Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Apaporis river – Colombia

(Path 007, Row 059, Quarter 4)

Joint Research Centre (JRC)

and

CIAT

Technical Report

Javier Puig, Grégoire Leclerc,
Carlos Nagles, Alexander Cuero, Rafael D. Hoyos

December 1999

CGIAR
Consultative Group on International Agricultural Research

TABLE OF CONTENTS

INTRODUCTION

Phase 2 of the TREES project is developing a prototype for an operational system for monitoring forests in the tropical belt (TFIS). The capacity to detect deforestation hot spots is being improved by analysing a sample of high-resolution imagery over known hot-spot areas (JRC, 1997). This work is being done partly by local organisations, in order to build partnerships for TFIS. Many locations scattered over virtually all of South America show evidence of accelerated deforestation, but principally so in the Colombian, Ecuadorian and Peruvian Andes and the western part of the Amazon region (JRC, 1997).

The objective of this component of TFIS development is to identify and quantify recent deforestation in the period between 1989-1991 and 1996-1998 for the selected samples. The changes of forest area between both dates were measured using high-resolution remote sensing data and techniques.

The International Centre for Tropical Agriculture (CIAT, its Spanish acronym) was responsible for studying 13 sample areas located in Colombia, Ecuador and Peru, covering some of the principal South American hot spots.

The methodology of this study involved the use of georeferenced satellite images, such as Landsat TM SPOT, and on-screen digitising of land-use and land-cover units, which are greater than 50 hectares for recognition purposes. Digitising was on a 1: 100 000 scale. The recognition and assignment of land-use codes to the image interpretation was supported by the use of historical data, such as land-use and forest maps, to evaluate past and present changes.

This report involves the study of an area located in the Colombian Amazon (Río Apaporis).

DEFORESTATION PATTERNS IN SOUTH AMERICA

According to WRI-UNEP-UNDP-World Bank (1998), an average of 0.5% annual deforestation occurred in South America during the 1990-1995 period. However, it is highly variable between countries, from 0% (Guyana and Uruguay) to 2.6% (Paraguay). Annex 5 gives statistics for South America's forests in the period 1990-1995.

The clearing of tropical forest shows different kinds of spatial patterns, which are influenced by the size of the remaining forest area and the customs of the inhabitants. One spatial pattern is of a small remnant of forest like an island within the cleared area. In this way, deforestation is increasingly advancing along the borders (Rudel, 1993).

In the case of a wide area of forest, such as the Amazon basin, the deforestation pattern has another shape; along the forest margins, in similar circumstances to the forest-island, fringes are opening into the border of the forest. This situation can be seen where the Amazon basin borders the Andes region. "The population overflowing from the Andes down to the Amazon plains do not settle there. They advance like a slow burning fire, concentrating along a narrow margin between the land they are destroying and are about to leave behind, and the forests lying ahead of them" (Myers, 1984). The land is used until yields begin to decline, then it is ceded or sold to cattle ranchers and the settlers move farther into the forest to restart the cycle of forest clearing and abandonment (Stearman, 1985). In some cases, the deforested area is abandoned for 5 to 10 years before secondary forest growth is established (Navas, 1982).

Deforestation may also occur along defined corridors, such as roads and rivers. One of the first situations revealing this pattern is in the upper reaches of the Amazon basin; the first spots of cleared land emerge in a linear pattern along mule trails from the Andes to the Amazon. Farther east, navigable rivers provide access to markets, so the first clearings occur in corridors of land along rivers (Rudel, 1993).

The governments sponsor colonisation zones into the forest, often resulting in grids with cleared land along the roads and islands of forest in the centre of the squares created by the roads. Both sides of the roads have a uniform width of farm clearings. These clearings form an additional corridor of cleared land that parallels the roadside corridor several kilometres into the forest (Hiroaka and Yamamoto, 1980). Other road-building agents are the "highly capitalised organisations like timber companies that begin the deforestation process by building a penetration road, and colonists quickly clear a corridor of land along the road. The subsequent construction of feeder roads induces further deforestation and swaths of cleared land appear in the zone, reducing the forests to island remnants away from the roads" (Rudel, 1993).

The building of a new road into the forest sometimes does not generate a corridor of cleared land. In Colombia, the penetration road into the state of Caqueta generated considerable land clearing, while the construction of a similar road into the state of Guaviare did not (Ortiz, 1984). Areas such as Guaviare and Amazonas in Colombia, even after roads had been completed, remained far from major markets and have had little economic or population growth.

In Frohn's (1998) study of the causes of landscape change in Rondonia, Brazil, he observed that the amount of deforested area is negatively correlated with the distance to the inhabited centres. The farmers closer to urban centres have difficult access to the forest because of lack of transport and services.

Many factors may have helped produce deforestation hot spots: political decisions, migration, marketplaces, fuelwood gathering, livestock farming, increase of population, climatic and compounded-impact, infrastructure, fires, illegal plantation, logging, appropriateness of land uses, dams, mining (Utting, 1993; Adger and Brown, 1994). But the causes of deforestation can be abridged into three principal ones, (1) land use conversion, (2) overexploitation of forest and (3) natural and environmental changes (Adger and Brown, 1994).

Deforestation has global consequences with respect to the carbon cycle. It has local impacts of increased rates of soil erosion, capacity of soils to retain water, other pollutants emitted from biomass burning, loss of biological diversity, loss of cultural diversity (when the indigenous people are displaced) and loss of indigenous knowledge (Adger and Brown, 1994).

STUDY AREA

LOCATION

The study site is located in the eastern part of Colombia, in the Amazon region, along the border between Caquetá and Guaviare States. There are no notable bounded within the study site, but the principal roughnesses are the Chiribiquete mountain range, and the Yaya-Ayaya, Leleya, Ajajú, Tunia and Apaporis Rivers. The area covers 792 403 ha.

TOPOGRAPHY

The relief of the region is composed of rolling hills (20-50 meters elevation differences) that turn into steep slopes near the piedmont. Along the rivers are intermediate terraces and low plains. Moving away from the Andes towards the south, the land becomes flatter (Navas, 1982).

Some of the highest hills are from the pre-Cambrian, Palaeozoic, Tertiary and Quaternary sediments in the eastern part. They constitute the geological platform called "Escudo Guayanes" (Acevedo, 1976; Martin, 1990). Generally, the topography is flat and in some places as high as from 90 to 400 metres (Sorzano, 1988, IGAC, 1999). The Chiribiquete mountain range, which reaches 500 metres, is one of these formations and extends between the Apaporis and Caquetá rivers (del Llano, 1997). According to IGAC (1999), this geological formation, also called Araracuara, is present in larger area in two principal sectors, one in Guaviare and Vaupés Departments and the other in Guainia Department.

The soils of this zone occupy hollows in the flat to rolling relief, where flood waters linger; these areas are generally covered by palms and other swamp vegetation (Sorzano, 1988).

CLIMATE AND VEGETATION

The climate is hot and very humid, increasing in temperature and humidity from north to south and from east to west, with a mean annual rainfall varying between 2000 and 3000 mm. The rainy season is April to November. A dry period occurs in December and February in the west and from June to October in the east of the Colombian Amazon region (Navas, 1982; Sorzano E., 1988; http://b- quilla.cetcol.net.co/colombia/ guaviare.htm).

The forest is of the humid tropical type, at its most marked with emergent trees of over 40 metres in height and covered by abundant parasitic and epiphytic plants (Sorzano, 1988).

The rocky soil of the Chiribiquete mountain range, which has a high quartz content, is where typical species develop that are stocky and generally mixed with numerous latex plants (Yanine et al., 1998). The vegetation reduces in height according to altitude, changing from tall trees to shrubland (IGAC, 1999).

DEFORESTATION

Indigenous communities, such as the Tanimuca, Yucuna, Barasano, Letuama, Matapí, Macuna and Macú tribes, inhabit the area. They practice agriculture in small areas, using a slash-and-burn technique to clear the land to be cultivated. They cultivate for a period of 2 to 3 years, then abandon the area to allow recovery of nutrients for future reuse of the land (Sorzano, 1988).

METHODOLOGIES

MATERIALS

For this work we used the fourth quarter of two Landsat TM images (path 007, row 059: 007059910401Q4geo.lan, 007059970908Q4geo.lan). The radiometric quality of the image data was good, but both images (1991, 1997) had important surface cloud cover, especially for the second date.

Land use was interpreted using forest as reference maps at a 1:500 000 scale from the Instituto Geográfico Agustín Codazzi (IGAC, 1987; 1983).

The interpretation key that we used for this project is given in annex 4.

GEOCODING

Both images were georeferenced to Universal Transversal of Mercator (UTM), zone 18 WGS84, using the Georeferencing module of the PCI software. Geographic reference information was extracted from topographical maps and associated to the image of the first date as ground control points. In the case of the second image, the georeferencing process used as a reference the product obtained from georeferencing the first image (first date). The topographical maps at a scale of 1:100 000 that were used for georeferencing were produced by the Defence Mapping Agency of the United States of America (NIMA). Annex 1 gives a list of maps used for georeferencing, root mean square (RMS) error for both processes as well as parameters and other georeferencing information.

Figures 1 and 2, in Annex 2, give an overview of the study area in both images after the georeferencing process.

LAND-USE AND LAND-COVER DIGITISING

Land uses and land cover were digitised on screen over the TM 4-5-3 colour composite. This process was completed using the Imageworks module of PCI software with the minimum mapping unit as described in TREES technical annex (50 ha; 300 m width for linear features). The images were displayed at a scale of 1:100 000 and all distinguishing characteristics were digitised and associated to a specific class code established by TREES (see Annex 3).

Digitised vectors on the first image were overlaid on the second and then the changes in land use and cover greater than 25 hectares were digitised. The result of this process forms the digitised product of land use and cover for the second image.

BUILDING POLYGONS

Both data groups were transferred to ARC/INFO to correct remaining errors (dangles, codes) and to build polygon coverages for both dates as well as their intersection.

In the intersection coverage, some polygons with size less than half the minimal mapping unit (i.e. 25 ha) were suppressed by using the ELIMINATE command, which allowed us to merge small polygons to the polygons with the longest common boundary. This was particularly useful to simplify areas with scattered clouds.

The intersection coverage was submitted to a final edition process in ArcView 3.1, using the imagery for both dates as background. In this step, remaining code errors and inconsistencies, as well as remaining digitising errors, were corrected on the intersection coverage. For example, polygons might be found going from a young regeneration stage to primary forest, which is impossible in a period of 9 years.

Final coverages for the overlapping area from both dates were produced from the corrected intersection coverage using the DISSOLVE command of ARC/INFO. These were used to generate the statistics reported in Annex 3. In compliance with contract requirements, the coverages for the total area covered by each image were obtained by merging (making codes and borders compatible) those produced by DISSOLVE with the originals (i.e., before intersection).

The attribute table of the intersection coverage was used to produce the land use change statistics and confusion matrix (see Annex 3).

INTERPRETATION OF CHANGES

Principally, the predominant land uses are lowland tropical forest (91.7%), periodically inundated tropical forest (5.8%), woodland and shrubland savannah (2.9%). The absence of forest in some areas is caused by natural factors such as natural emergent rocks that cannot sustain forest vegetation. In other areas it corresponds to a runway and to illegal coca plantations (2 areas of less than 100 hectares each), that didn't evolve in the 6 years period. There are located in the confluence of Majiña and Ajajú rivers before the last one turn to the north direction, near to Chiribiquete mountain range, in the south-east of the images

CONCLUSION

The study area showed no land use changes between 1991 and 1997. The changes that could be observed between both dates correspond to clouds and shadows in both images.

Nowhere can shifting cultivation be seen or any kind of settlers activity. Small areas of cultivation correspond to illegal plantations of coca located far from the main settlement of the Amazon region.

The areas classified as open and fragmented forest were related not some deforestation process, but to the presence of important water bodies.

The study area does not correspond to a deforestation hot spot, although neighbouring areas might be considered as such. The nearest villages to this study area are located towards the west in quarter 1 of this path and row, towards the north inside the path 007, row 058, and towards the east within the path 006 row 059. In these areas, more deforestation probably occurs than in the areas covered by the images selected for this study.

Annex 1

Geocoded image information

Río Apaporis (Path 007, Row 059, Quarter 4)

Maps Used for Georeferencing

DMAAC. 1991. Candilejas, Hoja 2073, Candilejas-Colombia, Topograhic map, Scale 1: 100 000, Defense Mapping Agency Aerospace Center, Serie J671, Edition 1. St. Louis.

DMAAC. 1991. Norte de Candilejas, Hoja 2074, Norte de Candilejas-Colombia, Topograhic map, Scale 1: 100 000, Defense Mapping Agency Aerospace Center, Serie J671, Edition 1. St. Louis.

DMAAC. 1990. Norte de Santa Rita, Hoja 2173, Norte de Santa Rita-Colombia, Topograhic map, Scale 1: 100 000, Defense Mapping Agency Aerospace Center, Serie J671, Edition 1. St. Louis.

DMAAC. 1992. Este de Yanguara, Hoja 2274, Este de Yanguara-Colombia, Topograhic map, Scale 1: 100 000, Defense Mapping Agency Aerospace Center Aerospace CenterAerospace Center, Serie J671, Edition 1. St. Louis.

DMAAC. 1992. Buenos Aires, Hoja 2273, Buenos Aires-Colombia, Topograhic map, Scale 1: 100 000, Defense Mapping Agency Aerospace Center, Serie J671, Edition 1. St. Louis.

DMAAC. 1990. Yanguara, Hoja 2174, Yanguara-Colombia, Topograhic map, Scale 1: 100 000, Defense Mapping Agency Aerospace Center, Serie J671, Edition 1. St. Louis.

Geocoded image information

Landsat TM image, Quarter 4
Path 007 Row 059
Date 01/04/91
Image name: **007059910401Q4geo.lan**

Channel 1	TM Band 3
Channel 2	TM Band 4
Channel 3	TM Band 5

Number of columns	3966
Number of lines	3434

Reference projection	UTM 18 N WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	638020	165020	73.7593 W	1.4926 N
Lower right corner	757000	62000	72.6909 W	0.5604 N

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	1.3
Number of GCP	25

Geocoded image information

Landsat TM image, Quarter 4
Path 007 Row 059
Date 08/09/97
Image name: **007059970908Q4geo.lan**

Channel 1	TM Band 3
Channel 2	TM Band 4
Channel 3	TM Band 5

Number of columns	3966
Number of lines	3434

Reference projection	UTM 18 N WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	638020	165020	73.7593 W	1.4926 N
Lower right corner	757000	62000	72.6909 W	0.5604 N

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	1.1
Number of GCP	22

Annex 2

False colour composites

Río Apaporis (Path 007, Row 059, Quarter 4)

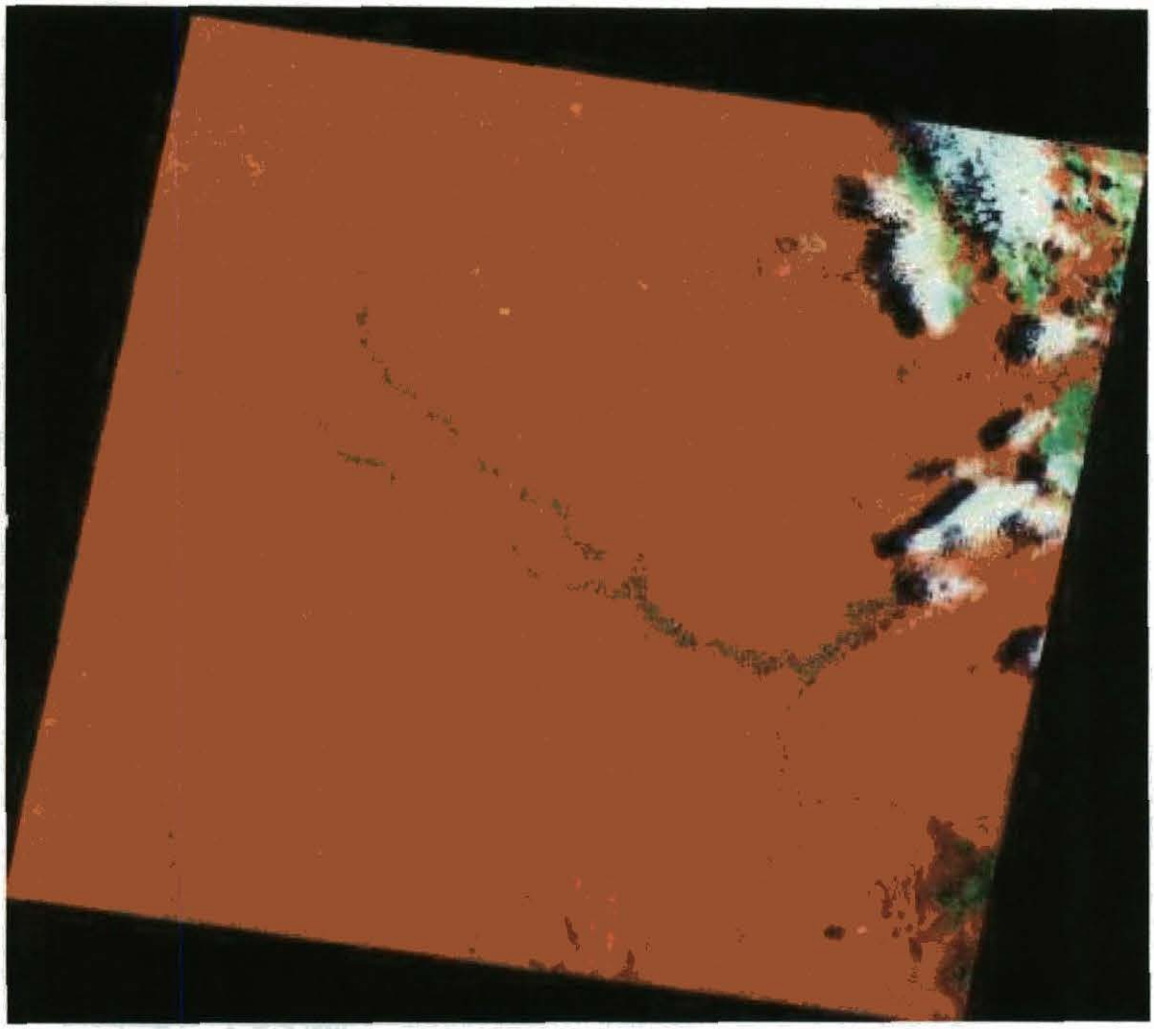


Figure 1: Landsat TM satellite image, bands 4,5,3, path 007, row 059, quarter 4, date 01-04-91. Upper left corner 73.7593 W, 1.4926 N, Lower right corner 72.6909 W, 0.5604 S. N

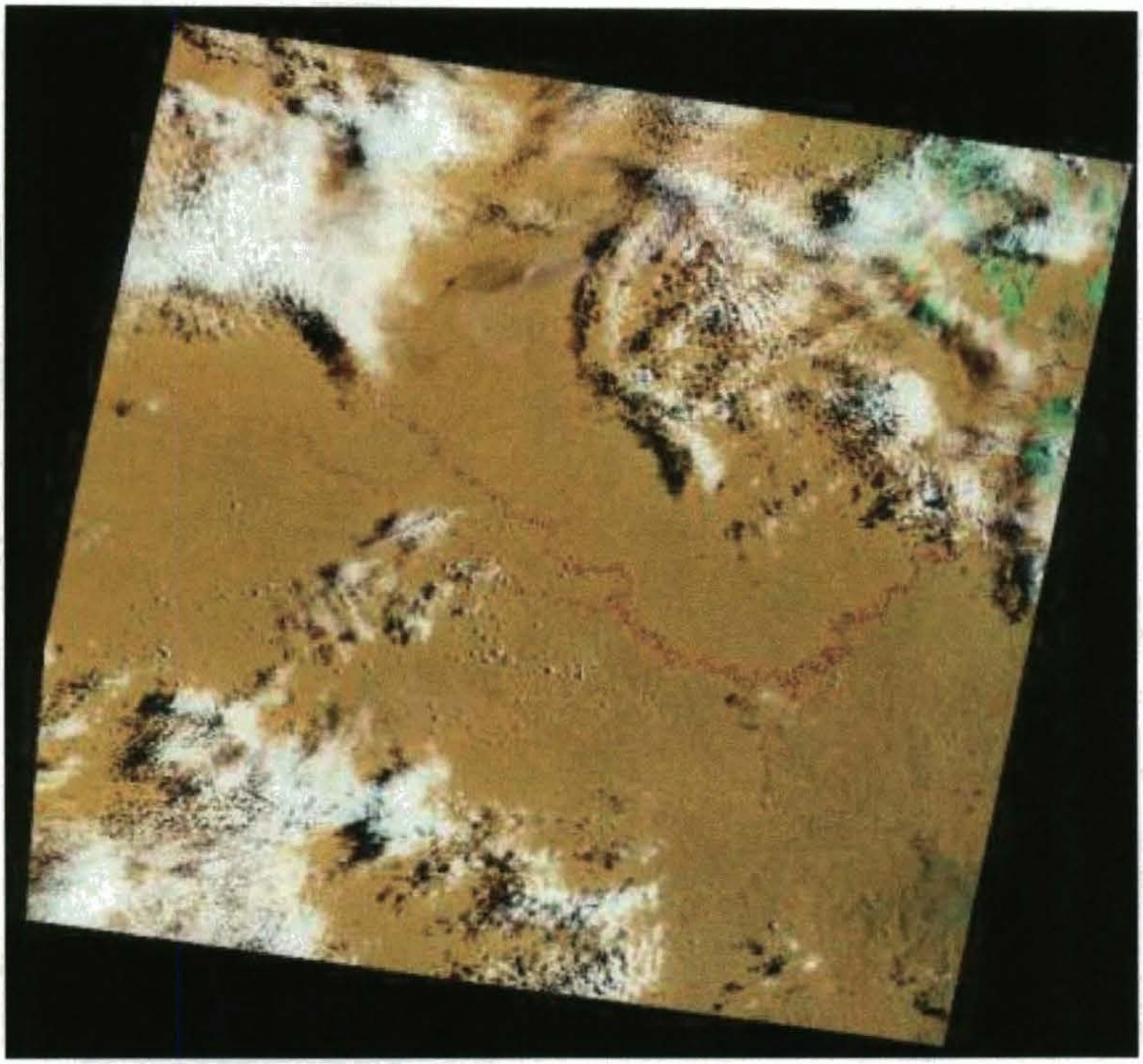


Figure 2: Landsat TM satellite image, bands 4,5,3, path 007, row 059, quarter 4, date 08-09-97. Upper left corner 73.7593 W, 1.4926 N, Lower right corner 72.6909 W, 0.5604 S.

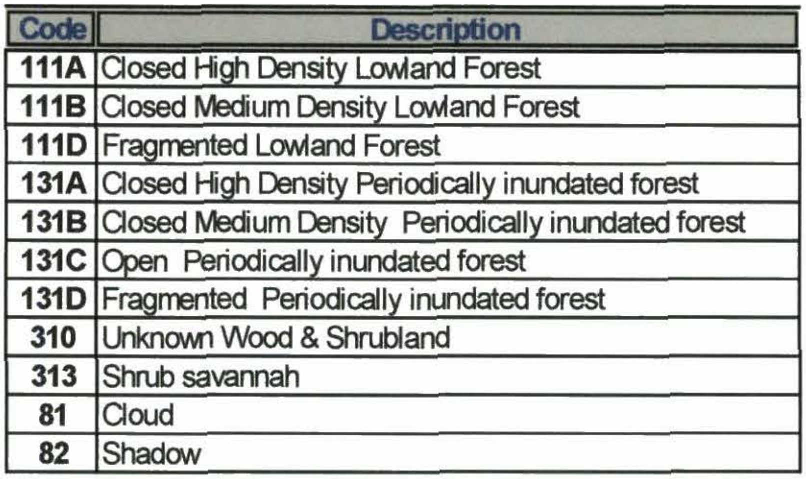
Annex 3

Land use / Land cover change
(Overlap area)

Río Apaporis (Path 007, Row 059, Quarter 4)

Land use / Land cover present in 1991 image

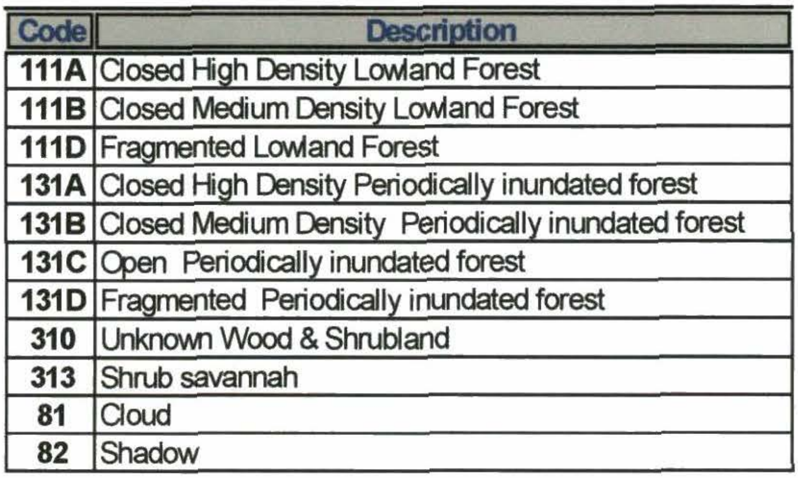
Río Apaporis (Path 007, Row 059; col_ciat_rap_91_cds.xls)



Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111D	Fragmented Lowland Forest
131A	Closed High Density Periodically inundated forest
131B	Closed Medium Density Periodically inundated forest
131C	Open Periodically inundated forest
131D	Fragmented Periodically inundated forest
310	Unknown Wood & Shrubland
313	Shrub savannah
81	Cloud
82	Shadow

Land use / Land cover present in 1997 image

Río Apaporis (Path 007,Row 059; col_ciat_rap_97_cds.xls)



Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111D	Fragmented Lowland Forest
131A	Closed High Density Periodically inundated forest
131B	Closed Medium Density Periodically inundated forest
131C	Open Periodically inundated forest
131D	Fragmented Periodically inundated forest
310	Unknown Wood & Shrubland
313	Shrub savannah
81	Cloud
82	Shadow

Statistics for 1991 image

Río Apaporis (Path 007, Row 059; col_ciat_rap_91_sts.xls)

Code 91	No. Polygons	Total Area	Mean Area	S. D. Area
111A	15	677943	45196	105281
111B	1	121	121	0
111D	2	194	97	69
131A	11	9202	837	518
131B	2	2872	1436	248
131C	3	29043	9681	12367
131D	1	1277	1277	0
310	16	4264	267	323
313	17	14580	858	1004
81	12	33900	2825	3995
82	23	19006	826	1119

Statistics for 1997 image

Río Apaporis (Path 007,Row 059; col_ciat_rap_97_sts.xls)

Code 97	No. Polygons	Total Area	Mean Area	S. D. Area
111A	21	507182	24152	63056
111B	1	121	121	0
111D	2	194	97	69
131A	11	4878	443	402
131B	2	1997	998	867
131C	5	21660	4332	7528
131D	1	1916	1916	0
310	20	5505	275	327
313	19	16463	866	921
81	19	193756	10198	18403
82	37	38731	1047	1139

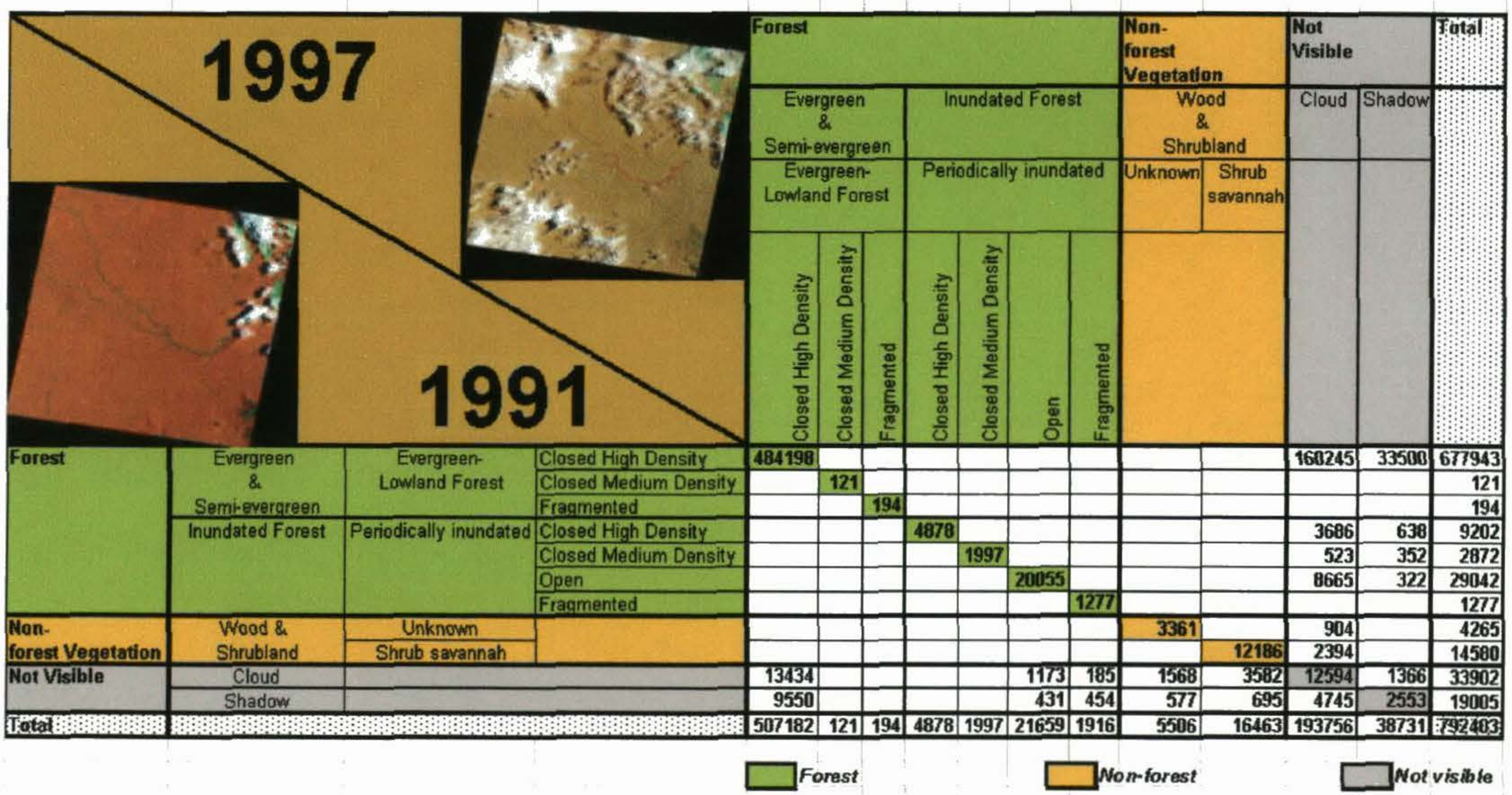
Land use change for 1991 and 1997 images

Río Apaporis (Path 007, Row 059; col_ciat_rap_chg.xls)
Images: **007059910401Q4geo.lan 007059970908Q4geo.lan**

No. Polygons	Code 91	Code 97	Total Area
23	111A	111A	484198
37	111A	81	160245
40	111A	82	33500
1	111B	111B	121
2	111D	111D	194
11	131A	131A	4878
11	131A	81	3686
4	131A	82	638
2	131B	131B	1997
1	131B	81	523
1	131B	82	352
5	131C	131C	20055
6	131C	81	8665
1	131C	82	322
1	131D	131D	1277
15	310	310	3361
7	310	81	904
14	313	313	12186
8	313	81	2394
15	81	111A	13434
1	81	131C	1173
1	81	131D	185
8	81	310	1568
20	81	313	3582
13	81	81	12594
10	81	82	1366
18	82	111A	9550
1	82	131C	431
2	82	131D	454
5	82	310	577
9	82	313	695
10	82	81	4745
7	82	82	2553

Land use change matrix

Río Apaporis (Path 007, Row 059; col_ciat_rap_mtx.xls)



1997 / 1991				Forest							Non-forest Vegetation		Not Visible		Total
				Evergreen & Semi-evergreen			Inundated Forest				Wood & Shrubland		Cloud	Shadow	
				Evergreen-Lowland Forest			Periodically inundated				Unknown	Shrub savannah			
				Closed High Density	Closed Medium Density	Fragmented	Closed High Density	Closed Medium Density	Open	Fragmented					
Forest	Evergreen & Semi-evergreen	Evergreen-Lowland Forest	Closed High Density	484198									160245	33500	677943
			Closed Medium Density		121										121
			Fragmented			194									194
	Inundated Forest	Periodically inundated	Closed High Density				4878						3686	638	9202
			Closed Medium Density					1997					523	352	2872
			Open						20055				8665	322	29042
			Fragmented							1277					1277
Non-forest Vegetation	Wood & Shrubland	Unknown									3361		904		4265
		Shrub savannah										12186	2394		14580
Not Visible	Cloud			13434					1173	185	1568	3582	12594	1366	33902
	Shadow			9550					431	454	577	695	4745	2553	19005
Total				507182	121	194	4878	1997	21659	1916	5506	16463	193756	38731	792403

🟩 *Forest* 🟧 *Non-forest* ⬜ *Not visible*

Annex 4

Land use interpretation key

The TREES project classification key was obtained from the first TREES II project proposal, modified during the TREES project workshop in Caracas, Venezuela (February-March 99), and finalised according to the recommendations of TREES advisor, Otto Huber.

During the Caracas workshop, the suitability of a TREES table codes proposal for describing real land use/land cover in the different Latin American countries (LAC) was discussed. The participants decided to add four classes in the 4th forest classification level (A, B, C, D), to add a "small holding" code (44) as well as "bare soil and rocks" code (54).

In July-August 99 Mr. Otto Huber visited the different institutions collaborating with the TREES project in South America to discuss and agree on the codes to be assigned to the different land-use and land-cover classes. Some important land uses/land cover appearing on the images that CIAT is processing did not have a specific code (even after the Caracas meeting). Following discussion we agreed to select existing codes to describe these ambiguous land uses/land covers instead of adding new ones. The "paramo" vegetation was assigned to code 39, the "jalca" and "puno" vegetation to 329, "shrimp farming" to 59, "deciduous forest" (129A, 129B, 129C, 129D) and snow cover to 59. The codes for "arable land for agriculture" (411 or 412) were used to describe industrial and technical high-input agriculture, such as sugar cane, cotton, pine, et cetera. Low-input, small area agriculture was assigned "small holding" code (44).

The "ranching" code (43) was used for large areas of cattle activities. This was a simple task for cases where the limits of the area were geometrical (e.g., a single large farm in the middle of the jungle). In other cases, the large area did not have geometrical boundaries, so it was impossible to tell if it corresponded to a single large farm or many small ones. We assumed that code 43 applied in these cases.

The regeneration areas ("vegetation re-growth" and "forest re-growth") are not easy to distinguish, especially because the period when the land was abandoned is unknown. In addition, the spectral response of healthy vegetation re-growth with forest re-growth is similar in some cases. We should reconsider the period of time that defines what is "vegetation re-growth "and "forest re-growth". In the tropical forest, re-growth can last 100 years until the forest structure corresponds to that of the primary forest. In theory, the succession process in the secondary forest starts at the moment the land is abandoned and ends when the tree species are totally replaced by primary forest.

The deciduous forest class should have a Level 3 code for the dry forests in the American Tropics (we used codes 129A-D, "other deciduous forests").

The classification key was translated to Spanish to ensure it could be clearly understood by our interpreters. Each translated code was checked and interpreted by Mr. Otto Huber to avoid interpretation mistakes.

Table 1. Spanish version of TREES Classification key used by CIAT

Nivel 1	**Nivel 2**	**Nivel 3**	**Nivel 4**
1 Bosque, mayor a 10% de coberturas de copas y mas del 40 % de cobertura forestal			
	1 Bosque siempre verde y semi siempre verde	0 Indefinido	A Cerrado alta densidad mas del 90% cobertura forestal
		1 Bosque siempre verde de tierras bajas (Selva Tropical)	
		2 Bosque siempre verde de montaña (Bosque montano o nublado)	B Cerrado media densidad 70-90% cobertura forestal
		3 Bosque semi siempreverde	
		4 Bosque de turba amazonica (Catinga)	C Abierto 60- 70% cobertura forestal
		5 Bosques de pinos	
		6 Bambú	D Fragmentado 40-60% cobertura forestal
		9 Otro	
	2 Bosque deciduo	0 Indefinido	
		1 Bosque seco denso (Africa)	
		2 Miombo (Africa)	
		3 Bosque seco de especies mixtas (Asia)	
		4 Bosque seco de Dipterocarpaceas (Asia)	
		9 Otro	
	3 Bosque inundado	0 Indefinido	
		1 Periodicamente inundado	
		2 Permanentemente inundado, (Bosque de pantano)	
		3 Bosque de pantano con palma (Aguajales)	
		4 Turba/Bosque (bosque de altura)	
		9 Otro	
	4 Bosque de galería (bordea los rios y esta rodeado de pasto)		
	5 Plantaciones	0 Indefinido	
		1 Teca	
		2 Pino	
		3 Eucalipto	
		9 Otro	
	6 Regeneración de bosques (más de 10 años)		
	7 Mangle		
	9 Otro		
2. Mosaico, entre un 10 y 40 % de cobertura forestal			
	1 Cultivos migratorios	0 Indefinido	
		1 Hasta 1/3 del area cultivada	
		2 Mas de 1/3 del area cultivada	
	2 Tierras agrícolas y bosques (pastos+cultivos+bosques)		
	3 Otra vegetación y bosque (regeneración y bosque)		
	9 Otro		
3. No bosque, menos del 10 % de cobertura de copas y menos del 10 % de cobertura forestal			
	1 Arboles y matorrales	0 Indefinido	
		1 Sabana con matorrales	
		2 Sabana arbolada	
		3 Sabana arbustiva	
		4 Bambu	
		5 Sabana inundada	
		6 sabana húmeda siempreverde (Asia)	
		7 Sabana seca (Asia)	
		9 Otro	
	2 Pradera	0 Indefinido	
		1 Pradera seca	
		2 Pradera inundadas (Pantanal)	
		9 Otro (Jalca, Puno)	
	3 Regeneración de vegetacion (menos a 10 años)		
	9 Otro (Páramos)		
4. Agricultura, menos del 10 % de cobertura de copas y menos del 10 % de cobertura forestal			
	1 Tierras arables (cultivos a gran escala)	0 Indefinido	
		1 Con riego artificial	
		2 Con riego natural (lluvia)	
	2 Plantaciones comerciales	0 Indefinido	
		2 Caucho	
		3 Palma africana (Palma aceitera)	
		3 Café, cacao, coca	
		9 Otro	
	3 Grandes fincas ganaderas		
	4 Pequeñas fincas		
	9 Otro		
5. No vegetación			
	1 Urbano (pueblo, ciudad)		
	2 Carreteras y caminos		
	3 Infraestructura	1 Minería	
		2 Hidrolelectrica	
		9 Otro (camaroneras, etc.)	
	4 Suelo descubierto y rocas		
	9 Otro		
6. Agua			
	1 Rios		
	2 Lago, Laguna	1 Natural	
		2 Artificial	
7. Mar			
8. No visible en la imagen			
	1 Nubes		
	2 Sombras		
9. Sin Información			

Annex 5

Forest cover change in South America

		Forest Area							
		Total Forest			Natural Forest			Plantations {a}	
	Land Area (000 ha)	Extent 1990 (000 ha)	Extent 1995 (000 ha)	Average Annual % Change 1990-95	Extent 1990 (000 ha)	Extent 1995 (000 ha)	Average Annual % Change 1990-95	Extent 1990 (000 ha)	Average Annual % Change 1980-90
SOUTH AMERICA	**1,752,925**	**894,466**	**870,594**	**0.5**	**887,187**	**863,315**	**0.5**	**7,264**	**5**
Argentina	273,669	34,389	33,942	0.3	33,842	33,395	0.3	547	1
Bolivia	108,438	51,217	48,310	1.2	51,189	48,282	1.2	28	4
Brazil	845,651	563,911	551,139	0.5	559,011	546,239	0.5	4,900	5
Chile	74,880	8,038	7,892	0.4	7,023	6,877	0.4	1,015	8
Colombia	103,870	54,299	52,988	0.5	54,173	52,862	0.5	126	12
Ecuador	27,684	12,082	11,137	1.6	12,037	11,092	1.6	45	4
Guyana	19,685	18,620	18,577	0.0	18,612	18,569	0.0	8	29
Paraguay	39,730	13,160	11,527	2.6	13,151	11,518	2.7	9	15
Peru	128,000	68,646	67,562	0.3	68,462	67,378	0.3	184	7
Suriname	15,600	14,782	14,721	0.1	14,774	14,713	0.1	8	4
Uruguay	17,481	816	814	0.0	660	658	0.1	156	1
Venezuela	88,205	46,512	43,995	1.1	46,259	43,742	1.1	253	11

Source: WRI-UNEP-UNDP-World Bank

REFERENCES

Adger, W.N. and Brown K. 1994. Land use and the causes of global warming. John Wiley, UK. 271 p.

Acevedo L, E. 1976. Colombia, trayectoria de un Pueblo. ARCO. Bogota, Colombia.

Frohn, R.C. 1998. Remote sensing for landscape ecology. New metric indicators for monitoring. Modeling and assessment of ecosystems. CRC Press, Boca Raton, FL. 99 p.

Hiroaka, M. and Yamamoto S. 1980. Agricultural development in the upper Amazon of Ecuador. Geographical Review. p. 431.

IGAC (Instituto Geográfico Agustín Codazzi). 1983. Mapa de bosques. Instituto Geográfico Agustín Codazzi. Bogotá, Colombia. escala 1:500000. Plancha N° 5-19.

IGAC (Instituto Geográfico Agustín Codazzi). 1987. Mapa de uso actual de la tierra. Instituto Geográfico Agustín Codazzi. Bogotá, Colombia. escala 1:500000. Plancha N° 5-19

IGAC (Instituto Geográfico Agustín Codazzi). 1999. Paisajes fisiográficos de la Orinoquía-Amazonía (ORAM) Colombia. Análisis Geográficos N° 27-28, IGAC, Colombia. 361 p.

JRC. 1997. Identification of deforestation hot spot areas in the humid tropics. TREES (Tropical Ecosystem Environment Observations by Satellites), Joint Research Centre, European Commission. Synthesis of expert consultation meeting, Ispra, Italy, 24-25 November 1997. TREES Publications Series B. Research Report n° 4. 99 p.

del Llano, M. 1997. Las cavernas: clasificación ecológica de sus obscuros ecosistema. Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales, 21:91-95.

Martin, M.A. 1990. Gran Vaupés. In: Colombia ¡que linda eres!, Orinoquía y Amazonía. Ed: Camacho, J, Educar Cultural Recreativa S.A. Bogotá, Colombia. p. 1041-1060.

Myers, N. 1984. The primary Source: tropical forests and our future. Norton, NY. 150 p.

Navas A., J. 1982. Considerations on the Colombian Amazon region. In: Amazonia, agriculture and land use research. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 41-59.

Ortiz, S. 1984. Colonization in the Colombian Amazon. In: Marianne, S. and Wood, C. (eds.) Frontier expansion in Amazonia. 206 p.

Rudel, T.K. 1993. Tropical deforestation. Small farmers and land clearing in the Ecuadorian Amazon. Columbia University Press, NY.

Sorzano E.L.G. 1988. Constitución del Resguardo Indígena Yaigojé - Río Apaporis. Resolución Nº 035. Instituto Colombiano de Reforma Agraria, Bogotá, Colombia.

Stearman, A.M. 1985. Camba and kolla: migration and development in Santa Cruz, Bolivia. University of Central Florida Press, Orlando, FL. 158 p.

Utting, P. 1993. Trees, people and power. Social dimensions of deforestation and forest protection in Central America. Earthscan Publications Ltd., London. p. 14.

Yanine, D.; Barbosa, C.; Cardona, M.C.; Gónzalez, Y.; Pinto, J.; Cuellar, M.; Castañeda M., J.; Gutiérrez Rey, H.; Barrera, C.R. and Alarcón J.C. 1998. Los ecosistemas. En: El medio ambiente en Colombia. Instituto de Hidrología, Metereología y Estudios Ambientales (IDEAM), Ministerio del Medio Ambiente. Bogota, Colombia. p. 227-274.

WRI-UNEP-UNDP-World Bank (World Resources Institute- United Nations Environment Programme-United Nations Development Programme-World Bank). 1998. World Resources, 1998-99. WRI-UNEP-UNDP-World Bank, NY. p. 291-302.