

Characterization and Performance of Amazonian Dark Earths – Opportunities for Future Soil Management

Johannes Lehmann

Department of Crop and Soil Sciences, Cornell University

Upland soils in the Amazon Basin

Constraints:

- Rapid nutrient leaching and mineralization of organic matter
- P-fixation to Fe-, Al-oxides
- Low total K, Ca, Mg contents
- Al toxicity possible through low pH

Extremely fertile soils in the midst of infertile Oxisols



Amazonian Dark Earths – soil fertility

High soil fertility



Oxisol



“Terra Preta de Indio”

Amazonian Dark Earths – highly valued resource

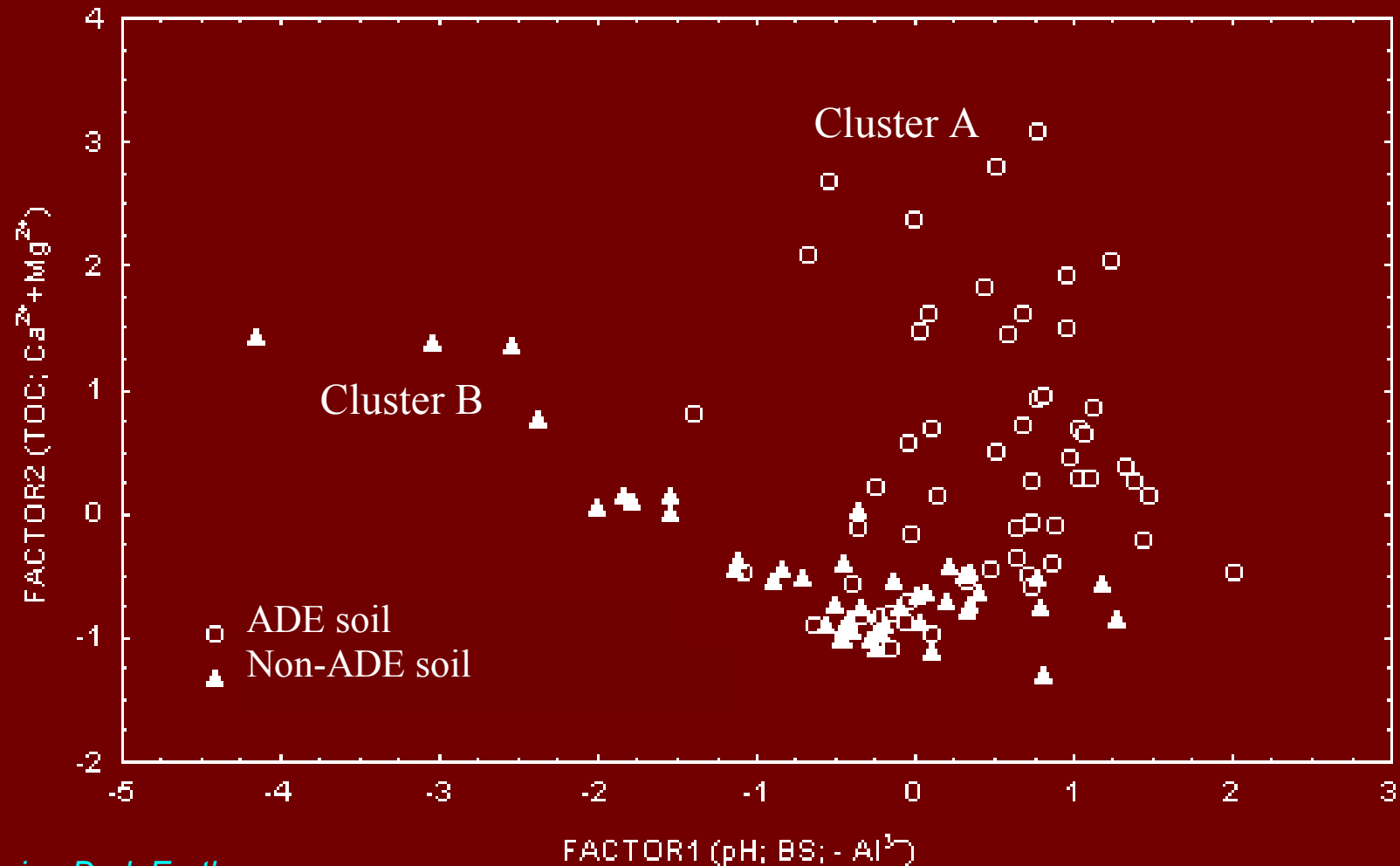
- ✓ Farming
- ✓ Ornamentals



Amazonian Dark Earths – soil fertility

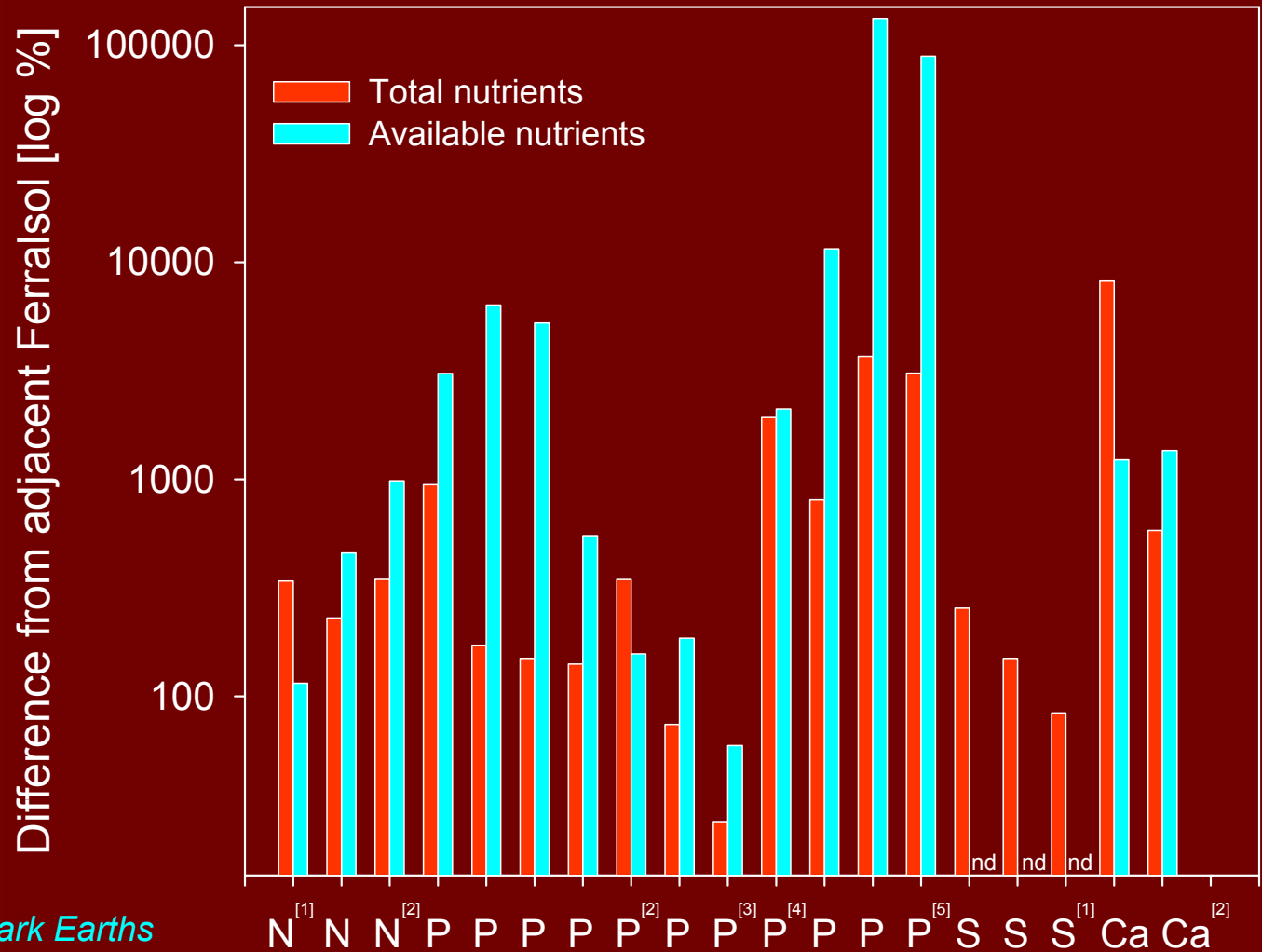
- ◆ High organic matter contents (to 150 mg C g⁻¹)
- ◆ High nutrient availability (e.g., P (>300 mg kg⁻¹) and Ca)
- ◆ High cation exchange capacity (CEC)

Amazonian Dark Earths – nutrient contents

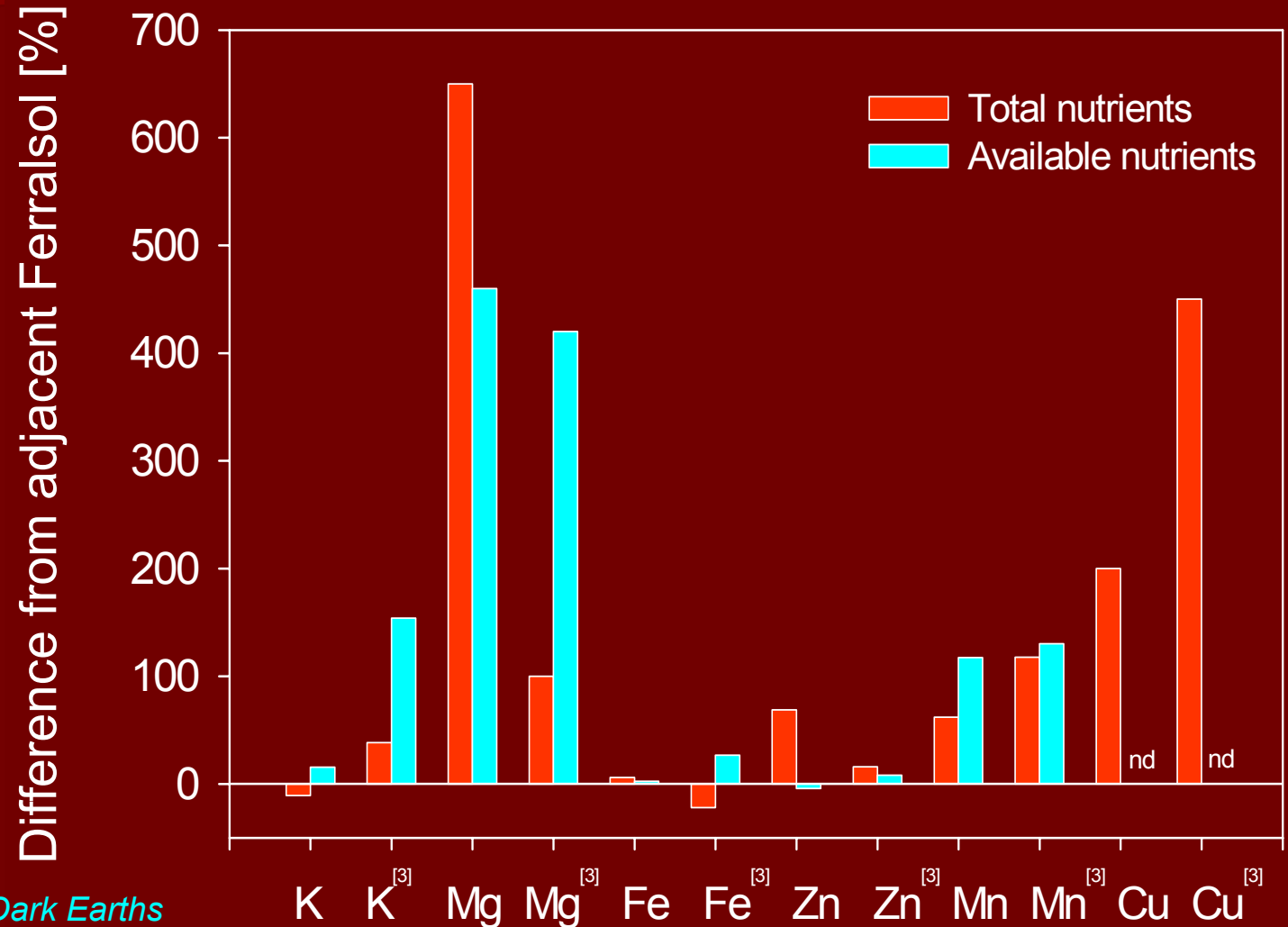


Amazonian Dark Earths – nutrient contents

Greater increase
in available
nutrients than
total nutrients

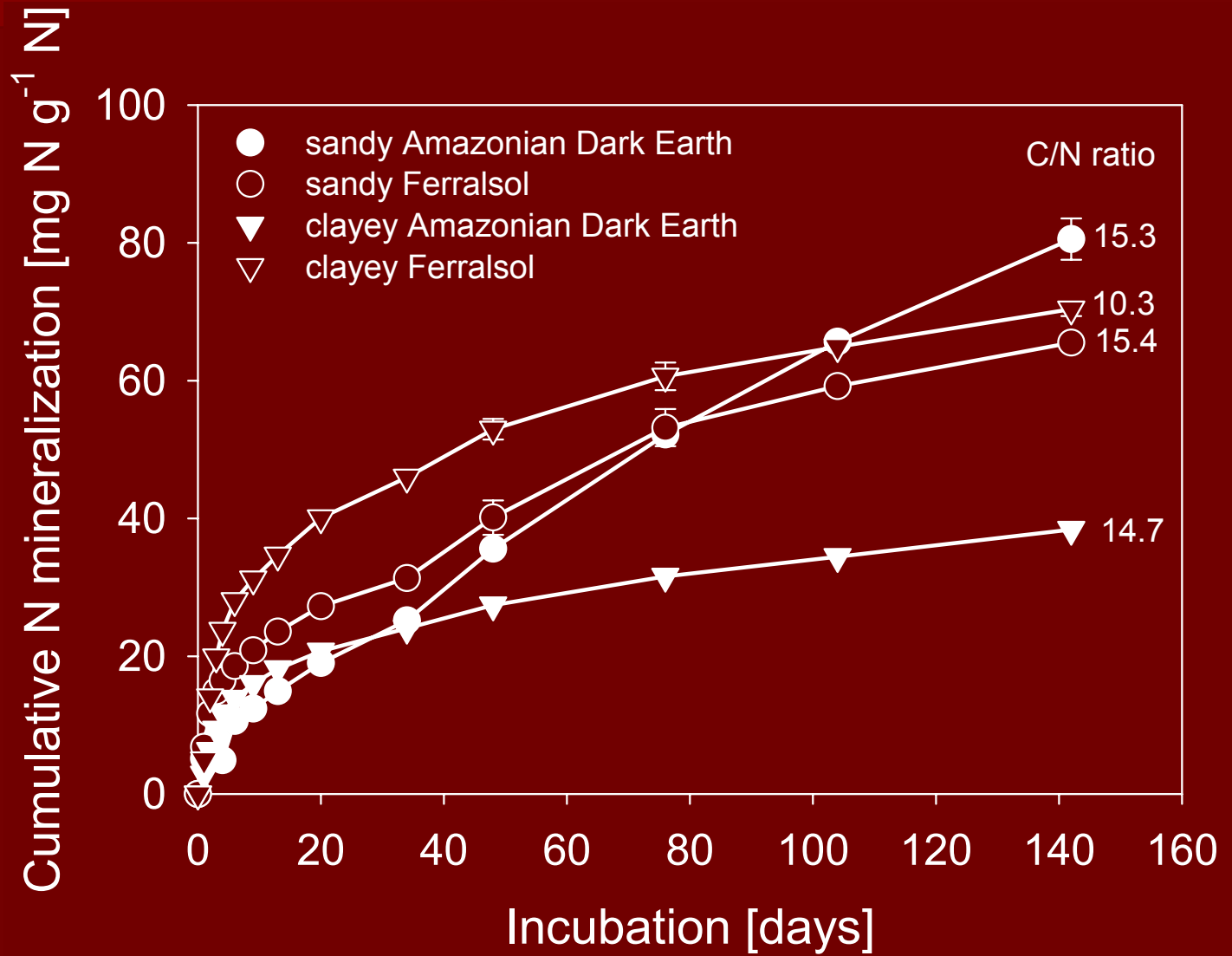


Amazonian Dark Earths – nutrient contents



Amazonian Dark Earths – N availability

Low N availability



Amazonian Dark Earths – Biological N₂ Fixation (Central Amazonia)

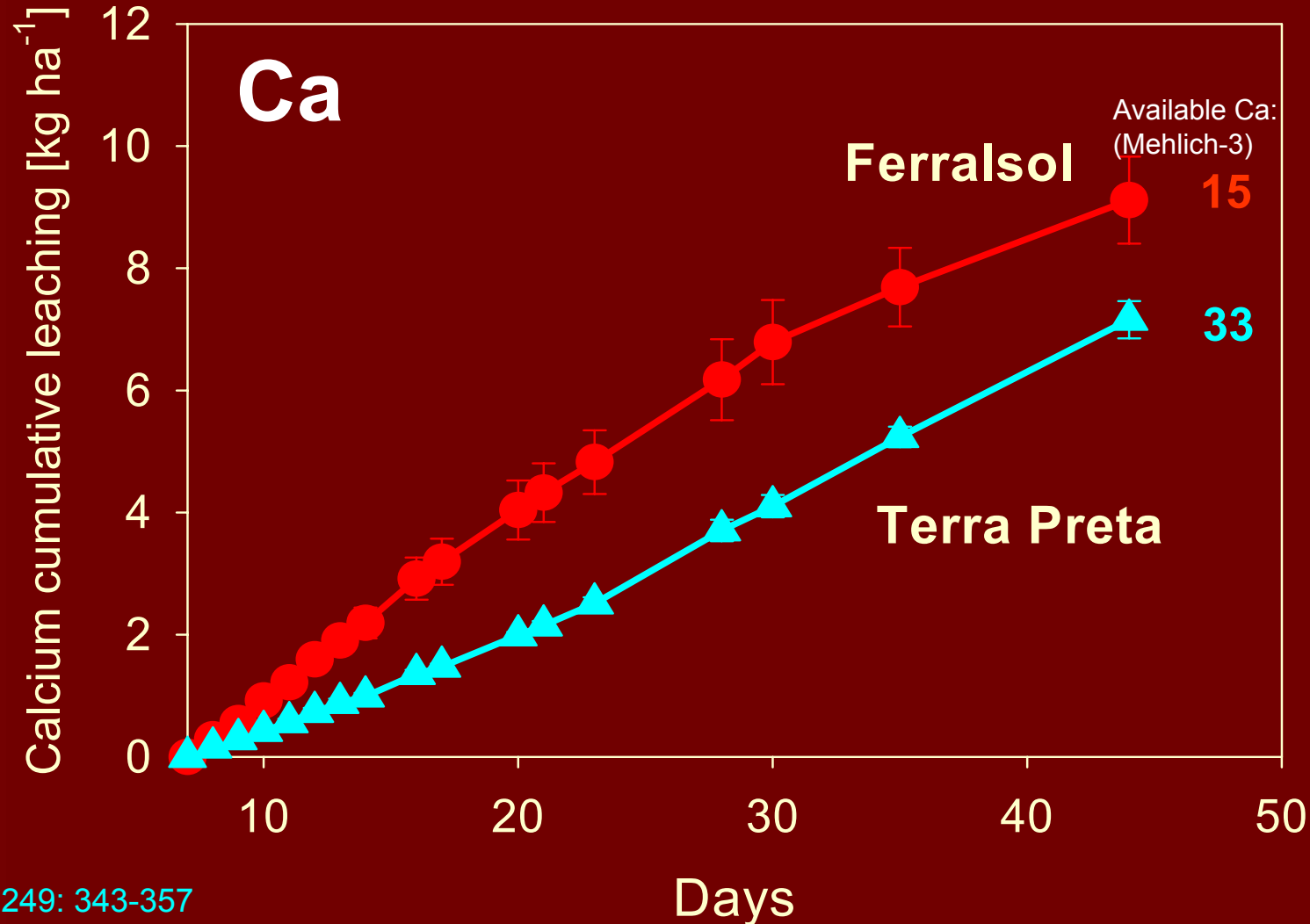
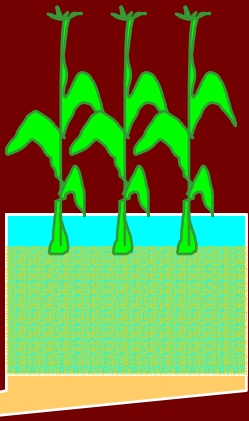
Low N availability

High P, Ca, and micronutrient availability

Parameter	ADE	Ferralsol
Leguminosae (% of all trees)	14	4
Foliar N conc. (mg g ⁻¹)	26	29
Foliar δ ¹⁵ N (‰)	1.75	3.59

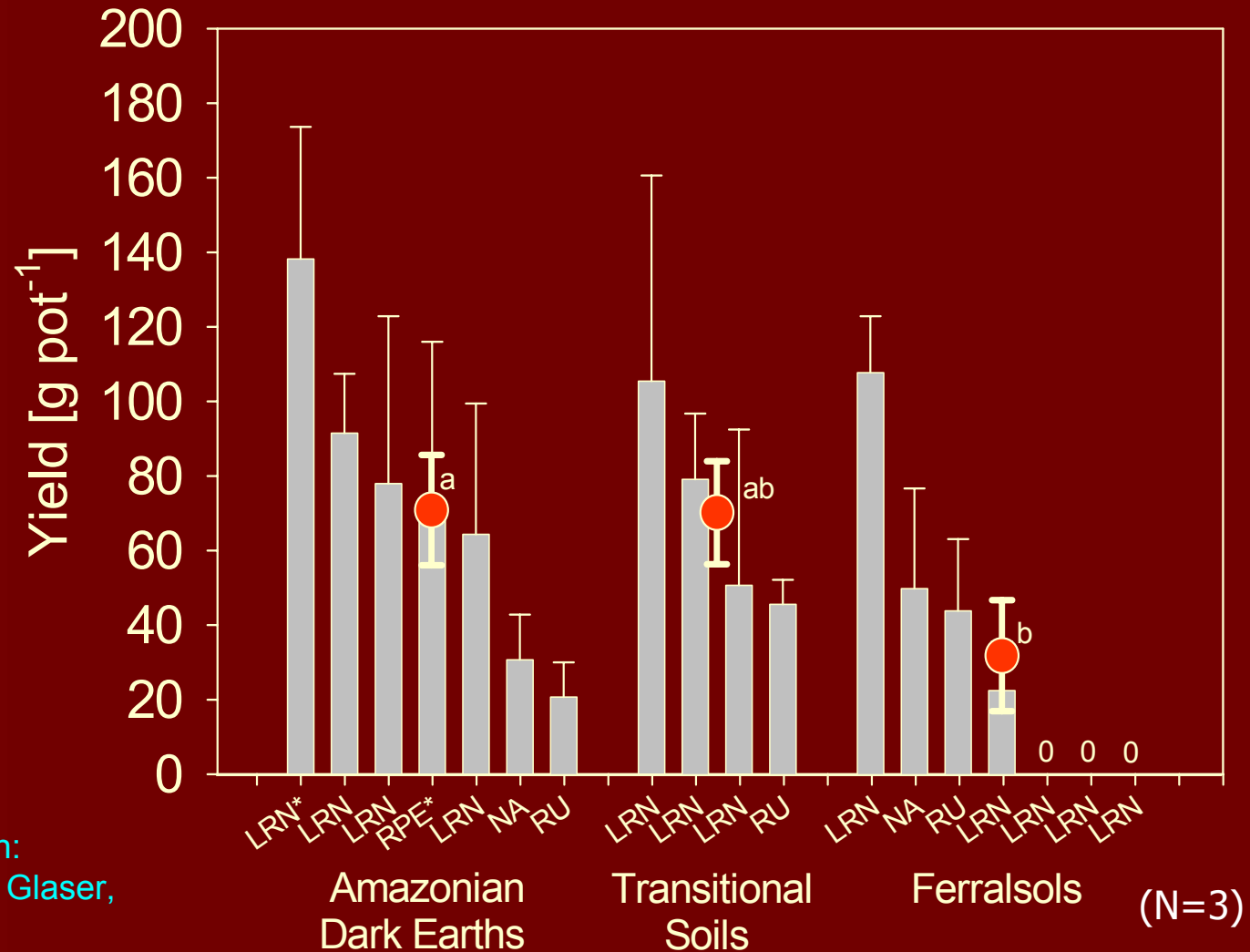
Amazonian Dark Earths – nutrient leaching

High nutrient availability at very low leaching!



Amazonian Dark Earths – production potential

Higher maize yields in ADE than adjacent soils - but large variability



German, 2002, in Lehmann et al., 2003, in:
Amazonian Dark Earths (Lehmann, Kern, Glaser,
Woods, eds.) Kluwer Ac, pp. 105-124.

Amazonian Dark Earths – production potential

Crop yields are higher on Amazonian Dark Earths than adjacent soils.

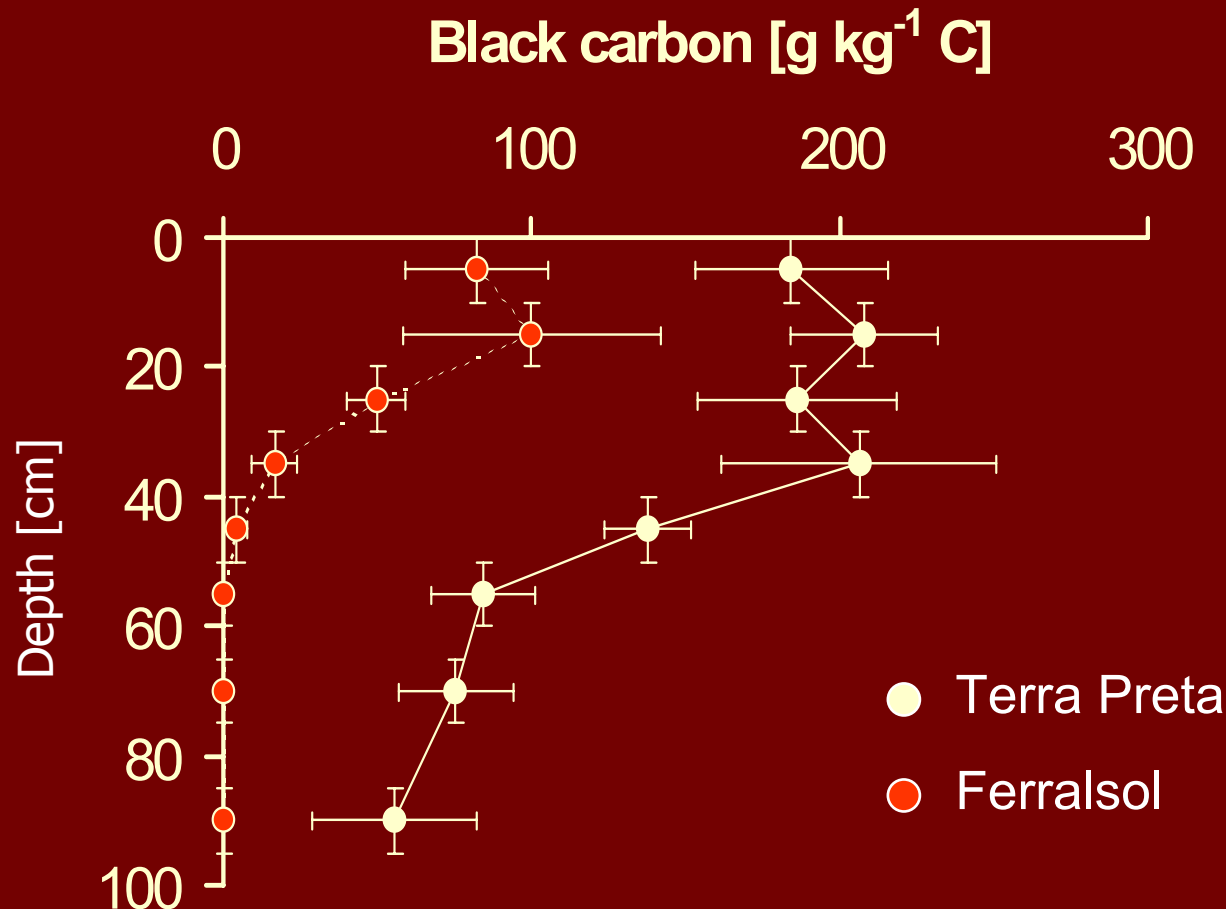
Crop	Location	ADE -----[Mg ha ⁻¹]-----	Ferralsol
Rice	Apui	1.9-3.4	1.5-1.8
Beans	Apui	0.1-1.9	0.3-0.8
Corn	Apui	2.2-4.7	3.5

Opportunities for Science

- Life in pre-Columbian Amazonia
- Basic biogeochemistry of soils
- Soil management

Amazonian Dark Earths – Black Carbon

Large proportion of Black-Carbon in soil organic matter of ADE



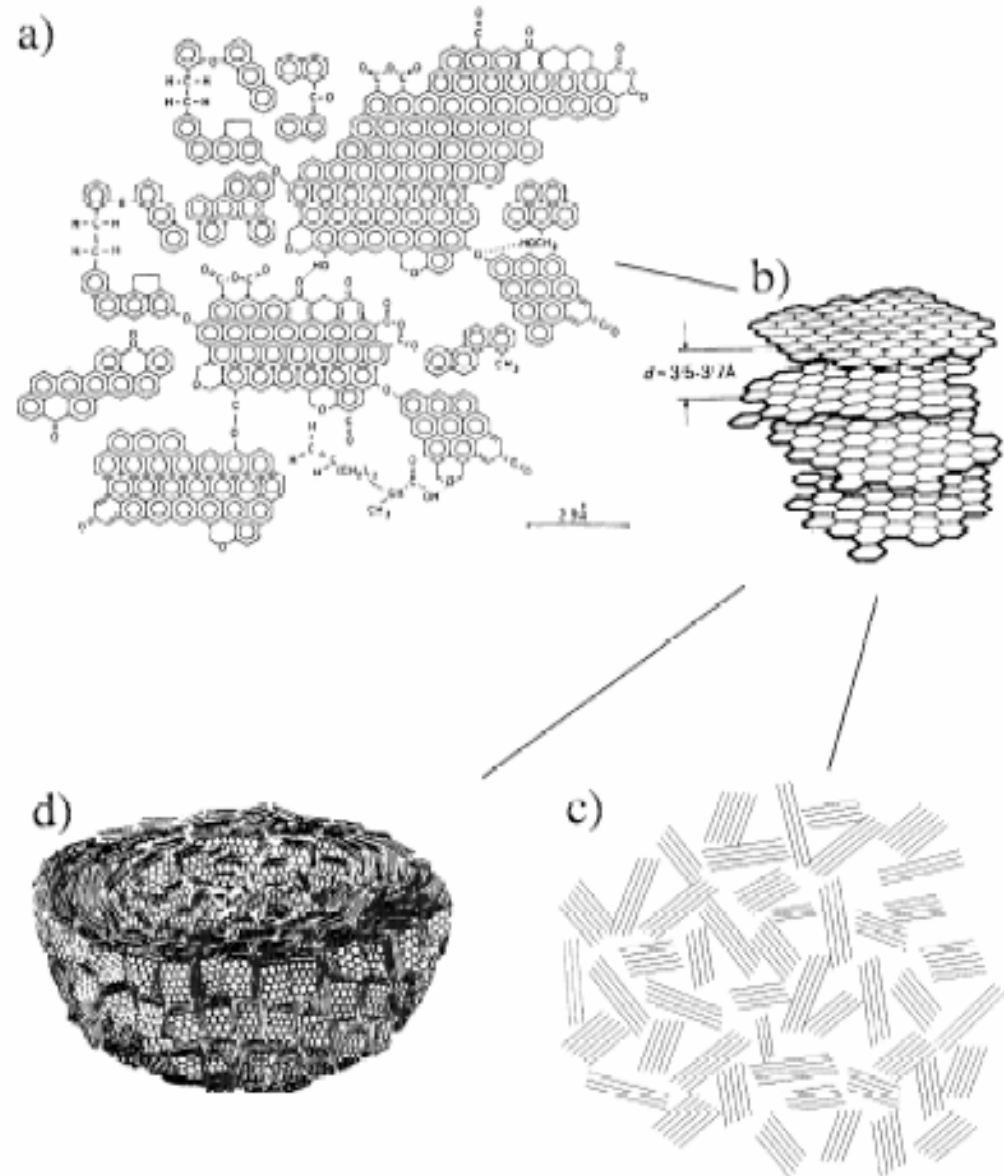
Amazonian Dark Earths – Black Carbon

What is Black Carbon?

What does Black Carbon?

Amazonian Dark Earths – Black Carbon

From charcoal
to graphite



Amazonian Dark Earths – Black Carbon

Large portion of Carbon and Black Carbon in “light organic matter” fractions of Terra Preta

Fraction	Density [g cm ⁻³]	Terra Preta -----[%]-----	Ferralsol -----[%]-----
<u>Carbon</u>			
Light	<2	35	28
Medium	2-2.4	36	25
Heavy	>2.4	29	48
<u>Black carbon</u>			
Light	<2	72	32
Medium	2-2.4	12	22
Heavy	>2.4	16	46

(N=5)

Glaser et al., 2000, *Org Geochem* 31, 669-678

Functions of biomass-derived Black Carbon (=charcoal)

Improving nutrient retention?

Increasing nutrient availability and crop yields?

Enhancing carbon sequestration?

...as in ADE?

Black Carbon Management Systems

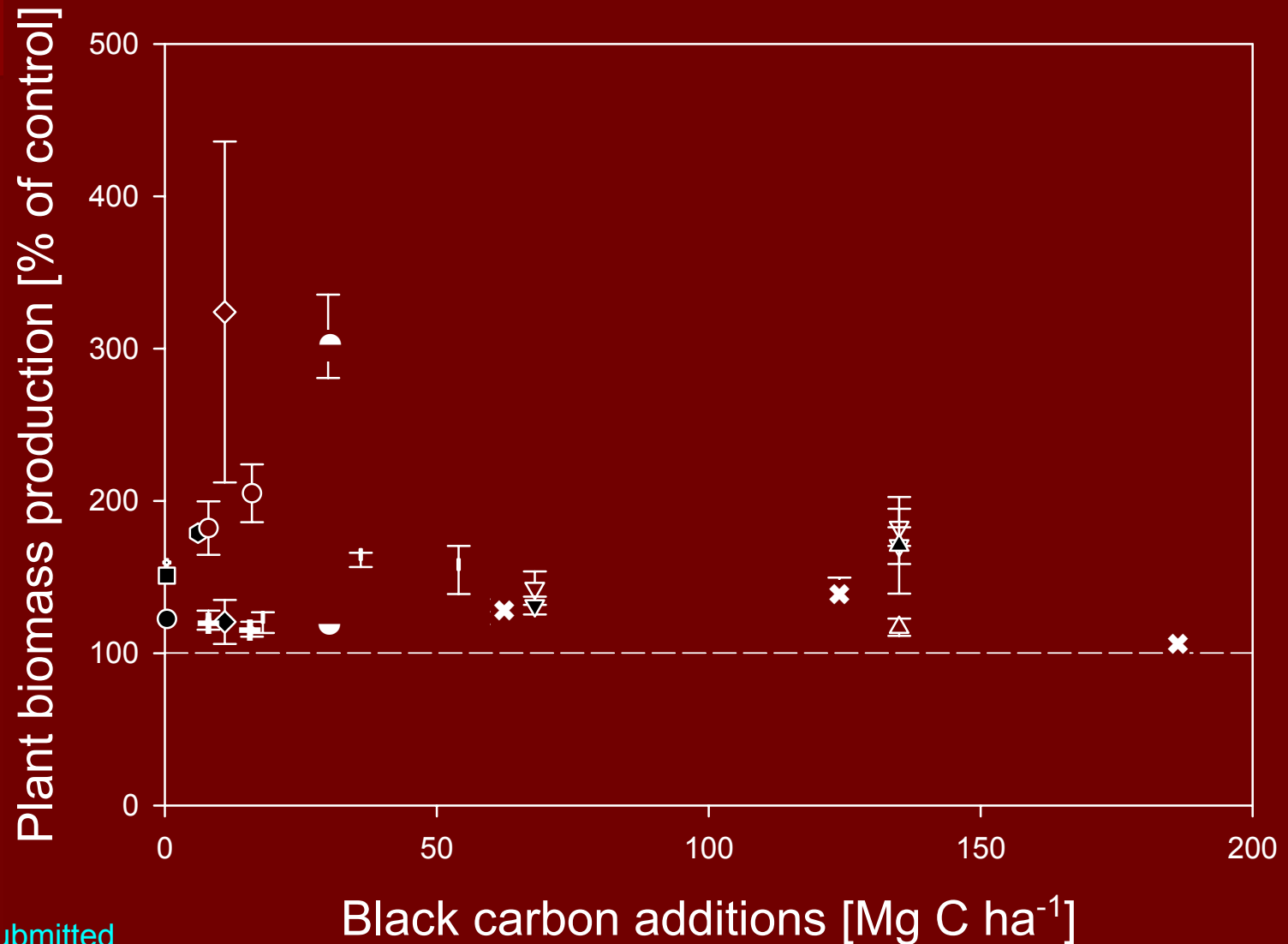
...evidence so far:

Better nutrient retention.

Greater nutrient availability and crop yields at high application rates or with additional fertilization.

Reduced greenhouse gas emissions.

Black Carbon Management Systems

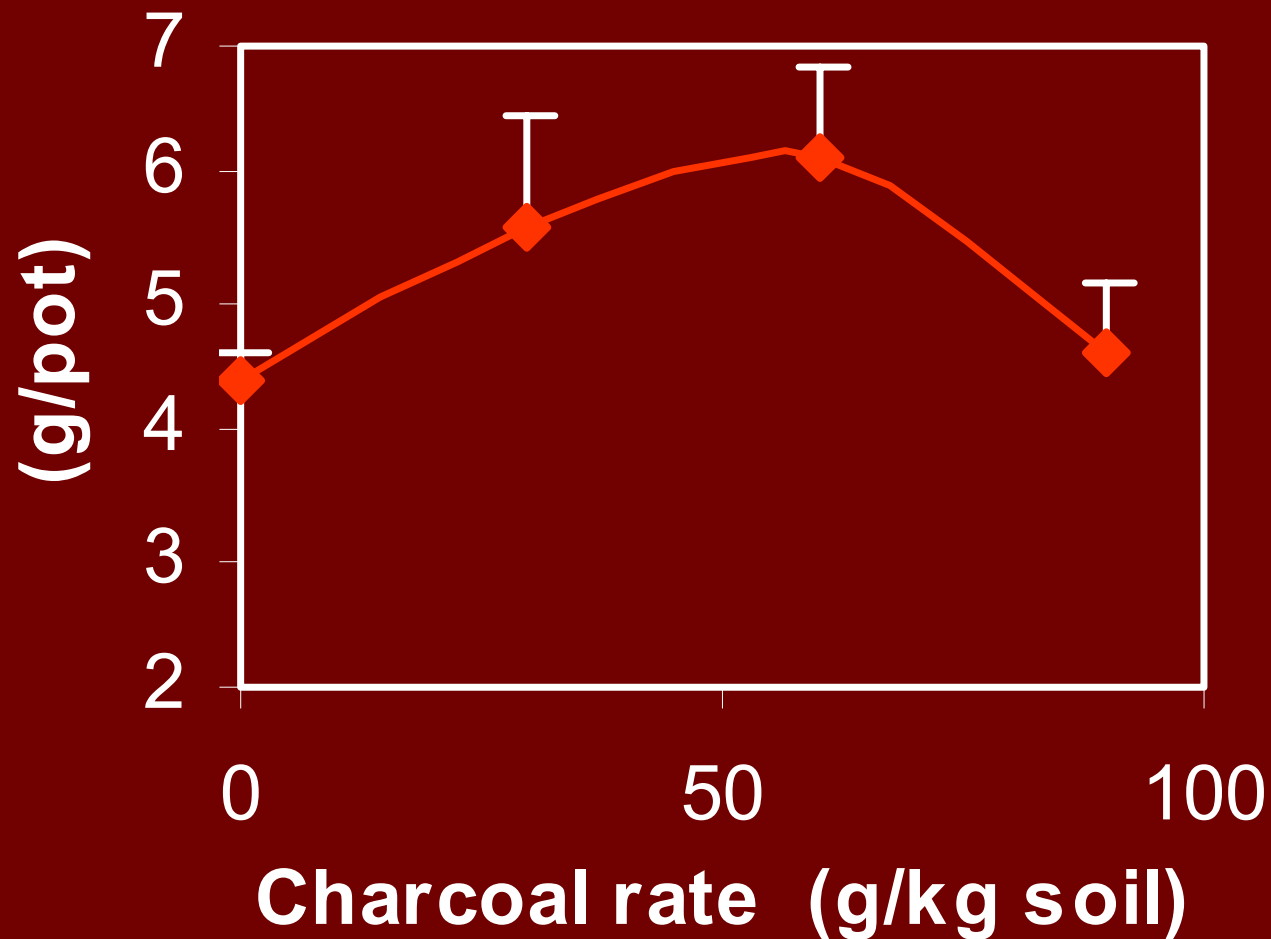


Black Carbon Management Systems

Optimum
response
curve

Biomass production of
common beans
(*Phaseolus vulgaris* L.)
(N=4)

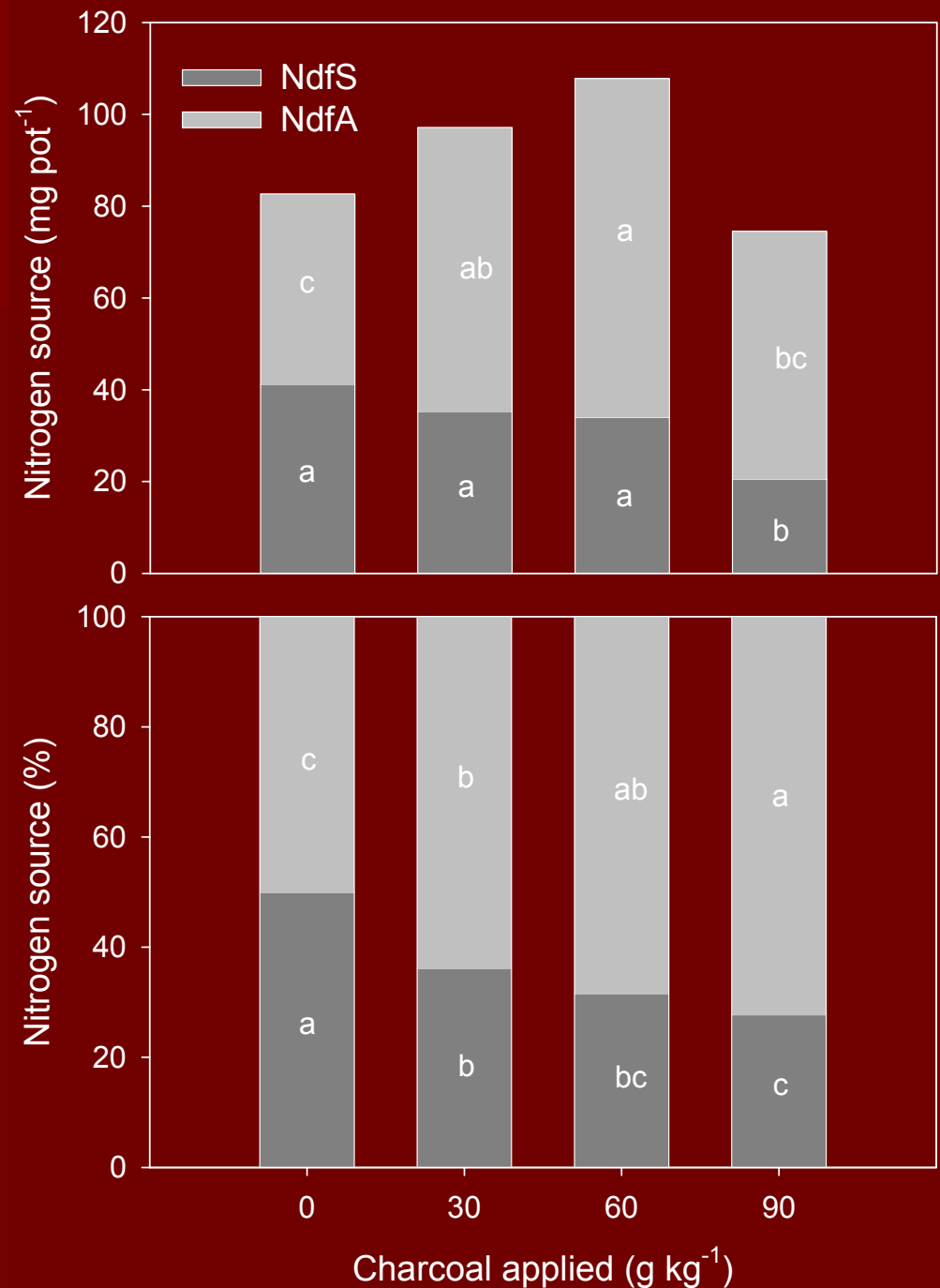
Rondon et al., in prep.



Black Carbon Management Systems – BNF

BNF of common beans (*Phaseolus vulgaris* L.) determined by isotope dilution (N=4)

Rondon et al., in prep.



Black Carbon Management Systems

- ❑ Multiple environmental and agricultural benefits
- ❑ Sustainability of soil amelioration
- ❑ Accountability of carbon sequestration
- ❑ Combination with existing land management systems (e.g. slash-and-burn) as well as charcoal and energy production systems