CIAT

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Nanay river – Peru

(Path 007, Row 062, Quarter 3)

Joint Research Centre (JRC)

and

CIAT

Technical Report

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TABLE OF CONTENTS

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. There is evidence of accelerated deforestation in a large number of locations scattered over virtually all South America, but principally in the Colombian, Ecuadorian and Peruvian Andes and the western part of the Amazon region (JRC, 1997).

The objective 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 Amazon region of Peru, near Iquitos. The Instituto de Investigación de la Amazonía Peruana (IIAP) was responsible of the interpretation and analysis of 4 scenes covering the Peruvian Amazon and part of the surrounding mountain areas (see Figure 1). CIAT has put the final touches to the coverages and final reports.

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. It is however highly variable between countries, from 0% (Guyana and Uruguay) to 2.6% (Paraguay). Statistics for South America's forests in the period 1990-1995 are given in annex 5.

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 corridors 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 organizations 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).

Deforestation in the TREES study area covered by IIAP.

The study area, with an estimated surface of 8 437 647 hectares, is located mostly in the central area of Peru, extending from high Andean areas to the Amazon plain, including natural mountain regions (agricultural land [*quechua*], paramo [*puna*] and scrub [*suni*]) and forest (low forest, high forest and dry low forest [*yunga*]). Politically, it covers a large part of the departments of Huánuco and Pasco and a sector of the departments of Ucayali, San Martin and Loreto. It is located approximately between 3° to 11° S and 74° to 77° W.

The relief varies from predominantly flat areas in the low forest (from 150 to 500 m) to highly rugged areas in the high forest and high Andean areas (from 500 to over 4000 m). According to the Holdridge bioclimatic classification system, the area under study includes a diversity of life zones varying from rainforest at lower levels to wet paramo at sub-Andean level. The vegetation varies from humid forest in the lower areas, to subhumid and humid brush in the intermediate areas, to steppe and puna grass in the high Andean areas.

Overall, four physical characteristics play an important part in conditioning social, economic and especially agricultural activity, which is the main cause of changes in forest cover in the study area:

1. An altitudinal gradient, which influences climatic conditions and the type of vegetation.
2. A highly heterogeneous morphology: the mountain range with deep valleys, the forest margins with long narrow valleys and the low forest of relatively flat relief with different degrees of drainage that condition land occupation and use.
3. A system of higher mountain ranges of up to 5000 metres that constitutes a natural barrier for human activities.
4. A pedological variability, influenced by parental material, relief, vegetation, climate and time, which determines soils of better natural fertility in the Andean areas and in the valleys, and soils of lesser fertility in compact ground especially in forest.

This geographical space has a population of about 1 323 496 distributed in areas adjacent to the road axes, with the city of Pucallpa and towns of Aguaytía, Tingo María, Tocache, Huánuco, Cerro de Pasco and Oxapampa prominent, connecting up a rural population

mainly located in the diverse valleys. In the case of the Nanay River area, the population is very scant and is connected with the town of Iquitos by means of the waterway.

The most relevant economic activities are related to natural resources, prominently mining in the high Andean areas, accompanied by small-scale commercial agriculture aimed at the Lima market, and migratory agriculture and forest exploitation in the forest area. In this last area, coca cultivation shows the most dynamism, its rate related to the demand of the international market for the basic paste and to the efficiency of policies for controlling the illicit traffic of this drug.

The forest covering expresses the characteristics of the biophysical environment, while actual land use in the study area reflects the dynamics of agricultural activity, conditioned by environmental factors.

The deforestation pattern is massive or mosaic in places of greater population density. In some places where physical obstacles exist, or where the population is very scant, the deforestation pattern is lineal. However, in both cases the deforested units are very small, where land under cultivation alternates with land in fallow.

The changes in forest cover in the study area are mainly caused by the agricultural activity of both local and migrant populations. Only a few enterprises are recorded, such as those related to palm oil in Tocache, cattle farming in Pucallpa, and coffee in Oxapampa, which become agents of deforestation in some specific sites, but do not signify big surfaces.

STUDY AREA: NANAY RIVER

The Nanay River study area is located to the north-west of the town of Iquitos and includes both areas of low and high terraces and ridges and hills, located in the high reaches of the Nanay River, as well as in a tract of the middle part of the Tigre River. It belongs to the life zones of tropical moist forest, tropical wet forest and tropical premontane wet forest; the predominant vegetation is tropical forest. The total area covered is 1076327 ha.

This area is a weakly linked with the town of Iquitos through the river system.

The population is scant, estimated at 5450 inhabitants (1996), with an average density of 0.3 inhabitants per square kilometre, and registers a negative growth rate of -1.2% between 1981 - 93.

Most of the population is rural (78%), in the category of poor to very poor. The urban population concentrates on small populated centres, such as Intuto on the Tigre River. The landscape corresponds to forest with little intervention by subsistence agriculture. However, this forest has been lightly exploited for forestry activity, basically by loggers from Iquitos.

Materials

For this work we used the full scene of two Landsat TM images (path 007, row 062: 0070628920918Q3geo.lan, 007062971010Q3geo.lan). The radiometric quality of the image data was good, although both images presented important cloud cover over all area, as big clouds and small ones (with respective shading).

Land use was interpreted based on quick field surveys to collect GPS coordinates, photographs and videotapes. A reference forest map at a 1:1 000 000 scale (MAG-INRENA, 1995), a landuse capacity map at a 1:1 000 000 scale (ONERN, 1981) and an ecological map at a 1:1 000 000 scale (INRENA, 1995) were also used.

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 ERDAS Imagine version 8.2. 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 Instituto Geográfico Nacional (IGN) of Peru produced the topographical maps to a scale of 1:100 000 that were used for georeferencing. Annex 1 refers about the maps used for georeferencing, root mean square (RMS) error for both processes as well as parameters and other georeferencing information.

Figures 2 and 3, in Annex 2, give an overview of the study area in both images after the georeferencing process.

Land uses and land cover digitising

Boundaries of Land use and land cover areas were digitised (as lines) and coded (as points) on printed images backed by on-screen visualisation over the TM 4-5-3 color composite, displayed at 1:100 000 scale, of the earlier date image. This process was completed using Arcview 3.1 software with the minimum mapping unit of 50 ha; 300 m width for linear features. 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 one, then 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 the use of 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 codes errors and inconsistencies, as well as remaining digitising errors, were corrected on the intersection coverage. For example, we could find polygons that went from young regeneration to primary forest, which is impossible in a period of 4 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. To comply with the contract requirements, the coverages for the total area covered by each image were obtained by merging (compatibilising codes and borders) the ones produced by DISSOLVE with the original ones (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

Based on results from the analysis of the satellite images, in 1997, 88% of the total area covered by the studied image (1 076 327 hectares) were covered by natural forest, with little human intervention (deforestation) and only less than 1% corresponded to areas where migratory agriculture predominated, the remaining area being water bodies (1.3%).

During the period 1992-1997, subsistence agriculture deforested 19467 hectares, of which 1.95% were of periodically flooded forest, and 0.27% of permanent flooded forest and evergreen lowland forest. The average annual rate of intervention was very low

(<0.1% of the Rio Nanay study area, 0.05% of the forest area) if is compared with WRI-UNEP-UNDP-World Bank (1998) deforestation rate to Peru of 0.3%. The deforestation pattern is mostly lineal. In agriculture, plantain, cassava and rice predominate on a small scale.

The causes of deforestation are related to migratory agriculture. The most significant causal agents are the native and mestizo population.

CONCLUSION

This conclusion addresses the results obtained for the 4 scenes processed by IIAP. The values for intervened areas are given for each of the departments covered by the satellite imagery, which can be compared to values obtained from independent studies (see Figure 1). Note that % figures by department are computed with respect to the area of the imagery overlapping departments, not with respect to the forest area, so these figures cannot be exactly compared to other deforestation figures. In general terms, during the study period (1989 -1998), the annual average of intervened area is reported as 21 504.54 hectares (deforested area including forest remnants within the farmers' plots), which represents an annual average rate of intervention of 0.3%. This rate varies according to area, being relatively higher in Pucallpa (0.6%), Aguaytia (0.5%), Oxapampa (0.7%) and Huánuco (0.5%), while Nanay (<0.1%) and Cerro de Pasco (0.1%) have a much lower rate. The areas of Tocache (0.29%) and Tingo María show intermediate rates.

These indicators are less than those reported for the areas of Pucallpa and Aguaytia, during the period 1974 -1981 with an annual average rate of intervention of 1.1% and 1981-1989 with 1.2% (Rodriguez 1996). However, the tendency in the decrease of the rate of intervention reported for this same area during the period 1989 - 1995 (0.5%) is maintained during the period of analysis of the present study (1989 - 1998). The inflection point, at which the intervention rate begins to decrease, is in 1989. This can be explained, in general terms, by radical changes in national policies starting at this time.

On this point, it must be emphasised that during this period a policy of support and subsidies changed to an economic policy of free market; state administration changed to individual administration; and an exporting country to a country importing products of basic consumption. The diverse programs of structural adjustment (from 1980 to 1994) in the national economy had negative effects on agricultural development: suppression of state companies for buying and selling of products and inputs, disactivation of the Agrarian Bank in 1992, minimisation of extension services and agrarian research, exchange and tariff policies favourable to imports, decrease in economic level and internal demand, elimination of subsidies, liberalisation of markets, et cetera.

Also intervening in this decreasing tendency is the impact of the policy of control and eradication of coca. According to USAID (1997) reports, during the period 1990 – 1997 the

cultivated area of coca leaf in the Amazon significantly decreased from 121 300 to 69 000 hectares because of operations to eradicate plantations and nurseries of coca and because of the interdiction of the Illicit Traffic of Drugs. Another factor that has impacted on the decreasing area planted to coca has been the fall in price per kilogram of coca leaf, in 1991 registered at US$1.73 and in 1997 falling to US$0.61. USAID identified areas of greater coca production in Tingo María, Aguyatía and Tocache, within the study area.

Nanay's scant population and Cerro de Pasco's limited area of forest and difficult accessibility explain their low intervention rates. In Tocache and Tingo María, which constitute one of the last havens of terrorism and drug trafficking, a decrease has been reported during the period of analysis, explaining in part the moderate levels of intervention rate.

The main forces determining deforestation are related with subsistence economy, public policies, the international market for illicit consumption of coca and the Andean population's migratory processes. However, the intensity and direction of these forces have been conditioned by physical limitations, accessibility, terrorism and drug trafficking. On this last aspect, the area under study during the period of analysis has been the main scenario of subversive activities of *the Sendero Luminoso* and *the Movimiento Revolucionario Tupac Amaru* (MRTA) in the country, generating in some areas of the high forest the escalation of illegal cultivation of coca and in others, migration from the countryside to the town.

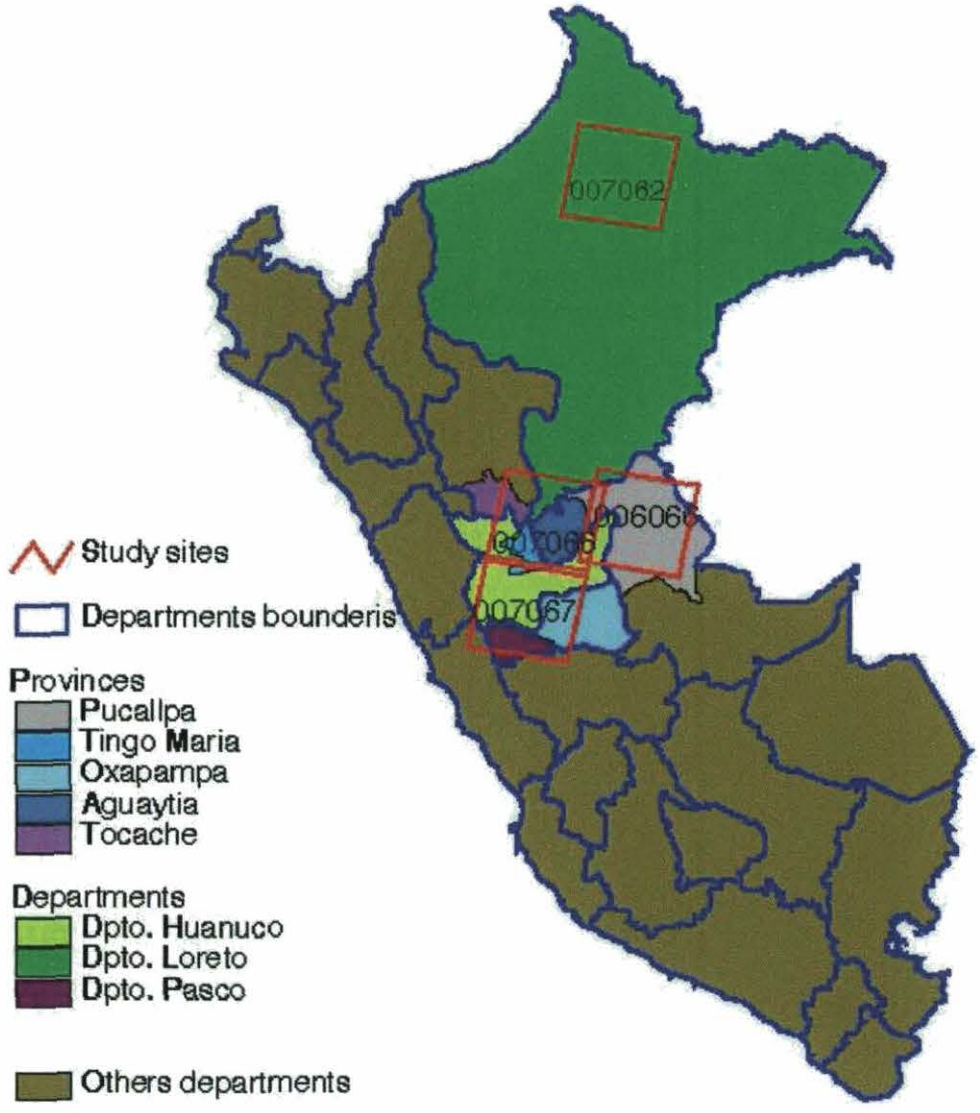

Figure 1: Provinces and Departments of Peru covered by the satellite images.

TABLE 1: INDICATORS RELATED TO LAND USE WITH RESPECT TO ADMINISTRATIVE AREA.

IMAGE	AREA	NATURAL REGION	RELIEF	VEGETATION	PATTERN OF DEFOREST.	CAUSES	CAUSAL AGENTS	FORCES DETERMINING DEFORESTATION	RATE OF DEFOREST.	FRONTS OF DEFOREST.
6-66 (SI)	PUCALLPA	Lowland forest	Flat	Humid forest	Massive and lineal	Cattle farming, migratory agriculture	Contractors, local and migrant populations	Trade, subsistence farming	Medium	
7-66 (image)	AGUAYTIA	Lowland forest and dry lowland forest	Flat and mountainous	Humid forest	Mosaic and lineal	Migratory agriculture, coca	Local and migrant populations	Illegal traffic of coca, subsistence farming	Medium	Padre Abad Province
	TINGO MARÍA	Montane forest and dry lowland forest	Flat and mountainous	Humid forest	Massive and lineal	Migratory agriculture, coca	Local and migrant populations	Illegal traffic of coca, subsistence farming	Low	
	TOCACHE	Montane and lowland forest	Flat and mountainous	Humid forest	Mosaic and massive	Migratory agriculture, palm oil, coca	Local and migrant populations, contractors	Illegal traffic of coca, industry, subsistence farming	Low	Tocache Province
	HUANUCO	Dry lowland forest, agricultural land and paramo	Flat and mountainous	Subhumid and humid brush	Mosaic, massive and lineal	Agriculture, coca	Local population	Illegal traffic of coca, subsistence farming	Medium	Provinces of Puerto Inca and Pachitea, Tomay Kichwa District
7-67 (image)	CERRO PASCO	Paramo, scrub and agricultural land	Mountainous	Steppe and puna grass	Lineal	Agriculture	Local population	Subsistence farming, trade	Very low	San Francisco of Asisi District
	OXAPAMPA	Montane forest and dry lowland forest	Flat and mountainous	Humid forest and steppe	Massive and lineal	Agriculture, cattle farming, coffee, coca	Local and migrant populations, companies	Illegal traffic of coca, trade, subsistence farming	Medium	Pozuzo District
7-62 (image)	NANAY	Lowland forest	Flat	Humid forest	Lineal	Migratory agriculture	Local population	Subsistence farming	Very low	

Annex 1

Geocoded image information

Nanay (Path 007, Row 062, Quarter 3)

Maps Used for Georeferencing

IGN. 1990. Topographic map, Scale 1: 100 000. . Instituto Geográfico Nacional (Peru), Defense Mapping Agency (USA).

IGN. 1987. Topographic map, Scale 1: 100 000. . Instituto Geográfico Nacional, Lima, Peru.

Geocoded image information

Landsat TM image, Full scene
Path 007 Row 062
Date 18/09/92
Image Name: **007062920918fsgeo.lan**

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

Number of columns	4301
Number of lines	4101

Reference projection	UTM 18 S WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	443020	9710024	75.5125 W	2.6234 S
Lower right corner	572020	9587024	74.3514 W	3.7360 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	0.3
Number of GCP	10

Geocoded image information

Landsat TM image, Full scene
Path 007 Row 062
Date 10/10/97
Image Name: **007062971010Q3geo.lan**

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

Number of columns	4000
Number of lines	3989

Reference projection	UTM 18 S WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	446405	9706514	75.4667 W	2.6551 S
Lower right corner	566375	9586874	74.4023 W	3.7333 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	0.99
Number of GCP	10

Annex 2

False color composites

Nanay (Path 007, Row 062, Quarter 3)

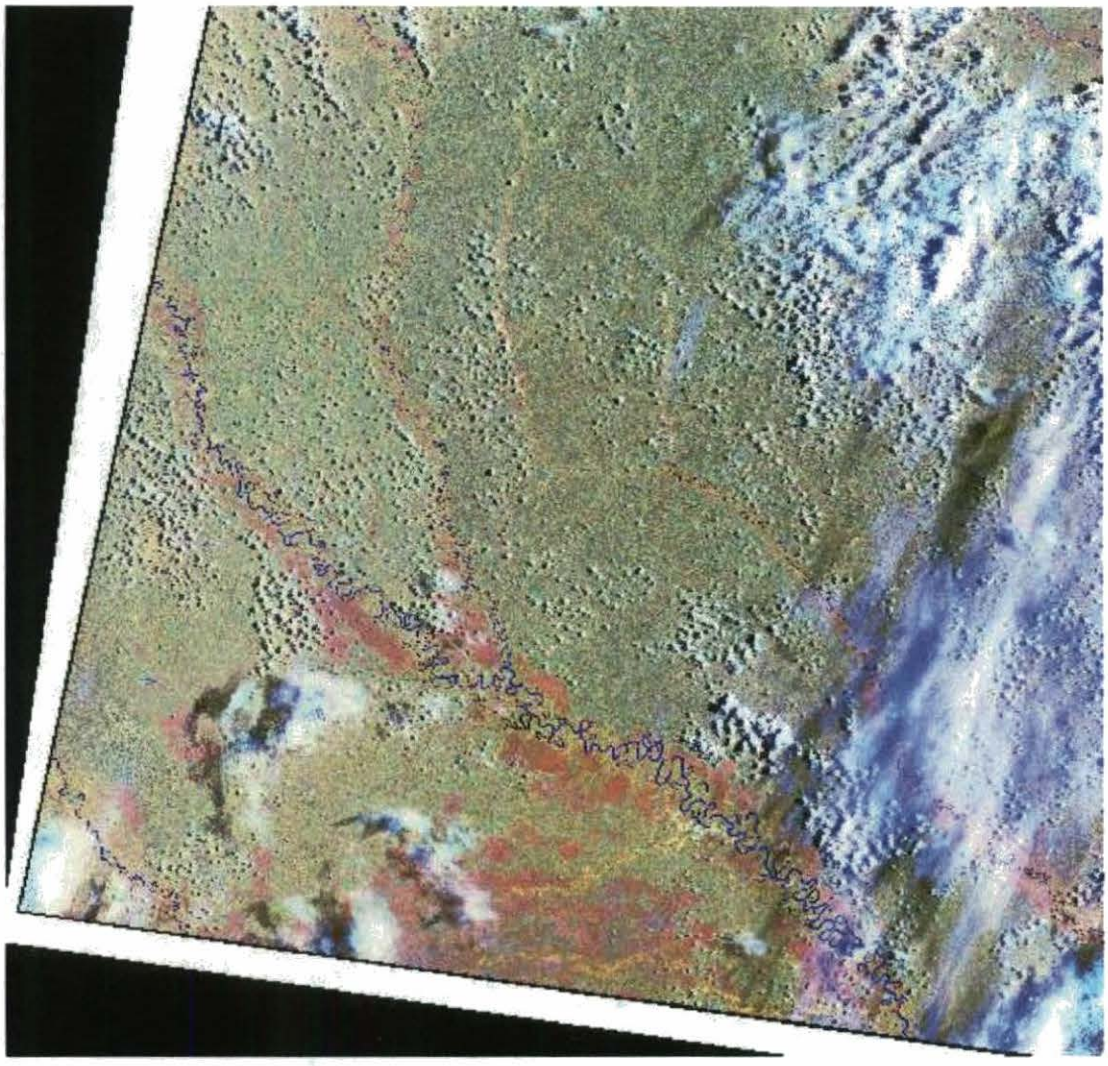

Figure 2. Landsat TM satellite image, bands 4, 5, 3, path 007, row 062, quarter 3, date 18-09-92. Upper left corner 75.5125 W, 2.6234 S, Lower right corner 74.3514 W, 3.7360 S.

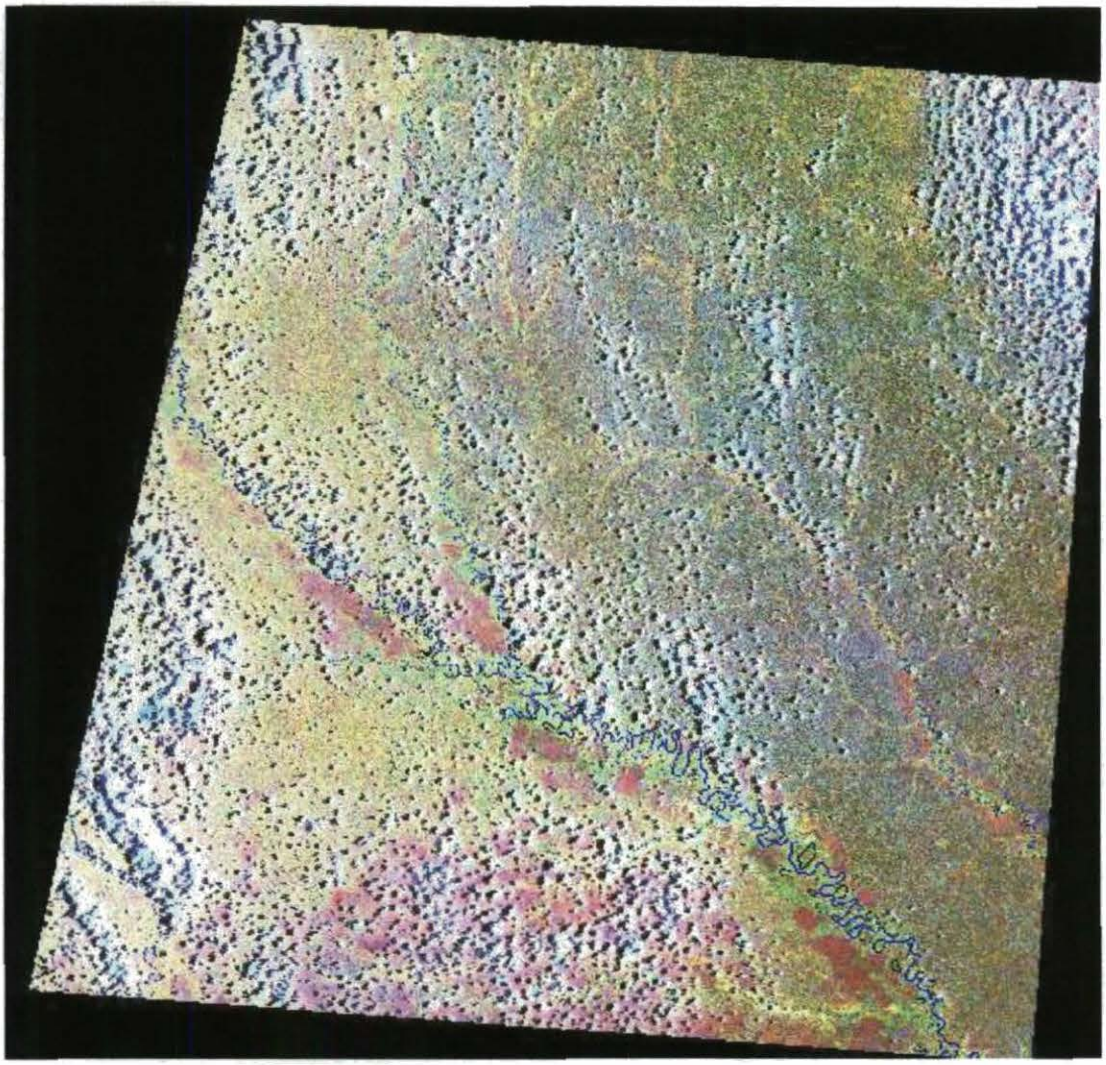

Figure 3. Landsat TM satellite image, bands 4, 5, 3, path 007, row 062, quarter 3, date 10-10-97. Upper left corner 75.4667 W, 2.6551 S, Lower right corner 74.4023 W, 3.7333 S.

Annex 3

Land use / Land cover change
(Overlap area)

Nanay (Path 007, Row 062, Quarter 3)

Land use / Land cover present in 1992 image

Nanay (Path 007, Row 062; per_ciat_nan_92_ cds.xls)

Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111C	Open 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
133A	Closed High Density Swamp Forest with Palms
133B	Closed Medium Density Swamp Forest with Palms
133C	Open Swamp Forest with Palms
133D	Fragmented Swamp Forest with Palms
211	Mosaic of Shifting Cultivation & forest with less than 1/3 cropping
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
539	Other Infrastructure
61	River
621	Natural Lake
81	Cloud
82	Shadow

Land use / Land cover present in 1997 image

Nanay (Path 007, Row 062; per_ciat_nan_97_ cds.xls)

Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111C	Open 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
133A	Closed High Density Swamp Forest with Palms
133B	Closed Medium Density Swamp Forest with Palms
133C	Open Swamp Forest with Palms
133D	Fragmented Swamp Forest with Palms
211	Mosaic of Shifting Cultivation & forest with less than 1/3 cropping
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
539	Other Infrastructure
61	River
621	Natural Lake
81	Cloud
82	Shadow

Statistics for 1992 image

Nanay (Path 007, Row 062; per_ciat_nan_92_sts.xls)

Code 92	No. Polygons	Total Area	Mean Area	S. D. Area
111A	42	597310	14222	46382
111B	16	36603	2288	5581
111C	2	2067	1033	387
131A	11	3157	287	407
131B	86	81045	942	2349
131C	7	5014	716	1182
131D	1	159	159	0
133A	50	62453	1249	4891
133B	52	9287	179	237
133C	18	8471	471	881
133D	9	5929	659	975
211	3	352	117	143
212	12	2618	218	387
539	1	55	55	0
61	16	7691	481	522
621	37	2008	54	30
81	268	159371	595	4316
82	283	92736	328	1630

Statistics for 1997 image

Nanay (Path 007, Row 062; per_ciat_nan_97_sts.xls)

Code 97	No. Polygons	Total Area	Mean Area	S. D. Area
111A	45	693758	15417	63495
111B	24	34765	1449	2602
111C	2	1351	675	12
111D	1	343	343	0
131A	11	1974	179	152
131B	101	99844	989	2034
131C	3	4529	1510	1565
133A	67	62163	928	3174
133B	65	9669	149	205
133C	16	7711	482	947
133D	9	5575	619	936
211	5	673	135	107
212	19	4391	231	321
539	1	55	55	0
61	14	8429	602	898
621	42	2405	57	32
81	718	88241	123	433
82	768	50451	66	56

Land use change for 1992 and 1997 images

Nanay (Path 007, Row 062; per_ciat_nan_chg.xls)
Images: 007062920918fsgeo.lan 007062971010Q3geo.lan

No. Polygons	Code 92	Code 97	Total Area
70	111A	111A	536680
2	111A	111B	76
2	111A	211	240
421	111A	81	37570
401	111A	82	22744
25	111B	111B	25502
1	111B	212	42
35	111B	81	7640
44	111B	82	3420
2	111C	111C	1254
6	111C	81	617
4	111C	82	196
11	131A	131A	1974
1	131A	212	833
4	131A	81	185
4	131A	82	165
104	131B	131B	76589
2	131B	211	255
1	131B	212	333
29	131B	81	1990
36	131B	82	1879
2	131C	131B	394
5	131C	131C	4321
1	131C	211	26
1	131C	212	26
4	131C	81	160
2	131C	82	88
1	131D	212	159
59	133A	133A	47479
2	133A	133B	204
3	133A	133C	118
1	133A	133D	101
96	133A	81	9080
90	133A	82	5472
55	133B	133B	6821
19	133B	81	1631
7	133B	82	834
1	133C	133A	113
16	133C	133C	7391
1	133C	133D	43
1	133C	212	32
13	133C	81	643
6	133C	82	248

No. Polygons	Code 92	Code 97	Total Area
1	133D	133B	212
9	133D	133D	5314
1	133D	211	71
1	133D	212	83
2	133D	81	113
2	133D	82	136
1	211	211	38
2	211	212	314
13	212	212	2122
4	212	81	398
2	212	82	97
1	539	539	55
16	61	61	7691
37	621	621	2008
282	81	111A	97978
14	81	111B	5387
1	81	111C	47
1	81	111D	27
53	81	131B	15623
3	81	131C	106
20	81	133A	9774
9	81	133B	751
3	81	212	329
1	81	61	493
2	81	621	143
141	81	81	18856
153	81	82	9857
275	82	111A	59101
12	82	111B	3801
1	82	111C	50
1	82	111D	316
37	82	131B	7239
3	82	131C	101
17	82	133A	4797
6	82	133B	1682
2	82	133C	201
2	82	133D	117
1	82	211	43
1	82	212	117
1	82	61	245
3	82	621	254
109	82	81	9358
85	82	82	5315

Land use change matrix

Nanay (Path 007, Row 062; per_ciat_nan_mtx.xls)

1997 \ 1992				Forest											Mosaic		Non-Vegetated	Water		Not Visible		Total
				Evergreen & Semi-evergreen				Inundated Forest							Shifting Cultivation		Infrastructure	River	Lake	Cloud	Shadow	
				Evergreen-Lowland Forest				Periodically inundated			Swamp forest with palms				less than 1/3 cropping	more than 1/3 cropping	Other		Natural			
				Closed High Density	Closed Medium Density	Open	Fragmented	Closed High Density	Closed Medium Density	Open	Closed High Density	Closed Medium Density	Open	Fragmented								
Forest	Evergreen & Semi-evergreen	Evergreen-Lowland Forest	Closed High Density	536680	76										240					37570	22744	597310
			Closed Medium Density		25502											42				7640	3420	36604
			Open			1254														617	196	2067
	Inundated Forest	Periodically inundated	Closed High Density					1974								833				185	165	3157
			Closed Medium Density						76589						255	333				1990	1879	81046
			Open						394	4321					26	26				160	88	5015
			Fragmented													159						159
		Swamp forest with palms	Closed High Density								47479	204	118	101						9080	5472	62454
			Closed Medium Density									6821								1631	834	9286
			Open								113		7391	43		32				643	248	8470
			Fragmented									212		5314	71	83				113	136	5929
Mosaic	Shifting Cultivation	less than 1/3 cropping													38	314						352
		more than 1/3 cropping														2122				398	97	2617
Non-Vegetated	Infrastructure	Other															55					55
Water	River																	7691				7691
	Lake	Natural																	2008			2008
Not Visible	Cloud			97978	5387	47	27		15623	106	9774	751				329		493	143	18856	9857	159371
	Shadow			59101	3801	50	316		7239	101	4797	1682	201	117	43	117		245	254	9358	5315	92737
Total				693759	34766	1351	343	1974	99845	4528	62163	9670	7710	5575	673	4390	55	8429	2405	88241	50451	1076328

Forest | Mosaic | Non-vegetated | Not visible

Forest changes | Other changes | Water

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 finalized according to the recommendations of TREES advisor Otto Huber.

During the Caracas workshop the suitability of 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 (TREES advisor) visited the different institutions collaborating with 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-use/land-cover appearing on the images that CIAT is processing did not have a specific code (even after the Caracas meeting). After discussion we agreed to select existing codes to describe these ambiguous land-use/land-cover instead of adding new ones. The "Páramo" vegetation was assigned to code 39, the "Jalca" and "Puno" vegetation to 329, the "shrimp farming" to 59, the "deciduous forest" (129A, 129B, 129C, 129D), the snow cover to 59. The codes for "arable land for agriculture" (411 or 412) were used to describe industrial and technical high-input agriculture, like sugar cane, cotton, pine, etc. Low-input, small area agriculture was assigned "small holding" code (44).

The "ranching" code (43) was used for areas of cattle activities over a large area. 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 big area did not have geometrical boundaries, so it was impossible to tell if it corresponded to one large farm or to 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 trees species are totally replaced by primary forest.

The deciduous forest class should 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

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