in predicted tree height for a liana-occupied tree relative to a liana-free tree ($\Delta\tilde{H}$ in %). We did so using the best performing allometric model (Weibull (b, k), Supplementary Table S2) for multiple tree diameters: for instance, we refer to $\Delta\tilde{H}_{50}$ as the relative change of tree height predicted for a 50 cm DBH tree under liana occupancy relative to a liana-free tree. According to this best pantropical model (Figure 1), tree height was reduced for both moderate ($\Delta\tilde{H}_{50} = -5.4\%$, 89% CI: -6.4% to -4.4%) and heavy ($\Delta\tilde{H}_{50} = -10.2\%$, -12.1% to -8.4%) liana occupancy levels. These relative tree height reductions corresponded to an absolute tree height change of respectively -1.5 m (-1.8 m to -1.1 m) and -2.8 m (-3.4 m to -2.2 m) for a 50 cm DBH tree.

The liana effect remained broadly constant up to approximately 50 cm DBH, after which it gradually weakened as DBH increased (Figure 1b–e, Supplementary Figure S3). Under heavy liana occupancy, the relative tree height reduction changed from -10.6% (-12.5% to -8.8%) to -7.1% (-9.1% to -5.3%) for a DBH of 25 and 150 cm.

Site-level and species-specific allometric models

Next, we assessed how the magnitude of liana-induced shifts in tree height varied among sites by comparing site-specific allometric models, using the same types of allometric equations used in the pantropical analysis. Moderate liana occupancy was associated with negative tree height effects ($\Delta\tilde{H}_{50}$) in more than half of the sites, with 36 of 66 sites (55%) exhibiting 89% CIs that excluded zero (Figure 2). Under heavy occupancy, this number increased to 46 sites (70%).

The intersite median of $\Delta\tilde{H}_{50}$ reached -3.7% and -7.3% for moderate and heavy liana occupancy levels but large intersite variability existed (Figure 2a-d). Estimated effects of

106 moderate liana occupancy were positive at 12 of the 66 sites ($\Delta\tilde{H}_{50} > 0$), of which 3 had 89%
 107 CIs that did not overlap zero. Under heavy liana occupancy, positive effects were observed at
 108 4 sites, and in all cases the 89% CIs overlapped zero. Liana effect intensified with the
 109 occupancy level (Supplementary Figure S4). Estimated heights of heavily occupied trees were
 110 lower than those of moderately occupied trees in 58 of 66 sites, and in 28 of these sites the
 111 89% CI of the distribution of their difference did not overlap with 0. Of the 8 sites showing the
 112 opposite pattern, only one had its 89% CI not overlapping with 0 (Los Fierros Bosque, Bolivia).
 113 For moderate liana occupancy, site-level $\Delta\tilde{H}_{50}$ ranged from -18.3% in *Luki, Democratic*
 114 *Republic of the Congo* (-24.7% to -11.6%) to +8.0% in *Rio Grande do Sul, Brazil* (+0.9% to
 115 +15.8%). For heavy liana occupancy, $\Delta\tilde{H}_{50}$ ranged from -39.3% in *WTWH Pre-montane,*
 116 *Queensland* (-59.3% to -14.9%) to +4.0% in *Gaúcha do Norte (Old-growth), Brazil* (-2.6% to
 117 10.8%), see Table 1 and Figure 2. Liana effects also tended to weaken slightly with increasing
 118 tree size, although the magnitude of this relationship varied considerably across sites
 119 (Supplementary Figure S5).

120 We also evaluated how liana effects varied across abundant tree species using species-specific
 121 allometric models. To do so, we compared and ranked all liana models, with a site random
 122 effect for species found across multiple sites. Out of the 42 and 36 abundant tree species that
 123 could be analyzed for moderate and heavy liana occupancy at a DBH of 50 cm (see methods
 124 for details), 36 and 31 were found to have a negative $\Delta\tilde{H}_{50}$ respectively, including 17 and 24
 125 with an 89% CI not overlapping with 0 (Supplementary Figure S6). For the abundant tree
 126 species, liana effect also mostly intensified with liana occupancy level (i.e., $\Delta\tilde{H}_{50}$ was more
 127 negative for heavy than moderate occupancy, Supplementary Figure S7) but did not
 128 dramatically change with DBH (Supplementary Figure S8).

Upscaling and projecting the liana effects

The diversity of responses across forest sites indicates that site characteristics, climate in particular^{38,39}, might mediate the magnitude of the liana effects. Because our dataset was strongly imbalanced with respect to disturbance and elevation classes (Supplementary Figures S9-10), we focused the analyses of climate drivers and future projections on lowland old-growth forests, which represent the majority of both sites (40) and individual observations (30,154).

To identify the climate drivers of variation in liana effects, we related the site-level effect sizes for heavy liana occupancy to WorldClim⁴⁵ bioclimatic variables ("*bioclim variables*", see supplementary S11). We first reduced the 19 bioclim variables using a PCA and retained the first five axes, which together captured 95% of the variance in bioclimatic space. Projection predictive variable selection identified PCA axes 1 and 4 as the best predictors of intersite variation in liana-associated tree height suppression, together explaining 40% of the variation among sites (Figure 3b–c). These axes mainly represented gradients in temperature regimes (Axis 1) and precipitation regimes (Axis 4). Liana-associated height reductions were stronger in warmer sites and weaker under wetter conditions, suggesting that climatic gradients modulate the magnitude of liana effects across lowland old-growth forests. PCA axes 2 and 3, which captured variations in average temperature and wet-season rainfall intensity and seasonality, respectively, showed comparatively weaker associations with the liana effect.

Upscaling these climate-liana effect relationships to all lowland old-growth forests revealed that lianas generally reduce tree height, with a pantropical averaged effect for heavy liana occupancy $\Delta\tilde{H}_{50}$ of -8.4% (-13.1% to -2.1%), see Figure 3d. Spatial differences reflected

underlying climatic variations with regionally averaged effects ranging from -9.9% (-12.2% to -7.6%) in Central America to -7.7% (-10.1% to -4.8%) in Australasia.

We then applied the climate–liana effect relationships to downscaled and bias-corrected CMIP6 climate projections^{45,46} to estimate how liana-induced tree height reductions for heavy liana occupancy may shift under alternative shared socioeconomic pathways (SSPs). Across all scenarios, liana effects intensified with climate change (Figure 3d). Pantropically averaged liana tree height suppression ($\Delta\tilde{H}_{50}$ for heavy liana occupancy) was projected to reach -10.2% (-15% to -3.5%) under SSP1-2.6, -12.1% (-16.9% to -5.5%) under SSP2-4.5, -14.1% (-18.9% to -7.2%) under SSP3-7.0, and -15.3% (-20.7% to -7.9%) under SSP5-8.5. These amplified effects arise from two climatic trends acting: rising temperatures, which increase PCA Axis 1, and changing precipitation patterns, which mostly decrease PCA Axis 4 (Supplementary Figure S12-13).

Regional patterns differed slightly. South America showed the strongest amplification of liana effects on individual tree heights ($\Delta\tilde{H}_{50}$ reaching on average -11.3% under SSP1-2.6 and -15.9% under SSP5-8.5), and Australasia consistently exhibited weaker intensification ($\Delta\tilde{H}_{50}$ varying from -8.2% to -11.4% across scenarios). These differences mainly stemmed from regional variation in projected precipitation seasonality (PCA Axis 4), whereas warming trends aligning with PCA Axis 1 were projected to intensify uniformly across the tropics (Supplementary Figures S12-13).

Linking liana effects and species traits

To relate interspecific variation in liana effects to functional strategies, we retained 55 abundant tree species for which observations of leaf mass per area (LMA) and/or wood

173 density (WD) were available in global or site-specific databases. LMA and WD are among the
174 most widely measured plant functional traits and capture key axes of the fast–slow plant
175 economics spectrum⁴⁷. We fitted multiple linear regression models of species-specific liana
176 effects on tree height under heavy occupancy against these traits which represent tree life
177 history strategies⁴⁸. Liana effects on tree height tended to strengthen for fast-growing tree
178 species (smaller LMA and lower WD) but the effects explained little variance (Bayesian R^2 =
179 0.03-0.09 across traits and target DBHs, see Supplementary Figure S14).

Discussion

While lianas are increasingly recognised for their effects on ecosystem dynamics^{22,29,49}, their role as potential modifiers of tree allometry had so far remained limited to a few sites^{31,32} and species³³. This study provides the first pantropical evidence that lianas are associated with tree height reduction. This structural effect could cascade through multiple dimensions of forest functions. Shorter trees tend to support smaller crowns⁵⁰, which reduces light interception⁵¹ and weakens their competitive position in the canopy⁵². Because tree height is a key determinant of biomass accumulation¹⁴, this reduction may lower individual tree carbon stocks³⁰, without being offset by liana biomass^{30,50}, contributing to weaker forest carbon sinks⁵³. Therefore liana-induced tree height suppression is not only an allometric effect, but one with implications for tree performance and ecosystem functioning.

Whether the observed height reduction reflects causal effects or pre-existing conditions remains an important question. Within a species, shorter trees may be more prone to colonisation by lianas, potentially generating feedback in which disadvantaged individuals accumulate lianas and remain suppressed (Supplementary Figure S15). Although our cross-sectional analysis cannot fully disentangle these mechanisms, comparisons among trees of similar DBH within the same species and site reduced the influence of pre-existing size differences. Experiment removals³⁰ and observations of arrested sapling development³² and liana-dense forest patches⁵⁴ further indicate that lianas can actively suppress tree growth. Several mechanistic pathways likely underpin tree height suppression, including mechanical stress that favors greater allocation to stem support over vertical extension^{32,55}, deformation of tree crowns⁵⁰ and reduced light availability for apical meristems^{56,57}. Stabilising effects of lianas could theoretically promote height growth⁵⁸ but the overall negative relationship

observed suggests that suppressive effects outweigh gains associated with thigmomorphogenic responses. Future longitudinal and experimental studies are, however, needed to quantify the relative importance of these processes.

The magnitude of liana effects on tree height varied markedly among sites, and was related to temperature and precipitation regimes. Because our analysis only considered broad climatic variables, these patterns should not be interpreted as evidence that climate alone determines the strength of liana effects. Soils, forest structure, disturbance history and variation in liana abundance are also likely contributors, but could not be formally evaluated here. Weaker effects observed in wetter forests may therefore reflect not only weaker liana–tree competition, but also lower liana abundance or lower realized tree-level loads within moderate or heavy occupancy classes. This interpretation is consistent with evidence that lianas are less abundant in aseasonal wet forests and more abundant in warmer, drier and disturbed sites^{38,59}. Climatic gradients may also be associated with shifts in liana and tree species composition and functional strategies⁶⁰, which could further alter liana effects.

The climatic associations identified here also imply that liana effects on tree height may intensify under global change. Although some predictions fall outside the calibration domain because of the expected large temperature increases, projections indicate that the climatic conditions associated with stronger liana effects are expected to become more widespread across the pantropics under all emission scenarios (Figure 3). This is particularly relevant given that liana abundance has increased in many tropical forests^{39,49,61}, although this increase is not uniform^{62–64} and their drivers remain uncertain. Climate change may favour lianas in some contexts, but hotter or drier conditions could also constrain them⁶⁵. In addition, climate change may alter disturbance regimes, and the taxonomic and functional composition of both

226 liana and tree communities, further modifying future liana effects. Predicting long-term
227 effects of lianas will require a better understanding of how lianas and trees respond to
228 ongoing climate change.

229 Species differed markedly in structural vulnerability to lianas, indicating that height
230 suppression is not uniform across host taxa (Supplementary Figures S6 and S14). Fast-growing
231 species appeared more affected, consistent with previous work from Barro Colorado Island²¹.
232 Although weak, these relationships may matter if future tropical forests become increasingly
233 dominated by acquisitive species⁶⁶. Because lianas also reduce growth, increase mortality risk
234 and lower reproductive probability^{2,29,50}, structural height suppression may form part of a
235 wider demographic effect on host trees. However, how structural suppression translates into
236 demographic outcomes (like survival and mortality risk) remains unclear. Traits associated
237 with liana tolerance and those associated with susceptibility to structural suppression may be
238 weakly aligned: large-statured species can show strong reproductive reductions despite
239 weaker growth suppression²¹, while shade tolerance is associated with persistence under
240 liana load⁶⁷. Future studies collecting coincident data on biomechanics (including bark traits),
241 architecture, and demographic performance are needed to identify which species are most
242 vulnerable and how these structural effects propagate over time. If liana abundance
243 continues to rise, such interspecific differences could also contribute to future shifts in tree
244 species composition, potentially interacting with climate-driven compositional change to
245 amplify changes in forest structure. This underscores the importance of identifying the traits
246 that mediate liana tolerance and susceptibility, an increasingly tractable goal with emerging
247 remote sensing approaches⁶⁸.

Despite the unprecedented scale of our dataset, several limitations remain. First, both liana occupancy and tree height measurements are uncertain. COI scores can vary among observers and provide only a semi-quantitative proxy for infestation intensity⁶⁹, while field-based tree height measurements are also prone to multiple sources of error⁷⁰. Second, we quantified individual-tree effects rather than stand- or plot-level consequences. Because liana abundance could not be incorporated explicitly, strong per-tree effects do not necessarily imply equally strong plot-level responses, and forests with similar per-tree effects may differ depending on liana prevalence. Third, montane and highly disturbed forests remain underrepresented, despite likely differences in liana effects at higher elevation³⁹ and in disturbed^{38,39,49} sites. Finally, lianas were treated as a single functional group, ignoring potentially important variation in traits⁷¹, and climbing mechanisms⁷². Addressing these gaps will require coordinated liana monitoring networks and harmonised protocols that systematically measure liana occupancy, abundance, composition and tree height.

Lianas are integral components of tropical forest biodiversity, animal food webs and habitat structure²², and our results show that they also regulate tree architecture. By reducing tree height across a wide range of environments, lianas alter the structural template on which tropical forest function is built. Better understanding of liana-tree interactions, and how they vary across environmental gradients, is essential for predicting how tropical forests function and reorganize under ongoing climate change and disturbance⁷³.

Methods

Tree height and liana occupancy database

We conducted an extensive search on the Web of Science platform to look for coincident observations of tree height and liana occupancy. We looked on the platform for papers including the following keywords: liana (or woody vine) and tree height. We retained the publications that included individual observations of tree height, crown occupancy index (COI) and diameter at breast height or metrics that would allow computation of the tree DBH like circumference or radius. COI is a typical 5-class index that indicates the degree of crown occupancy of a tree canopy by lianas^{56,69}: COI = 0 means no liana, COI = 1 means liana occupancy of 1-25% of the tree crown area, COI = 2 means liana occupancy of 26-50% of the tree crown area, COI = 3 means liana occupancy of 51-75% of the tree crown area, COI = 4 means the tree crown area is fully covered by lianas. As such, COI captures canopy coverage but not liana biomass or load. Hence, liana occupancy classes provide a proxy for infestation intensity/competition but may not fully reflect the strength of liana-tree interactions. Whenever available, we included tree identification at the species (or genus) level in our database. When part of the raw data was not directly linked to the publication, we contacted the corresponding authors to ask for access to those data in order to complement the missing variables. The database compilation was conducted up to Early 2025.

We completed this search by exploring the ForestPlots.net database^{74,75}. We asked the database managers for plots including coincident observations of tree DBH, height and COI. COI is often recorded as an additional metric when collecting plot recensus data which is typically used for quantifying carbon fluxes^{74,76}. We then contacted the list of PIs managing those plots to request formal authorization to use those data and after agreement, we added

those sites to our database. Finally, we also reached out to researchers known for their long-standing track record on lianas, to inquire about any additional, unpublished datasets covering the required variables, and adding those whenever it was made available upon our request.

Following the forestplots protocol⁷⁷, we also compiled some relevant plot metadata, including geographic location (latitude and longitude), forest status (old-growth, mature, secondary, mixed), edaphic type (terra firme/flooded), moisture (moist, dry) and elevation type (lowland, premontane, lower montane). We merged plot data belonging to the same plot cluster when their plot status, edaphic type, moisture and elevation type matched. When multiple data sources provided information for the same site, we merged them together keeping the most recent observation per individual. Similarly when multiple observations were available for a single tree individual from the same source (e.g. multiple inventories), we only retained the most recent record. We discarded all tree height records with identified broken stems. Due to the inconsistencies in the DBH cutoffs across the data sources and considering that lianas primarily affect canopy trees⁵⁵, we retained trees with $DBH \geq 10$ cm, which was the most frequent cutoff across sites, thereby focusing the analyses on tree individuals that contribute most to forest structure.

To decrease the impact of observer bias across different sites and to account for the insufficient observations in certain classes, we converted the five-point scale COI measurement to a coarser three-point scale for all analyses: no liana occupancy, moderate liana occupancy (1-50% of the tree crown covered by lianas), and heavy liana occupancy (> 50% of the tree crown covered by lianas). This three-point scale is referred to as the liana occupancy level in the manuscript. We only retained the sites that included at least 10

observations for each of the liana occupancy levels and 50 observations in total. An exception to the minimum 50 observations and minimum 10 observations per occupancy level rules was also made for Rio Grande do Sul, Brazil³³ because all 49 observations in this dataset were from a single species, providing sufficient information to estimate within-species height allometry despite falling marginally below the predefined threshold.

Because we did not have many plots in Australasia, we kept data from Pasoh in Malaysia despite the fact that tree height measurements and COI data were not collected concurrently: tree COI measurements were collected in 2002 and 2014 while tree height was measured approximately midway between those observations (2006-2008). For the trees that varied in their liana occupancy level over that time period (28%), we used a simple geometric mean of the tree COI over the two observation periods to characterise the average liana occupancy.

Allometric models

In order to test the effect of liana occupancy level on tree height allometry, we fitted multiple allometric models, using a Bayesian approach¹⁵ and the R package *BRMS*⁷⁸. We tested three functional forms, namely a generalised Michaelis–Menten (gMM) model (Equation 1), a Weibull function (Equation 2), and a power function (Equation 3):

$$H = a \cdot (1 - \exp(-b \cdot DBH^k)) \quad \text{Equation 1}$$

$$H = \frac{a \cdot DBH^b}{k + DBH^b} \quad \text{Equation 2}$$

$$H = a \cdot DBH^b \quad \text{Equation 3}$$

where H (tree height) is in m and DBH is in cm. The three allometric models have two (power) or three (gMM, Weibull) shape parameters. The gMM and Weibull allometric models

(Equations 1-2) offer a more accurate representation of tree height-diameter relationships compared to the power function, as they allow height to saturate with tree DBH¹⁵ at the cost of an additional parameter to estimate. All variables were log-transformed when fitting the data and all models were corrected for the bias introduced by the back transformation of log-transformed predictions⁷⁹.

Pantropical and site-level liana effects on tree height

We tested the effect of liana occupancy level by assessing multiple model formulations. We compared models without liana effect on model shape parameters (*null* models) and models with liana effects included on one or multiple model shape parameters (*liana models*). This approach resulted in a total of 2^N model formulations per functional form (with N the number of shape parameters for a given functional form): $2^N - 1$ forms of *liana* models and one additional *null* model. For the three allometric functional forms that we considered, this approach resulted in 20 model formulations (8 Weibull, 8 gMM and 4 power).

To evaluate the pantropical effect of lianas on tree allometry, we fitted the 20 possible allometric models using the entire dataset, covering all sites and species. For parameters where we explicitly tested the effect of liana, we specified liana occupancy level as a fixed effect and allowed both sites and species to vary in their intercepts and slopes with respect to occupancy. This formulation allowed us to capture not only baseline differences among sites and species, but also their differential responses to lianas. For parameters that were not influenced by liana occupancy, either in the liana models or in the null models, we used simpler random-effect structures, including sites and species as random intercepts only. This ensured that parameters uninfluenced by lianas still accounted for variability across sites and species. As an illustration, the *Weibull* model with a liana effect on the shape parameters b

354 and k (a.k.a. the best pantropical model, see Figure 1 and Supplementary Table S2) was
355 represented as:

$$H = a \cdot (1 - \exp(-b \cdot DBH^k)),$$

with:

$$\begin{cases} a \sim 1 + 1|site + 1|sp \\ b \sim 1 + liana|site + liana|sp \\ k \sim 1 + liana|site + liana|sp \end{cases} \quad \text{Equation 4}$$

356 where *liana*, *site*, and *sp* respectively represent the liana occupancy level (no, moderate,
357 heavy), the site and the species.

358 Given the large discrepancies in dataset sizes among sites, we repeated the allometric model
359 comparison for each site separately in order to quantify among-site variability in liana effect.

360 In this configuration, the only random effects were for species.

361 To estimate interspecific differences in liana effect, we selected the most abundant tree
362 species from the global dataset. Those were defined as species with at least 50 total tree
363 height observations across all sites combined, including at least 10 in each liana occupancy
364 level. In this configuration, we included the site as a random effect for the species present in
365 multiple sites.

366 All allometric models were fitted using Markov chain Monte Carlo (MCMC) methods.
367 Inference was based on 10,000 posterior samples obtained from four independent chains,
368 each run for 5,000 iterations with the first 2,500 iterations discarded as burn-in. We assessed
369 the convergence of the MCMC with the $\hat{R}$ factor (the potential scale reduction factor on split
370 chains). We considered that MCMC has successfully converged if $1 \leq \hat{R} < 1.05$. If the model
371 did not converge, we increased the burn-in iterations to 12,500 and discarded model

formulation that did not converge after that. The models were completed with the specification of uninformative prior distributions, based on previous work in the tropics¹⁵.

We ranked all model formulations and chose the one with the lowest value for the Watanabe-Akaike information criterion (WAIC)⁸⁰, as an indicator of the model predictive power. For the pantropical model fits, we compared all liana and null models. When investigating the variability of liana effects between sites and species, we only compared the liana models because we were interested more in the actual liana effects rather than the model predictive power.

After selecting the best model formulation, we computed the pantropical and site/species liana effect as the relative change of height of a liana occupied tree compared to a liana-free tree, for multiple tree sizes. For example, for a 50 cm DBH tree, the liana effect $\Delta\tilde{H}_{50}$ (%) was computed as :

$$\Delta\tilde{H}_{50} = 100 \cdot \frac{\hat{H}_{|50} - \hat{H}_0|_{50}}{\hat{H}_0|_{50}} \quad \text{Equation 5}$$

where tree height is predicted from the best allometric model formulation for the non-liana category ($\hat{H}_0$) and for the moderate/heavy liana occupancy category ($\hat{H}$). In many of the analyses included in this study, we use this reference diameter of 50 cm DBH to focus on canopy species.

All estimates were derived from the mean predictions of 10,000 samples drawn from the posterior distributions of all parameters of the corresponding model formulations, along with their 89% credible intervals or CIs. We specifically chose to report 89% CIs because they balance precision and interpretability, avoid overlap with the conventional 95% thresholds

used in frequentist approaches, and are sometimes recommended in Bayesian practice for clearer communication of uncertainty^{81,82}.

While uncertainty tended to decrease with increasing sample size, especially for abundant tree species, the magnitude of the estimated liana effects showed no simple dependence with the number of observations (Supplementary Figures S16–S17). The reduction in uncertainty was less apparent at the site level, likely because site-level estimates integrate responses from multiple species with differing sensitivities to liana occupancy, thereby introducing additional ecological variability.

Upscaling and projecting the liana effects

Because temperature and precipitation strongly influence liana abundance, and hence potentially their competitive effects on host trees, we explored whether climatic gradients drive the inter-site variation in liana effect across tropical forest investigated in this study. We restricted the upscaling and projection analyses to lowland old-growth forests, given the low representation of the other forest types in the dataset and the well-documented effects of altitude and forest age on liana abundance and impacts³⁹.

For this subset of sites, we compiled the 19 Worldclim bioclimatic variables from WorldClim version 2, characterising the climate for the time period 1970–2000 at 30'' resolution. To avoid multicollinearity among the bioclimatic variables and reduce the number of predictors relative to the number of study sites, we summarized climatic variation using a principal component analysis (PCA), which captures the major climatic gradients in a small number of orthogonal axes. We then modeled the site-specific effects of heavy liana occupancy on tree height ($\Delta\tilde{H}_{50}$) within a Bayesian framework, regressing these effects against the first five PCA axes (and their first-level interaction). Specifically, we fitted a Bayesian regression model in

415 which the estimated liana effect per site was treated as the response variable and the PCA
416 axes as predictors. To account for uncertainties in site-level estimates, we propagated the
417 uncertainty associated with each estimated liana effect by modelling its posterior standard
418 deviation within the regression framework. To identify the subset of PCA axes that best
419 explained variation in liana effects while maintaining model parsimony, we applied projection
420 predictive variable selection using forward search. Predictors were sequentially added based
421 on their contribution to out-of-sample predictive performance. Variable selection initially
422 selected a three-term model. However, because a reduced model containing only the first
423 and fourth PCA axes exhibited virtually identical predictive performance, the two-axis model
424 was retained as the most parsimonious representation of the climatic drivers of liana-induced
425 tree height suppression. We evaluated the contribution of each PCA axis through their
426 posterior distributions and associated CIs, and assessed their relative importance using
427 variance decomposition of the posterior predictive distributions.

428 To project historical and future liana effects, we extracted the same set of bioclimatic
429 variables from CMIP6 Earth System Models⁴⁶, downscaled and bias-corrected by WorldClim⁴⁵
430 at a spatial resolution of 5'. The bioclimatic variables were extracted from Earth System Model
431 (ESM) simulations covering the historical period and four future Shared Socioeconomic
432 Pathways covering low- and high-emission scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-
433 8.5). We applied the identified relationship between climatic axes and liana effects to the
434 historical period (1970–2000) and the projected climate conditions by the end of the century
435 (2081–2100) for each grid cell within the tropical forest biome. To reduce ESM-specific biases,
436 we used multi-model ensemble means, computed as the average of the bioclimatic variables
437 available for each period and scenario. This procedure enabled us to map and quantify the

potential future pantropical effects of lianas on tree allometry under alternative climate trajectories. We restricted the projections of historical and future liana effects to lowland old-growth forests. To do so, we generated a pantropical forest mask based on the evergreen broadleaf, deciduous broadleaf, and mixed forest land cover classes from MODIS⁸³, the global digital elevation model GMTED2010⁸⁴ and the forest age product of Besnard et al.⁸⁵. We retained only forested pixels that occurred below 600 m elevation and in stands older than 200 years (Supplementary Figure S18).

To evaluate the performance of WorldClim to capture the spatial climate gradients across the sites, we used daily station observations from GHCN-D⁸⁶. We first identified all tropical GHCN-D stations reporting daily minimum temperature, maximum temperature, and precipitation, and ranked stations around each study site by great-circle distance. Candidate stations were then screened sequentially using the original daily files, and the nearest station with the minimal data to compute all bioclimatic variables was retained. Monthly values were computed for each year and multi-year monthly climatologies were then derived for each station, and only stations with complete 12-month climatologies for temperature and precipitation were retained. From these monthly climatologies, we calculated station-based bioclimatic variables and compared them with the corresponding WorldClim values extracted at the station coordinates. Agreement between station and gridded climate was evaluated across all retained stations using regression-based comparisons of the 19 bioclimatic variables (Supplementary Figure S19). Overall agreement was high, with most variables showing strong correspondence between datasets ($R^2 > 0.75$), indicating that the gridded climate data adequately captured the major climatic gradients represented by the station observations.

Linking liana effects and tree traits

To test whether species-level traits mediate variation in the effect of lianas on tree height, we compiled trait data for the abundant tree species in our database. Trait information was obtained from multiple sources, including the TRY⁸⁷ and BIEN⁸⁸ global databases and, whenever made available upon our request, locally measured traits. For each species, we extracted or calculated mean values of wood density (WD) and leaf mass per area (LMA); these traits were selected because of their potential relevance to life history strategies (slow vs. fast growing)⁴⁸. When trait information was not available at the species level, we used genus-level averages instead. Trait records were converted to the same units (i.e. g cm⁻³ for WD and kg m⁻² for LMA), and merged with our species-specific effect-size estimates of the relative tree height changes with liana occupancy, derived from the species-specific Bayesian models. Given the low number of species, we decided to fit linear regressions between species-averaged trait values and liana-induced tree height changes without incorporating phylogenetic structure⁸⁹. As above, uncertainty was explicitly accounted for using the posterior distribution of each species-level liana effect estimate.

All the analyses were performed using R 4.5.1.

Code and data availability

All data and code to reproduce the results of this study will be made available upon publication of this manuscript.

Acknowledgements

This project and Sruthi M. Krishna Moorthy were funded by the European Research Council (ERC) Starting Grant TREECLIMBERS (Grant No. 637643). During the preparation of this manuscript, Félicien Meunier was supported by the Research Foundation – Flanders (FWO) as a junior and senior postdoctoral fellow (Grant Nos. 1214720N and 1214723N) under an ERC runner-up project (G0BHJ26N). Sruthi M. Krishna Moorthy is currently supported by the Smithsonian-Pembroke Junior Research Fellowship. Kim Calders was funded by the European Union through an ERC Starting Grant (Grant No. 101039795). Marijn Bauters was funded by the European Union through an ERC Starting Grant (Grant No. 101114639).

Permanent inventory plot data used in this study are products of the African Tropical Rainforest Observatory Network (AfriTRON), the Amazon Forest Inventory Network (RAINFOR), and the Tropical Forests in the Changing Earth System project (T-FORCES). Plot data from these networks are curated through ForestPlots.net and have been supported by numerous institutions, funding agencies, field teams and local communities since their inception. Funding supporting AfriTRON and associated data collection includes a Natural Environment Research Council (NERC) Doctoral Training Partnership Studentship (NE/L002574/1), an NERC Open CASE Award, the ERC Advanced Grant T-FORCES (Grant No. 291585), NERC Consortium Grant TROBIT (NE/D005590), CIFOR, the Gordon and Betty Moore Foundation, the David and Lucile Packard Foundation, a Royal Society University Research Fellowship, an NERC New Investigator Award, a Philip Leverhulme Prize, Gabon's National

499 Parks Agency, the Belgian Science Policy Office (BELSPO; BR/132/A1/AFRIFORD,
500 BR/143/A3/HERBAXYLAREDD, SD/AR/01A/COBIMFO, EF/211/TREE4FLUX,
501 B2/223/P1/DAMOCO, and FED-tWIN2019-prf-075/CongoFORCE), the Belgian Directorate-
502 General for Development Cooperation and Humanitarian Aid (DGD; PilotMAB and
503 PilotMABplus), and the Research Foundation – Flanders (FWO; G014123N COBARCHIVES). We
504 also acknowledge support from the Royal Society GCRF Fund International Collaboration
505 Award ICA\R1\180100 (“FORAMA”).

506 ForestPlots.net has been funded by numerous sources, including ERC Advanced Grant T-
507 FORCES (Grant No. 291585), NERC Grant NE/B503384/1, the Gordon and Betty Moore
508 Foundation (RAINFOR), European Union Framework 7 Grant GEOCARBON (Grant No.
509 283080), NERC Grant NE/I028122/1 (AMAZALERT), Grant NE/F005806/1 (AMAZONICA), an
510 NERC Impact Accelerator Award supporting development of the BiomasaFP R package, a
511 Royal Society University Research Fellowship, an NERC New Investigator Award, and NERC
512 Grant NE/P008755/1. T-FORCES was also supported by numerous institutions, NGOs,
513 government agencies and local communities in Malaysia, Brunei and Indonesia.

514 Six plots (NNN cluster) are also part of the Tropical Ecology Assessment and Monitoring
515 (TEAM) Network, a collaboration among Conservation International, the Missouri Botanical
516 Garden, the Smithsonian Institution and the Wildlife Conservation Society, funded by the
517 Gordon and Betty Moore Foundation and other donors. Plots in Tanzania and Australia and
518 the work of Andrew R. Marshall, were supported by ARC Future Fellowship FT170100279.

519 The Danum plot is a core project of the Southeast Asia Rain Forest Research Partnership
520 (SEARRP). We thank SEARRP partners, especially Yayasan Sabah, for their support, and HSBC

521 Malaysia and the University of Zurich for funding. Data collection for Danum Valley was made
522 possible by a NERC grant (NE/P004806/1 to David F. R. P. Burslem and Geertje M. F. van der
523 Heijden). We are grateful to the research assistants conducting the censuses, particularly
524 team leader Alex Karolus, and to Mike Bernados and Bill McDonald for species identifications.
525 We also thank Stuart Davies and Shameema Esufali for advice and training.

526 For AfriTRON, we acknowledge the valuable contributions of Jon Lloyd, Annette Hladik,
527 Mireille Hockemba, Hannsjoerg Woell, Edmond Dimoto and Seya Nshimba.

528 For the Loundougou site, data collection was supported by the European Union Horizon
529 2020 Research and Innovation Programme (Grant Agreement No. 824074), the French
530 National Research Institute for Sustainable Development (IRD), the DESSFOR ANR project
531 (ANR-20-CE32-0010), the DynAfFor (CZZ1636.01D) and P3FAC (CZZ1636.02D) projects
532 supported by the French Fund for the Global Environment (FFEM), the International
533 Foundation for Science (Grant D/5822-1), the F.R.S.-FNRS (Grant 2017/v3/5/332 – IB/JN –
534 9500), Nature+ (Belgium), and the Republic of Congo (OGES-Congo). We thank the CIB-Olam
535 logging company for hosting and facilitating field activities. Additional support was provided
536 through the CANOPi project funded by the Excellence of Science (EOS) programme of FWO
537 and F.R.S.-FNRS (EOS Grant O.0026.22), e.g. to Adeline Fayolle. Jefferson Hall acknowledges
538 financial support from the World Wildlife Fund, US and from USAID Congo Basin Forest
539 Partnership.

540 Data collection at the Gigante, Pasoh and Barro Colorado Island sites was supported by grants
541 from the Smithsonian Institution Scholarly Studies Program and the Andrew W. Mellon
542 Foundation to S. Joseph Wright. Helene C. Muller-Landau acknowledges support from

543 Smithsonian ForestGEO. Ted R. Feldpausch acknowledges support from NERC Grants
544 NE/W001691/1 and NE/N011570/1. William W.M. Verbiest acknowledges support from the
545 EOS programme (Grant O.0026.22). Yoshiko Iida acknowledges Abd Rahman Kassim and
546 support through a Grant-in-Aid for JSPS Fellows.

547 This publication is based on the Research Project “Investigating the effect of lianas on tree
548 allometries across the pantropics” of the ForestPlots.net global collaboration. This paper is
549 also a product of the UGent Congo Basin Centre of Excellence (CBCE).

References

1. Moles, A. T. *et al.* Global patterns in plant height. *J. Ecol.* **97**, 923–932 (2009).
2. Falster, D. S. & Westoby, M. Plant height and evolutionary games. *Trends Ecol. Evol.* **18**, 337–343 (2003).
3. P. Adams, T., W. Purves, D. & W. Pacala, S. Understanding height-structured competition in forests: is there an R* for light? *Proc. R. Soc. B Biol. Sci.* **274**, 3039–3048 (2007).
4. Shugart, H. H., Saatchi, S. & Hall, F. G. Importance of structure and its measurement in quantifying function of forest ecosystems. *J. Geophys. Res. Biogeosciences* **115**, (2010).
5. Mensah, S., Salako, V. K. & Seifert, T. Structural complexity and large-sized trees explain shifting species richness and carbon relationship across vegetation types. *Funct. Ecol.* **34**, 1731–1745 (2020).
6. Kearsley, E. *et al.* Conventional tree height–diameter relationships significantly overestimate aboveground carbon stocks in the Central Congo Basin. *Nat. Commun.* **4**, 2269 (2013).
7. Wohlgemuth, T., Hanewinkel, M. & Seidl, R. Wind Disturbances. in *Disturbance Ecology* (eds Wohlgemuth, T., Jentsch, A. & Seidl, R.) 173–194 (Springer International Publishing, Cham, 2022). doi:10.1007/978-3-030-98756-5_8.
8. Fernández-de-Uña, L., Martínez-Vilalta, J., Poyatos, R., Mencuccini, M. & McDowell, N. G. The role of height-driven constraints and compensations on tree vulnerability to drought. *New Phytol.* **239**, 2083–2098 (2023).
9. Feldpausch, T. R. *et al.* Height-diameter allometry of tropical forest trees. *Biogeosciences* **8**, 1081–1106 (2011).
10. Ehbrecht, M., Schall, P., Ammer, C. & Seidel, D. Quantifying stand structural complexity and its relationship with forest management, tree species diversity and microclimate. *Agric. For. Meteorol.* **242**, 1–9 (2017).
11. Sibret, T. *et al.* Photosynthetic traits scale linearly with relative height within the canopy in an African tropical forest. *New Phytol.* **246**, 2029–2045 (2025).
12. Fayolle, A., Doucet, J.-L., Gillet, J.-F., Bourland, N. & Lejeune, P. Tree allometry in Central Africa: Testing the validity of pantropical multi-species allometric equations for estimating biomass and carbon stocks. *For. Ecol. Manag.* <https://doi.org/10.1016/j.foreco.2013.05.036> (2013) doi:10.1016/j.foreco.2013.05.036.
13. Chave, J. *et al.* Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia* **145**, 87–99 (2005).
14. Chave, J. *et al.* Improved allometric models to estimate the aboveground biomass of tropical trees. *Glob. Change Biol.* **20**, 3177–3190 (2014).
15. Martínez Cano, I., Muller-Landau, H. C., Wright, S. J., Bohlman, S. A. & Pacala, S. W. Tropical tree height and crown allometries for the Barro Colorado Nature Monument, Panama: a comparison of alternative hierarchical models incorporating interspecific variation in relation to life history traits. *Biogeosciences* **16**, 847–862 (2019).

16. Jucker, T. *et al.* Tallo: A global tree allometry and crown architecture database. *Glob. Change Biol.* **28**, 5254–5268 (2022).
17. Koch, T. L. *et al.* Assessing Intraspecific Variation of Tree Species Based on Sentinel-2 Vegetation Indices Across Space and Time. *Remote Sens.* **17**, 2094 (2025).
18. Siefert, A. *et al.* A global meta-analysis of the relative extent of intraspecific trait variation in plant communities. *Ecol. Lett.* **18**, 1406–1419 (2015).
19. Reis, S. M. *et al.* Causes and consequences of liana infestation in southern Amazonia. *J. Ecol.* **108**, 2184–2197 (2020).
20. Moorthy, S. M. K. *et al.* Strong impacts of lianas on tree allometry lead to overestimation of tropical forest carbon stocks and sink. Preprint at <https://doi.org/10.21203/rs.3.rs-2094059/v1> (2022).
21. Visser, M. D. *et al.* Tree species vary widely in their tolerance for liana infestation: A case study of differential host response to generalist parasites. *J. Ecol.* 1–14 (2017) doi:10.1111/1365-2745.12815.
22. Schnitzer, S. A. & Bongers, F. The ecology of lianas and their role in forests. *Trends Ecol. Evol.* **17**, 223–230 (2002).
23. Verbeeck, H. *et al.* Towards a liana plant functional type for vegetation models. *Ecol. Model.* **498**, 110901 (2024).
24. Dossa, G. G. O. *et al.* Lianas from lives to afterlives. *New Phytol.* **242**, 1886–1890 (2024).
25. di Porcia e Brugnera, M. *et al.* Modeling the impact of liana infestation on the demography and carbon cycle of tropical forests. *Glob. Change Biol.* **25**, 3767–3780 (2019).
26. Meunier, F. *et al.* Unraveling the relative role of light and water competition between lianas and trees in tropical forests: A vegetation model analysis. *J. Ecol.* **109**, 519–540 (2021).
27. De Deurwaerder, H. *et al.* Liana and tree below-ground water competition—evidence for water resource partitioning during the dry season. *Tree Physiol.* **38**, 1071–1083 (2018).
28. van der Heijden, G., Powers, J. S. & Schnitzer, S. A. Lianas reduce forest-level carbon accumulation and storage. *PNAS* **112**, 13267–13271 (2015).
29. Estrada-Villegas, S., Pedraza Narvaez, S. S., Sanchez, A. & Schnitzer, S. A. Lianas Significantly Reduce Tree Performance and Biomass Accumulation Across Tropical Forests: A Global Meta-Analysis. *Front. For. Glob. Change* **4**, (2022).
30. Cao, X. *et al.* Lianas reduce tree height with negative consequences for carbon storage and growth estimates. *J. Ecol.* **113**, 1647–1658 (2025).
31. Loubota Panzou, G. J. *et al.* Intensity, determinants, and impacts of liana load on tropical trees in central Africa. *Ecosphere* <https://doi.org/10.1002/ecs2.4322> (2022) doi:10.1002/ecs2.4322.

32. Schnitzer, S. A., Kuzee, M. E. & Bongers, F. Disentangling above- and below-ground competition between lianas and trees in a tropical forest. *J. Ecol.* **93**, 1115–1125 (2005).
33. Dias, A. S., Dos Santos, K., Dos Santos, F. A. M. & Martins, F. R. How liana loads alter tree allometry in tropical forests. *Plant Ecol.* 1–7 (2016) doi:10.1007/s11258-016-0671-0.
34. Meunier, F., van der Heijden, G. M. F., Schnitzer, S. A., De Deurwaerder, H. P. T. & Verbeeck, H. Lianas Significantly Reduce Aboveground and Belowground Carbon Storage: A Virtual Removal Experiment. *Front. For. Glob. Change* **4**, 75 (2021).
35. Rutishauser, E., Barthélémy, D., Blanc, L. & Eric-André, N. Crown fragmentation assessment in tropical trees: Method, insights and perspectives. *For. Ecol. Manag.* **261**, 400–407 (2011).
36. Schnitzer, S. A. A mechanistic explanation for global patterns of liana abundance and distribution. *Am. Nat.* **166**, 262–276 (2005).
37. Schnitzer, S. A. & van der Heijden, G. M. F. Lianas have a seasonal growth advantage over co-occurring trees. *Ecology* **100**, e02655 (2019).
38. Schnitzer, S. A. & Bongers, F. Increasing liana abundance and biomass in tropical forests: emerging patterns and putative mechanisms. *Ecol. Lett.* **14**, 397–406 (2011).
39. Ngute, A. S. K. *et al.* Global dominance of lianas over trees is driven by forest disturbance, climate and topography. *Glob. Change Biol.* **30**, e17140 (2024).
40. Parolari, A. J. *et al.* Liana abundance and diversity increase with rainfall seasonality along a precipitation gradient in Panama. *Ecography* **43**, 25–33 (2020).
41. Lohbeck, M. *et al.* Functional Trait Strategies of Trees in Dry and Wet Tropical Forests Are Similar but Differ in Their Consequences for Succession. *PLOS ONE* **10**, e0123741 (2015).
42. Pfeifer, M. *et al.* Tropical forest canopies and their relationships with climate and disturbance: results from a global dataset of consistent field-based measurements. *For. Ecosyst.* **5**, 7 (2018).
43. Putz, F. E. How Trees Avoid and Shed Lianas. *Biotropica* **16**, 19–23 (1984).
44. Watanabe, S. Asymptotic Equivalence of Bayes Cross Validation and Widely Applicable Information Criterion in Singular Learning Theory.
45. Global climate and weather data — WorldClim 1 documentation. <https://worldclim.org/data/index.html>.
46. Eyring, V. *et al.* Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. *Geosci. Model Dev.* **9**, 1937–1958 (2016).
47. Díaz, S. *et al.* The global spectrum of plant form and function. *Nature* **529**, 167–171 (2016).
48. Wright, I. J. *et al.* The worldwide leaf economics spectrum. *Nature* **428**, 821–827 (2004).

49. Schnitzer, S. A. *et al.* Local canopy disturbance as an explanation for long-term increases in liana abundance. *Ecol. Lett.* **n/a**, (2021).
50. Moorthy, S. K. *et al.* Strong impacts of lianas on tree allometry lead to overestimation of tropical forest carbon stocks and sin. Preprint at <https://doi.org/10.21203/rs.3.rs-2094059/v1> (2022).
51. Rodríguez-Ronderos, M. E., Bohrer, G., Sanchez-Azofeifa, A., Powers, J. S. & Schnitzer, S. A. Contribution of lianas to plant area index and canopy structure in a Panamanian forest. *Ecology* **97**, 3271–3277 (2016).
52. Falster, D. S. & Westoby, M. Alternative height strategies among 45 dicot rain forest species from tropical Queensland, Australia. *J. Ecol.* **93**, 521–535 (2005).
53. Seidel, D. & Ammer, C. Towards a causal understanding of the relationship between structural complexity, productivity, and adaptability of forests based on principles of thermodynamics. *For. Ecol. Manag.* **544**, 121238 (2023).
54. Tymen, B. *et al.* Evidence for arrested succession in a liana-infested Amazonian forest. *J. Ecol.* **104**, 149–159 (2016).
55. Putz, F. E. The Natural History of Lianas on Barro Colorado Island, Panama. *Ecology* **65**, 1713–1724 (1984).
56. Clark, D. B. & Clark, D. a. Distribution and effects on tree growth of lianas and woody hemiepiphytes in a Costa Rican tropical wet forest. *J. Trop. Ecol.* **6**, 321–331 (1990).
57. Avalos, G. & Mulkey, S. S. Seasonal Changes in Liana Cover in the Upper Canopy of a Neotropical Dry Forest. *Biotropica* **31**, 186–192 (1999).
58. Holbrook, N. M. & Putz, F. E. Influence of Neighbors on Tree Form: Effects of Lateral Shade and Prevention of Sway on the Allometry of Liquidambar Styraciflua (sweet Gum). *Am. J. Bot.* **76**, 1740–1749 (1989).
59. DeWalt. Annual Rainfall and Seasonality Predict Pan-tropical Patterns of Liana Density and Basal Area. *Biotropica* **42**, 309–317 (2010).
60. Campbell, M., Magrach, A. & Laurance, W. Liana Diversity and the Future of Tropical Forests. in vol. 5 255–274 (2015).
61. Rueda-Trujillo, M. A., Veldhuis, M. P., van Bodegom, P. M., de Deurwaerder, H. P. T. & Visser, M. Global increase of lianas in tropical forests. *Glob. Change Biol.* **30**, e17485 (2024).
62. Gerolamo, C. S., Nogueira, A., Costa, F. R. C., de Castilho, C. V. & Angyalossy, V. Local dynamic variation of lianas along topography maintains unchanging abundance at the landscape scale in central Amazonia. *J. Veg. Sci.* **29**, 651–661 (2018).
63. Caballé, G. & Martin, A. Thirteen years of change in trees and lianas in a Gabonese rainforest. *Plant Ecol.* **152**, 167–173 (2001).
64. Bongers, F., Ewango, C. E. N., Sande, M. T. van der & Poorter, L. Liana species decline in Congo basin contrasts with global patterns. *Ecology* **101**, e03004 (2020).

65. Willson, A. M., Trugman, A. T., Powers, J. S., Smith-Martin, C. M. & Medvigy, D. Climate and hydraulic traits interact to set thresholds for liana viability. *Nat. Commun.* **13**, 3332 (2022).
66. Guo, W.-Y. *et al.* Global functional shifts in trees driven by alien naturalization and native extinction. *Nat. Plants* **12**, 308–318 (2026).
67. Muller-Landau, H. C. & Visser, M. D. How do lianas and vines influence competitive differences and niche differences among tree species? Concepts and a case study in a tropical forest. *J. Ecol.* **107**, 1469–1481 (2019).
68. Aguirre-Gutiérrez, J. *et al.* Canopy functional trait variation across Earth’s tropical forests. *Nature* **641**, 129–136 (2025).
69. van der Heijden, G. M. F., Feldpausch, T. R., Herrero, A. de la F., van der Velden, N. K. & Phillips, O. L. Calibrating the liana crown occupancy index in Amazonian forests. *For. Ecol. Manag.* **260**, 549–555 (2010).
70. Terryn, L. *et al.* New tree height allometries derived from terrestrial laser scanning reveal substantial discrepancies with forest inventory methods in tropical rainforests. *Glob. Change Biol.* **30**, e17473 (2024).
71. Kaçamak, B. *et al.* Linking Drone and Ground-Based Liana Measurements in a Congolese Forest. *Front. For. Glob. Change* **5**, (2022).
72. Dias, A. *et al.* *Climbing Mechanisms as a Central Trait to Understand the Ecology of Lianas -- a Global Synthesis.* (2021). doi:10.22541/au.162004148.87250667/v1.
73. Kaçamak, B. *et al.* Linking anatomical diversity with functional life strategies in a liana community of central Africa. *New Phytol.* **248**, 1225–1244 (2025).
74. ForestPlots.net *et al.* Taking the pulse of Earth’s tropical forests using networks of highly distributed plots. *Biol. Conserv.* **260**, 108849 (2021).
75. Lopez-Gonzalez, G., Lewis, S. L., Burkitt, M. & Phillips, O. L. ForestPlots.net: a web application and research tool to manage and analyse tropical forest plot data. *J. Veg. Sci.* **22**, 610–613 (2011).
76. Hubau, W. *et al.* Asynchronous carbon sink saturation in African and Amazonian tropical forests. *Nature* **579**, 80–87 (2020).
77. Marthews, T. R. *et al.* Measuring tropical forest carbon allocation and cycling. <https://ora.ox.ac.uk/objects/uuid:f33a0929-4675-43c6-91a3-8cbda962775> (2014).
78. Bürkner, P.-C. brms: An R Package for Bayesian Multilevel Models Using stan. *J. Stat. Softw.* **80**, (2017).
79. Sprugel, D. G. Correcting for Bias in Log-Transformed Allometric Equations. *Ecology* **64**, 209–210 (1983).
80. Watanabe, S. Asymptotic Equivalence of Bayes Cross Validation and Widely Applicable Information Criterion in Singular Learning Theory.

81. McElreath, R. *Statistical Rethinking: A Bayesian Course with Examples in R and Stan*. (Chapman and Hall/CRC, New York, 2018). doi:10.1201/9781315372495.
82. Porta Mana, P. What's special about 89% credibility intervals? Preprint at <https://doi.org/10.5281/ZENODO.17072200> (2025).
83. Earth Science Data Systems, N. MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 0.05Deg CMG V006 | NASA Earthdata. Earth Science Data Systems, NASA (2025).
84. Danielson, J. J. & Gesch, D. B. *Global Multi-Resolution Terrain Elevation Data 2010 (GMTED2010)*. *Open-File Report* <https://pubs.usgs.gov/publication/ofr20111073> (2011) doi:10.3133/ofr20111073.
85. Besnard, S. *et al.* Mapping global forest age from forest inventories, biomass and climate data. *Earth Syst. Sci. Data* **13**, 4881–4896 (2021).
86. Menne, M. J. *et al.* Global Historical Climatology Network - Daily (GHCN-Daily), Version 3. NOAA National Centers for Environmental Information <https://doi.org/10.7289/V5D21VHZ> (2012).
87. Fraser, L. H. TRY—A plant trait database of databases. *Glob. Change Biol.* **26**, 189–190 (2020).
88. Data – Botanical Information and Ecology Network. <https://bien.nceas.ucsb.edu/bien/biendata/>.
89. Westoby, M., Leishman, M. R. & Lord, J. M. On Misinterpreting the 'Phylogenetic Correction'. *J. Ecol.* **83**, 531 (1995).

717 Tables

718 **Table 1** Overview of the sites compiled in this study for investigating liana effect on individual tree size together
719 with the relative tree height change due to liana occupancy

Site (Country)	Coordinates	Total number of trees ¹	DBH range (cm)	Height range (m)	Best liana model	$\Delta\tilde{H}_{50}$ Moderate liana occupancy (%) ²	$\Delta\tilde{H}_{50}$ Heavy liana occupancy (%) ²
Alta Vista PPM2 (Bolivia)	16.1°S - 61.9°W	151 (58 - 62 - 31)	10.3 - 72.7	5 - 30.4	gMM (b, k)	4.8 (-4.2, 14.6)	2.1 (-8.3, 13.8)
Asenanyo (Ghana)	6.5°N - 2.2°W	116 (32 - 42 - 42)	10.2 - 226.5	8.8 - 54.4	Weibull (k)	-2.3 (-9.3, 5.2)	-10.3 (-16.1, -3.7)
Barito Ulu (Indonesia)	0.1°S - 114°E	191 (123 - 53 - 15)	10.4 - 117.1	11.7 - 49.5	gMM (a, b)	-8 (-11.9, -3.7)	-6.2 (-11.6, -0.1)
Barro Colorado Island (Panama)	9.2°N - 79.8°W	2763 (1310 - 683 - 770)	10 - 245.2	2.8 - 54.9	gMM (a, b)	-9.3 (-10.8, -7.8)	-14.5 (-15.9, -13.2)
Barro Colorado Island (Old secondary) (Panama)	9.1°N - 79.9°W	78 (22 - 41 - 15)	11 - 144.2	5 - 32.6	Weibull (b)	-8.1 (-13.7, -2.1)	-14.3 (-19.9, -7.9)
Barro Colorado Island (Secondary) (Panama)	9.2°N - 79.8°W	441 (217 - 116 - 108)	10 - 72.2	1.6 - 29.2	Weibull (a, b)	-6.9 (-11.3, -2.6)	-11.1 (-15.7, -5.9)
Campinas (EPA) (Brazil)	22.9°S - 47.1°W	122 (58 - 51 - 13)	10 - 53.8	7 - 28	gMM (k)	-1.8 (-6.5, 2.9)	-8.4 (-14.2, -2.4)
Campinas (Mixed) (Brazil)	22.8°S - 46.9°W	6418 (2189 - 3144 - 1085)	10.2 - 198.9	1 - 36	gMM (a, b, k)	-5.3 (-7.8, -2.7)	-12.9 (-15.4, -10.3)
Campinas (Secondary) (Brazil)	22.8°S - 46.9°W	280 (66 - 151 - 63)	10.2 - 254.6	2 - 22	power (b)	-10 (-16.6, -2.8)	-23.1 (-29.1, -16.2)
Canal (Old secondary) (Panama)	9.1°N - 79.7°W	1712 (893 - 523 - 296)	10 - 229.7	0.9 - 40.1	gMM (a)	-3.3 (-5.2, -1.5)	-10 (-11.9, -8.1)
Canal (Old-growth) (Panama)	9.2°N - 79.7°W	486 (280 - 129 - 77)	10 - 118.9	2.5 - 35.9	gMM (k)	-3.2 (-5.5, -1)	-5.1 (-7.6, -2.4)
Canal (Secondary) (Panama)	9.1°N - 79.7°W	146 (102 - 26 - 18)	10.1 - 129	6.5 - 35.3	Weibull (b, k)	-2.2 (-7.7, 3.5)	-5.3 (-10.1, 0.3)
Cape Three Points (Ghana)	4.8°N - 2°W	112 (41 - 51 - 20)	10.1 - 115	10.4 - 49.4	Weibull (b, k)	-9.7 (-14.5, -4.3)	-9.9 (-15.7, -3.3)
Casa Roubik (Panama)	9.3°N - 79.8°W	661 (270 - 287 - 104)	10 - 60	6.1 - 25.6	gMM (k)	-2.5 (-4.4, -0.6)	-7.1 (-9.4, -4.7)
Cavalla (Liberia)	6.2°N - 8.2°W	125 (50 - 53 - 22)	10.2 - 132.2	9.8 - 44.2	Weibull (a)	-6.8 (-11.1, -2.1)	-4 (-9.8, 2.1)
Cerro Pelao (Bolivia)	14.5°S - 61.5°W	434 (217 - 170 - 47)	10 - 84.4	5.1 - 29	Weibull (a)	-3.8 (-8.4, 0.9)	-9.7 (-15.2, -3.7)
Cuzco Amazonico (Peru)	12.5°S - 69.1°W	189 (121 - 54 - 14)	10.9 - 109	7.3 - 56.4	Weibull (b)	-3.4 (-7.5, 0.8)	-6.2 (-11.8, 0.8)
Dadieso (Ghana)	6°N - 3°W	87 (20 - 28 - 39)	10.1 - 166.7	7.8 - 60.4	power (a)	-4.3 (-12.3, 4.5)	-13.3 (-19.4, -6.3)
Danum Valley (Malaysia)	5°N - 117.8°E	179 (65 - 75 - 39)	10.9 - 179	11.2 - 70.2	Weibull (a, b, k)	-3.7 (-8.7, 1.5)	-13.2 (-17.6, -8.2)
Dja North (Cameroon)	3.3°N - 12.7°E	403 (170 - 192 - 41)	10 - 147.4	10.2 - 51.4	Weibull (a, b, k)	-1.7 (-5.6, 2.3)	-4.1 (-8.9, 1.5)

Fazenda Floresta (Brazil)	12.8°S - 51.9°W	728 (333 - 310 - 85)	10 - 96.5	6 - 26.5	gMM (a, b, k)	-4.9 (-8.6, -0.9)	-5.7 (-10.3, -0.3)
Fazenda Rio Preto (Brazil)	11.2°S - 51.7°W	348 (196 - 138 - 14)	10.1 - 91.5	4 - 28	gMM (a)	-4.9 (-7.7, -2)	-6.2 (-11.2, -0.4)
Fort Sherman (Panama)	9.3°N - 80°W	261 (143 - 82 - 36)	10 - 127.1	3.5 - 36.9	Weibull (k)	-2.3 (-5.7, 1.1)	-7.3 (-10.5, -3.8)
Gaúcha do Norte (Mixed) (Brazil)	13.3°S - 52.9°W	364 (74 - 161 - 129)	10 - 113.1	3.1 - 37	Weibull (a, b, k)	-6.8 (-13, -0.1)	-16.9 (-23.9, -9)
Gaúcha do Norte (Old-growth) (Brazil)	13.3°S - 52.9°W	1273 (749 - 407 - 117)	10 - 83.5	3.5 - 30	Weibull (a, b, k)	6.8 (0.6, 12.6)	4 (-2.6, 10.8)
Gigante (Panama)	9.1°N - 79.8°W	6445 (1910 - 3449 - 1086)	10 - 164	1.8 - 45.8	Weibull (a, k)	-9.2 (-10.8, -7.7)	-14.6 (-16.3, -12.8)
Grebo (Mixed) (Liberia)	5.4°N - 7.6°W	241 (94 - 104 - 43)	11.1 - 193.4	8.8 - 46.6	Weibull (a)	-3.2 (-6.7, 0.3)	-7.1 (-10.6, -3)
Grebo (Old-growth) (Liberia)	5.4°N - 7.6°W	144 (56 - 52 - 36)	10.5 - 114.6	8.8 - 41	Weibull (b, k)	0.5 (-5.7, 6.9)	-6 (-11.8, 0.1)
Isla Huanchaca (Bolivia)	14.5°S - 60.7°W	1352 (851 - 383 - 118)	10 - 133	4.9 - 40.3	gMM (k)	-1.2 (-2.6, 0.2)	-1.2 (-3.4, 1)
JBS-Chaqueño (Bolivia)	17.8°S - 63.1°W	257 (98 - 94 - 65)	10 - 108.3	5.8 - 30.7	Weibull (a)	1.1 (-3.9, 6.2)	-4.6 (-9.7, 0.8)
Kilombero Valley (United Republic of Tanzania)	7.8°S - 36.9°E	1976 (620 - 415 - 941)	10 - 120	1.6 - 40.3	Weibull (a, b, k)	-14.2 (-20.1, -8)	-17.7 (-22.5, -12.5)
Lambir (Malaysia)	4.2°N - 114°E	267 (187 - 57 - 23)	10.7 - 168.6	11.5 - 57.9	gMM (k)	-3.1 (-5.8, -0.1)	-3.6 (-6.6, -0.2)
Leke (Gabon)	1.7°S - 13.4°E	171 (113 - 37 - 21)	10.6 - 121.4	9.5 - 45	gMM (k)	-5 (-8.5, -1.2)	-3.5 (-7.9, 1)
Lope 3 (Gabon)	0.2°S - 11.6°E	481 (414 - 50 - 17)	10 - 130.8	3.1 - 48.3	gMM (a)	-5.1 (-9, -0.9)	-11 (-15.4, -5.8)
Los Fierros Bosque (Bolivia)	14.6°S - 60.8°W	630 (424 - 166 - 40)	10 - 115.4	3 - 43.6	Weibull (b, k)	-5.4 (-10.1, -0.7)	3.6 (-2.8, 10)
Loundoungou (Republic of the Congo)	2.5°N - 17°E	1234 (628 - 375 - 231)	10 - 204.5	2.3 - 53.1	Weibull (b, k)	-10 (-12.9, -7.3)	-14.2 (-17, -11.3)
Luki (Democratic Republic of the Congo)	5.7°S - 13.2°E	309 (179 - 111 - 19)	10 - 153.8	4.8 - 66.2	Weibull (a, k)	-18.3 (-24.7, -11.6)	-17 (-25.1, -8)
Metropolitano (Panama)	9°N - 79.5°W	573 (265 - 195 - 113)	10 - 146.1	2.5 - 38.5	Weibull (a, b, k)	-7.3 (-11.6, -2.8)	-6.3 (-11.5, -1)
Mokabi (Republic of the Congo)	3.3°N - 17°E	937 (621 - 262 - 54)	10.1 - 139.3	5.4 - 38.9	Weibull (b)	-2.5 (-4.1, -1)	-9.8 (-12.6, -7.1)
Monts du Cristal (Gabon)	0.6°N - 10.4°E	303 (202 - 74 - 27)	10.3 - 144.1	10.5 - 55.5	power (b)	-4.4 (-8.2, -0.5)	-6.7 (-10.8, -1.7)
Nguti (Cameroon)	5.2°N - 9.6°E	557 (249 - 199 - 109)	10 - 183.4	7.8 - 53.4	gMM (a, b, k)	-6.9 (-9.5, -4.3)	-9 (-11.9, -5.9)
Noubale-Ndoki (Republic of the Congo)	2.5°N - 16.5°E	335 (258 - 46 - 31)	10 - 250	10.3 - 51.4	Weibull (a, k)	-4.9 (-9.1, -0.2)	-6 (-9.9, -1.4)
Nova Xavantina (Dry) (Brazil)	14.7°S - 52.4°W	293 (146 - 115 - 32)	10 - 33.5	3.2 - 13.7	gMM (a, k)	3.8 (-5.8, 16.9)	-6.2 (-15.7, 4.8)
Nova Xavantina (Mixed) (Brazil)	14.7°S - 52.4°W	885 (778 - 82 - 25)	10 - 46.5	3.2 - 12	Weibull (b, k)	-0.5 (-9.7, 8.3)	-6.4 (-13.9, 2.2)
Nova Xavantina (Moist)	14.7°S - 52.4°W	828	10 - 43.2	3.1 - 17.5	gMM	2	0.5

(Brazil)		(425 - 295 - 108)			(k)	(0.6, 3.6)	(-1.4, 2.5)
Parque Cristalino (Brazil)	9.6°S - 55.9°W	829 (387 - 255 - 187)	10 - 118.2	3.5 - 40	Weibull (b, k)	-8.2 (-11.9, -4.5)	-11.1 (-14.7, -7.3)
Parque Estadual do Araguaia (Mixed) (Brazil)	12.3°S - 50.8°W	2787 (1757 - 978 - 52)	10 - 85.1	3.2 - 21.8	gMM (a, k)	-0.9 (-8.5, 6.9)	-13.1 (-30.3, 3)
Parque Estadual do Araguaia (Old-growth) (Brazil)	12.3°S - 50.8°W	1044 (612 - 391 - 41)	10 - 67.5	4 - 21	gMM (a, k)	1 (-5.6, 9.8)	-9.4 (-19.1, 1.8)
Pasoh (Malaysia)	3°N - 102.3°E	477 (157 - 200 - 120)	10 - 231	4.3 - 63.5	Weibull (a, b, k)	-2.7 (-7.1, 1.9)	-7.2 (-10.9, -3)
Plot 32 (Panama)	9.4°N - 79.7°W	67 (10 - 12 - 45)	12.6 - 99.9	10 - 42.2	power (a, b, k)	1.3 (-8.1, 11.5)	-6.1 (-13.1, 2)
Rio Grande do Sul (Brazil)	29.7°S - 53.6°W	49 (8 - 31 - 10)	10.5 - 49.3	8.4 - 22.2	gMM (k)	8 (0.9, 15.8)	-7.7 (-14, -1.1)
Salonga South Nguma (Democratic Republic of the Congo)	1.7°S - 20.5°E	580 (292 - 206 - 82)	10.1 - 153.9	9.7 - 47.2	Weibull (a)	-3.6 (-5.5, -1.8)	-6.8 (-8.7, -4.6)
Santa Terezinha (Brazil)	10.4°S - 50.6°W	403 (179 - 147 - 77)	10 - 95.8	6 - 25.2	Weibull (k)	-1.7 (-3.1, -0.6)	-4.9 (-7.3, -2.8)
Santana do Araguaia (Brazil)	9.7°S - 50.4°W	682 (206 - 263 - 213)	10 - 109	4 - 28	gMM (a, b, k)	-6.4 (-11.5, -1.3)	-13.2 (-17, -8.8)
Santarém-Belterra 129 (Brazil)	2.7°S - 54.8°W	158 (97 - 50 - 11)	10.1 - 61.7	8.7 - 40.5	gMM (b)	-4.9 (-10.6, 0.9)	-15.3 (-22.1, -7.3)
Santarém-Belterra 357 (Brazil)	3.3°S - 54.9°W	429 (206 - 198 - 25)	10.1 - 42.6	5.8 - 23.9	gMM (k)	-4.8 (-7.1, -2.6)	-10.3 (-14.1, -6.2)
Sinop (Brazil)	11.4°S - 55.3°W	409 (212 - 162 - 35)	10 - 77.9	5 - 31.2	Weibull (b)	-3.2 (-5.1, -1.3)	-4.4 (-7.5, -1.2)
Sungai Wain (Indonesia)	1.1°S - 116.8°E	150 (98 - 36 - 16)	10.4 - 139.2	9.8 - 53	gMM (b, k)	5.6 (-0.3, 11.3)	-5.3 (-10.8, 1.7)
Tambopata (Peru)	12.8°S - 69.3°W	338 (239 - 86 - 13)	11.4 - 149.8	11.3 - 54.9	Weibull (b)	-6.3 (-8.6, -3.8)	-4.5 (-8.8, 0.2)
Tanguro (Brazil)	12.9°S - 52.4°W	1097 (391 - 602 - 104)	10 - 94.1	3.5 - 28	Weibull (a, b, k)	0.3 (-3.3, 4)	-1.6 (-5.7, 2.9)
Udzungwa Mountains (Lower-montane) (United Republic of Tanzania)	8.5°S - 35.9°E	622 (75 - 134 - 413)	10 - 87.5	1.8 - 38.1	Weibull (b)	0.9 (-4.3, 6.4)	-8.1 (-12.6, -3.5)
Udzungwa Mountains (Montane) (United Republic of Tanzania)	7.8°S - 36.5°E	486 (251 - 86 - 149)	10 - 81.2	1.8 - 39.7	power (a)	-2.7 (-9.5, 4.3)	-8.9 (-14.2, -3.3)
Vera Cruz (Brazil)	14.8°S - 52.2°W	1521 (488 - 745 - 288)	10 - 104	3.5 - 30.5	Weibull (b)	-5.8 (-7.5, -4)	-6.6 (-8.7, -4.4)
WTHW, Queensland (Lowland) (Australia)	17.8°S - 146°E	465 (61 - 253 - 151)	10 - 160	1 - 32.6	Weibull (a, b, k)	-8.3 (-22, 7.6)	-23 (-32.3, -10.9)
WTHW, Queensland (Pre-montane) (Australia)	17.6°S - 145.6°E	406 (172 - 187 - 47)	10 - 120	1.5 - 40	Weibull (b, k)	-13.3 (-66.1, 16.7)	-39.3 (-59.3, -14.9)
Yoko (Democratic Republic of the Congo)	0.3°N - 25.3°E	1188 (710 - 266 - 212)	10 - 227.2	6.4 - 54.6	Weibull (k)	-4.8 (-6.9, -2.7)	-9 (-10.9, -7)

Total		50473 (22925 - 18878 - 8670)	10 - 254.6	0.9 - 70.2	Weibull (b, k)	-5.4 (-6.4, -4.4)	-10.2 (-12.1, -8.4)
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720 ¹The numbers between brackets correspond to the different levels of liana occupancy (No - Moderate - Heavy)

721 ²The numbers between brackets correspond to the 89% confidence interval

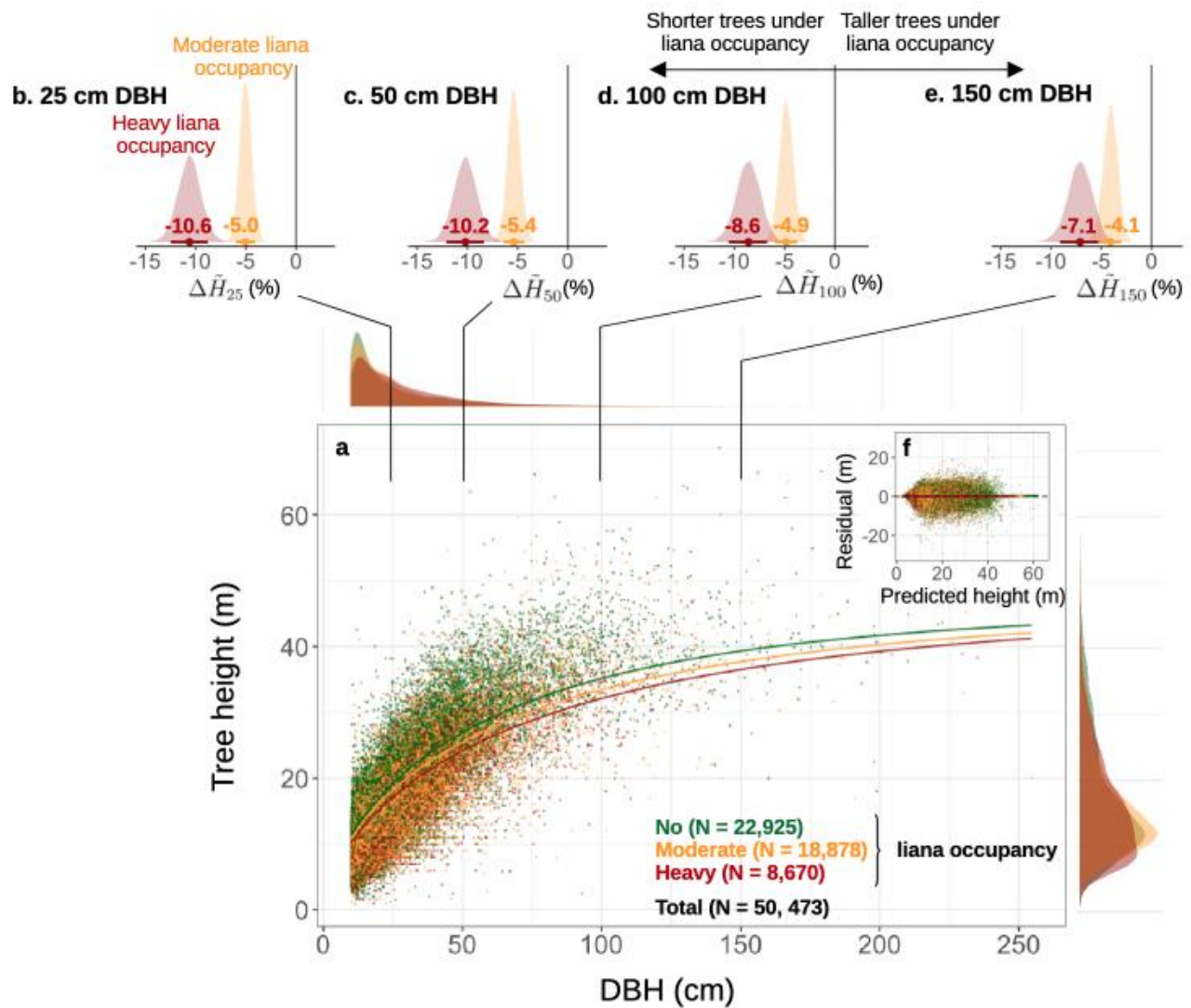


Figure 1 Pantropical tree height allometry for all sites compiled in this study. Panel (a) shows the tree height–diameter dataset across liana occupancy levels together with predictions from the Weibull (b, k) liana model (parameters b and k vary with liana occupancy), identified as the best pantropical model (see methods and Supplementary Table S2). Panels **b–e** show the posterior density distributions of the relative change (%) in predicted height for a tree of 25 (**b**), 50 (**c**), 100 (**d**), and 150 (**e**) cm DBH, and the 89% credible intervals of those changes for moderate (yellow) and heavy (red) liana occupancy. The residuals of the best allometric models per liana occupancy level are given in panel **f**.

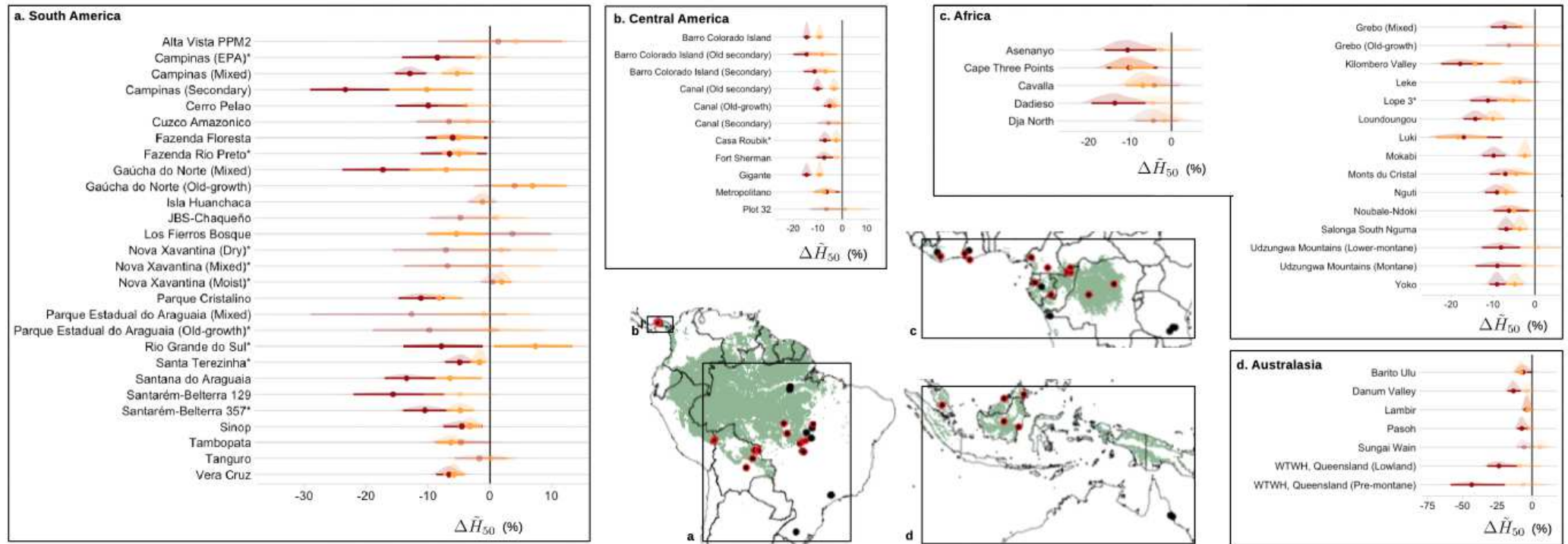
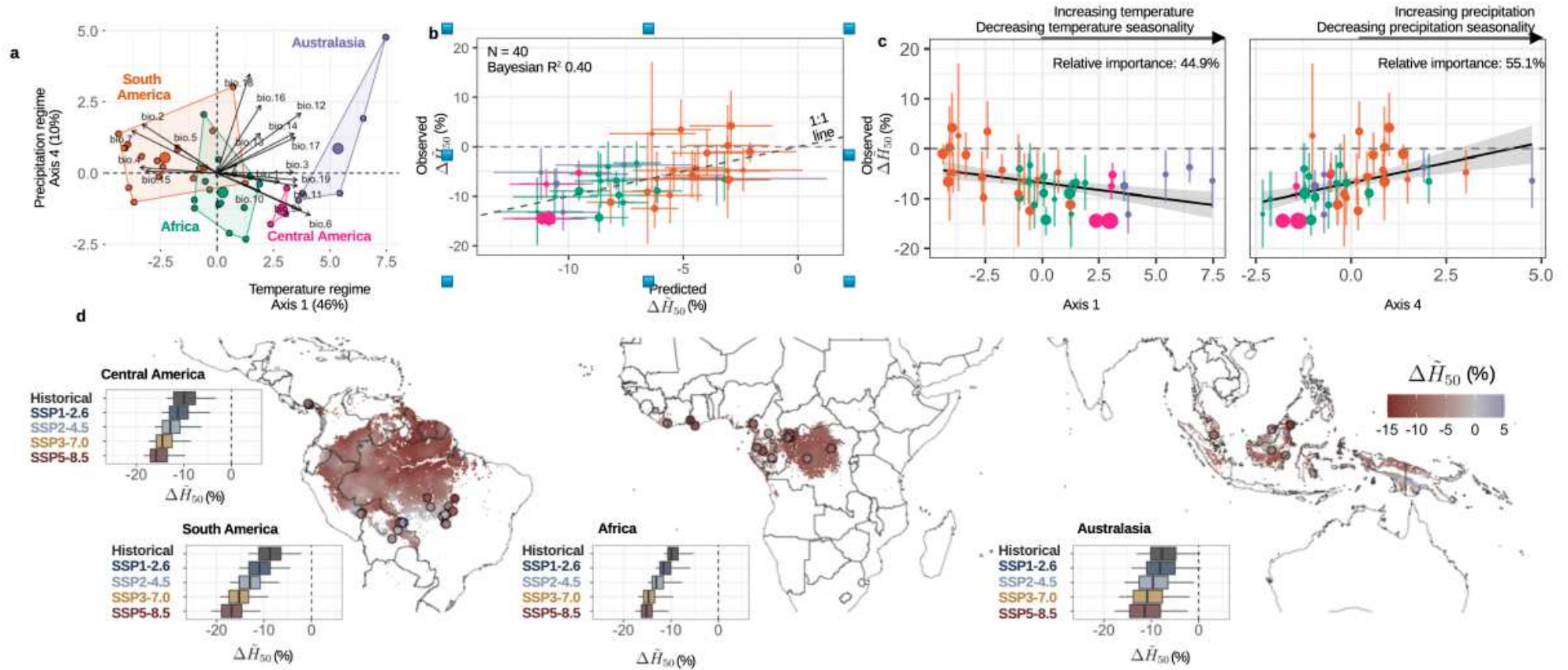


Figure 2 Liana effect on individual tree height across all sites included in this study together with their spatial distribution. Panel names refer to the highlighted areas in the central map (**a** = South America, **b** = Central America, **c** = Africa, **d** = Australasia). The liana effect is shown for moderate (yellow) and heavy (red) liana occupancy, as the distribution of relative changes (%) in predicted height for a tree of 50 cm DBH ($\Delta\tilde{H}_{50}$) compared to a liana-free state, and the 89% credible intervals of those changes. Distributions shown in bold correspond to sites for which the 89% credible interval does not overlap zero. The green background of the map shows the distribution of the lowland old-growth forests used to upscale the liana effect with climate using the sites highlighted in red in the map (lowland old-growth forest sites while the other black dots correspond to different forest status and/or/elevation). The range of DBH of the sites marked with an asterisk (*) have at least one of their liana occupancy levels which does not cover 50 cm and hence $\Delta\tilde{H}_{50}$ results from an extrapolation of their respective allometric model. Sample sizes for each site can be found in Table 1. Note that the x-axes slightly vary between panels to improve readability.



741 **Figure 3** Climate drivers of the liana effect on individual height of trees with heavy occupancy levels ($\Delta \tilde{H}_{50}$, panels a-c), the predicted current spatial distribution of $\Delta \tilde{H}_{50}$
 742 under heavy liana occupancy and its expected changes by the end of this century (2081-2100) for multiple shared socio-economic pathways (SSPs) and geographic zones
 743 (panel d). Panels a-c show the two most important PCA axes to predict $\Delta \tilde{H}_{50}$ from bioclimatic variables (a), the resulting model performance (b), and the relationship
 744 between these axes and the observed $\Delta \tilde{H}_{50}$ (c). In panel d, the predicted $\Delta \tilde{H}_{50}$ from the best linear model (gridcells) are mapped together with the site-level observations
 745 (dots) while the expected changes in $\Delta \tilde{H}_{50}$ according to multiple emission scenarios are shown as boxplot. For these boxplots, the center line represents the median; the
 746 box limits the upper and lower quartiles; and the whiskers encompass 89% of the datasets. Bioclimatic variable names can be found in Supplementary Figure S11. In panels
 747 a-c, point size is proportional to the sample size, and error bars encompass 89% of the observed or predicted credible intervals (see also Table S1).

748 Supplementary Figures and Tables

749 **Table S1** Overview of the study sites. Mean annual temperature (MAT) and mean annual precipitation (MAP)

750 are derived from Worldclim for the historical period (1970-2000).

Site name	Coordinates	Elevation	Status	MAT (°C)	MAP (mm)
Alta Vista PPM2 (Bolivia)	16.1°S - 61.9°W	Lowland	Old-growth	24.7	1150
Asenanyo (Ghana)	6.5°N - 2.2°W	Lowland	Mixed: Old-growth and Logged	26.2	1395
Barito Ulu (Indonesia)	0.1°S - 114°E	Lowland	Old-growth	26.7	3865
Barro Colorado Island (Panama)	9.2°N - 79.8°W	Lowland	Old-growth	26	2210
Barro Colorado Island (Old secondary) (Panama)	9.1°N - 79.9°W	Lowland	Mature	26.5	2257
Barro Colorado Island (Secondary) (Panama)	9.2°N - 79.8°W	Lowland	Secondary	26.6	2622
Campinas (EPA) (Brazil)	22.9°S - 47.1°W	Pre-montane	Secondary	20.4	1280
Campinas (Mixed) (Brazil)	22.8°S - 46.9°W	Pre-montane	Mixed: Old-growth and Burned	19.4	1291
Campinas (Secondary) (Brazil)	22.8°S - 46.9°W	Pre-montane	Secondary	19.9	1286
Canal (Old secondary) (Panama)	9.1°N - 79.7°W	Lowland	Mature	26.5	2498
Canal (Old-growth) (Panama)	9.2°N - 79.7°W	Lowland	Old-growth	25.9	2748
Canal (Secondary) (Panama)	9.1°N - 79.7°W	Lowland	Secondary	26.4	2453
Cape Three Points (Ghana)	4.8°N - 2°W	Lowland	Old-growth	25.4	1583
Casa Roubik (Panama)	9.3°N - 79.8°W	Lowland	Secondary	25.7	2585
Cavalla (Liberia)	6.2°N - 8.2°W	Lowland	Mixed: Old-growth and Logged	25.4	1993
Cerro Pelao (Bolivia)	14.5°S - 61.5°W	Lowland	Old-growth	25.2	1405
Cuzco Amazonico (Peru)	12.5°S - 69.1°W	Lowland	Old-growth	25.4	2052
Dadieso (Ghana)	6°N - 3°W	Lowland	Old-growth	26.4	1605

Danum Valley (Malaysia)	5°N - 117.8°E	Lowland	Old-growth	25.4	2187
Dja North (Cameroon)	3.3°N - 12.7°E	Lowland	Old-growth	23.7	1599
Fazenda Floresta (Brazil)	12.8°S - 51.9°W	Lowland	Old-growth	25.4	1584
Fazenda Rio Preto (Brazil)	11.2°S - 51.7°W	Lowland	Old-growth	26.6	1725
Fort Sherman (Panama)	9.3°N - 80°W	Lowland	Old-growth	26.1	2370
Gaúcha do Norte (Mixed) (Brazil)	13.3°S - 52.9°W	Lowland	Mixed: Old-growth and Burned	24.5	1592
Gaúcha do Norte (Old-growth) (Brazil)	13.3°S - 52.9°W	Lowland	Old-growth	24.5	1592
Gigante (Panama)	9.1°N - 79.8°W	Lowland	Old-growth	26.3	2402
Grebo (Mixed) (Liberia)	5.4°N - 7.6°W	Lowland	Mixed: Old-growth and Logged	25.8	2179
Grebo (Old-growth) (Liberia)	5.4°N - 7.6°W	Lowland	Old-growth	25.8	2199
Isla Huanchaca (Bolivia)	14.5°S - 60.7°W	Lowland	Old-growth	23.2	1562
JBS-Chaqueño (Bolivia)	17.8°S - 63.1°W	Lowland	Old-growth	24.4	1147
Kilombero Valley (United Republic of Tanzania)	7.8°S - 36.9°E	Lowland	Secondary	24.9	1521
Lambir (Malaysia)	4.2°N - 114°E	Lowland	Old-growth	26.5	3084
Leke (Gabon)	1.7°S - 13.4°E	Lowland	Old-growth	24.9	1786
Lope 3 (Gabon)	0.2°S - 11.6°E	Lowland	Old-growth	25.7	1735
Los Fierros Bosque (Bolivia)	14.6°S - 60.8°W	Lowland	Old-growth	25.5	1481
Loundoungou (Republic of the Congo)	2.5°N - 17°E	Lowland	Old-growth	24.5	1675
Luki (Democratic Republic of the Congo)	5.7°S - 13.2°E	Lowland	Mixed: Old-growth and Logged	24.1	1090
Metropolitano (Panama)	9°N - 79.5°W	Lowland	Secondary	26.9	2213
Mokabi (Republic of the Congo)	3.3°N - 17°E	Lowland	Old-growth	24	1624

Monts du Cristal (Gabon)	0.6°N - 10.4°E	Lowland	Old-growth	24.2	2395
Nguti (Cameroon)	5.2°N - 9.6°E	Lowland	Old-growth	23.3	2454
Noubale-Ndoki (Republic of the Congo)	2.5°N - 16.5°E	Lowland	Old-growth	24.6	1640
Nova Xavantina (Dry) (Brazil)	14.7°S - 52.4°W	Lowland	Old-growth	24.7	1551
Nova Xavantina (Mixed) (Brazil)	14.7°S - 52.4°W	Lowland	Mixed: Old-growth and Burned	24.7	1551
Nova Xavantina (Moist) (Brazil)	14.7°S - 52.4°W	Lowland	Old-growth	24.7	1551
Parque Cristalino (Brazil)	9.6°S - 55.9°W	Lowland	Old-growth	26.7	2213
Parque Estadual do Araguaia (Mixed) (Brazil)	12.3°S - 50.8°W	Lowland	Mixed: Old-growth and Burned	26.9	1610
Parque Estadual do Araguaia (Old-growth) (Brazil)	12.3°S - 50.8°W	Lowland	Old-growth	26.9	1610
Pasoh (Malaysia)	3°N - 102.3°E	Lowland	Old-growth	26.5	1940
Plot 32 (Panama)	9.4°N - 79.7°W	Lowland	Mature	25.3	2847
Rio Grande do Sul (Brazil)	29.7°S - 53.6°W	Lowland	Secondary	19.7	1639
Salonga South Nguma (Democratic Republic of the Congo)	1.7°S - 20.5°E	Lowland	Old-growth	24.8	1998
Santa Terezinha (Brazil)	10.4°S - 50.6°W	Lowland	Mixed: Old-growth and Burned	25.9	1773
Santana do Araguaia (Brazil)	9.7°S - 50.4°W	Lowland	Old-growth	26.1	1849
Santarém-Belterra 129 (Brazil)	2.7°S - 54.8°W	Lowland	Mixed: Old-growth and Burned	25.9	1971
Santarém-Belterra 357 (Brazil)	3.3°S - 54.9°W	Lowland	Secondary	25.9	1815
Sinop (Brazil)	11.4°S - 55.3°W	Lowland	Old-growth	25.2	1836
Sungai Wain (Indonesia)	1.1°S - 116.8°E	Lowland	Old-growth	27.2	2416
Tambopata (Peru)	12.8°S - 69.3°W	Lowland	Old-growth	25.2	2471
Tanguro (Brazil)	12.9°S - 52.4°W	Lowland	Old-growth	24.8	1566

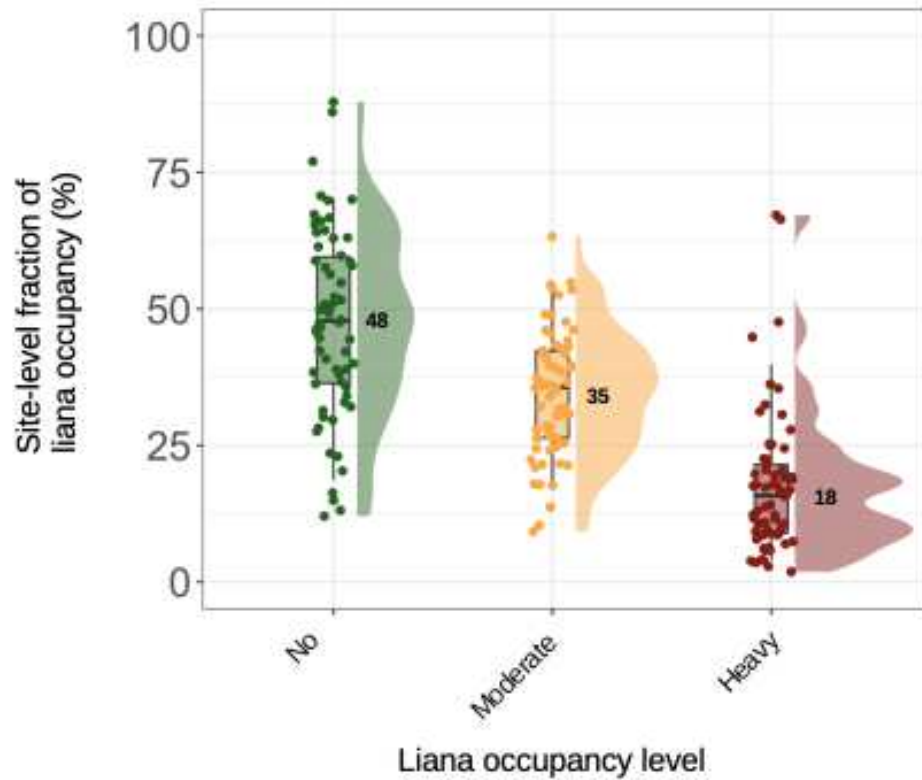
Udzungwa Mountains (Lower-montane) (United Republic of Tanzania)	8.5°S - 35.9°E	Lower montane	Secondary	18.8	1447
Udzungwa Mountains (Montane) (United Republic of Tanzania)	7.8°S - 36.5°E	Montane	Secondary	16.6	1265
Vera Cruz (Brazil)	14.8°S - 52.2°W	Lowland	Old-growth	24.8	1532
WTWH, Queensland (Lowland) (Australia)	17.8°S - 146°E	Lowland	Mixed: Logged and Secondary	23.9	3005
WTWH, Queensland (Pre-montane) (Australia)	17.6°S - 145.6°E	Pre-montane	Mixed: Logged and Secondary	20.1	3780
Yoko (Democratic Republic of the Congo)	0.3°N - 25.3°E	Lowland	Old-growth	24.7	1739

751

Supplementary Table S2 Comparison of the performance of the DBH–height allometry models based on the pantropical dataset and the Watanabe-Akaike Information Criterion (or WAIC: smaller values indicate better predictive accuracy); Δ WAIC = difference from the best model; SE = standard error of WAIC; pWAIC = effective number of parameters (acting as penalty term for model complexity); R^2 = posterior mean coefficient of determination $\pm$ posterior standard error. The first column specifies the model structure, defined by the choice of functional form (Weibull, gMM, or power) and by how liana effects are incorporated—either absent (null) or acting on one or multiple shape parameters (i.e. any combination of a, b, and k).

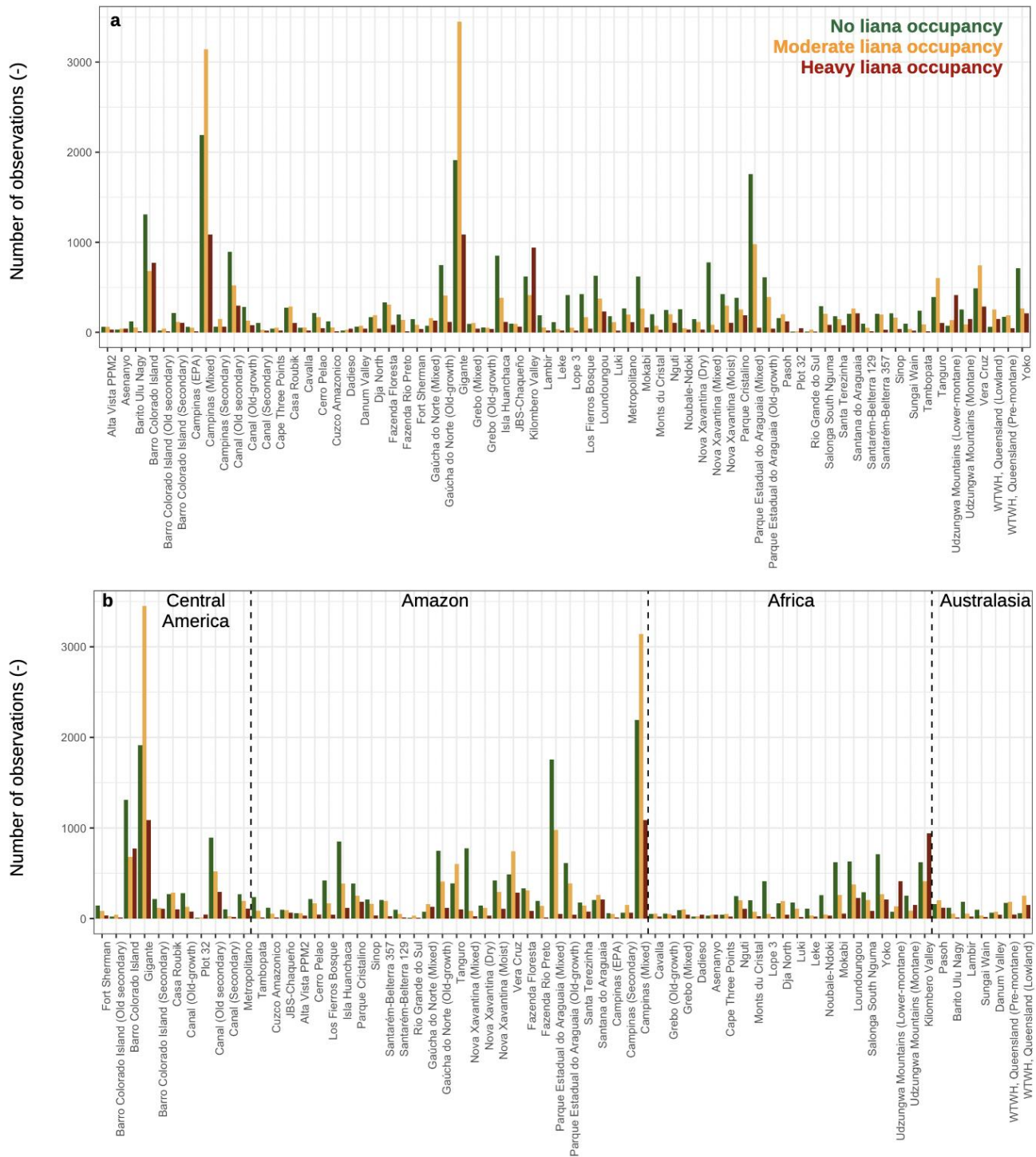
Model form	WAIC	Δ WAIC	SE	pWAIC	R^2
Weibull (b, k)	-15905.2	0	687	2613	0.832 ± 0.001
Weibull (a, b)	-15904.5	0.7	687	2609	0.832 ± 0.001
Weibull (a, b, k)	-15903.8	1.4	688	2622	0.832 ± 0.001
Weibull (b)	-15850.2	54.9	687	2603	0.832 ± 0.001
Weibull (a, k)	-15482.9	422.3	692	2425	0.83 ± 0.001
Weibull (a)	-15481	424.2	693	2396	0.83 ± 0.001
Weibull (k)	-15456.2	449	691	2422	0.83 ± 0.001
gMM ¹ (k)	-15237.6	667.6	699	2396	0.829 ± 0.001
gMM (a, b, k)	-15228.9	676.3	694	2553	0.829 ± 0.001
gMM (b, k)	-15223.8	681.4	694	2539	0.829 ± 0.001
gMM (a, b)	-15194.6	710.5	693	2557	0.829 ± 0.001
gMM (b)	-15183	722.2	694	2548	0.829 ± 0.001
gMM (a)	-15120.5	784.7	695	2403	0.828 ± 0.001
gMM (a, k)	-15118	787.2	697	2409	0.828 ± 0.001
power (a, b, k)	-13838.8	2066.4	685	2242	0.823 ± 0.001
power (a)	-13814.1	2091.1	686	2228	0.823 ± 0.001
power (b)	-13685.5	2219.7	684	2163	0.822 ± 0.001
Weibull (null)	-13581.4	2323.8	673	2030	0.822 ± 0.001
gMM (null)	-13252.2	2653	675	2028	0.82 ± 0.001
power (null)	-11869.7	4035.5	667	1780	0.814 ± 0.001

¹gMM refers to the generalized Michaelis–Menten allometric model

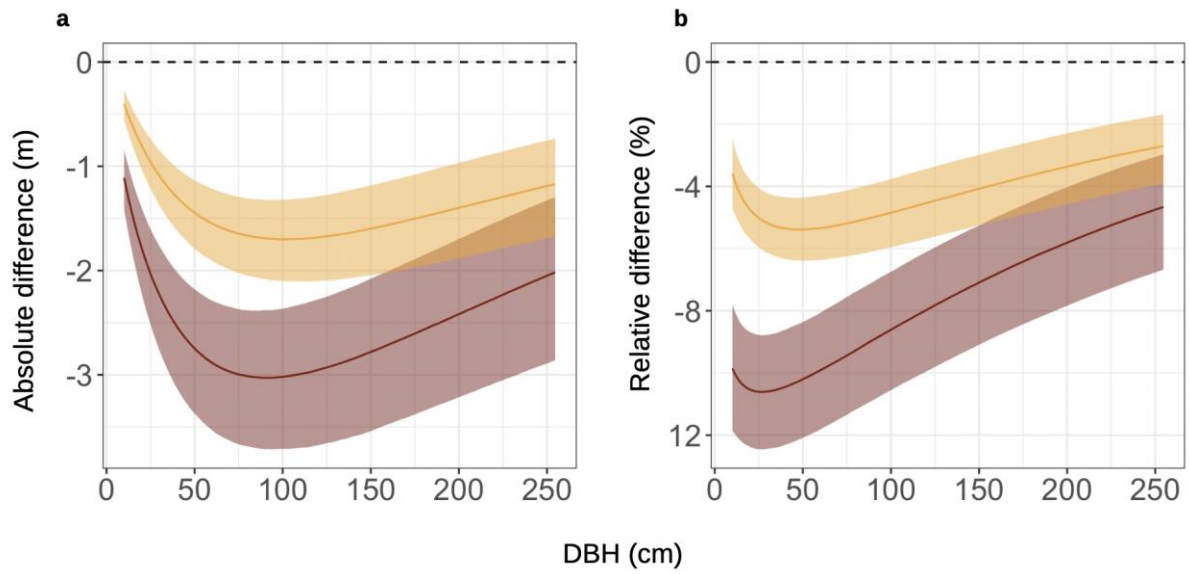


760

761 **Supplementary Figure S1:** Distribution of the site-level fraction of each liana occupancy level available in the
 762 compiled dataset. The numbers given inside the density distribution are the category means. For the boxplots,
 763 the center line represents the median; the box limits the upper and lower quartiles; while the whiskers extend
 764 to the last value located within a distance of 1.5 times the interquartile range from the 25th and 75th quantile,
 765 respectively.



767 **Supplementary Figure S2:** Number of site-level observations for each site and each liana occupancy level. For
 768 ease of reference, sites are ordered either alphabetically (panel a) or by longitude (panel b). More information
 769 on the sites can be found in Table 1 and Supplementary Table S1.



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Supplementary Figure S3 Effect of liana occupancy on tree height. Predicted differences in pantropical tree

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height between liana-occupied and liana-free trees across the observed DBH range. Panel **a** shows absolute

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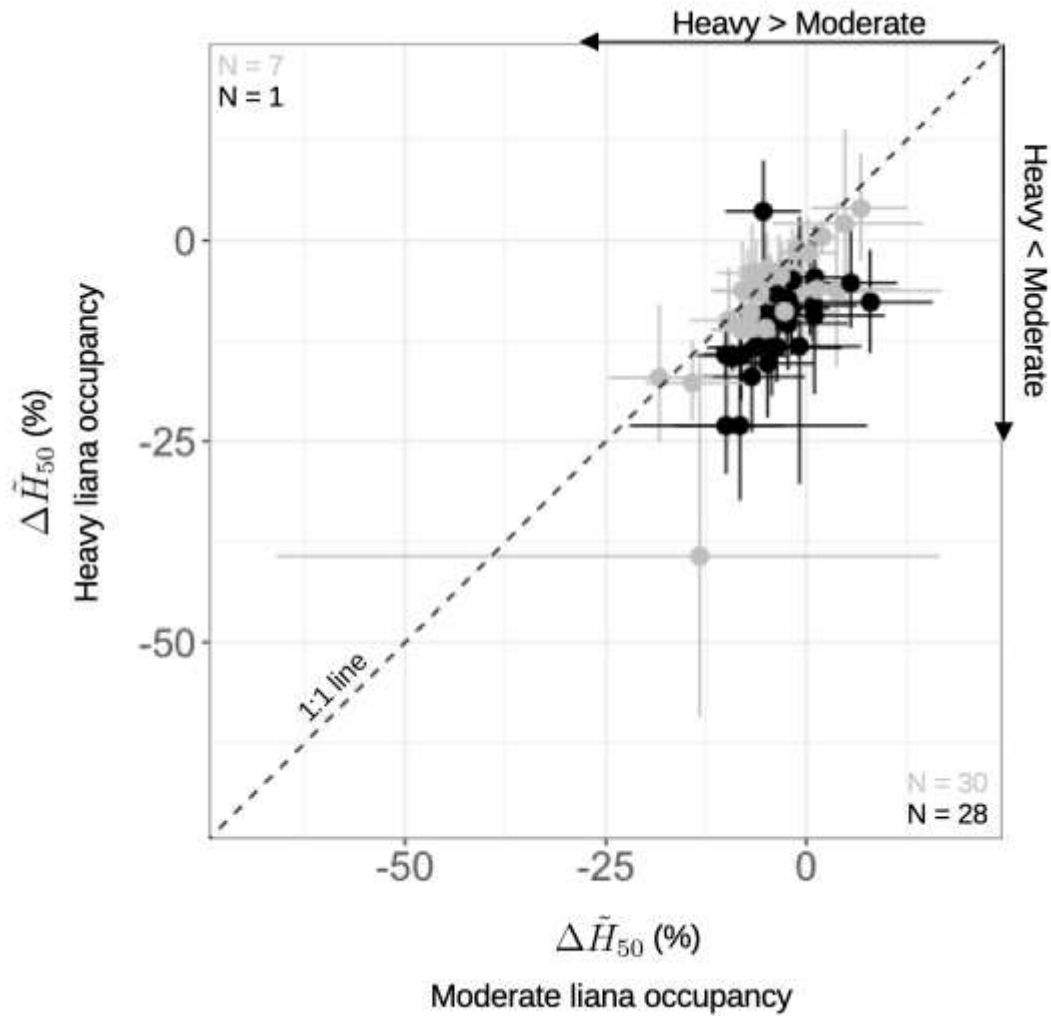
height differences, while panel **b** shows relative differences as a percentage of predicted liana-free tree height.

774

The lines indicate posterior median estimates and shaded ribbons show 89% CIs. Negative values indicate height

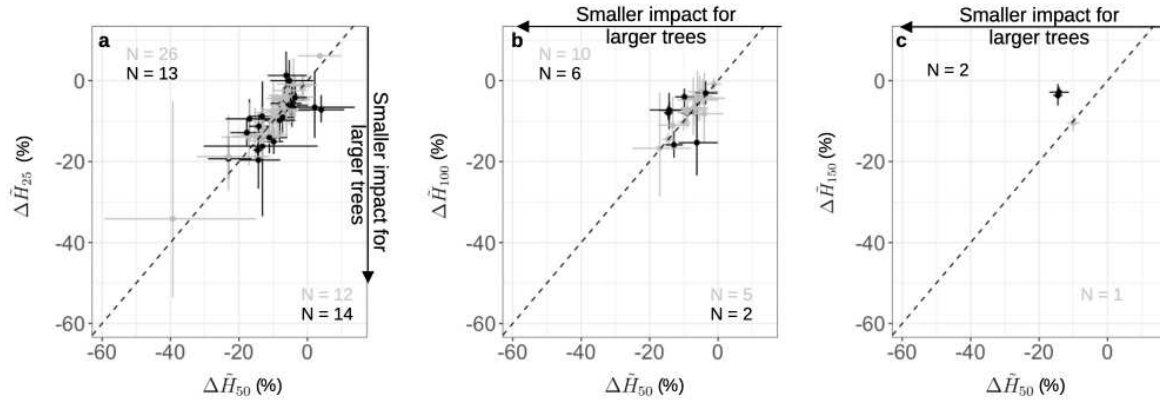
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suppression associated with liana occupancy.



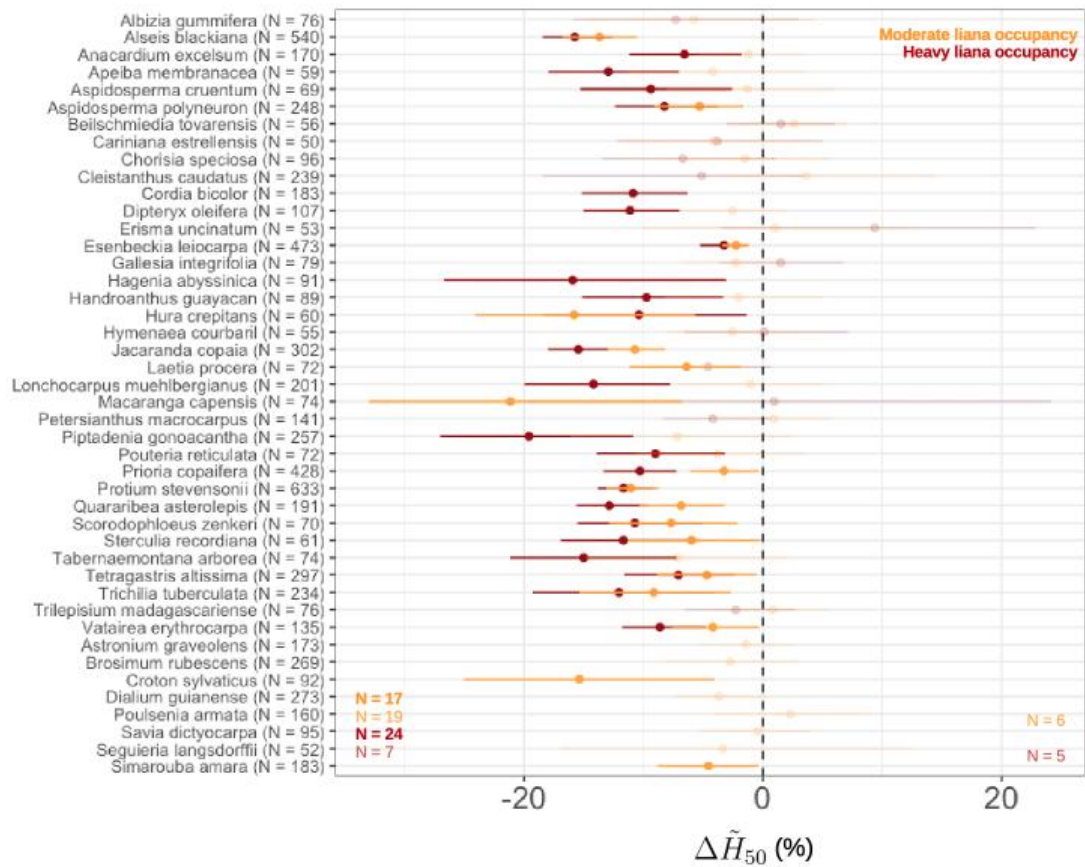
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777 **Supplementary Figure S4** Site-level means of the liana effect on tree height ($\Delta\tilde{H}_{50}$) for moderate vs heavy liana
 778 occupancy levels together with their respective 89% CI. Any site falling below the 1:1 line indicates a liana effect
 779 aggravated with stronger occupancy (i.e. shorter trees with increasing liana occupancy). We observed a decrease
 780 in tree height in 58 of the 66 sites associated with a transition from moderate to heavy liana occupancy
 781 categories, including 28 with a decrease whose 89% CI is not overlapping with zero (black dots).



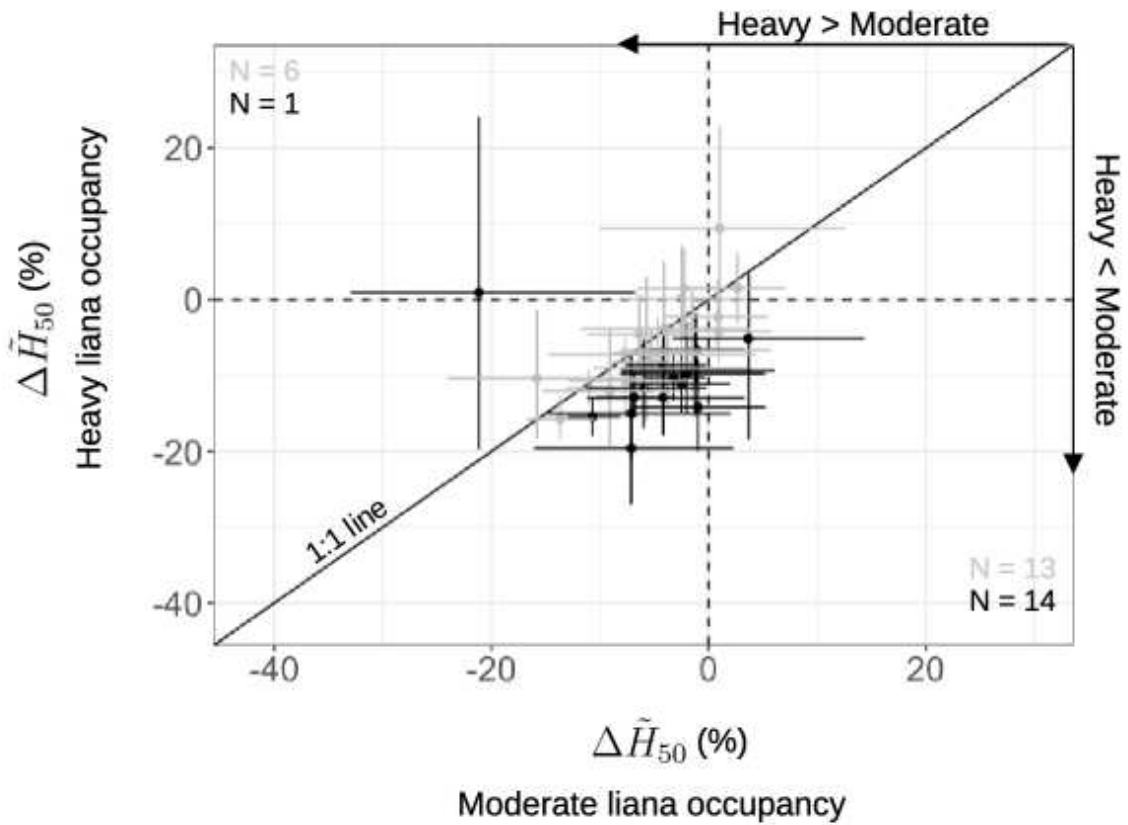
782

783 **Supplementary Figure S5** Site-level means of the liana effect on tree height for heavy liana occupancy levels
 784 together with their respective 89% CI for multiple DBHs, using 50 cm DBH as a reference. In the panels, a
 785 distinction is made when the CI of the difference of the relative change in tree height due to liana occupancy
 786 overlaps with 0 (grey) or not (black). We only kept the sites for which no DBH extrapolation was needed.



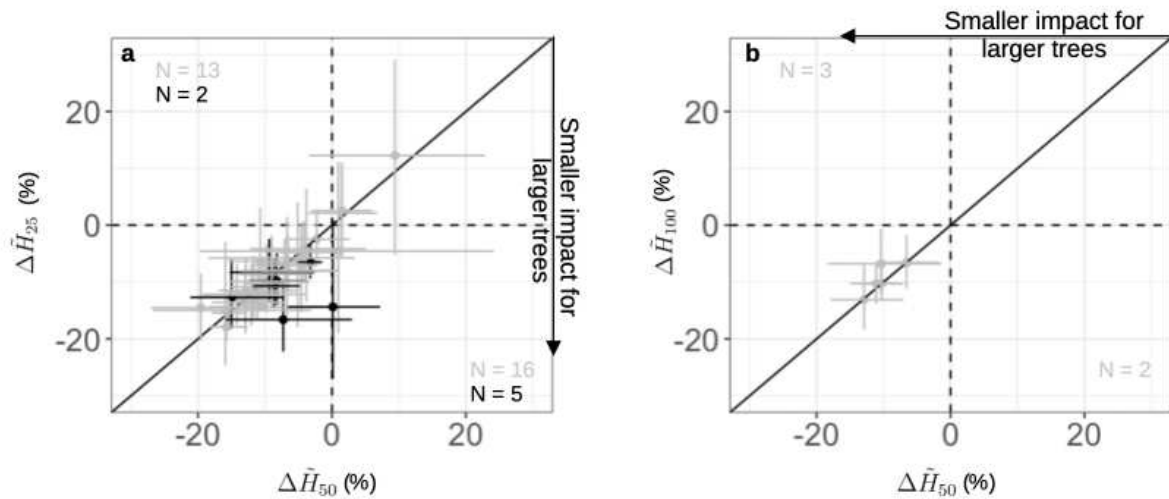
787

788 **Supplementary Figure S6** Liana effect on most abundant tree species height for 50 cm DBH individuals, relative
 789 to liana-free trees. Total sample size across liana occupancy levels are given for each species in the labels. Bold
 790 dots and numbers indicate that the corresponding 89% CIs do not overlap with 0. Only species for which no
 791 extrapolation was needed to compute $\Delta \tilde{H}_{50}$ are shown.



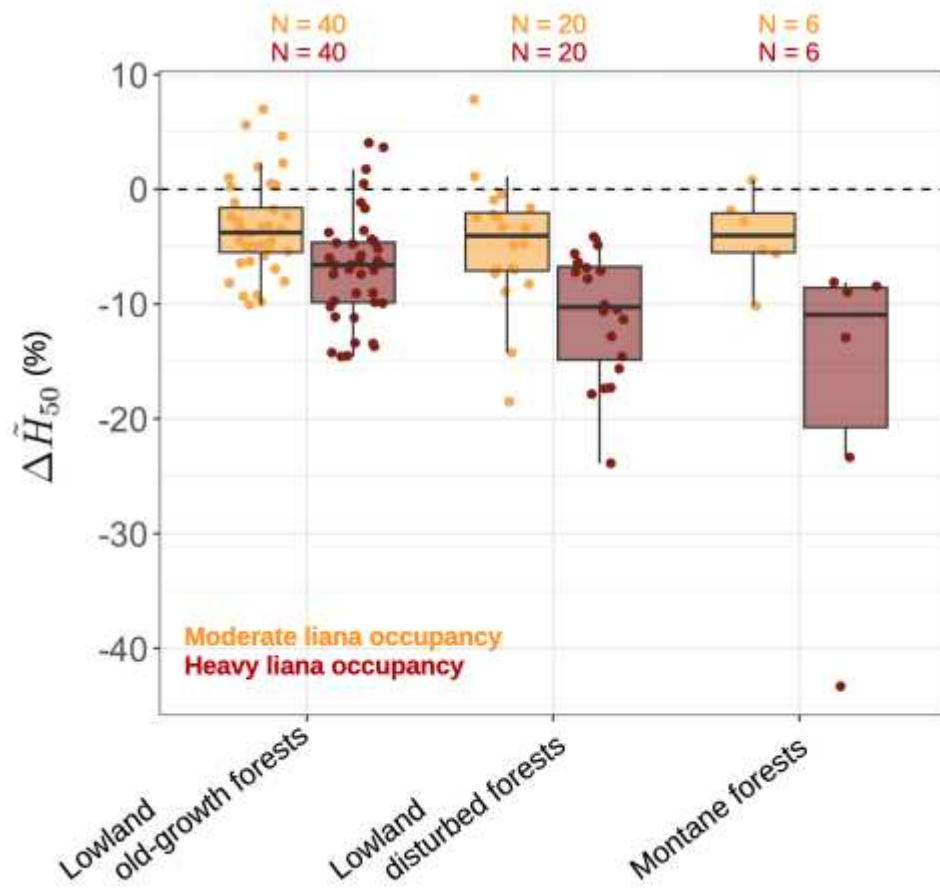
792

793 **Supplementary Figure S7** Species-level means of the liana effect on tree height ($\Delta\tilde{H}_{50}$) for moderate vs heavy
 794 liana occupancy levels together with their respective 89% CI. Any abundant tree species falling below the 1:1
 795 line indicates a liana effect aggravated with stronger occupancy (i.e. shorter trees with increasing liana
 796 occupancy). We observed a decrease in tree height in 27 of the 34 common species associated with a transition
 797 from moderate to heavy occupancy levels, including 14 with a decrease whose 89% CI is not overlapping with
 798 zero (black dots and numbers).



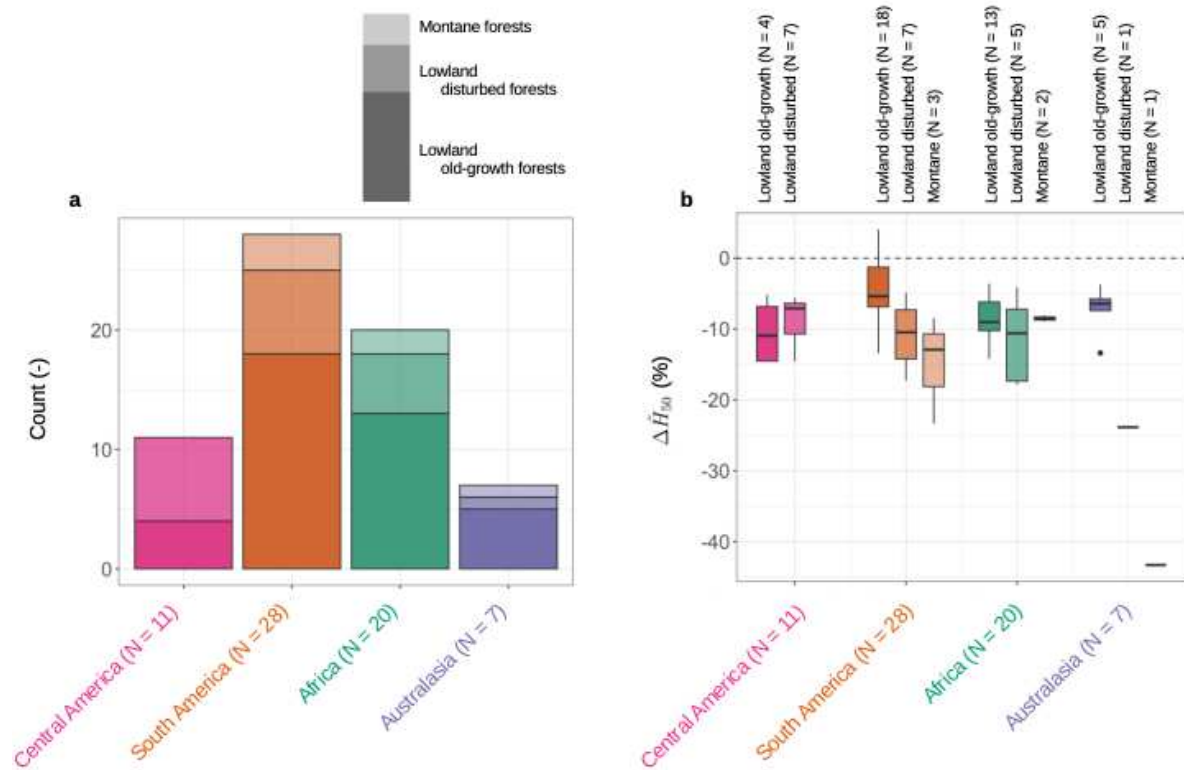
799

800 **Supplementary Figure S8** Means of the liana effect on tree height for heavy liana occupancy levels together with
 801 their respective 89% CI for multiple DBHs, using 50 cm DBH as a reference, for the abundant tree species
 802 identified in our database. We only kept the abundant tree species for which at least one observation was made
 803 for both the no and heavy liana occupancy levels on trees with DBH larger than the threshold to avoid
 804 extrapolation (see methods). In the subplots, a distinction is made when the 89% CI of the difference of the
 805 relative change in tree height due to liana occupancy overlaps with 0 (grey) or not (black).

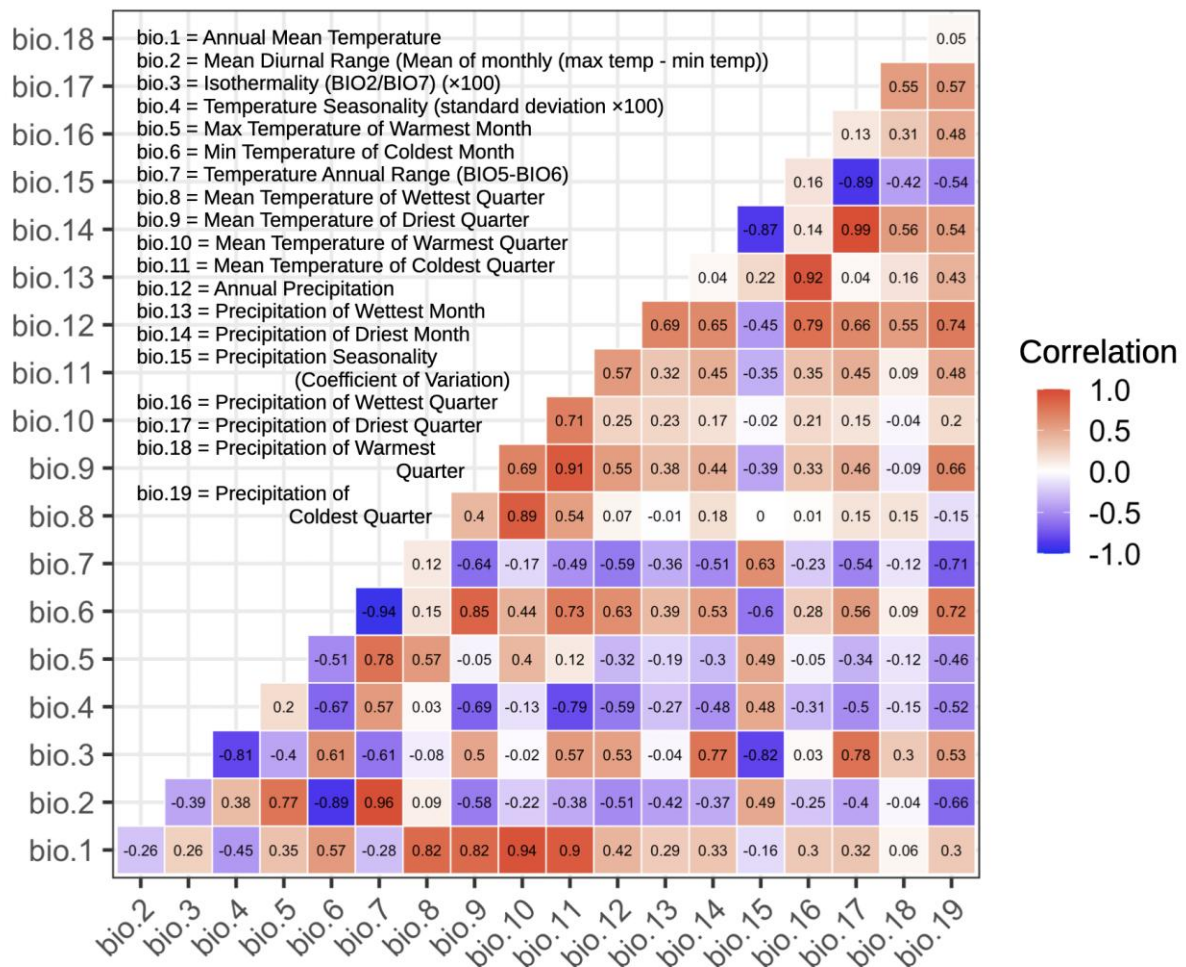


806

807 **Supplementary Figure S9** Liana effect on tree height ($\Delta \tilde{H}_{50}$) across different forest types. Sites were grouped
 808 by forest status (old-growth vs. disturbed) and elevation (lowland vs. Montane).



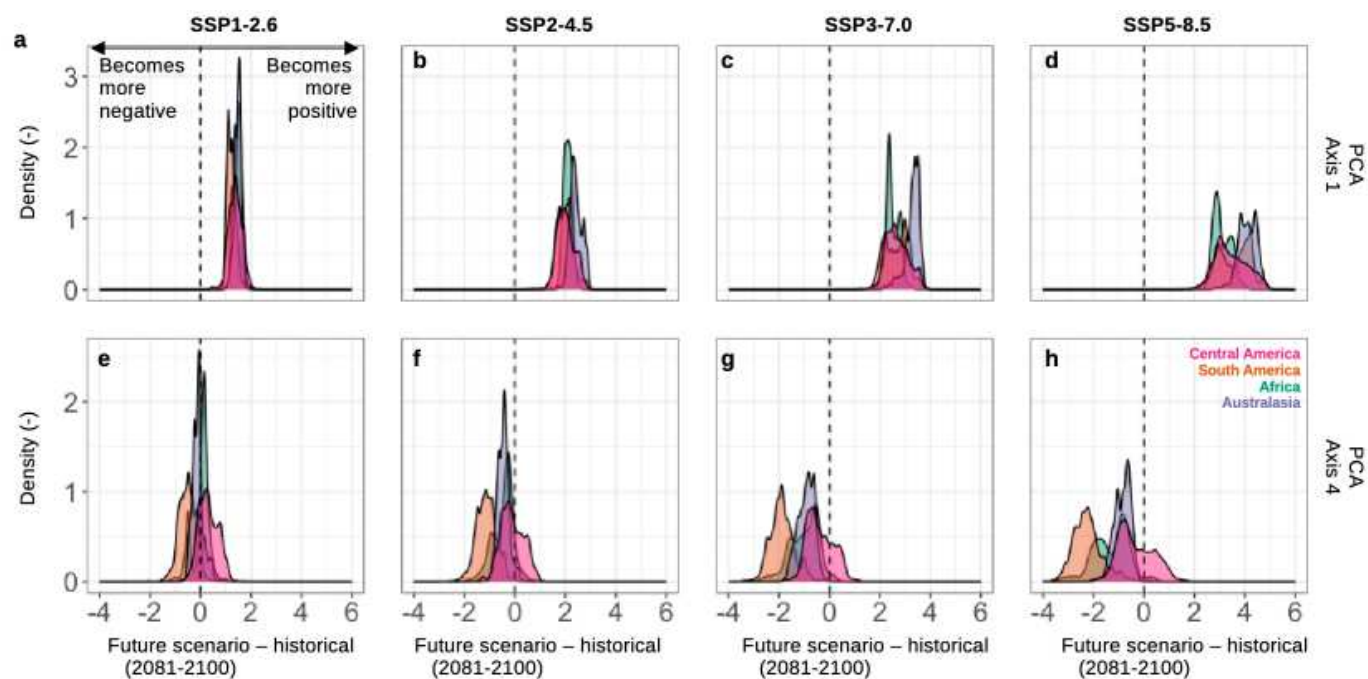
Supplementary Figure S10 Distribution of the sites compiled in this study across the different tropical regions (panel **a**). Panel **b** shows the distribution of the effect of heavy liana occupancy on height ($\Delta \hat{H}_{50}$) for each of the regions. In each panel, sites are differentiated according to their age and elevation.



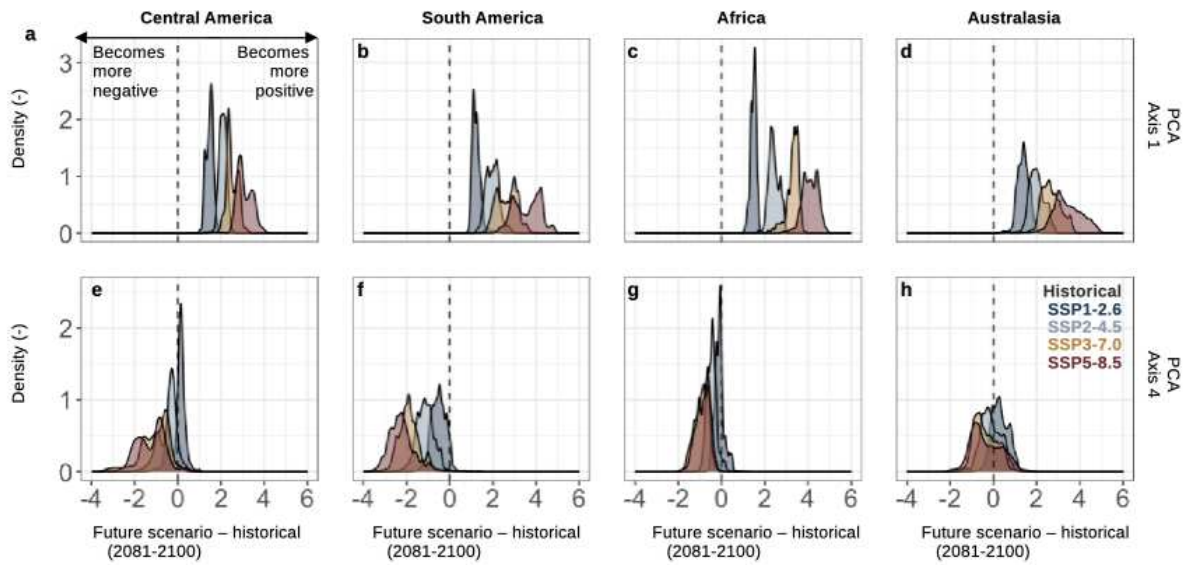
813

814 **Supplementary Figure S11** Correlation diagram of all 19 bioclimatic variables used in this study to characterize

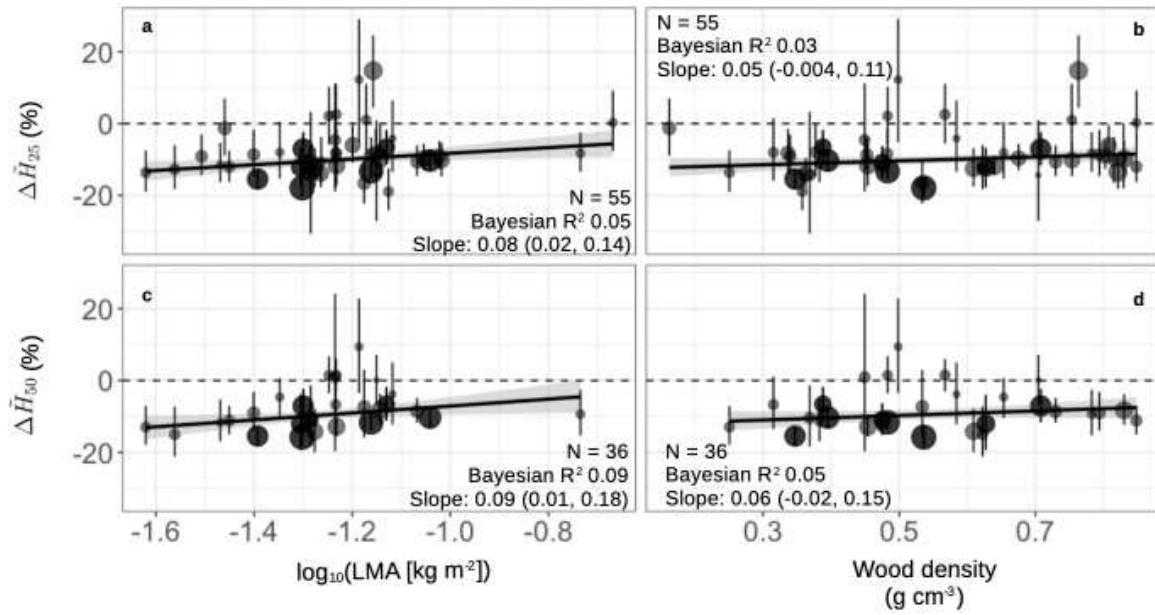
815 the intersite variability in liana effect on tree height for the lowland old-growth forest sites.



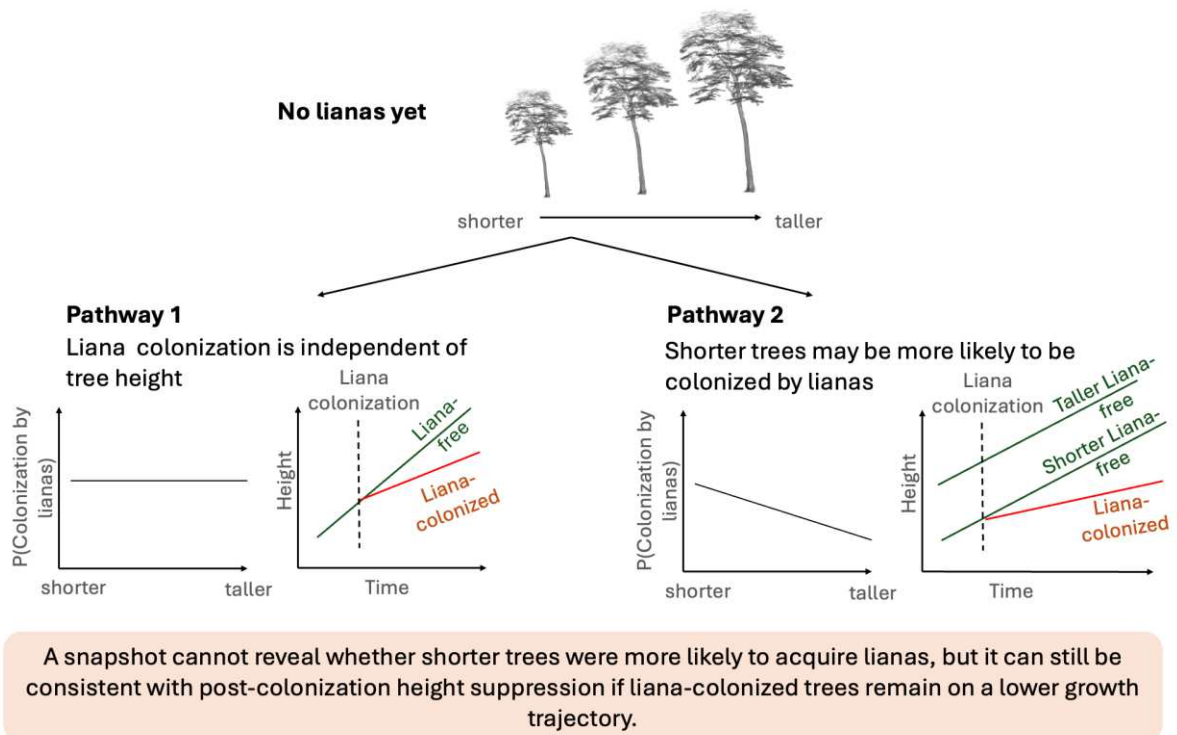
817 **Supplementary Figure S12** Projected changes in the first (panels **a-d**) and the fourth (panels **e-h**) PCA axes by
818 the end of the century according to multiple shared socio-economic pathways (SSPs) for each tropical region
819 considered in this study.



Supplementary Figure S13 Projected changes in the first (panels **a-d**) and the fourth (panels **e-h**) PCA axes by the end of the century across each tropical region considered in this study for multiple shared socio-economic pathways (SSP).

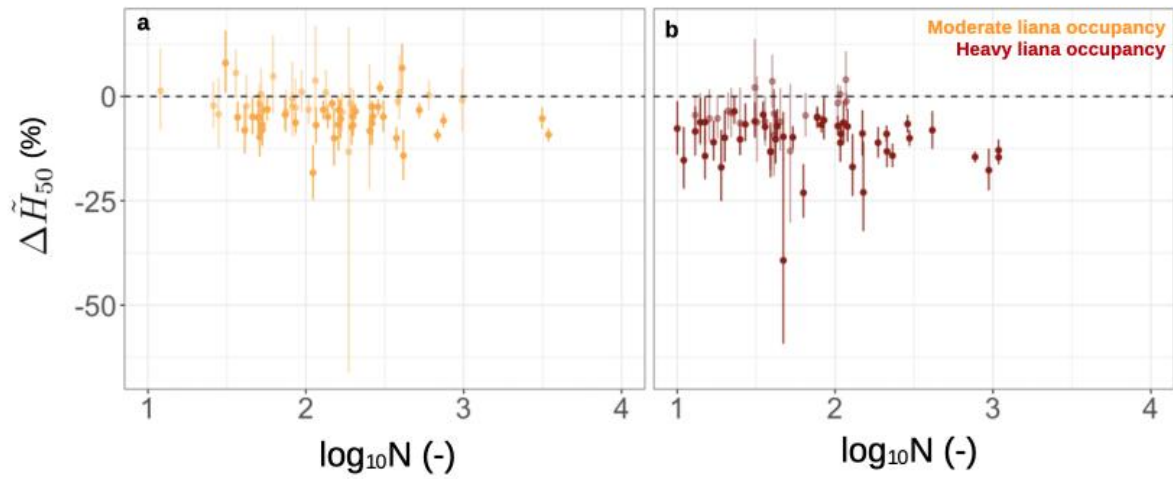


Supplementary Figure S14 Relationship of leaf mass per area (log-transformed, panels a and c) and Wood density (panels b and d) with the liana-effect on the height of heavily liana occupied trees of 25 cm (panels a-b) or 50 cm (panels c-d) DBH for most abundant tree species present in the dataset. Point size is proportional to the sample size while error bars encompass the 89% CI interval of the observed liana effects.

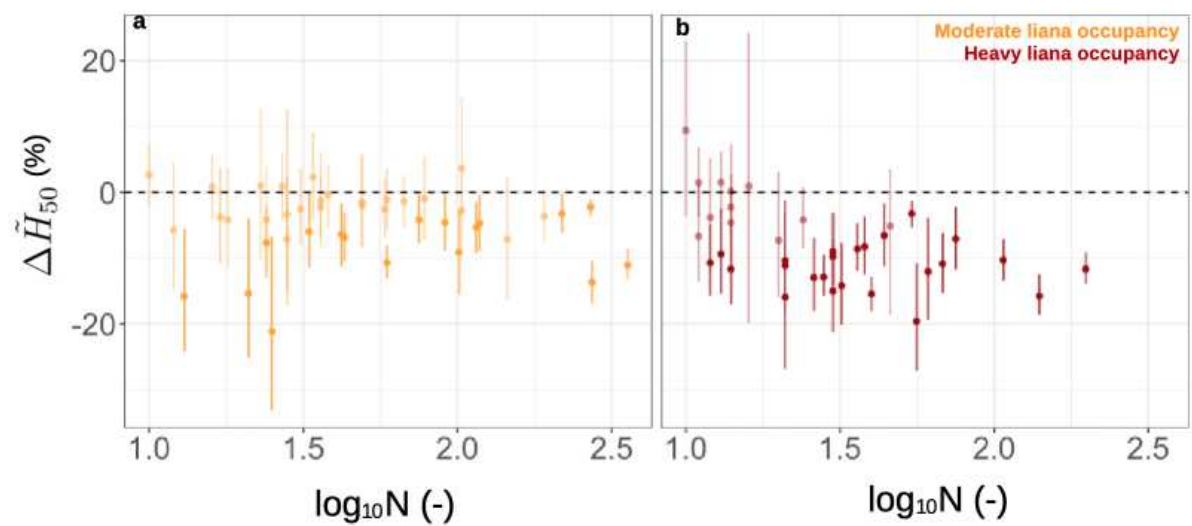


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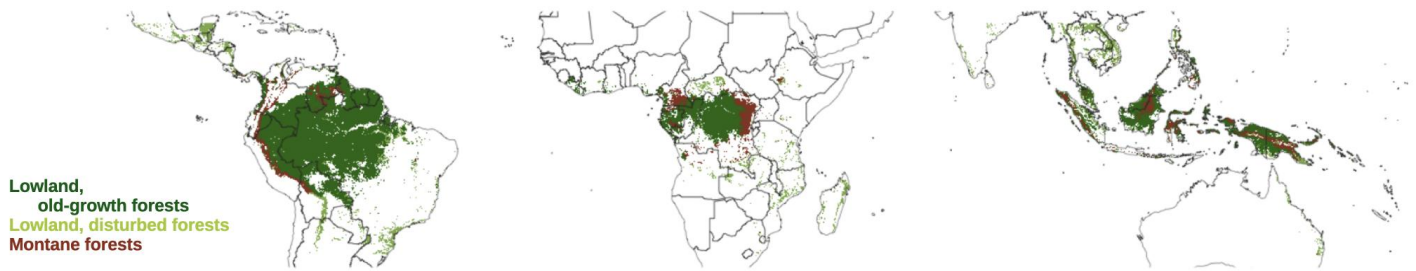
830 **Supplementary Figure S15** Conceptual pathways linking liana colonization and tree height. Before liana
 831 colonization, trees may vary in height along a natural height–diameter or growth trajectory. If liana colonization
 832 is independent of tree height (Pathway 1), liana-colonized trees diverge from comparable liana-free trees and
 833 follow a lower height-growth trajectory. If shorter trees are more likely to be colonized by lianas (Pathway 2),
 834 there is an initial height difference between future liana-colonized and liana-free trees.



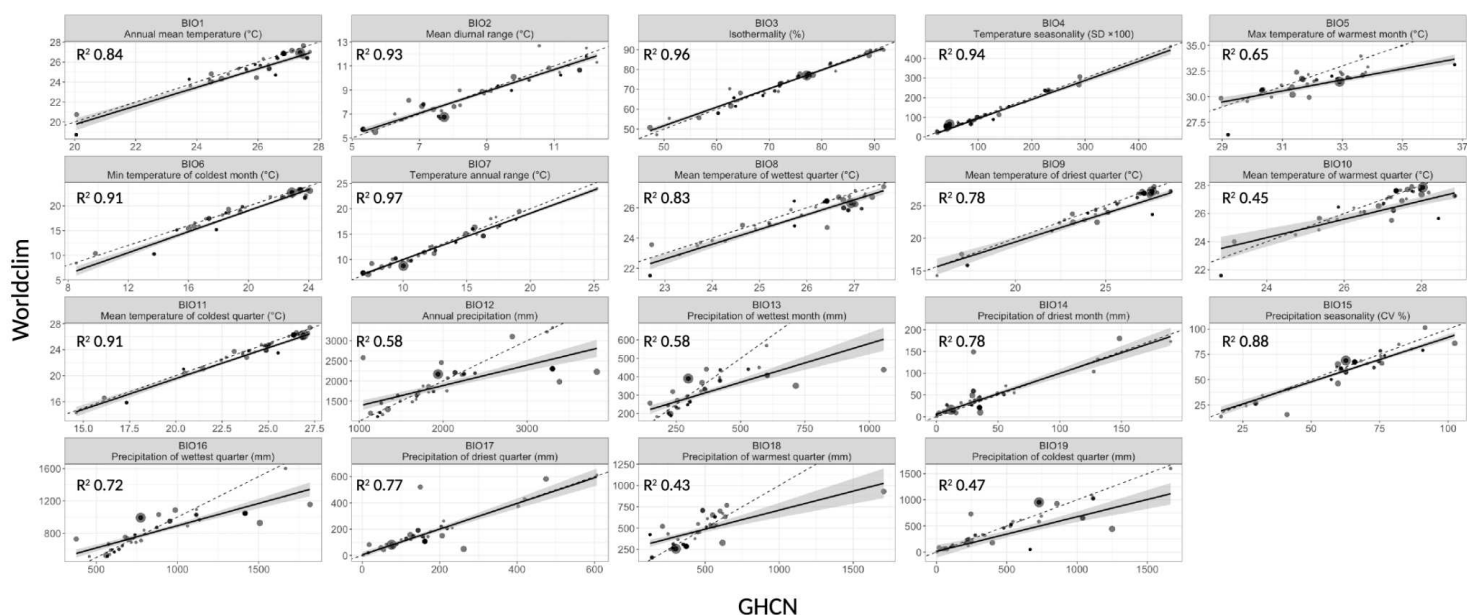
Supplementary Figure S16 Site-level liana effect on tree height ($\Delta\tilde{H}_{50}$) as a function of the number of observed trees for moderate (yellow, panel **a**) and high (red, panel **b**) liana occupancy levels.



Supplementary Figure S17 Species-level liana effect on tree height ($\Delta\tilde{H}_{50}$) as a function of the number of observed trees for moderate (yellow, panel **a**) and high (red, panel **b**) liana occupancy levels for the most abundant tree species identified in the dataset.



843 **Supplementary Figure S18** Spatial distribution of the forest categories used in this study. All upscaling and
 844 projection analyses were restricted to lowland old-growth forests. Pantropical forests were based on the
 845 evergreen broadleaf, deciduous broadleaf, and mixed forest land cover classes from MODIS⁸³. Disturbed and
 846 montane forests were respectively identified using the forest age product of Besnard et al.⁸⁵ and the global
 847 digital elevation model GMTED2010⁸⁴ (see methods).



849 **Supplementary Figure S19** Comparison of station-derived and gridded bioclimatic variables across study sites.

850 For each site, the nearest GHCN station with usable temperature and precipitation records was identified,
 851 monthly climatologies were computed from quality-controlled daily observations, and all 19 bioclimatic
 852 variables were derived from these station data. Corresponding WorldClim 2.1 values were extracted at the
 853 station coordinates. Black lines indicate fitted linear regressions with 95% confidence intervals (grey shading),
 854 and dashed lines indicate the 1:1 relationship. Point size is weighted by inverse site–station distance, so larger
 855 points represent stations located closer to the focal study site.