Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Florencia – Colombia

(Path 009, Row 059, Full Scene)

Joint Research Centre (JRC)

and

CIAT

Technical Report

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INTRODUCTION

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

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

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

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

This report involves the study of an area located in the Southern part of Colombian 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:

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).
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 (Stadtmüller, 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).

STUDY AREA

LOCATION

The study site is located in the southern part of Colombia. It is bounded in the south by the border with Ecuador, in the north by the town of Popayán and the Puracé volcano in Cauca State, in the west by the Cordillera Occidental within Colombia and to the east by the Amazonian plains. The whole area covers 3 285 212 hectares, the intersection between the Landsat TM5 and Spots images covers 721 177 hectares

TOPOGRAPHY

Within this area are the three principal Colombian mountain ranges, the Cordillera Occidental, the Cordillera Central and the Cordillera Oriental, and two main depressions – (1) the watershed of the Patia, Guaitará, Juanambú and Mayo rivers and (2) the valley of the Magdalena River.

The height of the Andes in the Amazon area ranges between 350 and 450 m. There are three different types of relief (1) alluvial terraces with little slope and flat lowland with seasonal flooding and good agricultural possibilities, (2) an undulating landscape formed by hills with more marked slopes and (3) mountainous landscape with steep slopes (Gonzáles, n.d.).

The relief in the Amazon plains is rolling hills that become steep slopes near the piedmont. Along the rivers are intermediate terraces and low plains. Moving away from the Andes towards the south, the land grows flatter. The hills range from 20-50 m from the summits to the hollows between hills (Navas A., 1982).

The presence of these high ranges with top reaches at 4600 m, valleys and the Amazon region below 400 m produces variable climate and soil conditions strongly influencing the type of land cover and land use.

CLIMATE AND VEGETATION

The climate is hot and humid with humidity increasing from north to south and from east to west. Ecologically, the zone falls into the category of tropical rain forest. Rainfall is plentiful all year; the annual average for the Amazon Basin is 2300 mm. A dry period occurs in December and February in the west and from June to October in the east of the Colombian Amazon region (Navas A., 1982). On the eastern slope of the Cordillera Oriental, the rainfall can reach as high as 4000 mm, distributed mainly in two periods of intense rains with peaks in the months of April and October. The relative humidity is higher than 80% all year, impeding slash-and-burn cultivation (González, n.d.).

A very dry tropical forest zone is located at the confluence of the Juanambú, Guaitará, Mayo and Patía rivers, where the annual rainfall is from 500 to 1000 mm (Peñuela Viveros, 1971; Yanine et al., 1998). Dry subtropical forest and several types of humid tropical forests dominate between 900 m and 3000 m (Peñuela Viveros, 1971).

Between 2000 m and 3000 m the climate is cold and intensive agricultural activities have changed the natural vegetation. Above 3000 m, paramo replaces humid forest and very humid montane forest (Peñuela Viveros, 1971). Paramo is found between 3200 m and a line between 4500 to 4700 m (Cuatrecasas, 1989). Paramo consists of shrub vegetation, grassland, typical plants called *frailejones* (*Speletia* sp.) and tussocks (Rangel Ch. et al., 1995).

PRODUCTION

Latitude and rainfall determine crops grown, but potato predominates in the crop rotations of the higher mountain areas (Rodriguez Q., 1993).

Coffee is grown in the high areas of the basins of the Juanambú and Mayo rivers. This zone is affected by warm air currents developing within the humid subtropical forest and ascending in the river canyons, where cultivation occurs between 1350 m and 2950 m. According to the Colombian National Fund of Cafeteros (FNCC, 1975) 91.6% of the coffee farms in this region are of less than 10 ha in size.

Agricultural activity is shifting towards the high Andean levels, invading the paramo vegetation and initiating a new belt of colonization which alters the mountain ecosystems. The pressure on the paramos, especially from potato and cattle farming, affects the water quality and the paramos' capacity to produce and retain water (Yanine et al., 1998).

In the Amazon region, most of the population relies on shifting agriculture with subsistence crops like maize and banana (García R., 1990; González, n.d.). Coca (*Erythroxylum coca*), has contributed to farmer income, liquidating differences in production costs of subsistence crops, allowing these to be considered a profitable activity. At present, coca is grown in areas of difficult access and in plots of about 4 ha, whereas traditional crops are grown in less than 1-ha plots (González, n.d.).

Like the indigenous people, new farmer-settlers in the Amazon region build their homes in the highest parts, on hills or terraces, to avoid flooding. The flat lowland can give two crops before stubble is left to grow, but river floods could occasion losses in production. (Acero V, n.d.).

Cattle farming develops in the part of the Amazon region not susceptible to flooding, but these lands have a fast productivity decline; cattle ranches must be large (e.g., 300 ha to 60-100 head of cattle) to be profitable (Myers, 1980).

SOCIAL CONFLICTS

In Colombia, 70% of the population now lives in cities, towns and villages, whereas 40 years ago that same proportion lived in the countryside (Rojas R., n.d.; Reyes P., n.d.). Over the last few years some cities, like Barranquilla, Medellín, Cali and Bogotá, have had a massive influx of farmers attempting to find better economical opportunities or escaping from the violence in the rural sector (Rojas R., n.d.).

The establishment of the guerrilla in certain territories and the illegal plantations of coca and marijuana have extended over the Amazon sector, bringing in an antisocial organization and violence. In turn, the armed paramilitary organization and the Colombian Armed Forces began fighting a war to recover territory, inflicting on the rural population frequent murders, kidnappings, missing persons and torture (Reyes P., n.d.).

In the rest of the country, the countryside is becoming less and less inhabited and is being transformed to modern agriculture with high productivity. In contrast, the Amazon sector shows the tendency of cutting the tropical forest for colonization, enlarging the agricultural border. This can only be explained by the urban unemployment, which is stimulating a search for new options, amongst them the coca crop in marginal zones (Reyes P., n.d.). The spread of coca leaf production in southern Colombia is a social phenomenon, involving hundreds of thousands of Colombian peasants displaced by landlessness from other regions of the country (The Light Party, 1997).

After colonists have settled and established an area, the traditional crops begin to be unproductive and natural or introduced grasses are all that the soils can sustain. Because of this, farmers have to change their production system to extensive cattle production. Many farmers succeed in acquiring new farmland and develop it as small- and medium-scale landowners. Another group, consisting of landowners, traders and private businessmen, participate in the transformation process of agriculture by buying improved lands. Nevertheless, a large group of settlers, unable to sustain the condition of mere subsistence, shift to new sites and thus move the agricultural border (Mora, w d)

Besides the settlers displaced by the violence or looking for new agricultural lands, the indigenous people are one of the most affected communities. They have been forced to move further and further east, especially to riversides, searching for new lands. This is another agent of the expansion of the agricultural border (Reyes P., n.d.).

The other important illegal crop affecting the forest of our study area, opium (*Papaver somniferum*), is planted in cleared montane rainforest and paramo areas. Although the quantity of deforestation caused by opium crops is small (only 0.5% of deforestation in Colombia), this quantity is significant for the remaining rainforest on the mountain ranges (Cavelier and Etter, 1995).

METHODOLOGY

MATERIALS

For this work we used a full-scene Landsat TM image (009059890807geo.lan) as information for the first date and two full-scene SPOT images (644346980102Xgeo.lan, 6443480980829Xgeo.lan) for the second date. Both SPOT images present important cloud and shadow covers.

At the begining of the study, a TM image was interpreted for the second date (009059971024Fsgeo.lan), but the great proportion of clouds and shadows did not allow any reliable analysis.

Land use was interpreted using as reference forest maps at a 1:500 000 scale from the

Instituto Geográfico Agustín Codazzi (IGAC, 1987; 1983).

GEOGRAPHIC CORRECTION

The images were georeferenced to Universal Transversal of Mercator (UTM), zone 18 WGS84, using the Georeferencing module of the Copilot 32 software for the first Landsat TM date and the Georeferencing module of the PCI software for the SPOT images. 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 images in the second date, 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 Agustin Codazzi (IGAC) of Colombia. Annex 1 gives a list of maps used for georeferencing, root mean square (RMS) error for the processes as well as parameters and other georeferencing information.

Figures 1, 2 and 3, in Annex 2, give an overview of the study area in the images after the georeferencing process.

LAND-USE AND LAND-COVER DIGITISING

Land uses and land cover were digitised on screen over the TM 4-5-3 colour and SPOT 3-2-1 composite. This process was completed using the Imageworks module of PCI software with the minimum mapping unit as described in TREES technical annex (50 ha; 300 m width for linear features). The images were displayed at a scale of 1:100 000 and all distinguishing characteristics were digitised and associated to a specific class code established by TREES (see Annex 3).

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

BUILDING POLYGONS

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

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

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

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

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

INTERPRETATION OF CHANGES

The tropical forest (lowland forest, mountain forest gallery forest and periodically inundated forest) cover the 54.6% of the intersection of the Landsat TM and SPOT image, considering data without clouds and shadows (later referred as overlap area). 6.3% of the forest area was cleared in 9 years (annual deforestation rate of 0.7%). The annual rate of recuperation of forest was 0.2%.

84.1 % of the total forest area correspond to forest that is not periodically inundated

Periodically inundated forest is cleared at a 0.2 % annual rate (1.0 % annual recuperation rate), while this figure rises to 0.8 % for the forest that is not periodically inundated (0.1 % annual recuperation rate).

Agricultural practices, vegetation re-growth and the mosaic types established by TREES cover 38.6% of the overlap area. Water bodies (0.3%) and natural vegetation of shrub savanna (2.8%) cover the remaining area.

CONCLUSIONS

The deforestation rate obtained for the study area was the same than the one published by the World Resources Institute and other institutions (WRI-UNEP-UNDP-World Bank, 1998), which was 0.5% for the whole of Colombia from 1990-1995, considering the annual rate of recuperation of forest.

The principal deforestation area is located in the Piedmont of The Andes, in the non-flooded land, over the hills and upper terrace of the rivers. Temporary agriculture exists along rivers.

In the area covered by 644346980102Xgeo.lan image the deforestation shows a diffuse pattern caused by the agricultural expansion by local people. The area covered by 6443480980829Xgeo.lan image showed different deforestation patterns (lineal and diffuse), mainly caused by shifting cultivation, cash crops and small holdings. Most of the people are immigrants and transmigrates from the other parts of the country because of regional violence.

The full Landsat TM scene of 1989 covers a very varied landscape. In the extreme south west of the image in the slopes and valley of the inter-Andean mountain there is an agricultural small holdings agricultural pattern related to indigenous population. The north-west and north-east corners present dry weather conditions, where cattle production and coffee plantation prevail in the upper part of the hillsides. The south east corner is located in the Amazon region, where shifting cultivation and illicit crops prevail, the rivers being the principal way to access the areas. The image is crossed by two mountain ranges the Cordillera Oriental y Cordillera Central.

Annex 1

Geocoded image information

Florencia (Path 009, Row 059, Full Scene)

Maps Used for Georeferencing

Larsa Ltda. 1987. Intendencia del Putumayo, Colombia., Plancha 430-I, Putumayo, Colombia.-Colombia, Topograhic map, Scale 1: 50 000, Larsa Ltda. Putumayo, Colombia.

IGAC. 1976. Timbio, Plancha 364, Cauca-Colombia, Topograhic map, Scale 1: 100 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

Larsa Ltda. 1987. Intendencia del Putumayo, Colombia., Plancha 430-II, Putumayo, Colombia.-Colombia, Topograhic map, Scale 1: 50 000, Larsa Ltda. Putumayo, Colombia.

IGAC. 1982. Carta General, Plancha 389-l-B, Huila-Colombia, Topograhic map, Scale 1: 25 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

IGAC. 1987. Garzón, Plancha 366, Huila-Colombia, Topograhic map, Scale 1: 100 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

Larsa Ltda. 1987. Intendencia del Putumayo, Colombia., Plancha 430-III, Putumayo, Colombia.-Colombia, Topograhic map, Scale 1: 50 000, Larsa Ltda. Putumayo, Colombia.

IGAC. 1989. Coconuco, Plancha 365, Cauca-Colombia, Topograhic map, Scale 1: 100 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

Larsa Ltda. 1987. Intendencia del Putumayo, Colombia., Plancha 430-IV, Putumayo, Colombia.-Colombia, Topograhic map, Scale 1: 50 000, Larsa Ltda. Putumayo, Colombia.

IGAC. 1989. La Unión, Plancha 410, Colombia, Topograhic map, Scale 1: 100 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

IGAC. 1977. Pasto, Plancha 429, Nariño-Colombia, Topograhic map, Scale 1: 100 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

IGAC. 1974. Bolivar, Plancha 387, Cauca-Colombia, Topograhic map, Scale 1: 100 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

IGAC. 1982. Carta General, Plancha 389, Huila-Colombia, Topograhic map, Scale 1: 25 000, Instituto Geográfico Agustín Codazzi. Santafé de Bogotá, Colombia.

Geocoded image information

Landsat TM image, Full scene
Path 009 Row 059
Date 07/08/89
Image name: **09059890807FSgeo.lan**

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

Number of columns	7455
Number of lines	7080

Reference projection	UTM 18 N WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	201466	265777	77.6842 W	2.4019 N
Lower right corner	425116	53377	75.6729 W	0.4828 N

Resampling mode	Nearest
Transformation order	2
Georeferencing error (pixel)	1.8
Number of GCP	18

Geocoded image information

SPOT image, Full scene
Path 644 Row 348
Date 29/08/98
Image name: **644348980829Xgeo.lan**

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

Number of columns	4473
Number of lines	3596

Reference projection	UTM 18 N WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	320159	146778	76.6163 W	1.3274 N
Lower right corner	409620	74857	75.8122 W	0.6771 N

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	1.1
Number of GCP	

SPOT image, Full scene
Path 644 Row 346
Date 02/11/98
Image name: **644346980102Xgeo.lan**

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

Number of columns	4450
Number of lines	3533

Reference projection	UTM 18 N WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	349653	256138	76.3521 W	2.3166 N
Lower right corner	434653	185478	75.5874 W	1.6779 N

Resampling mode	Nearest
Transformation order	3
Georeferencing error (pixel)	2.8
Number of GCP	

Annex 2

False colour composites

Florencia (Path 009, Row 059, Full Scene) → Para las 2 imagenes Spot

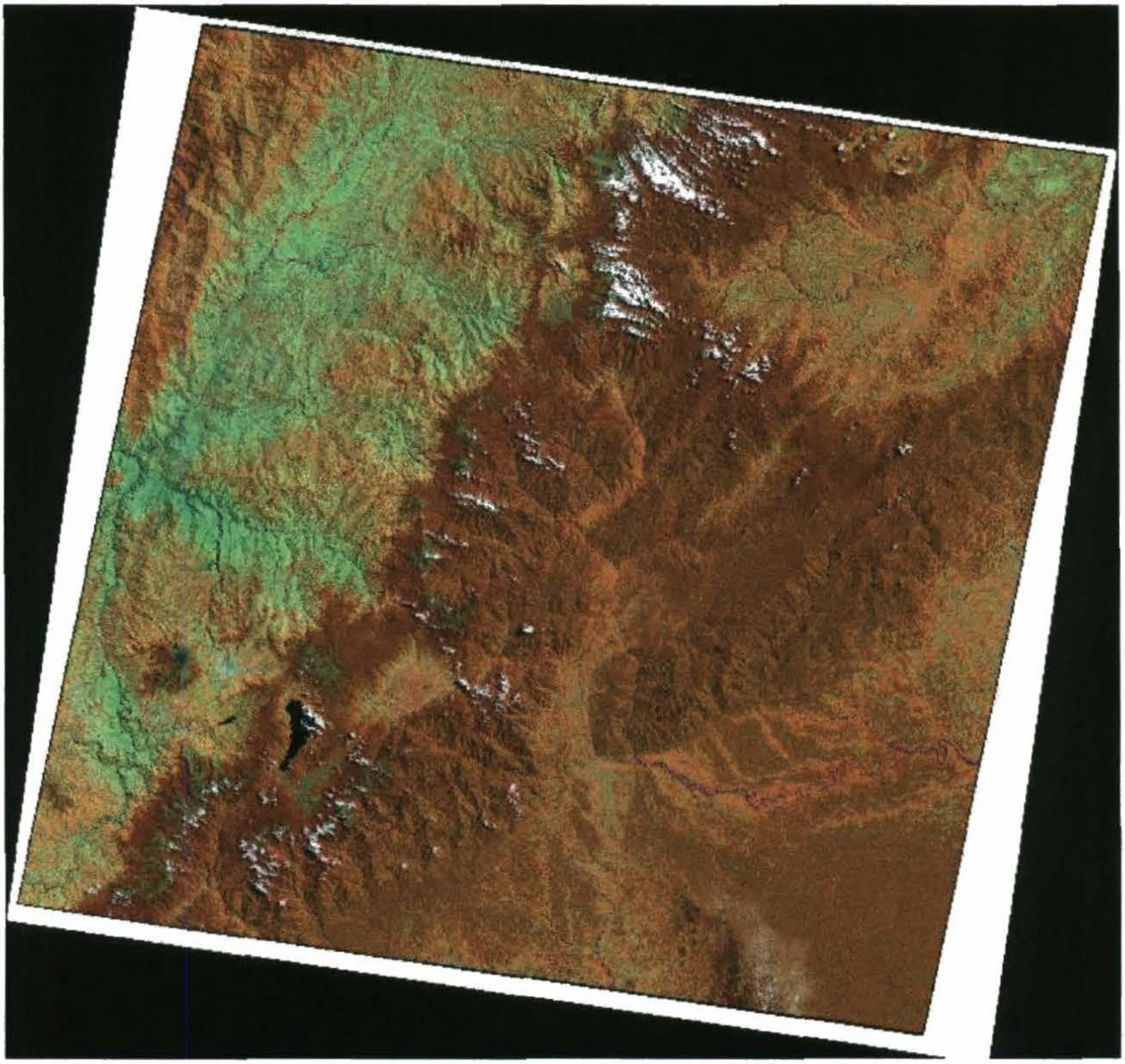


Figure 1. Landsat TM satellite image, bands 4, 5, 3, path 009, row 059, full scene, date 08-07-89. Upper left corner 77.6842 W, 2.4019 N, Lower right corner 75.6729 W, 0.4828 N.

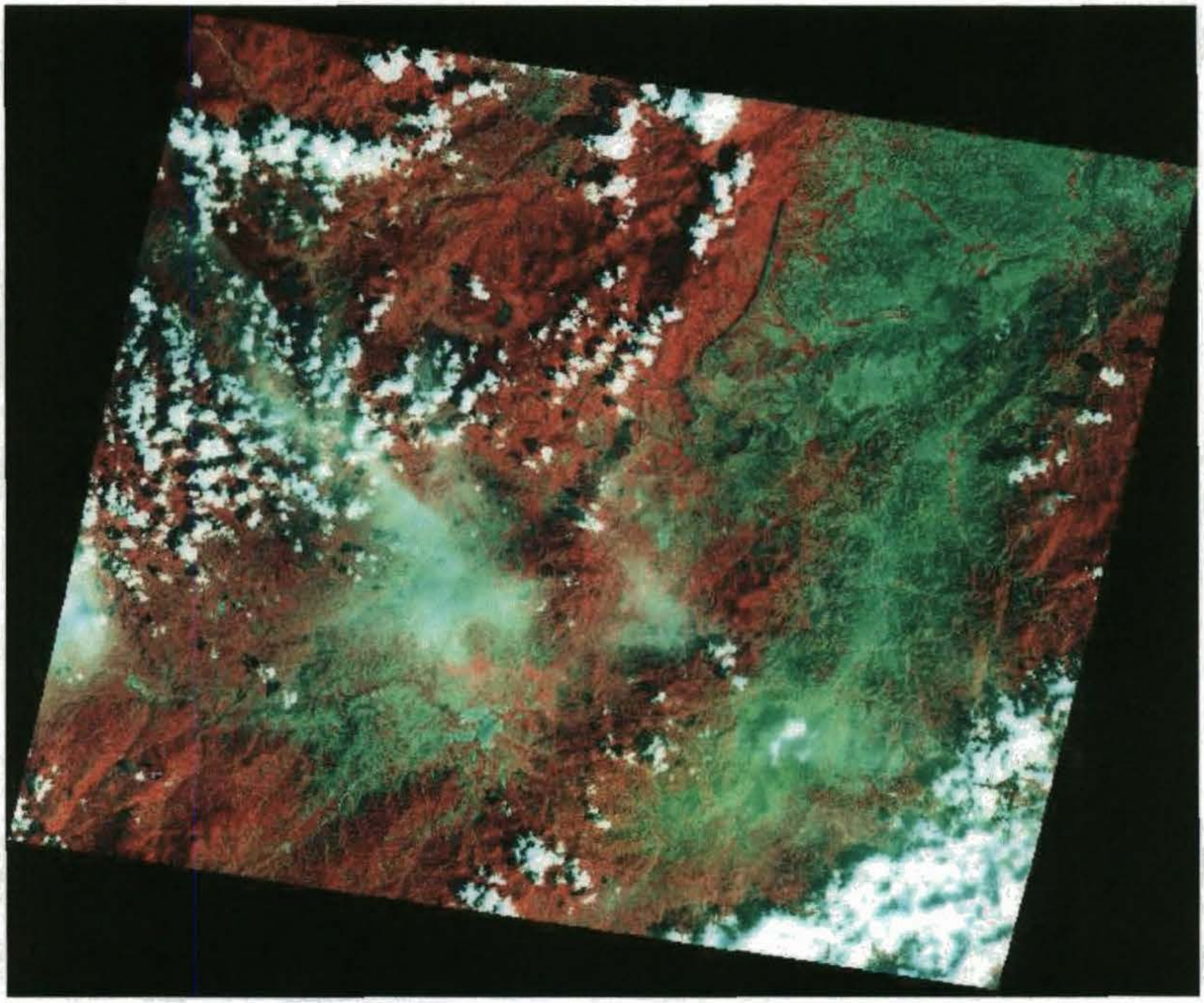


Figure 2. SPOT satellite image, bands 3, 2, 1, path 644 row 346, full scene, date 02-01-98. Upper left corner 76.3521 W, 2.3166 N, Lower right corner 75.5874 W, 1.6779 N

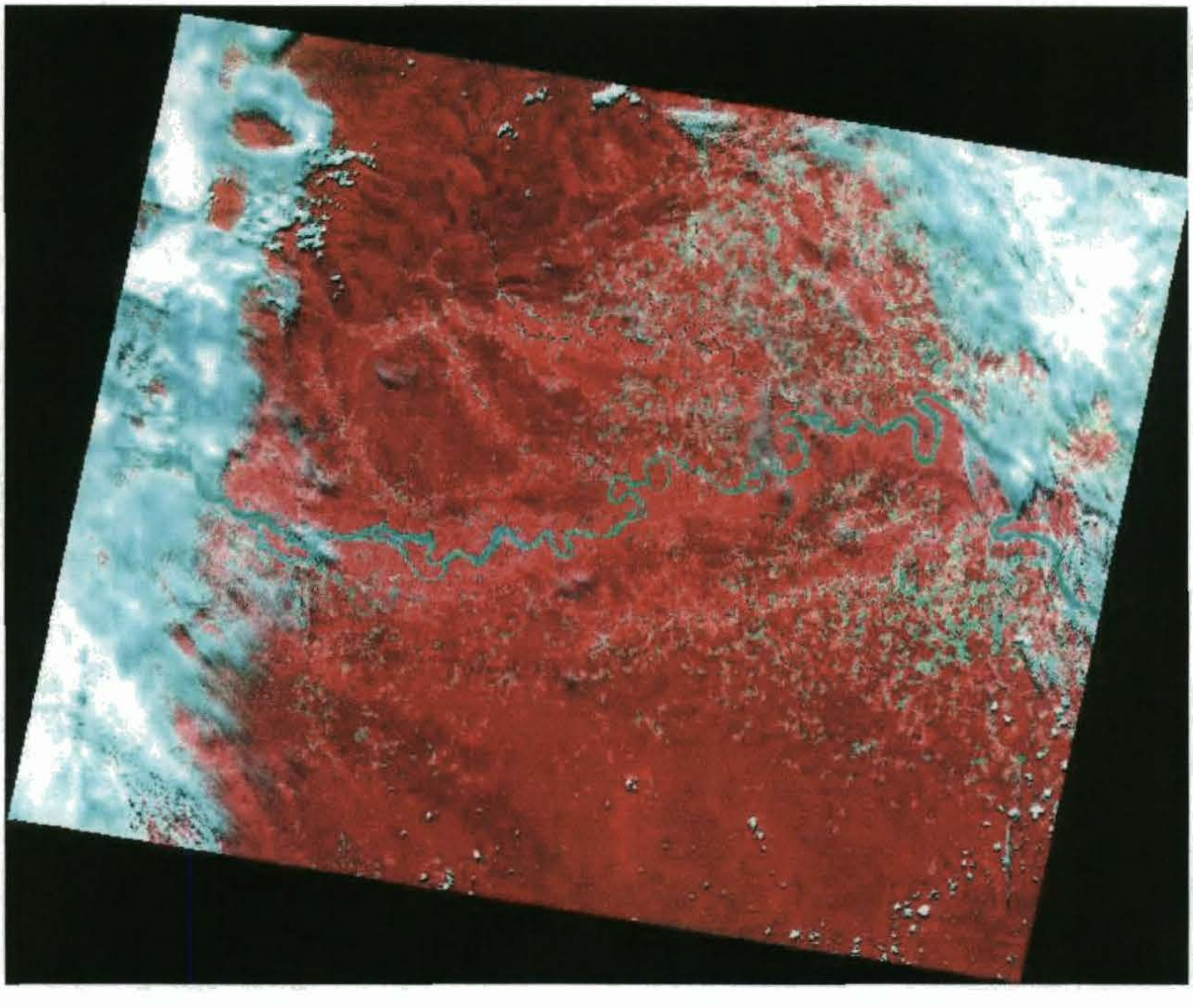


Figure 3. SPOT satellite image, bands 3, 2, 1, path 644 row 348, full scene date 29-08-98. Upper left corner 76.6163 W, 1.3274 N, Lower right corner 75.8122 W, 0.6771 N.

Annex 3

Land use / Land cover change
(Overlap area)

Florencia (Path 009, Row 059, Full Scene)

Land use/ Land cover present in 1989 image

Florencia (Path 009, Row 059; col_ciat_flo_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
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane Forest
131B	Closed Medium Density Periodically inundated forest
131C	Open Periodically inundated forest
131D	Fragmented Periodically inundated forest
133A	Closed High Density Swamp Forest with Palms
133C	Open Swamp Forest with Palms
14B	Closed Medium Density Gallery-forest
14C	Open Gallery-forest
16C	Open Forest Regrowth
211	Mosaic of Shifting Cultivation & forest with less than 1/3 cropping
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
22	Cropland & Forest
23	Other Vegetation & Forest
313	Shrub savannah
33	Regrowth of Vegetation
410	Unknown Arable land
411	Irrigated Arable land
412	Rain-fed Arable land
423	Coffe, cocoa Plantations
43	Ranching
44	Small holding
51	Urban
54	Bare soil
61	River
81	Cloud
82	Shadow

Land use / Land cover present in 1998 image

Florencia (Path 009, Row 059; col_ciat_flo_98_cds.xls)

Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111C	Open Lowland Forest
111D	Fragmented Lowland Forest
112A	Closed High Density Montane Forest
112B	Closed Medium Density Montane Forest
112C	Open Montane Forest
112D	Fragmented Montane Forest
131B	Closed Medium Density Periodically inundated forest
131C	Open Periodically inundated forest
131D	Fragmented Periodically inundated forest
133A	Closed High Density Swamp Forest with Palms
133B	Closed Medium Density Swamp Forest with Palms
133C	Open Swamp Forest with Palms
14C	Open Gallery-forest
14D	Fragmented Gallery-forest
16B	Closed Medium Density Forest Regrowth
211	Mosaic of Shifting Cultivation & forest with less than 1/3 cropping
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
22	Cropland & Forest
23	Other Vegetation & Forest
313	Shrub savannah
33	Regrowth of Vegetation
411	Irrigated Arable land
412	Rain-fed Arable land
423	Coffe, cocoa Plantations
43	Ranching
44	Small holding
51	Urban
54	Bare soil
61	River
81	Cloud
82	Shadow

Statistics for 1989 image

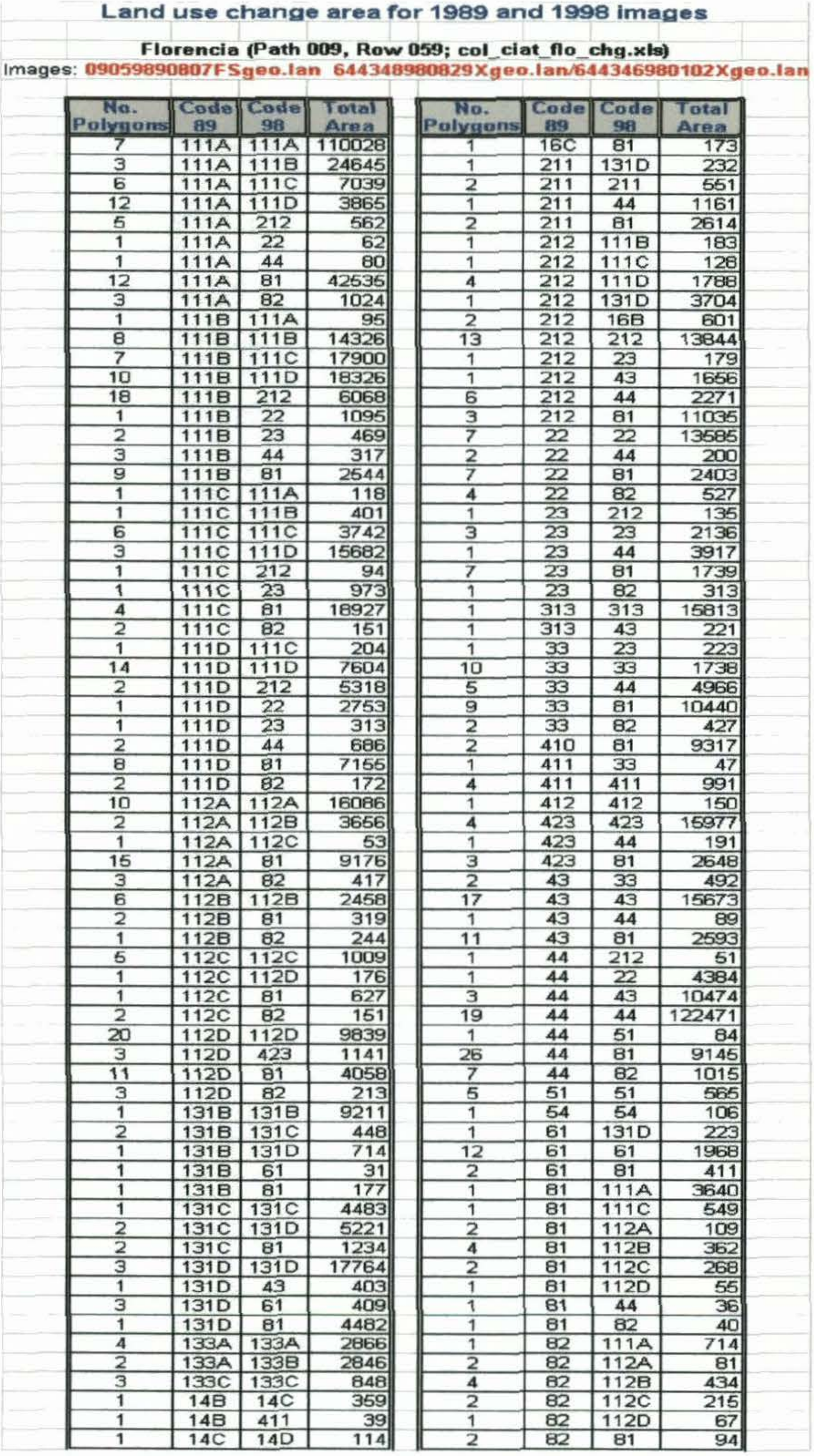
Florencia (Path 009, Row 059; col_ciat_flo_89_sts.xls)

Code 89	No. Polygons	Total Area	Mean Area	S. D. Area
111A	17	189840	11167	28407
111B	23	61139	2658	4599
111C	14	40088	2863	9345
111D	18	24204	1345	1841
112A	6	29388	4898	9879
112B	6	3021	503	615
112C	6	1962	327	354
112D	14	15251	1089	1333
131B	4	10580	2645	4974
131C	4	10937	2734	2358
131D	3	23057	7686	8929
133A	6	5712	952	619
133C	3	848	283	197
14B	1	399	399	0
14C	1	114	114	0
16C	1	173	173	0
211	4	4558	1140	876
212	15	35389	2359	4024
22	8	16715	2089	2123
23	4	8241	2060	2190
313	1	16034	16034	0
33	13	17794	1369	2042
410	2	9317	4659	4664
411	4	1038	259	144
412	1	150	150	0
423	3	18815	6272	8203
43	28	18847	673	981
44	17	147624	8684	21386
51	5	565	113	121
54	1	106	106	0
61	14	2602	186	176
81	11	5059	460	1238
82	11	1605	146	195

Statistics for 1998 image

Florencia (Path 009, Row 059; col_ciat_flo_98_sts.xls)

Code 98	No. Polygons	Total Area	Mean Area	S. D. Area
111A	8	114594	14324	25551
111B	9	39554	4395	5603
111C	21	29562	1408	2496
111D	23	47266	2055	3564
112A	9	16276	1808	3663
112B	9	6910	768	1738
112C	5	1545	309	182
112D	20	10136	507	456
131B	1	9211	9211	0
131C	3	4930	1643	2464
131D	6	27857	4643	4628
133A	4	2866	716	274
133B	2	2846	1423	1011
133C	3	848	283	197
14C	1	359	359	0
14D	1	114	114	0
16B	2	601	300	159
211	2	551	276	240
212	28	26072	931	1451
22	9	21878	2431	2065
23	8	4293	537	408
313	1	15813	15813	0
33	13	2277	175	96
411	4	1030	258	144
412	1	150	150	0
423	3	17118	5706	8008
43	17	28428	1672	2713
44	21	136384	6494	18377
51	5	649	130	159
54	1	106	106	0
61	13	2407	185	153
81	36	143846	3996	12909
82	22	4694	213	132



Land use change area for 1989 and 1998 images

Florencia (Path 009, Row 059; col_ciat_flo_chg.xls)

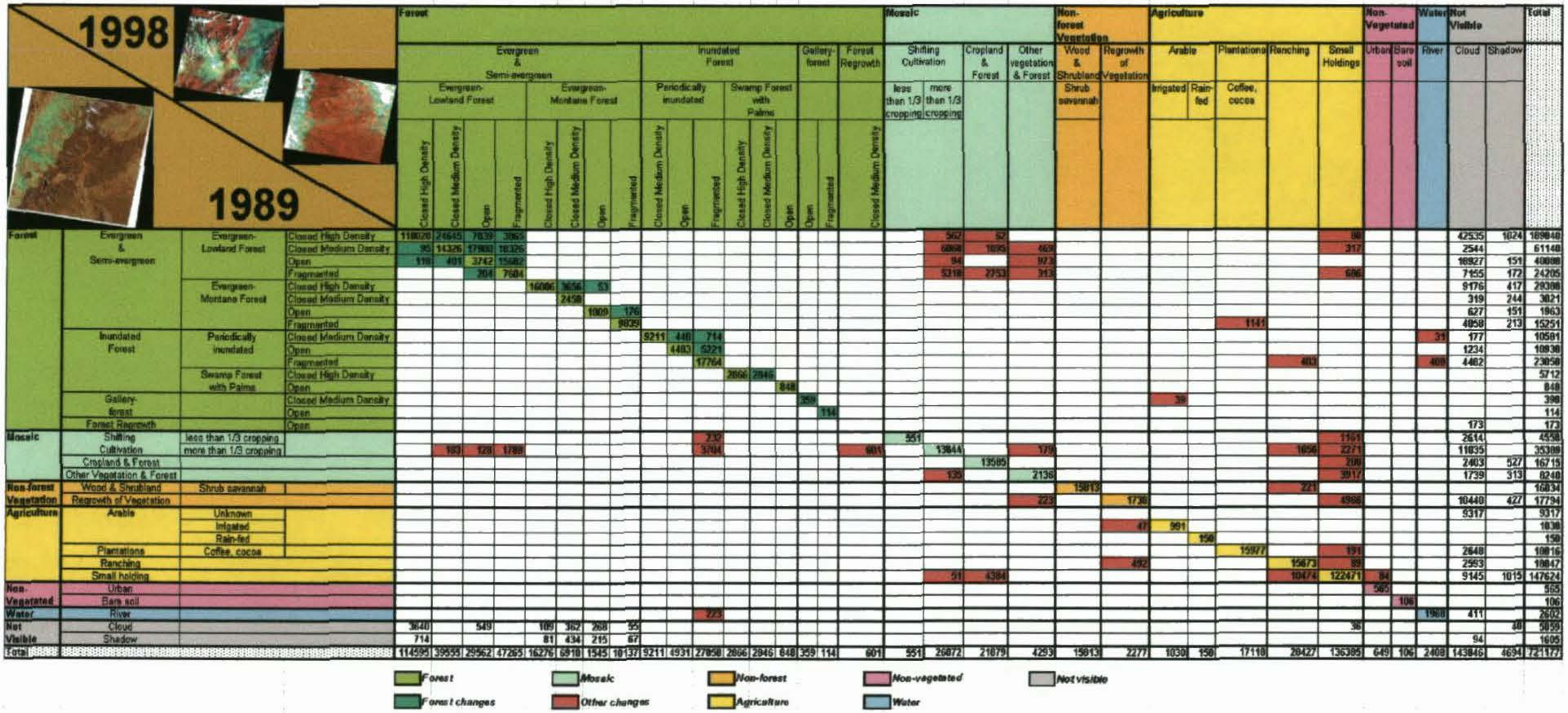
Images: 09059890807FSgeo.lan 644348980829Xgeo.lan/644346980102Xgeo.lan

No. Polygons	Code 89	Code 98	Total Area
7	111A	111A	110028
3	111A	111B	24645
6	111A	111C	7039
12	111A	111D	3865
5	111A	212	562
1	111A	22	62
1	111A	44	80
12	111A	81	42536
3	111A	82	1024
1	111B	111A	95
8	111B	111B	14326
7	111B	111C	17900
10	111B	111D	18326
18	111B	212	6068
1	111B	22	1095
2	111B	23	469
3	111B	44	317
9	111B	81	2544
1	111C	111A	118
1	111C	111B	401
6	111C	111C	3742
3	111C	111D	15682
1	111C	212	94
1	111C	23	973
4	111C	81	18927
2	111C	82	151
1	111D	111C	204
14	111D	111D	7604
2	111D	212	5318
1	111D	22	2753
1	111D	23	313
2	111D	44	686
8	111D	81	7166
2	111D	82	172
10	112A	112A	16086
2	112A	112B	3656
1	112A	112C	53
15	112A	81	9176
3	112A	82	417
6	112B	112B	2458
2	112B	81	319
1	112B	82	244
5	112C	112C	1009
1	112C	112D	176
1	112C	81	627
2	112C	82	151
20	112D	112D	9839
3	112D	423	1141
11	112D	81	4058
3	112D	82	213
1	131B	131B	9211
2	131B	131C	448
1	131B	131D	714
1	131B	61	31
1	131B	81	177
1	131C	131C	4483
2	131C	131D	5221
2	131C	81	1234
3	131D	131D	17764
1	131D	43	403
3	131D	61	409
1	131D	81	4482
4	133A	133A	2866
2	133A	133B	2846
3	133C	133C	848
1	14B	14C	359
1	14B	411	39
1	14C	14D	114

No. Polygons	Code 89	Code 98	Total Area
1	16C	81	173
1	211	131D	232
2	211	211	551
1	211	44	1161
2	211	81	2614
1	212	111B	183
1	212	111C	128
4	212	111D	1788
1	212	131D	3704
2	212	16B	601
13	212	212	13844
1	212	23	179
1	212	43	1656
6	212	44	2271
3	212	81	11035
7	22	22	13585
2	22	44	200
7	22	81	2403
4	22	82	527
1	23	212	135
3	23	23	2136
1	23	44	3917
7	23	81	1739
1	23	82	313
1	313	313	15813
1	313	43	221
1	33	23	223
10	33	33	1738
5	33	44	4966
9	33	81	10440
2	33	82	427
2	410	81	9317
1	411	33	47
4	411	411	991
1	412	412	150
4	423	423	15977
1	423	44	191
3	423	81	2648
2	43	33	492
17	43	43	15673
1	43	44	89
11	43	81	2593
1	44	212	51
1	44	22	4384
3	44	43	10474
19	44	44	122471
1	44	51	84
26	44	81	9145
7	44	82	1015
5	51	51	565
1	54	54	106
1	61	131D	223
12	61	61	1968
2	61	81	411
1	81	111A	3640
1	81	111C	549
2	81	112A	109
4	81	112B	362
2	81	112C	268
1	81	112D	55
1	81	44	36
1	81	82	40
1	82	111A	714
2	82	112A	81
4	82	112B	434
2	82	112C	215
1	82	112D	67
2	82	81	94

Land use change matrix

Florencia (Path 009, Row 059; col_ciat_flo_mtx.xls)



1998 / 1989				Forest																	Mosaic				Non-forest Vegetation		Agriculture					Non-Vegetated		Water	Not Visible		Total
				Evergreen & Semi-evergreen								Inundated Forest						Gallery-forest		Forest Regrowth	Shifting Cultivation		Cropland & Forest	Other vegetation & Forest	Wood & Shrubland	Regrowth of Vegetation	Arable		Plantations	Ranching	Small Holdings	Urban	Bare soil	River	Cloud	Shadow	
				Evergreen-Lowland Forest				Evergreen-Montane Forest				Periodically inundated			Swamp Forest with Palms						less than 1/3 cropping	more than 1/3 cropping			Shrub savannah		Irrigated	Rain-fed	Coffee, cocoa								
				Closed High Density	Closed Medium Density	Open	Fragmented	Closed High Density	Closed Medium Density	Open	Fragmented	Closed Medium Density	Open	Fragmented	Closed High Density	Closed Medium Density	Open	Open	Fragmented	Closed Medium Density																	
Forest	Evergreen & Semi-evergreen	Evergreen-Lowland Forest	Closed High Density	110028	24645	7839	3865															562	52								88				42535	1024	189840
			Closed Medium Density	95	14326	17900	18326															6868	1095	469							317				2544		61140
			Open	118	401	3742	15682															94		973											18927	151	40088
			Fragmented			704	7604															5218	2753	313							606				7155	172	24205
		Evergreen-Montane Forest	Closed High Density					16086	3656	53																								9176	417	29388
			Closed Medium Density						2458																									319	244	3021
			Open							1009	176																							627	151	1963
			Fragmented								9839																	1141						4058	213	15251
	Inundated Forest	Periodically inundated	Closed Medium Density									9211	440	714																			31	177		10581
			Open										4483	5221																				1234		10938
			Fragmented											17764															403				408	4482		23058
		Swamp Forest with Palms	Closed High Density												2866	2846																				5712
			Open														848																			848
	Gallery-forest		Closed Medium Density															359									39										398
			Open																114																		114
	Forest Regrowth		Open																																173		173
Mosaic	Shifting Cultivation	less than 1/3 cropping												232							551										1161				2614		4558
		more than 1/3 cropping			183	128	1788							3704						601		13844		179						1656	2271				11835		35389
	Cropland & Forest																						13585								200				2403	527	16715
	Other Vegetation & Forest																					135		2136							3917				1739	313	8248
Non-forest Vegetation	Wood & Shrubland	Shrub savannah																							15813					221							16834
	Regrowth of Vegetation																							223		1738					4986				10440	427	17794
Agriculture	Arable	Unknown																																	9317		9317
		Irrigated																								47	991										1038
		Rain-fed																										150									150
	Plantations	Coffee, cocoa																											15977		191				2648		18816
	Ranching																									492				15673	89				2593		18847
	Small holding																					51	4384							10474	122471	84			9145	1015	147624
Non-Vegetated	Urban																															565					565
	Bare soil																																106				106
Water	River													223																			1968	411		2602
Not Visible	Cloud			3640		549		109	362	268	55																				36					48	5059
	Shadow			714				81	434	215	67																								94		1605
Total				114595	39555	29562	47265	16276	6918	1545	10137	9211	4931	27858	2866	2846	848	359	114	601	551	26072	21879	4293	15813	2277	1030	150	17118	28427	136395	649	106	2408	143846	4694	721177

🟩 Forest

🟩 Forest changes

🟩 Mosaic

🟥 Other changes

🟧 Non-forest

🟨 Agriculture

🟪 Non-vegetated

🟦 Water

⬜ Not visible

Annex 4

Land use interpretation key

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

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

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

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

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

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

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

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

Nivel 1	Nivel 2	Nivel 3	Nivel 4
1 Bosque, mayor a 10% de coberturas de copas y mas del 40 % de cobertura forestal			
	1 Bosque siempre verde y semi siempre verde	0 Indefinido	A Cerrado alta densidad mas del 90% cobertura forestal
		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 rios y esta rodeado de pasto)		
	5 Plantaciones	0 Indefinido	
		1 Teca	
		2 Pino	
		3 Eucalipto	
		9 Otro	
	6 Regeneración de bosques (más de 10 años)		
	7 Mangle		
	9 Otro		
2. Mosaico, entre un 10 y 40 % de cobertura forestal			
	1 Cultivos migratorios	0 Indefinido	
		1 Hasta 1/3 del area cultivada	
		2 Mas de 1/3 del area cultivada	
	2 Tierras agrícolas y bosques (pastos+cultivos+bosques)		
	3 Otra vegetación y bosque (regeneración y bosque)		
	9 Otro		
3. No bosque, menos del 10 % de cobertura de copas y menos del 10 % de cobertura forestal			
	1 Arboles y matorrales	0 Indefinido	
		1 Sabana con matorrales	
		2 Sabana arbolada	
		3 Sabana arbustiva	
		4 Bambu	
		5 Sabana inundada	
		6 sabana húmeda siempreverde (Asia)	
		7 Sabana seca (Asia)	
		9 Otro	
	2 Pradera	0 Indefinido	
		1 Pradera seca	
		2 Pradera inundadas (Pantanal)	
		9 Otro (Jalca, Puno)	
	3 Regeneración de vegetacion (menos a 10 años)		
	9 Otro (Páramos)		
4. Agricultura, menos del 10 % de cobertura de copas y menos del 10 % de cobertura forestal			
	1 Tierras arables (cultivos a gran escala)	0 Indefinido	
		1 Con riego artificial	
		2 Con riego natural (lluvia)	
	2 Plantaciones comerciales	0 Indefinido	
		2 Caucho	
		3 Palma africana (Palma aceitera)	
		3 Café, cacao, coca	
		9 Otro	
	3 Grandes fincas ganaderas		
	4 Pequeñas fincas		
	9 Otro		
5. No vegetación			
	1 Urbano (pueblo, ciudad)		
	2 Carreteras y caminos		
	3 Infraestructura	1 Minería	
		2 Hidrolelectrica	
		9 Otro (camaroneras, etc.)	
	4 Suelo descubierto y rocas		
	9 Otro		
6. Agua			
	1 Rios		
	2 Lago, Laguna	1 Natural	
		2 Artificial	
7. Mar			
8. No visible en la imagen			
	1 Nubes		
	2 Sombras		
9. Sin Información			

Annex 5

Forest cover change in South America

		Forest Area							
		Total Forest			Natural Forest			Plantations {a}	
	Land Area (000 ha)	Extent 1990 (000 ha)	Extent 1995 (000 ha)	Average Annual % Change 1990-95	Extent 1990 (000 ha)	Extent 1995 (000 ha)	Average Annual % Change 1990-95	Extent 1990 (000 ha)	Average Annual % Change 1980-90
SOUTH AMERICA	**1,752,925**	**894,466**	**870,594**	**0.5**	**887,187**	**863,315**	**0.5**	**7,264**	**5**
Argentina	273,669	34,389	33,942	0.3	33,842	33,395	0.3	547	1
Bolivia	108,438	51,217	48,310	1.2	51,189	48,282	1.2	28	4
Brazil	845,651	563,911	551,139	0.5	559,011	546,239	0.5	4,900	5
Chile	74,880	8,038	7,892	0.4	7,023	6,877	0.4	1,015	8
Colombia	103,870	54,299	52,988	0.5	54,173	52,862	0.5	126	12
Ecuador	27,684	12,082	11,137	1.6	12,037	11,092	1.6	45	4
Guyana	19,685	18,620	18,577	0.0	18,612	18,569	0.0	8	29
Paraguay	39,730	13,160	11,527	2.6	13,151	11,518	2.7	9	15
Peru	128,000	68,646	67,562	0.3	68,462	67,378	0.3	184	7
Suriname	15,600	14,782	14,721	0.1	14,774	14,713	0.1	8	4
Uruguay	17,481	816	814	0.0	660	658	0.1	156	1
Venezuela	88,205	46,512	43,995	1.1	46,259	43,742	1.1	253	11

Source: WRI-UNEP-UNDP-World Bank

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