Managing *Terra Preta*: Modifications of an Agricultural System in a Nutrient-Poor Environment

Laura A. German[1]

[1]*Socio-Ecologist, African Highlands Initiative / World Agroforestry Centre*
PhD, Department of Anthropology, University of Georgia

Funding:
National Science Foundation
Wenner Gren Foundation for Anthropological Research

Overview

I. Background

II. Methodology

III. Findings

- Cultivation Practices
- Biophysical Correlates
- Ethnoecology (site ecology, pedology)

IV. Conclusions

I. Background

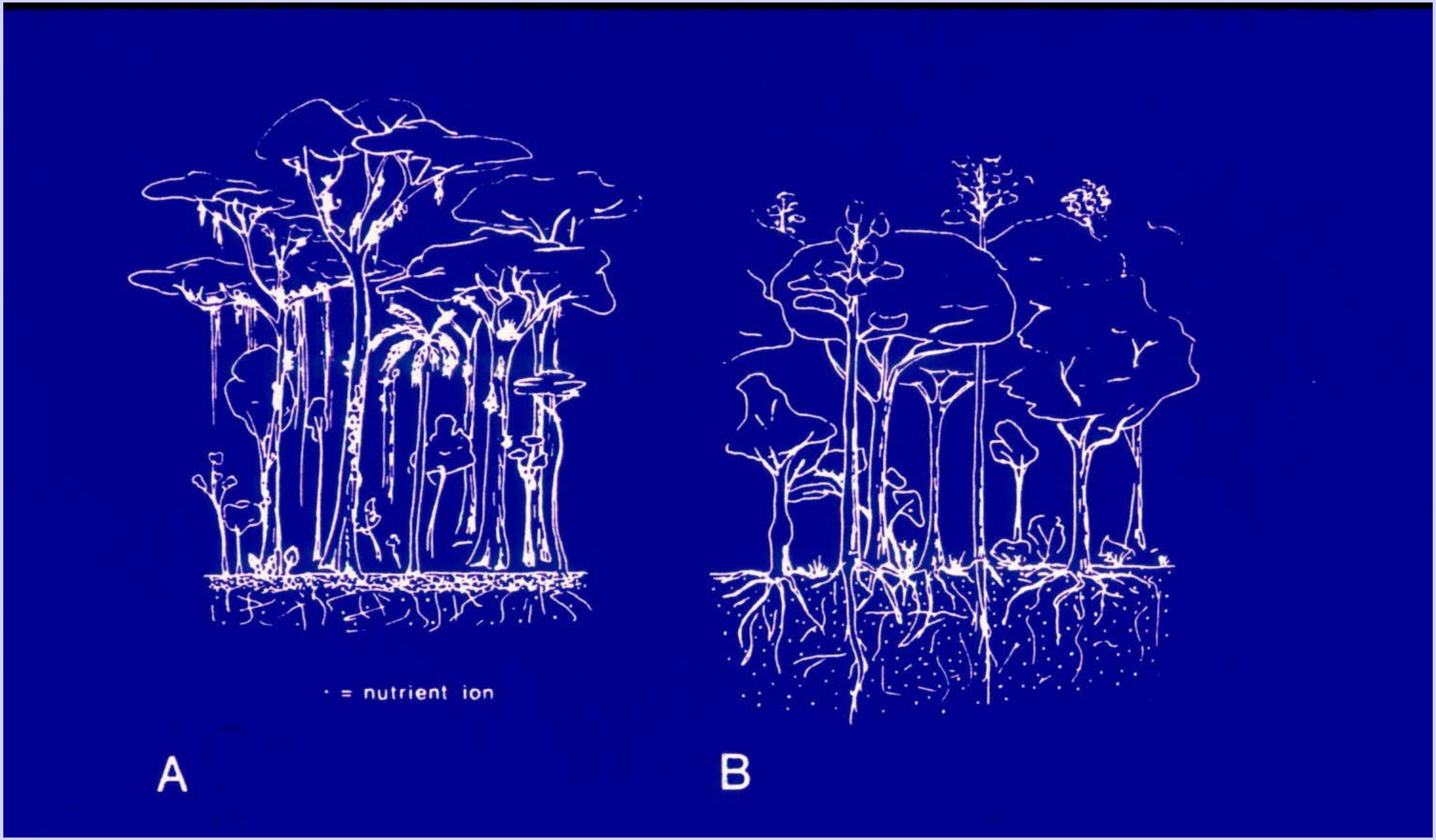


Figure 1. Distribution of Roots and Nutrient Ions in the Soil of a Typical Amazon Rainforest and a More Nutrient-Rich Forest (from Jordan 1985)

I. Background

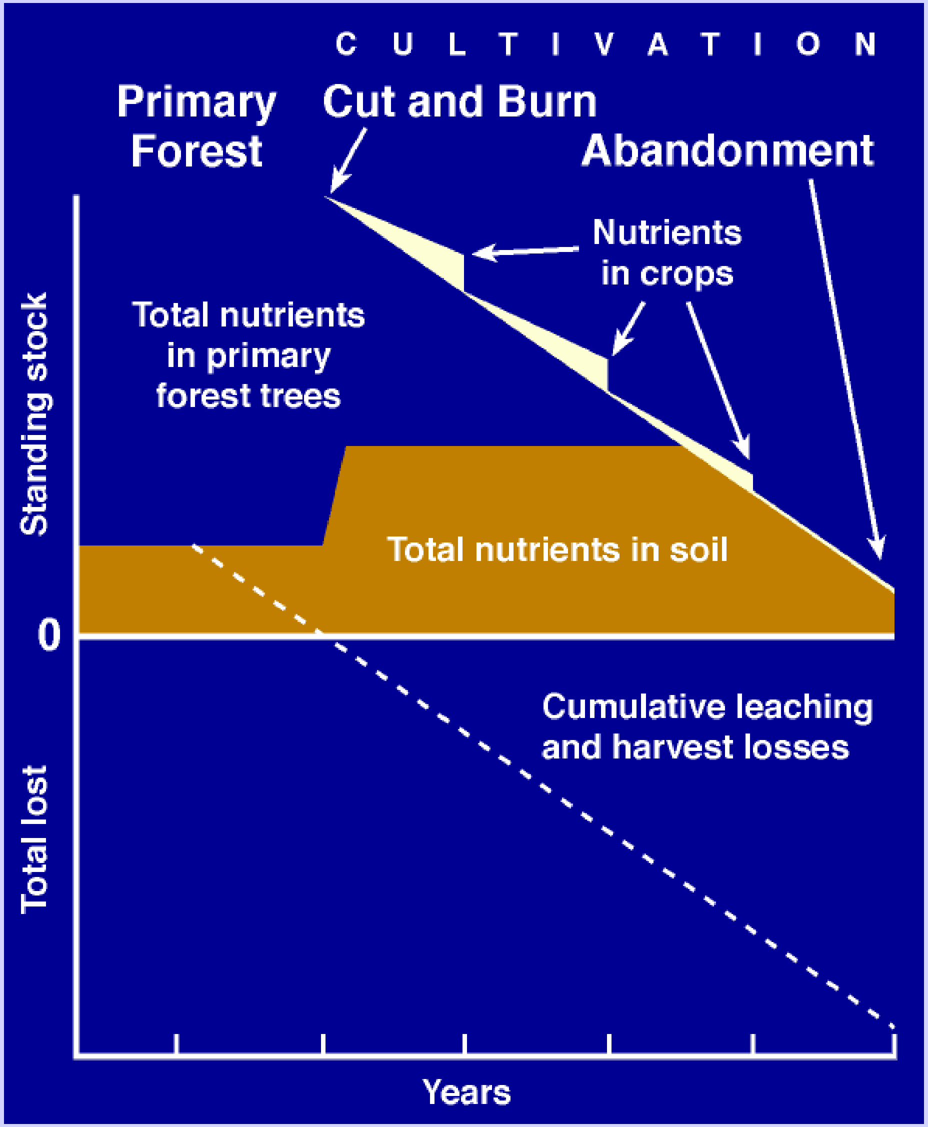


Figure 2. Standing Stocks of Nutrients as a Function of Time in a Slash and Burn Plot in the Amazon Basin (above) and Cumulative Nutrient Losses from the Soil (below). From Jordan 1985.

I. Background

Adaptations to Infertile Terra Firme Soils

- Dependence on the burn (high forest biomass)
- Itinerancy
- Bitter manioc

I. Background

***Terra Preta do Índio:* Environmental Anomaly**

- Phosphorous
- Exchangeable cations
- pH
- Al
- CEC
- organic matter stability

I. Background

Adaptations to Black Earth Environments

- How do the perception, use and nutrient dynamics of Black Earth swiddens differ from non-anthropogenic upland soils?

II. Methodology

Field Site

- Blackwater ecosystem
- Agriculture limited to terra firme soils

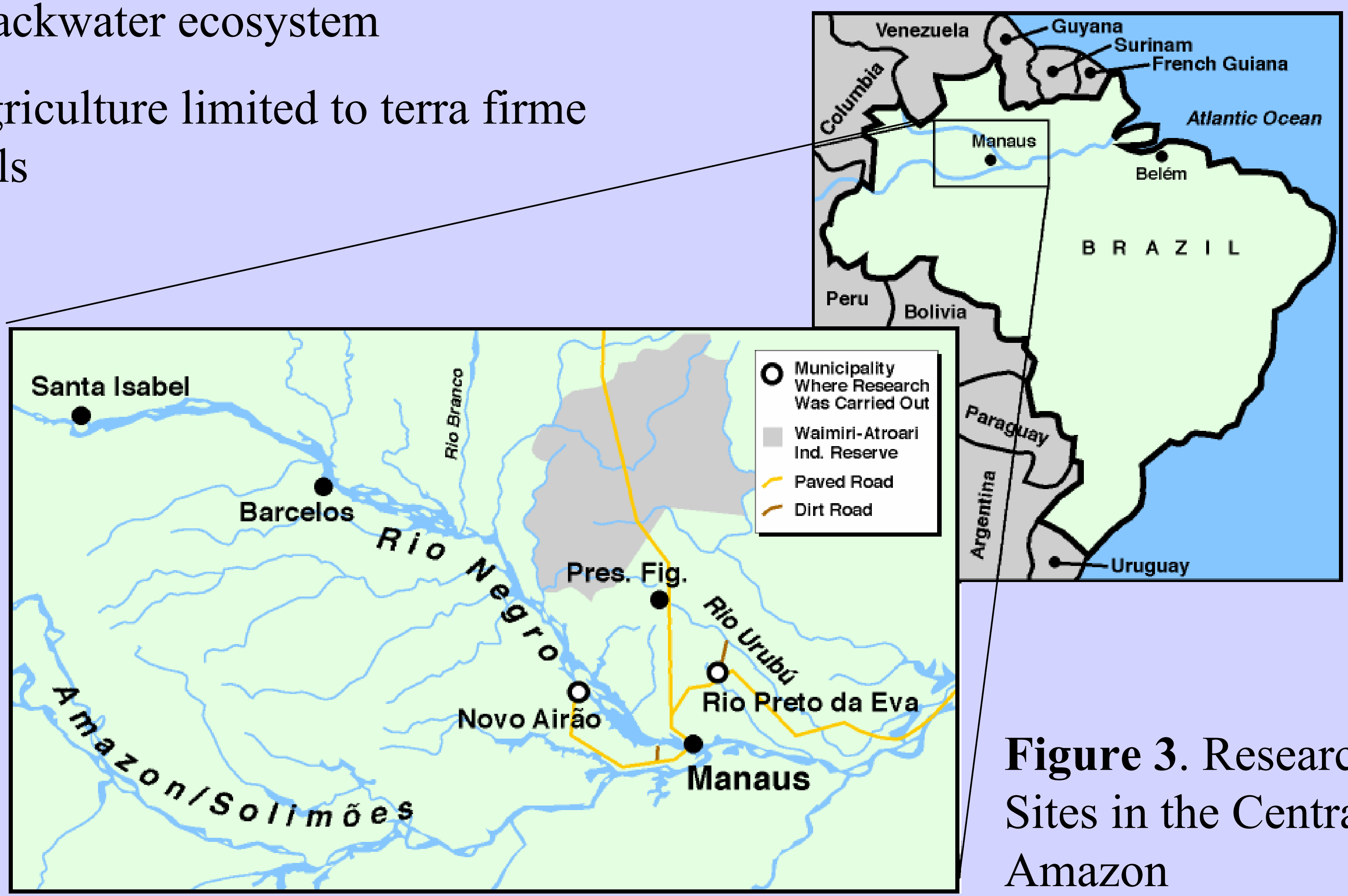
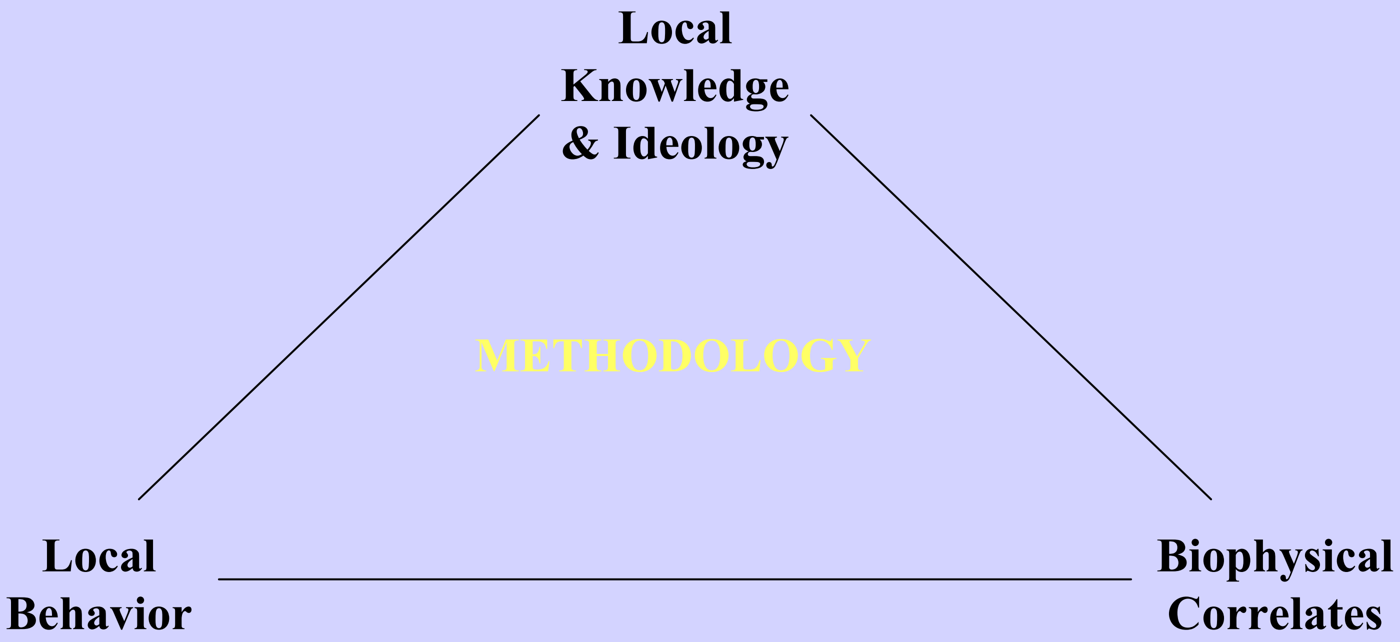


Figure 3. Research Sites in the Central Amazon

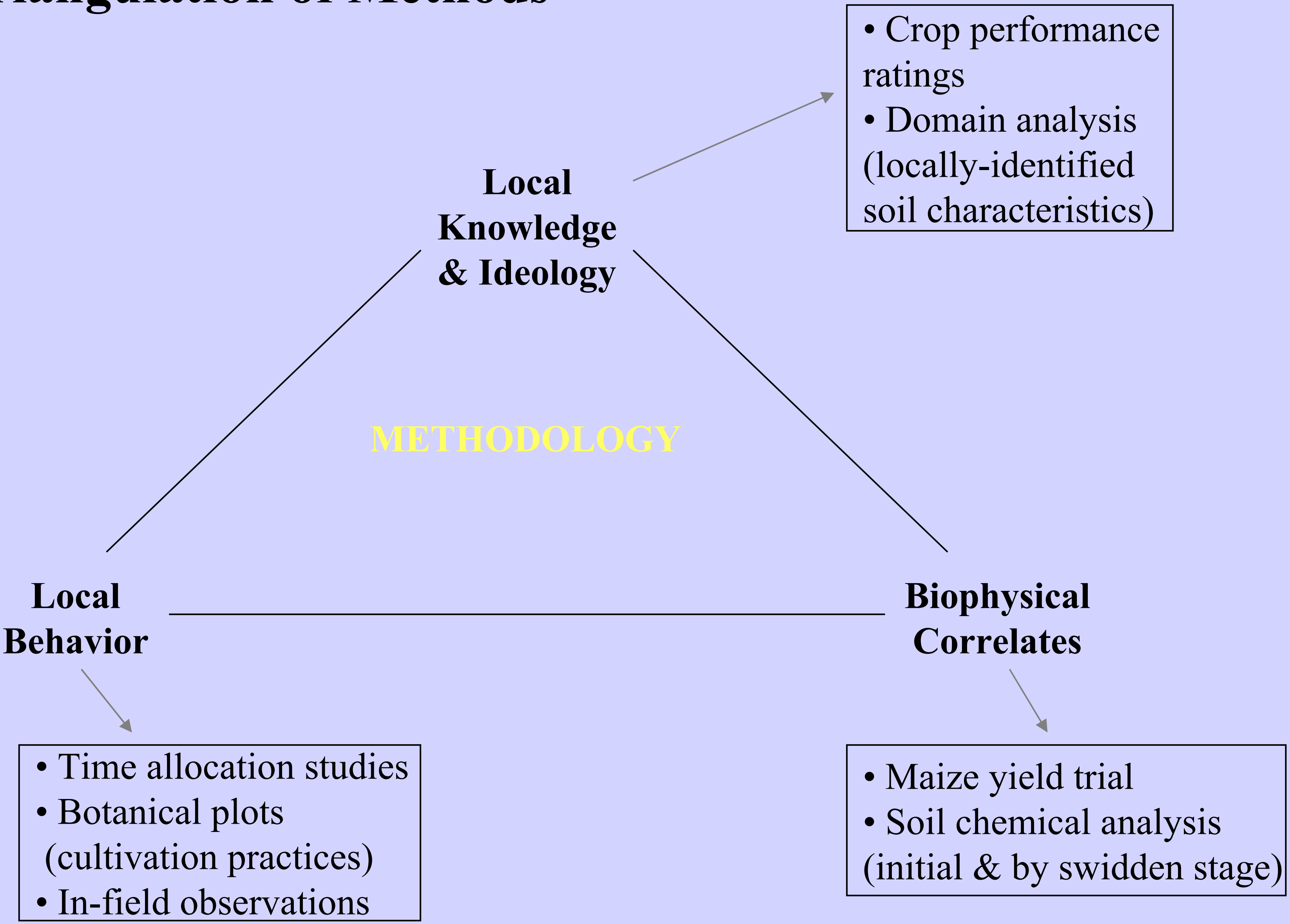
II. Methodology

- **Triangulation of Methods**



II. Methodology

- **Triangulation of Methods**



III. Findings

- **Behavior (cultivation practices)**

$$\text{\% Divergence of Averages} = \frac{(\text{Average}_{BE} - \text{Average}_{LAT})}{\text{Average}_{LAT}} \times 100$$

Table 1. Botanical Divergence of Black Earth from Latosol Cultivation System

	% Divergence:		
Crop Class:	In the % of Swiddens with Each Crop Class Present	In the % of Area with Each Crop Class Present	In the % of Individual Plants of Each Crop Class
Vegetable	541.53	704.85	3846.49
Perennial Fruit Trees	-75.13	-65.70	140.25
Tuber Crops	-66.42	-57.26	-59.09
Edible Graminea	-85.55	-78.33	-3.75
Grain Crops	*0, 11.7*[a]	*0, 51.8*[a]	*0,11.7*[a]
Non-Edible Utilitarian	-45.03	-58.92	-33.07
Voluntary Edibles	50.70	6.99	172.69
Manioc (M)	-73.18	-62.59	-61.01

[a] Original values are presented in italics where a zero value for Latosols makes the calculation of % Divergence impossible.

III. Findings

- **Behavior (cultivation practices)**

Table 2. Fallow Dynamics Contrasted for Black Earth and Latosol Swiddens

Parameter		**Black Earth** (months)	**Latosol** (months)
Total Time in Production:	Average*	8.68	28.73
	St. Dev.	11.07	10.61
Total Time in Production: (outlier removed)	Average*	4.56	28.73
	St. Dev.	6.32	10.61
Fallow Age:	Average*	51.54	131.11
	St. Dev.	36.68	29.82
% Swiddens Cleared from Primary Forest:		25.64	72.73

III. Findings

- **Behavior (time allocation)**

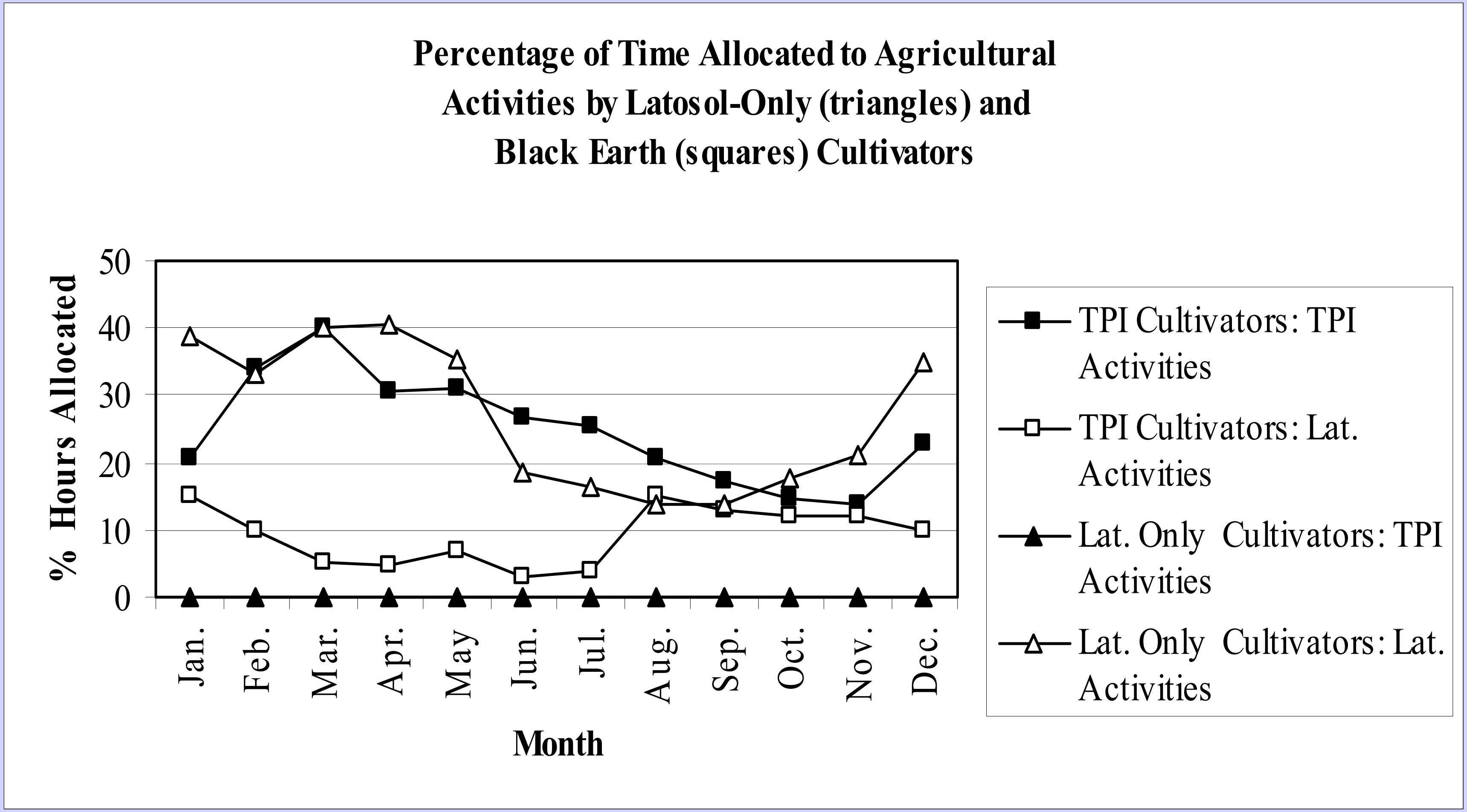


Figure 4. Time Allocated to Terra Preta & Latosol Production Systems

III. Findings

• **Biophysical Correlates** – Soil Chemical Analyses

Table 3. Fertility Indices by Stage of the Swidden Agricultural Cycle

Productive Phase and Soil Type		Ca^{++} ($mmol_c \cdot dm^{-3}$)	K^+ ($mg \cdot dm^{-3}$)	Mg^{++} ($mmol_c \cdot dm^{-3}$)	Na^+ ($mg \cdot dm^{-3}$)	Avail. P ($mg \cdot dm^{-3}$)	pH (*H2O*)	Al^{+++} ($mmol_c \cdot dm^{-3}$)
Forested	0-10	0.30	18.00	0.40	4.00	3.35	3.89	14.30
Latosol	10-30	0.10	11.00	0.30	2.50	2.18	4.01	15.90
Burnt	0-10	0.35	39.33	0.30	11.00	5.98	4.06	2.78
Latosol	10-30	0.08	25.67	0.10	7.42	2.92	4.11	2.22
Cultivated	0-10	4.60	36.95	3.20	12.58	7.88	4.09	22.20
Latosol	10-30	0.90	21.70	1.10	7.60	3.38	4.07	21.00
Abandoned	0-10	0.90	22.50	0.80	16.00	4.77	4.13	29.20
Latosol	10-30	0.20	12.50	0.40	12.75	2.09	4.26	20.30
Old Fallow	0-10	3.81	25.80	0.81	13.60	81.94	4.79	1.07
Black Earth*	10-30	2.74	12.20	0.35	7.90	25.21	4.79	1.41
Burnt	0-10	6.00	53.14	1.47	15.43	105.84	5.20	0.67
Black Earth	10-30	3.23	25.43	0.54	8.14	123.68	4.91	1.25
Cultivated	0-10	48.50	43.23	12.10	17.54	94.75	5.19	4.60
Black Earth	10-30	21.60	21.23	3.90	7.31	56.89	4.68	11.90
Abandoned	0-10	56.50	30.36	12.00	16.36	118.76	5.04	4.90
Black Earth*	10-30	37.60	16.91	5.10	9.64	47.99	4.94	8.00

III. Findings

- **Biophysical Correlates** – Maize yield trial

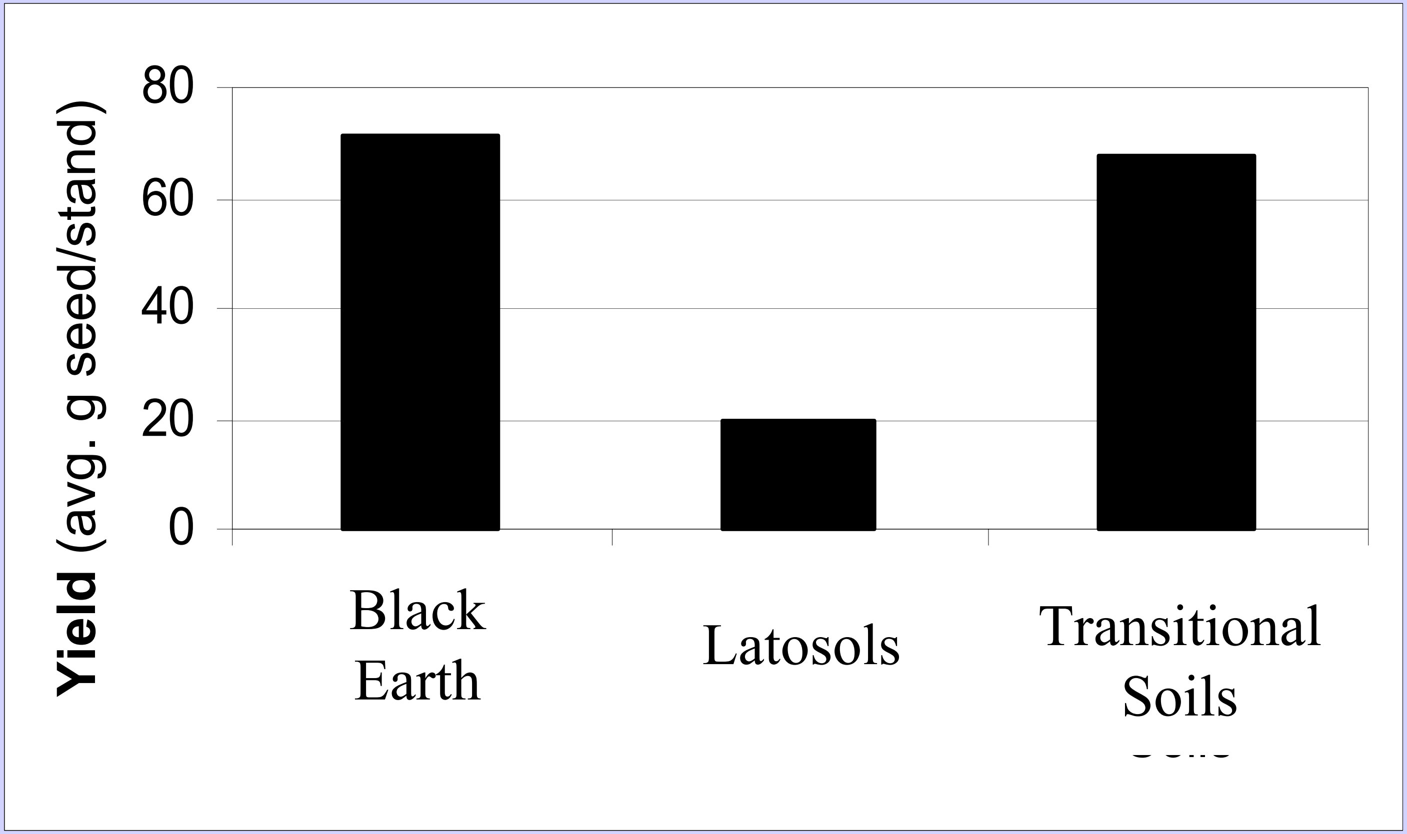


Figure 5. Maize (*Zea mays*) Yields as a Function of Soil Type

III. Findings

- **Local Knowledge**
  - ➢ Soil Quality
  - ability to cultivate broad array of crops

Table 4. Crop Performance Ratings by Soil Class

Crop	Terra Preta (Mean)	Terra Preta (St. Dev.)	Terra Comum (Mean)	Terra Comum (St. Dev.)
Pineapple	1.45	0.82	1.71	0.62
Banana	0.42	0.67	1.41	0.70
Sugar Cane	1.50	0.80	1.13	0.88
Yam	1.50	0.80	1.88	0.31
Cariru [a]	2.00	0.00	0.20	0.42
Onion	1.64	0.67	0.40	0.66
Coconut	2.00	0.00	0.55	0.69
Red Bean	2.00	0.00	0.38	0.64
Sweet Manioc	1.33	0.65	1.55	0.79
Papaya	2.00	0.00	0.50	0.80
Bitter Manioc	0.75	0.87	1.88	0.31
West Indian Gerkin	2.00	0.00	0.88	0.80
Watermelon	1.90	0.32	0.22	0.36
Maize	2.00	0.00	0.29	0.62
Lemon	1.42	0.90	1.42	0.79
Cucumber	2.00	0.00	0.50	0.67
Sweet Pepper	2.00	0.00	0.50	0.81
Bell Pepper	2.00	0.00	0.32	0.64
Okra	2.00	0.00	0.35	0.67
Tomato	2.00	0.00	0.10	0.32
Star Nut Palm [a]	1.83	0.39	1.92	0.29
Squash	1.92	0.29	0.50	0.67
	Avg. Mean	***Avg. S.D.***	***Avg. Mean***	***Avg. S.D.***
	1.72	0.37	0.82	0.19

[a] These species are voluntary edibles rather than intentionally-planted domesticates.

III. Findings

- **Local Knowledge**

  ➢ Soil Quality
  - ability to cultivate broad array of crops
  - these benefits can be qualified:

    → benefits are crop-specific:

“Latosol crops”	“Black earth crops”
banana (German)	banana (Mazurek pers.); *pacovão* (German)
bitter manioc (Ibid)	
fruit trees (Ibid)	citrus, papaya (Woods & McCann 1999)
rubber (Smith 1980)	
	vegetable crops (various)
	maize & beans (various)

III. Findings

- **Local Knowledge**

➢ Soil Quality

- ability to cultivate broad array of crops
- these benefits can be qualified:

→ benefits are crop-specific:

→ geographical variation in TP:

"Each black earth is different, one from the other. There is black earth in which manioc only produces tiny tubers..." – R. Urubú farmer

"Corn only grows on pure black earth; it doesn't grow in just any black earth." – Lower Rio Negro farmer

III. Findings

- **Local Knowledge**

➢ <u>Sustainability</u>

• Accounts of sustainability and persistence (Santarém, C. Amazon, Belém interior)

• Yet observations point to belief that extended cultivation periods are more viable on Latosols than Black Earth

• Farmer observations:

- whitening of epipedon (clay, OM loss)
- sharp decline in soil fertility with continuous cultivation

III. Findings

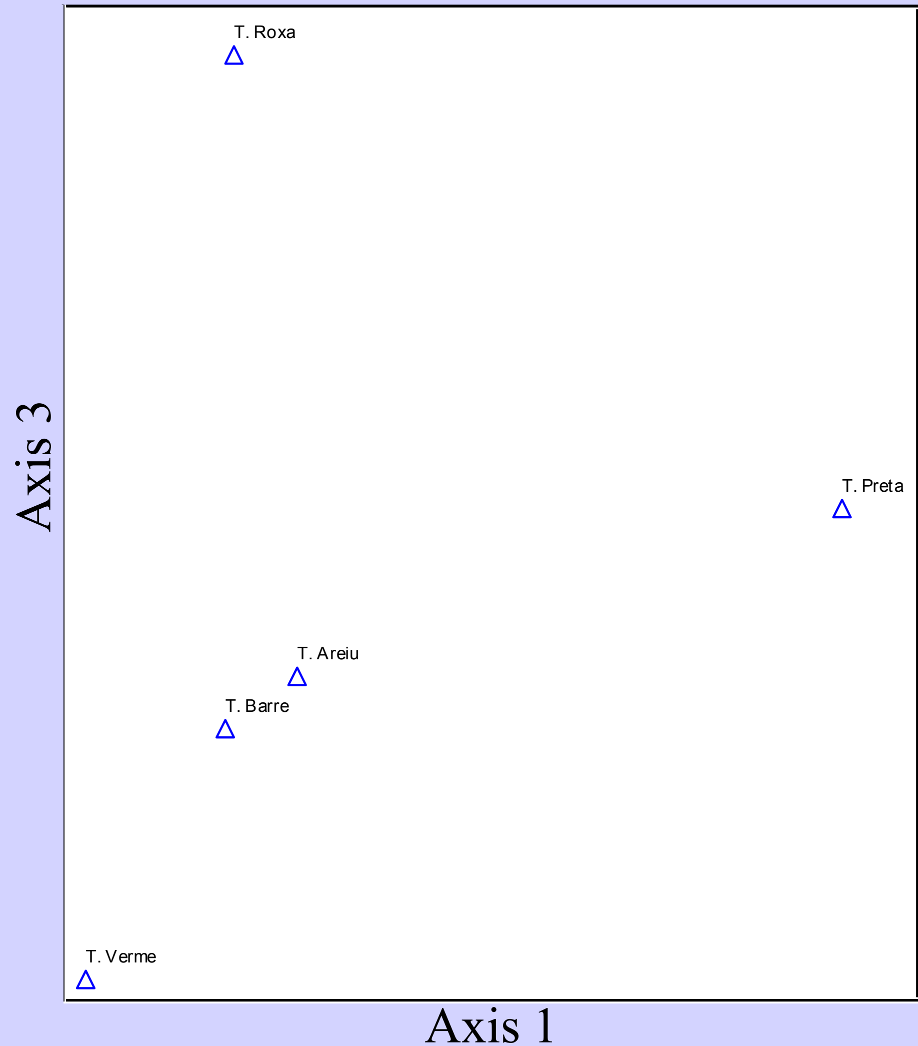
- **Local Knowledge**

  - ➢ Sustainability
    - Domain analysis

Table 4. R Values for Axes on Multidimensional Plot

Parameter	*Axis:* 1	2	3
Strong when worked	-.16	.51	.89
Weak when worked	-.24	-.37	-.98
Raw	-.70	-.58	-.77
Burnt	.70	.58	.77
Fertilized	.98	.01	.09
Maintains strength after burn	.48	.55	.93
Fully recuperates with fallow	.55	.18	.94
Always produces when weak	.35	-.76	-.63
Recup. quickly after weakens	.81	.40	.61
Tires quickly	-.26	.00	-.94
Economizes fertilizer	.84	.41	.67

Figure 6. Multidimensional Scaling of Soil Properties Related to Sustainability



III. Findings

- **Other Dimensions of Sustainability**

  - Residue management

Table 5a. Residue Management Strategies Identified by Smallholders for Yield Maximization

Management option:	**Terra Preta (% farmers)**	**Latosols (% farmers)**
Burn residues	50	40
Weed & leave residues in place	42	50
Remove residues from swidden	8	10

Table 5b. Residue Management Strategies Identified by Smallholders for Sustaining Soil 'Strength'

Management option:	**Terra Preta (% farmers)**	**Latosols (% farmers)**
Burn residues	8	20
Weed & leave residues in place	84	70
Remove residues from swidden	8	10

III. Findings

- **Other Dimensions of Sustainability**

  - Crop rotation

“*There are people that think that terra preta becomes weakened, but really she is weakened only for one thing, but remains strong for another.*”

“*Manioc, first crop grows well, the second doesn’t produce any longer. . . Manioc tires the soil more than vegetables do.*”

“*On black earth, you can only plant manioc one year, then let it rest. . . After planting corn and beans, it will be possible to plant manioc again.*”

III. Findings

- **Other Dimensions of Sustainability**

  - Leaching of Soil Nutrients

Table 6. The Leaching of Total Phosphorus on Black Earth as a Function of Use

Horizon *(Hx)*	**Intensively Farmed Sites** *P by Horizon (as % of total g of P found in soil profile)*	**Minimal Use Sites**
H1	52.9	79.1
H2	43.3	20.4
H3	3.8	0.5
H4	0.0	0.0

IV. Conclusions

- The benefits of Black Earth in relation to other predominant soil classes are clearly indicated by:
  - higher soil nutrient stocks at different stages of the swidden cycle
  - higher maize yields
  - the broader array of crops that can be grown on these soils
  - the lesser dependence on the burn / high forest biomass to make these areas viable for agriculture
  - the diversion of time away from manioc swiddens and toward Black Earth (due to the opportunity for farmers to cultivate high-value vegetable crops)

IV. Conclusions

- The benefits of Black Earth in relation to other predominant soil classes are clearly indicated by:
  - higher soil nutrient stocks at different stages of the swidden cycle
  - higher maize yields
  - the broader array of crops that can be grown on these soils
  - the lesser dependence on the burn / high forest biomass to make these areas viable for agriculture
  - the diversion of time away from manioc swiddens and toward Black Earth (due to the opportunity for farmers to cultivate high-value vegetable crops)

- However, these advantages must be qualified:
  - higher labor requirements due to higher incidence of weeds
  - quick decline in soil 'strength' after the burn (relative to crops grown?)
  - there is a need to develop appropriate management strategies to preserve its unique properties over the long run
  - further research on management and sustainability is required

Acknowledgements

Funding Agencies:

National Science Foundation

Wenner Gren Foundation for Anthropological Research

Host Institutions:

EMBRAPA (Dr. Manoel Cravo)

Fundação Vitória Amazônica

Doctoral Committee:

Ted Gragson, Ben Blount, Pete Brosius (Anthropology), Ron Carroll, Frank Golley (Institute of Ecology), Larry West (Soil Science)

Black Earth Scholars & Amazonianists:

Bill Balée, Emilio Moran, Darrell Posey, Dirse Kern, Ítalo Falesi, William Denevan, James Petersen, Bill Woods, Michael Heckenberger, Eduardo Neves, Nigel Smith, Johannes Lehmann, Bruno Glaser