Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Tingo María – Peru

(Path 007, Row 066, Full Scene)

Joint Research Centre (JRC)

and

CIAT

Technical Report

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

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

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

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

This report involves the study of an area located in the Central Peruvian Andes. The Instituto de Investigación de la Amazonía Peruana (IIAP) was responsible of the interpretation and analysis of 4 scenes covering the Peruvian Amazon and part of the surrounding mountain areas (see Figure 1). CIAT has put the final touches to the coverages and final reports.

Deforestation Patterns in South America

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

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

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

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

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

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

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

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

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

Deforestation in the TREES study area processed by IIAP.

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

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

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

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

This geographical space has a population of about 1 323 496 distributed in areas adjacent to the road axes, with the city of Pucallpa and towns of Aguaytía, Tingo María, Tocache, Huánuco, Cerro de Pasco and Oxapampa prominent, connecting up a rural population mainly located in the diverse valleys. In the case of the Nanay River area, the population is very scant and is connected with the town of Iquitos by means of the waterway.

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

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

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

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

STUDY AREA: TINGO MARÍA

The study site is located over areas of high terraces and hills, as well as a mountainous sector on the eastern side of the Andes. It spans the tropical moist forest, tropical premontane wet forest and tropical premontane rainforest life zones, with tropical forest as the predominant vegetation.

It is connected with the city of Pucallpa and with Tingo María by the Federico Basadre highway. The Aguaytía River complements the transport network of the area.

This area has 42 000 inhabitants (1996), with an average density of five inhabitants per square kilometre. It shows a relatively high population growth rate of 10% between 1981 and 1993, significantly higher than the one registered in the period 1972 to 1981 (2.6%). This tendency in the rate of population growth is explained fundamentally by the high level of fecundity and by the effect of immigration.

Most of the population is rural and poor (55.7%). The urban population concentrates in the town of Aguaytía and in small urban centres such as San Alejandro, Neshuya and Curimaná. The landscape shows intervention in the areas of influence of the road network, where subsistence agriculture prevails. The rest of this area is covered with vegetation remaining after forestry activities.

Based on results from the analysis of the 1997 satellite images, of the total area covered by the studied image, 1 698 332 hectares (75%) were covered by natural vegetation, with little human activity (as deforestation), 9.1% corresponded to areas where migratory agriculture predominated and 9.0% was pasture associated with small regeneration areas and migratory agriculture crops. The deforested areas are located mainly in areas adjacent to the Federico Basadre highway and along the banks of the Aguaytia River.

During the study period (1989 - 1997) 70 878 hectares of forest were deforested for agricultural ends. The average annual rate of intervention in this period was 0.52% (8859 hectares of primary forest affected per year).

This area is a known deforestation front. With respect to agriculture, plantain cultivation prevails (6484 hectares harvested), followed by rice (2115 ha), cassava (1858 ha), maize (1715 ha), cotton (1430 ha) and palm oil (1062 ha).

The deforestation pattern is mostly massive. A lineal pattern can be observed especially along both the axes of some secondary highways and the axis of the natural gas line and of the electric power network. In some areas, especially in the less accessible mountainous area, a mosaic-type deforestation pattern is present, related with the illegal cultivation of coca.

The causes of deforestation are mainly migratory agriculture, small-scale commercial agriculture, cultivation of coca and natural gas exploitation. The most significant causal agents are the migrant population, and forces determining this deforestation process include the illicit coca productionc and the subsistence economy.

METHODOLOGY

Materials

For this work we used the full scene of two Landsat TM5 images of the path 007, row 066 (007066890724fsgeo.img and 007066970908fsgeo.img). The radiometric quality of the image data was good, although both images presented important cloud cover over all part of the tropical montane cloud forest (with respective shading).

Land use was interpreted based on quick field surveys to collect GPS coordinates, photographs and videotapes. In addition we used a reference forest map at a 1:1 000 000 scale (MAG-INRENA, 1995), a land-use capacity map at a 1:1 000 000 scale (ONERN, 1981), a planimetric map from satellite image at a 1:250 000 scale (IFG, 1984), an ecological map at a 1:1 000 000 scale (INRENA, 1995), a deforestation map in the influence area of highway Federico Basadre at a 1:250 000 scale (CRP-IIAP, 1995), a vegetation types map in Aguaytia watershed at a 1:250 000 scale (CTARU-IIAP, 1995) and a forest zoning map of Huánuco department (INRENA 1997).

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 ERDAS Imagine version 8.2. Geographic reference information was extracted from topographical maps and associated to the image of the first date as ground control points. In the case of the second image, the georeferencing process used as a reference the product obtained from georeferencing the first image (first date). The Instituto Geográfico Nacional (IGN) of Peru produced the topographical maps to a scale of 1:100 000 that were used for georeferencing. Annex 1 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 2 and 3, in Annex 2, give an overview of the study area in both images after the georeferencing process.

Land uses and land cover digitising

Boundaries of Land use and land cover areas were digitised (as lines) and coded (as points) on printed images backed by on-screen visualisation over the Landsat TM 4,5,3 color composite (histogram equalized), displayed at 1:100 000 scale, of the earlier date image. This process was completed using ERDAS Imagine 8.2 and ArcView 3.1, considering a minimum mapping unit of 50 ha and 300 m width for linear features. All distinguishing characteristics were digitised and associated to a specific class code established by TREES (see annex 3).

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

Because we didn't see any clear demarcation between montane and lowland evergreen forest, all the evergreen non-inundated forest, starting from the amazon plain to the upper part of the Andes mountain range, was classified as evergreen lowland forest. We suggest to use a DEM to establish the limit between the two forest types.

Building polygons

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

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

The intersection coverage was submitted to a final edition process in ArcView 3.1, using the imagery for both dates as background. In this step remaining codes errors and inconsistencies, as well as remaining digitising errors, were corrected on the intersection coverage. For example, we could find polygons that went from young regeneration to primary forest, which is impossible in a period of 4 years.

Final coverages for the overlapping area from both dates were produced from the corrected intersection coverage using the DISSOLVE command of ARC/INFO. These were used to generate the statistics reported in annex 3. To comply with the contract requirements, the coverages for the total area covered by each image were obtained by merging (compatibilising codes and borders) the ones produced by DISSOLVE with the original ones (i.e. before intersection).

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

Interpretation of changes

Based on results from the analysis of the 1997 satellite images, of the total area covered by the studied image without clouds (later referred to as overlap area), 2 080 407 hectares (80.8%) were covered by natural forest, with little human intervention, 2.4% corresponded to areas where is possible distinguish human activities, like urban area, migratory agriculture, pasture associated with small regeneration areas and agriculture. The water bodies and *Jalca*, a typical vegetal formation of grassland developing in the upper part of the Peruvian Mountains, each covered less to 0.5% of the area.

During the study period (1989 - 1997) 49 618 hectares of forest were cut for agricultural ends. The average annual rate of intervention in this period was 0.3% (6 202 hectares of primary forest per year), while the annual rate of recuperation of forest was 0.38% (7 947 hectares per year). The principal area of recuperation of forest is located in the valley of the Hullaga river.

CONCLUSION

This conclusion addresses the results obtained for the 4 scenes processed by IIAP. The values for intervened areas are given for each of the departments covered by the satellite imagery, which can be compared to values obtained from independent studies (see Figure 1). Note that % figures by department are computed with respect to the area of the imagery overlapping departments, not with respect to the forest area, so these figures cannot be exactly compared to other deforestation figures. In general terms, during the study period (1989 -1998), the annual average of intervened area is reported as 21 504.54 hectares (deforested area including forest remnants within the farmers' plots), which represents an annual average rate of intervention of 0.34%. This rate varies according to area, being relatively higher in Pucallpa (0.7%), Aguaytia (0.5%), Oxapampa (0.7%) and Huánuco (0.5%), while Nanay (<0.1%) and Cerro de Pasco (0.1%) have a much lower rate. The areas of Tocache (0.29%) and Tingo María show intermediate rates.

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

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

Also intervening in this decreasing tendency is the impact of the policy of control and eradication of coca. According to USAID (1997) reports, during the period 1990 – 1997 the cultivated area of coca leaf in the Amazon significantly decreased from 121 300 to 69 000 hectares because of operations to eradicate plantations and nurseries of coca and because of the interdiction of the Illicit Traffic of Drugs. Another factor that has impacted on the decreasing area planted to coca has been the fall in price per kilogram of coca leaf, in 1991 registered at US$1.73 and in 1997 falling to US$0.61. USAID identified areas of greater coca production in Tingo María, Aguyatía and Tocache, within the study area.

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

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

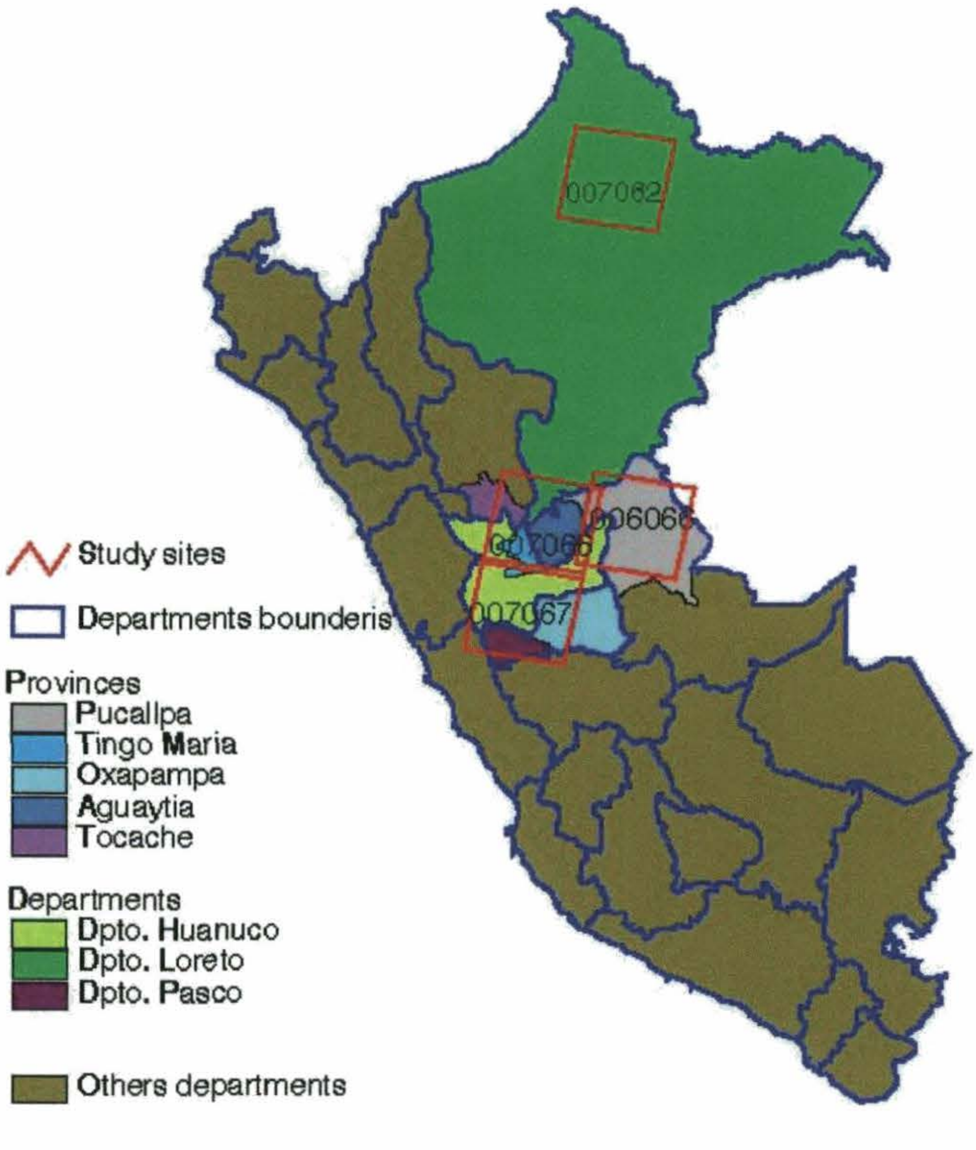


Figure 1: Provinces and Departments of Peru covered by the satellite images..

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

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

Annex 1

Geocoded image information

Huánuco (Path 007, Row 066, Full Scene)

Maps Used for Georeferencing

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

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

Geocoded image information

Landsat TM image, Full Scene
Path 007 Row 066
Date 24/07/89
Image Name: **007066890724fsgeo.img**

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

Number of columns	7443
Number of lines	6944

Reference projection	UTM 18 S WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	306251	9145434	76.7568 W	7.7274 S
Lower right corner	529511	8937144	74.7310 W	9.6150 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	0.9
Number of GCP	20

Geocoded image information

Landsat TM 5 image, Full Scene
Path 007 Row 066
Date 97/09/08
Image Name: **007066970908fsgeo.img**

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

Number of columns	7480
Number of lines	7053

Reference projection	UTM 18 S WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	311158	9145212	76.7123 W	7.7296 S
Lower right corner	535528	8933652	74.6762 W	9.6465 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	0.9
Number of GCP	20

Annex 2

False color composites

Huánuco (Path 007, Row 066, Full Scene)

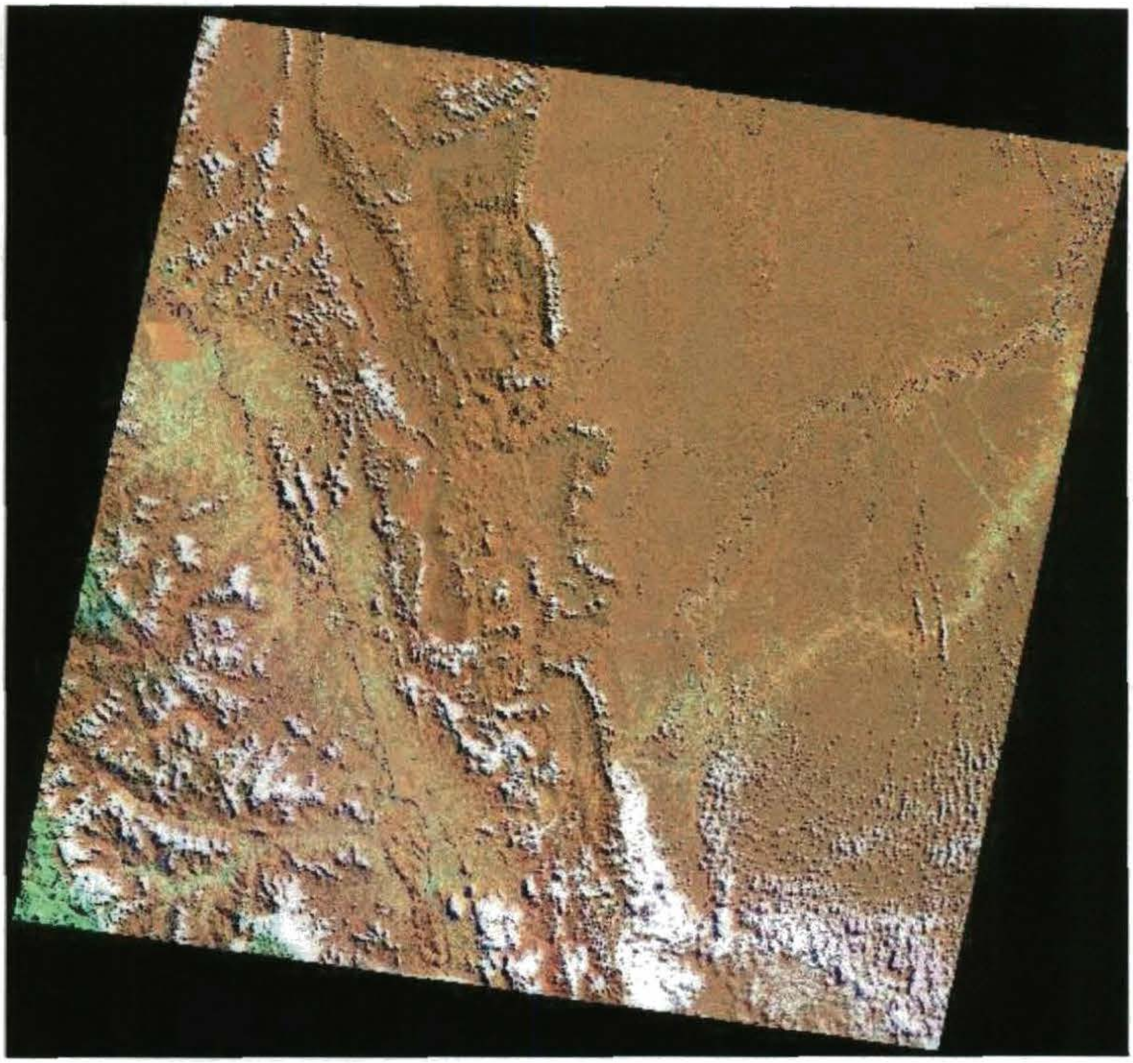


Figure 2. Landsat TM5 satellite image, bands 4,5,3, path 007, row 066, full scene, date 24-07-89. Upper left corner 76.7568 W, 7.7274 S, Lower right corner 74.7310 W, 9.6150 S.

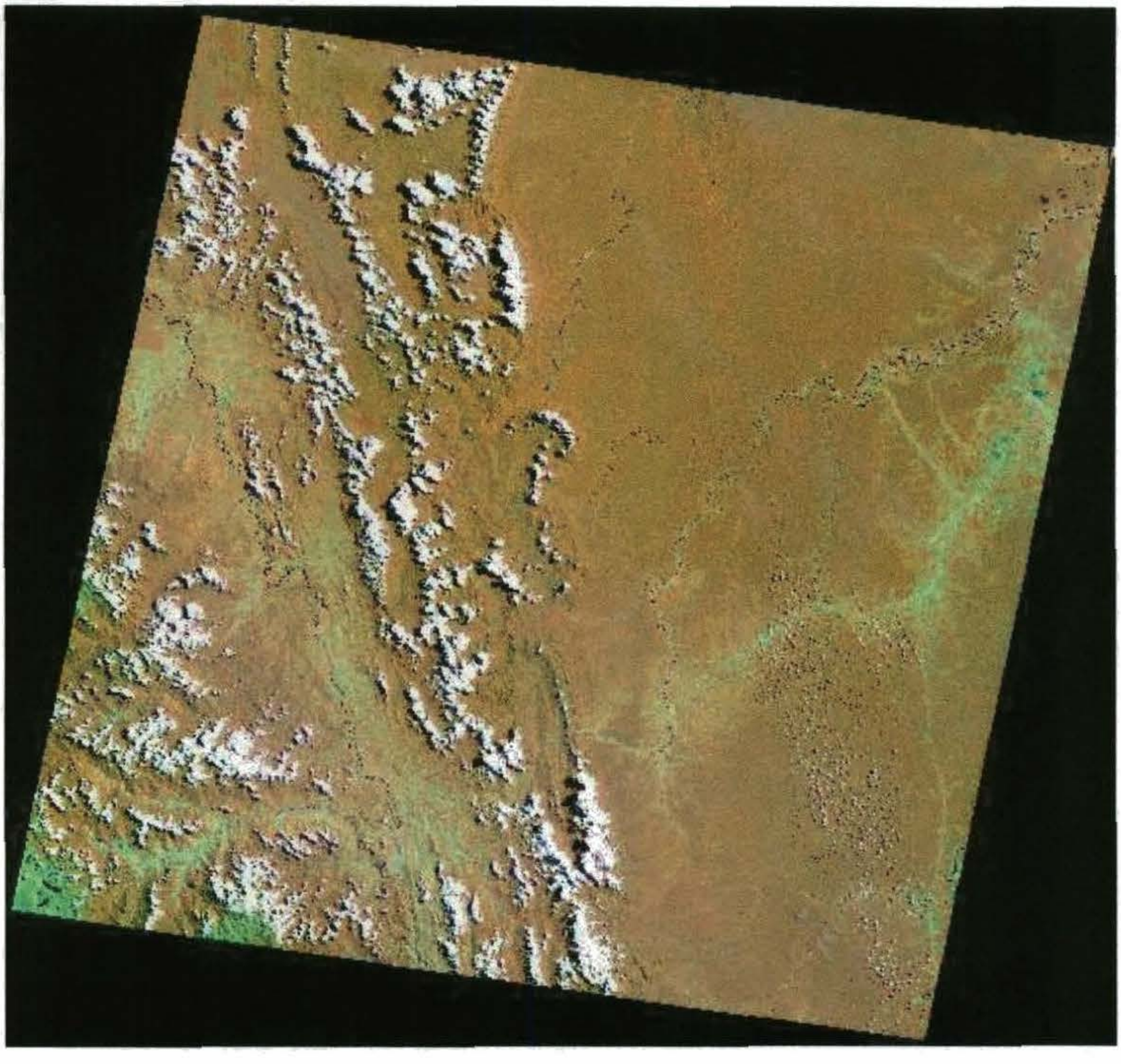


Figure 3. Landsat TM5 satellite image, bands 4,5,3, path 007, row 066, full scene, date 08-09-97. Upper left corner 76.7123 W, 7.7296 S, Lower right corner 74.6762 W, 9.6465 S.

Annex 3

Land use / Land cover change
(Overlap area)

Tingo María (Path 007, Row 066, Full Scene)

Land use / Land cover present in 1989 image

Tingo María (Path 007, Row 066; per_ciat_tma_89_ cds.xls)

Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111C	Open Lowland Forest
111D	Fragmented Lowland Forest
131B	Closed Medium Density Periodically inundated forest
131C	Open Periodically inundated forest
131D	Fragmented Periodically inundated forest
132B	Closed Medium Density Swamp Forest
132C	Open Swamp Forest
210	Mosaic of Shifting Cultivation & forest Undefined
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
329	Other Grassland
422	Oil Palm Plantations
43	Ranching
44	Small holding
49	Other Agriculture
51	Urban
61	River
621	Natural Lake
81	Cloud
82	Shadow

Land use / Land cover present in 1997 image

Tingo María (Path 007, Row 066; per_ciat_tma_97_ cds.xls)

Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111C	Open Lowland Forest
111D	Fragmented Lowland Forest
131B	Closed Medium Density Periodically Inundated Forest
131C	Open Periodically Inundated Forest
131D	Fragmented Periodically Inundated Forest
132B	Closed Medium Density Swamp Forest
132C	Open Swamp Forest
132D	Fragmented Swamp Forest
210	Mosaic of Shifting Cultivation & forest Undefined
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
329	Other Grassland
420	Unknown Plantations
422	Oil Palm Plantations
43	Ranching
44	Small holding
49	Other Agriculture
51	Urban
531	Mine Infrastructure
61	River
621	Natural Lake
81	Cloud
82	Shadow

Statistics for 1989 image

Tingo María (Path 007, Row 066; per_ciat_tma_89_sts.xls

Code 89	No. Polygons	Total Area	Mean Area	S. D. Area
111A	41	2074519	50598	250864
111B	84	64197	764	2232
111C	52	14162	272	360
111D	86	37880	440	609
131B	14	11147	796	1918
131C	33	63850	1935	4812
131D	49	11921	243	599
132B	11	10585	962	1118
132C	5	4245	849	1476
210	17	9876	581	581
211	92	56049	609	1328
212	55	113362	2061	4896
22	147	160379	1091	3379
23	88	132483	1505	6813
329	12	13466	1122	2248
422	3	4626	1542	1858
43	11	4147	377	339
44	35	2938	84	84
49	3	2633	878	719
51	4	614	154	85
61	56	12983	232	244
621	18	1773	99	82
81	713	335584	471	2202
82	798	118145	148	434

Statistics for 1997 image

Tingo María (Path 007, Row 066; per_ciat_tma_97_sts.xls)

Code 97	No. Polygons	Total Area	Mean Area	S. D. Area
111A	42	2027119.11	48264.74	218705.73
111B	65	73958.35	1137.82	3540.80
111C	70	26284.62	375.49	668.10
111D	214	104239.99	487.10	1126.22
131B	12	11039.02	919.92	1851.57
131C	37	50225.60	1357.45	4562.85
131D	47	40109.67	853.40	1540.58
132B	12	10471.33	872.61	1099.65
132C	4	3787.79	946.95	1506.66
132D	2	732.80	366.40	419.06
210	17	14755.26	867.96	1935.74
211	66	29363.64	444.90	677.26
212	97	152361.31	1570.74	5280.77
22	128	122876.11	959.97	3616.31
23	76	119332.20	1570.16	6273.32
329	12	18674.59	1556.22	3067.85
420	1	266.52	266.52	0.00
422	5	18056.27	3611.25	7316.49
43	7	4624.64	660.66	706.52
44	28	3040.68	108.60	113.15
49	34	32276.34	949.30	2976.50
51	4	614.27	153.57	84.77
531	1	35.64	35.64	0.00
61	56	13334.54	238.12	520.09
621	16	1625.23	101.58	86.77
81	431	267161.41	619.86	1730.81
82	577	115195.97	199.65	280.73

Land use change for 1989 and 1997 images

Tingo María (Path 007, Row 066; per_ciat_tma_chg_sts.xls)
Images: 007066890724FSgeo.lan 007066890724FSgeo.lan

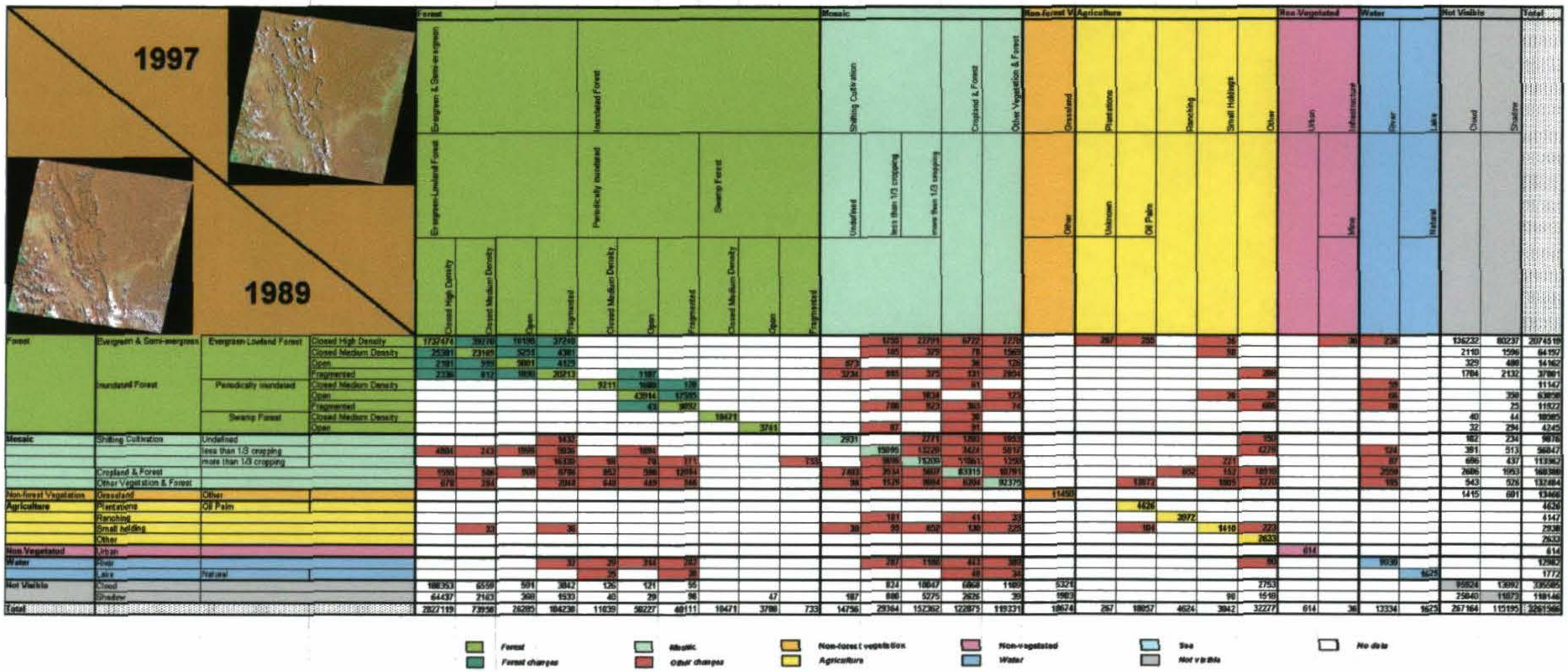
No. Polygons	Code 89	Code 97	Total Area
91	111A	111A	1737474
37	111A	111B	39270
21	111A	111C	10198
93	111A	111D	37240
5	111A	211	1255
14	111A	212	22791
15	111A	22	6722
4	111A	23	2270
1	111A	420	267
3	111A	422	255
1	111A	44	36
1	111A	531	36
3	111A	61	236
461	111A	81	136232
454	111A	82	80237
47	111B	111A	25381
28	111B	111B	23169
11	111B	111C	5251
14	111B	111D	4381
3	111B	211	185
2	111B	212	379
2	111B	22	78
2	111B	23	1569
2	111B	44	98
20	111B	81	2110
15	111B	82	1596
8	111C	111A	2101
1	111C	111B	999
20	111C	111C	5081
16	111C	111D	4129
2	111C	210	873
1	111C	22	36
1	111C	23	126
6	111C	81	329
8	111C	82	488
8	111D	111A	2336
1	111D	111B	812
5	111D	111C	1890
51	111D	111D	20213
2	111D	131C	1107
5	111D	210	3234
4	111D	211	885
2	111D	212	375
1	111D	22	131
3	111D	23	2854
1	111D	49	208
20	111D	81	1704
20	111D	82	2132
8	131B	131B	9211
6	131B	131C	1688
2	131B	131D	128
1	131B	22	61
2	131B	61	59
28	131C	131C	43914
18	131C	131D	17506
3	131C	212	1834
2	131C	23	123
1	131C	44	30
1	131C	49	28
1	131C	61	66
3	131C	82	350
1	131D	131C	43
37	131D	131D	9092
3	131D	211	708
5	131D	212	923
3	131D	22	363
1	131D	23	74
1	131D	49	606
2	131D	61	88
1	131D	82	25
12	132B	132B	10471
1	132B	22	30

No. Polygons	Code 89	Code 97	Total Area
1	132B	81	40
1	132B	82	44
4	132C	132C	3741
1	132C	211	87
1	132C	22	91
1	132C	81	32
1	132C	82	294
1	210	111D	1432
6	210	210	2931
4	210	212	2771
3	210	22	1203
2	210	23	1053
1	210	49	150
2	210	81	102
1	210	82	234
4	211	111A	4804
1	211	111B	243
3	211	111C	1998
17	211	111D	5036
2	211	131C	1894
30	211	211	15095
20	211	212	13229
13	211	22	3424
5	211	23	5017
3	211	49	4279
3	211	61	124
6	211	81	391
7	211	82	513
3	212	111D	16330
1	212	131B	98
1	212	131C	70
2	212	131D	271
2	212	132D	733
5	212	211	3899
35	212	212	78209
7	212	22	11061
1	212	23	1250
2	212	44	221
3	212	61	87
11	212	81	696
7	212	82	437
16	22	111A	1555
4	22	111B	506
2	22	111C	908
14	22	111D	8786
1	22	131B	852
1	22	131C	598
5	22	131D	12084
2	22	210	7403
6	22	211	3534
17	22	212	5607
65	22	22	83315
29	22	23	10791
2	22	43	652
2	22	44	152
9	22	49	16519
9	22	61	2559
25	22	81	2606
15	22	82	1953
3	23	111A	678
1	23	111B	204
5	23	111D	2048
1	23	131B	648
3	23	131C	449
4	23	131D	566
1	23	210	98
5	23	211	1529
15	23	212	9084
24	23	22	6204
32	23	23	92375
2	23	422	13072
8	23	44	1005

No. Polygons	Code 87	Code 97	Total Area
8	23	49	3270
4	23	61	185
6	23	81	543
9	23	82	526
11	329	329	11450
13	329	81	1415
8	329	82	601
3	422	422	4626
1	43	211	101
1	43	22	41
1	43	23	33
8	43	43	3972
1	44	111B	33
1	44	111D	36
1	44	210	30
2	44	211	95
7	44	212	652
4	44	22	130
4	44	23	225
1	44	422	104
13	44	44	1410
3	44	49	223
3	49	49	2633
4	51	51	614
1	61	111D	32
1	61	131B	29
4	61	131C	314
3	61	131D	282
5	61	211	287
12	61	212	1186
9	61	22	443
3	61	23	389
2	61	49	90
53	61	61	9930
1	621	131B	35
1	621	131D	30
1	621	22	48
1	621	23	34
16	621	621	1625
583	81	111A	188353
30	81	111B	6559
7	81	111C	591
35	81	111D	3042
1	81	131B	126
2	81	131C	121
1	81	131D	55
8	81	211	824
61	81	212	10047
47	81	22	6868
6	81	23	1109
21	81	329	5321
18	81	49	2753
440	81	81	95924
166	81	82	13892
447	82	111A	64437
21	82	111B	2163
5	82	111C	368
27	82	111D	1533
1	82	131B	40
1	82	131C	29
2	82	131D	98
1	82	132C	47
3	82	210	187
11	82	211	880
69	82	212	6275
33	82	22	2626
1	82	23	39
17	82	329	1903
1	82	44	90
15	82	49	1518
315	82	81	25040
183	82	82	11873

Land use change matrix

Tingo María (Path 007, Row 066; per_ciat_tma_mtx.xls)



Annex 4

Land use interpretation key

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

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

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

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

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

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

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

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

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