

Tracking the recovery of degraded tropical forests using repeat airborne LiDAR.

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Restoring tropical forests is vital for combating climate change and preserving biodiversity, but the effectiveness of restoration efforts remains uncertain. We address this using repeat airborne LiDAR to measure the effects of enrichment tree planting and liana cutting on aboveground carbon density (ACD) and canopy cover (CC) in the Sabah Biodiversity Experiment (SBE) and nearby old growth forests at Danum Valley in Malaysian Borneo. We tested 4 main hypotheses:

- H1) Enrichment planting increases CC and ACD in logged tropical forests.
- H2) Removal of lianas increases CC and ACD in logged tropical forests through competitive release.
- H3) Higher diversity of planted trees increases CC and ACD by promoting greater levels of natural regeneration.
- H4) Enrichment planting increases CC and ACD in logged tropical forests relative to background topographic variation.

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The Sabah Biodiversity Experiment

SBE is restoration experiment covering 500-ha of logged forest in Sabah⁶. 124 plots (4-ha) were assigned one of three treatments: unplanted (control), enrichment planting (using different combinations of 16 native tree species), or enrichment planting with liana cutting. Danum valley is a conservation area of primary forest, with similar environmental conditions to SBE.

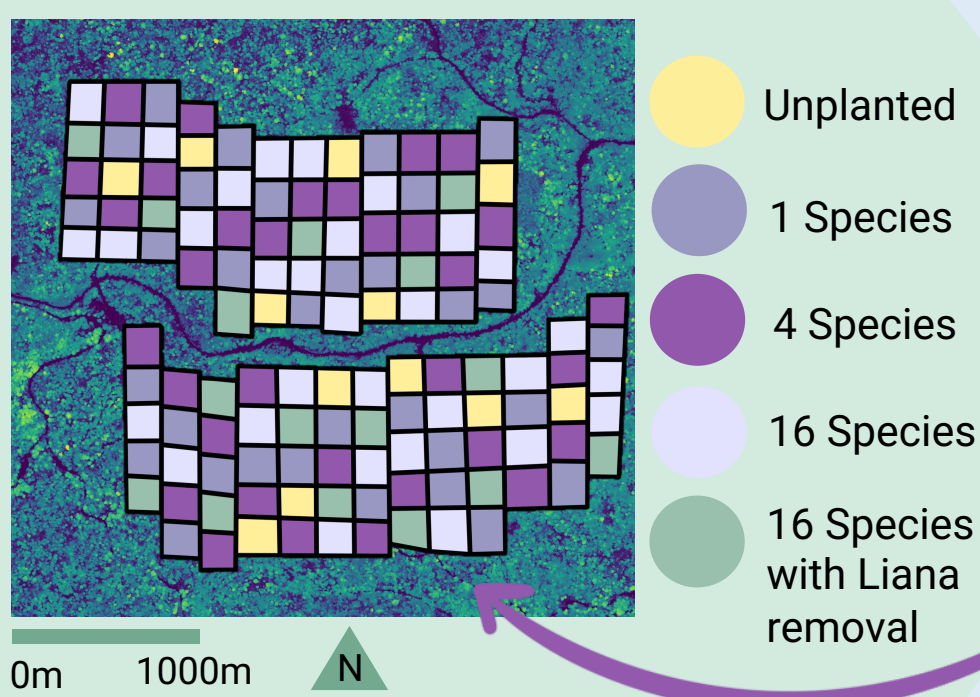
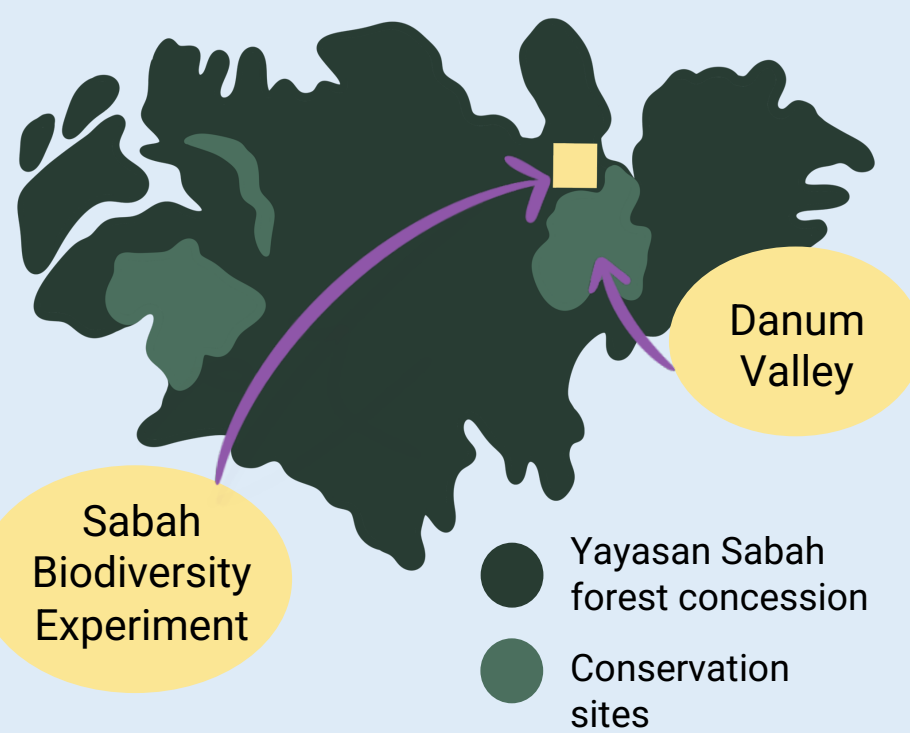


Fig. 1: SBE experimental plots on a 2013 Canopy height model.



Methods

Airborne LiDAR data were acquired in 2013 and 2020. Using these, we calculated rates of CC and ACD accumulation over this 7-year period. ACD was estimated from the LiDAR data using a regional model developed in 2018⁷.

H1) Enrichment Planting

Planted plots showed only a very small increase of in ACD gains (0.5 Mg C/ha/yr) compared to control plots. Planting also had no significant impact on CC, with planted plots only increasing CC by 0.2%/yr compared to controls. Site had no effect on ACD or CC with no significant difference between SBE and Danum (Fig. 2).

H2) Liana Cutting

Liana cutting in planted plots had a profound impact on rates of ACD accumulation (+ 3.2 Mg C ha⁻¹ yr⁻¹ relative to controls and +2.45 Mg C ha⁻¹ yr⁻¹ compared to Danum). Liana removal also significantly affected CC rates, gaining 0.9%/yr more CC than both controls and Danum (Fig. 2).

H3) Species Richness

The only significant differences in ACD change due to species richness across SBE plots was between the 16 species plot and the 1 species plot, with the former gaining 1.2 Mg C/ha/yr than the controls. For CC, significant increases were observed between 16 species and control, and 16 species and monoculture, with increases of 0.5%/yr and 0.3%/yr for the 16 species mix respectively.

H4) Topography

We used HAND (height above nearest drainage) as a measure of topographic variation. CC and ACD change on ridges was 1.0%/yr and 2.9 Mg C/ha/yr slower than near rivers, respectively. The effects of local topography were similarly important in determining changes in both ACD accumulation and CC as restoration treatments (Fig. 3).

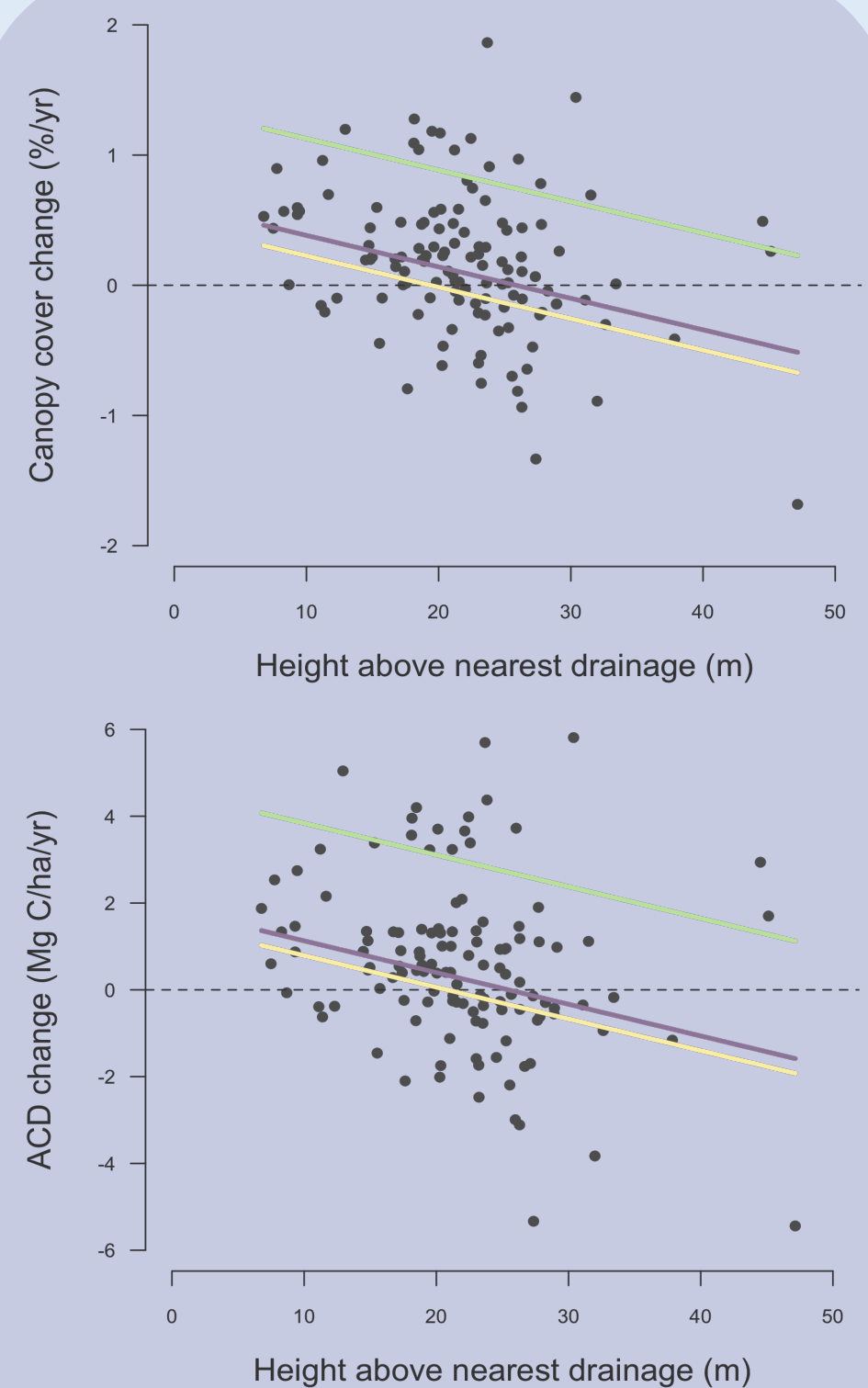


Fig 3. ACD and CC change per year in relation to topographic metric HAND. Colours correspond to treatments as in Fig. 2.

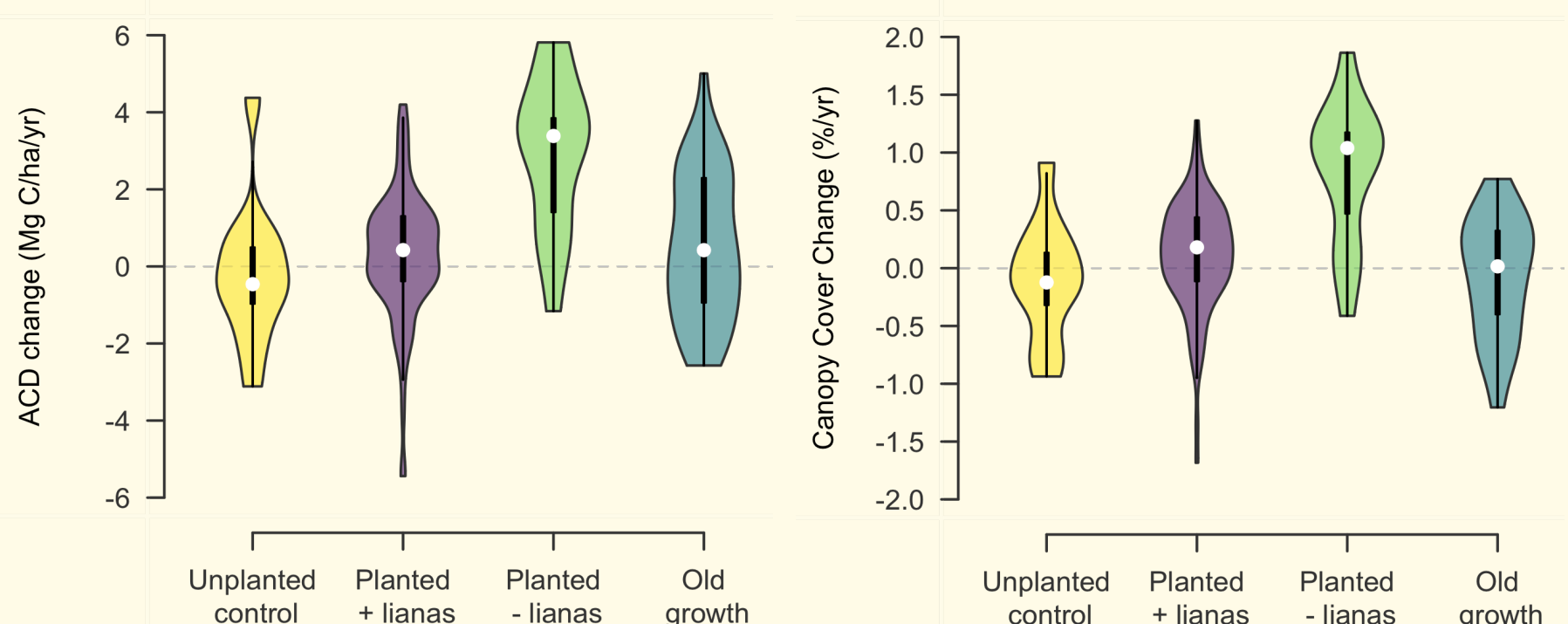


Fig. 2: ACD and CC change between 2013 and 2020 for different treatments.

Conclusions

- 1) Enrichment planting alone had little effect on ACD or CC, though highly diverse mixtures had better restoration outcomes than monocultures.
- 2) Removing lianas had a large positive effect on both CC and ACD, but this practice should be investigated thoroughly before widespread use.
- 3) We found large variation in the rates of ACD and CC linked to topography, and this must be accounted for when assessing restoration success.