Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Huanay – Peru

(Path 006, Row 068, Quarter 2)

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)

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TECHNICAL REPORT

Huanay – Peru

LANDSAT TM PATH 006, ROW 068 (QUARTER 2)

IMAGE DATE 020492 AND 161096

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 Central 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 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 central part of the Peruvian Andes. It is bounded in the south by the border between Junin and Huanca States, in the north by La Merced town in the Chanchamayo river valley, in the west by the Peruvian Cordillera Occidental and in the east by the eastern side of the Cordillera Oriental in the Amazon region. The total area covered is 1 189 249 ha.

TOPOGRAPHY

This part of the Andes has some of the highest mountains in Peru and some smooth and extensive plateaux in between. Some peaks reach over 5000 metres, and are permanently covered with snow. In the east, the Andes descend steeply to the Amazon region, with deep valleys and major rivers.

CLIMATE AND VEGETATION

The great heights reached in the study area determine the climate and vegetation. Above 3900 m, temperatures are mainly low and precipitation only just exceeds 1000 mm annually.

The study area is principally covered with *Jalca*, a typical vegetal formation of grassland developing in the upper part of the Peruvian Mountains and tropical montane cloud forest, both ranging over the whole area. The *Jalca* vegetation is dominated by grasses, and some small trees that are located in ravines or at the edge of the tree line.

Descending the eastern hillsides of the Andean Cordillera, the tropical montane cloud forest begins to appear and the small bushes and trees found at the edge of the *Jalca* mix increasingly with trees of greater size and density.

PRODUCTION

Towns like Huancayo and Junin are important markets for the agricultural production of the region; root and cereals are the main typical crops. The images mostly show *Jalca*, but within this vegetation cover are various agricultural production systems and natural grasses are used as pasture for ruminants.

METHODOLOGY

MATERIALS

For this work we used the second quarter of two Landsat TM images (path 006, row 068: 006068920420Q2geo.lan, 006068961016Q2geo.lan). The radiometric quality of the image data was good, although the first image presented important cloud cover over part of the tropical montane cloud forest and the second image had scattered small clouds (with respective shading).
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).

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

GEOCODING

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

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

LAND-USE AND LAND-COVER DIGITISING

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

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

BUILDING POLYGONS

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

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

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

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

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

INTERPRETATION OF CHANGES

In the study area, distinguishing land use changes was difficult, especially in the forest cover. The great cloud cover over the forest area in the first image made it impossible to analyse deforestation over the area covered by the images. However, some changes show the existence of most agricultural expansion in small forested areas, for example, 1069 hectares changed from a forest type to another class with less forest cover, representing 1.2% of the total area annual without cloud and shadow (later referred as overlap area), representing the 0.3% of deforestation annual rate.

The forest only represents 11 % of the overlap area while the *Jalca* covered 66.4% of the overlap area. The later does not show important changes in the 6 years period. It reduced its size by 307 hectares which represent only 0.02 % of the overlap area.

Agricultural land increased 126 hectares over the *Jalca* land, but on the other hand it reduced 111 hectares, changing to bare soil. Extreme weather conditions are important factors that prevent the growth of agricultural activities and the advance of the agricultural frontier in the upper part of the *Jalca*.

Other natural land cover (shrubland savannah, grassland, swamp grassland, other shrubland, bare soil, lake, snow - 11.6% of the overlap area) didn't show changes to other land-use/land-cover. The urban area also was maintained constant with 2577 ha (0.3%).

CONCLUSION

The deforestation follows a diffuse pattern, small patches of forests being progressively degraded. The main causes of this deforestation process are connected to migratory agriculture, especially in the hillsides of the Amazon region

These images do not cover important deforestation hot spots: what could be deforested is already deforested, and the remaining natural areas are not suitable for agriculture. Neighbouring areas (located inside path 006 and row 067) could present more deforestation since they are areas of colonisation of the Amazon piedmont.

Annex 1

Geocoded image information

Huanay (Path 006, Row 068, Quarter 2)

Maps Used for Georeferencing

IGN. 1998. La Oroya, Hoja 24-l, Junín-Peru, Topographic map, Scale 1: 100 000. Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1998. Tarma, Hoja 23-l, Junín-Peru, Topographic map, Scale 1: 100 000. Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1999. Huancavelica, Hoja 26-n, Huancavelica-Peru, Topographic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1992. Satipo, Hoja 1948(23-n), Satipo-Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1999. La Merced, Hoja 1848(23-m), La Merced-Peru, Topographic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1999. Andamarca, Hoja 1947(24-n), Andamarca-Peru, Topographic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1994. Jauja, Hoja 24-m, Junín-Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1996. Quiteni, Hoja 2047(24-ñ), Quiteni-Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1996. Canaíre, Hoja 2046(25-ñ), Canaíre-Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1998. Huancayo, Hoja 25-m, Junín-Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1994. Yauyos, Hoja 25-l, Lima, Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1995. Pampas, Hoja 25-n, Huancavelica-Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

IGN. 1999. Tupe, Hoja 26-l, Lima, Peru, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J631, edition 1. Lima, Peru.

Geocoded image information

Landsat TM image, Quarter 2
Path 006 Row 068
Date 20/04/92
Image name: **00606892042OQ2geo.lan**

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

Number of columns	4025
Number of lines	4071

Reference projection	UTM 18 L WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	419005	8770110	75.7417 W	11.1248 S
Lower right corner	539775	8647980	74.6344 W	12.2300 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	2.6
Number of GCP	25

Geocoded image information

Landsat TM image, Quarter 2
Path 006 Row 068
Date 16/10/96
Image name: **006068961016Q2geo.lan**

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

Number of columns	4025
Number of lines	4018

Reference projection	UTM 18 L WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	419005	8770110	75.7417 W	11.1248 S
Lower right corner	539775	8649570	74.6345 W	12.2156 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	0.5
Number of GCP	20

Annex 2

False colour composites

Huanay (Path 006, Row 068, Quarter 2)

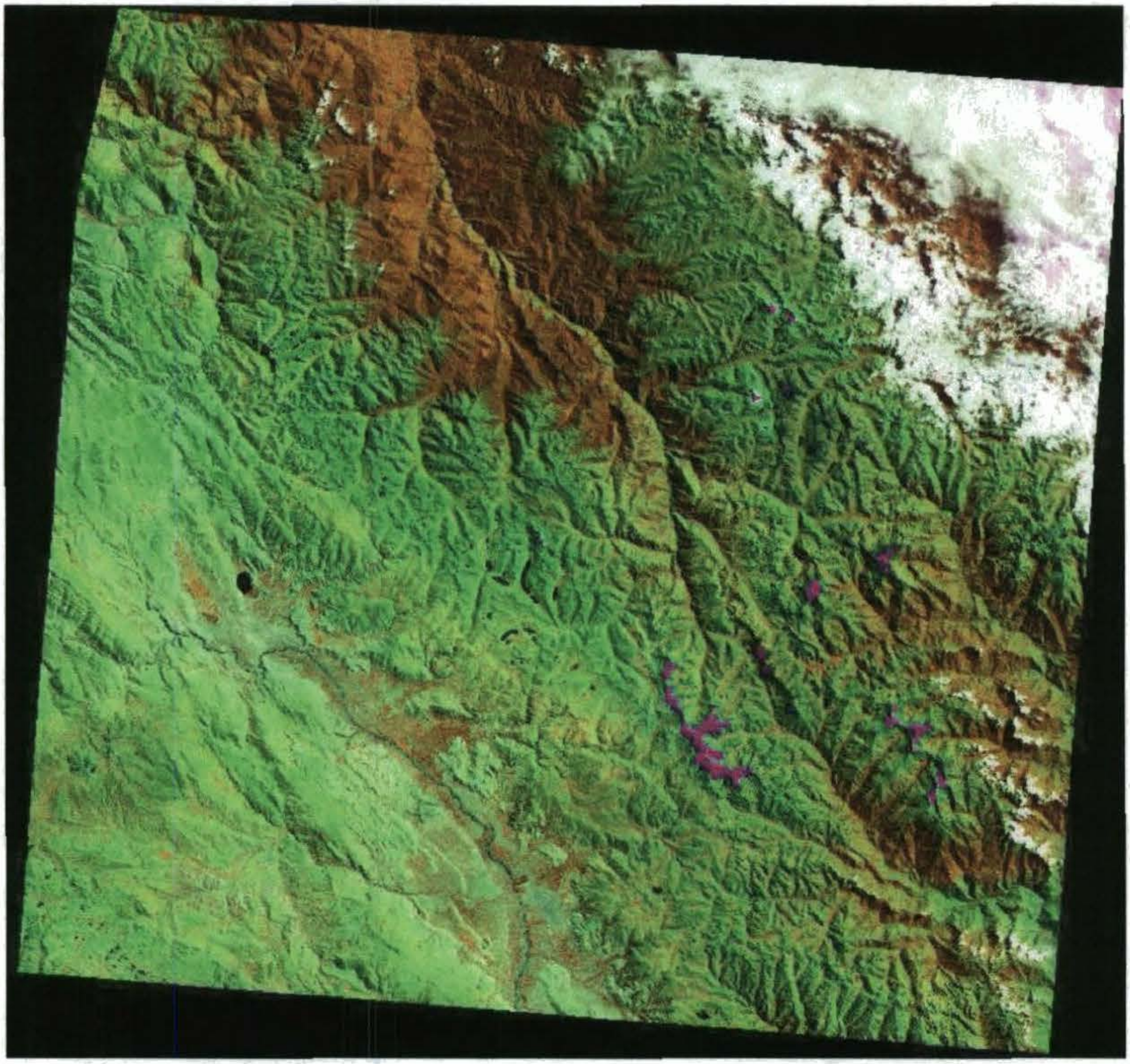


Figure 1. Landsat TM satellite image, bands 4, 5, 3, path 006, row 068, quarter 2, date 20-04-92. Upper left corner 75.7417 W, 11.1248 S, Lower right corner 74.6344 W, 12.23 S.

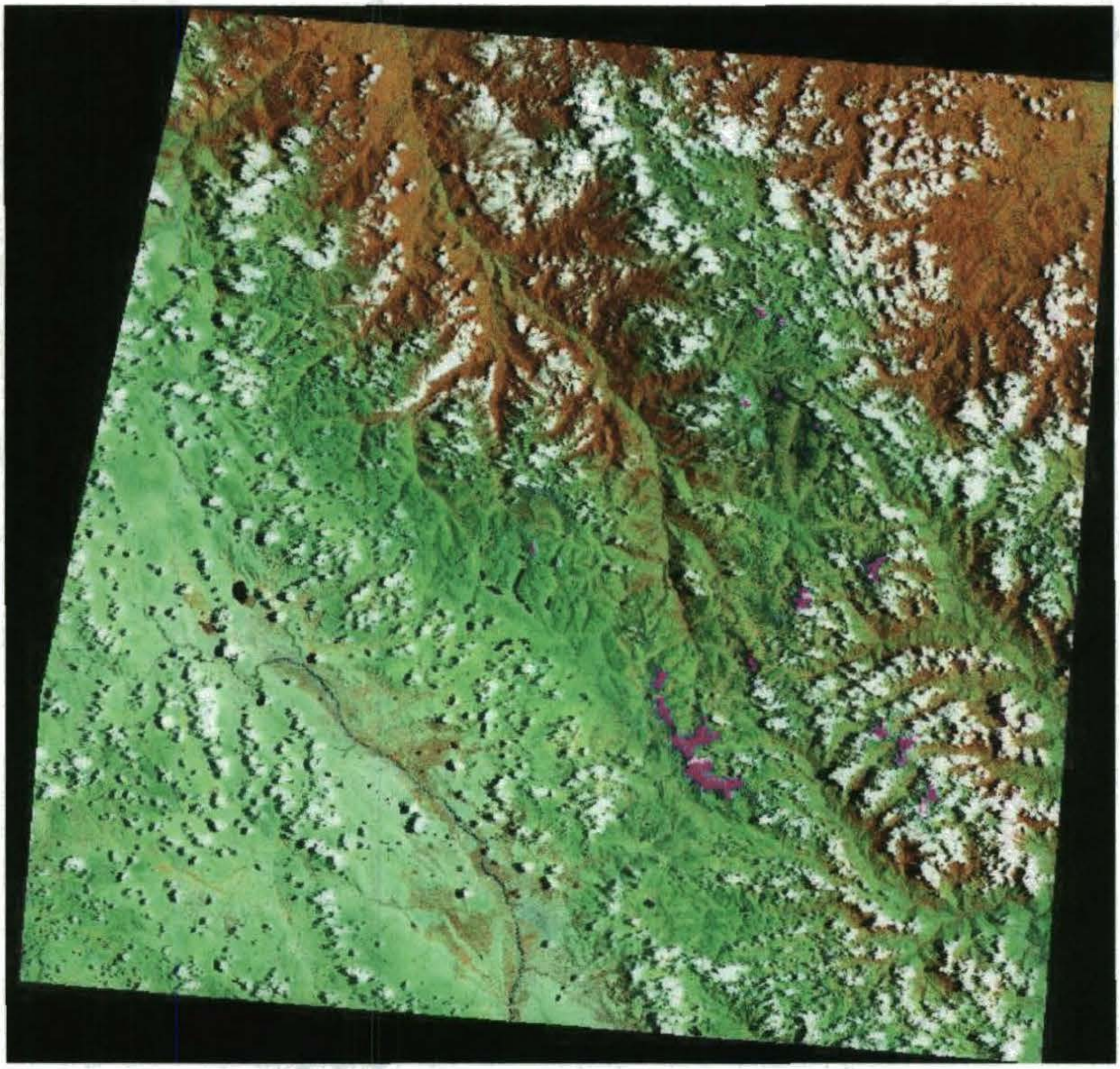


Figure 2. Landsat TM satellite image, bands 4, 5, 3, path 006, row 068, quarter 2, date 16-10-96. Upper left corner 75.7417 W, 11.1248 S, Lower right corner 74.6345 W, 12.2156 S.

Annex 3

Land use / Land cover change
(Overlap area)

Huanay (Path 006, Row 068, Quarter 2)

Land use / Land cover present in 1992 image

Huanay (Path 006, Row 068; per_ciat_hua_92_ cds.xls)

Code	Description
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane Forest
150C	Open Unknown Plantation
22	Cropland & Forest
23	Other Vegetation & Forest
310	Unknown Wood & Shrubland
313	Shrub savannah
319	Other Wood & Shrubland
322	Swamp Grassland
329	Other Grassland
44	Small holding
51	Urban
54	Bare soil
59	Other Non-Vegetated
621	Natural Lake
81	Cloud
82	Shadow

Land use / Land cover present in 1996 image

Huanay (Path 006, Row 068; per_ciat_hua_96_cds.xls)

Code	Description
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane Forest
150C	Open Unknown Plantation
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 savannah
319	Other Wood & Shrubland
322	Swamp Grassland
329	Other Grassland
44	Small holding
51	Urban
54	Bare soil
59	Other Non-Vegetated
621	Natural Lake
81	Cloud
82	Shadow

Statistics for 1992 image

Huanay (Path 006, Row 068; per_ciat_hua_92_sts.xls)

Code 92	No. Polygons	Total Area	Mean Area	S. D. Area
112A	1	4565	4565	0
112B	26	113313	4358	18916
112C	9	10397	1155	1371
112D	6	1302	217	175
150C	1	79	79	0
22	1	16561	16561	0
23	8	1880	235	214
310	3	2743	914	712
313	2	23875	11937	437
319	49	67627	1380	3400
322	2	258	129	13
329	17	716880	42169	169164
44	11	69239	6294	17507
51	3	2577	859	1292
54	10	10874	1087	2159
59	13	4356	335	627
621	21	1758	84	68
81	25	138199	5528	25740
82	17	2771	163	136

Statistics for 1996 image

Huanay (Path 006, Row 068; per_ciat_hua_96_sts.xls)

Code 96	No. Polygons	Total Area	Mean Area	S. D. Area
112A	1	4059	4059	0
112B	37	113297	3062	6948
112C	14	10657	761	1012
112D	8	6825	853	1037
150C	1	79	79	0
211	1	406	406	0
212	5	1386	277	264
22	1	16400	16400	0
23	10	25005	2500	7399
310	2	2854	1427	438
313	3	21547	7182	5638
319	61	54405	892	1810
322	2	258	129	13
329	85	540191	6355	53188
44	15	68070	4538	14011
51	4	2732	683	1112
54	10	10416	1042	2153
59	14	3988	285	373
621	15	1304	87	75
81	324	266841	824	1893
82	335	38534	115	98

Land use change for 1992 and 1996 images

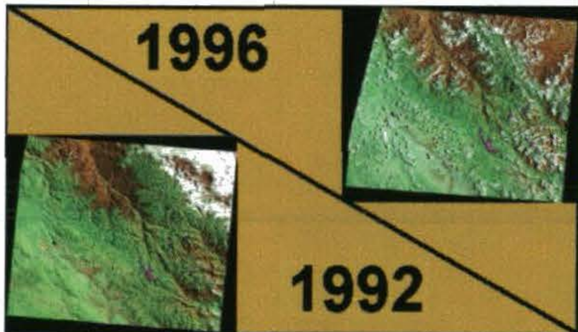
Huanay (Path 006, Row 068; per_ciat_hua_chg.xls)
Images: **00606892042OQ2geo.lan** **006068961016Q2geo.lan**

No. Polygons	Code 92	Code 96	Total Area
1	112A	112A	4059
1	112A	112B	257
2	112A	81	249
44	112B	112B	72562
5	112B	112C	693
1	112B	112D	631
1	112B	211	406
4	112B	212	664
57	112B	81	35301
29	112B	82	2683
9	112C	112C	9349
2	112C	81	491
6	112C	82	930
4	112D	112D	783
2	112D	81	519
1	150C	150C	79
1	22	22	16400
2	22	81	111
1	22	82	50
1	23	212	722
7	23	23	1158
3	310	310	2743
3	313	313	21547
13	313	81	2109
4	313	82	218
78	319	319	52950
70	319	81	11262
37	319	82	3335
2	322	322	258
80	329	329	533035
2	329	44	126

No. Polygons	Code 92	Code 96	Total Area
1	329	59	181
273	329	81	159913
213	329	82	23779
1	44	310	111
13	44	44	66051
14	44	81	1791
18	44	82	1210
3	51	51	2577
10	54	54	10416
4	54	81	458
14	59	59	3807
7	59	81	549
15	621	621	1304
6	621	81	398
2	621	82	56
27	81	112B	40391
3	81	112C	615
3	81	112D	4938
3	81	23	23847
11	81	319	1287
31	81	329	6925
2	81	44	1892
1	81	51	155
82	81	81	52543
72	81	82	5605
2	82	112B	129
1	82	112D	473
2	82	319	168
4	82	329	231
13	82	81	1102
7	82	82	667

Land use change matrix

Huanay (Path 006, Row 068; per_ciat_hua_mtx.xls)



1992 \ 1996	Forest – Evergreen & Semi-evergreen – Evergreen-Montane Forest – Closed High Density	Forest – Closed Medium Density	Forest – Open	Forest – Fragmented	Forest – Plantation – Unknown – Open	Mosaic – Shifting Cultivation – less than 1/3 cropping	Mosaic – Shifting Cultivation – more than 1/3 cropping	Mosaic – Cropland & Forest	Mosaic – Other vegetation & Forest	Non-forest Vegetation – Wood & Shrubland – Unknown	Non-forest Vegetation – Wood & Shrubland – Shrub savannah	Non-forest Vegetation – Wood & Shrubland – Other	Non-forest Vegetation – Grassland – Swamp grassland	Non-forest Vegetation – Grassland – Other	Agriculture – Small holdings	Non-Vegetated – Urban	Non-Vegetated – Bare soil	Non-Vegetated – Other	Water – Lake – Natural	Not Visible – Cloud	Not Visible – Shadow	Total
Forest – Evergreen & Semi-evergreen – Evergreen-Montane Forest – Closed High Density	4059	257																		249		4565
Forest – Evergreen & Semi-evergreen – Evergreen-Montane Forest – Closed Medium Density		72562	693	631		406	664													35301	2603	112940
Forest – Evergreen & Semi-evergreen – Evergreen-Montane Forest – Open			9349																	491	930	10770
Forest – Evergreen & Semi-evergreen – Evergreen-Montane Forest – Fragmented				783																519		1302
Forest – Plantation – Unknown – Open					79																	79
Mosaic – Cropland & Forest								16400												111	50	16561
Mosaic – Other Vegetation & Forest							722		1158													1880
Non-forest Vegetation – Wood & Shrubland – Unknown										2743												2743
Non-forest Vegetation – Wood & Shrubland – Shrub savannah											21547									2109	218	23874
Non-forest Vegetation – Wood & Shrubland – Other												52950								11262	3335	67547
Non-forest Vegetation – Grassland – Swamp Grassland													258									258
Non-forest Vegetation – Grassland – Other														533035	126			181		159913	23779	717034
Agriculture – Small holding										111					66051					1791	1210	69163
Non-Vegetated – Urban																2577						2577
Non-Vegetated – Bare soil																	10416			458		10874
Non-Vegetated – Other																		3807		549		4356
Water – Lake – Natural																			1304	398	56	1758
Not Visible – Clouds		40391	615	4938					23847			1287		6925	1892	155				52543	5605	130198
Not Visible – Shadow		129		473								168		231						1102	667	2770
Total	4059	113339	10657	6825	79	406	1386	16400	25005	2854	21547	54405	258	540191	68069	2732	10416	3988	1304	266796	30533	1089249

Forest | Mosaic | Non-forest | Non-vegetated | Not visible

Forest changes | Other changes | Agriculture | 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 finalised according to the recommendations of TREES advisor, Otto Huber.

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

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

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

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

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

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

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

Nivel 1	Nivel 2	Nivel 3	Nivel 4
1 Bosque, mayor a 10% de coberturas de copas y mas del 40 % de cobertura forestal			
	1 Bosque siempre verde y semi siempre verde	0 Indefinido	A Cerrado alta densidad mas del 90% cobertura forestal
		1 Bosque siempre verde de tierras bajas (Selva Tropical)	
		2 Bosque siempre verde de montaña (Bosque montano o nublado)	B Cerrado media densidad 70-90% cobertura forestal
		3 Bosque semi siempreverde	
		4 Bosque de turba amazonica (Catinga)	C Abierto 60- 70% cobertura forestal
		5 Bosques de pinos	
		6 Bambú	D Fragmentado 40-60% cobertura forestal
		9 Otro	
	2 Bosque deciduo	0 Indefinido	
		1 Bosque seco denso (Africa)	
		2 Miombo (Africa)	
		3 Bosque seco de especies mixtas (Asia)	
		4 Bosque seco de Dipterocarpaceas (Asia)	
		9 Otro	
	3 Bosque inundado	0 Indefinido	
		1 Periodicamente inundado	
		2 Permanenternente 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

	Land Area (000 ha)	Forest Area							
		Total Forest			Natural Forest			Plantations {a}	
		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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