Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

TREES PROJECT

Tumbes – Ecuador/Peru

(Path 011, Row 062, Quarter 2)

Joint Research Centre (JRC)

and

CIAT

Technical Report

Javier Puig, Grégoire Leclerc,

Carlos Nagles, Alexander Cuero, Rafael D. Hoyos

December 1999

Consultative Group on International Agricultural Research

TABLE OF CONTENTS

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 on the south-west coast of Ecuador and the north-west coast of Peru.

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 across the international border between Ecuador and Peru, near to the Pacific Coast. This study area includes the southern Pacific mangrove forest in Latin America and the northern Peruvian montane forest on the western slopes of the Andes. The principal boundaries are, in the west the Pacific Ocean, in the north the city of Machala and the Guayaquil Gulf, in the east the international border and the agricultural land of Ecuador and to the south the Tumbes National Reserve and the Peruvian coastal desert. The total area covered is 1 076 930 hectares, with ocean comprising 52.2% of the total area.

CLIMATE AND VEGETATION

The Peruvian coastal region is one of the driest places on the planet. This is because the Andes forms a barrier to the movement of humid masses of air coming from the Amazon region in the east. Also the cold Humboldt Current in the Pacific Ocean constantly cools the air masses forming banks of fog, which reach the coast especially between June and September. It only rains along the coast when the temperature of the sea exceeds that of the masses of air over the land. This situation occurs when "El Niño" manifests with abundant precipitation in the zone (Begler, 1980).

Rainfall is frequent between December and March, although some years can have total drought. Another form of precipitation is the drizzle that often covers the coast (Feininger, 1975). The drought conditions lessen moving north to Ecuador (Brawer, 1991).

Feininger (1975), in his study carried out in El Oro State in southern Ecuador bordering with Peru, describes the climatic conditions and vegetation in most of the area as semi-arid, even sub-humid. In the driest zones toward the north-west, the rains permit the growth of sporadic vegetation such as cactus and small shrub. Toward the south-east, the weather becomes more and more humid reaching a maximum on the north flank of Tahuin Hill (1295 m) in the Tahuin mountain range, where there are patches of humid tropical forest. Then the weather conditions change and become dry again.

COASTAL FOREST

The mangrove forest is an important tropical ecosystem dominated by mangrove, varied numbers of vegetable species and animals that interact in a delicate device for their survival. The mangrove forest has highly important functions in the coastal ecosystem, such as:

- Repressing the effects of the tides and waves along the coast,
- Facilitating sedimentation,
- Diminishing wind speed,
- Impeding sea air loaded with salt from lapping the coastal fields and
- Facilitating the development of numerous species

(PMRC, 1992; Lasso, 1992; Diaz, 1998).

In South America, between 10 and 15 mangrove species exist. Although these forests are distributed along latitude 30° North, in the southern hemisphere they are found only along latitude 3° South on the Pacific Coast, up to about the mouth of the River Tumbes in the north of Peru (PMRC, 1992).

In the Jambelli Archipelago in the south of Ecuador and the north of Peru, mangroves are located in the mouths of many rivers coming from the Andean mountain range, such as the Rivers Pagua and Arenillas in El Oro State, Ecuador. But, in El Oro State the mangroves have been destroyed in 90 % of their potential area (PMRC, 1992). The indiscriminate logging is to clear surfaces to construct pools for shrimp breeding in captivity, which is the principal cause of damage to this kind of forest (PMRC, 1992; Lasso, 1992).

The cutting of mangrove facilitates erosion along the coast and increases the desertification process in the interior of the continent, as well as salinization and water contamination on the coast (PMRC, 1992; Lasso, 1992).

MOUNTAIN FOREST

On the northern limit of Tumbes State, beside the international boundary with Ecuador, the Tumbes National Reserve is located. This has an area of 72 102 ha and a variety in forest type and fauna (http://www3.rcp.net.pe/peru/tumbes/reservas_naturales. html). Outside this forest, more than half of the original forest zone has become grassland and is unused.

METHODOLOGY

MATERIALS

For this work we used the second quarter of two Landsat TM images (path 011 row 062: 011062910819geo.lan, 011062971006.lan). The radiometric quality of data of both images was good, showing some cloud coverage in the upper right corners. We didn't dispose of a land use or forest map as reference, the interpretation of land use and land cover was done on the basis of the literature.

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 17 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 georeferencing, root mean square (RMS) error for both processes as well as parameters and other georeferencing information.

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

LAND-USE AND LAND-COVER DIGITISING

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

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

BUILDING POLYGONS

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

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

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

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

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

INTERPRETATION OF CHANGES

Different types of natural vegetation and agricultural practices were observed in the images, such as evergreen montane forest, deciduous forest (dry forest), gallery and mangrove forests, as well as banana plantations and shrimp farming. All types of forest cover around 38% of the land without clouds (later referred to as overlap area). Montane forest cover 21.3% of the forest area, semi-evergreen forest cover 30.8%, deciduous forest 35.1%, gallery-forest 1.4% and mangrove 11.7%. Sea cover 50.5% of the overlap area.

Net annual deforestation rate for the different types of forest was: montane forest 0.03%, semi-evergreen forest 0.02%, deciduous forest 0.2% and mangrove forest 1%. Total annual deforestation was 0.21% (excluding recuperation) on the overlap area..

Shrimp farming is located mainly within mangrove areas, the forest being cleared and large pools constructed. This activity exists on 6.6% of the overlap area, the shrimp farming area having a net annual increase of 3%.

Industrial banana plantations have replaced the gallery forest of some rivers. This agricultural activity covers 3% of the overlap area, with an net annual increment of 0.4%.

Montane and deciduous forests are mainly located in the Piura Nature Reserve in Peru over the Amctape hills. Deciduous forest is found along the Pacific coastal plain or on small hills. Gallery forest occurs along some rivers that descend from the Piura Nature Reserve and the mangrove forest exists along the coast and the islands of the Jambelli Archipelago.

CONCLUSIONS

The study site is a deforestation hot spot of special importance because it presents a combination of different types of forest in a marginal area. Although some are protected by a nature reserve, this does not mean that they are safe. It was possible to observe deforestation, (especially along the lower parts of the Amctape hills) and the pressure on the reserve by Ecuadorians near the international border with Peru.

The mangrove forest was the most affected, its net annual deforestation rate (1%) is close to national average of 1.6% (WRI-UNEP-UNDP-World Bank, 1998). The principal agents responsible of mangrove deforestation are the shrimp farmers who use the forest, wood and shrubland area to build new pools. Also they are beginning to expand their activity to other coastal lands.

Annex 1

Geocoded image information

Tumbes (Path 011, Row 062, Quarter 2)

Maps Used for Georeferencing

IGN. 1982. Zorritos, Hoja 8-b, Tumbes-Perú, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J632, Edition 2. Lima, Peru.

IGM. 1988. Alamor, CT-MVII-B2, 3581-I, Provincia de Loja-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721-Edition 3, Quito-Ecuador

IGM. 1989. Puyango, CT-MVI-F4, 3582-II, Puyango-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721, Edition 2. Quito-Ecuador

IGN. 1995. Zarumilla, Hoja 7-c, Tumbes-Perú, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J632, Edition 2. Lima, Peru.

IGM. 1984. Jambelí, CT-MVI-B4, 3584-II, Provincia de El Oro-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721-Edition 1, Quito-Ecuador

IGN. 1985. Tumbes, Hoja 8-c, Tumbes-Perú, Topograhic map, Scale 1: 100 000, Instituto Geográfico Nacional, Serie J632, Edition 2. Lima, Peru.

IGM. 1988. Santa Rosa de El Oro, CT-NVI-C1, 3683-IV, Provincia de El Oro-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721, Edition 2. Quito-Ecuador

IGM. 1990. Machala, CT-NVI-A3, 3684-III, Provincia de El Oro-Ecuador, Topograhic map, Scale 1: 50 000, Instituto Geográfico Militar, Serie J721, Edition 2. Quito-Ecuador

IGM. 1990. Huaquillas,CT-MVI-D2, 3583-I, Provincia de El Oro-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 011 Row 062
Date 19/08/91
Image name: **011062910819Q2geo.lan**

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

Number of columns	3988
Number of lines	4003

Reference projection	UTM 17 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	511901	9671241	80.8834 W	2.9727 S
Lower right corner	631541	9551151	79.8054 W	4.0535 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	2.0
Number of GCP	22

Geocoded image information

Landsat TM image, Quarter 2
Path 011 Row 062
Date 06/10/97
Image name: **011062971006Q2geo.lan**

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

Number of columns	4120
Number of lines	4135

Reference projection	UTM 17 M WGS84		Lat/Long WGS84	
Units	Metres		Degree	
Upper left corner	508200	9670977	80.9234 W	2.9736 S
Lower right corner	631800	9546926	79.8045 W	4.0853 S

Resampling mode	Nearest
Transformation order	1
Georeferencing error (pixel)	1.0
Number of GCP	28

Annex 2

False colour composites

Tumbes (Path 011, Row 062, Quarter 2)

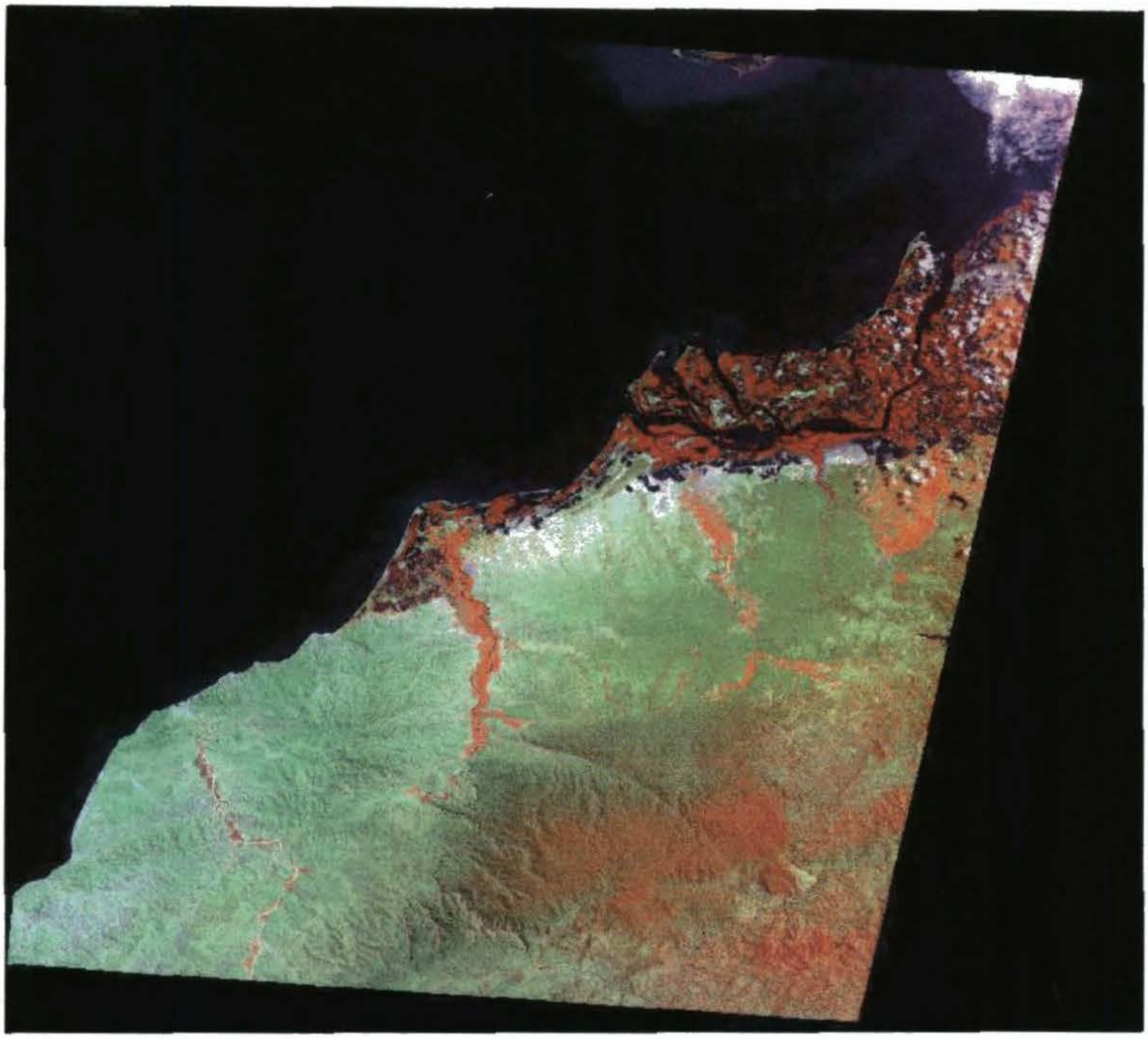


Figure 1. Landsat TM satellite image, bands 4, 5, 3, path 011, row 062, quarter 2, date 19-08-91. Upper left corner 80.8834 W, 2.9727 S, Lower right corner 79.8054 W, 4.0535 S.

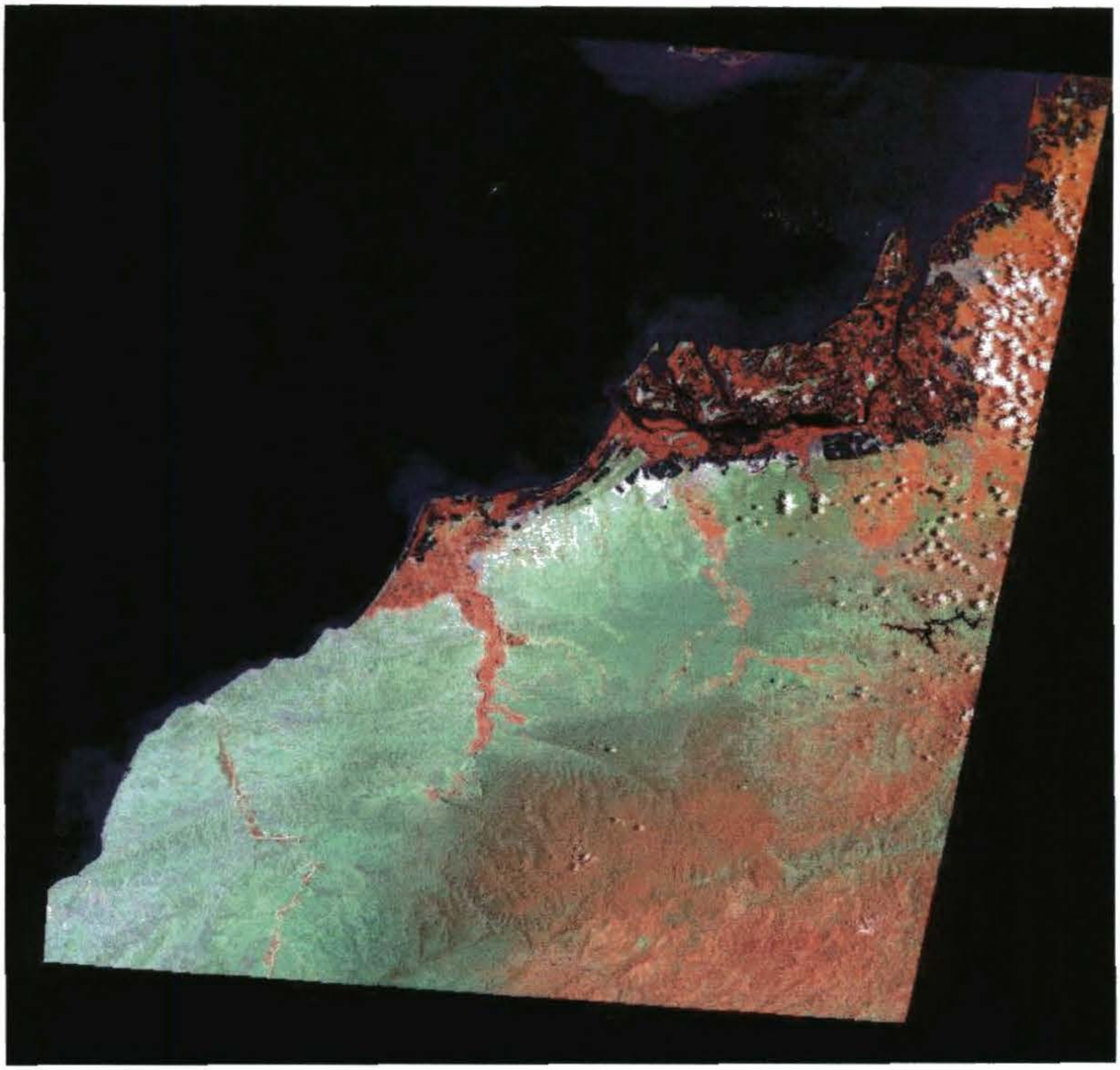


Figure 2. Landsat TM satellite image, bands 4, 5, 3, path 011, row 062, quarter 2, date 10-06-97. Upper left corner 80.9234 W, 2.9736 S, Lower right corner 79.8045 W, 4.0853 S.

Annex 3

Land use / Land cover change
(Overlap area)

Latacunga (Path 011, Row 062, Quarter 4)

Land use / Land cover present in 1991 image

Tumbes (Path 011, Row 062; ecu_ciat_tum_91_cds.xls)

Code	Description
112B	Closed Medium Density Montane Forest
112D	Fragmented Montane Forest
113B	Closed Medium Density Semi-evergreen Forest
113C	Open Semi-evergreen Forest
113D	Fragmented Semi-evergreen Forest
129B	Closed Medium Density Other Deciduous Forest
129C	Open Other Deciduous Forest
129D	Fragmented Other Deciduous Forest
14B	Closed Medium Density Gallery-forest
14C	Open Gallery-forest
14D	Fragmented Gallery-forest
17A	Closed High Density Mangrove forest
17B	Closed Medium Density Mangrove forest
17C	Open Mangrove forest
17D	Fragmented Mangrove forest
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
22	Cropland & Forest
23	Other Vegetation & Forest
29	Other Mosaic
310	Unknown Wood & Shrubland
319	Other Wood & Shrubland
410	Unknown Arable land
411	Irrigated Arable land
429	Other Plantations
43	Ranching
44	Small holding
49	Other Agriculture
51	Urban
539	Other Infrastructure
54	Bare soil
622	Artificial Lake
7	Sea
81	Cloud
82	Shadow

Land use / Land cover present in 1997 image

Tumbes (Path 011, Row 062; ecu_ciat_tum_97_cds.xls)

Code	Description
112B	Closed Medium Density Montane Forest
112D	Fragmented Montane Forest
113B	Closed Medium Density Semi-evergreen Forest
113D	Fragmented Semi-evergreen Forest
129B	Closed Medium Density Other Deciduous Forest
129C	Open Other Deciduous Forest
129D	Fragmented Other Deciduous Forest
14B	Closed Medium Density Gallery-forest
14D	Fragmented Gallery-forest
17A	Closed High Density Mangrove forest
17B	Closed Medium Density Mangrove forest
17C	Open Mangrove forest
17D	Fragmented Mangrove forest
212	Mosaic of Shifting Cultivation & forest with more than 1/3 cropping
22	Cropland & Forest
23	Other Vegetation & Forest
29	Other Mosaic
310	Unknown Wood & Shrubland
319	Other Wood & Shrubland
33	Regrowth of Vegetation
410	Unknown Arable land
411	Irrigated Arable land
429	Other Plantations
43	Ranching
44	Small holding
49	Other Agriculture
51	Urban
539	Other Infrastructure
54	Bare soil
622	Artificial Lake
7	Sea
81	Cloud
82	Shadow

Statistics for 1991 image

Tumbes (Path 011, Row 062; ecu_ciat_tum_91_sts.xls)

Code 91	Number Polygons	Total Area	Mean Area	S. D. Area
112B	2	33757	16879	21067
112D	5	8822	1764	2730
113B	4	59712	14928	18987
113C	1	490	490	0
113D	4	1746	437	430
129B	3	66172	22057	22914
129C	1	701	701	0
129D	1	3729	3729	0
14B	6	2253	376	283
14C	1	35	35	0
14D	1	487	487	0
17A	2	113	57	44
17B	32	6203	194	494
17C	24	4775	199	360
17D	18	14050	781	1228
212	1	2725	2725	0
22	1	2488	2488	0
23	11	21728	1975	3876
29	1	161	161	0
310	13	141789	10907	27690
319	42	7008	167	318
410	1	2232	2232	0
411	3	2546	849	666
429	18	16081	893	1507
43	12	10982	915	1523
44	12	32278	2690	7484
49	17	7497	441	415
51	7	3118	445	435
539	81	28519	352	504
54	62	42736	689	1878
622	2	276	138	2
7	1	534316	534316	0
81	29	15601	538	1980
82	18	1802	100	64

Statistics for 1997 image

Tumbes (Path 011, Row 062; ecu_ciat_tum_97_sts.xls)

Code 97	Number Polygons	Total Area	Mean Area	S. D. Area
112B	2	33757	16879	21067
112D	5	8647	1729	2659
113B	4	59712	14928	18987
113D	5	1487	17	0
129B	4	65298	297	385
129C	1	701	16306	20921
129D	1	3729	701	0
14B	6	2253	3729	0
14D	2	522	376	283
17A	1	26	261	319
17B	22	5900	26	0
17C	25	3849	267	590
17D	30	14486	140	333
212	1	2725	460	817
22	1	2488	2725	0
23	12	21961	2488	0
29	1	161	1830	3728
310	12	140578	161	0
319	20	4521	11713	28762
33	2	341	216	416
410	1	67	120	122
411	2	5318	44	0
429	19	16827	2650	3010
43	15	11267	767	1495
44	18	33603	753	1451
49	21	6039	1768	5983
51	9	3826	273	308
539	72	37210	425	582
54	47	41052	504	830
622	2	326	856	2196
7	2	544403	113	91
81	18	2660	272202	384844
82	15	1188	130	257

Land use change for 1991 and 1997 images

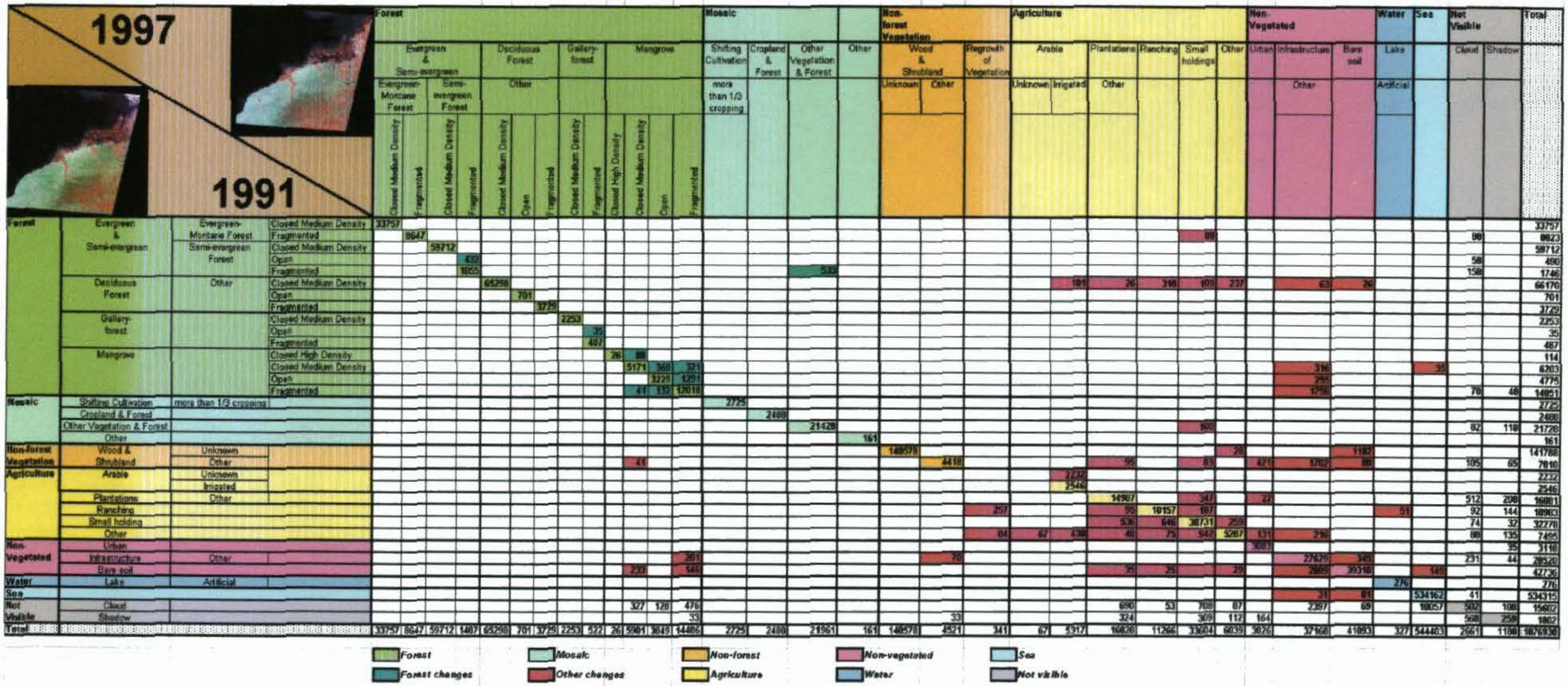
Tumbes (Path 011, Row 062; ecu_ciat_tum_chg.xls)
Images: **011062910819Q2geo.lan 011062971006Q2geo.lan**

No. Polygons	Code 91	Code 97	Total Area
2	112B	112B	33757
5	112D	112D	8647
1	112D	44	88
1	112D	81	88
4	113B	113B	59712
2	113C	113D	432
1	113C	81	58
3	113D	113D	1055
1	113D	23	533
2	113D	81	158
4	129B	129B	65298
2	129B	411	101
1	129B	429	26
3	129B	43	310
3	129B	44	109
2	129B	49	237
2	129B	539	63
1	129B	54	26
1	129C	129C	701
1	129D	129D	3729
6	14B	14B	2253
1	14C	14D	35
1	14D	14D	487
1	17A	17A	26
1	17A	17B	88
18	17B	17B	5171
6	17B	17C	360
6	17B	17D	321
8	17B	539	316
1	17B	7	35
17	17C	17C	3229
9	17C	17D	1291
5	17C	539	255
1	17D	17B	41
2	17D	17C	132
20	17D	17D	12018
22	17D	539	1750
2	17D	81	70
1	17D	82	40
1	212	212	2725
1	22	22	2488
11	23	23	21428
1	23	44	100
1	23	81	82
1	23	82	118
1	29	29	161
12	310	310	140578
1	310	49	28
1	310	54	1182
1	319	17B	41
22	319	319	4418
2	319	429	95
1	319	44	83
2	319	51	421
27	319	539	1702
2	319	54	80
2	319	81	105
1	319	82	65
1	410	411	2232
4	411	411	2546
18	429	429	14987
2	429	44	347
1	429	51	27
8	429	81	512
3	429	82	208

No. Polygons	Code 91	Code 97	Total Area
1	43	33	257
1	43	429	95
12	43	43	10157
1	43	44	187
1	43	622	51
2	43	81	92
2	43	82	144
2	44	429	536
4	44	43	646
15	44	44	30731
5	44	49	259
2	44	81	74
1	44	82	32
1	49	33	84
1	49	410	67
1	49	411	438
1	49	429	40
1	49	43	75
14	49	44	942
23	49	49	5287
2	49	51	131
4	49	539	216
2	49	81	80
3	49	82	135
7	51	51	3083
1	51	82	35
2	539	17D	201
1	539	319	70
85	539	539	27629
4	539	54	345
4	539	81	231
1	539	82	44
2	54	17B	233
3	54	17D	146
1	54	429	35
1	54	43	25
1	54	49	29
29	54	539	2809
47	54	54	39310
3	54	7	149
2	622	622	276
1	7	539	31
2	7	54	81
2	7	7	534162
1	7	81	41
1	81	17B	327
2	81	17C	128
8	81	17D	476
8	81	429	690
1	81	43	53
5	81	44	708
2	81	49	87
17	81	539	2397
1	81	54	69
3	81	7	10057
6	81	81	502
3	81	82	108
1	82	17D	33
1	82	319	33
6	82	429	324
4	82	44	309
3	82	49	112
2	82	51	164
7	82	81	568
5	82	82	259

Land use change matrix

Tumbes (Path 011,Row 062; ecu_ciat_tum_mtx.xls)



1997				Forest													Mosaic				Non-forest Vegetation			Agriculture						Non-Vegetated			Water	Sea	Not Visible		Total
				Evergreen & Semi-evergreen				Deciduous Forest			Gallery-forest		Mangrove				Shifting Cultivation	Cropland & Forest	Other Vegetation & Forest	Other	Wood & Shrubland		Regrowth of Vegetation	Arable		Plantations	Ranching	Small holdings	Other	Urban	Infrastructure	Bare soil	Lake		Cloud	Shadow	
				Evergreen-Montane Forest		Semi-evergreen Forest		Other									more than 1/3 cropping				Unknown	Other		Unknown	Irrigated	Other					Other		Artificial				
1991				Closed Medium Density	Fragmented	Closed Medium Density	Fragmented	Closed Medium Density	Open	Fragmented	Closed Medium Density	Fragmented	Closed High Density	Closed Medium Density	Open	Fragmented																					
Forest	Evergreen & Semi-evergreen	Evergreen-Montane Forest	Closed Medium Density	33757																																	33757
			Fragmented		8647																							88							88		8823
		Semi-evergreen Forest	Closed Medium Density			59712																															59712
			Open				432																												58		490
			Fragmented				1055												533																158		1746
	Deciduous Forest	Other	Closed Medium Density					65298																	101	26	310	109	237		63	26					66170
			Open						701																												701
			Fragmented							3729																											3729
	Gallery-forest		Closed Medium Density								2253																										2253
			Open									35																									35
			Fragmented									487																									487
	Mangrove		Closed High Density										26	88																							114
			Closed Medium Density											5171	360	321															316			35			6203
			Open												3229	1291															255						4775
			Fragmented											41	132	12018															1758				70	48	14851
Mosaic	Shifting Cultivation	more than 1/3 cropping															2725																				2725
	Cropland & Forest																	2488																			2488
	Other Vegetation & Forest																		21428									100							82	118	21728
	Other																			161																	161
Non-forest Vegetation	Wood & Shrubland	Unknown																			140578								28			1182					141788
		Other												41								4418				95		83		471	1702	88			105	65	7010
Agriculture	Arable	Unknown																							2232												2232
		Irrigated																							2546												2546
	Plantations	Other																								14987		347		27					512	208	16081
	Ranching																						257			95	10157	187					51		92	144	10983
	Small holding																									536	646	30731	259						74	32	32278
	Other																						84	67	438	46	75	542	5287	131	218				88	135	7495
Non-Vegetated	Urban																													3083						35	3118
	Infrastructure	Other														201						78									27679	349			231	44	28520
	Bare soil													233		146										35	25		29		2889	39318		149			42736
Water	Lake	Artificial																															276				276
Sea																															31	81		534162	41		534315
Not Visible	Cloud													327	128	476										690	53	708	87		2397	69		10057	502	108	15602
	Shadow															33						33				324		309	112	164					568	259	1802
Total				33757	8647	59712	1487	65298	701	3729	2253	522	26	5901	3849	14486	2725	2488	21961	161	140578	4521	341	67	5317	16828	11266	33604	6039	3826	37168	41893	327	544403	2661	1188	1076930

■ *Forest*

■ *Forest changes*

■ *Mosaic*

■ *Other changes*

■ *Non-forest*

■ *Agriculture*

■ *Non-vegetated*

■ *Water*

■ *Sea*

■ *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

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

Begler, E.B. 1980. Modernization of agricultural production and the problem of rural unemployment: the search for work among the rural proletariat of the Peruvian North Coast. University Microfilms International, Michigan, USA. 258 p.

Brawer, M. 1991. Atlas of South America. Simon and Schuster, NY. p.52-56.

Diaz-P., S. 1998. El medio ambiente Colombiano y los cultivos ilícitos. Rev. Acad. Colombiana de Ciencias Exactas Física y Naturales, Bogotá, Colombia. 22:173-186.

Feininger, T. 1975. Geología de la zona Arenillas – Puyango, Provincia de El Oro. Programa Regional para Desarrollo del Sur del Ecuador (PREDESUR). Publicació no. 37. 143 p.

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

Hiroaka, M. and Yamamoto S. 1980. Agricultural development in the Upper Amazon of Ecuador. Geog. Rev. p. 431.

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.

Lasso, G. 1992. Deterioro de los bosques en Ecuador. Bosques y Desarrollo, Cali, Colombia. Año 3 (5-mayo):29-32/58.

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.

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.

PMRC. 1992. El manglar un ecosistema fundamental. Ecuador visison global para el desarrollo de la costa. PMRC, Bosques y Desarrollo, Cali, Colombia. Año3(6-octubre):46-48.

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

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

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

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. p. 291-302.