# Pretreatment carbon cycling assessment will aid detection of responses to elevated $CO_2$ in the AmazonFACE experiment

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# The AmazonFACE experiment has a long history

1991: Hal Mooney: "At minimum, [FACE] experiments should be undertaken in each of the world's six major biomes (tundra, boreal forest, temperate forest, **tropical forest,** grassland, and desert)." *BioScience* 41: 96-104

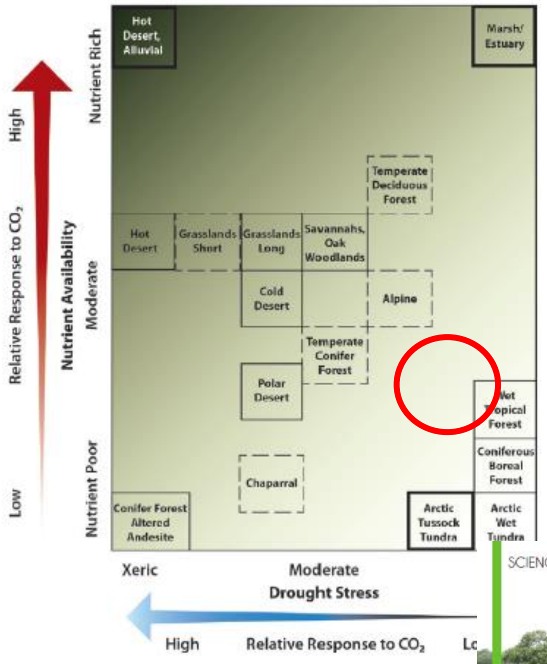
2011: A workshop in Manaus initiated consideration of a Free-Air $CO_2$ Enrichment (FACE) experiment in the Amazon forest

2013: Science community workshop, InterAmerican Development Bank, Washington DC, led to site selection and development of a science plan

2014: Postdoctoral researchers initiated measurements of tree growth, fine-root production, leaf demography, soil biogeochemistry, and model-data integration

2021: The UK Foreign, Commonwealth & Development Office, in coordination with the UK Met Office, Brazil's National Institute for Amazon Research, and the University of Campinus, announced at COP26 that AmazonFACE was now funded

2022: Construction of a two plots is currently underway, and a full, replicated experiment, with three $eCO_2$ (+200 ppm) and three control rings anticipated by late 2023




**How will rising atmospheric $CO_2$ affect the *resilience* of the Amazon forest, the *biodiversity* it harbors, and the *ecosystem services* it provides?**


(a)


(b)
Legend
ZF2-EEST
Venezuela
Suriname
Colombia
Equator
ZF2-EEST
Peru
Brazil
Amazon Forest Biome
Bolivia
Google Earth
Image Landsat / Copernicus
US Dept of State Geographer
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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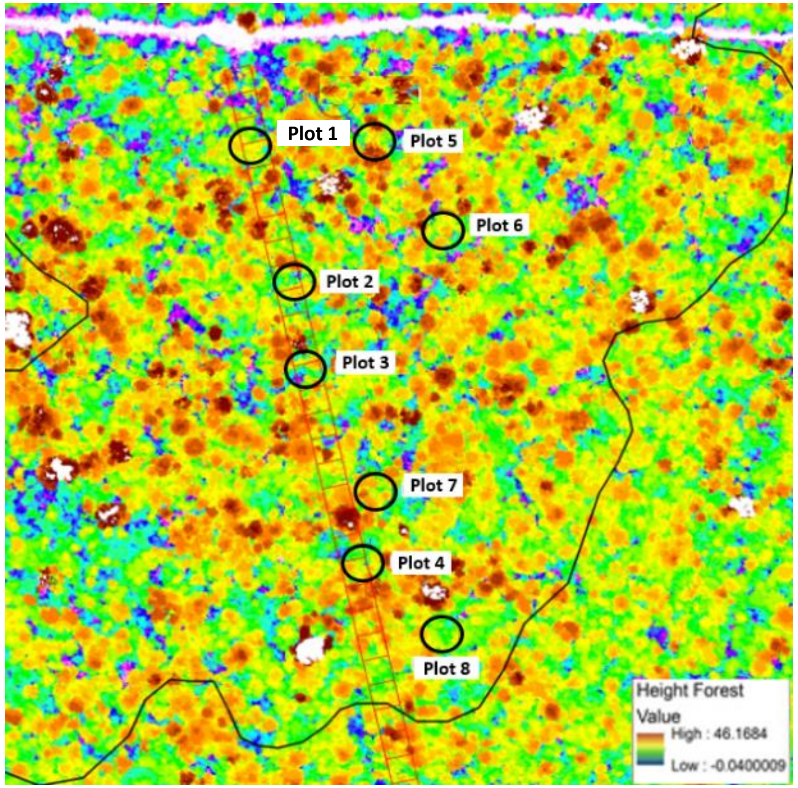
# A lightly replicated experiment in a highly heterogeneous environment requires strong pretreatment characterization




Eight 30-m diameter plots laid out, avoiding super dominant, emergent trees and gaps – a necessary simplification of the Amazon forest

Plots 1 and 2 instrumented for full characterization of net primary productivity, soil biogeochemistry, physiological processes, and species identity

21 families in plots 1 and 2, with 10 common to both plots

52 species, with just 5 common to both plots

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# Net Primary Productivity is a key metric for evaluating forest response to elevated $CO_2$

*NPP describes the rate at which all the autotrophs in an ecosystem produce net useful chemical energy available for heterotrophs in the food web*

Model-derived hypotheses:

Hickler (2008) – 35% increase in NPP of tropical forests in $eCO_2$

Fleischer *et al.* (2019) – P limitation reduces $eCO_2$ effect to 9%

Missing components

- coarse roots
- exudation
- volatiles
- insect herbivory
- fruit consumption

stem (wood) + leaf + flowers/fruit + fine roots





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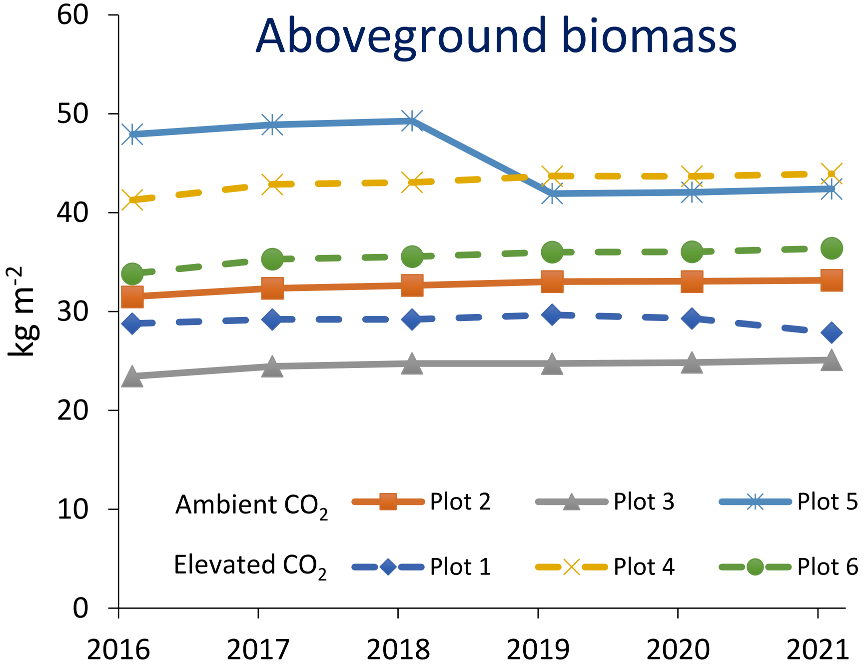
# Wood production

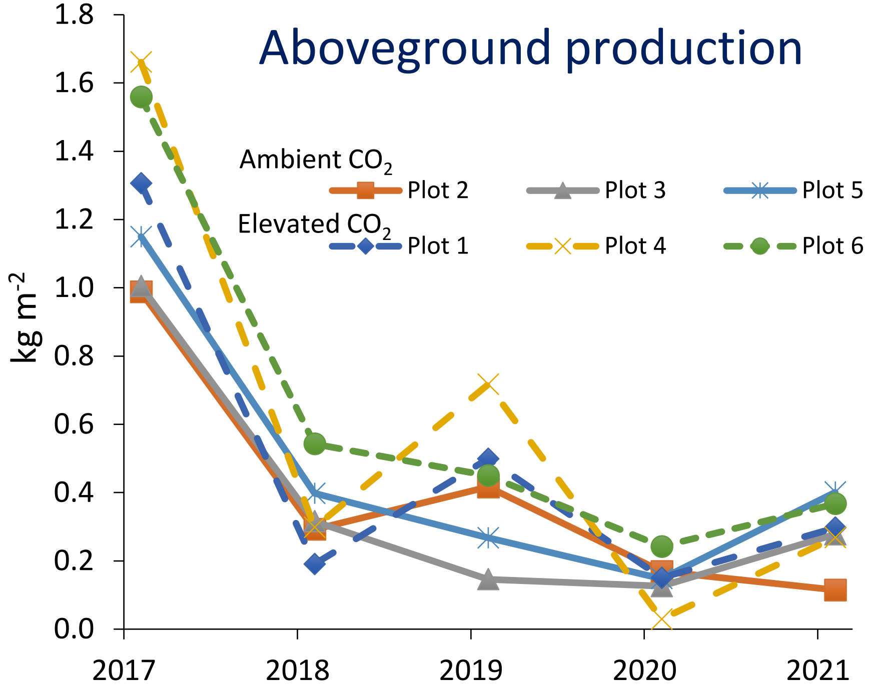
Tree diameter measured on all trees > 2 cm dbh in October in 6 plots (~1400 trees)

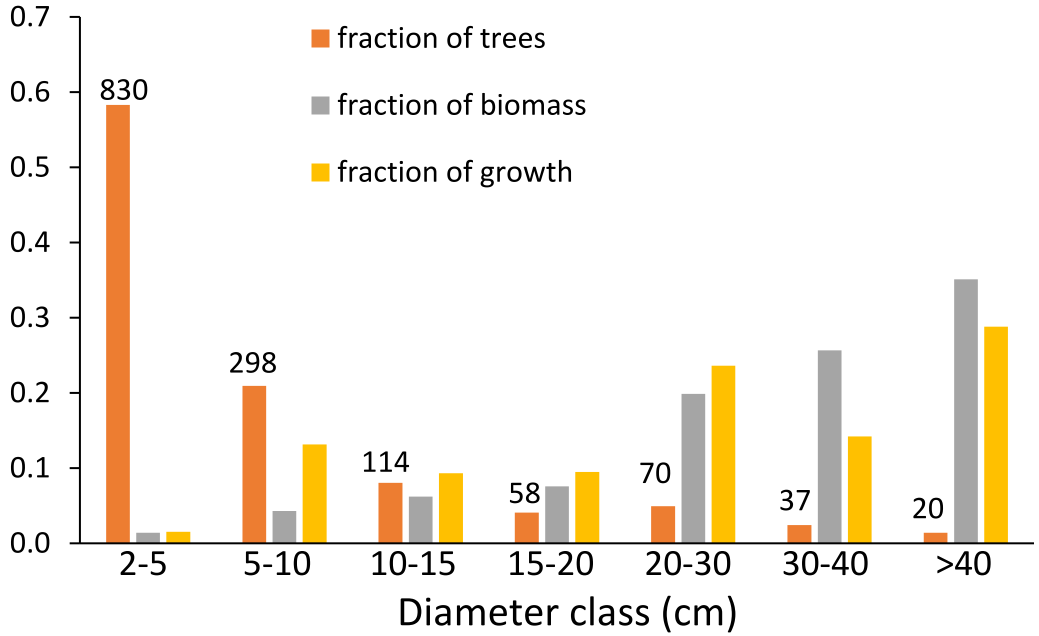
Tree mass calculated using allometric equation from Chave, including height when available, and wood density from wood density database

Wood production calculated as change in biomass over the year. Mortality calculated as tree mass in year prior to death.

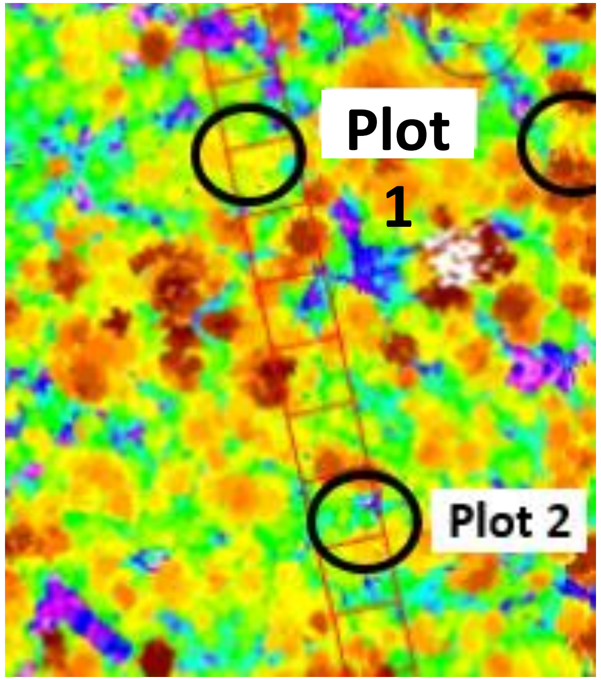
Coarse root production assume to be 21% of aboveground production (Malhi)

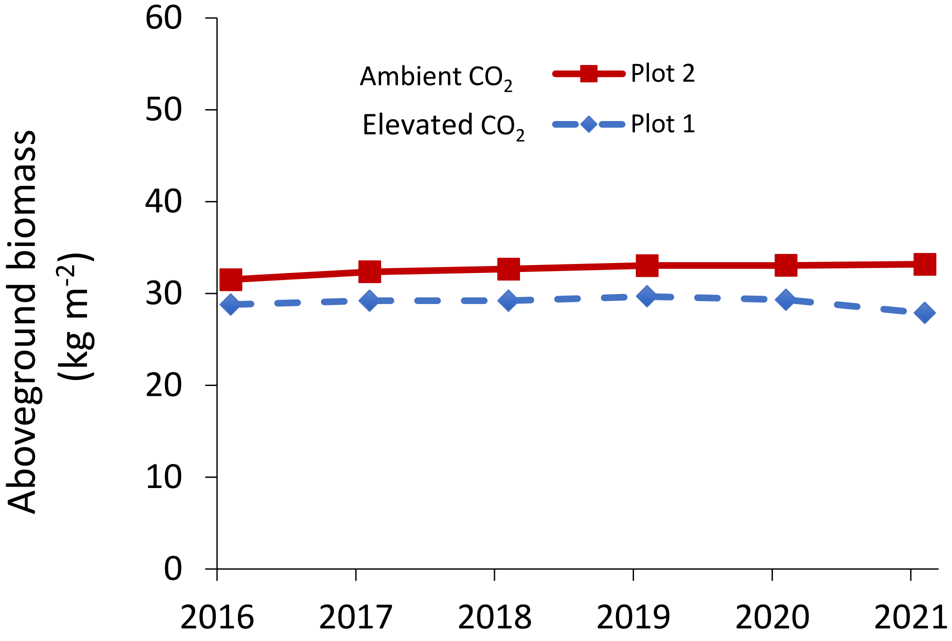


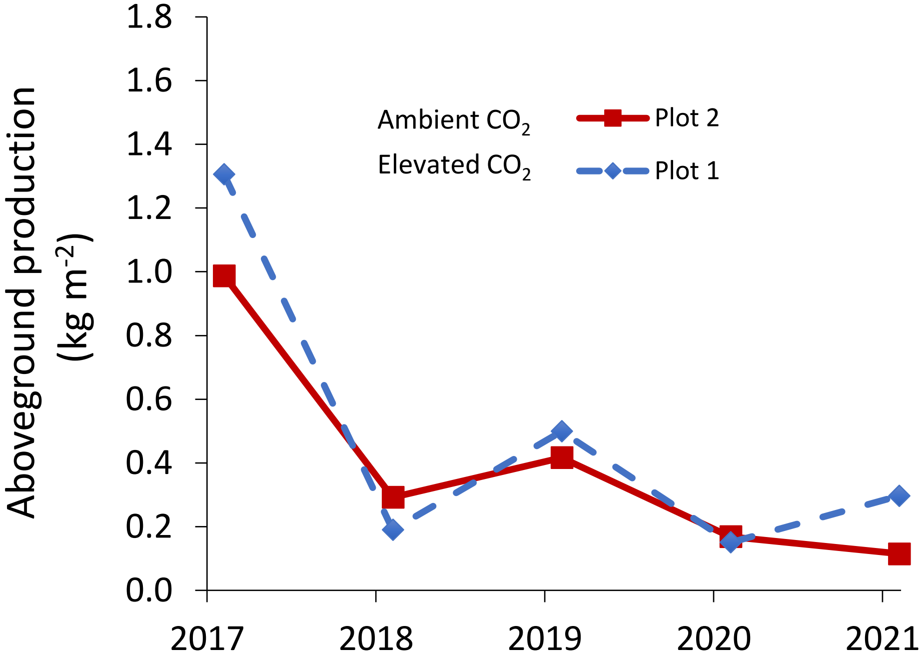




71% of biomass and 66% of production is in trees > 20 cm dbh




Plots 1 and 2 are fairly well matched, which should facilitate detection of a possible response to $eCO_2$ in plot 1

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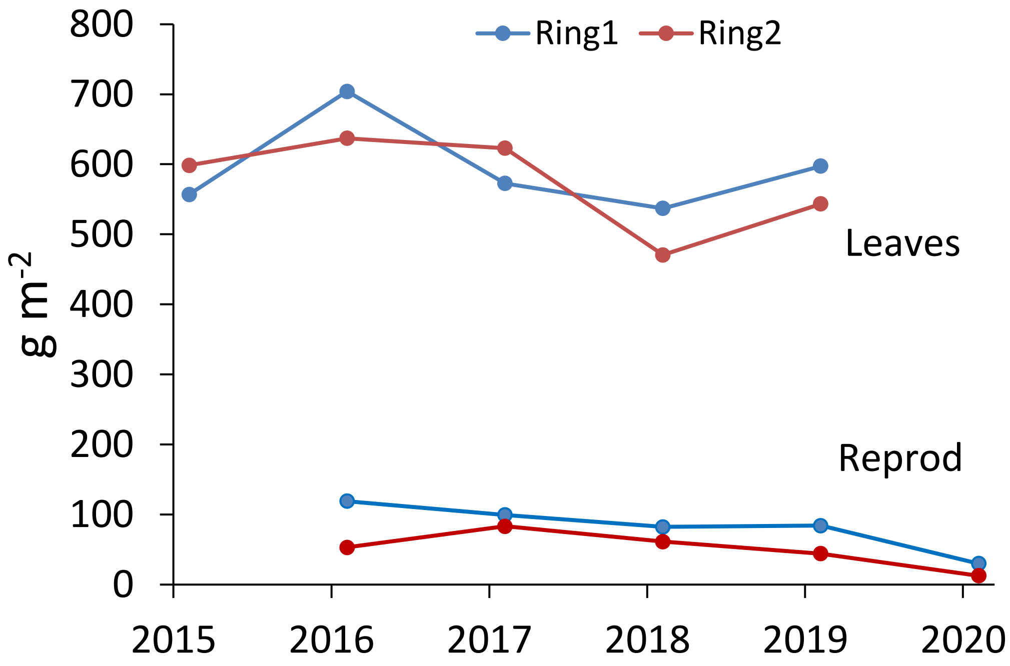
# Leaf production

Leaves, fruit, flowers, and twigs collected biweekly from 12 0.25-m2 litter baskets per plot, oven-dried and weighed

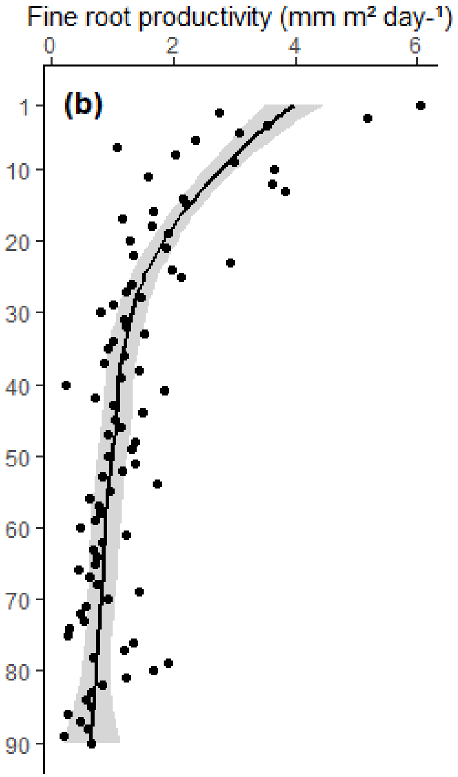
Assume litter fall represents previous year's leaf production, based on careful tracking of leaf phenology

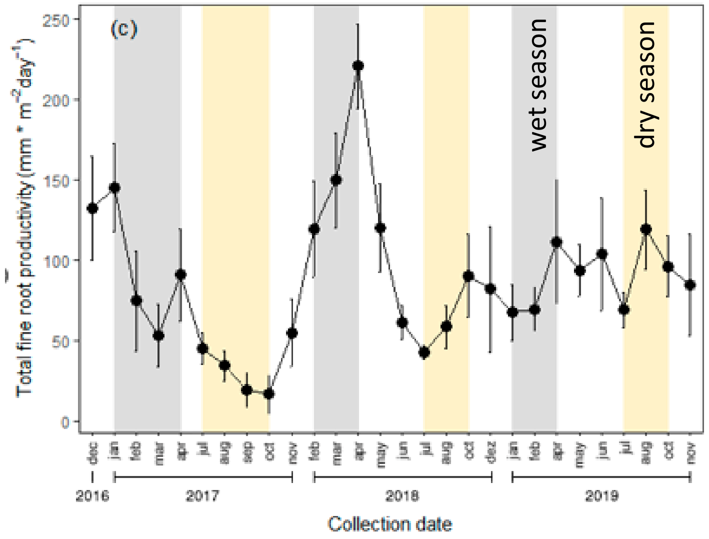
Total for year (October 1 – September 30) corrected for change in mass per area of green leaves vs litter (1.4%)

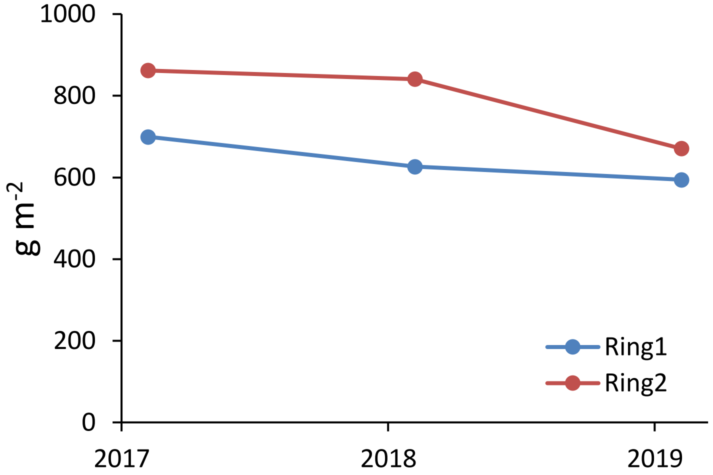




# Fine-root production



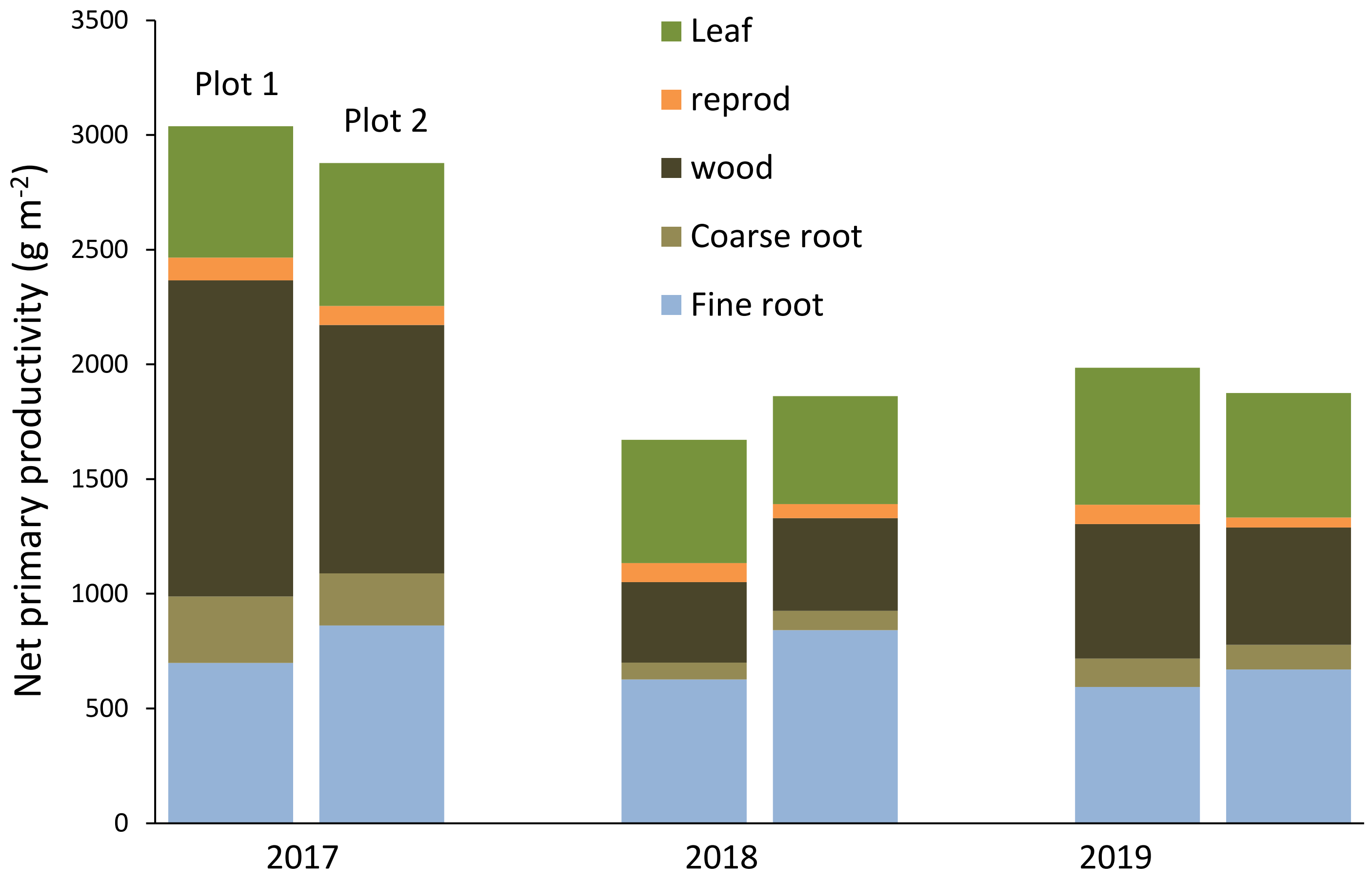




| Depth | Fraction of standing stock | Fraction of productivity | Turnover (year-1) |
|---|---|---|---|
| 0-30 | 0.51 | 0.60 | 1.02 |
| 30-60 | 0.38 | 0.26 | 0.61 |
| 60-90 | 0.12 | 0.13 | 0.40 |

Miron AC. 2022 Fine root dynamics in a Central Amazon rainforest: Interactions with soil depth, climate and litterfall production. MS thesis. INPA.

Cordeiro AL et al. 2020. Fine-root dynamics vary with soil depth and precipitation in a low nutrient tropical forest in the Central Amazonia. *Plant-Environment Interactions* 1:3-16

# Net primary productivity



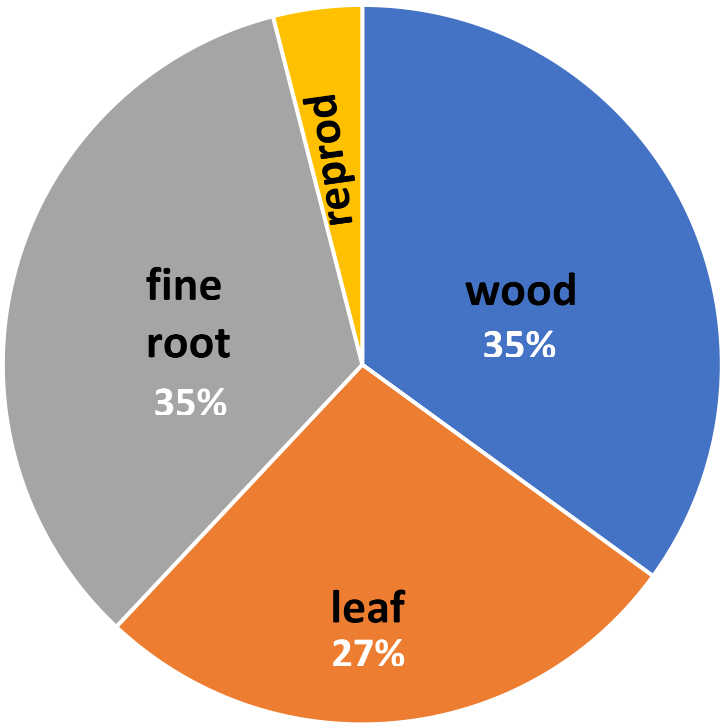

Boyd Strain & Fakhri Bazzaz

"…the initial effect of elevated $CO_2$ will be to increase NPP in most plant communities. …a critical question is the extent to which the increase in NPP will lead to a substantial increase in plant biomass. Alternatively, increased NPP could simply increase the rate of turnover of leaves or roots without changing plant biomass."

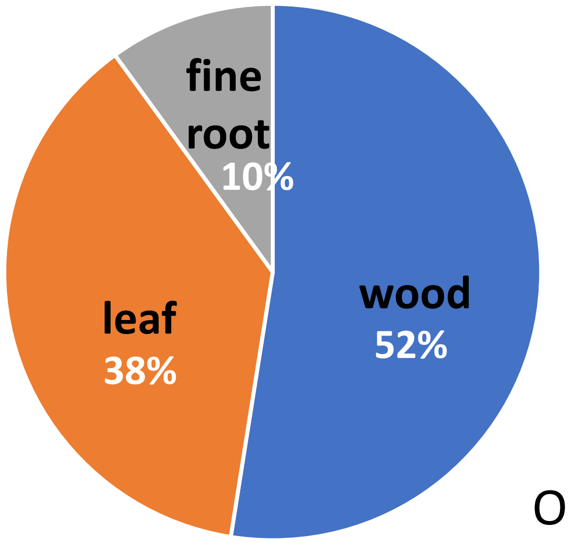
In Lemon ER. 1982. *$CO_2$ and Plants*

# Allocation to fine-root production is especially high at AmazonFACE

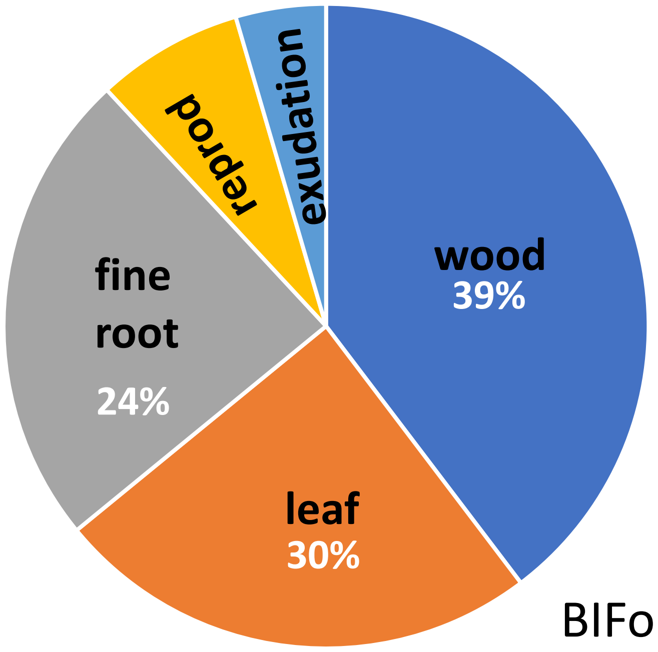
The distribution of NPP to leaves, wood, and roots controls carbon turnover, biogeochemical processes, and feedbacks between the tree and the environment




AmazonFACE
NPP=2049 g/m$^2$



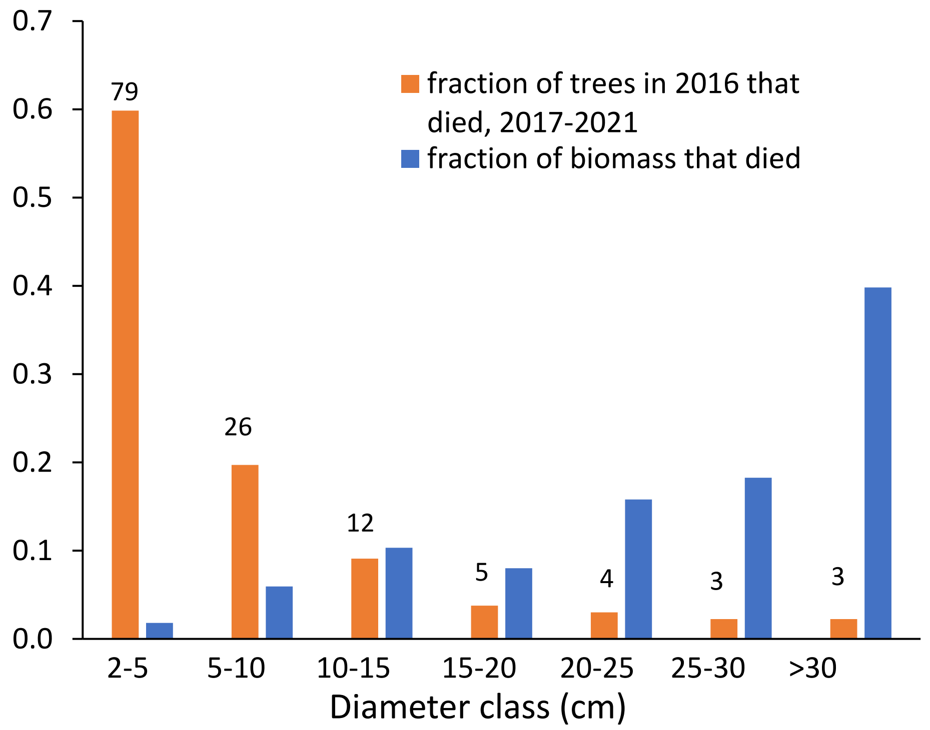

ORNL-FACE
NPP=1129 g/m$^2$




BIFoR
NPP=1743 g/m$^2$

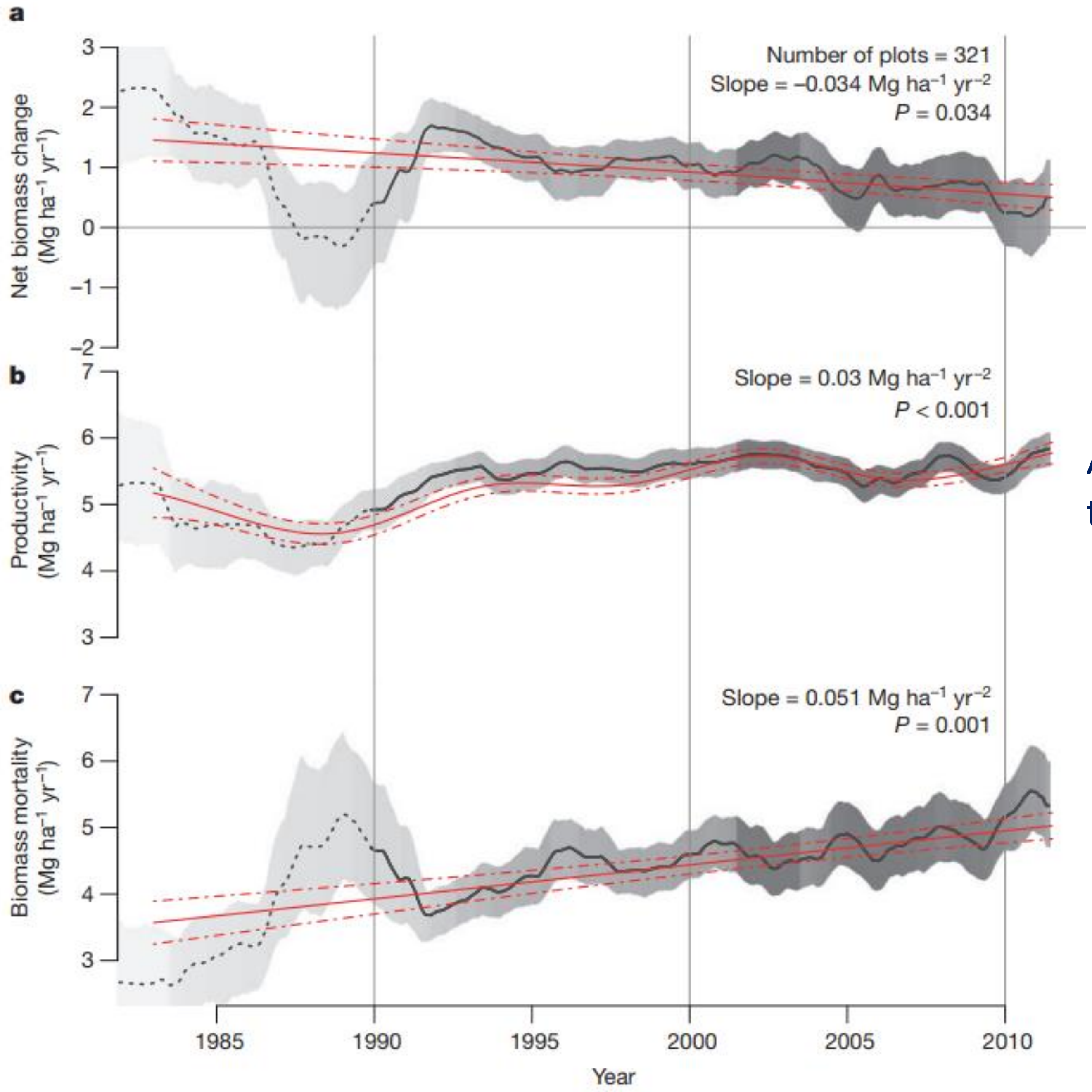
# Will NPP inform questions about carbon storage in the Amazon forest?

- Change in forest biomass = new production minus mortality
- In 2021, over 6 plots, tree biomass increased 1.72 g $m^{-2}$, but this was offset by tree mortality of 1.83 g $m^{-2}$, for a net loss of 0.11 g $m^{-2}$ in aboveground biomass
- 132 trees of the total alive in 2016 died in 2017-2021 (8.4% or 1.7% per year)
- 10 trees accounted for 74% of the lost biomass




## Implications

- Tree mortality occurs at a much larger spatial and temporal scale than our plot-scale measurements of NPP
- Prospective analyses of productivity responses to elevated $CO_2$ from Amazon FACE should be combined with retrospective analyses of basin-wide mortality




AmazonFACE can inform this part of the analysis

Brienen R *et al*. 2015. Long-term decline of the Amazon carbon sink. *Nature* 519: 344-348.

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# Conclusions

- The AmazonFACE experiment will assess responses to elevated $CO_2$ in a highly diverse and heterogeneous forest
- The pretreatment characterization we have described will be essential for detecting a response to $eCO_2$
- Those measurements are now being extended to all 6 plots
- We are excited to begin this long-awaited experiment!



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# Acknowledgements

We are grateful for the financial support from the UK Met Office

Many students, postdocs, and technicians participated in the measurements described here




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Met Office