CIAT

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Bagua – Peru

(Path 009, Row 064, Full Scene)

Joint Research Centre (JRC)

and

CIAT

Technical Report

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TECHNICAL REPORT

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IMAGE DATE 111189, 190997 AND 151097

December, 1999

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 Peruvian Central Andes.

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).

THE ANDES

The Andes is the longest of all mountain ranges. It is over 4500 miles long, stretching along the entire western coast of South America. In several places, this mountain range rises to over 6000 m, the highest mountain being Aconcagua in Argentina at 6960 m. The tropical regions of the Andes reach heights of 5007 m in Venezuela, 5775 m in Colombia, 6310 m in Ecuador and 6768 m in Peru. These high mountains form a barrier of great importance to circulation of air masses, resulting in extreme changes in climate conditions over short distances. Two characteristics of the Andes are:

1) Abrupt changes in altitude giving ecozones ranging from rainy forest to desert at the lowest to snow and ice at the highest extreme (Gastó, 1993).

2) Compensation of the latitudinal increment by the altitudinal increment generated continuous ecozones of simultaneous latitudinal - altitudinal gradients (Czaijka, 1968).

Clouds are observed frequently and constantly in the Andes and are an important factor in determining the distribution of several types of vegetation. In the tropical regions on both sides of the Andes, associated with the mantles of clouds, forest has developed with 1500-2500 m as its lower limit and 2400-3300 m as its upper limit (Stadmüller, 1987).

"The arboreal vegetation often forms the superior limit of the tropical montane forest or it covers the summits and hills of isolated mountains. The trees of this vegetation are characterised generally by their low stature, their trunks twisted with profuse ramifications, and by a great quantity of epiphytes, especially mosses that could cover trunks, branches and the surface of the floor completely" (Stadtmüller, 1987).

HIGHLANDS IN PERU

Production

"The highlands (Andes) in Peru are generally considered to consist of two parallel ranges, the Cordillera Occidental and the Cordillera Oriental, extending in a north-west to south-east direction" (Brawer, 1991). Both ranges have peaks rising to over 6000 metres and are not continuous. Between the ranges are basins and valleys forming the inter-mount high-level surface where historically most of Peru's population has been concentrated (Brawer, 1991; Torres, 1993).

"Only the lower basins and valleys of the high level surface are climatically within the zone suitable for agriculture. The altitude of most of this surface is outside the limit of cultivation or is marginal for some crops" (Brawer, 1991) even so, 78% of the agriculture is concentrated here (Torres, 1993).

The marked changes in altitude in the Andes establish strong gradients of temperature and humidity that permit different crops to be grown depending on the soil type and weather conditions (Tapia, 1986; Altieri, 1996). Below 3000 m, in the river canyons, the climatic conditions are arid; above this height, the rains increase from 300 mm to 1000 mm and up to 4500 m. This zone holds most of the cultivated land (Altieri, 1996).

Several agroclimatic zones can be distinguished in the Central Andes such as those used for:

- Grassland above 3800 m,
- Tuber and root crops between 3000 and 4200 m,
- Cereals between 1500 and 3000 m, and
- Tropical fruits between 500 and 1500 m.

In some Andean communities, cereals may be cultivated above 3000 m, reaching altitudes as great as 4200 m, such as in rotation with root crops and fallow (Altieri, 1996).

Cattle are a major source of income in the mountains, and goats are bred principally on the Pacific Coast. More than 80% of the cattle, 98% of the sheep and 100% of the South American camels are in the mountain ranges (Brawer, 1991; Torres, 1993). All these depend almost exclusively on the consumption of endemic grasses growing above 3800 m (Tapia, 1993; Altieri, 1996).

In Peru, 91% of farms are under 10 ha in size; in the mountain ranges, many are under 2 ha for crop growing and 20 ha for cattle (Tapia, 1993). According to the National Agricultural census in 1972, in the Peruvian mountain ranges, 45.1% of farms were under 2 ha and 31.5% were from 2 to 5 ha in size (Torres, 1993).

In the high mountains, some of the farm holdings are managed by communal village landholdings as single units, which have an average size of 1985 ha. This is divided among the entire village population of some 100 to 1000 families (Handelman, 1975).

In 1993, the population in the mountain ranges was calculated as 30% of the national total. In contrast, the population along the Pacific Coast has continued to increase, rising from 39% in 1961 to perhaps over 60% in 1993, keeping in mind the forced migrations that occurred because of the terrorism in the 1980s (Torres, 1993).

STUDY AREA

LOCATION

The study site is located in the Amazona and Cajamarca Departments in the northern part of Peru. This area has elevations from about 150 in the Amazon basin to above 4000 m in the Chachapoyas paramo. Its limits are to the south, the Cutervo National Park in Cajamarca State of Peru, to the north is the Utcubamba River and Pamacocha Lake in the Chachapoyas paramo, to the west are the Chotano and Chamaya Rivers in Cajamarca and to the east the Chachapoyas paramo. The Marañón River crosses the study area from south east to north. The total area covered is 643 836 ha.

CLIMATE AND VEGETATION

Precipitation is over 3000 mm annually in the very humid subtropical forest, about 2000 mm in the humid tropical forest and nearly 1200 mm in the dry tropical forest areas. The dry season occurs in June, July and August (Gazzo, 1982). Formations of humid and subhumid scrub are first encountered in the higher areas of the Andean cordillera between 2500 and 3400 m, with precipitation between 500 and 2000 mm. The subhumid scrub is found in the inter-Andean valleys between 2000 and 3700 m with precipitation from 220 to 1000 mm.

The paramo occurs in the higher areas of the mountains from 3200 m up to a line between 4500 to 4700 m (Cuatrecasas, 1989). The paramo is made up of bushy vegetation, grasses and low cushion- or mattress-like vegetation (Rangel Ch. et al., 1995).

PRODUCTION

The area shows intense agricultural activity, concentrating in the open countryside of Cajarmaca, with important dairy cattle production (Lajo L., 1983).

The government has three main rural settlement projects located within the study area and surrounding areas, in different places in the jungle. All three were begun in the late 1970s. The objective was to consolidate farmers and native communities on the agricultural frontier. The settlement of Jaén-San Ignacio Agricultural and Livestock Development involved 17 000 new farm families, while the Alto Marañón Rural Settlement had 3000 new families and the Alto Mayo Rural Settlement 7000 families (Gazzo, 1982).

METHODOLOGY

MATERIALS

For this work we used a full-scene Landsat TM image (009064891111FSgeo.lan) as information for the first date and two full-scene SPOT images (642362971015Xgeo.lan, 643362970919Xgeo.lan) for the second date. The Landsat TM image presents important cloud cover in the second quarter.

Land use was interpreted using, as reference, forest maps at a 1:1 000 000 scale from the Ministerio de Agricultura y Ganadería and the Instituto Nacional de Recursos Naturales (MAG-INRENA, 1995).

Annex 4 gives the interpretation key that we used for this project.

GEOCODING

The images were georeferenced to Universal Transversal of Mercator (UTM), zone 17 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 SPOT images, 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 Instituto Geográfico Nacional (IGN) of Peru. Annex 1 gives a list of maps used for georeferencing, root mean square (RMS) error for the processes as well as parameters and other georeferencing information.

Figures 1 and 2, in Annex 2, give an overview of the study area in the 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 and SPOT 3-2-1 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

On intersection area of the Landsat and SPOT images, evergreen montane forest predominates in the high parts of the mountains and dry and semi-evergreen forest in the inter-Andean valleys. The forest area showing no change between the dates represents 38.6% of the intersection not taking cloud and shadow into consideration (later referred to as overlap area). Overall the forest has not degrading annual rate, however, the evergreen montane forest has a net rate of deforestation of 0.2%, while the dry forest has –0.7%. The semi-evergreen forest recovers at an annual rate of 1.9%.

Over 53.3% of the overlap area there are no forest vegetation, agricultural practices, vegetation re-growth or the mosaic types established by TREES. The paramos vegetation cover 3% and the bodies of water 0.3%.

CONCLUSIONS

The main focuses of deforestation are in the semi-evergreen and humid evergreen montane forests where the advance of agricultural areas moves the agricultural frontier toward those high parts of the mountains as far as places of difficult access and extreme climatic conditions.

The main concentrations are located halfway up hillsides between the dry inter-Andean valleys and the humid, cold areas of the high mountains.

The deforestation is of fragmented type in the high areas and of degradation in the valleys having useful timber; the pattern is typically diffuse in almost all the overlap area. The main causes of deforestation are agricultural expansion caused by shifting cultivation and smallholdings and also selective logging.

The fire and different agricultural practices are degrading the paramos and natural montane grass land.

Annex 1

Geocoded image information

Bagua (Path 009, Row 064, Full Scene)

Maps Used for Georeferencing

IGM (Instituto Geográfico Militar). 1979. Cutervo, Hoja 13-f, Cajamarca-Perú, Topograhic map, Scale 1: 100 000, IGM, Serie J632-Edition 2, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1996. Cahuapanas, Hoja 1460(11-i), Cahuapanas-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1996. Nueva Cajamarca, Hoja 1459(12-i), Nueva Cajamarca-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1995. Río Santa Agueda, Hoja 1161(10-f), Río Santa Agueda-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1993. Barranca, Hoja 1561(10-f), Barranca-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1996. Puerto América, Hoja 1461(10-i), Puerto América-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1996. Rioja, Hoja 1458(13-i), Rioja-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1995. Jaen, Hoja 12-f, Cajamarca-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1998. Lonya Grande, Hoja 1258 (13-g), Lonya Grande-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

IGN (Instituto Geográfico Nacional). 1998. Chachapoyas, Hoja 1358 (13-h), Chachapoyas-Perú, Topograhic map, Scale 1: 100 000, IGN, Serie J631-Edition 1, Lima, Peru.

DMAAC (Defense Mapping Agency Aerospace Center). 1993. West of Jeberos, Hoja 1560, West of Jeberos-Perú, Topograhic map, Scale 1: 100 000, DMAAC, Serie J632-Edition 1, St. Louis.

DMAAC (Defense Mapping Agency Aerospace Center). 1993. Moyobamba, Hoja 1558, Moyobamba-Perú, Topograhic map, Scale 1: 100 000, DMAAC, Serie J632-Edition 1, St. Louis.

Geocoded image information

Landsat TM image, Subset of Full Scene
Path 009 Row 064
Date 11/11/89
Image name: **009064891111FSgeo.lan**

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

Number of columns	7465
Number of lines	7026

Reference projection	UTM 17 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	699662	9466105	79.1996 W	4.4278 S
Lower right corner	923611	9255325	77.1697 W	6.7219 S

Resampling mode	Nearest
Transformation order	2
Georeferencing error (pixel)	2.4
Number of GCP	23

Geocoded image information

SPOT Mosaic images
Path 642 Row 362
Path 643 Row 362
Date 19/09/97
Date 15/10/97
Image name: **spotmosaic97geo.lan**

Channel 1	Band 1
Channel 2	Band 2
Channel 3	Band 3

Number of columns	6786
Number of lines	3500

Reference projection	UTM 17 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	730137	9370001	78.9220 W	5.6958 S
Lower right corner	865857	9300001	77.6939 W	6.3223 S

Resampling mode	Nearest
Transformation order (1st date)	1
Transformation order (2nd date)	1
Georeferencing error (pixel) (1st date)	1.8
Georeferencing error (pixel) (2nd date)	1.5
Number of GCP (1st date)	18
Number of GCP (2nd date)	14

Annex 2

False colour composites

Bagua (Path 009, Row 064, Full Scene)

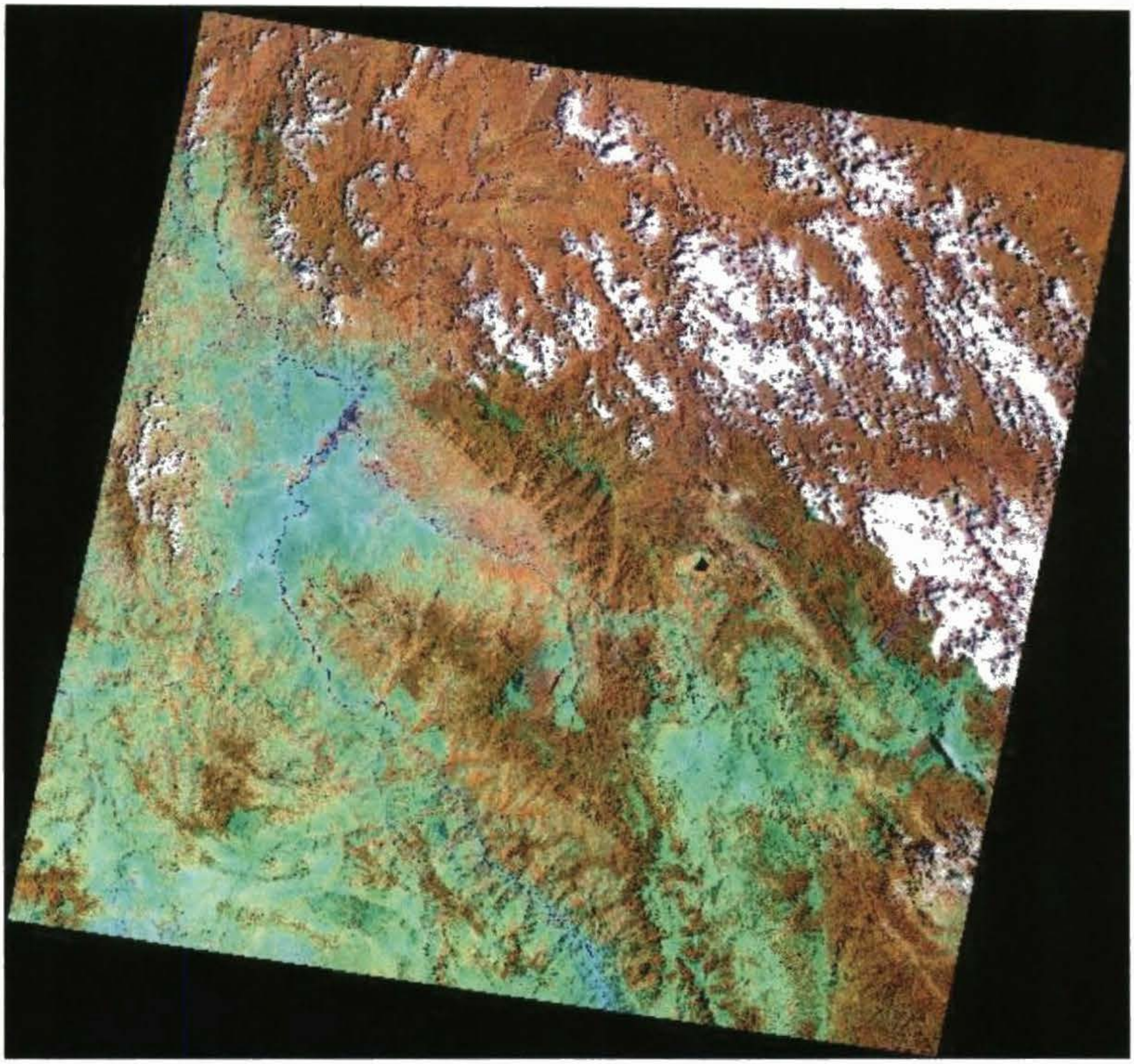


Figure 1. Landsat TM satellite image, bands 4, 5, 3, path 009, row 064, full scene, date 11-11-89. Upper left corner 77.6842 W, 2.4019 N, Lower right corner 75.6729 W, 0.4828 N.

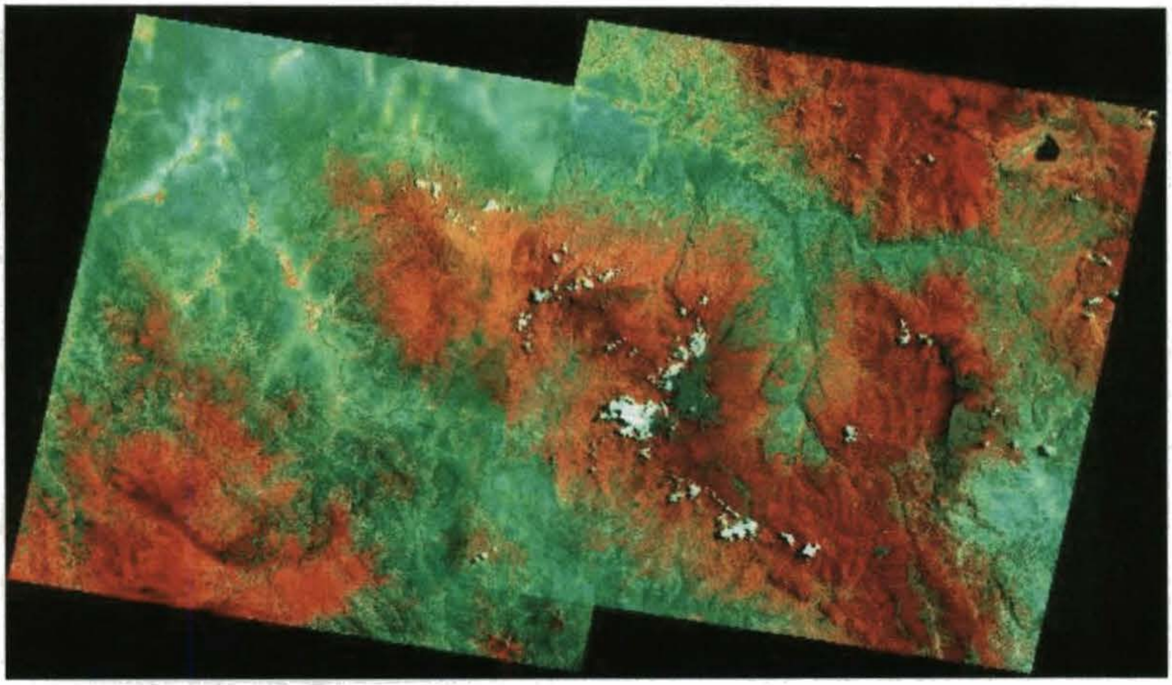


Figure 2. SPOT mosaic satellite image, bands 3, 2, 1, path 642, 643 row 362, full scene, date 15-10-97 and 19-09-97. Upper left corner 79.9220 W, 5.6962 S, Lower right corner 77.7838 W, 6.3229 S

Annex 3

Land use / Land cover change
(Overlap area)

Bagua (Path 009, Row 064, Full Scene)

Land use / Land cover present in 1989 image

Bagua (Path 009, Row 064; per_ciat_bag_89_ cds.xls)

Code	Description
111A	Closed High Density Evegreen Lowland Forest
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane Forest
113A	Closed High Density Semi-evergreen Forest
113B	Closed Medium Density Semi-evergreen Forest
113C	Open Semi-evergreen Forest
113D	Fragmented Semi-evergreen Forest
129A	Closed High Density Other Deciduous Forest
129B	Closed Medium Density Other Deciduous Forest
129C	Open Other Deciduous Forest
129D	Fragmented Other Deciduous Forest
211	Mosaic of Shifting Cultivation & Forest with less than 1/3 cropping
212	Mosaic of Shifting Cultivation & Forest with more than 1/3 cropping
22	Cropland & Forest
23	Other Vegetation & Forest
310	Unknown Wood & Shrubland
313	Shrub Savanna
319	Other Wood & Shrubland
33	Regrowth of Vegetation
39	Other Non-forest Vegetation
410	Unknown Arable Land
43	Ranching
44	Small Holding
51	Urban
54	Bare Soil
61	River
621	Natural Lake
81	Cloud
82	Shadow

Land use / Land cover present in 1997 image

Bagua (Path 009, Row 064; per_ciat_bag_97_ cds.xls)

Code	Description
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane Forest
113B	Closed Medium Density Semi-evergreen Forest
113C	Open Semi-evergreen Forest
113D	Fragmented Semi-evergreen Forest
129A	Closed High Density Other Deciduous Forest
129B	Closed Medium Density Other Deciduous Forest
129C	Open Other Deciduous Forest
129D	Fragmented Other Deciduous Forest
16A	Closed High Density Forest Regrowth
16B	Closed Medium Density Forest Regrowth
16C	Open Forest Regrowth
16D	Fragmented Forest Regrowth
211	Mosaic of Shifting Cultivation & forest with less than 1/3 cropping
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
22	Cropland & Forest
23	Other Vegetation & Forest
310	Unknown Wood & Shrubland
319	Other Wood & Shrubland
33	Regrowth of Vegetation
39	Other Non-forest Vegetation
410	Unknown Arable land
43	Ranching
44	Small holding
51	Urban
54	Bare soil
61	River
621	Natural Lake
81	Cloud
82	Shadow

Statistics for 1989 image

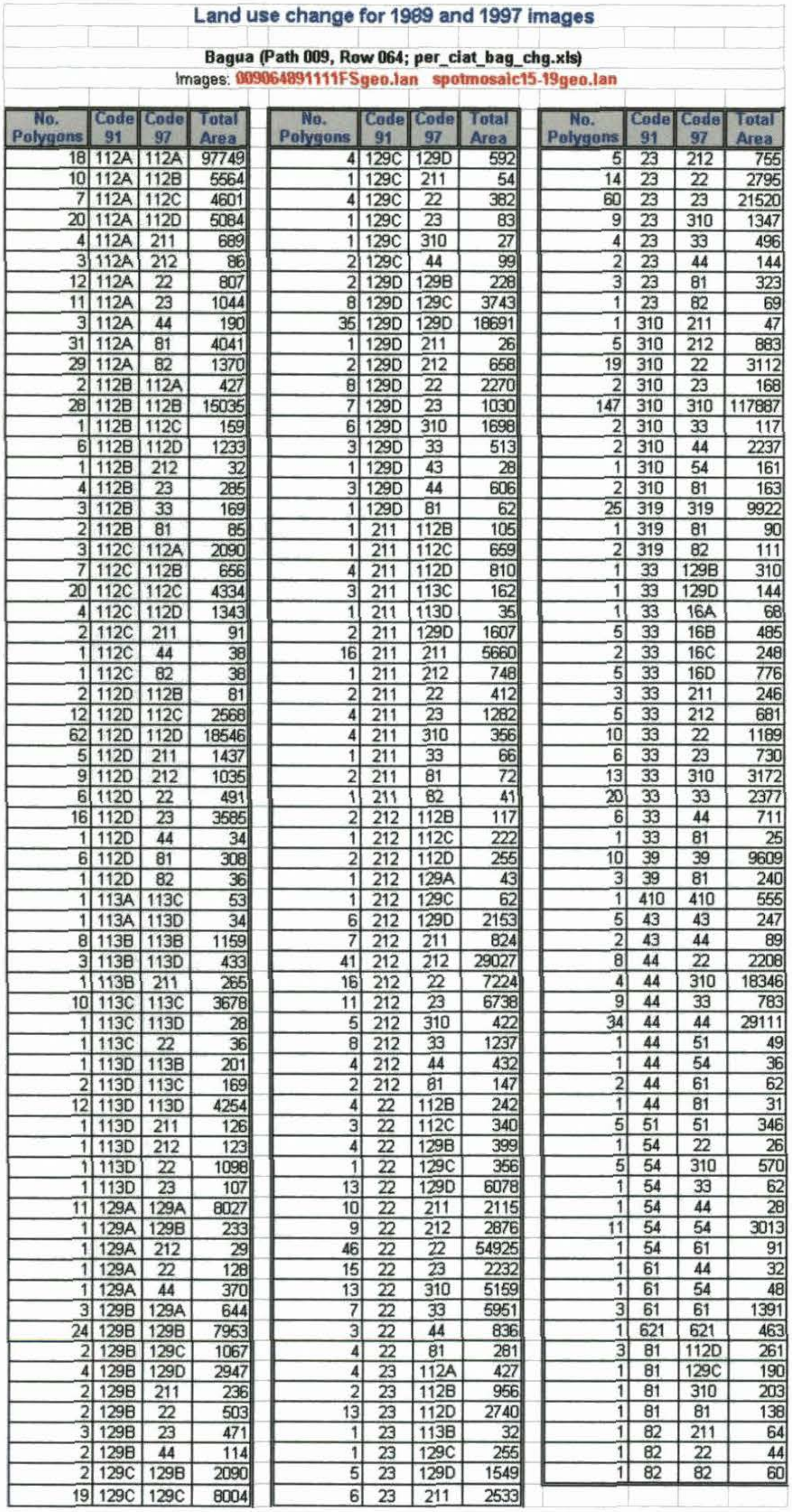
Bagua (Path 009, Row 064; per_ciat_bag_89_sts.xls)

Code 91	No. Polygons	Total Area	Mean Area	S. D. Area
111A	1	17257	17257	0
112A	96	1078728	11237	82655
112B	107	66341	620	1020
112C	64	92628	1447	3337
112D	108	56621	524	749
113A	2	88	44	14
113B	11	1935	176	133
113C	11	3741	340	328
113D	14	6079	434	350
129A	15	12627	842	1604
129B	40	105029	2626	7260
129C	37	24894	673	1113
129D	66	54696	829	1369
211	38	31086	818	1012
212	76	110084	1448	3561
22	101	246684	2442	5042
23	154	126597	822	1711
310	222	376873	1698	6704
313	1	5030	5030	0
319	85	160458	1888	5188
33	99	65714	664	3510
39	10	18853	1885	2426
410	1	590	590	0
43	9	564	63	40
44	55	214479	3900	12285
51	8	1290	161	146
54	26	16805	646	2036
61	3	3276	1092	1454
621	5	674	135	184
81	150	462963	3086	13885
82	4	261	65	29

Statistics for 1997 image

Bagua (Path 009, Row 064; per_ciat_bag_97_sts.xls)

Code 97	No. Polygons	Total Area	Mean Area	S. D. Area
112A	16	100694	6293	17790
112B	48	22755	474	860
112C	40	12884	322	527
112D	87	30271	348	477
113B	9	1393	155	84
113C	10	4063	406	421
113D	17	4784	281	251
129A	13	8714	670	1072
129B	31	11212	362	501
129C	31	13677	441	443
129D	55	33762	614	877
16A	1	68	68	0
16B	5	485	97	87
16C	2	248	124	50
16D	5	776	155	102
211	39	14412	370	402
212	56	36933	660	1126
22	71	77650	1094	2274
23	98	39276	401	662
310	156	149189	956	5032
319	25	9887	395	487
33	49	11773	240	693
39	10	9644	964	1759
410	1	555	555	0
43	6	276	46	14
44	38	35069	923	2809
51	6	395	66	50
54	10	3258	326	543
61	2	1544	772	309
621	1	463	463	0
81	46	6007	131	220
82	35	1726	49	21



Land use change for 1989 and 1997 images

Bagua (Path 009, Row 064; per_ciat_bag_chg.xls)

Images: **009064891111FSgeo.lan spotmosaic15-19geo.lan**

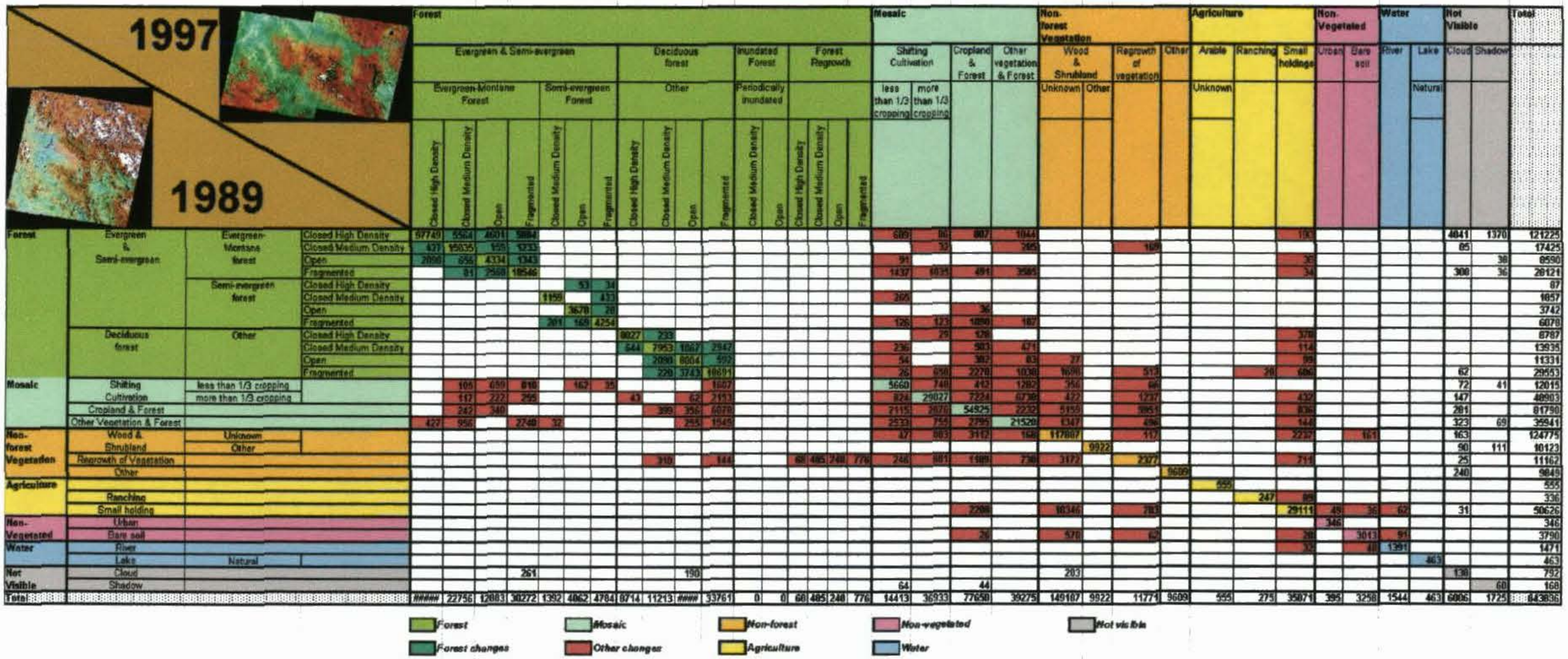
No. Polygons	Code 91	Code 97	Total Area
18	112A	112A	97749
10	112A	112B	5564
7	112A	112C	4601
20	112A	112D	5084
4	112A	211	689
3	112A	212	86
12	112A	22	807
11	112A	23	1044
3	112A	44	190
31	112A	81	4041
29	112A	82	1370
2	112B	112A	427
28	112B	112B	15035
1	112B	112C	159
6	112B	112D	1233
1	112B	212	32
4	112B	23	285
3	112B	33	169
2	112B	81	85
3	112C	112A	2090
7	112C	112B	656
20	112C	112C	4334
4	112C	112D	1343
2	112C	211	91
1	112C	44	38
1	112C	82	38
2	112D	112B	81
12	112D	112C	2568
62	112D	112D	18546
5	112D	211	1437
9	112D	212	1035
6	112D	22	491
16	112D	23	3585
1	112D	44	34
6	112D	81	308
1	112D	82	36
1	113A	113C	53
1	113A	113D	34
8	113B	113B	1159
3	113B	113D	433
1	113B	211	265
10	113C	113C	3678
1	113C	113D	28
1	113C	22	36
1	113D	113B	201
2	113D	113C	169
12	113D	113D	4254
1	113D	211	126
1	113D	212	123
1	113D	22	1098
1	113D	23	107
11	129A	129A	8027
1	129A	129B	233
1	129A	212	29
1	129A	22	128
1	129A	44	370
3	129B	129A	644
24	129B	129B	7953
2	129B	129C	1067
4	129B	129D	2947
2	129B	211	236
2	129B	22	503
3	129B	23	471
2	129B	44	114
2	129C	129B	2090
19	129C	129C	8004

No. Polygons	Code 91	Code 97	Total Area
4	129C	129D	592
1	129C	211	54
4	129C	22	382
1	129C	23	83
1	129C	310	27
2	129C	44	99
2	129D	129B	228
8	129D	129C	3743
35	129D	129D	18691
1	129D	211	26
2	129D	212	658
8	129D	22	2270
7	129D	23	1030
6	129D	310	1698
3	129D	33	513
1	129D	43	28
3	129D	44	606
1	129D	81	62
1	211	112B	105
1	211	112C	659
4	211	112D	810
3	211	113C	162
1	211	113D	35
2	211	129D	1607
16	211	211	5660
1	211	212	748
2	211	22	412
4	211	23	1282
4	211	310	356
1	211	33	66
2	211	81	72
1	211	82	41
2	212	112B	117
1	212	112C	222
2	212	112D	255
1	212	129A	43
1	212	129C	62
6	212	129D	2153
7	212	211	824
41	212	212	29027
16	212	22	7224
11	212	23	6738
5	212	310	422
8	212	33	1237
4	212	44	432
2	212	81	147
4	22	112B	242
3	22	112C	340
4	22	129B	399
1	22	129C	356
13	22	129D	6078
10	22	211	2115
9	22	212	2876
46	22	22	54925
15	22	23	2232
13	22	310	5159
7	22	33	5951
3	22	44	836
4	22	81	281
4	23	112A	427
2	23	112B	956
13	23	112D	2740
1	23	113B	32
1	23	129C	255
5	23	129D	1549
6	23	211	2533

No. Polygons	Code 91	Code 97	Total Area
5	23	212	755
14	23	22	2795
60	23	23	21520
9	23	310	1347
4	23	33	496
2	23	44	144
3	23	81	323
1	23	82	69
1	310	211	47
5	310	212	883
19	310	22	3112
2	310	23	168
147	310	310	117887
2	310	33	117
2	310	44	2237
1	310	54	161
2	310	81	163
25	319	319	9922
1	319	81	90
2	319	82	111
1	33	129B	310
1	33	129D	144
1	33	16A	68
5	33	16B	485
2	33	16C	248
5	33	16D	776
3	33	211	246
5	33	212	681
10	33	22	1189
6	33	23	730
13	33	310	3172
20	33	33	2377
6	33	44	711
1	33	81	25
10	39	39	9609
3	39	81	240
1	410	410	555
5	43	43	247
2	43	44	89
8	44	22	2208
4	44	310	18346
9	44	33	783
34	44	44	29111
1	44	51	49
1	44	54	36
2	44	61	62
1	44	81	31
5	51	51	346
1	54	22	26
5	54	310	570
1	54	33	62
1	54	44	28
11	54	54	3013
1	54	61	91
1	61	44	32
1	61	54	48
3	61	61	1391
1	621	621	463
3	81	112D	261
1	81	129C	190
1	81	310	203
1	81	81	138
1	82	211	64
1	82	22	44
1	82	82	60

Land use change matrix

Bagua (Path 009, Row 064; per_ciat_bag_mtx.xls)



1997				Forest																	Mosaic				Non-forest Vegetation				Agriculture			Non-Vegetated		Water		Not Visible		Total
				Evergreen & Semi-evergreen							Deciduous forest				Inundated Forest		Forest Regrowth				Shifting Cultivation		Cropland & Forest	Other vegetation & Forest	Wood & Shrubland		Regrowth of vegetation	Other	Arable	Ranching	Small holdings	Urban	Bare soil	River	Lake	Cloud	Shadow	
				Evergreen-Montane Forest				Semi-evergreen Forest			Other				Periodically inundated						less than 1/3 cropping	more than 1/3 cropping			Unknown	Other			Unknown						Natural			
			1989	Closed High Density	Closed Medium Density	Open	Fragmented	Closed Medium Density	Open	Fragmented	Closed High Density	Closed Medium Density	Open	Fragmented	Closed Medium Density	Open	Closed High Density	Closed Medium Density	Open	Fragmented																		
Forest	Evergreen & Semi-evergreen	Evergreen-Montane forest	Closed High Density	97749	5564	4601	5884														689	80	807	1044							190					4841	1370	121225
			Closed Medium Density	477	15835	155	1233															32		295			109									85		17425
			Open	2090	656	4334	1343														91										38						38	8590
			Fragmented		81	2568	18546														1437	1035	491	3585							34					308	36	28121
		Semi-evergreen forest	Closed High Density						53	34																												87
			Closed Medium Density					1159		433											265																	1857
			Open						3678	28													36															3742
			Fragmented					201	169	4254											126	123	1090	187														6078
	Deciduous forest	Other	Closed High Density								8027	233										29	128								370							8787
			Closed Medium Density								644	7953	1067	2947							236		503	471							114							13935
			Open									2090	8004	592							54		382	83	27						99							11331
			Fragmented									220	3743	18691							26	650	2278	1038	1698		513			28	606					62		29553
Mosaic	Shifting Cultivation	less than 1/3 cropping			105	659	810		162	35				1607							5660	748	412	1282	356		66									72	41	12015
		more than 1/3 cropping			117	222	295				43		62	2153							824	29027	7224	6738	422		1237				432					147		48903
	Cropland & Forest				242	340						399	356	6078							2115	2076	54925	2232	5155		9951				836					281		81790
	Other Vegetation & Forest			427	956		2740	32					255	1549							2533	755	2795	21520	1347		496				144					323	69	35941
Non-forest Vegetation	Wood & Shrubland	Unknown																			47	883	3112	168	117887		117				2237		161			163		124775
		Other																								9922										90	111	10123
	Regrowth of Vegetation											310		144			68	485	240	776	246	881	1989	738	3172		2377				711					25		11162
	Other																											9609								240		9849
Agriculture																													555									555
	Ranching																													247	89							336
	Small holding																						2208		18346		783				29111	49	36	62		31		50626
Non-Vegetated	Urban																															346						346
	Bare soil																						26		570		62				28		3013	91				3790
Water	River																														32		48	1391				1471
	Lake	Natural																																	463			463
Not Visible	Cloud						261						190												203											138		792
	Shadow																				64		44														60	168
Total				#####	22756	12883	30272	1392	4862	4784	8714	11213	####	33761	0	0	68	485	240	776	14413	36933	77650	39275	149107	9922	11771	9609	555	275	35071	395	3258	1544	463	6806	1725	843836

🟩 Forest
🟩 Forest changes
🟩 Mosaic
🟥 Other changes
🟧 Non-forest
🟨 Agriculture
🟪 Non-vegetated
🟦 Water
⬜ 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 B Cerrado media densidad 70-90% cobertura forestal C Abierto 60- 70% cobertura forestal D Fragmentado 40-60% cobertura forestal
		1 Bosque siempre verde de tierras bajas (Selva Tropical)	
		2 Bosque siempre verde de montaña (Bosque montano o nublado)	
		3 Bosque semi siempreverde	
		4 Bosque de turba amazonica (Catinga)	
		5 Bosques de pinos	
		6 Bambú	
		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.

Altieri, M. 1996. Enfoque agroecológico para el desarrolllo de sistemas de producción sostenibles en Los Andes. Universidad de California, Berkeley/Clades. Centro de Investigación, Educación y Desarrollo (CIED), Lima, Perú. 92 p.

Brawer, M. 1991. In: Atlas of South America. Simon and Schuster, NY. p. 58-62.

Cuatrecasas, J. 1989. Frailejón típico de la vegetación en los páramos Andinos. En: Perez-Arbelaezia. Vol. 2, no. 8. Bogotá, Colombia.

Czaijka, W. 1968. Los perfiles vegetales de la cordillera entre Alaska y Tierra del Fuego. In: Troll, C. (ed). Geoecology of the mountain regions of the Tropical Americas. Fend, Dummlers Verlag, Bonn. p. 117-121.

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.

Gastó, J. 1993. Aproximación agroecosistemica. El agroecosistema Andino, problemas, limitaciones y perspectivas. En: Anales del Taller Internacional sobre el Agroecosistema Andino, 30 Mar-2 Abr, 1992, Centro Internacional de La Papa (CIP). CIP, Lima, Peru. p. 31-49.

Gazzo, J. 1982. Development policies and plans for Peru's Amazon region. In: Amazonia, agriculture and land use research. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 85-105.

Handelman, H. 1975. Struggle in the Andes: peasant political mobilization in Peru. Institute of Latin American Studies, University of Texas Press, Austin, TX. p. 23.

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

JRC (Joint Research Centre). 1997. Identification of deforestation hot spot areas in the humid tropics. Tropical Ecosystem Environment Observations by Satellites (TREES), European Commission. Synthesis of expert consultation meeting, 24-25 Nov 1997, Ispra, Italy. TREES Publications Series B. Research Report no. 4. 99 p.

Lajo L., M. 1983. Alternativa agraria y alimentaria: diagnóstico y propuesta para el Perú. Centro de Investigacion y Promoción del Campesino, Piura, Peru. 415 p.

MAG–INRENA (Ministerio de Agricultura–Instituto Nacional de Recursos Naturales). 1995. Mapa forestal del Perú. Dirección General de Bosques, MAG-INRENA, Lima, Peru.

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: Schmink M. and Wood C. (eds.) Frontier expansion in Amazonia. University Presses of Florida, FL. 206 p.

Rangel Ch. J; Lowy C.; Petter; and Cleef A.M. 1995. El páramo: ecosistema de alta montaña. Serie Montañas Tropoandinas. Vol 1. 168 p.

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

Stadtmüller, T. 1987. Los bosques nublados en los trópicos húmedos. Universidad de Las Naciones Unidas y Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica. 85 p.

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

Tapia, M.E. 1986. Alternativas para el desarrollo agropecuario del trapecio Andino. En: Anales V Congreso Internacional de Sistemas Agropecuarios Andinos, 10-14 Marzo, 1986, Puno, Peru. Proyecto de Investigación de Sistemas Agropecuarios Andinos (PISA), Lima, Peru. p. 44-52.

Tapia, M.E. 1993. Vision general y características del agroecosistema Andino. En: Anales del Taller Internacional sobre el Agroecosistema Andino, 30 Mar-2 Abr, 1992, Centro Internacional de La Papa (CIP). CIP, Lima, Peru. p. 51-61.

Torres G., J. 1993. Los agroecosistemas Andinos del Peru: La oferta ambiental de los Andes y algunas sugerencias para optimizar su utilizacion. In: El Agroescosistema Andino, Anales del Taller Internacional sobre Agroecosistemas Andino, 30 Marzo-2 Abril, 1992, Centro Internacional de la Papa (CIP). Lima, Peru. p. 97-108.

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

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