Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Piura – Peru

(Path 010, Row 063, Quarter 1)

Joint Research Centre (JRC)

and

CIAT

Technical Report

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CGIAR Consultative Group on International Agricultural Research

TREES PROJECT

Joint Research Centre (JRC)

International Center for Tropical Agriculture (CIAT)

TECHNICAL REPORT

Piura – Peru

LANDSAT TM IMAGES PATH 010, ROW 063 (QUARTER 1)

IMAGE DATE 281289 AND 281096

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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 northwestern Peruvian 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 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 heights as great as 4200 m, such as in rotation with root crops and fallow (Altieri, 1996).

Cattle is 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 northwestern part of the Peruvian Andes. It includes part of the Piura River watershed, from the highest mountain in the Piura mountain range to the flood plain of the Pacific Coast. The total area covered is 1 079 477ha.

CLIMATE AND VEGETATION

The Peruvian coastal region is one of the driest places on the planet. This is because the Andes forms a barrier to the movement of humid masses of air coming from the Amazon region in the east. Also, the cold Humboldt Current in the Pacific Ocean constantly cools the air masses, forming banks of fog, which reach the coast especially between June and September. It only rains along the coast when the temperature of the sea exceeds that of the masses of air over the land. This situation occurs when *El Niño* manifests with abundant precipitation in the zone (Begler, 1980).

The Piura mountain range is of relatively low altitude. It allows passage of humid air coming from the Amazon region in the east, causing 80% of the rainfall between the months of December and April. Nevertheless, two phenomena modify the seasonal climate conditions, the San Francisco rainfall in the month of September and the influence of *El Niño*, each of which contributes plentiful rainfall from the mass of humid air of the Pacific at certain periods. Even with these contributions, the mountains can have a great annual variation in precipitation, even including years of extreme drought (Feininger, 1975; Etesse, 1988; Zarela R., 1996). In the plains and coastal areas, the rainy season is well defined between the months of January and March (http://www.canatur.org.pe/empiura.htm).

The extreme drought conditions in the piedmont and the continuous increase of humidity with altitude lead to a succession of types of vegetation from uncovered soil or xerophytic scrub in the lower parts to montane forest and paramo in the high parts of the mountain range to over 4000 m. In the extreme northwest of Peru lie the last remnants of the great belt of rainforest of the Pacific Coast extending from Panama (Myers, 1980).

PRODUCTION

Deforestation in this part of Peru reaches irreversible levels, caused by the extending agricultural frontier. The deforested soils are overgrazed, lack conservation infrastructure and are subject to mechanical erosion. On the alluvial terraces in the valley bottoms, an irrigation system has been developed, using river water descending from the mountains, that allows development of annual crops such as rice under irrigation. In the drier areas, the main crop is maize of different varieties according to the available rainfall. In the river valleys are irrigated plantations of coffee, plantains, citrus or other crops (also irrigated) such as cassava and vegetables (Etesse, 1988; Roux, 1988; Bedoya, 1995). Other agricultural activities of economic importance for the region are cotton, which is cultivated near the city of Piura, and the gathering of carob pods for preparing carob pulp a typical drink, *algarrobilla*, (http://www.canatur.org.pe/empiura.htm; http://www.seyarns.com/pima.htm). At higher altitudes, crops and plantations are replaced by others, adapted to the new climatic conditions, such as walnuts, wheat, barley, pea, bean, potato, *olluco* and cattle and sheep raising, among others (Etesse, 1988; Roux, 1988; Bedoya, 1995).

SOCIAL SITUATION

"The Piura mountain range is experiencing a strong demographic growth never before reached in its history." Nowadays, there are over 20 inhabitants per km^2. "The consequence of the increase in population is greater pressure on the land, that translates into small holdings for the greater part of the productive units and a concentration for a reduced number" (Etesse, 1988).

METHODOLOGY

MATERIALS

For this work we used the second quarter of two Landsat TM images (path 010, row 063: 010063891228Q1geo.lan, 010063961028Q1geo.lan). The radiometric quality of the image data was good, although the first image presented some cloud coverage (with respective shading) over the desert and agricultural area.

Land use was interpreted using as a 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).

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 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 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 Instituto Geográfico Nacional (IGN) of Peru. Annex 1 shows a list of georeference maps, 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

The study area presents remnants of various types of forest in the upper part of coastal mountain range, as well as in the lower part in the coastal plains.

Forest covers 28% of the total area without clouds and shadow (later referred to as overlap area). The forest is composed of montane forest (8.7%), semi-evergreen forest (22.3%), deciduous forest (66%), other deciduous forest (0.1%), gallery forest (1.8%)

2.2% of the forest has disappeared in the 7 years period, which represents an net annual rate of deforestation of 0.3%.

Non-forest cover (agricultural systems and natural formations such as paramo, bare soil, inundated savannahs, wood and shrubland) cover 71.2% of the overlap area, where 68.3% correspond to natural no-forest vegetation, 16.4% to agricultural and cattle land and 15.3% to bare soil.

CONCLUSION

Deforestation occurs in small patches of montane evergreen forest (1.8% net annual rate), gallery forest (3.6% net annual rate), and "Other deciduous forest" (code 129 – 8.5% net annual rate). In the first two cases good water availability has favoured colonisation of new areas, principally along the agricultural frontier along the piedmont of the cordillera.

Cattle and Irrigated agriculture are important activities in the piedmont, covering 16.4% of the non-forest area. Good rainfall on the upper part of the cordillera provides numerous streams that permit irrigation at the foothills.

A substantial part of the study area overlaps with the coastal desert of Peru (bare soil - 15.3% of the overlap area) where dry shrub formations are unaffected because of the extreme aridity that prevail in the region

Annex 1

Geocoded image information

Piura (Path 010, Row 063, Quarter 1)

Georeference maps

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

IGN. 1994. Celendin, Hoja 1257(14-g), Celendin-Perú, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631-Edition 2, Lima-Perú

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

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

IGN. 1994. Chota, Hoja 1157(14-f), Chota-Perú, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, Edition 1. Lima, Peru

IFG. 1984. Piura, Hoja SB17-7, Piura-Perú, Topograhic map, Scale 1: 250 000, Institute for Applied Geosciencies, Lima-Perú

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

IGM. 1979. Cutervo, Hoja 1161(13-f), Cajamarca-Perú, Topograhic map, Scale 1: 100 000, Instituto Geográfico Militar, Serie J632-Edition 2, Lima-Perú

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

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

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

Geocoded image information

Landsat TM image, Quarter 1
Path 010 Row 063
Date 28/12/89
Image name: **010063891228Q1geo.lan**

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

Number of columns	4030
Number of lines	3976

Reference projection	UTM 17 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	540455	9467052	80.6351 W	4.8215 S
Lower right corner	661355	9347773	79.5424 W	5.8987 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	1.3
Number of GCP	16

Geocoded image information

Landsat TM image, Quarter 1
Path 010 Row 063
Date 28/10/96
Image name: **010063961028Q1geo.lan**

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

Number of columns	4030
Number of lines	3977

Reference projection	UTM 17 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	545337	9466690	80.5911 W	4.8247 S
~~***Lower right corner***~~	~~666237~~	~~9347380~~	79.4983 W	5.9022 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	1.2
Number of GCP	26

Annex 2

False colour composites

Piura (Path 010, Row 063, Quarter 1)

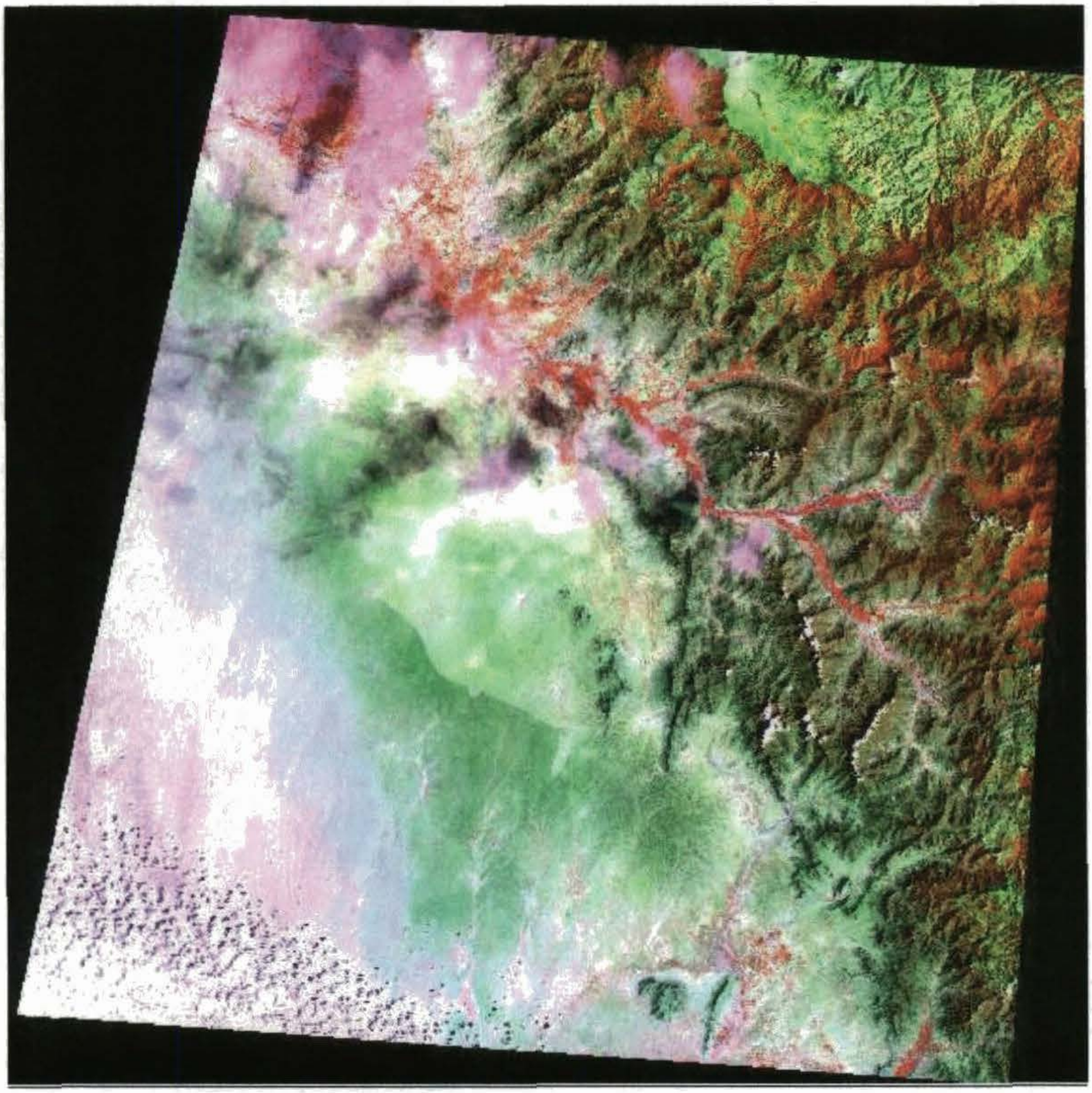


Figure 1. Landsat TM satellite image, bands 4, 5, 3, path 010, row 063, quarter 1, date 12-28-89. Upper left corner 80.6351 W, 4.8215 S, Lower right corner 79.5424 W, 5.8987 S.

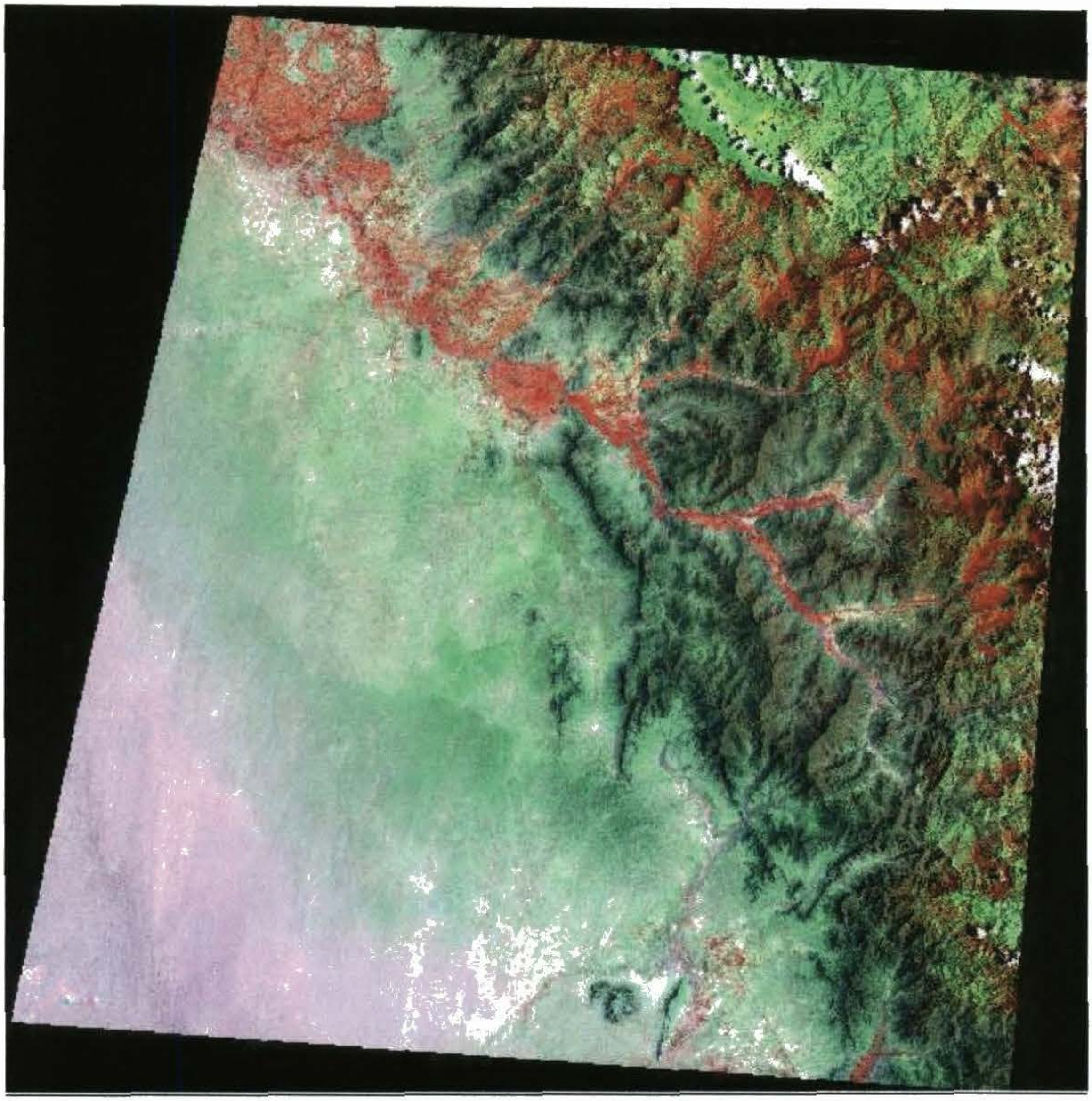


Figure 2. Landsat TM satellite image, bands 4, 5, 3, path 010, row 063, quarter 1, date 10-28-96. Upper left corner 80.5911 W, 4.8247 S, Lower right corner 79.4983 W, 5.9022 S.

Annex 3

Land use / Land cover change
(Overlap area)

Piura (Path 010, Row 063, Quarter 1)

Land use / Land cover present in 1989 image

Piura (Path 010, Row 063; per_ciat_piu_89_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
120B	Closed Medium Density Unknown Deciduous Forest
120C	Open Unknown Deciduous Forest
120D	Fragmented Unknown Deciduous Forest
129D	Fragmented Other Deciduous Forest
14B	Closed Medium Density Gallery-forest
14C	Open Gallery-forest
14D	Fragmented Gallery-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
315	Swamp savannah
319	Other Wood & Shrubland
33	Regrowth of Vegetation
39	Other Non-forest Vegetation
410	Unknown Arable land
411	Irrigated Arable land
420	Unknown Plantations
43	Ranching
44	Small holding
51	Urban
54	Bare soil
81	Cloud

Land use / Land cover present in 1996 image

Piura (Path 010, Row 063; per_ciat_piu_96_cds.xls)

Code	Description
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
120B	Closed Medium Density Unknown Deciduous Forest
120C	Open Unknown Deciduous Forest
120D	Fragmented Unknown Deciduous Forest
129D	Fragmented Other Deciduous Forest
14C	Open Gallery-forest
14D	Fragmented Gallery-forest
16C	Open 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
315	Swamp savannah
319	Other Wood & Shrubland
33	Regrowth of Vegetation
39	Other Non-forest Vegetation
410	Unknown Arable land
411	Irrigated Arable land
420	Unknown Plantations
43	Ranching
44	Small holding
51	Urban
54	Bare soil
81	Cloud

Statistics for 1989 image

Piura (Path 010, Row 063; per_ciat_piu_89_sts.xls)

Code 89	No. Polygons	Total Area	Mean Area	S. D. Area
112A	1	112	112	0
112B	10	2932	293	374
112C	10	3783	378	390
112D	15	26033	1736	3861
113B	11	48858	4442	3436
113C	8	8390	1049	835
113D	7	10117	1445	1061
120B	9	120750	13417	36674
120C	7	56086	8012	7501
120D	8	24304	3038	4112
129D	2	1111	555	247
14B	3	589	196	114
14C	7	2592	370	339
14D	10	4279	428	792
211	1	2833	2833	0
212	13	14513	1116	1394
22	32	38397	1200	1446
23	41	30007	732	1097
310	34	430316	12656	67582
315	3	754	251	302
319	8	6663	833	992
33	5	584	117	104
39	1	1514	1514	0
410	22	9245	420	428
411	16	4173	261	233
420	24	6017	251	382
43	73	26132	358	585
44	35	79200	2263	5657
51	3	724	241	199
54	26	116227	4470	20444
81	9	2242	249	199

Statistics for 1996 image

Piura (Path 010, Row 063; per_ciat_piu_96_sts.xls)

Code 96	No. Polygons	Total Area	Mean Area	S. D. Area
112B	6	1272	212	172
112C	9	1652	184	206
112D	19	23135	1218	1850
113B	9	40109	4457	3839
113C	7	12012	1716	1277
113D	9	15816	1757	1851
120B	9	119910	13323	36707
120C	7	56086	8012	7501
120D	10	24075	2408	3820
129D	2	493	247	190
14C	3	1513	504	453
14D	14	4159	297	446
16C	2	127	63	30
211	1	5219	5219	0
212	16	14030	877	879
22	30	42461	1415	1491
23	44	36057	819	1155
310	35	427599	12217	66593
315	3	553	184	134
319	10	5760	576	633
33	3	465	155	127
39	1	1360	1360	0
410	20	14077	704	866
411	24	5699	237	389
420	14	4436	317	456
43	63	26065	414	756
44	37	66417	1795	3302
51	3	724	241	199
54	31	118553	3824	18724
81	25	9644	386	468

Land use change for 1989 and 1996 images

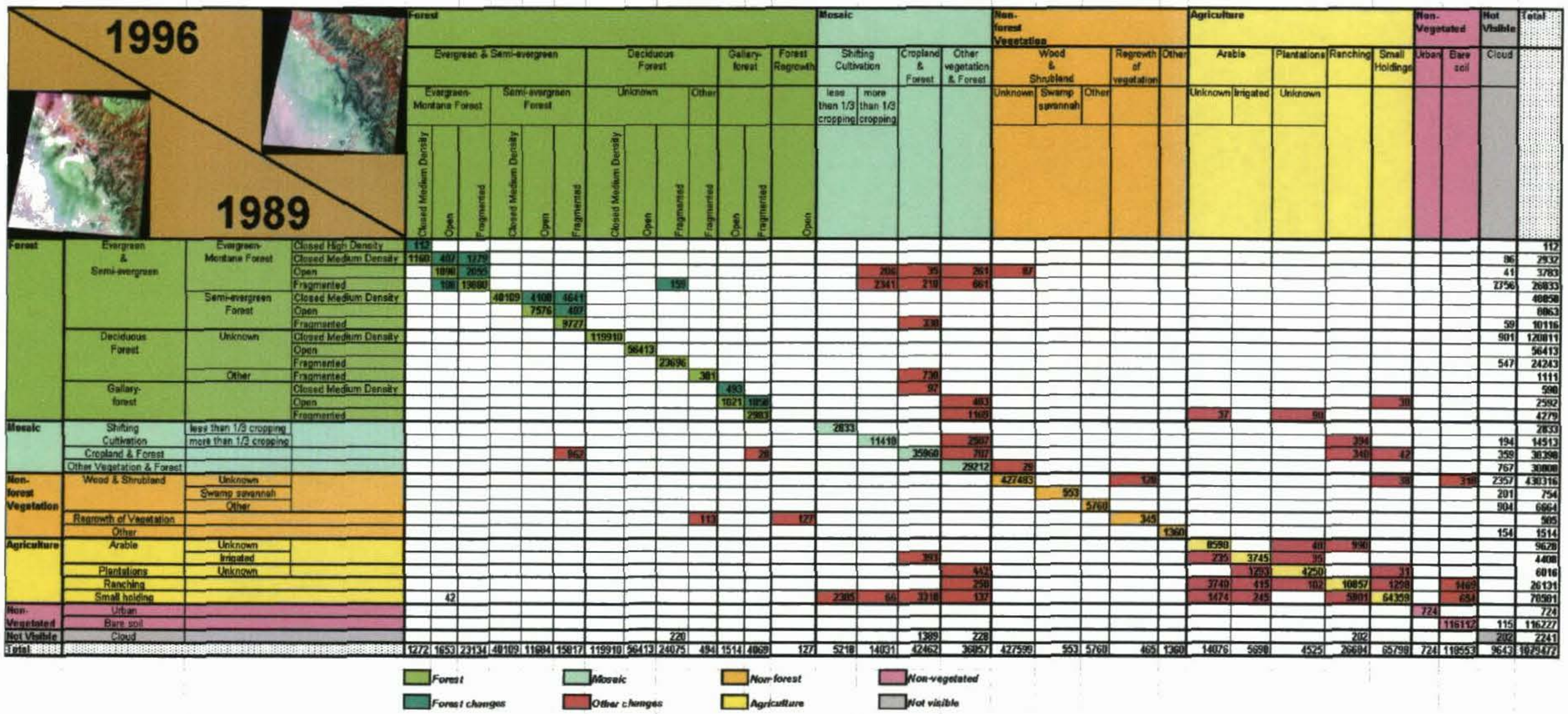
Piura (Path 006, Row 068; per_ciat_piu_chg.xls)

Images: **010063891228Q1geo.lan 010063961028Q1geo.lan**

No. Polygons	Code 89	Code 96	Total Area
1	112A	112B	112
5	112B	112B	1160
3	112B	112C	407
1	112B	112D	1279
1	112B	81	86
5	112C	112C	1098
5	112C	112D	2055
1	112C	212	206
1	112C	22	35
1	112C	23	261
1	112C	310	87
1	112C	81	41
1	112D	112C	106
21	112D	112D	19800
2	112D	120D	159
4	112D	212	2341
1	112D	22	210
4	112D	23	661
13	112D	81	2756
9	113B	113B	40109
1	113B	113C	4108
1	113B	113D	4641
6	113C	113C	7576
2	113C	113D	487
9	113D	113D	9727
1	113D	22	330
1	113D	81	59
9	120B	120B	119910
2	120B	81	901
9	120C	120C	56413
9	120D	120D	23696
5	120D	81	547
1	129D	129D	381
1	129D	22	730
2	14B	14C	493
1	14B	22	97
1	14C	14C	1021
5	14C	14D	1058
1	14C	23	483
1	14C	44	30
8	14D	14D	2983
4	14D	23	1169
1	14D	410	37
1	14D	420	90
1	211	211	2833
13	212	212	11418
5	212	23	2507
1	212	43	394
1	212	81	194
1	22	113D	962
1	22	14D	28
30	22	22	35960
1	22	23	707
2	22	43	340
1	22	44	42
2	22	81	359
40	23	23	29212
1	23	310	29
9	23	81	767
38	310	310	427483
1	310	33	120
1	310	44	38
3	310	54	318
10	310	81	2357
3	315	315	553
3	315	81	201
10	319	319	5760
3	319	81	904
1	33	129D	113
2	33	16C	127
2	33	33	345
1	39	39	1360
2	39	81	154
22	410	410	8590
1	410	420	48
3	410	43	990
1	411	22	393
1	411	410	235
15	411	411	3745
1	411	420	35
2	420	23	442
12	420	411	1293
11	420	420	4250
1	420	44	31
1	43	23	250
14	43	410	3740
2	43	411	415
2	43	420	102
56	43	43	18857
5	43	44	1298
3	43	54	1469
1	44	112C	42
1	44	211	2385
1	44	212	66
3	44	22	3318
1	44	23	137
5	44	410	1474
1	44	411	245
8	44	43	5901
38	44	44	64359
1	44	54	654
3	51	51	724
31	54	54	116112
1	54	81	115
2	81	120D	220
6	81	22	1389
1	81	23	228
2	81	43	202
2	81	81	202

Land use change matrix

Piura (Path 010, Row 063; per_ciat_piu_mtx.xls)



1996				Forest													Mosaic				Non-forest Vegetation					Agriculture					Non-Vegetated		Not Visible	Total
				Evergreen & Semi-evergreen						Deciduous Forest				Gallery-forest		Forest Regrowth	Shifting Cultivation		Cropland & Forest	Other vegetation & Forest	Wood & Shrubland			Regrowth of vegetation	Other	Arable		Plantations	Ranching	Small Holdings	Urban	Bare soil	Cloud	
				Evergreen-Montane Forest			Semi-evergreen Forest			Unknown			Other				less than 1/3 cropping	more than 1/3 cropping			Unknown	Swamp savannah	Other			Unknown	Irrigated	Unknown						
1989				Closed Medium Density	Open	Fragmented	Closed Medium Density	Open	Fragmented	Closed Medium Density	Open	Fragmented	Fragmented	Open	Fragmented	Open																		
Forest	Evergreen & Semi-evergreen	Evergreen-Montane Forest	Closed High Density	112																														112
			Closed Medium Density	1160	407	1279																											86	2932
			Open		1098	2055												206	35	261	87												41	3783
			Fragmented		108	19800						159						2341	219	661													2756	26033
		Semi-evergreen Forest	Closed Medium Density				40109	4108	4641																									48858
			Open					7576	487																									8063
			Fragmented						9727										330														59	10116
	Deciduous Forest	Unknown	Closed Medium Density							119910																							901	120811
			Open								56413																							56413
			Fragmented									23696																					547	24243
		Other	Fragmented										381						730															1111
	Gallery-forest		Closed Medium Density											493					97															590
			Open											1021	1058					483										30				2592
			Fragmented												2983					1169						37		90						4279
Mosaic	Shifting Cultivation	less than 1/3 cropping															2833																	2833
		more than 1/3 cropping																11410		2507									394				194	14513
	Cropland & Forest								962						28				35960	707									340	42			359	38398
	Other Vegetation & Forest																			29212	29												767	30008
Non-forest Vegetation	Wood & Shrubland	Unknown																			427483			120						38		318	2357	430316
		Swamp savannah																				553											201	754
		Other																					5760										904	6664
	Regrowth of Vegetation												113			127								345										585
	Other																								1360								154	1514
Agriculture	Arable	Unknown																								8590		48	990					9628
		Irrigated																	393							235	3745	35						4408
	Plantations	Unknown																		442							1293	4250		31				6016
	Ranching																			250						3740	415	102	18857	1298		1469		26131
	Small holding				42												2385	66	3318	137						1474	245		5801	64359		654		78581
Non-Vegetated	Urban																														724			724
	Bare soil																															116112	115	116227
Not Visible	Cloud												220							1389	228									202				202	2241
Total				1272	1653	23134	40109	11684	15817	119910	56413	24075	494	1514	4069	127	5218	14031	42462	36057	427599	553	5760	465	1360	14076	5698	4525	26684	65798	724	118553	9643	1029477

🟩 Forest
🟦 Forest changes
🟩 Mosaic
🟥 Other changes
🟧 Non-forest
🟨 Agriculture
🟪 Non-vegetated
⬜ 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

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