The ecosystem service and biodiversity contributions and trade-offs of contrasting forest restoration approaches

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Abstract: Forest restoration is being scaled-up globally to deliver critical ecosystem services and biodiversity benefits, yet we lack rigorous comparison of co-benefit delivery across different restoration approaches. In a global synthesis, we use 25,950 matched data pairs from 264 studies in 53 countries to assess how delivery of climate, soil, water, and wood production services as well as biodiversity compares across a range of tree plantations and native forests. Carbon storage, water provisioning, and especially soil erosion control and biodiversity benefits are all delivered better by native forests, with compositionally simpler, younger plantations in drier regions performing particularly poorly. However, plantations exhibit an advantage in wood production. These results underscore important trade-offs among environmental and production goals that policymakers must navigate in meeting forest restoration commitments.

One-Sentence Summary: Critical ecosystem services and biodiversity are typically delivered more effectively by native forests than by plantations.

Main Text: As the UN Decade on Ecosystem Restoration gets underway (*1*), forest restoration on degraded and deforested land is being scaled-up globally, with far-reaching environmental and social implications (*2–4*). The Bonn Challenge alone pledges to restore 350 million hectares of land by 2030 (*5*), and many other initiatives are similarly ambitious (*6*, *7*). Large-scale programs to restore forests are frequently motivated by a desire to recover ecosystem services such as carbon storage (*8*), soil erosion control (*9*), water provisioning (*10*), and wood production (*11*). Based on an implicit assumption that these services can be effectively delivered by forests regardless of their composition, these programs frequently gravitate toward reforesting with compositionally simple tree plantations rather than restoring native forests (*7*, *10*, *12*). However, this premise has yet to be tested rigorously using paired data that limit potential confounding factors (*13*) (Supplementary Text). This is a critically important omission for reasons beyond the target ecosystem services *per se*, because by having limited (*14*) and at times negative (*9*) effects on native biodiversity, a focus on tree plantations risks severely limiting the conservation potential of large-scale forest restoration, in turn hampering progress toward global commitments to halt and reverse biodiversity loss (*15–17*) and ecosystem degradation (*1*).

We present a global synthesis of paired data from the world's main forest biomes to assess the merits of forest restoration approaches, in particular reforesting with tree plantations *versus* restoring native forests, on deforested land that would have been naturally forested in recent history (Materials and Methods (*18*)). We compare the performance of a range of compositionally simple tree plantations spanning a wide spectrum of management regimes ('tree plantations' hereafter (*18*)) *versus* native forests (including restored and pre-existing native forests) in delivering the key ecosystem services of carbon storage, soil erosion control, water provisioning, and wood production, as well as in supporting biodiversity. We further assess how variation in the relative performance of tree plantations *versus* native forests may be explained by plantation features and biophysical conditions. Our study aims to enable forest restoration to achieve co-benefits in addressing today's multiple environmental challenges (*4*), including the dual climate and biodiversity crises (*8*, *17*). By simultaneously considering forests' performance in carbon, soil, water, and biodiversity (*i.e.* environmental outcomes), plus in wood production, our study also provides a critical assessment of the trade-offs likely to confront forest restoration decision-makers.

For each environmental outcome, we identified the most informative metric with a reasonable amount of empirical data: aboveground biomass (Mg ha^{-1}), amount of eroded soil (kg m^{-2} y^{-1}), catchment- or plot-scale water yield (% of rainfall), and species-specific abundance (individuals ha^{-1}, compiled for each species in a given ecological community; see (*18*) for rationale of metric choices). Searching the peer-reviewed and grey literature and corresponding with authors, we compiled pairs of data that involved a tree plantation (classified into three types) and a matching native forest (classified into four types; Fig. 1A) from the same study system (*18*). For wood production, we compiled pairs of empirical data on wood yield (m^3 ha^{-1}) or profit (USD ha^{-1}) that involved a tree plantation and a matching restored native forest (Fig. 1A) over equal time horizons (*18*); we excluded native forests not resulting from restoration because the sustainability of their wood harvest could rarely be confirmed. Given the paucity of paired wood production data, we relaxed the matching requirement to also compile annualized yield data just from restored native forests (m^3 ha^{-1} y^{-1}; (*18*)), which we compared with known annualized yields of some of the world's main monoculture plantations (*19*).

We assessed the rigor of matching for each data pair and weighed it accordingly in subsequent analyses (*18*). We calculated a log response ratio (RR; ln(tree plantation over native forest)) from each data pair to represent the relative performance of tree plantations *versus* native forests; we reversed the RR signs for eroded soil to represent soil erosion control. In total, our searches ((*18*); Fig. S1; Tables S1–S3) yielded 25,535 RRs for species-specific abundance on 13 species groups from 405 plantation-native forest pairs, 146 RRs for aboveground biomass, 82 RRs for eroded soil, 167 RRs for water yield, and 20 RRs for wood production, from 264 studies in 53 countries (Fig. 1; Table S4). In addition, we collated 223 records on the standing wood volume of restored native forests with known age from 10 studies in six countries (Fig. S2; Table S4).

We first asked how well tree plantations performed in environmental outcomes relative to reference native forests not resulting from restoration, namely old-growth forests and 'generic' native forests (*i.e.* other non-restored native forests not reported as old-growth). Not having undergone deforestation, these native forests represent reference environmental conditions (*20*) toward which forest restoration can aspire (Fig. 2A; (*18*)). Consistent with prevailing understanding (*14*, *21*), tree plantations supported on average 30.4% lower species-specific abundance than did reference native forests (95% confidence interval ('CI' hereafter): 17.4–41.4%; Fig. 2B, upper panel; Table S5; for differences among species groups, see Fig. S3). This biodiversity contrast was echoed across the other three environmental metrics, with tree plantations delivering 32.8% lower aboveground biomass (95% CI: 16.5–45.9%), 60.9% lower soil erosion control (17.5–81.5%), and 13.4% lower water yield (4.3–21.7%; Fig. 2B, upper panel; Table S5). These patterns were mainly driven by the poor performance of monoculture plantations, which exhibited the greatest contrasts with reference native forests (Fig. 2B, upper panel; Table S5). Prolonged age (≥40 years) or abandonment appeared to somewhat improve the environmental performance of plantations (*18*), with water yield shortfall no longer significant (mean: 6.3%; 95% CI: -28.9–31.9%; Fig. 2B, lower panel; Table S5). However, differences for the other metrics persisted, albeit less marked: 15.4% (3.6–25.8%) for species-specific abundance, and 24.0% (6.2–38.5%) for aboveground biomass; there were too few data to assess soil erosion control (Fig. 2B, lower panel; Fig. S3; Table S5).

We next asked how well tree plantations performed relative to restored native forests of similar age (*i.e.* with ≤10 years of age difference), represented by secondary forests resulting from natural regeneration, as well as actively restored native forests resulting from the planting of a diverse native tree mix (typically ≥50 species; Figs. 1A and S4, and 2A lower panel; (*18*)). On environmental performance, tree plantations performed significantly more poorly than restored native forests of similar age in species-specific abundance (32.6% poorer; 95% CI: 15.8–46.0%; there were insufficient data to contrast between species groups; Fig. S3) and marginally so for soil erosion control (80.2% poorer; -57.9–97.5%), but not aboveground biomass (4.1% greater; -23.1–40.9% and spanning zero; Fig. 2C, upper panel; Table S5; data paucity precluded analysis for water yield). The similarity in aboveground biomass appeared to be due to the strong performance of abandoned plantations that seemed to outperform both monocultures and mixed plantations (Fig. 2C, upper panel; although data paucity precluded formal analysis on this).

For wood production, the limited paired data showed that tree plantations had a clear advantage over restored native forests, with 222.7% (105.8%–406.0%) higher wood volumes at comparable age (Fig. 2C, lower panel; Table S5; data paucity precluded analysis of profits from wood production). This advantage was apparent for both intensively managed and abandoned plantations, and regardless of whether wood volumes included all woody species or only merchantable species (Fig. S5). The same conclusion was reached using supplementary non-paired data on annualized wood yields of restored native forests and various prominent monocultures: average annual volume increments for restored native forests were 61.3% (Welch two-sample t-test: $t_{28.8} = -6.40$, $P < 0.0001$) and 86.9% ($t_{26.4} = -9.76$, $P < 0.0001$) lower than the lower and upper bounds of the monocultures, respectively (Fig. 2D).

For all the above meta-analyses, we found high levels of heterogeneity (*18*), with I^2 – the metric for heterogeneity – generally ≥80% (Table S5). Findings were robust to publication bias (Supplementary Text; Fig. S6) and various sensitivity analyses related to weighting schemes and model structure ((*18*); Table S5). They also showed that across the environmental metrics examined, tree plantations performed particularly poorly for soil erosion control (Fig. 2, right-hand panels). Because data for different metrics were obtained for different regions (Fig. 2, left-hand panels), the difference among environmental outcomes might reflect inherent biophysical differences among ecosystems. To address this potential geographical confounding effect, we next focused on a subset of our database in which data for different metrics could be geographically matched to a given ecosystem type whose biophysical conditions were largely coherent. Overlaying our data onto the Holdridge Life Zones map (*22*, *23*), we identified 'data bundles' for each forest biome where RRs were available for ≥2 metrics. In total, we identified 11 such data bundles for the comparison between tree plantations and reference native forests (Fig. 3A), and seven for the comparison between tree plantations and restored native forests of similar age (Fig. 3B). The patterns of how RRs for soil erosion control compared with other environmental metrics within each data bundle corroborated our earlier findings: relative to reference native forests, plantation shortfalls were almost always greatest for soil erosion control and the least for water yield (Fig. 3).

We also asked what factors might underlie the variation in environmental performance of tree plantations relative to native forests. For the comparisons of plantations *versus* reference native forests and plantations *versus* restored native forests of similar age, respectively, we assessed the relationship between RRs and a set of variables representing plantation features and site biophysical conditions ((*18*); analyses of wood production were dropped because of data paucity). We considered plantation type, plantation age (except for the comparison involving restored native forests of similar age), and mean annual temperature (in °C; 'MAT' hereafter; (*18*)). The rationale for considering MAT was that by supporting higher plant diversity (*24*), warmer climates may show greater contrasts between plantations *versus* native forests in vegetation complexity, and in turn, in delivery of carbon, soil, and water ecosystem services (*25*). We also considered mean annual precipitation (in mm y^{-1}; 'MAP' hereafter) for soil erosion due to its likely influence on protective ground cover, as well as MAP and the seasonality of native forests (evergreen or deciduous) for water yield due to their likely influence on the hydrological behaviors of forest ecosystems (*18*, *26*, *27*).

The most parsimonious models selected *via* small-sample corrected Akaike Information Criterion (AICc) scores ((*18*); Table S6) showed that increasing plantation age improved plantations' performance relative to that of reference native forests in species-specific abundance and aboveground biomass (Table S7), although such improvement was limited (Figs. 4A): particularly for aboveground biomass, even old (≥40 years) plantations performed less well than reference native forests. Combined with the environmental shortfalls of old or abandoned plantations (Fig. 2B, lower panel), this finding suggests that old plantations no longer intended for productive use (*e.g.* (*28*)) would deliver environmental benefits more effectively if they were restored to native forests or native forest-like conditions. That such areas are common in our database (Figs. 1A and 2A) indicates the sizeable environmental gains that such 'forgotten lands' offer, underscoring the need to assess their global distribution and restoration potential (*29*).

We also found that increasing MAP (range covered by our data: 490–4210 mm y^{-1}) predicted more positive RRs for water yield when comparing tree plantations against reference native forests (Fig. 4B; Table S7), indicating greater plantation shortfalls in water provisioning in drier climates. Clearly, water-oriented forest restoration initiatives should re-examine the practise of establishing large areas of tree plantations in the world's drier regions (*30*). We did not find evidence of other variables explaining variation in RR values, or for any variable explaining plantation performance relative to restored native forests of similar age (Fig. S7; Table S6). These findings were again robust to various sensitivity analyses related to weighting schemes and model structure ((*18*); Table S7).

Our findings have important implications for forest restoration as it is scaled-up globally (*7*), providing a knowledge base for exploring how outcomes can be best delivered by alternative restoration approaches. We found that restoring native forests typically delivers greater – and certainly no less – environmental benefits than establishing tree plantations, in terms of biodiversity conservation and the key ecosystem services of aboveground carbon storage, soil erosion control, and water provisioning. However, delivering these outcomes will typically result in a trade-off with wood production because of the yield advantage of plantations over restored native forests (*31*–*33*), as measured in wood volumes (distinct from aboveground carbon storage, which in addition to wood volumes also factors in wood densities).

These findings provide evidence that if the goal of forest restoration is to recover environmental services on the land being restored, and if wood production is not a primary concern, native forest restoration should be prioritized, using site-appropriate measures including unassisted and assisted natural regeneration and active planting of diverse native species (*34*–*36*). Beyond biodiversity, the stakes are especially high for soil erosion control – given its far poorer delivery by tree plantations relative to native forests. Our synthesis refutes the implicit assumptions of ecosystem service-oriented forest restoration initiatives such as China's Grain-for-Green Program covering >34 million hectares (*37*, *38*), and a large collection of projects targeting carbon storage (*39*), soil conservation (*40*), and water provisioning (*41*) that have focused mostly on establishing (monoculture) tree plantations.

However, where the goals of forest restoration include wood production, decision-making must navigate the trade-off between environmental and production outcomes (*42*). Beyond weighing competing goals and adopting restoration approaches accordingly (*43*), larger-scale land-use planning must be invoked to also consider the 'leakage' of forgone production to land parcels elsewhere: such leakage could alter – and even reverse – the overall environmental gains of forest restoration (*44*). Ensuring environmental gains while meeting production goals under forest restoration hinges on understanding their trade-offs for a range of restored forest covers, making the acquisition of such information an urgent research priority.

Interpretation of our results and associated policy recommendations raises three additional issues. First, while the environmental metrics assessed were our best choices given data availability (*18*), they each characterize one aspect of a focal outcome. For example, beyond aboveground biomass, an assessment of forest carbon storage must also consider carbon stored belowground (*45*) as well as in long-lived wood products. Second, because our data came from established tree covers, they represent achievable outcomes of successful forest restoration (*13*). In reality, restoration approaches and outcomes are often constrained by factors including funding limitations, recurrent disturbances, livelihood needs, and regeneration stochasticity, etc (*46*, *47*). Third, while we used paired data and accounted for the rigor of site matching in our analyses (*18*), we cannot rule out the potential influence of pre-existing site differences incurred by land-use history (*13*) and species turnover across space (beta-diversity; (*48*)), both of which are often difficult to ascertain.

By presenting a global comparison between tree plantations and native forests that simultaneously assesses their impacts on biodiversity, climate, soil, water, and wood production based on rigorously paired data, our study provides insights into the alignment among these environmental goals and the trade-offs between environmental and production goals under forest restoration. Previous research on the co-benefits of forest restoration has focused on '*where to* *restore*' (*29*, *49*). By addressing '*how to restore*', our study will help to improve the realism of future spatial prioritization efforts. Finally, other forest restoration outcomes, such as food and nutrition security, will be important in some contexts (*50*). Future research should address how these outcomes fare under different restoration approaches, and their co-benefit opportunities and unavoidable trade-offs with other environmental and production goals.

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Supplementary Materials

Materials and Methods

Supplementary Text

Figs. S1 to S11

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References (*51–535*)

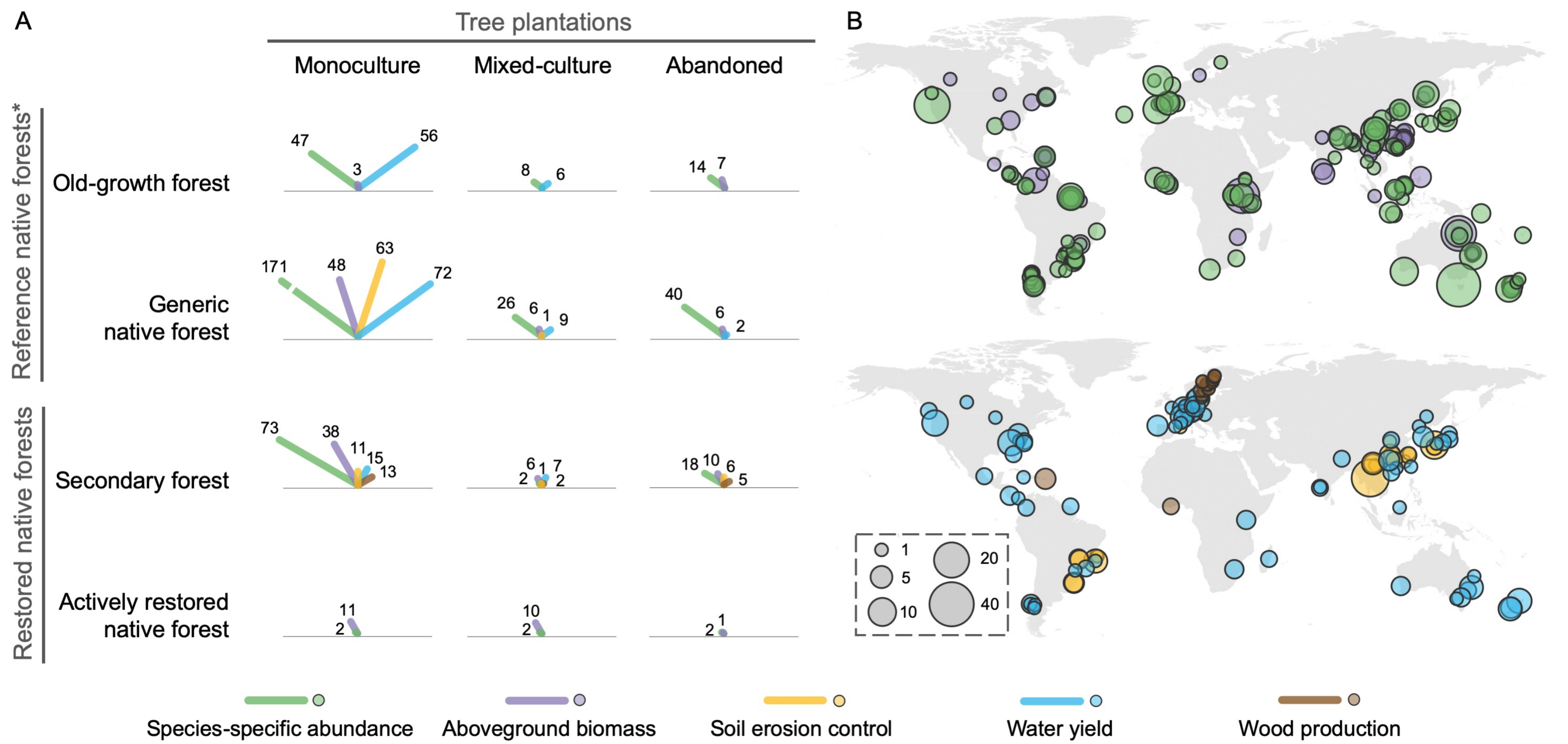

Fig. 1. Database overview. (**A**) The amount of paired data compiled into our database for different combinations of plantations and native forests. For species-specific abundance, the amount of data is represented by the number of plantation-native forest pairs that supplied species-level RRs for entire ecological communities; for all other metrics, it is represented by the number of RRs. (**B**) Geographical distribution of RRs of different metrics, displayed in two maps for better visualization: species-specific abundance and aboveground biomass in the upper panel, and soil erosion control, water yield, and wood production in the lower panel. Bubble size in maps is proportional to the cube root of the amount of data for a given geographical location. *: We did not compile paired wood production data for the comparison between tree plantations and reference native forests.

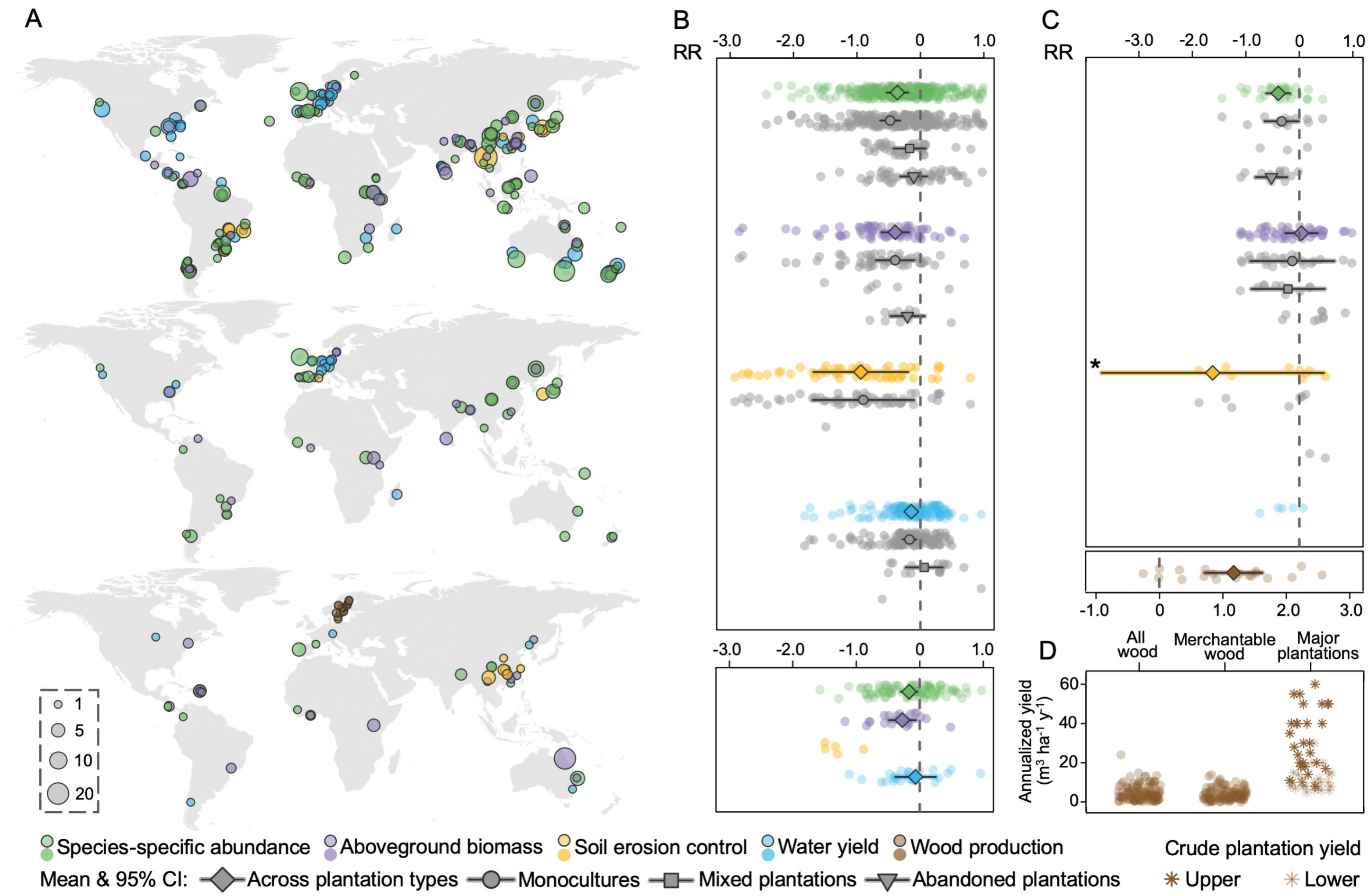

Fig. 2. Relative performance of tree plantations *versus* native forests across the metrics assessed. (**A**) Maps displaying the distribution and amount of data analyzed, for three types of comparisons: plantations *versus* reference native forests (upper panel), old (≥40 years of age) or abandoned plantations *versus* reference native forests (middle panel), and plantations *versus* restored native forests of similar age (*i.e.* with ≤10 years of age difference; lower panel). As with Fig. 1, bubble size is proportional to the cube root of the amount of data for a given geographical location. (**B**) Relative performance of plantations *versus* reference native forests (upper panel) and of old or abandoned plantations *versus* reference native forests (lower panel), in environmental metrics. Scattered dots in color represent RR from primary studies across all types of plantations, and diamonds and associated error bars represent the mean

and 95% confidence intervals (CI) of RR values obtained from meta-analyses where the number of RR ≥10 (in the case of species-specific abundance, where the number of plantation-native forest pairs ≥10). For the comparison between plantations and reference native forests (upper panel), we also analyzed RRs separately for different types of plantations where the number of RR ≥10. For these analyses, we display their RR values from primary studies in grey, distinguishing among plantation types with different symbols for their meta-analysis-derived means and 95% CI. (**C**) Relative performance of plantations *versus* restored native forests of similar age in environmental (upper panel) and production (lower panel) metrics, with symbol use following that of (B). For soil erosion control, * indicates five highly negative RRs that fell outside the display area. (**D**) Annualized wood volume increment of restored native forests compared with the lower and upper bounds of the annual wood increment of the world's major monoculture plantations. In our display, we differentiate between records on all woody plants and those on only merchantable species for restored native forests, and between the lower and upper bound for plantations. In panels (B) and (C), scattered dots for species-specific abundance data represent the average RR within the ecological community concerned in each plantation-native forest pair.

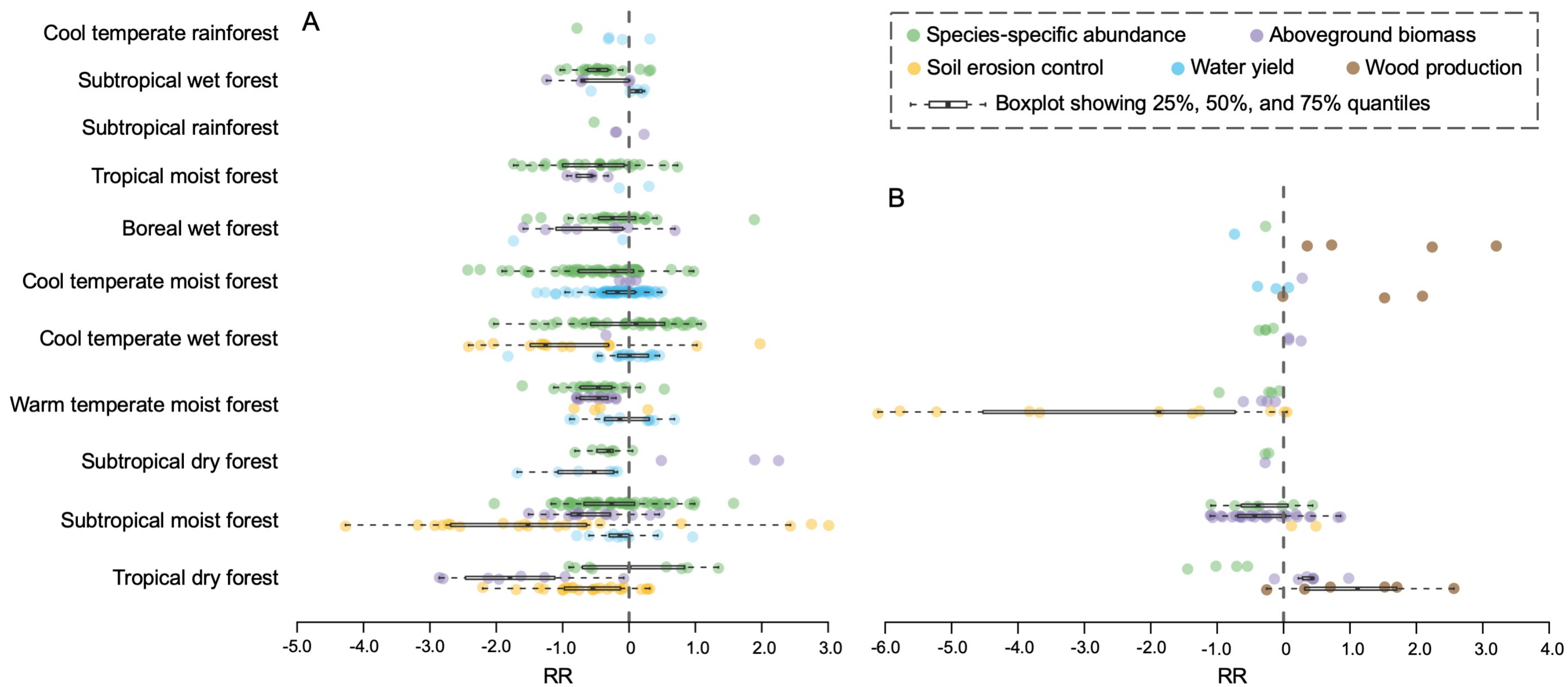

Fig. 3. Relative performance of plantations *versus* native forests compared among the metrics assessed, based on geographically matched data bundles for individual forest biomes. (**A**) Plantations *versus* reference native forests. (**B**) Plantations *versus* restored native forests of similar age (*i.e.* with ≤10 years of age difference). RR values (in the case of species-specific abundance, the average RR within the ecological community concerned in each plantation-native forest pair) are represented by scattered dots, and their quartiles by boxplots where the number of RRs ≥5. For the comparison between plantations and restored native forests of similar age, data bundles were not available for four forest biomes on the top.

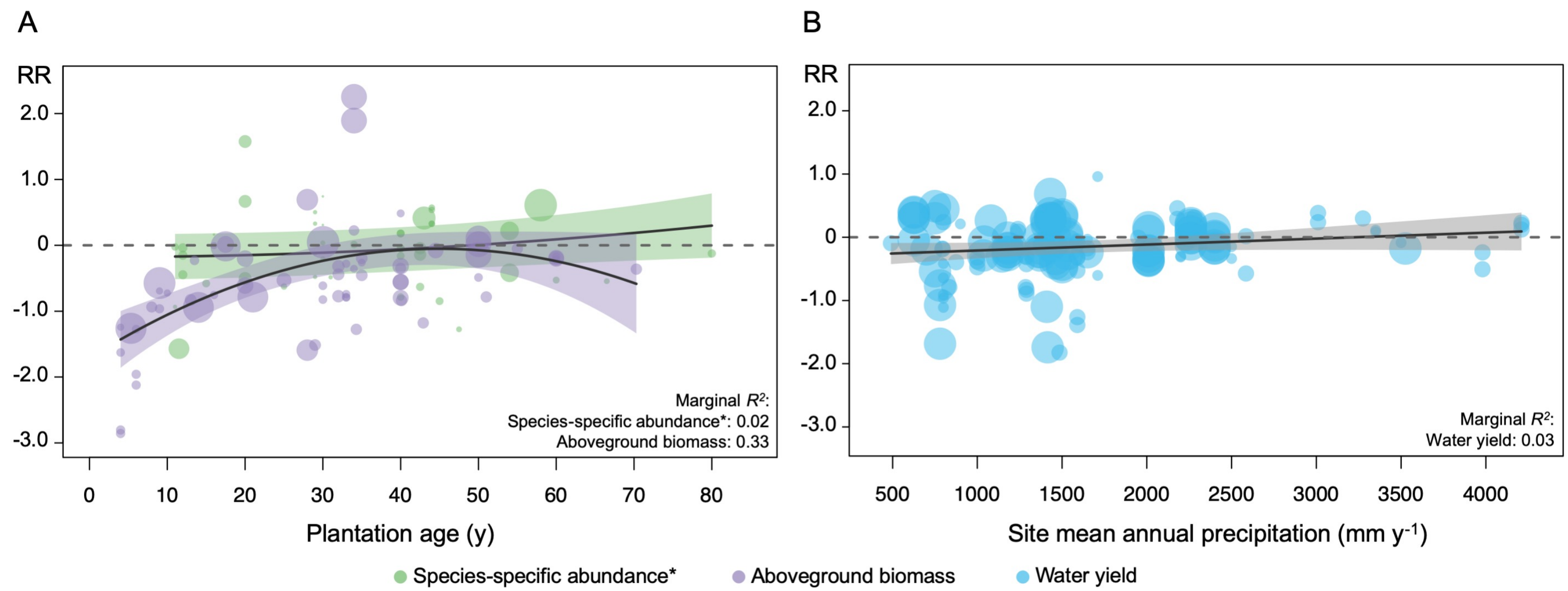

Fig. 4. Factors explaining the relative performance of plantations *versus* reference native forests. Best models selected based on AICc scores identified the following factors as explaining RRs: (**A**) plantation age for aboveground biomass and for species-specific abundance (*: the latter concerning the comparison between abandoned plantations and reference native forests only), and (**B**) MAP for water yield. Scattered dots represent RR values from primary studies (in the case of species-specific abundance, average RR within the ecological community concerned in each plantation-native forest pair), with dot size proportional to the weight of each RR in the meta-regressions, standardized within each metric to the RR with the greatest weight. Fitted curves (black lines) and 95% confidence bands (colored polygons; colored grey for water yield for better visualization) were generated from meta-regressions.

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Supplementary Materials for

The ecosystem service and biodiversity contributions and trade-offs of contrasting forest restoration approaches

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Materials and Methods

Terminology and study scope pertaining to forest restoration

Following the terminology used by FAO and the Bonn Challenge, we used broad definitions for forest cover and forest restoration, with the former referring to a wide spectrum of tree cover types from compositionally simple tree plantations to native forests (*51*), and the latter referring to the action of re-establishing tree cover for a wide range of purposes on degraded or deforested land that would have been naturally forested in recent history (*52*). We limited our study to the comparison of compositionally simple tree plantations ('tree plantations' hereafter) *versus* native forests (Fig. 1A; see below for definitions and requirements), given their dominance in discussions about the approaches to and outcomes of forest restoration. Our study therefore did not cover the agroforestry form of forest restoration. For tree plantations, we included those intended for wood but not food production (*e.g.* fruits and oil palm), because the environmental and production functions addressed in our study did not apply to the latter category. We also did not include rubber plantations because of its high water use, which may penalize its water provisioning performance (*53*, *54*).

For both tree plantations and native forests, we required them to have reasonably extensive cover such that the environmental and production functions assessed reflected their performance rather than that of the wider landscape (see 'Data inclusion criteria' below). Tree plantations resulted from the active planting of a small number of tree species (≤5 species) on formerly deforested land, regardless of whether the trees were native or exotic (*e.g.* (*55*, *56*)). For inclusion into our databases, they had to have been labelled by primary studies explicitly as 'plantations', and they had to have a tree canopy; we therefore required that they were ≥4 years old and stated or implied by the primary studies to have a tree canopy. We included and differentiated among three types of tree plantations: 'monoculture' for when the plantations involved a single species, 'mixed-culture' for 2–5 species, and 'abandoned' for when the primary studies noted or implied that the maintenance of a plantation had been suspended and the plantation allowed to naturally develop for ≥5 years. This last criterion meant that we tended toward being strict with classifying a plantation as abandoned, and that some monoculture or mixed-culture plantations that were in fact abandoned were not labelled as such because their primary studies did not indicate so.

The native forests considered in our study included four types that fell into two categories: reference native forests and restored native forests. For reference native forests, 'old-growth forests' were native forests that had not been degraded or otherwise disturbed by humans; only when the primary studies explicitly labelled a forest as 'primary', 'old-growth', 'pristine', or otherwise undisturbed by humans and when we had no reason to doubt such labelling did we consider it as old-growth forest. 'Generic native forests' were native forests that were neither old-growth nor resulting from restoration starting from a deforested state. They typically had an unclear history of anthropogenic disturbance or condition, or were noted by the primary studies to have been anthropogenically disturbed (*e.g.* by logging or grazing) or naturally regenerating (although the disturbance from which the forests were regenerating was not clear). Therefore, the reference environmental conditions that generic native forests provided in our study were likely to be poorer than what truly undisturbed reference systems should be, rendering any contrasts between tree plantations and reference native forests quantified by our study more conservative.

For restored native forests, in keeping with the criteria used for tree plantations, we considered only those that started from complete deforestation. Specifically, 'secondary forests' resulted from natural regeneration on formerly deforested land, and 'actively restored native forests' from the active planting of a diverse (required to be ≥6, but in reality, most studies included had much higher numbers) native species mix on formerly deforested land with the goal of restoring native forests. As with tree plantations, we required these two types of restored native forests to be ≥6 years old and stated or implied by primary studies to have a tree canopy; the higher age threshold than that used for tree plantations was considering the potentially slower development of restored native forests. We did not consider the managed mixed forest system as used in Scandinavia (the dominant boreal forest ecosystem in Europe) because of its mixed use of planting a small number of trees and natural regeneration. Given that these mixed forests represent a dominant form of forest management regime within the boreal zone, our database thus contained little data from the boreal ecosystem.

Biodiversity and ecosystem service metrics

We used one metric for each of the four environmental outcomes to ensure comparability across primary studies and the interpretability of findings. In addition to meaningfully representing the corresponding outcome, metrics must have good empirical data availability. For biodiversity, we used the metric of species-specific abundance, *i.e.* the number of individuals for a given species, collected by the same sampling method and adjusted for equal sampling effort between the tree covers being compared (because of varied sampling designs and methods, data compiled from primary studies did not allow accounting for imperfect detection). We chose this metric over species richness, the most obvious alternative metric that has been used in other syntheses (*21*, *57*), because the former provides much fuller information on the profile of ecological communities. Whereas species richness reduces the profile of ecological communities to the presence/absence of each species, species-specific abundance reflects the population size of each species, which is a more sensitive and ecologically meaningful representation of species' responses to habitat change. Moreover, the RR we derived from species-specific abundance data, expressed in Equation 1 below, was conceptually linked to the geometric mean of species abundance (*58*) – a widely adopted metric in assessing biodiversity change (*59*, *60*). A notable advantage of this metric is its sensitivity to abundance changes of rare species, which is a desirable property in the context of our study; this is in contrast to the species richness metric, which does not distinguish between rare and abundant species (*58*, *60*). Finally, a synthesis of biodiversity contrasts between tree plantations and native forests based on this metric would also make a much-needed contribution to existing syntheses, which have predominantly relied on species richness. Nonetheless, species-specific abundance has the disadvantage of not accommodating zeros; we addressed this issue by adding a small quantity to zero values following previous (see 'Data analysis' below).

$$RR = ln\frac{m_p}{m_f} \qquad \text{(Equation 1)}$$

(Here, m_p and m_f represent the metric values (*i.e.* species-specific abundance in the case of biodiversity) for tree plantations and native forests, respectively.)

Aboveground biomass is the most widely studied component of carbon storage for forest ecosystems (*61*), especially given the paucity of data on full ecosystem carbon storage (*45*). The amount of eroded soil is obviously the most direct, non-proxy-based (*e.g.* litter standing crop (*62*) or soil erodibility (*63*)) measure of the lack of soil conservation benefit. For water provisioning, we used water yield, *i.e.* the amount of water draining annually from forested catchments (as streamflow) or plots, expressed as % of rainfall, as a direct measure of the ability of forest ecosystems to provide water. A small number of studies also separated streamflow into baseflow (*i.e.* the part of streamflow sustained between rainfall events and fed to streamflow by delayed pathways (*64*)) and stormflow (*i.e.* the extra streamflow generated during and shortly after rainfall events (*65*)). While the former is unambiguously useful to humans, the latter is often sediment-laden and presents a flood risk, constituting mostly a disbenefit. For these studies, we therefore used the separated baseflow and stormflow (with RR signs of the latter reversed to represent the flood control benefit) data as better representations of the water yield benefit. We referred to all water yield, baseflow, and stormflow (RR sign reversed) measures collectively as 'water yield'.

We used both wood yield and wood profit for the production function because we foresaw paired data to be limited based on our preliminary searches, and because the two metrics provide complementary information on a forest's production function. Whereas the former gauges the physical amount of wood produced, the latter also incorporates price information, which not only matters in land-use decision-making but also converts wood intended for different uses into the same currency.

Data inclusion criteria

Data used to calculate RR had to be empirically measured and reported by primary studies as matched data pairs. The rigor of matching concerned all biophysical (*e.g.* elevation, slope, landscape context, land-use history) and study conditions (notably sampling methods) that may affect the metric performance of the tree covers in question. Based on information reported in the primary studies, we discarded data pairs that were obviously incomparable for the metric concerned (*i.e.* major differences in biophysical or study conditions). For each retained data pair, we assigned a 'match rigor score' on a 1–3 scale based on the extent to which the primary study made explicit efforts to ensure the matching of biophysical and methodological conditions between data pairs: 1 for 'highly matched', if the above efforts concerned most, if not all, biophysical and methodological conditions; 2 for 'likely matched', if the above efforts concerned at least some biophysical and methodological conditions; and 3 for 'matching extent unclear' if little information was provided on the efforts to ensure the matching, despite data being presented by the primary study as matched. We incorporated the match rigor score into subsequent analyses (see 'Data analysis' below).

We applied additional sets of criteria on paired data depending on the metric. For species-specific abundance, in addition to the requirement-by-definition that data must be on the resolution of species or morpho-species (rather than on coarser resolutions such as genera), paired data must meet four additional criteria. First, the ecological communities studied in each primary study must not be defined by functional traits that may influence species' abundance response to habitat change (*e.g.* cavity-nesting birds, whose requirement for cavities may predispose the species susceptible to forest degradation; we considered 'small mammals' – *i.e.* mice, rats, shrews – a special case where the small body size did not necessarily mean higher or lower sensitivity to habitat change). Second, the ecological communities studied in each primary study must cover ≥6 species, and ≥10% of the species must have been recorded as present. Third, sampling efforts for the tree covers being compared must be equivalent or known, such that species raw counts could be adjusted for equal sampling effort, or the quality and comparability of density estimates could be confirmed (Supplementary Text). Finally, the size of the tree cover expanses sampled must be large enough for the study taxa such that the species-specific abundance data reflected the habitat value of the tree covers, rather than the influence of the wider landscape (*66*). We used the following criteria to decide whether a tree cover expanse was 'large enough' for the study taxa: ≥1 ha regardless of taxa, or ≥5 ha for more mobile taxa including birds or mammals (other than small mammals, *i.e.*, mice, rats, shrews). Provided that the above criteria were met, we allowed primary studies to be on any taxa, and to report species-specific abundance in a range of data formats: raw counts, estimated density, or abundance indices (indices based on occurrence frequencies were not admitted because they are fundamentally about presence/absence rather than abundance).

Paired data on aboveground biomass must be reported in the form of aboveground biomass or carbon per unit area directly by the primary studies, and they must cover at least the tree component of the plant community. In addition, tree cover expanses from which data were obtained must be ≥20 m × 20 m in size. Provided that these requirements were met, we allowed primary studies to address a range of aboveground vegetation components (*e.g.* woody vegetation only or all vegetation), impose different size thresholds for vegetation measured (*e.g.* 10 cm or 1 cm in diameter-at-breast-height), use different methods to calculate biomass (*e.g.* direct harvesting or measurement-based calculation using allometric equations), and express biomass values in different units (*e.g.* kg biomass m^{-2} or ton carbon ha^{-1}).

Paired data on the amount of eroded soil must have been measured on small scales to avoid geological effects on sediment production (*e.g.* bank erosion along perennial stream channels, or mass wasting); the scales we considered included those of a plot, hill slope, or zero-order catchment with ephemeral surface runoff only during and/or shortly after rainfall. Data also must not have been obtained by erosion pin- (e.g. (*67*)) or isotope-based (e.g. (*68*)) methods, because data from the former may be confounded by re-deposition of material eroded further upslope, while the validity of the latter method relies on the assumption that the tree covers being compared had equivalent land-use histories, which we could rarely verify from the primary studies. Accepted primary studies that measured soil mass lost per unit area over a certain time span involved a range of plot sizes (*e.g.* several m^2 to several ha) and temporal scales of measurement (*e.g.* a full rainy season to multiple years), with erosion values expressed in a range of units (*e.g.* kg m^{-2} y^{-1} or ton ha^{-1} y^{-1}).

For paired data on water yield, while additional requirements varied depending on the rigor of the matching between tree covers (see later in this paragraph), we required catchments to have perennial streamflow and observations spanning at least one full seasonal cycle. For plot-scale studies, we required them to have measured the total amount of water leaving the experimental plots as surface runoff and drainage for at least one full seasonal cycle. We admitted a small number of studies that provided paired data based on longitudinal comparisons between different periods for the same site, provided that those periods had similar rainfall totals (usually <10% difference) to minimize possible confounding effects of differences in climatic conditions. Unlike with the other metrics, multiple primary studies were often needed to derive the water yield RR for a given pair of tree plantation and native forest. In tallying the number of and gauging the rigor of matching for primary studies, we therefore approached studies as 'sets' that contributed data for a given study system.

For sets of primary studies on water yield that were assigned a match rigor score of 3, we allowed rainfall conditions to deviate from the prevailing conditions during the original calibration period; we also allowed sites to have different geology and hence possibly different deep-leakage losses (*69*, *70*) for catchment studies, or drainage to have been estimated using chloride or sodium mass balances for plot-scale studies (*71*, *72*). For sets of primary studies assigned a match rigor score of 2, rainfall for the tree covers being compared must be similar and geological conditions identical and not susceptible to deep leakage. Finally and most strictly, for studies assigned a match rigor score of 1, they must either: (i) have used the paired-catchment design to eliminate confounding effects resulting from possible differences in rainfall and/or geologically-controlled deep-leakage losses between catchments or time periods (*73*), or (ii) catchment leakage losses must be known from a full water budget analysis (*74*), or (iii) at the plot scale, the main water budget components (including vegetation water use) must be measured separately, or modelled drainage validated against measured soil water dynamics (*75*, *76*). Methods employed at paired sites were normally the same, but occasionally we paired a catchment to a plot-scale study and assigned a match rigor score of 2–3 depending on the comprehensiveness of the plot-scale measurements (*75*, *76*). Finally, for the small subset of primary studies that separated streamflow into baseflow and stormflow, we required the studies to have used either the straight-line or recursive filter flow separation methods (*65*, *77*).

For paired data on wood yield or profit, we required primary studies to report empirically measured data on the volume, income, or profit (income minus cost) of wood from equal-aged (age difference ≤5 years) pairs of tree plantations and restored native forests, regardless of whether the measurements were from standing woody vegetation or actual harvest. Given the paucity of data, we did not impose further requirements on the age of tree covers, nor did we require the woody vegetation to be of merchantable species only. Barring the paired-data requirement, we applied the same criteria above to non-paired data on the wood yield of restored native forests, but we additionally required that the age of the forests must have been reported.

<u>Search strategy for suitable primary studies</u>

We used a combination of keyword searches, indexing from published syntheses or databases, snowballing, and expert inquiries to identify as many relevant primary studies in as many languages as possible up until November 12th, 2020 for the environmental metrics and October 1st, 2021 for the wood production metrics (Supplementary Text; Fig. S1; Tables S1–S3). The full lists of primary studies included are provided in Table S4. We considered a wide range of publications including peer-reviewed literature, technical reports, conference or symposium proceedings, books, book chapters, and theses/dissertations.

For species-specific abundance, we conducted two complementary primary searches on Web of Science on October 4th 2020 to identify relevant primary studies (Table S1), the collection of which we further supplemented by (i) screening a series of published 'tier-1' reviews, meta-analyses, or databases, (ii) gleaning from these 'tier-1' syntheses relevant primary studies and 'tier-2' syntheses, (iii) gleaning from these 'tier-2' syntheses additional primary studies. The list of 'tier-1' and 'tier-2' syntheses is provided in Table S2. For aboveground biomass, we conducted two complementary primary searches on Web of Science on October 4th, 2020 to identify relevant primary studies (Table S1), the collection of which we further supplemented by screening a series of published 'tier-1' and 'tier-2' reviews, meta-analyses, or databases (with 'tier-1' and 'tier-2' in similar senses as above; Table S2). For the amount of eroded soil, we similarly conducted two complementary primary searches on Web of Science on May 8th, 2018 and on November 12th, 2020 to identify relevant primary studies (Table S1), and we supplemented this collection by screening a series of published reviews, meta-analyses, or databases (Table S2) located via a separate Web of Science search (Table S1) on November 17th, 2017 and via 'snowballing' (i.e. locating other relevant studies referred to in the studied being checked). We additionally reached out to soil experts with knowledge on regions that had apparent data gaps to inquire about possible additional paired sites for the Americas, Eurasia, and

Africa (Table S3). For both aboveground biomass and eroded soil, we identified further relevant primary studies via snowballing during the above processes of search and screening.

For water yield, we systematically consulted: (i) reviews of the early (mostly pre-1990) literature as well as more recent reviews and meta-analyses on forest and hydrology (both general and on specific regions, countries or tree species; Table S2); (ii) site water budget studies conducted in the context of research networks on soil acidification (*e.g.* (*78*, *79*)) or eutrophication (*e.g.* nitrogen deposition (*80*, *81*)), atmospheric carbon and moisture exchange (*e.g.* FLUXNET and ICOS (*75*, *76*, *82*, *83*)), and general ecosystem research (*e.g.* US-LTERs and CFERN (*84*–*86*)); (iii) catchment studies participating in UNESCO-IHP's FRIEND program (Flow Regimes from International Experimental and Network Data (*87*, *88*)); (iv) solute budget studies conducted in the context of biogeochemical cycling and rock weathering (*89*, *90*); and (v) nearly 70 experts in 22 countries and regions (Table S3) with whom we inquired about possible additional data. The above efforts supplemented and considerably added to a primary search we had conducted earlier on Web of Science on June 1st, 2018 that targeted relevant primary studies on water yield, as well as an earlier screening of a series of published reviews/meta-analyses/databases (Table S2) that we had located via a separate Web of Science search (Table S1) on November 17th, 2017 and via snowballing. Given this highly extensive effort, and the fact that our water yield database includes far more records than those of existing meta-analyses (*e.g.* (*91*)), we are confident that our search has located the vast majority of existing hydrological datasets and publications that compare plantations *versus* native forests.

Finally, for wood yield and wood profit, we conducted a series of primary searches on Web of Science on October 1st 2021 to identify relevant primary studies (Table S1), the collection of which we further supplemented by screening all studies that cited the seminal study published in 1992 by Lugo (*33*) on comparing the wood production function of tree plantations and secondary forests, as of October 1st 2021 on Google Scholar (Table S1). In all, our process of primary data search is depicted in the flowchart in Fig. S1.

Data compilation

For all metrics, we screened abstract hits in any language that they came in, but for water yield in particular, we systematically covered the following languages: English, Bahasa Malaysia, Danish, Dutch, French, German, Japanese, Mandarin, Portuguese, and Spanish. We extracted metric values and meta-data (Supplementary Text) directly from primary studies wherever possible, following the data resolution (*i.e.* whether each set of paired data corresponded to a replicate sampling unit, or the mean or sum of multiple sampling units) reported in the primary studies. Where primary studies did not report study site mean annual temperature (*i.e.* MAT), we extracted it from the WorldClim database (*92*) based on site coordinates. Where necessary, we used DataThief III (*93*) to extract data presented in figures for aboveground biomass, soil erosion control, wood yield, and wood profit; for water yield, we approached authors for original data (these studies are marked with an asterisk in Table S4). We double-checked all extracted data to minimize transcriptional error.

For species-specific abundance data in formats other than density (*e.g.* individuals ha^{-1}), we adjusted their values by sampling effort to ensure that data for tree plantations and native forests corresponded to equal sampling effort. For example, if a plantation was sampled with 1.5 times the amount of effort as the native forest against which it was compared, for each species, the abundance or relative abundance associated with the plantation would be divided by 1.5 before comparison with the abundance or relative abundance associated with the native forest.

We measured sampling effort by the unit used in the primary studies. Our requirement that each primary study used the same sampling method for the plantation and native forest ensured that sampling units were directly comparable between the tree covers. We assumed that density data had already corrected for sampling effort.

For species-specific abundance, aboveground biomass, soil erosion control, wood yield, and wood profit, we scored the sampling effort for each RR to incorporate into analyses (see 'Data analysis' below), considering it an important determinant of data quality. For water yield, we used the rigor of matching to represent data quality. We scored the sampling effort for each RR as follows. For species-specific abundance, we tallied the number of the finest sampling-unit hierarchy that could be considered independent, based on their spacing in comparison with our knowledge of the presumed accepted study design for the study taxa (Supplementary Text). For aboveground biomass, because primary studies rarely reported the spatial distance between sampling units, making it impossible to gauge the number of independent sampling units, we calculated the total area sampled (*i.e.* plot areas summed between the tree-cover pair, in m^2) as a surrogate for sampling effort. For soil erosion studies, we used the duration of the observations (in months) as a surrogate for sampling effort. For wood yield and wood profit, we also used the total area sampled (*i.e.* plot areas summed between the tree-cover pair, in m^2) as a measure of sampling effort.

For species-specific abundance, we additionally assigned a 'habitat certainty score' to each RR to represent the extent to which it reflected the influence of tree covers *per se* as habitat for the species, rather than the influence of the wider landscape, and we incorporated this score into subsequent analyses (see 'Data analysis' below): 1 for 'certain or almost certain reflection of habitat influence', and 2 for 'unclear or uncertain reflection of habitat influence' (Supplementary Text).

Data analysis

We conducted multi-level meta-analyses and meta-regressions of RR (*94*) using the 'lme()' function, which implements a linear mixed-effects model, in package 'nlme' (version 3.1-152; (*95*)) in the R programming language (version 4.0.4; (*96*)). For meta-analyses assessing the performance of tree plantations relative to native forests, we used an intercept-only fixed effect, and we fitted a group of random intercept variables specific to each metric to account for (and model) potential shared variation and data non-independence. For data on aboveground biomass, soil erosion, and water yield, we used the following random intercept variables in descending order of nestedness (*i.e.* later variables were nested within earlier variables and they are referred to as 'of lower tier'):

(i) Level 1: the combination of tree cover types (*i.e.* as shown in Fig. 1A);
(ii) Level 2: the identity of the primary study;
(iii) Level 3: the site identity of the native forest, used to account for possible data correlations resulting from multiple plantation sites being compared against the same native forest site within a given study.

For data on species-specific abundance, we added two more variables to the above list, resulting in five nested random intercept variables (in descending order of hierarchy):

(i) Level 1: species' taxonomic group identity (Supplementary Text; our database on species-specific covered 13 taxonomic groups), used to account for the possible inter-group differences in their RR;
(ii) Level 2: the combination of tree cover types;

(iii) Level 3: the identity of the primary study;
(iv) Level 4: the site identity of the native forest;
(v) Level 5: the identity of the ecological community to which each RR belonged.

This list for species-specific abundance should ideally also account for phylogenetic correlation among species, but the large number of taxa included in our database and the lack of reliable phylogenetic trees for many of them precluded this. For wood production, because of data paucity, we only retained the identity of primary studies as a random intercept variable. Finally, for all metrics, we added one more, lowest-tier random intercept variable to the above lists to enable the estimation of I^2, the measure of the heterogeneity of meta-analytic data or, in other words, variation not due to sampling variance arising from differences in sampling efforts among effect sizes (*97*). We note that I^2 ranges from 0 to 100%; an earlier meta-analysis (*98*) found that in ecological studies, I^2 is often over 90% (see below on how we calculated I^2 and associated statistics from our models).

For species-specific abundance, considering that different taxonomic groups may exhibit considerably different contrasts between plantations and native forests, we additionally conducted separate meta-analyses for individual taxonomic groups with adequate amount of data (*i.e.* ≥10 plantation-native forest pairs). For these analyses, we similarly used an intercept-only fixed effect, and we used the same random effect structure as above, except that we removed taxonomic group identity as a random intercept variable.

For each comparison, the above models provided estimated mean and 95% confidence intervals – calculated based on model-estimated mean and standard error, based on *t* distributions with adjusted degrees of freedom from the lme() models – of RR (expressed as RR' below). Based on the way RR was calculated (Equation 1 above), we back-transformed these estimates using Equation 2 below to estimate, in percentage terms, the shortfalls of plantations relative to the native forests against which they were compared:

$$\%\,shortfall = (1 - e^{RR'}) \times 100 \qquad \text{(Equation 2)}$$

For meta-regressions assessing the factors that may affect the performance of tree plantations relative to native forests, we adopted the same random effect structures as used in meta-analyses except for species-specific abundance (see below in this paragraph), and we conducted model selection based on global models of fixed effects that we constructed separately for each metric (see below). For species-specific abundance, considering that in addition to the focal variables of interest (see below), species with different habitat preferences would have vastly different RRs – an effect that we were unable to account for because of the large range of species concerned that lack reliable habitat preference information – we first derived the community-level RR by calculating the mean of all RRs within an ecological community. Conceptually, this mean is akin to the geometric mean of species abundance, albeit without being exponentiated (*58*). We used this community-level RR to represent the biodiversity contrast between tree plantations and native forests in subsequent meta-regressions. Because of this community-level aggregation, for data on species-specific abundance, we removed the identity of the ecological community to which each RR belonged from the random effect structure.

For the comparison between tree plantations and reference native forests, our global models for each environmental metric are described in Equations 3–7 below. Specifically, our predictor variables included plantation type, plantation age and its quadratic term, mean annual temperature (MAT; in °C) and its interaction with plantation age; we used the quadratic term to accommodate potential nonlinear relationships between RR and plantation age. For species-specific abundance, because AICc-based model selection identified the model containing only plantation type as the best model (Table S6), we in turn assessed, for each plantation type, the factors that may affect its performance relative to reference native forests, using the same global model structure noted above except that we removed the predictor variable of plantation type. For soil erosion control, we additionally included mean annual precipitation (MAP; in mm y^{-1}), as well as its interaction with plantation age and with MAT; the latter interaction was considering the possibility that more humid climates may facilitate forest understory growth and in turn, buffer soil erosion. For water yield, we additionally included native forest seasonality (evergreen or deciduous), as well as MAP and its interaction with plantation age. We used MAP instead of the potentially more relevant aridity index (*99*) because data on the latter were not available from primary studies, while globally available data derived from remote sensing and modelling (*100*) may be too coarse to reflect site-level conditions.

We checked for collinearity among predictor variables before running all global models. Collinearity was not an issue ($|r_{Pearson}| < 0.7$) for species-specific abundance or aboveground biomass, but there was a correlation between plantation age and MAT for soil erosion control, and native forest seasonality was correlated with MAP and MAT for water yield. We therefore constructed two versions of global model for soil erosion control, one retaining plantation age (Equation 4) and the other MAT (Equation 5). Similarly, we constructed two versions of global model for water yield, one retaining MAT and MAP (Equation 6) and the other native forest seasonality (Equation 7).

$$\text{RR} \sim \text{Plantation type} + \text{Plantation age} + \text{Plantation age}^2 + \text{MAT} + \text{Plantation age} \times \text{MAT}$$
(Equation 3, for species-specific abundance and aboveground biomass)

$$\text{RR} \sim \text{Plantation type} + \text{Plantation age} + \text{Plantation age}^2 + \text{MAP} + \text{Plantation age} \times \text{MAP}$$
(Equation 4, for soil erosion control)

$$\text{RR} \sim \text{Plantation type} + \text{MAT} + \text{MAP} + \text{MAT} \times \text{MAP}$$
(Equation 5, for soil erosion control)

$$\text{RR} \sim \text{Plantation type} + \text{Plantation age} + \text{Plantation age}^2 + \text{MAT} + \text{Plantation age} \times \text{MAT} + \text{MAP} + \text{Plantation age} \times \text{MAP}$$
(Equation 6, for water yield)

$$\text{RR} \sim \text{Plantation type} + \text{Plantation age} + \text{Plantation age}^2 + \text{Seasonality of reference native forest}$$
(Equation 7, for water yield)

For the comparison between tree plantations and restored native forests of similar age, our global models for species-specific abundance and aboveground biomass followed Equation 3 above except that they dropped plantation age and its quadratic term, and they were run after confirming the absence of collinearity ($|r_{Pearson}| < 0.7$) among predictor variables. For soil erosion control, due to the small size of the dataset (n=14), we dropped MAP from the global model (given that ($|r_{Pearson}| = 0.65$ between MAT and MAP, much of the variation associated with MAP should have been represented by MAT). In all, the above procedures led to the same global model structure for species-specific abundance, aboveground biomass, and soil erosion control, expressed in Equation 8 below; we did not conduct meta-regressions on water yield because of insufficient data.

RR ~ Plantation type + MAT
(Equation 8, for species-specific abundance, aboveground biomass, and soil erosion control)

We then used model selection based on the small-sample-corrected Akaike Information Criterion (AICc) from these global models to identify the best model for each metric, *i.e.* the fixed effect configuration that produced the lowest AICc scores, using package 'MuMIn' (version 1.43.17; (*101*)) in the R programming language. We in turn re-ran these best models to make inferences about the effects of the variables retained based on model estimates of mean and standard error, according to t distributions with adjusted degrees of freedom from the lme() models.

In all meta-analyses and meta-regressions above, we applied a weighting scheme that reflected the data quality of RR that may result from: (i) data comparability between tree plantations and matched native forests (gauged by the match rigor score; see the first paragraph in the section 'Data inclusion criteria' above); (ii) the sampling effort that went into producing the RRs, for all metrics except for water yield; and (iii) for data on species-specific abundance, the degree to which species' abundance counts reflected the influence of tree covers *per se* as habitat for the species rather than the influence of the wider landscape (gauged by the habitat certainty score; see the last paragraph in the section 'Data compilation' above). We did not follow the conventional weighting scheme based on the sampling variance of RR because this information was available for only a small subset of primary studies, particularly considering the species-specific abundance format of our biodiversity data. Our view was that it would be far more preferable to apply a defensible, albeit alternative, weighting scheme than discarding the majority of available data. We used the following equations to calculate weight for RR for the different metrics:

$$w_i = \frac{\ln(n_i)}{\sqrt{c_i \times h_i}} \quad \text{(Equation 9, for species-specific abundance)}$$
$$w_i = \frac{\ln(n_i)}{c_i} \quad \text{(Equation 10, for aboveground biomass and soil erosion control)}$$
$$w_i = \frac{1}{c_i} \quad \text{(Equation 11, for water yield)}$$

For RR i, w_i represented its weight in the linear mixed-effect models (RRs with higher w_i would be given more weight in the analyses), c_i its match rigor score, and n_i the sampling effort (applicable to all metrics except for water yield; see the second paragraph in the section titled 'Additional note on data entry' below). For data on species-specific abundance, h_i additionally represented the larger habitat certainty score for the two tree covers being compared (*i.e.* the habitat certainty score of the tree cover more susceptible to the influence of landscape context). Because of the way the function 'lme()' in package 'nlme' works, we supplied the above w_i values in the form of 'weights = ~I(1/w_i)' in running the function 'lme()'.

To calculate I^2, we adopted the following procedures. Due to the above unconventional weighting scheme and the lack of sampling variance information for RR, we assumed that the inverse of weight for each RR was proportional to its sampling variance. We could then extend a traditional weighted regression to use the multilevel meta-analytic framework following the equations below:

$$\mathrm{RR}_{[i]} = \beta_0 + \sum_{h=1}^{p} \beta_h x_h + \sum_{l=1}^{q} u_l + e_{[i]} + m_{[i]}, \text{with } u_l \sim \mathrm{N}\left(0, \sigma_{u_l}^2\right), e_{[i]} \sim \mathrm{N}(0, \sigma_e^2),\ m_{[i]} \sim \mathrm{N}\left(0, \frac{\phi}{w_i}\right)$$
(Equation 12)

$$v_i = \frac{\phi}{w_i}$$
(Equation 13)

For RR i, β_0 represented the overall mean (*i.e.* when other moderators did not exist), $\sum_{h=1}^{p} \beta_h x_h$ the sum of fixed effects for all p fixed effect variables, $\sum_{l=1}^{q} u_l$ the sum of random effects for all q random intercept variables (assuming these random intercept variables were normally distributed with the variance components of $\sigma_{u_l}^2$), $e_{[i]}$ the effect-size-level effect (equivalent to residuals) with the variance of σ_e^2, and finally, $m_{[i]}$ the sampling variance effect with the effect-size-specific variance of $v_i = \frac{\phi}{w_i}$. We estimated v_i from the lme() models and, in turn, calculated I^2 (*94*) using the following equations:

$$I_{total}^2 = \frac{\sum_{l=1}^{q} \sigma_{u_l}^2 + \sigma_e^2}{\sum_{l=1}^{q} \sigma_{u_l}^2 + \sigma_e^2 + \sigma_m^2}$$
(Equation 14)

$$\sigma_m^2 = \frac{(k-1)\sum_{i=1}^{k} \frac{1}{v_i}}{\left(\sum_{j=1}^{k} \frac{1}{v_i}\right)^2 - \sum_{i=1}^{k} \frac{1}{v_i}^2}$$
(Equation 15)

where σ_m^2 represented the typical sampling variance. We note that I_{total}^2 represented the heterogeneity I^2 for meta-analyses, but that one can obtain I^2 for each level of random effect including the residual (*i.e.* effect size) level. Similarly, we calculated marginal R^2 using the following equations:

$$R_{marginal}^2 = \frac{\sigma_f^2}{\sigma_f^2 + \sum_{l=1}^{q} \sigma_{u_l}^2 + \sigma_e^2}$$
(Equation 16)

$$\sigma_f^2 = \mathrm{Variance}\left(\sum_{h=1}^{p} \beta_h x_h\right)$$
(Equation 17)

where σ_f^2 represented the variance of fixed effects and $R_{marginal}^2$ the marginal R^2, which quantifies how much total variance is explained by fixed effects apart from sampling variance, which is assumed to be known in a meta-analytic model (*102*, *103*).

For all linear mixed-effect models (i.e. multi-level meta-analysis and meta-regression models), we visually assessed residual and QQ plots, which indicated general satisfaction of the assumption of residual normality (Figs. S8–S11). Concerns about any potential violation of this assumption should be alleviated by the fact that mixed-effect models are known to be generally robust to violations of model assumptions (*104*). We also confirmed findings to be generally free from publication bias (Supplementary Text). For geographical matching of a subset of RRs, we overlaid the geographical locations of all RRs with the Holdridge Life Zones map (*22*, *23*), using packages ‘rgdal’ (version 1.5-12; (*105*)) and ‘spatialEco’ (version 1.3-5; (*106*)) in the R programming language. Finally, we conducted Welch two-sample t-tests to compare the non-paired wood yield data on restored native forests with the crude yield estimates (low and high bounds) for the world’s main monoculture plantations.

<u>Sensitivity analyses</u>

For all metrics, we conducted two sets of sensitivity analyses for our meta-analyses and meta-regressions, one concerning the weighting schemes, and the other the random effect structures. The former was in light of the potential subjectivity and varying standards of reporting from primary studies (especially for the habitat certainty score and sampling effort) involved in the calculation of the weighting scores. We first repeated all analyses using a consistent weight score calculated based on Equation 11 for all metrics (*i.e.* the inverse of the match rigor score, assuming it alone represented the quality of a given RR), and we additionally repeated all analyses without a weight score. For the random effect structure of meta-analyses and meta-regressions, considering that the sharing of a same reference native forest site among multiple RRs did not apply to many primary studies, we additionally repeated all analyses without using the site identity of the native forest as a random intercept variable.

Supplementary Text

<u>Assumptions about plantations' effectiveness in delivering key ecosystem services</u>

Widespread forest restoration via tree plantations to meet climate, soil, water, and wood production goals (*7*, *10–12*) rests on the implicit assumption that tree plantations are as effective as native forests in delivering these goals. Despite numerous global-scale databases and meta-analyses addressing the carbon storage, soil erosion control, and water provisioning functions of forests (including tree plantations; Table S2), direct comparison of tree plantations *versus* native forests founded on paired empirical data that are needed to rigorously test the above assumption (*13*) is lacking, with the vast majority of existing databases and meta-analyses not involving paired plantation and native forest sites (Table S2). The handful of analyses that do involve paired data tend to have regional or generally poor data coverage (*e.g.* because the study was not designed to target the comparison of paired plantations and native forests, or because the study was older and thus did not cover the larger amount of more recent data; Table S2). The lack of a global-scale evidence synthesis is particularly acute for soil erosion and water provisioning (Table S2). In sum, the assumption that tree plantations are as effective as native forests in delivering the ecosystem services of carbon storage, soil erosion control, and water provisioning is yet to be rigorously tested through a global-scale synthesis of paired empirical data. Similarly, despite the widely held belief that tree plantations outperform native forests in sustainably producing wood (*31*, *32*), rigorous comparisons of their production function relative to restored native forests based on paired data – crucial for understanding the relative merits of the two alternative restoration approaches – have been lacking.

<u>Note on reducing and testing publication bias</u>

Our data compilation covered a wide range of publication types, including peer-reviewed literature, technical reports, conference/symposium proceedings, books, book chapters, and theses/dissertations (Table S4). This wide coverage of publication type should aid in reducing potential publication bias of our database (*97*). Funnel plots produced using package 'metafor' (version 2.4-0; (*107*)) in the R programming language additionally indicated that publication bias (the small-study effect where studies with small sample sizes can have effect sizes with large magnitudes) was most likely not a problem for our database (Fig. S2): any asymmetry in the funnel plots for individual analyses on species-specific abundance, aboveground biomass, and soil erosion control did not appear to be linked to smaller studies (*i.e.* those with lower sampling efforts). For water yield studies, we considered lower sampling effort – if present – unlikely to render lower publication rates and therefore publication bias, given the large amount of effort involved in typical water yield studies. This method of using sampling efforts is consistent with the current recommendation for examining the publication bias (the small-study effect) in multilevel meta-analytic models (*108*).

Additional note on data entry

For species-specific abundance, metric values entered comprised either estimated density, or the abundance of individual species within the ecological community studied, measured by (i) tallying up raw counts across multiple sampling units for the tree cover in question and (ii) adjusting for sampling effort (see below). Whenever both estimated density and raw counts were available, we used the former, assuming that they had accounted for factors that may affect the comparability of raw counts (*e.g.* capture/detection probability). For primary studies that reported abundance information for the same ecological community that was obtained using multiple sampling methods, we used only data from the method that we considered most capable of describing the community (*e.g.* between data on bird communities collected by point counts *versus* by mist-netting, we used those from the former). Importantly, we retained species that were not detected in either of the tree covers being compared but that were part of the ecological community studied, given that shared absence also informs the contrast between tree covers. This situation arose if the primary study involved additional land cover types than the plantation and native forest we considered here. We excluded non-native species whenever possible, noting however that the vast majority of primary studies did not differentiate between native *versus* non-native species. Similarly, we were unable to distinguish between forest- *versus* non-forest-dwelling species or exclude the latter because the vast majority of primary species did not provide such information. For subsequent analyses, we streamlined the identity of study taxa into the following main groups to facilitate the use of taxonomic group identity as a random intercept variable: macrofungi, epiphyte plants, climber plants, herbs, standing woody plants, understory plants (where it was not possible to classify the study plant species into the previous groups), arthropods, other invertebrates, amphibians, reptiles, birds, bats, and terrestrial mammals (totaling 13 taxonomic groups). For water yield, catchment data were averaged over a period of 5–7 years where possible, often using original basic rainfall and streamflow data obtained from the primary study authors themselves or from institutional websites.

To score sampling effort for species-specific abundance, we delineated and tallied the number of the finest sampling-unit hierarchy that we considered eligible to be considered as independent, based on the spatial distance between sampling units and what we considered as acceptable minimum spacing for the study taxa. Where spatial distance among sampling units was unclear, we defaulted to the coarsest sampling unit hierarchy as independent sampling units. For example, for a primary study on ground beetles, if traps laid within sampling plots were too close to be considered as independent (*e.g.* 5 m) while the sampling plots were spaced far enough (*e.g.* 500 m), we would consider the plots, rather than traps, as independent sampling units. We used a 500 m distance as the minimum spacing among independent sampling units for large-bodied organisms (mammals other than 'small mammals' – *i.e.* mice, rats, shrews) and flying organisms sampled using active attraction (*e.g.* moths sampled using light traps), 200 m for small mammals, birds, herpetofauna, and flying insects sampled passively, and 100 m for small-bodied or immobile organisms (*e.g.* ants, plants).

To assign 'habitat certainty score' to RR on species-specific abundance, we used the following criteria: 1 for certain or almost certain absence of landscape effects (*i.e.* tree cover expanses were known to be ≥50 ha or otherwise extensive, regardless of study taxa), and 2 for unclear (*i.e.* the area of tree cover expanses was unknown) or uncertain (*i.e.* tree cover expanses were known to be <50 ha, regardless of study taxa) absence of landscape effects. In calculating RR for species-specific abundance, for data pairs involving zero abundance values (which would make it impossible to calculate RR), we handled these zero values separately for each community dataset (*i.e.* for each pair of tree cover). For each community dataset that had zero values, we first identified the smallest non-zero abundance value for any species in the community, and we added half of this value to each zero value following O'Brien and colleagues (*109*). The need to handle zero values applied to species-specific abundance data only.

In addition to metric values, we extracted the following meta-data from all primary studies whenever they were reported: (i) on study sites: their geographical coordinates, MAT, MAP; (ii) on both tree plantations and native forests: their type, age, and patch size; (iii) on tree plantations only: vertical vegetation structure (presence/absence of the shrub and herbaceous layers), presence/absence of groundcover, land-use history (length of deforested period and intensity of degradation), and landscape context (whether the study site was ≤2 km from extensive native forests); (4) on sampling method: sampling unit area, number of sampling units, length of study period, unit of metric, standard deviation/error of the metric values. For age information expressed in a range, we took the middle value of the range. We extracted metric values and meta-data directly from primary studies wherever possible, and we only used secondary sources for data extraction for a small number of studies that did not provide data.

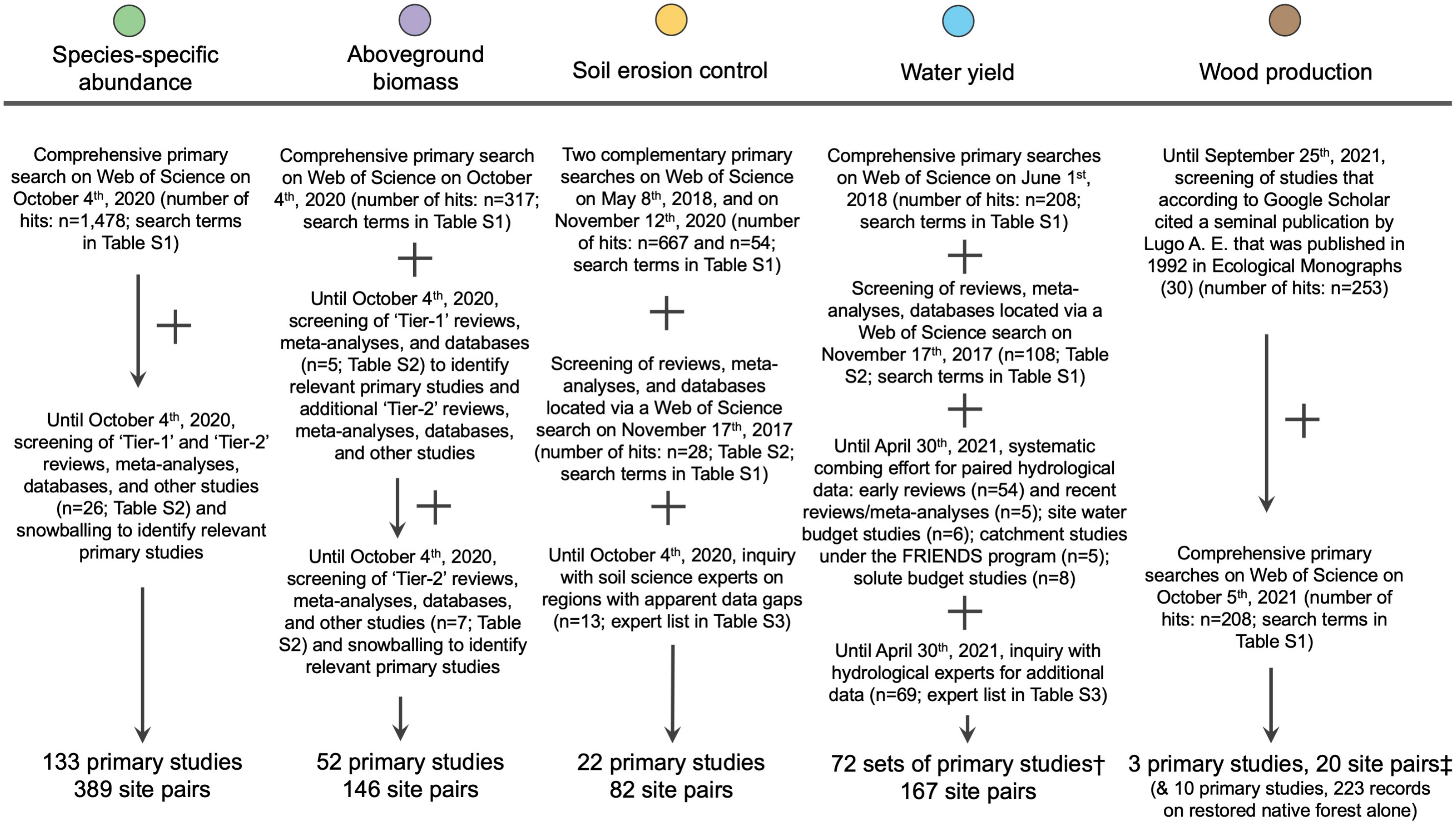

Fig. S1. Process of primary data compilation. †: For water yield, multiple primary studies were often needed to derive the RR for a given pair of plantation and native forest. In tallying the number of primary studies for water yield, we therefore counted the number of such 'sets' of, instead of individual, primary studies. ‡ For wood production, our search targeted paired data on wood yield or profit, as well as non-paired data on the wood yield of restored native forests with known age.

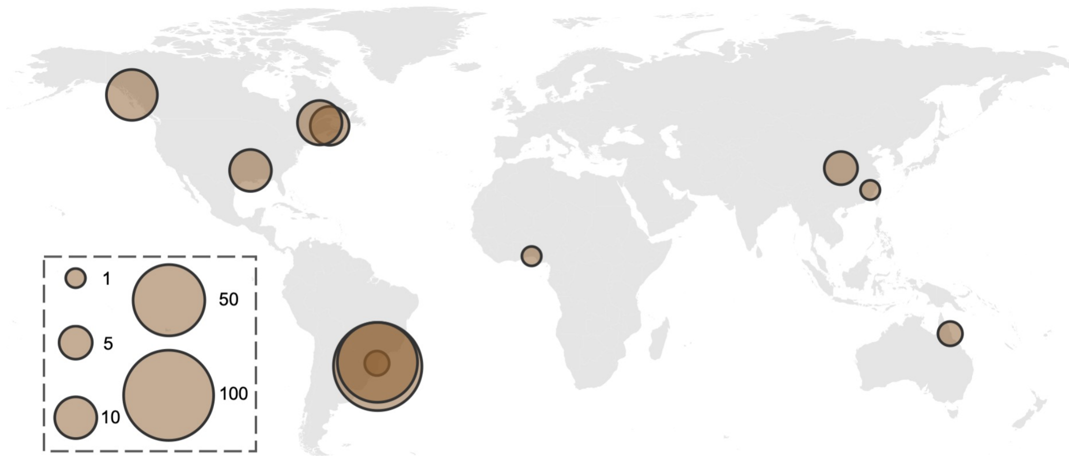

Fig. S2. Geographic distribution of wood yield records compiled for restored native forests. Bubble size in maps is proportional to the cube root of the amount of data for a given geographic location.

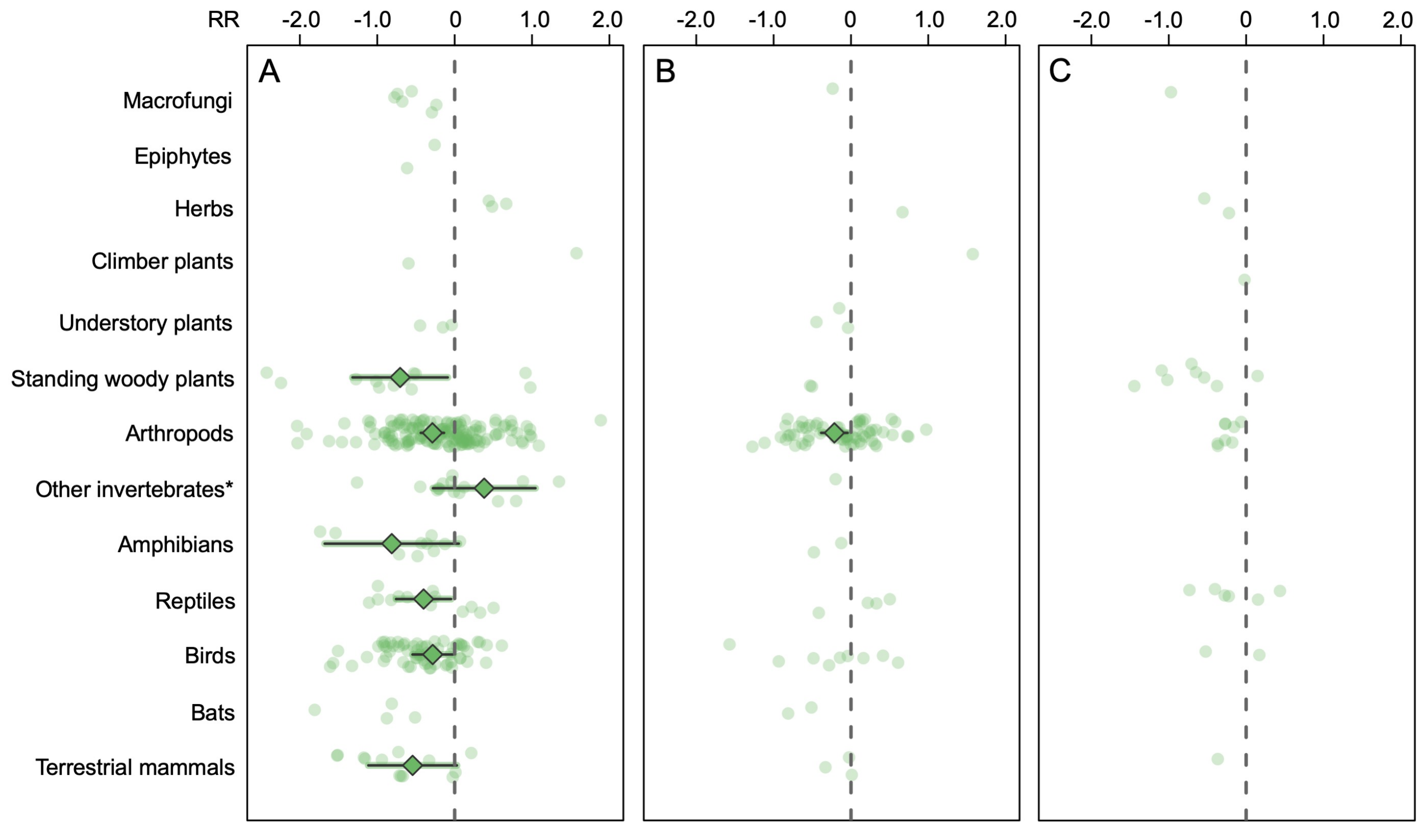

Fig. S3. Relative performance of species-specific abundance for different taxonomic groups. Results are displayed separately for the comparison between (**A**) plantations *versus* reference native forests, (**B**) old or abandoned plantations *versus* reference native forests, and (**C**) plantations *versus* restored native forests of similar age. Scattered dots represent the average RR within the ecological community concerned in each plantation-native forest pair, from primary studies across all types of plantations, and diamonds and associated error bars represent the mean and 95% confidence intervals (CI) of RR values obtained from meta-analyses for taxonomic groups for which the number of plantation-native forest pairs was ≥10. *: Data on 'other invertebrates' were from three primary studies that concerned two taxa: land snails and earthworms.

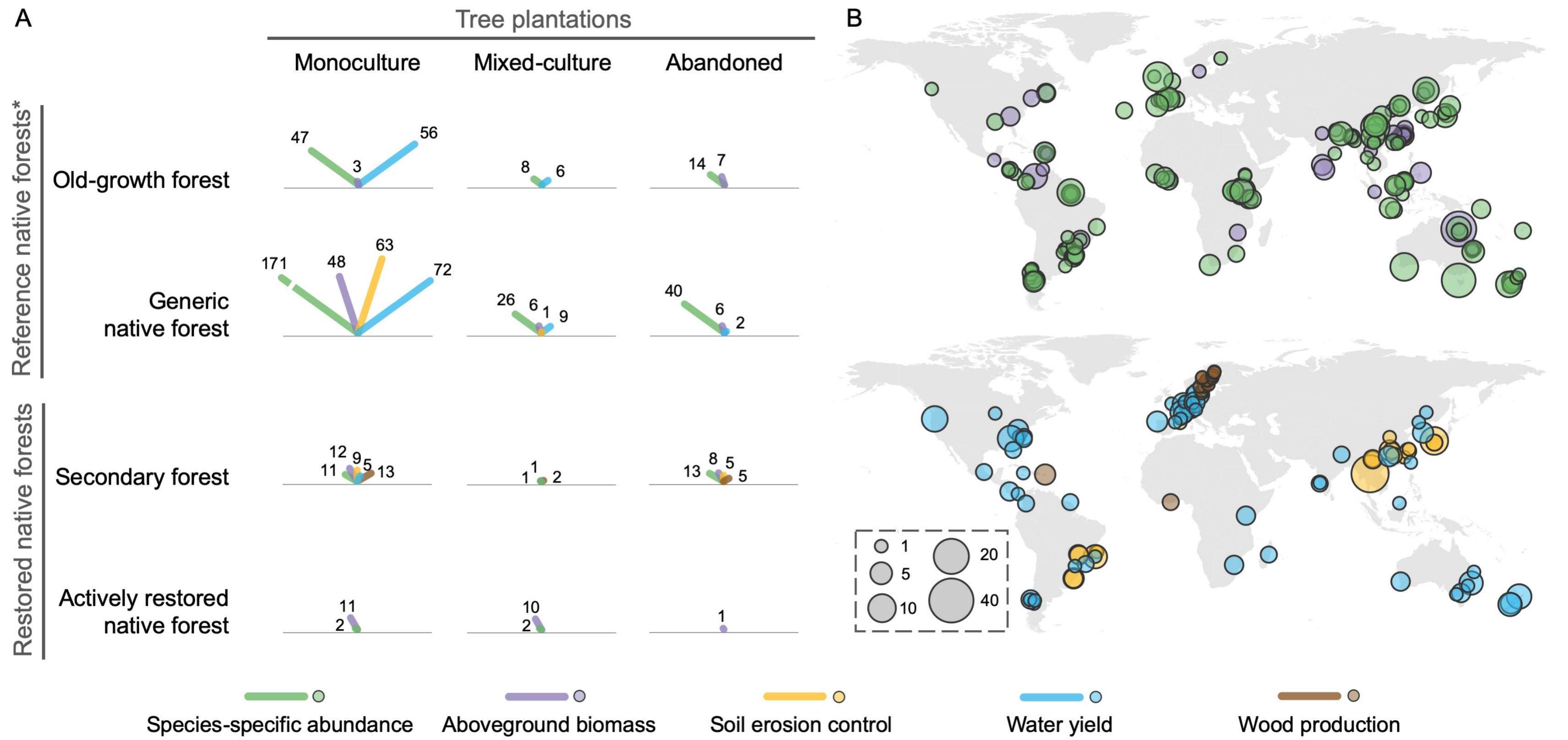

Fig. S4. Overview of the part of database that went into our analyses. Figure contents are equivalent to those in Fig. 1, except that for the comparison between tree plantations and restored native forests, only data for the tree cover pairs of similar age (*i.e.* with ≤10 years of age difference) are displayed. (**A**) The amount of paired data compiled into our database for different combinations of plantations and native forests. For species-specific abundance, the amount of data is represented by the number of plantation-native forest pairs that supplied species-level RRs for entire ecological communities; for all other metrics, it is represented by the number of RRs. (**B**) Geographical distribution of RRs of different metrics, displayed in two maps for better visualization: species-specific abundance and aboveground biomass in the upper panel, and soil erosion control, water yield, and wood production in the lower panel. Bubble size in maps is proportional to the cube root of the amount of data for a given geographical location.

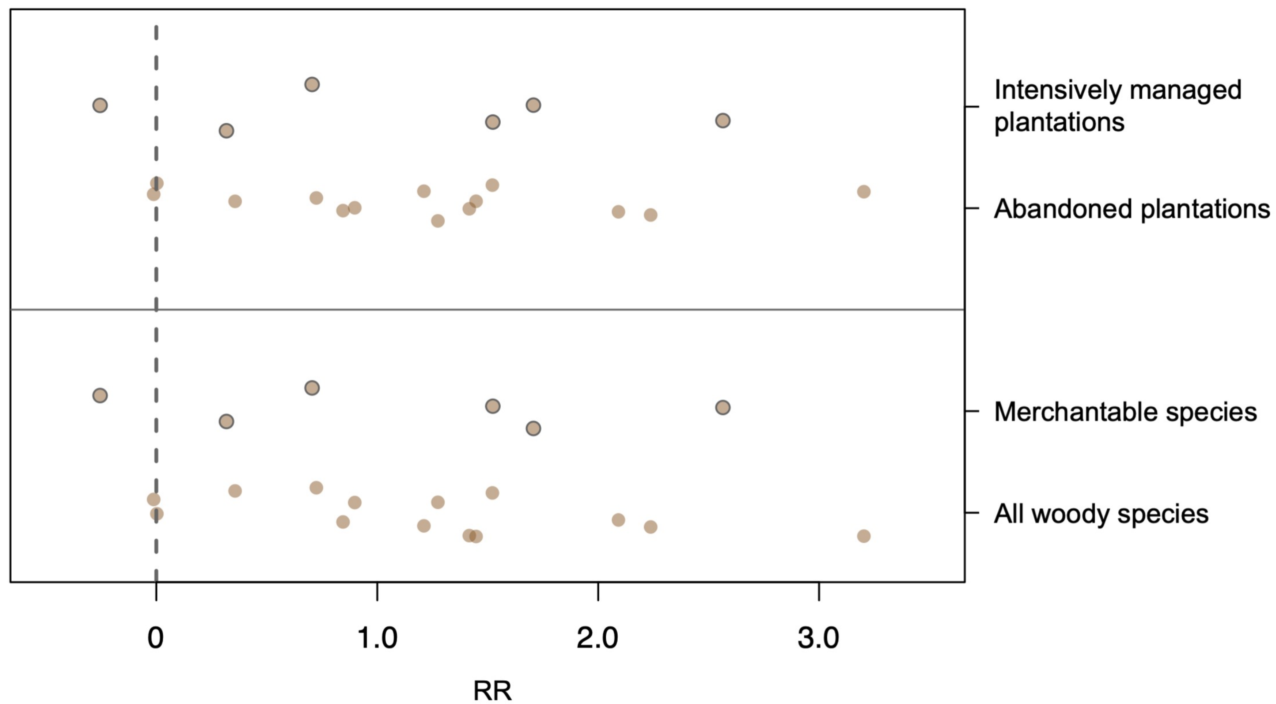

Fig. S5. Paired data on wood production plotted separately based on the type of plantations or species measured.

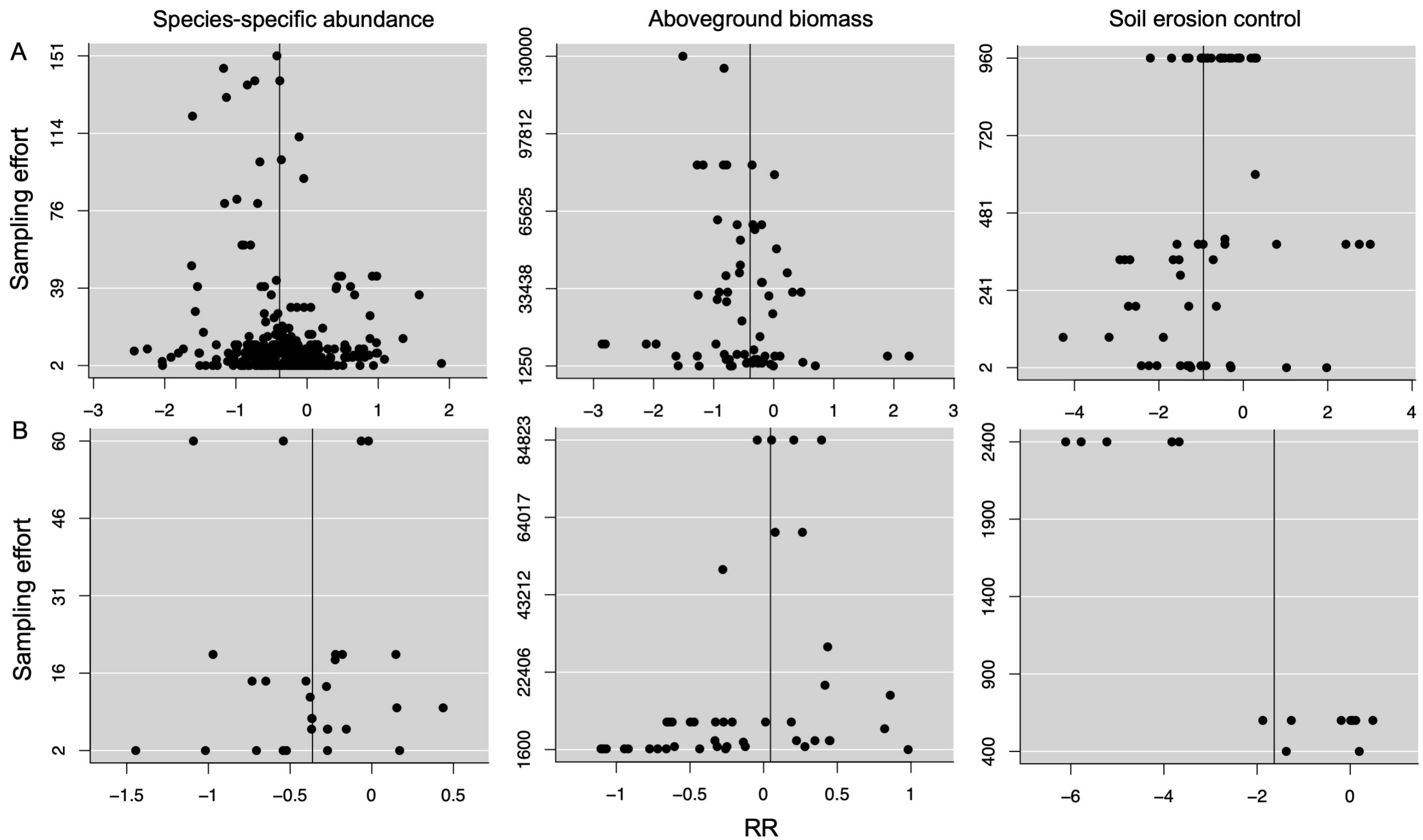

Fig. S6. Funnel plots for data going into meta-analyses based on effect size (RR) and study size (sampling effort). (**A**) Data on the comparison between plantations and reference native forests. (**B**) Data on the comparison between plantations and restored native forests of similar age (*i.e.* with ≤10 years of age difference). For each RR data point, sample effort is measured based on the total number of independent sampling units between the two tree covers for species-specific abundance, the total area of sampling plots between the two tree covers for aboveground biomass, and the number of months over which the study was carried out for soil erosion control. The solid vertical line represents the mean effect size as produced by the corresponding meta-analysis.

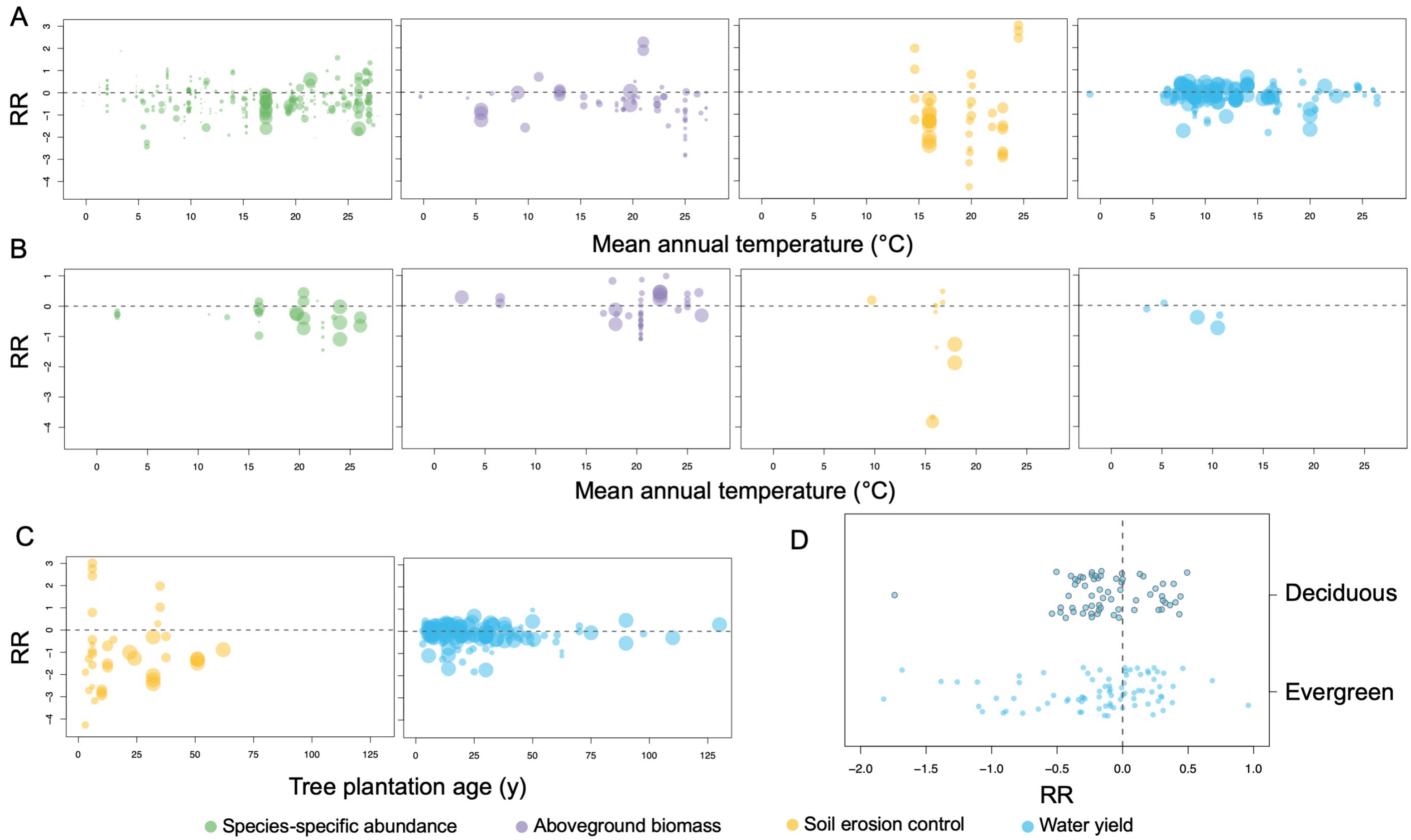

Fig. S7. Scatterplot displaying the lack of relationship between RR and predictor variables. (**A**) RR for the comparison between tree plantations and reference native forests, plotted against mean annual temperature. (**B**) RR for the comparison between tree plantations and restored native forests, plotted against mean annual temperature. (**C**) RR for the comparison between tree plantations and reference native forests, plotted against plantation age. (**D**) RR for the comparison between tree plantations and reference native forests in water yield, plotted separately for data pairs whose reference native forests were deciduous or evergreen.

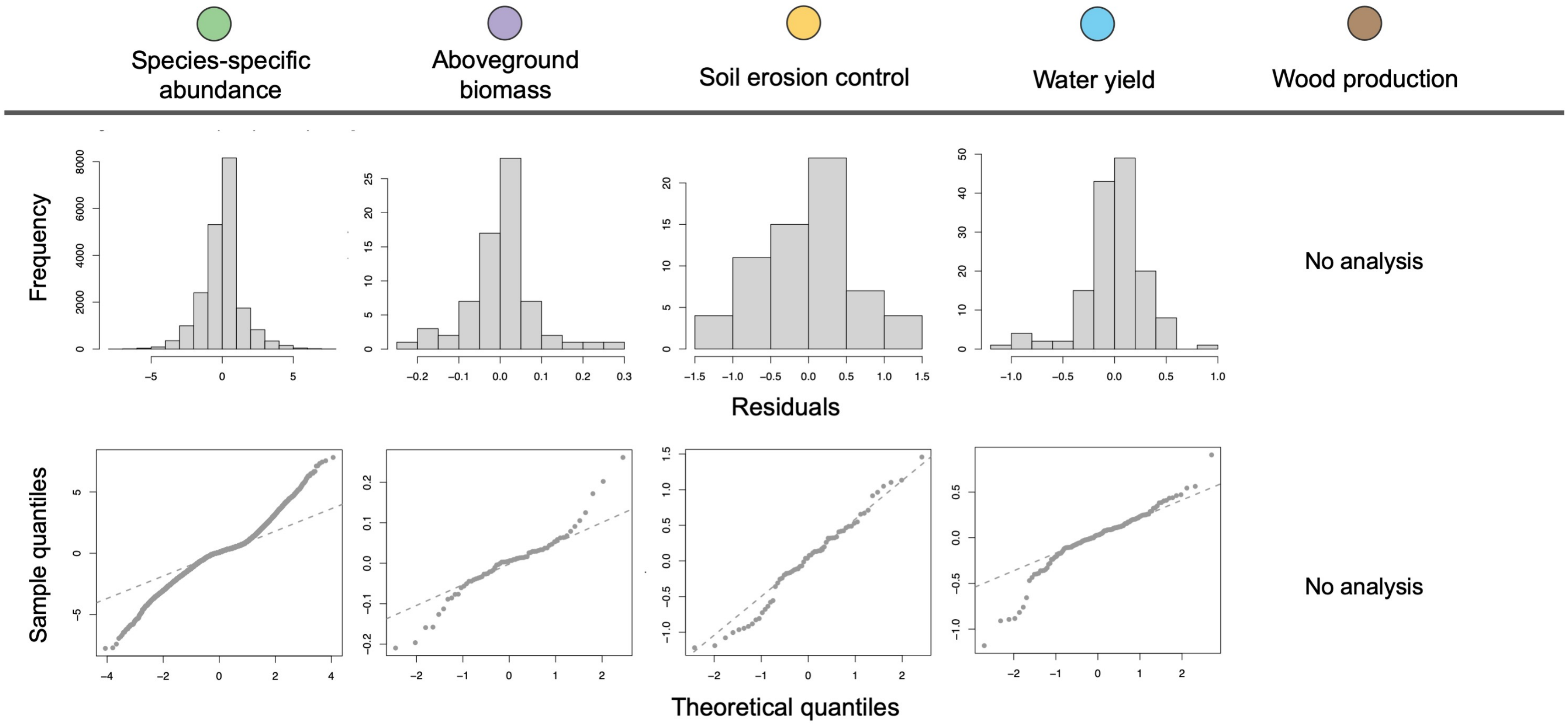

Fig. S8. Model diagnostic plots for the comparison between tree plantations and reference native forests. For each metric, residual plots (upper) and QQ plots (lower) are displayed for each of the linear mixed-effect models used to produce the results displayed in Fig. 2B, upper panel.

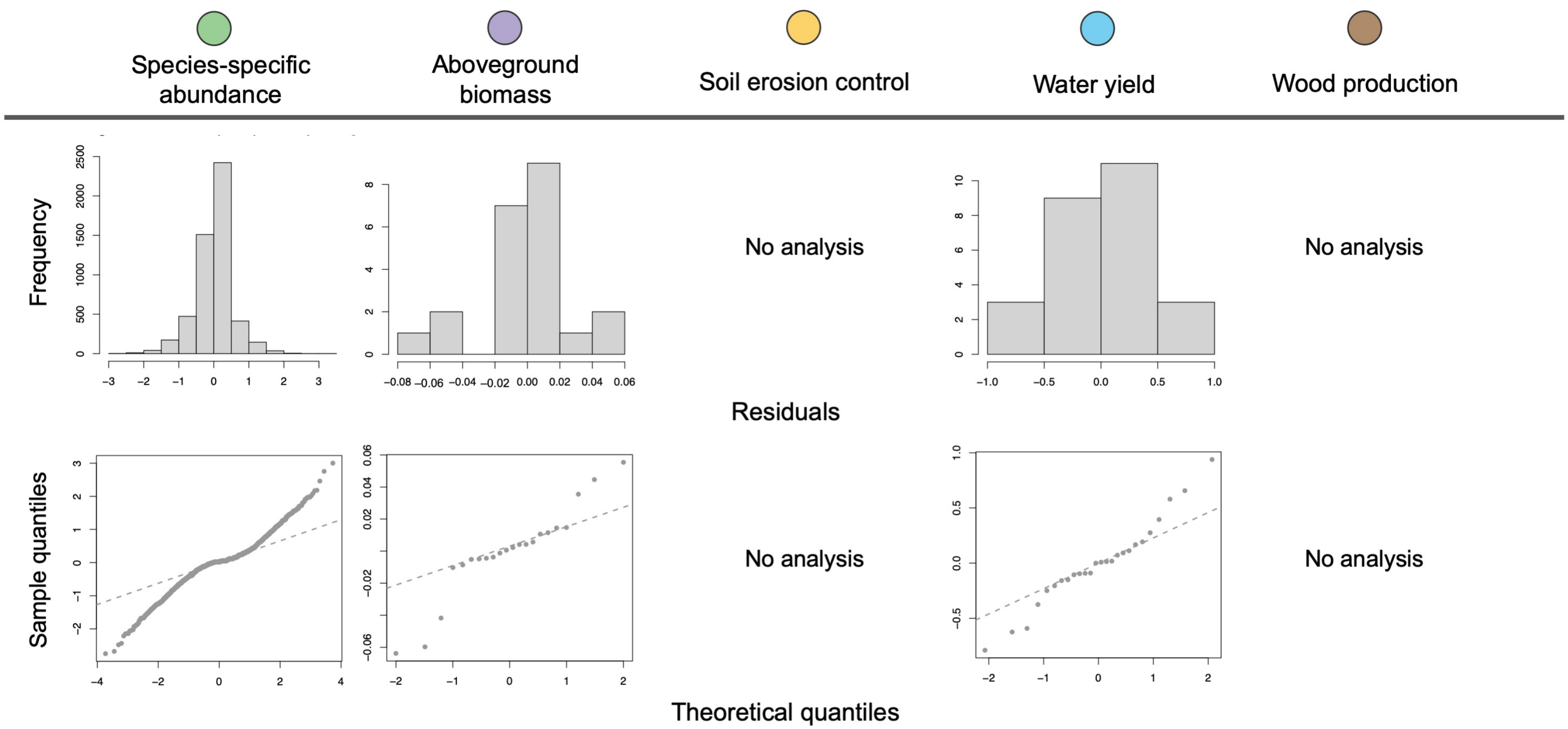

Fig. S9. Model diagnostic plots for the comparison between old or abandoned tree plantations and reference native forests. For each metric, residual plots (upper) and QQ plots (lower) are displayed for each of the linear mixed-effect models used to produce the results displayed in Fig. 2B, lower panel.

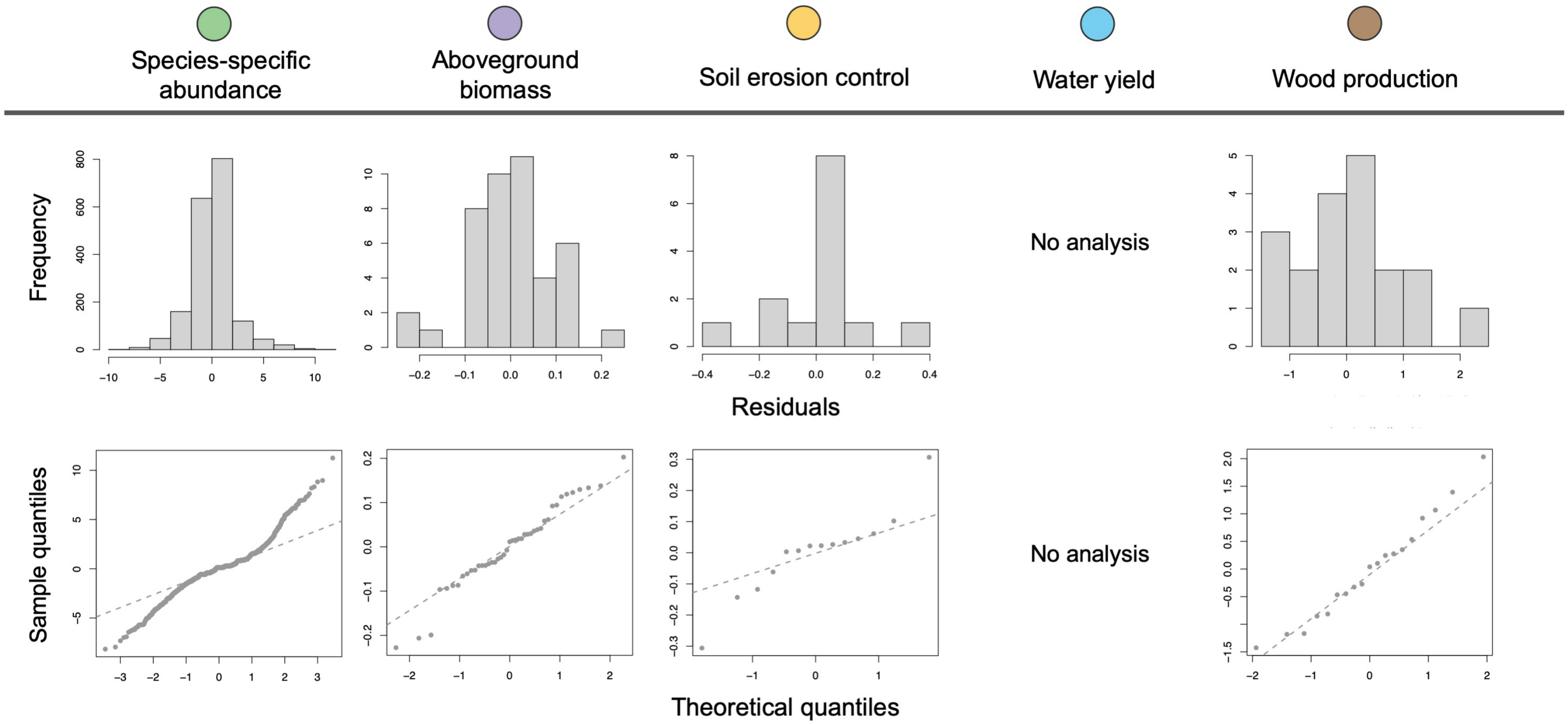

Fig. S10. Model diagnostic plots for the comparison tree plantations and restored native forests of similar age (*i.e.* with ≤10 years of age difference). For each metric, residual plots (upper) and QQ plots (lower) are displayed for each of the linear mixed-effect models used to produce the results displayed in Fig. 2C.

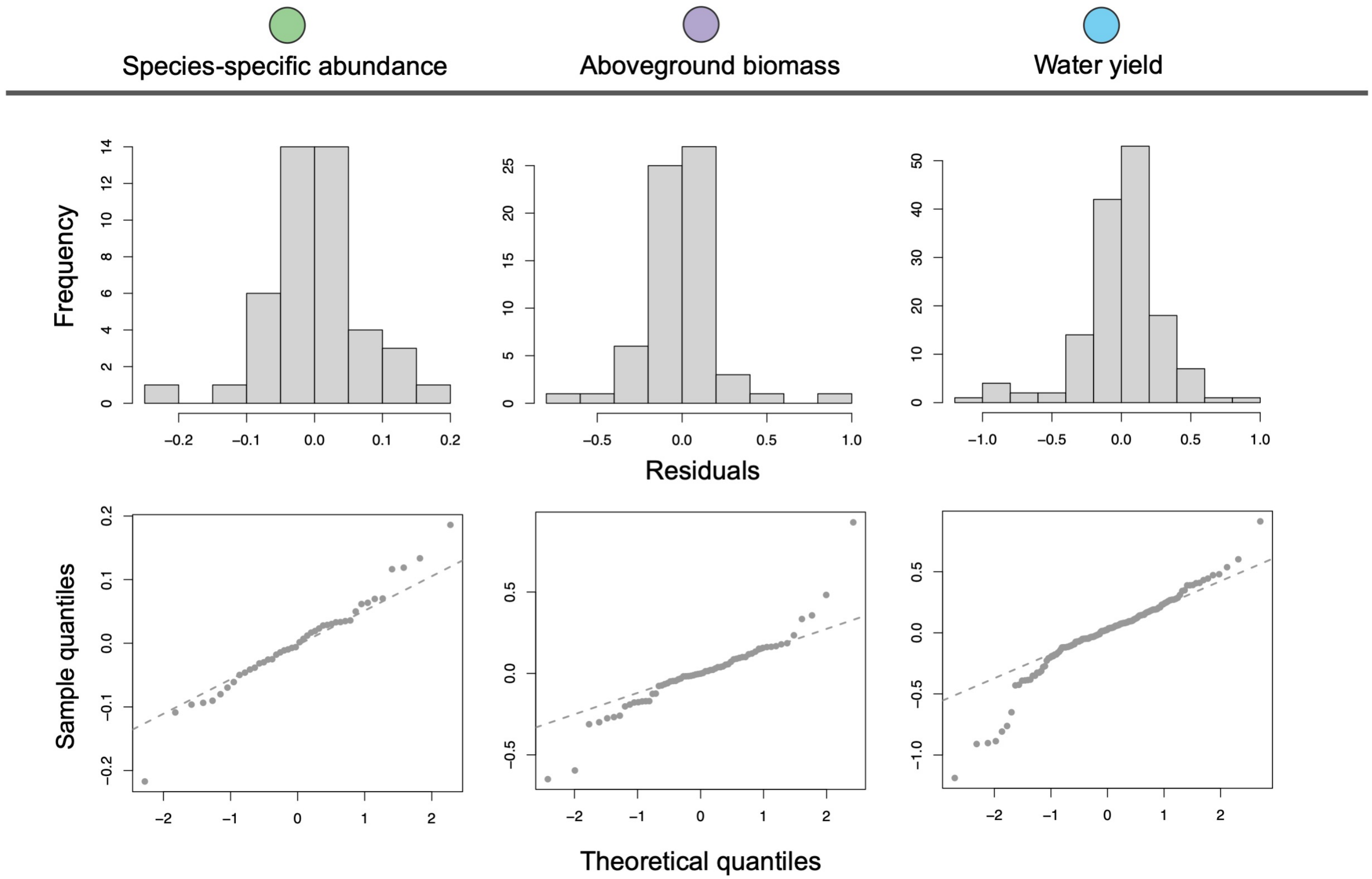

Fig. S11. Model diagnostic plots for analyzing the relationship between RR and predictor variables. For each metric, residual plots (upper) and QQ plots (lower) are displayed for each of the linear mixed-effect models used to produce the results displayed in Fig. 4.

Table S1. List of search terms used in Web of Science searches.

Target of search	Search terms	Search date	Number of studies retrieved
Primary studies that reported on species-specific abundance and that involved old-growth forests as the reference native forest (published since October 1st, 2010) OR Primary studies that reported on species-specific abundance and that involved any kind of native forest that was not old-growth forest	("old-growth forest*" OR "old growth forest*" OR "primary forest*" OR "undisturbed forest*" OR "virgin forest*") AND plantation* AND (abundanc* OR densit*) AND (anima* OR bird* OR mammal* OR reptil* OR amphibia* OR insect* OR arthropod* OR butterfl* OR bee OR bees OR spider* OR earthworm* OR plant* OR tree* OR epiphyt*) AND (biodiversity OR communit*) OR ("secondary forest*" OR "secondary growth*" OR "naturally regenerat*" OR "natural regeneration" OR "natural regrowth" OR "natural forest*" OR "native forest*" OR "logged forest*" OR "environmental planting* OR "native planting*) AND plantation* AND (abundanc* OR densit*) AND (animal* OR bird* OR mammal* OR reptil* OR amphibia* OR insect* OR arthropod* OR butterfl* OR bee OR bees OR spider* OR earthworm* OR plant* OR tree* OR epiphyt*) AND (biodiversity OR communit*)	October 4th, 2020	1,478
Primary studies reporting on aboveground biomass that involved old-growth forests as the reference native forest	("old-growth forest*" OR "old growth forest*" OR "primary forest*" OR "undisturbed forest*" OR "virgin forest*") AND (plantation* OR planting* OR "secondary forest*" OR "secondary growth*" OR "naturally regenerat*" OR "natural regeneration" OR "natural regrowth") AND ("aboveground biomass" OR "above-ground biomass" OR "aboveground carbon" OR "above-ground carbon")	October 4th, 2020	130
Primary studies reporting on aboveground biomass that involved plantations	(plantation* AND ("secondary forest*" OR "secondary growth*" OR "naturally regenerat*" OR "natural regeneration" OR "natural regrowth" OR "natural forest*" OR "native forest*" OR "logged forest*" OR planting*)) AND ("aboveground biomass" OR "above-ground biomass" OR "aboveground carbon" OR "above-ground carbon")	October 4th, 2020	317
Primary studies reporting on the amount of eroded soil that involved plantations	(soil AND (loss OR erosion OR sedimen*)) AND (plantation* AND forest) AND (in title) (Soil OR erosion OR sedimen* OR hydrolog* OR water)	May 8th, 2018	667
Primary studies reporting on the amount of eroded soil	(soil AND (loss OR erosion OR sedimen*)) AND	November 12th, 2020	54

that involved plantations (between 2018-2020)	(plantation* AND ("old-growth forest*" OR "old growth forest*" OR "primary forest*" OR "undisturbed forest*" OR "virgin forest*" OR "secondary forest*" OR "secondary growth*" OR "naturally regenerat*" OR "natural regeneration" OR "natural regrowth" OR "natural forest*" OR "native forest*" OR "logged forest*" OR "native planting*" OR "environmental planting*"))		
"Tier-1" syntheses and databases on the amount of eroded soil	(((forest* OR forests) AND (primary OR old-growth OR "old growth" OR oldgrowth OR secondary OR logg* OR degrad* OR disturb* OR manage* OR regenerat* OR restor*)) OR refores* OR plantation* OR monocultur* OR polycultur* OR agrofores*) AND (review* OR meta-analys* OR metaanalys* OR "meta analys*") AND (((soil OR soils) AND (erosion OR fertility OR quality OR nutrien* OR degrad* OR retention OR loss OR losses OR carbon)) OR sedimen*) AND (in title) (soil OR soils OR erosion OR sedimen*)	November 17th, 2017	507
Primary studies reporting on water yield	(plantatio* AND forest AND tree) AND (streamflow OR baseflow OR stormflow OR "peak flow" OR quickflow)	June 1st, 2018	208
Syntheses and databases on water yield	(((forest* OR forests) AND (primary OR old-growth OR "old growth" OR oldgrowth OR secondary OR logg* OR degrad* OR disturb* OR manage* OR regenerat* OR restor*)) OR refores* OR plantation* OR monocultur* OR polycultur* OR agrofores*) AND (review* OR meta-analys* OR metaanalys* OR "meta analys*") AND ((water OR hydrolog*) AND (quality OR qualities OR yield OR yields OR streamflow OR streamflows OR stream-flow OR stream-flows OR "stream flow" OR "stream flows" OR baseflow OR baseflows OR base-flow OR base-flows OR "base flow" OR "base flows" OR lowflow OR lowflows OR low-flow OR low-flows OR "low flow" OR "low flows")) AND (in title) (water OR hydrolog* OR streamflow OR streamflows OR stream-flow OR stream-flows OR "stream flow" OR "stream flows" OR baseflow OR baseflows OR base-flow OR base-flows OR "base flow" OR "base flows" OR lowflow OR lowflows OR low-flow OR low-flows OR "low flow" OR "low flows")	November 17th, 2017	108

Preliminary search on wood yield	(plantation AND forest AND (native OR natural OR primary OR old-growth OR secondary OR log* OR managed)) AND (yield AND (timber OR wood OR roundlog OR sawlog))	March 8th, 2018	250
Primary studies reporting paired data on wood yield	plantation* AND ("secondary forest*" OR "natural regeneration" OR "naturally regenerat*" OR "regenerat* naturally" OR "natural regrowth" OR "secondary growth" OR '"native planting*" OR "environmental planting*" OR "biodiversity planting*"') AND (timber OR wood OR roundlog* OR sawlog* OR fuelwood OR firewood OR pulpwood) AND (yield OR producti* OR volume)	October 5th, 2021	423
Primary studies reporting paired data on wood profit	plantation* AND ("secondary forest*" OR "natural regeneration" OR "naturally regenerat*" OR "regenerat* naturally" OR "natural regrowth" OR "secondary growth" OR '"native planting*" OR "environmental planting*" OR "biodiversity planting*"') AND (timber OR wood OR roundlog* OR sawlog* OR fuelwood OR firewood OR pulpwood) AND (profit* OR NPV OR "net present value*" OR "land rent" OR "land expectation value*" OR EAV OR "equivalent annual value*" OR annuity OR "internal rate of return*")	October 5th, 2021	28
Studies that cited Lugo 1992 (*33*)	--	September 25th, 2021	253
Primary studies reporting non-paired data for restored native forests on wood yield	(timber OR wood OR roundlog* OR sawlog* OR fuelwood OR firewood) AND (yield OR producti* OR volume) AND (in title) ("secondary forest*" OR "natural regeneration" OR "naturally regenerat*" OR "regenerat* naturally" OR "natural regrowth" OR "secondary growth" OR '"native planting*" OR "environmental planting*" OR "biodiversity planting*"')	October 1st, 2021	200

Table S2. List of databases, reviews, meta-analyses, and other studies consulted for data compilation.

Metric	Tier	No.	Study	Type†	Geographical scope	Nature of database/meta-analysis††
Species-specific abundance	1	1	Barlow et al. 2007 (*110*)	Other	Not applicable	--
		2	Brockerhoff et al. 2008 (*14*)	Review	Global	--
		3	Crouzeilles et al. 2016‡ (*111*)	Meta-analysis	Global	Plantation and native forest not paired
		4	Gardner et al. 2009 (*112*)	Review	Pan-tropics	--
		5	Hartley 2002 (*113*)	Review	Global	--
		6	Hudson et al. 2014* (*114*)	Database	Global	Plantation and native forest not paired
		7	Lindenmayer and Hobbs 2004 (*115*)	Review	Australia	--
		8	Mang and Brodie 2015 (*116*)	Meta-analysis	South-east Asia	Regional
		9	Meli et al. 2017 (*117*)	Meta-analysis	Global	Plantation and native forest not paired
		10	Moreno-Mateos et al. 2017 (*118*)	Meta-analysis	Global	Plantation and native forest not paired
		11	Ramírez and Simonetti 2011 (*119*)	Meta-analysis	Global	Taxa limited to mammals
	2	12	Bradshaw et al. 2013 (*120*)	Review	Australia	--
		13	Christian et al. 1998 (*121*)	Review	North America	--
		14	Holbech 2009 (*122*)	Other	Not applicable	--
		15	Kanowski et al. 2005 (*123*)	Review	Australia	--
		16	Lamb 1998 (*124*)	Review	Pan-tropics	--
		17	Lawton et al. 1998 (*125*)	Other	Not applicable	--
		18	Lugo 1997 (*126*)	Review	Pan-tropics	--
		19	Munro et al. 2007 (*127*)	Review	Australia	--
		20	Nichols et al. 2007 (*128*)	Meta-analysis	Pan-tropics	Focus not on plantation *vs* native forest; taxa limited to dung beetles
		21	Norton 1998 (*129*)	Review	New Zealand	--
		22	Parrotta et al. 1997 (*130*)	Other	Not applicable	--
		23	Spake et al. 2015 (*131*)	Meta-analysis	Outside tropics	Focus not on plantation *vs* native forest; taxa limited to fungi, lichen, and beetles
		24	Stephens and Wagner 2007 (*132*)	Review	Global	--
		25	Thompson and Donnelly 2018 (*133*)	Meta-analysis	Global	Focus not on plantation *vs* native forest; taxa limited to amphibians
		26	Wilson et al. 2017 (*134*)	Review	Global	--
Aboveground biomass	1	1	Anderson-Teixeira et al. 2016 (*61*)	Database	Pan-tropics	Plantation and native forest not paired
		2	Bonner et al. 2013 (*135*)	Meta-analysis	Pan-tropics	Plantation and native forest not paired
		3	Crouzeilles et al. 2016‡ (*111*)	Meta-analysis	Global	Plantation and native forest not paired
		4	Liao et al. 2010 (*45*)	Meta-analysis	Global	Older publication, missing recent data
		5	Moreno-Mateos et al. 2017 (*118*)	Meta-analysis	Global	Plantation and native forest not paired

	2	6	Bernal et al. 2018 (*136*)	Database	Global	Plantation and native forest not paired
		7	Kauffman et al. 2009 (*137*)	Review	Neotropics	--
		8	Lasco 2002 (*138*)	Review	South-east Asia	--
		9	Lasco and Pulhin 2009 (*139*)	Review	Philippines	--
		10	Locatelli et al. 2017 (*140*)	Review	Global mountains	--
		11	Mascaro et al. 2012 (*141*)	Other	Not applicable	--
		12	Wilson et al. 2017 (*134*)	Review	Global	--
Soil erosion	NA	1	Anache et al. 2017 (*142*)	Meta-analysis	Brazil	Regional
		2	Anderson and Lockaby 2011 (*143*)	Review	United States	--
		3	Bonell 1993 (*144*)	Review	Global	--
		4	Chanasyk et al. 2003 (*145*)	Review	Temperate regions	--
		5	Dotterweich 2013 (*146*)	Review	Global	--
		6	Douglas 1999 (*147*)	Review	Southeast Asia	--
		7	Fernández-Moya et al. 2014 (*67*)	Review	Global	--
		8	García-Ruiz et al. 2010 (*148*)	Review	Spain	--
		9	García-Ruiz et al. 2015 (*149*)	Meta-analysis	Global	Plantation and native forest not paired
		10	Gomi et al. 2005 (*150*)	Review	Pacific Northwest	--
		11	Guo et al. 2015 (*151*)	Database	China	Plantation and native forest not paired
		12	Gupta 1996 (*152*)	Review	Southeast Asia	--
		13	Hamilton and King 1983 (*153*)	Review	Pan-tropics	--
		14	Holz 2015 (*154*)	Review	Humid regions	--
		15	Jaafar et al. 2011 (*155*)	Other	Not applicable	--
		16	Labrière et al. 2015 (*156*)	Meta-analysis	Pan-tropics	Plantation and native forest not paired
		17	Laudon et al. 2011 (*157*)	Review	Sweden	--
		18	Lü et al. 2008 (*158*)	Meta-analysis	China	Focus not on plantation *vs* native forest; regional
		19	Maetens et al. 2012 (*159*)	Database	Europe/Mediterranean	Plantation and native forest not paired
		20	Scheurer et al. 2009 (*160*)	Review	Alpine countries	--
		21	Sidle et al. 2006 (*161*)	Review	Southeast Asia	--
		22	Stott and Mount 2004 (*162*)	Review	United Kingdom	--
		23	Valentin et al. 2008 (*163*)	Other	Southeast Asia	--
		24	Vanmaercke et al. 2011 (*164*)	Database	Europe	Plantation and native forest not paired
		25	Walling and Webb 1996 (*165*)	Review	Global	--
		26	Wallis 1994 (*166*)	Review	New Zealand	--
		27	Wiersum 1984 (*167*)	Review	Global	--
		28	Wondzell 2001 (*168*)	Other	United States (Oregon & Washington states)	--
Water yield	NA	1	Amatya et al. 2016 (*169*)	Other	North America	--

2	Anderson and Spencer 1991 (*170*)	Review	Pan-tropics	--
3	Andréassian 2004 (*171*)	Review	Global	--
4	Bentley and Coomes 2020 (*99*)	Meta-analysis	Global	Focus on comparing tree cover with non-tree cover
5	Bonnesoeur et al. 2019 (*172*)	Meta-analysis	Andean Mountains	Plantation and native forest not paired; focus not on plantation *vs* native forest
6	Bosch and Hewlett 1982 (*26*)	Review	Global	--
7	Brown et al. 2005 (*73*)	Review	Global	--
8	Brown et al. 2013 (*173*)	Review	Africa, Australia, New Zealand	--
9	Bruijnzeel 1990 (*174*)	Review	Pan-tropics	--
10	Bruijnzeel 1997 (*175*)	Review	Pan-tropics	--
11	Bruijnzeel 2004 (*176*)	Review	Pan-tropics	--
12	Bruijnzeel et al. 2011 (*177*)	Review	Pan-tropics	--
13	Calder 1986 (*178*)	Review	Australia, India, South Africa	--
14	Chanasyk et al. 2003 (*145*)	Review	Temperate regions	--
15	Cheng et al. 2002 (*179*)	Review	Taiwan	--
16	Coble et al. 2020 (*180*)	Review	North America	--
17	Cornish 1989 (*181*)	Review	Australia, New Zealand, South Africa	--
18	Cosandey et al. 2005 (*182*)	Review	Mediterranean France	--
19	Creed et al. 2014 (*85*)	Other	North America	--
20	Creed and Van Noordwijk 2018 (*183*)	Review	Global	--
21	Farley et al. 2005 (*184*)	Mete-analysis	Global	Focus not on plantation *vs* native forest
22	Ffolliott and Guertin 1987 (*185*)	Other	China	--
23	Filoso et al. 2017 (*186*)	Review	Global	--
24	García-Ruiz et al. 2011 (*187*)	Review	Mediterranean region	--
25	Gush et al. 2002 (*188*)	Review	South Africa	--
26	Gyenge et al. 2010 (*189*)	Review	Argentina	--
27	Hamilton and King 1983 (*153*)	Review	Pan-tropics	--
28	Heil et al. 2007 (*81*)	Other	North-western Europe	--
29	Hermann and Schumann 2010 (*88*)	Other	Europe	--
30	Hibbert 1967 (*190*)	Review	Global	--
31	Hornbeck et al. 1993 (*191*)	Review	North-eastern United States	--
32	Huber and Iroumé 2001 (*192*)	Review	Chile	--
33	Jackson et al. 2005 (*193*)	Meta-analysis	Global	Focus not on plantation *vs* native forest

34	Jones and Post 2004 (*84*)	Review	United States	--
35	Jones et al. 2012 (*194*)	Other	North America	--
36	Jones et al. 2017 (*195*)	Review	South America	--
37	Komatsu et al. 2007 (*196*)	Review	Japan	--
38	Komatsu et al. 2008 (*197*)	Review	Japan	--
39	Lane et al. 2005 (*198*)	Review	Australia, New Zealand, South Africa	--
40	Laudon et al. 2011 (*157*)	Review	Sweden	--
41	Li et al. 2017 (*199*)	Meta-analysis	Global	Focus not on plantation *vs* native forest
42	Lima 1987 (*200*)	Review	Global	--
43	Lima 1993 (*201*)	Review	Global	--
44	Llorens and Domingo 2007 (*202*)	Review	Mediterranean	--
45	Locatelli and Vignola 2009 (*203*)	Meta-analysis	Pan-tropical	Focus not on plantation *vs* native forest
46	Merheb et al. 2016 (*204*)	Meta-analysis	Mediterranean	Focus not on plantation *vs* native forest
47	Molchanov 1971 (*205*)	Review	Russia	--
48	Nakano 1967 (*206*)	Review	Japan	--
49	Niu et al. 2013 (*86*)	Other	China	--
50	Oyebande 1988 (*207*)	Review	Pan-tropics	--
51	Peck 2004 (*208*)	Review	Germany	--
52	Penman 1963 (*209*)	Review	Global	--
53	Price 2011 (*210*)	Review	Humid regions	--
54	Robinson 1992 (*211*)	Other	Europe	--
55	Rowe et al. 2002 (*212*)	Review	Australia, New Zealand	--
56	Rowe 2003 (*213*)	Review	Australia, New Zealand	--
57	Sahin and Hall 1996 (*214*)	Review	Global	--
58	Schmalz et al. 2015 (*215*)	Other	Austria, Germany, Switzerland	--
59	Scott et al. 2005 (*216*)	Review	Pan-tropics	--
60	Shiklomanov and Krestovsky 1988 (*217*)	Review	Russia	--
61	Sopper and Lull 1967 (*218*)	Other	Global	--
62	Soto-Schönherr and Iroumé 2016 (*219*)	Review	Chile	--
63	Stednick 1996 (*220*)	Review	United States	--
64	Van Dijk and Keenan 2007 (*221*)	Review	Global	--
65	Van Lanen and Gertsen 1997 (*87*)	Other	Global	--
66	Venkatesh et al. 2014 (*222*)	Review	India	--

67	Wang et al. 2020 (*223*)	Meta-analysis	Global	Focus not on plantation *vs* native forest; large river basins mostly
68	Wei et al. 2005 (*224*)	Review	China	--
69	Wei et al. 2008 (*225*)	Review	China	--
70	Whitehead and Robinson 1993 (*226*)	Review	Kenya, South Africa, Switzerland, United Kingdom, United States	
71	Zhang et al. 2017 (*227*)	Review	Global	--
72	Zhou et al. 2015 (*228*)	Review	Global	

Note: † Some entries are not reviews/meta-analyses/ databases, but they index to useful primary studies; these entries are denoted as 'Other'. †† For databases/meta-analyses that are relevant to the quantitative comparison of plantations and native forests, this column notes how they may have fallen short of enabling a rigorous comparison. '--' indicates that the database/meta-analysis concerned is not relevant to the quantitative comparison of plantations and native forests. ‡: This meta-analysis combined data from seven previous reviews/meta-analyses ((*21*, *229–234*). *: The PREDICTS database was consulted in November 2017.

Table S3. List of experts consulted for data on eroded soil and water yield. We consulted these experts for (i) additional data on eroded soil, and (ii) background information, literature references, unpublished theses and reports, and access to original data pertaining to water yield.

Metric	Geographical region	Expert name	Expert affiliation
Soil erosion	Belgium	Jean Poesen	KU Leuven
		Matthias Vanmaercke	KU Leuven
	Canada	Werner Kurz	Canadian Forest Service
	Finland	Jari Liski	Finnish Meteorological Institute
		Liisa Kulmala	Finnish Meteorological Institute
	The Netherlands	Gert-Jan Nabuurs	Wageningen University and Research
	Russia	Vladimir Korotkov	Moscow State University
	Senegal	Idrissa Guiro	Cheikh Anta Diop University, Dakar
	United Kingdom	Elena Vanguelova	Forest Research, United Kingdom
		Russel Anderson	Forest Research, United Kingdom
		Mike Perks	Forest Research, United Kingdom
		Robert Matthews	Forest Research, United Kingdom
	United States	Cheikh Mbow	START, Washington DC
Water yield	Argentina	Javier Gyenge	National Scientific & Technical Research Council, Buenos Aires
	Australia	Auro Almeida	CSIRO, Hobart
		Richard Benyon	University of Melbourne
		Leon Bren	University of Melbourne
		Shane Haydon	Melbourne Water Authority, Melbourne
		Patrick Lane	University of Melbourne, Melbourne
		Mike Sutton	Forestry Corporation NSW, Sydney
		Lisa Turner	Forestry Corporation NSW, Sydney
		Rob Vertessy	University of Melbourne, Melbourne
		Ashley Webb	WaterNSW, Sydney
	Belgium	Bart Muys	KU Leuven, Leuven
		Willem Verstraeten	Royal Meteorological Institute, Uckel
		Caroline Vincke	Catholic University of Louvain, Louvain
	Brazil	Felipe Salemi	Universidade de Brasilia, Brasilia
	Canada	Brian Amiro	University of Manitoba
		Jane Elliott	Environment Canada, Saskatoon
		David Scott	University of British Columbia, Kelowna
		Adam Wei	University of British Columbia, Kelowna
	Chile	Carlos Fuentes	Universidad de Chile, Santiago
		Pedro Hervé-Fernández	Universidad de Magallanes, Puntarenas
		Andrés Iroumé	Universidad Austral, Valdivia
		Carlos Oyarzún	Universidad Austral, Valdivia
	China	Wenjie Liu	CAS Key Laboratory of Tropical Forest Ecology, Menglun, Yunnan
		Yanghui Wang	Chinese Academy of Forestry, Beijing
		Yuefen Yao	(Formerly) Northeastern Forestry University, Harbin
		JianJun Zhang	Beijing Forestry University, Beijing
	(Taiwan)	Yue-Joe Hsia	Taiwan National Dong-Hwa University, Hualien
		Shiang Yue Lu	Taiwan National University, Taipei
	Colombia	Conrado Tobón	Universidad Nacional de Colombia, Medellin
		Juan Camilo Villegas	Universidad de Antioquia, Medellin

Denmark	Per Gundersen	University of Copenhagen, Copenhagen
	Lars Vesterdal	University of Copenhagen, Copenhagen
France	Arnaud Legout	National Institute for Agricultural Research, Champenoux
	Jacques Ranger	National Institute for Agricultural Research, Champenoux
Germany	Sonja Germer	Leibnitz Institute for Agricultural Engineering and Bioeconomy, Potsdam
	Mathias Herbst	Deutscher Wetterdienst, Offenbach
	Dirk Hölscher	University of Göttingen, Göttingen
	Henning Meesenburg	NW German Forest Research Institute, Göttingen
	Birte Scheler	NW German Forest Research Institute, Göttingen
India	Basappa Venkatesh	National Institute of Hydrology, Belgaum
Japan	Mie Gomyo	Tokyo University, Tokyo
	Shin'ichi Iida	Forestry & Forest Products Research Institute, Tsukuba
	Hikaru Komatsu	(Formerly) University of Kyoto
	Koichiro Kuraji	University of Tokyo, Tokyo
	Kazuho Matsumoto	University of the Ryukyus, Okinawa, Japan
	Shoji Noguchi	Forestry & Forest Products Research Institute, Tsukuba
	Shimizu Takanori	Forestry & Forest Products Research Institute, Kyoto
Malaysia	Aishah Shamsuddin	Forest Research Institute, Malaysia, Kepong
Mexico	Friso Holwerda	Universidad Autonoma de México, México City
The Netherlands	Eddy Moors	UNESCO-IHE, Delft
	Carolina van der Salm	Wageningen University & Research, Wageningen
New Zealand	Peter Beets	(Formerly) Scion, Rotorua
	Chandra Prasad Ghimire	AgResearch, Lincoln
	Lindsay Rowe	(Formerly) Landcare, Lincoln
Spain	Cristina Fernández Filgueira	Centre for Forestry Research, Galicia
	Noemí Lana-Renault	Universidad de la Rioja, Logroño
	Estela Nadal-Romero	Instituto Pirenaico de Ecología, Zaragoza
	Rafael Poyatos	Universitat Autonoma de Barcelona, Cerdanyola del Vallès, Catalonia
Sweden	Anders Malmer	Swedish University of Agricultural Sciences, Ůmeå
United Kingdom	Mark Gush	Kew Botanical Garden, London
	Mike Morecroft	Natural England, York
United States	Mary Beth Adams	US Forest Service, West Virginia
	Devendra Amatya	US Forest Service, South Carolina
	John Campbell	US Forest Service, New Hampshire
	Julia Jones	Oregon State University, Corvallis
	Chelcy Ford Miniat	US Forest Service, North Carolina
	Benjamin Rau	US Forest Service, West Virginia

	Ge Sun	US Forest Service, Research Triangle Park, North Carolina
	James Vose	US Forest Service, North Carolina

Table S4. List of primary studies included in our database.

Metric	No.	Primary study	Country	Native forest type	Plantation type
Species-specific abundance	1	Alem and Woldemariam 2009 (*235*)	Ethiopia	Generic native forest	Monoculture
	2	Barlow et al. 2007a (*110*)	Brazil	Old-growth forest; Secondary forest	Monoculture
	3	Barlow et al. 2007b (*236*)	Brazil	Old-growth forest; Secondary forest	Monoculture
	4	Barlow et al. 2007c (*237*)	Brazil	Old-growth forest; Secondary forest	Monoculture
	5	Beehler et al. 1987 (*238*)	India	Generic native forest	Monoculture
	6	Bentley et al. 2000 (*239*)	Australia	Generic native forest	Monoculture
	7	Berndt et al. 2008 (*240*)	New Zealand	Generic native forest	Monoculture
	8	Berndt et al. 2019 (*241*)	New Zealand	Generic native forest	Monoculture
	9	Bonham et al. 2002 (*242*)	Australia	Old-growth forest; Secondary forest	Monoculture
	10	Boonrotpong et al. 2004 (*243*)	Thailand	Old-growth forest	Abandoned plantation
	11	Caballero-Gini et al. 2020 (*244*)	Paraguay	Generic native forest	Monoculture
	12	Carey and Johnson 1995 (*245*)	United States	Old-growth forest	Mixed-culture plantation
	13	Ceia et al. 2009 (*246*)	Azores	Generic native forest	Monoculture
	14	Chauhan et al. 2006 (*247*)	India	Generic native forest	Mixed-culture plantation
	15	Cheng et al. 2018 (*248*)	China	Old-growth forest; Generic native forest	Monoculture
	16	Chiawo et al. 2018 (*249*)	Kenya	Generic native forest	Mixed-culture plantation
	17	Clout and Gaze 1984 (*250*)	New Zealand	Generic native forest	Monoculture; Abandoned plantation
	18	da Silva et al. 2019‡ (*251*)	Portugal	Secondary forest	Monoculture
	19	Davis et al. 2000 (*252*)	Malaysia	Old-growth forest	Mixed-culture plantation
	20	Deharveng 1996 (*253*)	France	Generic native forest; Secondary forest	Monoculture
	21	Do and Joo 2013‡ (*254*)	Korea	Generic native forest	Monoculture
	22	Einzmann and Zotz 2016 (*255*)	Panama	Generic native forest	Monoculture
	23	Fahy and Gormally 1998 (*256*)	Ireland	Generic native forest	Monoculture
	24	Farwig et al. 2008 (*257*)	Kenya	Generic native forest	Monoculture Mixed-culture plantation
	25	Fierro and Vergara 2019 (*258*)	Chile	Generic native forest	Monoculture
	26	Fierro et al. 2017‡ (*259*)	Chile	Secondary forest	Monoculture
	27	Fontúrbel et al. 2016 (*260*)	Chile	Old-growth forest	Abandoned plantation

28	Fuller et al. 2008 (*261*)	United Kingdom	Generic native forest	Monoculture; Mixed-culture plantation
29	Gangenova et al. 2018 (*262*)	Argentina	Generic native forest	Monoculture
30	Gardner et al. 2007 (*263*)	Brazil	Old-growth forest; Secondary forest	Monoculture
31	Gardner et al. 2008 (*264*)	Brazil	Old-growth forest; Secondary forest	Monoculture
32	Goded et al. 2019 (*265*)	Spain	Generic native forest	Abandoned plantation
33	Gómez et al. 2018 (*266*)	Argentina	Generic native forest	Monoculture
34	Gómez-Cifuentes et al. 2017 (*267*)	Argentina	Generic native forest	Monoculture
35	González-Vainer et al. 2012 (*268*)	Uruguay	Generic native forest	Monoculture
36	Gu et al. 2015 (*269*)	China	Old-growth forest; Generic native forest	Abandoned plantation
37	Habel et al. 2018 (*270*)	Kenya	Generic native forest	Mixed-culture plantation
38	Hawes et al. 2009 (*271*)	Brazil	Old-growth forest; Secondary forest	Monoculture
39	Hobbs et al. 2003 (*272*)	Australia	Generic native forest	Monoculture
40	Hodge et al. 2010 (*273*)	New Zealand	Generic native forest	Monoculture
41	Holbech 2009 (*122*)	Ghana	Generic native forest	Mixed plantation
42	Hua et al. 2016 (*9*)	China	Generic native forest	Monoculture; Mixed-culture plantation
43	Iezzi et al. 2020 (*274*)	Argentina	Generic native forest	Monoculture
44	Jacoboski et al. 2016 (*275*)	Brazil	Generic native forest	Monoculture
45	Kanowski et al. 2006 (*276*)	Australia	Old-growth forest; Secondary forest; Actively restored native forest	Monoculture; Mixed-culture plantation; Abandoned plantation
46	Katovai et al. 2012 (*277*)	Solomon Islands	Old-growth forest	Abandoned plantation
47	Kattan et al. 2010 (*278*)	Colombia	Old-growth forest; Secondary forest	Abandoned plantation
48	Kwok and Corlett 2000 (*279*)	China	Secondary forest	Monoculture
49	Lantschner and Rusch 2007 (*280*)	Argentina	Generic native forest	Monoculture
50	Lantschner et al. 2008 (*281*)	Argentina	Generic native forest	Monoculture
51	Li et al. 2017 (*282*)	China	Generic native forest	Monoculture Mixed-culture plantation
52	Longworth and Williamson 2018 (*283*)	Costa Rica	Secondary forest	Monoculture
53	Lu et al. 2016 (*284*)	China	Generic native forest	Monoculture
54	Lugo 1992 (*33*)	Puerto Rico	Secondary forest	Monoculture; Abandoned plantation

55	Luo et al. 2013 (*285*)	China	Generic native forest; Secondary forest	Abandoned plantation
56	Maglianesi 2010 (*286*)	Costa Rica	Secondary forest	Abandoned plantation
57	Magnano et al. 2019‡ (*287*)	Argentina	Secondary forest	Monoculture
58	Mandal and Raman 2016 (*288*)	India	Generic native forest	Monoculture
59	Martínez et al. 2009 (*289*)	Spain	Generic native forest	Monoculture; Abandoned plantation
60	Medina et al. 2002‡ (*290*)	Colombia	Secondary forest	Abandoned plantation
61	Merino-Sáinz and Anadón 2018 (*291*)	Spain	Generic native forest	Monoculture; Mixed-culture plantation
62	Milheiras et al. 2020 (*292*)	Brazil	Old-growth forest Generic native forest	Monoculture
63	Minor 2008 (*293*)	New Zealand	Generic native forest	Monoculture
64	Mitra and Sheldon 1993 (*294*)	Malaysia	Old-growth forest	Monoculture
65	Moreira-Arce et al. 2015 (*295*)	Chile	Generic native forest	Monoculture
66	Mott et al. 2010 (*296*)	Australia	Generic native forest	Monoculture
67	N'Dri et al. 2013 (*297*)	Ivory Coast	Old-growth forest	Monoculture
68	Nicolas et al. 2009 (*298*)	Guinea	Old-growth forest; Secondary forest	Abandoned plantation
69	Norfolk et al. 2017 (*299*)	Ethiopia	Generic native forest	Monoculture
70	Nummelin and Hanski 1989 (*300*)	Uganda	Old-growth forest; Generic native forest	Monoculture
71	Nurinsiyah et al. 2016 (*301*)	Indonesia	Old-growth forest	Monoculture
72	Ogai and Kenta 2016 (*302*)	Japan	Generic native forest	Monoculture
73	Ohwaki et al. 2017 (*303*)	Japan	Generic native forest	Monoculture
74	Palladini et al. 2007‡ (*304*)	United States	Secondary forest	Monoculture
75	Paritsis and Aizen 2008 (*305*)	Chile	Generic native forest	Mixed-culture plantation
76	Pawson et al. 2008 (*306*)	New Zealand	Generic native forest	Monoculture
77	Paz et al. 2015 (*307*)	Brazil	Generic native forest	Monoculture
78	Pedley et al. 2014 (*308*)	Ireland	Generic native forest	Monoculture
79	Penteado et al. 2016 (*309*)	Brazil	Generic native forest	Monoculture
80	Punttila et al. 1991 (*310*)	Finland	Generic native forest	Mixed-culture plantation
81	Ratsirarson et al. 2002 (*311*)	South Africa	Generic native forest	Monoculture
82	Rios et al. 2015 (*312*)	Colombia	Generic native forest	Monoculture
83	Rodrigues et al. 2017 (*313*)	Brazil	Generic native forest	Monoculture
84	Saavedra and Simonetti 2005 (*314*)	Chile	Generic native forest	Monoculture
85	Sakchoowong et al. 2008 (*315*)	Thailand	Generic native forest	Monoculture
86	Sarrionandia et al. 2015 (*316*)	Spain	Generic native forest	Monoculture

87	Sekercioglu 2002 (*317*)	Uganda	Old-growth forest	Mixed-culture plantation
88	Sheldon and Styring 2011 (*318*)	Malaysia	Generic native forest	Monoculture
89	Sheldon et al. 2010 (*319*)	Malaysia	Generic native forest	Monoculture
90	Soares et al. 2010 (*320*)	Brazil	Generic native forest	Abandoned plantation
91	Stuebing and Gasis 1989 (*321*)	Malaysia	Generic native forest	Monoculture
92	Styring et al. 2011 (*322*)	Malaysia	Generic native forest	Monoculture
93	Sung et al. 2012‡ (*323*)	China	Secondary forest	Monoculture
94	Taboada et al. 2008 (*324*)	Spain	Generic native forest	Monoculture; Abandoned plantation
95	Tikoca et al. 2017 (*325*)	Fiji	Generic native forest	Monoculture
96	Tondoh et al. 2011 (*326*)	Ivory Coast	Old-growth forest; Generic native forest	Monoculture; Mixed-culture plantation
97	Trimble and van Aarde 2014 (*327*)	South Africa	Generic native forest	Monoculture
98	Twedt et al. 1999 (*328*)	United States	Generic native forest	Monoculture
99	Udayana et al. 2020 (*329*)	Indonesia	Generic native forest	Monoculture
100	Ueda et al. 2015 (*330*)	Indonesia	Generic native forest	Monoculture
101	Upadhaya et al. 2015 (*331*)	India	Old-growth forest	Abandoned plantation
102	Vasconcelos et al. 2019 (*332*)	Brazil	Old-growth forest; Generic native forest	Monoculture
103	Vergara and Simonetti 2004 (*333*)	Chile	Generic native forest	Monoculture
104	Volpato et al. 2010 (*334*)	Brazil	Generic native forest	Abandoned plantation
105	Vonesh 2006 (*335*)	Uganda	Generic native forest	Abandoned plantation
106	Waldick et al. 1999 (*336*)	Canada	Generic native forest	Monoculture
107	Wang et al. 2008 (*337*)	China	Generic native forest	Monoculture
108	Warren-Thomas et al. 2014 (*338*)	China	Generic native forest	Abandoned plantation
109	Webb and Sah 2003 (*339*)	Nepal	Generic native forest; Secondary forest	Abandoned plantation
110	Yamamoto et al. 2014 (*340*)	Japan	Generic native forest	Monoculture
111	Yamaura et al. 2011 (*341*)	Japan	Generic native forest	Monoculture Abandoned plantation
112	Yang et al. 2010 (*342*)	China	Generic native forest	Monoculture
113	Yoshikura et al. 2011 (*343*)	Japan	Old-growth forest	Monoculture
114	Yu et al. 2004 (*344*)	China	Generic native forest	Abandoned plantation
115	Yu et al. 2006 (*345*)	China	Generic native forest	Abandoned plantation
116	Yu et al. 2008 (*346*)	China	Generic native forest Secondary forest	Abandoned plantation
117	Yu et al. 2010 (*347*)	China	Generic native forest	Abandoned plantation
118	Zhang et al. 2011 (*348*)	China	Old-growth forest	Abandoned plantation

	119	Zhao et al. 2017 (*349*)	China	Generic native forest	Monoculture
Aboveground biomass	1	Araujo and Austin 2020 (*350*)	Argentina	Generic native forest	Monoculture
	2	Arevalo et al. 2009‡ (*351*)	Canada	Secondary forest	Monoculture
	3	Atkinson and Marín-Spiotta 2015 (*352*)	United States Virgin Islands	Secondary forest	Abandoned plantation
	4	Baishya et al. 2009 (*353*)	India	Generic native forest	Monoculture
	5	Baruch et al. 2019 (*354*)	Venezuela	Generic native forest	Abandoned plantation
	6	Behera et al. 2017 (*355*)	India	Generic native forest	Abandoned plantation
	7	Brown et al. 2020 (*28*)	Ghana	Old-growth forest; Secondary forest	Abandoned plantation
	8	Cai et al. 2016 (*356*)	Canada	Old-growth forest	Abandoned plantation
	9	Cesar et al. 2018 (*357*)	Brazil	Old-growth forest; Secondary forest; Actively restored native forest	Abandoned plantation
	10	Chen et al. 2005 (*358*)	China	Generic native forest	Monoculture
	11	Cuevas et al. 1991 (*359*)	Puerto Rico	Secondary forest	Monoculture
	12	Devagiri et al. 2020 (*360*)	India	Generic native forest	Monoculture; Mixed-culture plantation
	13	Di et al. 2012 (*361*)	China	Old-growth forest; Secondary forest	Abandoned plantation
	14	Fan et al. 2016‡ (*362*)	China	Secondary forest	Monoculture
	15	Fleming and Freedman 1998 (*363*)	Canada	Generic native forest	Monoculture
	16	Gahagan et al. 2015‡ (*364*)	United States	Secondary forest	Monoculture
	17	Guedes et al. 2018 (*365*)	Mozambique	Generic native forest	Monoculture
	18	Haggar et al. 2013 (*366*)	Guatemala	Generic native forest	Monoculture
	19	Hagger et al. 2019 (*367*)	Australia	Actively restored native forest	Monoculture
	20	Hase and Foelster 1983 (*368*)	Venezuela	Generic native forest	Monoculture
	21	Jordan and Farnworth 1982 (*369*)	Puerto Rico	Secondary forest	Monoculture
	22	Kanowski and Catterall 2010 (*35*)	Australia	Actively restored native forest	Monoculture; Mixed-culture plantation
	23	Kawahara et al. 1981 (*370*)	Philippines	Generic native forest	Monoculture; Mixed-culture plantation
	24	Kumar et al. 2010 (*371*)	India	Generic native forest	Mixed-culture plantation
	25	Laclau 2003 (*372*)	Argentina	Generic native forest	Monoculture
	26	Lewis et al. 2016 (*373*)	Australia	Generic native forest	Monoculture
	27	Li et al. 2015 (*374*)	China	Secondary forest	Monoculture
	28	Li et al. 2013 (*375*)	China	Generic native forest	Monoculture
	29	Lin et al. 2015 (*376*)	China	Old-growth forest; Generic native forest;	Monoculture

	30	Lin et al. 2017 (*377*)	China	Secondary forest Old-growth forest; Generic native forest	Monoculture
	31	Lugo 1992 (*33*)	Puerto Rico	Secondary forest	Monoculture; Abandoned plantation
	32	N'Gbala et al. 2017‡ (*378*)	Cote d'Ivoire	Secondary forest	Monoculture
	33	Nihlgård 1972 (*379*)	Sweden	Generic native forest	Monoculture
	34	Omoro et al. 2013 (*380*)	Kenya	Generic native forest	Monoculture
	35	Osuri et al. 2020 (*381*)	India	Generic native forest	Abandoned plantation
	36	Otuoma et al. 2016 (*382*)	Kenya	Generic native forest; Secondary forest	Monoculture; Mixed-culture plantation
	37	Pangle et al. 2009 (*383*)	United States	Generic native forest	Monoculture
	38	Pibumrung et al. 2008 (*384*)	Thailand	Generic native forest	Mixed-culture plantation
	39	Preece et al. 2012 (*385*)	Australia	Generic native forest	Monoculture
	40	Raich et al. 2014 (*386*)	Costa Rica	Old-growth forest	Monoculture
	41	Silva et al. 2011‡ (*387*)	Brazil	Secondary forest	Monoculture
	42	Thapa et al. 2015 (*388*)	Indonesia	Generic native forest	Monoculture
	43	Upadhaya et al. 2015 (*331*)	India	Old-growth forest	Abandoned plantation
	44	Urbano and Keeton 2017 (*389*)	United States	Secondary forest	Monoculture
	45	Xie et al. 2013‡ (*390*)	China	Secondary forest	Abandoned plantation
	46	Yang et al. 2005 (*391*)	China	Secondary forest	Monoculture
	47	Yang et al. 2007 (*392*)	China	Generic native forest	Monoculture
	48	Yang et al. 2018 (*393*)	China	Generic native forest	Monoculture
	49	Zhang et al. 2020 (*394*)	China	Secondary forest	Abandoned plantation
	50	Zheng et al. 2008 (*395*)	China	Secondary forest	Monoculture
	51	Zhou et al. 2019 (*396*)	China	Generic native forest	Monoculture
	52	Zhu et al. 2016‡ (*397*)	China	Secondary forest	Monoculture; Mixed-culture plantation
Soil erosion	1	Fu et al. 2009 (*398*)	China	Secondary forest	Abandoned plantation
	2	Guimarães 2015 (*399*)	Brazil	Generic native forest	Monoculture
	3	Hou et al. 2010 (*400*)	China	Secondary forest	Monoculture; Abandoned plantation
	4	Huang et al. 2010 (*401*)	China	Secondary forest	Monoculture; Abandoned plantation
	5	Jirasuktaveekul et al. 2000 (*402*)	Thailand	Generic native forest	Monoculture
	6	Ma et al. 2014 (*403*)	China	Secondary forest	Abandoned plantation
	7	Martins 2005 (*404*)	Brazil	Generic native forest	Monoculture
	8	Oliveira 2011 (*405*)	Brazil	Generic native forest	Monoculture

	10	Oliveira et al. 2013 (*406*)	Brazil	Generic native forest	Monoculture
	11	Pardini et al. 2003 (*407*)	Spain	Generic native forest	Mixed-culture plantation
	12	Qi et al. 2008 (*408*)	China	Secondary forest	Monoculture
	13	Razafindrabe et al. 2010 (*409*)	Japan	Generic native forest	Monoculture
	14	Silva et al. 2011 (*410*)	Brazil	Generic native forest	Monoculture
	15	Silva et al. 2016 (*411*)	Brazil	Generic native forest	Monoculture
	16	Tang et al. 2007 (*412*)	China	Secondary forest	Monoculture; Abandoned plantation
	17	Wakiyama et al. 2010 (*68*)	Japan	Generic native forest	Monoculture
	18	Wu et al. 2015‡ (*413*)	China	Secondary forest	Mixed-culture plantation
	19	Yang et al. 2004 (*414*)	China	Generic native forest	Monoculture
	20	Yang et al. 2018 (*393*)	China	Generic native forest	Monoculture
	21	Zheng et al. 2008 (*415*)	China	Secondary forest	Monoculture
	22	Zhou et al. 2010 (*416*)	China	Generic native forest; Secondary forest	Monoculture
	23	Zhou et al. 2012 (*417*)	China	Secondary forest	Monoculture
Water yield†	1	Adams et al. 1994* (*418*); Adams and Kochenderfer 2014* (*419*)	United States	Generic native forest	Monoculture
	2	Aguilos et al. 2021* (*82*); Liu et al. 2018* (*420*)	United States	Generic native forest	Monoculture
	3	Amatya and Skaggs 2011 (*421*); Chescheir et al. 2008	United States	Generic native forest	Monoculture
	4	Aubinet et al. 2016 (*422*); Soubie et al. 2016 (*76*)	Belgium	Generic native forest	Monoculture
	5	Aussenac and Boulangeat 1980 (*423*); Beaulieu et al. 2016 (*424*); Granier et al. 2000 (*83*)	France	Generic native forest	Monoculture
	6	Bailly et al. 1974 (*425*)	Madagascar	Generic native forest	Abandoned plantation
	7	Beets and Oliver 2007* (*426*); Rowe 2003 (*213*)	New Zealand	Old-growth forest	Monoculture
	8	Benecke 1984 (*427*); Bouten and Jansson 1995 (*428*)	Germany	Generic native forest	Monoculture
	9	Benecke 1984 (*427*); Sutmöller and Meesenburg 2018* (*429*)	Germany	Generic native forest	Monoculture
	10	Berger et al. 2009‡ (*430*)	Austria	Secondary forest	Monoculture
	11	Bergkvist and Folkeson 1995 (*78*)	Sweden	Generic native forest	Monoculture
	12	Bigelow 2001 (*431*);	Costa Rica	Old-growth forest	Monoculture

	Loescher et al. 2005 (*432*)			
13	Blackie 1979 (*433*)	Kenya	Old-growth forest	Monoculture
14	Bren and Hopmans 2007 (*434*); Bren and Papworth 1991 (*435*)	Australia	Old-growth forest	Monoculture
15	Buttle and Farnsworth 2012 (*436*); Sun et al. 2008* (*437*); Verry and Timmons 1977 (*438*)	United States	Secondary forest	Monoculture
16	Calvo de Anta and Gómez Rey 2002 (*439*); Dambrine et al. 2000* (*440*); González and Viqueira 1985 (*441*); Rodríguez-Suárez et al. 2011 (*442*)	Spain	Generic native forest	Monoculture
17	Carbon et al. 1982 (*443*)	Australia	Old-growth forest	Monoculture
18	Cornish and Vertessy 2001* (*444*); Webb et al. 2012* (*445*)	Australia	Old-growth forest	Mixed-culture plantation
19	de Almeida and Soares 2003 (*446*); Soares and de Almeida 2001 (*447*)	Brazil	Generic native forest	Monoculture
20	De Schrijver et al. 2004 (*71*); De Schrijver et al. 2008 (*72*); Verstraeten et al. 2001 (*448*)	Belgium	Generic native forest	Monoculture
21	Dolman et al. 2000* (*449*); Tiktak and Bouten 1994 (*79*)	The Netherlands	Generic native forest	Monoculture
22	Dolman et al. 2000* (*449*); Verstraeten et al. 2001 (*448*)	The Netherlands	Generic native forest	Monoculture
23	Duan and Zhang 2014 (*450*); Yan et al. 2009 (*451*); Yan et al. 2015 (*452*)	China	Secondary forest	Monoculture
24	Echeverria et al. 2007 (*453*); Huber and Trecaman 2004 (*454*); Lara et al. 2009 (*455*); Oyarzún and Huber 1999 (*456*)	Chile	Old-growth forest; Generic native forest	Monoculture
25	Einsele et al. 1983 (*457*)	Germany	Generic native forest	Monoculture
26	Elliott et al. 1998*‡ (*458*); Pomeroy et al. 1997*‡ (*459*)	Canada	Secondary forest	Monoculture
27	Fahey and Jackson (*460*)	New Zealand	Old-growth forest	Monoculture
28	Fan et al. 2014 (*461*)	Australia	Generic native forest	Monoculture
29	Ford et al. 2011* (*462*)	United States	Generic native forest	Monoculture

30	Forest Influences Unit and Kansai Branch Station 1979*‡ (*463*); Hosoda et al. 2019*‡ (*464*); Tamai et al. 2008*‡ (*465*)	Japan	Secondary forest	Monoculture
31	Fritsch 1993 (*69*)	French Guyana	Old-growth forest	Monoculture
32	Führer 1990* (*466*)	Germany	Generic native forest	Monoculture
33	Ghimire et al. 2014 (*467*)	Nepal	Old-growth forest	Monoculture
34	Gholz and Clark 2002 (*468*); Riekerk 1989 (*469*); Sun et al. 2002 (*470*)	United States	Generic native forest	Monoculture
35	Gyenge et al. 2009* (*471*); Gyenge et al. 2011* (*472*)	Argentina	Generic native forest	Monoculture
36	Herbst et al. 2008 (*473*); Neal et al. 1993 (*474*); Roberts et al. 2005 (*475*)	United Kingdom	Generic native forest	Monoculture
37	Herbst et al. 2015 (*476*)	Germany	Old-growth forest	Monoculture
38	Hervé-Fernandez et al. 2016 (*477*); Oyarzún et al. 2012 (*478*)	Chile	Generic native forest	Monoculture
39	Hirata 1929‡ (*479*); Murakami et al. 2000‡ (*480*)	Japan	Secondary forest	Mixed-culture plantation
40	Hosoda et al. 1999*‡ (*481*); Hosoda and Murakami 2006*‡ (*482*); Hosoda et al. 2009*‡ (*483*)	Japan	Secondary forest	Monoculture
41	Hwong et al. 2002* (*484*)	China (Taiwan)	Old-growth forest	Monoculture
42	Jassal et al. 2009‡ (*485*)	Canada	Secondary forest	Mixed-culture plantation
43	Ji and Cai 2015 (*486*); Sheng et al. 2014 (*487*); Yao 2011 (*488*)	China	Old-growth forest	Monoculture
44	Jones and Post 2004* (*84*)	United States	Old-growth forest; Generic native forest	Monoculture
45	Juez et al. 2020* (*489*); Nadal-Romero et al. 2016* (*70*)	Spain	Old-growth forest	Monoculture
46/47	Krishnaswamy et al. 2012 (*490*)	India	Generic native forest	Mixed-culture plantation
48	Ladekarl et al. 2005 (*491*); Ringgaard et al. 2014 (*492*)	Denmark	Old-growth forest	Monoculture
49	Legout et al. 2016* (*90*)	France	Generic native forest	Monoculture
50	Legout et al. 2016* (*90*);	France	Generic native forest	Monoculture

	Marques et al. 1997 (*89*)			
51	Licata et al. 2008‡ (*493*)	Argentina	Secondary forest	Monoculture
52	Liu et al. 2015 (*494*); Tian et al. 2008 (*495*); Yu et al. 2008 (*496*)	China	Old-growth forest	Monoculture
53	Malmer 1992* (*497*); Malmer et al. 2005* (*498*)	Malaysia	Generic native forest	Monoculture
54	Martin et al. 2003 (*499*)	France	Generic native forest	Monoculture
55	Matsumoto et al. 2008*‡ (*500*); Gomyo and Kuraji 2013*‡ (*501*); Kuraji et al. 2019*‡ (*502*)	Japan	Secondary forest	Monoculture
56	Muñoz-Villers et al. 2015 (*74*)	Mexico	Old-growth forest	Monoculture
57	Nandakumar and Mein 1993 (*503*); Tsykin et al. 1982 (*504*)	Australia	Generic native forest	Monoculture
58	Ogden et al. 2013 (*505*); Wolf et al. 2011 (*506*)	Panama	Generic native forest	Mixed-culture plantation
59	Oishi et al. 2010 (*75*); Schäfer et al. 2002 (*507*)	United States	Generic native forest	Monoculture
60	Pilgrim et al. 1982‡ (*508*); Putuhena and Cordery 2000‡ (*509*)	Australia	Secondary forest	Monoculture
61	Richardson 1982 (*510*)	Jamaica	Generic native forest	Monoculture
62	Rosenqvist et al. 2010* (*80*)	Denmark	Generic native forest	Monoculture
63	Rothe et al. 2002 (*511*)	Germany	Secondary forest	Monoculture
64	Rowe and Pearce 1994 (*512*); Rowe et al. 1994 (*513*)	New Zealand	Old-growth forest	Monoculture
65	Salemi et al. 2013 (*514*)	Brazil	Old-growth forest	Monoculture
66	Scott and Smith 1997 (*515*); Scott and Prinsloo 2008 (*516*)	South Africa	Generic native forest	Monoculture
67	Vásquez-Velásquez 2016 (*517*)	Colombia	Old-growth forest	Monoculture
68	Voigtlaender 2007 (*518*)	Brazil	Generic native forest	Mixed-culture plantation
69	Wang 2015‡ (*519*); Zhang et al. 2008‡ (*520*)	China	Secondary forest	Mixed-culture plantation
70	Yang et al. 2019 (*521*)	South Korea	Generic native forest	Mixed-culture plantation
71	Zhou et al. 1999‡ (*522*); Zhou et al. 2002‡ (*523*); Zou and Chen 2017‡ (*524*)	China	Secondary forest	Monoculture; mixed-culture plantation
72	Zou and Chen 2017‡ (*524*)	China	Secondary forest	Monoculture

wood production (paired data)	1	Brown et al. 2020 (*28*)	Ghana	Secondary forest	Abandoned plantation
	2	Hallsby et al. 2015 (*525*)	Sweden	Secondary forest	Monoculture
	3	Lugo 1992 (*33*)	Puerto Rico	Secondary forest	Monoculture; Mixed-culture plantation; Abandoned plantation
Wood production (data on only restored native forest)	1	Cain 1996 (*526*)	United States	Secondary forest	--
	2	Doua-Bi et al. 2021 (*527*)	Ivory Coast	Secondary forest	--
	3	Fantini et al. 2019 (*528*)	Brazil	Secondary forest	--
	4	Julin and D'Amore 2003 (*529*)	United States	Secondary forest	--
	5	Pitt et al. 2013 (*530*)	Canada	Secondary forest	--
	6	Shoo et al. 2016 (*531*)	Australia	Secondary forest Actively restored native forest	--
	7	Wu et al. 2018 (*532*)	China	Secondary forest	--
	8	Zambiazi et al. 2021 (*533*)	Brazil	Secondary forest	--
	9	Zhang et al 2006 (*534*)	Canada	Secondary forest	--
	10	Zhang et al. 2015 (*535*)	China	Secondary forest	--

Note: †: For compilation of data on water yield, frequently multiple studies were needed to derive the RR for a given plantation and native forest pair. In listing primary studies for water yield, we therefore place such groups of primary studies together, in the column 'No.', organizing them in alphabetical order (within groups and among groups). *: For these water yield studies, we relied on original data provided by the primary study authors to derive water yield. ‡: Studies marked with this sign were not included in the analyses because they involved comparisons between tree plantations and restored native forests that differed by >10 years in age.

Table S5. Meta-analysis results for RR (*i.e.* on the transformed ln() scale), as corresponding to those shown in Fig. 2 (including sensitivity analyses).

Comparison	Metric	Mean	Lower 95% CI	Upper 95% CI	I^2
Main analysis					
Plantations *versus* reference native forests	Species-specific abundance	-0.363	-0.534	-0.192	88.4%
	Aboveground biomass	-0.398	-0.615	-0.180	84.1%
	Soil erosion control	-0.939	-1.686	-0.192	100%
	Water yield	-0.144	-0.244	-0.043	100%
Monoculture plantations *versus* reference native forests	Species-specific abundance	-0.477	-0.634	-0.319	86.3%
	Aboveground biomass	-0.398	-0.702	-0.095	85.7%
	Soil erosion control	-0.900	-1.696	-0.104	100%
	Water yield	-0.173	-0.281	-0.065	100%
Mixed-culture plantations *versus* reference native forests	Species-specific abundance	-0.171	-0.422	0.081	100%
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	0.059	-0.231	0.350	42.6%
Abandoned plantations *versus* reference native forests	Species-specific abundance	-0.105	-0.315	0.105	49.1%
	Aboveground biomass	-0.205	-0.472	0.063	100%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Old or abandoned plantations *versus* reference native forests	Species-specific abundance	-0.168	-0.298	-0.037	43.0%
	Aboveground biomass	-0.275	-0.486	-0.064	81.4%
	Soil erosion control	NA	NA	NA	NA
	Water yield	-0.065	-0.384	0.254	100%
Plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.395	-0.617	-0.172	100%
	Aboveground biomass	0.040	-0.263	0.343	91.0%
	Soil erosion control	-1.621	-3.698	0.457	100%
	Water yield	NA	NA	NA	NA
	Wood yield	1.172	0.722	1.621	100%
Monoculture plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.330	-0.645	-0.015	100%
	Aboveground biomass	-0.132	-0.915	0.651	100%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Mixed plantations *versus* restored native forests (similar age)	Species-specific abundance	NA	NA	NA	NA
	Aboveground biomass	-0.211	-0.894	0.472	92.6%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA

Abandoned plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.522	-0.817	-0.227	87.3%
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Sensitivity analysis 1: weighting scores all based on Equation 11†					
Plantations *versus* reference native forests	Species-specific abundance	-0.361	-0.538	-0.184	88.7%
	Aboveground biomass	-0.397	-0.614	-0.179	84.7%
	Soil erosion control	-0.939	-1.686	-0.192	100%
	Water yield	NA	NA	NA	NA
Monoculture plantations *versus* reference native forests	Species-specific abundance	-0.477	-0.636	-0.318	86.1%
	Aboveground biomass	-0.398	-0.702	-0.095	85.2%
	Soil erosion control	-0.900	-1.696	-0.104	100%
	Water yield	NA	NA	NA	NA
Mixed-culture plantations *versus* reference native forests	Species-specific abundance	-0.171	-0.422	0.081	100%
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Abandoned plantations *versus* reference native forests	Species-specific abundance	-0.051	-0.304	0.203	100%
	Aboveground biomass	-0.205	-0.472	0.063	100%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Old or abandoned plantations *versus* reference native forests	Species-specific abundance	-0.147	-0.297	0.004	74.7%
	Aboveground biomass	-0.270	-0.482	-0.058	83.9%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.394	-0.597	-0.190	9.8%
	Aboveground biomass	0.036	-0.271	0.344	94.4%
	Soil erosion control	-1.621	-3.698	0.457	100%
	Water yield	NA	NA	NA	NA
	Wood yield	1.172	0.727	1.616	49.3%
Monoculture plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.326	-0.631	-0.022	61.8%
	Aboveground biomass	-0.132	-0.915	0.651	100%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA

Mixed plantations *versus* restored native forests (similar age)	Species-specific abundance	NA	NA	NA	NA
	Aboveground biomass	-0.216	-0.896	0.465	81.5%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Abandoned plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.518	-0.806	-0.229	1.3%
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Sensitivity analysis 2: no weighting scheme used‡					
Plantations *versus* reference native forests	Species-specific abundance	-0.364	-0.540	-0.188	NA
	Aboveground biomass	-0.405	-0.621	-0.190	NA
	Soil erosion control	-0.939	-1.686	-0.192	NA
	Water yield	-0.144	-0.244	-0.043	NA
Monoculture plantations *versus* reference native forests	Species-specific abundance	-0.479	-0.639	-0.318	NA
	Aboveground biomass	-0.410	-0.711	-0.109	NA
	Soil erosion control	-0.900	-1.725	-0.075	NA
	Water yield	-0.173	-0.281	-0.065	NA
Mixed-culture plantations *versus* reference native forests	Species-specific abundance	-0.171	-0.422	0.081	NA
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	0.105	-0.293	0.502	NA
Abandoned plantations *versus* reference native forests	Species-specific abundance	-0.051	-0.304	0.203	NA
	Aboveground biomass	-0.205	-0.472	0.063	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Old or abandoned plantations *versus* reference native forests	Species-specific abundance	-0.149	-0.294	-0.004	NA
	Aboveground biomass	-0.270	-0.484	-0.055	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	-0.065	-0.384	0.254	NA
Plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.395	-0.617	-0.172	NA
	Aboveground biomass	0.032	-0.281	0.346	NA
	Soil erosion control	-1.621	-3.698	0.457	NA
	Water yield	NA	NA	NA	NA
	Wood yield	1.172	0.722	1.621	NA

Monoculture plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.330	-0.645	-0.015	NA
	Aboveground biomass	-0.132	-0.915	0.651	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Mixed plantations *versus* restored native forests (similar age)	Species-specific abundance	NA	NA	NA	NA
	Aboveground biomass	-0.216	-0.896	0.465	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Abandoned plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.525	-0.827	-0.223	NA
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Sensitivity analysis 3: random effect structure not including the site identity of the native forests*					
Plantations *versus* reference native forests	Species-specific abundance	-0.363	-0.534	-0.191	88.4%
	Aboveground biomass	-0.407	-0.627	-0.187	100%
	Soil erosion control	-0.931	-1.660	-0.202	100%
	Water yield	-0.144	-0.244	-0.044	100%
Monoculture plantations *versus* reference native forests	Species-specific abundance	-0.477	-0.634	-0.319	86.3%
	Aboveground biomass	-0.412	-0.717	-0.107	100%
	Soil erosion control	-0.892	-1.668	-0.116	100%
	Water yield	-0.173	-0.280	-0.065	100%
Mixed-culture plantations *versus* reference native forests	Species-specific abundance	-0.171	-0.422	0.081	100%
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Abandoned plantations *versus* reference native forests	Species-specific abundance	-0.095	-0.316	0.127	49.1%
	Aboveground biomass	-0.205	-0.472	0.063	100%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Old or abandoned plantations *versus* reference native forests	Species-specific abundance	-0.168	-0.298	-0.037	43.0%
	Aboveground biomass	-0.275	-0.486	-0.064	81.4%
	Soil erosion control	NA	NA	NA	NA
	Water yield	-0.065	-0.384	0.254	100%
Plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.395	-0.617	-0.172	100%
	Aboveground biomass	0.089	-0.134	0.312	71.5%
	Soil erosion control	-1.573	-3.600	0.454	100%
	Water yield	NA	NA	NA	NA
	Wood yield	NA	NA	NA	NA

Monoculture plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.330	-0.645	-0.015	100%
	Aboveground biomass	-0.130	-0.885	0.624	96.9%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Mixed plantations *versus* restored native forests (similar age)	Species-specific abundance	NA	NA	NA	NA
	Aboveground biomass	-0.176	-0.838	0.487	45.9%
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA
Abandoned plantations *versus* restored native forests (similar age)	Species-specific abundance	-0.522	-0.817	-0.227	87.3%
	Aboveground biomass	NA	NA	NA	NA
	Soil erosion control	NA	NA	NA	NA
	Water yield	NA	NA	NA	NA

Note: †: This sensitivity analysis did not concern water yield, because Equation 11 (in 'Data analysis' under Materials and Methods) was used to calculate weight scores for water yield RR in the main analyses. ‡: The lack of model weight from this set of sensitivity analyses meant that I^2 was not calculated because its calculation depended on model weight (see 'Data analysis' under Materials and Methods). *: This sensitivity analysis did not concern wood yield, because the main models did not include the site identity of the native forest as a random variable (due to data paucity)

Table S6. AICc-based model selection results. '✓' and '--' indicate that the variable concerned was included and not included, respectively, in the top-ranking models as selected by AICc scores (*i.e.* ΔAICc ≤2); 'NA' indicates that the variable concerned was not relevant to the corresponding analysis.

Model ranking	AICc	ΔAICc	Plantation type	Age	Age^2	MAT	MAT × Age	MAP	MAP × Age	MAT × MAP	Seasonality
Main analysis											
Species-species abundance, plantations (all types combined) *versus* reference native forests											
1	376.5	0	✓	--	--	--	--	NA	NA	NA	NA
2	377.7	1.15	✓	--	✓	--	--	NA	NA	NA	NA
3	377.7	1.21	✓	✓	--	--	--	NA	NA	NA	NA
4	377.8	1.31	--	✓	--	--	--	NA	NA	NA	NA
5	378.2	1.63	--	--	✓	--	--	NA	NA	NA	NA
6	378.5	1.93	--	--	--	--	--	NA	NA	NA	NA
Species-species abundance, monoculture plantations *versus* reference native forests											
1	280.2	0	NA	--	--	--	--	NA	NA	NA	NA
2	281.2	0.96	NA	✓	--	--	--	NA	NA	NA	NA
3	281.5	1.24	NA	--	✓	--	--	NA	NA	NA	NA
4	282.2	1.96	NA	--	--	✓	--	NA	NA	NA	NA
Species-species abundance, mixed plantations *versus* reference native forests											
1	47.3	0	NA	--	--	--	--	NA	NA	NA	NA
Species-species abundance, abandoned plantations *versus* reference native forests											
1	72.8	0	NA	--	✓	--	--	NA	NA	NA	NA
2	73.1	0.37	NA	✓	✓	--	--	NA	NA	NA	NA
3	74.7	1.99	NA	✓	--	--	--	NA	NA	NA	NA
Species-species abundance, plantations *versus* restored native forest of similar age											
1	43.3	0	--	NA	NA	--	NA	NA	NA	NA	NA
Aboveground biomass, plantations *versus* reference native forests											
1	121.4	0	--	✓	✓	--	--	NA	NA	NA	NA
Aboveground biomass, plantations *versus* restored native forest of similar age											
1	53.9	0	--	NA	NA	--	NA	NA	NA	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including MAT)											
1	140.6	0	--	--	--	NA	NA	--	--	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including plantation age)											
1	198.9	0	--	NA	NA	--	NA	--	NA	--	NA
2	200.1	1.17	--	NA	NA	--	NA	✓	NA	--	NA
3	200.1	1.20	--	NA	NA	✓	NA	--	NA	--	NA
4	200.4	1.52	--	NA	NA	✓	NA	✓	NA	--	NA
Soil erosion control, plantations *versus* restored native forest of similar age											
1	70.9	0	--	NA	NA	--	NA	NA	NA	NA	NA
Water yield, plantations *versus* reference native forests (not including seasonality)											
1	164.3	0	--	--	--	--	--	✓	--	NA	NA
2	164.8	0.45	--	--	--	--	--	--	--	NA	NA
3	165.5	1.14	--	--	--	✓	--	✓	--	NA	NA
4	165.5	1.17	--	✓	✓	--	--	--	--	NA	NA
5	166.0	1.65	--	--	✓	--	--	✓	--	NA	NA
6	166.1	1.75	--	✓	✓	--	--	✓	--	NA	NA
7	166.3	1.95	✓	--	--	✓	--	✓	--	NA	NA
Water yield, plantations *versus* reference native forests (not including MAT or MAP)†											

1	164.8	0	--	--	--	NA	NA	NA	NA	NA	--
2	165.5	0.72	--	✓	✓	NA	NA	NA	NA	NA	--
3	166.3	1.56	✓	--	--	NA	NA	NA	NA	NA	--
4	166.6	1.78	--	--	--	NA	NA	NA	NA	NA	✓
5	166.6	1.82	✓	✓	✓	NA	NA	NA	NA	NA	--
6	166.7	1.91	--	✓	--	NA	NA	NA	NA	NA	--
Sensitivity analysis 1: weighting scores all based on Equation 11*											
Species-species abundance, plantations (all types combined) *versus* reference native forests											
1	380.6	0	✓	--	--	--	--	NA	NA	NA	NA
2	381.7	1.12	✓	--	✓	--	--	NA	NA	NA	NA
3	381.7	1.16	✓	✓	--	--	--	NA	NA	NA	NA
4	381.8	1.17	--	✓	--	--	--	NA	NA	NA	NA
5	382.1	1.54	--	--	✓	--	--	NA	NA	NA	NA
Species-species abundance, monoculture plantations *versus* reference native forests											
1	283.8	0	NA	--	--	--	--	NA	NA	NA	NA
2	284.7	0.95	NA	✓	--	--	--	NA	NA	NA	NA
3	285.0	1.21	NA	--	✓	--	--	NA	NA	NA	NA
4	285.7	1.92	NA	--	--	✓	--	NA	NA	NA	NA
Species-species abundance, mixed plantations *versus* reference native forests (null model did not converge and therefore did not enter model selection)											
1	52.7	0	NA	--	--	✓	--	NA	NA	NA	NA
2	52.8	0.18	NA	--	✓	✓	--	NA	NA	NA	NA
3	53.4	0.70	NA	✓	--	✓	--	NA	NA	NA	NA
4	53.8	1.17	NA	✓	--	--	--	NA	NA	NA	NA
5	54.5	1.85	NA	--	✓	--	--	NA	NA	NA	NA
Species-species abundance, abandoned plantations *versus* reference native forests											
1	72.8	0	NA	--	✓	--	--	NA	NA	NA	NA
2	73.1	0.37	NA	✓	✓	--	--	NA	NA	NA	NA
3	73.5	0.78	NA	--	--	--	--	NA	NA	NA	NA
4	74.7	1.99	NA	✓	--	--	--	NA	NA	NA	NA
Species-species abundance, plantations *versus* restored native forest of similar age											
1	42.7	0	--	NA	NA	--	NA	NA	NA	NA	NA
Aboveground biomass, plantations *versus* reference native forests											
1	121.4	0	--	✓	✓	--	--	NA	NA	NA	NA
Aboveground biomass, plantations *versus* restored native forest of similar age											
1	53.9	0	--	NA	NA	--	NA	NA	NA	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including MAT)											
1	140.6	0	--	--	--	NA	NA	NA	NA	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including plantation age) (the variable MAT × MAP dropped from global model because of non-convergence)											
1	198.9	0	--	NA	NA	--	NA	--	NA	NA	NA
2	200.1	1.17	--	NA	NA	--	NA	✓	NA	NA	NA
3	200.1	1.20	--	NA	NA	✓	NA	--	NA	NA	NA
4	200.4	1.52	--	NA	NA	✓	NA	✓	NA	NA	NA
Soil erosion control, plantations *versus* restored native forest of similar age											
1	71.0	0	--	NA	NA	--	NA	NA	NA	NA	NA
Sensitivity analysis 2: no weighting scheme used											
Species-species abundance, plantations (all types combined) *versus* reference native forests											
1	380.6	0	✓	--	--	--	--	NA	NA	NA	NA

2	381.7	1.12	✓	--	✓	--	--	NA	NA	NA	NA
3	381.7	1.16	--	✓	--	--	--	NA	NA	NA	NA
4	381.8	1.16	✓	✓	--	--	--	NA	NA	NA	NA
5	382.1	1.54	--	--	✓	--	--	NA	NA	NA	NA
Species-species abundance, monoculture plantations *versus* reference native forests											
1	283.8	0	NA	--	--	--	--	NA	NA	NA	NA
2	284.7	0.95	NA	✓	--	--	--	NA	NA	NA	NA
3	285.0	1.21	NA	--	✓	--	--	NA	NA	NA	NA
4	285.7	1.92	NA	--	--	✓	--	NA	NA	NA	NA
Species-species abundance, mixed plantations *versus* reference native forests											
1	49.4	0	NA	--	--	--	--	NA	NA	NA	NA
Species-species abundance, abandoned plantations *versus* reference native forests											
1	72.8	0	NA	--	✓	--	--	NA	NA	NA	NA
2	73.5	0.78	NA	--	--	--	--	NA	NA	NA	NA
3	74.7	1.99	NA	✓	--	--	--	NA	NA	NA	NA
Species-species abundance, plantations *versus* restored native forest of similar age											
1	43.5	0	--	NA	NA	--	NA	NA	NA	NA	NA
Aboveground biomass, plantations *versus* reference native forests											
1	121.4	0	--	✓	✓	--	--	NA	NA	NA	NA
Aboveground biomass, plantations *versus* restored native forest of similar age											
1	53.9	0	--	NA	NA	--	NA	NA	NA	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including MAT)											
1	140.6	0	--	--	--	NA	NA	NA	NA	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including plantation age)											
1	198.9	0	--	NA	NA	--	NA	--	NA	--	NA
2	200.1	1.17	--	NA	NA	--	NA	✓	NA	--	NA
3	200.1	1.20	--	NA	NA	✓	NA	--	NA	--	NA
4	200.4	1.52	--	NA	NA	✓	NA	✓	NA	--	NA
Soil erosion control, plantations *versus* restored native forest of similar age											
1	72.4	0	--	NA	NA	--	NA	NA	NA	NA	NA
Water yield, plantations *versus* reference native forests (not including seasonality)											
1	164.3	0	--	--	--	--	--	✓	--	NA	NA
2	164.8	0.45	--	--	--	--	--	--	--	NA	NA
3	165.5	1.14	--	--	--	✓	--	✓	--	NA	NA
4	165.5	1.17	--	✓	✓	--	--	--	--	NA	NA
5	166.0	1.65	--	--	✓	--	--	✓	--	NA	NA
6	166.1	1.75	--	✓	✓	--	--	✓	--	NA	NA
7	166.3	1.95	✓	--	--	✓	--	✓	--	NA	NA
Water yield, plantations *versus* reference native forests (not including MAT or MAP)†											
1	164.8	0	--	--	--	NA	NA	NA	NA	NA	--
2	165.5	0.72	--	✓	✓	NA	NA	NA	NA	NA	--
3	166.3	1.56	✓	--	--	NA	NA	NA	NA	NA	--
4	166.6	1.78	--	--	--	NA	NA	NA	NA	NA	✓
5	166.6	1.82	✓	✓	✓	NA	NA	NA	NA	NA	--
6	166.7	1.91	--	✓	--	NA	NA	NA	NA	NA	--
Sensitivity analysis 3: random effect structure not including the site identity of the native forests											
Species-species abundance, plantations (all types combined) *versus* reference native forests											
1	374.4	0	✓	--	--	--	--	NA	NA	NA	NA
2	375.5	1.13	✓	--	✓	--	--	NA	NA	NA	NA

3	375.6	1.19	✓	✓	--	--	--	NA	NA	NA	NA
4	375.7	1.33	--	✓	--	--	--	NA	NA	NA	NA
5	376.0	1.65	--	--	✓	--	--	NA	NA	NA	NA
6	376.3	1.97	--	--	--	--	--	NA	NA	NA	NA
Species-species abundance, monoculture plantations *versus* reference native forests											
1	278.0	0	NA	--	--	--	--	NA	NA	NA	NA
2	279.0	0.94	NA	✓	--	--	--	NA	NA	NA	NA
3	279.3	1.21	NA	--	✓	--	--	NA	NA	NA	NA
4	280.0	1.93	NA	--	--	✓	--	NA	NA	NA	NA
Species-species abundance, mixed plantations *versus* reference native forests											
1	42.4	0	NA	--	--	--	--	NA	NA	NA	NA
2	43.1	0.72	NA	--	✓	✓	--	NA	NA	NA	NA
3	43.6	1.20	NA	✓	--	✓	--	NA	NA	NA	NA
Species-species abundance, abandoned plantations *versus* reference native forests											
1	74.1	0	NA	--	--	--	--	NA	NA	NA	NA
2	75.0	0.92	NA	--	✓	--	--	NA	NA	NA	NA
3	75.4	1.31	NA	✓	--	--	--	NA	NA	NA	NA
4	76.0	1.85	NA	--	--	✓	--	NA	NA	NA	NA
Species-species abundance, plantations *versus* restored native forest of similar age											
1	41.6	0	--	NA	NA	--	NA	NA	NA	NA	NA
Aboveground biomass, plantations *versus* reference native forests											
1	127.9	0	--	✓	✓	--	--	NA	NA	NA	NA
Aboveground biomass, plantations *versus* restored native forest of similar age											
1	56.9	0	--	NA	NA	--	NA	NA	NA	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including MAT)											
1	141.9	0	--	--	--	NA	NA	NA	NA	NA	NA
Soil erosion control, plantations *versus* reference native forests (not including plantation age)											
1	199.3	0	--	NA	NA	✓	NA	✓	NA	--	NA
1	199.7	0.34	--	NA	NA	✓	NA	--	NA	--	NA
1	201.1	1.73	✓	NA	NA	✓	NA	✓	NA	--	NA
1	201.1	1.74	✓	NA	NA	✓	NA	✓	NA	✓	NA
1	201.1	1.79	--	NA	NA	✓	NA	✓	NA	✓	NA
Soil erosion control, plantations *versus* restored native forest of similar age (null model did not converge and therefore did not enter model selection)											
1	74.8	0	--	NA	NA	✓	NA	NA	NA	NA	NA
2	75.2	0.37	✓	NA	NA	--	NA	NA	NA	NA	NA
Water yield, plantations *versus* reference native forests (not including seasonality)											
1	162.1	0	--	--	--	--	--	✓	--	NA	NA
2	162.6	0.48	--	--	--	--	--	--	--	NA	NA
3	163.2	1.10	--	--	--	✓	--	✓	--	NA	NA
4	163.3	1.14	--	✓	✓	--	--	--	--	NA	NA
5	163.7	1.62	--	--	✓	--	--	✓	--	NA	NA
6	163.8	1.68	--	✓	✓	--	--	✓	--	NA	NA
7	164.0	1.85	✓	--	--	✓	--	✓	--	NA	NA
8	164.1	1.98	✓	--	--	--	--	--	--	NA	NA
Water yield, plantations *versus* reference native forests (only including seasonality)†											
1	162.6	0	--	--	--	NA	NA	NA	NA	NA	--
2	163.3	0.65	--	✓	✓	NA	NA	NA	NA	NA	--
3	164.1	1.49	✓	--	--	NA	NA	NA	NA	NA	--

4	164.3	1.69	✓	✓	✓	NA	NA	NA	NA	NA	--
5	164.4	1.75	--	--	--	NA	NA	NA	NA	NA	✓
6	164.5	1.88	--	✓	--	NA	NA	NA	NA	NA	--

Note: †: The number of water yield RR for the comparison between plantations *versus* restored native forests of similar age was exceptionally small (n=5); we therefore did not conduct formal analysis on it. * This sensitivity analysis did not concern water yield, because Equation 11 (in 'Data analysis' under Materials and Methods) was used to calculate weight scores for water yield RR in the main analyses.

Table S7. Meta-regression results, as corresponding to those shown in Fig. 4 (including sensitivity analyses).

Metric	Variable	Mean	Lower 95% CI	Upper 95% CI	R^2
Main analysis					
Species-specific abundance*	Intercept	-0.18	-0.56	0.20	0.018
	Age^2	7.48×10^{-5}	-0.65×10^{-5}	15.62×10^{-5}	
Aboveground biomass	Intercept	-1.71	-2.27	-1.15	0.332
	Age	0.07	0.04	0.11	
	Age^2	-82.32×10^{-5}	-134.54×10^{-5}	-30.10×10^{-5}	
Water yield	intercept	-0.30	-0.52	-0.09	0.028
	MAP	9.38×10^{-5}	-2.16×10^{-5}	20.92×10^{-5}	
Sensitivity analysis 1: weighting scores all based on Equation 11*					
Species-specific abundance*	Intercept	-0.18	-0.56	0.20	0.018
	Age^2	7.48×10^{-5}	-0.65×10^{-5}	15.62×10^{-5}	
Aboveground biomass	Intercept	-1.71	-2.27	-1.15	0.332
	Age	0.07	0.04	0.11	
	Age^2	-82.32×10^{-5}	-134.54×10^{-5}	-30.10×10^{-5}	
Sensitivity analysis 2: no weighting scheme used					
Species-specific abundance*	Intercept	-0.18	-0.56	0.20	0.018
	Age^2	7.48×10^{-5}	-0.65×10^{-5}	15.62×10^{-5}	
Aboveground biomass	Intercept	-1.71	-2.27	-1.15	0.332
	Age	0.07	0.04	0.11	
	Age^2	-82.32×10^{-5}	-134.54×10^{-5}	-30.10×10^{-5}	
Water yield	intercept	-0.30	-0.52	-0.09	0.028
	MAP	9.38×10^{-5}	-2.16×10^{-5}	20.92×10^{-5}	
Sensitivity analysis 3: random effect structure not including the site identity of the native forests					
Species-specific abundance*	Intercept	-0.08	-0.43	0.26	NA‡
Aboveground biomass	Intercept	-1.67	-2.28	-1.05	0.508
	Age	0.07	0.03	0.11	
	Age^2	-77.53×10^{-5}	-133.12×10^{-5}	-21.95×10^{-5}	
Water yield	intercept	-0.30	-0.52	-0.09	0.028
	MAP	9.38×10^{-5}	-2.16×10^{-5}	20.92×10^{-5}	

Note: †: This sensitivity analysis did not concern water yield, because Equation 11 was used to calculate weight scores for water yield RR in the main analyses. * This analysis was for the subset of data comparing abandoned plantations *versus* reference native forests. ‡: No R^2 was calculated because the best model was an intercept-only model.