Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Huánuco – Peru

(Path 007, Row 067, Full Scene)

Joint Research Centre (JRC)

and

CIAT

Technical Report

Javier Puig, Gregoire Leclerc, Carlos Nagles, Alexander Cuero, Rafael D. Hoyos, Fernando Rodríguez, Leon Bendayán, José Sanjurjo

March 2000

CGIAR Consultative Group on International Agricultural Research

TABLE OF CONTENTS

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

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

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

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

This report involves the study of an area located in the 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 (see Figure 1). It is located approximately between 3° to 11° S and 74° to 77° W.

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

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

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

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

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

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

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

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

STUDY AREA: HUANUCO

Politically, the study area covers a large part of the departments of Huánuco and Pasco. The study site is located at the source of the Huallaga River, in a natural region of dry low forest and agricultural land, on the eastern slopes of the Andes. The relief is mountainous, crossed by narrow valleys. In addition, a great proportion of the study area is located in the highest part of the Andes, with natural extensions of jalca, scrub and agricultural land, within a landscape of steep mountains and small high Andean plateaus.

An important road network crosses this area, interconnecting Lima with Huancayo and Huánuco.

In the eastern part of the image is the forefront of agricultural expansion, which connects with the rest of the country via the central highway by means of the Oxapampa-La Merced road. The total area covered is 3 248 201 hectares.

The vegetation varies from humid forest in the lower areas, to subhumid and humid brush in the intermediate areas, to steppe-type in the high Andean areas.

In the inter Andean valley one can find forest in tropical premontane thorny woodland, lower tropical montane thorny steppe, and tropical premontane dry forest life zones.

In the highest parts are of the Andean basin one finds tropical subalpine very moist paramo and tropical subalpine wet paramo life zones, where the predominant vegetation is herbaceous of steppe type and of puna grass.

To the east, moisture increases with elevation so the area shows a transition between dry lowland forest, lowland forest and montane forest. The landscape consists in wide valleys bounded by small mountain chains. In this area one can find tropical lower montane moist forest, tropical premontane wet forest and tropical montane wet forest life zones, where the predominant vegetation is tropical moist forest and steppe-type vegetation in the highest parts.

The population is distributed in areas adjacent to the road axes that connect rural populations in the valleys with the principal cities. The road network consists of a main road, part of the central highway of Peru, and many secondary roads.

Population in the three provinces that the image covers, Huánuco, Cerro de Pasco y Oxapampa, was of 1.468.832 in 1996, mostly concentrated in the cities of Huánuco, Cerro de Pasco and Oxapampa. The average population density in each province is 19.4%, 9.62% and 3.69% inhabitants per square kilometre, and the population growth rate was 2.6% between 1981 and 1993, 0.30% and 1.2% between 1981 – 1993. The district of Pozuzo registers a population growth rate relatively as high as 5.5%.

In Huánuco as Oxapamapa the population is mainly rural (61% and 68.8%), distributed in small populated centres, except in Cerro de Pasco where 59% of the population is concentrated in the capital because of the shortage of agricultural land. The population of these provinces is categorised as poor and very poor.

The production activities vary depending on the province. In Cerro de Pasco the economy depends upon mining and is supplemented by small-scale agriculture, whose surpluses are directed to the Lima market (50% of the GDP in this area corresponds to mining activities (mainly lead, zinc and silver) and only 18% to agriculture); while in Huánuco the small-scale agriculture is to cover the demand of the city of Lima. In Oxapampa we find subsistence agriculture, supplemented with the cultivation of coffee, cattle farming and wood extraction.

In the Huánuco province the economy is based on small-scale agriculture whose surpluses are directed mainly to the town of Lima. In 1997, 92.6% of the agricultural production, in terms of volume, corresponded to potato (79.5%), starchy maize (4.3%), olluco (*Ullucus tuberosus*) (4.2%) [que es eso?], wheat (2.3%) and barley (2.3%). In 1996 three crops covered over 90% of the sowed surface, i.e. potato (32 094 ha), wheat (10 030 ha) and barley (6697 ha).

Cattle farming is gaining in importance in this area; in 1997 there were 763 000 sheep, 93 000 cattle heads, 69 000 llamas and alpacas and 25 000 goats.

In Pasco, part of the natural vegetation has been converted to agricultural lands, mainly for the cultivation of potato, and in some places, in localised form, for mining activities. Natural grasses support a significant part of this livestock.

METHODOLOGY

Materials

For this work we used the full scene of two Landsat TM5 images of the path 007, row 067 (007067890724FSgeo.lan, 007067970908FSgeo.lan). The radiometric quality of the image data was good, although the first image presented important cloud cover over all part of the tropical montane cloud forest and evergreen low land forest and the second image had scattered small clouds (with respective shading) in the higher part of the eastern slope of the Andes.

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 1:250000 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 1:250000 scale (CRP-IIAP, 1995), a vegetation types map in Aguaytia watershed at a 1:250000 scale (CTARU-IIAP, 1995) and a forest zone map of Huánuco, Pasco and Junin departments (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 of ERDAS Imagine version 8.2. Geographic reference information was extracted from topographical maps and associated to the image of the first date as ground control points. In the case of the second image, the georeferencing process used as a reference the product obtained from georeferencing the first image (first date). The Instituto Geográfico Nacional (IGN) of Peru produced the topographical maps to a scale of 1:100 000 that were used for georeferencing. Annex 1 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 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.

Building polygons

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

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

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

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

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

Interpretation of changes

Based on results from the analysis of the satellite images, in 1997, of the total area without clouds covered by the studied image (later referred to as overlap area), 1 691 162 hectares (65.2%) were covered by pajonal-type vegetation and only 19.9% by natural forest, with little human intervention (deforestation), 12.4% 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 covered less to 0.5% of the area.

During the study period (1989 - 1997) 55 498 hectares of forest were converted to agricultural land. The average annual rate of intervention in this period was 1.3% (6 937.3 ha of primary forest lost every year).

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.

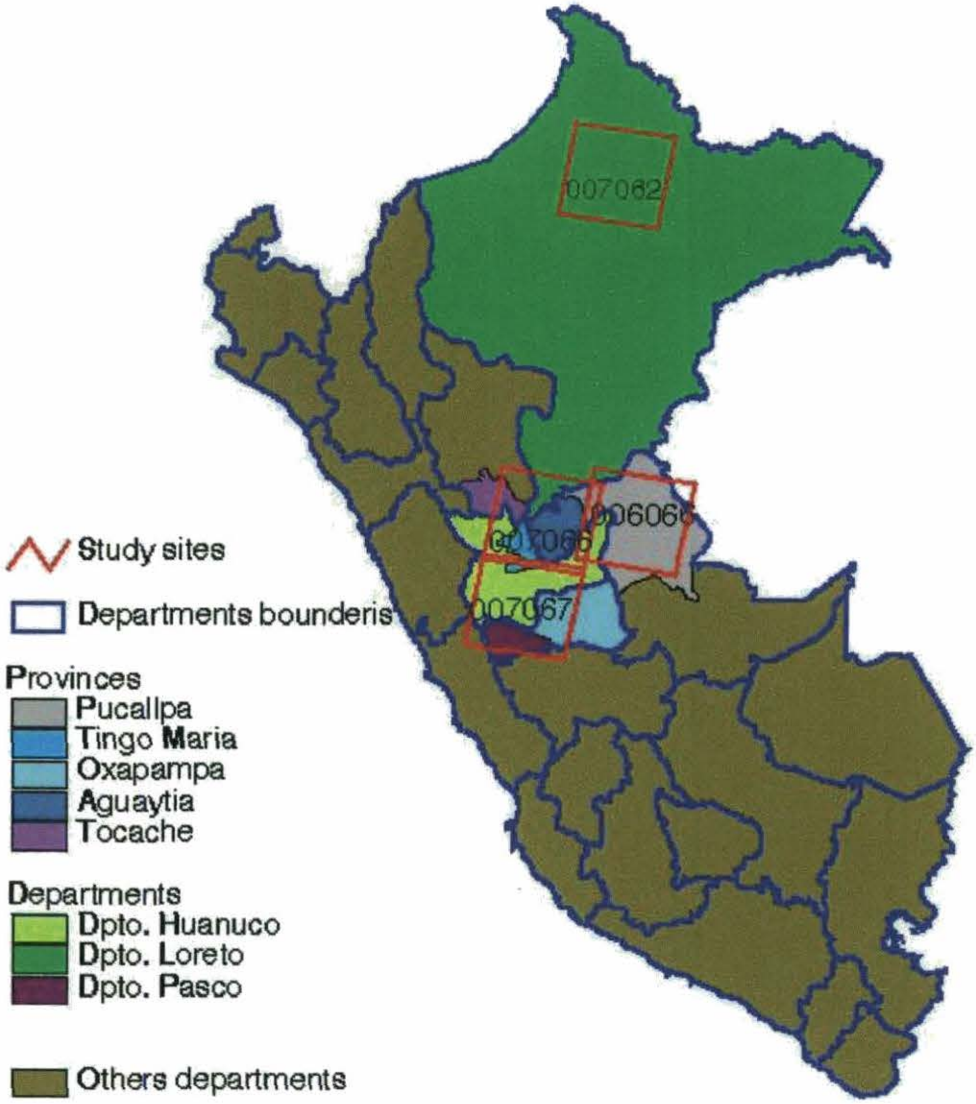


Figure 1: Provinces and Departments of Peru covered by the satellite images.

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 067, 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 067
Date 24/07/89
Image Name: **007067890724FSgeo.lan**

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

Number of columns	7416
Number of lines	6927

Reference projection	UTM 18 S WGS84		Lat/Long WGS84	
Units	Meters		Degree	
Upper left corner	273020	8986067	77.0356 W	9.1000 S
Lower right corner	495470	8778287	75.0229 W	11.0365 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	0.3
Number of GCP	20

Geocoded image information

Landsat TM image, full scene
Path 007 Row 067
Date 08/09/97
Image Name: **007067970908FSgeo.lan**

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

Number of columns	7445
Number of lines	7039

Reference projection	UTM 18 S WGS84		Lat/Long WGS84	
Units	Meters		Degree	
Upper left corner	277917	8986277	77.0115 W	9.0954 S
Lower right corner	501237	8775137	74.5919 W	11.0449 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	0.3
Number of GCP	20

Annex 2

False color composites

Huánuco (Path 007, Row 067, Full Scene)

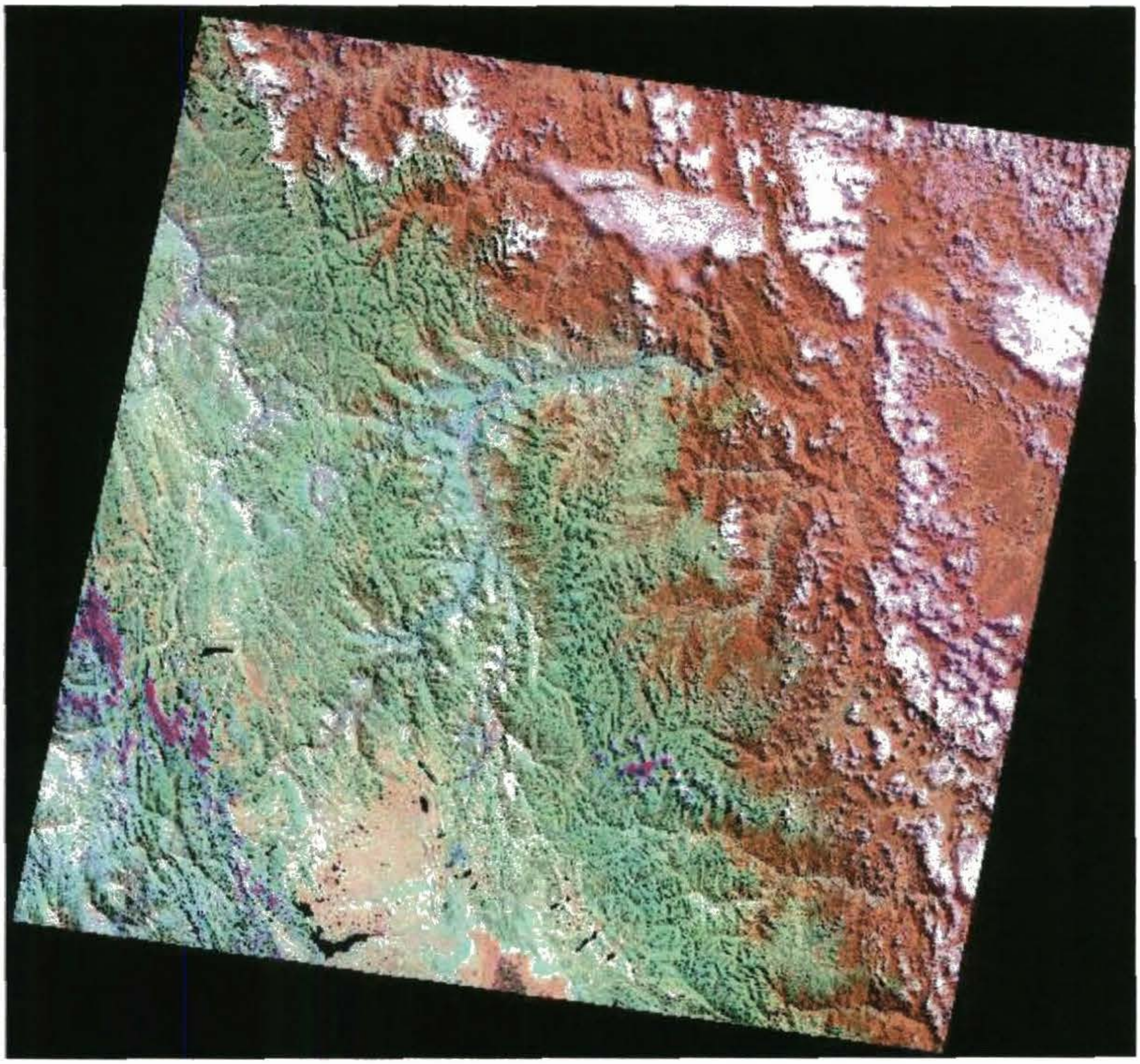


Figure 2. Landsat TM5 satellite image, bands 4,5,3, path 007, row 067, full scene, date 24-07-89. Upper left corner 77.0356 W , 9.1000 S, Lower right corner 75.0229 W, 11.0365 S.

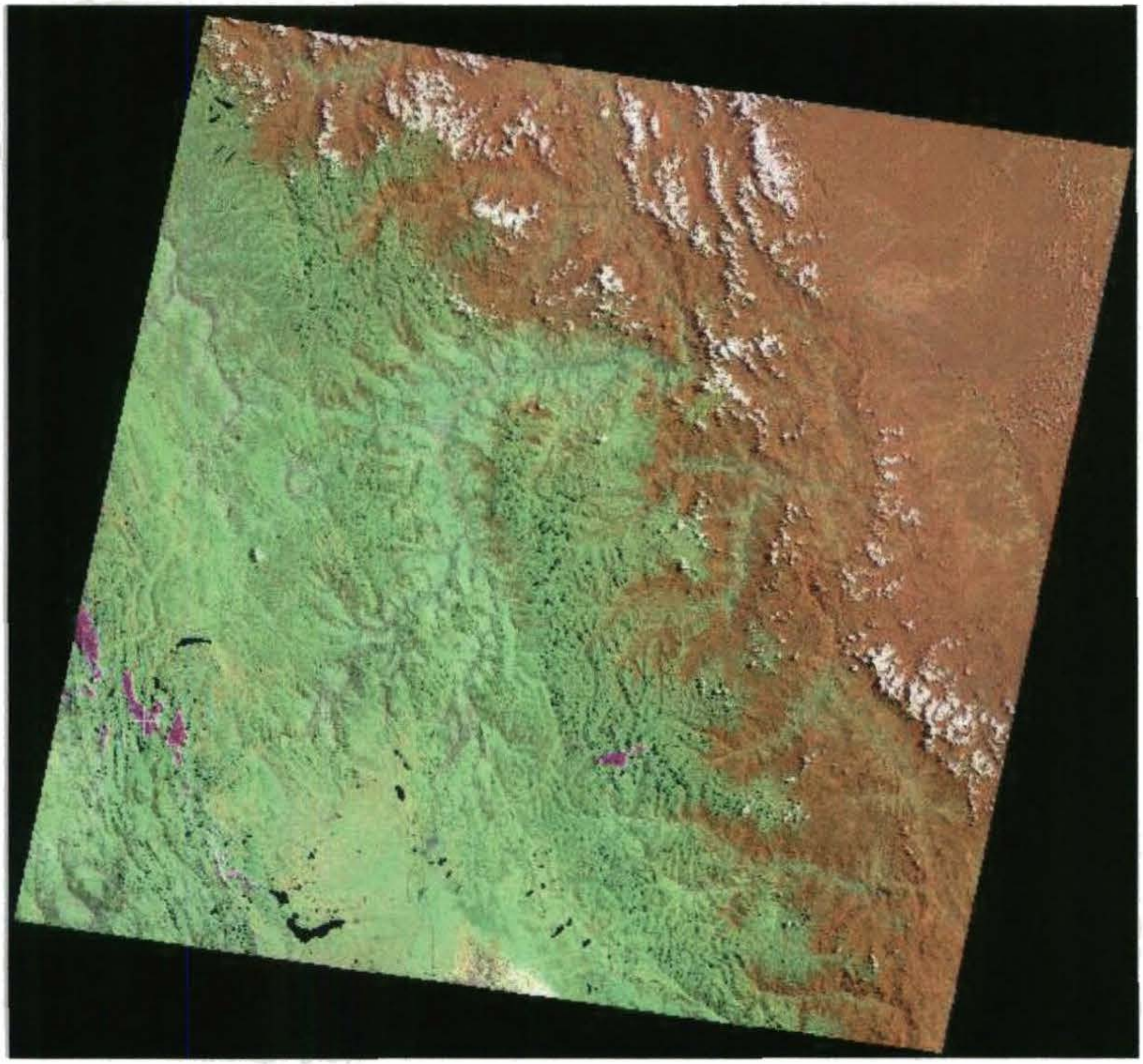


Figure 3. Landsat TM5 satellite image, bands 4,5,3, path 007, row 067, full scene, date 08-09-97. Upper left corner 77.0115 W, 9.0954 S, Lower right corner 74.5919 W, 11.0449 S.

Annex 3

Land use / Land cover change
(Overlap area)

Huánuco (Path 007, Row 067, Full Scene)

Land use / Land cover present in 1989 image

Huanuco (Path 007, Row 067; per_ciat_huanuco_89_ cds.xls)

Code	Description
111A	Closed High Density Evegreen Lowland Forest
111B	Closed Medium Density Evegreen Lowland Forest
111C	Open Evegreen Lowland Forest
111D	Fragmented Evegreen Lowland Forest
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane Forest
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
22	Cropland & Forest
23	Other Vegetation & Forest
329	Other Grassland
44	Small holding
49	Other Agriculture
51	Urban
54	Bare Soil
59	Other Non-Vegetated
61	River
621	Natural Lake
81	Cloud
82	Shadow

Land use / Land cover present in 1997 image

Huanuco (Path 007, Row 067; per_ciat_huanuco_97_ cds.xls)

Code	Description
111A	Closed High Density Evegreen Lowland Forest
111B	Closed Medium Density Evegreen Lowland Forest
111C	Open Evegreen Lowland Forest
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane 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
329	Other Grassland
44	Small holding
51	Urban
54	Bare soil
59	Other Non-Vegetated
61	River
621	Natural Lake
81	Cloud
82	Shadow

Statistics for 1989 image

Huanuco (Path 007, Row 067; per_ciat_huanuco_89_sts.xls)

Code 89	No. Polygons	Total Area	Mean Area	S. D. Area
111A	47	126524	2692	6895
111B	30	18818	627	1257
111C	1	75	75	0
111D	1	111	111	0
112A	93	529703	5696	20192
112B	72	32787	455	505
112C	15	10751	717	1131
112D	14	3848	275	232
212	3	412	137	60
22	98	168536	1720	4993
23	29	18575	641	1750
329	26	1695618	65216	318631
44	87	121944	1402	4146
51	5	831	166	124
54	4	1866	466	430
59	31	12236	395	753
61	4	1060	265	179
621	55	9423	171	348
81	337	408676	1213	5174
82	315	86409	274	435

Statistics for 1997 image

Huanuco (Path 007, Row 067; per_ciat_huanuco_97_sts.xls)

Code 97	No. Polygons	Total Area	Mean Area	S. D. Area
111A	31	240233	7749	33585
111B	2	313	156	46
111C	1	431	431	0
112A	32	571172	17849	70569
112B	41	19834	484	573
112C	17	4332	255	251
112D	8	1970	246	149
211	2	254	127	13
212	10	1446	145	72
22	147	270759	1842	7105
23	36	19644	546	1579
329	28	1709120	61040	308964
44	94	122907	1308	4001
51	5	831	166	124
54	4	2671	668	711
59	32	12411	388	742
61	4	1060	265	179
621	55	9423	171	348
81	191	252723	1323	11198
82	26	6668	256	270

Land use change for 1989 and 1997 images

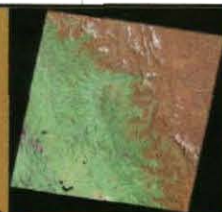
Huanuco (Path 007, Row 067; per_ciat_huanuco_chg.xls)
Images: **007067890724FSgeo.lan 007067970908FSgeo.lan**

No. Polygons	Code 89	Code 97	Total Area
60	111A	111A	117091
1	111A	111C	431
2	111A	211	254
3	111A	212	311
46	111A	22	7837
6	111A	44	532
1	111A	81	68
12	111B	111A	9776
1	111B	111B	189
1	111B	212	152
25	111B	22	8641
1	111B	44	60
1	111C	22	75
1	111D	22	111
89	112A	112A	362483
10	112A	112B	3587
5	112A	112C	656
59	112A	22	11963
2	112A	23	265
1	112A	44	51
99	112A	81	146691
13	112A	82	4006
30	112B	112B	14411
2	112B	112C	464
2	112B	112D	728
40	112B	22	15957
1	112B	44	138
6	112B	81	1028
1	112B	82	62
9	112C	112C	3018
1	112C	112D	286
7	112C	22	7067
1	112C	23	37
2	112C	81	344
1	112D	112B	844
5	112D	112D	956
5	112D	22	1471
3	112D	23	576
3	212	212	412

No. Polygons	Code 89	Code 97	Total Area
95	22	22	167047
9	22	81	1174
1	22	82	315
29	23	23	18575
1	329	22	45
1	329	23	85
27	329	329	1691162
26	329	81	3656
7	329	82	670
87	44	44	121944
5	51	51	831
4	54	54	1866
31	59	59	12236
4	61	61	1060
55	621	621	9423
77	81	111A	94339
1	81	111B	124
261	81	112A	168953
7	81	112B	827
1	81	112C	194
4	81	212	478
87	81	22	39475
1	81	23	105
56	81	329	12641
3	81	44	183
1	81	54	461
1	81	59	175
206	81	81	89688
9	81	82	1033
71	82	111A	19027
151	82	112A	39737
1	82	112B	164
1	82	212	93
55	82	22	11069
33	82	329	5318
1	82	54	345
61	82	81	10075
4	82	82	583

Land use change matrix

Huanuco (Path 007, Row 067; per_ciat_huanuco_mtx.xls)



1989 \ 1997				Forest: Evergreen & Semi-evergreen: Evergreen-Lowland Forest: Closed High Density	Closed Medium Density	Open	Evergreen-Montane Forest: Closed High Density	Closed Medium Density	Open	Fragmented	Mosaic: Shifting Cultivation: less than 1/3 cropping	more than 1/3 cropping	Cropland & Forest	Other Veget & Forest	Non-forest Vegetation: Grassland: Other	Agriculture: Small holding	Non-vegetated: Urban	Bare soil	Other	Water: River	Lake: Natural	Not Visible: Cloud	Shadow	Total
Forest	Evergreen & Semi-evergreen	Evergreen-Lowland Forest	Closed High Density	117091		431					264	311	7837			532						68		126524
			Closed Medium Density	9776	189							152	8641			60								18818
			Open										75											75
			Fragmented										111											111
		Evergreen-Montane Forest	Closed High Density				362483	3597	666				11963	266		51						140691	4006	529702
			Closed Medium Density					14411	464	728			16967			136						1028	82	32788
			Open						3018	288			7067	37								344		10752
			Fragmented					544		955			1471	576										3547
Mosaic	Shifting Cultivation	more than 1/3 cropping										412												412
	Cropland & Forest												167047									1174	315	168536
	Other Vegetation & Forest													18575										18575
Non-forest Vegetation	Grassland	Other											45	95	1691162							3656	670	1695618
Agriculture	Small holding															121944								121944
Non-Vegetated	Urban																831							831
	Bare soil																	1866						1866
	Other																		12236					12236
Water	River																			1060				1060
	Lake	Natural																			9423			9423
Not Visible	Cloud			94339	124		188963	827	194			478	39475	106	12641	183		461	176			89688	1033	408676
	Shadow			19027			39737	164				93	11069		5318			345				10075	583	86411
Total				240233	313	431	571173	19833	4332	1970	254	1446	270758	19643	1709121	122908	831	2672	12411	1060	9423	252724	6669	3248205

Forest
Forest changes
Mosaic
Other changes
Non-forest vegetation
Agriculture
Non-vegetated
Water
Sea
Not visible
No data

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 Ríos		
	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

Adger, W.N. and Brown K. 1994. Land use and the causes of global warming. John Wiley, UK. 271 p.

Altieri, M. 1996. Enfoque agroecológico para el desarrollo de sistemas de producción sostenibles en Los Andes. University of California, Berkeley/Clades. Centro de Investigación , Eduación y Desarrollo (CIED), Lima, Peru. 92 p.

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

CRP- IIAP, 1995. Mapa de Evolución de la Deforestación en el Area de Influencia de la Carretera Federico Basadre 1955–1995, Scale 1:250 000. Comité de Reforestación de Pucallpa (CRP); Instituto de Investigaciones de la Amazonía Peruana (IIAP). Iquito, Peru.

CTARU-IIAP, 1995. Mapa de Vegetación de la Cuenca del Aguaytía, Scala 1:250 000. Estudio de Zonificación Ecológica Económica de la Cuenca del Río Aguaytía. Consejo Transitorio de Administración Regional del Ucayali (CTARU), Instituto de Investigaciones de la Amazonía Peruana (IIAP). Iquito, Peru.

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

Frohn, R.C. 1998. Remote sensing for landscape ecology. New metric indicators for monitoring. Modelling and assessment of Ecosystems. CRC Press, Boca Raton, FL. 99 p.

Gastó, J. 1993. Aproximación agroecosistemica. El agroecosistema Andino, problemas, limitaciones y perspectivas. En: Anuales del Taller Internacional sobre el Agroecosistema Andino (Lima 30/3-2/4/1992). Centro Internacional de la Papa (CIP), Lima, Peru. p. 31-49.

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

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

IFG, 1984. Mapa planimétrico de imágenes de satélite, Scale 1:250 000. Instituto de Geociencias Aplicadas. Lima, Peru.

INRENA. 1995. Mapa Ecológico del Perú, Scale 1:1 000 000. Instituto Nacional de Recursos Naturales, Lima, Peru.

INRENA. 1997. Mapa de Zonificación de Bosques del Departamento de Huánuco. Scale 1:1 000 000. Instituto Nacional de Recursos Naturales (INRENA). Lima, Peru.

INRENA. 1997. Mapa de Zonificación de Bosques del Departamento de Pasco. Scale 1:1 000 000. Instituto Nacional de Recursos Naturales (INRENA). Lima, Peru.

INRENA. 1997. Mapa de Zonificación de Bosques del Departamento de Junin. Scale 1:1 000 000. Instituto Nacional de Recursos Naturales (INRENA). Lima, Peru.

JRC. 1997. Identification of deforestation hot spot areas in the humid tropics. TREES (Tropical Ecosystem Environment Observations by Satellites), Joint Research Centre, European Commission. Synthesis of expert consultation meeting, Ispra, Italy, 24-25 November 1997. TREES Publications Series B. Research Report n° 4. 99 p.

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

Myers, N. 1984. The primary source: tropical forests and our future. Norton, NY. 150 p.

Navas A..J. 1982. Considerations on the Colombian Amazon region. In: Amazonia, agriculture and land use research. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. p. 41-59.

ONERN. 1981. Mapa de Capacidad de Uso Mayor de las Tierras del Perú, , Scale 1:1 000 000. Oficina de Evaluación de Recursos Naturales. Lima, Peru.

Ortiz, S. 1984. Colonization in the Colombian Amazon. In: Schmink M. and Wood C. (eds.) Frontier expansion in Amazonia. University Presses of Florida, FL. 206 p.

Rodriguez, F. 1996. Estudio de la Deforestación en el Area de Influencia de la Carretera Federico Basadre. IIAP – Comité de reforestación de Pucallpa. 72 p.

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

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

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

Tapia, M.E. 1986. Alternativas para el desarrollo agropecuario del trapecio Andino. En: AnalesV Congreso Internacional de Sistemas Agropecuarios Andinos (10-14/3/86, Puno, Peru). Proyecto de Investigación de Sistemas Agropecuarios Andinos (PISA), Lima, Peru. p. 44-52.

Tapia, M.E. 1993. Vision general y características del agroecosistema Andino. En: Anales del Taller Internacional sobre el Agroecosistema Andino (Lima 30/3-2/4/1992). Centro Internacional de la Papa (CIP), Lima, Peru. p. 51-61.

Torres, G.J. 1993. Los agroecosistemas Andinos del Peru: la oferta ambiental de los Andes y algunas sugerencias para optimizar su utilizacion. En: El Agroescosistema Andino, Anales del Taller Internacional sobre Agroecosistemas Andino (Lima, 30/3-2/4/92), Centro Internacional de la Papa (CIP), Lima, Peru. p. 97-108.

USAID. 1997, cited by INEI (1998). Estadísticas de Producción, Tráfico y Consumo de Drogas 1996-1997. Lima, Peru. 104 p.

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

WRI-UNEP-UNDP-World Bank (World Resources Institute- United Nations Environment Programme-United Nations Development Programme-World Bank). 1998. World Resources, 1998-99. WRI-UNEP-UNDP-World Bank, NY. 293 p.