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International Center for Tropical Agriculture

Multiple Scale Land Characterization on the Hillsides Zone of Honduras using Integrated Remote Sensing, GIS, and Agricultural Census

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Mayo 1998

MULTIPLE SCALE LAND CHARACTERIZATION OF THE HILLSIDES ZONE OF HONDURAS USING INTEGRATED REMOTE SENSING, GIS AND AGRICULTURAL CENSUS.

MAY 1998

JULIETTE A. COX MSC.

HILLSIDES PROGRAMME
CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL, CALI, COLOMBIA

CONTENTS:

CHAPTER 2

II. Land Characterization of Study Areas in Honduras.

CHAPTER 5

Comparison between Landsat TM classifications and Agricultural Census in their estimations of land use areas.

CHAPTER 6

LIST OF DATA

List of Biophysical data sets, maps and geographical information for the Atlantida Study Areas (Francisco de Saco and La Masica), Honduras - GIS Lab, CIAT, Cali, Colombia.

1. Satellite Data
1.1 Original Landsat TM images
1.2 Original Landsat TM subscenes
1.3 Classified Landsat TM images
2. Air Photographs
3. (No digital orthophotographs)
4. GIS Coverages (Arc/Info)
4.1 Vector coverages
4.2 Raster coverages
5a. Hardcopy Maps
5b. Digital Maps, composed with IMAGINE software
6. Reports

Biophysical Data sets and Geographical Information for the Yorito Study area (sub-catchment of Rio Tascalapa), Municipalities of Yorito and Sulaco and Yoro Department, Honduras.

1. Satellite Data
1.1 Original Landsat TM images
1.2 Classified Landsat TM images
1.3 Other classified images

2. Air Photographs, including digital coverages and derived images/digital elevation models

3. Digital Orthophotographs

4. GIS coverages (Arc/Info)
4.1 Vector coverages
4.1.1 study area coverages
4.1.2 national coverages
4..2 Rasterized Vector coverages

5. Hardcopy Maps

6. Digital Maps composed with IMAGINE software

7. Reports

8. Other information

List of Biophysical data sets and geographical information for the Danli study area, a sub-catchment of Rio Cuseateca, Danli Municipality, El Paraiso, Honduras.

1. Satellite Data
1.1 Original Landsat TM images
1.2 Classified Landsat TM images
1.3 Other classified images

2. Air Photographs

3. Digital Orthophotographs

4. GIS coverages (Arc/Info)
4.1 Vector Coverages
4.1.1 National coverages
4.2 Rasterized vector coverages
4.3 Poster Maps

5. Hardcopy Maps

6. Reports

Biophysical Data Sets and Geographical Information for Honduras, and, more particularly, the central Hillsides zone.

1. Satellite Data
1.1 Original Landsat TM images
1.2 Classified Landsat TM Images

2. Aerial Photographs

3. No Digital orthophotographs

4. GIS Coverages (Arc/Info)
4.1 Vector coverages
4.1.1 National coverages
4.2 Rasterized Vector coverages

5. Hardcopy maps

6. Digital Maps composed using IMAGINE software

7. Reports/bibliography

Appendices

CHAPTER 1

LAND CHARACTERIZATION OF HONDURAS (AT DEPARTMENT, MUNICIPALITY AND SUB-CATCHMENT LEVELS).

I. Land Characterization of Honduras (at department, municipality and sub-catchment levels)

The Swiss Agency-funded Hillside programme required that a land-characterization study be carried out in the four pre-selected study areas and the departments in which they are located, making use of remote sensing, GIS and Agricultural Census data sets. This work was carried out during the period October 1994 to April 1998.

Three departments in Honduras are characterized in terms of their biophysical characteristics. These are Atlantida, El Paraiso and Yoro. (Map 1)

1. Land Characterization of Atlantida Department

1.1 Location

Atlantida is the northern department of Honduras and covers a total area of 4,404 square kilometers. It lies between lines of longitude 88 00 W and 86 20 W and between lines of latitude 16 00 N and 15 20 N. The Hillsides Programme has two sub-catchment study areas, one located in the municipality of Arizona, near San Francisco de Saco, (Rio de Saco) and another in the municipality of La Masica, to the north of San Marcos (Rio El Cuero). These study sites cover areas of 1,193 hectares and 4,074 hectares respectively. Areas of municipalities comprising Atlantida vary between 28,040 hectares and 117,819 hectares for San Francisco and Tela respectively (Map 1.1 and Figure 1.1).

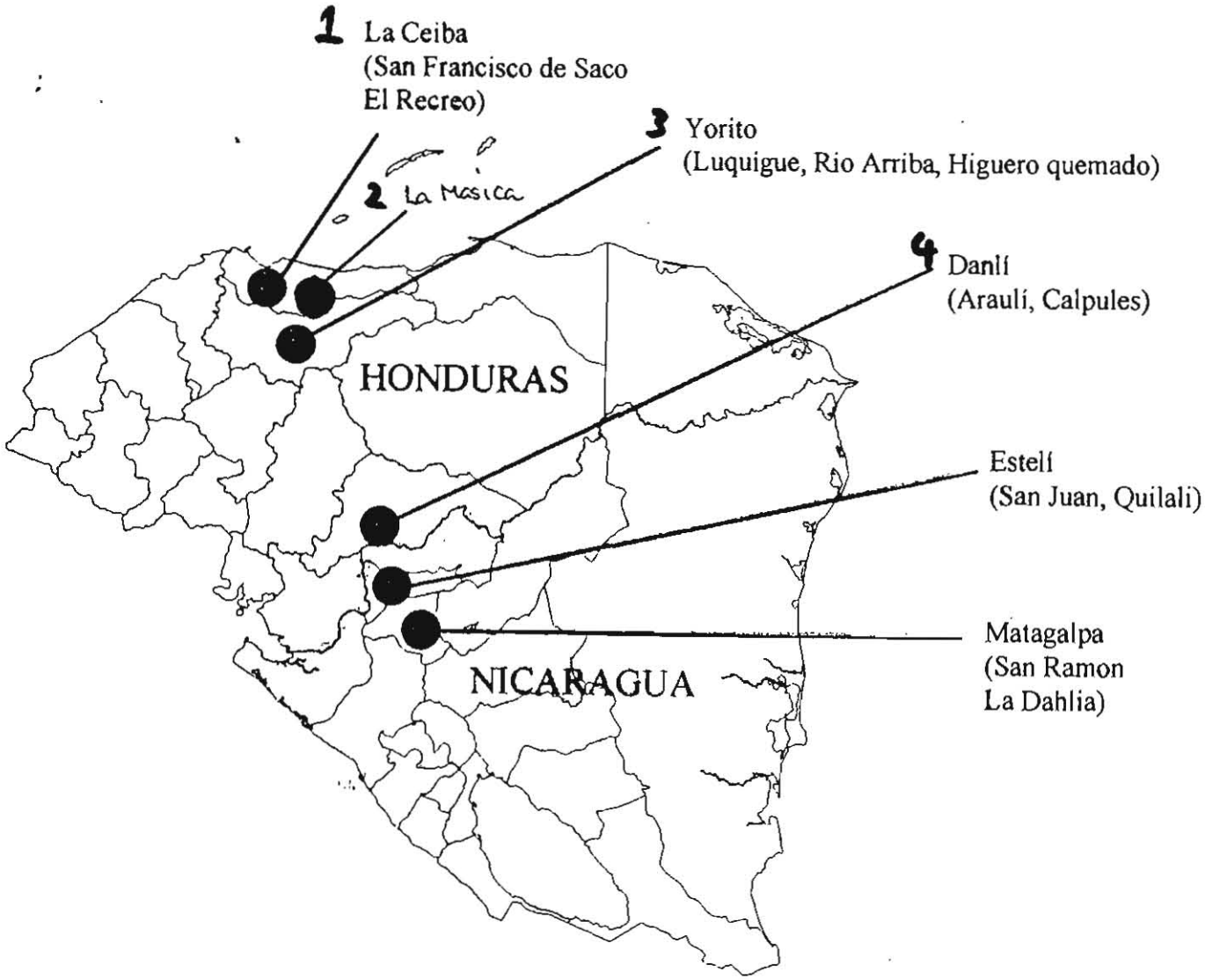
1.2 Climate

Average annual rainfall of Atlantida is one of the highest in Honduras – only equalled by Gracias a Dios (Map 1.2). Most of the region receives 2,000 mm or more a year. Both the study areas lie within the maximum rainfall zone of 2,500 mm or more. The dryer time of year in Atlantida occurs during the period February to May and the wet season generally occurs between June to January. The dryest month is April and the wettest month is November. Temperatures remain high thoughout the year with a minimum of 10 C in January and a maximum of 28 C in May/June. Monthly rainfall data are presented in Figure 1.2. E.Z. Andrade (1983) describes the following climatic zones for the department of Atlantida:

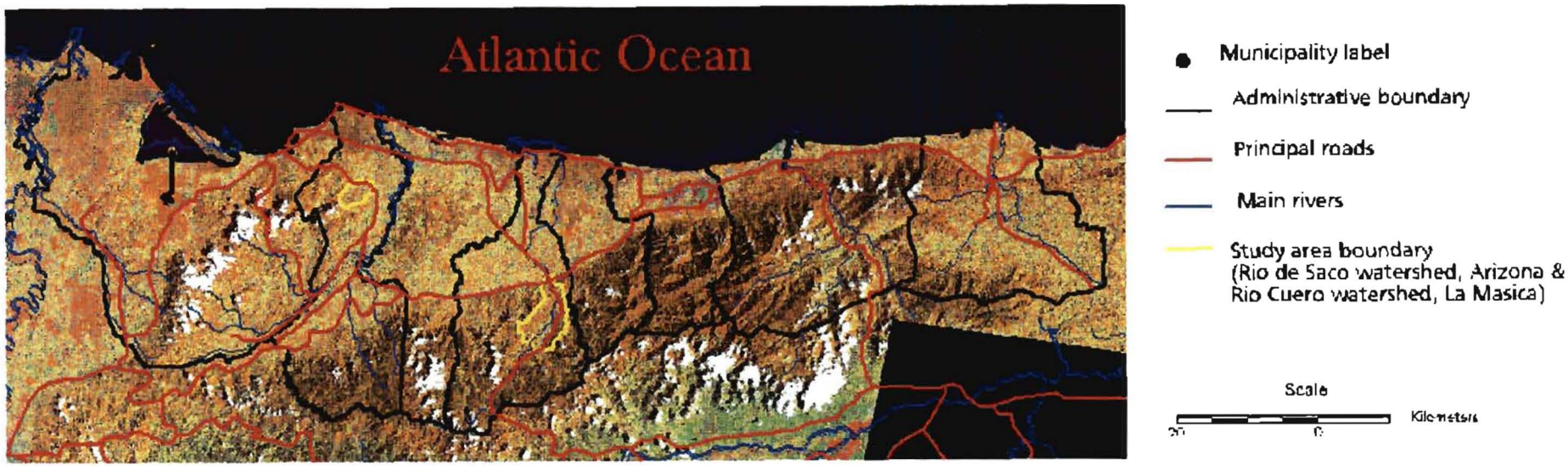
Lz "very rainy with regular distribution of rain"
Sz "very rainy with winter rain" (climate Af type of Koppen)
(these two zones are located in the coastal plain area)
Lk "very rainy and tropical"
Yk " very rainy of transition zone".
(the latter two zones are located in the mountain zone of Atlantida)

The first two climatic zones have a dry season in April /May and the latter two climatic zones have a dry period earlier in March and April.

Areas de Trabajo del Proyecto CIAT-laderas para Centro América



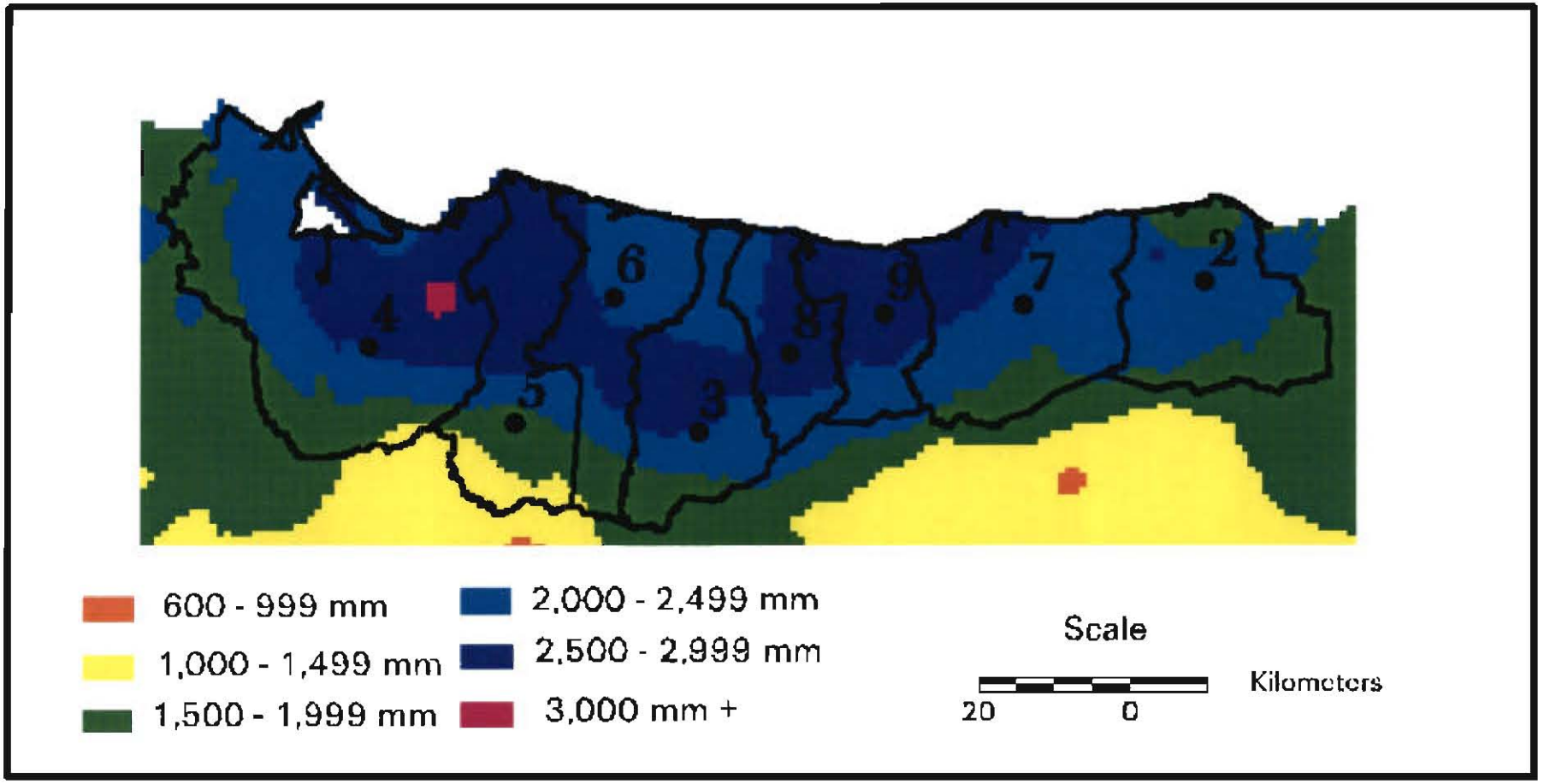
Landsat TM false colour mosaic of dates 5 March, 1994 and 23 February, 1993:

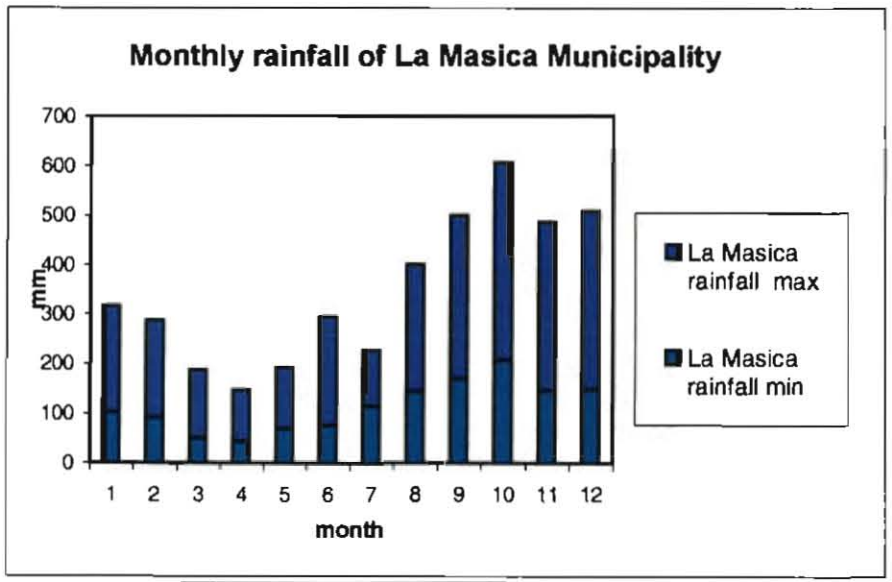


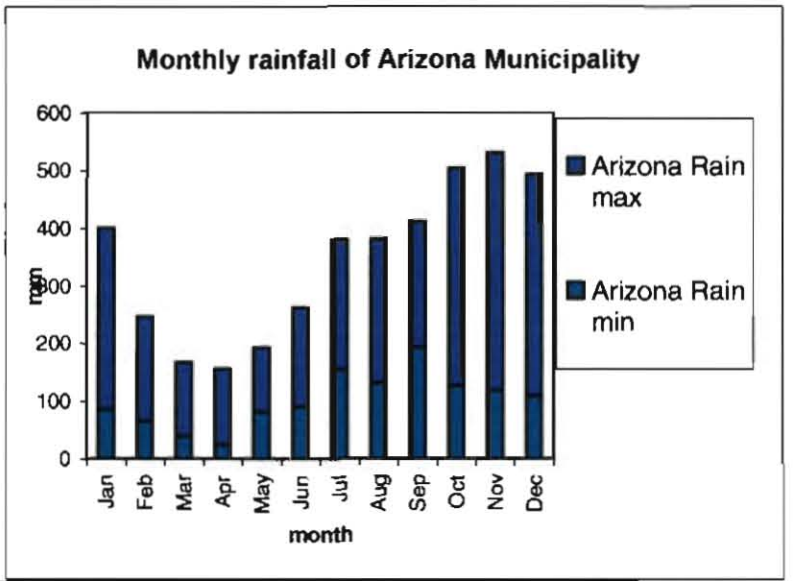
List of Municipalities of Atlantida Department:

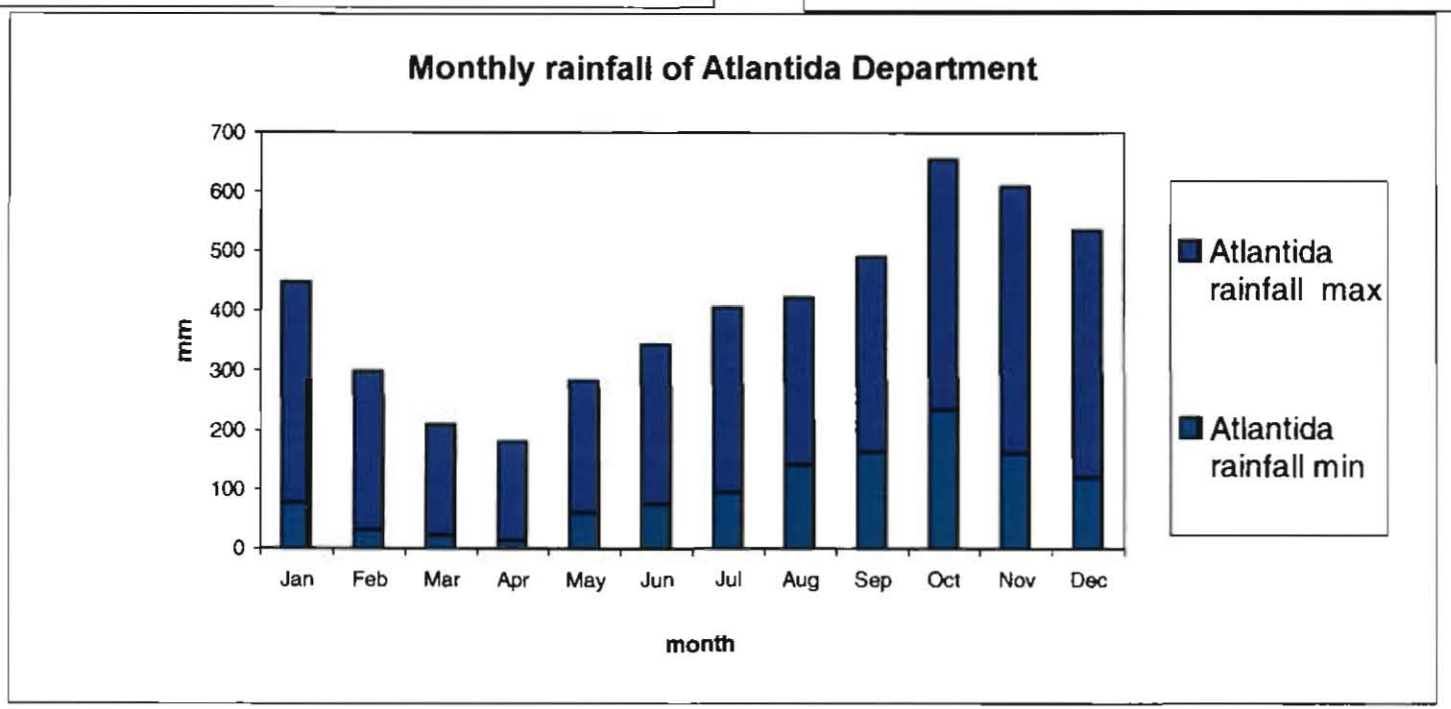
Code	*Municipality*	*Area (ha)*
4.	Tela	117,819 ha
5.	Arizona	51,276 ha
6.	Esparta	46,966 ha
3.	La Masica	46,621 ha
8.	San Francisco	28,040 ha
9.	El Porvenir	28,317 ha
7.	La Ceiba	64,116 ha
2.	Jutiapa	52,571 ha

Average Total Annual Rainfall




Monthly rainfall of La Masica Municipality
700
600
500
400
300
200
100
0
mm
1 2 3 4 5 6 7 8 9 10 11 12
month
La Masica rainfall max
La Masica rainfall min


Monthly rainfall of Arizona Municipality
600
500
400
300
200
100
0
mm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
month
Arizona Rain max
Arizona Rain min


Monthly rainfall of Atlantida Department
700
600
500
400
300
200
100
0
mm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
month
Atlantida rainfall max
Atlantida rainfall min

Map-poster 1 summarizes the rainfall pattern at departmental level (Jones, P.G. 1997) The wettest areas are situated in Tela, Arizona and La Ceiba. The orographic effect on rainfall is very noticeable here. The seasonally dry areas are in the coastal plain region with sparse tree cover. During fieldwork undertaken in May 1997, the rivers normally flowing from the Sierra were extremely low and some of the tributary channels were completely dry.

1.3 Geology

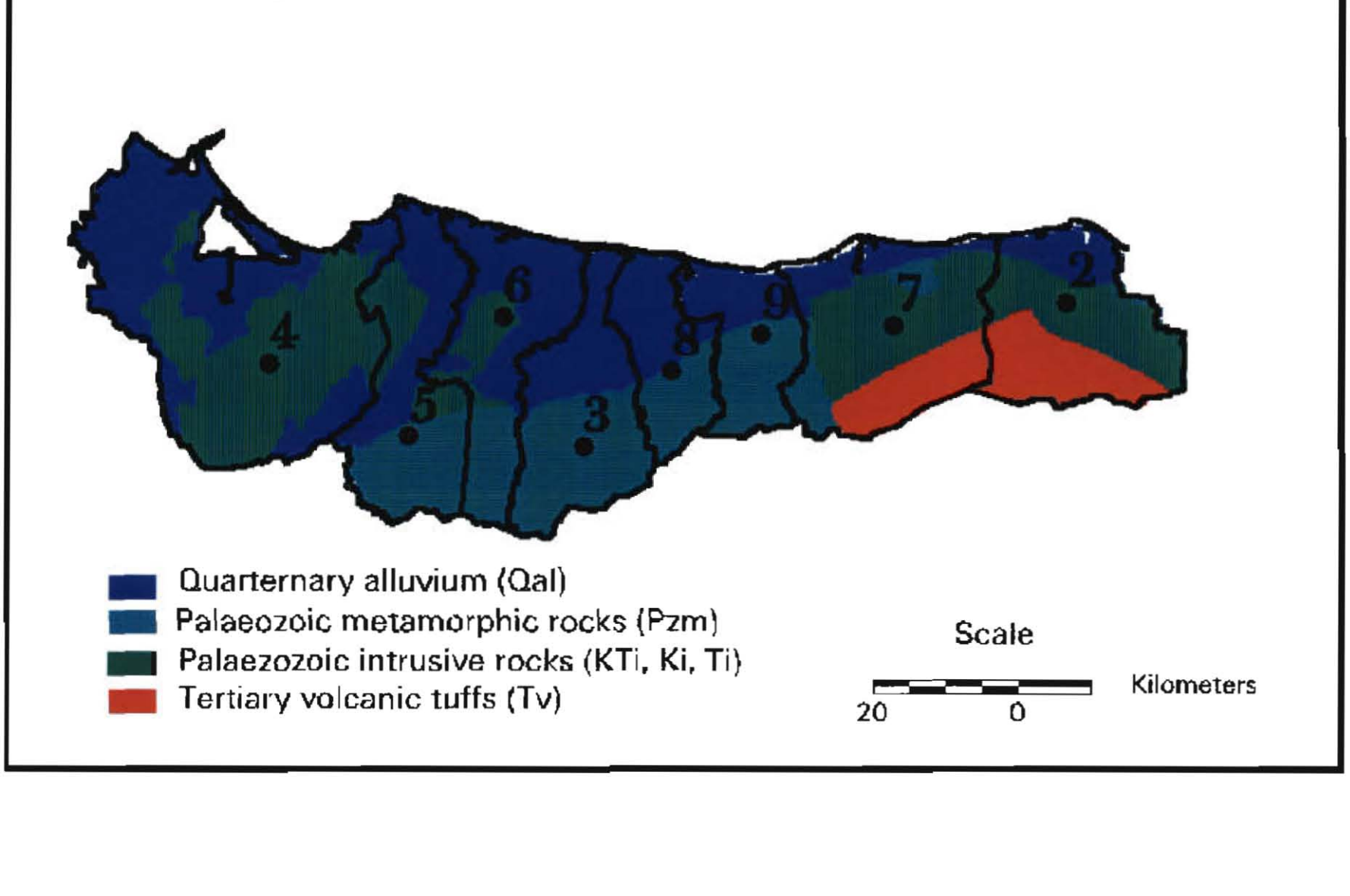
About half of the department consists of Quarternary alluvium deposits and these are generally located in the coastal plain zone. The mountain zone is composed of Palaezoic metamorphic and igneous rocks with a contrasting zone of Tertiary volcanic tuffs in the southern parts of La Ceiba and Jutiapa municipalities. The Tiburon mountain (which is a lower hilly area) consist of Palaeozoic intrusives. (Map 1.3).

1.4 Topography and Drainage

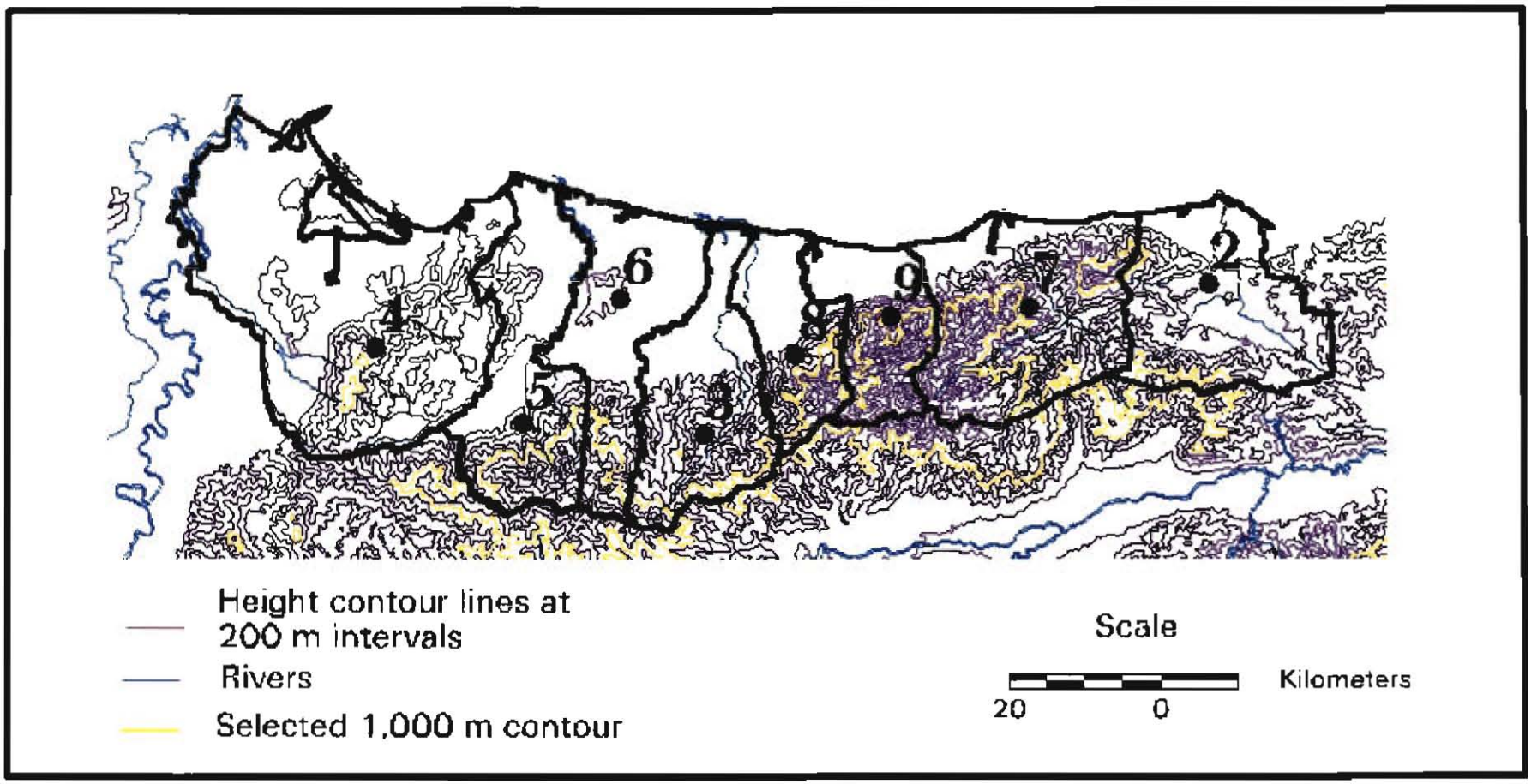
Atlantida consists of eight municipalities and seven of these contain parts of the 'Sierra Nombre de Dios' which rises to an altitude of 2,435 metres at Pico Bonito, and a coastal plain zone in the northern Caribbean coastal areas with an altitudinal range of 0 to 200 metres (Map 1.4). The densest contours occur in El Porvenir in the vicinity of Pico Bonito. The municipalities with the highest proportion of their area above 1,000 m include El Porvenir, La Ceiba, San Francisco and Arizona. 16% of the total department has an altitidue greater than 1,000 metres. Both study areas are located well below this altitude in the foothills, but nevertheless comprise the steep slopes characteristic of hillside agriculture in Honduras.

There are five river systems flowing into the Caribbean. They include Rio Sula and Rio de Saco in Tela and Arizona respectively. Rio Cuero in La Masica flows to the coast via the wetland wildlife reserve of Cuero y Salado, as does Rio San Juan. Rio Cangrejal, Rio Yaruca and its two adjoining tributaries Rio Viejo and Rio Blanco flow from the mountain region of Pico Bonito and reach the Atlantic coast at La Ceiba. Rio Papatoteca and its tributaries Rio Jutiapa and Rio Tomala drain from the footslopes of the Sierra Nombre De Dios in the municipality of Jutiapa. The two central adjoining municipalities of El Porvenir and San Francisco appear to be without a major river system – however, a commercial pineapple plantation is situated in the coastal plain of El Porvenir and must receive its water requirements through runoff supplemented by irrigation. A lagoon 'Laguna de Los Micos' is located in Tela within the Punta Sal national park (Map 1.4).

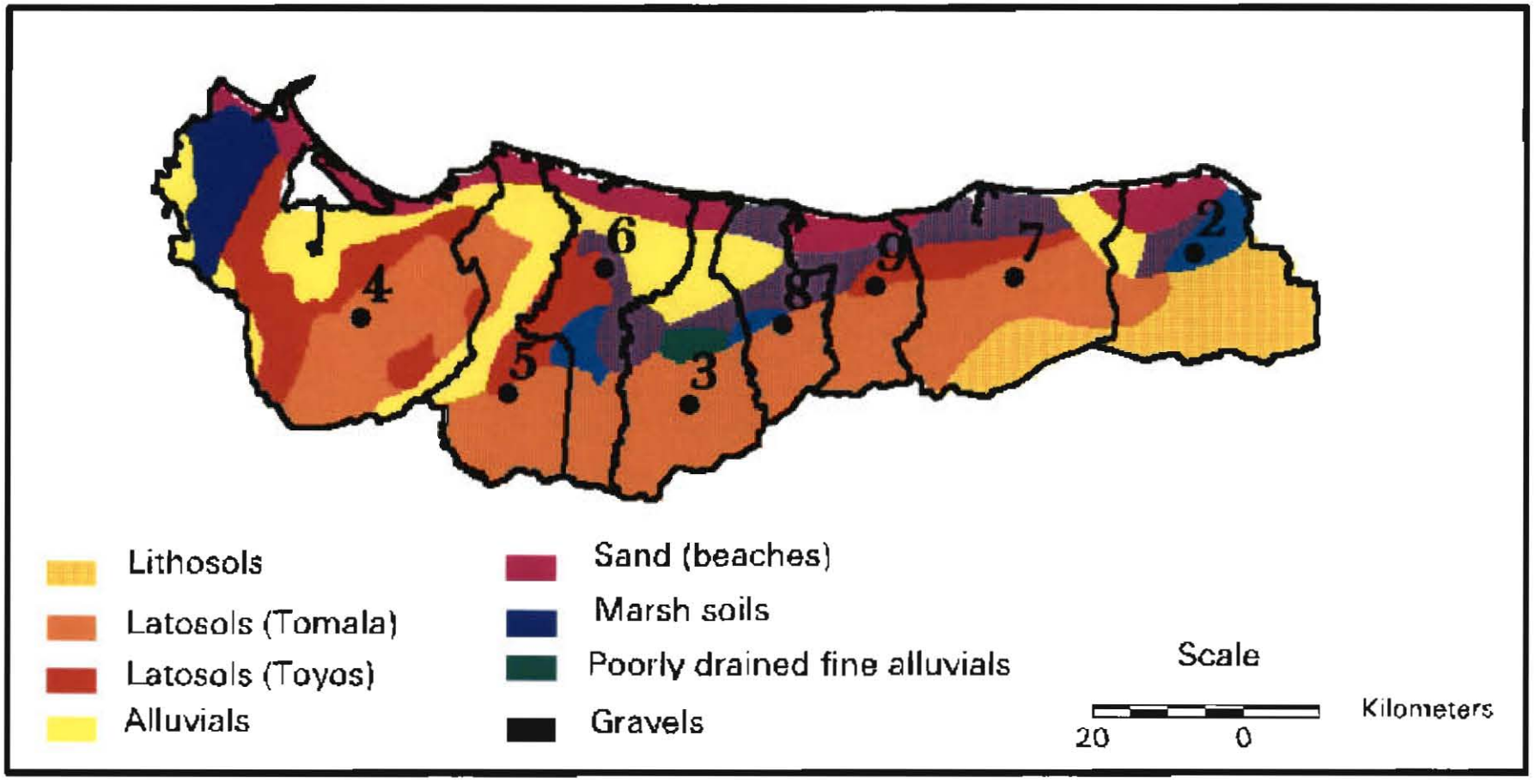
Geology


1
2
3
4
5
6
7
8
9
Quarternary alluvium (Qal)
Palaeozoic metamorphic rocks (Pzm)
Palaeozoic intrusive rocks (KTi, Ki, Ti)
Tertiary volcanic tuffs (Tv)
Scale
20
0
Kilometers

Topography and Drainage



Soils
(Based on Simmons' Classification)



1.5 Soils

Lithosols are associated with the Tertiary volcanics in the eastern extremity of the department. Latosols are predominant in the mountain zone. The richer alluvial soils support commercial tree plantations. There are also less suitable coastal zone soils consisting of gravels, marsh soils, poorly drained fine alluvials as well as sandy beaches (Map 1.5).

1.6.1 Natural Resources/Protected areas

The majority of broad-leaved forest lies within the mountain zone and in certain protected sections of coastal mangrove (Map 1.6.1). There are two national parks: Pico Bonito and Punta Sal and three wildlife refuges: Texiguat striding the municipalities of Arizona and Esparta, Punta Izopo centered in Arizona and Cuero y Salado centered in the coastal strip of La Masica and San Francisco. Lancetilla Botanical Garden is situated in Arizona . Although we have no map showing the limits of these gardens, air photographs are available for the area which show that it is mostly forested (Appendix 1).

Pico Bonito National Park and Texiguat Wildlife Refuge boundaries approximately coincide with the 1,000 metre contour. Pico Bonito spans across the highland area of San Francisco, El Porvenir and the western half of La Ceiba, the latter having been encorached upon, especially in the area drained by Rio Viejo and Rio Blanco. The Cuero y Salado Wildlife Refuge lies in the coastal strip between eastern Esparta, La Masica, San Francisco and the western part of El Porvenir.

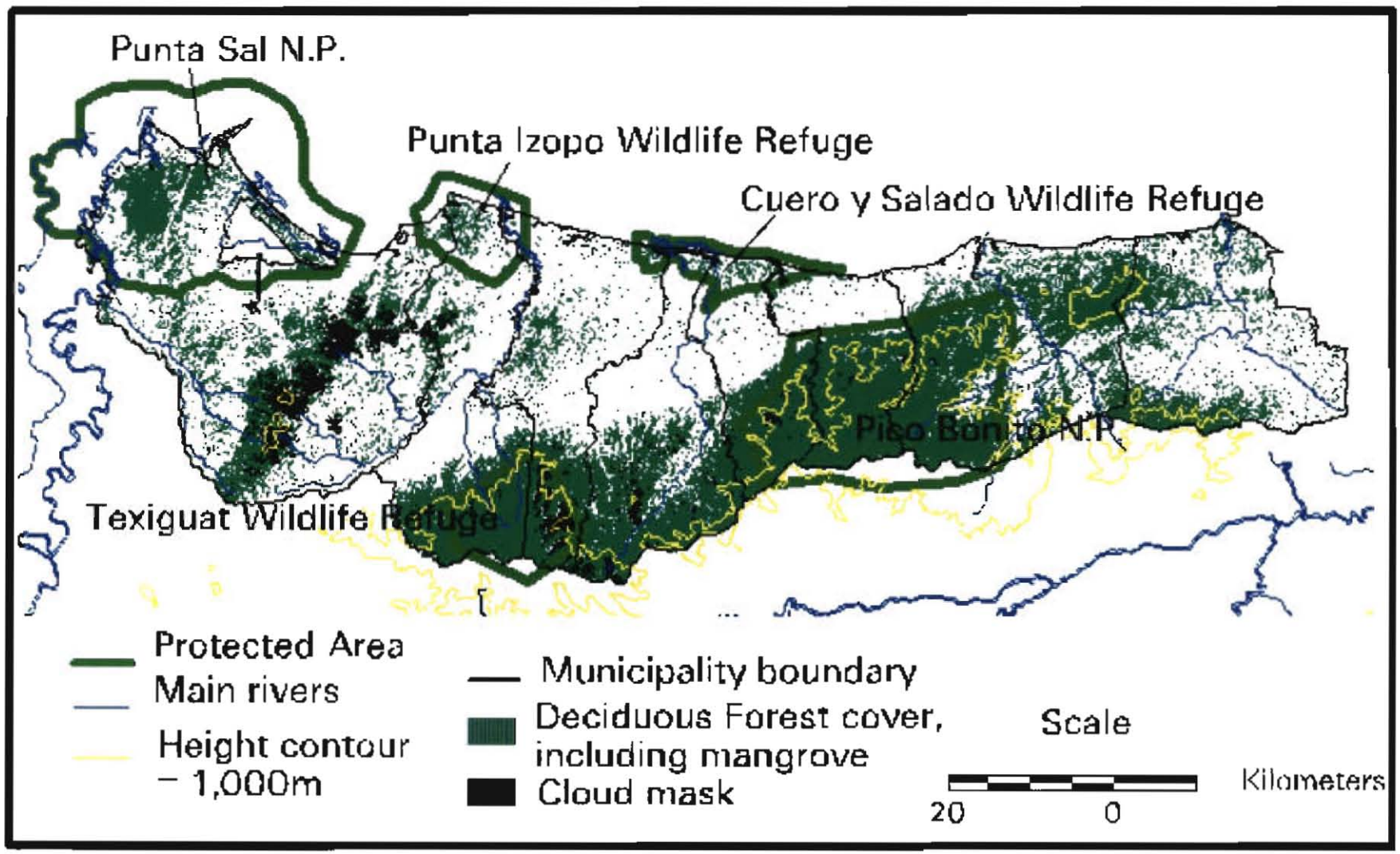
1.6.2 Forest Monitoring

It appears that there has been little encroachment on forest resources of protected reserve areas and there exists substantial forest outside these areas (Map 1.6.2). Perhaps the greatest population pressure exists in La Masica where some deforestation is evident in the southern portion of the watershed of the Rio Cuero during the 7-year period (1987 - 1994).

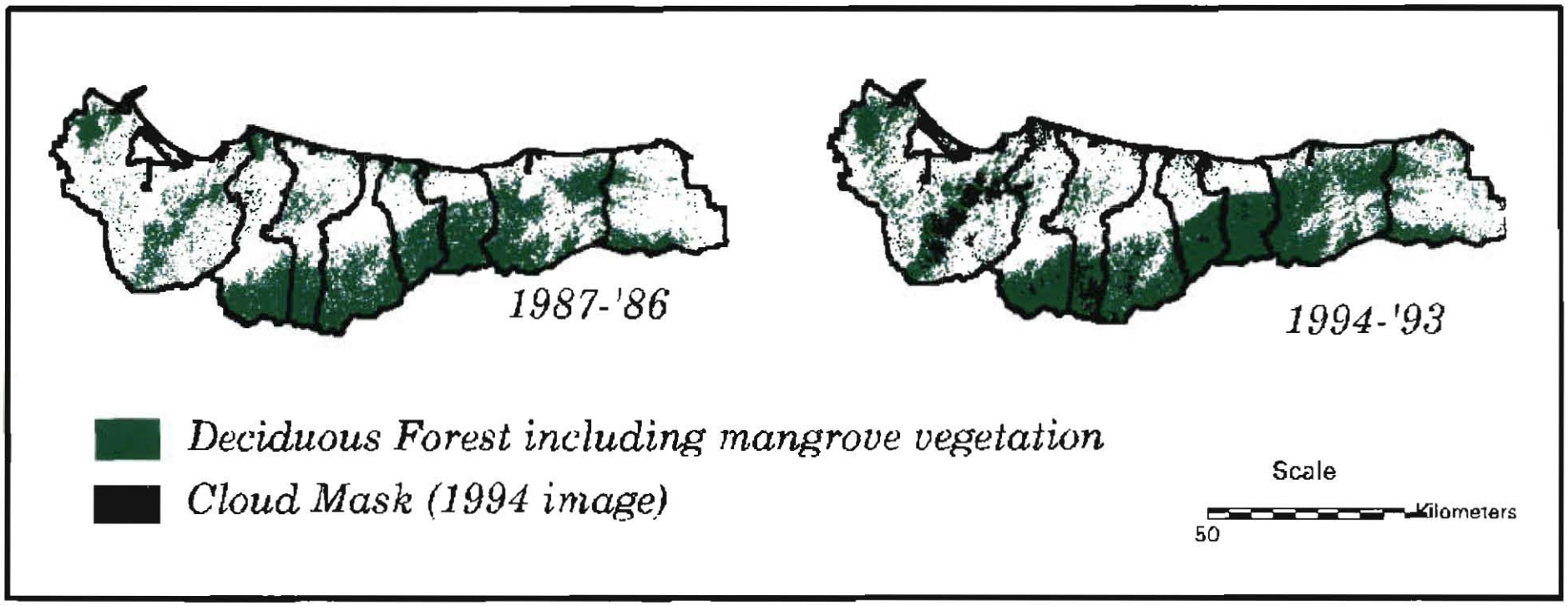
1.7 Settlement/Infrastructure

There are seven towns corresponding to the centres of each municipality: Tela, Arizona, Esparta, La Masica, San Francisco, El Porvenir, La Ceiba and Jutiapa. Aldea/villages (distribution based on the 1988 population census) are mostly located in the lowland coastal zone and river valleys in the mountainous zone (Map 1.7).
The roads displayed in map 1.7 are not entirely correct (this national road coverage was taken from the Digital Chart of the World (DCW), which is really only useful at very coarse scales. The most northerly mapped route is a rail-track. A coastal road passes from Tela via the river outlet from San Francisco de Saco study area and continues along the foot of the mountain zone, eastward to La Ceiba and Jutiapa and continues east to Trujillo. There is no principal road crossing north-south through the Sierra Nombre de Dios except within the municipalities of La Ceiba and Jutiapa. Tela is easily accessible with a major road and rail link with San Pedro Sula. A better series of road maps were later acquired from the Secretariat of Communications, public works and transport (1992). These are published for each department. (Secretaria de Communicaciones, Obras Publicas y Transporte, 1992)

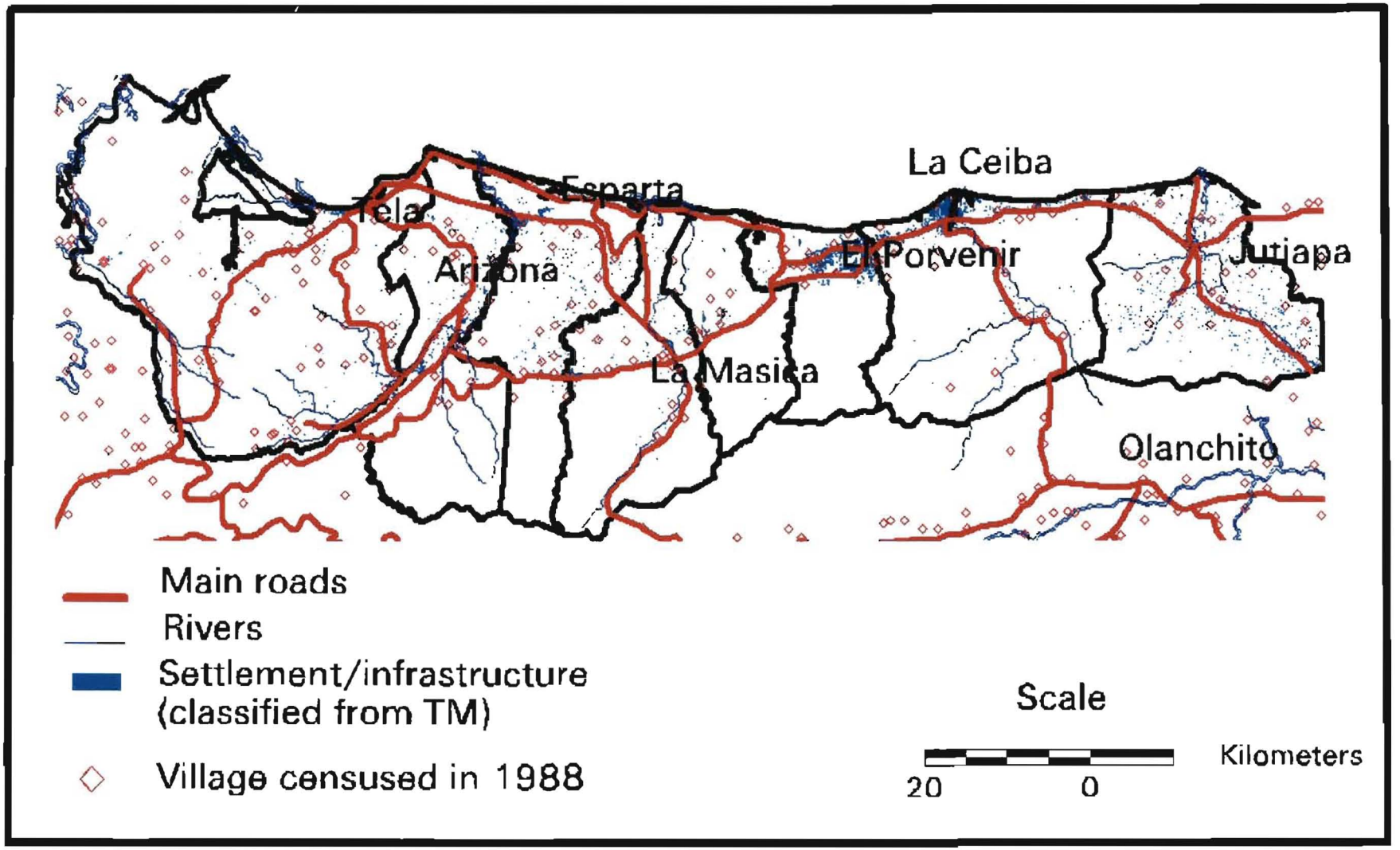
Natural Resources



Forest Stability over a 7 year period



Settlement/Infrastructure



1.8 Land Tenure

Of the 12,503 farms censused in Atlantida in 1993, (covering a total area of 162,494 hectares, giving an average farm size of 13 hectares), 11,408 holdings covering a total area of 139,049 hectares (average farm size 12 hectares) were under simple tenancy (private, national, rented, other) and 1,095 holdings, covering an area of 23,446 hectares (average farm size 21 hectares) were reported as having a mixed tenancy (private and national, private and rented, national and rented, private, national and rented, other). See Figure 1.8.

Table 1.8.1 Farm Size Statistics for Atlantida:

<1 ha	3,150 holdings	1,690 ha
1-2	1,994	2,718
2-3	1,293	3,101
3-5	1,252	4,990
5-10	1,477	10,530
10-20	1,268	17,867
20-50	1,447	44,584
50-100	408	27,278
100-200	153	19,973
200-500	52	13,366
500-1,000	2	1,264
1,000 – 2,500	5	8,169
2,500	2	6,963

139,049 hectares Simple Tenancy

Private 61,028 ha (2,933 farms)
National 71,900 ha (4,987 farms)
Rented 4,205 ha (2,587 farms)
Other 1,915 ha (901 farms)

23,446 hectares Mixed Tenancy

Private & National 13,109 ha (158 farms)
Private and rented 4,327 ha (157 farms)
National and rented 3,149 ha (500 farms)
Private, national, rented 62 ha (4 farms)
Other 2,799 ha (276 farms)

Figure 1.8

	Private	National	Rented	Other, incl. Mixed tenancy	Area censused
Tela	12266	27051	984	9068	49369
Arizona	3365	12742	444	3794	20345
Esparta	7307	9169	606	3203	20285
La Masica	6438	8075	408	2834	17755
San Francisco	6363	949	198	1166	8676
El Porvenir	5608	565	95	401	6669
La Ceiba	11032	2732	391	3355	17510
Jutiapa	8649	10615	1080	1542	21886
Atlantida Department	61028	71898	4206	25363	

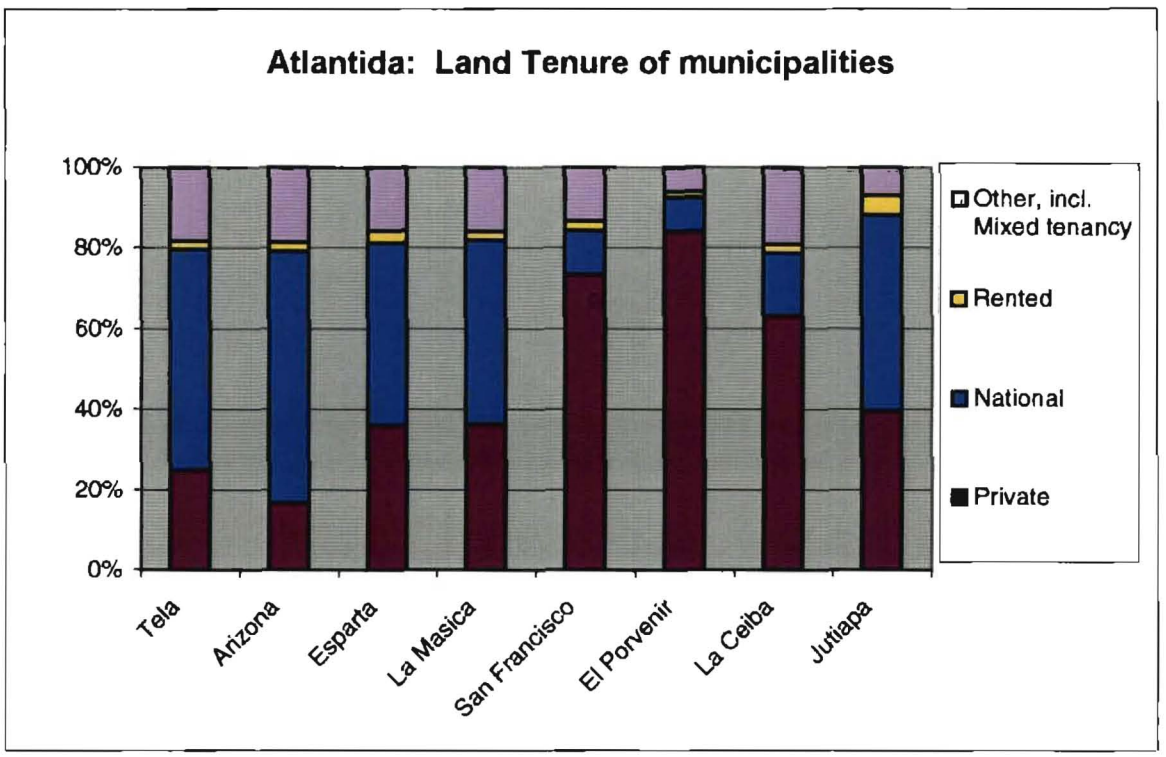


Table 1.8.2 Average Size of Land-Use holdings/municipality

Municipality	Annuals/1yr fallow	Perennials	Pasture Improved/Natural	Scrub fallow	"Forest"
La Ceiba	2 ha /farm	6 ha /farm	30 ha/11 ha	10 ha	25 ha
El Porvenir	2.8 ha	26 ha	20 ha/9 ha	5.6 ha	4.6 ha
Esparta	1.6 ha	1.8 ha	16 ha/8 ha	7.5 ha	8 ha
Jutiapa	2.4 ha	3 ha	14 ha/10 ha	7 ha	4 ha
La Masica	2.2 ha	2 ha	18 ha/7 ha	6.8 ha	7 ha
San Francisco	1.7 ha	8 ha	15 ha/6.7 ha	7 ha	6 ha
Tela	2 ha	7 ha	14 ha/9.6 ha	7 ha	10 ha
Arizona	1.2 ha	7.6 ha	19 ha/9.4 ha	7 ha	4 ha

Land holdings are largest in El Porvenir (for perennials) and La Ceiba (for improved pasture), although Arizona also has large improved pasture holdings.

Table 1.8.3: Size of farm holdings according to land use (1993 Agricultural Census)

Annual Cropping	1.2- 2.8 ha holdings
Perennials	1.8 – 26 ha
Improved Pasture	14 – 30 ha
Natural pasture	6.7 – 11 ha
Scrub fallow	5.6 – 10 ha
Forest	4- 25 ha

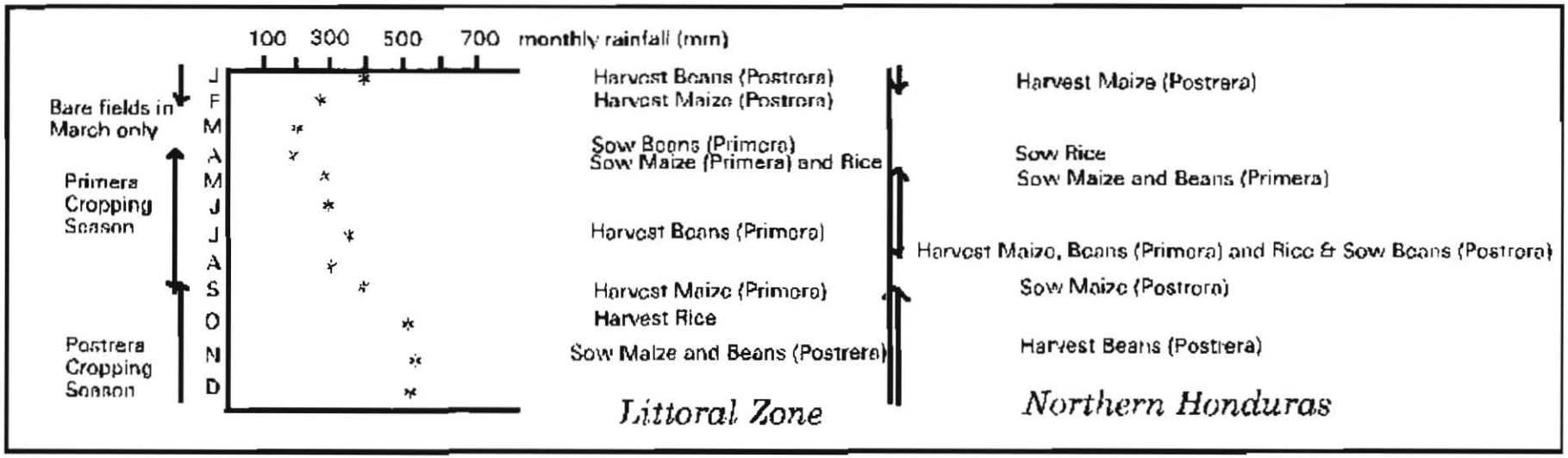
The municipalities with smallest annual cultivation holdings appear to be Arizona, Esparta and San Francisco (having average sized holdings of 1.2, 1.6, 1.7 ha respectively). El Porvenir, by contrast, has annual cultivation holdings averaging almost 3 hectares.

1.9 Cropping Calendar

There are two cropping seasons in Atlantida: the Primera (crops are sown in April and harvested in July) and the Postrera (crops are sown in November and harvested in January and February).

Further inland there is a more definite dry season and cultivation of annuals is less continuous – 'postrera' maize is sown earlier in August-September, whilst on the coast this is the time of the maize 'primera' harvest. Further inland, the 'postrera' cropping season is longer (six months) compared with three to four months in the coastal zone). Unlike the 'postrera' season, the 'primera' cropping season appears to be of simlar length between the two cropping zones. (Fig. 1.9).

Cropping Calendar for 'Coastal Atlantic' and 'Northern Honduras' zones



1.10 Agriculture/Land Cover (Landsat TM Classification)

A land cover/land use classification of the department consists of ten classes. They are classes which were intended to match up as much as possible with the agricultural census variables. They are described as follows:

Class 1: "Annual cultivation and fallows under a year old", are mainly found in the coastal plain according to the TM classification; only a few plots appear at higher altitudes (Map 1.10).

Class 2: "Perennial cultivation, excluding coffee and other shade-tree crops" has partly been confused with mangrove forest, but oil palm plantations in Tela and San Francisco and the large pineapple plantation in El Porvenir have been classified correctly, although the latter includes a lot of bare field areas which are classified accordingly as bare.

(There is no Class 3, as originally this class was designated for improved pasture, but as it was found impossible to distinguish spectrally between natural and improved pasture, this class was dropped).

Class 4: "Pasture, improved and natural". is largely concentrated in the coastal zone of the four municipalities of Arizona, Esparta, La Masica and Jutiapa.

Class 5: "Scrub fallow, generally up to 5 years of regrowth)" is concentrated in the foothills of El Tiburon mountain range, Tela and also on the edges of protected coastal reserves and along drainage lines in the mountain zone.

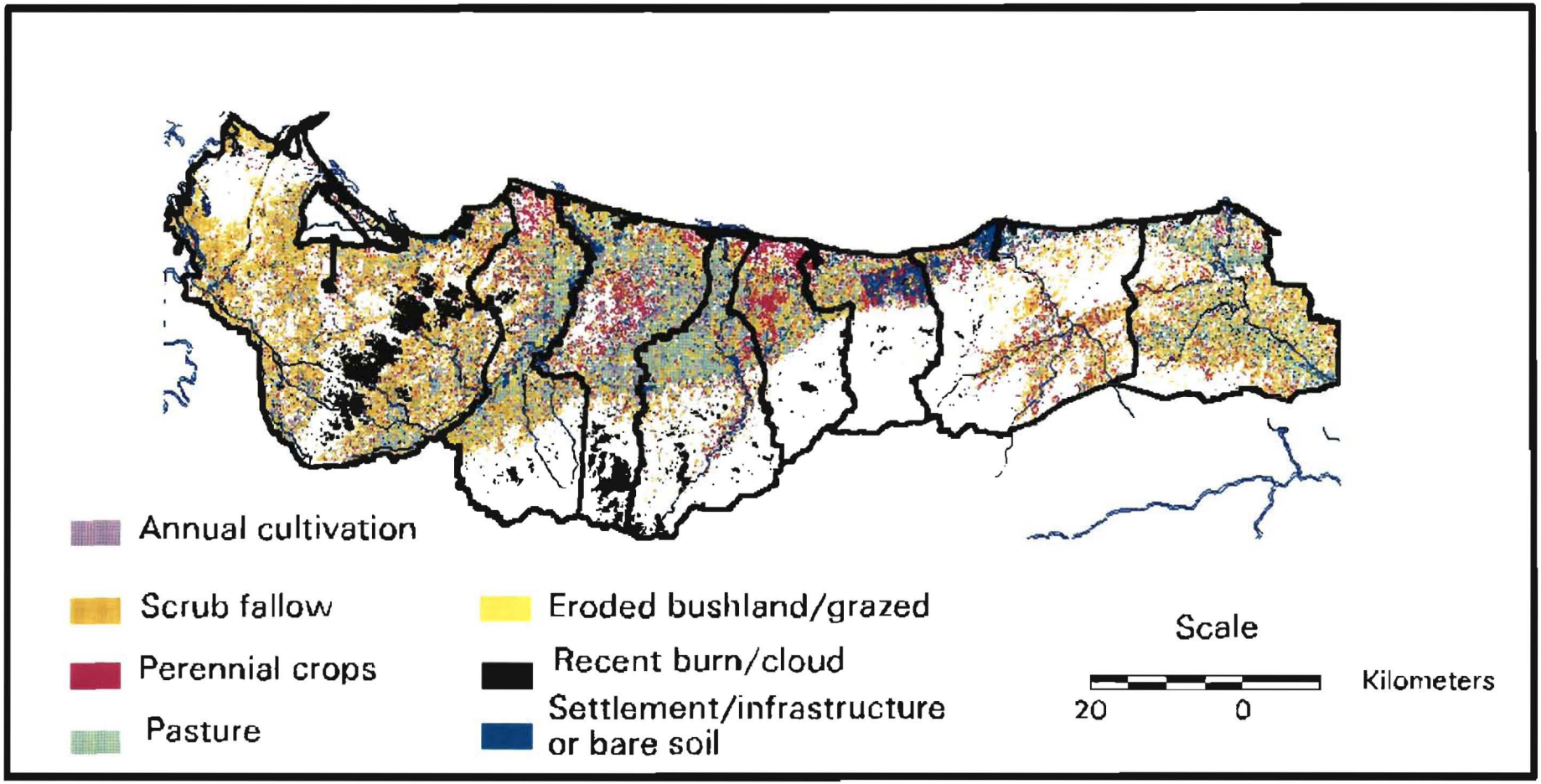
Class 10: "Eroded bushland" and Class 8: "sparse conifer rangeland" (both represent rough grazing) are largely absent from this more humid zone of Honduras.
Class S: "Settlement/infrastructure" : The largest settlement in Atlantida is La Ceiba (Map 1.10).

1.11.1 Land Cover/Land Use Classification of Atlantida Department

A further four forest classes were defined in order to map the non-agricultural land cover types as well.

Map 1.11 shows the land cover /land use classification of the department and includes a legend consisting of a total of 17 classes, including agricultural and non-agricultural land use. This seems to be excessive, but this is because Atlantida is a humid zone and can support a diverse range of land uses as well as a range of natural habitats including wetland and mangrove. As the classification of agricultural classes has already been described in Section 1.10, the land cover description here will continue with the forest classes:

Agriculture



Land-Cover/Land-Use Classification of Landsat TM Images

Land Cover/Land Use Legend:

- Municipality code (see table above)
- Annual Cultivation
- Perennial Cultivation, excluding shade-tree crops
- Pasture
- Scrub fallow
- Deciduous forest/woodland
- Coniferous forest/woodland
- Sparse pine rangeland
- Mixed forest/wood and
- Eroded area and
- Settlement/infrastructure
- Recent burn/shadow, unclassified
- Sea/lagoon
- Cloud cover, unclassified
- coastal reef/shallow waters
- Wetland
- Marshland
- Mangrove forest/scrub

Scale

Kilometers

Class 6: "Deciduous forest" largely coincides with the mountainous zone. The edges of this forest block have been encroached by smallholder farmers who are cultivating annual crops. The greatest rate of entry by smallholders has been in the vicinity of river valleys which have provided access routes. This is clearly seen from the Map 1.11. The existence of this dense humid tropical forest is essential for the formation of rain clouds as can be seen from the image. It is a well accepted fact in Atlantida, that with the cutting back of the forest cover, the rainfall amounts are being reduced more and more and hence water levels in the rivers flowing off the mountain range often reduce to zero flow during the dry season. Pico Bonito national park provides a contrast to the situation and the footslopes continue to be well protected.

Class 7: "Coniferous forest" should be entirely absent from this Atlantic coastal zone – if either class 7 or class 8, 'sparse pine rangeland' appear in this department, then one can assume that it has been misclassified for shaded deciduous forest.

Class 9: "Mixed forest" is not a cover class that should be present in this ecological zone, like the coniferous forest classes. Misclassifications are caused by shading effect of the deciduous forest areas.

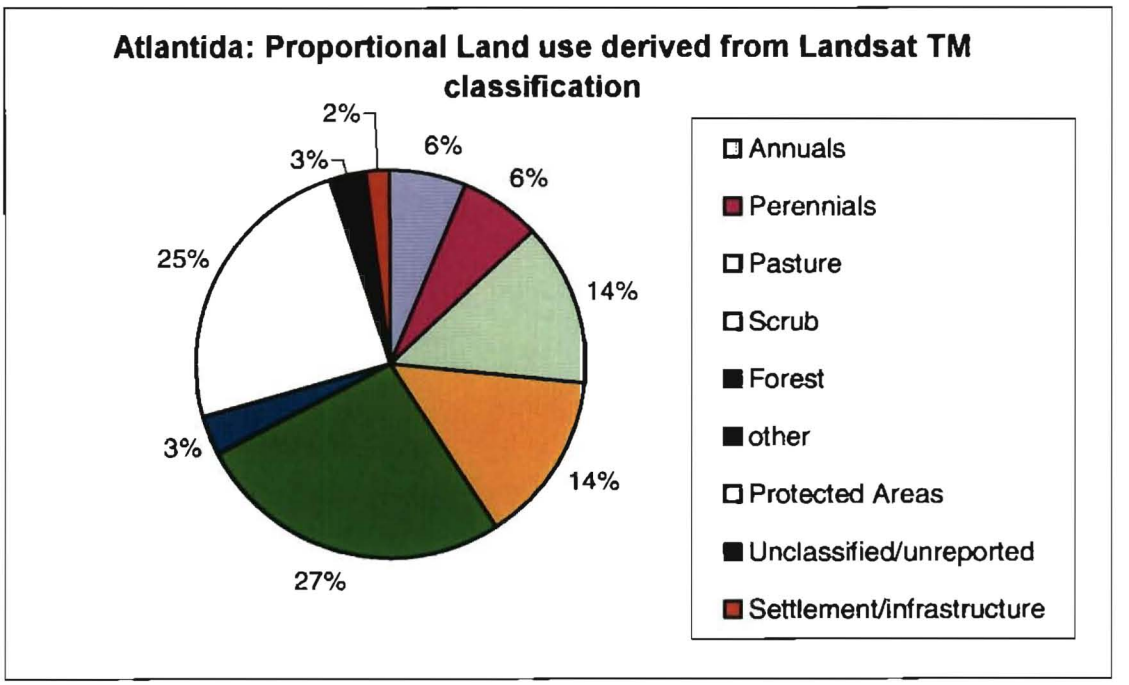
Class 19: "Mangrove forest" exists in certain parts of the coastline, particularly in the municipalities of Tela, Arizona, Esparta and San Francisco.

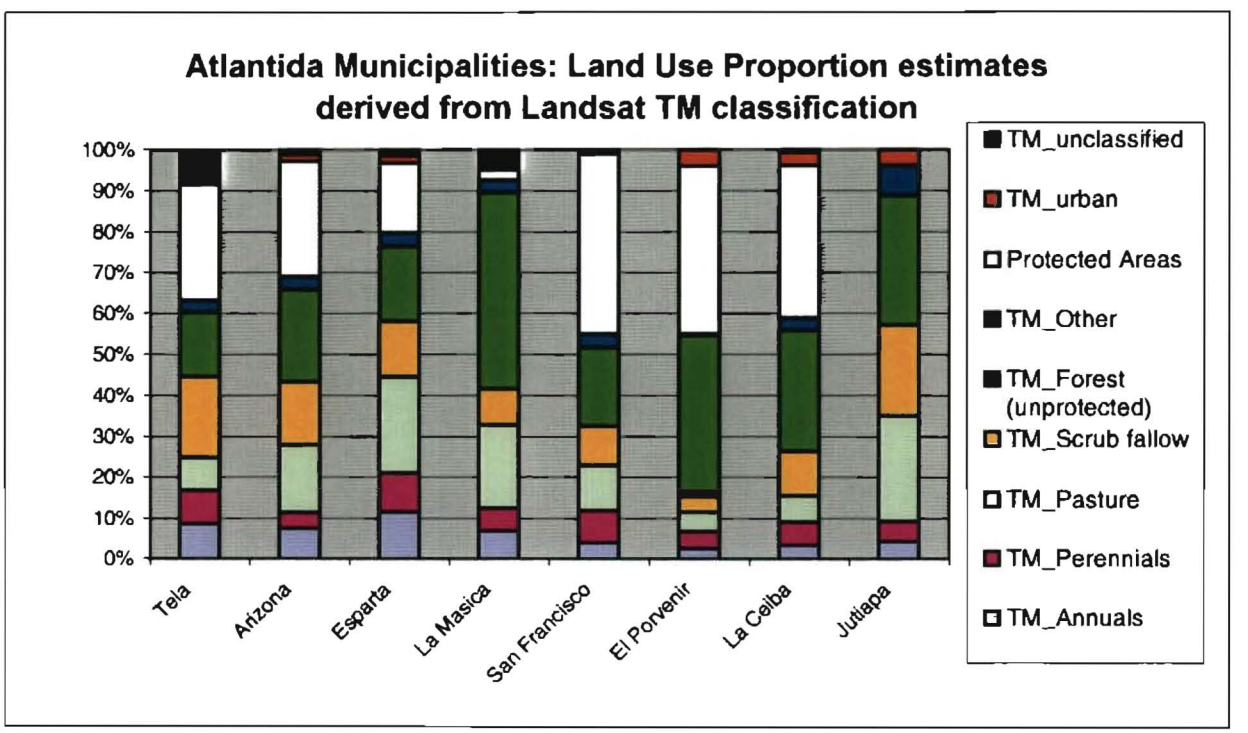
In addition the classification includes the classes for recent burn/intense shadow which represents unclassified areas, as does cloud cover. Water (including sea, lagoon and parts of rivers) is classified as is shallow coastal water and reefs around islands and wetland habitat which is primarily located in Punta Sal national park.

From purely visual inspection, it is possible to estimate that under a half of the total departmental area is composed of semi-natural vegetation cover, the majority of the land area being devoted to agricultural land uses.

1.11.2 Land Cover Proportion Estimates for Atlantida

If one wants to gain an idea of the relative importance of the major land cover/land use types, it is useful to examine pie-charts and other graphical representations using the data derived from both the spectral classification of Landsat TM imagery and from the Agricultural Census figures. Figure 1.11.2 shows two representations: a pie chart summarizing the land use of the department as a whole and a bar chart showing proportional land use estimates for the individual municipalities. Atlantida contains substantial deciduous forest - over 50% including protected areas (25%). The remaining land use is more or less split evenly, with annuals and perennials each covering some 6% of the department and pasture and scrub each covering 14% of the department. The bar chart shows that El Porvenir, San Francisco, La Ceiba and La Masica are the most forest covered municipalities and that Jutiapa and Esparta possess higher proportions of agricultural land.


Atlantida: Proportional Land use derived from Landsat TM classification
2%
6%
3%
6%
25%
14%
3%
14%
27%
Annuals
Perennials
Pasture
Scrub
Forest
other
Protected Areas
Unclassified/unreported
Settlement/infrastructure


Atlantida Municipalities: Land Use Proportion estimates derived from Landsat TM classification
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Tela
Arizona
Esparta
La Masica
San Francisco
El Porvenir
La Ceiba
Jutiapa
TM_unclassified
TM_urban
Protected Areas
TM_Other
TM_Forest (unprotected)
TM_Scrub fallow
TM_Pasture
TM_Perennials
TM_Annuals

2. Land Characterization of Yoro Department

2.1 Location

Yoro Department is located in north-central Honduras between lines of longitude 88 00 W and 86 10 W and between lines of latitude 15 50 N and 14 50 N.

Yoro consists of 11 municipalities (Map 2.1 and Fig 2.1) covering a total area of 777,671 hectares, nearly twice as large as that of Atlantida (435,726 hectares). The Hillside Programme's study area is a sub-catchment of the Rio Tascalapa, which strides the smaller municipalities of Yorito and Sulaco.

2.2 Climate

The average annual rainfall appears quite homogeneous over the department (1,000 – 1,500 mm for about 80% of the total area) with a higher than average rainfall occurring along the northern boundary with Atlantida and along the southwestern edge of Victoria municipality, with an annual rainfall rising to 2,000 mm.

There are a couple of dryer spots, one in the northern part of Yoro municipality and another in Olanchito, in the rainshadow of Sierra " Nombre de Dios" (Map 2.2).

The average monthly rainfall graphs (Figure 2.2) shows the typical seasonal variation with a wet season starting in May followed by a slight reduction in rainfall in August and becomes progressively dryer in December and January; a dry season generally occurs between February and April (average monthly rainfall of 80 mm is typical) . The average monthly rainfall figure for the wet season (of about 9 months duration) is 260 mm.

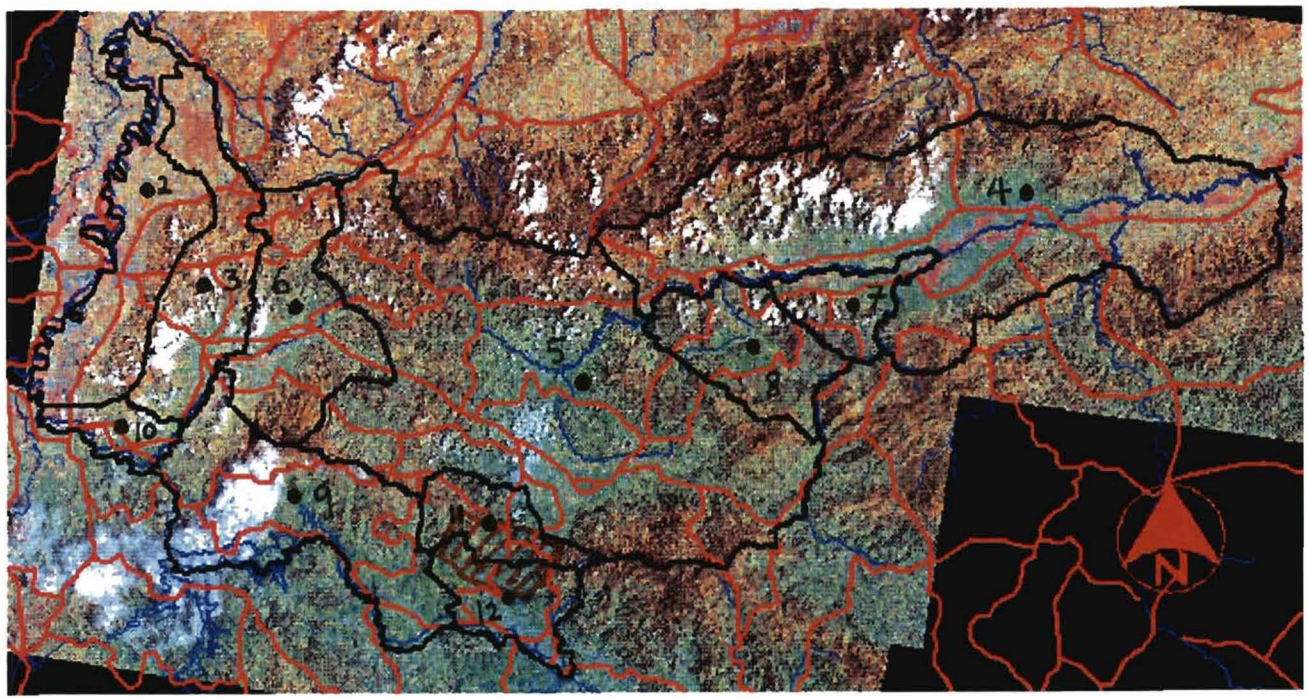
Temperatures remain fairly constant throughout the year ranging from 13 C to 30 C, the hottest period ocurrng between March and September.

In the dry season there is a more marked north-south gradient/increasing dryness through the department. In the wet season the highest rainfall is in the west and central eastern parts with a pronounced peak ocurring around Cerro La Pena on the boundary between Yoro and Jocon. (Map poster 1)

The 'Climas de Honduras' map (Andrade, E., 1983) is based on records from 1966 to 1985. It shows a great variety of climatic zones for this region including:

Lz: "Very rainy with regular rainfall distribution (wet months: OctoberNovember and dry months April-May);
Lk: " Tropical rainy" (wet months October/November and dry months March-April);

Landsat TM false colour mosaic of images dated 5 March, 1994, 13 April, 1995 and 23 February, 1993:



- Municipality label
- Paved roads
- Main rivers
- S.A.

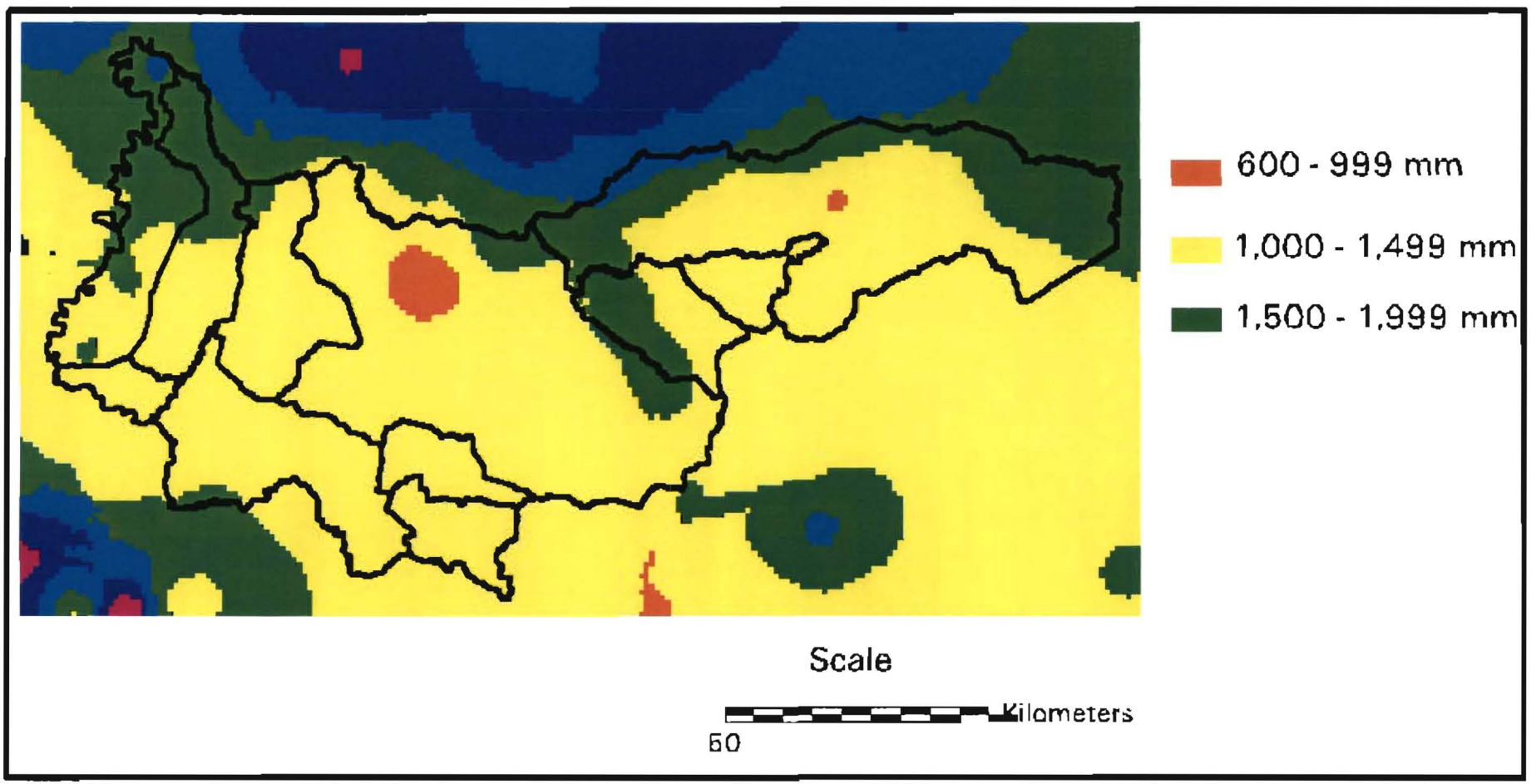
Scale

20 0 20 Kilometers

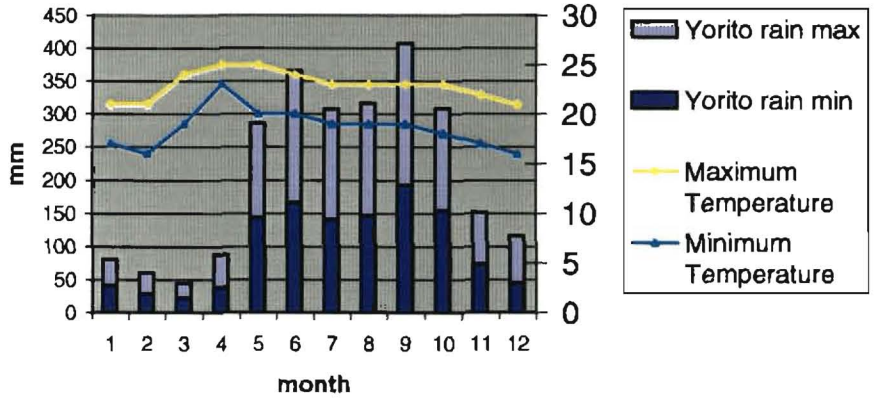
List of Municipalities:

Code	Municipality	Area (ha)
2	El Progreso	55,866
3	El Negrito	50,778
4	Olanchito	202,767
5	Yoro	229,291
6	Morazan	52,163
7	Arenal	18,096
8	Jocon	36,086
9	Victoria	54,083
10	Santa Rita	12,271
11	Yorito	20,455
12	Sulaco	23,687
Total	Yoro Department	777,671 ha

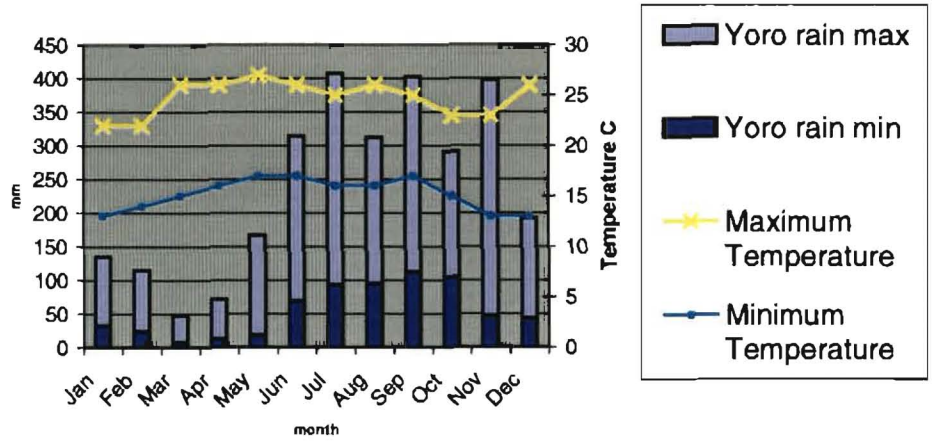
Average Total Annual Rainfall



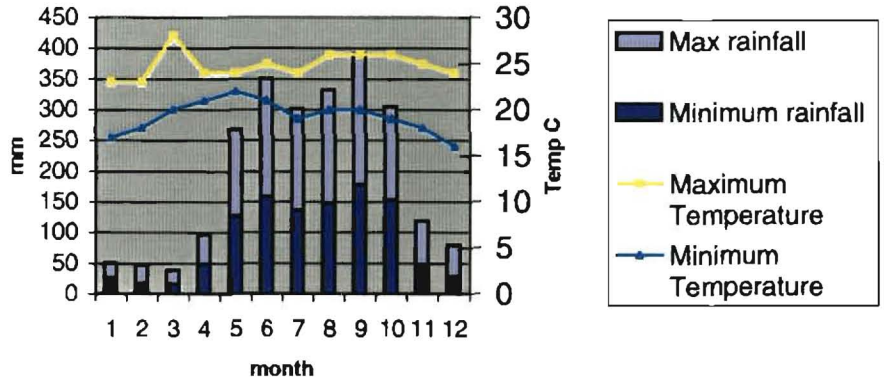
Monthly rainfall of Yorito Municipality



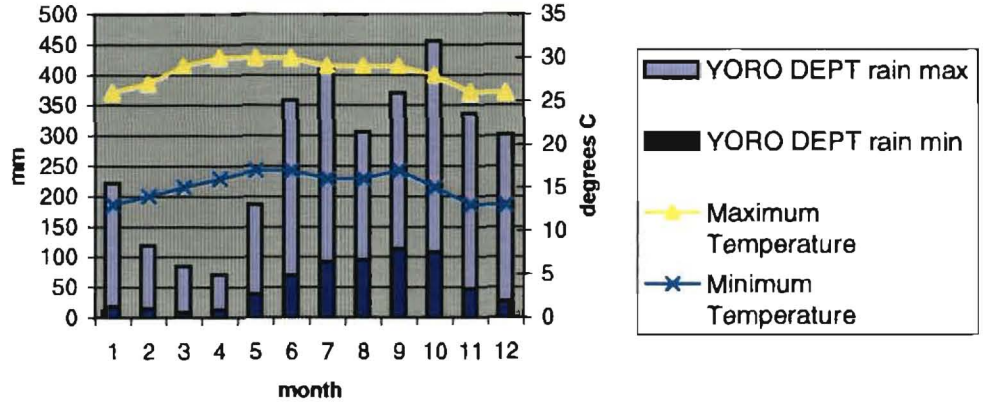
Mean Monthly rainfall of Yoro Municipality



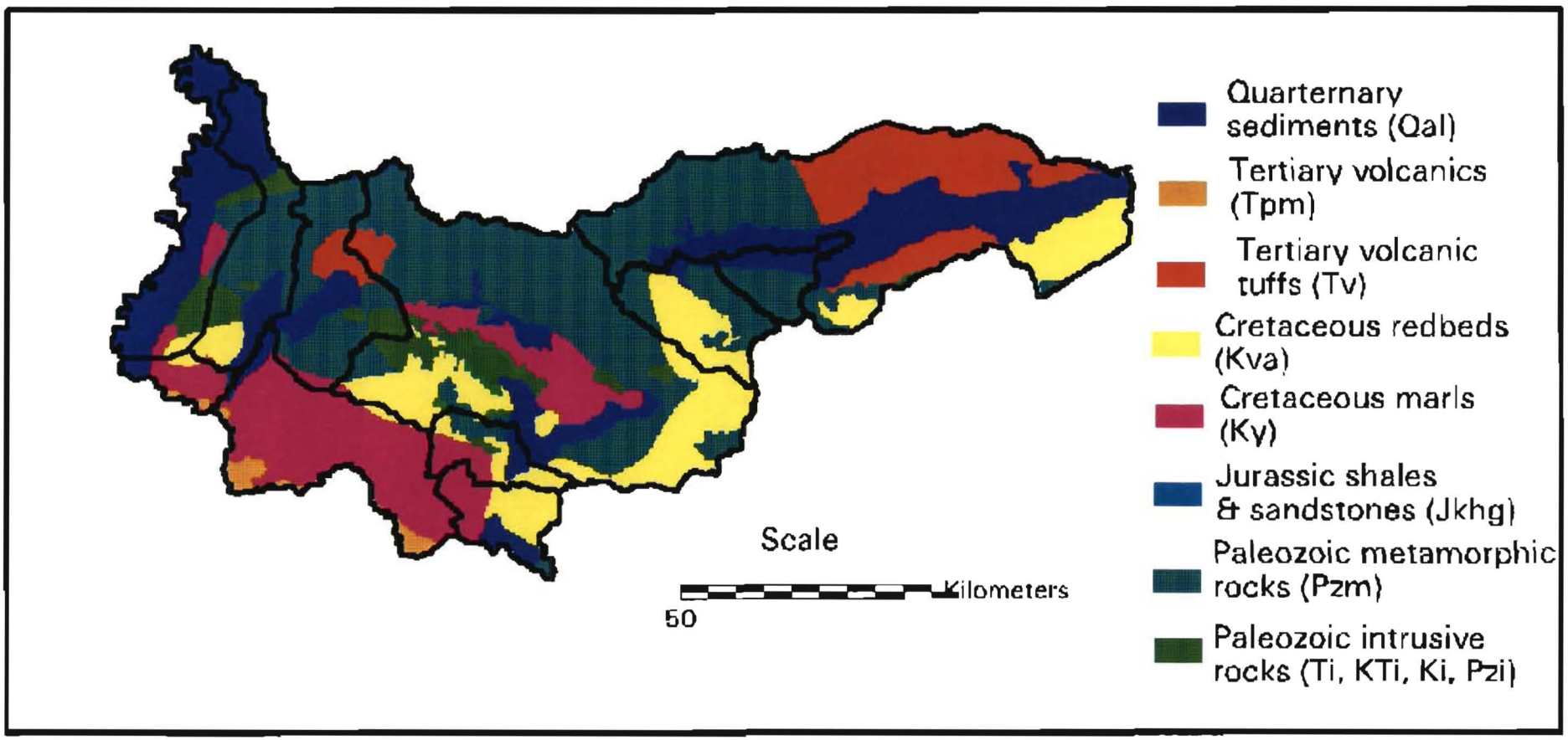
Mean Monthly rainfall of Sulaco Municipality



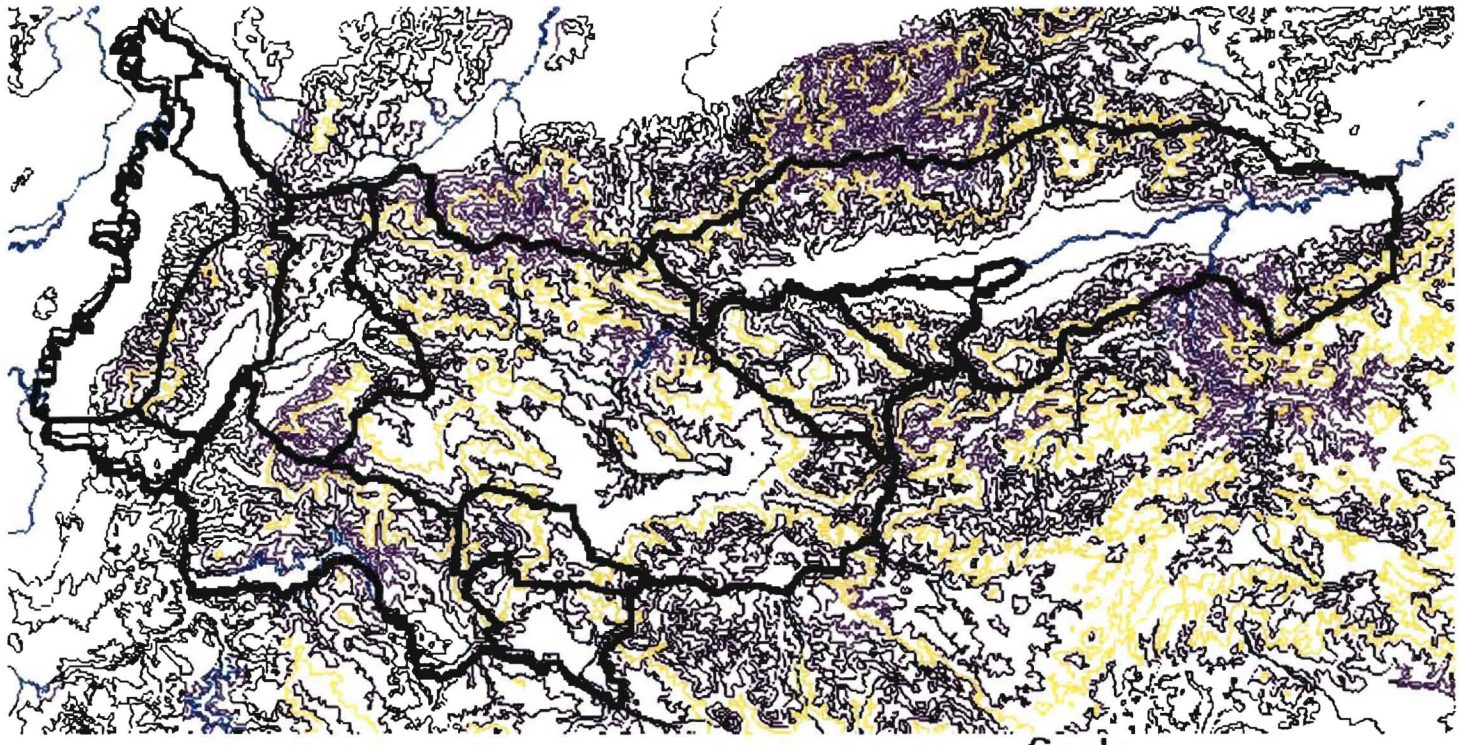
Mean Monthly rainfall of Yoro Department



Geology


Quarternary sediments (Qal)
Tertiary volcanics (Tpm)
Tertiary volcanic tuffs (Tv)
Cretaceous redbeds (Kva)
Cretaceous marls (Ky)
Jurassic shales & sandstones (Jkhg)
Paleozoic metamorphic rocks (Pzm)
Paleozoic intrusive rocks (Ti, KTi, Ki, Pzi)
Scale
Kilometers
50

Topography and Drainage



Height contours at 200m intervals

Selected 1,000m contour

rivers

Scale

50 Kilometers

Fk:"variant of Lk – (wet months June & November and dry months March-April);
Vk:"very rainy 'de Barlovento – semi estacional' (wet months June & September and dry months March-April);
Vx:"rainfall related to altitude (wet months June & September and dry months February-March);
Cx: variant of Vx (wet months June and August and dry months February-March).

2.3 Geology

Major valley zones are associated with Quarternary sediments ("Qal" class in Map 2.3). Tertiary volcanics and tuffs occur along the southwestern border in Victoria and Morazan and in the eastern mountains of Olanchito. Cretaceous redbeds and marls occur mainly in the south of the department, covering a good portion of the upland zone in the study-area municipalities of Yorito and Sulaco.

Palaeozoic metamorphic rocks constitute much of the central-northern zone. These rocks include some intrusions of similar aged volcanics distributed through El Progreso, El Negrito, Morazan and Yoro municipalities.

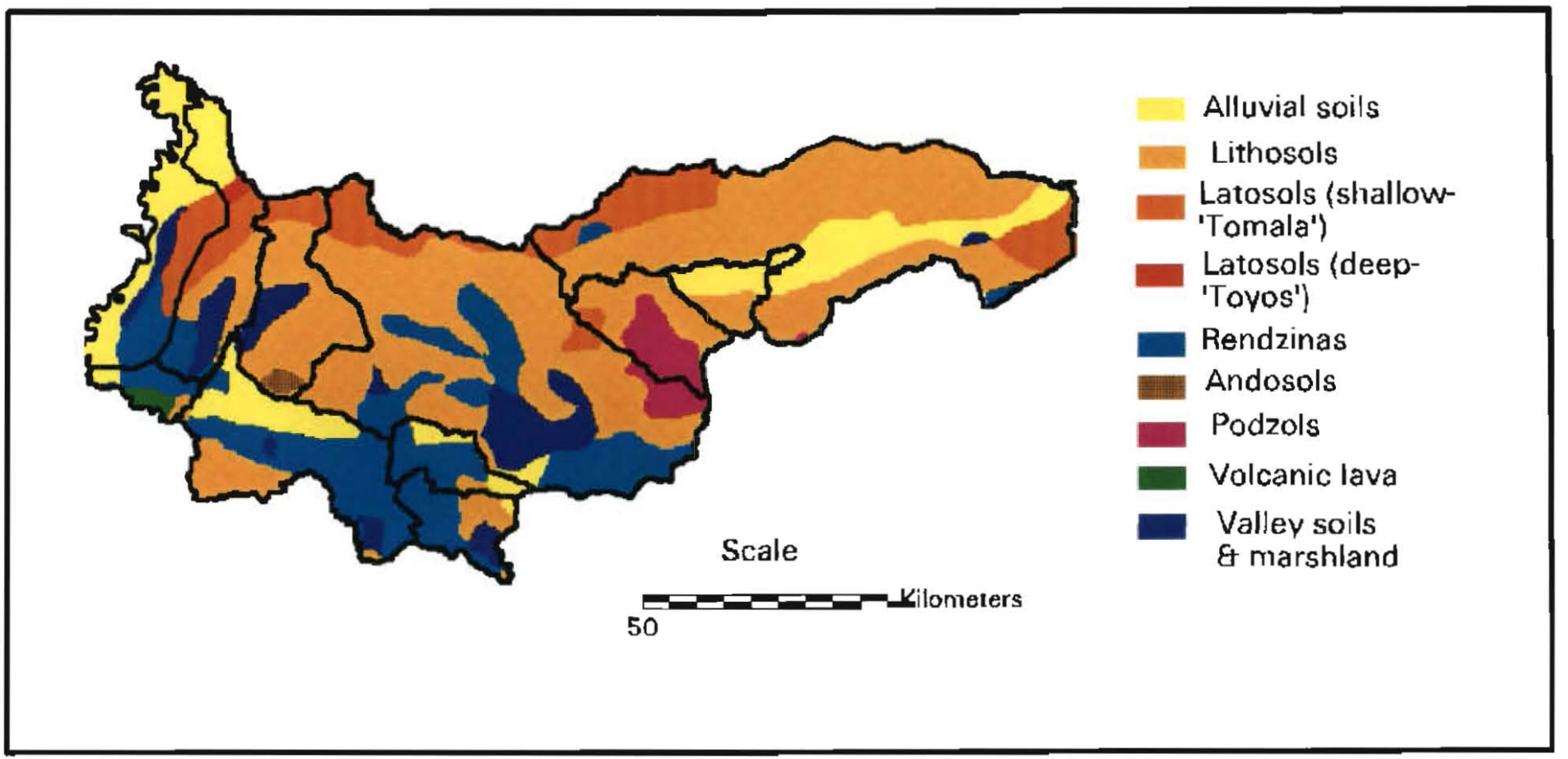
2.4 Topography and Drainage

Seven of the municipalites encompass large areas of land below an altitude of 400 metres including El Progreso, El Negrito (Rio Ulua and Valle de Sula), Santa Rita (Rio Comayagua), Olanchito and Arenal (Rio Aguan, Valle de Aguan), Yoro (Valle de Yoro), Morazan (Rio Cuyamapa) and Sulaco (Valle de Sulaco).

Jocon, Victoria, Yorito are largely mountainous. The dam of Francisco Morazan ('El Cajon') forms part of the department boundary along the southern limit of Victoria. Rio Sulaco is one of the rivers which flows into the reservoir.

Yoro contains several mountain ranges (Mapa oficial, Republica de Honduras, 1994 and Map 2.4). Land over 1,000 metres is concentrated in the municipalities of Yoro and Yorito and covers 21% of the department area. The highest peaks include Montana El Pijol (2,282 metres), Montana de Yoro (2,282 metres), Montana de Santa Barbara and the southern slopes of Pico Bonito (2,480 metres).

Soils
(based on Simmons' Classification)



2.5 Soils

Areas have geologies of metamorphic rocks and Tertiary volcanics largely coincide with an extensive zone of lithosols and shallow latosols. The major valleys consist of alluvial and marsh valley soils. Cretaceous marls are associated with rendzina soils. There is an area of podzols in Jocon associated with Cretaceous redbeds. A pocket of richer andosol soils is located in the southern part of Morazan municipality near Pico de Pijol National Park, above 1,000 metres altitude. Horticulture is the typical land use of these more temperate zones which characteristically have dark humus-rich soils (Map 2.5).

2.6.1 Natural Resources/Protected Areas

Map 2.6.1 shows the areas of deciduous forest (associated with zones above 1,000 metres) and the distribution of protected areas which include:

the southern edge of Pico Bonito NP Olanchito, 5,925 hectares;
the southern edge of Texiguat Wildlife Refuge, Yoro, 1,341 hectares;
Pico Pijol National Park, Morazan (8,337 ha), Yoro (1,444 ha) and Victoria, (1,919 hectares);
Montana de Yoro National Park, Yoro, 6,168 hectares and
Cuenca El Cajon Reservoir, Victoria, 16,790 hectares.

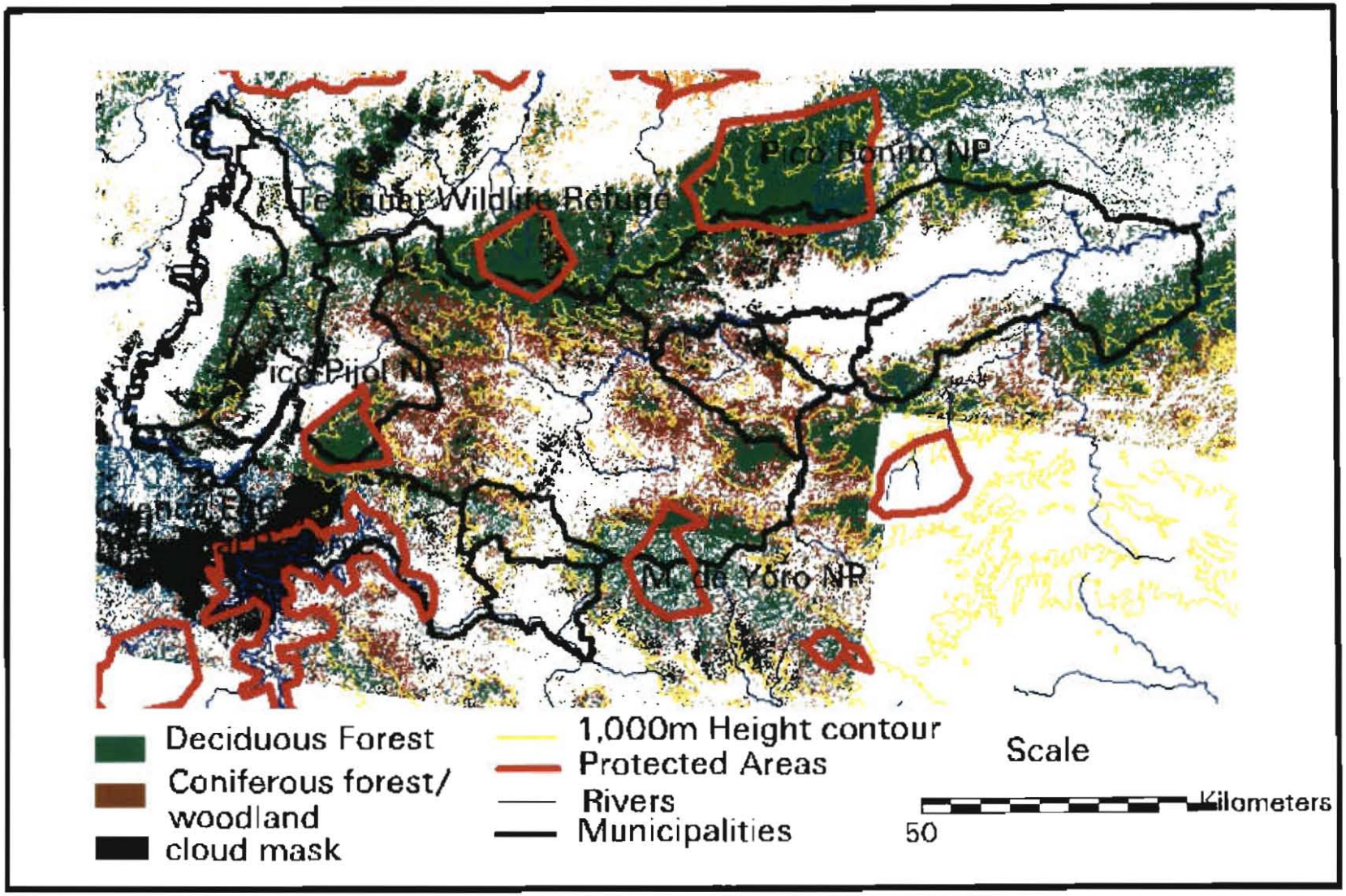
Coniferous forest appears to be concentrated in Yoro municipality, that is in the central area of Yoro Department (Map 2.6.1).

2.6.2 Forest Monitoring

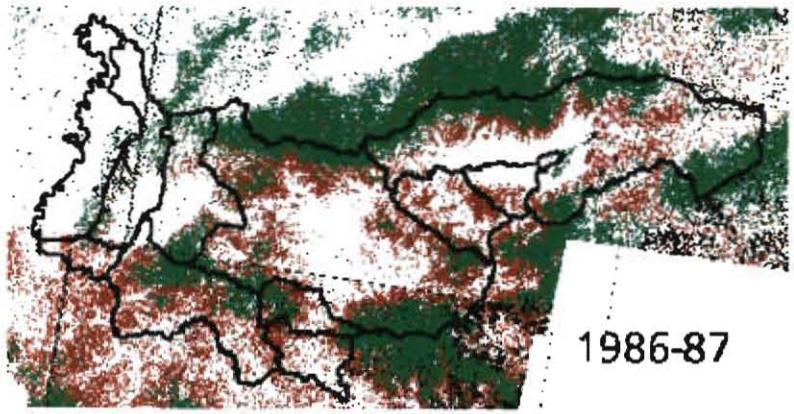
There is not much evidence of major deforestation during the seven year lapse between the two image dates of 1987 and 1993 (Map 2.6.2). Deciduous forest cover has largely remained protected, or at least replaced by planted shade tree species in coffee plantations. Scrub fallow occurs at all altitudes, but is largely absent from major valley floors which tend to be permanently cultivated.

Deciduous forest occurs predominantly in the mountainous and hilly regions of the department as a more solid block than say scrub or annual cultivation. Very often the boundary of a block of deciduous forest coincides with the 1,000 metre contour. (Map 2.6.1) Deciduous forest has largely been cleared from the central region of Yoro municipality, below 1,000 metres and in valleys to the west, east and southwest. However, there remain significant areas of forested land in the Sierra de Mico Quemado, predominantly within the altitudinal zone 600-900 metres, which is unprotected and also another sizeable patch along the southeastern border of Olanchito, extending between altitudes of 400 and 1,000m along the northern footslopes of Montana de Jaguaca, also 'unprotected'. If anything the overall impression one receives after comparing the two maps is that the forested area shown in the more recent 1993 image

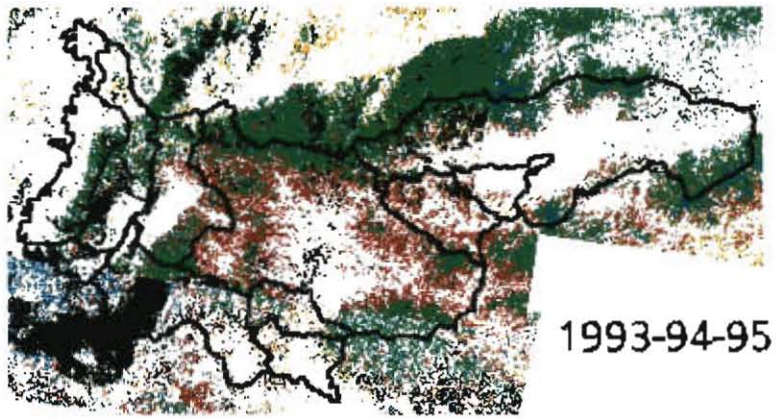
Natural Resources



Forest Monitoring 1986 - 1995



1986-87



1993-94-95

Deciduous forest/woodland

Coniferous forest/woodland

Cloud mask

Scale

50 0 Kilometers

classification, appears equal or perhaps more dense than the forest classified from the older 1987 TM image data.

Pine forest distribution appears in a roughly circular pattern around the valley of Yoro and is mostly situated in the mountain foothills. The sparse pine rangeland class which is extensively grazed by horses and cattle, does not appear to be important here, apart from some areas within Yorito and Sulaco municipalities. However, the classifier may have confused this class with scrub fallow in other parts of the department.

2.7 Settlement/Infrastructure

The road network appears to be quite evenly distributed (GIS coverage, shown in Map 2.7) apart from the southern slopes of Sierra 'Nombre de Dios'. Aldeas/villages are mainly concentrated in valleys or along mountain drainage lines. Much of this road network consists of minor tracks. The map produced by Secretaria de Communicaciones, Obra Publicas y Transporte, 1992 may give a more accurate representation of the road distribution within the department. The latter indicates a principal west-east route passing from El Progreso via Santa Rita, El Negrito, Morazan, Yoro, Jocon, Arenal, Olanchito to Potrerillos. Minor routes run north-south from La Coroza to Sulaco and parallel to the east-west route in Olanchito along the Rio Aguan.

2.8 Land Tenure

Of the 19,974 farm holdings censused in 1993 (covering an area of 272,654 hectares), 17,440 (total of 223,303 hectares, averaging 13 hectares/farm) were under simple tenancy (private, national, rented) and 2,534 (total of 49,351 ha, averaging 19.5 hectares/farm) were reported as having a mixed tenancy (private and national, private and rented, national and rented, private, national and rented, other) (Figure 2.8).

Table 2.8.1: Farm size statistics for Yoro Department

Farm size (ha)	No. Holdings	Total area (ha)
<1	4,218	2,488
1-2	4,381	6,007
2-3	3,057	7,269
3-5	2,261	8,869
5-10	2,056	14,614
10-20	1,387	19,345
20-50	1,545	48,509
50-100	553	37,560
100-200	310	42,257
200-500	172	48,201
500-1,000	27	18,148

Settlement/infrastructure

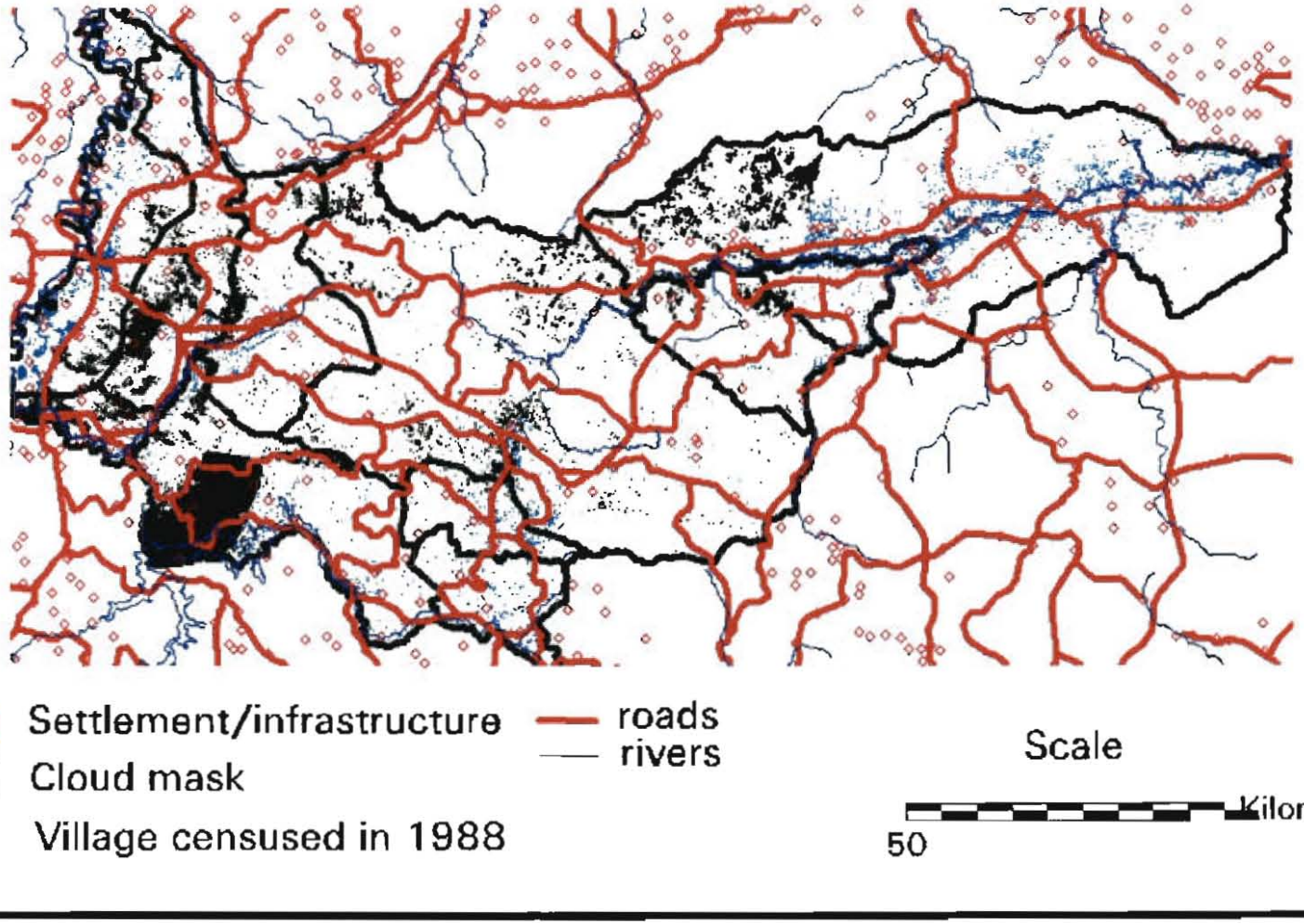
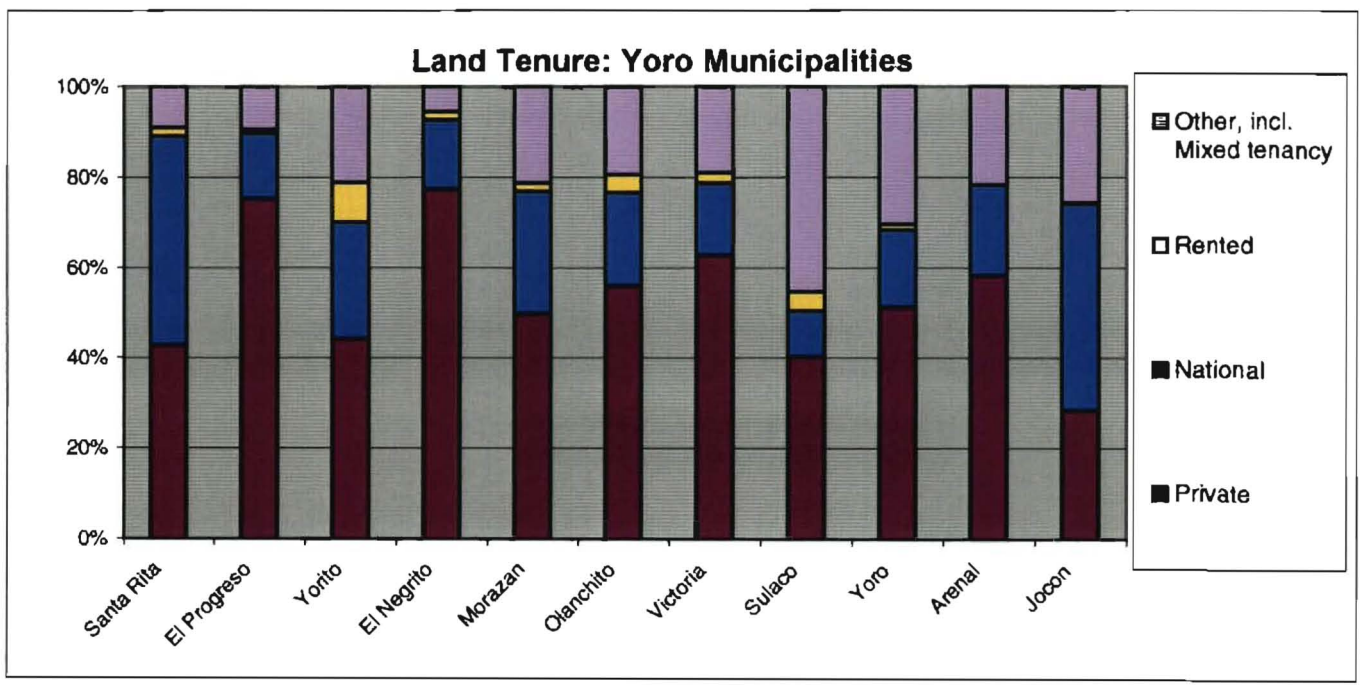


Figure 2.8

	Private	National	Rented	Other, incl. Mixed tenancy	Area censused
Santa Rita	3210	3460	143	677	7490
El Progreso	19159	3617	222	2429	25427
Yorito	3913	2264	773	1870	8820
El Negrito	16836	3296	409	1193	21734
Morazan	10907	5897	409	4649	21862
Olanchito	42864	15839	3016	14885	76604
Victoria	17779	4494	643	5393	28309
Sulaco	3298	827	350	3714	8189
Yoro	31587	10500	761	18737	61585
Arenal	2468	854	0	920	4242
Jocon	2380	3838	14	2160	8392
Yoro Total	154401	54886	6740	56627	



1,000-2,500	3	5,156
>2,500	4	14,229

223,303 hectares under simple tenancy Private 154,401 (8,559 farms)
National 54,886 (3,904 farms)
Rented 6,740 (2,728 farms)
Other 7,276 (2,249 farms)

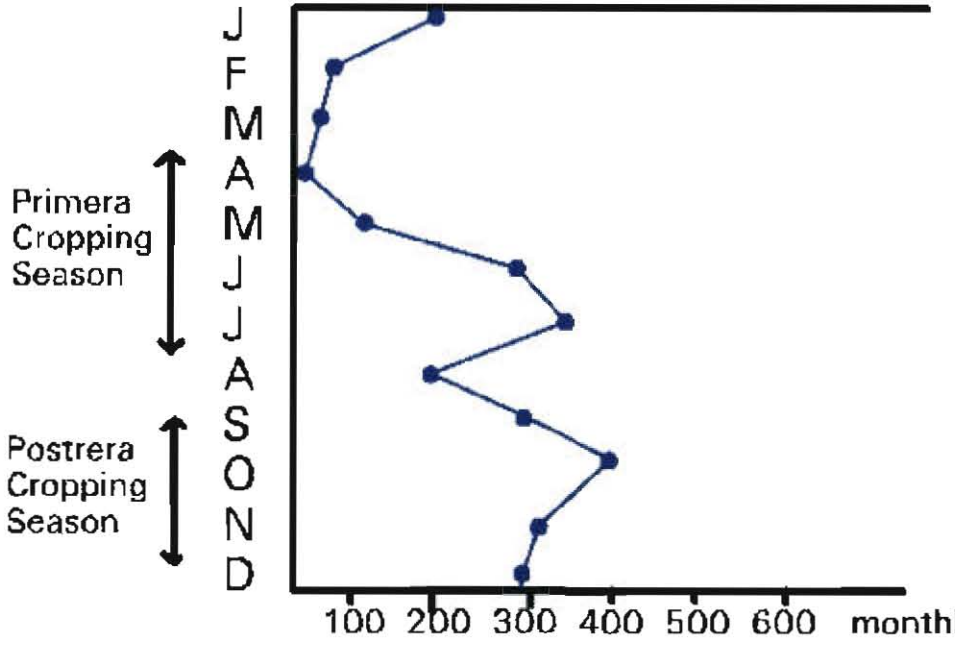
49,351 hectares under mixed tenancy Private and national 28,713 (623 farms)
Private and rented 5,629 (749 farms)
National and rented 2,769 (378 farms)
Private, national and rented 5,904 (61 farms)
Other 6,337 (723 farms)

Average size of Land Use Holdings
Yoro Department: 272,654 hectares (19,974 exploitations); averaging 13.6 hectares/holding for Department

Table 2.8.2: Average farm size within different land use zones

Municipality	Annuals & <1yr fallow	Perennials	Pasture (improved & natural)	Scrub fallow (1-5yrs)	Forest
Yoro	2.2 ha/farm	2.4 ha	27.6ha/26ha	5.9 ha	30 ha
Arenal	3.5 ha/farm	1.6 ha	23.5 ha/25 ha	14.4 ha	12.5 ha
El Negrito	2.4 ha/farm	7.2 ha	20 ha/12 ha	7.6 ha	6.9 ha
El Progreso	2.2 ha/farm	9 ha	26.6ha/12.5 ha	15.6 ha	7 ha
Jocon	2.5 ha/farm	2 ha	23 ha/24 ha	5.9 ha	12.4 ha
Morazan	1.9 ha/farm	2.2 ha	13.5 ha/14 ha	5.5 ha	7.7 ha
Olanchito	3.5 ha/farm	11.3 ha	38 ha/29 ha	19.6 ha	27 ha
Santa Rita	2.7 ha/farm	4.7 ha	15.7ha/14 ha	12 ha	5.7 ha
Sulaco	1.9 ha/farm	1.9 ha	13.5 ha/7 ha	3.4 ha	11.4 ha
Victoria	2.5 ha/farm	3.2 ha	19.7 ha/12 ha	10.3 ha	8.6 ha
Yorito	2 ha/farm	2.2 ha	15 ha/8 ha	7.3 ha	19.7 ha
Average	2.5 ha/farm	4.3 ha	21.5 ha/17 ha	9.7 ha	13.5 ha

Cropping Calendar for 'West-Central' Honduras



Sow Primera Maize
Sow Primera Beans
Sow Rice
Sow Sorghum

Harvest Primera Beans

Harvest Primera Maize & Rice/ Sow Postrera Beans

Sow Postrera Maize

Harvest Postrera Beans & Sorghum
Harvest Postrera Maize

From Table 1.2.8b, one might deduce that greatest land pressure (indicated by plot size of annuals) exists in Yorito, Sulaco, Morazan and least in Arenal and Olanchito. Olanchito, El Progreso and El Negrito have the largest areas under commercial plantations. Grazing is commercially important in Olanchito with improved pasture holdings averaging 38 hectares in size. Yoro is next in importance with 50/50 ratio improved/unimproved pasture. Sulaco and Morazan have the smallest average pasture holdings. Scrub fallow under 5 years typically has a holding size of about 10 hectares and forest/tree lots on farms average 13.5 hectares in size. Arenal, El Progreso, Santa Rita and Victoria have generally larger holdings of scrub fallow than of forest. Yoro stands out as having sizeable forest lots averaging 30 ha followed by Yorito which is reported to have tree lots with an average size of 20 hectares.

2.9 Cropping Calendar

Yoro has two cropping seasons: the primera which lasts about five months from April to August and the postrera which lasts about four months from September to December. Maize, beans, rice and sorghum are cultivated as annual crops in the primera season and a second crop of maize/beans is sown in September. Annual crops of rice and sorghum are harvested at the end of the primera in December (Figure 2.9).

2.10 Agricultural Land Use

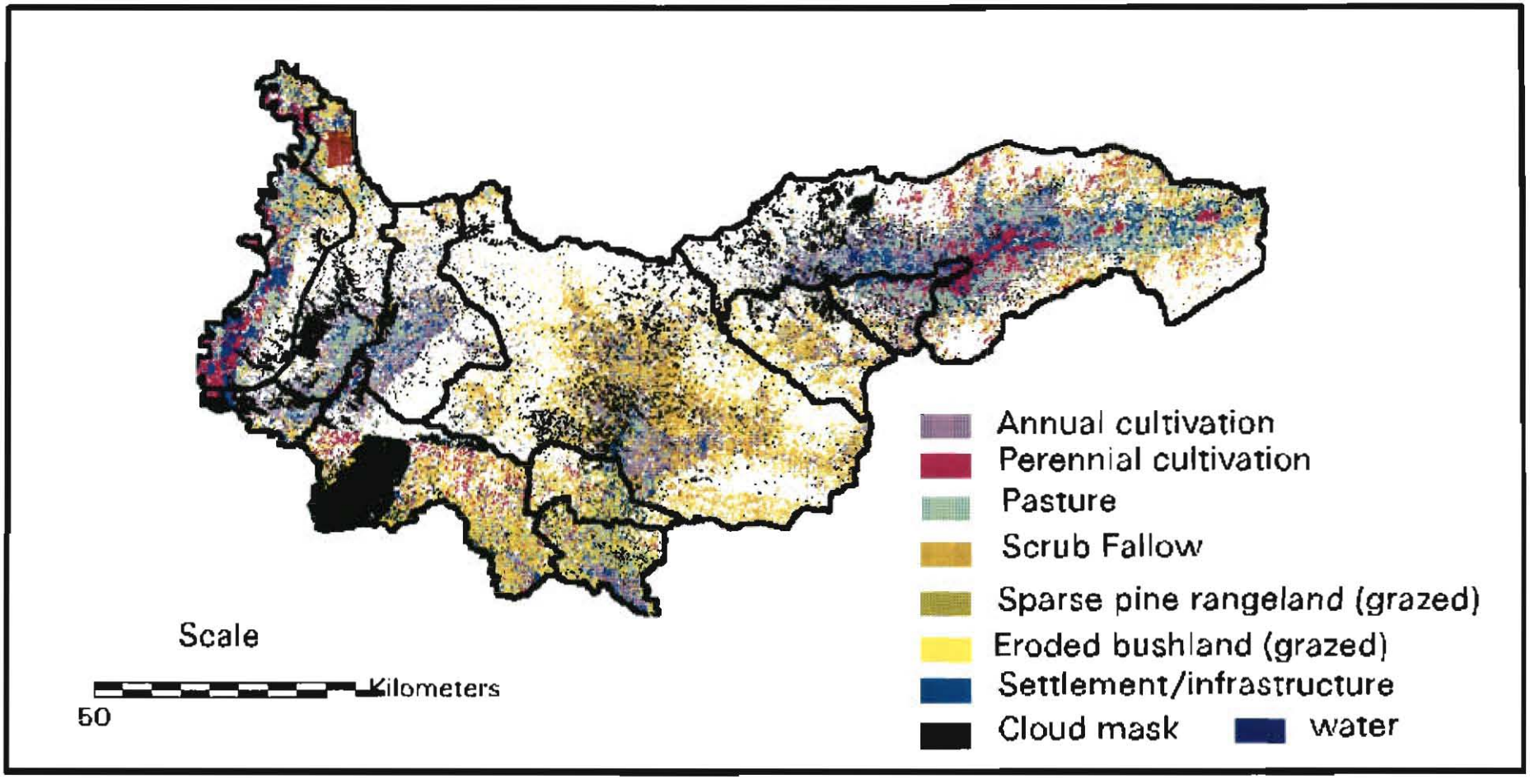
The most intensive land use is located in the municipalities of El Progreso and Olanchito where perennial crops are grown on commercial plantations – oil palm, banana/plantain. Coffee tends to be grown at the smallholder level in the mountainous zones. Elsewhere land use is extensive, consisting of annual cultivation, scrub fallow and grazing, the latter predominantly consisting of unimproved pastures, as seen from the image-classification. The agricultural census, however, indicates equal importance of improved and natural pastures within the department of Yoro. Municipalities with least intensive land use and maximum forest resources include Yoro, Morazan and Jocon. (Map 2.10).

Annual cultivation: Like Atlantida department, the distribution of annual cultivation is predominantly in the valleys and foothill zones. However this land use occurs more in the hillsides in northwest Sulaco and central Yorito.

Perennial crops, excluding shade-tree crops such as coffee/cocoa, are predominantly found in the river valleys, along river courses and in flood-plains, especially in the valleys of Rio Ulua and Rio Aguan. These are mostly large-scale commercial plantations.

Pasture is more evenly distributed through the department, excluding to a large degree, the mountainous zones – this is especially noticeable in the municipalities of Yorito and Sulaco. Improved pasture is most important in the valley of Rio Aguan, Olanchito and in

Agriculture



Arenal and Jocon – the field sizes here are large and conditions are dryer than the departmental average, as the valley receives a rainshadow effect from the Sierra along its northern boundary, and the vegetation is dominated by a low thorn scrub. There is a noticeable absence of grazing land in the northwest section of Victoria, an areas lower than 1,000 metres altitude. The soils are very thin here consisting of lithosols and rendzinas (Map 2.5) – but this area was obscured by cloud in the 1994 image of the 'Yoro' scene (Map 2.11).

Scrub fallow (1 to 5 years old) appears to be one of the more dominant cover classes and is found to be most frequent in the municipality of Yoro. The classification of "Yoro94" image is likely to have overclassified scrub and has included some deciduous forest areas. The brightly lit forest on the edge of clearings is often classified wrongly as scrub.

Eroded bushland occurs more in the south of the department and is most noticeable on the northern banks of 'El Cajon' reservoir, where a secondary pine forest is establishing itself gradually on the very shallow soils. Also the eroded bushland cover type is present in the study area municipalities of Yorito and Sulaco. One reason why this class is more representative of the study area municipalities and near-surroundings is probably because the training areas for these classes were generated here rather than elsewhere in the department; therefore the clssification result could be somewhat biased. This could be corrected for by reviewing reconnaissance field data/photographs or perhaps acquiring more extensive field-data.

2.11.1 Land Cover/Land Use (Landsat TM Image classification)

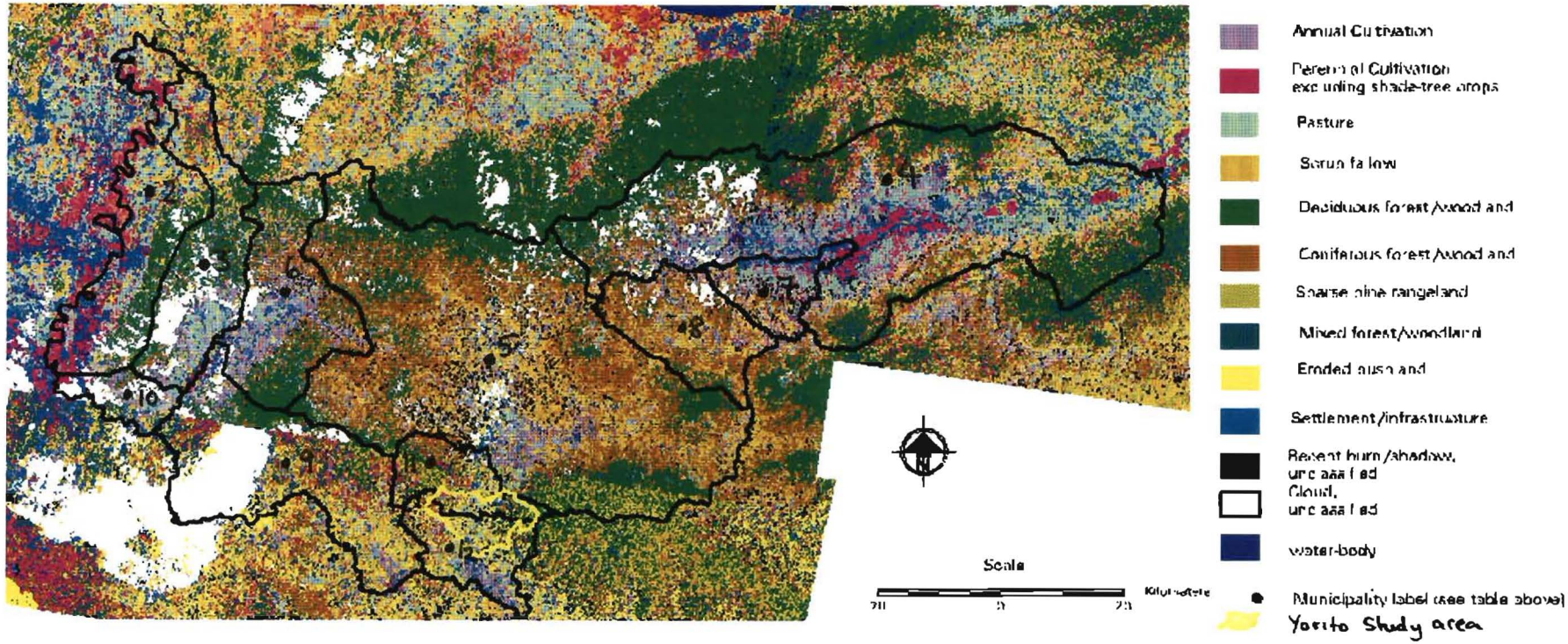
To continue with the non-agriculture classes:

Deciduous Forest Within the mountainous zone of Sierra 'Nombre de Dios', any forest classified as mixed can be assumed as incorrect as this humid zone supports only dense deciduous forest. Difficulties have arisen in separating forest classes due to differences in shading caused by irregular topography combined with a low sun-angle.

Wetland classes have, like in Atlantida, probably been misclassified for permanent crops on wet/dark soils perhaps.

Settlement is concentrated along river courses. Major towns classified include El Progreso, Olanchito, Yoro, Morazan, and other smaller towns such as Yorito, Sulaco, Arenal and Jocon. Burnt areas, densely shaded/unclassified areas are negligible in this classified mosaic, however patchy cloud has obscured certain areas of Olanchito, El Negrito, Santa Rita (Map 2.11)

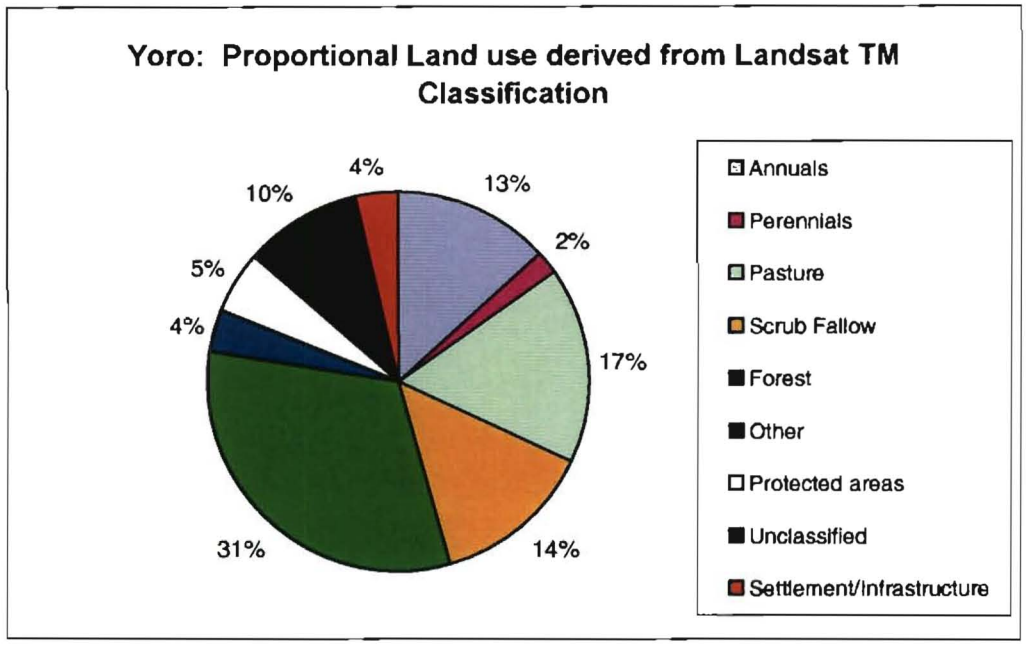
Land-Cover/Land-Use Classification of Landsat TM Images

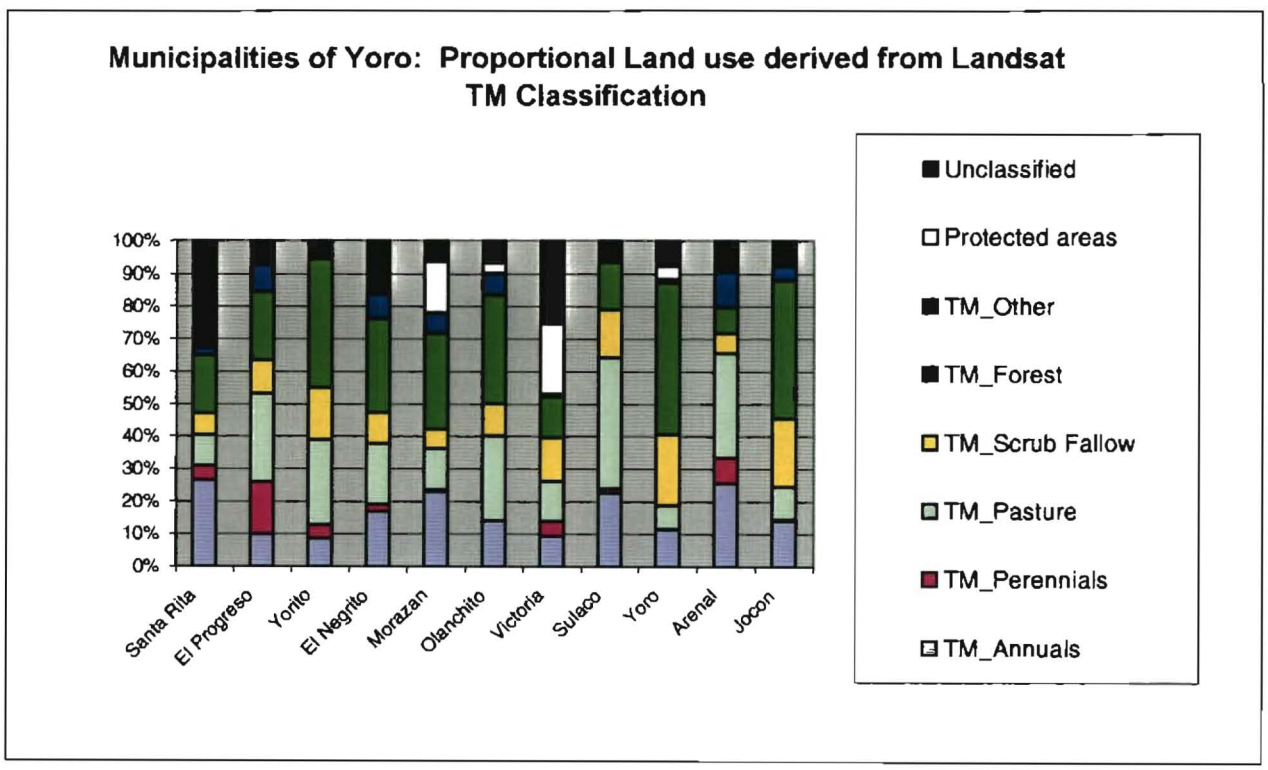


2.11.2 Land Cover Proportion Estimates for Yoro Department

Figure 2.11.2 shows a pie-chart summarizing the land cover/land use proportions for the whole department of Yoro, and a bar-chart giving the individual municipalities. One can see that annual cultivation, pasture and scrub fallow have roughly equal shares of the department. Forest covers about 36% of the department, and includes some protected deciduous forest (5%). The bar chart shows that the proportions are not homogenous across the municipalities. Santa Rita, Morazan, Sulaco and Arenal have over 20% of their areas under annual cultivation according to the image classification. Municipalities with most land under grazing include Sulaco, Arenal and El Progreso. Certain municipalities have most of their area under forest cover including Yorito, El Negrito, Morazan, Olanchito, yoro and Jocon. Victoria and Arenal have relatively small areas with forest cover. Victoria includes a protected area around the reservoir, but as yet forest has not regenerated. Yoro and Jocon have the higher proportions under scrub fallow than the remaining municipalities.

Fig 2.1.1.2


Yoro: Proportional Land use derived from Landsat TM Classification
4%
13%
10%
2%
5%
4%
17%
31%
14%
Annuals
Perennials
Pasture
Scrub Fallow
Forest
Other
Protected areas
Unclassified
Settlement/Infrastructure


Municipalities of Yoro: Proportional Land use derived from Landsat TM Classification
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Santa Rita
El Progreso
Yorito
El Negrito
Morazan
Olanchito
Victoria
Sulaco
Yoro
Arenal
Jocon
Unclassified
Protected areas
TM_Other
TM_Forest
TM_Scrub Fallow
TM_Pasture
TM_Perennials
TM_Annuals

3. Land Characterization of El Paraiso Department

3.1 Location

El Paraiso consists of nineteen municipalities (Map 3.1 and Figure 3.1) . The department lies between lines of longitude 87 20 W and 85 30 W and between lines of latitude 14 30 N and 13 20 N and covers a total area of 734,846 hectares.

The municipality containing the study area, Danli, occupies a high proportion (34%) of the department area. Other large municipalities are also in the eastern part of the department and include Trojes municipality (18% of department area) and Teupasenti (9%). The remaining sixteen municipalities occupy each between 0.9 and 5.6% of the department. The study area in Danli consists of the sub-catchment of Rio Cuseateca which covers an area of 6,779 hectares.

3.2 Climate

The whole department with the exception of some extreme eastern parts of Trojes, receives an average annual rainfall of under 1,500 mm (Map 3.2).
Climatic zones contained within Yoro department boundary include Mb, Mx, Vx, Yb and Yk (Appendix 2).

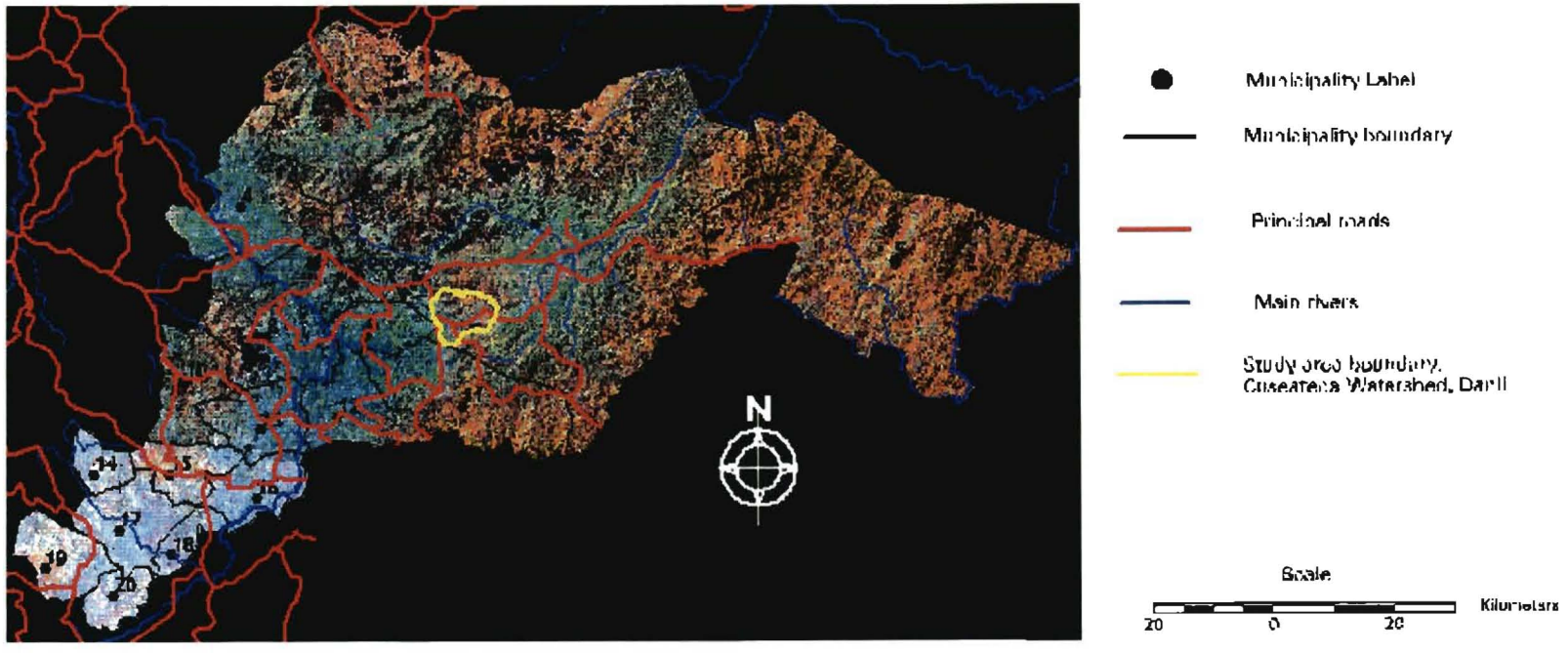
Figure 3.2 shows the monthly rainfall pattern for the department. Maximum rainfall occurs between June and October when monthly rainfall is in excess of 200 mm and is followed by a dry season between November and May. Temperatures are pretty constant, ranging from 15 C to 28 C, maximum temperatures occurring in the months of April, May and June. El Paraiso's dryest month is February which has less than 50mm, and the wettest month is June averaging 150-300 mm/month for most of the department. (Poster Map 1)

3.3 Geology

There is a noticeable northwest – southeast division across the department, with different geologies ocurring on either side. In the southwest, the geology is dominated by Tertiary pyroclastic rocks (map code: Tpm) with inclusions of Tertiary basalt and andesite (Tm). There are areas of alluvium and a localized area of Palaeozoic granites in eastern Oropoli and southern El Paraiso. In the northeast a broad geological zone, covering Trojes, Danli and Teupasenti, consists of Jurassic shales and sandstones, centered on Danli municipality, Palaeozoic metamorphic rocks and cretaceous shales in Teupasenti and Trojes. A belt of Palaeozoic granites runs through the southeastern section of Danli municipality and across the central part of Trojes municipality (Map 3.3).

The study area, which consists of the sub-catchment of the Rio Cuseateca, has a geology dominated by alluvium which occupies the valleys, as well as a small intrusion of Tertiary pyroclastics in the north. Although the study area is situated in the border zone between two contrasting geologies, the geological map indicates that it is a rather homogeneous area consisting largely of recent alluvial material. The northern and

Landsat TM false colour mosaic of dates 22 Jan 1987 and 2 Jan 1985:



List of the Municipalities of El Paraiso Department:

Code	Municipality	Area	% Dept
2.	Teupasenti	67,334 ha	9%
3.	Danli	249,281 ha	34%
4.	Morocelli	36,126 ha	5%
5.	Trojes	132,444 ha	18%
6.	Jacaleapa	11,089 ha	1·5%
7.	Potrerillos	12,469 ha	1·7%
8.	Yuscaran	32,920 ha	4·5%
9.	San Matias	11,335 ha	1·5%
10.	Günope	19,993 ha	2·7%
11.	El Paraiso	40,984 ha	5·6%
12.	Alauca	19,902 ha	2·7%
13.	Oropoli	16,937 ha	2·3%
14.	Yauyupe	7,276 ha	0·1%
15.	San Lucas	12,556 ha	1·7%
16.	San Antonio de Flores	14,306 ha	2%
17.	Texiguat	19,046 ha	2·6%
18.	Vado Ancho	6,503 ha	0·9%
19.	Soledad	15,851 ha	2·1%
20.	Liure	8,494 ha	1·1%

Total Gross Area = 734,846 ha

Rio Pusecabrera Sub-catchment, Dan
Area = 6,779 ha

List of the Municipalities of El Paraiso Department:

Code	Municipality	Area
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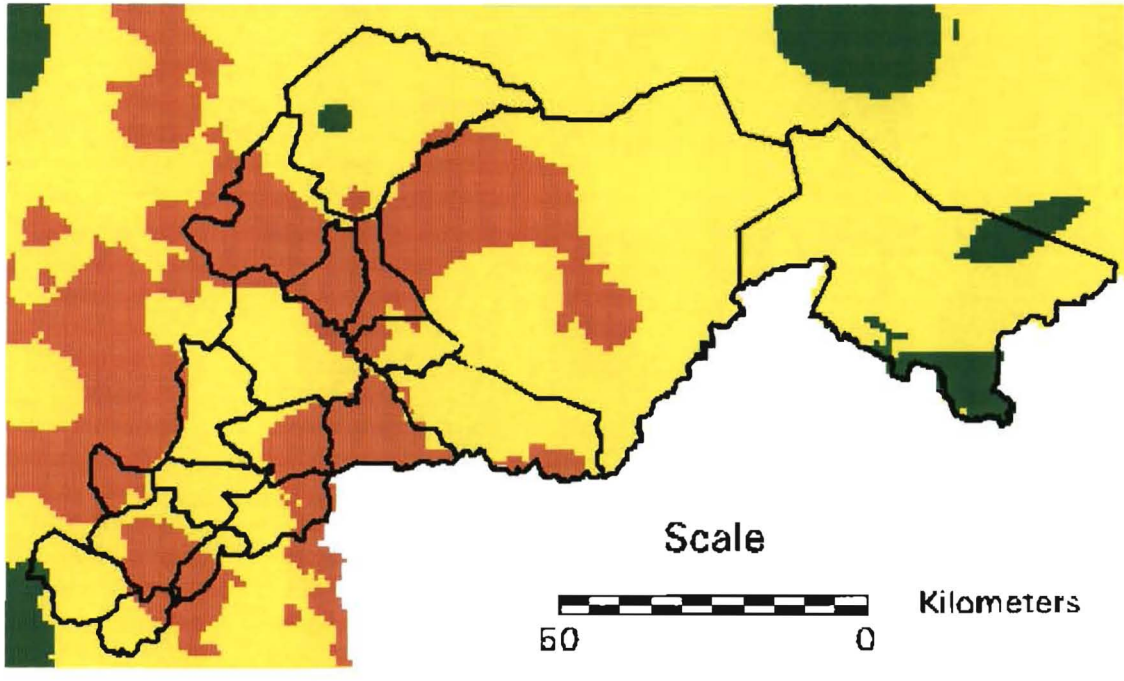
17.	Texiguat	19,046 ha
18.	Vado Ancho	6,503 ha
19.	Soledad	15,851 ha
20.	Liure	8,494 ha

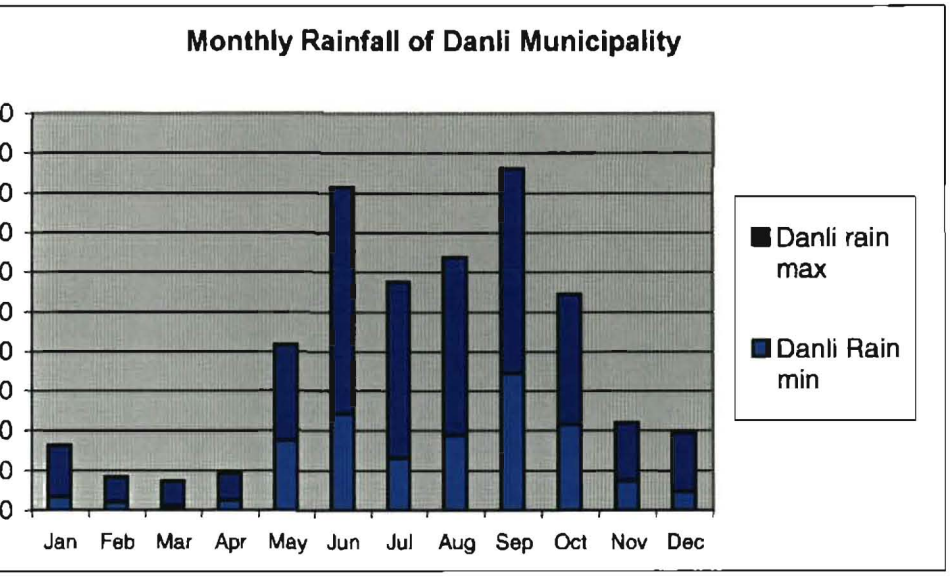
AverageTotal Rainfall Map

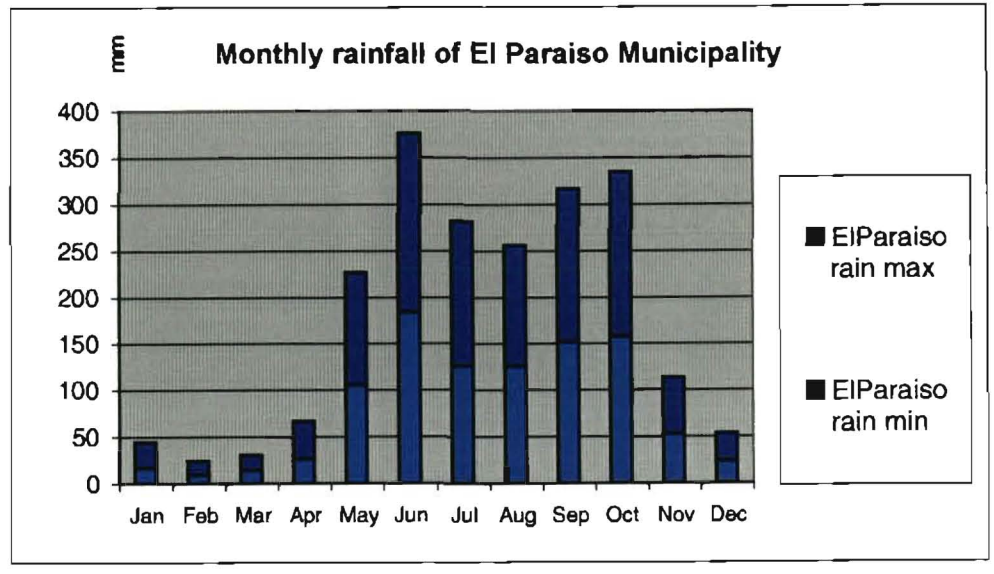


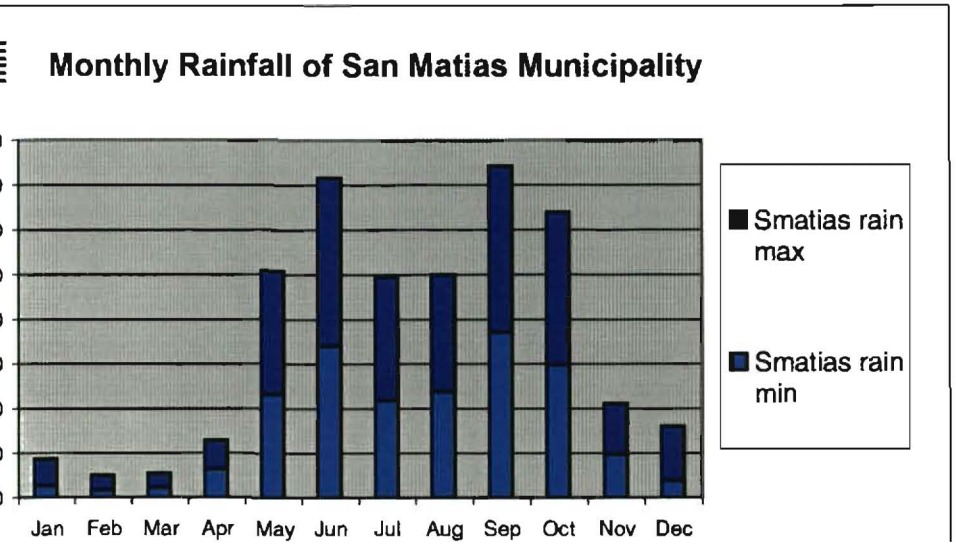
< 999 mm

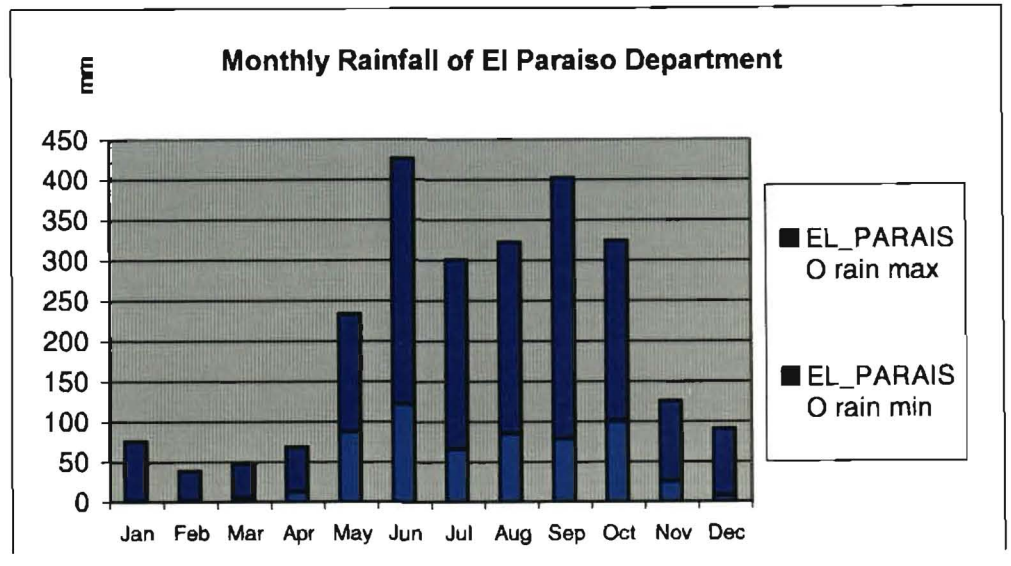
1,000 mm - 1,499 mm

1,500 mm - 2,000 mm


Monthly Rainfall of Danli Municipality
Danli rain max
Danli Rain min
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

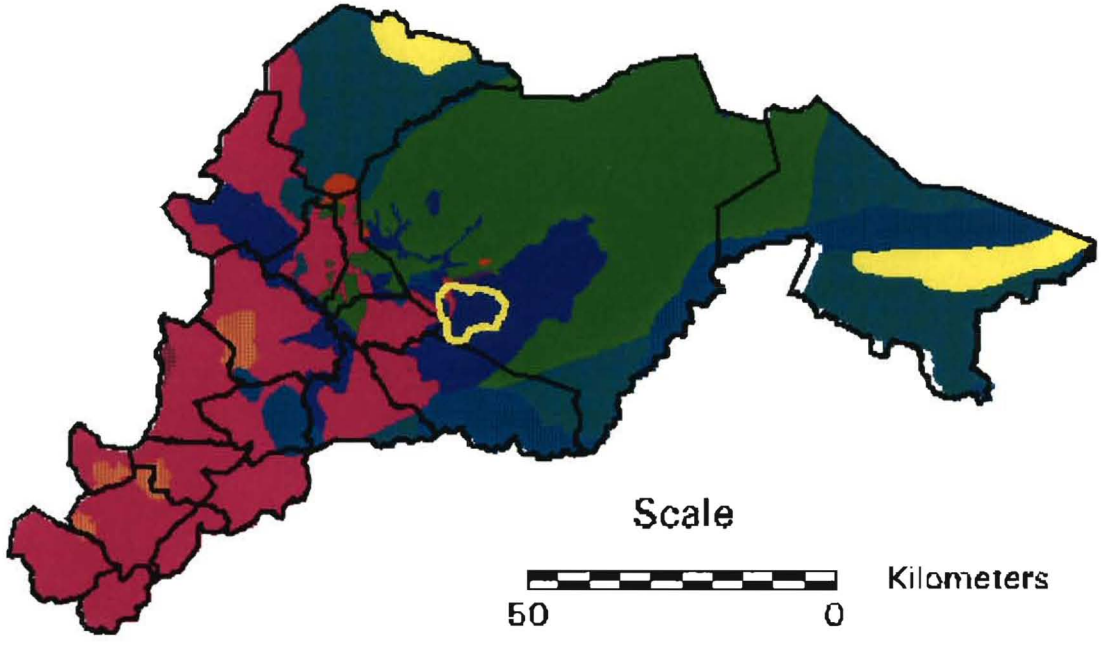

Monthly rainfall of El Paraiso Municipality
mm
400
350
300
250
200
150
100
50
0
ElParaiso rain max
ElParaiso rain min
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Monthly Rainfall of San Matias Municipality
Smatias rain max
Smatias rain min
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Monthly Rainfall of El Paraiso Department
mm
450
400
350
300
250
200
150
100
50
0
EL_PARAISO rain max
EL_PARAISO rain min
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Map 3.3

Geology Map



- Quarternary alluvium (Qal)
- Quarternary volcanics (Qv)
- Tertiary pyroclastic rocks (Tpm)
- Tertiary basalt & andesite (Tm)
- Tertiary volcanic tuffs (Tv)
- Cretaceous mudstones (Kva)
- Cretaceous shales (Ky)
- Jurassic shales & sandstones (JKhg)
- Palaeozoic metamorphic rocks (Pzm)
- Palaeozoic granites (Ti, KTi & Ki)

southern limits of the study area include mountainous terrain and are composed of igneous and metamorphic rocks. This points to the fact that all country-scale maps are generalizations and are somewhat inadequate for describing the geology of local areas.

3.4 Topography and Drainage

The percentage of the departmental area above an altitude of 1,000 m (ie. mountainous terrain) is 25%. El Paraiso has a good combination of valley and mountain topography with the exception of the south-western zone where the smaller municipalities appear to have a more continuous hilly topography (Map 3.4).
The highest mountain ranges occur in the northern and southern regions of the central departmental zone. There is also a high altitude area centered on Gunope. Mountain peaks include those of Yuscaran (1,825 m), Montana Cuyamapa in northern Danli (1,600 m), Cerro Granadillo (1,664 m), Teupasenti and Montana de Chile (2,000 m) situated to the northwest of Morocelli.

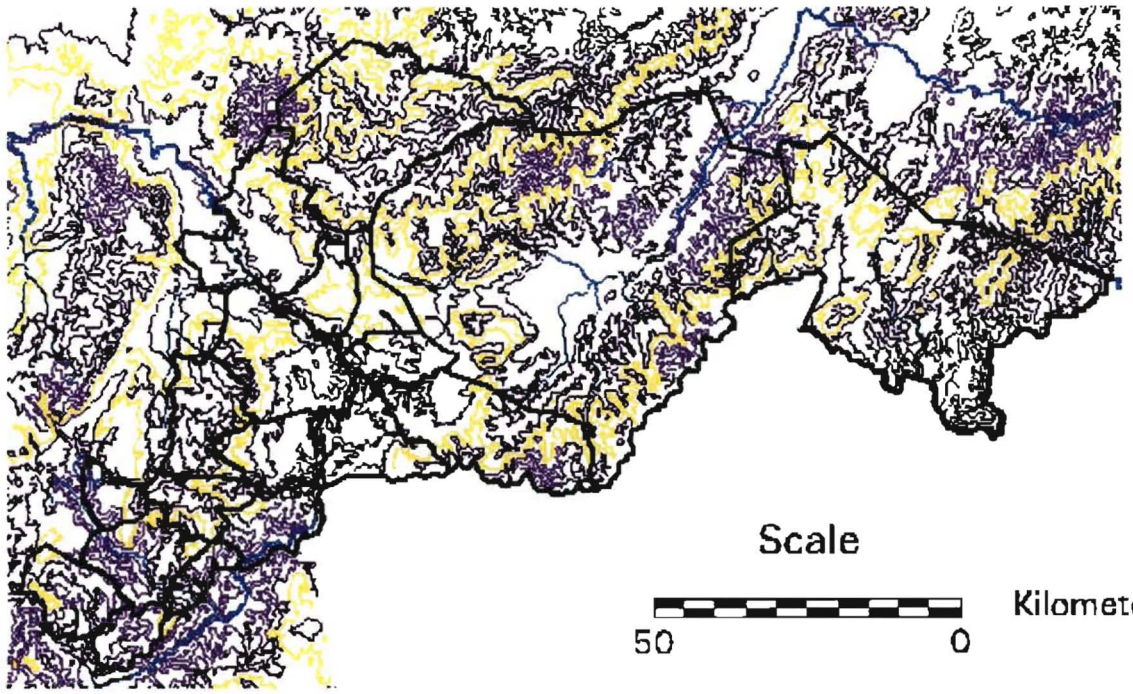
There are two major drainage systems: one, the Rio Grande o Choluteca, which flows north-south to the west of Danli municipality. The river flows out of the department to the southwest of San Antonio de Flores and flows through Choluteca to the coast at Golfo de Fonseca (where there are three other river mouths). The other river system, Rio Guayambre, has its headwaters in Montana de Potrerillos (Qda El Barro) and to the west of Apali (Rio Apali) in Montana de los Nuves on the border with Nicaragua. The river flows north-east and divides after a distance of about 250 kilometres outside the department which then takes on the name Rio Patuca and flows through Gracias a Dios to the north-eastern coast of Honduras near Brus Laguna. It is not clear from the topographic sheet of Honduras 1:500,000 scale where the river Guayambre ends – it appears to dry up soon after the confluence of Rio Guayape, in the area of Catacamas where two other tributaries flowing off the mountains join the main channel (Map 3.4). In addition, the municipality of Trojes has Rio Guano which rises in Montana de Rio Guano and flows southward through the central eastern part of the municipality into Nicaragua.

3.5 Soils

A similar division can be seen in the distribution of soil types. The eastern half of the department has a broader pattern with larger soil units, comprising predominantly lithosols with podzols ocurring along the northern and southern sections. The study area is located within the lithosol zone. It is interesting to note that the valley and gravel soils that one would expect to have been derived from alluvium (Map 3.3) are located further east in the central valley zone of Danli municipality. The soil map certainly appears to reflect what is visible from the satellite imagery and what was observed in the field. Trojes municipality has a zone of Tomala Latosols in the extreme southeast. The southwestern half of the department has a more complex pattern of soil units: valley and gravel soils, lithosols and some rendzina and podzolic soils comprise this western zone (Map 3.5).

Map 3.4

Topography and Drainage



Height contours at 200m intervals

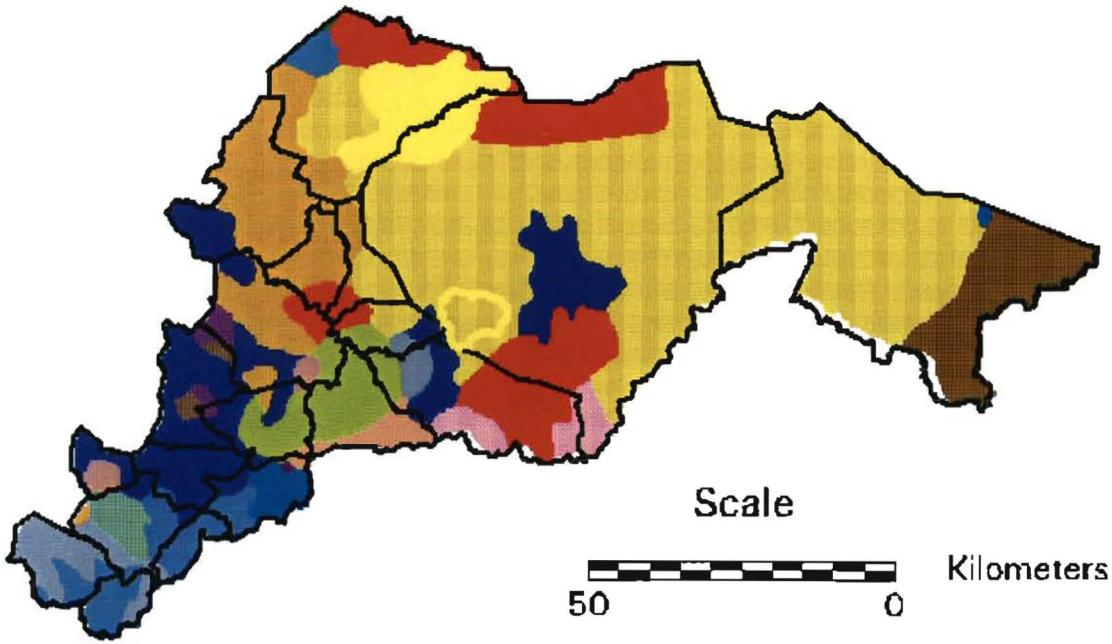
Selected 1,000m contour

Rivers

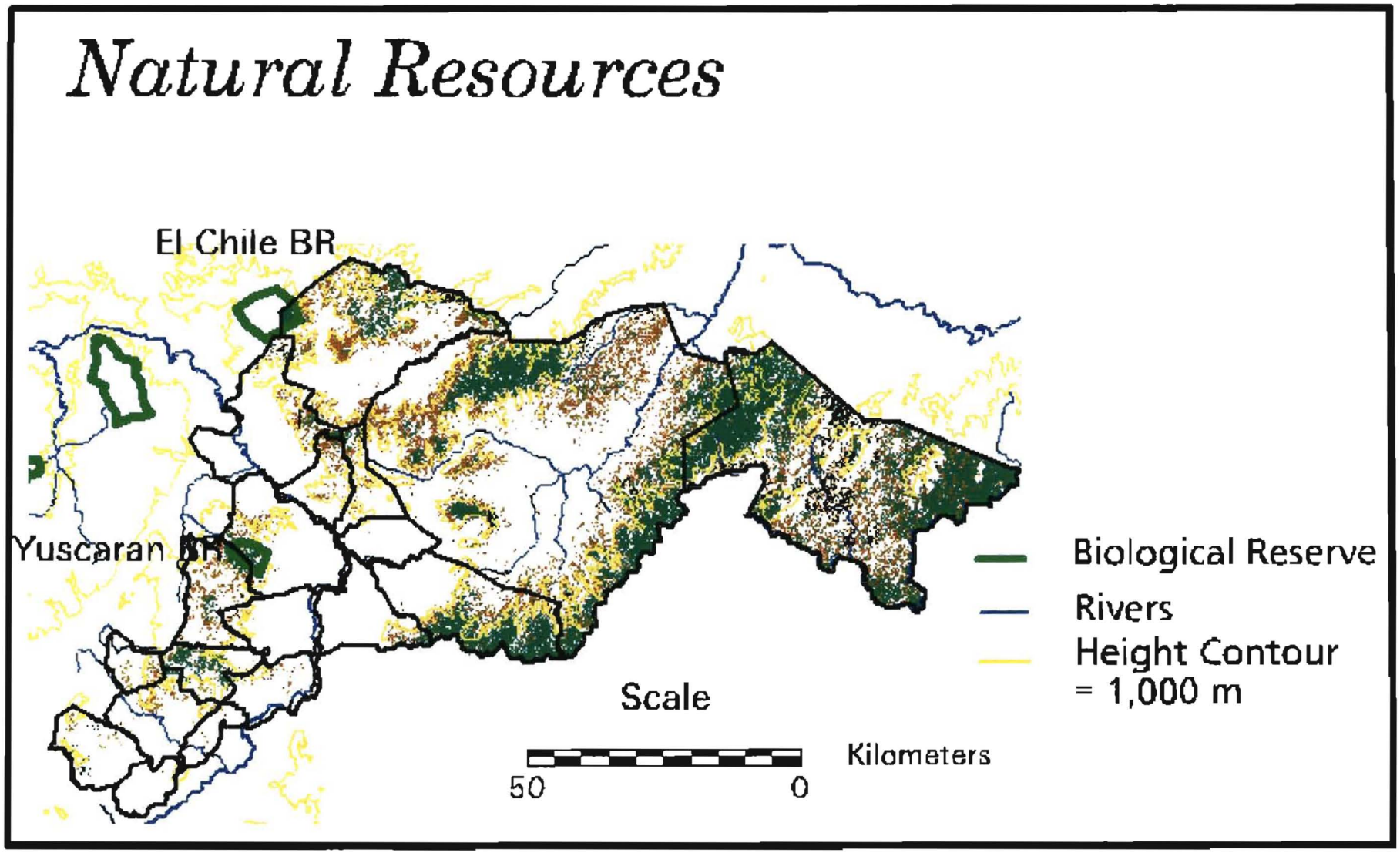
59

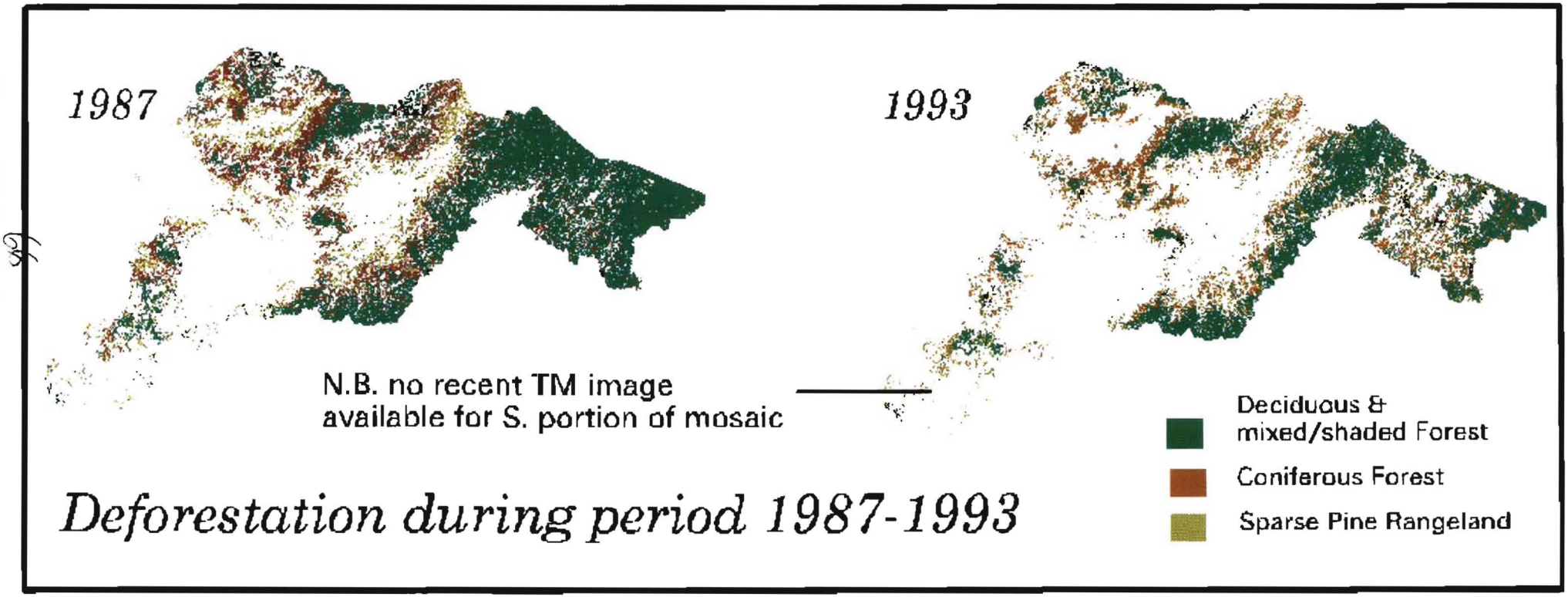
Soils Map

(Based on Simmons' Classification)



- Podzols
- Lithosols
- Latosols
- Rendzinas
- Andosols
- Grumosols
- Valley and gravel soils
- Other


Natural Resources
El Chile BR
Yuscaran BR
Biological Reserve
Rivers
Height Contour
= 1,000 m
Scale
50
0
Kilometers



Deforestation during period 1987-1993

3.6.1 Natural resources and protected areas

Deciduous forest cover is largely concentrated in peripheral areas of the department, although Trojes has comparatively more forest cover than the other municipalities. All forest is unprotected with the exception of El Chile Biological Reserve adjoining the northwestern municipality boundary of Teupasenti, and Yuscaran Biological Reserve striding the municipalities of Yuscaran and Gunope. These are both relatively small reserves. But compared with the other two departments, El Paraiso has the greatest area of unprotected forest, as it is located closer to the 'frontier' zone where encroachment by smallholders is increasing. To the east lies the dense lowland tropical forest of Mosquitia in the department of Gracias a Dios. Also, forest is generally more dense above 1,000 metres of elevation (Map 3.6.1).

3.6.2 Forest Monitoring

There is not a great difference between the two dates of TM data/land cover classifications. The 1987 mosaiced classification shows more coniferous forest and indicates that a denser deciduous forest cover existed in Trojes. However, some of the areas that seem to have been deforested in the 1993 map are actually areas obscured by cloud cover. There does seem to have been some deforestation, though, in the central part of Trojes municipality (Map 3.6.2).

3.7 Settlement/Infrastructure

The immediate thing visible from Map 3.7 is the dense concentration of aldeas/villages in the western half of the department where the road network is also denser. The department map of Secretaria de Communicaciones, Obras Publicas y Transporte (1992), however, shows a different distribution of roads which is more even with the exception of northwestern areas of Teupasenti and eastern zone of Trojes. The greatest concentration of roads is found in the central southern part of El Paraiso and within the central valley of Danli municipality. Settlements, identified in the TM classification, include Danli, Teupasenti and El Paraiso.

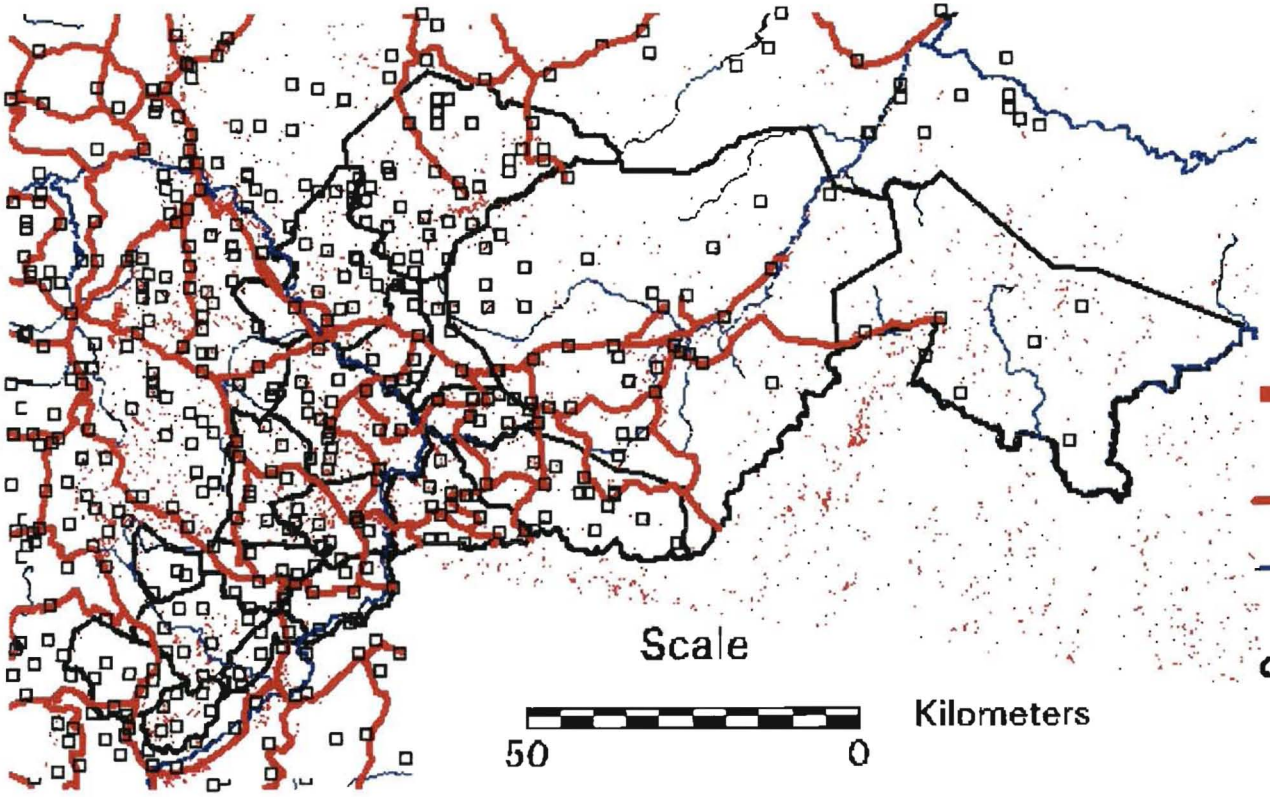
3.8 Land Tenure – El Paraiso

Of the 25,217 farm holdings in El Paraiso that were censused in 1993 (covering an area of 374,086 hectares), 22,053 (area of 322,182 hectares) were under simple tenancy and 3,164 (51,904 hectares) were under mixed tenancy (Figure 3.8).

Table 3.8.1: Farm Size Stratification in El Paraiso Department:

Farm Size (ha)	No. holdings	Total land area (ha)
< 1	5,560	3,340
1-2	4,910	6,712
2-3	3,410	8,160

Settlement/Infrastructure



3-5	2,855	11,314
5-10	2,803	19,954
10-20	2,124	29,237
20-50	2,179	67,493
50-100	727	48,615
100-200	352	46,411
200-500	230	69,841
500-1000	52	34,835
1000-2500	13	21,006
>2,500	2	7,167

(The average size of holdings reported in the 1993 Agricultural census is about 15 hectares)

Land Tenure Summary: El Paraiso Department:

322,182 ha under simple tenancy: Private 195,365 ha (9,761 farms)
National 115,069 (6,885 farms)
Rented 8,069 (3,891 farms)
Other 3,778 (1,516 farms)

51,904 ha mixed tenany: Private and National 30,478 ha (814 farms)
Private and rented 8,602 ha (998 farms)
National and rented 5,036 ha (714 farms)
Private, national and rented 1,803 (73 farms)
Other 5,985 ha (565 farms)

Fig 3.8

	Private	National	Rented	Other, incl. Mixed tenancy	Area censused
Danli	101751	24901	2711	25589	154952
El Paraiso	19354	2664	383	3072	25473
Trojes	7908	64109	590	2716	75323
San Matias	3907	325	199	1036	5467
Teupasenti	10248	10739	223	10605	31815
Alauca	6424	920	343	991	8678
Morocelli	11426	719	691	2232	15068
Liure	2749	36	358	373	3516
Yuscaran	9045	511	804	2420	12780
Jacaleapa	2791	684	87	271	3833
Oropoli	4230	542	172	862	5806
San Lucas	484	2496	238	968	4186
San Antonio de Flores	922	2301	93	1071	4387
Vado Ancho	1622	122	161	103	2008
Texiguat	5346	7	254	330	5937
Guinope	1600	2187	66	1921	5774
Yauyupe	1719	15	49	193	1976
Soledad	3380	3	608	184	4175
Potrerillos	357	1788	41	742	2928
El Paraiso Dept	195263	115069	8071	55679	

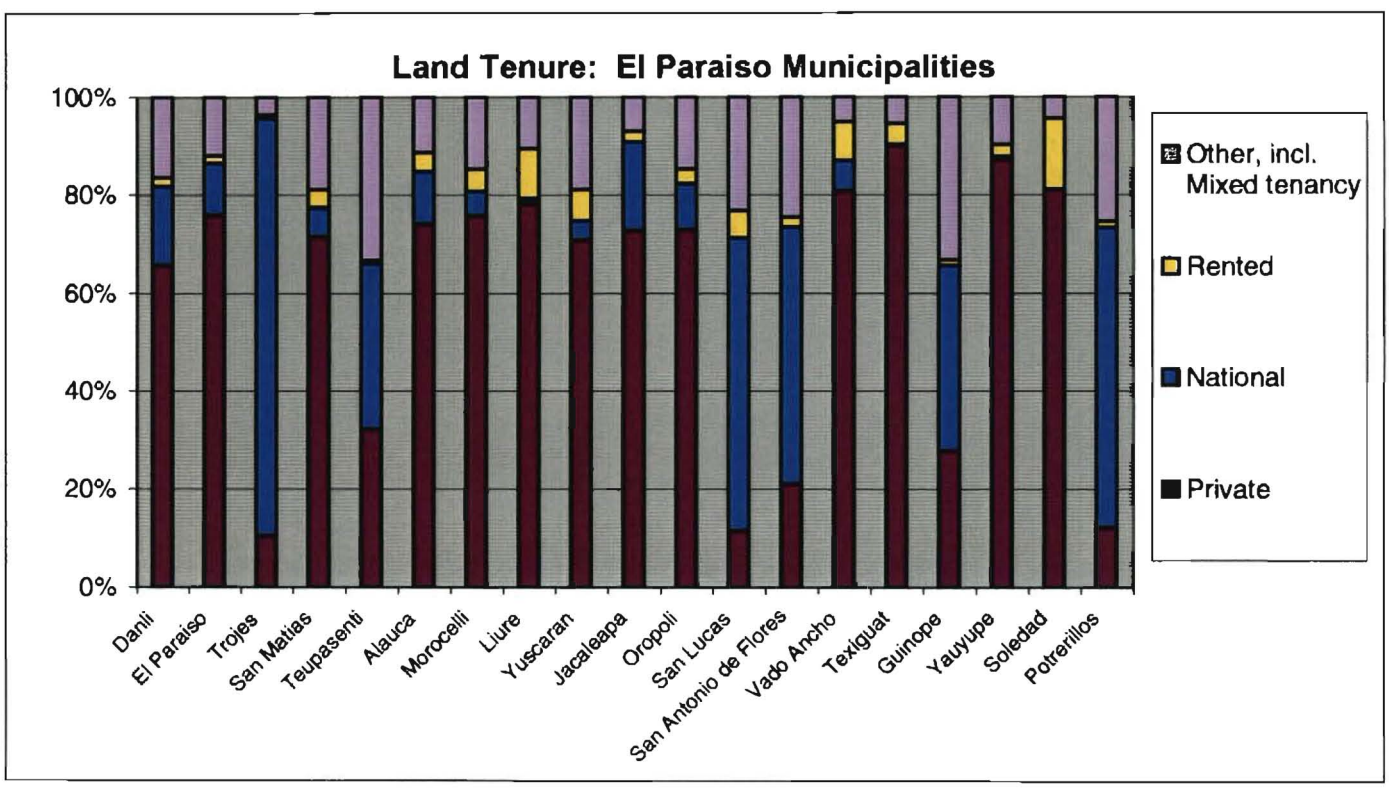


Table 3.8.2: Average size of farms/landuse type for municipalities of El Paraiso:

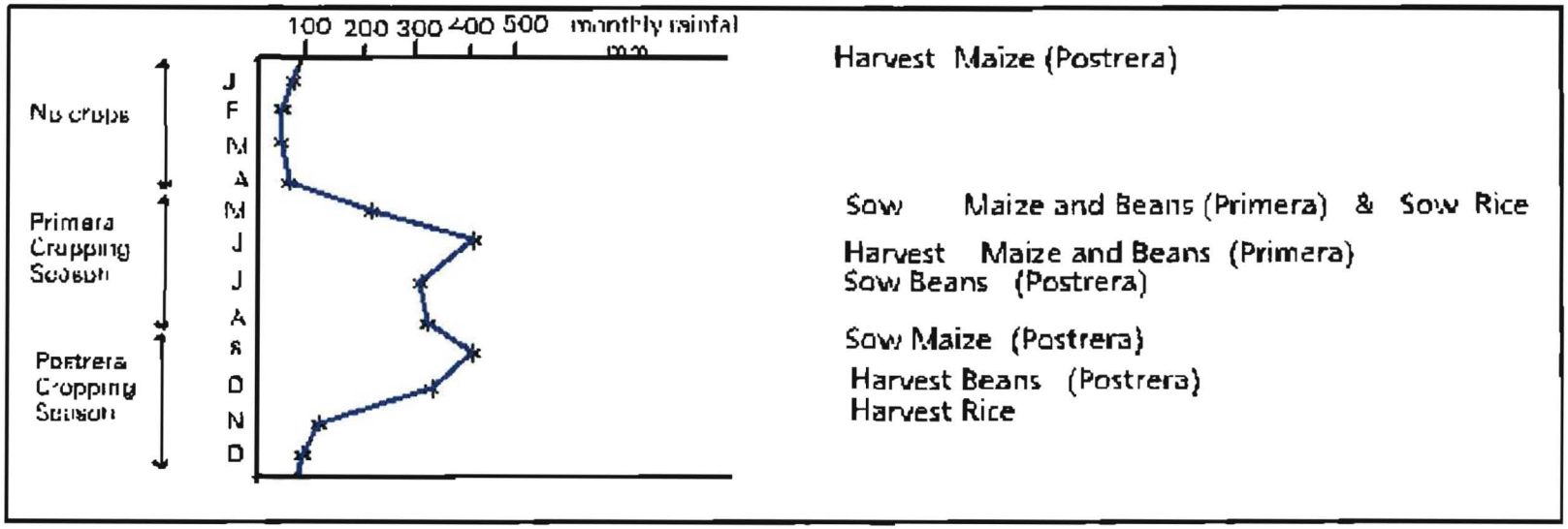
Municipality	Annuals & <1 yr fallow	Perennials	Pasture improved / natural	Scrub fallow (<5yrs)	Forest/tree-lots
Yuscaran	1.9 ha/farm	1.1 ha/farm	21 ha/14 ha	7.5 ha	21 ha
Alauca	1.5 ha/farm	3 ha/farm	20 ha/18.6 ha	17 ha	4 ha
Danli	2.8 ha/farm	3.1 ha/farm	50 ha/28 ha	9 ha	28 ha
El Paraiso	2.4 ha/farm	3.1 ha/farm	50.5 ha/26 ha	8.8 ha	15.3 ha
Guinope	1.3 ha/farm	1 ha/farm	5.3 ha/4.3 ha	2.9 ha	7.5 ha
Jacaleapa	2.4 ha/farm	3.5 ha/farm	11.5 ha/9.1 ha	20 ha	23.4 ha
Liure	1.1 ha/farm	0.7 ha/farm	8.9 ha/4.3 ha	3 ha	3 ha
Moroceli	2.2 ha/farm	2.6 ha/farm	38 ha/19 ha	6.2 ha	25.7 ha
Oropoli	1.5 ha/farm	1.0 ha/farm	13.4 ha/10.5 ha	10.2 ha	9.3 ha
Potrerillos	1.9 ha/farm	1.8 ha/farm	12.4 ha/12.6 ha	3.5 ha	11 ha
San Antonio de Flores	1.4 ha/farm	1.1 ha/farm	14.5 ha/14 ha	9.2 ha	4.9 ha
San Lucas	1.2 ha/farm	0.8 ha/farm	4.9 ha/5.7 ha	4 ha	5.4 ha
San Matias	3.1 ha/farm	0.9 ha/farm	33.4 ha/8.9 ha	7.5 ha	13 ha
Soledad	1.5 ha/farm	1 ha ha/farm	3.7 ha/4.2 ha	4.2 ha	6.3 ha
Teupasenti	1.7 ha/farm	1.8 ha/farm	16.4 ha/12.4 ha	4.8 ha	13.7 ha
Texiguat	1.8 ha/farm	0.8 ha/farm	5.9 ha/7.2 ha	5.7 ha	4.6 ha
Vado Ancho	1.8 ha/farm	0.7 ha/farm	5.6 ha/5 ha	3.5 ha	4.7 ha
Yauyupe	1.5 ha/farm	0.5 ha/farm	5.1 ha/3.4 ha	3.2 ha	4.6 ha
Trojes	3.1 ha/farm	2.8 ha/farm	25.6 ha/12.9 ha	9.5 ha	13.4 ha
Department Average	1.9 ha/farm	1.8 ha/farm	18.2/farm	7.3 ha	11.5 ha

Municipalities with the smallest land-holdings include Liure, San Lucas, San Antonio de Flores, Alauca, Guinope, Oropoli, Soledad and Yauyupe (less than 1.5 hectares in size). The average plot size in Danli is significantly larger, being nearly 3 hectares. Jacaleapa has the largest average farm size for permanent crops. However, the average size is almost identical to annual cultivation.

In Danli municipality the dominant land use is pasture; this is clearly seen from census statistics as well as from the TM classification. The average land-holding size for

Fig 39

Cropping Calendar for Central East Honduras:



improved pasture and forest far exceed that of all the other land use variables censused. El Paraiso municipality has an average pasture holding size of 50 or more hectares. Jacaleapa and Oropoli have average scrub fallow holdings of more than 10 hectares and forest/tree lots average just over 20 hectares in the municipalities of Jacaleapa and Moroceli.

3.9 Cropping Calendar

Figure 3.9 shows the cropping calendar for El Paraiso (Jimenez,P. 1997: Appendix 3). Maize and beans are sown in the primera and postrera seasons of July and September respectively. Rice is also sown in the primera season. This season is very short: maize and beans are harvested only two months after sowing, whereas for postrera crops, harvesting of beans and maize takes place four months after sowing. The maize harvest takes place after the bean harvest, in January.

3.10 Agricultural Land Use

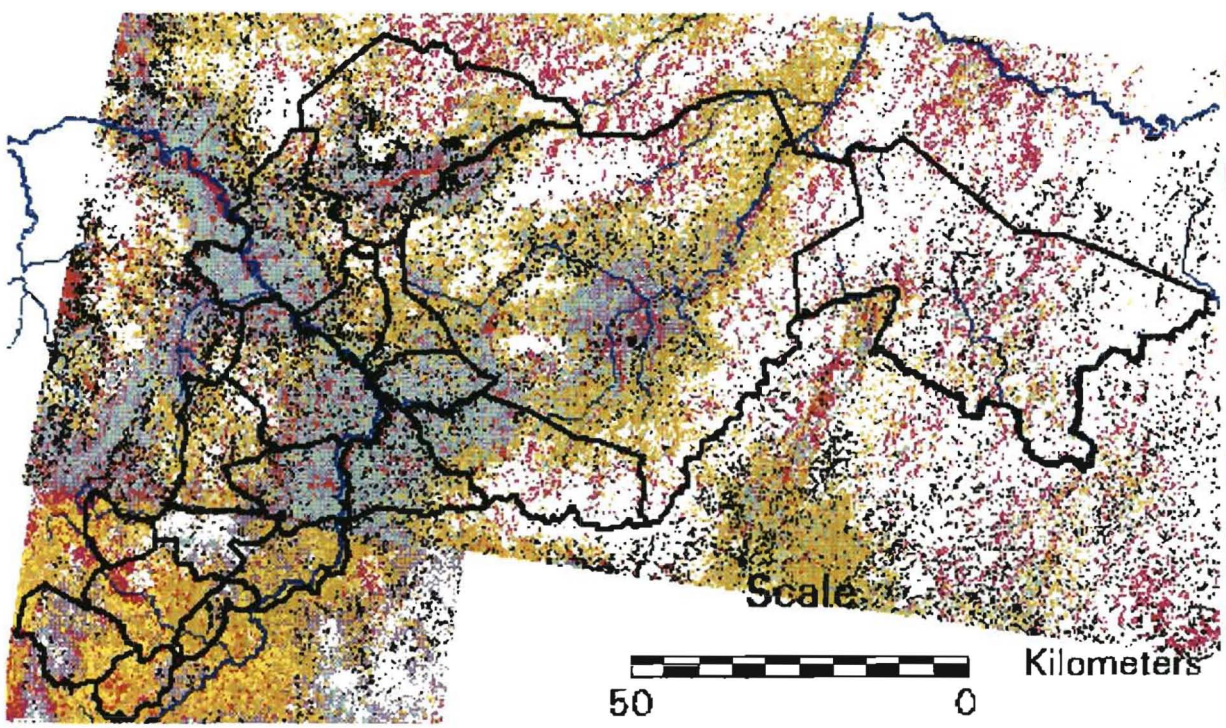
Agriculture appears from the TM classification to be most important in the valley zones under 400 metres of elevation.. Annual cropping in mountainous terrain does not appear to be important here, indicating perhaps greater availability of land. However, it may be that the plots are so small that they are misclassified as disturbed forest or perennial crops (Map 3.10).

The problem of distinguishing between the cover types annual clearing and perennial crops in a forest surrounding, was noticed whist classifying various TM scenes: the spectral signatures of disturbed/brightly sunlit deciduous forest are very similar to those of permanent crops. This may be due to some smoothing done on the original data, as one would think that annual plots would be distinguishable using 32 metre resolution data.

It may be possible to improve the classification by generating further training areas for both perennial plots and annual plots. If not, it may be worth trying to acquire an algorithm to "un-smooth" the data so as to bring it back to its original state which would make the signatures more distinct. (Leclerc, G. personal communication).

There is quite a lot of coffee grown in El Paraiso, especially in the central and eastern areas, where forest cover increases, but this crop is very difficult to map using Landsat TM imagery, or indeed air photographs, due to the presence of shade-trees, but the tree canopy of coffee is relatively smooth as only two or three species of broadleaved trees are planted at the same time – radar imagery may prove to be of potential here, capable of distinguishing canopy smoothness. The project intends to attempt coffee-mapping using remote sensing methods and any map information that can be obtained from the Coffee Corporation.

Agriculture



- Annual Cultivation
- Scrub Fallow
- Perennial Cultivation
- Pasture
- Eroded Bushland
- Settlement
- Recent burn/ intense shadow

Description of Agricultural Land Use Classes:

Annual cultivation

With the exception of Danli and Trojes, the remaining seventeen municipalities have a good proportion of their land under annual cultivation. Danli municipality, the largest of the departments' municipalities, has annual cultivation concentrated in its central valley. Trojes has very little, as it is dominated by pine forest and grazing land. The areas over 1,000 metres largely exclude annual cultivation. The valley-based annual cultivation indicates that fallow periods are almost non-existent or certainly less than a year. The more extensive cultivation on isolated plots which is so characteristic of hillside agriculture in Honduras perhaps has been underclassified in this department owing to the problem discussed above.

Perennial Cultivation

The accuracy of the classification is questionable and there are significant differences in dominance of this land use type between the mosaiced TM scenes. Areas of perennial cultivation in the image classification appear to exclude mountainous regions – except for the municipality of Teupasenti.

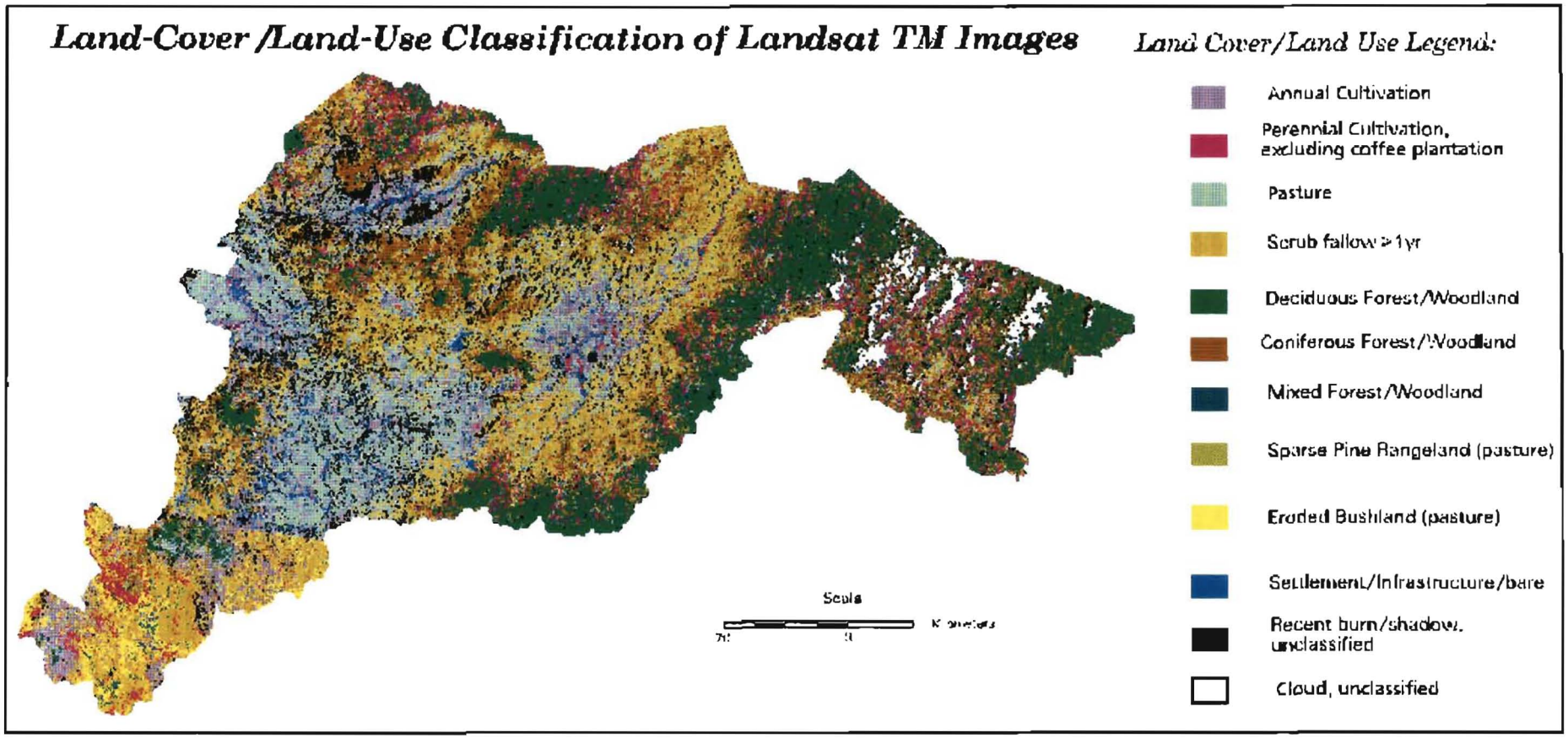
Pasture

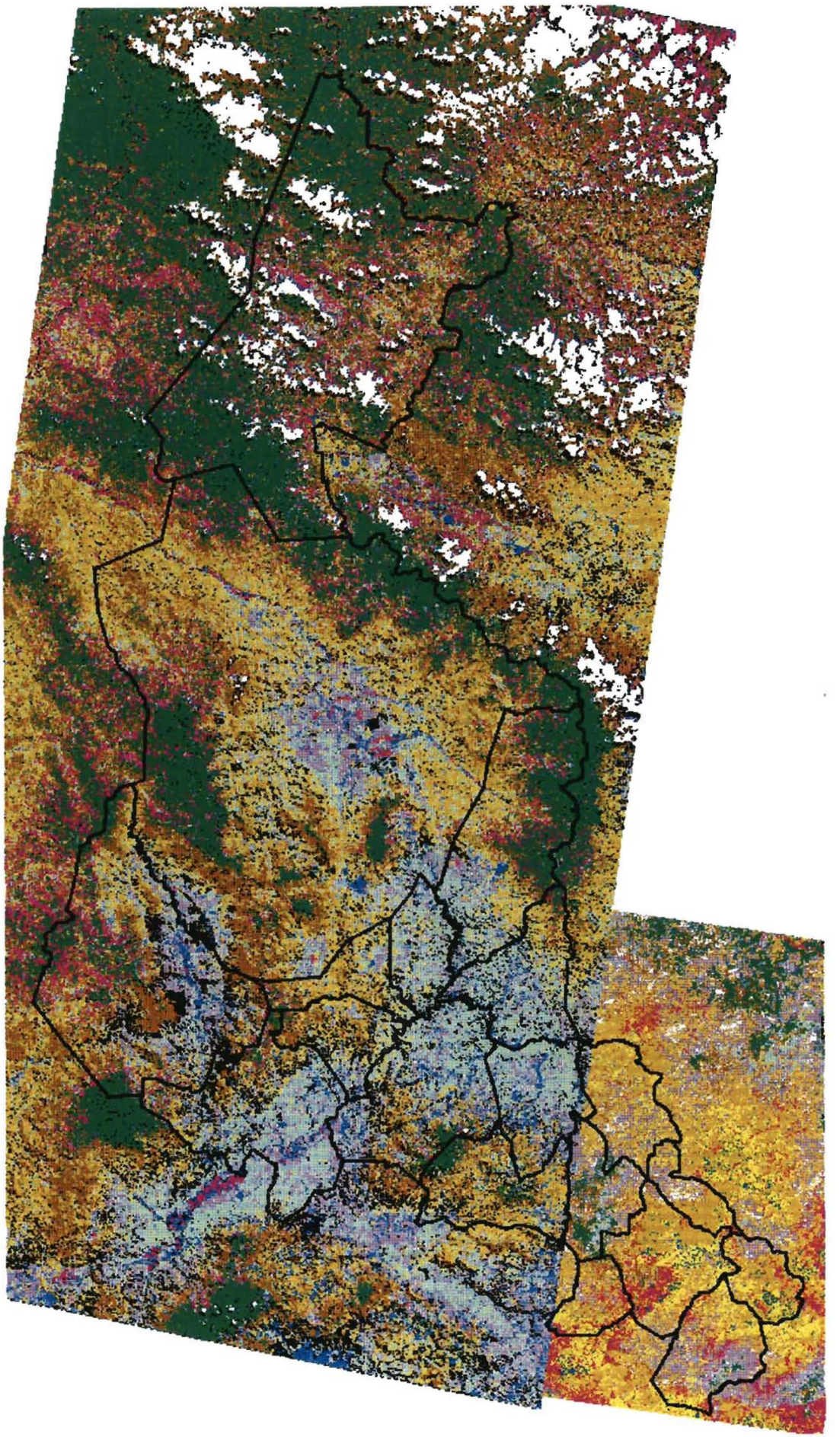
The distribution of pasture, like annuals tends to be concentrated below 1,000 metres, especially in the valley area centered on Alauca, including the municipalities of San Matias, Yuscaran, Oropoli and Alauca and El Paraiso and extending northwest into Morocelli and the valley of Rio Grande o Choluteca. Less dense cover exists in the other municipalities and is possibly underclassified in the southwestern-most municipalities due to the contrasting spectral properties of the older date imagery. The latter has made the mosaicing of the two classified scenes extremely difficult and the apparant mismatch has not been possible to overcome. Pasture appears to be more widely distributed in the municipalities of Danli, Teupasenti and Trojes.

There are two additional land cover classes which represent grazing land:
Sparse pine rangeland cover class has a minimum cover in this department.
and eroded bushland cover class seems to be important in the older 1986/87 coverage of the 'Matagalpa' scene (Path 17/Row 51) but does not occur at all in the 'Danli'scene (Path 17/Row 50). One may conclude that much depends on the climatic conditions that prevailed and hence the density and greenness of the vegetation, prior to image acquisition.

Scrub fallow

This land use type is unequally distributed in the department, being absent from the valley region of Rio Grande o Choluteca, the zones above 1,000 metres and from the central valley region of Danli. In addition, the densely forested areas of Trojes exclude this land cover/land use type. There are some dense areas of scrub in the southwestern region and within the Danli municipality. The spatial distribution of scrub-fallow compared with annual cultivation is very different which suggests that scrub in the TM classification is more likely to be disturbed forest than true fallow.


Land-Cover /Land-Use Classification of Landsat TM Images
Land Cover/Land Use Legend:
Annual Cultivation
Perennial Cultivation, excluding coffee plantation
Pasture
Scrub fallow > 1yr
Deciduous Forest/Woodland
Coniferous Forest/Woodland
Mixed Forest/Woodland
Sparse Pine Rangeland (pasture)
Eroded Bushland (pasture)
Settlement/Infrastructure/bare
Recent burn/shadow, unclassified
Cloud, unclassified
Scale



3.11.1 Land Cover/Land Use (Landsat TM Classification)

(Refer to Maps 3.11.1a and 3.11.1b which is printed at larger scale)

The non-agricultural class-descriptions follow:

Forest Cover

Dense deciduous and mixed forest/woodland is located largely above 1,000 metres of elevation, as is the case in the other two departments, alghough, as mentioned before, extends to lower altitudes in Trojes. Pine forest generally occupies an altitudinal belt below the deciduous zones.

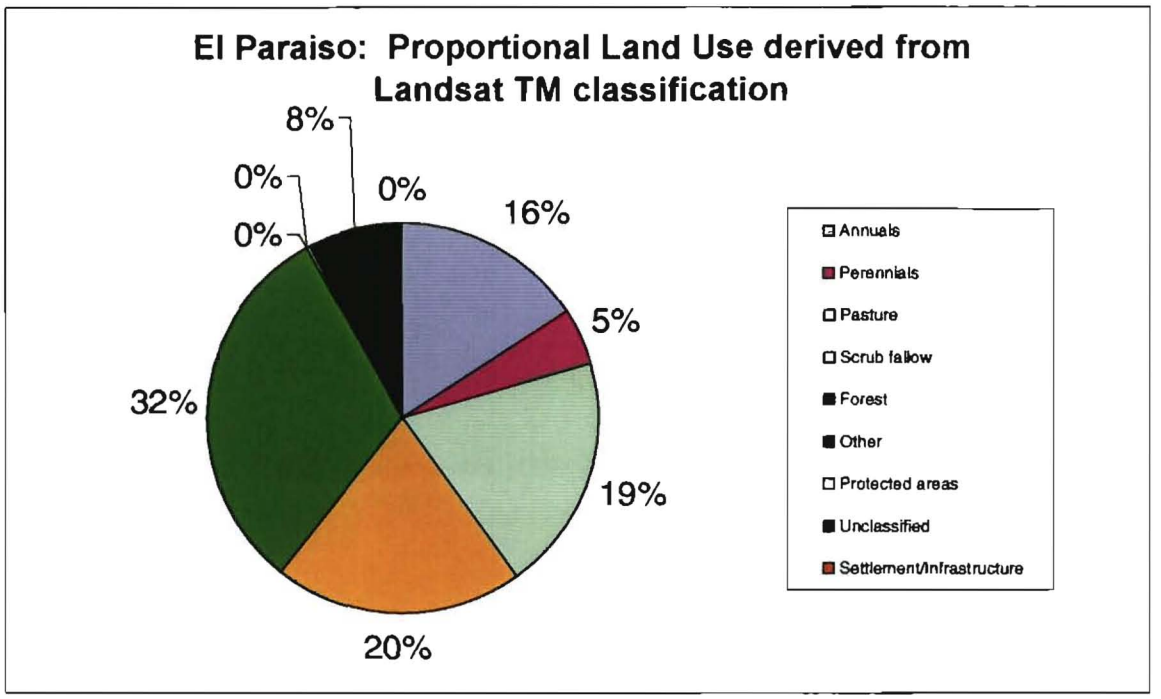
Settlement

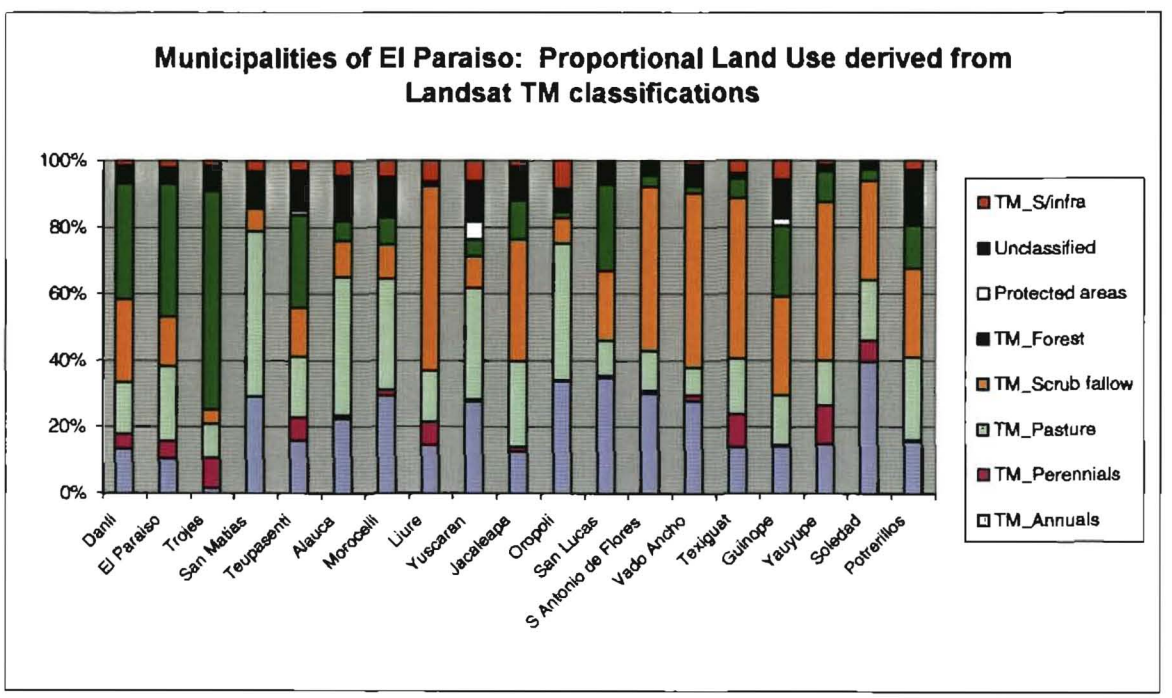
The major settlements, that can be mapped from satellite imagery include Teupasenti, along the Rio Jalan, Danli, a linear stretch of settlement along the valley of Rio Guayambre, El Paraiso and dispersed settlement along the north-south valley through Morocelli, Potrerillos, Alauca and Oropoli.

Burnt fields, intensely shaded, unclassified categories are more noticeable in El Paraiso compared with the Yoro and Atlantida departments. Burning seems to have affected much of the area, particularly in the cultivation zones adjacent to settlement areas. Signs of encroachment are visible within the altitudinal zone above 1,000 m, indicating forest fires, although some of those could also be deeply shaded escarpments. Cloud obscures about 15 to 20% of Trojes, but largely unaffects the remaining area of the department.

3.11.2 Land Cover/Land Use Proportion Estimates

Forest covers 32% of the department according to the Landsat classification estimates. This is perhaps surprisingly low when compared with Atlantida for example. Both the pie chart and the bar graph indicate the importance of agricultural land use. The classes annual cultivation, pasture and scrub fallow appear to have more or less equal proportions of the department area. Scrub fallow varies a lot across the municipalities as does pasture. Annual cultivation is more consistent apart from the municipalities of Trojes, Jacaleapa, Texiguat, Guinope and Jacaleapa and some other which have low percentages of their areas under annual cropping. One would expect some sort of consistency in the dual importance of annuals and scrub fallow since they are part of the same system. However, if one inspects the bar graph, there is not a consistent relationship between the two; some municipalities with more area under annuals may have very little land under scrub fallow and municipalities with minimal areas under annuals may have considerably larger areas under fallow land. It is hoped that the census estimates may provide results which are perhaps more meaningful and consistent.


El Paraiso: Proportional Land Use derived from Landsat TM classification
8%
0%
0%
0%
16%
5%
32%
19%
20%
Annuals
Perennials
Pasture
Scrub fallow
Forest
Other
Protected areas
Unclassified
Settlement/Infrastructure


Municipalities of El Paraiso: Proportional Land Use derived from Landsat TM classifications
100%
80%
60%
40%
20%
0%
Danli
El Paraiso
Trojes
San Matias
Teupasenti
Alauca
Morocelli
Liure
Yuscaran
Jacaleapa
Oropoli
San Lucas
S Antonio de Flores
Vado Ancho
Texiguat
Guimope
Yauyupe
Soledad
Potrerillos
TM_S/infra
Unclassified
Protected areas
TM_Forest
TM_Scrub fallow
TM_Pasture
TM_Perennials
TM_Annuals

CHAPTER 2

LAND CHARACTERIZATION OF STUDY AREAS IN HONDURAS.

II Land characterization of Study areas in Honduras

1. Atlantida study areas: San Francisco de Saco, Arizona and La Masica, La Masica.

1.1 Location

The San Francisco de Saco study area is the smallest of the study areas, located in the municipality of Arizona, consisting of the watershed of the Rio de Saco, tributary of the Rio Lean. The watershed covers an area of 1,200 hectares and extends from the Cerro Pico de Botella southeast and east to the north-south section of the coastal road between Tela and La Ceiba. The study area lies between lines of latitude 15 41' N and 15 45'N and between lines of longitude 87 17' W and 87 23' W.

The second study area of Atlantida department is in the watershed of the Rio Cuero which covers an area of 20,000 hectares in the municipality of La Masica, between lines of latitude 15 31' N and 15 38' N and between lines of longitude 87 03 W and 87 08 W. this study area lies about 1.5 kilometers south of La Masica, southward for about 10 kilometers (Map I_1.1 and Poster Map 6).

1.2 Climate

The San Francisco de Saco (SF de S) study area is located within the Lz climatic zone (Andrade, 1983). Unlike the other study areas, the climate is very wet with a regular distribution of rain. this climatic zone extends from sea level to the foot of the mountain slopes of the Cordillera de Nombre de Dios. The wettest months are October and November. The average annual rainfall is 2,900 mm (Map I_1.2) with, on average, 190 days in the year having rain. A reduction in rainfall occurs between March and May, with monthly totals of 1,500 mm (Map I_1.2). The average temperature is 26 C with a maximum of 29 C and a minimum of 19 C. The annual range of temperature is only 7 C. Humidity is high all year round.

The climate of La Masica study area is characterized by two rainfall regimes: Lz and Lk classes ie. 'very wet with regular annual distribution' and 'very wet, tropical' climate in the southwest. Most of the rain falls between October and November. The Lz climate has a dry season during April and May and the Lk climate has one between March and April. For the southern half of the study area, the climate Lk is described as follows: the wettest months are October and November. The average annual rainfall totals 2,900 mm rising to 3,100 mm in the higher mountain slopes of the Cordillera de Nombre de Dios. The rainy season may last eleven months within this zone. The least wet months are March and April. the canicula appears to be a little more marked in this municipality, occuring in the month of July in the lower areas and in August in the higher altitude zones (Fig I_1.2).

1.3 Geology

The SF de S study area has two geologies, split more or less down the centre of the study area: the western portion, ie. the upland zone, and is composed of intrusive granites, granodioirtes, diorites (Ki) and the eastern portion is composed of recent sediments (Qal, Map I_1.3).

There are two geology types within the study area of La Masicz and they coincide more or less with the upland/lowland division. The coastal plain is composed of recent sedimentary rocks (Qal) and the upland portion is composed of Palaeozoic Cacaguapa Shcist: a metamorphic basement complex made up of sericitic and graphitic schists, phyllites, gneisses, quartzite, marble and thick quartz veins and lenses (Map I_1.3).

1.4 Topography and Drainage

The general terrain is rolling to mountainous for much of the SF de S watershed, although the elevation is considerably less than in the other study areas. Maximum elevation is 737 metres in the wouthwest at Cerror Pico de Botella and Cerro Tiburon (230-551 m altitude along the northern boundar and the altitude of these hills drops to 135 metres at the coastal plain/road junction. The average elevation of the coastal plain to the east of the study area is 15 metres above sea level.

The Rio Cuero watershed rises from 20 metres at the coastal plain level in the north to 948 metres in the southeast and 788 metres in the southwest sector. The southern cut-off point is just to the south of San Marcos, where the altitude is 255 metres. The majority of the watershed lies between 100 metres and 700 metres and is typically hilly and steeply dissected. Slopes area generally steeper to the east of the Rio Cuero. The rio Cuero is one of the main rivers driaing off the cordillera - the volume of rocks on the river bed suggests seasonal flash-floods (Map I_1.4).

1.5.1 Soils - Simmons' Classification

Most of the upland zone of SF de S study area is characterized by Toyos soils. These are deep well drained latosols, yellow-brown silt loams and silty clay loams with a pH of 6 on slopes of between 20 and 40 percent. The northeastern third of the watershed is dominated by well-drained fine textured alluvials (Map I_1.5).

The majority of the La Masica study area is composed of Tomala Latosols. These area shallow well-drained silty loams. They are very acid with a pH of 5, yellow brown in colour and found on steep scarp slopes of 60% These are susceptible to erosion and are of limited agricultural value. For general cultivation, extreme conservation measures area necessary. The area also includes classes As and Sv which are poorly-drained fine textured alluvials and valley soils respectively (Map I_1.5).

1.5.2 Soils : Leforrest Miller Classification

This map has similar class boundaries as the Simmons' classification, but also includes a third class in the extreme southwest of the SF de S watershed: UHTa-3, Typic Tropohumults and associated soils from acid igneous or metamorphic rocks, in mountainous terrain. The central portion is composed of UATa-1, Umbric Tropuquults and associated soils from old alluvium, on level terraces. The eastern part which coincides with the valley is composed of EAFh-1. Tropic Fluvaquents and associated soils from alluvium, on level plains. The soils of the upper slopes are characteristically shallow to moderately deep, well drained and acid with pH5. Texture is a friable silt-loam or clay. The soils of the footslopes, covering the greater part of this watershed are characteristically deep, poorly drained and moderately to very acid. They are very dark grey or black friable very fine sandy loams and silt loams. The clay-loam to silty clay soils of the valley zone are moderately well to well drained, subject to brief annual flooding.

The prdominant soil class in the La Masica study area is UHTa-3 with a small area of EAFh-1 near the coastal plain boundary. The former soils are Typic Tropohumults and associated soils from acid igneous or metamorphic rocks, on rolling to hilly topography. They are shallow to moderately deep and well drained. Soil acidity is pH 5, texture ranges from friable silt loam to friable clay loam and clays. The other soil type is the Tropic Fluvaquents and associated soils, derived from alluvium on level plains. Soil texture is a clay loam to silty clay loam and very fine sandy loams. Soils are moderately well drained but subject to brief seasonal flooding.

1.6 Natural Resources and Forest Montoring

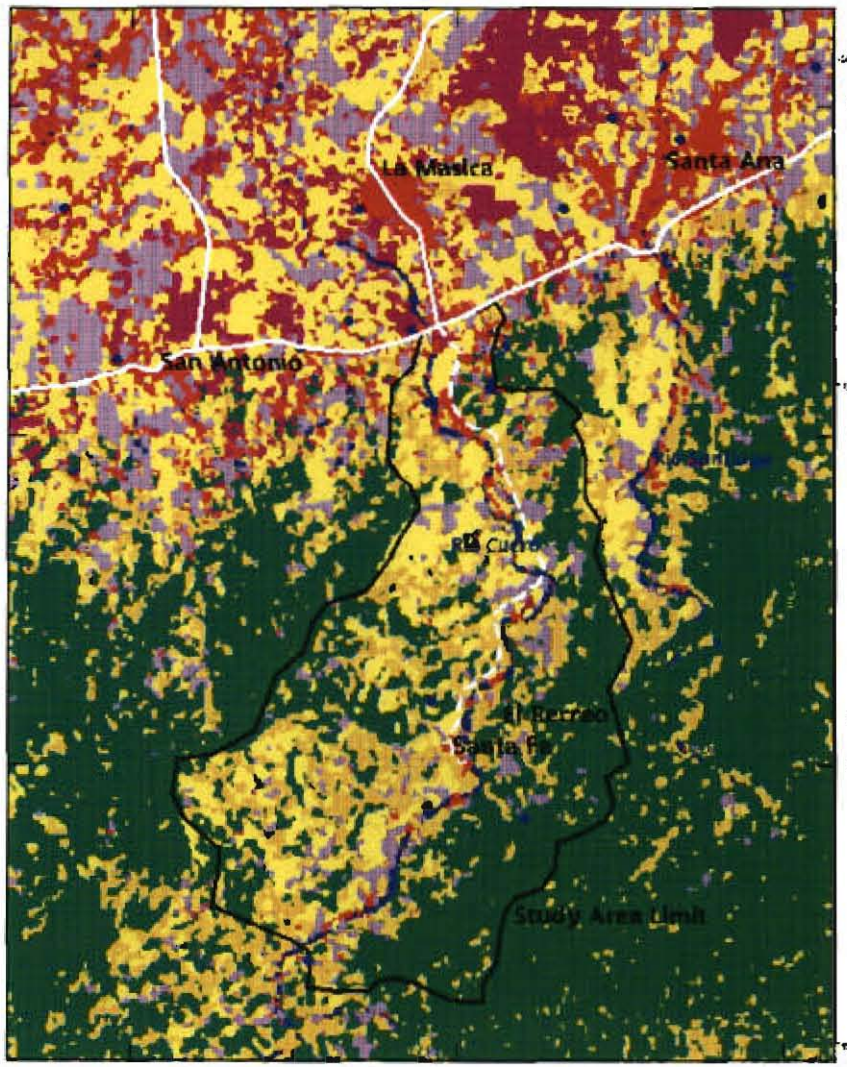
There are no protected areas within the two study areas in Atlantida. Deciduous forest covers 13% (158 hectares) of the SF de S study area and 35% (1412 hectares) of La Masica watershed (Maps I_1.6.1 and 1.6.2). From maps II_1.11.1 and 1.11.2 it is possible to gain some idea of the extent of deforestation in the two watershed between March 1987 and March 1994 (a seven year time lapse).

Deforestation is clearly seen in the SF de S study area being most noticeable along the northern boundary of the watershed which has been opened up for annual cultivation. Also substantial areas have been cleared in the headwaters of the Rio de Saco and in the central part of the study area. Land use to the east of the road appears to have intensified with greater settlement areas and permanent crops/citrus plots as well as improved pasture (Map 1.11.2).

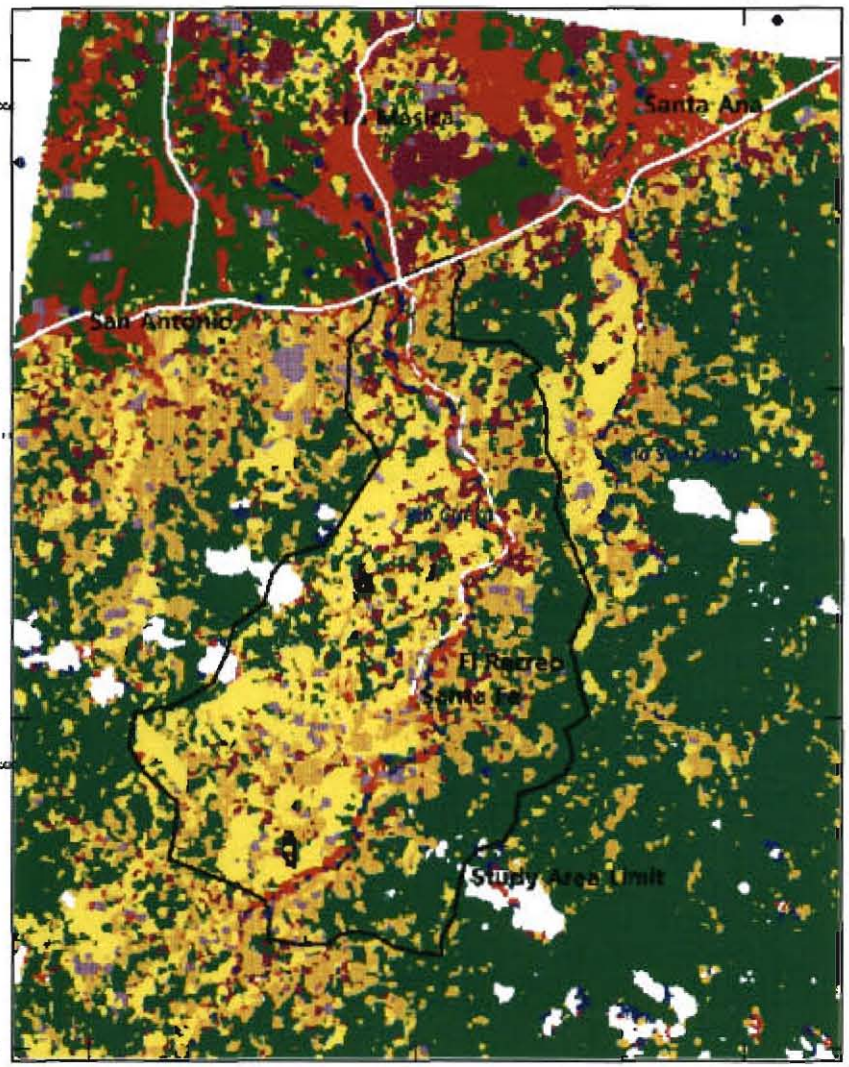
La Masica study area (Map 1.11.1) also shows marked deforestation during the same period. Clearance of forest has taken place both sides of the Rio Cuero, perhaps being most noticeable in the vicinity of El Recreo and Santa Fe. The coastal plain section has been classified as improved pasture in 1994, having been a combination of natural pasture and annual cultivation in the earlier date of 1987.

Land Use Classifications of La Masica Study area, La Masica, Atlantida, using multi-date Landsat TM data.

Landsat TM, 18 March 1987



Landsat TM 5 March 1994



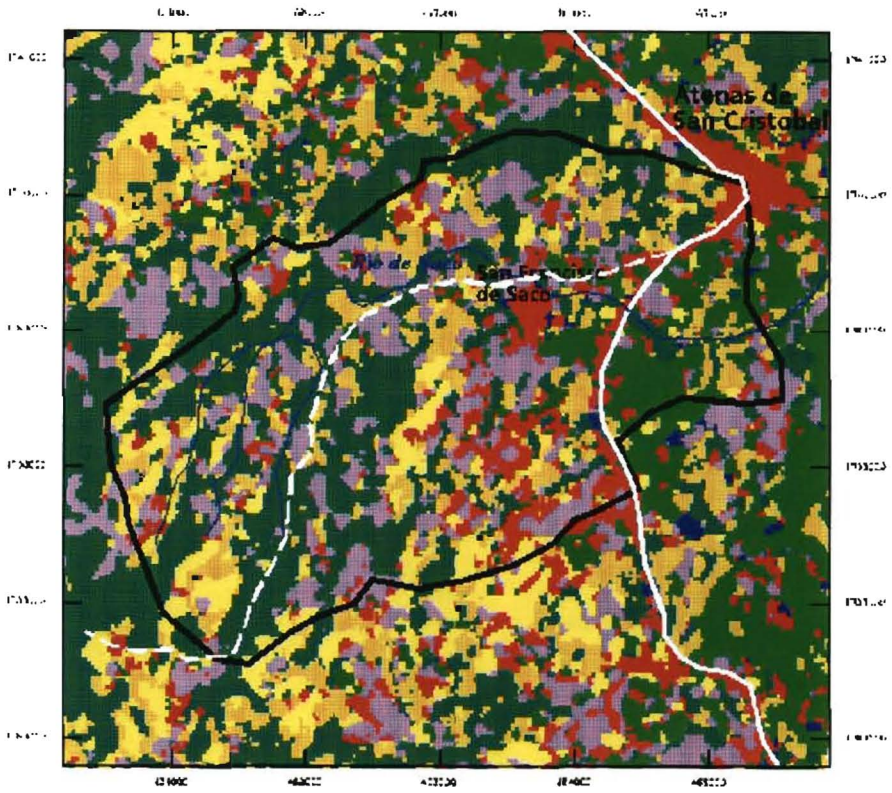
(Refer to Common Legend for Land Cover/Land Use Classes)

Air Photographs available of study area dated 15 Feb 1987 at 1:20,000 scale.

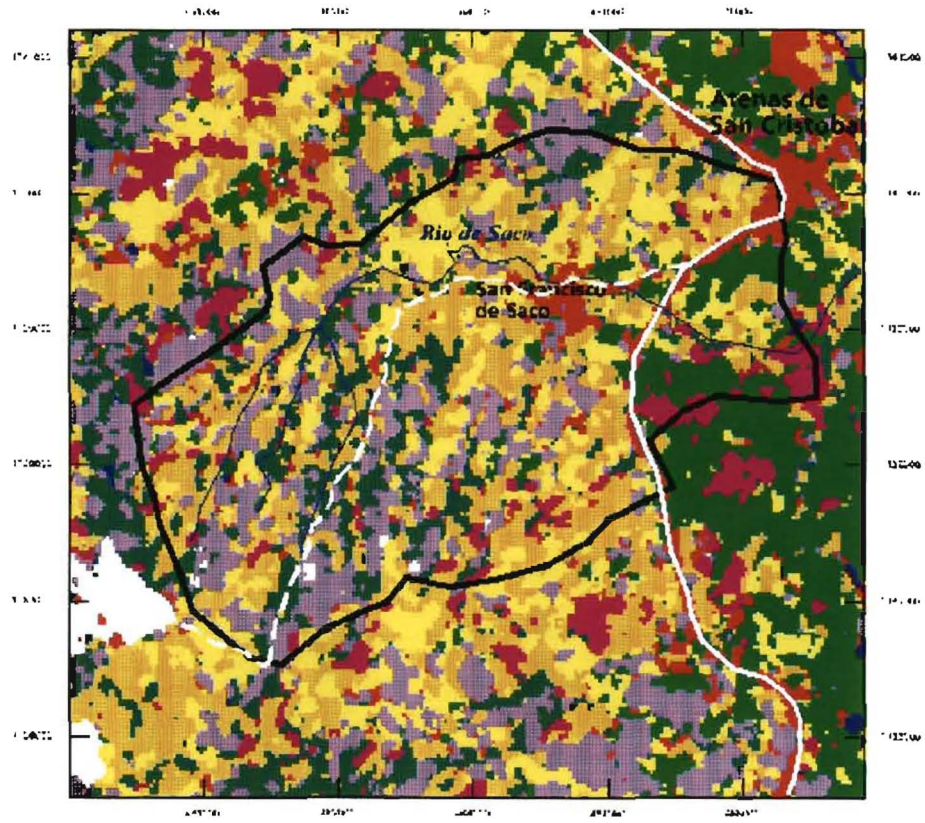
Scale

Land Cover/Land Use Classification of San Francisco de Saco Study area, Arizona, Atlantida, using multi-date Landsat TM data.

Landsat TM, 18 March 1987



Landsat TM 5 March 1994



(Refer to Common Legend for Land Cover/Land Use Classes)

Air Photographs available of study area dated 15 Feb 1987 at 1:20,000 scale.

Scale

Kilometers

0

Signature Editor (Mas87SA_rev.sig)

File Edit View Evaluate Feature Classify Help

Class #	>	Signature Name	Color	Value	Order	Count
1	>	Class 6_Deciduous forest		6	7	141
2		Class 6_Deciduous_2(shaded)		6	8	177
3		Class 2_ Perennial tree crops		2	3	384
4		Class 2_Plantation land		2	4	61
5		Class 4_unimproved pasture		4	5	224
6		Water		13	10	142
7		Class 2_Horticulture		2	2	89
8		Class 5_scrub fallow		5	6	310
9		Class 1_annual clearings		1	1	429
10		Class S		11	9	285

Signature Editor (SFran87rev.sig)

File Edit View Evaluate Feature Classify Help

Class #	>	Signature Name	Color	Value	Order	Count
1	>	Class S and homesteads		11	12	103
2		Class W		13	13	69
3		Class 1_annuals, sunlit		1	2	247
4		Class 3_wet grassland		3	4	128
5		Class 3_Improved pasture		3	5	123
6		Class 4_unimproved pasture		4	6	210
7		Class 6_Deciduous forest, deeply shaded		6	9	257
8		Class 5_Scrub fallow, shaded		5	7	68
9		Class 5_Scrub fallow, sunlit		5	8	359
10		Class 6_sunlit		6	10	106
11		Class 6/2, incl. cocoa		2	3	298
12		Class 10_eroded bushland/shaded annual clearances		1	3	257

Signature Editor (Mas94_SArev.sig)

File Edit View Evaluate Feature Classify Help

Class #	>	Signature Name	Color	Value	Order	Count	Prob.	P	I	H	A
1	>	cloud		17	10	172	1.000	X	X	X	X
2		Mask_cloud shadow		17	11	247	1.000	X	X	X	X
3		Class2_horticulture		2	2	98	1.000	X	X	X	X
4		Class2_perennial tree crops		2	3	152	1.000	X	X	X	X
5		Class1_annual clearings		1	1	172	1.000	X	X	X	X
6		Class3_Improved pasture		3	4	397	1.000	X	X	X	X
7		Class6_Deciduous forest		6	7	2237	1.000	X	X	X	X
8		Cloud fringe1		17	12	54	1.000	X	X	X	X
9		Cloud fringe 2		17	13	96	1.000	X	X	X	X
10		Class water2		13	9	32	1.000	X	X	X	X
11		Class S/homesteads		11	8	444	1.000	X	X	X	X
12		Class 4_rough grazing		4	5	400	1.000	X	X	X	X
13		Class 5_scrub fallow		5	6	855	1.000	X	X	X	X

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Class #	>	Signature Name	Color	Value	Order	Count	Prob.	P	I
1	>	Mask_water1		13	13	46	1.000	X	X
2		Class 1_Annuals,densely shaded		1	3	260	1.000	X	X
3		Class cloud fringe		17	14	67	1.000	X	X
4		Class cloud shadow		17	15	106	1.000	X	X
5		Class cloud		17	16	92	1.000	X	X
6		Class 1_annuals, shaded		1	1	95	1.000	X	X
7		Class 6_deciduous Forest, shaded		6	10	429	1.000	X	X
8		Class 3_improved pasture with trees		3	5	197	1.000	X	X
9		Class 3_dry improved pasture		3	6	444	1.000	X	X
10		Class 4_unimproved pasture		4	7	97	1.000	X	X
11		Class 4_upland grazing		4	8	51	1.000	X	X
12		Class 5_scrub fallow		5	9	311	1.000	X	X
13		Class 1_annuals		1	2	144	1.000	X	X
14		Class S/homesteads		11	11	276	1.000	X	X
15		Class S/roads		11	12	87	1.000	X	X
16		Class 6_Deciduous forest +cocoa		2	4	225	1.000	X	X

1.7 Settlement and Infrastructure

Atena de San Cristobal is located at the north-east corner of the SF de S watershed. San Francisco de Saco is about 1.5 kilometers west from the eastern boundary of the study area. The 1988 population census includes only two aldeas in the central area. the 1988 population census includes only two aldeas in the central area, the eastern aldea being La Guadalupe and the other aldea is unlabelled (Poster Map 6). The coastal road enters the eastern portion of the study area and then a track continues to San Francisco de Saco and leads up into the hills of the southwest. Although this is a small area, accessiblity was regarded as a problem when this site was visited for fieldwork in November 1996. The terrain if not steep is dissected and irregular.

Apart from the main coastal route, the La Masica study area has a navigeable road along the eastern bank of the Rio Cuero. It is accessible as far as San Marcos, but during the rainy season may not be passable beyond El Recreo: in November 1996, it was only possible to reach El Recreo as there was a road block further south caused by a landslip, triggered by heavy rainfall. There are scattered settlements along the Rio Cuero including Le Cumbre, Santa Fe and Rio Santiago as well as El Recreo and San Marcos. They area all relatively small. Five aldeas were censused in the 1988 population census: Lombardia, Piedras de Afilar, El Recreo and Jutiapa on the southern boundary of the watershed. the fifth was unlabelled and is centrally located on the left river bank (PosterMap 6).

1.8 Land Tenure (See Section I_1.8)

1.9 Cropping Calendar (See Section I_1.9)

1.10 Agricultural Land Use

From visual inspection of the classified TM subset image of SF de S study area (Map II_1.11.2), dated 1994 it was possible to conclude that the dominant land uses are fallow and pasture, the latter class including three sub-classes: pasture, pasture including weeds and scrub and wetland pasture (Figure I_1.11.1). In the hilly zone, ie west of the road, annual cultivation and perennial crops cover a greater area, being concentrated in the lower slopes, nearest to the river channels and gullies. An observation made is that those areas classified as perennials in the mountain slopes may in fact be mature annual crops, as the cropping season in humid Atlantida is elongated compared with the other study areas. the perennial cultivation class may better be described to include 'smallholder crop.

1.11.1 Land Cover/land use (See Section II_1.6)

Classification problems experienced: The maximum likelihood classification, based on TM image dated 5/3/94, was produced prior to the fieldwork visit of November 1996. A revision of this classification was not possible as the observations made were at reconnaissance level only. This was primarily due to restricted access and the rainy weather. A more dependable classification result perhaps is the classification of the older TM image data of 18 March, 1987, as the air photographs of the study area were also of that same year, making cross reference and validation a possibility. Most of the land use classes were subdivided in order to include the variations of spectral signature for a given class due to different lighting conditions and marked relief shadow.

Pasture was a difficult land use class to map and it is just about impossible to separate improved from natural pasture. However, a subdivision was made between predominant grass swards and pasture including weeds and low shrubs. In addition, marshy land and pasture was mapped but these classes are changeable due to fluctuations in surface water. Indeed, likely seasonal changes in land cover should be taken into account especially when comparing imagery of different dates.

Other land cover/land use classes which were classified with less of a problem include scrub fallow, deciduous forest/woodland, homesteads and settlement and open water.

A Comparison between the classification results of 1987 and 1994 images:

In this study area of La Masica, improved pasture has become dominant in the coastal plain, which is backed up by the findings of S. Humphries (1994). Humphries noted that previously annual cultivated lands have been taken over by richer landowners and converted to pasture.

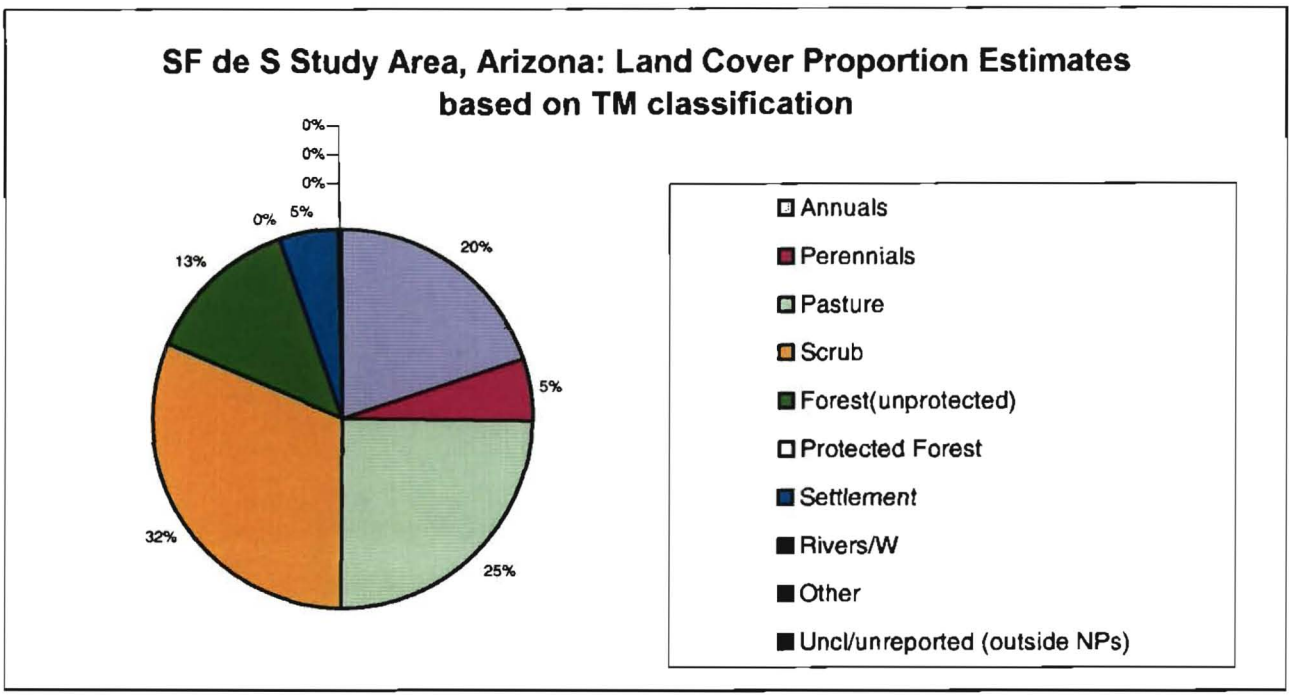
Plantations have increased in the coastal plain, including the oil palm and orange plantations. The pasture classification of the 1994 scene is more dominant than in 1987 where it seems to be more evenly mixed with scrub fallow land (Map 1.11.1).

Forest cover shows considerable reduction between the two dates, due to annual cultivation, timber and fuelwood demands. Most of the developement in the watershed has occurred on the western side of the Rio Cuero, due presumably to a more favourable aspect for cultivation.

Both TM images were acquired in the month of March, when the maize crop is maturing and the mucuna beans/abonera system have just been planted. So some fields may have been partially bare still. This makes the classification of annual cultivated lands more difficult due to the variation in cover densisty ie. partially bare, young crop and mature crop.

1.11.2 Land Cover/land use Proportion Estimates

Fig 1.11.2


SF de S Study Area, Arizona: Land Cover Proportion Estimates based on TM classification
0%
0%
0%
0%
5%
20%
13%
5%
32%
25%
Annuals
Perennials
Pasture
Scrub
Forest(unprotected)
Protected Forest
Settlement
Rivers/W
Other
Uncl/unreported (outside NPs)

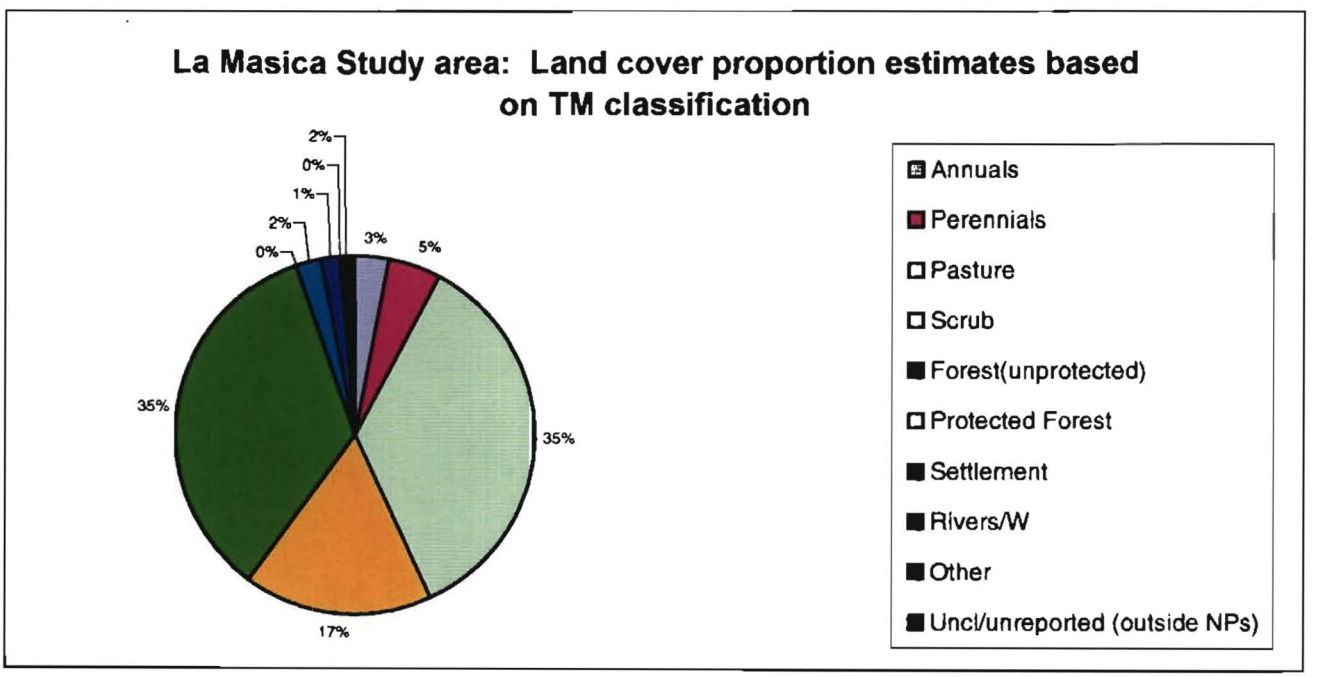

La Masica Study area: Land cover proportion estimates based on TM classification
2%
0%
1%
2%
0%
3%
5%
35%
35%
17%
Annuals
Perennials
Pasture
Scrub
Forest(unprotected)
Protected Forest
Settlement
Rivers/W
Other
Uncl/unreported (outside NPs)

Figure 1.11.2 summarizes land cover proportions for the two study areas in Atlantida, using TM classification of the more recent 1994 data. In SF de S study area pasture and annual cultivation appear to have equal areas whereas in La Masica study area pasture occupies much more land area. Forest cover has been most reduced in the SF de Saco study area, La Masica study area still possessing more than a third of its area under forest.

2. Yorito Study Area: Land Characterization

2.1 Location

The watershed strides the municipalities of Yorito and Sulaco, in Yoro Department in west-central Honduras (Maps 2.1 and 3.6). The study area covers an area of 12,275 hectares. This could be underestimated by up to 20% due to the relief effect (Byne, S., 1996). The area is situated between lines of latitude 14 56' N and 15 10'N and between lines of longitude 87 10;W and 87 23' W.

2.2 Climate

The area is classified as Vx, 'Lluvioso de Altura' (Andrade, E.Z., 1985). It is an intr-montane sub-climate corresponding with the central part of the country. Annual precipitation varies from between 1,600 mm and 2,000 mm in the mountains and somewhat less on the plains. June and September are the wettest months. The dry season extends between November and April, February and March being the driest months (Map I_2.2 and Figure I_ 2.2).

2.3 Geology

The major part of the watershed is composed of a sequence of lithologically heterogeneous reedbeds consisting of mudstones, shales, sandstones, conglomerates and limestones (Kva-Valle de Angeles Group). The northwestern mountains are composed of ccalcareous marine rocks including well stratified massive shales, calcareous shales, calcareous calcarenites, marls and dolomite (Ky - Yojoa Group). Another area of contrasting geology lies to the north of the study area - recent continental and marine sediments including talus deposites, gravel terraces, flood plain deposits and alluvium (Qal class , Kozuch, 1991) (Map I_2.3).

2.4 Topography and drainage

The general topography of the watershed is mountainous, elevations rising to 1,638 metres in the west and 1,418 metres in the east. However, about half of the area has an elevation lower than 800 metres, comprising the valleys and lower hills in the central zone (Map I_2.4 and Poster Map 14). The distribution of slopes is as follows:

Slope (degrees)	Slope (%)	Area (hectares)	% of the study area
0-9	0-20	1,417	11.5
10-19	20-42	2,627	21.4
20-29	42-64	4,124	33.6

30-39	64-87	2,455	20
40-49	87-109	1,110	9
50-59	109-131	392	3.2
70-79	131-175	18	0.1
80-89	175-198	7	0.06

The Rio Tascalapa flows south into the Rio Sulaco which flows westward, draining into the El Cajon reservoir which outflows as the Rio Comayagua which flows into the Rio Ulua and finally enters the Caribbean coast.

2.5.1 Soils - Simmons' Classification

The study area is composed of three soil classes: Ja - Jacaleapa lithosols in the eastern mountains; Chi: Chimbo lithosols in the foothill zone of the eastern mountains and central valley; Su: Sulaco rendzinas in the western footslopes and mountainous area of the northwest. Generally soil acidity decreases in an east-west direction. Effective soil depth is generally shallow. The Jacaleapa and Sulaco soils area dark brown but the Chimbo soils are reddish brown in colour. Texture varies between silty-loams and silty-sands of the lithosols to clays of the rendzinas (Map I_2.5).

2.5.2 Soils - Leforrest Miller Classification

The central valley is characterized by ITYe-1 soils. To the east and west are TYf-2 soils. Soil class ITUa-1 just clips the watershed in the north. the soils are as follows: ITYe-1: Oxic Dystropepts and associated soils from old alluvium on dissected terraces; ITYf-2: Lithic Dystropepts and associated soils from acid igneous or metamorphic rocks on mountains; ITUa-1: Typic Ustropepts and associated soils from old alluvium on terraces. A reconnaissance survey of soils was made within the watershed zone along a NW-SE transect. A soil report including soil profile descriptions was produced by R. Vaquero, L. Brizuela and J.A. Cox, 1997

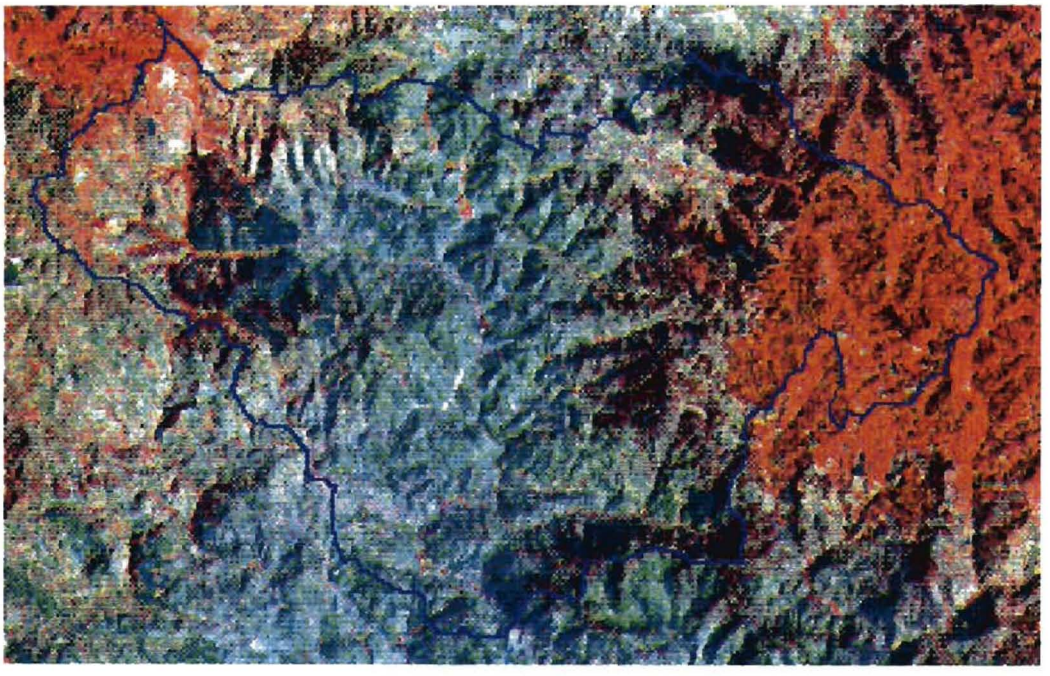
2.6.1. Natural Resources

Within the watershed zone, the deciduous forest is confined to the western and eastern portions of the highest elevation zones. The national park, Montana de Yoro is located east of the study area. The forest block of the northwest becomes more continuous just outside the study area, above Mina Honda. This forest includes some areas of Liquidamber which used to be more abundant in Honduras. The majority of the forest cover inside the study area of planted shade trees for perennial cultivation of coffee. Map I_2.6.2 does not indicate very mucy deforestation, which is confirmed when one refers to Maps 3.1.2 and 3.6. The two images acquired eight years apart look identical apart from some differences in shading/burnt areas. This shows that the population pressure on natural resources is not as grave as one might imagine. Some deforestation is apparent however in the northwestern border of the watershed where some agricultural intensification has taken place. But dense forest areas remain the same in both dates.

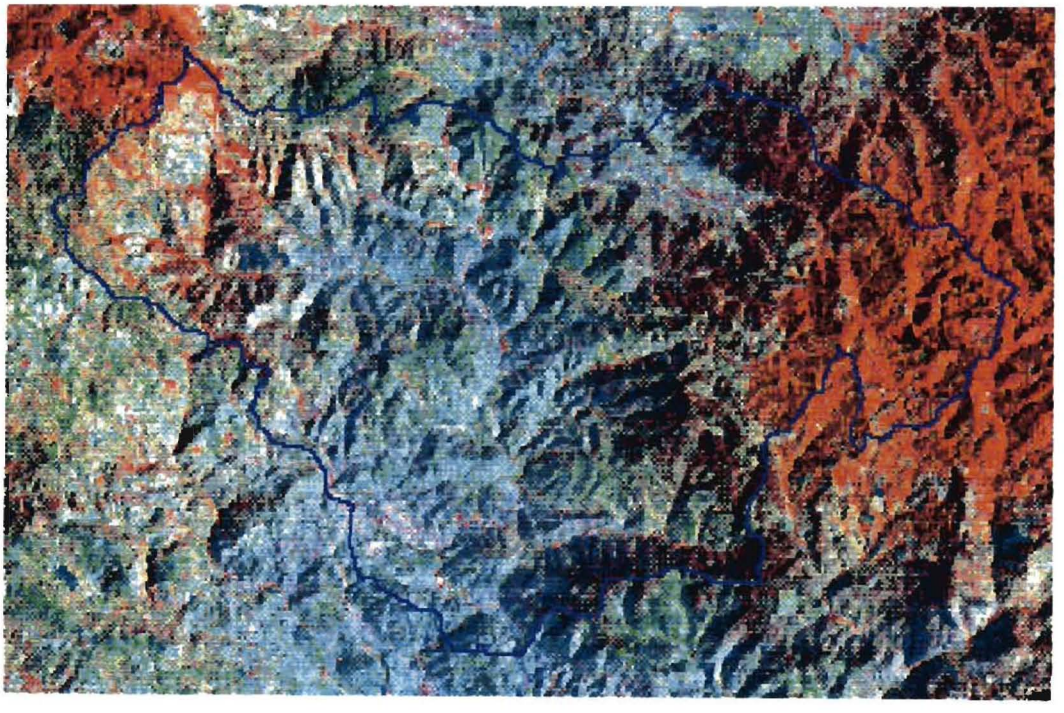
2.6.2 Forest Monitoring

The two dates of TM imagery are presented in Map 2.6.2 (false-colour sub-scenes) and Map 2.6.3 (classifications). The classification map indicates most of the change in land

Landsat TM False Colour Composites of the Yorito Watershed for dates 15 March, 1986 and 8 March, 1995



1986

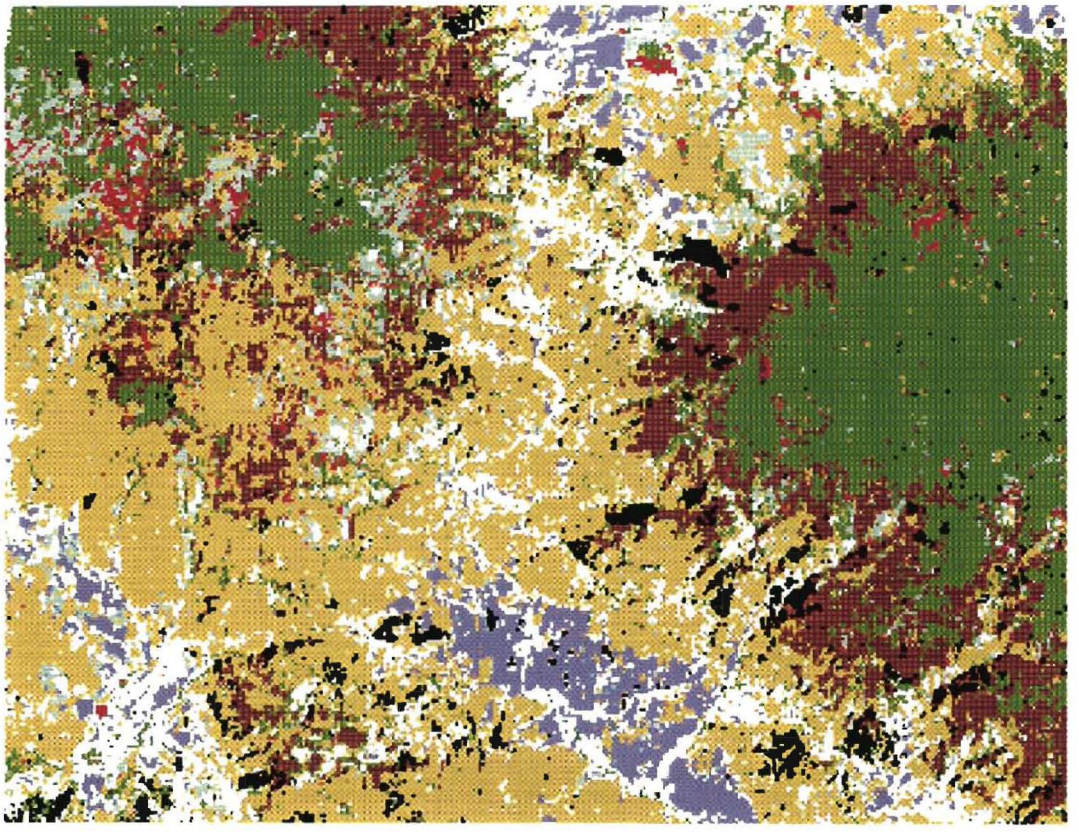


1994

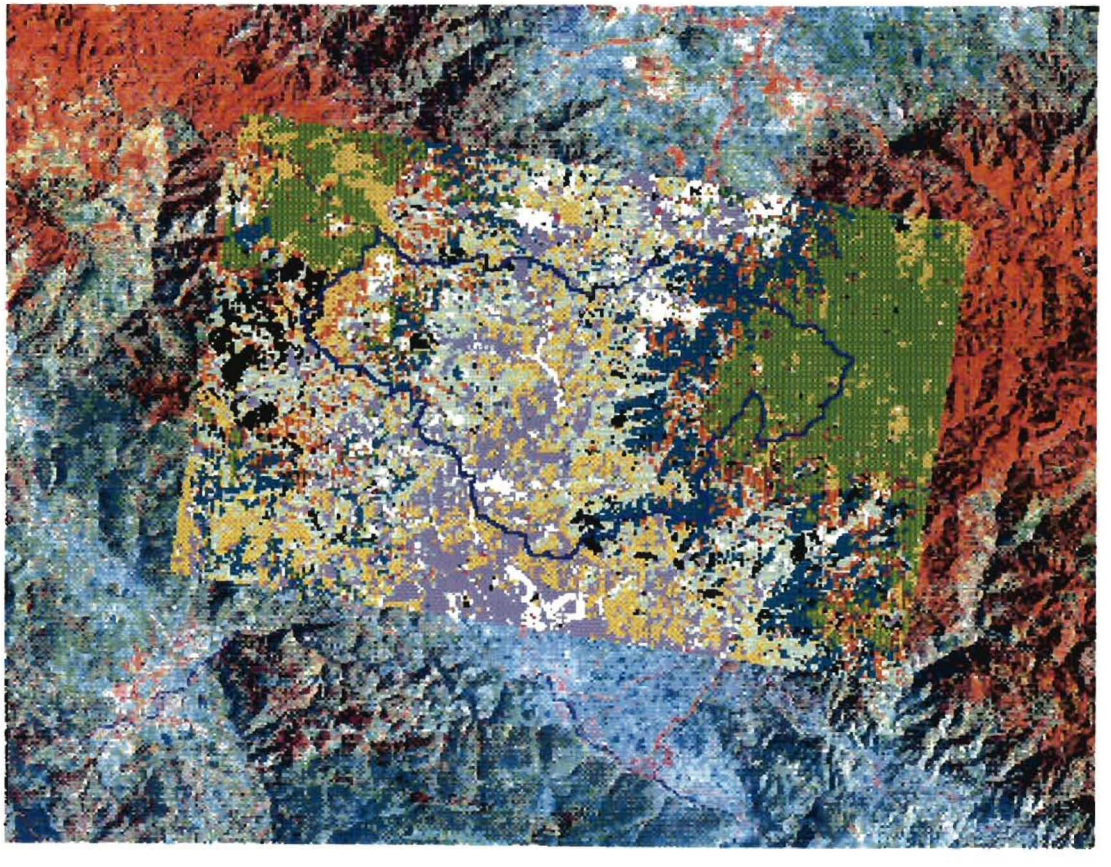
Scale

Kilometers

Land Cover classifications of Yorito study area, using multi-date Landsat TM images.



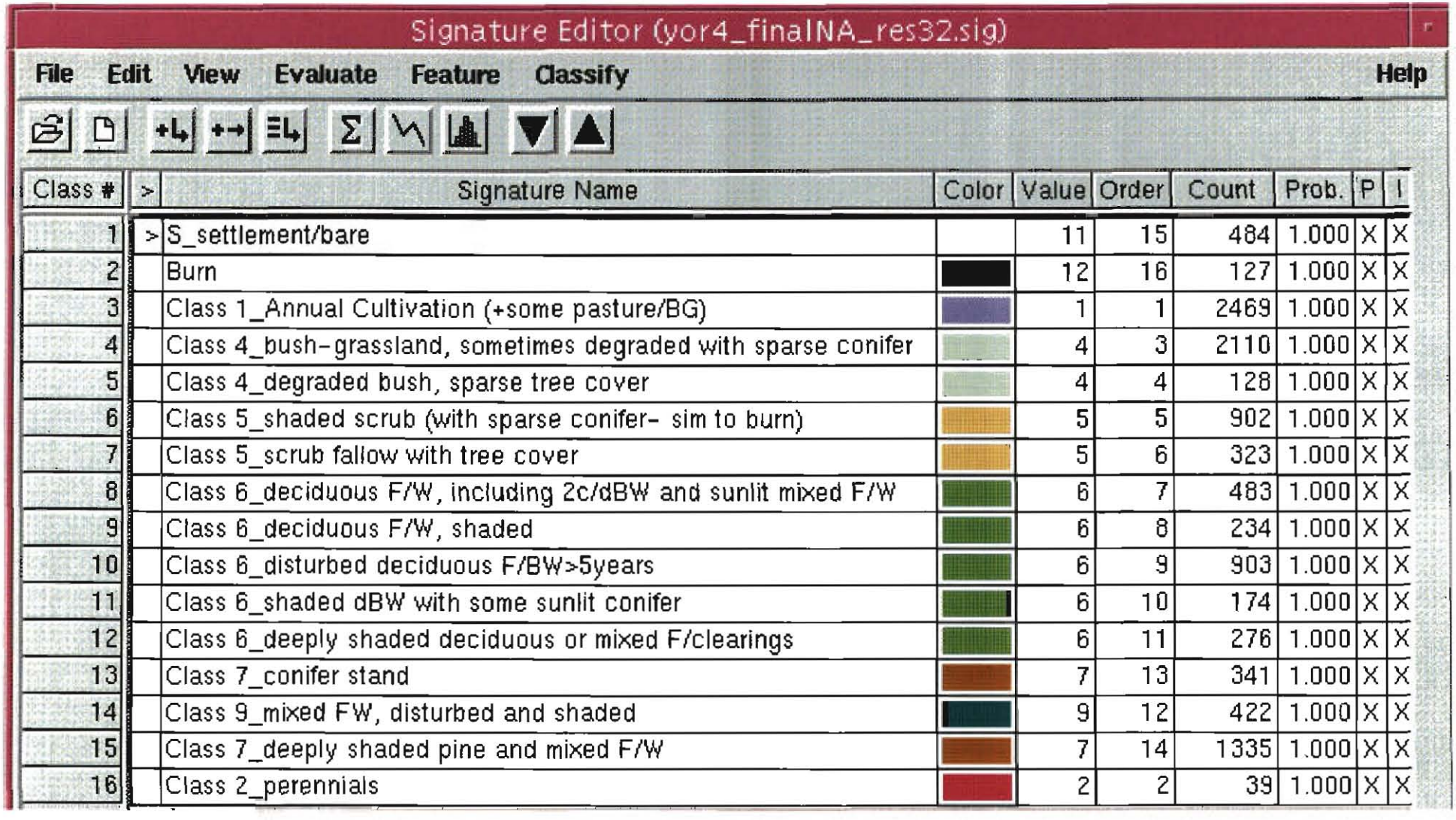
1986



1995

Scale

10 0 5 Scale 10 Kilometers



Class #	>	Signature Name	Color	Value	Order	Count	Prob.	P	I
1	>	S_settlement/bare		11	15	484	1.000	X	X
2		Burn		12	16	127	1.000	X	X
3		Class 1_Annual Cultivation (+some pasture/BG)		1	1	2469	1.000	X	X
4		Class 4_bush-grassland, sometimes degraded with sparse conifer		4	3	2110	1.000	X	X
5		Class 4_degraded bush, sparse tree cover		4	4	128	1.000	X	X
6		Class 5_shaded scrub (with sparse conifer- sim to burn)		5	5	902	1.000	X	X
7		Class 5_scrub fallow with tree cover		5	6	323	1.000	X	X
8		Class 6_deciduous F/W, including 2c/dBW and sunlit mixed F/W		6	7	483	1.000	X	X
9		Class 6_deciduous F/W, shaded		6	8	234	1.000	X	X
10		Class 6_disturbed deciduous F/BW>5years		6	9	903	1.000	X	X
11		Class 6_shaded dBW with some sunlit conifer		6	10	174	1.000	X	X
12		Class 6_deeply shaded deciduous or mixed F/clearings		6	11	276	1.000	X	X
13		Class 7_conifer stand		7	13	341	1.000	X	X
14		Class 9_mixed FW, disturbed and shaded		9	12	422	1.000	X	X
15		Class 7_deeply shaded pine and mixed F/W		7	14	1335	1.000	X	X
16		Class 2_perennials		2	2	39	1.000	X	X

cover has taken place in the valley and foothill-zones, with scrub-fallow vegetation converted to pasture and annual cropping. The forest cover including mixed forest on the mountain foothills of the eastern zone shows a discrepancy in classification between the two dates: the 1986 classification has mapped these areas as conifer, as the deciduous component is subsidiary consisting of regenerating scrub under a pine canopy. From this visual analysis one can suggest that there has been a certain intensification in smallholder agricultural land use in the nine year period, with a shortening of scrub-fallow periods and increased land under pasture.

2.7 Settlement/Infrastructure

Yorito is the prinicpal settlement of the area, and is just located to the north of the watershed. Other settlement areas include Luquigue, Rio Arriba, San Antonio, Albardilla and Capiro. The Arc/Info vector coverage for aldeas, derived from the National Population Census 1988 includes those covered in the census, and, in this study area, only two are included within the area, Yorito and Luquigue.

The surfaced roads are limited to parts of the north-south route ie. Yorito via Jalapa, Rio Arriba, La Libertad, San Antonio to El Desmonte, continuing beyond the study area to Sulaco. A western route passes from Yorito via Vallecillos to Mina Honda and up to Higero Quemado. This is largely unmade road. An easterly route passes from Yorito to Luquigue. Other routes are only accessible by mule or on foot (Poster Map 12 and Map 2.11.1)

2.8 Land Tenure

Referring to the Land Tenure maps for the Yorito and Sulaco municipalities it can be seen that the mountainous zones of the watershed are mainly under private ownership, whereas the valley and footslope zones are mainly national lands and some of the more settled areas are designated as 'Ejidal'/government-owned, including land titles. It is interesting to note that the municipality boundaries differ from those given in the 'Atlas Geograficao de Honduras' and the series of municipality maps produced by the IGN. It is not know which is the more accurate or most up to date as the Tenure maps of Direccion Ejecutiva del Catastro are not dated. It is apparent that the national lands are the most degraded, and the deciduous forest/coffee zones are privately owned (Poster-Map 15).

2.9 Cropping Calendar (See Section I_2.9)

Cropping seasons are traditionally 'primera' (March to July) and 'postrera' (September to November). the 'canicula' which is a dryer interlude between the primera and postrera seasons, occurs in July in this part of the country.

2.10 Agriculture

Several classifications were carried out for the Yorito study area: we will discuss here results of the pre-fieldwork and post-fieldwork classifications.

Firstly Pre-fieldwork classification: pasture, largely unimproved and including a sparse cover of pine, is mainly confined to the lower hills/valley of the Rio Tascalapa and Luquigue. Usually scrub and pasture occur as a complex and this represents the fourth

dominant land cover class which occurs most extensively on elevations immediately below the conifer forest/woodland and scattered within the forest classes and in the central valley. Annual cultivation and 'land under fallows of less than a year' are fifth in importance and are mainly concentrated along valleys and in the mountains of the northwest. this class is also scattered throughout the eastern mountain zone.

Secondly the post-fieldwork classification: shows that pasture is clearly the most dominant land use with 34% of the total area under pasture. Annual cultivation and scrub fallow follow with equal proportions of 16%.

2.11.1 Land cover (Landsat TM) Classification

Pine forest or woodland is second in dominance in both pre and post-classification attempts, being concentrated in the mountain footslopes, both east and west. Scrub fallow, 1- 5 years old includes deciduous regrowth, generally borders the dense deciduous cover and is very often found in small field plots within the forest block, representing encroachment by smallholder farmers. The deciduous forest/woodland class follows which includes areas of coffee plantation. This class is largely limited to the higher elevations. Much of the original forest has been disturbed, coffee traditionally being established on cleared plots planted with one of two or three shade species.
The land cover/land use classification of Yorito study area demonstrates the annual cultivation-fallow association with pasture on higher land which may border with sparse pine rangeland and scrub fallows before merging into dense deciduous forest/woodland. This classification which has received by far the most attention of all classifications in this study still does not present a high accuracy result (about 65% at best) owing to the relation between the spatial resolution of 32 metre of the TM sensor and the small average size of land parcels and the degree of shading and corresponding reduction in clarity of spectral signatures of the classes of interest.

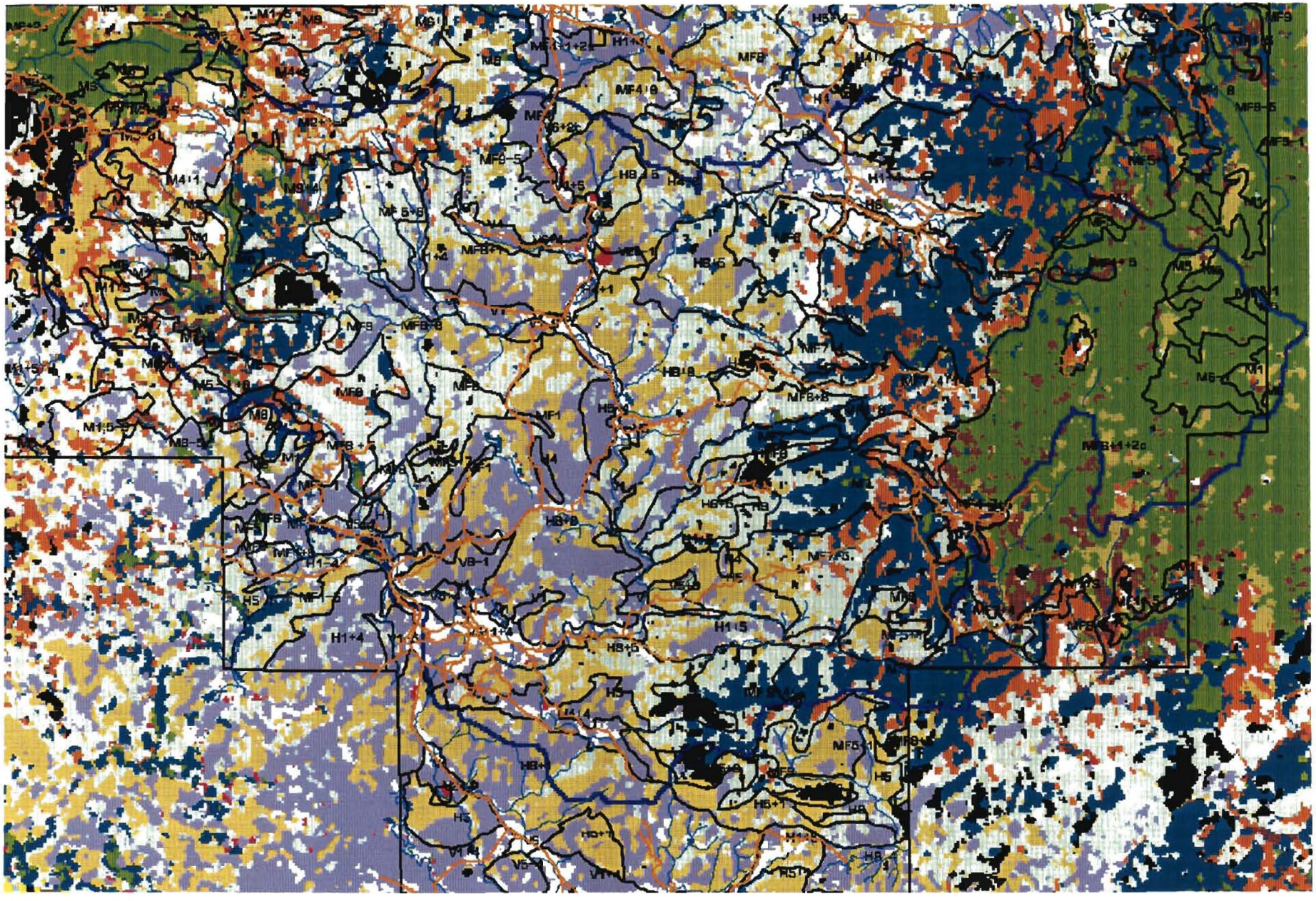
The first classification result contained considerable speckle and so a 3X3 majority filter was used to give a clearer result shown in map 2.11.1a. Map 2.11.b is a polygon-shaded map which may be useful for persons who do not need so much detail and are only interested in the dominant land use typ of a given area - this map was drawn and digitized from the 1:20,000 air photo interpretation.

2.11.2 Land cover proportion estimates

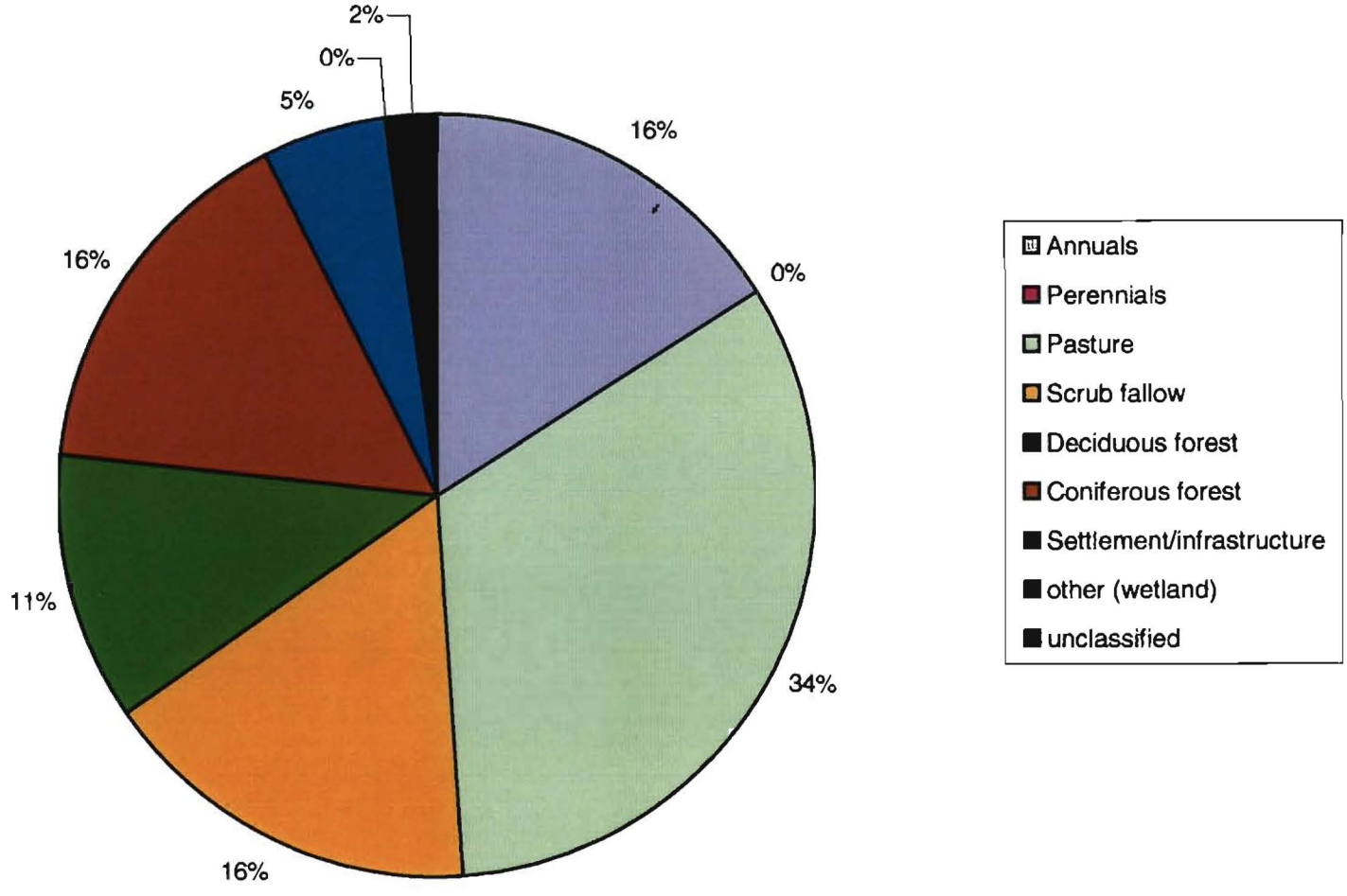
Summary of land cover/land use classes and their % area contribution:

Land Cover/land use class	Area (hectares) pre-field classification	% cover (pre-field classification)	% cover (post field classification)
Unimproved pasture	3,010	27	34
Conifer Forest/woodland	2,351	21	16

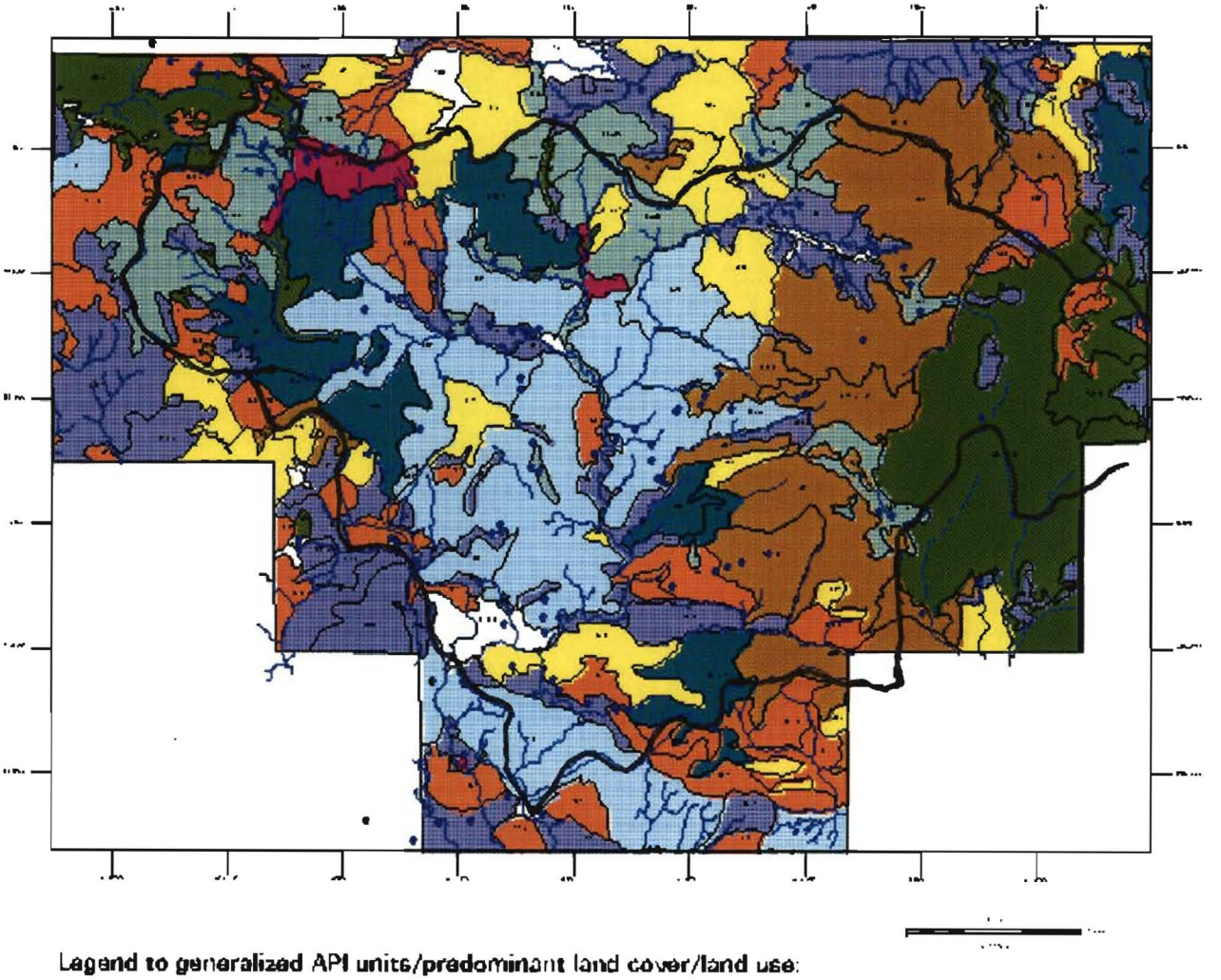
Land Cover/land use classification of the Yorito study area



Land Cover Proportion Estimates derived from Landsat TM subscene of Yorito Study Area, Yoro, Honduras



Air Photo Interpretation of Land cover/land use in the Yorito Study area, Yorito and Sulaco Municipalities, Yoro, Honduras



Legend to generalized API units/predominant land cover/land use:

- Annual cultivation
- Perennial cultivation, excluding coffee
- Natural pasture
- Scrub Fallow
- Deciduous Forest/Woodland including coffee
- Coniferous Forest/Woodland
- Mixed forest/woodland
- Sparse pine rangeland/scrub
- Eroded bushland
- Settlement/infrastructure
- Field observation points (March/April 1997)

Scrub (1-5 yrs)	2,024	18	16
Scrub-pasture complex	1,612	14	
Annual crops	1,262	11	16
Deciduous Forest/woodland	815	7	11
Settlement/infrastructure	178	2	5

(See also figure 2.11.1 and Poster-Maps 12 and 13)

The pre-fieldwork image classification was revised using the final air photo interpretation map compiled after fieldwork. The results are shown in Maps 2.11.1a and 2.11.1b .
Comments on the post fieldwork proportions:
The majority of the watershed zone is under pasture (34%) which may include some eroded bushland areas and sparse pine rangelands. Annual cultivation and scrub fallow and pine forest show equal proportions (16%). Deciduous forest covers 11%; settlement and infrastructure covers 5% and perennial cultivation which was not easy to map does not even register 1%. Of course, there are areas of coffee included within the deciduous forest class and certain areas of sugar cane, banana etc. are concentrated along the main river channel (Fig 2.11.2).

3. Danli Study Area

3.1 Location

This study area consitutes the watershed of the Rio Cuseateca and the Quebrada de Arauli, located in the municipality of Danli and the department of El Paraiso. The area lies between lines of latitude 13 55 N and 14 02 N and between lines of longitude 86 26 W and 86 35 W. The study area covers about 4,000 hectares. The digital elevation model created for this study area includes a slightly extended area to the south of the formerly defined study area (Map I_3.1 and II_3.1).

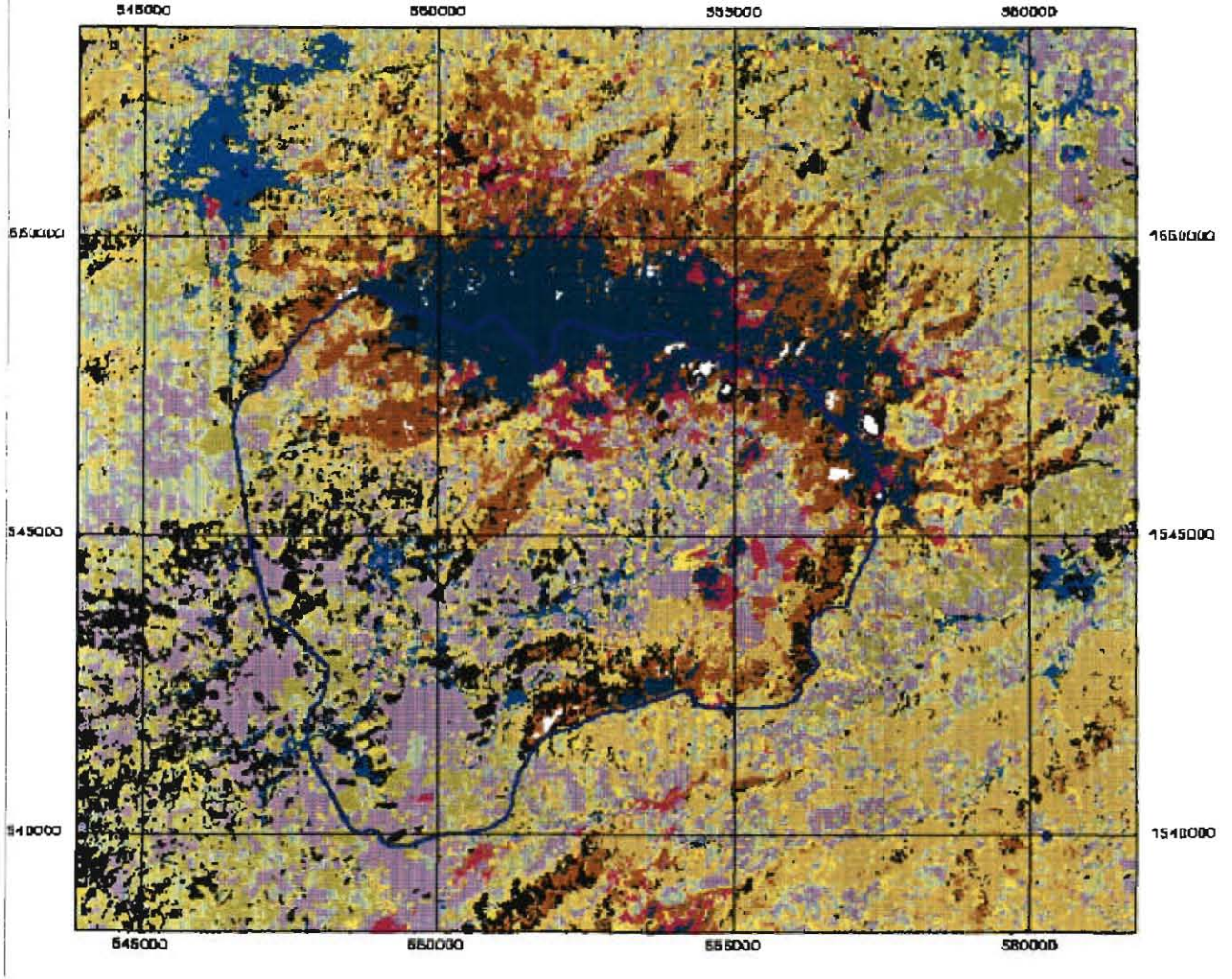
3.2 Climate

The climatic zone is identical to that described for the Yorito study area. The only difference is that the canicula spell during the rainy season, typically occurs several weeks later in August in this dryer part of the country. The rainfall is associated with the Inter-Tropical Convergence Zone, anticyclones and cold front activity. (Figure I_3.2).

3.3 Geology

Most of the watershed, including the hills, is composed of Tertiary volcanics, non-differentiated of unknown age - generally tuffs, andesites and pyroclastic rocks. The mountain tops along the northern edge of the watershed are composed of Cretaceous Valle de Angeles Group; a sequence of lithologically heterogeneous redbeds consisting

Land Cover/Land Use Classification of Danli Study area
a sub-catchment of Rio Cuseateca - from Landsat TM data dated 23 Feb, 1993.



Legend:

- Annual Cultivation
- Perennial Cultivation
- Pasture
- Scrub Fallow
- Mixed forest, *including* coffee under deciduous shade-trees
- Pine Forest/woodland
- Sparse Pine rangeland
- Eroded bushland, bare
- Settlement/infrastructure
- Recent burn/deeply shaded
- *cloud cover*

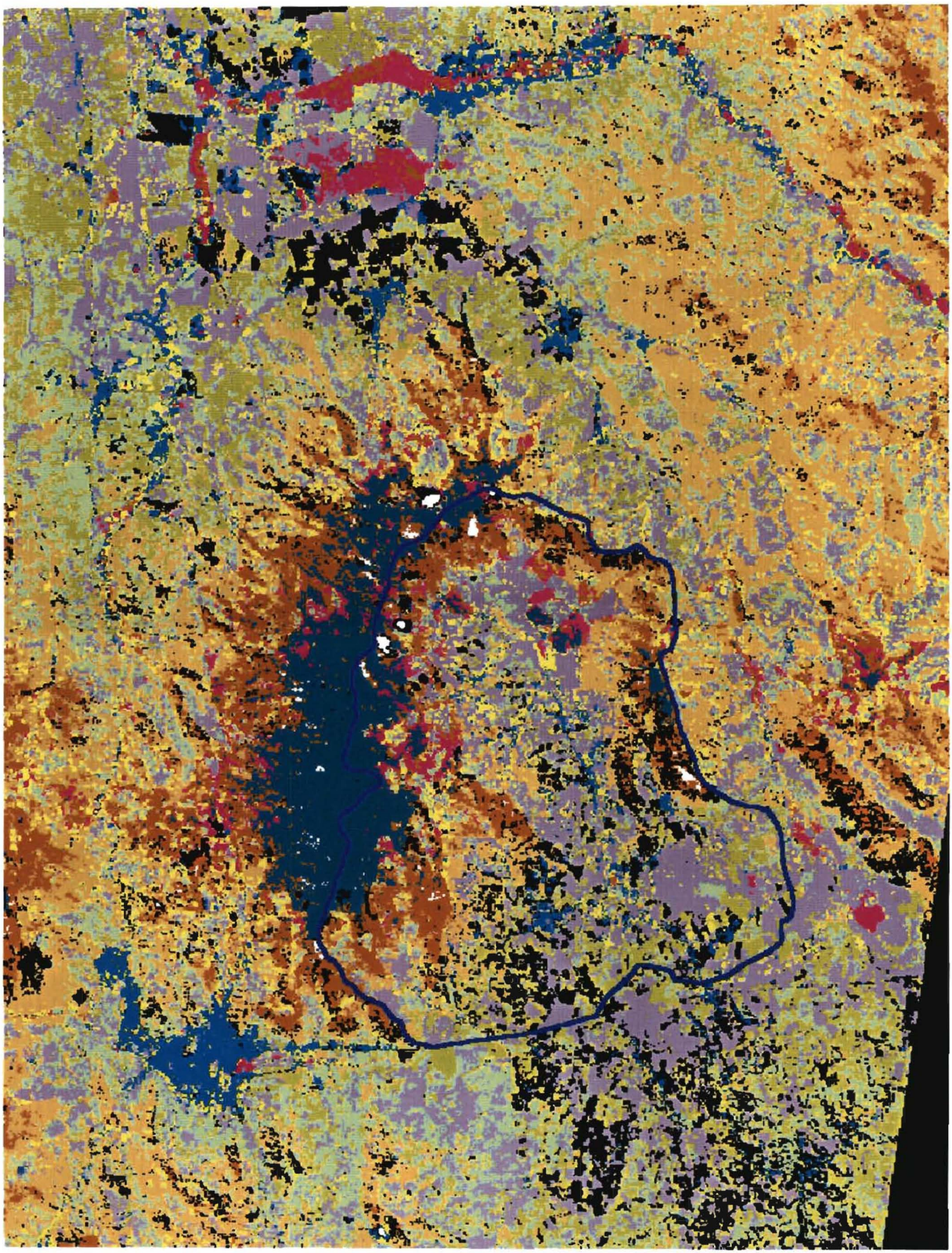
Scale

2 0 2 4 Kilometers

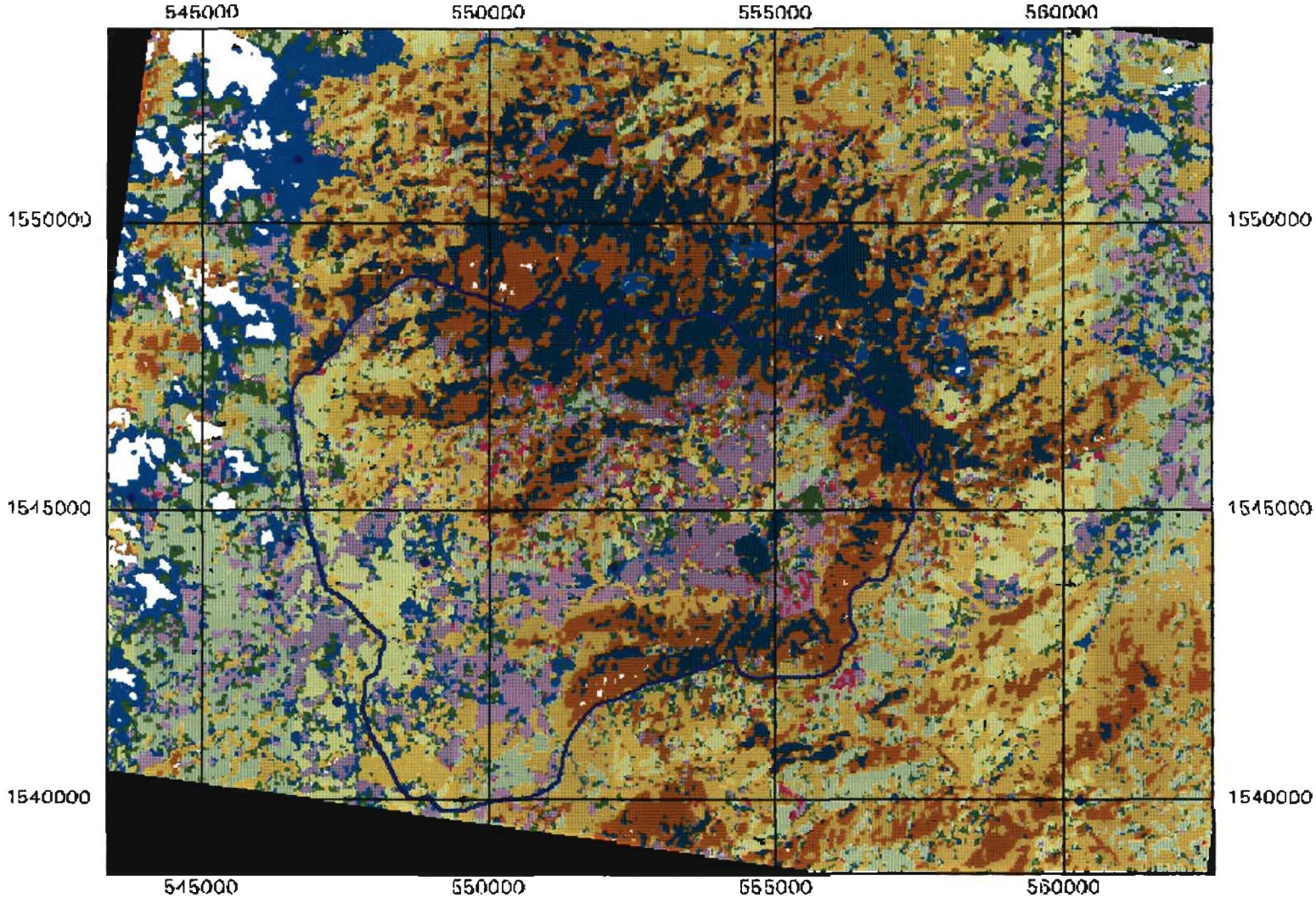
N

Study Area Boundary

aldeas (from 1988 population census)



Land Cover/Land Use Classification of Danli study area. based on Landsat TM Image dated 22 Jan, 1987.



For Legend, see class-descriptions on Map of Danli Study Area, based on Feb 1993 TM image.

Scale

2 0 2

Kilometers

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#	>	Signature Name	Color	Value	Order	Count	Prob.	P	I	H	A	FS
1	>	Class 10_bare		10	13	45	1.000	X	X	X	X	
2		Cloud shadow		17	15	257	1.000	X	X	X	X	
3		cloud		17	16	349	1.000	X	X	X	X	
4		Class 4_natural pasture		4	6	497	1.000	X	X	X	X	
5		Class 6_Deciduous F/W		6	10	34	1.000	X		X	X	
6		Class 2_banana/sugar cane		2	5	678	1.000	X	X	X	X	
7		Class 6/9_Decid F/W, shaded incl coffee		6	9	177	1.000	X	X	X	X	
8		Class 1_clearings		1	1	508	1.000	X	X	X	X	
9		Class 7_Pine F/W		7	11	951	1.000	X	X	X	X	
0		Class S		11	14	281	1.000	X	X	X	X	
1		Class 8_scrub/pasture + scattered pine		8	12	184	1.000	X	X	X	X	
2		Class 5_shaded scrub fallow		5	7	476	1.000	X	X	X	X	
3		Class 6_deciduous F/W incl. coffee		6	8	1749	1.000	X	X	X	X	
4		Class 1_1 yr fallow		1	2	430	1.000	X	X	X		
5		Class Burn_on annual cultiv plots		1	4	958	1.000	X	X	X		
6		Class 1_crop		1	3	370	1.000	X	X	X	X	

Raster Attribute Editor – danli93saML_res32.img(:Layer_1)

lle Edit He

Row	Class_Names	Histogram	Color	Area
0	Unclassified	169693		17376.6
1	Class 1_1 yr fallow	102231		10468.5
2	Class 2_banana	10224		1046.94
3		0		0
4	Class 4_pasture	90978		9316.15
5	Class 5_shaded scrub fallow	139109		14244.8
6	Class 6/9_shaded incl coffee	22488		2302.77
7	Class 7_Pine F/W	52337		5359.31
8	Class 8_scrub/pasture + scattered pine	63926		6546.02
9	Class 6_Deciduous F/W	0		0
10	Class 10_bare	22740		2328.58
11	Class S	16766		1716.84
12		0		0
13	Class B_on plots	45471		4656.23
14		0		0
15		0		0
16		0		0

of mudstones, shales, sandstones, conglomerates and limestones. The lower hills and quebrada del Horno/Quebrada de Pozo Bendito are composed of class Jkhg - Jurassic Honduras Group, consisting of Agua Fria formation, the El Plan Formation and a superior siliclastic unit. Shales, sandstones and coal beds are present. The western fringe of the study area which covers Rio San Marcos and the Quebrada de Arauli belongs geologically to the Tertiary Padre Miguel Group: volcanic rocks consisting of pyroclastic rocks of the rhyolitic and andesitic suite; sedimentary rocks are derived from the volcanic rocks and flows of rhyolite andesite and basalt. the north-south valley floor to the west of the study area and the Valle de Jamastran, to the northeast of the study area, are composed of recent sediments, including talus deposits, gravel terraces, flood plain deposits and alluvium (Map I_3.3).

3.4 Topography and drainage

This study area consists of a well defined basin - a relatively flat valley floor, extending east-west as far as the north-south road which passes between Danli and El Paraiso. The valley floor has a general elevation of between 740 metres and 798 metres and is bounded by hills and mountains along its northern, easter and southern edges. The highest peak on the watershed boundary is that of El Lucero - 1,438 metres, on the southern flanks of Cerro El Lucero. Other hills indicated on the topographic map sheets include Calabaceras, 1,158 metres, Sierra Morena, 1,280 metres, Buena Vista, 1,417 metres, La Piedra Hoyosa, 1,115 metres, Quiebra Cajon, 1,120 metres, El Naranjo, 725 metres and El Ocotal, 952 metres.

The Rio Cuseateca is a tributary to the Rio del Pescadero and Rio Namale, which meanders westward to the Rio Choluteca. The Rio Choluteca flows south and then southwest to the Pacific coast's Golfo de Fonseca.

3.5.1 Soils - Simmons' Classification

The whole of the watershed is composed of one soil class ie. Jacaleapa soils. These are lithosols, well drained, very acid, dark brown sandy clasy and sandy loams. They are formed on slates, micas and are commonly found on slopes of more than 40%, but are also found on inferior slopes of 20% The areas to the southwest and east of the watershed are composed of valley soils and there is an area of 'Danli' soils in the southeast corner of the subset TM image. The latter are red-yellow podzols, deep well drained with pH 6, very dark brown silt-loams. These are typically formed on slates and commonly occur on hilly-scarp slopes, generally up to 40% (Map I_3.5).

3.5.2 Soils - Leforrest Miller classification

The central portion of the area is composed of soils in the ITYf-2 class which comprise Lithic Dystropepts and associated soils from acid igneous and metamorphic mountainous topography. The western edges of the watershed are composed of ITYf and ITUa-1 types. ITYf-3 consists of Lithic Dystropepts and associated soils from acid igneous and metamorphic rocks, on rolling to hilly topography. Soils descriptions have been carried out in Danli by the CIAT Hillsides Programme team, in March/April, 1997.

3.6.1 Natural Resources (See Section I_3.6.1)

3.6.2 Forest Monitoring (Refer to Poster-Map 16 which shows the classifications of the two dates of imager, ie 1987 and 1993). Apart from deforestation of the lower hills during these six years, there appears to have been little change. (Map 3.6.1a and Map 3.6.1b).

3.7 Settlement and Infrastructure
The 1988 population census distribution of aldeas indicates only two within the study area, ie. Linaca and Arauli, and twelve in the outer surrounding area. Other settlement areas which fall within the limits of the watershed include Cuseateca, El Chaguite, Los Calpules and the farm complex of Hacienda Santa Elisa. A main surfaced road connects Danli and El Paraiso and another passes west-east along the northern edge of the watershed from Danli to San Diego and a north-south route along the western side of the Valle de Jamastran connecting San Diego and El Coyolar, only accessible by mule or on foot.

3.8 Land Tenure (See Section I_3.8)

3.9 Cropping Calendar (See Section I_3.9)

3.10 Agricultural Land use
A classification of the Landsat TM image dated 22/1/87 was carried out prior to November 1996 fieldwork and subsequently revised to produce a map with 19 sub-classes but which were aggregated later by assigning similar colours in the ERDAS raster attribute editor - the final classification consists of eight classes. The areas for each of the classes were summed in the GIS anaysis-report option for the subset image. (Maps 3.6.1a and 3.6.1b).

3.11 Land Cover/Land Use (Landsat TM classification)
The plains are dominated by grazing land with annual cultivation or a complex of annual cultivation and settlement and infrastructure usually along water courses.

Homesteads were classified as a separate class and distributed along the roads/tracks. Danli is the nearest urban settlement to the study area and there are some other built-up areas in the Valle de Jamastran.

The mountain foothill-zone is characterized by a range of land cover types including a complex of conifer forest, pasture with sparse pine cover, unimproved pasture, annual cultivation and settlement, mixed forest and scrub and fragments of reminaing deciduous forest.

The summits of the hills are characterized by deciduous forest and coffee plantation. this cover appears to be more encroached upon on the south-facing slopes, where it is replaced by secondary regrowth/scrub.

The Cuseateca valley is broad and dominated by maize cultivation with some pine/pasture and homesteads along its northern section. The coffee plantation of Santa Elisa Hacienda is located at the head of the valley. There seems to be some general corresponedence between the study area land cover proportions estimates and those derived from census for the Danli municipality (Table 3.11.1).

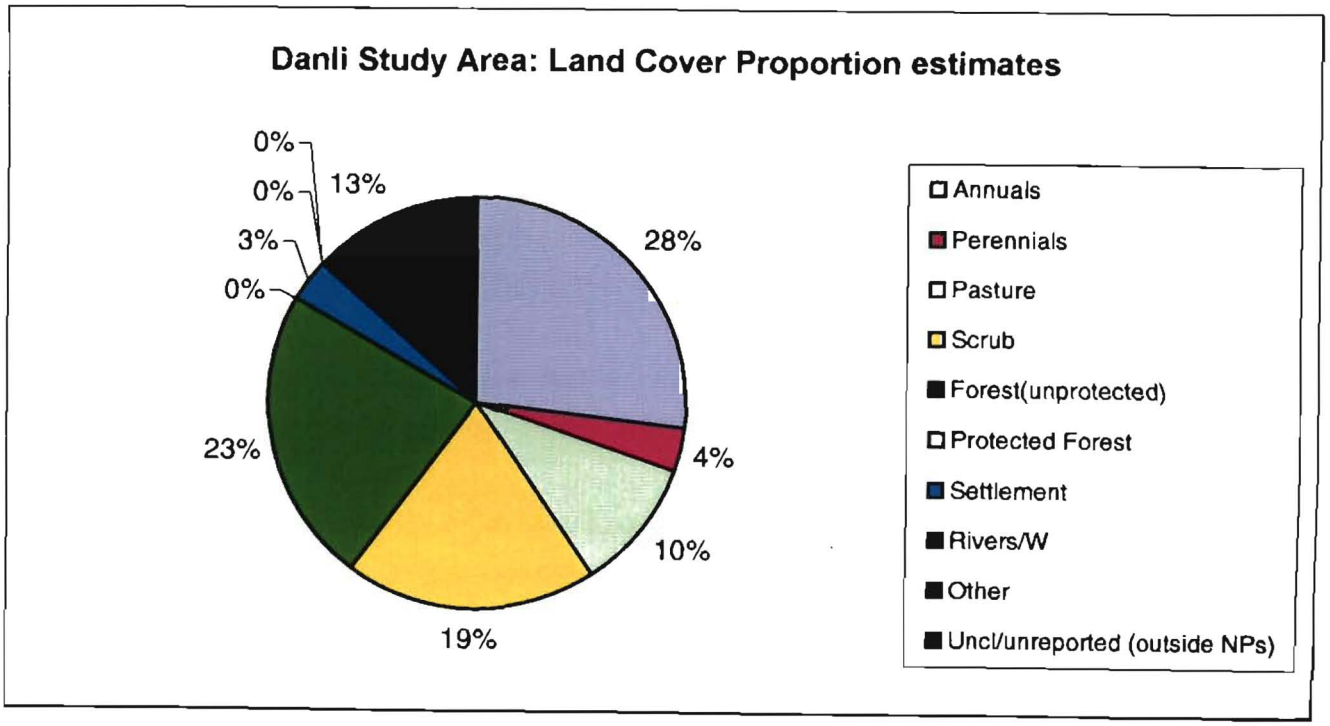
3.11.2 Land Cover/Land Use Proportion Estimates

Pasture, with or without pine cover, is the dominant land use follwed by pine forest and annual cultivation/scrub in roughly equal proportions. Deciduous forest/coffee and perennial crops cover lesser areas.

Table 3.11.1

Class	TM Classification (1987), study area (pre-field)	TM Classification (1993), study area (post-field)	Agricultural census, (1993) Danli municipality
Annual cultivation	3,204 ha (11.5%)	1,568 ha (23%)	16,892 ha + 2,662 (fallow 1yr) (13%)
Perennial cultivation	1,080 ha (4%)	205 ha (3%)	10,709 ha (incl. coffee) (7
Plantation crop (coffee)	1,658 ha (6%)		1,389 ha (1%)
Pasture	4,863 ha (17%)	594 ha (9%)	45,495 ha + 40,633 ha
Sparse conifer rangeland	7,437 ha (27%)	587 ha (9%)	
Scrub fallow	3,619 ha (13%)	1,131 ha (17%)	16,767 ha (11%)
Deciduous Forest/woodland	1,658 ha (6%)	562 ha (8%)	20,696 ha (13%) incl. conif and mixed forest
Conifer forest/woodland	1,658 ha (15%)	810 ha (12%)	

Figure 3.11.2 shows the pie chart summarising proportion estimates for the land use of Danli study area, derived from the image classification of the more recent date.



CHAPTER 3

BIOPHYSICAL REPRESENTATIVITY OF THE FOUR SELECTED STUDY SITES WITH RESPECT TO THEIR MUNICIPALITIES AND DEPARTMENT ZONE.

III Biophysical Representativity of the four selected study sites with respect to their municipalities and department zones.

1. Introduction

One of the objectives of the Hillsides programme is to estimate how representative the chosen study sites are with respect to the hillsides zone of Honduras. To answer this in a comprehensive manner, one would need to undertake a cluster analysis including as many biophysical variables as possible, or at least the most important ones/indicators and compare results for the study areas, municipalities, departments and the Hillsides zone.

In this study, which has concentrated mainly on the classification of land cover and land use from Landsat TM satellite imagery for the different levels of investigation, it is possible to give a general overview based on the final proportional estimates derived from the class/area listings which are reports of the individual classifications. These listings provide an estimation of the relative importance of the different land use classes.

This section of the report describes the similarities and differences between each study area and their municipality(ies), their department and the wider Hillsides zone. However, first it is important to review the broad biophysical characteristics of the study areas in terms of climage, geology and soils which, together with topography, determine to a large extent the character of land use in a particular region.

2. Climate

The study areas are located along a north-south transect through the central part of Honduras. The Atlantida sites have a total average annual rainfall of between 2,000 and 3,000 mm. They are located in the most humid zone of Honduras which has a short period of slight rain deficit (less than 200 mm) during March and April. Maximum rainfall occurs between October and November with monthly surpluses exceeding 250mm.

The Yorito study area has a dryer climate compared with Atlantida, and has an average total annual rainfall of between 1,000 and 1,500 mm. Rainfall deficit occurs during the period December through to April (five months, March being the most critical period with more than 200 mm deficit). Rainfall reaches a climax in this location in the month of September with a 100 to 250 mm surplus (Poster Map 2, composed by Leclerc, G. , 1997).

The Danli study area is located in the dryer southern region of Honduras, near to the border with Nicaragua. Here the average annual rainfall totals less than 1000 mm. A monthly deficit occurs during the period November to April. Maximum rainfall with a monthly surplus may occur between June and October, the most humid months being June and September.

The three study areas, (the two study areas in Atlantida counted as one) appear to have contrasting rainfall regimes, becoming progressively dryer southwards.

If one refers to the map 'Climas de Honduras', (see also Appendix 2) one may notice that there are two major climatic zones in Honduras: 'Muy lluvioso con invierno lluviosa" and "Poco lluvioso con invierno seco" These are coded as Lz and Yx respectively. The other classes are in fact subclasses of these two climates. The study areas selected in Honduras are located within the following climatic zones: Lz, Sz, Vx. In addition there are the subclimates of Lz which include Lk, Yk and Vk as well as Yx and its subclimates Mx, Mb, Vf and Vb.

To understand the seasonal differences of the three study area locations, refer to Figure below:

months of the year

Study area	J	F	M	A	M	J	J	A	S	O	N	D	Total annual rainfall
Atlantida			DRY						WET	WET		WET	2000 - 3000
Yoro	DRY					WET			WET			DRY	1000-1500
Danli	DRY					WET			WET		DRY		600-1000

3. Geology

The study areas include a variety of geologies as listed below:

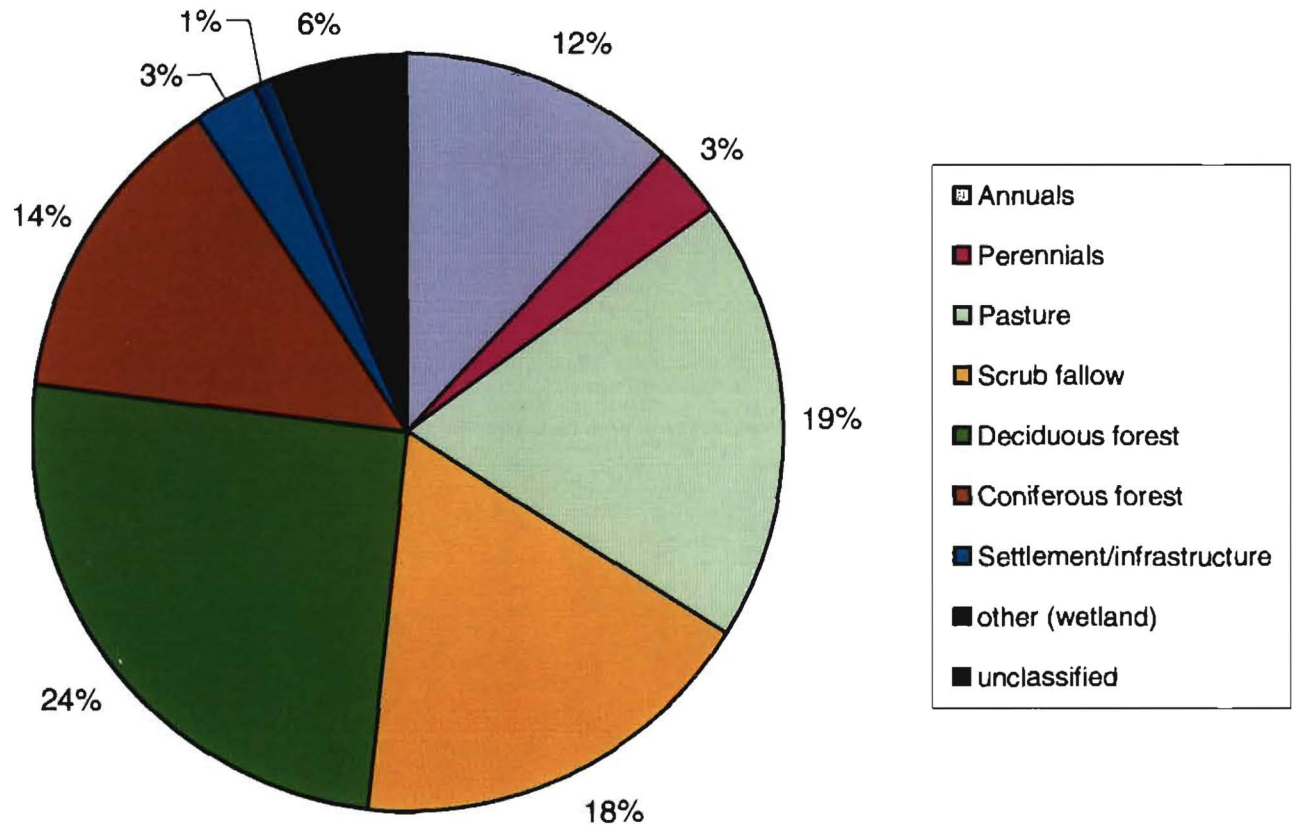
Atlantida: Ki - Cretaceous
Qal - Quarternary
Pzm - Paleozoic

Yoro: Kva - Cretaceous
Ky
Qal - Quarternary

Danli: Tv - Tertiary
Tpm
Kva - Cretaceous
Jkhg - Jurassic
Qal - Quarternary

Other classes not included within the study areas : Qv, Quarternary volcanic sills/flows; QTbb (eastern Honduras: Gracias a Dios Department) consisting of shales, limestones and sandstones; Ty (western Honduras) and Ts, Tm and Kay; all occupy relatively small areas in Honduras.

Land Cover Proportion Estimates derived from Four mosaiced Landsat TM scenes, covering the Hillsides Region of Honduras



It appears that the study areas selected cover a good range of rock types of different ages. The only rock-type not represented in the selected areas that would have an influence on land use patterns is the class Qv, which consist of recent volcanic rocks, near to Lago de Yojoa. This region was observed to have a extensive range of horticulture, and appeared very different to anything else seen during the reconnaissance survey. However, again this represents a localized area within Honduras and is therefore not particularly representative of the hillsides zone in general.

4. Soils (Simmons' Classification)

The Atlantida study areas have a range of soils including alluvials, valley soils and latosols. Yorito study area has a gradation between acid lithosols and calcareous rendzinas and Danli study area has a range of valley soils, lithosols and podzols.

Other soil types which are not included within these selected areas include Grumosols (codes Al, Yu), volcanic lavas (Ur), Andosols with have high organic matter content (Mi, Yo). These soils tend to be localized in their distribution, and one can assume therefore that the major soil types are indeed represented within the selected study areas.

5. Land Cover/Land Use: Representativity Analysis

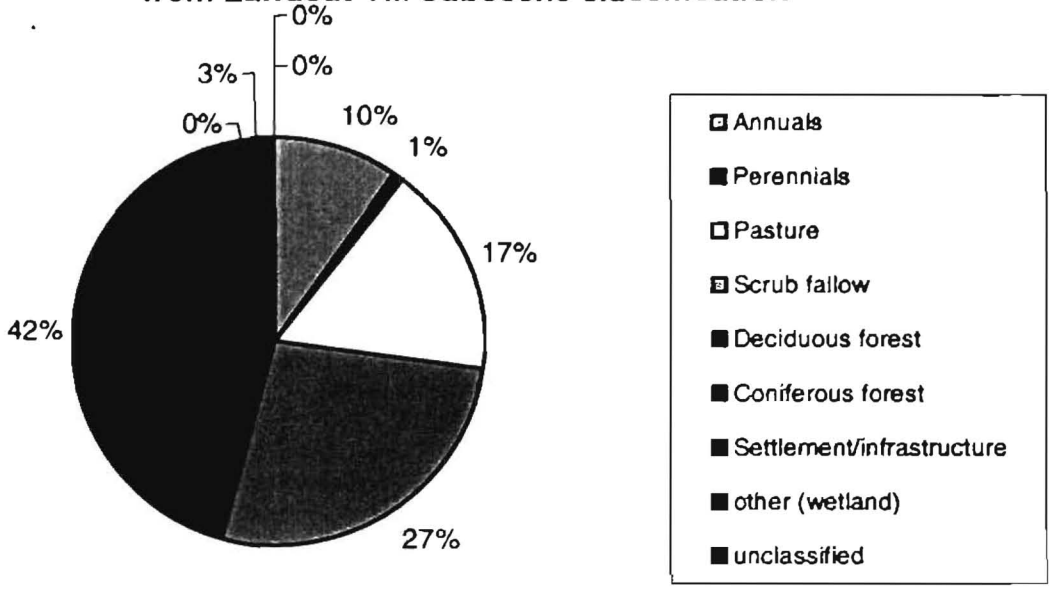
The land cover proportion estimates derived from Landsat TM imagery were used to form pie charts for the different regions in order to analyse the major similarities/differences in land-cover characterization. The Hillsides region (four complete TM scenes excluding the sea area) gives a pie-chart with the land cover types annuals, pasture, scrub fallow, deciduous forest and coniferous forest having more or less equal proportions (between 12 and 24 % each), whilst perennial cultivation and settlement/other land use/unclassified classes occupy 12% of the total area (Figure III_5).

5.1 Representativity of La Masica and San Francisco de Saco study areas in the context of their respective municipalities and Atlantida department and the Hillsides zone

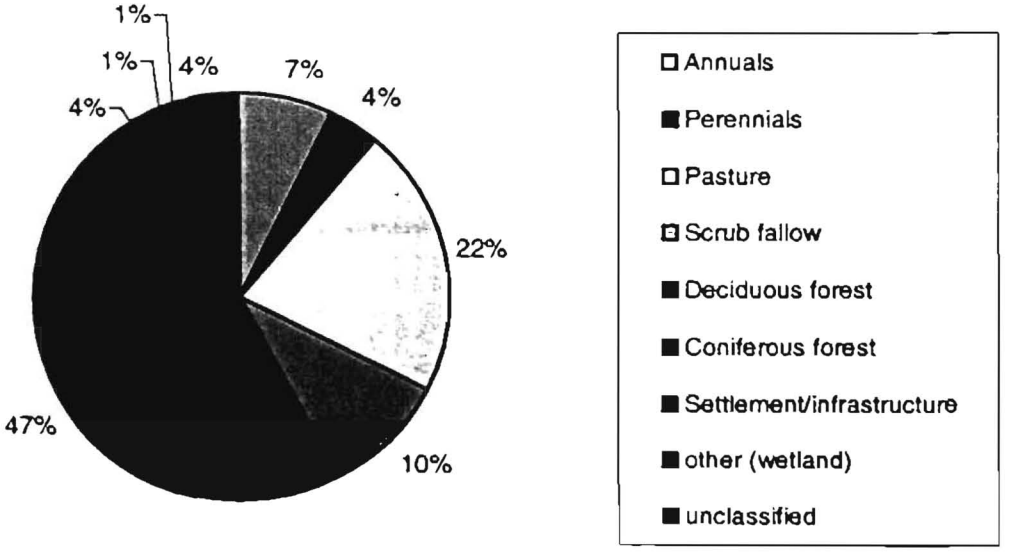
The Atlantida study areas have generally more deciduous forest cover and negligible pine. These study areas show least similarity with the general hillsides zone characteristics. La Masica has 10% and 17% annuals and pasture respectivelly and San Francisco de Saco has 20% and 25% annuals and pasture and a dominant scrub fallow of 32%. The latter study area also has more pasture (25% compared with 17% for La Masica). The combination of the two sites is good as one indicates more resource usage than the other, the San Francisco de Saco study area being located nearer to the coastal plain grazing area and situated on lower hills.

Compared with the municipalities, in the case of La Masica, proportions remain the same but the municipality has a greater proportion of deciduous forest; pasture notably

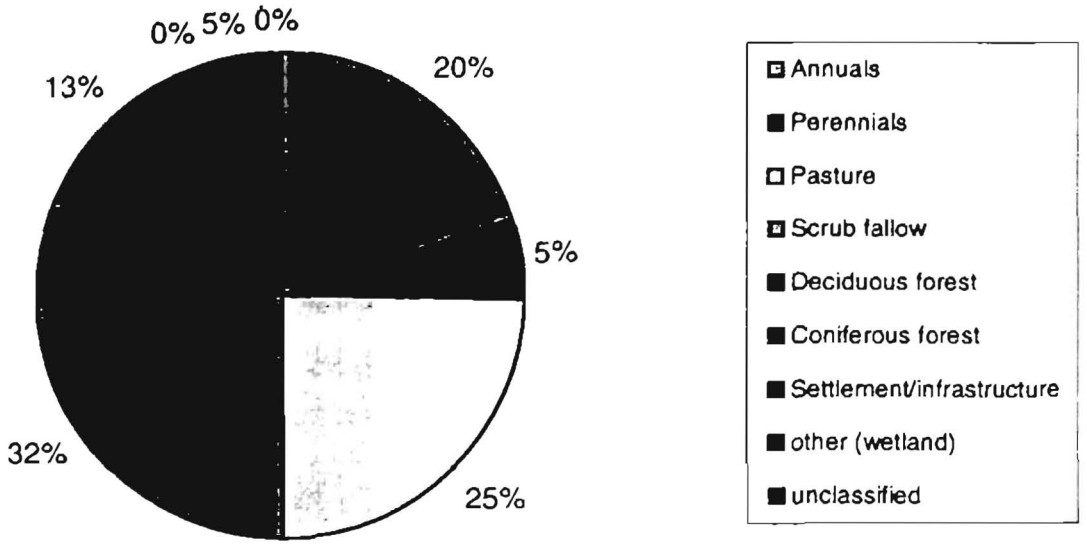
Land Cover Proportion estimates of La Masica study area, derived from Landsat TM subscene classification



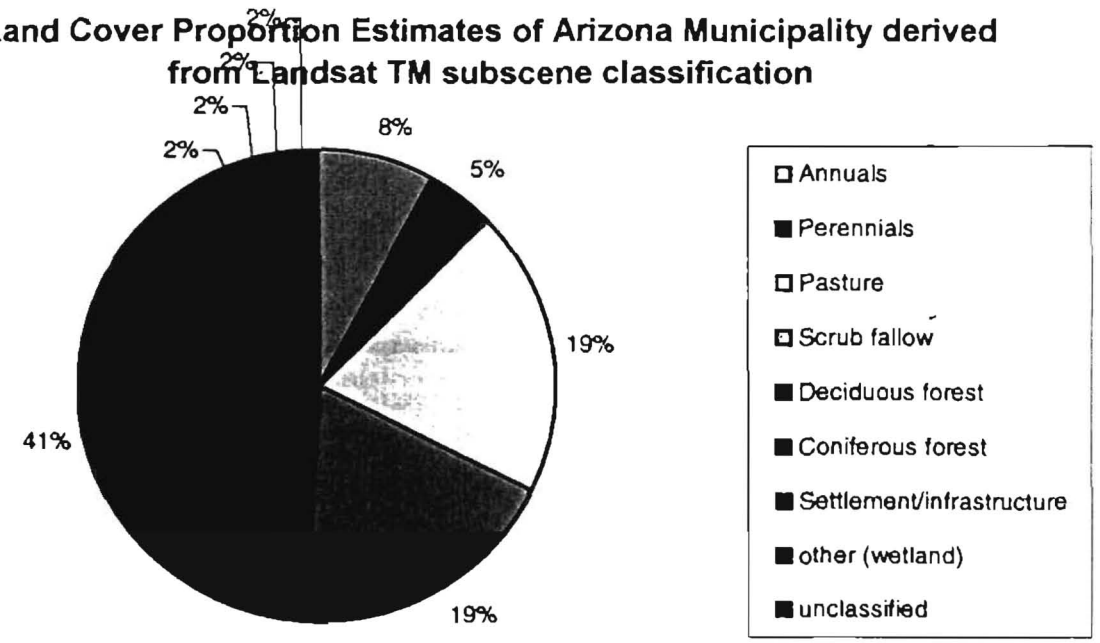
Land Cover Proportion Estimates for La Masica Municipality derived from Landsat TM subscene classification.



Land Cover Proportion Estimates of San Francisco de Saco Study Area derived from Landsat TM subscene classification



Land Cover Proportion Estimates of Arizona Municipality derived from Landsat TM subscene classification



maintains its relative importance and scrub fallow is relatively less important (Fig III_5.1.1).

In the case of San Francisco de Saco, the scrub fallow and annual cultivation proportions are markedly reduced. Perennials and pasture maintain their importance at the municipality level (Figure III_5.1.2)

5.2 Representativity of Yorito study area in the context of Yorito and Sulaco municipalities, Yoro department and the Hillsides zone.

Yorito study area is dominated by unimproved pasture (34%) and comparable covers for annuals, scrub and the two forest classes (11-16%). The Yorito municipality pie chart shows that deciduous forest cover (including coffee plantation) is more important with 37% cover compared with 11% within the watershed boundary (Figure III_5.2). Sulaco municipality pie-chart shows a dominance of unimproved pasture and increased annual cultivation proportion and noticeably reduced covers of the two forest classes. In this example one can appreciate how much the pie-charts can differ within a small distance and between one scale of analysis and another. Much depends on the general terrain and proportion of land area in hillsides as opposed to valley floors.

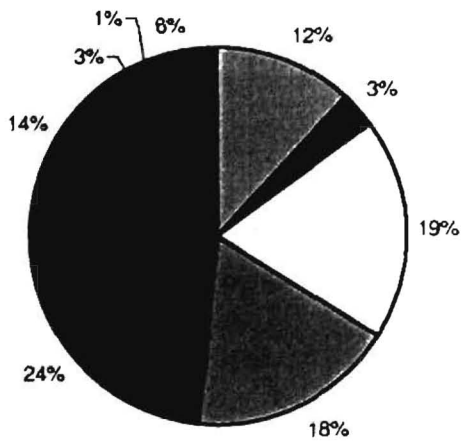
The Yoro department land use summary (Section I_2) includes a pie chart representing the land use of the eleven municipalities. The result looks very similar to the Hillsides Zone chart, indicating that Yoro is representative of the country in terms of its land cover and land use. Forest at this scale of analysis includes coniferous forest as well as deciduous and mixed types. This is because the former analysis was carried out primarily to compare TM-estimates with Census derived land use proportion estimates and the latter includes a forest category, not differentiating between sub-types.

5.3 Representativity of Danli study area in the context of Danli municipality and El Paraiso department and the hillsides zone.

Danli study area and Danli municipality compare well, which is a little surprising as Danli covers an area about thiry-seven times as large (the study area occupies only 3% of the municipality: 6,782 hectares compared with 249,279 hectares). This is most probably because they share similar proportions of hills/valley topography. Danli study area pie chart shows a greater proportion of annual cultivation. This is because the Rio Cuseateca has a wide valley floor important for maize cultivation. Danli municipality is comparable with the Hillsides region as a whole, but Danli has more scrub fallow and slightly less deciduous forest than the whole region.

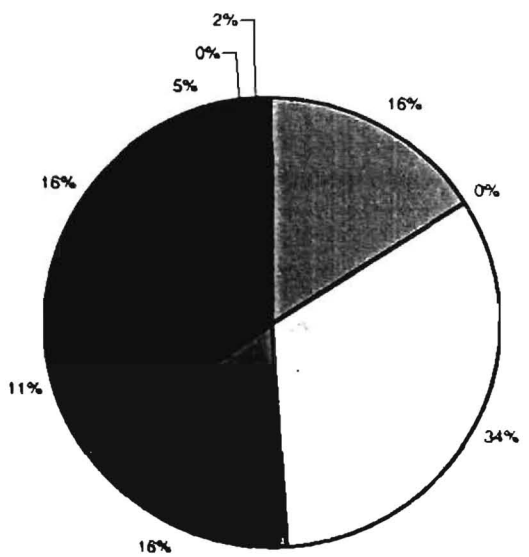
The pie chart of the El Paraiso department (Section I_3) looks almost identical to the municipality of Danli (Figure III_5.3), if one adds the two forest classes together in the municipality version. One can summarise therefore that this study area together with its

Land Cover Proportion Estimates derived from Four mosaiced Landsat TM scenes, covering the Hillsides Region of Honduras



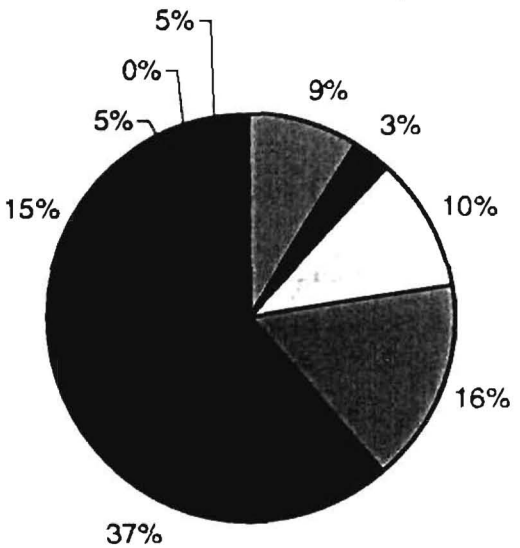
- Annuals
- Perennials
- Pasture
- Scrub fallow
- Deciduous forest
- Coniferous forest
- Settlement/infrastructure
- other (wetland)
- unclassified

Land Cover Proportion Estimates derived from Landsat TM subscene of Yorito Study Area, Yoro, Honduras



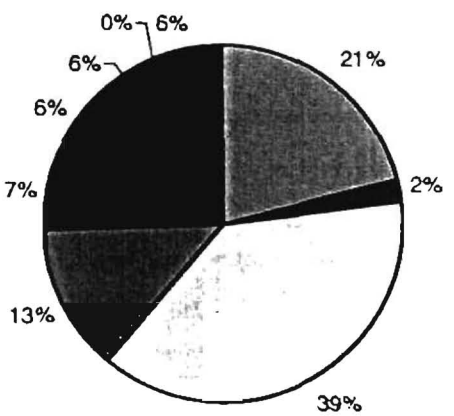
- Annuals
- Perennials
- Pasture
- Scrub fallow
- Deciduous forest
- Coniferous forest
- Settlement/infrastructure
- other (wetland)
- unclassified

Land Cover Proportion Estimates for Yorito Municipality, based on Landsat TM subscene classification



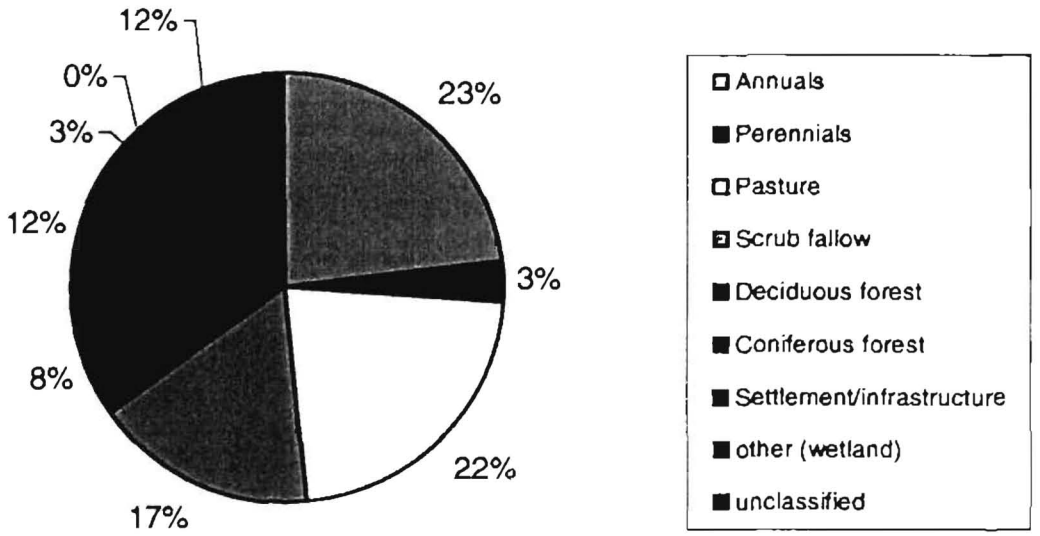
- Annuals
- Perennials
- Pasture
- Scrub fallow
- Deciduous forest
- Coniferous forest
- Settlement/infrastructure
- other (wetland)
- unclassified

Land Cover Proportion Estimates of Sulaco Municipality based on Landsat TM subscene classification

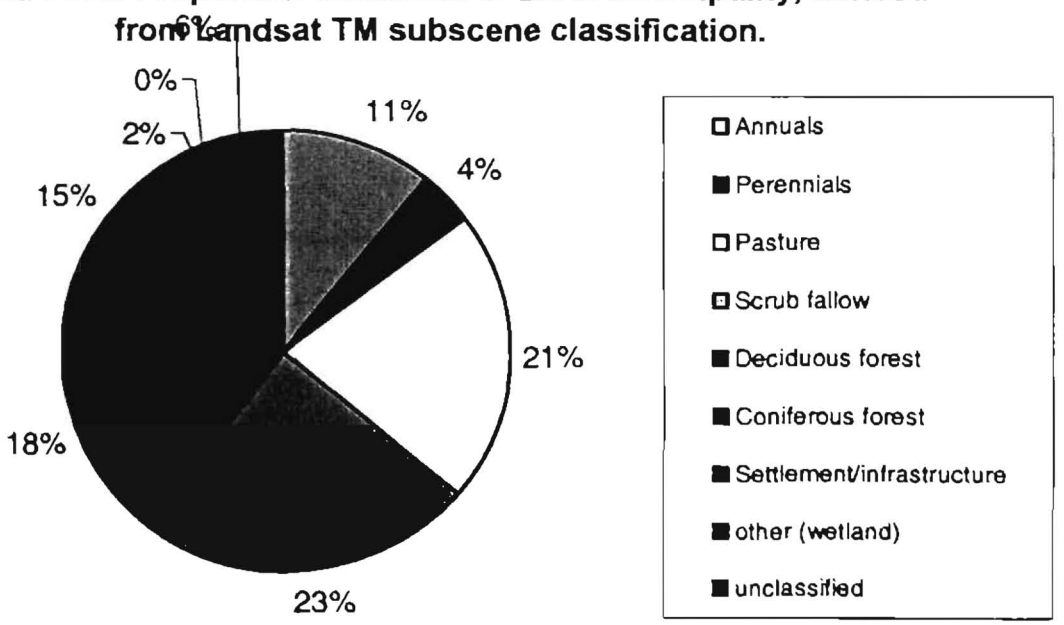


- Annuals
- Perennials
- Pasture
- Scrub fallow
- Deciduous forest
- Coniferous forest
- Settlement/infrastructure
- other (wetland)
- unclassified

Land Cover Proportion Estimates for Danli Study area, derived from Landsat TM subscene classification



Land cover Proportion estimates of Danli Municipality, derived from Landsat TM subscene classification.



municipality and department are representative of the land cover/land use proportions of the whole hillsides region.

At the department level it is seen that forest (deciduous forest and coffee in this case) covers just over half of the total land area and the pie chart is similar to those of the two study areas, but is questionable whether this region is representative of the whole of the hillsides, as forest covers an additional 24% of the land area than for the hillsides region as a whole. Hence the other land use types occupy lesser areas in this northern region of Honduras, especially annual cultivation. Pasture and scrub fallow cover comparable proportions of the total area and perennials are seemingly more important, due to the commercial plantations of banana and oil palm in the valley regions.

Sumary of the land use representativity of the study areas in the context of the Hillsides Zone of Honduras:

Land use	Yorito SA	Danli SA	Arizona SA	La Masica SA	Average of SA's	Hillsides zone
Annuals	16%	23%	5%	1%	11%	12%
Perennials	0%	3%	**5%**	1%	2%	3%
Pasture	**34%**	22%	25%	25%	26%	19%
Scrub fallow	16%	17%	**32%**	27%	23%	18%
Deciduous forest	11%	8%	13%	**42%**	18%	24%
Coniferous forest	16%	12%	0%	0%	7%	14%
Settlement/infrastructure	5%	3%	5%	3%	4%	3%

The combined study areas provide a good range of land cover/land use characteristics with each study area having contrasting dominant classes ie. the Atlantida sites have greater proportions of scrub fallow and perennials; the Yorito study area has the highest proportion of pasture/grazing lands and annual cultivation is also important; Danli study area is most representative of the whole region with annual cultivation occupying the largest area.

If one calculates the average percentage land use covers for the study areas and compares these figures with the Landsat TM classification estimates for the hillsides region as a whole, it is possible to conclude that the land cover/land use classes are mostly comparable with the exception of pasture and scrub fallow which have slightly higher percentages within the study areas and the forest classes are perhaps a little under-represented within the study areas as the hillsides region shows higher percentage covers for the two forest classes. This is not too surprising as the Hillsides programme is focused on the agricultural communities and quite a large percentage of this forest of the hilllsides zone is within national parks.

A final observation I would like to make is that the conclusions arrived at here were actually observed during field visits. It was possible to ascertain the dominant land use types in the given study areas and their overall character. This pie-chart analysis only confirms what was already observed in the field. This point may indicate an acceptable level of accuracy of the Landsat TM image classifications at the various scales of analysis.

It is worth adding the point that the image classifications were not simply carried out for the hillsides region as a whole and then classifications of the subscenes and study areas clipped out; the study areas were classified separately, as were the municipalities. Only the departments were clipped out of the hillsides zone classification. This would imply a considerably greater amount of work, which was necessary to ensure higher accuracies for the local-level studies. It was also not possible to extrapolate the signature files of the study areas to the whole hillsides region, nor was it possible for that matter to apply the files to the department zones without losing out on accuracy.

Although the older date imagery was classified, these classifications require further work to make them firstly compatible with one another, so that classes are continuous across image boundaries, and secondly they need to be adjusted so that they are compatible with the recent date classifications in order for land use change studies to be made possible. Different atmospheric conditions make this slightly difficult, but it should be possible for a trained remote sensing scientist to recognize the similarities and differences in land cover/land use between the two dates of original false colour composites.

CHAPTER 4

COMPARISON OF MULTI-DATE LAND COVER/LAND USE CLASSIFICATIONS WITH COHDEFOR'S 'MAPA FORESTAL' AT SCALE 1:500,000.

IV Comparison of multi-date Land Cover/Land Use classifications with the Cohdefor 'Forestry' Map at scale 1:500,000

1. Comparison with Central Hillside Zone (TM Dates 1994-1993)

Deciduous Forest (Fig IV-1)

It seems that the Cohdefor map has delineated only non-encorached forest, as the (Poster-Map 9) polygons are very much smaller than the classified areas in the mosaiced classification map corresponding to deciduous forest. The pale yellow areas on the map indicate areas of migratory agriculture ie annual cultivation and fallow - but this gives the impression that there is very little deciduous forest left in tact which isn' t quite true. The distribution of the centres of dense deciduous forest are all correct and comparable with my TM classification. The Cohdefor map was also compiled using classified Landsat TM imagery but using older images from the mid 1980's. In the second half of this account some comments are made on the comparability of the map with the attempted classification of 1980's imagery also carried out for the CIAT's Hillsides Programme.

Mangrove forest does not appear to be complete on the Cohdefor map - missing from part of the Atlantic shoreline in the department of Atlantida. The protected areas of Punta Sal and Cuero y Salado include areas of mangrove vegetation. These were observed during reconnaissance field work carried out in Honduras in 1996. This would seem to be quite an error, seeing that this map is primarily a Forest Cover map. The interest looks to be very much more concentrated in commercial timber production and the mapping of conifer vegetation appears not to be in balance with other land use types.

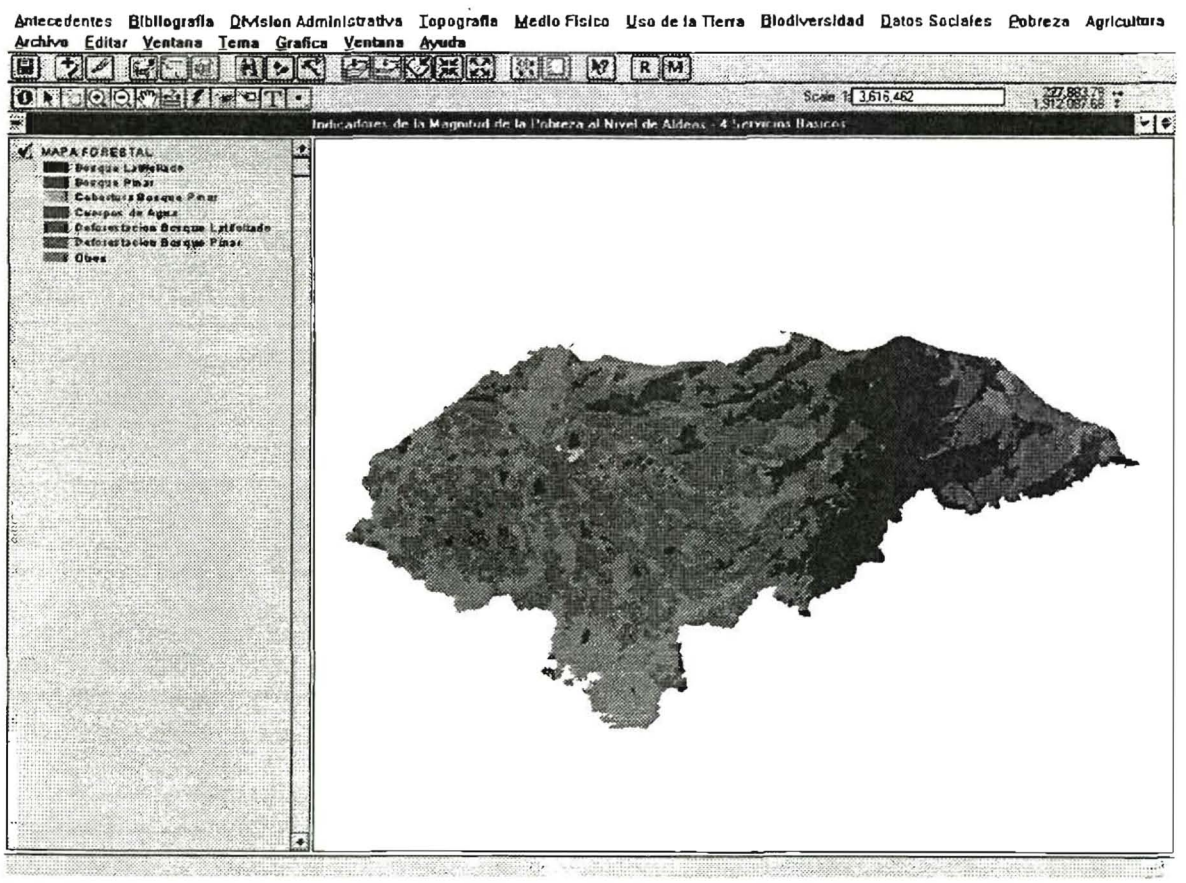
Even the national parks and other protected areas are mapped as having only sometimes a third or less of the original deciduous forest - as other land use types have impinged on their boundaries to a great extent. The map certainly gives an alarming image to an ecologist! It is difficult to believe that the basis of their map was also a mosaiced satellite image - perhaps the lines delineating the various units had been adjusted substantially by the Forestry department according to their own larger-scale forestry maps.

Coniferous Forest

As mentioned above, the cover of coniferous forest presents the most striking difference between the two land use presentations of Honduras. In the TM classification, pine forest is concentrated in the scarp slopes and footslopes, and areas of sparse pine have been classified as rough grazing rather than forest lands in my representation. Much of the sparse pine stands of the map coincide with scrub fallow areas of the TM classification. They appear from the classification to be areas of annual cultivation more than forest lands, as they already have been opened up and very often are degraded lands.

Mixed Forest

This class is generally difficult to map using satellite data as the spectral signature is very similar to coniferous forest - the eastern two images are classified with more mixed forest than the western two images - the two halves, each consisting of two scenes, have the


Antecedentes Bibliografia DMsion Administrativa Topografia Medio Fisico Uso de la Tierra Biodiversidad Datos Sociales Pobreza Agricultura
Archivo Editar Ventana Tema Grafica Ventana Ayuda
Scale 1: 3,616,462
MAPA FORESTAL
Bosque Latifoliado
Bosque Pinar
Cobertura Bosque Pinar
Cuerpos de Agua
Deforestacion Bosque Latifoliado
Deforestacion Bosque Pinar
Obes

same date and hence the same spectral characteristics. Perhaps much of this mixed forest in the eastern two scenes would have been better classified as shaded deciduous forest. However, much mixed tree composition was seen in Olancho whilst the author was undertaking reconnaissance fieldwork. So the classification could be partially correct. More certain errors exist in the classification in the northeastern scene, in the area of the Rio Aguan valley, where coastal marsh/reed vegetation has been classified in a much dryer zone, to the south of the Cordillera Nombre de Dios which is rather dubious.

The Forestry map show this class to be substantially fragmented and intermixed with the coniferous stands throughout the hillsides zone.

Permanent Cultivation

Perennial cultivation appears to be fairly accurate on the Forestry map - more so than the TM classification - this supports the argument that this map was produced using air-photograph coverages and the like - and the complications of image classification have been sidelined by producing a polygon map. It is an interesting product and it would be enlightening to compare the final product with the initial image classifications that were produced as a 'basis' for the map. If one looks at the major valley of the Rio Ulua, the built-up zone of San Pedro Sula is not included - only a dot symbol marks the centre of the city, which consists of a large expanse of infrastructure. The same is true for Tegucigalpa and, on a smaller scale for La Ceiba, Olanchito, Catacamus and Comayagua. On the whole these areas have been wrongly mapped as permanent agriculture!

The TM classification of perennial cultivation was of mixed precision sometimes there would be too much confusion between tree crops and scrub vegetation/mangrove forest etc.

Pasture

Pasture does not show much similarity between the two maps. One or two clear errors exist in the Forestry Map including the absence of dominant improved pasturelands in the coastal plain of Atlantida department.

The class 'Tierra con pastos' could actually include bushland, as there is no category for scrub vegetation, in which case there would be more similarities between the two maps. However, I suspect that bushland would have been incorporated within the class Migratory agriculture - this would therefore include a whole range of cover types including bare, ploughed fields, short fallows and scrub fallows of 5 years regrowth or more.

The TM classification shows scrub fallow extending down from the forest edges to the valley zones which are dominated by cultivation and pasture. There seems therefore to be another major disagreement between the two classifications as the forestry map indicates large areas of land with grassland, which implies grazing land use and my classification is showing the corresponding areas primarily to be scrub fallow which is part of the annual cultivation cycle and hence more cultivation type land use. However, there is often a mix of land uses in these transitional areas and annual cultivation lands

are often grazed upon; likewise pasture lands may be sown with annual crops and the two land uses would occupy a given tract of land at different time periods. However, usually it is not difficult to ascertain the dominant land use in a given area - and I believe a map would be more accurate if it were to map the dominante land use - in this particular case, it is more likely to be scrub fallow, as these lands have not been long cleared of forest and 'slash and burn' agriculture is very much practiced. The author's perception is that pasture is more extensive than the Forestry map suggests; however, in the cases of annual cultivation and pasture, changes do occur as a result of government policy decisions - and one must consider this possibility before assessing the accuracy of one or other map. Indeed, the more recent classification indicates dominant pasture lands in coastal plains of Atlantida - but on the Forestry map, which used late 1980's data, the dominant land use was migratory agriculture.

The Forestry map indicates that Landsat TM images were acquired between the years 1986 and 1989. The much reduced extent of deciduous forest in the Cohdefor map is even more questionable when one assumes that there has been some deforestation between the time periods of 1989 say and 1993/4 which are the dates of the TM Classification. Classifications of the study areas and surrounding regions for two dates has shown that there has been minimal deforestation. This is an interesting point as the seemingly drastic management used by smallholders to clear their plots tended to suggest in ones mind that forest destruction is part of these peoples' livelihoods - but when one checks the image for confirmation, smallholder farming apparently has not had such a major an impact on land resources as first imagined.

Water

The water class is of course very simlar, however, some of the major rivers in the TM classification area also shown as water - and the Cohdefor map includes only line symbols for the rivers.

2. Comparison of the Cohdefor Forestry Map with the older date TM Classification (1980's).

Deciduous Forest

It seems that the Cohdefor map has only delineated non-encroached forest as the polygons of deciduous forest as they are very much smaller than the classified areas in the classification. The pale yellow areas in the Foresty map designate areas of migratory agriculture, that is annual cultivation and scrub fallow. Although there is a substantial difference in the extent of the map units, the location of the centres of deciduous forest are comparable.

The map includes information on protected areas and the boundaries of all reserves is shown, often to include substantial areas of 'migratory agriculture'. Although certain encroachment is likely, if one checks the TM imagery, it would seem that in the majority of cases, forest cover extends at least to part of the boundary. Also, it is common to find coniferous forest within these zones, which indicates possible forestry operations within protected zones. However, there is a close linkage between office management of Forestry Department and National Parks.

Mangrove forest shows certain disagreement between the two maps: the Cohdefor map has excluded mangrove classified in the north coast of Atlantida department; it only includes some mangrove in the vicinity of Trujillo.

Coniferous Forest

The major difference between the two maps is in the mapping of coniferous forest: in the classification, coniferous forest/woodland is confined to the perimeters of some of the deciduous forest blocks, usually along escarpments and on footslopes. The Forestry Map seems to be dominated by dense and sparse conifer stands which are more general in their distribution.

Sparse Pine Rangeland

Much of the sparse pine area of the Cohdefor map coincides with scrub-fallow in the TM classification. These are areas that are more related with annual cultivation/migratory agriculture, than with pasture. The classification incorporated this class with that of pasture, as the trees are self-sown and smallholders use these government lands to graze their animals. The difference in definition of this class indicates the difference in interest/bias of the map-maker - forestry as opposed to general land cover/land use.

Mixed Forest

This class is difficult to classify, as the spectral signatures are very similar to coniferous forest. The eastern two images classified more mixed forest than the western two images. Much of the mixed forest in retrospect, would have been more accurately classified as

shaded deciduous forest. However, much mixed forest was seen in the department of Olancho. So the classification could be partially correct.

Errors exist in the Trujillo image around the Valle de Aguan where some coastal marshes have been classified. These could possibly be rich/dark valley soils.

The mixed forest class in the Forestry map appears in very fragmented patches throughout the hillside zone. The general conclusion is that the Cohdefor map tends to exaggerate the combined classes: coniferous forest, sparse conifer and mixed forest.

Perennial Cultivation

The distribution of perennial cultivation seems to be quite accurate on the forestry map, with the exception of the valley zone around San Pedro Sula. The TM classification had mixed successes in mapping this class due to the spectral confusion. Perennials include various tree crops such as oil palm, banana, plantain, citrus and other plantation crops such as pineapple and sugar cane. Coffee and cocoa being shade-tree crops were mapped as deciduous forest.

One major limitation of the forestry map is its omittance of an urban class - the imagery indicates that significant areas are built up and represent settlement and infrastructure. In most cases, the map includes these areas within the class permanent cultivation. The map displays a dot symbol marking the centre of towns. The TM classification shows that at least six towns had sufficiently large mapping units to be included in the map at the scale of 1:500,000. They include Tegucigalpa, San Pedro Sula, La Ceiba, Olanchito, Catacamus and Comayagua.

Comparison of the 1980's Classification with the Cohdefor Forestry Map - examining the different regions of Honduras.

Brus Laguna: Deciduous forest compares well between the two maps. It seems strange that there is a zone of sparse conifer with some patches of dense pine in this region eg. Llanos de Auca. The classification indicates opened up areas: pasture and scrub fallow. The wet soils contribute to the dark appearance of the false colour composite image, and is similar to the tone recognized as sparse pine rangeland. Certainly, these areas have been cleared for annual cultivation. Areas of wetland on the Cohdefor map are clear as the dense network of meandering streams and ponds is discernible in the original composite scene. However, there is some mangrove and dense vegetation growth along the littoral zone between Puerto Lempira and Cabo de Gracias a Dios, which is not included.

Trujillo Southwards: Deciduous forest in the Cohdefor map relates well with the solid/continuous blocks of forest in the classification. There are marked differences for all other land cover classes. However, the extended band of conifer from Chichicaste

northeast to Dulce Nombre de Culmi can be recognized in the classification. Perennial cultivation in the valley of Juticalpa-Catacamus is absent from the map. The deciduous forest areas of El Armado and north of the rio Juticalpa are almost entirely lacking from the map: the majortiy of these areas have been mapped as extensive cultivation. This may be so to a degree, but, the image suggests that there was substantisl forest cover between the plots.

A problem is noted in the classification: where cloud fringes have been misclassified as perennial crops: this needs additional training areas to correct. Also, on inspection, there is a substantial mismatch between the north and south scenes which were dated March 1986 (north) and January 1987 (south). The latter is dominated by sparse pine rangeland outside of the deciduous forest blocks whereas the adjoining areas of the northern scene have been classified as scrub - which I believe is the error, looking at the original scene - the area in question is in an area of speckled cloud, to the south of Monana de Botaderos. Some of the difference may be due to the green-up /die-back differences in the two images; another area of noticeable disagreement is in the valley area north of Sierra de Agalta where the southern scene indicates a complex of deciduous cover, perennials and some pine. In the northern image there does not appear to be so much green vegetation cover apart from some perennials along the river channel. A large ahas been classified as annual cultivation. The map indicates annual cultivation but only in the central zone with pasture occupying a greater area. I have more conifidence in the mixed forest mapped by Cohdefor in the area south-east of Montana de Botaderos.

My overall impression is that the map underestimates deciduous forest cover and perennial cultivation and overestimates migratory agriculture; the latter class would have been more correctly described as a complex of secondary deciduous forest and small annual clearances/scrub fallow, but predominantly forest cover. A good part of the map to refer to would be in the vicinity of Montana de Almendares and southeast along the northern perimeter of El Paraiso Department and El Chile Biological Reserve. Also one will notice an inconsistency if this area is compared with that of the northern part of the Danli study area watershed, to the east of Danli, where the deciduous forest has been mapped completely.

Choluteca: The map indicates a large block of predominantly annual cultivation, but the corresponding area in the classification indicates predominantly eroded bushland, ie. thorn scrub and exposed rock/thin soils with sparse pine cover. Perennial cultivation is found in the valleys of Rio Nacaome, Goascoran and Choluteca. This is an area of very thin soils and my estimateion after observing the area in the field and attempting to classify the region, would be that it is perdominantly an area of extensive grazing land with self-sown pine. It seems that the map would have done better swopping the classes pasture-extensive agriculture - this would have approached reality more.

The coniferous forest to the south and southwest of Tegucigalpa corresponds well between the map and the classification. The omittance of so much deciduous forest makes me think that the production of the map may have included certain overlays to mask out certain zones, eg. perhaps government-lands/land tenure map to draw

boundaries around smallholder agricultural land use which would include secondary forest areas. But, this would not explain the pervading migratory agriculture inside protected areas. Also perhaps various height contours were also referred to in the mapping of protected forest reserves.

The 1980's classification of the central block (for which we have recent imagery) supports the conclusions previously made. (Section IV-1)

Atlantida (1980's classification-map comparison): One noticeable difference is that in the valley of the Rio Ulua, the map indicates perennial crops over much of the valley. However, the classification shows that a part of this is in fact heavily built up and the majority is in fact improved pasture.

Copan: The image 19/50 needs to be extended further south to include the south-west border between Honduras and El Salvador. The only clear similarity between the map and the classification is Montana Verde, a circular area of dense deciduous cover. The large area classified as forest to the west of Santa Barbara is mapped as migratory agriculture. The dense conifer block mapped to the west of Gracias is just about discernible in ones imagination, examining the corresponding foothill zone in the classification, slightly better from the original false colour scene, but, only a fragment of what is mapped.

Included in the map is a table summarizing areas of forest/other land use (11 land use classes in total) by 'forest zone' which in some areas coincides with departmental boundaries. There area ten forest zones: Comayagua, Copan, El Paraiso, Francisco Morazan, La Mosquitia, Nor occidental, Olancho, Yoro, Atlantida, Zona Sur. These cover respective areas: 10,794 square kilometers, 9,177 square kilometers, 6,885 square kilometers, 8,457 square kilometers, 17,846 square kilometers, 8,991 square kilometers, 23,022 square kilometers, 7,324 square kilometers, 13,331 square kilometers, 6,665 square kilometers and the total (country estimate) 112,492 square kilometers.

Comparison of land use totals:

1. Dense coniferous forest	8,281 square kilometers
2. Sparse coniferous forest	19,692 square kilometers
3. Deciduous Forest	27,066
4. Mixed Forest	5,288
5. Mangrove	543
6. Intensive/permanent cultivation	1,859
7. Pasture	17,937
8. Extensive/migratory cultivation	27,164
9. Marshes/wetlands	3,200
10. Lakes/lagoons	1,392
11. "Camarones" -(shrimp farm SE of Choluteca)	70
TOTAL	112,492 square kilometers

CHAPTER 5

COMPARISON BETWEEN LANDSAT TM CLASSIFICATIONS AND AGRICULTURAL CENSUS IN THE ESTIMATION OF LAND USE AREAS PER ADMINISTRATIVE UNIT: FOR BASELINE MUNICIPALITIES

Comparison between Landsat TM classifications and Agricultural Census in the estimation of land use areas

Introduction

Perhaps the principal research objective of this remote sensing study which will contribute most to the PhD study is the investigation into whether it is possible to combine information derived from ancillary data, such as census information, to enhance the accuracies of an image-classification. GIS projects integrate data from many different sources, and the specialist need to take care that the data are compatible, especially in terms of accuracy and scale. During the characterization study of Honduras, it was possible to compare land cover proportion estimates derived from image classifications of various regions with proportions derived from census estimates for municipalities and departments. First it was necessary to conclude whether the results showed sufficient consistency to apply weighting factors in the form of probabilities to the Maximum Likelihood classifier.

V. Analysis of Land Cover estimates derived from Landsat TM Classifications and Agricultural Census: Baseline Municipalities.

The percentage of the total area of municipalities censused in the National Agricultural Census of Honduras in 1993 varied between 0.01% (Brus Laguna, Gracias a Dios) and 102.7% (Namasigue, Choluteca).

Five sample municipalities, having high percentages of administrative area censused and the possibility of comparison with recent date Landsat TM imagery, were chosen for a baseline study. (Map V_1, Poster Map 10) They include the following:

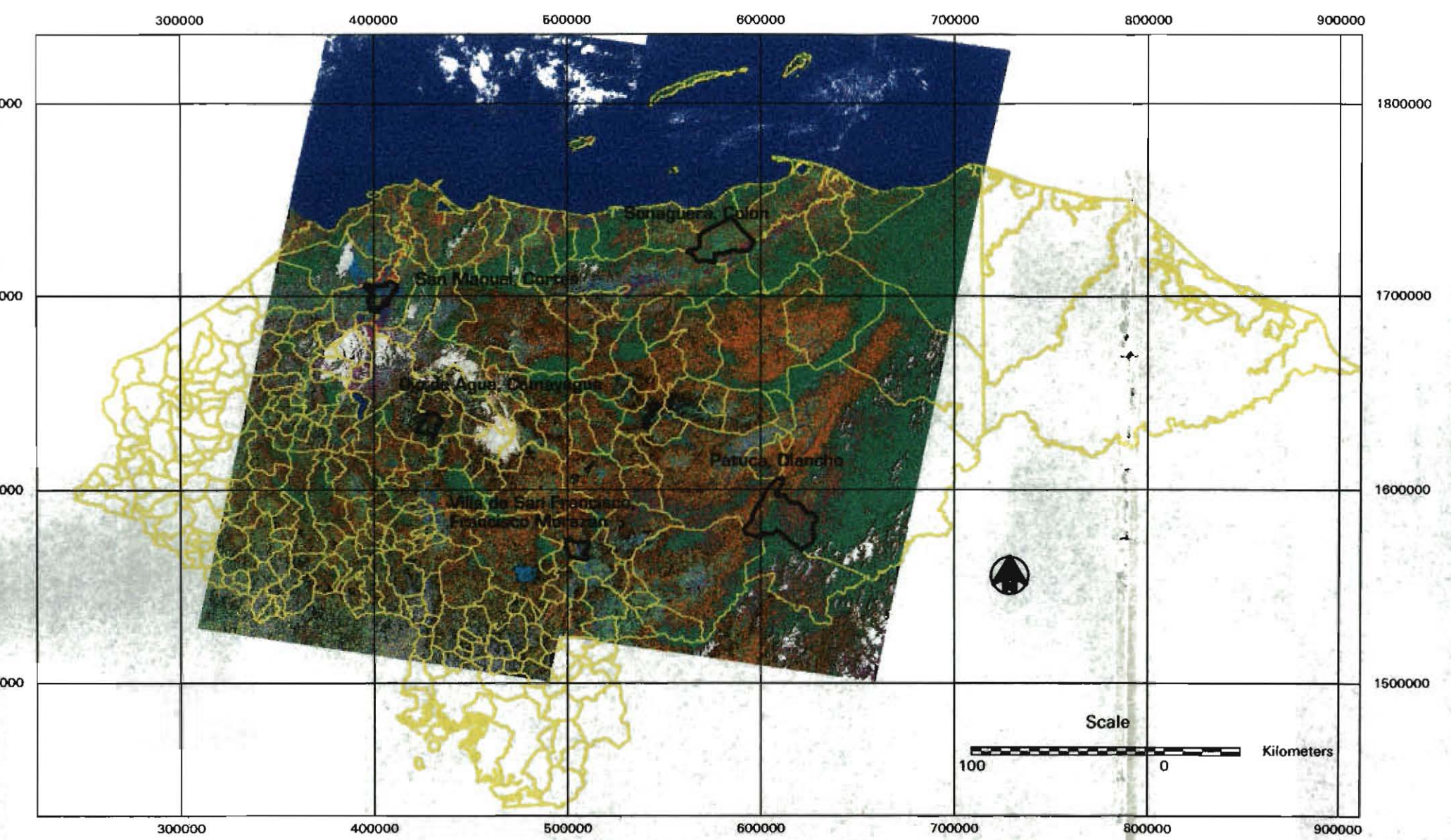
San Manuel, Cortes: Area = 13,607 ha; Area reported = 11,599 ha (85% censused)

Ojo de Agua, Comayagua: Area = 9,177 ha; Area reported = 7,472 ha (81% censused)

Villa de San Francisco, Francisco Morazan: Area = 8,841 ha; Area reported = 7,113 ha (65% censused)

Sonaguera, Colon: Area = 40,781 ha; Area reported = 26,102 ha; Area reported = 26,102 ha (64% censused)

Patuca, Olancho: Area = 67,160 ha; Area reported = 40,180 ha; Area reported = 40,180 ha (60% censused).



Location of Baseline Municipalities used in a study of land cover estimate comparability between the 1994-3 TM classification and the 1993 Agricultural Census.

1. San Manuel, Cortes

1.1 Land Cover Description (based on Landsat TM classification)

San Manuel is situated just to the west of El Progreso urban area. It is heavily built-up, being in the major river valley of Rio Ulua. The Landsat TM Classification indicates that about one quarter of the area is settlement/infrastructure. The dominant land use type classified is perennial cultivation covering 26% of the municipality. Plantation crops (banana and plantain) are cultivated on the fertile valley floor. (Table V_1.1). There is a small hilly area in the central southwest where the land cover consists of forest and scrub fallow. Some of the municipality is obscured by cloud cover - ie. a total of 528 hectares are unclassified (including dense shadow).

Table V_1.1 Land cover proportion estimates for San Manuel Municipality using Landsat TM classification /img2/ceiba94ML_res.img:

Class Name	Area Classified (ha)	Area Censused (ha)
Annual cultivation	1057 (7.8%)	820 ha (7%)
Perennial cultivation (Banana/Plantain)	3543 (26%)	5652 ha (49%)
Pasture	3177 (23%)	4207 (36%)
Eroded bushland (Pasture)	13 (0.1%)	
Wetland (Pasture)	195 (1.4%)	
Scrub Fallow	588	327 (3%)
Deciduous Forest	486	202 (2%)
Deciduous Forest2	108	
Settlement/infrastructure	3188	0
Unclassified: shadow/burn	183	
Unclassified: cloud	345	
Water/river	948	37
Other uses (agricultural and non-agricultural)	0	353
Total land cover/land use	**13607**	**11598**
Area unclassified/unreported	**528**	**2009**

1.2 Comparison between Classification results and National Census estimates:

From the regression graph (file E:\users\jacox\Windows\baseline_TMcensus.xls) it is clearly seen that the two dominant land use types are perennial crops and pasture; scrub, forest and annuals occupy relatively small percentages of the total area being clustered near the origin of the graph. The exceedingly high regression coefficient of 0.98 indicates a strong correlation between the estimates, but this may be exaggerated due to the few points plotted.

One major limitation of the Census is that it doesn't include urban land areas in the total summation and, in this municipality, occupies a good percentage of the land area ie. 23%. Urban areas presumably fall under 'other non-agricultural land use' in the census, but this only amounted to 232 hectares.

In general, the agricultural census estimates of annual cultivation are not to be interpreted as reported areas - since these were rounded off figures. However, in this case, annual cultivation shows similar figures and proportions between TM classification and census.

A total of 11,598 hectares were reported in the census, representing 85% of the municipality. It appears that the larger the reporting zone, the greater the correlation with the satellite-image classification estimates of land cover/land use. This also infers that remote sensing can give reliable estimates of land use and can greatly assist in checking and perhaps in filling in gaps apparent in the census

2. Ojos de Agua, Comayagua

Ojos de Agua municipality lies just to the west of the urban area La Libertad in north central Comayagua.

2.1 Land Cover Description (based on Landsat TM classification

Two classification results are available - one was a pre-fieldwork attempt and the other was carried out after field-data and air-photograph acquisition. The pre-fieldwork classification gave a better regression result with the census data. The two classifications area very different particularly in the mapping of forest, scrub fallow and annual cultivation. After inspection of the photographs (28 in total in four runs), it is apparent that the dominant land use is a bush-grassland (or scrub fallow) and sparse pine rangeland which from the land-use point of view has dual foresty and pasture uses. The trees are self-sown and therefore the author decided to describe these areas as natural pasture rather than forest. The whole of this 1994 image is cloud-free, but some densely shaded areas, possibly recent burns were unclassified (0.3%). (Table V_2.1). A limitation of the pre-fieldwork classification is that it did not include pasture and scrub as separate classes. This was due to the difficulty of image recognition without use of photography and the small size of land parcels. The area was visited on a field visit made in November-December of 1996. The area appeared to be predominantly hilly with views toward the south. The general appearance was pine rangeland with cultivation concentrated in the valleys. The region also appeared dry. Grazing and forestry were the dominant land uses.

Table V_2.1

Class Name	Area Classified (ha)	Area Censused (ha)
Annual Cultivation	2505 ha (27%)	1156 ha (15%)
Perennial Cultivation	904 ha (10%)	1161 ha (15%)
Pasture	2,018 ha (22%)	3,812 ha (41%)
Scrub fallow	2768 ha (30%)	738 ha (8%)
Forest, deciduous	13 (0.1%)	556 ha (6%)
Forest, coniferous	847 ha (9%)	
Settlement/infrastructure	74 ha (0.8%)	-
Rivers/Water	18 ha (0.2%)	5 ha
Other	0	44 ha
Unclassified/unreported	**29 ha (0.3%)**	**1704 ha (18.5%)**
Total land cover/land use	**9176 ha**	**7473 ha (81.4%)**

2.2 Comparison between Classification and National census estimates:

From the regression graph, it is clear that pasture and forest occupy the greatest areas in the pre-fieldwork classification and that scrub-fallow, annuals and pasture are dominant in the post-fieldwork classification. The major confusion here has been with the scrub fallow class, as it was not always clear whether these bushlands were in fact annual cultivation fallow lands or rough pasture. The regression coefficients were 0.26 for the pre-fieldwork classification, but only 0.02 for the supposedly better classification. This result points to the fact that spectral classification may not be sufficiently accurate due to inseparability of chosen classes, and the relief factor could further exacerbate the problem. Also, fieldwork and air-photograph examination do not always produce better results in a computer classification. Perennials and forest did appear to converge more with the census figures on this post-field attempt.

In a municipality where 81% or the area had been reported, one could assume that the inaccuracies lie more in the image classification. On revision, it appears that the scrub fallow class has been overclassified and these areas should probably have been classified as sparse pine rangeland. There was not too much evidence of annual cultivation in the hills of the north.

An explanation for this apparent inaccuracy is as follows: certain land cover/land use types are easier to classify than others and their situation (including size of holding/pattern in the landscape) in the relative terrain will also have an affect on overall accuracies. This happened to be a difficult piece of terrain to classify. Indeed this was a very different result to the one previously described. This could be mostly due to the charcter of the terrain and the size of the land units in relation to the spatial resolution of the TM sensor (32metres).

3. Villa de San Francisco, Francisco Morazan

3.1 Land Cover description (based on Landsat TM classification)

Villa de San Francisco is located to the northeast of Tegucigalpa city in the department of Francisco Morazan. It is primarily situated in a valley and so is dominated by commercial cultivation. The valley is that of the Rio Grande O Choluteca. There are footslopes of mountainous regions in the east and west of the municipality. The classification shows a transition of land cover/land use types away from the river: perennial crops (7%), settlement and infrastructure (9%) on the valley floor with annual cultivation (30%) extending to the footslope zone, which is dominated by pasture (41%). the footslopes have some more annual cultivation and scrub fallow (4%) as well as scattered settlement. There is no deciduous forest cover within the municipality, only pine forest (0.6%) in the highest areas (Postermap 10 and Table V_3.1)

Table V_3.1:

Class Name	**Area Classified (ha)**	**Area Censused (ha)**
Annual cultivation	2610 ha (30%)	1064 ha (18%)
Perennial cultivation	624 (7%)	734 ha (13%)
Scrub fallow	348 ha (4%)	911 ha (16%)
Forest	65 ha (0.7%)	1281 ha (22%)
Settlement/infrastructure	825 ha (9%)	0
Rivers/water	0 ha	9 ha
Other land use	0	44 ha
Unclassified/unreported	722 ha (8%)	3086 ha (35%)
Total land cover/land use	8841 ha (100%)	5755 ha (65%)

3.2 Comparison between Classification results and National census estimates:

The regression graph shows that the land use types are spread apart quite evenly; pasture is the dominant land use followed by annual cultivation. Forest, scrub fallow and perennials occupy relatively smaller proportions of the municipality. The regression coefficient is 0.6 which is fairly high. This is an interesting case as the area of land reported to have been censused was 7,113 hectares; however, it was seen after summing the individual land uses that the total came to only 5,755 hectares. Pasture seems to the be the dominant class followed by annual cultivation and forest. The classes that converge the most include scrub fallow and perennial cultivation. which in the municipality occupy well defined areas, related with the terrain units. The latter has helped in the separation of spectral classes.

4. Sonaguera, Colon

4.1 Land Cover Description, based on Landsat TM Classification

Sonaguera is located in the northeast of the hillsides zone in the department of Colon. It is much larger than the previous baseline municipalities described, covering a total area of 40,781 hectares or 407 square kilometres. The classification based on Landsat TM data dated 1993, shows a predominant land use of pasture. The settlement of Sonaguera is located in the centre of the municipality on fertile valley soils. Deciduous forest only occurs on the mountains of the Cordillera Nombre de Dios along the northern boundary. There is an area of commercial plantation crops in the southeastern corner bordering the river Aguan. The image is a cloud free scene and there is limited shadow to contend with resulting in a complete classification. (Poster Map 10 and Table V_4.1).

Table V_4.1 :

Class Name	**Area Classified (ha)**	**Area Censused (ha)**
Annual cultivation	1981 ha (5%)	3900 ha (10%)
Perennial cultivation	5054 ha (12.5%)	9097 ha (23%)
Pasture	15201 ha (37.5%)	10185 ha (26%)
Scrub fallow	8,543 ha (21%)	2,432 ha (6%)
Forest	5,867 ha (14%)	361 ha (1%)
Settlement/infrastructure	3828 ha (9%)	0
Rivers, water	0	38 ha
other land use	0	89 ha
Unclassified/unreported	65 ha	14679 ha
Total land cover/land use	40781 ha (100%)	26102 ha (64%)

4.2 Comparison between Classification results and National census estimates:

The plotted land use variables in the regression graph are all widely distributed about the regression line, suggesting a weak correlation between the two land use data sets. The coefficient is 0.2. This municipality has an almost identical intensity of sampling by the census as the previous municipality Villa San Francisco - with 64% of its area having been reported. The census, like the classification, indicates the dominance of grazing as a land use type. It appears from the graph that perennial cultivation has been underclassified and that scrub fallow and forest have been overclassified compared with the census estimates. The fact is though, that accessibility and location of area censused is unequally distributed and therefore naturally undersamples the mountainous area with less in-roads. Therefore it is not certain that the image classification lacks accuracy here - it may actually indicate error more in the census estimates.

5. Patuca, Olancho

5.1 Land cover description (based on Landsat TM classification)

Patuca is the last baseline municipality to be considered in this study and contrasts again with the others selected. This time there is a predominance of deciduous forest (52%) which is concentrated in the highlands. The lower areas are characterized by a complex of scrub fallow (13%), perennial cultivation (15%), which does not include shade-tree crops such as coffee) and pasture (15%). Surprisingly little annual cultivation has been mapped (1%). Some settlement occurs in the western and central areas. The Rio Patuca marks the northeastern boundary of the municipality and another river, the Rio Guayambre flows through the western zone. Patuca is one of the 23 municipalities of Olancho. From about this line of longitude east, the land cover is predominantly forest, this eastern part of Honduras merging with the dense tropical forests of the Mosquitia. Cloud and shadow obscure only 2.5% of the total area. (Poster map 10 and Table V_5.1).

Table V_5.1

Class Name	Area Classified (ha)	Area Censused (ha)
Annual cultivation	703 ha (1%)	4,904 ha (12%)
Perennial cultivation (Coffee)	10,192 ha (15%) part of the deciduous forest	163 ha (2%) 754 ha (1%)
Pasture	10,204 ha (15%)	23,013 ha (57%)
Scrub fallow	9,094 ha (13.5%)	4,049 ha (10%)
Forest	34,769 ha (52%)	7,230 ha + 754 ha (coffee) (18%)
Settlement/infrastructure	515 ha (0.1%)	0
Rivers/Water	0	40 ha
other land use	0	27 ha
Unclassified/unreported	1679 ha (0.3%)	26980 ha (40%)
Total land cover/land use	67160 ha (100%)	40,180 ha (60%)

5.2 Comparison between Classification results and national census estimates.

The regression figure for this final baseline municipality indicates a weak relation between the two land cover data sets. The coefficient this time is only 0.001.
The land use variable points are widely scattered, the highest figures occurring in the census for Pasture and in the image classification for forest. Due to the extent of the area, the author is more confident with the satellite image representation. This zone is one of the least accessible, and even though a relatively high percentage of the total administrative zone is reported to have been censused (60%), which seems exaggerated, as the forest cover contributes over half of the area, and only 2% of this area is reported

as coffee plantation. However, it is possible that the land tenure is rather different here - and the land holdings are large, in which case the area censused will rapidly rise. The most common size of holding is about 50 hectares.

Census is totally inadequate to make estimations of forest cover, as the variable considered in the agricultural survey is confined to tree stands on farms. Therefore, unless farmers interviewed own large tracts of forested land, the actual forested area is never approached. Satellite imagery is probably the only method for rapid appraisal of forest area, and the Department of Forestry in Honduras are actively making use of this source of information.

It appears the perennial cultivation has been over-classified. A problem of classifying the densely forested areas is that the encroachments, ie the areas cleared for annual cropping, homesteads, pasture etc are different in spectral information to simlar land use types in more open surroundings. This may be due to the method of sampling of the original data - and the smearing affect of the forest spectral signiature across the smaller areas of agricultural land use. Certainly a good proportion of these islolated clearings are annual croplands - and the image classification result fell short of the census estimate for annual cultivation: 703 hectares compared with 4,904 hectares in the census. After the area under coffee has been subracted from the perennial variable, only a very low proportion is left (2%) for perennial crops. There are several river valleys and it is very likely that significant areas of land are under perennial crops. This may account further for the discrepancy between the two data sets.

Pasture classification appears to have been underestimated by half - if we assume that the census is more correct, it may be that a certain proportion of the area classified as perennial crops, especially the isolated plots in the mountainous region, most probably should have been mapped as pasture.. Some cloud cover obscures the image amounting to about 2% of the municipality.

The combined regression plot for all five municipalities gives a diffuse result which suggests that there is little consistency in how the the two data sets relate to one another. The overall regression coefficient is 0.2. Forest and scrub fallow appear to have the best correlation with the census. Annuals, perennials and pasture have very mixed results and a generally low correlation with the census in these particular municipalities. Perhaps the analysis of the study area municipalities will shed further light on the problem.

CHAPTER 6

COMPARISON BETWEEN LANDSAT TM CLASSIFICATIONS AND AGRICULTURAL CENSUS IN THE ESTIMATION OF LAND USE AREAS PER ADMINISTRATIVE UNIT: FOR STUDY AREA MUNICIPALITIES.

VI. Analysis of Land Cover estimates derived from Landsat TM Classifications and Agricultural Census: Study Area Municipalities.

The study areas of the Hillsides Programme in Honduras are located within the following municipalities: Arizona, La Masica, Yorito, Sulaco and Danli. (Poster Map 11 and Excel file SAs_TMCensus.xls).

The spatial and census coverage details are as follows:

Arizona, Atlantida: Area = 51,273 ha; Protected area = 15,742 ha (31%); Area unprotected = 35,533 ha (69%); Area reported = 20,344 ha (40% censused and 57% of the unprotected municipality area);

La Masica, Atlantida: Area = 46,620 ha; Area reported = 17,755 ha (38% censused);

Yorito, Yoro: Area = 20,472 ha; Area reported = 8,820 ha (43% censused);

Sulaco, Yoro: Area = 23,638 ha; Area reported = 8,189 ha (34% censused);

Danli, El Paraiso: Area = 249,280 ha; Area reported = 154,951 ha (62% censused).

1. Arizona, Atlantida

1.1 Land cover description (based on Landsat TM classification)

Arizona is located on the northern coast of Honduras, to the east of Tela. There are no major settlement areas and the municipality is dominated by pasture and citrus trees in the coastal zone with deciduous forest covered mountain slopes coming off the Cordillera Nombre de Dios to the south. There is a large area of mangrove forest in the littoral zone. Forest cover constitutes 42% of the municipality. Pasture and scrub fallow occupy a further 38% and annual cultivation 8% of the total area. The latter is concentrated in the mountain foothill zone.

Protected natural resource areas include the following: Texiguat Wildlife Refuge (deciduous forest 8,235 ha); Punta Izopo Wildlife Refuge of the mangrove zone (6,148 ha) (see /julie/hondarc/nps_atlan) and the Lancetilla Botanical Gardens which has an area of 1,359 hectares reserved for research/recreation purposes. The latter park area has not been digitized as yet. We do however have photographs covering the area: a stereo-triplet at scale 1:40,000, dated 1992. It is probably more correct to compare the area unprotected in the classified image with the total reported area of the census: 35,533 ha and 20,344 ha respectively. We could then derive an estimate of area actually censused to be 57%, as clearly the census did not visit the national parks to interview farmers.

If the protected areas are excluded, the dominant land use types are pasture (29%) and scrub fallow (26%) followed by unprotected forest and annual cropping. Three per cent of the municipality is unclassified due to cloud cover and shadow (Table VI_1.1)

Table VI_1.1: Land cover proportion estimates for Arizona municipality using Landsat TM classification (/img1/grego/atlan_res100.img) dated 1994 and Agricultural census, 1993.
(proportions calculated as % unprotected zone since this represents the area of agricultural land use)

Class Name	**Area Classified (ha)**	**Area Censused (ha)**
Annual Cultivation	4,008 ha (11%)	2,058 ha (6%)
Perennial Cultivation	3,403 ha (9%)	1,871 ha (6%)
Pasture	10,320 ha (29%)	13,664 ha (38%)
Scrub fallow	9,106 ha (26%)	1631 ha (4%)
Forest, protected	15,742 ha (outside survey zone)	0
Forest	5,679 ha (16%)	592 ha (331 ha of shade-tree crops) (2 %)
Settlement/Infrastructure	816 ha (2%)	0
Rivers/water	1,200 ha (3%)	152 ha
other	0	376 ha (1%)
Unclassified/unreported	999 ha (3%)	15,189 ha (43% of the survey zone)
Total land use	51,273 ha (municipality) and 35,533 ha (survey zone)	20,344 ha (57% of the survey zone)

1.2 Comparison between Classification results and National Census estimates:

The regression graph indicates the dominant land use type as being pasture. It appears that the forest and scrub fallow classes have been undersampled in the census. Perennial cultivation showed the closest correspondence. Commercial plantation crops include oil palm, banana/plantain and orange/citrus in roughly equal proportion according to the census (2.2% -2.8% of the area censused). The classification combined these different crop types into the same class - particularly because the latter two crop types were invariably on small plots. The regression coefficient is 0.45. This seems quite realistic, given the limitations of both data sets. There has been some misclassification, the confusion being mainly between the classes mangrove forest, perennial crops wetland and scrub fallow, these cover-types having similar spectral signatures.

This municipality is another demonstration of the potential for making combined use of two sources of land cover/land use information before final estimates of land cover proportions are made public.

2. La Masica, Atlantida

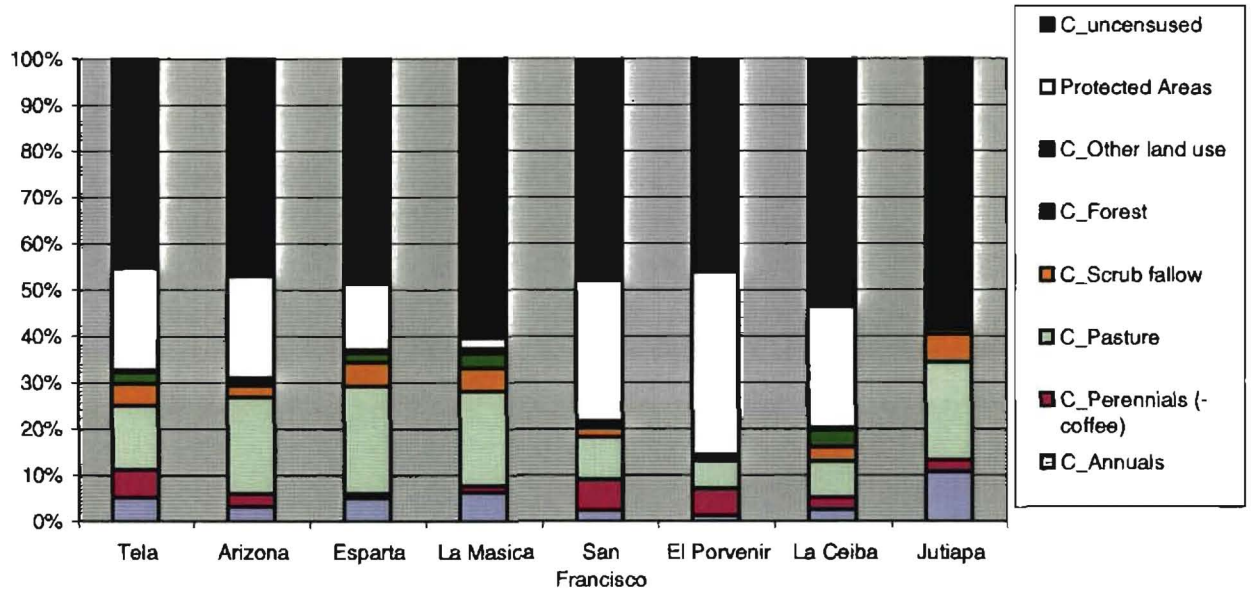
2.1 Land cover description (based on Landsat TM classification)

La Masica is located in the central part of Atlantida department on the northern coast of Honduras. The southern half of the municipality is forest covered and the coastal plain, like Arizona, is pasture-dominated. La Masica narrows substantially in its coastal zone - part of which is the Cuero y Salado Wildlife Refuge, a protected mangrove on the coast. Forest covers 47% of the survey zone which is much more than the equivalent figure of 16% for Arizona. La Masica has a significant forest resource, being situated midway between Texiguat wildlife refuge and Pico Bonito National Park. About 4% of the municipality is cloud covered which is most likely to be deciduous forest which will raise the proportion to over 50% of the municipality. Pasture has the next in highest proportion of cover (22%). (Table VI_2.1)

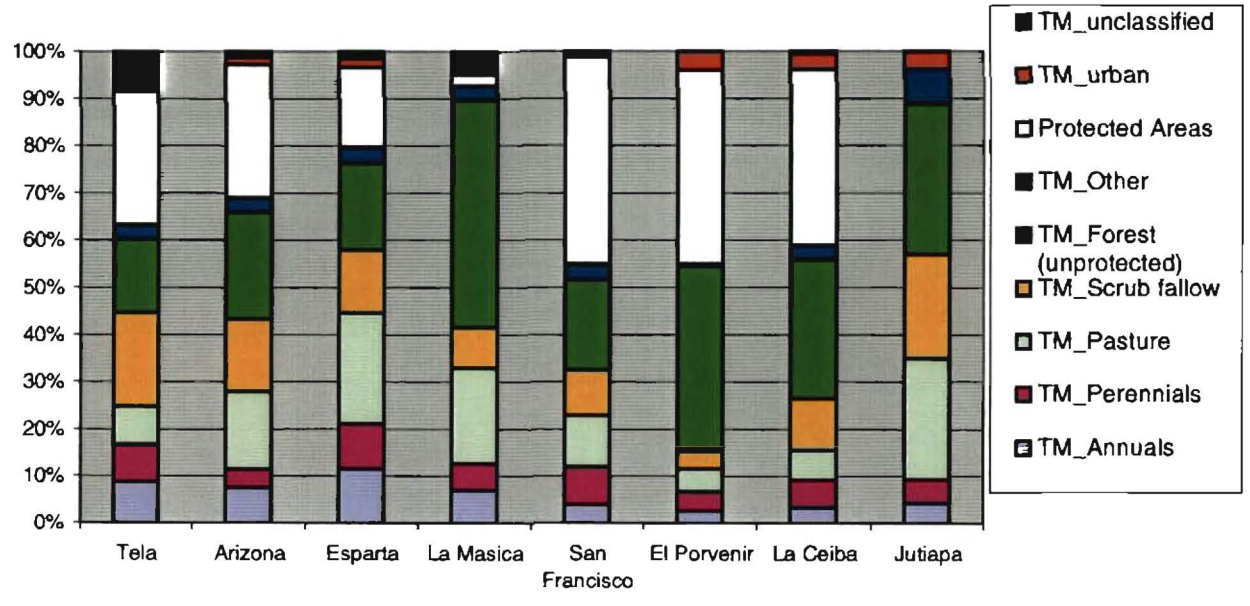
Table VI_2.1: Land Cover proportion estimates for La Masica Municipality using Landsat TM classification /img1/grego/atlan_res100.img
(Proportion estimates are derived by dividing by the survey zone (ie municipality area - protected areas in the case of the classification and by the area censused for the census data).

Class Name	Area Classified (ha)	Area Censused (ha)
Annual cultivation	3,255 (7%)	2,958 (17%)
Perennial cultivation (excluding shade tree crops)	2,896 (6%)	666 (4%)
Pasture	10,142 (22%)	9,768 (55%)
Scrub fallow	4,276 (9%)	2,428 (14%)
Forest (unprotected)	21,626 (47%)	1,477 (8%) (coffee = 531 ha)
Protected Forest (Mangrove)	1,181 (2.5%)	0
Settlement/infrastructure	445 (1%)	0
Rivers/water	897 (2%)	350 (1%)
other	0	108
Unclassified/unreported (outside protected area)	1,902 (4%)	27,684 (61%)
Total land cover/land use	45,440 (excluding protected area) 46,621 (municipality)	17,756 (39% survey zone)

Municipalities of Atlantida: Land use proportion estimates derived from Census



Atlantida Municipalities: Land Use Proportion estimates derived from Landsat TM classification



2.2 Comparison between classification results and National Census estimates:

From the regression graph a clear conclusion is made that there hardly any correlation between the two data sets - but this overlooks certain points. Firstly, one has to assess each land use variable in turn - forest example was largely unrecorded by census and so it deflects the trend line form an otherwise stronger slant. The coefficient for the other land use variables is 0.96.

Apart from forest estimates, the other major discrepancy for this municipality appears to be that of Perennial cultivation where the classification gives a figure over four times the estimate given by census. The major commercial crops are orange/citrus trees and some oil palm plantation. There was some misclassification - perennials for mangrove. Also, it is quite likely that some of the perennial cropland classified along the Rio Cuero, may have been misclassified for annual cultivation, again due to the characteristics of the satellite data as described for Arizona.

Although the original area estimates may be similar, the proportions do not necessarily appear to be so similar. The derived proportion estimates are useful to gain an idea of the relative importance of the different land cover/land use types but it is not very meaningful to compare the proportions between the two data-sets, as the sampling is very different. The classes pasture and annual cultivation have similar areal estimates, but this does not necessarily mean that the two data sets correspond exactly. The census figures can give an idea (with the aid of the satellite classification and knowledge of accessibility) of the most likely areas censused or ommitted from the census as the case may be. In the initial comparisons made between the two data sets it was attempted to derive figures to make direct comparisons, ie by applying a weighting factor to the census estimates to compensate for the area uncensused. It did not give rise to statistically valid results and was therfore not carried out in the latest analyses carried out. It is usually best to examine the original data one against the other to make an interpretation. (Fig VI -2.2)

3. Yorito, Yoro

3.1 Land cover description (based on Landsat TM classification)

Yorito is the northern municipality covering northern part of the Tascalapa watershed study area. It has a diverse terrain and hence a diverse pattern of land use. (Poster Map 11 and Table VI_3.1). Yorito has a substantial cover of deciduous forest (including coffee plantations) amounting to 39% of the municipality. Other important land uses include scrub (15%) and annual cultivation (8%). Some intense shading obscures the image contributing to the 3% unclassified area.

Eroded bushland is significant here as it is in a dryer zone and overgrazing leads to thorn scrub and bare soils. These areas are assumed to be classed by the census as pasture land

use. But they are showing signs of degradation. This is an additional advantage of using satellite imagery as it is possible to assess the state of the vegetation cover, and no just rely on the area estimates of 'pasture' that a land owner might remember as being correct or perhaps even a figure which is hypothetical, given in order to disguise reality. The latter cases are probably infrequent.

The other cover type which has a dual land use: sparse pine rangeland which provides rough pasture as well as timber from self-seeded trees. This cover type is common along the footslopes of the mountainous zones on both eastern and western sides of the municipality, although primarily on the west-facing slopes as the east- and south-east facing slopes are more intensively cultivated.

Table VI_3.1: Land Cover proportion estimates for Yorito Municipality using Landsat TM classification /julie/Honduras/Yor_SulML_NA3_res32m.img

Class Name	**Area Classified (ha)**	**Area Censused (ha)**
Annual cultivation	1,686 ha (8%)	2,266 ha (26%)
Perennial cultivation	839 (4%)	151 (2%)
Pasture	5,261 (2.5%)	2,369 (3%)
Scrub fallow	3,159 ha (15%)	1,636 ha (18%)
Forest	7,918 (39%)	2,334 (26%)
Settlement/infrastructure	1,048 (5%)	0
Rivers/water	0	2
other	0	61
Unclassified/unreported	561 (3%)	11,654 (57%)
Total land cover/land use	20,472 (100%)	8,820 (43%)

3.2 Comparison between Classification results and National Census estimates:

The regression graph for Yorito indicates a correlation of 0.42. This is fair compared with the results so far. One would expect that the classification is as accurated as any of the classifications as this study area was visited several times and a semi-detailed field survey was carried out. The discrepancies between the two data sets are therefore more likely to be due to incompleteness of the census, the area reported only covering 43% of the municipality. There are no national parks this time to reduce the total area of interest. Montana de Yoro is located to the east of the municality and the protected area around the reservor of El Cajon is located to the west.

The classes scrub fallow, pasture and forest seem to be quite close to the best-fit regression line. However, the classes annual and perennial cultivation are offset by large amounts. There is still a sizeable forest reserve, but according to the census, it represents the coffee plantations which total 1585 hectares, 68% of the census variable 'forest'. This represents 20% of the classified forest which seems a more realistic estimate. In this zone it is known that the census was concentrated around the villages/'aldeas'.

4. Sulaco, Yoro

4.1 Land cover description (based on TM classification)

Sulaco lies adjacent to Yorito and covers the southern part of the Tascalapa watershed study area. This municipality compared with its neighbour to the north, is dryer and lower in elevation, which results in there being less forest and more agriculture in a broader valley zone. Forest does exist in the northeastern corner of the municipality, but the dominant land covers are pasture and annual cultivation (Poster Map 11 and Table VI_4.1) As much as 6% of the municipality is unclassified due to recent burns/shaded terrain.

Table VI_4.1: Land cover proportion estimates for Sulaco Municipality using Landsat TM classification /julie/Honduras/Yor_SulML_NA3_res32m.img

Class Name	**Area classified (ha)**	**Area Censused (ha)**
Annual cultivation	5,059 (21%)	2,589 (31%)
Perennial cultivation	329 (1%)	74 (excl. coffee: 645 ha) (1%)
Pasture	9,035 (38%)	4,198 (51%)
Scrub fallow	3,317 (14%)	438 (5%)
Forest (unprotected)	3,262 (14%)	850 (incl. coffee) (10%)
Settlement/infrastructure	1,254 (5%)	0
Rivers/water	5	1
other	0	38
Unclassified/unreported	1,427 (6%)	15,500 (65%)
Total land cover/land use	23,,688 (100%)	8,189 (34.5%)

4.2 Comparison between Classification results and National Census estimates:

The regression shows s very strong relation (r2=0.9) between the image classification and census estimates for the five land use variables. The municipality of Sulaco was covered 34% by the census, less than the area reported for Yorito. Nevertheless, the relation is much stronger. This may be due to the following factors: the municipality is dominated by a wide central valley which tends to make mapping more accurate, as shading is minimal and land units tend to be bigger. Also, accessibility is easier throughout this municipality than for Yorito, hence the census would have had little problem in collecting a good cross section of the administrative zone.

The land use variable having the greatest offset from the regression line is scrub fallow. This is frequently underestimated by the census - perhaps due to farmers' unwillingness

to report total areas under fallow. However, after saying this the Yorito estimate of scrub fallow appears to be one of the better estimates.

Both census and TM estimates show that pasture is the dominant land use type, followed by annual crops, which consist mainly of maize fields in the valley zone.Perennial crops are minimal. (Fig VI_4.2)

5. Danli, El Paraiso

5.1 Land Cover description (based on Landsat TM classification)

Danli is situated in the centre of the department El Paraiso and is its largest municipality, covering an area of 249,280 hectares. The general terrain pattern is a large central depression/valley, the Valle de Jamastran, which extends northeast and southwest, surrounded by mountainous areas, especially to the north and east. There are four main centres of population concentration: Danli, Chichicaste and Teupasenti. The classification shows a dominance of forest and scrub fallow (37% and 27% respectively) with pasture and annual cultivation dominant in the valley zones. There are no national parks or other protected areas within the municipality of Danli. and only 0.3% of the zone was unclassified due to some cloud cover. (PosterMap 11 and Table VI_5.1)

Table VI_5.1: Land cover proportion estimates for Danli Municipality using Landsat TM classification /img1/danli93MLf3_res32MUN.img

Class Name	Area Classified (ha)	Area Censused (ha)
Annual cultivation	35,106 (14%)	19,554 (13%)
Perennial cultivation (excluding coffee)	11,750 (5%)	594 (0.4%)
Pasture	41,211 (17%)	86,128 (55%)
Scrub fallow	66,066 (27%)	16,767 (11%)
Forest (including coffee)	91,659 (37%)	30,811 (20%) coffee 10115 (4%)
Settlement/infrastructure	2,696 (1%)	0
River/water	0	143
other	0	954
Unclassified/unreported	792 (0.3%)	94,327 (38%)
Total Land cover/land use	249,280 (100%)	154,953 (62%)

5.2 Comparison between Classification results and National Census estimates:

The regression graph indicates a very weak correlation between the two land use data sets. Pasture has probably been relatively overestimated by the census and the forest and scrub fallow variables have been underestimated in the census figures. It is probably a correct deduction that the image classification is more reliable in giving land cover proportion estimates than the census for increasingly larger geographical areas. However, it is seen that the Danli municipality has a high percentage of the total area reported (62%). If this is true, it does not hold much hope for a good correspondence between the data sets at department level but it does stress the importance of making use of satellite data to map land use at these larger scales. (Fig VI – 5.2)

CHAPTER 7

ANALYSIS OF LAND COVER ESTIMATES DERIVED FROM LANDSAT TM CLASSIFICATIONS AND AGRICULTURAL CENSUS: DEPARTMENTS AND THEIR MUNICIPALITIES.

VII Analysis of Land Cover estimates derived from Landsat TM classifications and Agricultural census: departments and their municipalities.

1. Atlantida Department

1.1 Comparison between classification results and National census estimates for Atlantida department

The Agricultural Census covered 51% of the total area of Atlantida department, and by the appearance of Figure VII_1.2.1, did not enter the areas of forest cover which total more than 50% of the department, including the national parks (Figure VII_1.2.3). If one examines the proportions of classes 1,2 4 and 5 ie. the agricultural classes, classes 1 and 4 (annuals and pasture) compare favourably, class 2 (perennials) slightly less favourably and class 5 (scrub fallow) appears to have been undersampled by the Census.
In this example, I would favour the estimates derived from the image classification more than from the census, which noticeably concentrated in the coastal plain region.

1.2 Comparison between classification results and National Census estimates for the municipalities of Atlantida Department

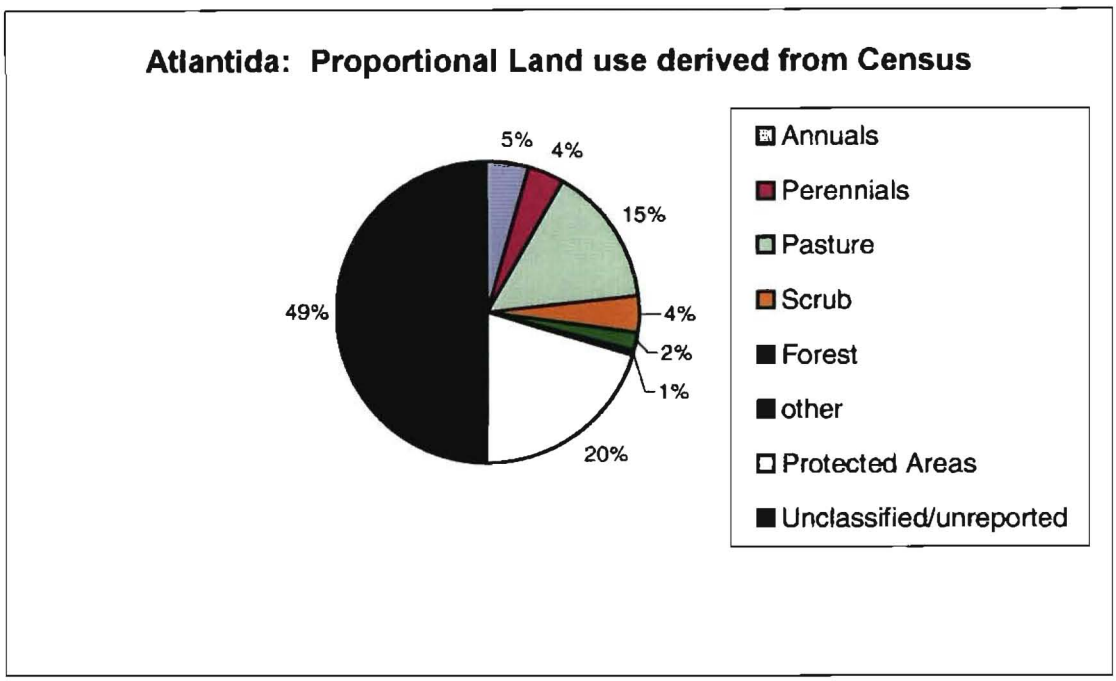
The proportions for annuals, pasture and scrub expand and diminish in a similar way between the two data sets, if one looks across the individual bars of the chart. Perennial cultivation shows little relation. It may be worthwhile using census information to improve accuracies of the TM classification. This may also be true for perennial crops, as often the classification is at error, confusing perennials with scrub fallow and sunlit deciduous forest (Figures VII_1.2.3 and VII_1.2.4).

2. Yoro Department

2.1 Comparison between classification results and National Census estimates for Yoro department

Only 34% of the total area of Yoro department was censused. Less than one-seventh of the deciduous forest (including conifer forest) was censused. The relative proportions of the agricultural classes do not match up between the image classification and the census, although the two data sets show that pasture is the most important land use, followed by annual cultivation. It looks as though both annual cultivation and scrub fallow have been undersampled, but it may be more correct to accept the relative proportions given by the census to be more accurate. This would be quite a debate however (Figures VII_2.1.1 and 2.1.2).

Fig VII 2.1


Atlantida: Proportional Land use derived from Census
5%
4%
15%
4%
2%
1%
20%
49%
Annuals
Perennials
Pasture
Scrub
Forest
other
Protected Areas
Unclassified/unreported

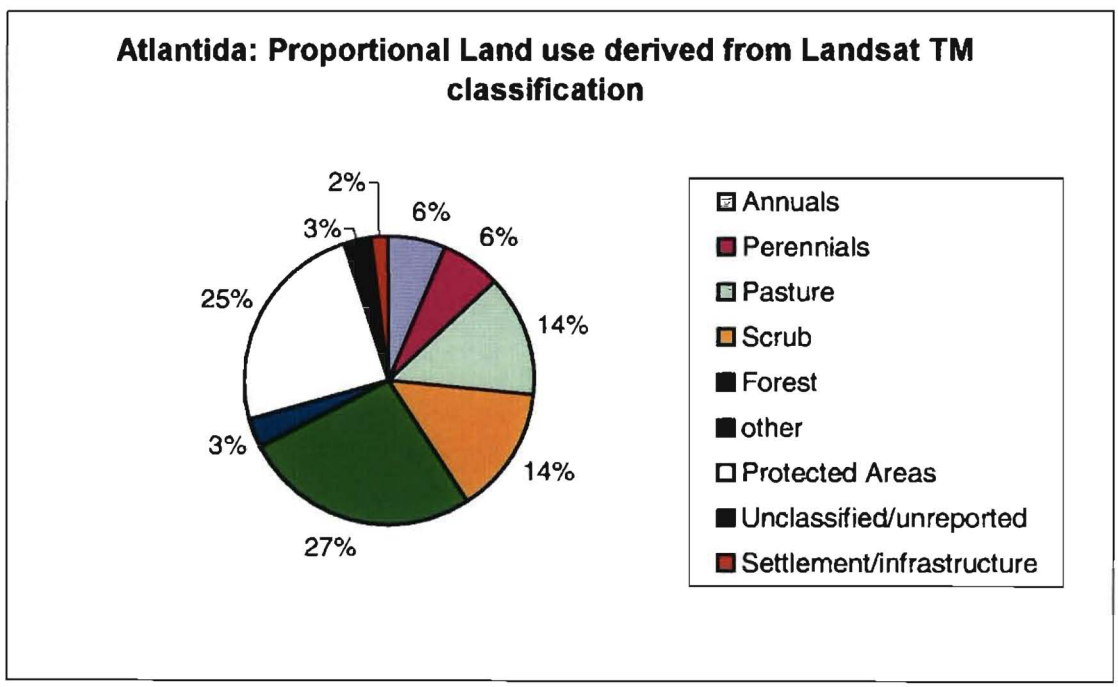

Atlantida: Proportional Land use derived from Landsat TM classification
2%
6%
3%
6%
25%
14%
3%
14%
27%
Annuals
Perennials
Pasture
Scrub
Forest
other
Protected Areas
Unclassified/unreported
Settlement/infrastructure

Fig VII 1.2.3

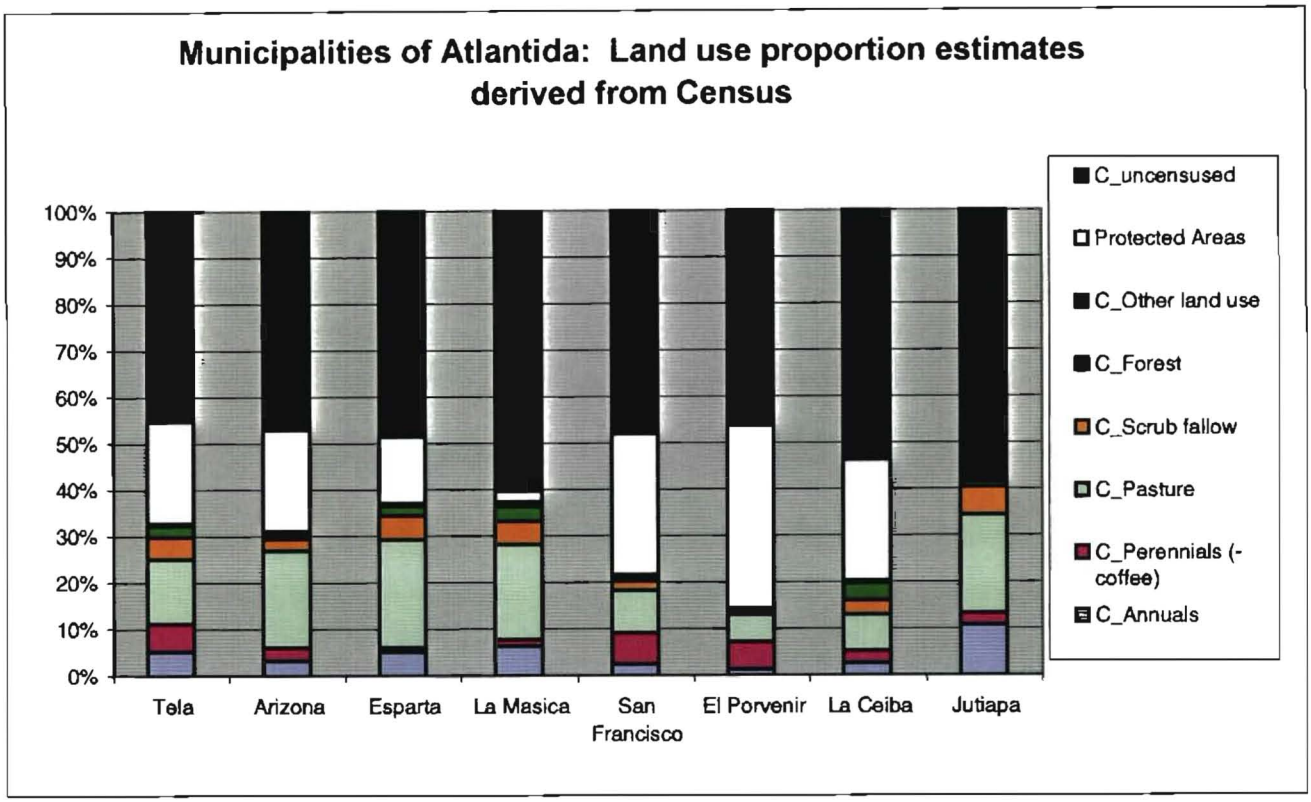
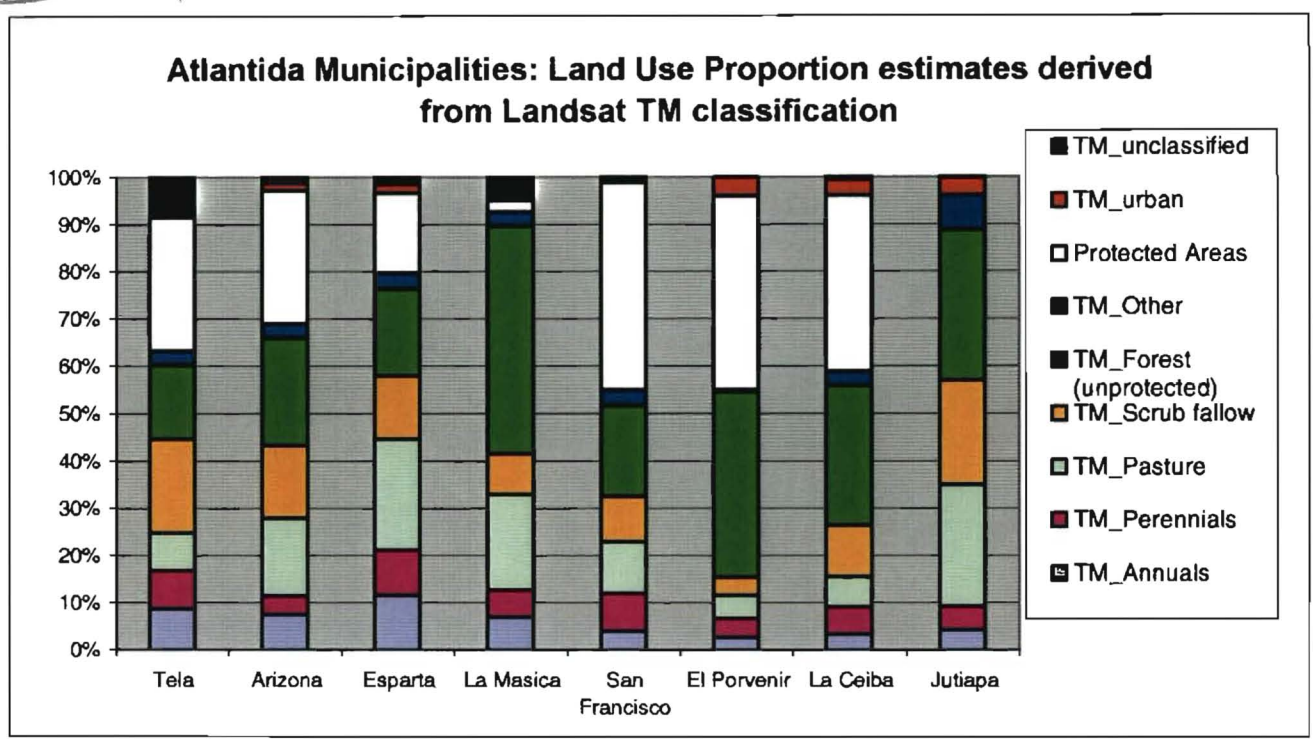
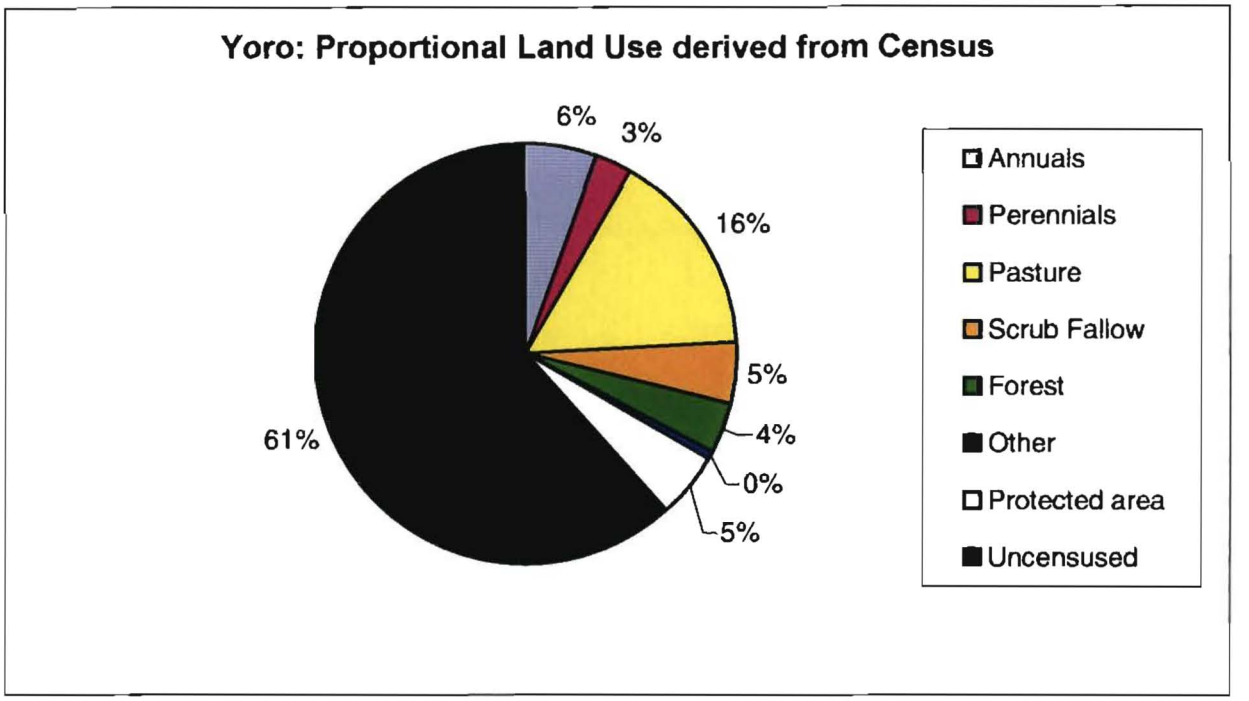
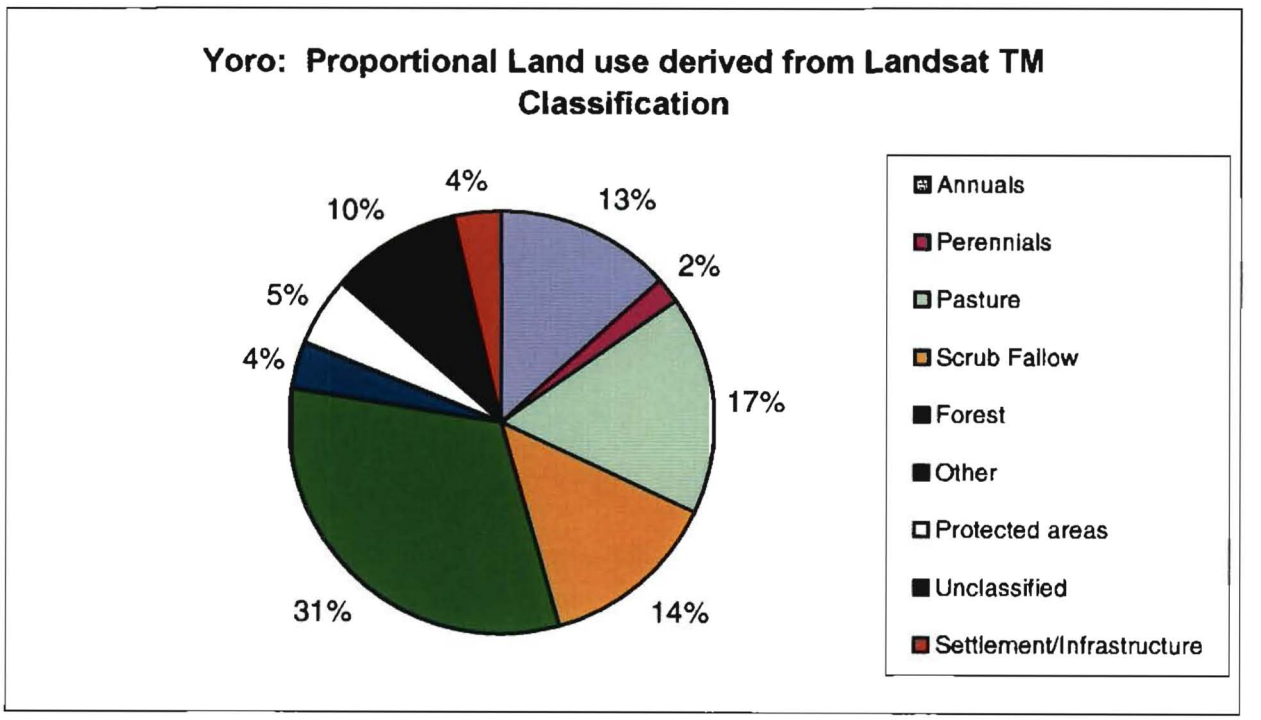
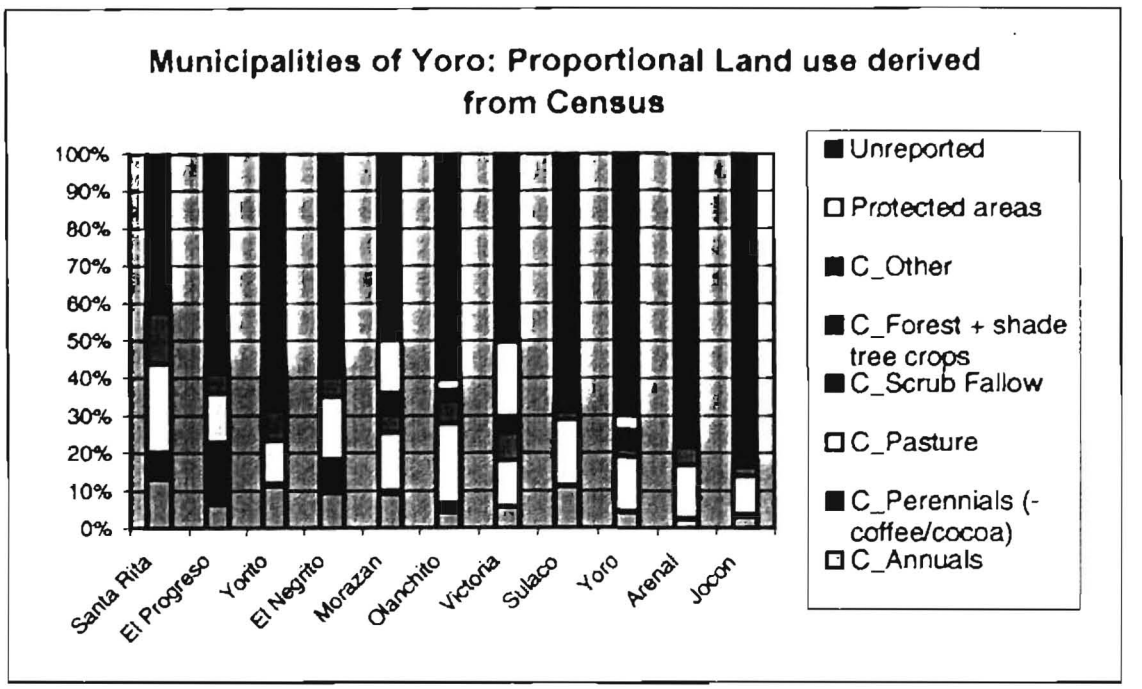


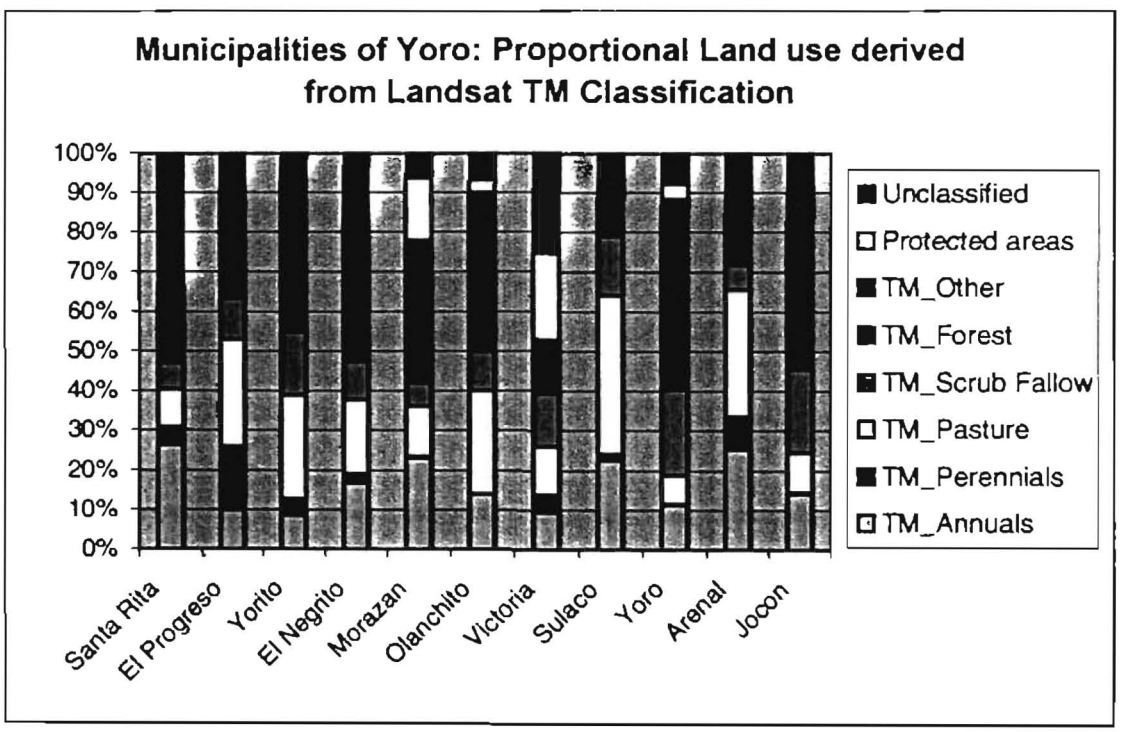
Fig VII 1.2.4




Yoro: Proportional Land Use derived from Census
6%
3%
16%
5%
4%
0%
5%
61%
Annuals
Perennials
Pasture
Scrub Fallow
Forest
Other
Protected area
Uncensused


Yoro: Proportional Land use derived from Landsat TM Classification
4%
13%
10%
2%
5%
4%
17%
31%
14%
Annuals
Perennials
Pasture
Scrub Fallow
Forest
Other
Protected areas
Unclassified
Settlement/Infrastructure


Municipalities of Yoro: Proportional Land use derived from Census
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Santa Rita
El Progreso
Yorito
El Negrito
Morazan
Olanchito
Victoria
Sulaco
Yoro
Arenal
Jocon
Unreported
Protected areas
C_Other
C_Forest + shade tree crops
C_Scrub Fallow
C_Pasture
C_Perennials (- coffee/cocoa)
C_Annuals


Municipalities of Yoro: Proportional Land use derived from Landsat TM Classification
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Santa Rita
El Progreso
Yorito
El Negrito
Morazan
Olanchito
Victoria
Sulaco
Yoro
Arenal
Jocon
Unclassified
Protected areas
TM_Other
TM_Forest
TM_Scrub Fallow
TM_Pasture
TM_Perennials
TM_Annuals

2.2 Comparison between classification results and National Census estimates for the municipalities of Yoro Department

There appears to be less similarity between the relative proportions of land use between image classification and census, than for the department of Atlantida. Annual cultivation shows some similarity, especially in the municipalities Santa Rita to Yoro. Arenal and Jocon both have very low percentage of their total areas censused. Pasture also shows some degree of similarity (Figures VII_2.1.3 and 2.1.4).

3. El Paraiso Department

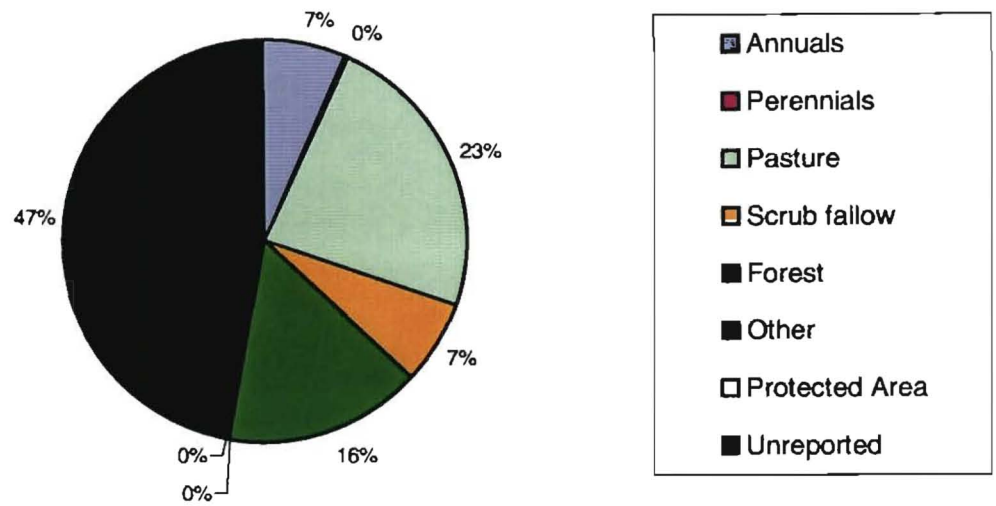
3.1 Comparison between classification results and National Census estimates for El Paraiso department.

Aparently, just over 50% of the total departmental area was censused. This is quite a high proportion considering the extent of the department. Unlike the other two departments there is a very limited area protected. The relative proportions given in the census pie-chart I think are more dependable than those produced by the image classification. The census indicates equal proportions for annual cultivation and scrub fallow; in the image classification, scrub occupies a slightly greater proportion than annual cultivation. The proportion of forest given by the census approaches that derived from the image classification, but is still falling short by about 50% (Figures VII_3.1.1 and 3.1.2).

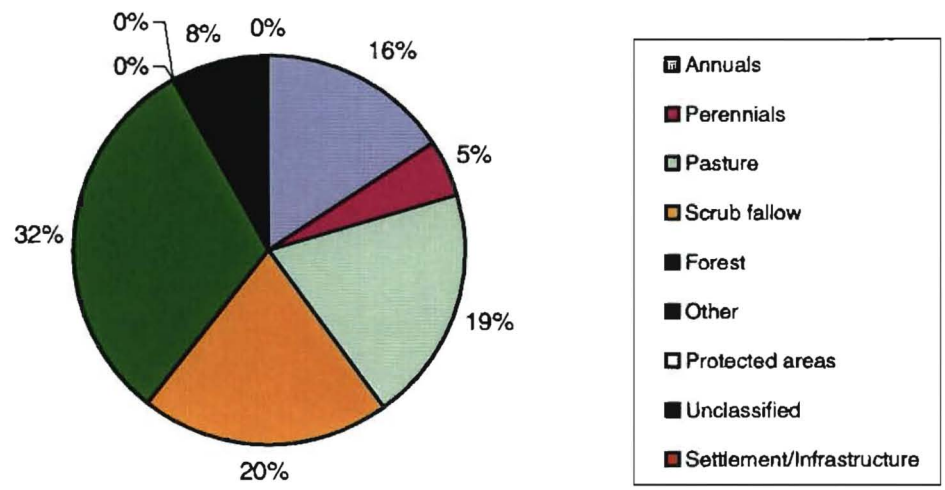
3.2 Comparison between classification results and national Census estimates for the municipalities of El Paraiso Department.

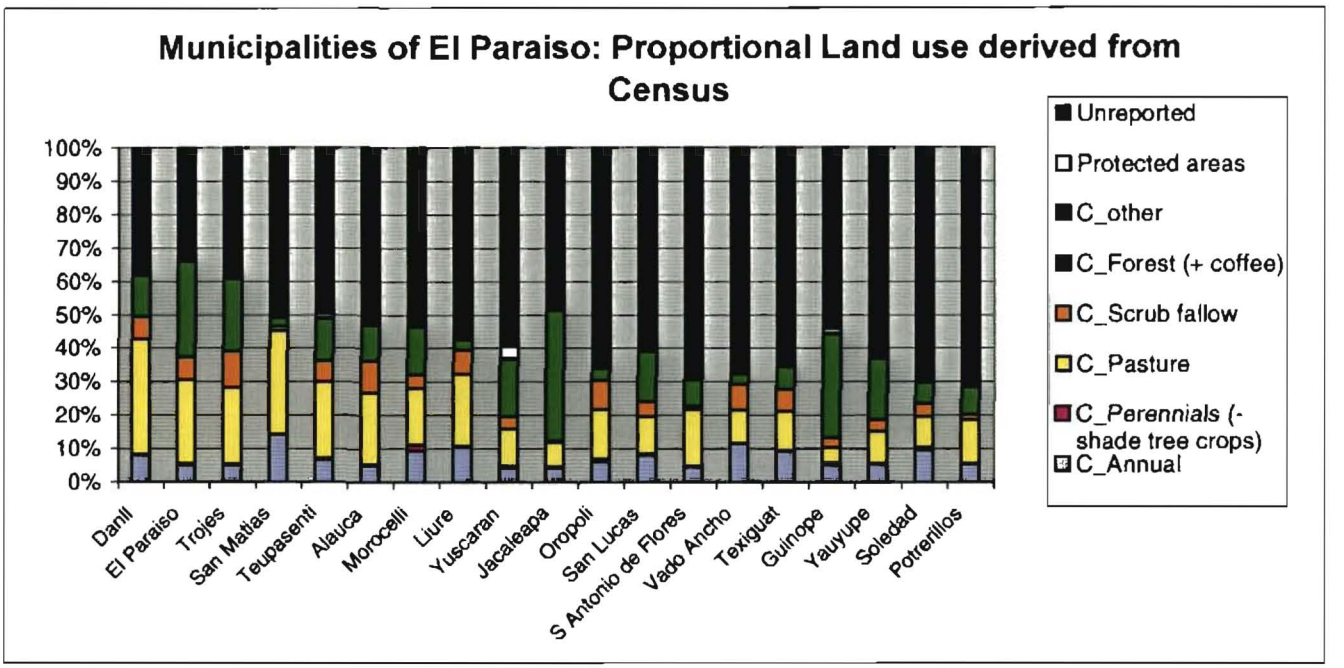
If one examines the bar-charts for the municipalities (Figures VII_3.1.3 and 3.1.4). Scrub fallow seems to have been grossly underestimated for the municipalities of Liure, Jacaleapa, San Antonio de Flores, Vado Ancho, Texiguat, Guinope, Yauyupe, Soledad and Potrerillos. The apparent reduced cover of pasture shown by the image classification for the municipalities of San Lucas, San Antonio de Flores and Vado Ancho is not reflected in the census graph. The census shows that perennial cultivation in this department is quite insignificant, but the image classification indicates otherwise. This may be explained in part by the fact that coffee plantation is the most important perennial crop and the areas reported for coffee were subtracted from the totals given for perennial crops, and this resulted in the figures being much diminished. It is questionable whether the census proportion estimates could improve the image classification - possibly those for annuals and pasture could offer some assistance as these classes are particularly difficult to distinguish in the images and to classify adequately.

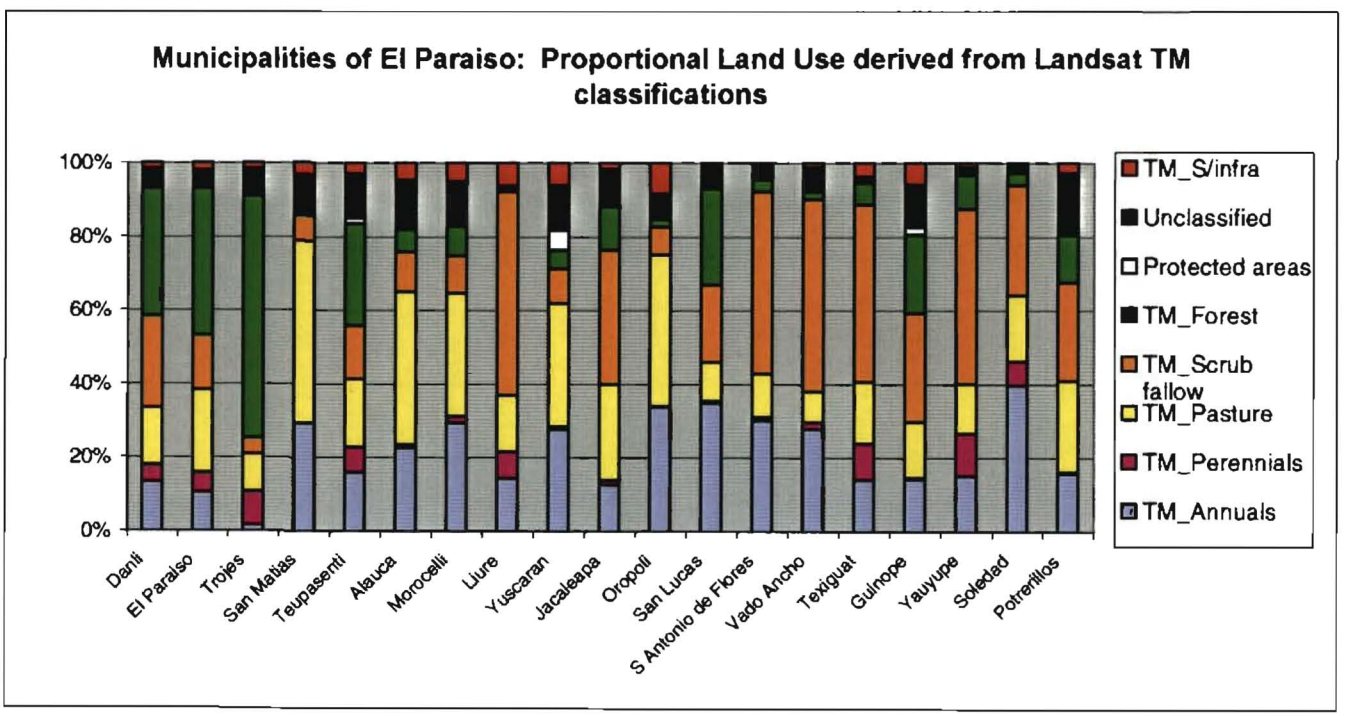
El Paraiso: Proportional Land use derived from Census



El Paraiso: Proportional Land Use derived from Landsat TM classification




Municipalities of El Paraiso: Proportional Land use derived from Census
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Danli
El Paraiso
Trojes
San Matias
Teupasenti
Alauca
Morocelli
Liure
Yuscaran
Jacaleapa
Oropoli
San Lucas
S Antonio de Flores
Vado Ancho
Texiguat
Guinope
Yauyupe
Soledad
Potrerillos
Unreported
Protected areas
C_other
C_Forest (+ coffee)
C_Scrub fallow
C_Pasture
C_Perennials (- shade tree crops)
C_Annual


Municipalities of El Paraiso: Proportional Land Use derived from Landsat TM classifications
100%
80%
60%
40%
20%
0%
Danli
El Paraiso
Trojes
San Matias
Teupasenti
Alauca
Morocelli
Liure
Yuscaran
Jacaleapa
Oropoli
San Lucas
S Antonio de Flores
Vado Ancho
Texiguat
Guinope
Yauyupe
Soledad
Potrerillos
TM_S/infra
Unclassified
Protected areas
TM_Forest
TM_Scrub fallow
TM_Pasture
TM_Perennials
TM_Annuals

LISTS OF DATA

I ATLANTIDA

II YORO

III EL PARAISO

IV HILLSIDES ZONE AND NATIONAL DATA SETS.

List of Biophysical data sets, maps and geographical information for the Atlantida Study Areas (Francisco de Saco and La Masica), Honduras - GIS Lab, CIAT, Cali, Colombia.

(File: \users\jacox\Windows\personal\Archive_Atlantida.doc)

1. Satellite Data

1.1 Original Landsat TM images, purchased from EROS/EOSAT:

Path 18 /Row 49 'Ceiba' Scene, 2 dates: 18 March, 1987 and 5 March, 1994
Path 17 /Row 49 'Trujillo' Scene , 3 dates: 1 Feb, 1985, 8 March, 1986 and 23 Feb, 1993

/julie1/Honduras/ceiba/ceiba87_2.img, ceiba87_2ss.img (most of the sea portion is omitted in this subset image) ceiba87_3.img, ceiba87_4.img

/img1/ceiba94ss.img (ocean part of scene excluded from this subset image and it is composed of 6 bands, the thermal band omitted), ceiba94ss_res100.img

/img1/grego/1749.img ('Trujillo' scene, all bands), img2/1749ss.img (subset scene covering E Atlantida),
/img2/trujillo/trujil86_3at.img (subscene covering Atlantida's eastern section),
/img2/trujillo/trujss25.img (no geocorrection, but covers a wider area - extending more to the south to include the department of Yoro - compared with the subset image trujil86_3at.img)
/julie1/Honduras/trujillo86/trujil1.img, /img2/trujillo/Truj1_86res100.img,
/julie1/Honduras/trujillo86/trujil2.img, /img2/trujillo/truj2res100.img
/img2/trujillo/truj3.img Truj3_86res.img (100m resolution), truj4.img, Truj4_86res.img (100m resolution)
/img2/atlanFC.img (100m resolution mosaic of 'Ceiba' and 'Trujillo" scenes dated 1994/1993 respectively), atlantidaFC.img (mosaic of 'Ceiba' and a small subset image of Trujillo scene, covering Atlantida department only - ceibaE_res100.img,

1.2 Original Landsat TM subscenes:

/julie/Honduras/Saco87_res25.img (study area), ariz94_res25.img (municipality), ariz94_res25mun.img (clipped image), Mas94.img, Mas87_res32.img, Mas94_sa.img, Mas94_SAres25.img, Mas94_res25.img, Mas94_res25_mun.img,

1.3 Classified Landsat TM Images:

/img1/grego/ceiba87ML_2.img, ceiba87ML_3.img, ceiba87ML_4.img

/img1/grego/ceiba94ML_6B.img (classified 'Ceiba' scene of 5 March, 1994, based on 6 spectral bands, excluding the thermal band)
/img2/trujillo/trujil86ML_1.img, /julie/Honduras/trujil86ML_1.img,
/img2/trujillo/trujil86ML_2.img, trujil86ML_3.img, (original:
/julie/Honduras/trujil86ML_3.img, /img2/trujillo/ trujil86ML_4.img, (original before national mosaic:/julie/Honduras/trujil86ML_4.img
/img2/trujillo/trujil86_3at.img (classification of the eastern section of Atlantida)
trujil86_3atcls_res100.img, trujil86_3atcls_res25.img, trujil86_3atcls_res50.img, trujil86_3atcls_res250.img, trujil86_3atcls_res500.img (this sequence of classifications represents a multi-resolution study to examine the changing proportions of land cover as a function of pixel size)
/img1/trujil93ss_ML1.img (eastern section of Atlantida department mosaic, dated 1994-93), trujil93ss_ML1_res100.img,

Mosaiced classified 'Ceiba' and 'Trujillo' scenes, dated 1994/1993 respectively:
/img1/grego/atlan_res100.img,

Department classifications: /img2/Atlantida100ML.img (1994-93)
/img1/grego/atlan_res100.img

Study area Classifications:

(a) San Francisco de Saco, Arizona
/julie/Honduras/FranSArev_ML94.img, FranSArev_ML94res32.img,
FranSArev_ML94res32f3.img, SFran87rev_ML.img, SFran87rev_ML25mf3.img,
Saco94_res25.img (municipality), /julie1/Honduras/ArizSA94_1.img,
(b) La Masica , La Masica
/julie/Honduras/Mas94_MLres25cl3.img, /julie/Honduras/Mas87SA_rev32m.img,
Mas87SA_rev32mf3.img,

Municipality classifications:

/julie/Honduras/Ariz94ML.img, Ariz94_res25f3.img(clipped image) (sig file:
Ariz94_simp.sig
/julie/Honduras/Mas94_MLres25.img, Mas94_MLres25_mun.img (clipped image),

2. Air Photographs

Tela (study area)	14-2-1987	1:20,000	3	1	Paper Diapositives
Tela (Lancetilla)	23-1-1992	1:40,000	3	1	Paper
La Masica (study area)	15-2-1987	1:20,000	6	2	Paper Diapositives
Pico Bonito, La Ceiba	23-1-1992	1:40,000	3	1	Paper

(3. No digital Orthophotographs).

4. GIS Coverages (Arc/Info)

4.1 Vector coverages

/julie/hondarc/dep_atlan (department boundary only), atlantida (department boundary containing municipality boundaries), ariz1 and arizona (municipality of Arizona), masica (municipality), atlantidasas (study area boundaries), masica_sa (La Masica study area boundary), sfran (San Francisco de Saco study area), atlan_geol, atlan_nps, atlan_soils, topogc_utm, topog_utm1 (1,000m contour) /data1/camerica/honduras/yoro_* (various thematic layers derived from digitized 1:50,000 topographic map sheets, source: GTZ , Siguatepeque.)

4.2 Raster coverages

/julie/hondarc/dep_atlan (department only), atlan_rast.img (department, including municipalities), ariz2rast.img (municipality), sfran_rast.img (study area), mas_rast.img (municipality), masica_sa_rast.img, atlan_geol.img, atlan_soils.img (Simmons' classification within department zone),

(See list of National thematic coverages)

5.1 Hardcopy Maps

Topographic map sheets (Source IGN):

San Francisco Study Area located on Tela map 2763 III

La Masica Study Area located on La Masica map 2762 I

Road Map of Atlantida: 'Republica de Honduras Secretaria de Comunicaciones obras publicas y transporte, (1992) "Red Vial Depto. de Atlantida

5.2 Digital Maps, composed with IMAGINE software:

/pkg/users/jacox/Atlantida_Poster.map (upper section) and Atlantida_Poster2.map (lower half of poster) - Title: 'Bio-Physical Land-Characterization of Atlantida Department, Honduras, Central America' Prepared as working document, Jan 1998.

/julie/Honduras/Masica.map ('Land Use Classifications of La Masica Study Area, La Masica, Atlantida using multi-dated Landsat TM data'), SFran1.map ('Land Use Classifications of San Francisco de Saco Study area, Arizona, Atlantida using multi-dated Landsat TM data')

Biophysical Data Sets and Geographical Information for the Yorito Study Area (sub-catchment of Rio Tascalapa), Municipalities of Yorito and Sulaco and Yoro Department, Honduras.

GIS Lab, CIAT, Cali, Colombia. (File: \users\jacox\Archive_Yorito.doc)

1. Satellite Data

1.1 Original Landsat TM images, purchased from EROS/EOSAT:

Path 18/ Row 50: 'Yoro' Scene, 3 dates:

15 March 1986 (/julie/Honduras/yoro86nw.img, yoro86ne.img, yoro86sw.img, yoro86se.img)
5 March 1994 (/julie/Honduras/yoro94.img, /julie1/Honduras/yor_sulaco.img)
8 March 1995 (/julie/Honduras/yoro95-1.img, yoro95-1res32.img and /julie1/Honduras/yoro95res100.img)
8 March 1995 (department of Yoro subscene) /img1/Yoro_Mosaic93-95.img (this image does not include the thermal band 6)

Path 18/ Row 49: 'Ceiba' Scene, 2 dates:

18 March, 1987 (/julie1/Honduras/ceiba87_3.img, ceiba87_4.img)
5 March, 1994 (/img1/ceiba94ss.img, ceiba94ss_res100.img)

Path 17/ Row 49: 'Trujillo' Scene, 3 dates:

1 Feb 1985 (on 8mm tape in GIS lab)
8 March 1986 (/img2/trujillo/trujil3.img and trujil4.img)
23 Feb 1993 (/img1/grego/1749.img, 1749ss_yoro.img, 1749ss_yoro_res100.img and yoroDept93ss_3..img)

1.2 Classified Landsat TM images:

1986 'Yoro' Scene Classification: /julie/Honduras/yoro86ML_1.img, yoro86ML_2.img, yoro86ML_3.img, yoro86ML_4.img (signature files: /julie/Honduras/yoro86nwa.sig, yoro86ned.sig, yoro86swb.sig, yoro86sec.sig)
1986 Department Classification: /pkg/users/jacox/yoroDept87-86ML100.img
1987 'Ceiba' Scene Classification: /img1/grego/ceiba87ML_3.img and ceiba87ML_4.img
1986 'Trujillo' Scene Classification: /img2/trujillo/trujil86ML_3.img, tujil86ML_4.img
1986 Study area Classification: /julie/Honduras/yoro86sacl.img
1994 Municipality classification: /julie/Honduras/Yor_SulML_NA3_res32m.img (sig file /julie/Honduras/Yor_Sul_final.sig)
1994 Scene Classification: /img2/yoro94ML.img (signature files: /img1/grego/yoro94.sig

1995: Department Classification: /img1/yoro_mosaicML.img, clipped - 'Yoro' scene 1995 image; /img2/yoro95deptML_res32.img; scene:/img1/yoro_deptML_muns.img (signature file: /img1/yoro_deptML_muns.img)
Classified scenes belonging to the department mosaic: /img1/yorodept94_NW.img, yorosw_ML_res100.img, trujil93ss_ML1_res100.img and /pkg/users/jacox/yoro_agric.img and depYoro_agric.img; /img2/YoroDept95_3ML.img.

1.3 Other classified images:

8 March 1995: /pkg/users/jacox/yoro95_3forest.img

8 March 1995: Municipality Classification: /julie/Honduras/Yor_Sul_Final.map, Yor_SulMLNA5_Final32m.img (Sig file: Yor_Sul_final.sig); Yor_Sul1f3_res32.img, Yor_Sul1f3_res100.img, Yor_Sul1f3_res250.img, Yor_Sul1f3_res500.img, Yor_Sul1f3_res1000.img
Signature file: Yor_Sul_finalVAL.sig
1995: Study Area Classification: /pkg/users/jacox/yoritoML95_NA.img; /julie/Honduras/yor4_finalNA_res32.img (Signature file: yor4_finalNA_res32.sig) /julie1/Honduras/yoro95-1_wsd.img (6 bands), yoro95-1allbands_sa.img, yoro95_1sa_res32.img, /julie/Honduras/yoro95sa_res32.img, yoro95sa_slope.img, yoro95sa_NDVI.img

2. Air Photographs, including digital coverages and derived images/digital elevation models:

AREA	DATE	SCALE	NUMBER OF PHOTOS	N0. RUNS	FORMAT
Yorito (study area)	1977	1:40,000	15	3	Paper copies missing but Diapositive set complete
Yorito (study area)	1993 (northern two runs L 36A and L 35B dated April whilst southern two runs L 34A and L 33A dated September)	1:20,000	40 (37 original and 3 additional photo's to complete coverage of watershed along its eastern limit)	4	Paper Diapositives (scanned) Orthophotos (derived) (Note the three new diapositives need to be scanned and added to the orthophotograph coverage – at the moment the orthophoto mosaic is based on the original set of 37 photographs).
Yorito (study area)	1956	1:70,000	11	3	Diapositive
Yoro (north of study area)	1977	1:40,000	3	1	Paper
Yorito/Sul aco sample runs for	El Ocotal – La Trinidad L039A: August 1993	1:20,000	8	1	Paper

ground-truthing the 2 municipalities.					
" " "	Piedra Blanca-El Higuero Quemado: L037A: Sep 1993	1:20,000	6	1	Paper
" " "	Piedra Blanca: L036A: Sep 1993	1:20,000	3	1	Paper
" " "	El Zapate-Las Vegas: L035B: Sep 1993	1:20,000	3	1	Paper
" " "	El Eden-Coyol Dulce:L033 A: April 1993	1:20,000	3	1	Paper
" " "	Sulaco: L031A: May 1993	1:20,000	3	1	Paper
" " "	El Jaral-Marale: L030B: May 1995	1:20,000	3	1	Paper

3. Digital Orthophotographs

Mosaiced orthophoto coverage, covering Yorito Study area:

/julie1/Honduras/Yoritoslope.img (original scene without raster attribute coding)
/julie1/Honduras/Yorito_Slope10.img (slopes classified according to plain/valley, undulating, rolling to hilly, steeply dissected, mountainous topography)
/julie1/Honduras/Yoritodem10.img (elevation zones classified to every 100m increase in elevation)

/ortho2/dems/slope_fi17.img (5m resolution) original slope mosaic
/ortho2/dems/aspect.img (5m resolution)
/ortho2/dems/elev.img (200m elevation zones displayed)
/ortho2/dems/mos4.img (100m elevation zones displayed)

List of Orthophotographs covering the Yorito Study Area:

All orthophotographs are held in the directory /ortho2/orthos:

Flight Line 36A: o162-63utm16.img 11 Stereopairs (12 photographs)
o163-64utm16.img
o164-65utm16.img
o165-66utm16.img
o166-67utm16.img
o167-68utm16.img
o168-69utm16.img
o169-70utm16.img
o170-71utm16.img
o171-72utm16.img
o172-73utm16.img

Flight Line 35B: o140-39utm16.img 10 Stereopairs (12 photographs including an additional one at
o139-38utm16.img the end of the flight line:
frame number 2129)
o138-37utm16.img
o137-36utm16.img
o136-35utm16.img
o135-34utm16.img
o134-33utm16.img
o133-32utm16.img
o132-31utm16.img
o131-30utm16.img

Flight Line 34A: o918-17utm16.img 8 Stereopairs (10 photographs including an additional one
o917-16utm16.img at the end of the flight line: frame number 0909.
o916-15utm16.img
o915-14utm16.img
o914-13utm16.img
o913-12utm16.img
o912-11utm16.img

o911-10utm16.img

Flight Line 33A: o996_97utm16.img
o997-98utm16.img
o998-99utm16.img
o999-1000utm16.img

4 Stereopairs (6 photographs including an additional photograph, but it is of a different flight line No. 33B: frame number 2061.

4. GIS Coverages (Arc/Info)

4.1 Vector Coverages:

All coverages projected in UTM, zone 16 and are located in the directory: /julie/hondarc/:

4.1.1 Study area Coverages:

lcover - air photo interpretation of the Yorito Study area
wsd-yorito - original study area boundary, created by S. Byne, 1995 and used for display of study area location)
api-yorito (more recent boudary of catchment, but with a gap as the additonal orthophotographs required have yet to be scanned and processed; also contains location of semi-detailed fieldwork carried out in the study area during March-April 1997.
yor-rivers -(river coverage hand-drawn over orthophotograph mosaic)
yor-roads (road coverage hand drawn over orthophotograph mosaic)
aldeas (point coverage of aldeas censused during the 1988 population census in Honduras)
yorito_gtruth (field observation points in Yorito/Sulaco municipalities)
yorito_muns (municipality boundaries of Yorito and Sulaco)
yoro1 (department of Yoro boundaries)
yoro1_nps (national parks "intersected" by the municipality boundaries)
yoro_geol (geology coverage "clipped" by Yoro department boundary)
yoro_soils (Simmons' classification of soils, clipped by Yoro department boundary)
yorosul_cat (land tenure coverage of the two municipalities Yorito and Sulaco)
/julie/Honduras/yorito_tenancy.map (Land tenure for the two municipalities Yorito and Sulaco)
/data1/camerica/honduras/yoro_* (topographic maps 1:50,000, digitized by GTZ, Siguatepeque, Honduras).
/julie/hondarc/ yoro1000 (areas above 1,000 metres altitude, within the department of Yoro.

National Coverages:

dcw_riverutm (Digital Chart of the World coverage of rivers – less accurate than the following:)

riosutm (digitized off IGN(1994) Mapa Oficial Republica de Honduras 1:50,000)

hh88utm (municipalities of Honduras)

horizonsutm (soil profile description locations in Honduras (used in cluster analysis/database compilation of P. G. Jones (1997)

Mean Monthly rainfall maps (imported from IDRISI coverages of P.G. Jones (1997) "Interpolated climate surfaces for Honduras ona 30-second grid." CIAT, Cali, Colombia Files as follows: /img2/rainjan.img, rainfeb.img, rainmar.img, rainapr.img, rainmay.img, rainjun.img, rainjul.img, rainaug.img, rainsep.img, rainoct.img, rainnov.img, raindec.img

Total annual rainfall map (source as above) Imagine File: /img2/raintot

Mean monthly temperature maps (source as above) Imagine Files: /img2/tempjan.img, tempfeb.img, tempmar.img, tempapr.img, tempmay.img, tempjun.img, tempjul.img, tempaug.img, tempsep.img, tempoct.img, tempnov.img, tempdec.img

geology (digitized from Geology hardcopy map)

leeforr (digitized from Leforrest Miller Soils Classification)

soils-simms (digitized from Simmons' Soils Classification)

list1 and list2 (reconnaissance field observation points - fieldwork March-April, 1995

natparks (digitized from GAF (Gesellschaft fur Angewandte Rernerkundung mbH, Munchen, FRG (1995)
for Cohdefor (Corporacion Hondurena de Desarrollo Forestal, Tegucigalpa, Honduras and KfW, Frankfurt/Main, FRG (revised by Ing Jose Cristobal Vasquez V (1992-95) "Republica de Honduras Mapa Forestal 1:500,000" (a digital coverage is available but does not include the vector overlay information)

roadsutm (only useful for national-scale maps, digitized from ¿????????????

topogc_utm (contours at 200m intervals, source: IGN (1994) Mapa oficial 1:500,000

topog_utm1 (contour 1,000m to highlight mountainous areas; source as above)

4.2 Rasterized Vector Coverages:

(all files found in /julie/hondarc unless otherwise stated)

dep_yoro-rast.img
wsd_yorito.img
yor_sul_muns.img
yorito_muns2_rast.img (two municipalities of Yorito and Sulaco merged into one polygon)
yorito_muns4_rast.img (two municipalities and map border)
yoritomun.img
yoro_dept_rast.img
yoro_geol.img
yoro_soils.img
yoro_rast.img (contains all municipalities within department)
/julie/Honduras/lcover.img (air-photo interpretation of land cover/land use in the Yorito Study area).

DTM derived from digitzed contour coverage /data1/camerica/honduras/yoro_*

5. Hardcopy Maps

Topographic sheets (Source: Secretaria de Comunicaciones, obras publicas y transporte, Instituto Geografico Nacional (IGN) 2761 III Yorito (NW quadrant)
2761 II Yoro (NE quadrant)
2760 IV Victoria (SW quadrant)
2760 I Marale (SE quadrant)

Cohdefor Aerial Photography Project (1993)
USAID Air Photograph Index Map including Yoro Department 1:400,000

Cohdefor National Air Photograph Index: coverage of 1:20,000 scale photography taken in the years 1979, 1980, 1981, 1989, 1993.

Simmons Soils classification Map: 'Mapa General de Suelos, Republica de Honduras' Accompanying document with legend description: 'Sintesis de los suelos de Honduras'Vladimiso Castellanos, Jefe Depto de Suelos, Ministerio de Recursos Naturales) (1973) Seminario nacional sobre zonifacacion, ecologica de cultivos y regionalizacion agricola de Honduras' 4 – 7 Sep, 1973 Tegucigalpa.

Leforrest Miller Soils Classification Map: 'Soil mapping units for 1:1,000,000 Honduras, Direccion Ejecutiva del Catastro (Legend attached)

Mapa geologico de Honduras (1991) Secretaria de Comunicaciones obras publicas y transporte IGN (1991) 1:500,000 Compiled by Michael J. Kozuch.

Republica de Honduras, Direccion Ejecutiva del Catastro Mapa Municipal de sitios Municipio de Yoro, Depto de Yoro 1:100,000 (acetate map containing agricultural holdings and land tenure information and roads)
Republica de Honduras, Direccion Ejecutiva del Catastro Mapa Municipal de sitios Municipio de Yorito, Depto de Yoro 1:100,000
Republica de Honduras, Direccion Ejecutiva del Catastro Mapa Municipal de sitios Municipio de Sulaco, Depto de Yoro 1:50,000
Republica de Honduras, Direccion Ejecutiva del Catastro Mapa Municipal de sitios Municipio de Victoria, Depto de Yoro 1:75,000

Republica de Honduras, Direccion Ejecutiva del Catastro Mapa Departmental de Yoro, municipios y sitios 1:200,000)colour-shaded according to major land tenure system: national/private/'Ejidal' and 'Fiscal'.

6. Digital Maps composed with IMAGINE software:

/img2/Rainfall1.map (referred to in report as "Poster Map 1")

/pkg/users/jacox/Hond94-3.map (Land cover/land use classification of recent date TM mosaic covering central Hillsides Region of Honduras)

/pkg/users/jacox/yoro_Poster2.map (First/top half of poster summarizing the land characterization of Yoro Department: 'Biophysical Land Characterization of Yoro Department, Honduras, Central America.') Jan 1998

/pkg/users/jacox/Yoro_Poster.map (Second/bottom half of poster summarizing the land characterization of Yoro Department and Agricultural Census comparison) Jan 1998

/img1/POSTER.map "Land Use Characterization of Yoro Department, North Honduras for Rio Tascalapa study area, municipality and department zones"

/img1/POSTER1.map " Caracterizacion del uso de la tierra del departamento de Yoro, Honduras para el area de estudio del Rio Tascalapa, y zonas de los municipios y del departamento".

Poster Map: /julie/Honduras/lcover_terrain.map 'Land cover maps stratified according to land elevation' (a working document prepared for fieldwork in March 1997, consisting of a series of 4 maps and the pre-fieldwork land classification with legend)

/julie/Honduras/prefieldML.map - untitled working document (pre-fieldwork classification)

/julie/Honduras/yor_ML_aggcl.map - untitled working document showing two study area classifications, the first one being the result of an aggregation of classes in the signature editor.

/julie/Honduras/finalML_yorito.map - untitled working document (second post-fieldwork classification)

/julie/Honduras/yor4.map (untitled working document - fourth post-classification revision of watershed area)

/julie/Honduras/yorito_wsdML_NA.map (untitled working document - fourth post fieldwork classification of study area)

/img1/yorito-arcs.map (untitled working document - showing land tenure at watershed and municipality levels with other vector information)

/julie/Honduras/yor_final.map - (untitled working document - final post-fieldwork classification of the study area)

/julie/Honduras/yorito4_final.map -(untitled working document - final post-fieldwork classification of the study area)

Poster Map: /julie1/Honduras/yor1_ML.map 'Land cover map of Rio Tascalapa watershed, Yoro, based on Landsat TM classification March 1995 and air photo interpretation, March and September 1993' (first post-fieldwork classification attempt)

/julie/Honduras/yor1_focal7.map: 'Land cover classification(smoothed by a 7x7 window) of TM Image of the Tascalapa watershed, Yorito, March 1995' (working document of the above classification filtered using a nearest neighbour majority filter 7x7 window)

/julie/Honduras/Yor_Sul_Final.map "Land cover classification of Yorito and Sulaco municipalities' (post field-work classification)

/julie/Honduras/Yorito1.map 'Land cover map of Yorito Study area, Yoro, Honduras (Landsat TM classification and air-photo interpretation of the watershed area)'

Study Area Map: /julie/Honduras/YoritoSA.map:' Final land cover/ land use classification of Yorito watershed (sub-catchment of Rio Tascalapa)'

/julie/Honduras/api_yorito_rast.map: 'Air Photo Interpretation of Land cover/land use in the Yorito Study area, Yorito and Sulaco municipalities, Yoro, Honduras' (includes shaded air photo interpretation units, legend to complex land units and overlay coverages of field point distribution and rivers (from air-photographs).

/julie/Honduras/yor_sul_pop.map: 'Map showing land cover classification and population information from the 1988 Populstion census for the study area in Yorito/Sulaco, Department of Yoro' (Map showing land cover classification and population information from the 1988 Population Census for the study area in Yorito/Sulaco, Department of Yoro)

/julie/Honduras/Yor_Sul_Resolutions.map: "Yorito and Sulaco Municipalities - Land cover classification at 6 different spatial resolutions: 32m, 50m, 100m, 250m, 500m and 1 km" (working document to visualize whether resampling a classification at successivelly coarser resolutions affects land cover proportion estimates.)

/julie/Honduras/LC_yor+aldeas.map "Land cover/classification of Yorito and Sulaco Municipalities, Yoro, Honduras" (includes a summary of census-TM estimates and locations of aldeas censused in 1988. Classification is pre-fieldwork version;

List of Biophysical data sets and geographical information for the Danli Study Area, a sub-catchment of Rio Cuseateca, Danli Municipality, El Paraiso, Honduras.

GIS Lab, CIAT, Cali, Colombia

(File: \users\jacox\Archive_Danli.doc)

1. Satellite Data

1.1 Original Landsat TM images, purchased from EROS/EOSAT:

Path 17/ Row 50 'Danli' Scene, 3 Dates: 22 Jan 1987, 1 Feb 1985 and 23 Feb 1993
1987 subscene: /julie1/Honduras/danli/danli3_res32.img, danli4_res32.img,

Landsat TM Subscenes of study area: /img1/grego/Danli93sa.img, Danli93sa_res32.img, /julie/Honduras/danlisa_85.img, danli87SA.img,
Subscene covering municipality: /julie1/Honduras/danli/danli3mun.img, danli4mun.img, clipped mosaiced image:/julie1/Honduras/danli/ danimun.img,
Subscene covering department: /img1/grego/El_ParaisoDepFC85_7.img, danli93ss.img, danli93ss_100.img, matag1_2_85.img, /julie1/Honduras/danli/danli_munFC.img,
Subscene images belonging to department mosaic: /img1/grego/Matag85_res100.img, matag85_res32.img,

1.2 Classified Landsat TM Images:

1987 Study area classification: /img1/danli87ML.img, danli87MLf.img;
/img1/grego/danli93saML_res32.img (sig file: /img1/grego/danli93sa.sig);
/julie1/Honduras/danli/Danli87sa3ML.img (final classification), Danli87sa3MLf3.img, Danli87sa3MLf3_res32.img, danli87SAml.img, danli87SAmlf.img, danli87SAmlf_res32.img, danli_ML1sa.img, danli_ML1sa_res32.img, danli_ML1sa_res32f.img,
1993 Study area classification: /img1/grego/danli93saML.img, danli93saML_res32.img,
1993 Scene Classification: /img1/danli93ML.img, danli93MLf3.img, danli93MLf3_res32.img,
1987 Municipality Classification: /julie1/Honduras/danli./danli3mun_cl.img, danli3mun_cl25.img, danli4mun_cl.img, danli4mun_cl25.img, danli_munML.img, danli_munMLf3.img, danliml2clip.img, danlimun_cl25.img (mosaiced image), danlimunclip_cl25.img (mosaiced and clipped image),
1993 Municipality Classification: /img1/danli93MLf3_res32MUN.img; (sig file: /img1/grego/danli_trujil93.sig); /img1/grego/Danli93ssML_res32.img, /julie1/Honduras/danliml2.img, ,
1987 Department classification (without the 'Matagalpa' scene mosaiced - ie missing southern section: /julie1/Honduras/danli/elparaisml.img
1993 Department Classification: /img1/grego/El_ParaisoML_32.img, El_ParaisoML_agric.img, danli93ssML.img, danli93ssML_32.img, matag85ML.img, matag85ML_100.img, matag85ML_res32.img, paraisoML_res32.img, paraisoS_ML32.img, paraisoS_ML32f3.img,

1.3 Other classified images:

/img1/grego/El_ParMLclip85_7.img (forest cover within department in 1985-7), El_ParaisoML_dept32.img (forest cover within department in 1993)

2. Air Photographs

Danli (study area)	1980	1:20,000	16 4	2	Paper Diapositives
Cifuentes, El Paraiso	1981	1:42,000	17	4	Paper

3. Digital Orthophotographs

/ortho2/Danli/ortho/

/ortho2/Danli2/dtm/fulldtm.img (5m resolution, continuous coverage), fulldtmrastcont.img (5m resolution, thematic coverage)

4. GIS Coverages (Arc/Info)

4.1 Vector Coverages

/julie/hondarc/danli_sa, danlimu, elparaiso, nps-elparaiso, geol-paraiso, paraisoutm, soils-paraiso, topogc_utm, topoge_utm, topogs_utm, (topog_utm1, topoge1000, topogs-1000 - these are the highlighted 1,000m contour coverages);

4.1.1 National Coverages:

dcw_riverutm (Digital Chart of the World coverage of rivers – less accurate than the following:)

riosutm (digitized off IGN(1994) Mapa Oficial Republica de Honduras 1:50,000)

hh88utm (municipalities of Honduras)

horizonsutm (soil profile description locations in Honduras (used in cluster analysis/database compilation of P. G. Jones (1997)

Mean Monthly rainfall maps (imported from IDRISI coverages of P.G. *Jones* (1997) "Interpolated climate surfaces for Honduras ona 30-second grid." CIAT, Cali, Colombia Files as follows: /img2/rainjan.img, rainfeb.img, rainmar.img, rainapr.img, rainmay.img, rainjun.img, rainjul.img, rainaug.img, rainsep.img, rainoct.img, rainnov.img, raindec.img

Total annual rainfall map (source as above) Imagine File: /img2/raintot

Mean monthly temperature maps (source as above) Imagine Files: /img2/tempjan.img, tempfeb.img, tempmar.img, tempapr.img, tempmay.img, tempjun.img, tempjul.img, tempaug.img, tempsep.img, tempoct.img, tempnov.img, tempdec.img

geology (digitized from Geology hardcopy map)

leeforr (digitized from Leforrest Miller Soils Classification)

soils-simms (digitized from Simmons' Soils Classification)

list1 and list2 (reconnaissance field observation points - fieldwork March-April, 1995

natparks (digitized from GAF (Gesellschaft fur Angewandte Rernerkundung mbH, Munchen, FRG (1995)
for Cohdefor (Corporacion Hondurena de Desarrollo Forestal, Tegucigalpa, Honduras and KfW, Frankfurt/Main, FRG (revised by Ing Jose Cristobal Vasquez V (1992-95) "Republica de Honduras Mapa Forestal 1:500,000" (a digital coverage is available but does not include the vector overlay information)

roadsutm (only useful for national-scale maps)

topogc_utm (contours at 200m intervals, source: IGN (1994) Mapa oficial 1:500,000

topog_utm1 (contour 1,000m to highlight mountainous areas; source as above)

4.2 Rasterized Coverages

/julie1/Honduras/geoldanli.img (resolution 669 m), soilsdanli.img (71 m resolution), El_Paraiso.img (department polygon only), elparaiso_rast.img (municipality polygons contained within department), danli_rast.img (study area polygon), danlimu.img (municipality polygon), geol-paraisR.img,

4.3 Poster Maps

'Biophysical Land Characterization of El Paraiso Department, Honduras, Central America'
'Danli Study Area Classifications of 1987 and 1993 TM Data'

5. Hardcopy Maps

Topographic sheets (Source: Secretaria de Comunicaciones, obras publicas y transporte, Instituto Geografico Nacional (IGN): Map sheets covering the study area:

2858 II Danli (NW quadrant)
2958 III Valle de Jamastran (NE quadrant)
2857 I El Paraiso (SW quadrant)
2957 IV Rio de Apali (SE quadrant)

Road Map of El Paraiso: Republica de Honduras Secretaria de Comunicaciones obras publicas y transporte, (1992) "Red Vial Depto. de El Paraiso"

Biophysical Data Sets and Geographical Information for Honduras and, more particularly, the central hillsides zone. GIS Lab, CIAT, Cali, Colombia (File: \users\jacox\Windows\personal\Archive_national.doc)

1. Satellite Data

1.1 Original Landsat TM images, purchased from EROS/EOSAT:

/julie1/Honduras/mosaic_hill.img (mosaic of four scenes: 'Ceiba' 5 March, 1994, 'Yoro' 8 March, 1995 (has less cloud than the 1994 scene), 'Trujillo' 8 March, 1986 and 'Danli' 22 Jan 1987 (the latter two scenes were the only images available until 1998 when the GIS Lab acquired 1993 data for these two scenes and of the same date). Note that the fourth quarter of the 'Danli' scene did not join up well with the other quarters of the scene due to the geo-correction - appears that it could be improved - as more points were available for identification in the other three quarters (100m resolution)

Original image for the more recent mosaic consisting of 'Ceiba' 5 and 'Yoro' 5 March, 1994, with 'Trujillo' and 'Danli' dated 23 February, 1993, was carried out by Gregoire Leclerc using PCI software and is held in directory ????????

Also a mosaiced image covering the whole of Honduras, using the older set of scenes from the mid to late 1980's has yet to be generated as some geocorrections are required - it would seem the most rapid method might be to use a digital terrain model - one derived from the contour map at 1:500,000 scale. (refer to Gregoire Leclerc)

1.2 Classified Landsat TM Images/subscenes:

/pkg/users/jacox/hon94.img (original classification of the mosaiced four central scenes, recent dates), honduras94.img (32m resolution, coded for comparison with Cohdefor national forest map), honduras94_NA.img (100m resolution, colour coded for comparison with Forest Map),

2. Aerial Photographs

Ojos de Agua, Comayagua (baseline municipality for Image-Census comparison)	Feb, Mar and Apr & May 1995	1:20,000	26	4

This is the final set of photographs covering the entire small municipality which had been covered 80% in the Agricultural census.

We do not have any further coverages of air photographs apart from the study areas and various samples within the municipalities of Yorito and Sulaco.

3. No Digital Orthophotographs (see study area lists)

4. GIS Coverages (Arc/Info)

4.1 National Vector Coverages:

dcw_riverutm (Digital Chart of the World coverage of rivers – less accurate than the following:)

riosutm (digitized off IGN(1994) Mapa Oficial Republica de Honduras 1:50,000)

hh88utm (municipalities of Honduras)

horizonsutm (soil profile description locations in Honduras (used in cluster analysis/database compilation of P. G. Jones (1997)

Mean Monthly rainfall maps (imported from IDRISI coverages of P.G. Jones (1997) "Interpolated climate surfaces for Honduras ona 30-second grid." CIAT, Cali, Colombia Files as follows: /img2/rainjan.img, rainfeb.img, rainmar.img, rainapr.img, rainmay.img, rainjun.img, rainjul.img, rainaug.img, rainsep.img, rainoct.img, rainnov.img, raindec.img

Total annual rainfall map (source as above) Imagine File: /img2/raintot

Mean monthly temperature maps (source as above) Imagine Files: /img2/tempjan.img, tempfeb.img, tempmar.img, tempapr.img, tempmay.img, tempjun.img, tempjul.img, tempaug.img, tempsep.img, tempoct.img, tempnov.img, tempdec.img

geology (digitized from Geology hardcopy map)

leeforr (digitized from Leforrest Miller Soils Classification)

soils-simms (digitized from Simmons' Soils Classification)

list1 and list2 (reconnaissance field observation points - fieldwork March-April, 1995

natparks (digitized from GAF (Gesellschaft fur Angewandte Rernerkundung mbH, Munchen, FRG (1995)
for Cohdefor (Corporacion Hondurena de Desarrollo Forestal, Tegucigalpa, Honduras and KfW, Frankfurt/Main, FRG (revised by Ing Jose Cristobal Vasquez V (1992-95) "Republica de Honduras Mapa Forestal 1:500,000" (a digital coverage is available but does not include the vector overlay information)

roadsutm (only useful for national-scale maps)

topogc_utm (contours at 200m intervals, source: IGN (1994) Mapa oficial 1:500,000

topog_utm1 (contour 1,000m to highlight mountainous areas; source as above)

4.2 Rasterized Vector coverages:
images of municipalities with a high percentage of total land area censused in the Agricultural census of 1993: /julie/hondarc/namasig_rast.img (municipality of Namasigue), ojo_rast.img, (municipality of Ojo de Agua) smanuel_rast.img, (municipality of San Manuel).

5. Hardcopy maps

Topographic sheets (Source: Secretaria de Comunicaciones, obras publicas y transporte, Instituto Geografico Nacional (IGN) - see GIS Lab Map Archive information - most of the national set are available with additional copies of the study areas. (Appendix 2_ topographic sheet index, IGN)

Cohdefor National Air Photograph Index: coverage of 1:20,000 scale photography taken in the years 1979, 1980, 1981, 1989, 1993.

Simmons Soils classification Map: 'Mapa General de Suelos, Republica de Honduras' Accompanying document with legend description: 'Sintesis de los suelos de Honduras' Vladimiso Castellanos, Jefe Depto de Suelos, Ministerio de Recursos Naturales) (1973) Seminario nacional sobre zonifacacion, ecologica de cultivos y regionalizacion agricola de Honduras' 4 – 7 Sep, 1973 Tegucigalpa.

Leforrest Miller Soils Classification Map: 'Soil mapping units for 1:1,000,000 Honduras, Direccion Ejecutiva del Catastro (Legend attached)

Mapa geologico de Honduras (1991) Secretaria de Comunicaciones obras publicas y transporte IGN (1991) 1:500,000 Compiled by Michael J. Kozuch.

6. Digital Maps composed using IMAGINE software:

/pkg/users/jacox/Hond94-3.map (classification of the four central scenes of Honduras with legend; map includes overlays of road network, rivers and municipalities with the study areas marked.)

honduras94_NA.map (same mosaiced classification as above, but colour coded differently so as to match up better with the Forestry Map of Honduras for the comparison - both maps are based on Landsat TM classifications).

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APPENDICES:

Landsat TM Information

REFERENCE	LOCATION/NAME CODE	FECHA	COMMENTS
Path 19/Row 49	Cortes	25 March 87	
Path 19/Row 50	Copan	25 March 87	
Path 18/Row 49	Ceiba (contains 2 study areas)	18 March 87 5 March 94	This scene is used in the recent date classified image mosaic of Honduras
Path 18/ Row 50	Yoro (contains the major study area)	15 March 86 5 March 94 8 March 95	This scene is included in the mosaic
Path 18/Row 51	Choluteca	13 April 85	
Path 17/Row 49	Trujillo	1 Feb 85 8 March 86 23 Feb 93	This scene is included in the mosaic
Path 17/ Row 50	Danli (contains the fourth study area)	22 Jan 87 1 Feb 85 23 Feb 93	This scene is included in the mosaic
Path 17/Row 51	Matagalpa	1 Feb 85 8 May 88 23 Feb 93	This scene is included in the mosaic
Path 17/Row 52	Nicaragua (west)	1 Feb 85	Missing NW quadrant
Path 16/Row49	Colon	15 Jan 87	
Path 16/Row 50 Path 16/Row 51 (multiple scene)	Olancho	15 Jan 87	

Path 16/Row 52	Nicaragua (east)	14 March 85	
Path 15/Row 49 (includes a Southerly shift)	Gracias	21 Jan 86	This scene extends part of the way into the frame 15/50 in order to cover Honduras

Aerial Photographs

AREA	DATE	SCALE	NUMBER OF PHOTOS	NO. RUNS	FORMAT
Yorito (study area)	1977	1:40,000	3	1	Paper
Yorito (study area)	1993 (northern two runs L 36A and L 35B dated April whilst southern two runs L 34A and L 33A dated September)	1:20,000	37	4	Paper Diapositives (scanned) Orthophotos (derived)
Yorito (study area)	1956	1:70,000	11	3	Diapositive
Danli (study area)	1980	1:20,000	16 4	2	Paper . Diapositives
Tela (study area)	14-2-1987	1:20,000	3	1	Paper Diapositives
Tela (Lancetilla)	23-1-1992	1:40,000	3	1	Paper
La Masica (study area)	15-2-1987	1:20,000	6	2	Paper Diapositives
Cifuentes, El Paraiso	1981	1:42,000	17	4	Paper
Pico Bonito, La Ceiba	23-1-1992	1:40,000	3	1	Paper
Ojos de Agua, Comayagua (baseline municipality for Image-Census comparison)	Feb, Mar and Apr & May 1995	1:20,000	26	4	Paper

CLASIFICACION CLIMATICA DE HONDURAS BASADA EN LOS REGIMENES PLUVIALES DEL PAIS

Estudio del Clima de Honduras realizado por Edgardo Zúniga Andrade, finalizado en el año de 1983.

PROVINCIAS CLIMATICAS	CODIGO	VARIANTES
MUY LLUVIOSO CON INVIERNO LLUVIOSO. (Idem Clima Af de Koppen.)	Sz	.....
MUY LLUVIOSO CON DISTRIBUCION REGULAR DE LLUVIAS.	Lz	Fz, Yz
MUY LLUVIOSO TROPICAL.	Lk	Fk
MUY LLUVIOSO DE TRANSICION.	Yk	Gk, Ck
MUY LLUVIOSO DE BARLOVENTO (Semiestacional).	Vk	Ek
LLUVIOSO DE ALTURA	Vx	Cx, Gx, Rx
POCO LLUVIOSO CON INVIERNO SECO (Idem clima Aw de Koppen)	Yx	Yb
POCO LLUVIOSO CON INVIERNO LLUVIOSO EN LADERA A SOTAVENTO.	Mx	.....
POCO LLUVIOSO DE TRANSICION.	Mb	.....
DE ALTURA A SOTAVENTO.	Vt	.....
LLUVIOSO CON INVIERNO MUY SECO.	Vb	.....

NOTA: Las provincias climáticas Lz, Lk, Yk, Vk y Vx son subclimas del MUY LLUVIOSO CON INVIERNO LLUVIOSO. Las provincias climáticas Mx, Mb, Vt y Vb son subclimas del POCO LLUVIOSO CON INVIERNO SECO.

NOTA: En esta clasificación la palabra "invierno" corresponde al período del año que abarca el Solsticio de Invierno del hemisferio Norte.

MESES MAS LLUVIOSOS DEL AÑO

MESES	CODIGO
MAYO Y SEPTIEMBRE	M
MAYO Y OCTUBRE	N
JUNIO Y JULIO	R
JUNIO Y AGOSTO	C
JUNIO Y SEPTIEMBRE	V
JUNIO Y OCTUBRE	Y
JUNIO Y NOVIEMBRE	F
JULIO Y AGOSTO	G
JULIO Y SEPTIEMBRE	E
JULIO Y OCTUBRE	H
OCTUBRE Y NOVIEMBRE	L
NOVIEMBRE Y DICIEMBRE	S

MESES MAS SECOS DEL AÑO

MESES	CODIGO
DICIEMBRE Y ENERO	t
ENERO Y FEBRERO	b
FEBRERO Y MARZO	x
MARZO Y ABRIL	k
ABRIL Y MAYO	z

PERIODO DE REGISTRO CONSIDERADO

1966 – 1985

14°30'
14°00'
13°30'
13°00'
12°50'

Appendix 2

Calendario.xls

Honduras: Calendario de Siembra y Cosecha de Granos Básicos por Ciclo, mes de Siembra y Cosecha Según Región, 1988

Regiones	Maíz				Frijol				Arroz		Sorgo	
	Primera		Postrera		Primera		Postrera		Una vez por Año		Una vez por Año	
	Siembra	Cosecha	Siembra	Cosecha	Siembra	Cosecha	Siembra	Cosecha	Siembra	Cosecha	Siembra	Cosecha
Sur	04-06	07-09/12	08-09	11-01					05-07	10-12	40-06	11-01
Centro Occidental	04-06	08-01	09-11	12-04	04-06	07-11	08-10	11-03	05-06	08/11-12	06-07	11/01-03
Norte Atlántico	05-07	08-01	09-12	02-06	05-06	08-11	08-10	11-01	04-06	08-10		
Litoral Atlántico	05-07	09-11	11-12	02-04	04-06	07-08	09-12	01-04	05-07	10-11		
Nor Oriental	05-07	09-12	10-12	01-04	05-06	08-10	09-11	01-03	05-07	09-11		
Centro Oriental	05-07	08-02	09-12	01-04	05-07	08-09	08-10	11-01	05-06	11-12	7	12
Occidental	05-07	08-01	10-01	03-05	05-07	08-10	08-10	12-01/03-04	05-06	10-11	05-08	12-01

Nota: Algunas regiones practican la doble del maíz por esta razón; la cosecha sobrepasa los 120 días del período vegetativo.
La pleca (/) significa que dentro de una región existen dos épocas de cosecha dentro de un mismo ciclo.

Fuente: Compendio Estadístico Agropecuario 1994

List of Posters

1. Rainfall maps showing average total annual rainfall for Honduras and seasonal variation in mean monthly totals for each of the three study area departments.

2. Monthly rainfall surplus and deficit maps of Honduras

3. Biophysical land-characterization of Atlantida Department, Honduras, Central America.

4. Biophysical land-characterization of Yoro Department, Honduras, Central America.

5. Biophysical land-characterization of El Paraiso Department, Honduras, Central America.

6. Maps of the two study areas in Atlantida Department: Rio Cuero and Rio de Saco.

7. Land cover classification of Arizona municipality and study area

8. Landsat TM False Colour composite and Maximum likelihood classification of La Masica Municipality, Honduras, 5 March, 1995.

9. Land use classification of Central Honduras

10. Baseline municipalities and their land cover classifications

11. Study area municipalities and their land cover classifications

12. Land cover map of Rio Tascalapa watershed, Yoro, based on post-fieldwork Landsat TM classification dated March, 1995 and 1:20,000 air photo interpretation, March and September, 1993.

13. Air photo interpretation of land cover and land use in the Yorito study area, Yorito and Sulaco municipalities, Yoro, Honduras.

14. Elevation and slope characteristics of the Yoro watershed.

15. Land Tenure of the Yorito and Sulaco municipalities

16. Danli study area classifications of 1987 and 1993 TM Data.

17. Caracterizacion de Uso de la Tierra del Departamento de Yoro, Honduras para el area de estudio del Rio Tascalapa, y zonas de los municipios y del departamento.