Classification of Secondary Succession Stages Using Remotely Sensed Data in the Brazilian Amazon

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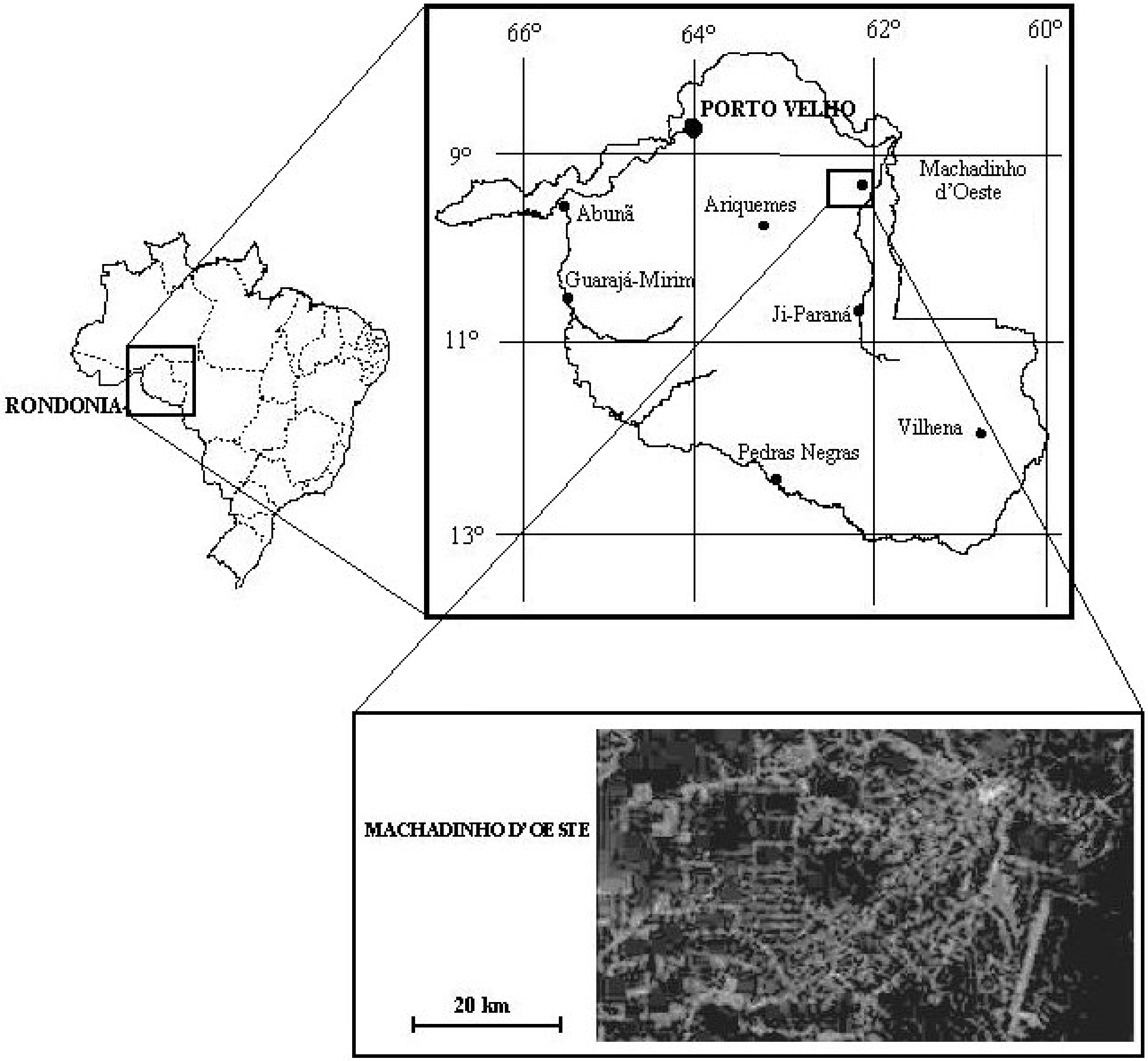
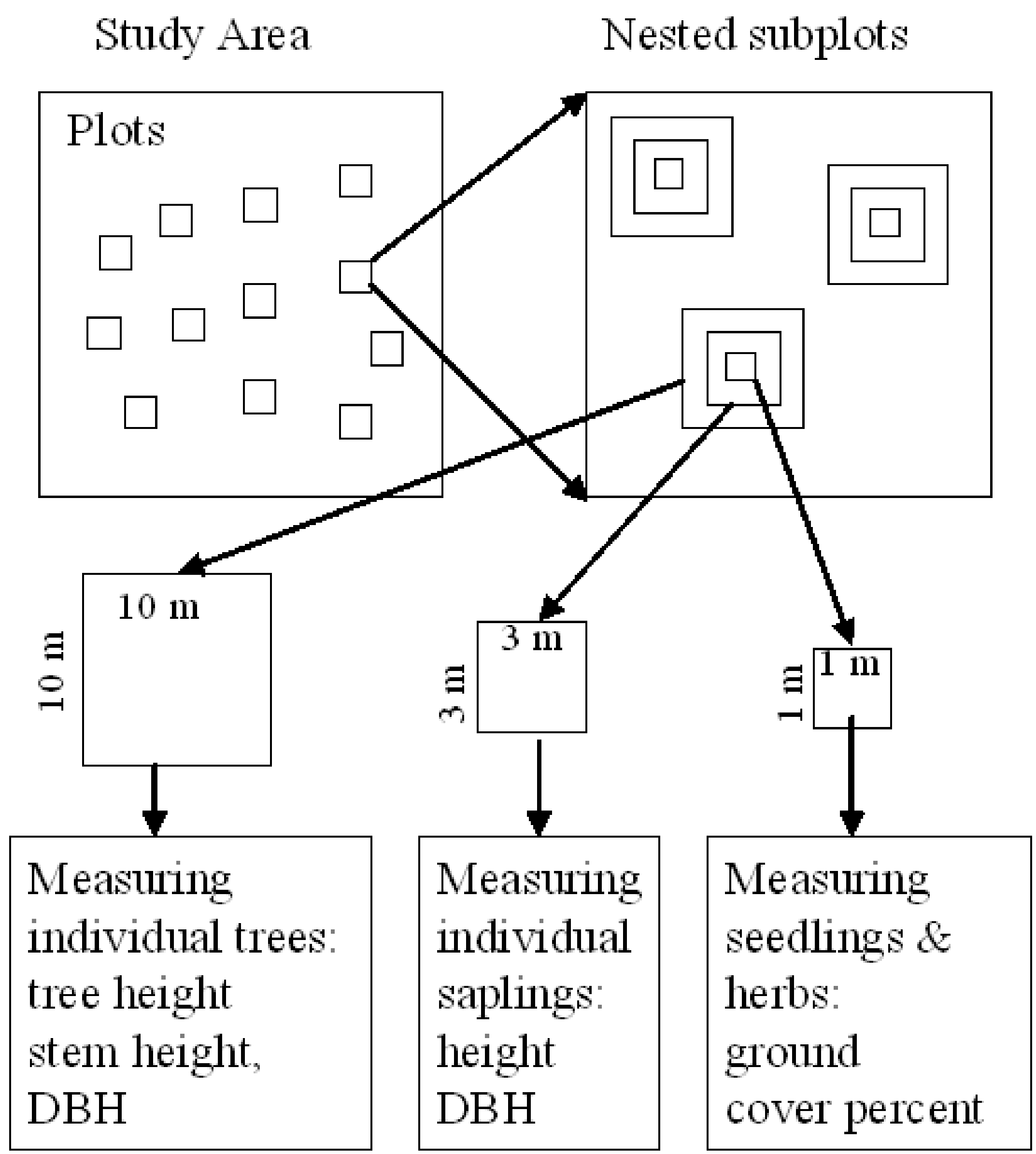
Study Area in Machadinho, Rondonia State



Field Data Collection



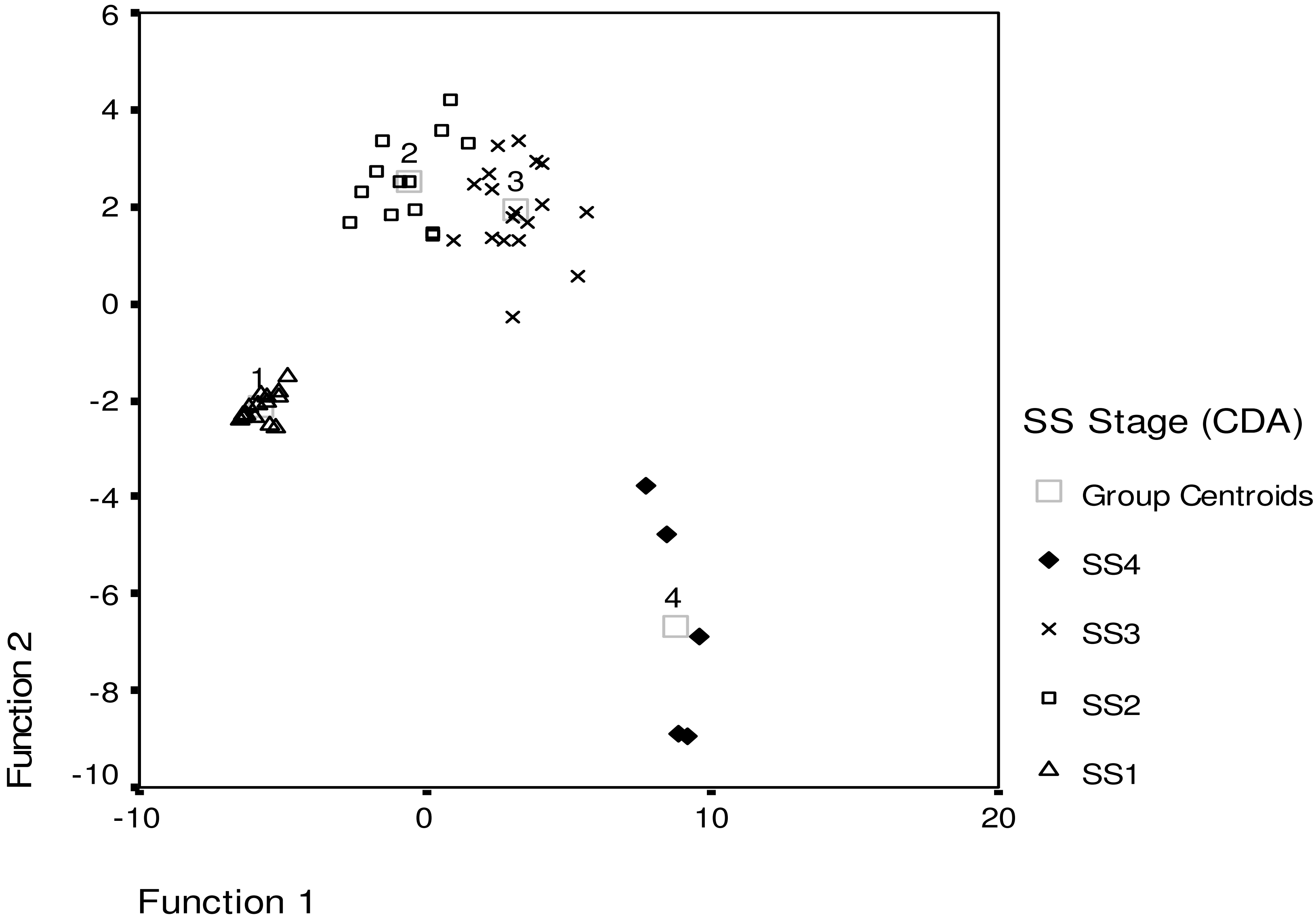
Data sets used in research

- Images:
  - Landsat TM (1998, 2003) and ETM+ (2001)
  - Terra ASTER (2003)
  - SPOT 5 HRG (2003)
  - Radarsat C-band (2001)
- Field data:
  - Field measurement for plots in 1998
  - Collection of training samples for different land cover types in 1999 and 2003
  - Land use history

Criteria for separation of secondary succession stages

- Lu, D., Mausel, P., Brondízio, E., and Moran, E. 2003. Classification of Successional Forest Stages in the Brazilian Amazon Basin. Forest Ecology and Management, 181(3), 301–312.
  – Based on field measurement variables (e.g., DBH, tree height) and derived parameters (e.g., biomass)
  – Canon discriminant analysis

Four SS stages were separated



Characteristics of forest stand parameters for successional stages and mature forest

Variables	SS1	SS2	SS3	SS4	MF
RTB	0	0.15 – 0.45	0.48 – 0.89	0.91 – 0.99	0.89 – 1.00
AGB (kg/m2)	0 – 4.62	3.41 – 7.03	7.28 – 13.55	20.34 – 29.30	17.45 – 39.45
BA (m2/ha)	0 – 13.33	9.94 – 19.21	15.45 – 32.24	26.13 – 36.78	27.38 – 56.13
ASD (cm)	0 – 4.61	10.84 – 15.42	12.85 – 22.14	19.82 – 29.25	23.11 – 39.27
ASH (m)	0 – 6.03	6.40 – 11.24	8.73 – 14.45	11.51 – 20.27	15.20 – 20.09
Age (year)	1 – 5	3 – 15	7 – 29	15 – 25	unknown

Note: RTB – ratio of tree biomass to total aboveground biomass
AGB – aboveground biomass
BA – basal area
ASD – average stand diameter
ASH – average stand height

Land cover classification with different classifiers or different image combination

- Lu, D., Batistella, M., and Moran, E., in press. Land Cover Classification in the Brazilian Amazon with the Integration of Landsat ETM+ and RADARSAT Data. International Journal of Remote Sensing.
- Lu, D., Batistella, M., Moran, E., and de Miranda, E. E., (in press). A Comparative Study of Landsat TM and SPOT HRG Images for Vegetation Classification in the Brazilian Amazon. Photogrammetric Engineering and Remote Sensing.
- Lu, D., Batistella, M., Moran, E., and Mausel, P. 2004. Application of Spectral Mixture Analysis to Amazonian Land-Use and Land-Cover Classification. International Journal of Remote Sensing, 25(23), 5345–5358.
- Lu, D., Mausel, P., Batistella, M., and Moran, E. 2004. Comparison of Land-Cover Classification Methods in the Brazilian Amazon Basin. Photogrammetric Engineering and Remote Sensing, 70(6), 723–731.

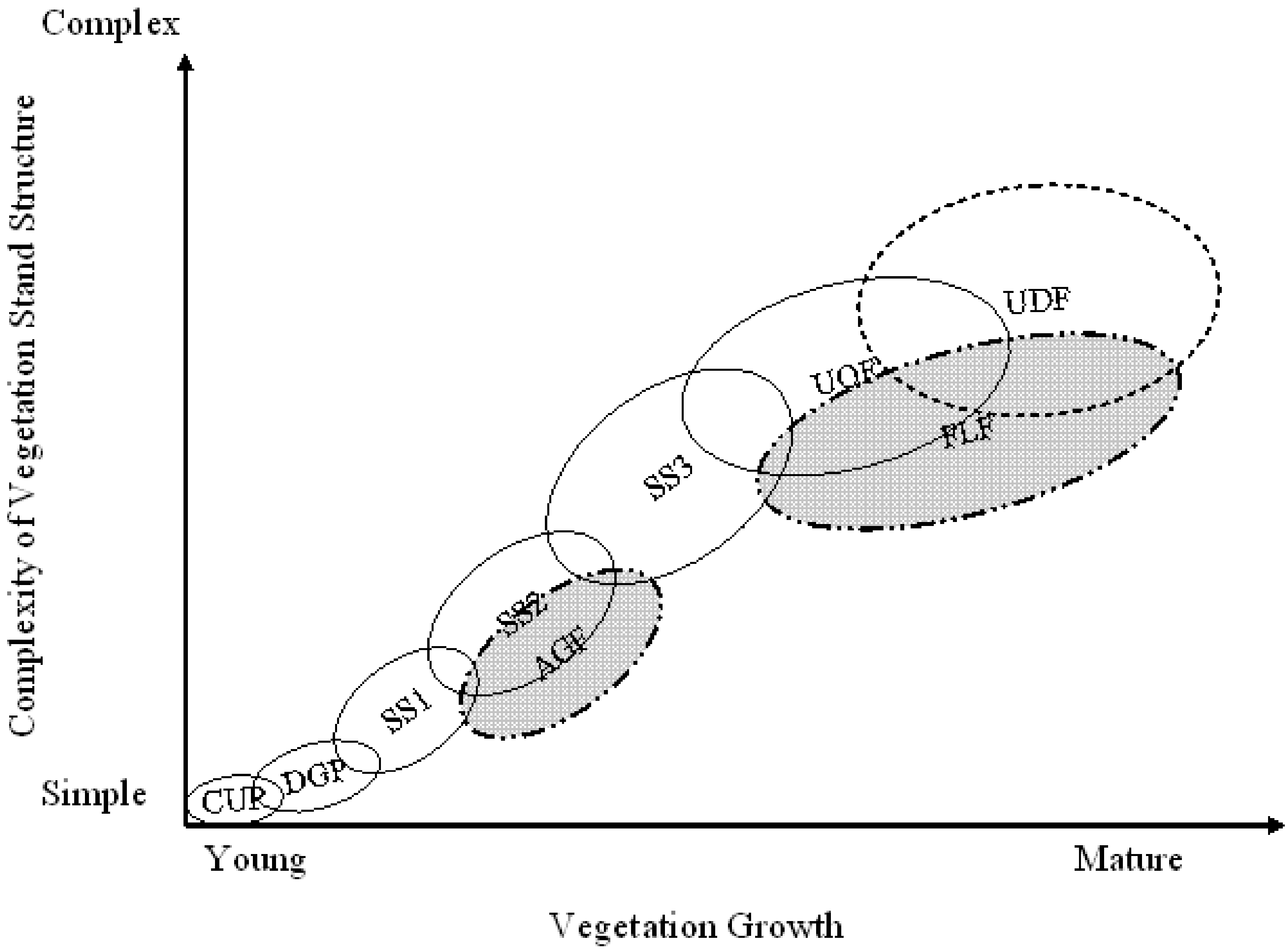
Comparison of classification accuracies among different sensor data

	Dataset	Code	SS1		SS2		SS3	
			PA%	UA%	PA%	UA%	PA%	UA%
Spectral signatures	SPOT HRG	HRG-ALL	62.00	63.27	47.22	38.64	66.67	30.00
	Landsat 5 TM	TM2345	58.00	60.42	36.11	35.14	66.67	23.08
		TM-ALL	68.00	51.52	31.11	23.53	33.33	20.00
	Terra ASTER	AST123	9.38	30.00	41.67	31.25	42.86	13.64
		AST1234	50.00	45.71	37.50	40.91	42.86	20.00
		AST12345	50.00	48.48	41.67	45.45	42.86	20.00
		AST-ALL	59.38	55.88	41.67	50.00	71.43	21.74
	Landsat ETM+	ETM345	52.31	59.65	26.19	45.83	53.85	17.50
		ETM-ALL	64.62	63.64	21.43	45.00	46.15	18.18

Comparison of classification accuracies among different image combinations

Combination	Dataset	Code	SS1		SS2		SS3	
			PA%	UA%	PA%	UA%	PA%	UA%
Data fusion	HRG MS & PAN	HRG-PAN	62.00	65.96	41.67	35.71	55.56	20.83
	TM MS & HRG PAN	TM-HRG-PAN	66.00	56.90	25.00	25.00	11.11	7.14
	ETM MS & PAN	ETM-PAN	53.85	61.40	21.43	36.00	69.23	22.50
Combination of spectral and textures	HRG MS + PAN texture	HRG-PANText	54.00	62.79	50.00	45.00	77.78	43.75
	(HRG MS & PAN) fusion + PAN texture	HRG-PAN-PANText	64.00	66.67	50.00	42.86	55.56	26.32
	ETM + PAN texture	ETM-PANText	61.54	63.49	21.43	52.94	84.62	27.50
	(ETM & PAN) fusion + PAN texture	ETM-PAN-PANText	63.08	62.12	23.81	52.63	84.62	32.35

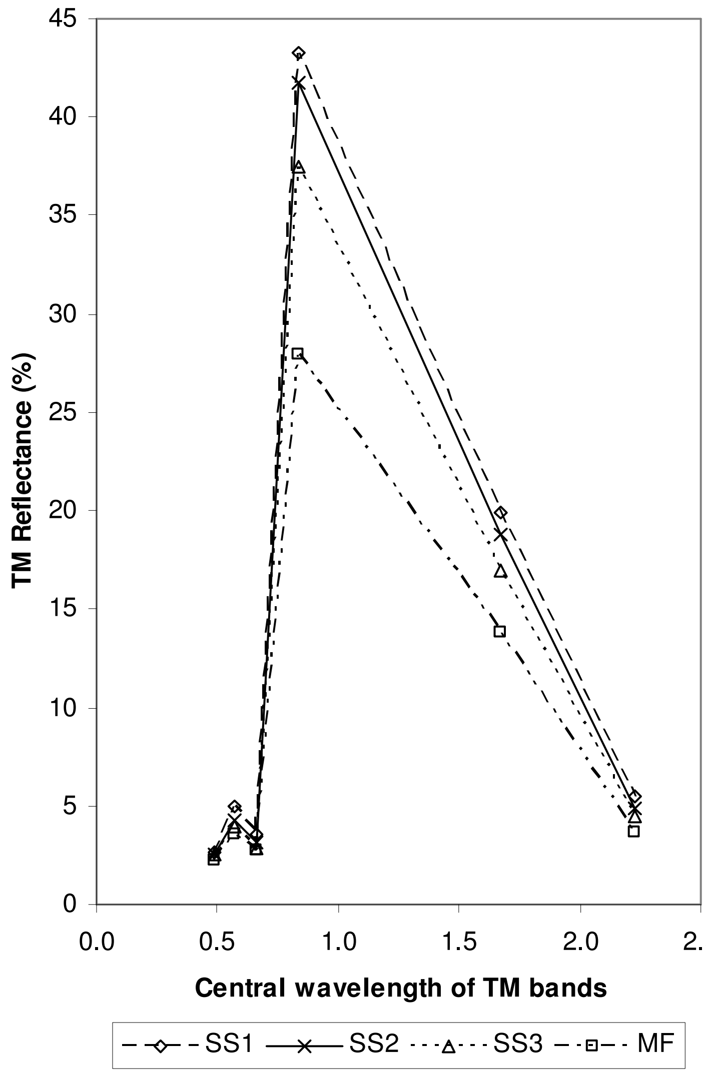
A concept of vegetation stand structure complexity among different vegetation classes

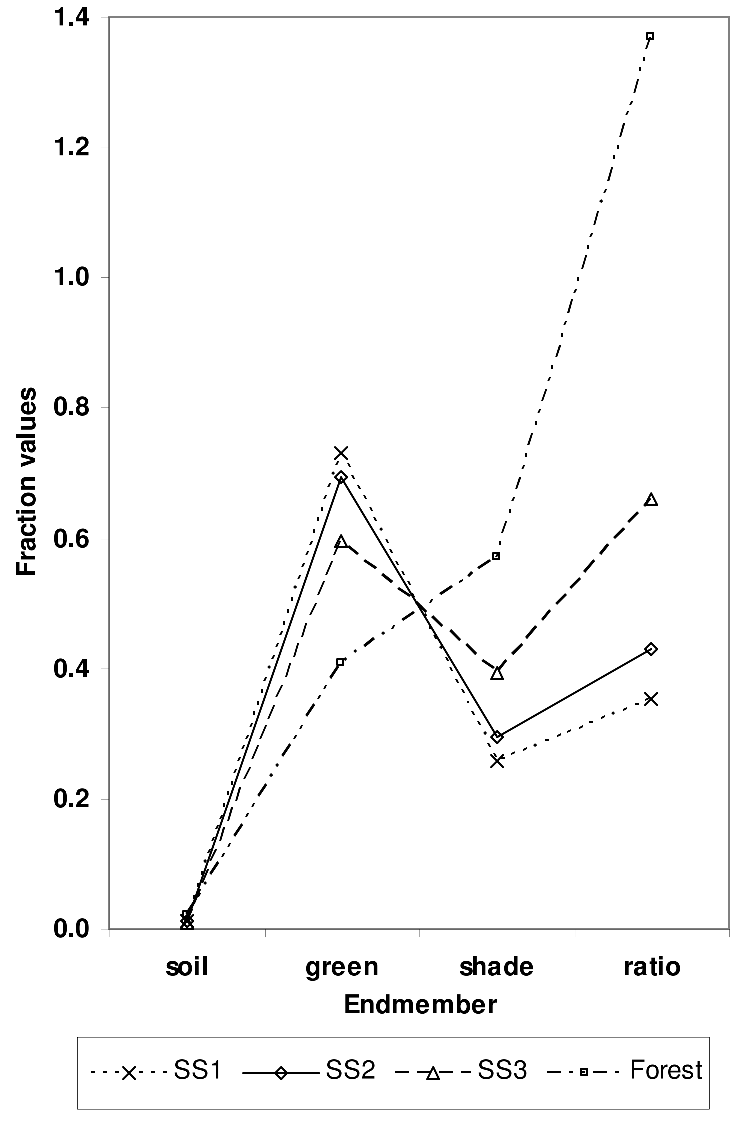


Classification of secondary succession stages based on fraction images

- Lu, D., Moran, E., and Batistella, M. 2003. Linear Mixture Model Applied to Amazonian Vegetation Classification. Remote Sensing of Environment, 87(4), 456–469.
  - Based on ratioed images with vegetation and shade, which was developed using spectral mixture analysis of TM image

A comparison of different succession stages in spectral features and fraction images





Classification of secondary succession stages based on the estimated forest stand parameter

- Lu, D. 2005. Integration of Vegetation Inventory Data and Landsat TM Image for Vegetation Classification in the Western Brazilian Amazon. Forest Ecology and Management, 213(1-3), 369–383.
  - Based on the entropy variable describing tree height distribution

Case study 2: vegetation classification based on forest stand structure

Entropy calculation

– entropy is used to evaluate the complexity of a stand structure for each plot based on tree height probability distribution

$$ENT = -\sum_{i=j}^{h} P_i \log_2(P_i)$$

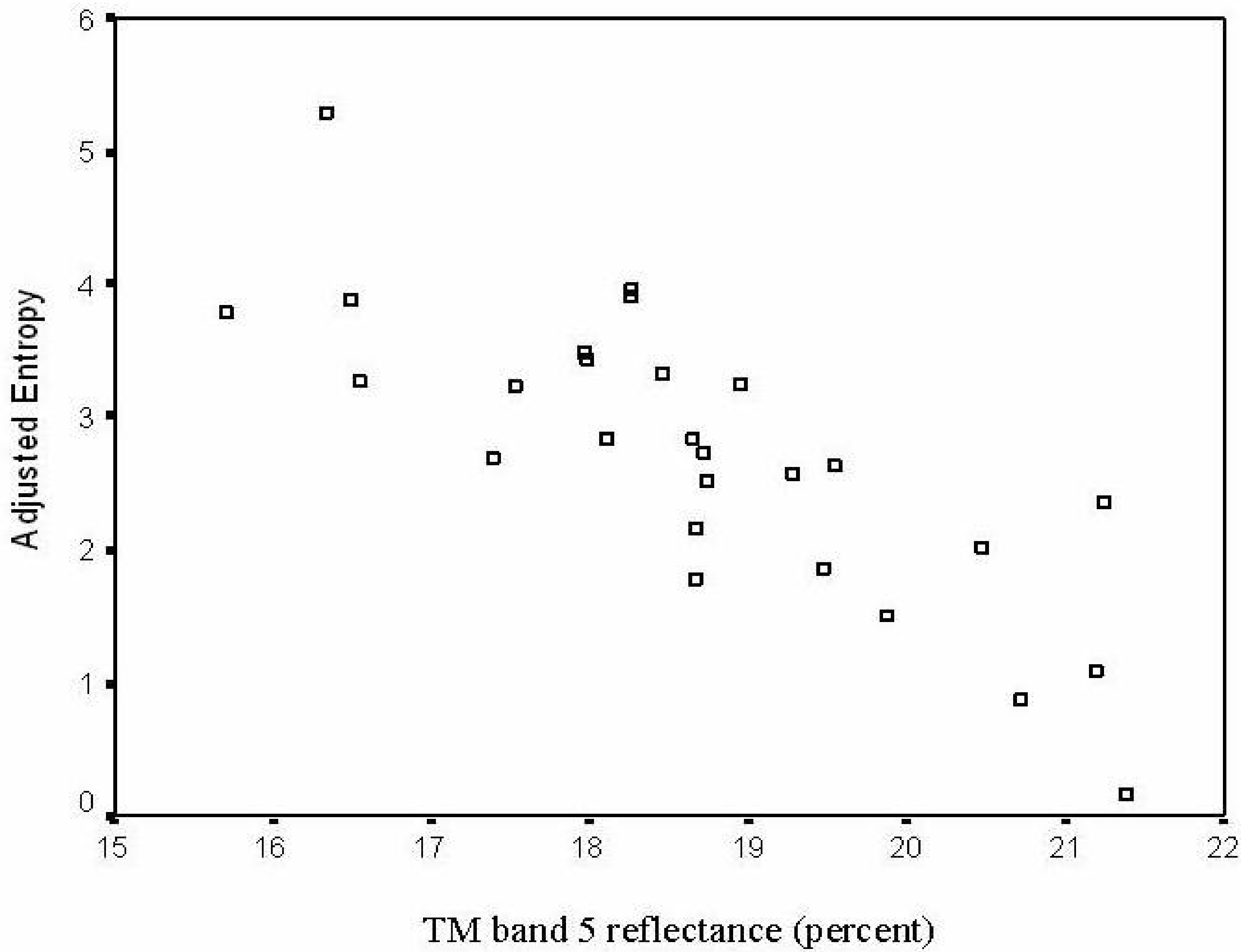
$$P_i = n_i \Big/ \sum_{i=j}^{h} n_i$$

$$adjENT = 0.1 * avgH * ENT$$

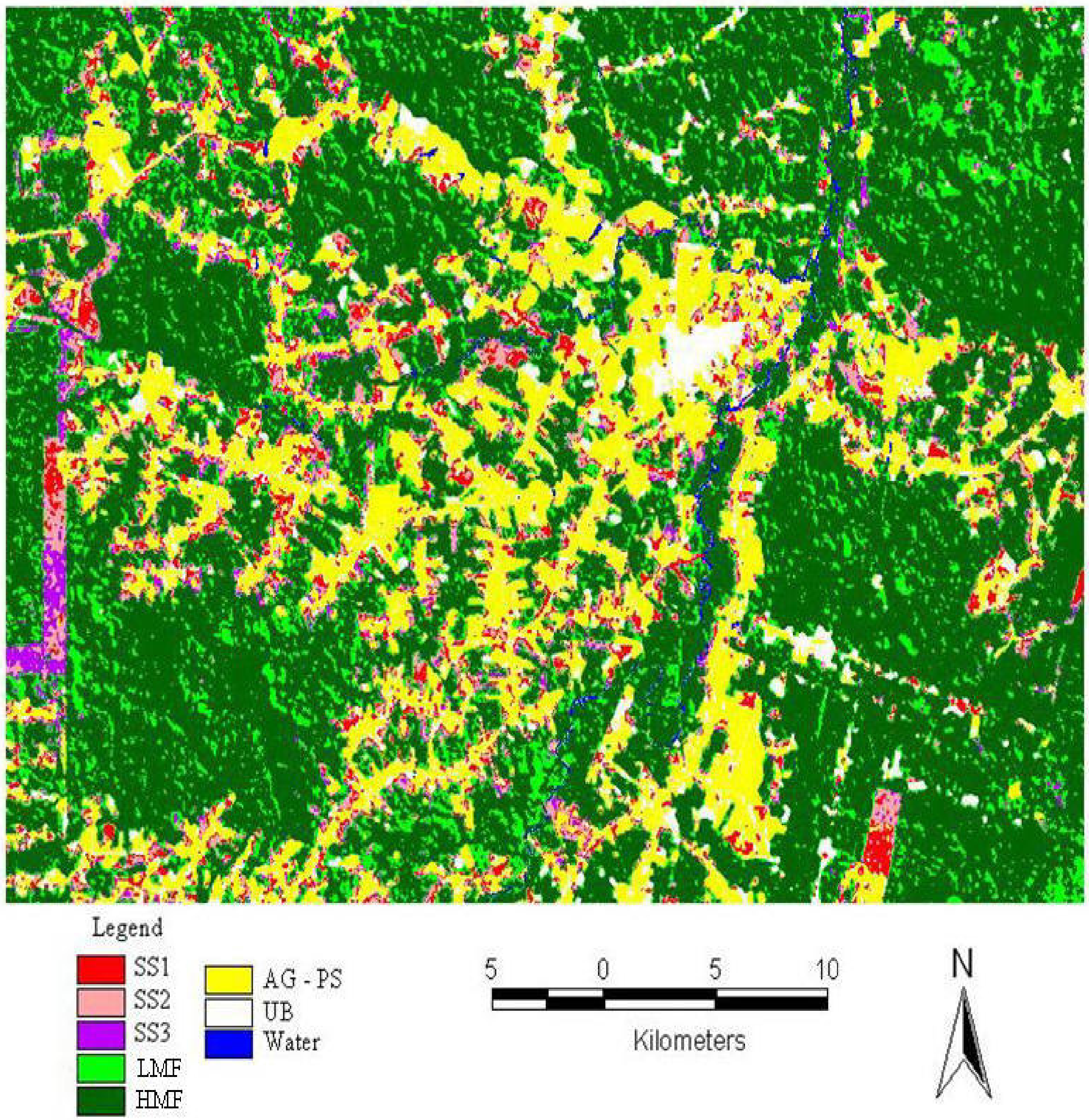
A Summary of Major Features and Thresholds Used for Vegetation Classification

Vegetation classes	Age (year)	Biomass density (kg/m^2)	Average tree height (m)	*adjENT*	Thresholds of *adjENT*
SS1	<5	< 5	< 8	< 1.5	0 – 1.6
SS2	5 – 9	4 – 10	8 – 11	1.7 – 2.9	1.6 – 3.0
SS3	8 – 13	> 11	> 10	> 3.2	≥ 3.0
LMF		10 – 20	12 – 15	<4.0	<4.0
HMF		> 20	12 – 19	> 3.8	≥ 4.0

Relationships between TM band 5 and adjust entropy variable



Classification image based on adjust entropy variable



Comparison of Accuracy Assessment Results between *adjENT* Approach and MLC

Accuracy assessment for *adjENT* based approach								MLC*	
	SS1	SS2	SS3	RT	CT	UA%	PA%	UA%	PA%
SS1	17	5	0	22	19	77.27	89.47	44.74	51.52
SS2	2	11	1	14	18	78.57	61.11	61.11	56.41
SS3	0	2	7	9	8	77.78	87.50	42.11	53.33

Conclusion

- Classification of secondary succession is very difficulty directly using remotely sensed data. Much confusions are between successional stages and agroforestry, advanced succession and mature forest, initial succession and degraded pasture.
- Estimated forest stand parameter representing forest structure complexity is useful for separation of secondary succession stages

Discussion

- Smooth transition between secondary succession stages
- Similar stand structure and spectral features between secondary succession and agroforestry
- Environmental factors, such as soil condition, affect vegetation growth rates, and then vegetation stand structures