ACT Publication No. 94-06

Mapping Anthropogenic Forest: Using Remote Sensing in a Multi-level Approach to Estimate Production and Distribution of Managed Palm Forest in the Amazon Estuary

E. S. Brondizio, E. F. Moran, A. D. Siqueira,
P. Mausel, Y. Wu, and Y. Li

Reprinted from: **Proceedings of the International Society for Photogrammetry and Remote Sensing. Eco-Rio 94. Rio de Janeiro (1994)**

Anthropological Center for Training and Research on Global Environmental Change
Indiana University, Student Building 331, 701 E. Kirkwood Ave., 47405-7100, U.S.A.
Phone: (812) 855-6181, Fax: (812) 855-3000, Email: act@indiana.edu, internet: www.Indiana.edu/~act

ISPRS
Rio de Janeiro, Brazil
1994

INTERNATIONAL SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING
SOCIÉTÉ INTERNATIONALE DE PHOTOGRAMMÉTRIE ET DE TÉLÉDÉTECTION
INTERNATIONALE GESELLSCHAFT FÜR PHOTOGRAMMETRIE UND FERNERKUNDUNG

INTERNATIONAL ARCHIVES OF PHOTOGRAMMETRY AND REMOTE SENSING
ARCHIVES INTERNATIONALES DE PHOTOGRAMMÉTRIE ET DE TÉLÉDÉTECTION
INTERNATIONALES ARCHIV FÜR PHOTOGRAMMETRIE UND FERNERKUNDUNG

Volume / Volume / Band **30** Part / Tome / Teil **7a**

PROCEEDINGS

ISPRS Commission VII Symposium

RESOURCE AND ENVIRONMENTAL MONITORING

September 26-30, 1994
Rio de Janeiro, Brazil

Published by: The National Institute of Space Research (INPE)

pg 184-191

Brondizio, E. S., E.F. Moran, A.D.Siqueira, P. Mausel, Y. Wu, and Y. Li. "Mapping Anthropogenic Forest: Using Remote Sensing in a Multi-level Approach to Estimate Productio and Distribution of Managed Palm Forest in the Amazon Estuary". *Proceedings of the International Soc. for Photogrammetry and Remote Sensing*. Eco-Rio94. Rio de Janeiro.

MAPPING ANTHROPOGENIC FOREST: USING REMOTE SENSING IN A MULTI-LEVEL APPROACH TO ESTIMATE PRODUCTION AND DISTRIBUTION OF MANAGED PALM FOREST (Euterpe oleracea) IN THE AMAZON ESTUARY.

Eduardo S. Brondizio, Emilio F. Moran, Andrea D. Siqueira
ACT-Global Change Center; Indiana University, Bloomington, IN,47405 USA
Paul Mausel, You wu, Yinghong Li
Dept. of Geography and Geology, Indiana State University, Terre Haute, IN, 47809 USA

Commission VII, Working Group 3

KEY WORDS: Forest management, Euterpe oleracea, Amazon estuary, Land use, Human ecology, GPS

ABSTRACT

This paper demonstrates the applicability of Landsat Thematic Mapper data to mapping Acai palm forest distribution and point out the feasibility of estimating fruit production at local and regional level. Production figures from the literature and fieldwork are used to estimate production of Acai fruit under two levels of forest management (intensive managed and unmanaged). The analysis presented on the paper incorporates spectral modeling and ground-based data about land use history and site-specific vegetation stand inventories for several areas of Floodplain and Acai palm forest located at Ponta de Pedras, Marajo island, Brazil. Hybrid process of image classification using a parametric classifier (ECHO) was used for a TM image of 1991. This methodology allowed to define spectral signatures of 15 land cover features, specially between managed (Acai palm forest) and unmanaged floodplain forest, and between three stages of secondary succession. Acai palm forest covers 5.7% of the area, while unmanaged Floodplain forest covers 16.3%. Accuracy assessment using test fields showed 85.7% accuracy for the classification of Acai palm forest. Management of Floodplain forest increases up to fivefold the production of Acai fruit.

1. INTRODUCTION

Amazon deforestation has attracted worldwide attention due to its multifaced socio-economic and ecological consequences at local, regional and global scales. In the global change research community a large body of studies have focused on monitoring large scale deforestation rates (see Skole and Tucker 1993 for the most recent assessment), its impact on climate change and atmospheric trace gases (Dickinson 1987, Shukla et al. 1990), and its effects on biodiversity (Wilson 1988). Less attention has been paid to local-level trajectories of land use change, to post-deforestation processes of forest regrowth, and to the contribution of local knowledge to the development of intensive systems of food production (Moran et al. 1994, Dale et al. 1993). The assessment of land cover change as a function of socio-economic and ecological factors is a fundamental step to understanding the sustainability of current forms of land use, and the consequences of these actions on the region's land cover (Brondizio et al. in press).

Forest management is a widespread activity in Amazonia with significant economic importance for local populations. So far, the remote sensing community has not paid enough attention to differentiate between natural and anthropogenic forest using satellite data. The goal of this paper is to demonstrate that Landsat TM image can be effectively used to mapping subtle forms of anthropogenic forest, such as the case of Acai palm forest when integrated with ground level research that includes ecological and socio-economic dimensions of land use. As an example, secondary data on acai fruit production is used to provide a demonstrative estimation of fruit production considering the spatial distribution of acai palm forest provided by image classification.

In the last twenty years, increases in demand for cultivated and forest products by a growing urban market have led to increased levels of agriculture intensification and extractivism with different socio-economic and environmental results. In the Amazon estuary, local populations have managed floodplain forest to increase production of Acai fruit (Euterpe oleracea), creating extensive areas of palm forest, which, nevertheless has become one of the most important economic resource in the region. The Acai fruit is a staple food of regional population, providing a considerable portion of total caloric intake (Siqueira and Murrieta 1993). This region was intensively exploited for palm heart production (a sub-product of Euterpe oleracea) in the 60's and 70's. Palm heart exploitation, which requires clear cutting of palm tree, has in some cases depleted the palm stock on the region. However, as a result of the combination between market demand, floodplain productivity, and the fast rate of regrowth and maturation of the 'acai palm', production of fruit has boomed in the last two decades. For instance, in Ponta de Pedras (study area of this paper), in Marajo island, fruit production went from 4,000 tons in 1975 to 11,158 tons in 1985 to 38,450 tons in 1989, while palm heart production has dropped in the same proportion (FIBGE 1974-1989).

Studies have suggested that this agroforestry practice, which incorporates structural and functional aspects of the forest, can maintain the functional integrity of an ecosystem, while providing reliable income for local producers (Anderson and Ioris 1989). However, so far, this agricultural strategy has been neglected by government policies as a viable alternative for rural development in the estuary context. Distribution and production were never mapped before.

As a tool, remote sensing can bring important contributions to encourage alternatives solutions to Amazon deforestation, as far as more attention is paid to multi-level analysis concerning the integration of local subsistence strategies and regional land use dynamics.

2. STUDY AREA

2.1 Environmental Settings

The study area is located in the estuarine region of the lower Amazon, on Marajo island, in the county of Ponta de Pedras, state of Para'. It is a transitional region between two macro-environments: natural grassland and forest, most of which are flooded forest (Pires 1973; Prance 1980). According to Lima (1956) floodplain occurs in 25,000 square kilometers of the Amazon estuary. Acai palm forest is a vegetation type in the floodplain area characterized by the high concentration of Euterpe oleracea. It is an anthropogenic formation resulting from different means of management of floodplain forest (for more information see Jardim and Anderson 1987). According to Calzavara (1972) these palms forests occupy 10,000 square kilometers in the lower Amazon. Another major vegetation class in the floodplain is Mangrove.

Upland forest occurs at sites that date from the tertiary period. These sedimentary areas are dominated by Oxisols with sandy texture and low pH. Vegetation regrowth in different stages of secondary succession are widely scattered in the area as a result of shifting- and conventional-based agriculture and cattle ranching. Secondary succession occurs along a continuum that reflects numerous factors such as land use history, opportunistic colonization by opportunistic and gap species, and landscape features such as soil quality and topography.

Grassland savannas (Radam 1974) are one of the most prominent features in the study area. Three grassland savannas types may be characterized in the area (Brondizio et al. 1993). Between the grassland areas and the forest one can identify a transitional forest characterized by the dominance of palms and vines.

2.2 Cultural and Socio-economic Context

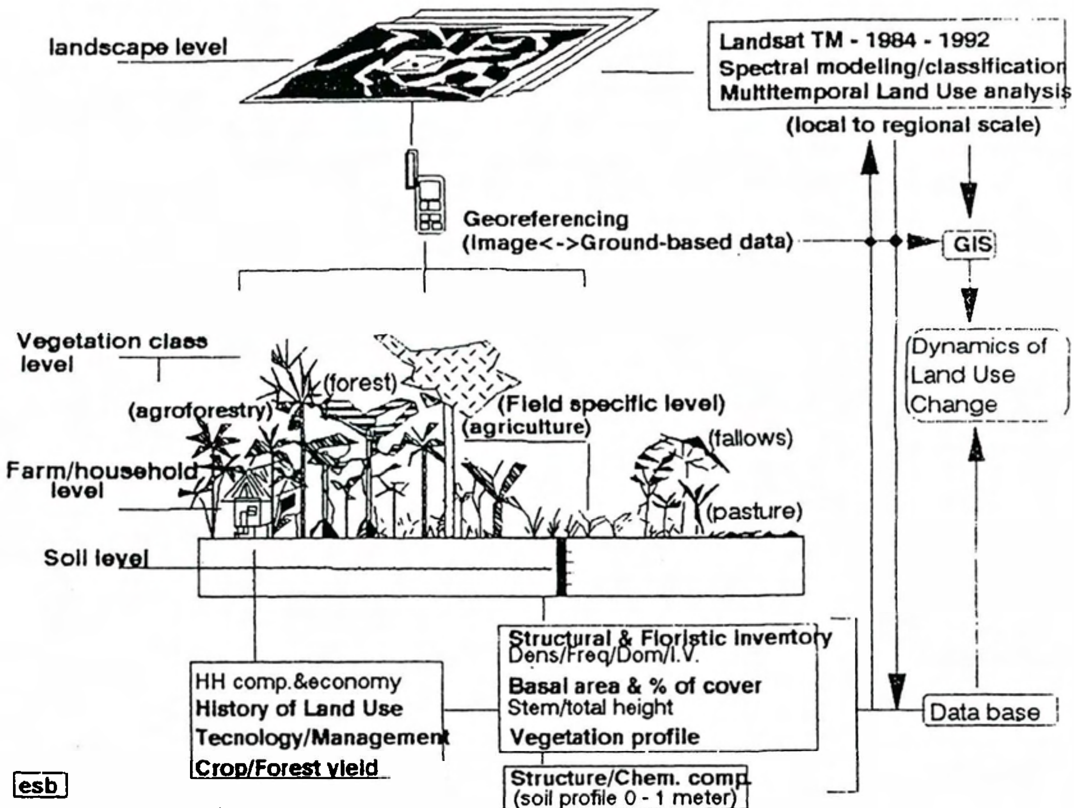
The human populations of Marajo island may be found in a small number of urban centers, or scattered along the river banks in a typical pattern going back at least to the rubber boom period (Wagley 1953; Moran 1974; Parker 1985). In the last 20 years, the rate of socio-economic change in Amazonia has motivated fundamental transformation of Caboclo populations. The increasing influence of market and development projects, as well as a greater proximity of a national political structure have motivated these populations to a variety of changes in subsistence strategies and social organization. The effects of these changes in demographic patterns, social organization, economy, and well-being, as well as its environment impact is still lacking for studies that seeks to understand the adaptive and sociological responses of these changes (Neves, ed. 1992).

3. METHODS

3.1 The Method of Multilevel Analysis of Land Use

What is referred here as a multilevel analysis of land use involves data integration at four different scales and contexts: landscape, vegetation class, farm/household, and soil level (FIGURE 1). This model of data collection relies upon a nested sampling procedure that produces data that can be scaled up and down independently or in integrated fashion. The combined use of multi-temporal, high resolution satellite images with local based data on land use history and site specific vegetation inventories makes it possible to understand ecological and social dimensions of land use at local scale, and link them to regional and global scales of land use dynamics. Through this procedure one can estimate the spatial distribution and production of Acai palm forest.

Figure 1 Method of Multilevel Analysis of Land Use



3.2 Image Processing and Classification

A Landsat TM image (path/row 224/61) was acquired from the Brazilian Agency on Space Research (INPE), from July of 1991. The image was geo-corrected to a UTM grid using available 1:100,000 topographic maps (FIBGE 1984). In this fashion, the geo-processed image could be related to waypoints collected in the field through use of a GPS (Global Positioning System) device.

Classification procedure was based on a hybrid approach that combined unsupervised and supervised classifications. A hybrid approach allows us to develop an analysis of the spectral patterns presented in the TM bands in conjunction with ground information to arrive at spectral signature patterns which account for detailed differentiation of land cover features. Processing started with high-dimensional clustering (40 to 60 classes) of the whole image as well as in small subsets. Classes were analyzed based on their statistical values (mean, standard deviation and co-variance). Training samples with known vegetation and history of land use were used to develop spectral signatures for the classes of interest. In this fashion, a conceptual spectral model can be developed in which the features of interest can be incorporated. The analysis considers the reflection and absorption characteristics of the physical components that comprise each feature. It attempts to account for chlorophyll absorption in the visible TM bands (1-3), for mesophyll reflectance in the near-infrared TM band 4, and for both plant and soil water absorption in the mid-infrared bands 5 and 7 (Jensen 1986). The integration of these spectral features with field data on vegetation height, density and dominance of species is necessary to differentiate management in floodplain forest and stages of secondary regrowth (Mausel et al. 1993). For example, the stratification of the floodplain forest creates energy sinks as manifested by shadowing. This influence is particularly noticeable in the near- and mid-infrared. This factor analyzed together with variation in canopy height is necessary to differentiate unmanaged from managed areas. The lesser shadowing of the managed area and its lower canopy is manifested in the near-infrared.

The analysis of spectral statistics derived from clustering and from areas of known features (training samples) allows the development of representative statistics for supervised classification. Transformed divergence analysis was applied in the training samples. Although it is not a definitive predictor of classification accuracy, it can provide insights into the spectral distinction of training fields (Li et al. 1994). Each image was submitted to separability analysis, which indicated that channels 2,3,4 and 5 were the best set of bands to be used for image classification. The 15 final classes were submitted to a spatial-spectral classifier available in Multispec (Ver.07/15/93), ECHO - a texture-maximum likelihood classifier (for a description of Multispec and ECHO see Landgrebe and Biehl 1993). Test fields were used during classification to assess accuracy of feature discrimination.

3.3 Land Use History

Household level interviews have been carried out to record the sequence of management steps applied in the land used in the sampling area. Data include the date since the forest was cut or thinned, pruning of Acai clumps, planting of seeds and seedlings, burning, the crop yield, etc. The fieldwork protocol was prepared based on a NASA fieldwork guide developed for MSS image analysis (Joyce 1978).

3.4 Methods on Vegetation Inventory

Six areas of Acai palm forest and one of floodplain forest were inventoried during May and June 1992. Selection of areas with differential management was based on interviews with local producers, although a concern with the spatial distribution of the sites on the map was taken into account. For each area the floristic composition and structural factors such as DBH (diameter at breath height), number of individuals, percentage cover, stem (first branch) and total height were collected. Four plots of 25 x 25 meters, and four subplots of 5 x 2 meters were randomly located on the area appointed by the producers. In the plots all the trees with DBH >= 10 cm were measured for DBH, stem and total height. In these plots, all acai trees (DBH >=5 cm) were counted taking into account the number of stems per clump. In the subplots, all the individuals were identified and counted, and saplings (trees with DBH >=2 cm) were measured. In the unmanaged forest, the number of plots and sub-plots were doubled.

Botanical identification was made by experienced 'mateiros' familiar with the species of the region of the Botany Dept. at EMBRAPA in Belem in site and in herbarium. In each area, soil samples were collected at 20 cm intervals to one meter depth. Soil sample were analyzed in CEPLAC and EMBRAPA labs in Belem for both chemical and physical properties.

Sampled areas were located on the satellite image and its coordinates were obtained with a geopositional system device (GPS), a Magellan Nav 1000 Pro receiver. The use of GPS to locate sampled areas of Acai palm forest in the image ensures a fundamental step to improve spectral discrimination of land features with subtle differences, such as between these vegetation types.

3.5 Secondary Data

Secondary data were used from two main sources: Jardim and Anderson 1987, and Anderson and Jardim (1989). These sources provided information on number of individuals, basal area, and importance value for two sites (managed and unmanaged floodplain forest) located at Ilha das Oncas, Barcarena, PA, Brazil.

4 ESTIMATION OF ACAI FRUIT PRODUCTION

4.1 Assumptions

Table 1 shows the changes on the number of individuals of acai palms in areas with different intensities of management in relation to the total number of individuals of the area. Considering the information presented in Table 1, and in accord to the availability of secondary data for calculation of production-Tab 5, some preliminary assumptions need to be made before one proceed w/ calculations.

1. Two classes will be considered: unmanaged and managed. These classes are consistent with the land cover map generated by the classification of the satellite data, although vegetation data may suggest differences between extensive and intensive management of acai palm forest, these classes could not be differentiated so far during classification. The calculation will be based on the classification of the 1991 scene, which has more than 80% accuracy in the training and test fields for acai palm forest class.
2. The data used to calculate productivity is based on Jardim and Anderson (ibid:12), which estimate productivity of fruits per stem as showed in *Table 4*. However, due to the large standard deviation and to account for the most realistic scenario, the lowest value of productivity (Kg/Stem/year) will be used here, i.e. 4.4 Kg/Stem/year. This value will be used for both unmanaged and managed forest.
3. The number of stems per hectare will be also based on the lowest number reported on Table 1, i.e. 354 stems/ha (site 1) for unmanaged forest, and 1880 stems/ha (site 5) for managed forest. 4.The final production will be also converted to 'rasas' which is the regional measure for marketing of acai fruit. A 'rasa' is the equivalent to 15 kg (Calzavara 1972; Lopes et al. 1982).
5. The price per kilo is estimated in US$ 0.15. Thus, the price per 'rasa' is US$ 2.2 (Field notes - 1993).

4.2 Spatial Distribution of Acai Palm Forest

Acai palm forest represents 5.7% (2088 ha) of the whole area comprised by the TM image, while Floodplain forest is the most dominant land cover feature with an extent of 16.3% (5971 ha) (Table 2). Table 3 shows the spectral signatures for the land cover classes. Table 4 provides a matrix of accuracy, showing the percentage correctly classified of the test fields for 15 classes. Overall land cover classification accuracy is high (97.8%), while Acai palm forest alone has lower accuracy (85.7%). Due to space restriction the classified image is not shown in the paper. For more information see Brondizio et al. in press).

4.3 Production of Acai Fruit

Table 5 shows the calculation of production of acai fruits for the whole area comprised by the TM scene. According to the assumptions made, the economic return of fruit in a unmanaged forest in Ponta de Pedras (US$ 231/ha/year) is consistent with those of Jardim and Anderson (1987:16) estimate for the same vegetation type (US$ 234/ha/year) in Ilha das Oncas. However, difference is up to threefold in areas of managed forest between Ponta de Pedras (US$ 1239/ha/year) and Ilha das Oncas (US$ 504 -best estimate). This difference is explained by the higher number of stems per hectare that were measured in Ponta de Pedras. However, a question concerning the differences in management techniques between these two areas remains.

Such scenario shows that a smallholder with 3 hectares of managed acai palm forest may achieved over US$ 3,000/year. The data shows that management of acai palm forest increases up to fivefold the return of a hectare of floodplain forest. This analysis does not take into account the costs of management, such as contracted labor. It is also important to consider that prices are subjected to fluctuations in accord to the "acai market" in Belem. In addition, small producers of Ponta de Pedras are subjected to middleman intermediation to transport production.

Considering the production figures of FIBGE (1989) we can derived that the area covered by the image (36,634 ha) supplies 68% of the total production of acai fruit of Ponta de Pedras as measured by FIBGE. It seems a reasonable amount considering the large area of floodplain forest presents in the studied area in relation to the county area as a whole, which has large areas of natural grasslands.

Ongoing research is focusing on the increase of sampling areas, and on the definition of spectral signature for Acai palm forest under intermediary stages of management. The role of land tenure in defining levels of intensification has also been analyzed. At the population level, the majority of the households takes part in the activity independent of ownership. In fact, acai fruit production is the main activity of share croppers. However, it is expected that land ownership guarantees more autonomy to define management levels, since it ensures the long term value of the land, increasing the security of the household. Besides that, share-croppers are frequently subjected to the price paid by the land owner, which acts as middleman.

5. CONCLUSION AND FUTURE WORK

This experimental work has pointed out the possibility of monitoring acai palm forest through the combination of satellite images, ground-based information and use of secondary data. However, refinement of methods and assumptions need to be achieved. As mentioned before, on going research (between August and December of 1994 - peak of production season) will measure productivity of acai fruit in areas under different intensities of management and will collect data on property boundaries in three different populations. Local producers have agreed on collaborate with historical data about acai production. The use of GPS will be specially useful to delimitate property boundaries and geo-reference it to the satellite image. Understanding the spatial and temporal dimensions of floodplain agroforestry and its integration with other land use activities will provide information to support future rural development policy for the region that combines local knowledge of management and market.

Although it represents the main source of income in the region, the production systems of floodplain agroforestry is still little known in the Amazon estuary. Studies need to include a better understanding of land tenure, and market relationship between producer, middleman, and central market, as well as, the integration between floodplain agroforestry with other types of land use, such as upland agriculture. Floodplain agroforestry presents an outstanding opportunity to intensification of food production in the region without displacement of local populations, without constraining diversification of land use, and without destruction of the resource basis.

6. ACKNOWLEDGMENT

The authors would like to thanks the support from the Brazilian Research Council (CNPq - 403534/90; 150043/90-2 - PI Walter Neves) which allowed Brondizio and Siqueira to work in the area between 1990 and 1991; from the National Science

Foundation (NSF 91-00526) to Prof. Moran; a grant from the Macarthur-funded Indiana Center on Global Change and World Peace to Brondizio during the academic year of 1993-1994. Current research in the area has been supported by a grant from NASA (3708-GC94-0096) to Eduardo Brondizio. The authors would like to thanks Lucival Marinho and Jair Rodrigues for their work on vegetation inventories. Responsability for the views expressed in this paper are the sole responsability of the authors and do not reflect the views of the funding sources or collaborators.

7. REFERENCES CITED

-Anderson, A. & E. Iorys. 1989. The Logic of Extraction: Resource Management and Income Generation by Extractive Producers in the Amazon Estuary. In R. Kent and C.Padoch, Conservation of Neotrop-ical Forests, Columbia University Press, New York.

-Anderson A.B. and Jardim M.A.G. 1989. Costs and Benefits of floodplain forest management by rural inhabitants in the Amazon estuary: A case study of Acai palm production. In Browder J.O.-(ed.) Fragile Lands of Latim America.Westview Press, Boulder.

-Brondizio E.S., Moran E.F., Mausel P., and Wu Y. (in press). Land use change in the Amazon estuary: Patterns of Caboclo settlement and landscape management. Human Ecology.

-Brondizio E.S., Moran E.F., Mausel P., You W. (1993) 'Dinamica da vegetacao no Baixo Amazonas: Analise temporal do uso da terra integrando imagens Landsat TM, levantamento floristico e dados etnograficos'. Proceedings of to the 7th Brazilian Symposium of Remote Sensing. Curitiba, May 1993.

-Calzavara, B.B.G. 1972.As possibilidades do acaizeiro no estu-ario Amazonico. Boletim da Fundacao de Ciencias Agrarias do Para 5:1-103.

-Dale V. et all. (1993). Cause and effects of land-use change in central Rondonia, Brazil. Photogrammetric Engineering and Remote Sensing, Jun(6):997-1005.

-Dickinson R.E. (ed.) (1987). The Geophysiology of Amazonia: Vegetation and Climate Interactions. Wiley. New York.

-FIBGE (1984). Base cartografica-Folha Cachoeira do Arari. Escala 1:100,000.

-FIGGE 1974-1989 Producao da Estracao Vegetal e da Silvicultura, Depto. Agropecuario, Diretoria de Pesquisas.

-Joyce A.T. (1978). Procedures for gathering ground truth infor-mation for a supervised approach to a computer-implemented land cover classification of Landsat-acquired multispectral scanner data. NASA Ref. Publication 1015.

-Jardim M.A. and Anderson A. 1987. Manejo de Populacoes Nativas de Acaizeiro no Estuario Amazonico, Resultados Preliminares. Boletim de Pesquisa Florestal, (15): 1-18, Curitiba.

-Jensen J.R. 1986. Introductory Digital Image Processing. Prent-ice-Hall, New York.

-Landgrebe D. and L. Biehl 1993. An Introduction to MULTISPEC, Purdue University, West Lafayette, IN.

-Lima R.R. (1956). Agricultura nas varzea do estuario do Amazo-nas. Boletim Tecnico do Instituto Agronomico do Norte, 33:1-164.

-Li Y., Mausel P., Wu Y., Moran E., and Brondizio E. (in press). Discrimination between advanced secondary succession and moist mature forest near Altamira, Brazil, using TM multitemporal data. ASPRS Proceedings, American Society for Photogrammetry and Remote Sensing. 11 pp.

-Mausel P., Wu Y., Li Y., Moran E., and Brondizio E.S. (1993). Spectral identification of successional stages following defores-tation in the Amazon. Geocarto International, Vol.8, No.4,10pp.

-Moran E.F., Brondizio E.S., Mausel P., You W. (1994) Deforestation in Amazonia: Land use change from ground and space level perspective. Bioscience, 44(5): 329-339.

-Moran, E. 1974. The Adaptive System of the Amazonian Caboclo. In: Man in the Amazon, ed. C. Wagley, pp.136-59. Gainesville: The University of Florida Press.

-Neves, W.A. (ed.) 1992. Antropologia Ecologica de Populacoes Ribeirinhas do Estuario do Amazonas: Subsistencia e Adapatacao. Relatorio Cientifico. CNPq, Brazil.

-Parker, E. 1985. Caboclization: The Transformation of the Amerindian in Amazonia, 1615-1800. Studies in Third World Societ-ies, 29:xvii-li.

-Pires, J.M. 1973. Tipos de Vegetacao da Amazonia, Museu Paraense Emilio Goeldi, Belem.

-Prance G.T. (1980). A terminologia dos tipos de florestas Amazonicas sujeitas a inundacoes. Acta Amazonica 10:495-504.

-RADAM 1974. Levantamento de Recursos Naturais. Rio de Janeiro.

-Shukla J., Nobre C., and Sellers P. (1990). Amazon deforestation and climate change. Science 247: 1322-1325.

-Siqueira A.D. and Murrieta R.S.S. 1993. Dietary intake: a parameter of nutritional status of 3 Caboclo populations of Marajo Island, Lower Amazon, Brazil. Proceedings of the 4th. World Academic Conference in Human Ecology, July, 1993, Merida, Mexico.

-Skole D. and Tucker C.J. (1993). Tropical deforestation and habitat fragmentation in the Amazon: Satellite data from 1978 to 1988. Science 260: 1905-1910.

-Wagley, C. 1953. Amazon Town. New York: Macmillan.

-Wilson E.O. (ed.) 1988. Biodiversity. National Academic Press. Washington, D.C..

Table 1

INDICATORS OF ACAI PALM FOREST MANAGEMENT

Ponta de Pedras, Marajo Island, PA, Brazil (dbh >=5 cm)				LOCATION	
SITES	Tot #Spc	Tot #Indi	Tot # Acai	Latitude	Longitude
Site 1 (5000 m2)-Unmanage	43	395	177	1o23'06"S	48o55'00"
Site 2 (2500 m2)-Managed	13	603	562	1o20'49"S	48o54'20"
Site 3 (2500 m2)-Managed	28	697	587	1o25'43"S	48o52'11"
Site 4 (2500 m2)-Managed	18	913	857	1o22'01"S	48o54'27"
Site 5 (2500 m2)-Managed	11	501	470	1o26'48"S	48o52'18"
Site 6 (2500 m2)-Managed	15	542	496	1o25'45"S	48o52'18"
Site 7 (2500 m2)Managed	14	746	708	1o21'43"S	48o52'46"
Anderson (1990), Anderson & Jardim (1989) Ilha das Onças, Barcarena, PA, Brazil (Plots=2500 m2)					
Unmanaged (dbh>2cm)	53	261	100	1o25' S	48o27'W
Managed (dbh>5 cm)	28	323	163	1o25' S	48o27'W

Table 2 Land cover classes (% area)

	CLASSES	% 1991
1	WATER	15.2
2	UPLAND FOREST	13.2
3	FLOODPLAIN FOREST	16.3
4	ACAI PALM FOREST	5.7
5	MANGROVE	2.9
6	BARE SOIL	2.8
7	PASTURE	0.9
8	PASTURE W/ PALMS	0.6
9	COCONUT PLANTATION	0.5
10	INITIAL S.S.	2.3
11	INTERMEDIATE S.S.	3.1
12	ADVANCED S.S.	12.2
13	HIGH SAVANNA	9.6
14	LOW SAVANNA	13.4
15	"IMPERATA" SAVANNA	1.2

Table 3

SPECTRAL SIGNATURES OF LAND USE CLASSES

Relative Spectral Response in Digital Numbers for TM Bands 2-5

CLASSES	BAND 2	S D	BAND 3	S D	BAND 4	S D	BAND 5	S D
WATER	34.8	0.7	35.8	1.2	32.1	4.4	10.1	4.2
UPLAND FOREST	30.5	0.5	24.8	0.4	81.7	1.6	66.4	4
FLOODPLAIN FOREST	30.6	0.3	28.4	0.5	71	4.2	46.9	4.7
ACAI PALM FOREST	30.9	0.6	28.9	0.6	77.6	3.9	46.3	6
MANGROVE	32.8	0.9	32.9	1.6	52.36	8	32.6	0.4
BARE SOIL	45.6	2.4	52.5	3.5	60.9	4.2	107.9	7.2
PASTURE	39	0.8	35.8	2.3	98	3.3	115	3.5
PASTURE W/ PALMS	37	0.2	34.1	0.6	96.7	2.6	112.5	4.1
INITIAL S S	36.1	0.2	33	1.1	96.9	6.3	100.9	4.5
INTERMEDIATE S S.	35.9	0.7	31.8	1.3	93.6	3.8	92.6	5
ADVANCED S S.	32.6	0.4	26.3	0.7	91.7	3.5	71.2	5.4
HIGH SAVANNA	31.7	0.4	33.9	0.2	44	3.7	69.8	3.8
LOW SAVANNA	33.2	0.8	35	1.2	55.5	3.5	78.1	2.2
"IMPERATA" SAVANNA	32.3	0.6	31.4	1.1	65.6	1.8	61.5	2.1

Table 4

ACCURACY OF TEST FIELDS

	% correct class	# samples	Water	Upland fore	Floodplain f	Acai palm f	Mangrove	Bare soil	Pasture	Pasture w/	Coconut pl	Initial S Suc	Interm S Su	Advanced	High savan	Low savan	Imperata sa
Water	99.9	1207	1206	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Upland forest	87.7	148	0	128	19	0	0	0	0	0	0	0	0	0	0	0	0
Floodplain forest	99.2	120	0	0	119	1	0	0	0	0	0	0	0	0	0	0	0
Acai palm forest	85.7	21	0	0	0	18	3	0	0	0	0	0	0	0	0	0	0
Mangrove	100	43	0	0	0	0	43	0	0	0	0	0	0	0	0	0	0
Bare soil	100	13	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
Pasture	79.5	39	0	0	0	0	0	8	31	0	0	0	0	0	0	0	0
Pasture w/ palms	100	8	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0
Coconut plant.	91.7	12	0	0	0	0	0	0	1	0	11	0	0	0	0	0	0
Initial S.Suc.	100	42	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0
Interm.S.Suc.	100	90	0	0	0	0	0	0	0	0	0	0	90	0	0	0	0
Advanced S.S.	90	20	0	0	2	0	0	0	0	0	0	0	0	18	0	0	0
High savanna	94.8	174	0	0	0	0	0	0	0	0	0	9	0	0	165	0	0
Low savanna	97.5	120	0	0	0	0	0	0	0	0	0	0	0	0	3	117	0
Imperata savann	100	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
TOTAL		2070	1206	128	139	19	47	21	32	8	11	51	90	18	168	117	15

Overall Performance (2024 / 2070) = 97.8

Table 5

ESTIMATIVES OF ACAI FRUIT PRODUCTION

			Acai production					Total Area (TM scene	
Sampled Areas @	Mean&@	Type	Kg/Stem/year	#Stems/ha	Kg/ha/year	US$/ha/year	Rasas/ha/yr*	Area(ha)	Rasas/year
Control area	4.4a	Unmanage	4.4	354	1557	233.5	103	5971	615013
Selective Pruning (A) Forest thining (B) (A) + (B)	6.6ab 7.5b 7.4b	Managed		1880	8272	1239.75	551	2088	1150488
							Total		1765501
							*US$		3972377
							**%Fibge(1989)		68%

@ Adapted from Jardim & Anderson (1987)

@& Mean productivity of Fruits (Kg/ano) of Acai, per STEM (adapted from Jardim and Anderson 1987)

A,B: averages followed by the same leter do not differ among thenselves, in accord to 5 % T test

*"Rasas" = 15 Kg

** Percentage contribution of the area to the total production of Ponta de Pedras estimated by FIBGE (1989)

ACT Publications 1993

No. 93-01
Mausel, P., Y. Wu, Y. Li, E.F. Moran, and E.S. Brondizio. "Spectral Identification of Successional Stages following Deforestation in the Amazon." *Geocarto International* 8(4):61-81.

No. 93-02
Moran, E. F. "Managing Amazonian Variability with Indigenous Knowledge" In *Tropical Forests, People and Food: Biocultural Interactions and Applications to Development.* C.M. Hadlik et al. (eds.). Pp. 753-765. Paris: UNESCO/Parthenon Publ. Vol. 15 in Man and the Biosphere Series.

No. 93-03
Moran, E.F. "Deforestation and Land Use in the Brazilian Amazon." *Human Ecology* 21:1-21.

No. 93-04
Moran, E.F., E.S. Brondizio, P. Mausel, and Y. Li. "Assinaturas Espectrais Diferenciando Etapas de Sucessao Secundaria no Leste Amazonico" *Anais do VII Simposio Brasileiro de Sensoriamento Remoto.* 2: 202-209.

No. 93-05
Brondizio, E.S., E.F. Moran, P. Mausel, and Y. Wu. "Padroes de Assentamento Caboclo no Baixo Amazonas: Analise Temporal de Imagens de Satelite para estudos de Ecologia Humana de Populacoes da Amazonia". *Anais do VII Simposio Brasileiro de Sensoriamento Remoto* 1: 16-26.

No. 93-06
Brondizio, E.S., E.F. Moran, P. Mausel, and Y. Wu. "Dinamica na Vegetacao do Baixo Amazonas: Analise temporal do Uso da Terra integrando imagens Landsat TM, levantamentos florísticos, e etnograficos" . *Anais do VII Simposio Brasileiro de Sensoriamento Remoto* 2: 38-46.

No. 93-07
Moran, E.F. "Minimum Data for Comparative Human Ecological Studies: Examples From Studies in Amazonia." *Advances in Human Ecology* 2:187-209.

No. 93-08
A. Siqueira, E. Brondizio, R. Murrieta, H. da Silva, W. Neves, R. Viertler. " Estratégias de Subsistência da Populaçâo Ribeirinha Do Igarapé Paricatuba, Ilha de Marajó, Brasil." Bol. Mus. Para. Emilio Goeldt. Sér Antropol. 9(2): 153-170. 1993.

No. 92-01
R. Murrieta, E. Brondizio, A. Siqueira, E.F. Moran. " Estratégias de Subsistência da Comunidade de Praia Grande, Ilha de Marajó, Pará, Brasil." Bol. Mus. Para. Emilio Goeldt. Sér Antropol. 8(2): 185-201. 1992.