CARBON PAYMENT STRATEGIES IN COFFEE AGROFORESTS SHAPE CLIMATE AND BIODIVERSITY OUTCOMES

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CONTEXT

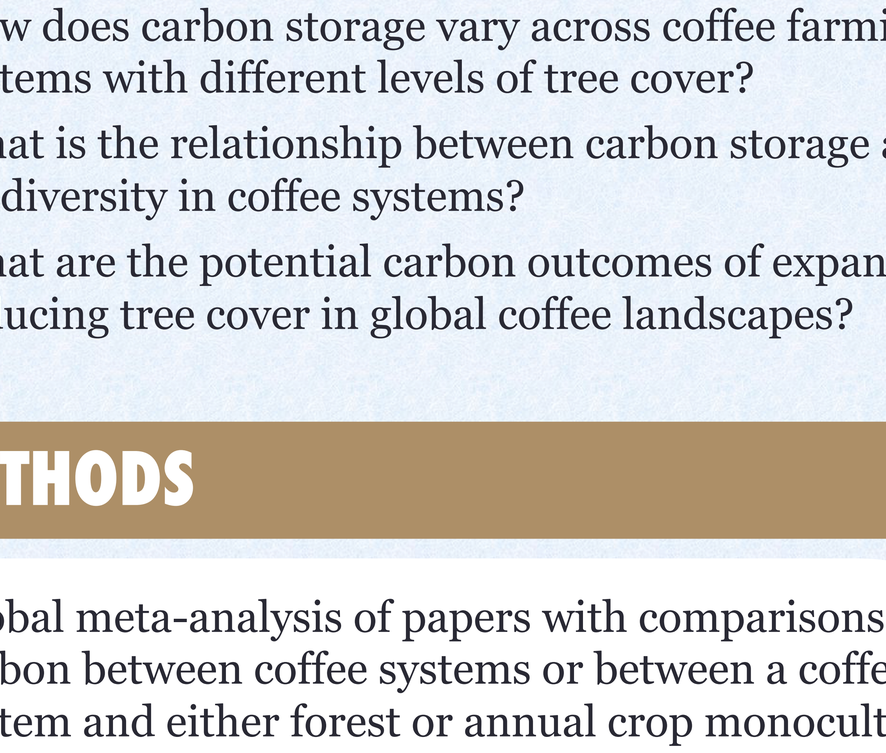
- Agroforestry offers climate and biodiversity benefits, but farmers often face financial pressures to remove trees, limiting its adoption without incentives.
- Carbon payment programs aim to support agroforestry by incentivizing either 1) tree planting or 2) conservation of existing tree cover.
- Protection of existing agroforests may deliver greater climate and biodiversity benefits than tree planting, yet the latter is often prioritized in supply chains.
- Coffee farming systems offer a global case study to evaluate the effectiveness of these strategies for maximizing carbon storage and biodiversity.

RESEARCH QUESTIONS

- How does carbon storage vary across coffee farming systems with different levels of tree cover?
- What is the relationship between carbon storage and biodiversity in coffee systems?
- What are the potential carbon outcomes of expanding or reducing tree cover in global coffee landscapes?

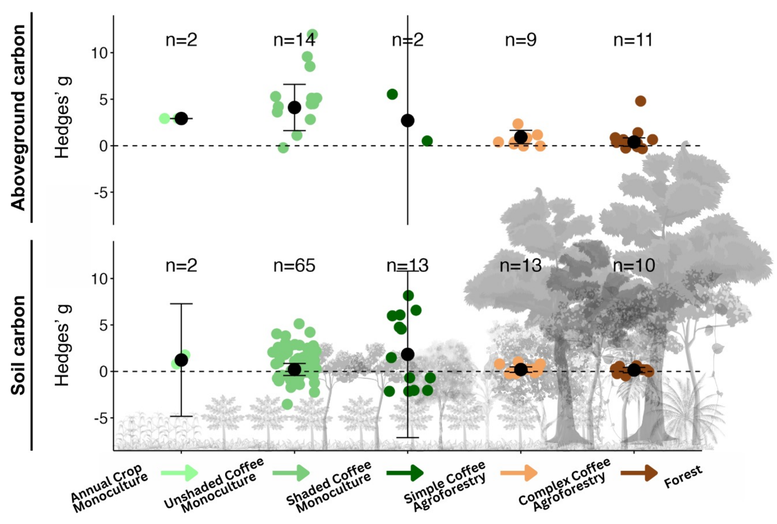
METHODS

- Global meta-analysis of papers with comparisons of carbon between coffee systems or between a coffee system and either forest or annual crop monocultures
- 67 papers included, with aboveground (n=242), soil (n=287), litter (n=133), and coarse woody debris (n=24) carbon measurements

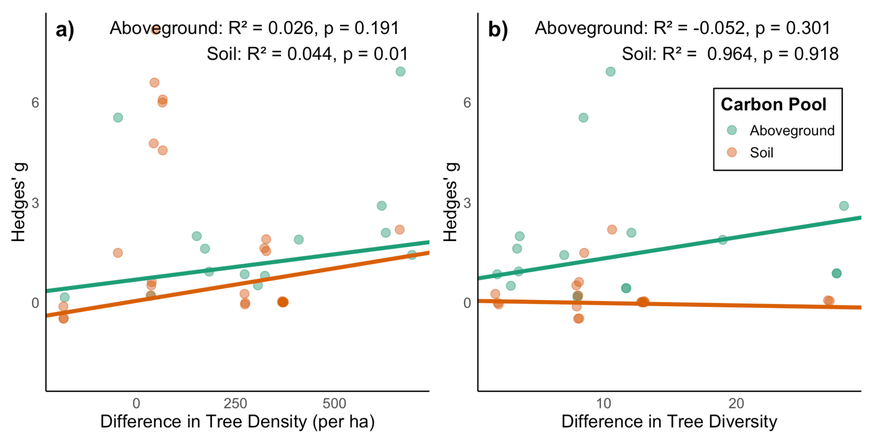


Top: Global distribution of studies included in this meta-analysis. **Bottom:** Count of measurement sites representing each of six land management systems spanning the vegetation complexity gradient of coffee farming landscapes within the included studies.

RESULTS



Adding trees to the least complex coffee systems—like unshaded monocultures—offers the greatest gains in aboveground carbon, while increases taper off as systems become more complex. The above figure shows the effect size (Hedges' g) with 95% confidence intervals (CIs) for sequential carbon comparisons across a management gradient of complexity. Positive values indicate the more complex system has greater carbon, with significance inferred when CIs do not overlap zero.



Tree density—but not tree diversity—was modestly associated with higher carbon stocks, suggesting carbon-focused programs may not reliably deliver biodiversity benefits without explicit design. The above figure shows the effect size differences in stored carbon (Hedges' g) for comparisons of coffee monoculture to coffee agroforests plotted against the difference in a) tree density and b) tree diversity between systems.

Potential global carbon losses from shade tree removal are likely more than double the gains from tree planting in coffee. Table (below) shows the estimated global aboveground carbon stock in coffee systems under scenarios of coffee agroforestry adoption and intensification. Agroforestry adoption scenarios assume conversion of monocultures to simple agroforestry, as complex agroforestry here is defined by the presence of remnant forest trees. Scenarios hold total global coffee land use constant.

Scenario	Aboveground Carbon (TgC)	SE (TgC)	Change from baseline (%)
Baseline: Current estimated global coffee aboveground carbon stock	481.59	123.11	0.00
Agroforestry adoption scenarios			
Scenario 1: All unshaded monoculture coffee becomes shaded monoculture coffee	568.09	159.37	+17.96
Scenario 2: All unshaded monoculture coffee becomes shaded monoculture coffee, and all shaded monoculture coffee becomes simple coffee agroforestry	563.12	123.32	+16.93
Intensification scenarios			
Scenario 3: All coffee becomes unshaded monoculture	260.14	206.19	-45.98
Scenario 4: All complex coffee agroforestry becomes simple coffee agroforestry, and all shaded monoculture coffee becomes unshaded monoculture coffee	307.36	164.69	-36.18
Mixed scenario			
Scenario 5: All coffee becomes simple agroforestry	456.90	211.06	-5.13

KEY TAKEAWAY

To meet both climate and biodiversity goals, carbon payment programs in coffee supply chains must prioritize protecting existing agroforests—especially those with mature, diverse trees—alongside targeted tree planting initiatives.

WANT MORE INFO?

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