Repeated disturbance in the Southern Yucatan: Biogeochemical and hydrological feedbacks on carbon and phosphorus cycling

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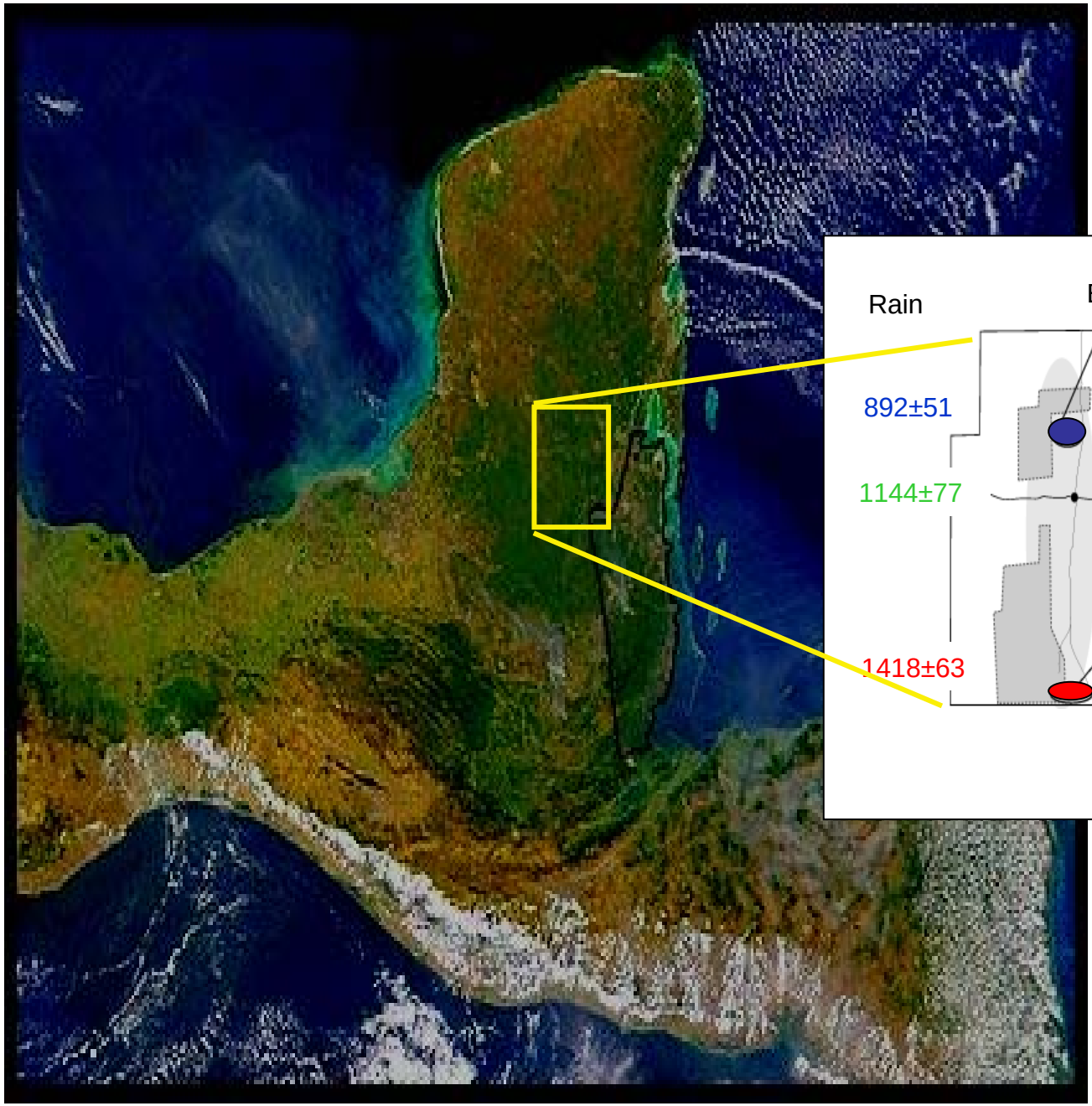
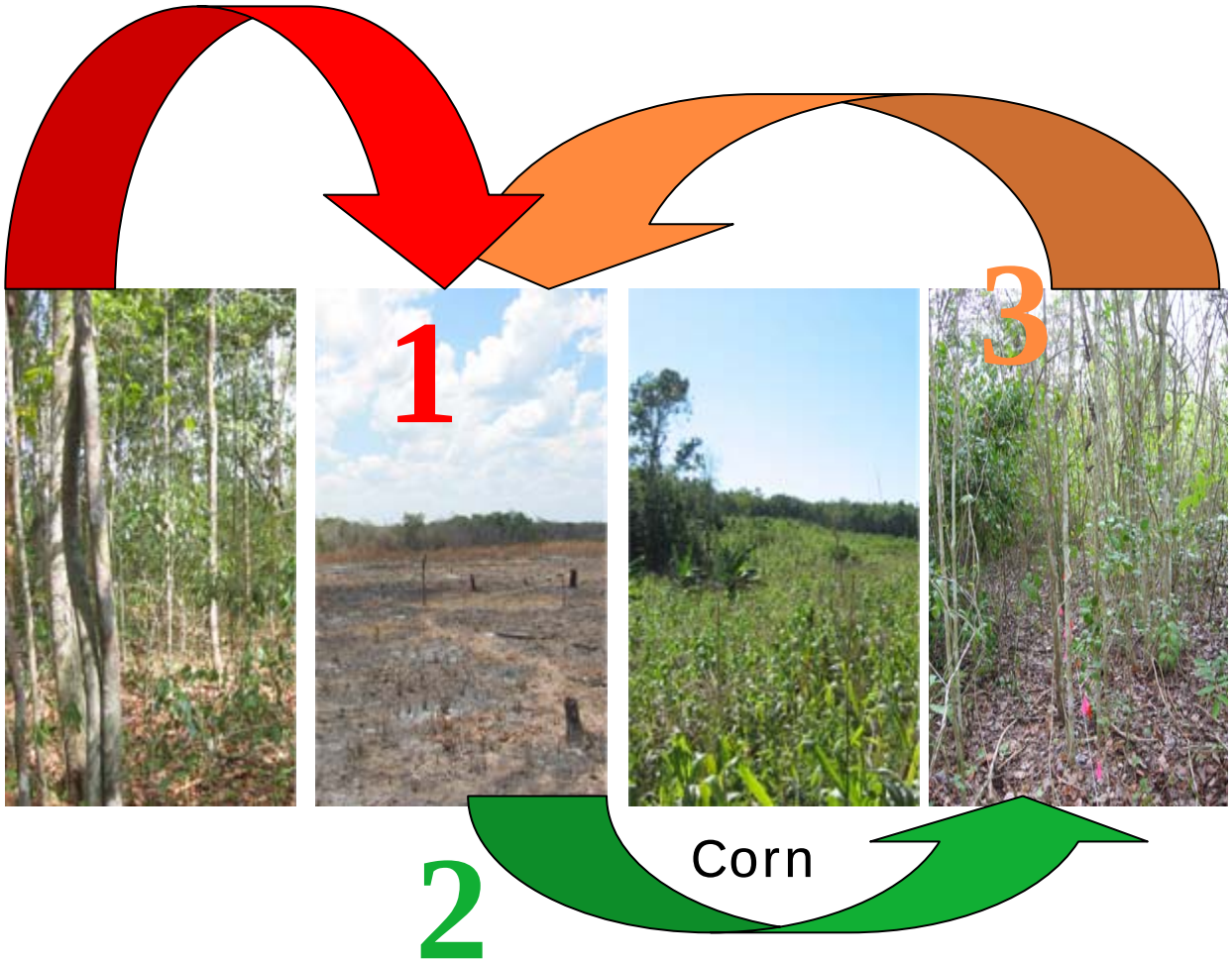
ABSTRACT

Shifting cultivation depends on using, retaining, and recycling nutrient inputs from biomass burning. We use a case study in the Southern Yucatan Peninsula Region (SYPR, Mexico) to examine the potential for positive feedbacks on nutrient loss in short-fallow, dry tropical forest systems. We draw from studies of soil phosphorus availability, biomass distribution, litterfall, throughfall and leaching to propose a conceptual model of catastrophic ecosystem shifts following deforestation.


Rain
El Refugio
892±51
Nicolas
Bravo
1144±77
Arroyo
Negro
1418±63
Mean Precipitation (mm/mo)
0
50
100
150
200
J F M A M J J A S O N D
Month

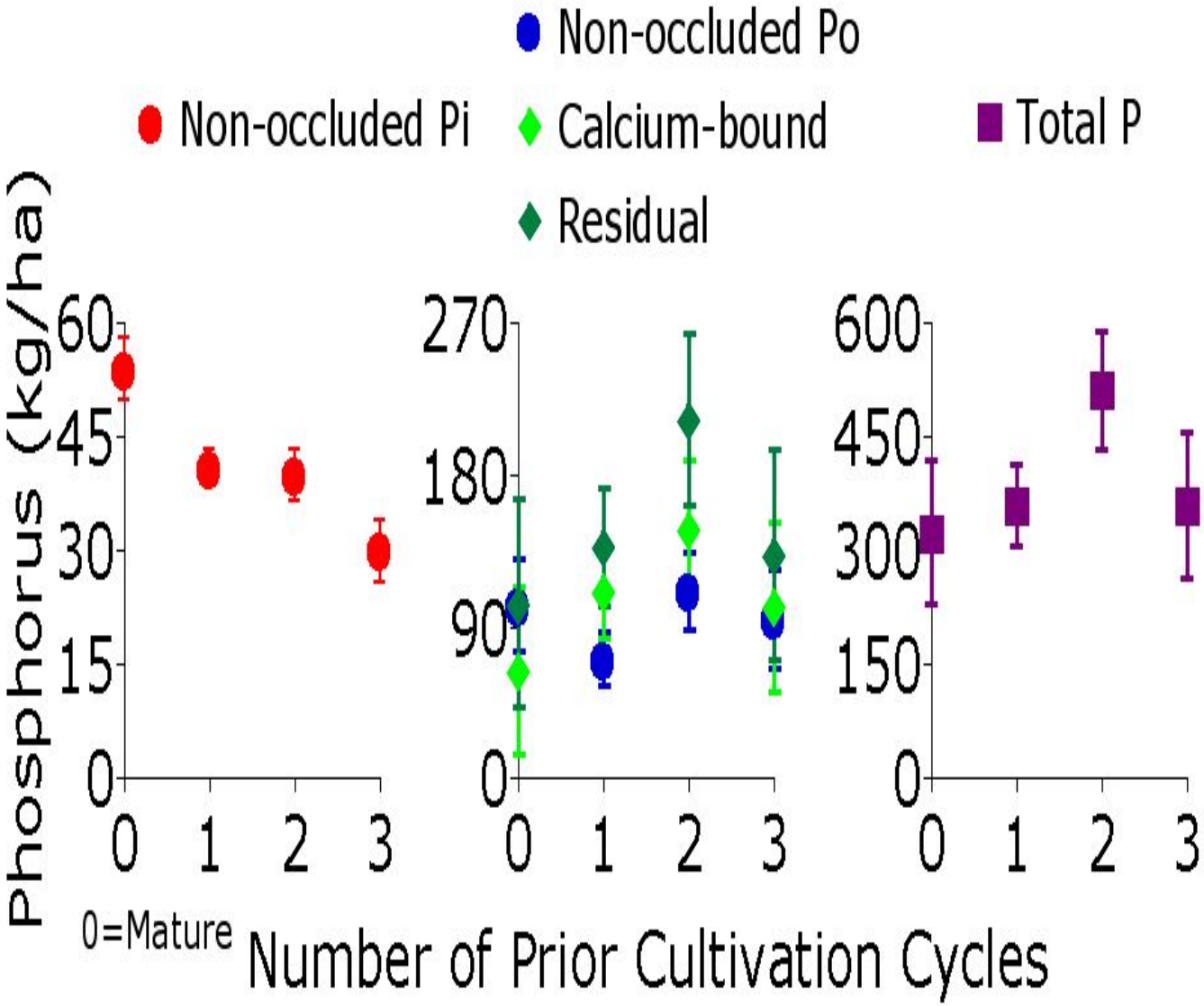
A cycle of shifting cultivation

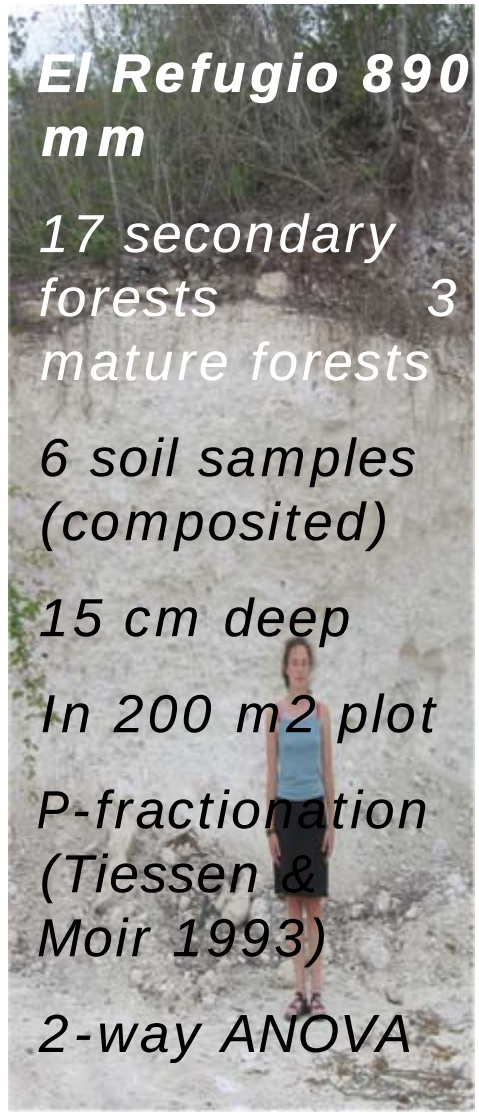


Is P availability enhanced beyond the first cycle?

Does P deposited in the initial burn remain in the system?

Available (non-occluded) P declines significantly by the third cycle of shifting cultivation (below). Some of the P mobilized by biomass burning appears to move into less-available forms. Total P does not vary significantly among mature and secondary forest following one to three cycles. Thus far, P seems to be conserved. However, the data suggest a potential for decline after the second cycle.

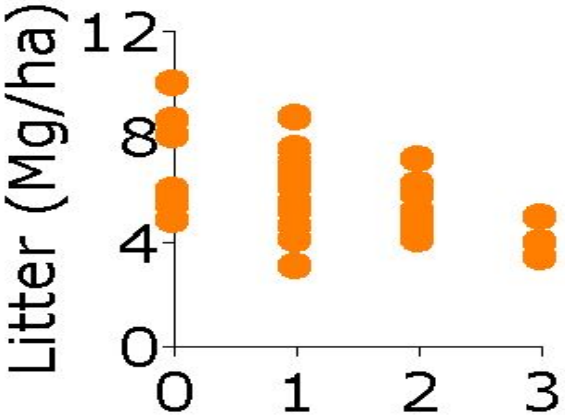

Non-occluded Po
Non-occluded Pi
Calcium-bound
Total P
Residual
Phosphorus (kg/ha)
60
45
30
15
0
270
180
90
0
600
450
300
150
0
0 1 2 3
0 1 2 3
0 1 2 3
0=Mature
Number of Prior Cultivation Cycles

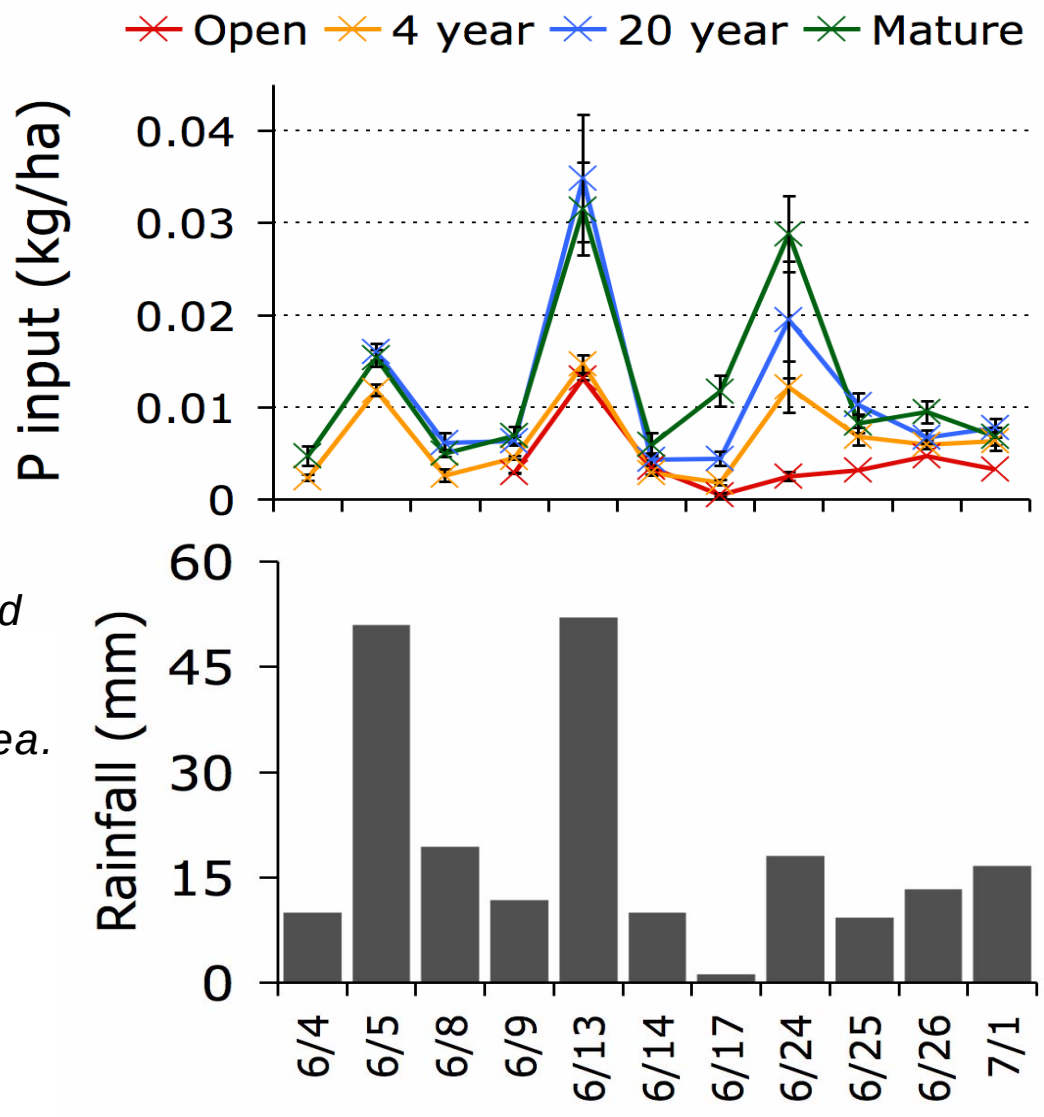

El Refugio 890 mm
17 secondary forests 3 mature forests
6 soil samples (composited)
15 cm deep
In 200 m2 plot
P-fractionation (Tiessen & Moir 1993)
2-way ANOVA

Do recurrent nutrient inputs decline in secondary forest?

Litterfall declines significantly with each cycle of cultivation (below), and with it, phosphorus inputs. Also, long-term, external inputs of throughfall P from dust and biomass burning decline by ca. 50% in young secondary forests, most likely as a result of lower leaf area and a decline in canopy P trapping.

Lower P inputs from litter and atmosphere





El Refugio 890 mm

Open field, 4 yr, 20 yr, and mature forest

14 throughfall collectors (ea. 716 cm2)

1 month Onset of wet-season

Inorganic, dissolved P

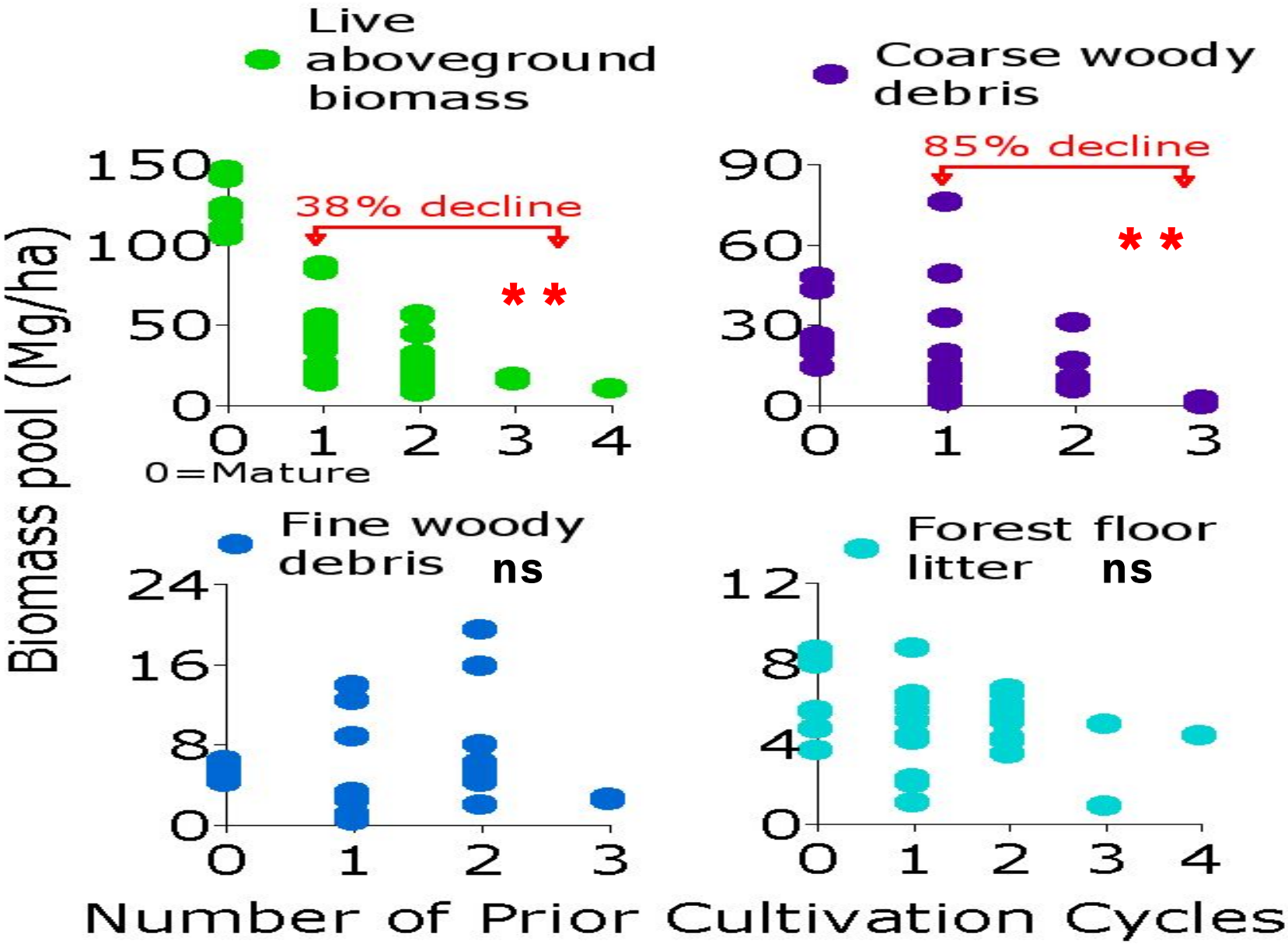
Rep. Meas. ANOVA

How do nutrient pools in biomass vary over many cycles?

Response and feedback on nutrient cycling

Live aboveground biomass (LAB) and coarse woody debris (CWD) decline significantly—38% and 85%, respectively—from the first to the third cycle (below). Decline in live biomass may reflect decreasing P availability. Much CWD is left after an incomplete, first burn. Subsequently, secondary forest produces very little CWD diminishing the pool in the second and third cycles. LAB and CWD are the two largest pools contributing nutrients following the burn. Shrinking pools of LAB and CWD feedback on crop and forest productivity from cycle to cycle by lowering nutrient inputs during the burn.

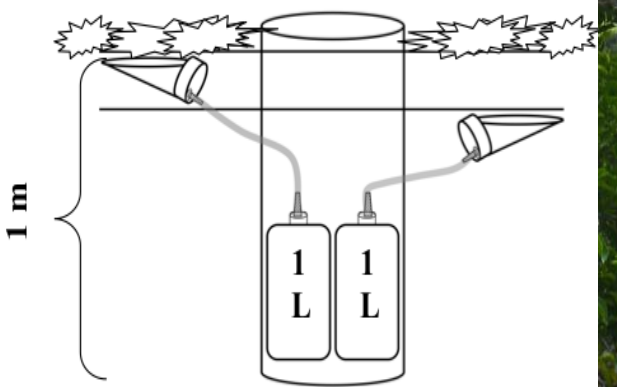
Decline in biomass accumulation and thus nutrient inputs from biomass



Is secondary forest leakier than mature forest?

Are nutrient outputs higher after deforestation?

Leachate P in deep samples (below the root zone) declined significantly with forest age (below). The difference between deep [P]D and shallow [P]S leachate also indicated potential losses from young secondary forests and recapture, or conservation, in mature forests. Secondary forest is potentially losing more P than mature forest.



Subsurface

Root zone

El Refugio to Zoh Laguna 890 mm

6 matched pairs of secondary and mature forest

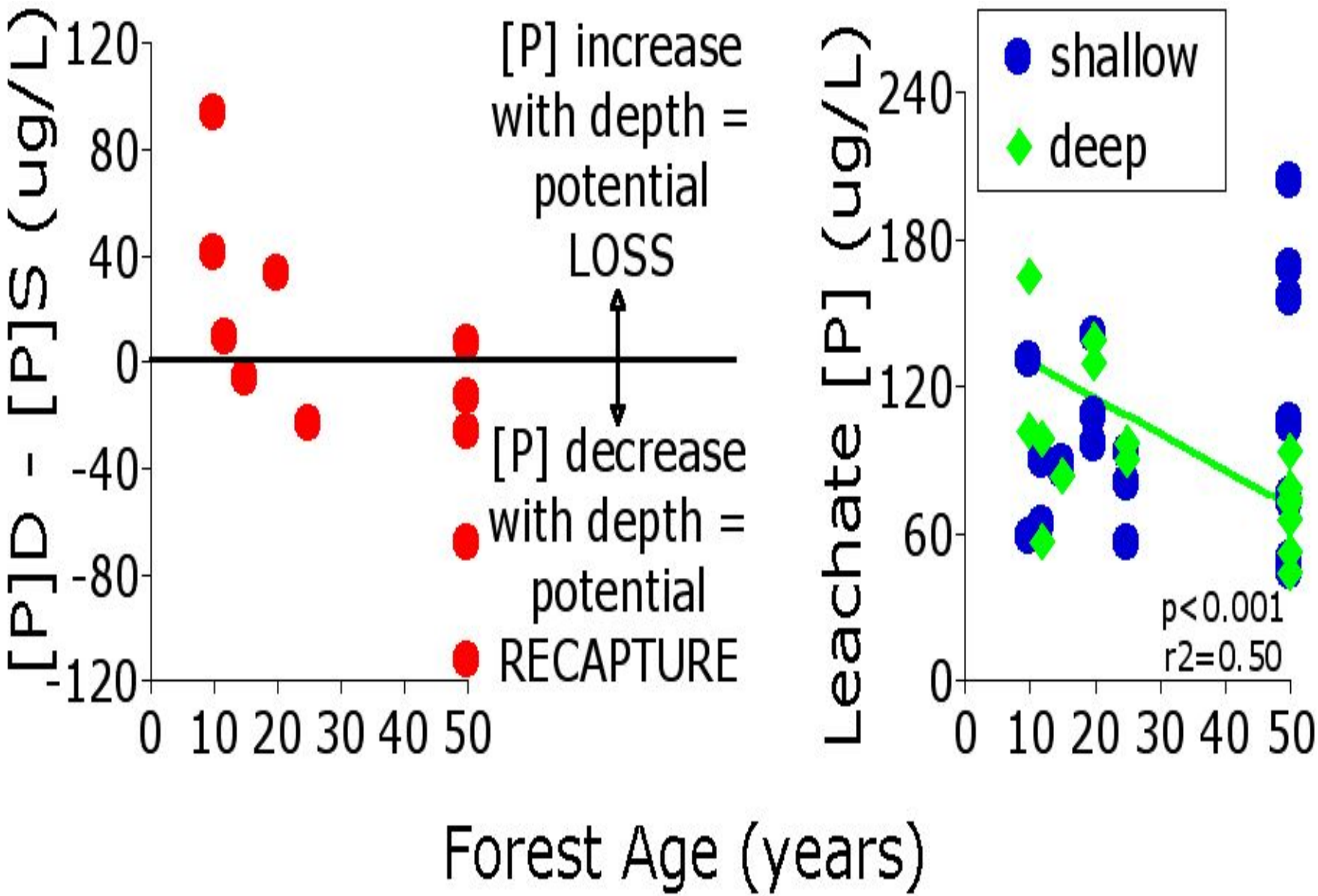
2 shallow, 2 deep no-tension lysimeters

Collections every 2-4 weeks of the entire wet-season

Inorganic, dissolved P

Regression

Lower potential P losses from older forest



Conclusions: *Potentially catastrophic feedbacks on carbon and phosphorus cycling*

Declining soil P availability over many cycles seems to limit biomass accumulation, which results in a positive feedback by decreasing P inputs from biomass-burning and from litterfall. Smaller forests trap less P from the atmosphere and potentially lose more through leaching, exacerbating the decline in the size of the internal P cycle following deforestation. With time, forest recovery may be severely impeded, resulting in conversion to shrublands. The impact on farmers and ecosystem processes could be large.

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