The Future of the Global P Cycle: Nutrient Limitation, Soils and Biofuel Production in the Tropics

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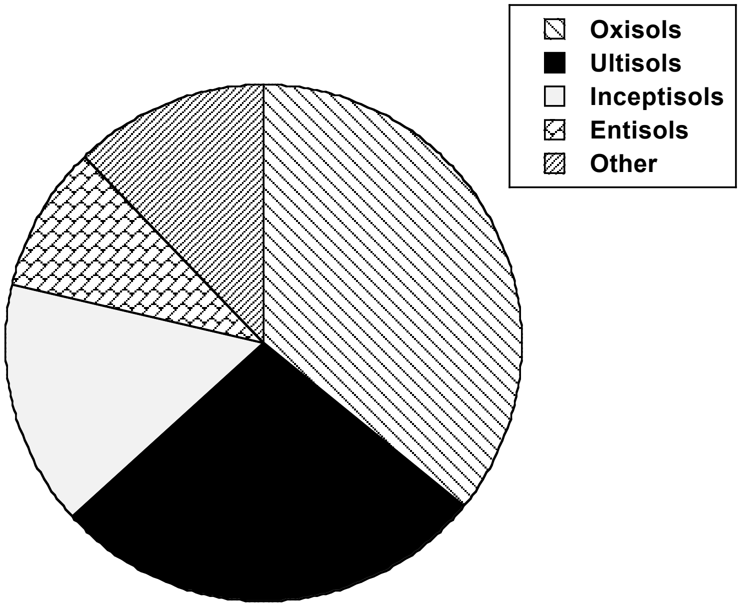
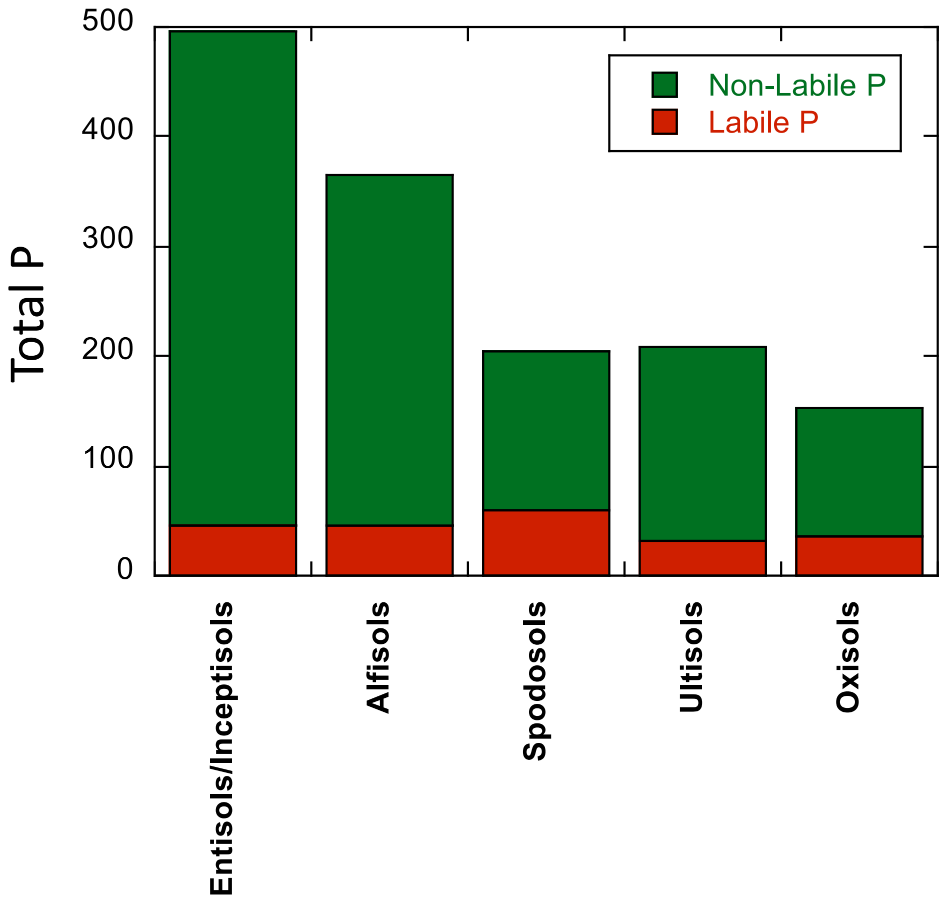
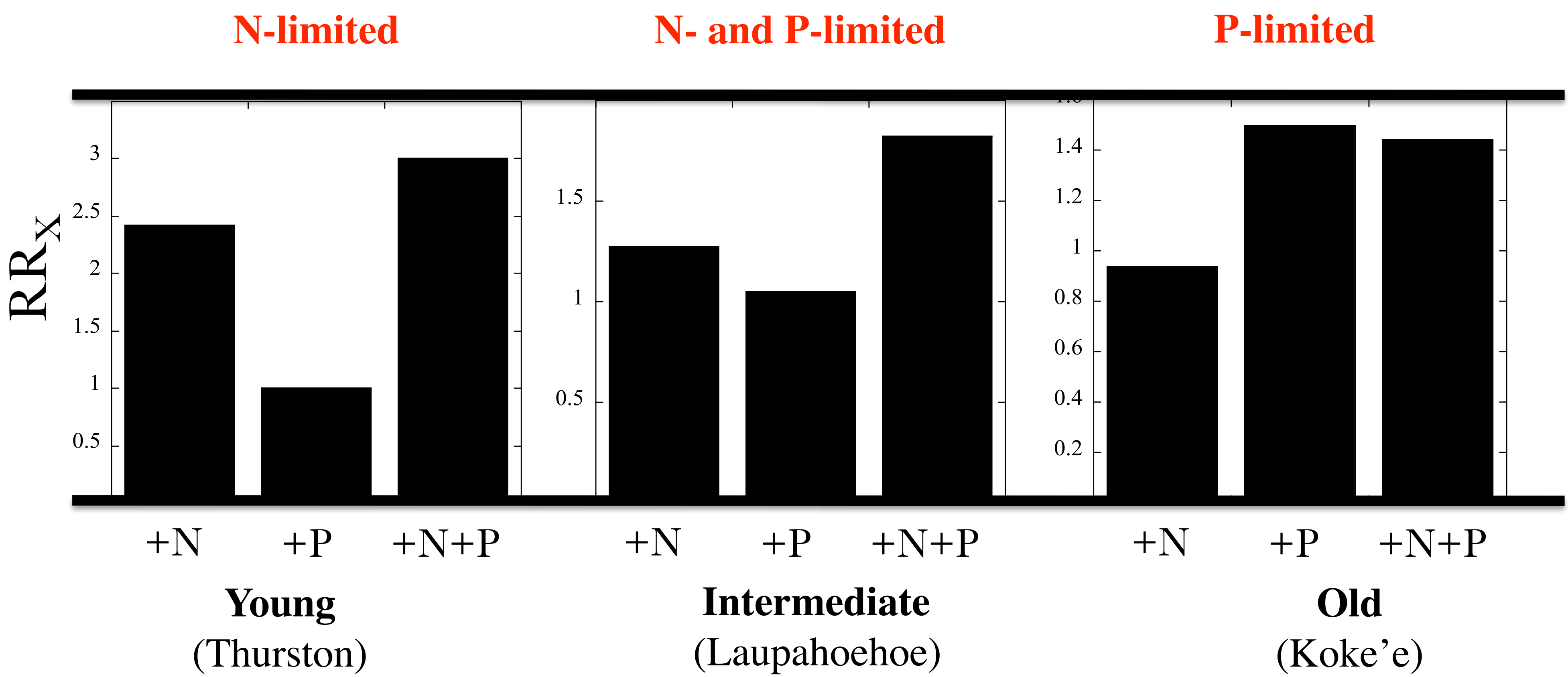
P Limitation Appears to be Widespread in Much of the Humid Tropics

Indirect Evidence



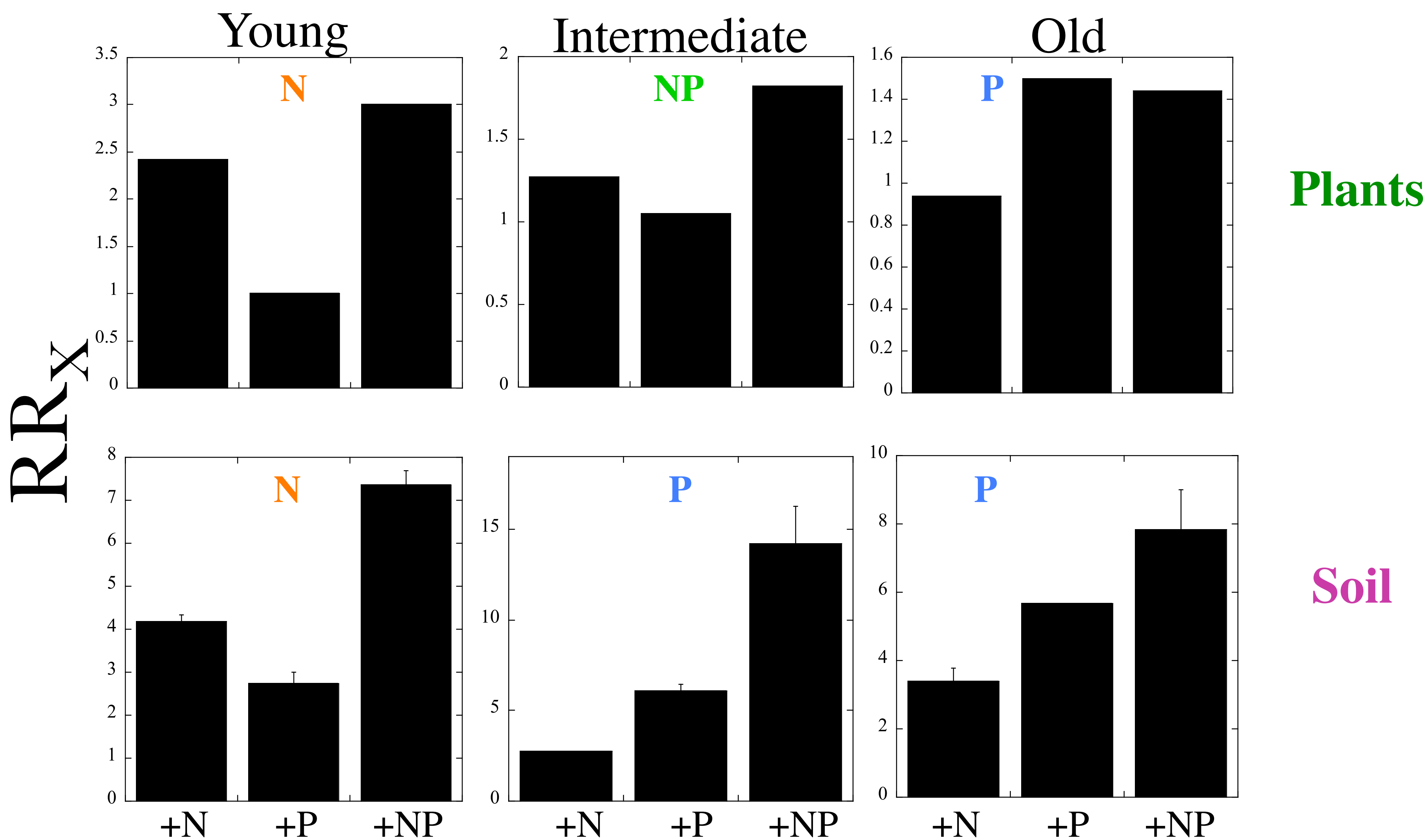


Direct Evidence of P Limitation

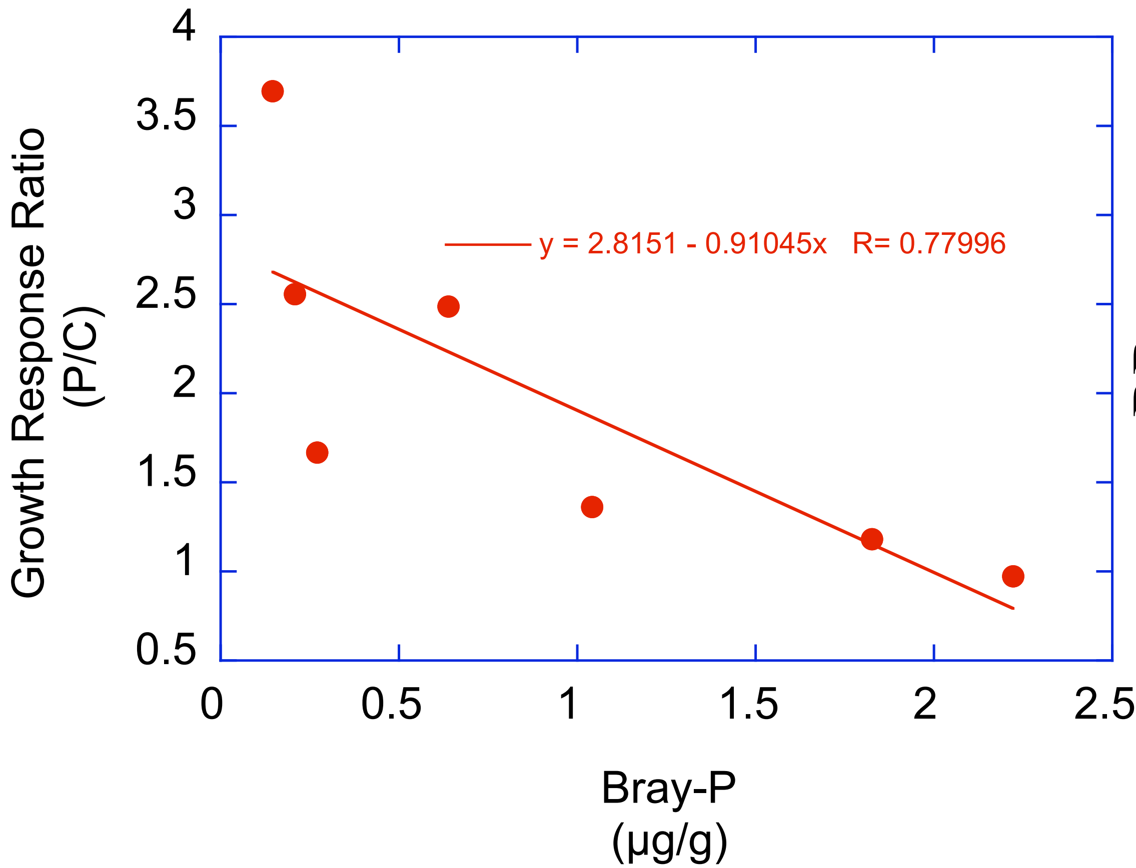


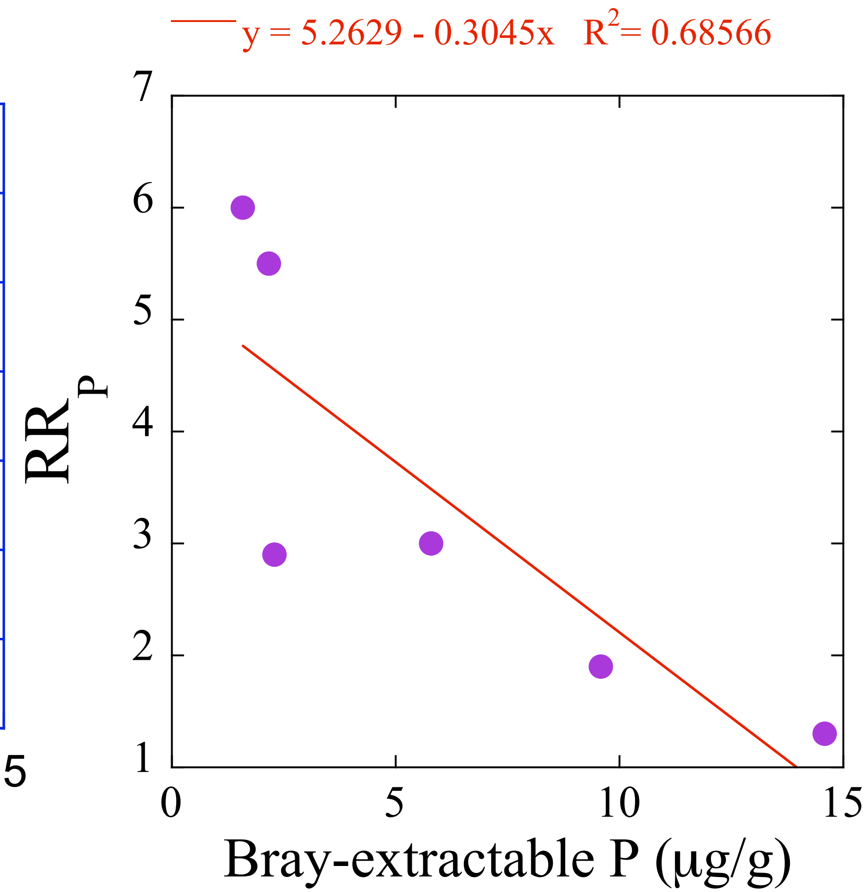
Modified from Vitousek & Farrington 1997

Relative nutrient limitation above- and below-ground



Reed et al. (In review)



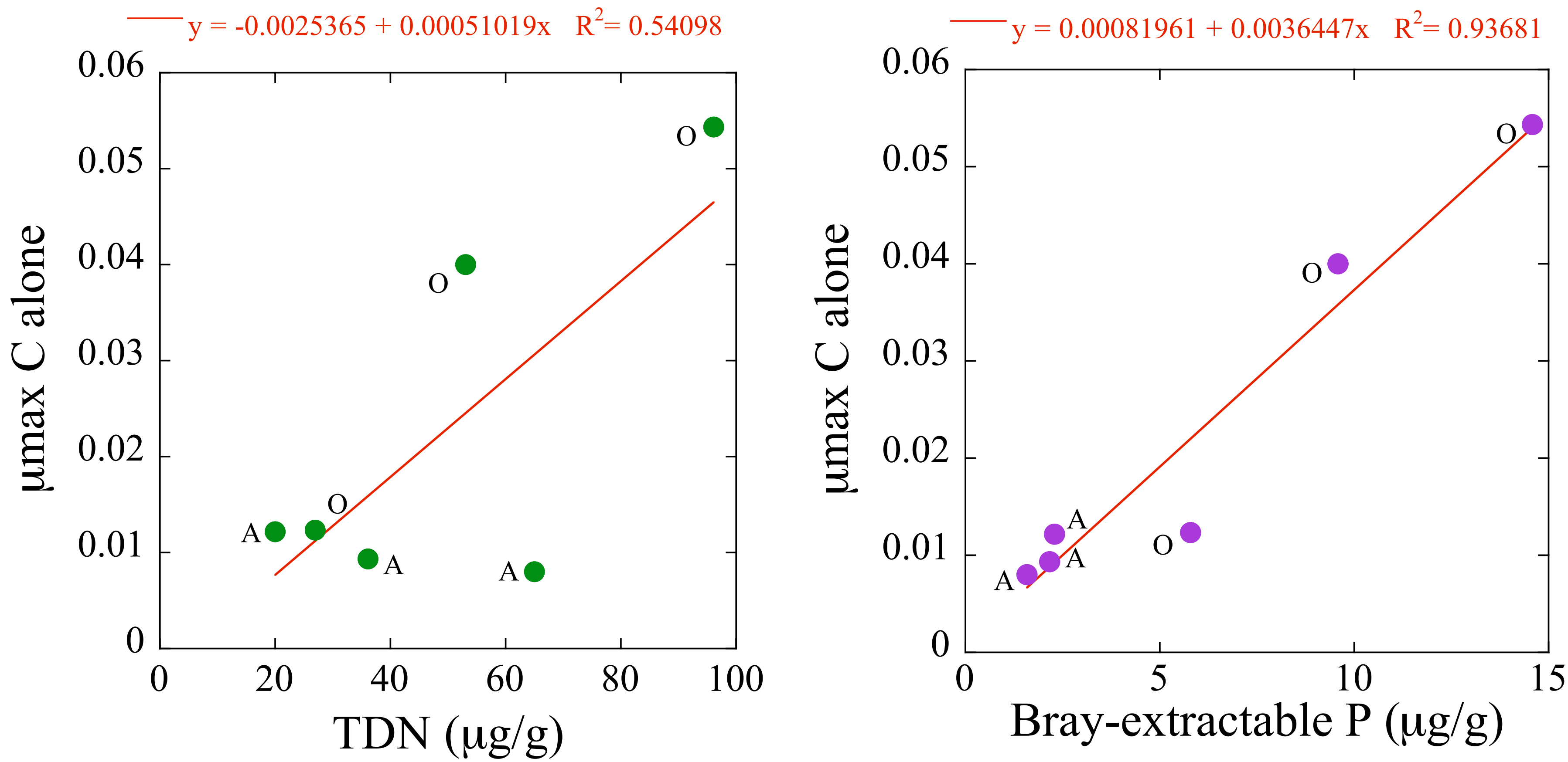


Puerto Rico, Costa Rica

Hawaii

Reed et al. (In review)

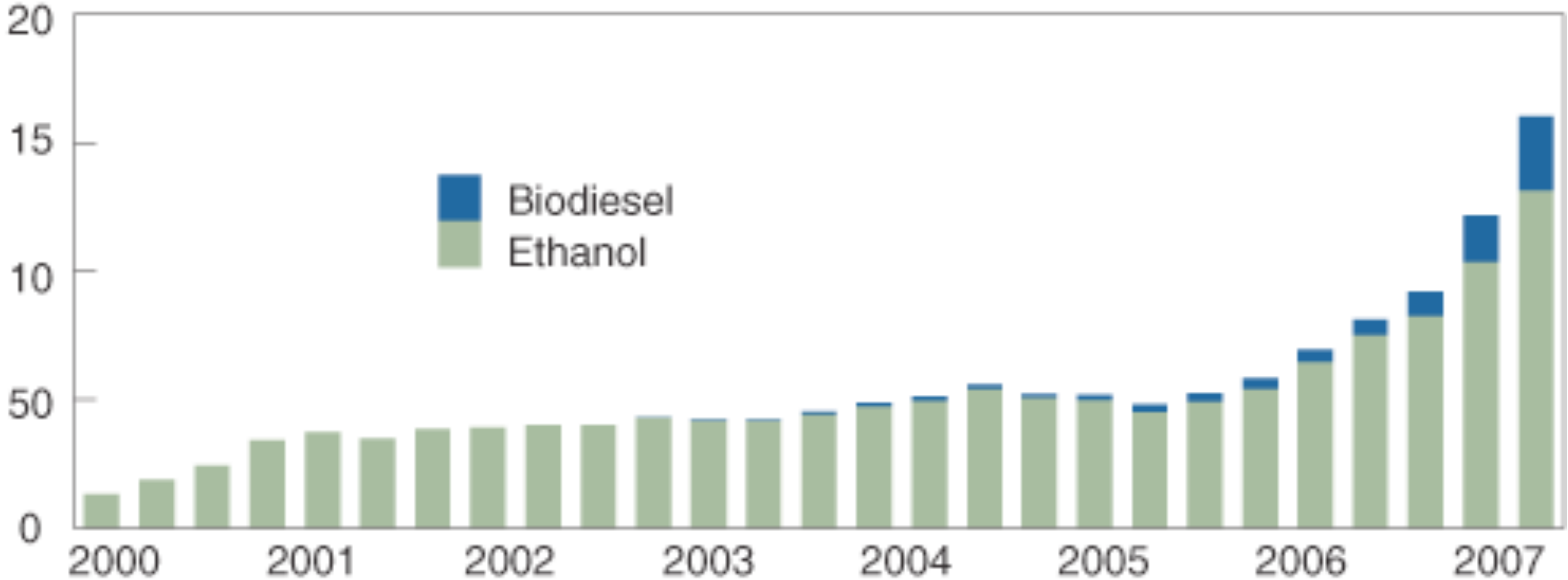
As well as help determine unfertilized C efflux



Reed et al. (In review)

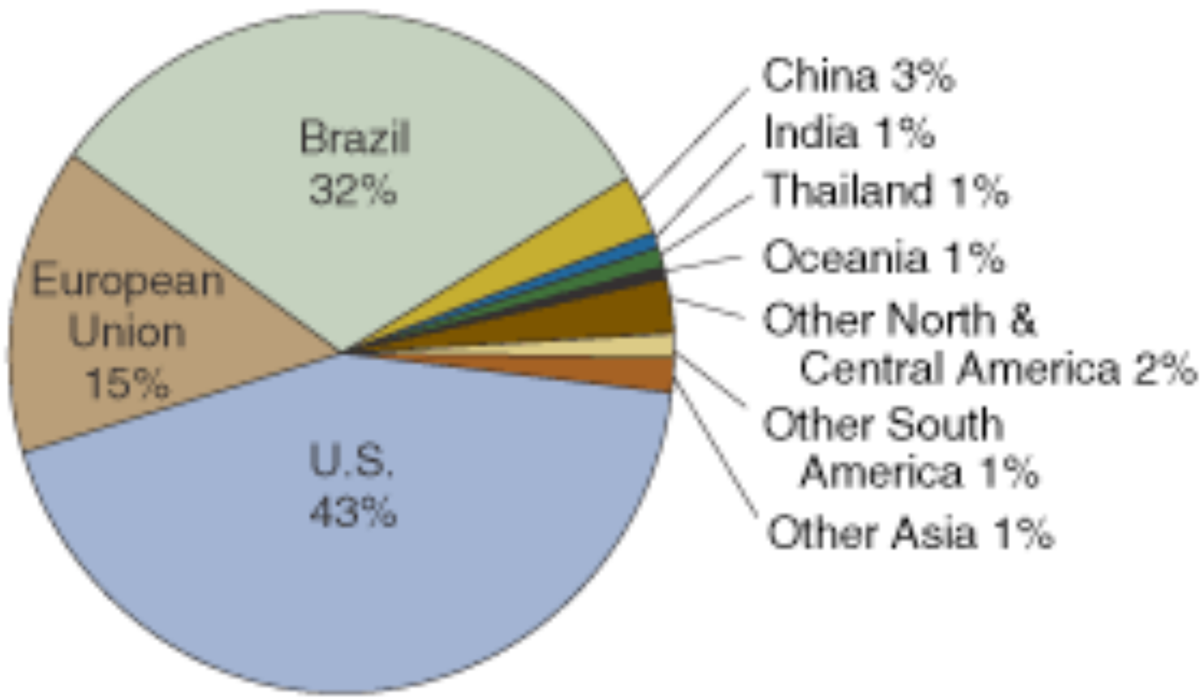
Global biofuel production tripled between 2000 and 2007

Billion gallons



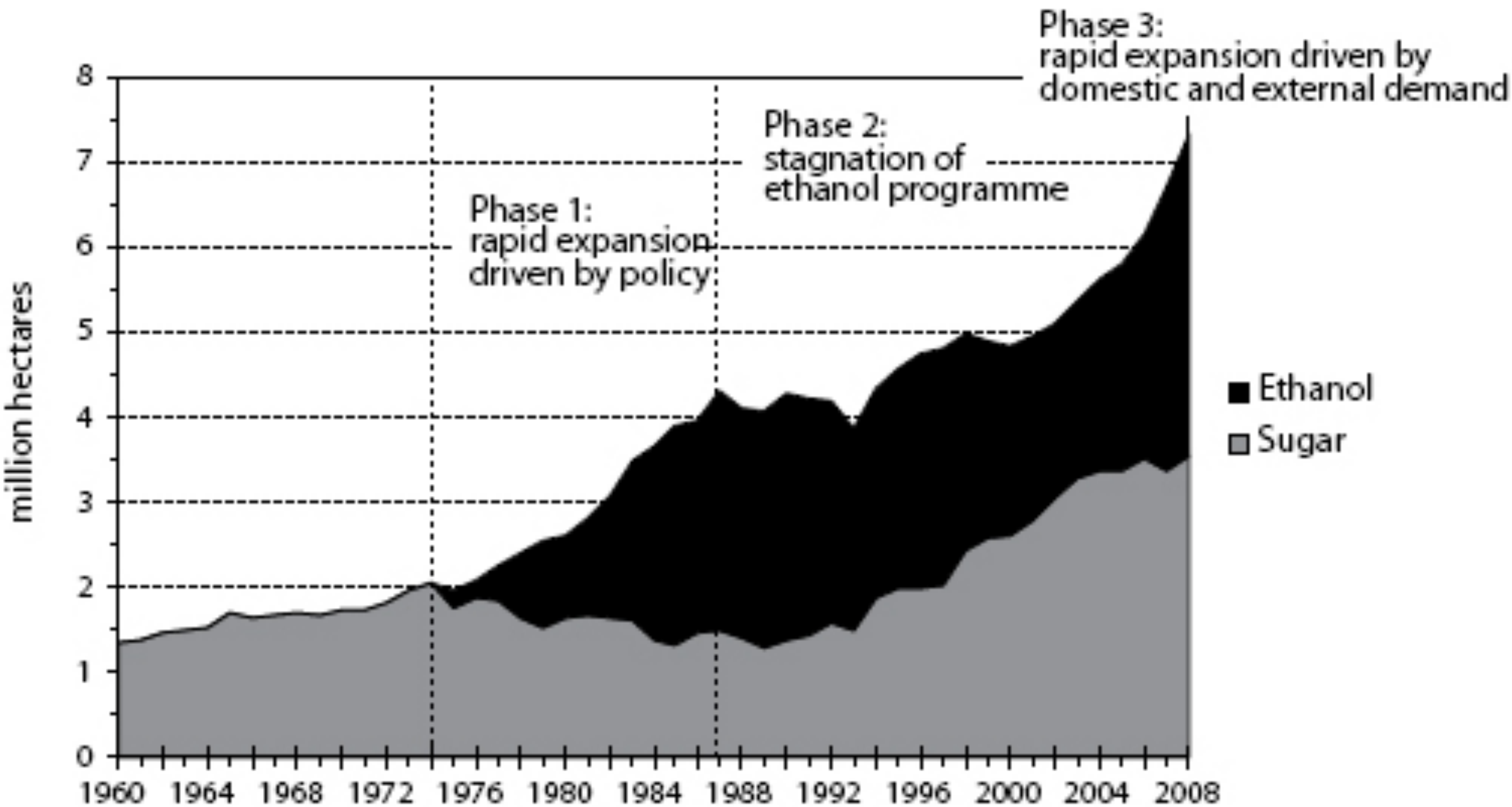
Source: International Energy Agency; FO Licht.

About 90 percent of global biofuel production is concentrated in U.S., Brazil, and Europe, 2007



Source: FO Licht, includes only ethanol for fuel.

Figure 3: Land in Brazil under sugar cane cultivation



Source: Peter Zuurbier and Jos van de Vooren (eds), *Sugarcane ethanol: Contributions to climate change mitigation and the environment*, Wageningen Academic Publishers, The Netherlands, 2008

Biofuels Now Fueling Deforestation

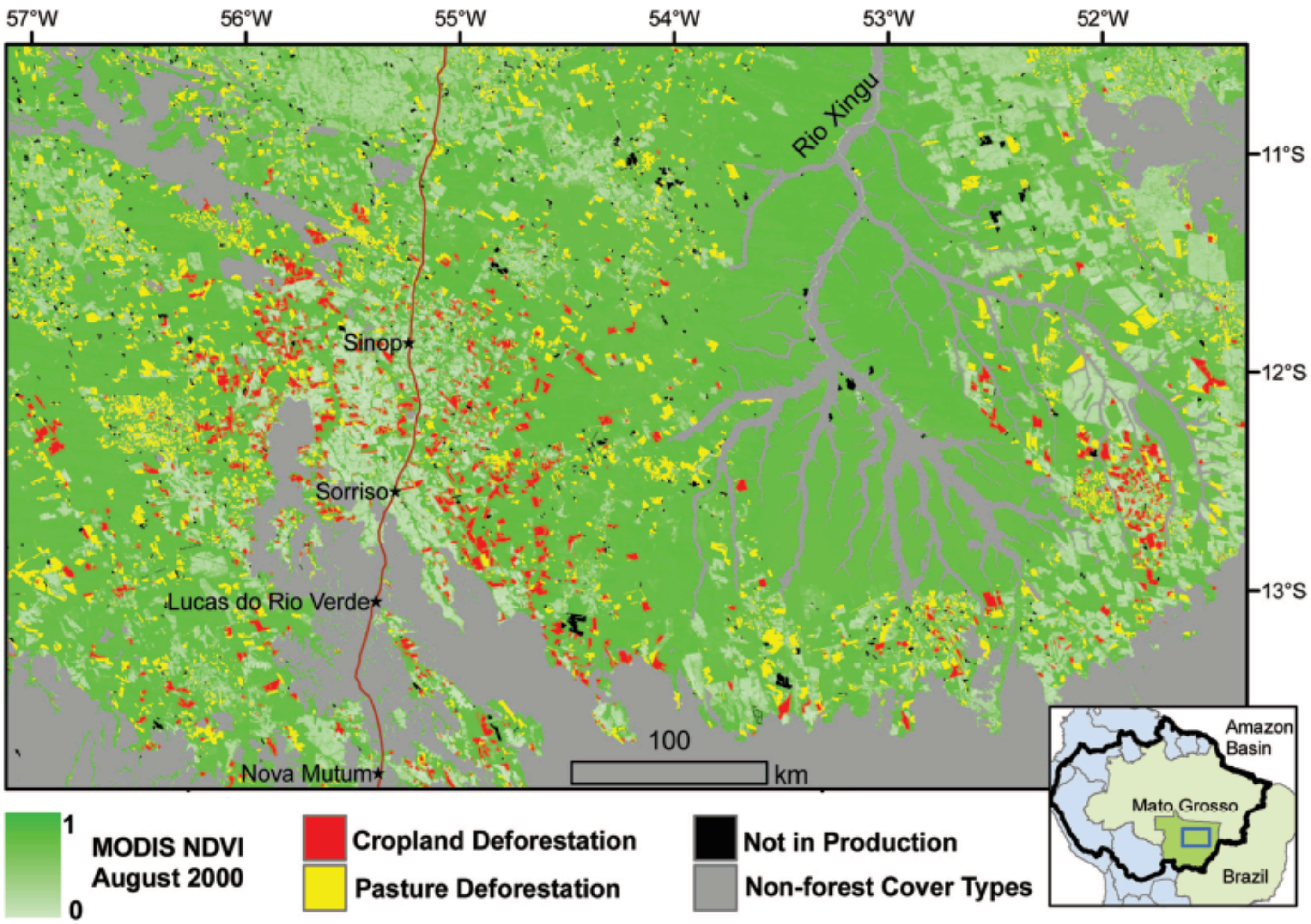


Fig. 1. Tropical deforestation for cropland agriculture in Mato Grosso state (2001–2004) is concentrated along the existing agricultural frontier. (*Inset*) Location of the study area subset within Mato Grosso state and the Amazon Basin.

Supply Versus Demand Questions?

World Mine Production, Reserves, and Reserve Base:

	Mine production		Reserves[4]	Reserve base[4]
	2005	2006[e]		
United States	36,300	30,700	1,200,000	3,400,000
Australia	2,050	2,050	77,000	1,200,000
Brazil	6,100	5,500	260,000	370,000
Canada	1,000	1,000	25,000	200,000
China	30,400	32,000	6,600,000	13,000,000
Egypt	2,730	2,740	100,000	760,000
Israel	2,900	3,000	180,000	800,000
Jordan	6,230	6,400	900,000	1,700,000
Morocco and Western Sahara	25,200	25,300	5,700,000	21,000,000
Russia	11,000	11,000	200,000	1,000,000
Senegal	1,520	1,500	50,000	160,000
South Africa	2,580	2,600	1,500,000	2,500,000
Syria	3,500	3,600	100,000	800,000
Togo	1,220	1,200	30,000	60,000
Tunisia	8,000	8,400	100,000	600,000
Other countries	6,500	6,700	890,000	2,200,000
World total (rounded)	147,000	145,000	18,000,000	50,000,000

US Geological Survey

Table 2. Agricultural land use and fertilizer application rates within the Guayas Basin.

Land use	Area (km^2)	% of Guayas	N fertilizer ($kg\ ha^{-1}\ yr^{-1}$)	P fertilizer ($kg\ ha^{-1}\ yr^{-1}$)
Permanent crops and other	2783	9	99	13
Annual crops and other	8801	28	58	6
Cocoa and coffee	381	1	90	8
Banana	1221	4	250	20
Maize	331	1	46	5
Sugar cane	481	2	150	20
Rice	2222	7	68	0
Pastures, native & cultivated	2805	9	0	0
Paramo & pasture	1325	4	–	–
Forests (native & cultivated)	9206	29	0	0
Shrubs & barren lands	1169	4	–	–
Shrimp ponds	19	0	200	70
Urban	223	1	–	–
Mangroves	8	0	–	–
Water	487	2	–	–
Soybeans	495	2	50	10

Cordova et al. (2006)

Increased P Use in the Tropics: Fate & Consequences?

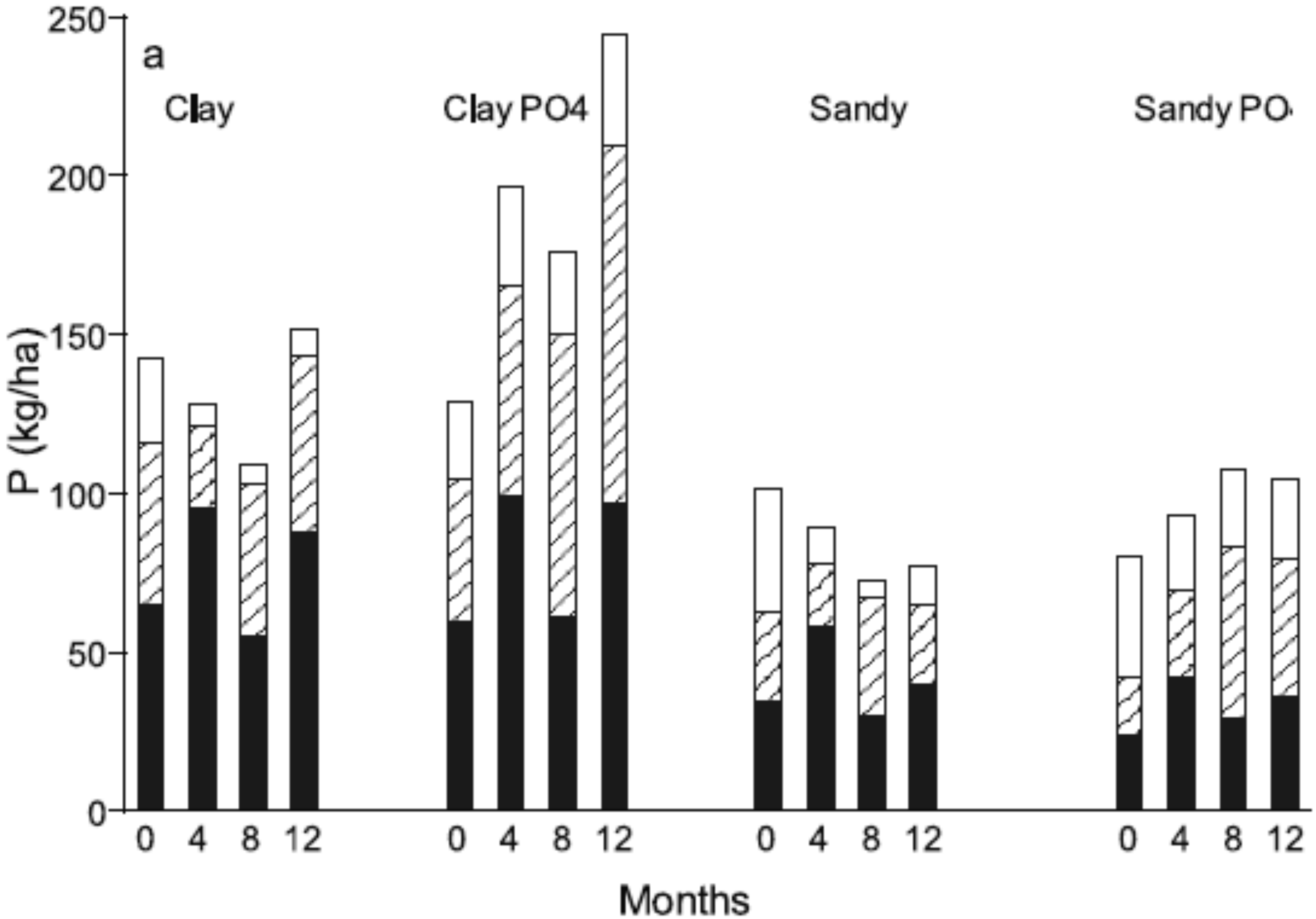


Figure 1. Soil P fractions in experimental plots in the FLONA Tapajós, Pará, Brazil. (a) Fractions have been bulked into three pools; available pool (resin and $NaHCO_3$ extractable fractions) represented by the open bar, intermediate pool (NaOH and 1M HCl extractable fractions) represented by the hatched bar and recalcitrant pool (concentrated HCl and H_2SO_4 extractable fractions) represented by the solid bar. (b and c)

McGroddy et al. (2008)

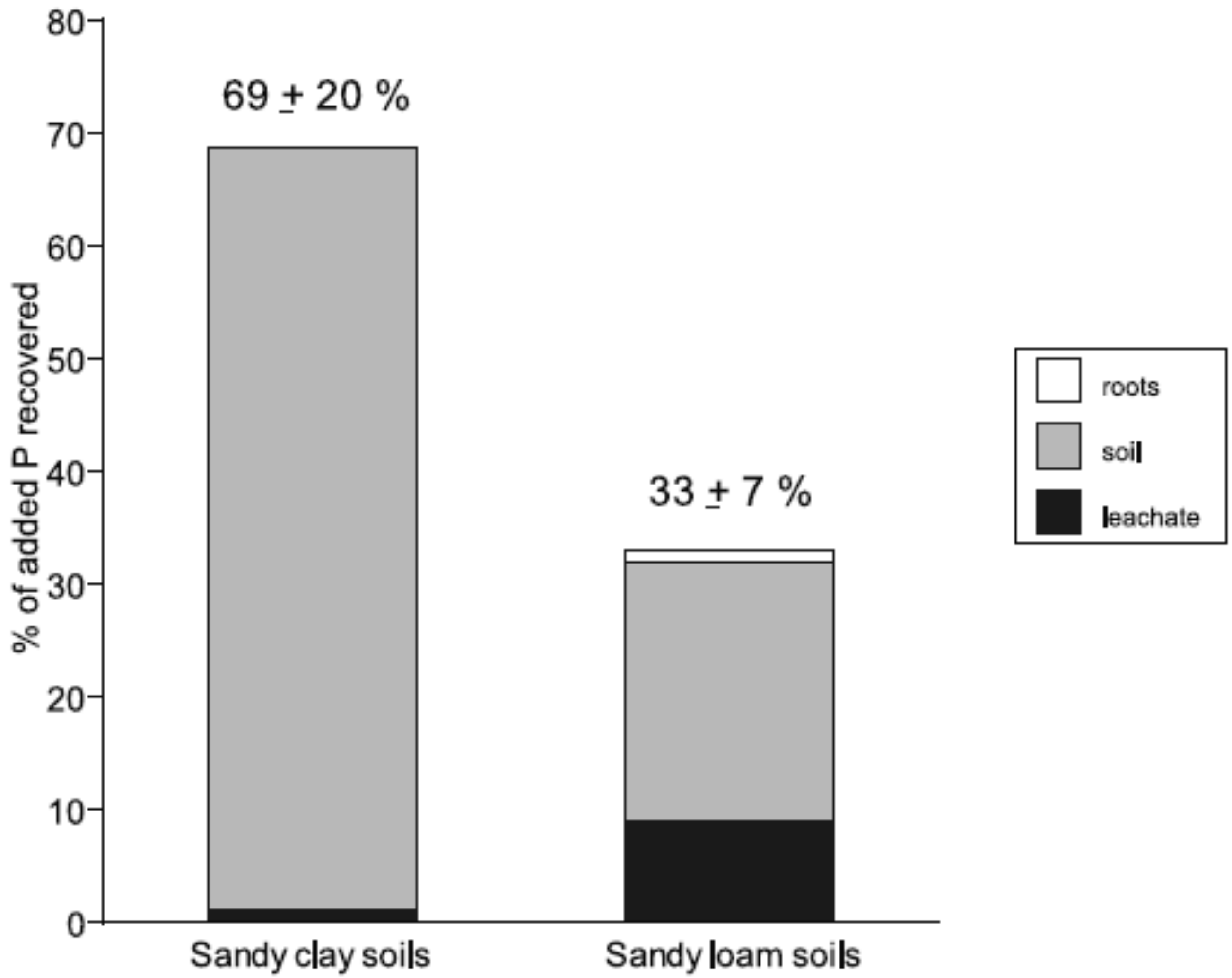
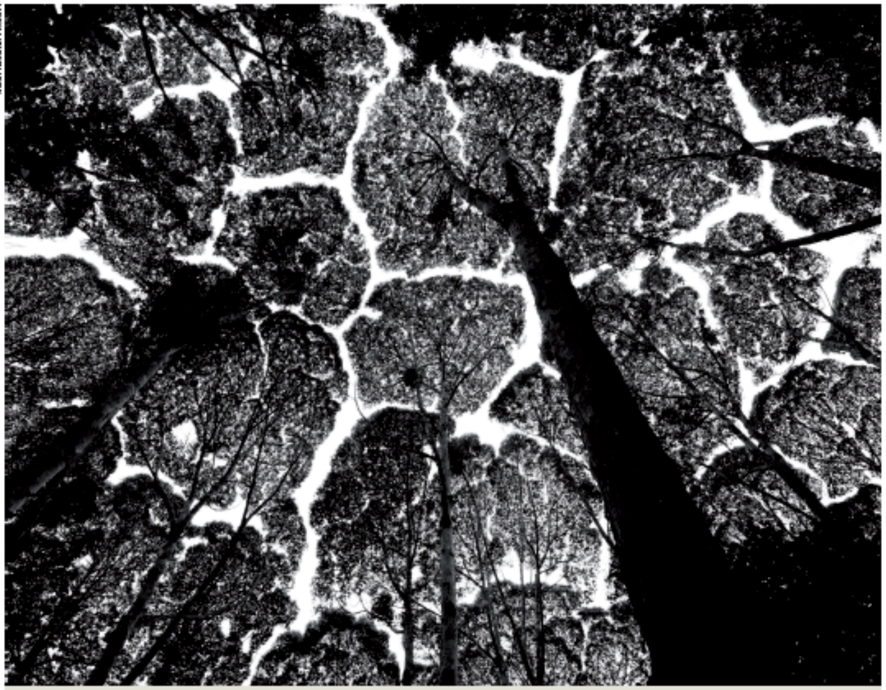


Figure 4. Retention of P added as super triple phosphate in surface soils at the FLONA Tapajós, Pará, Brazil. Retention is calculated as the difference between a given pool in the fertilized treatment and the same pool in the control treatment divided by the total amount of P added. Mean retention ±1 standard error is reported above each column.

McGroddy et al. (2008)

In brief



Fertilisers give the lungs of the planet bad breath

RAINFOREST soils polluted with phosphorus and nitrogen from agriculture are bad news for the climate. The presence of these fertilisers in the soil could trigger the release of disproportionately large amounts of carbon dioxide.

Cory Cleveland and Alan Townsend of the University of Colorado at Boulder added phosphorus fertiliser to a tropical forest plot in Costa Rica for two years and found the amount of carbon dioxide released per year was 18 per cent higher than in control plots. Nitrogen fertiliser raised the carbon dioxide output by 22 per cent, and a mixture of the two by 14 per cent.

Since tropical forests contain 40 per cent of the world's terrestrial carbon, the impact on global warming could be large (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.0600989103).

Although no one deliberately adds fertiliser to rainforests soils, the amount of airborne phosphorus and nitrogen reaching tropical forests is increasing because of human activity, especially agriculture.

"Easterly winds carry significant quantities of phosphorus-containing dust from Africa to the Amazon basin, and are increasing due to desertification of the Sahel," says Cleveland. Levels of nitrogen in the air are rising because of increased fossil fuel and fertiliser use. The researchers suggest that even small amounts of fertiliser can have a damaging effect.

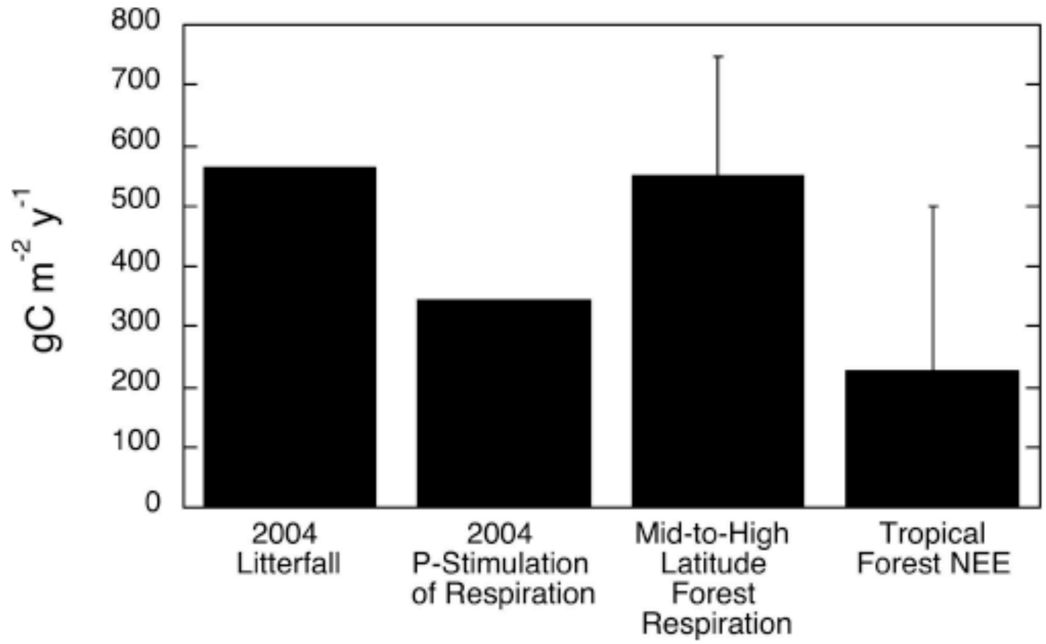


Fig. 4. Annual litterfall and net annual P-stimulated increase in soil respiration from the Costa Rican sites compared with a mean of soil respiration values from mid- and high-latitude forest biomes and with a mean of net ecosystem exchange (NEE) values from several tropical forest sites. The mid-latitude forest soil respiration value is the mean of values from deciduous temperate forests, coniferous temperate forests, and boreal forests (44). The NEE value is derived from seven recent estimates based on eddy-covariance flux tower measurements, including sites in Costa Rica (45) and the Brazilian Amazon (36, 46). "Mean NEE" represents a net uptake of C, but for comparative purposes, it is depicted here as a positive value.

Cleveland et al. (2006)

Beyond the Tropics

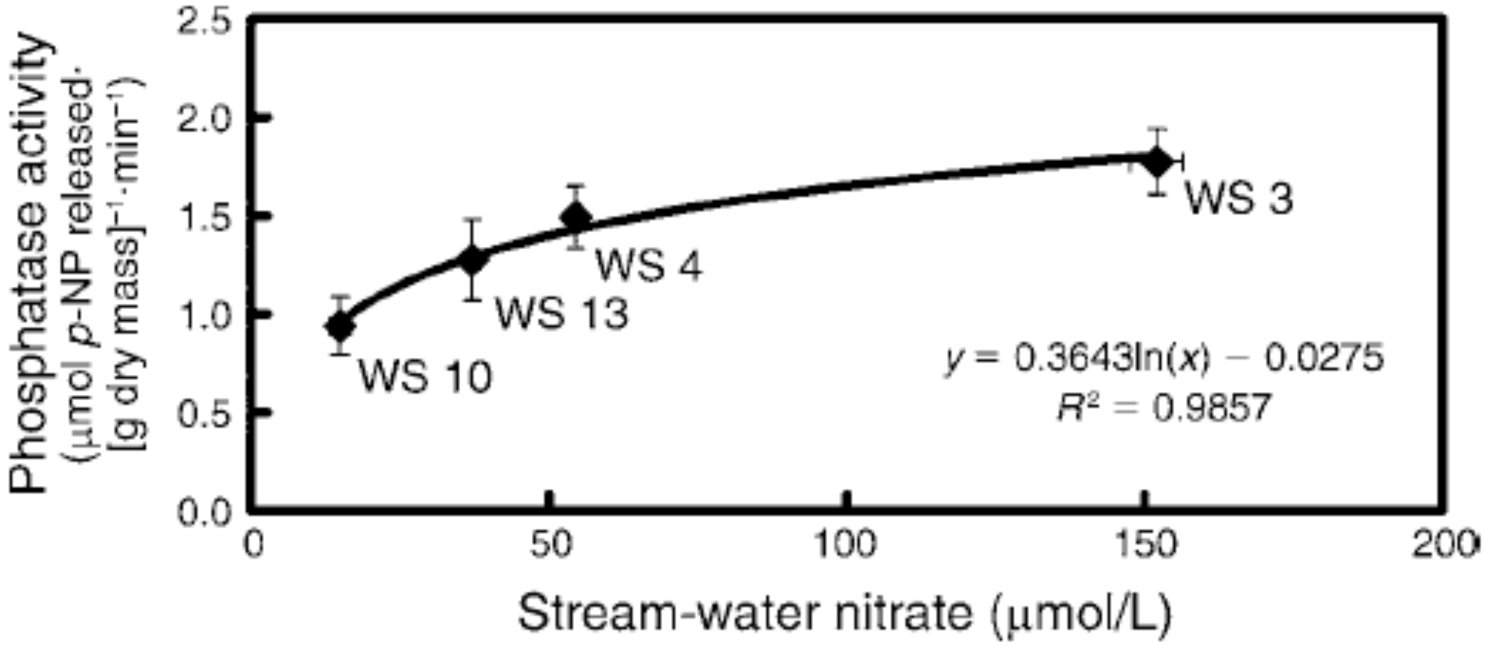


FIG. 2. Root-associated phosphatase activity of *Viola rotundifolia* growing in watersheds (WS) with different stream-water nitrate concentrations. Stream-water nitrate values are the average of monthly, volume-weighted concentrations for January 1995–December 1999. Data are means ± SE. Phosphomonoesterase (PME) activity is assessed by the release of *p*-nitrophenol (*p*-NP).

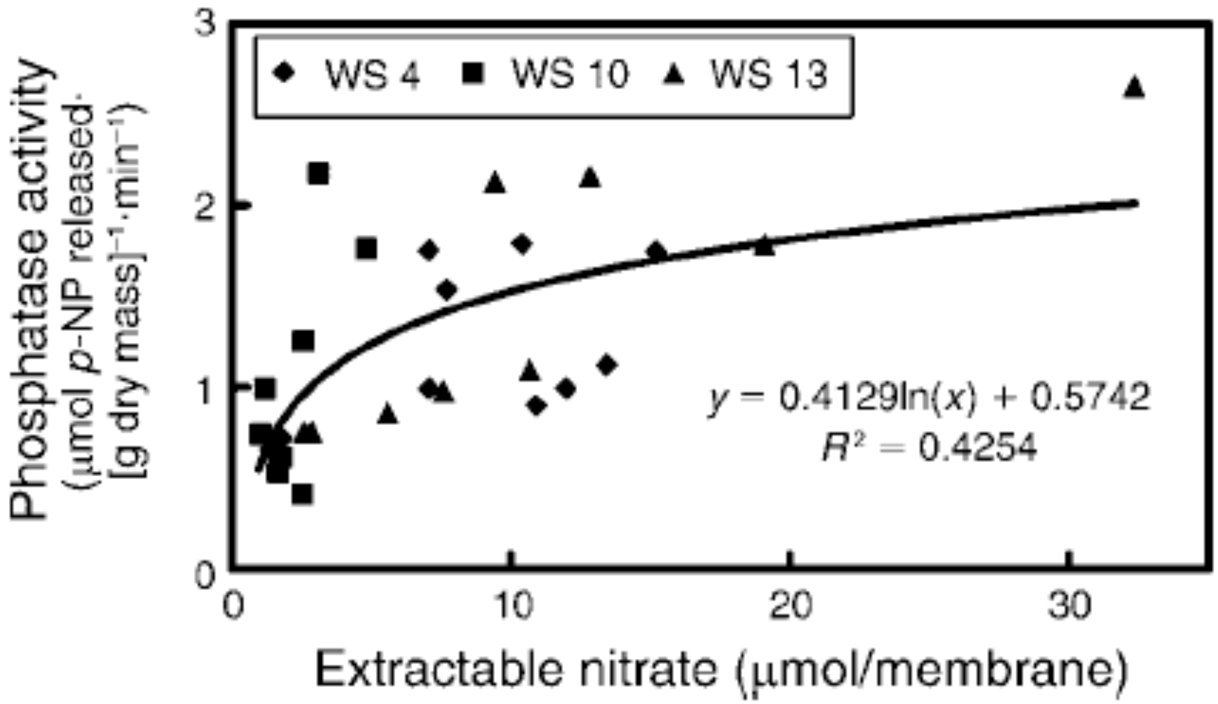


FIG. 3. Root-associated phosphatase activity of *Viola rotundifolia* growing in individual 10 m radius plots compared to nitrate availability in the same plots. Nitrate availability was assessed by the accumulation of nitrate on buried anion-exchange membranes (2 × 5 cm). Symbols represent the three watersheds (WS) with paired data. Phosphomonoesterase (PME) activity is assessed by the release of *p*-nitrophpenol (*p*-NP).

Questions:

How does future energy production reconcile with limited P supply?

Are P requirements used to make projections appropriate for P-deficient tropics?

What is the short/long-term fate of P applications in the P-sorbing tropical soils?

What are the consequences of increasing P use, and are they being adequately considered in the debate about biomass energy?