Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Napo river – Ecuador

(Path 009, Row 060, Quarter 2)

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 Ecuadorian Amazon region.

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).

STUDY AREA

LOCATION

The study site is located in the Ecuadorian Amazon region and includes part of the Napo and Coca Rivers and the principal settlements of Sucumbio and Napo provinces. It is bounded in the west by the Amazon Piedmont and inter-oceanic highway, in the north-east by a big oil palm plantation and in the north by the Aguarico River. The total area covered is 1 258 050 hectares.

The relief is relatively flat from the confluence of the Coca and Napo Rivers towards the east. From this point to the west, the land is irregular with important hills in the Andean Piedmont.

CLIMATE

The Coca region is between 200 m and 600 m in the low tropical forest area. It has an average annual precipitation of 3100 mm and no marked dry season (Peck, 1990; Ramirez et al., 1992).

COLONISATION

Since 1950, the population in the high ranges of the Amazon region has been increasing. With the discovery of oil in the late 1960s, there has been some intensive road building (Myers, 1980); most important was the construction of the highway from Baeza to Lake Agrio and Puerto de Orellana (Coca). This highway has made the lower jungle more accessible and facilitated settlement along the roadsides (de la Torre, 1982). "The oil exploitation and road construction has converted eastern Ecuador into one of the most active areas of colonisation in the Amazon Basin" (Peck, 1990).

The oil companies' activity has had direct environmental impacts such as deforestation, and soil, water and air contamination, affecting the quality of life of the people and damaging vegetation and Amazon wildlife. The opening of tracks for oil exploitation was and is taken advantage of by timber companies and by the settlers' need to obtain wood and agricultural lands. They have logged about 700 000 ha in the Amazon region (Fundación Natura - UICN, 1995a, 1995b; Peña, 1996), of which 200 000 ha were logged by oil company activity when the tracks were opened (Lasso, 1992).

The oil company zone is located on the Andean eastern slopes from the flat Amazon region up to the height of 600 m. In this zone, oil development and the improvement of the road network promoted until 1992 the emigration of almost 30 000 families of settlers from the densely inhabited mountain range (Ramirez et al., 1992).

The Ecuadorian Amazon had an important colonisation program in the 1980s, with about 750 000 hectares being occupied in a rational manner. The Program emphasised the importance of defining a regional development policy focussed on: "The need for harmonious development, adequate settlement and utilisation of the territory in relation to economic and social needs and the soil's characteristic and use; communication among regions and provinces; complementarity between diverse territorial localities based on economic production capacity and on the types of settlements" (de la Torre, 1982).

As an incentive to occupation of the Amazon region, the national government through the Ecuadorian Institute of Agrarian Reformation and Colonisation (IERAC) distributed 50-ha plots along lines parallel to the oil companies' highways. These plots were given preferentially to colonists organised in productive co-operatives and to indigenous communities, mostly of the Quichua people and some Shuar communities. From a total 507 980 ha awarded in 1992 in the lowland forest, 102 300 ha corresponded to secondary forests (Ramirez et al., 1992; Peña, 1996).

Now the Amazon Ecuadorian population registers an increase of 4.4% annually and is made up of diverse groups such as indigenous natives, colonists, urban areas and companies (Reyes, 1996).

The colonisation of the low tropical forest caused high deforestation, wood extraction and increased the pressure of ethnic groups in the settlement area in the primary forest. Additionally, some colonists are doing a form of sustainable management of the secondary forest by means of agroforestry systems for coffee production and cattle raising (Ramirez et al., 1992).

PRODUCTION SYSTEMS

The principal uses of the land by farmers the land after cutting the forest are subsistence agriculture, pasture, cattle ranching and coffee plantations (Peck, 1990).

After colonising the land, the farmers replaced forests with robust coffee plantations (*Coffea canephora*). Following the drop in coffee prices, colonists began to replace certain areas with grassland to raise cattle (Reyes, 1996).

"The good soils of the Napo Forest are being rapidly converted to oil palm plantations". "As much as 81% of agricultural lands are under pasture, many in 30- to 50-ha plots" (Myers, 1980).

"The surface dedicated to agricultural use is 8%, of which 80% is pasture, about 17% annual and perennial crops and the remaining 3% corresponds to abandoned lands" (Reyes, 1996).

METHODOLOGY

MATERIALS

For this work we used the second quarter of two Landsat TM images (path 009, row 060: 009060900207Q2geo.lan, 009060960903Q2geo.lan). The radiometric quality of the image data was good, although the first image presented important cloud coverage over part of the area with the most intervened forest and in part of the Andean Piedmont.

Land use was interpreted using as reference land use and vegetal maps at a 1:250 000 scale from the Instituto para el Ecodesarrollo de la Región Amazónica Ecuatoriana (ECORAE , 1998)

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

GEOCODING

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

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

LAND-USE AND LAND-COVER DIGITISING

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

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

BUILDING POLYGONS

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

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

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

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

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

INTERPRETATION OF CHANGES

The forest area without important land use / land cover change extends over 78.4% of the area without cloud and shadow cover (later referred as overlap area). Agricultural practices (AP), vegetation re-growth (VR) and the mosaic types (MT) established by TREES covered 17.8%. Bodies of water (2.2%) cover the remaining area. The oil palm plantation represents 5 % of the AP, VR and MT, being the annual increase rate of 1.2%.

In the 1990–1996 period, the study area showed a total decrease of forest area of about 6.8%, which represents an annual deforestation rate of 1.1%. Recuperation of the forest was slow, only 0.03% per year.

CONCLUSIONS

The annual deforestation rate obtained in the study area is less than that the published national average of 1.6% (WRI-UNEP-UNDP-World Bank, 1998). However, we found that 8679 hectares of forest is cleared every year in the study area.

The rate of recuperation of forest is low because after applying slash-and-burn practices to the land, settlers leave the farms for a few years until the soils recuperate their nutrients or switch to other types of agricultural practices (e.g., oil palm plantation).

The area is being developed rapidly, with numerous oil company concessions and industrial plantations of oil palms. These companies need local workers for their activities, which creates food demand that is supplied by new settlers, which results in increased pressure in the forest.

The area's deforestation pattern is complex. The linear pattern caused by intensive logging, settlements, agricultural expansion, oil exploration and exploitation is prevalent, but there are clear regions that experienced massive deforestation in order to introduce oil palm industrial plantations.

Annex 1

Geocoded image information

Río Napo (Path 090, Row 060, Quarter 2)

Maps Used for Georeferencing

IGM. 1993. Francisco de Orellana, CT-PIII-C1, 4292-IV, Pronvincia de Napo-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721, Edition 1. Quito, Ecuador.

IGM. 1979. San Pedro de Los Cofanes, CT-PIII-A1, 4293-IV, Provincia de Napo-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721, Edition 1. Quito, Ecuador.

IGM. 1993. Laguna de Limoncocha, CT-PIII-C2, 4292-I, Limoncocha-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721-Edition 2, Quito-Ecuador

IGM. 1993. Pacayacu, Hoja 4293-I, Pacayacu-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721, Edition 1. Quito, Ecuador.

IGM. 1994. La Joya de Los Sachas, Hoja 4293-III, La Joya de Los Sachas-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721, Edition 1. Quito, Ecuador.

IGM. 1996. San Sebastián del Coca, CT-OIII-D2, 4192-I, Provincia de Napo-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721-Edition 2, Quito-Ecuador

IGM. 1993. Shushufindi, CT-PII-A4, 4293-II, Provincia de Sucumbíos-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721-Edition 2, Quito-Ecuador

Geocoded image information

Landsat TM image, Quarter 2
Path 009 Row 060
Date 07/02/90
Image name : **00906090020728geo.lan**

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

Number of columns	4027
Number of lines	4042

Reference projection	UTM 18 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	224294	9998114	77.4769 W	0.0170 S
Lower right corner	345104	9876854	76.3921 W	1.1138 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	2.6
Number of GCP	21

Geocoded image information

Landsat TM image, Quarter 2
Path 009 Row 060
Date 03/09/96
Image name: **00906096090328geo.lan**

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

Number of columns	4026
Number of lines	4041

Reference projection	UTM 18 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	224117	9997719	77.4785 W	0.0206 S
Lower right corner	344897	9876489	76.3939 W	1.1171 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	2.1
Number of GCP	21

Annex 2

False colour composites

Río Napo (Path 090, Row 060, Quarter 2)

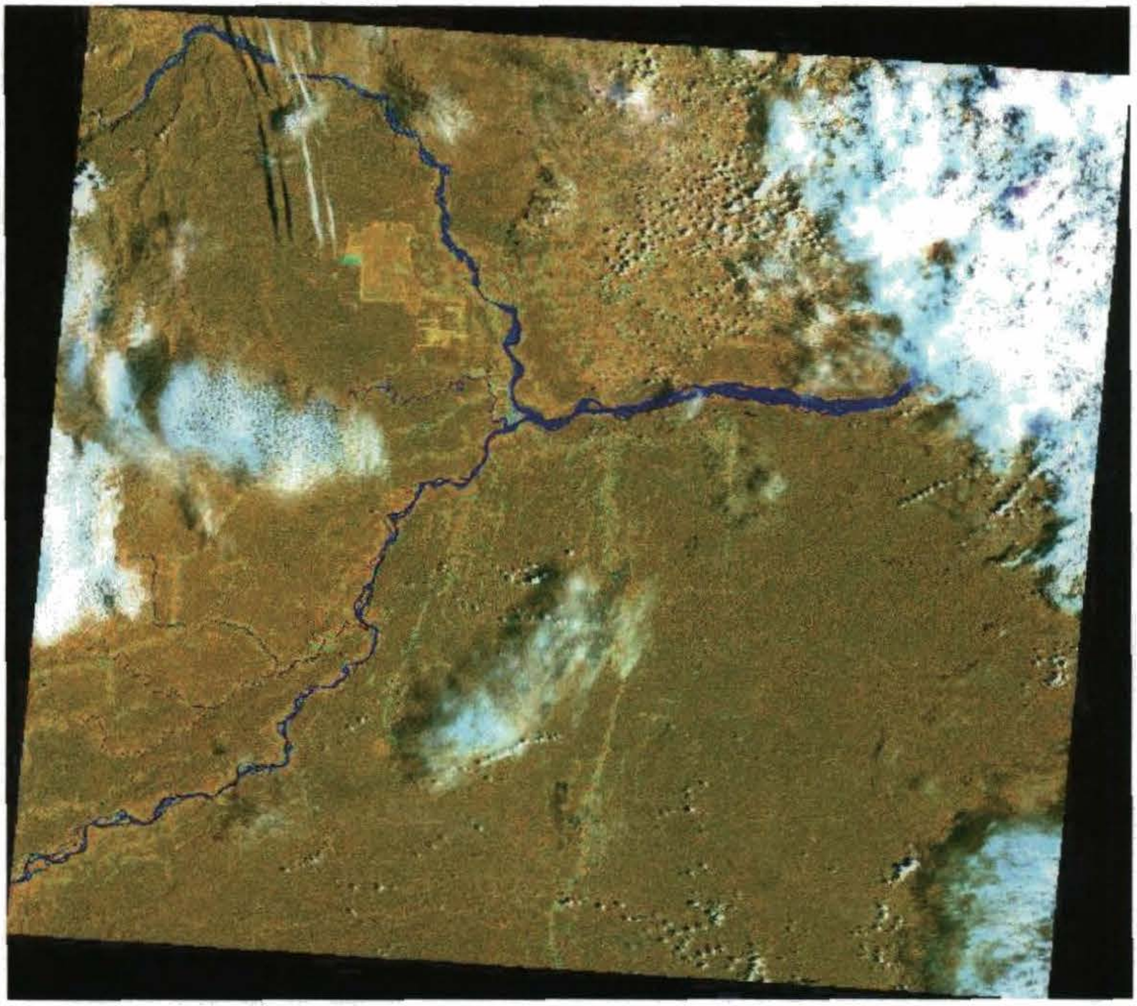


Figure 1. Landsat TM satellite image, bands 4, 5, 3, path 090, row 060, quarter 2, date 07-02-90. Upper left corner 77.4769 W, 0.0170 S, Lower right corner 76.3921 W, 1.1138 S.

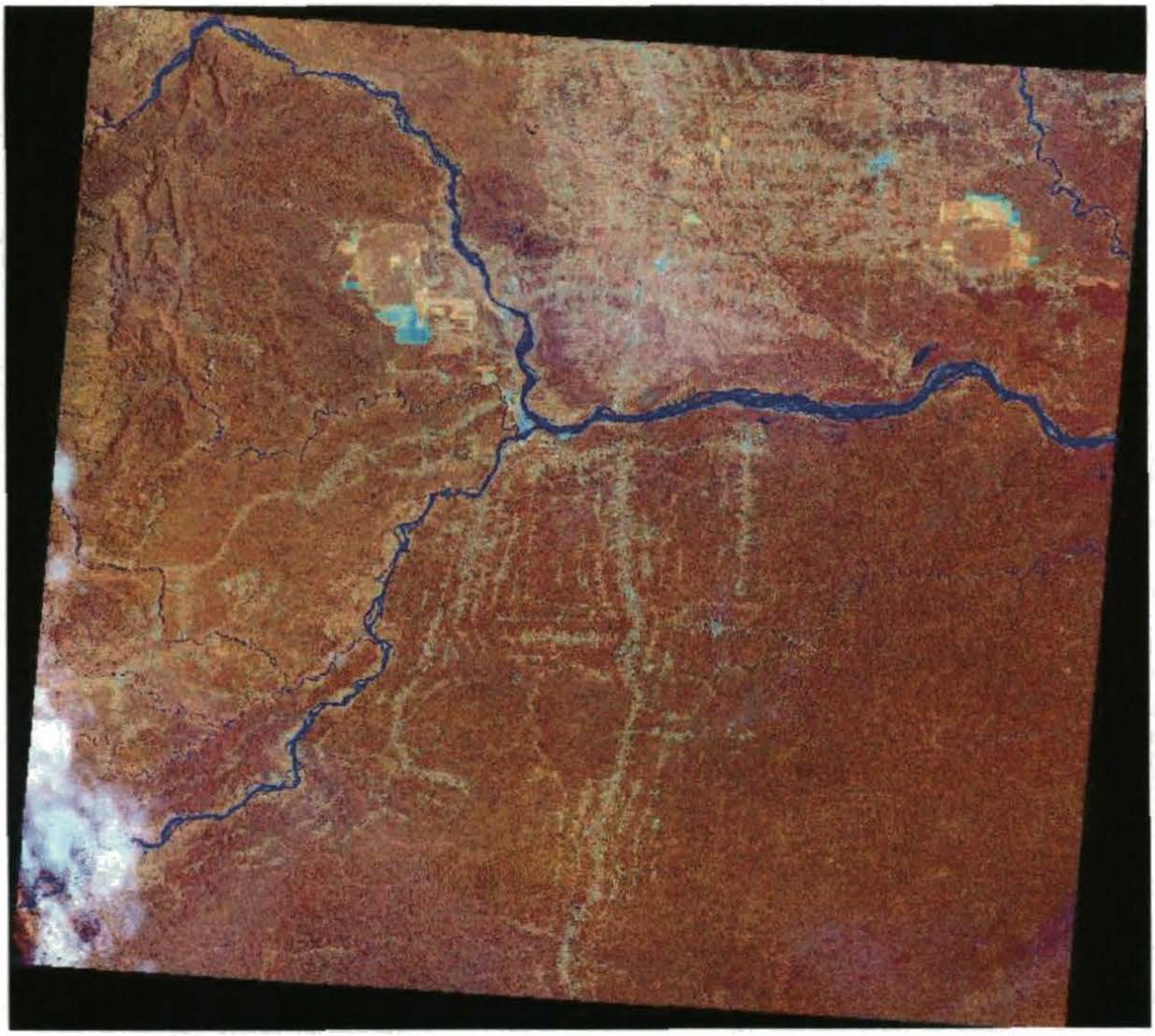


Figure 2. Landsat TM satellite image, bands 4, 5, 3, path 090, row 060, quarter 2, date 03-09-96. Upper left corner 77.4785 W, 0.0206 S, Lower right corner 76.3939 W, 1.1171 S.

Annex 3

Land use / Land cover change
(Overlap area)

Río Napo (Path 090, Row 060, Quarter 2)

Land use / Land cover present in 1990 image

Río Napo (Path 009, Row 060; ecu_ciat_ran_90_cds.xls)

Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111C	Open Lowland Forest
111D	Fragmented Lowland Forest
131A	Closed High Density Periodically inundated forest
131B	Closed Medium Density Periodically inundated forest
131C	Open 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
133D	Fragmented Swamp Forest with Palms
16A	Closed High Density Forest Regrowth
16C	Open Forest Regrowth
16D	Fragmented 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
23	Other Vegetation & Forest
322	Swamp Grassland
33	Regrowth of Vegetation
422	Oil Palm Plantations
43	Ranching
44	Small holding
51	Urban
54	Bare soil
59	Other Non-Vegetated
61	River
621	Natural Lake
81	Cloud
82	Shadow

Land use / Land cover present in 1996 image

Río Napo (Path 009, Row 060; ecu_ciat_ran_96_cds.xls)

Code	Description
111A	Closed High Density Lowland Forest
111B	Closed Medium Density Lowland Forest
111C	Open Lowland Forest
111D	Fragmented Lowland Forest
131B	Closed Medium Density Periodically inundated forest
131C	Open Periodically inundated forest
131D	Fragmented Periodically inundated forest
133A	Closed High Density Swamp Forest with Palms
133B	Closed Medium Density Swamp Forest with Palms
133C	Open Swamp Forest with Palms
133D	Fragmented Swamp Forest with Palms
16A	Closed High Density Forest Regrowth
16B	Closed Medium Density Forest Regrowth
16D	Fragmented 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
23	Other Vegetation & Forest
322	Swamp Grassland
33	Regrowth of Vegetation
420	Unknown Plantations
422	Oil Palm Plantations
429	Other Plantations
43	Ranching
44	Small holding
51	Urban
54	Bare soil
59	Other Non-Vegetated
61	River
621	Natural Lake
81	Cloud
82	Shadow

Statistics for 1990 image

Río Napo (Path 009, Row 060; ecu_ciat_ran_90_sts.xls)

Code 90	No. Polygons	Total Area	Mean Area	S. D. Area
111A	61	702668	11519	44080
111B	94	34836	371	1035
111C	49	15788	322	378
111D	79	22998	291	463
131A	1	411	411	0
131B	8	2437	305	234
131C	6	828	138	80
133A	4	329	82	49
133B	16	3741	234	254
133C	6	1632	272	290
133D	6	961	160	123
16A	6	709	118	103
16C	1	31	31	0
16D	2	551	275	204
211	18	5039	280	229
212	6	910	152	179
23	53	12091	228	301
322	1	52	52	0
33	103	30621	297	438
422	2	6463	3232	4471
43	8	1730	216	313
44	74	76086	1028	6248
51	2	450	225	214
54	3	356	119	99
59	1	45	45	0
61	4	17304	4326	8226
621	2	97	49	2
81	66	293124	4441	20591
82	77	30650	398	1137

Statistics for 1996 image

Río Napo (Path 009, Row 060; ecu_ciat_ran_96_sts.xls)

Code 96	No. Polygons	Total Area	Mean Area	S. D. Area
111A	36	873773	24271	75408
111B	164	49850	304	792
111C	49	9442	193	210
111D	45	11085	246	299
131B	9	3000	333	382
131C	3	477	159	94
131D	1	395	395	0
133A	10	4795	480	597
133B	17	4374	257	288
133C	15	7063	471	514
133D	8	1346	168	107
16A	7	860	123	137
16B	7	472	67	43
16D	6	930	155	128
211	60	16074	268	385
212	55	11169	203	189
23	61	17554	288	498
322	1	52	52	0
33	140	40269	288	653
420	4	1084	271	243
422	2	15186	7593	939
429	1	372	372	0
43	8	2171	271	393
44	88	143496	1631	11365
51	9	1243	138	150
54	10	1248	125	176
59	2	1672	836	1135
61	6	16661	2777	5962
621	5	382	76	87
81	3	24658	8219	12147
82	4	1472	368	262

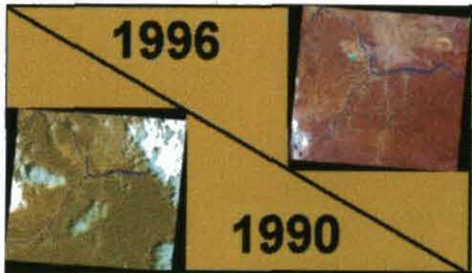
Land use change area for 1990 and 1996 images

Rio Napo (Path 009, Row 060; ecu_ciat_rna_chg.xls)
Images: 00906090020728geo.lan 00906096090328geo.lan

No. Polygons	Code 90	Code 96	Total Area
44	111A	111A	655307
22	111A	111B	2837
12	111A	111C	1345
5	111A	111D	870
34	111A	211	3232
25	111A	212	2749
23	111A	23	3535
41	111A	33	3570
7	111A	422	1192
2	111A	43	504
103	111A	44	9852
1	111A	54	130
1	111A	59	1638
1	111A	621	27
7	111A	81	13395
2	111A	82	787
13	111B	111A	2404
66	111B	111B	23678
6	111B	111C	535
10	111B	111D	935
9	111B	211	1104
5	111B	212	359
8	111B	23	701
20	111B	33	1805
1	111B	420	54
42	111B	44	3213
17	111C	111B	2350
21	111C	111C	4878
5	111C	111D	516
3	111C	211	438
1	111C	212	217
3	111C	23	394
8	111C	33	1282
25	111C	44	3648
4	111C	81	1723
1	111C	82	69
20	111D	111B	3617
5	111D	111C	537
19	111D	111D	6503
11	111D	211	1607
6	111D	212	671
9	111D	23	1274
12	111D	33	1310
1	111D	422	114
26	111D	44	5493
1	111D	54	59
1	111D	59	34
8	111D	81	1160
2	111D	82	61
1	131A	131B	86
1	131A	212	296
1	131A	43	30
9	131B	131B	2323
2	131B	33	89
1	131B	44	26
2	131C	131C	404
1	131C	211	46
1	131C	23	60
1	131C	33	131
2	131C	44	187
2	133A	133A	187
1	133A	133C	93
1	133A	61	49
1	133B	133A	64
12	133B	133B	2792
2	133B	133C	615
1	133B	44	271
1	133C	133B	75
5	133C	133C	1558
1	133D	133B	27
5	133D	133D	934
1	16A	111D	221
2	16A	16A	98
1	16A	16B	152
1	16A	211	92
2	16A	33	147
1	16C	33	31
1	16D	23	420
1	16D	81	131
5	211	211	1002
2	211	212	344
4	211	23	604
6	211	33	1372
7	211	44	1656
1	211	81	60
2	212	211	475
3	212	212	192
1	212	33	133
1	212	44	111
1	23	111B	125
1	23	111D	539
1	23	131B	68
1	23	16A	67
10	23	211	1502
7	23	212	973
16	23	23	4137
13	23	33	1581
9	23	44	1106
4	23	81	1993
1	322	322	52
2	33	16A	249
2	33	16B	117
2	33	16D	82
6	33	211	565
9	33	212	1622
9	33	23	1404
56	33	33	18093
1	33	420	186
3	33	43	211
28	33	44	5768
2	33	51	76
1	33	54	53
2	33	61	87
10	33	81	1782
2	33	82	178
2	422	422	6463
1	43	23	52
2	43	33	172
3	43	422	256
4	43	43	1249
10	44	211	3930
5	44	212	1008
9	44	23	1308
18	44	33	1818
3	44	420	845
1	44	43	147
41	44	44	65309
2	44	51	160
2	44	54	173
4	44	81	1136
2	51	51	450
1	54	33	103
1	54	422	225
1	54	44	28
1	59	54	45
16	61	33	829
1	61	54	32
5	61	61	15829
3	61	81	613
2	621	621	97
61	81	111A	191698
57	81	111B	15185
12	81	111C	2039
8	81	111D	1305
1	81	131B	204
1	81	131C	73
1	81	131D	395
7	81	133A	4545
5	81	133B	1366
9	81	133C	4352
2	81	133D	335
2	81	16A	447
4	81	16B	203
4	81	16D	848
15	81	211	1606
10	81	212	2614
18	81	23	3440
40	81	33	7615
3	81	422	6432
1	81	429	372
1	81	43	31
67	81	44	41402
3	81	51	556
3	81	54	755
2	81	61	696
2	81	621	258
2	81	81	2415
1	81	82	242
42	82	111A	20203
25	82	111B	1985
1	82	111C	107
2	82	111D	195
3	82	131B	318
1	82	133B	114
3	82	133C	445
1	82	133D	77
4	82	211	473
2	82	212	119
3	82	23	225
4	82	33	188
1	82	422	504
36	82	44	5387
1	82	82	92

Land use change matrix

Río Napo (Path 009,Row 060; ecu_ciat_rna_mtx.xls)



				Forest															Mosaic			Non-forest Vegetation		Agriculture					Non-Vegetated			Water		Not Visible		Total
				Evergreen & Semi-evergreen				Inundated Forest							Forest Regrowth			Shifting Cultivation		Other vegetation & Forest	Grassland	Regrowth of Vegetation	Plantations			Ranching	Small holdings	Urban	Bare soil	Other	River	Lake	Cloud	Shadow	
				Evergreen-Lowland Forest				Periodically inundated			Swamp Forest with Palms							less than 1/3 cropping	more than 1/3 cropping		Swamp Grassland		Unknown	Oil Palm	Other							Natural			
				Closed High Density	Closed Medium Density	Open	Fragmented	Closed Medium Density	Open	Fragmented	Closed High Density	Closed Medium Density	Open	Fragmented	Closed High Density	Closed Medium Density	Fragmented																		
Forest	Evergreen & Semi-evergreen	Evergreen-Lowland Forest	Closed High Density	655307	2837	1345	870											3232	2749	3535		3570		1192		504	9857		130	1630		27	13395	787	700970
			Closed Medium Density	2404	23678	535	935											1104	399	791		1805	54				3213								34788
			Open		7350	4878	516											438	217	394		1282					3646						1723	69	15515
			Fragmented		3617	537	6503											1007	671	1374		1310		114			5493		55	34			1168	51	22440
	Inundated Forest	Periodically inundated	Closed High Density					86											296							30									412
			Closed Medium Density					2323														89					26								2438
			Open						404									46		60		131					187								828
		Swamp Forest with Palms	Closed High Density								187		93																		49				329
			Closed Medium Density								64	2792	615														271								3742
			Open									75	1558																						1633
			Fragmented									77		934																					961
	Forest Regrowth		Closed High Density				221								98	152		92				147													710
			Open																			31													31
			Fragmented																	420													131		551
Mosaic	Shifting Cultivation	less than 1/3 cropping																1002	344	694		1372					1656						60		5038
		more than 1/3 cropping																475	192			133					111								911
	Other Vegetation & Forest				125		539	68							67			1582	573	4137		1581					1186						1993		12091
Non-forest Vegetation	Grassland	Swamp Grassland																			52														52
	Regrowth of Vegetation														249	117	82	565	1622	1404		18893	186			211	5768	76	53		87		1782	178	38473
Agriculture	Oil Palm																							6463											6463
	Ranching																			57		172		256		1249									1729
	Small holding																	3930	1080	1300		1816	845			147	65309	160	173				1136		75834
Non-Vegetated	Urban																											450							450
	Bare soil																					103		225			28								356
	Other																												45						45
Water	River																					829							32		15829		613		17303
	Lake	Natural																														97			97
Not Visible	Cloud			191698	15185	2038	1305	204	73	395	4545	1366	4352	335	447	203	848	1606	2614	3440		7615		6432	372	31	41481	556	755		696	250	2415	242	291428
	Shadow			20203	1985	107	195	318				114	445	77				473	119	225		188		504			5387							92	38432
Total				869612	49777	9441	11084	2999	477	395	4796	4374	7063	1346	861	472	930	16072	11164	17554	52	40269	1085	15186	372	2172	143456	1242	1242	1672	16661	382	24408	1429	1298068

🟩 *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 agricolas 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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