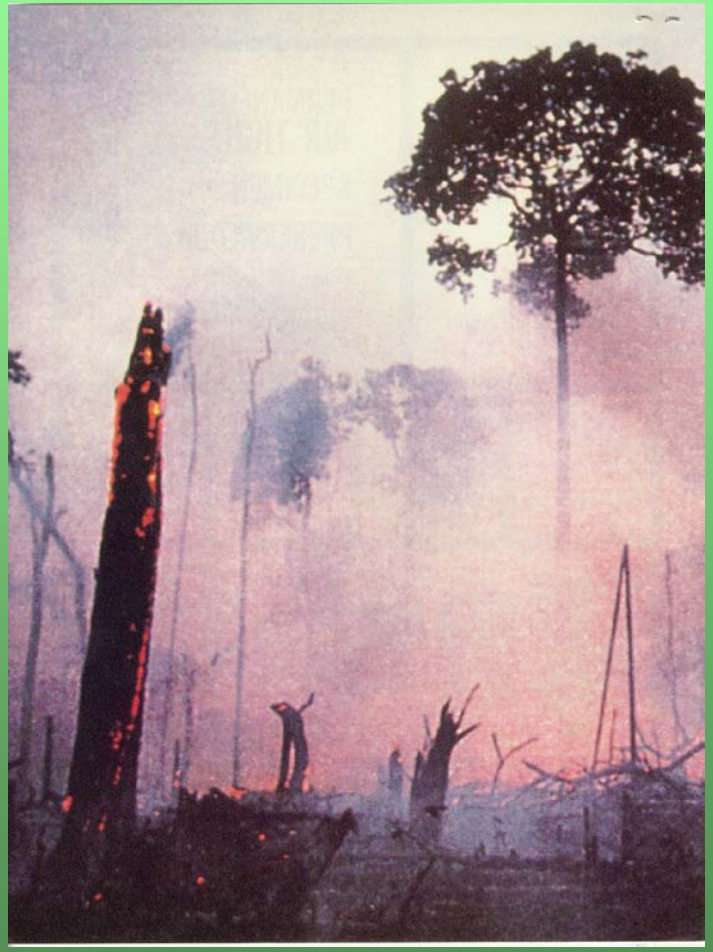
Human and Physical Dimensions of Land Use and Land Cover Change inAmazonia:



Forest Regeneration and Landscape Structure

Emilio F. Moran

Indiana University

Leader, Focus 1, LUCC

Principal Scientists

Emilio Moran, IU

Eduardo Brondizio, IU

J.C. Randolph, IU

Paul Mausel, ISU

Dalton Valeriano, INPE

Flavio Ponzoni, INPE

Research Locations

1. Altamira
2. Marajo
3. Tome-Acu
4. Igarape-Acu
5. Yapu
6. Rondonia
7. Santarem

Field Research 2001

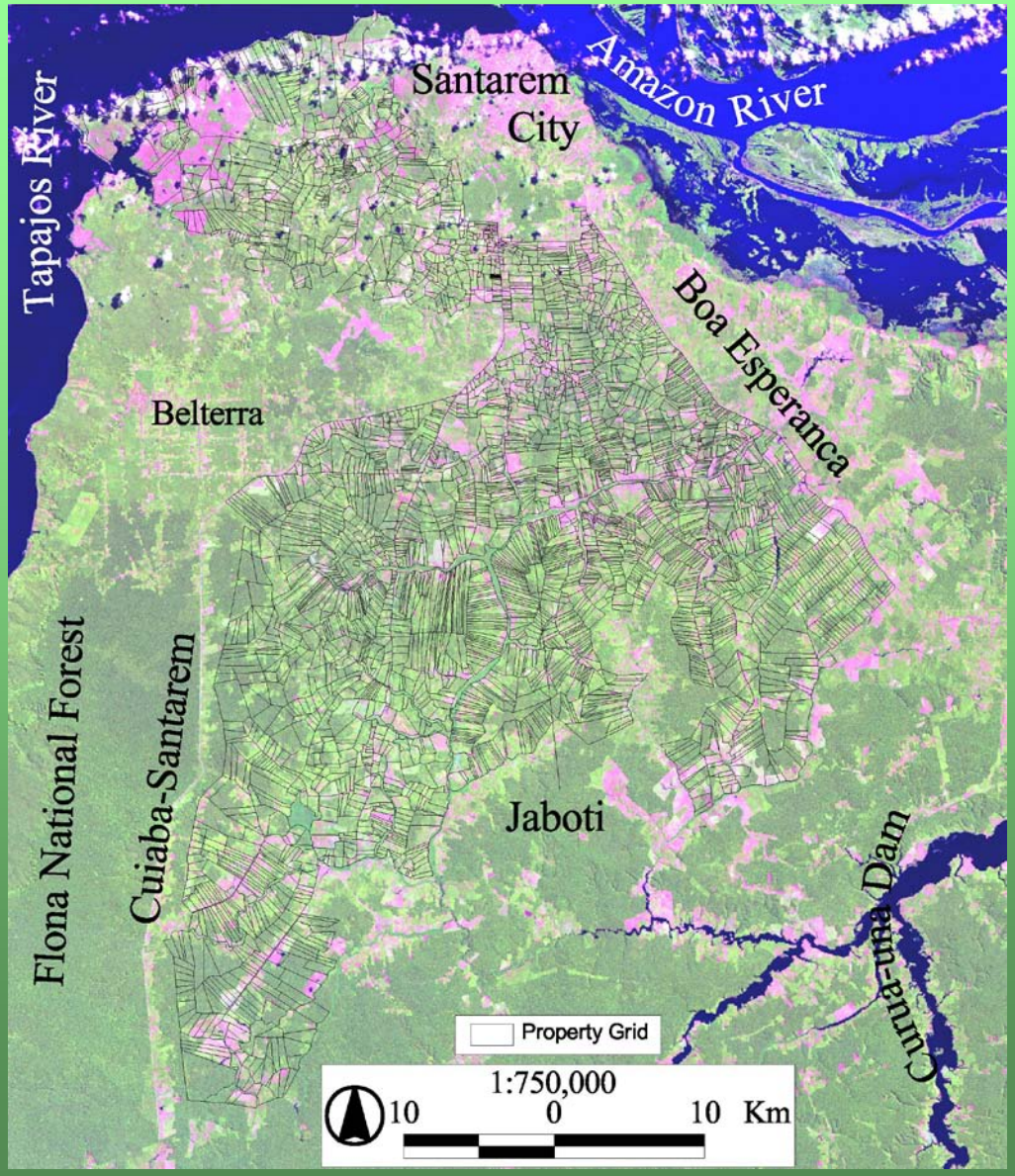
Altamira and Santarem sites

Field Team 2001

Altamira 1991 TM Image with Property Grid

Figure 10. Property Sampling Strategy

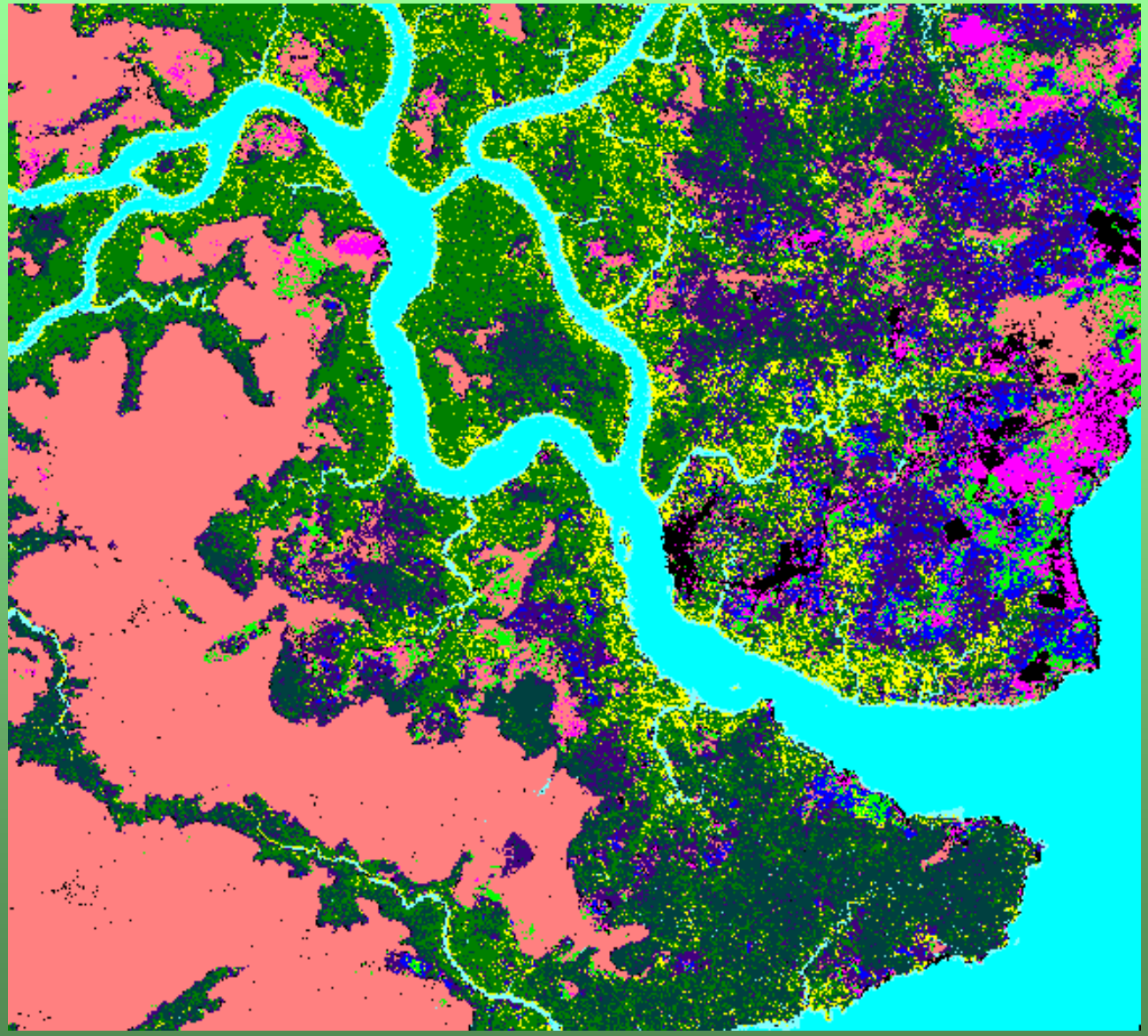
Santarem


Tapajos River
Santarem City
Amazon River
Boa Esperanca
Belterra
Flona National Forest
Cuiaba-Santarem
Jaboti
Curua-una Dam
Property Grid
1:750,000
10 0 10 Km

Book in preparation during 2001. Focus on land cover transitions in Marajo island and the role of acai management

Author: Eduardo Brondizio

Ponta de Pedras, Marajo Island

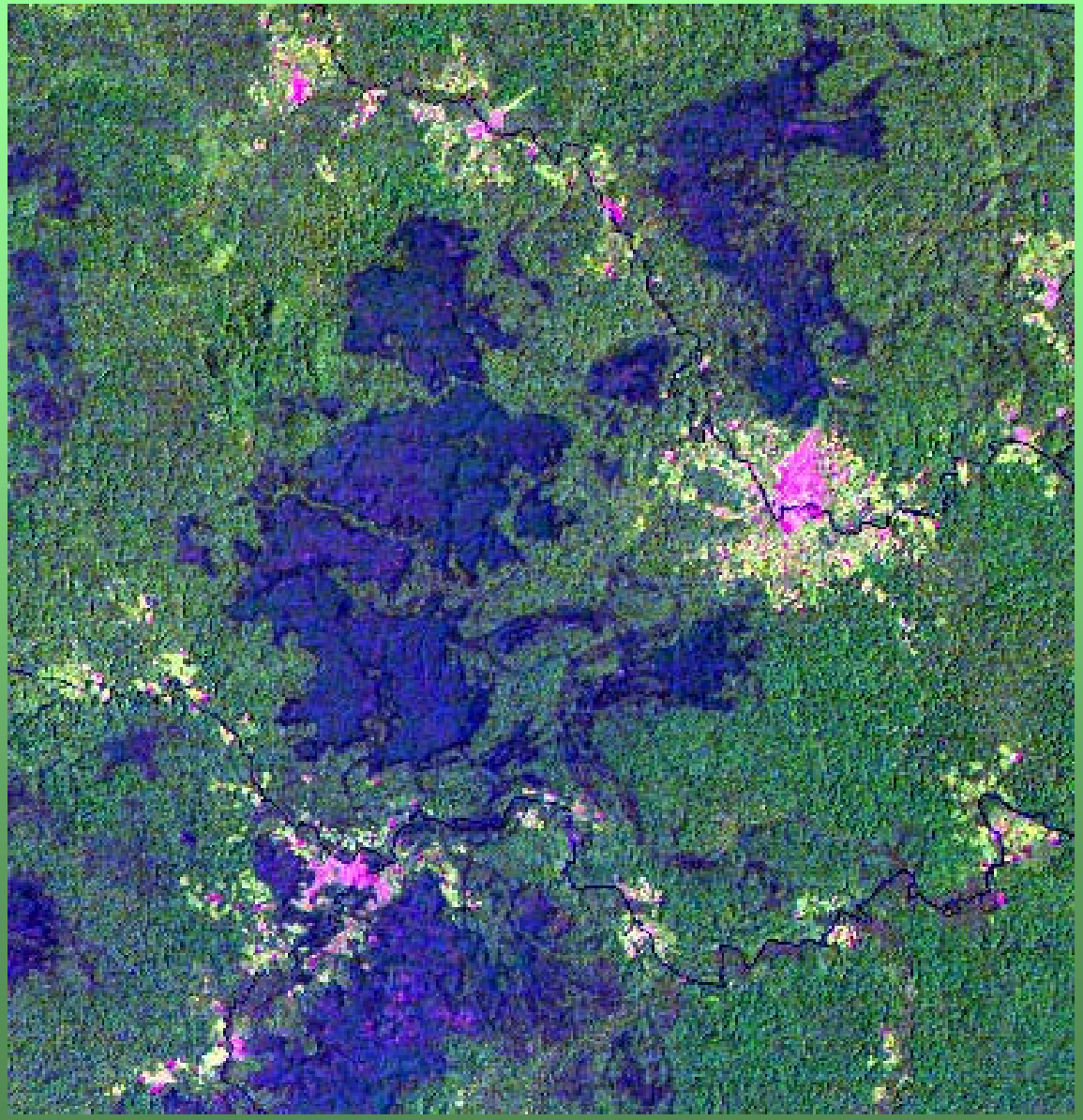


Environmental Limitations in two Tukanoan communities

Fabio de Castro, Eduardo Brondizio, Maria Clara Silva-Fosberg and E. Moran

Field Methods, in press

Yapu

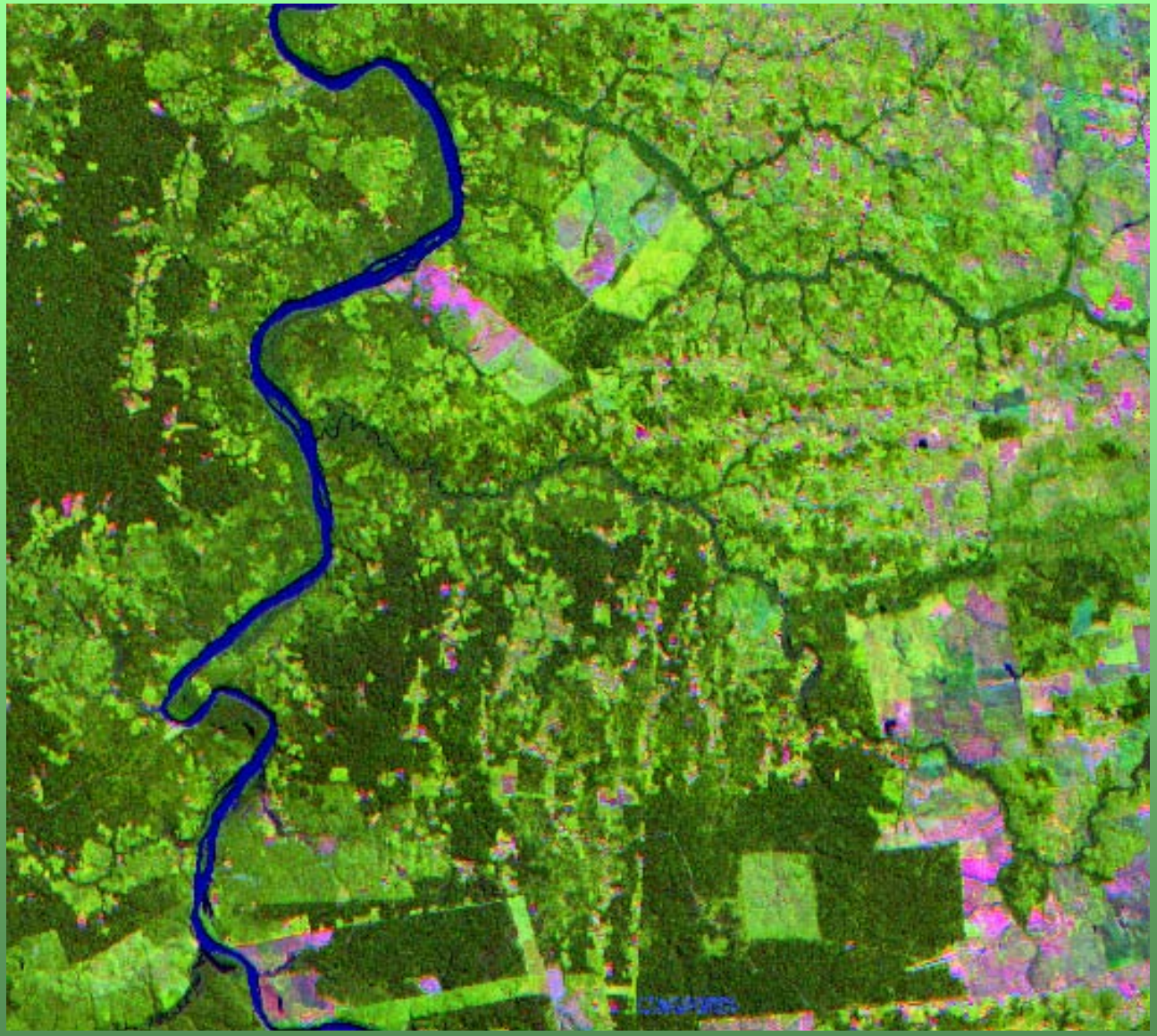


Biomass, Carbon and Nutrients of Successional Forests in the Eastern Amazon

J.C. Randolph, E. Moran
and E. Brondizio
Indiana University

Bragantina /Igarape Acu

Tome-acu

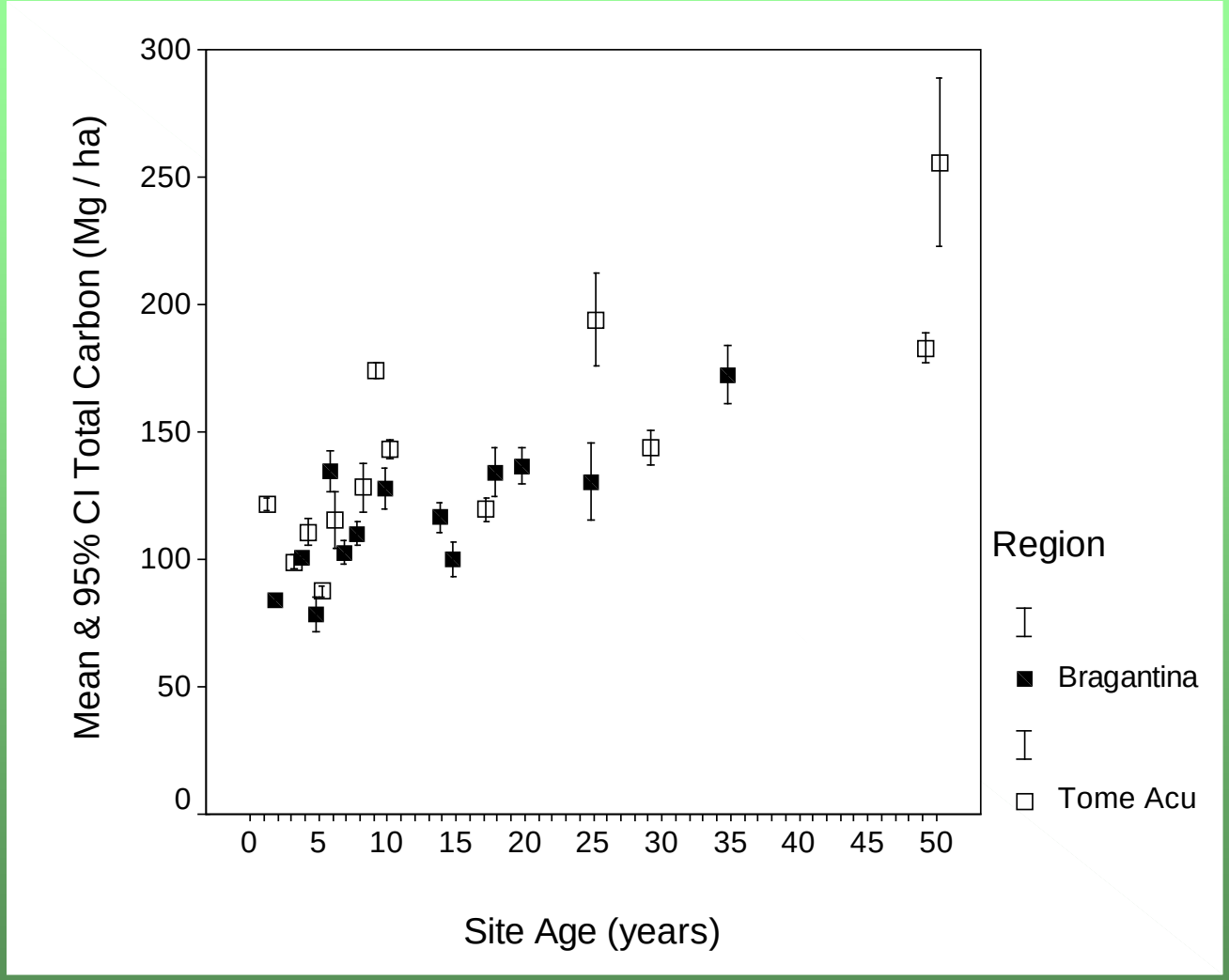


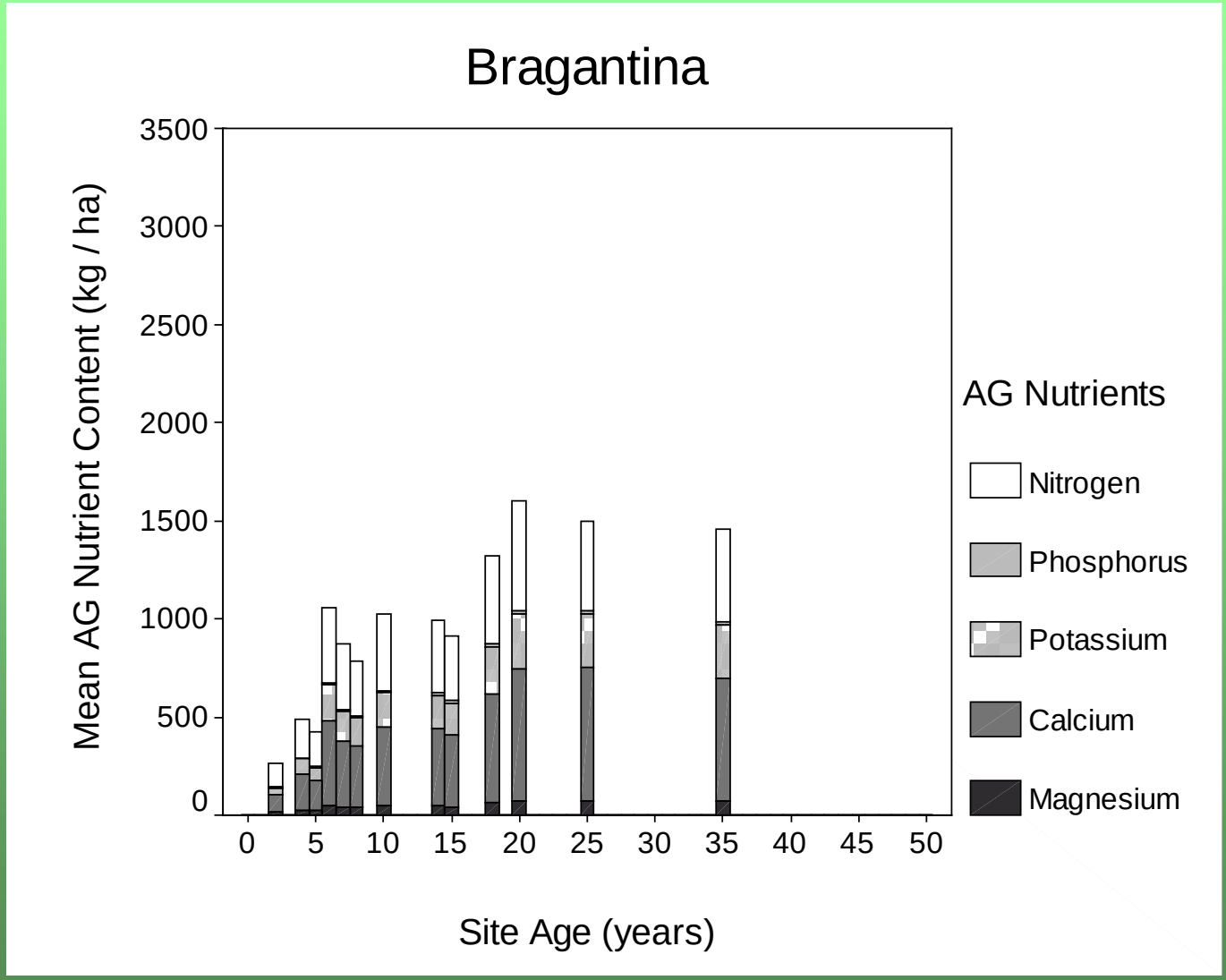
*Concentrations of C and nutrients (N,P, K, Ca, Mg) not significantly different between the secondary successional forests studied

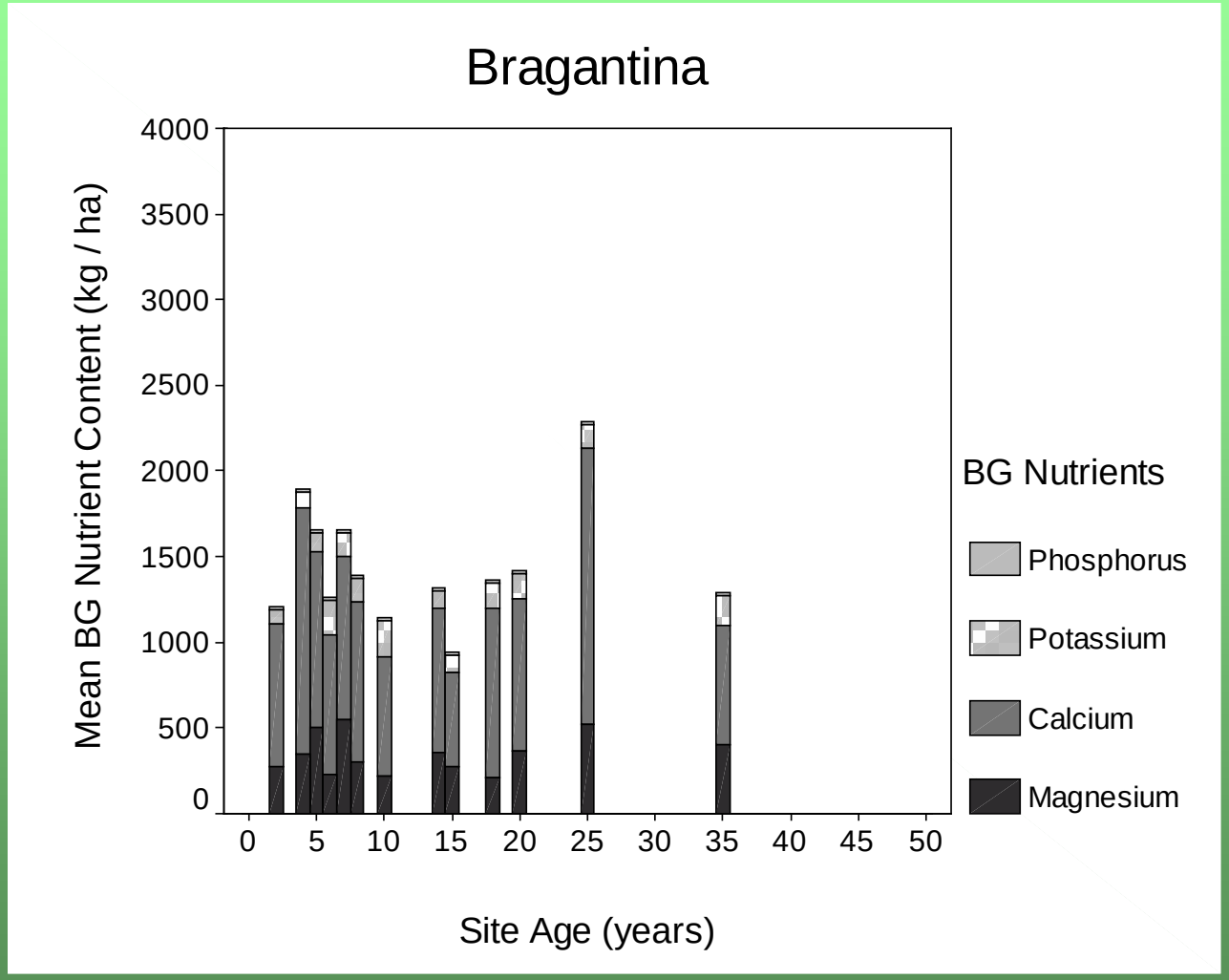
*Soils in Tome-Acu had significantly higher concentrations of N,P,K,Ca, Mg and percent clay than Bragantina soils

*Similar results to Johnson et al (2001) study
e.g. similar live biomass for 10 yr old site or 49.8 Mg per ha per year
and comparably low P in live trees and 0-20 cm in soils

*Similar results to Alves et al. 1997 study in Rondonia in estimates of above ground carbon stocks


Mean & 95% CI Total Carbon (Mg / ha)
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
Site Age (years)
Region
Bragantina
Tome Acu

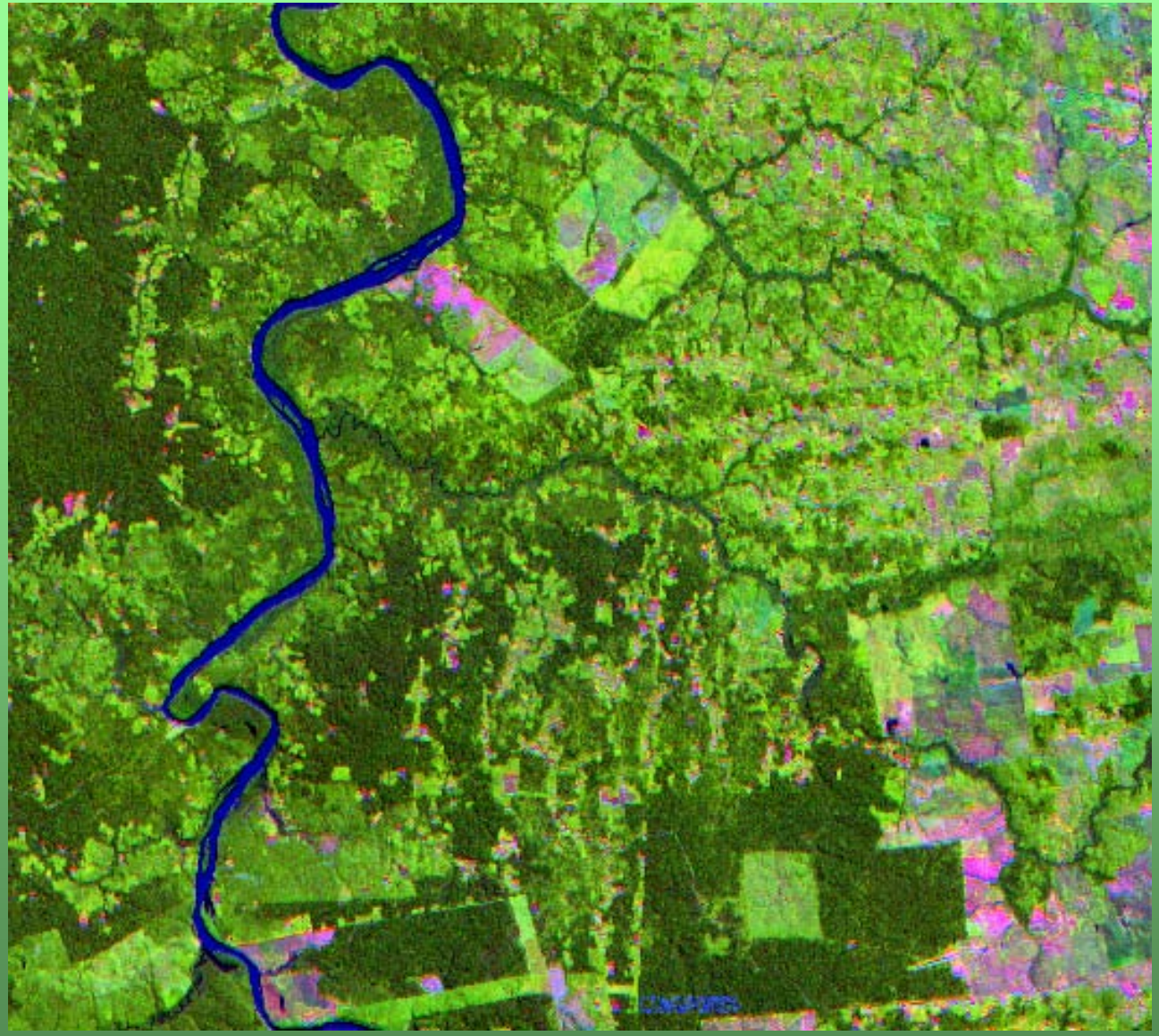

Bragantina
Mean AG Nutrient Content (kg / ha)
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
50
Site Age (years)
AG Nutrients
Nitrogen
Phosphorus
Potassium
Calcium
Magnesium


Bragantina
Mean BG Nutrient Content (kg / ha)
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
50
Site Age (years)
BG Nutrients
Phosphorus
Potassium
Calcium
Magnesium

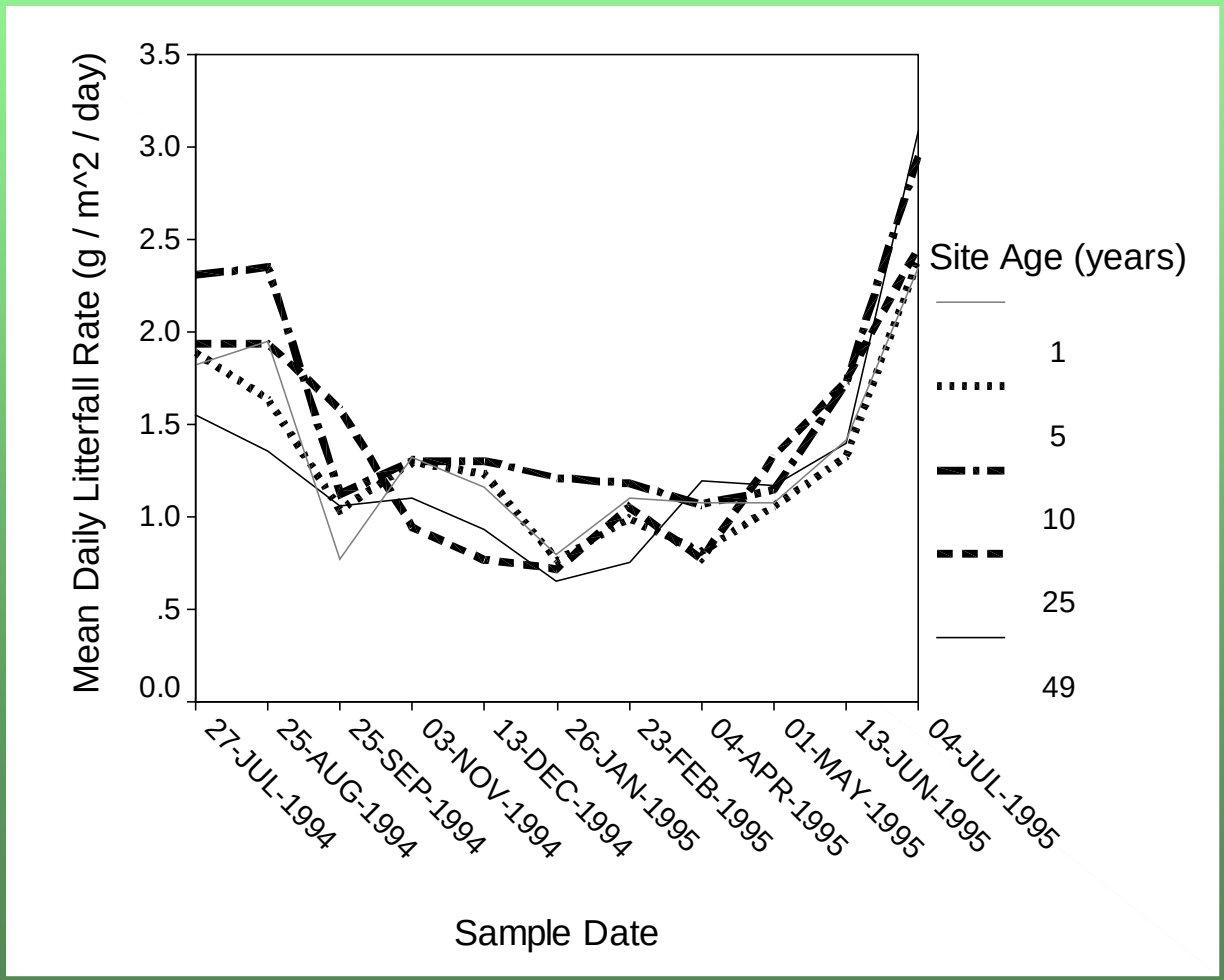
Litterfall and Decomposition in Successional Forests in the Eastern Amazon

J.C. Randolph*, E.J. Castellanos,*
E. Moran* and T. Bastos**
*Indiana University and
**EMBRAPA/CPATU

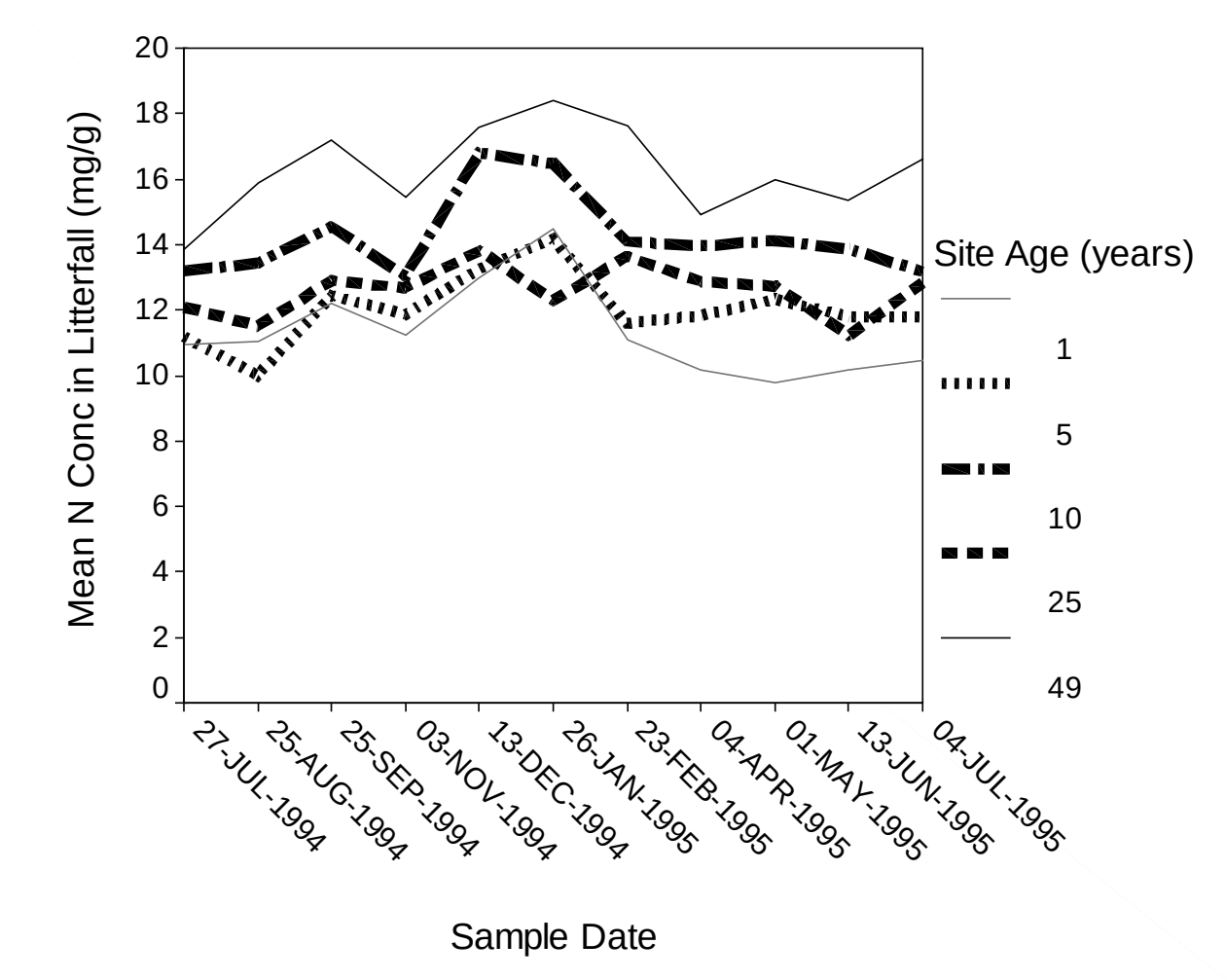
Tome-acu



*Highest litterfall rates in June and July, the lowest in Jan. (similar to findings of Mesquita et al. 1998)
Annual litterfall rates similar to other studies in Brazil and Guatemala, 5.0 to 6.9 Mg per ha per yr

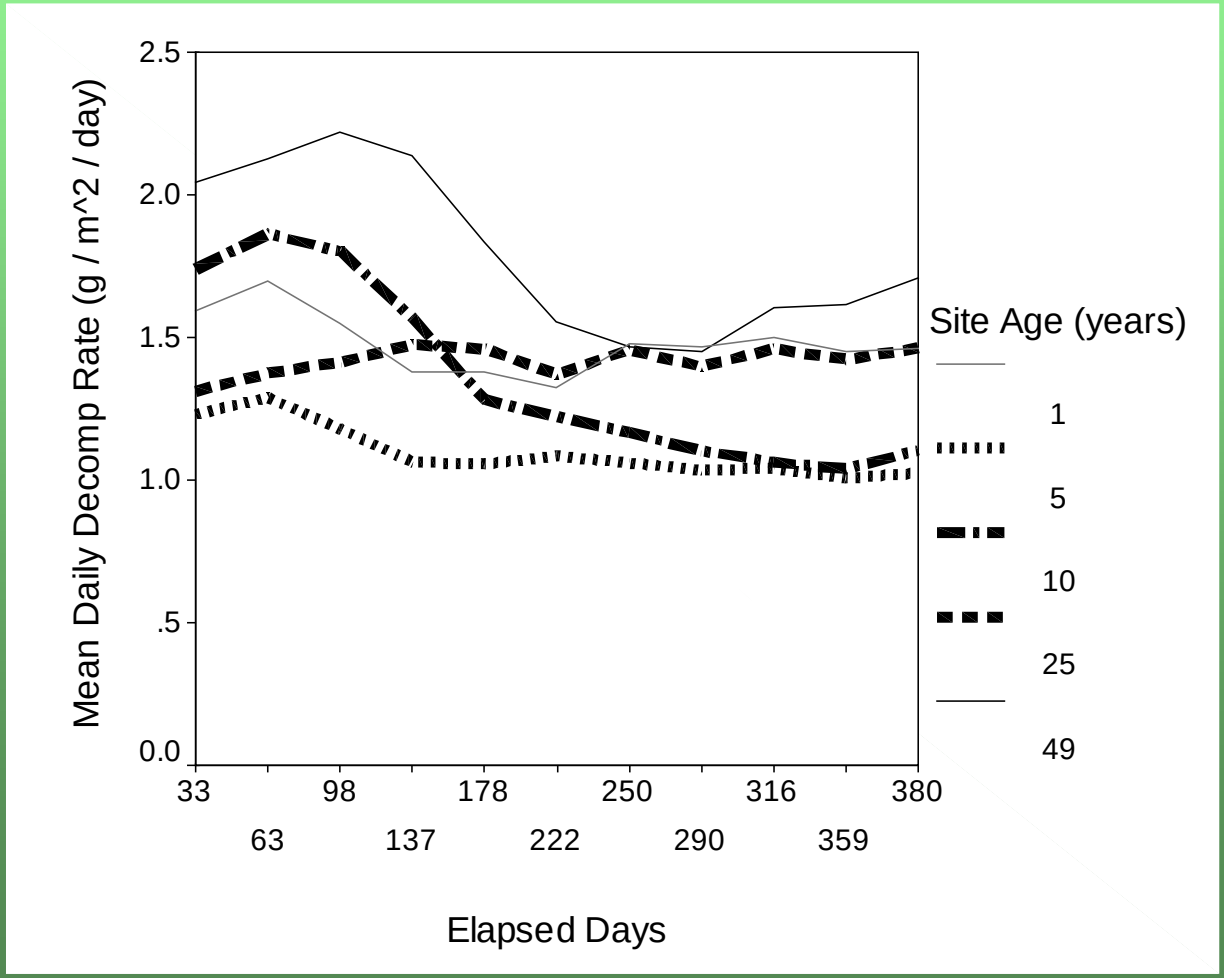


*K, Ca and Mg concentrations in litter are similar, but lower in P and N than other studies



*Mean monthly litterfall rate and mean monthly decomposition rates are not significantly different

*Fertilizer residuals from black pepper cultivation resulted in higher concentrations of P in soil, litter, and foliage but not in higher biomass production or carbon sequestration



The Developmental Cycle of Domestic Groups and Amazonian Deforestation

E. Moran, S. McCracken and B. Boucek

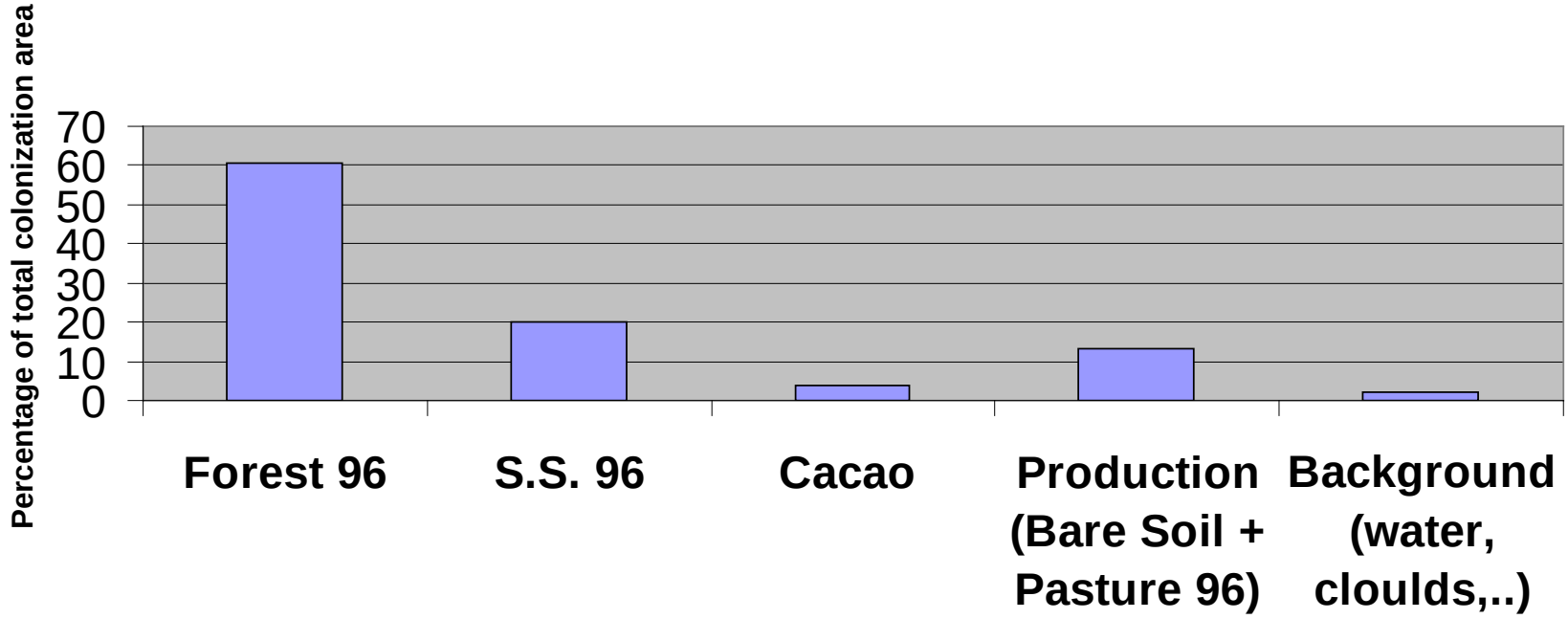
Under review

Landscape Dynamics

INCRA Colonization area: Altamira, Brasil Novo, Medicilandia 1996 Landscape Composition

(Forest, SS, Production estimated from remote sensing data, Cacao estimated from CEPLAC data)

(Colonization area = 355295.5 Hectares)



A Young Colonist Family on the Agricultural Frontier: Clearing Forest for Annual Cash Crop Production

The theory of the developmental cycle of domestic groups posits that households follow a cycle in which a young couple marry, have young children, and form a household

Pasture Formation and Raising Cattle: Need for Capital

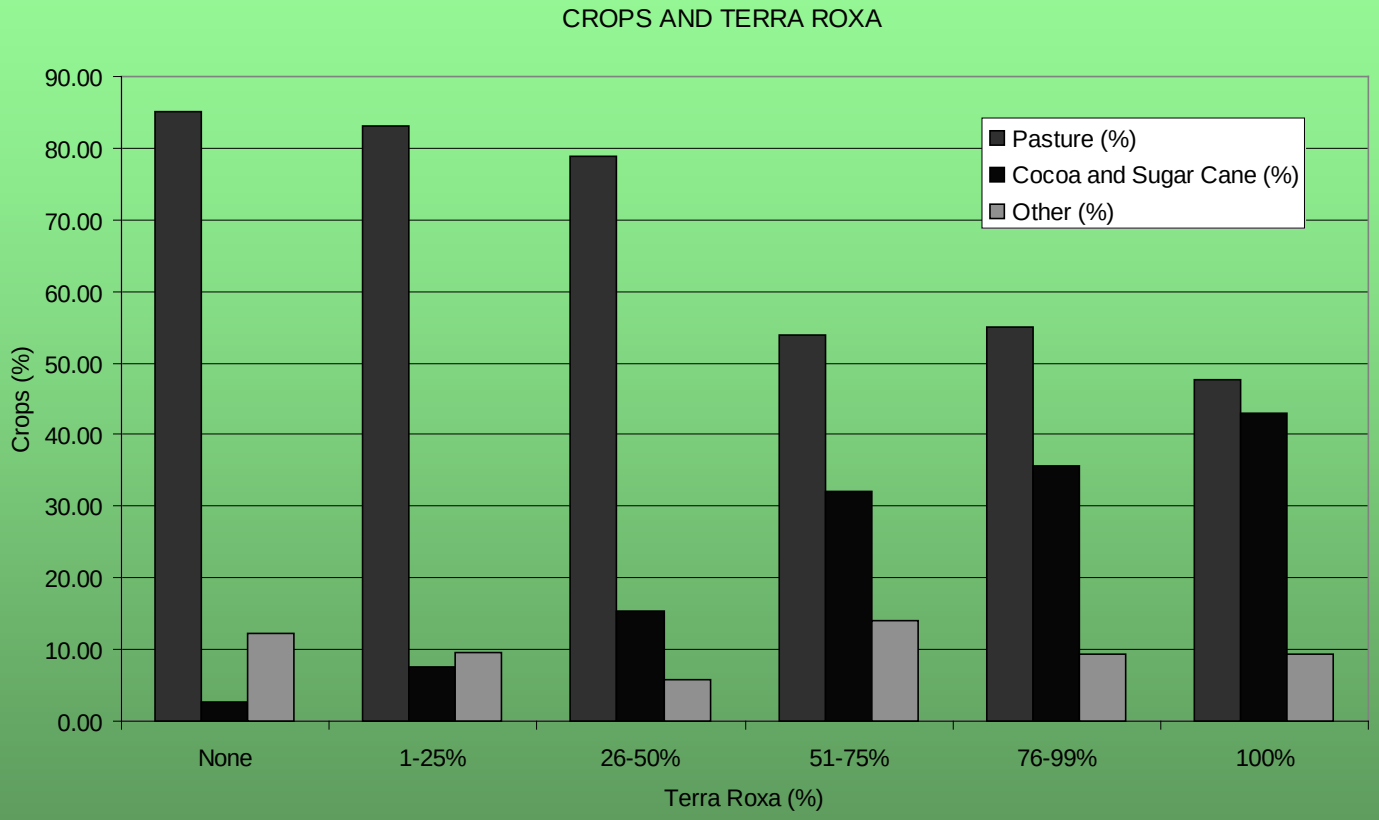
As they all age, they undertake different activities because they have changing needs as households, and they also gain in capacity to do different things as they accumulate capital, and their labor force grows with children growing to young adults

Agroforestry and Perennial Crops: A Later Strategy?

As heads of households age and begin to lose labor, they again reallocate their production priorities and favor less labor demanding activities

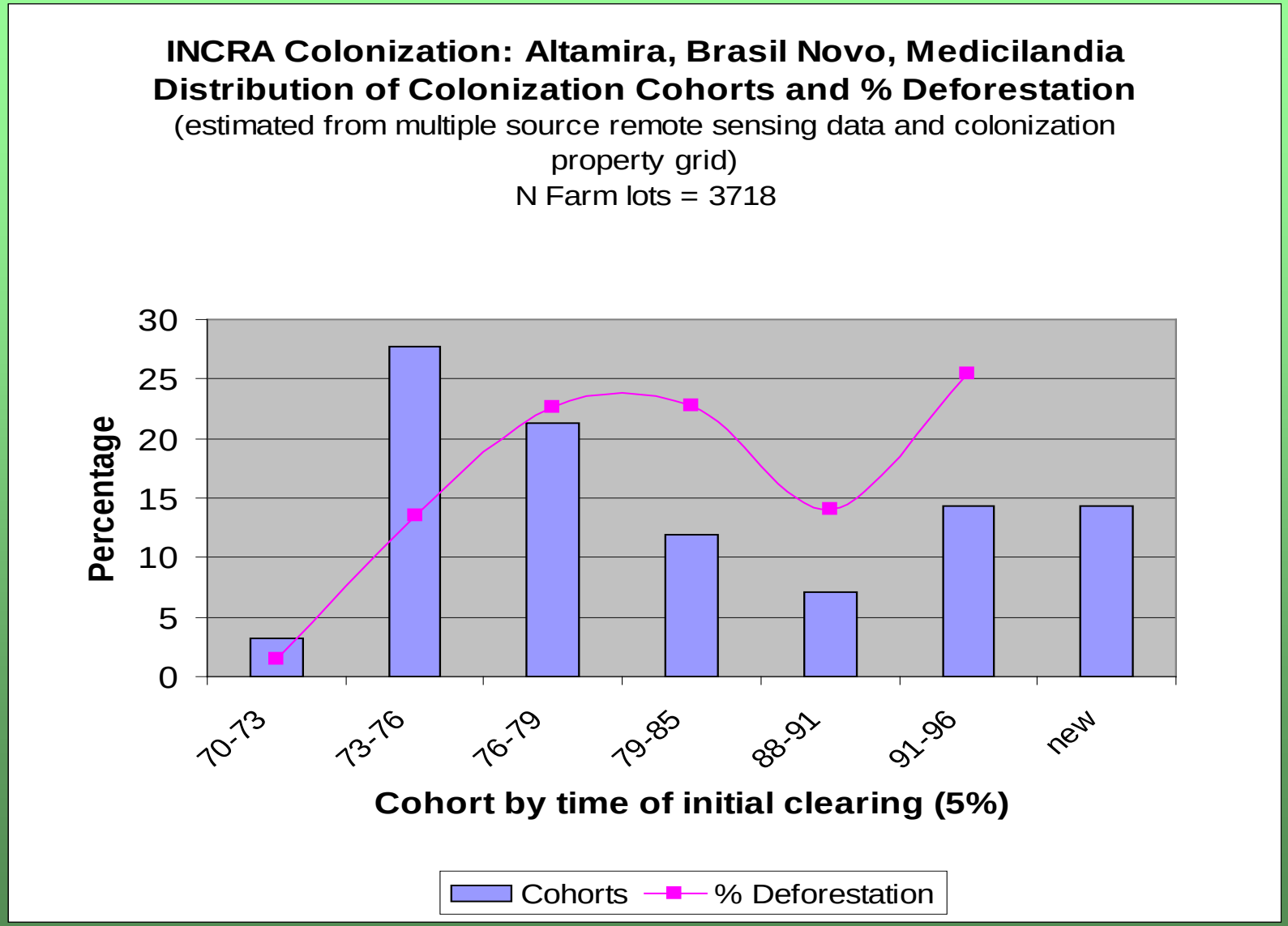
- Cocoa
- Coffee
- Fruit Crops
- Hardwood Trees

Figure 12



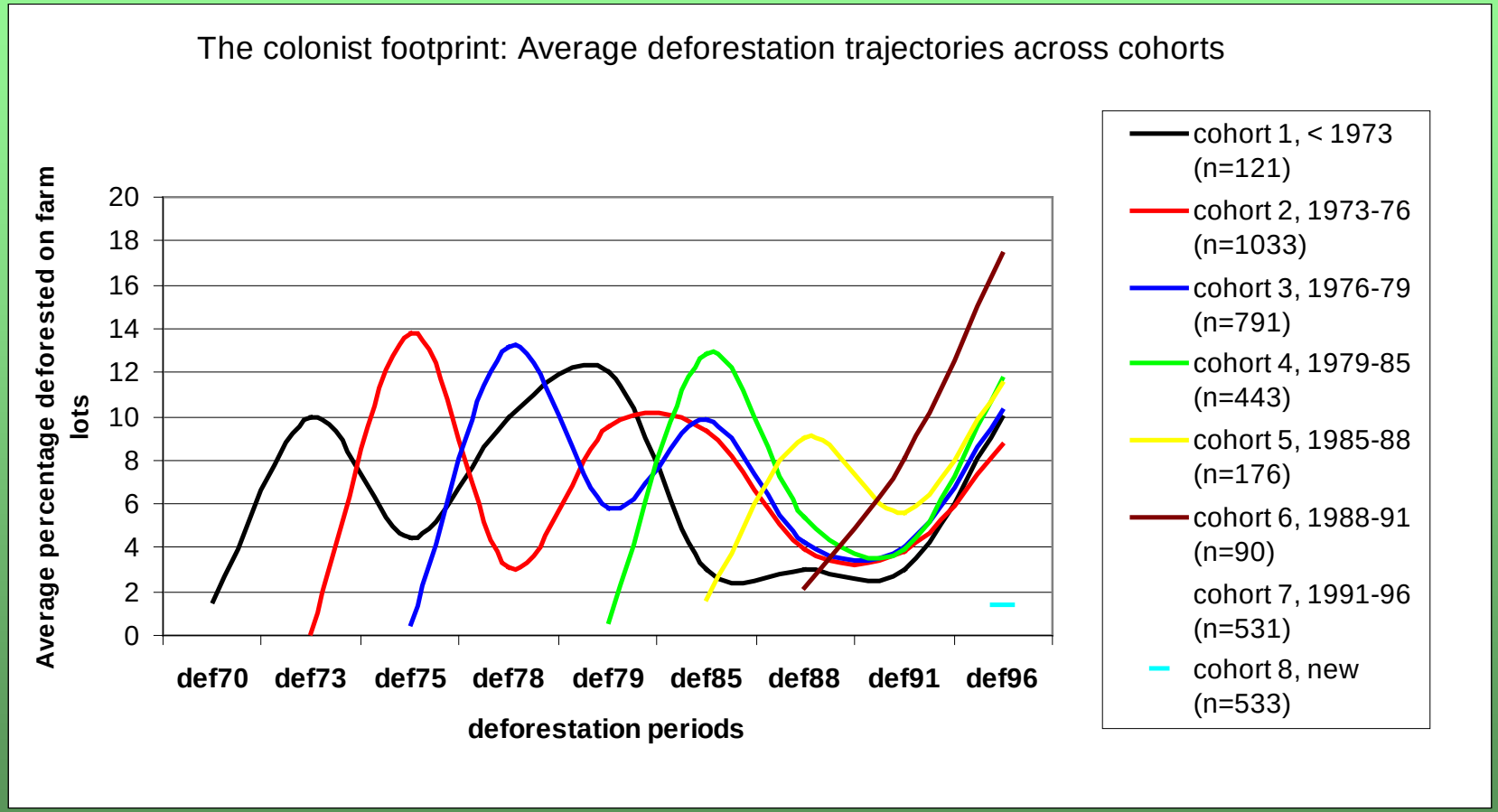
Source: Survey in Altamira 1998, N=402

Deforestation by Different Cohorts



Farm Cohort Arrival & Deforestation Levels

Average Distribution of Deforestation Events by Cohorts

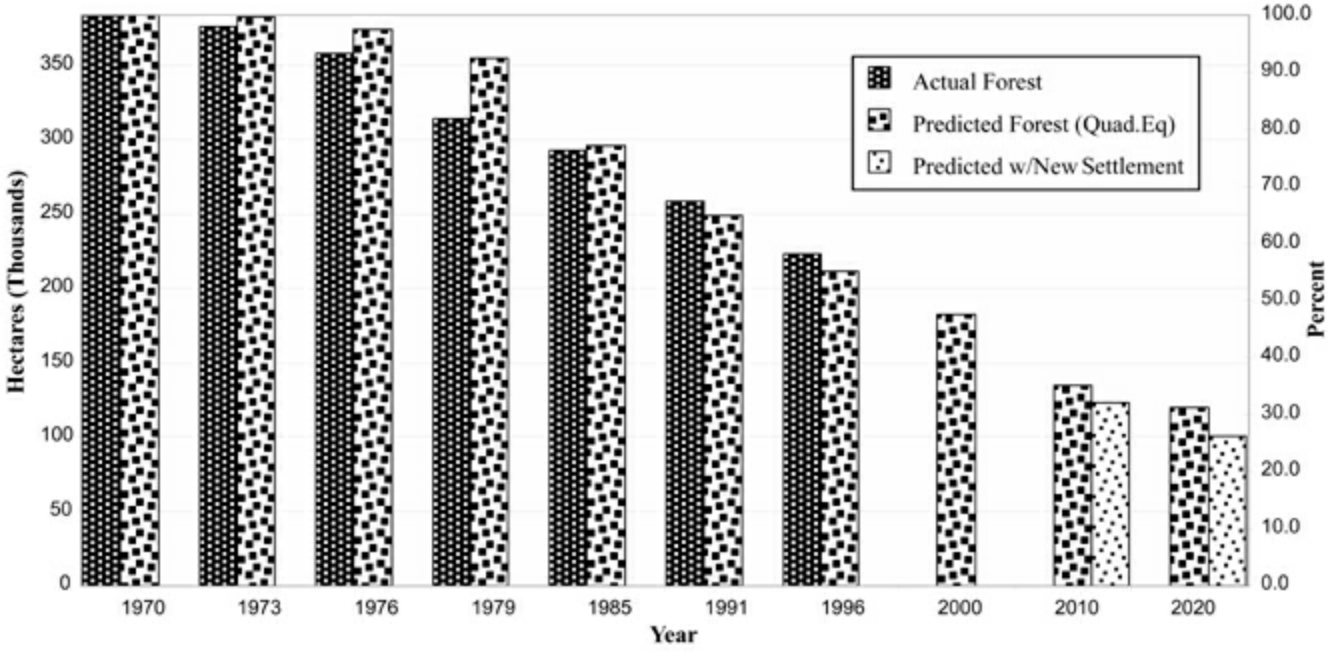


Deforestation Trajectories in a Frontier Region of the Brazilian Amazon

S. McCracken, B. Boucek, E. Moran

Book chapter, Kluwer Press, in press

Figure 3c. Property Grid and Landscape


Hectares (Thousands)
0
50
100
150
200
250
300
350
Percent
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
1970
1973
1976
1979
1985
1991
1996
2000
2010
2020
Year
Actual Forest
Predicted Forest (Quad.Eq)
Predicted w/New Settlement

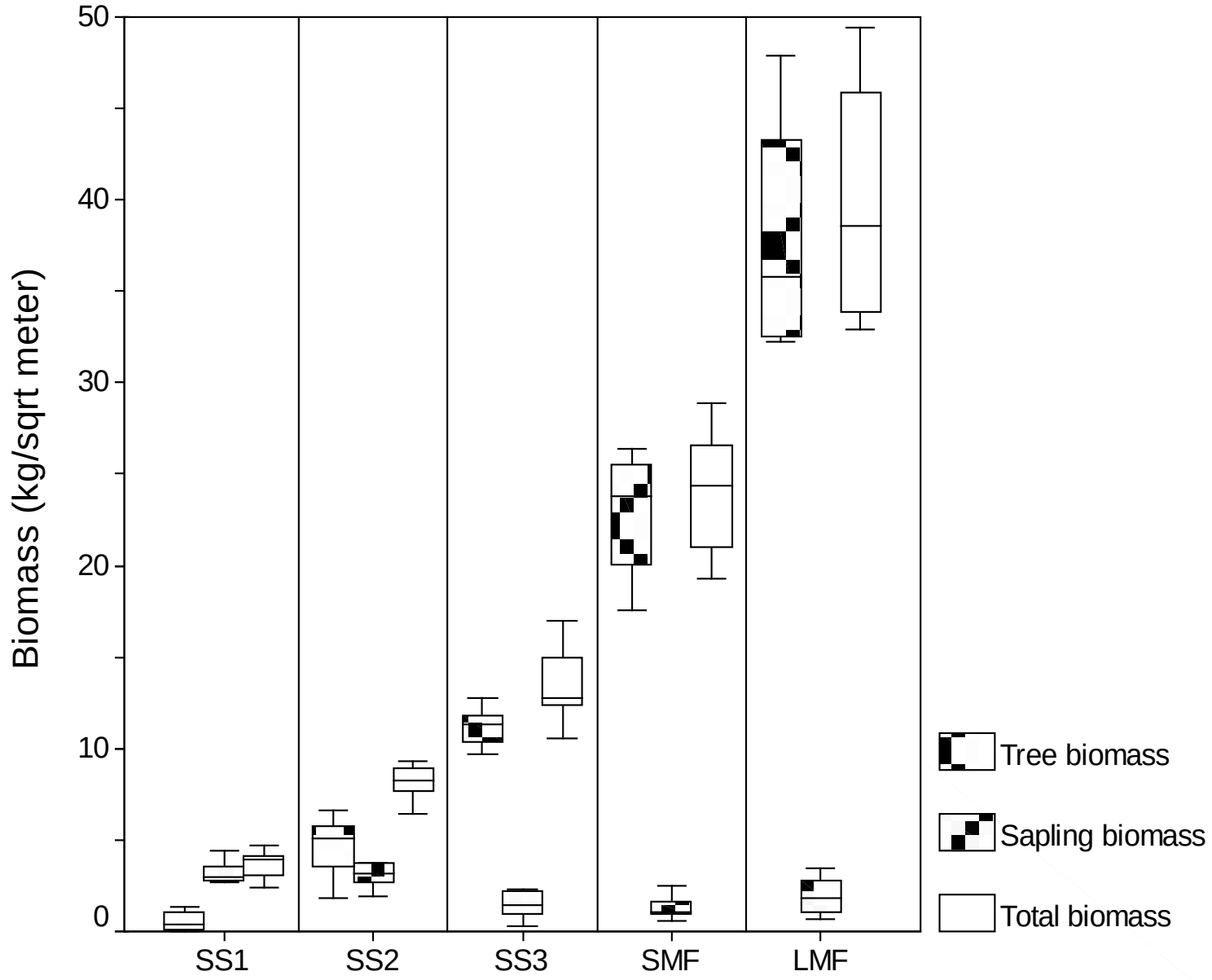
Linear Mixture Modeling applied to Amazonian Vegetation

D.Lu, E. Moran, M. Batistella

Provides better visual interpretation than spectral bands, and improves classification accuracy over Maximum Likelihood classifiers.

The greatest challenge is selecting the most appropriate endmembers

Submitted to RSE

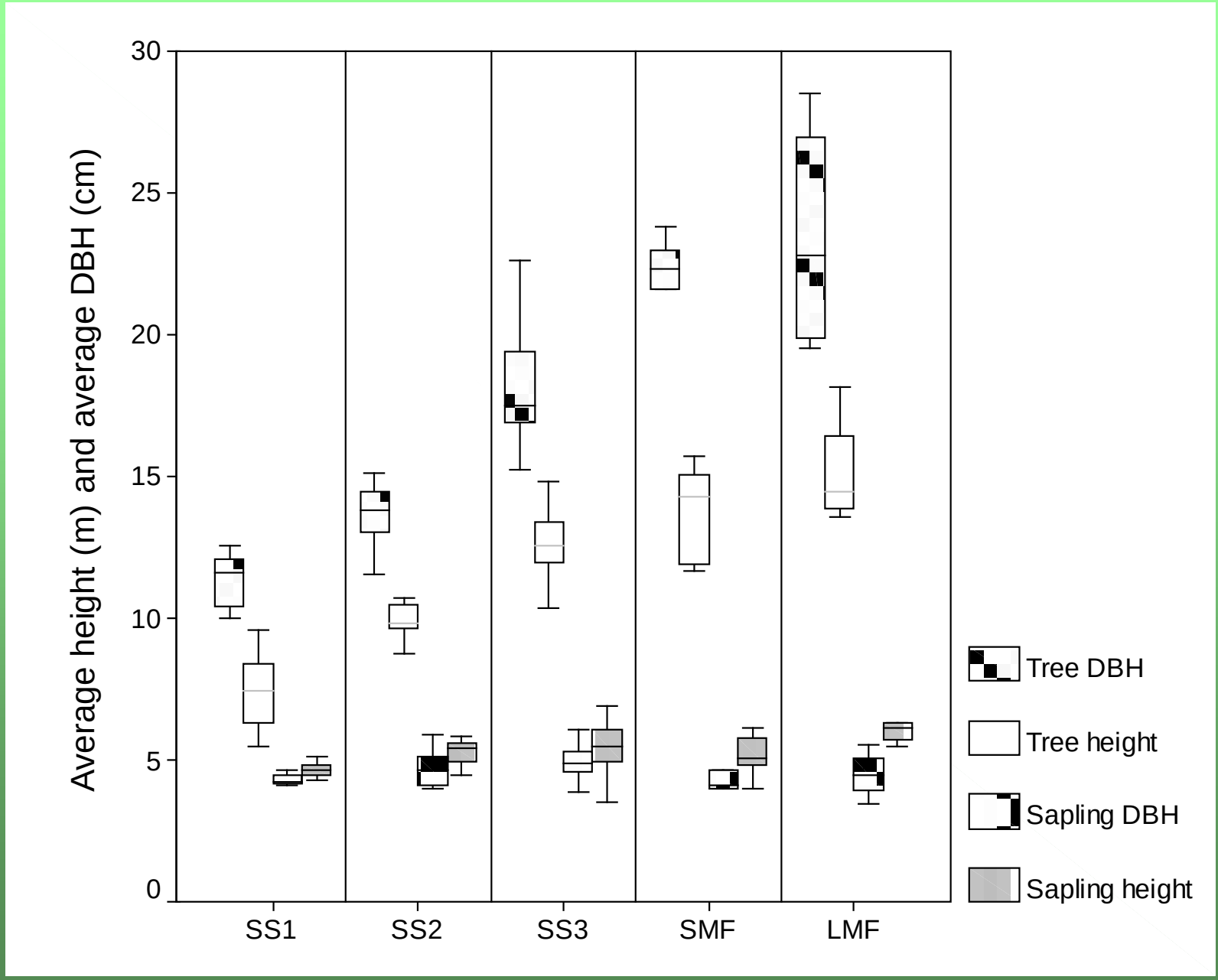

Biomass (kg/sqrt meter)
50
40
30
20
10
0
SS1
SS2
SS3
SMF
LMF
Tree biomass
Sapling biomass
Total biomass

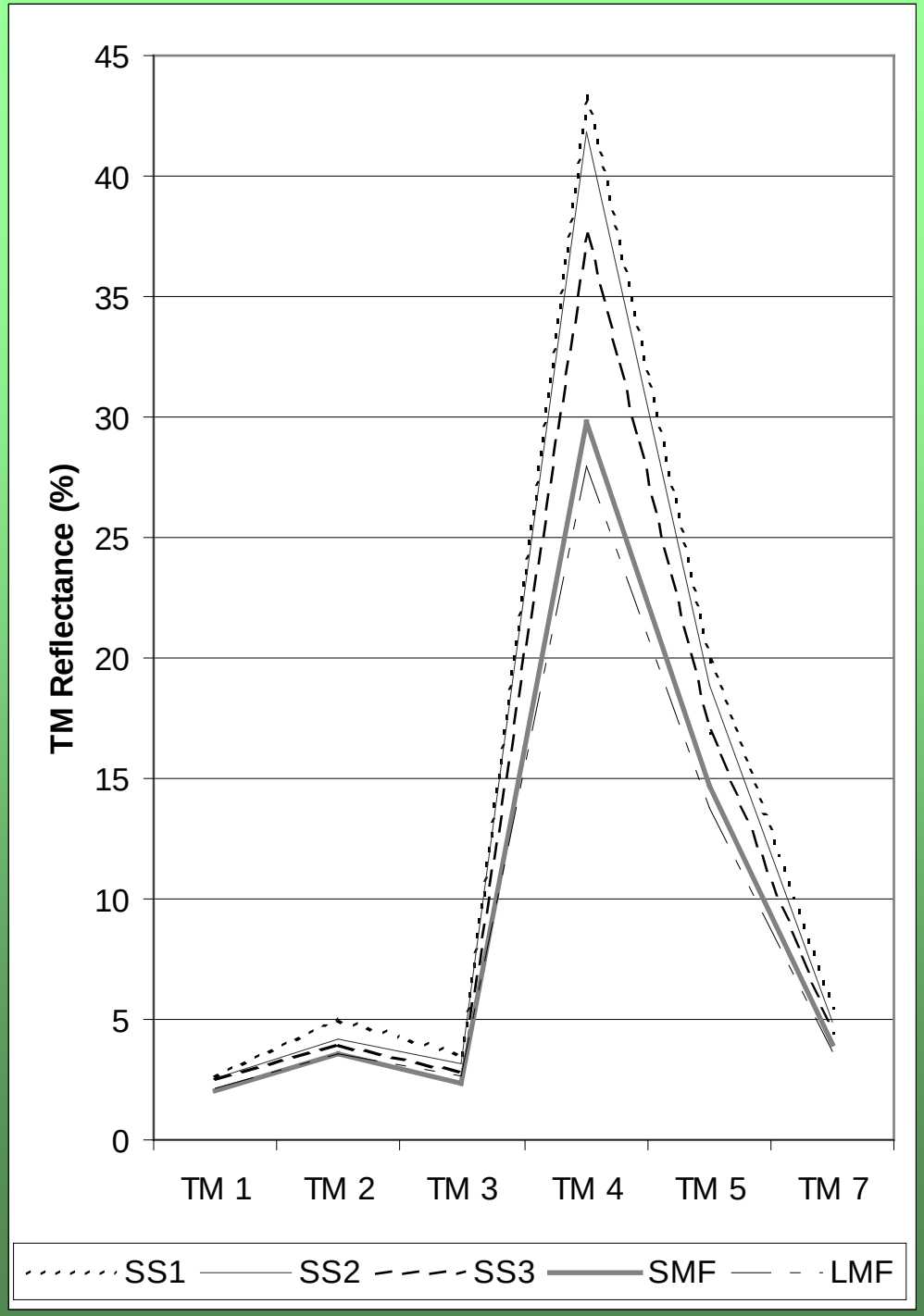
Linking Amazonian Vegetation Stand Characteristics and TM Imagery

D. Lu, E. Moran and M. Batistella

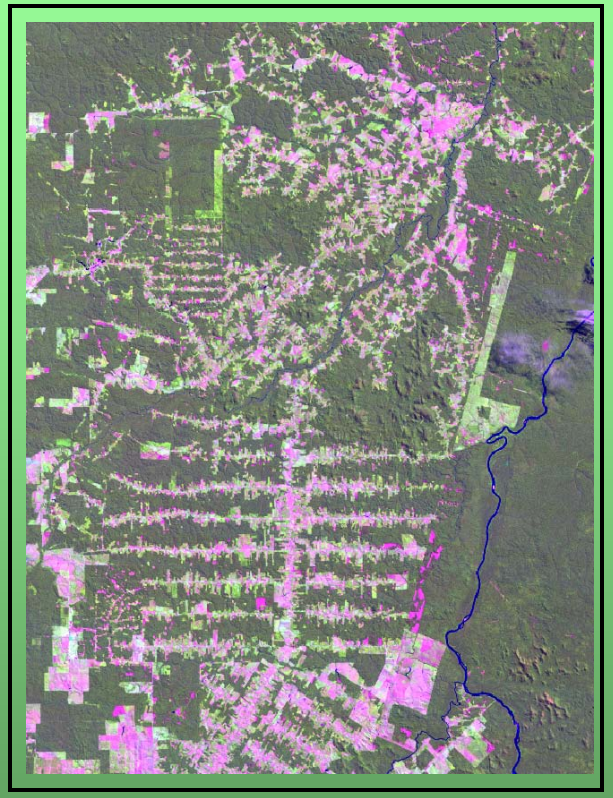
Submitted to Ecological Applications

Linear transforms of TM bands based on canonical discriminant analysis correlations can improve separability between different vegetation types when using remotely-sensed data


Average height (m) and average DBH (cm)
30
25
20
15
10
5
0
SS1
SS2
SS3
SMF
LMF
Tree DBH
Tree height
Sapling DBH
Sapling height

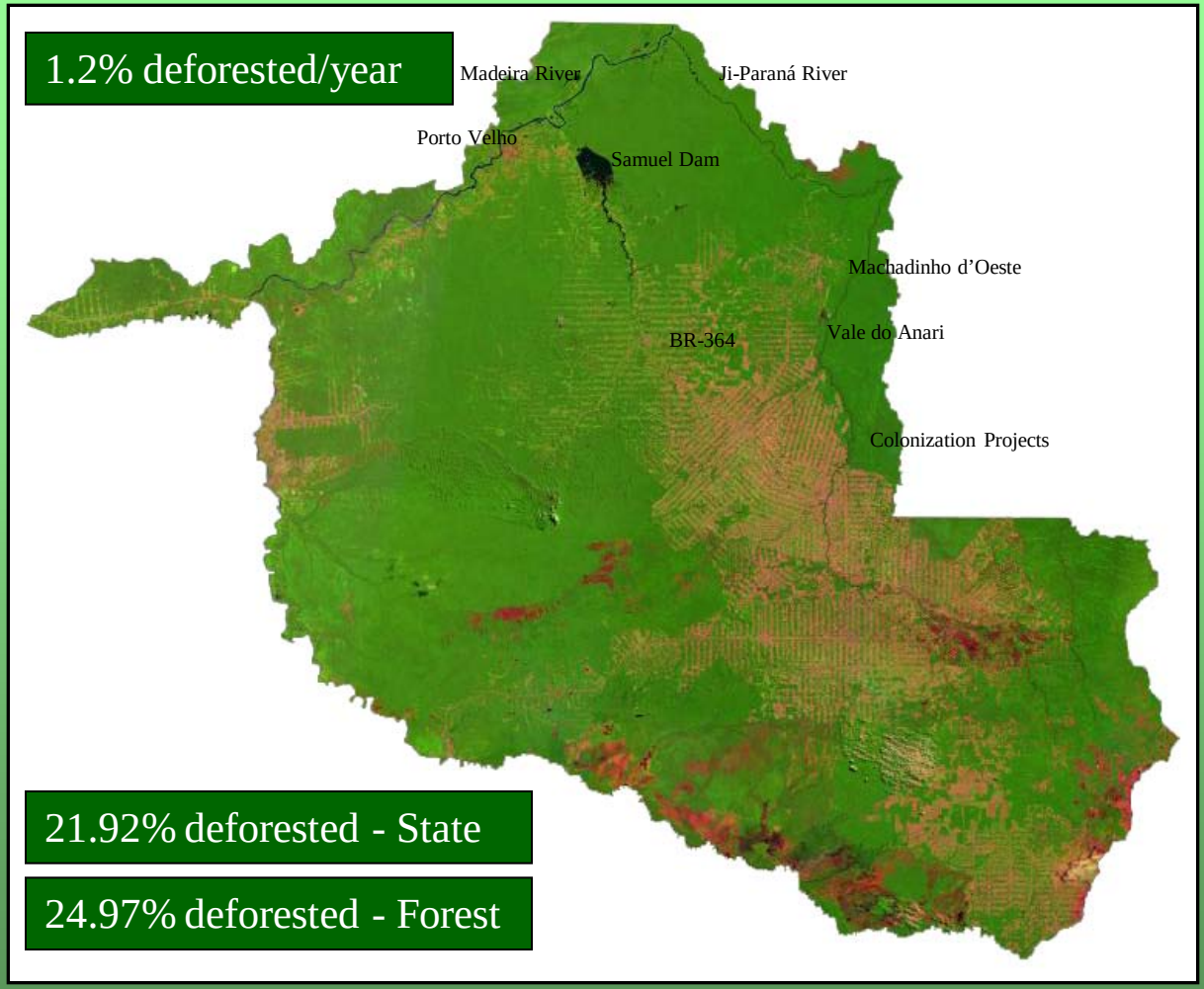

45
40
35
30
25
20
15
10
5
0
TM Reflectance (%)
TM 1
TM 2
TM 3
TM 4
TM 5
TM 7
SS1
SS2
SS3
SMF
LMF

Landscape Change and Land-Use/Land-Cover Dynamics in Rondônia, Brazilian Amazon



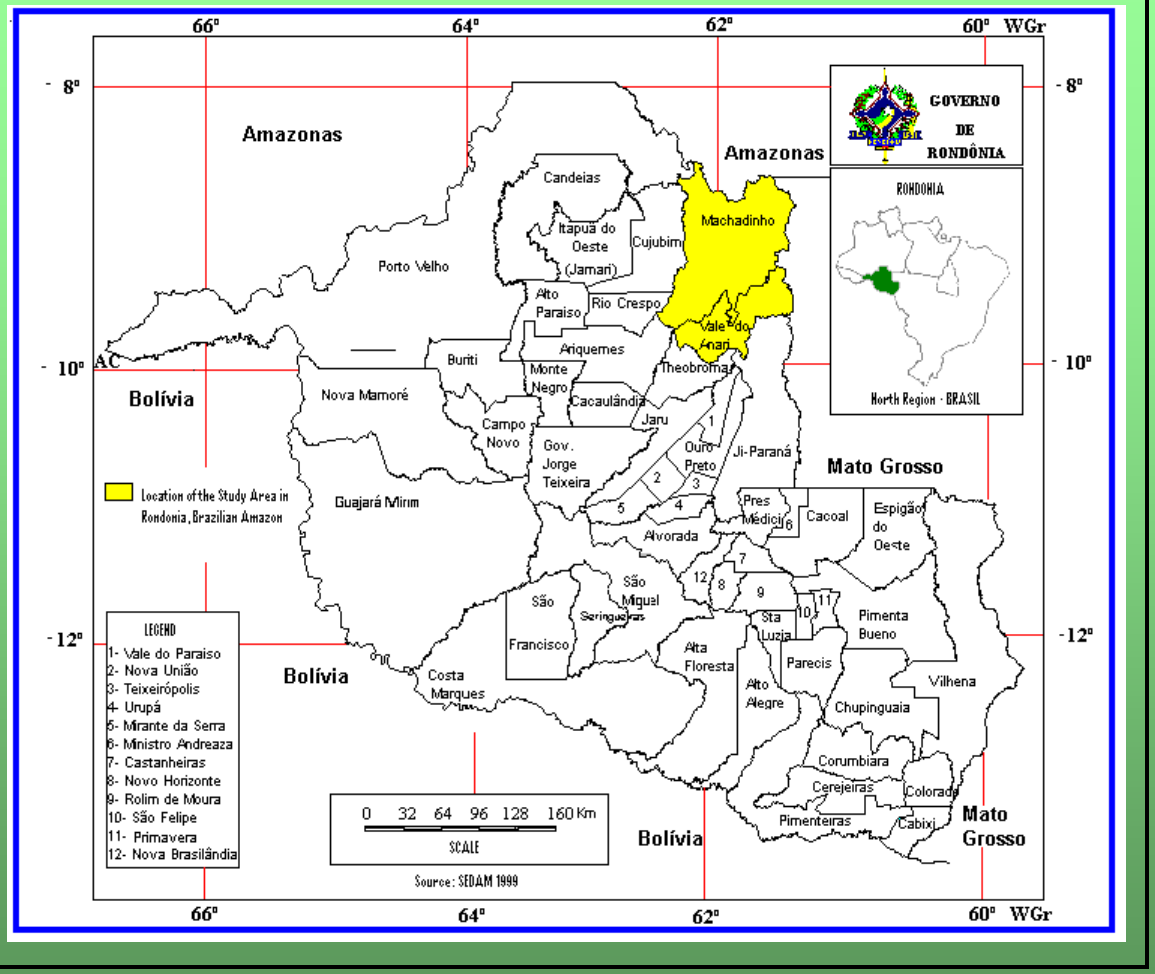
Mateus Batistella

mbatiste@indiana.edu

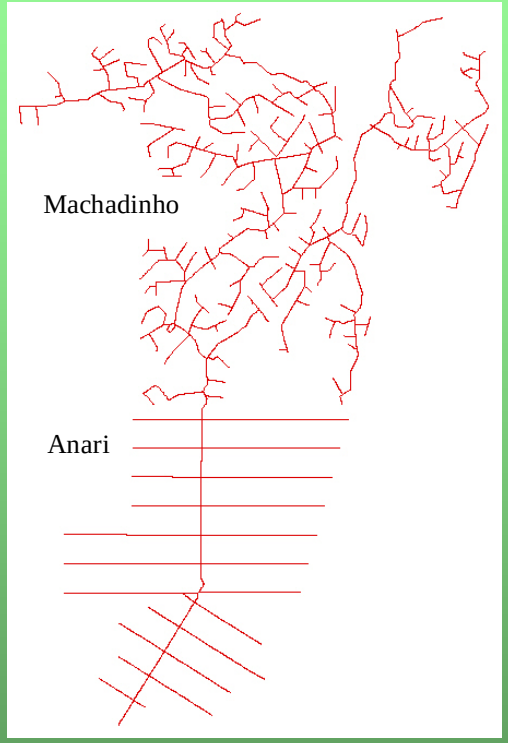


The State of Rondônia seen through a mosaic of Landsat TM images from year 2000 (Embrapa 2001)

- Similar biophysical features
- Similar age: early 80's
- Similar colonists assets



Machadinho d'Oeste and Vale do Anari in the State of Rondônia



- Different architectures
- Different institutions

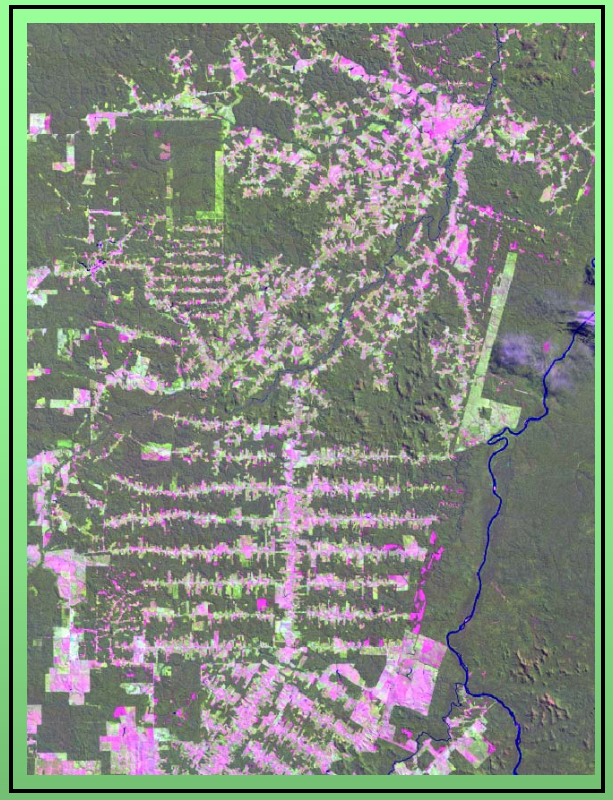
- Total area: 3,383 Km^2

Hypotheses

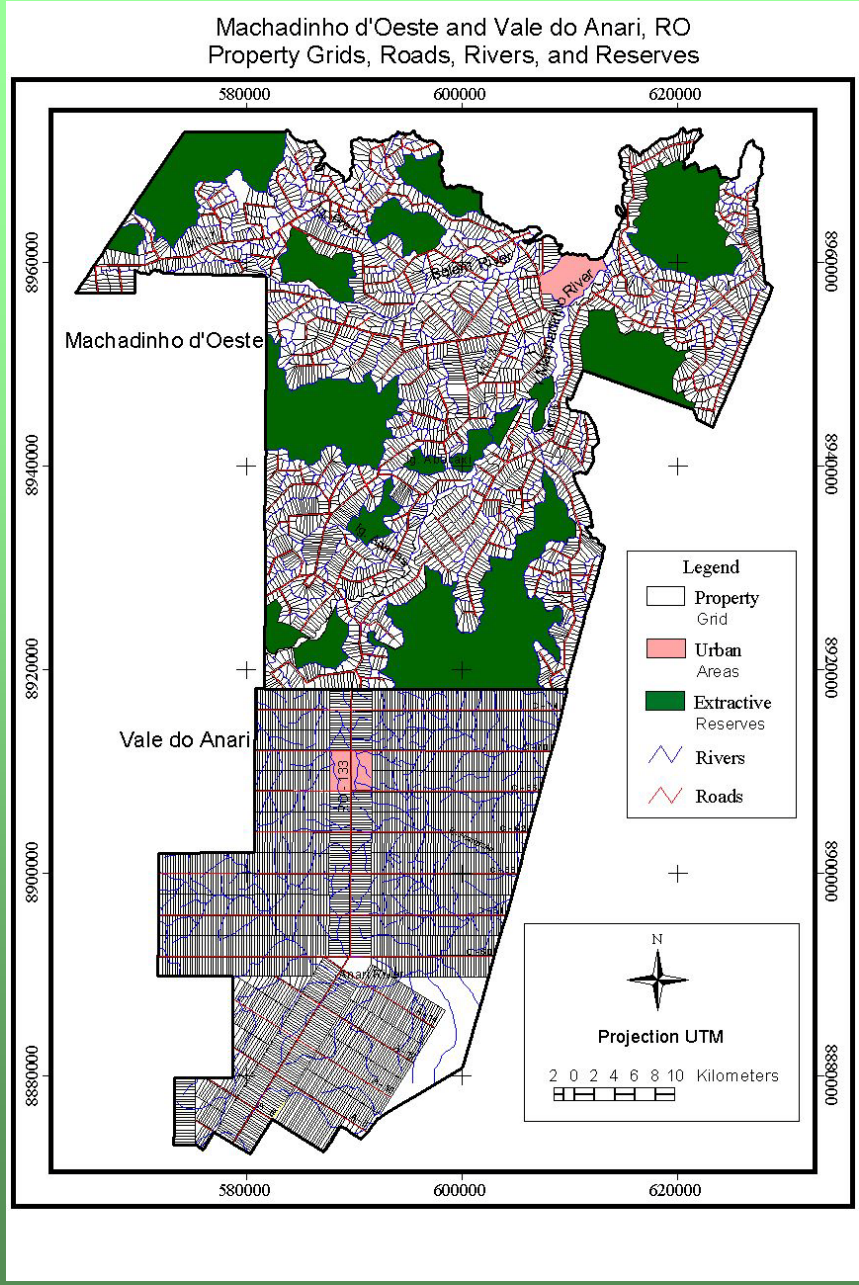
- Fishbone settlement design leads to faster deforestation than an architecture based on topographic features and including communal forest reserves

- Landscape fragmentation is higher in the fishbone settlement

- Institutional arrangements that account for different social actors and allow local actors to govern natural resources produce better environmental and social outcomes in Amazonian settlements

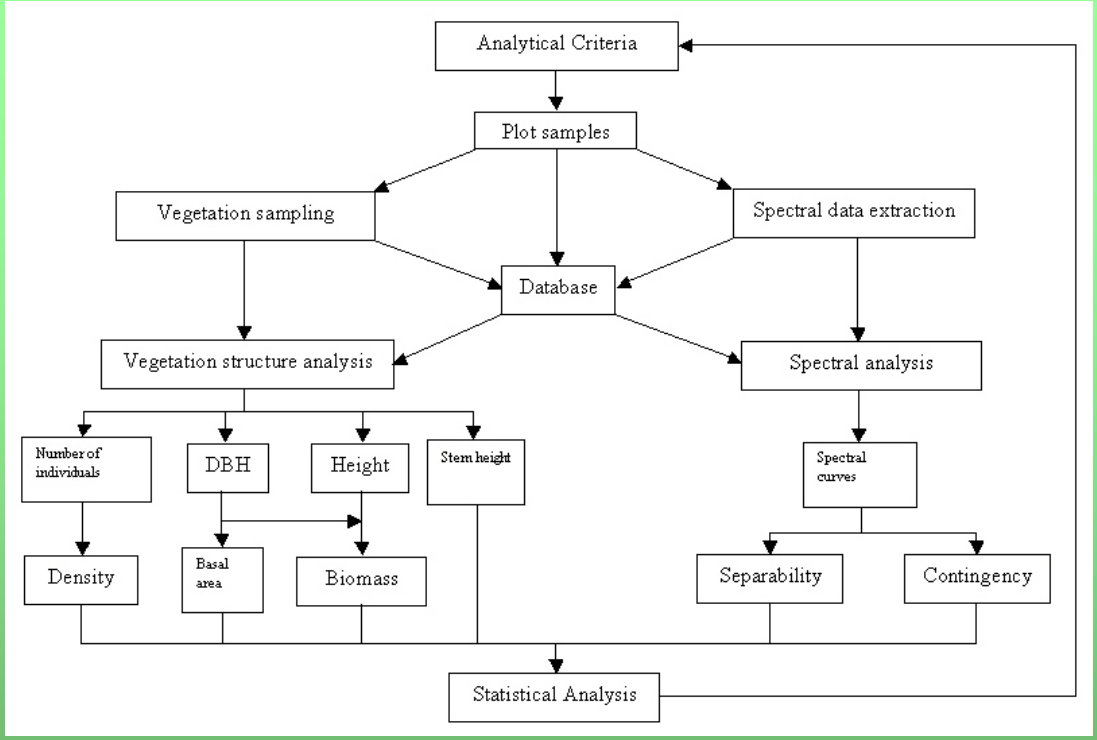


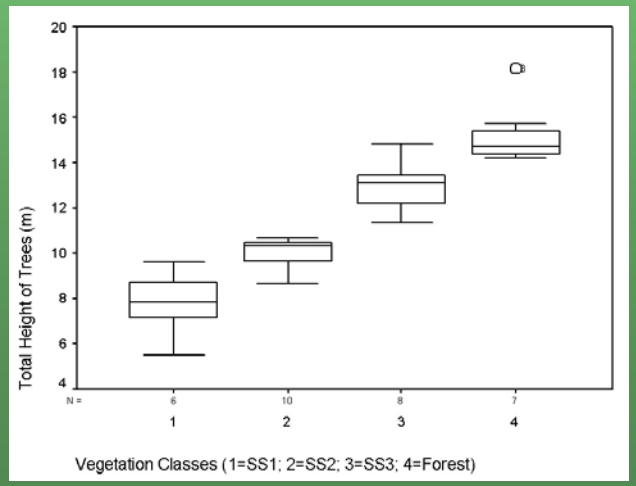
- Fieldwork in 1999 and 2000: training samples
- Vegetation structure analysis: SS1, SS2, SS3, forest
- Multitemporal LULC classification : 1988, 1994, 1998
- GIS integration
- Landscape metrics calculation
- Institutional analysis

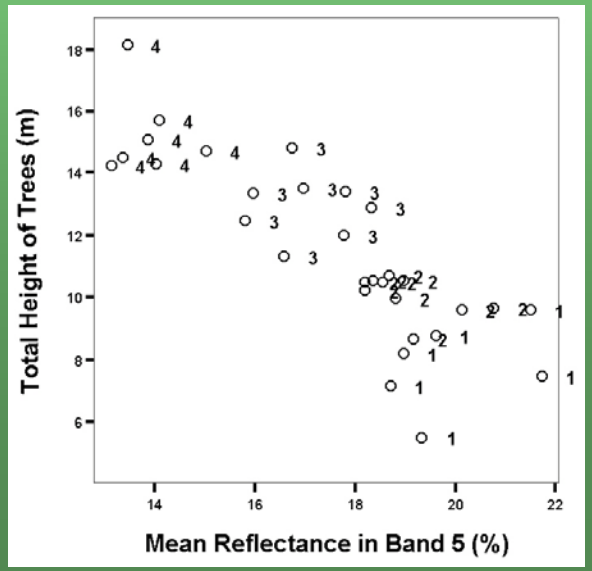


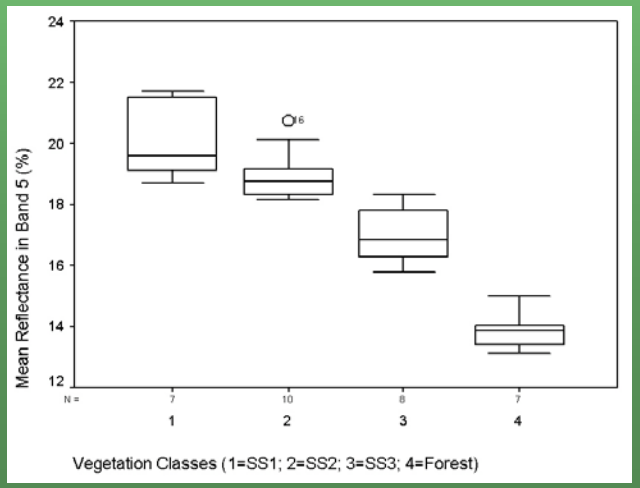
Vegetation Structure

Spectral Responses



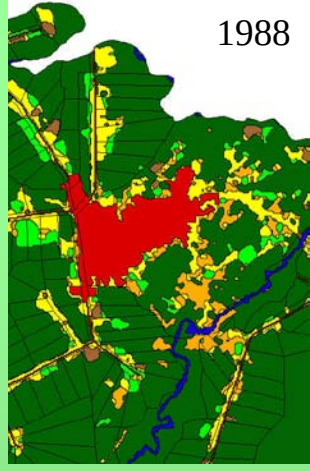


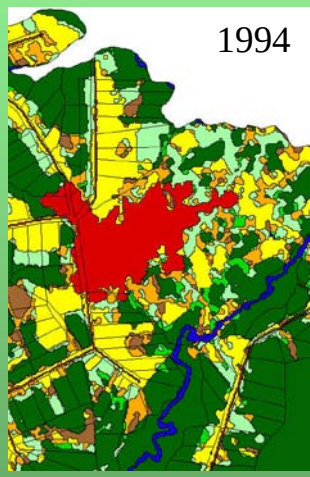


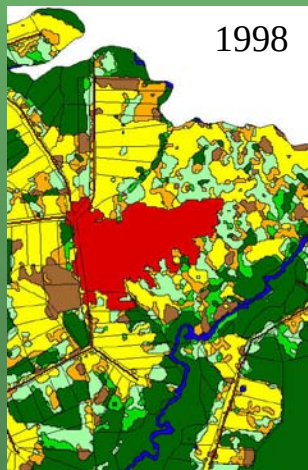


Land-use/Land-Cover Dynamics: Settlements

	MACHADINHO D'OESTE			VALE DO ANARI		
LAND USE/ LAND COVER	% in 1988	% in 1994	% in 1998	% in 1988	% in 1994	% in 1998
FOREST	88.36	75.83	65.66	86.83	68.47	50.76
ADVANCED SS	0.00	1.30	2.97	0.00	1.34	4.44
INITIAL SS	1.62	7.11	10.51	1.47	6.58	12.40
PASTURE	5.69	7.91	9.78	6.55	12.56	18.47
AGRICULTURE	0.98	3.93	7.12	3.25	5.92	10.35
BARE	1.76	2.06	2.10	0.93	3.98	2.52
INFRASTRUCTURE	1.22	1.26	1.31	0.86	1.02	0.90
WATER	0.37	0.60	0.56	0.11	0.13	0.16
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00







- Less forest cover in Anari (fishbone) after 15 years of colonization
- Similar forest cover in both settlements when considering just private properties (51%)
- Pasture conversion increased threefold in fishbone and less than twofold in Machadinho

Land-use/Land-Cover Dynamics: Roads and Properties

- Deforestation goes further from roads in Anari (design)

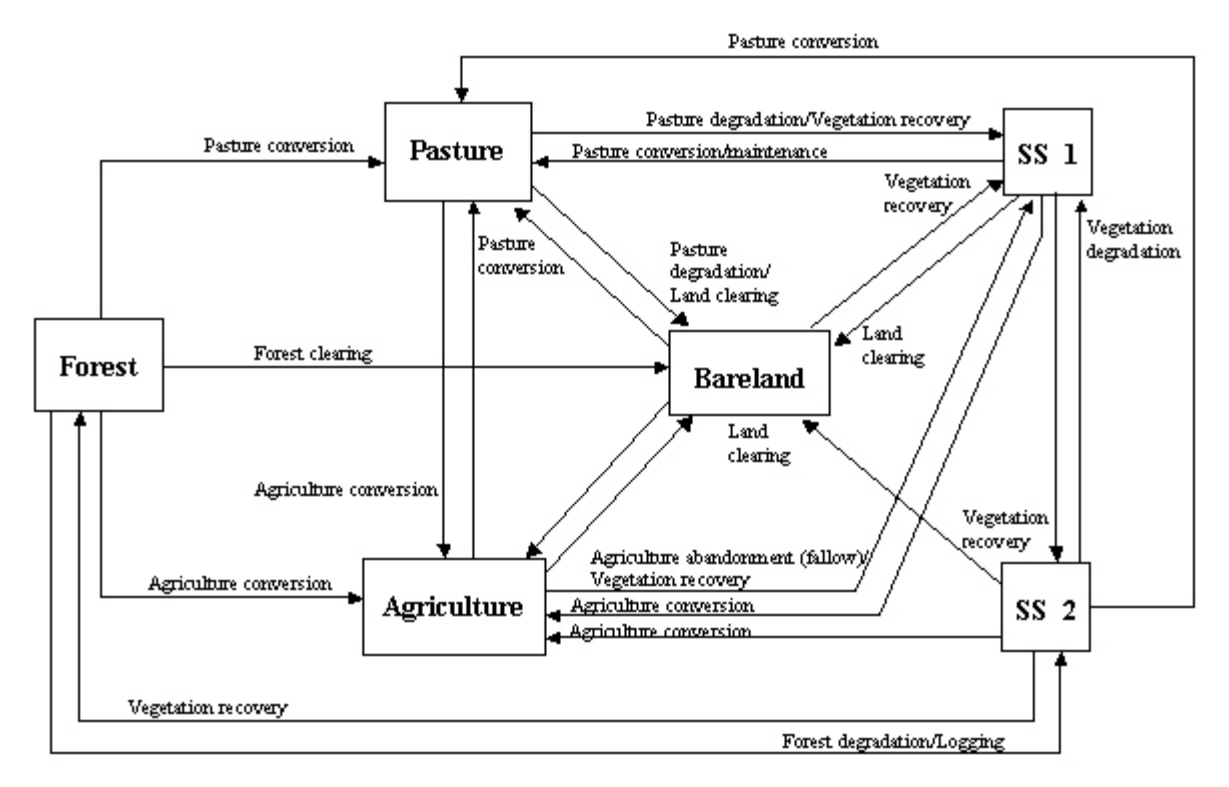
- Percentage of areas of recent clearing increases with distance from roads in Anari and is barely constant in Machadinho (occupation)

Deforestation	MACHADINHO D'OESTE		VALE DO ANARI	
	% per year	ha/year	% per year	ha/year
Before 1988	2.4	1.1	1.6	0.8
1988 - 1994	3.1	1.3	2.9	1.4
1994 - 1998	3.9	1.7	4.5	2.2

- Property size: 43.8ha in Machadinho and 50ha in Anari

- Rates of deforestation increased through time in both settlements, but more significantly in Anari, where the rate was lower before 1988 but higher between 94 and 98

Land-use/Land-Cover Dynamics: Trajectories



Landscape Structure and Change

METRICS TYPE	ACRONYM	METRICS
Area metrics		
Patch	AREA	Area (ha)
Patch	PERIMETER	Perimeter (m)
Class	PLAND	Percentage of landscape (%)
Class/landscape	LPI	Largest patch index (%)
Patch density, patch size and variability metrics		
Class/landscape	PD	Patch density (#/100ha)
Class/landscape	MPS	Mean patch size (ha)
Class/landscape	PSSD	Patch size standard deviation (ha)
Class/landscape	PSCV	Patch size coefficient of variation (%)
Edge metrics		
Class/landscape	ED	Edge density (m/ha)
Shape metrics		
Patch	SHAPE	Shape index
Patch	FRACT	Fractal dimension
Class/landscape	LSI	Landscape shape index
Class/landscape	AWMSI	Area-weighted mean shape index
Core area metrics		
Landscape	TCAI	Total core area index (%)
Class	MCAI	Mean core area index (%)
Diversity metrics		
Landscape	MSIDI	Modified Simpson's diversity index
Landscape	MSIEI	Modified Simpson's evenness index
Interspersion and juxtaposition metrics		
Class/landscape	IJI	Interspersion and juxtaposition index (%)

Multi-temporal analyses of landscape metrics

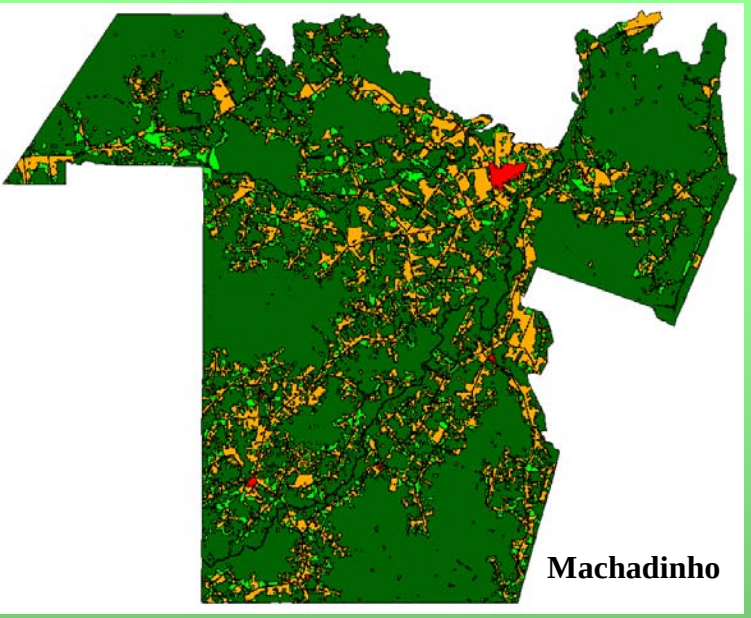
Goals:

To compare landscape structure across settlements

To produce background data for further studies

Keywords: Composition (amount of patches), Configuration (distribution of patches), Fragmentation (patch density and size), Heterogeneity (patch variability), Edge effects (edge and core area), Complexity (shape), Diversity, Interspersion

Landscape Structure and Change



Machadinho

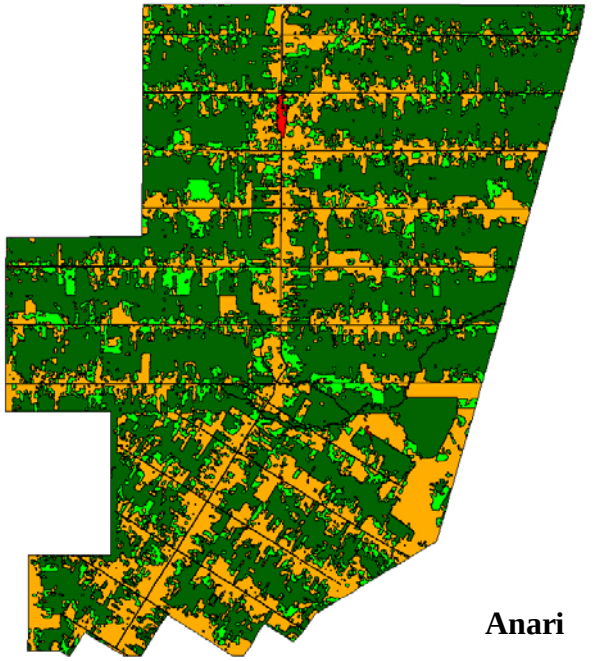
LPI (%)	MACHADINHO D'OESTE INCLUDING RESERVES			MACHADINHO D'OESTE EXCLUDING RESERVES			VALE DO ANARI		
	1988	1994	1998	1988	1994	1998	1988	1994	1998
Forest	17.7	13.3	10.7	15.2	8.0	2.6	13.2	5.5	4.5
Succession	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.3
Production	0.1	0.4	0.5	0.2	0.5	0.8	0.3	1.1	2.9
Others	0.2	0.3	0.3	0.3	0.4	0.4	0.2	0.2	0.2

• In 1998, the largest patch index of forest is higher in Machadinho, but lower when excluding reserves

MPS (ha)	MACHADINHO D'OESTE INCLUDING RESERVES			MACHADINHO D'OESTE EXCLUDING RESERVES			VALE DO ANARI		
	1988	1994	1998	1988	1994	1998	1988	1994	1998
Forest	319.0	219.1	167.4	182.1	107.8	65.7	556.4	224.9	126.7
Succession	2.0	4.2	5.9	2.0	4.1	5.9	2.4	4.4	8.3
Production	7.0	12.9	15.0	7.2	12.9	15.2	13.5	27.8	25.2
Others	0.4	0.4	0.4	0.3	0.4	0.4	0.7	0.7	0.8

• Mean patch size of forest decreases at a higher rate in fishbone. In 1994, MPS is similar in both settlements

• Mean patch size of farmland is greater in fishbone



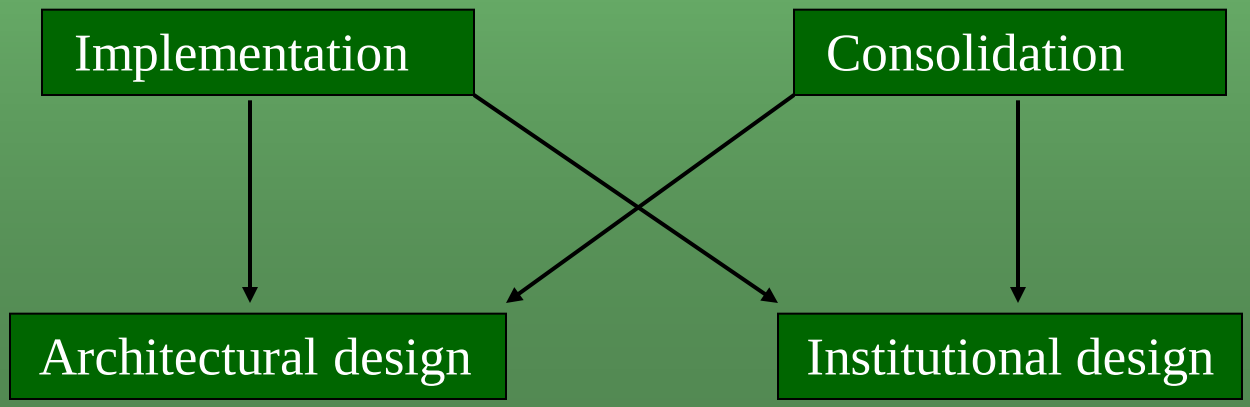
Anari

Beyond the metrics: Institutions Making a Difference

- Rural settlements in the Amazon: demand to settle landless migrants
- Different arrangements: rapid projects vs. well planned initiatives
- Accountability to distinct actors: settlers, loggers, rubber tappers

- The diversity of situations involving multiple actors, biophysical features, and rules leads to a mosaic of land-use trajectories and landscape patterns

- Two major sets of events: a starting point (implementation) when initial rules delineate the structure of incentives to the actors, and processual changes (consolidation), affecting the structure of incentives toward land-use



Beyond the metrics: Institutions Making a Difference

• Machadinho illustrates how settlement implementation can incorporate ecological (topography-based), economic (infrastructure), and social (accountability to local populations) attributes that are usually overlooked in other development projects

• Higher pasture conversion in Anari is related to poor access to resources and infrastructure. Better efficiency of agricultural systems in Machadinho is related to the access to water, better roads, and agricultural extension

• The communal reserves in Machadinho corroborate the importance of governance over resources by local people. Not the reserves per se, but rubber tappers organized in associations and with clear strategies regarding their rights over these lands are the key factor in maintaining large patches of forest preserved

Hypotheses revisited

• Fishbone settlement design leads to faster deforestation than an architecture based on topographic features and including communal forest reserves

Accepted as it is, but the communal forest reserves are playing the important role, not the design itself

• Landscape fragmentation is higher in the fishbone settlement

Accepted as it is; rejected if excluding reserves in Machadinho

• Institutional arrangements that account for different social actors and allow local actors to govern natural resources produce better environmental and social outcomes in Amazonian settlements

Accepted. The accountability to different actors has created opportunities for interactions with positive outcomes

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