Tropical tree diversity enhances light capture through crown plasticity and spatial and temporal niche differences

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Appendix E: Supplementary methods and results for the virtual biodiversity experiments.

Supplementary Methods

We ran four virtual biodiversity experiments to explore diversity effects on light capture over a full calendar year while removing the confounding effects of overyielding. These virtual experiments were designed to investigate in turn the combined (M1+M3, see Fig. 1B in the main text) and independent effects of differences in (M1a) crown openness, (M1b) crown shape and position, and (M3) phenology among species.

In the first experiment (M1+M3), we explored the combined effects of all architectural and phenological differences among species . We generated a gradient of functional diversity by systematically varying the proportions $p = (p_1, p_2, p_3, p_4, p_5 = 1 - p_1 - p_2 - p_3 - p_4)$ of the 5 species included in the virtual experiment in increments of 0.1. We excluded *C. alliodora* from the species pool since it failed to establish in the plantation and its parameters in the light model were thus poorly constrained by the little data available. Apart from that, the particular proportions included

in the Sardinilla experiment are covered in the virtual experiment. Mortality was not incorporated

to isolate the effects of differences in architecture and phenology among species. Each virtual

stand consisted of 225 trees placed on a spatially uniform grid and separated by 3 meters within

a row or column to mimic our plantation's experimental design, notably its plot size. We used a

torus wrapping to avoid edge effects. The spatial distribution of species identities within a stand

was random. Stands were created by sampling trees with replacement from species' respective

monocultures, thereby controlling for overyileding and propagating uncertainty due to intraspecific

variability in tree size. For each vector p, 20 replicate stands were created, yielding a total of 19500

virtual stands. We numerically integrated over time (a whole year) and space (the whole stand)

to calculate the percentage of total PAR captured by the trees as total PAR above the canopy

minus PAR reaching ground. Data from the closest meteorological station (BCI) were used to pa-

rameterize the light model and reproduce the annual variations in PAR with a monthly resolution.

Due to reduced cloud cover, daily PAR is indeed ca. 50% higher in the dry season than in the

wet season (Kunert et al., 2012). The species-specific crown openness (CO) calibrated from light

measures in September was used for fully foliated periods. The CO for leafless trees was obtained

from hemispherical photographs taken in March, June and December (Appendix B). We computed

PAR reaching ground on a uniform grid with points distant by 1.5 m to integrate over space. The

grid was shifted compared to tree's positions so that no PAR was calculated from within a tree's

trunc.

The three other experiments (M1a), (M1b) and (M3) shared the same design except that some

traits were fixed to that of a reference species j to break correlations across species. To isolate

differences in crown openness only (M1a), mixtures were created by sampling trees' diameters and

heights from the monoculture of j and we applied the leaf phenology and crown allometry of j to

all trees. The only difference among the virtual species was thus crown openness. We focused on

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architectural differences related to crown shape and position (M1b) by setting the leaf phenology
and the CO of all species to that of j. All other differences among species were conserved. In particular, trees' diameters and heights were sampled from their respective monocultures. Finally, we isolated the effects of (M3) temporal niche differences by setting all species traits except phenology to that of j and by sampling trees' diameters and heights from the monoculture of j. Results were similar with any species j used as a reference and are presented with $j = L.$ *seemanii.*

In all four experiments, we measured the magnitude of diversity effects on light capture Δ as the surplus yearly PAR captured by a mixture compared to null expectations based on monoculture performance:

$$\Delta = L_{\mathrm{mix}} - \sum_i p_i L_i \tag{E.1}$$

where L_i is the average light captured by monocultures of species i, p_i the proportion of species i in the mixture and L_{mix} the total PAR captured by the mixture. We also defined Δ^T to test whether mixtures transgressively overperformed:

$$\Delta^T = L_{\mathrm{mix}} - \max_{i \in \mathrm{mixture}} \{L_i\} \tag{E.2}$$

Supplementary results

Consistent with results presented in appendix D (Fig. D1), the effects of architectural differences among species were not strong enough for polycultures to capture more light than their 'best' constituent monoculture (mean polyculture $\Delta^T = -8.4$ and -6.4, $p < 2.2E - 6$; Fig. E1). The same pattern was found, albeit to a lesser extent, for temporal niche differences alone (mean polyculture $\Delta^T = -3.5$, $p < 2.2E - 6$). Overall, polycultures captured on average 12.3% less light

than their best monoculture (mean polyculture $\Delta^T = -12.3$, $p < 2.2E - 6$).
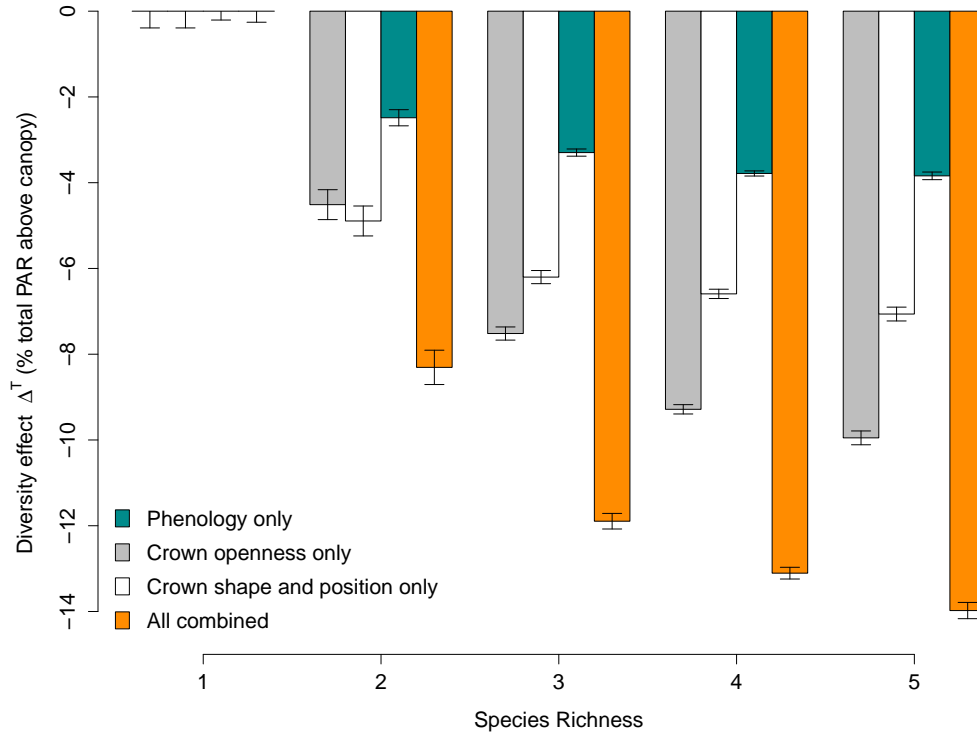

Fig. E1. Transgressive diversity effects on light capture in virtual biodiversity experiments discarding diversity effects on tree size. Δ^T measures the deviation in the amount of light captured over a full year between a polyculture and its consituent monoculture that captures most light. Colors code for virtual biodiversity experiment alternatively including phenological differences only (blue bars), architectural differences only (white bars for crown shape and position; gray bars for crown openness) and combined differences among species. Error bars show 95% confidence interval around the mean.