Changes in tropical rainforests landscapes as a consequence of selective logging and indigenous shifting cultivation in Forest Reserve Imataca (central zone) Bolívar State, Venezuela.

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Dipl. Geogr. MSc. Glenda Ysolina Rodríguez Aponte

aus Puerto Cabello (Venezuela)

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Referent:	Prof. Dr. Martin Kappas
Korreferent:	Prof. Dr. Pierre Ibisch
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Abstract

The degradation process of tropical land forests caused by traditional indigenous agriculture and commercial logging was evaluated in the central sector of the Forest Reserve Imataca in the Venezuelan Guayana.

The landscape conceptual approach enabled us to combine two levels of analysis namely local and landscape, in order to detect spatial relationships that shape patterns, gradient, and structures, all of them helpful in monitoring tropical forests uses and their conservation status.

The evaluation integrated several methods aimed at describing and analysing the forest communities' composition, structure, and distribution, taking into account two forest conditions namely undisturbed and disturbed.

We made a social survey dealing with information about the land uses under study, and to perform measurements of the production areas in the Kariñas people communities, as well as some logging concessions sampling. A forest inventory in sample plots was carried out to collect a dataset of forest structure parameters that allowed the calculation of indexes such as diversity alpha and beta, structural complexity, and others. Techniques regarding remote sensing were applied such as texture analysis, vegetation index and fractional cover.

We mapped the distribution of undisturbed forests and three levels of forest degradation regarding the land uses under consideration. As well, areas of overlapping (superposition) between traditional Kariñas territories and commercial logging concessions were calculated. These areas are expected to be the object of new conflicts that will worsen, since traditional territories demarcation is still going on, and the mining exploitation is close to begin.

The interest to study this complex situation in the Forest Reserve Imataca represents a challenge to achieve a sustainable model of forest management and conservation in the Venezuelan Guayana.

Problem Statement

Tropical rain forests clearing and degradation are ongoing processes which are only partially evaluated in Venezuela, though they have severe implications: Indigenous people have been affected, and damages to soils and rivers are a serious threat to ecosystem sustainability. Concerns are growing because most of the remaining primary forests in Venezuela are located in the Guayana region where indigenous people are the traditional forest dwellers. Indeed, in 1999 the Venezuelan Constitution approved the land rights of indigenous people over their ancestral territories. Since then, negotiations to carry out land demarcation have been initiated. The high proportion of commercial logging in central Forest Reserve Imataca complicates land demarcation, however. At least for the next 20 years timber harvesting on a large scale and the related forest degradation are expected to continue due to the current concessions.

The evaluation of logging performance with regard to the exploitation of lowland forest along Los Andes piedmont indicated a variety of harmful effects such as the depletion of commercial species and their eventual disappearance, damages to the residual stand due to logging methods and disturbances of structure and species composition of residual stands. In addition, it has been pointed out that the official control of logging is superficial or does not take place at all. Consequently, management practices and forest legislation seem to be unsuitable for forest conservation in western Venezuela (Kammesheidt et al., 2001).

In the year 2000 the government requested selected Venezuelan universities to conduct an evaluation of the Reserve with regard to land use and management plans of Forest Reserve Imataca. This evaluation was intended to provide a sound basis for the elaboration of a suitable plan to replace the controversial Decree 1850. The resulting technical documents and maps suggested that the Reserve bears huge land use conflicts, as well as endangered areas of fauna, flora, and soils. Social and economic concerns overlap and emerge through conflicts among indigenous people, loggers and miners (UCV 2000, ULA 2000, UNEG 2000). A more recent overview of the Guayana region forests lists important information gaps, and calls for an impact assessment of commercial logging (GFW, 2002). But perhaps the most interesting conclusion from this study was that logging and mining activities produce low revenues for the Venezuelan economy.

In spite of the fact that commercial logging has experienced unsatisfactory results, provides low benefits to the Venezuelan State, and despite the warnings of researchers emphasizing the current lack of knowledge about tropical forest dynamics, the authorities of environmental administration seem to consider selective logging based on sustained yield the best option for forest management. Evidence of this situation are the lack of enhancement on the selective logging model transferred from western Venezuela to the Guayana region, although forests are quite different to those located in Los Andes piedmont plains. The technical document on the land use plan limits itself to recommend the reduction of area sizes of future forest concessions. The lack of awareness about forest degradation seems to underlie the Land Use and Management Plan of Forest Reserve Imataca (2004), as it does not propose measures to manage the problem. On the contrary, it approves the current forestry model and also opens the Reserve to mining by providing it legal status (MARN, 2004).

Forests can be considered as ecosystems that are used in their multiple dimensions by and for the people. Keeping the balance between the whole array of components (WRF, 2004) means including disturbance regimes as part of the system. However, natural or creative disturbances like indigenous management systems and their ability to promote changes should be differentiated from those based on high energy and technology inputs.

Natural disturbances are inherently different from those of silviculture. One difference relates to the amount of carbon removed from the site when harvesting a forest. A fundamental feature of a natural disturbance regime is its variation in extent, timing, intensity, and spatial location (Crow and Perera, 2004).

On the other hand, the presence of indigenous people in the highest biodiversity areas in Middle and South America, including lowlands, highlands and coastlines, has been recognized. The evidence of natural environment conservation in these areas highlights the suitability of traditional management models that, albeit not market-oriented, led to use patterns that proved to be sustainable.

A number of research projects on ethno botany, ethno zoology, ethno ecology, and so on have been conducted; demonstrating the huge traditional knowledge, technologies and management strategies owned by indigenous people in Latin America (Toledo and Castillo, 1999). The Amazonian heterogeneity and particularly the current configuration of Amazon forest has been documented as an outcome of natural and anthropogenic disturbances. In this approach native human population are “creative” agents of disturbance, acting on a small to medium scale within the Amazonian landscape (Lopez-Zent, 1998).

While in deforestation literature extraction of wood or logging and shifting cultivation rank as primary causes of deforestation, there seems to be a considerable difference between two modes of farming, (i) traditional shifting cultivation (or swidden-fallow farming practiced by indigenous people) and (ii) colonist shifting cultivation (or slash-and-burn agriculture practiced by migrant settlers) (Geist and Lambin, 2001).

Governments of tropical countries, however, classify indigenous forest management practices that imply a sustainable rotation system together with those of settlers-farmers - accusing them both indigenous peoples and farmers of being the main agents causing forest degradation (WRF, 2004).

On the other hand, the Venezuelan government does not seem to consider commercial selective logging as a cause of tropical forest degradation. In fact, the government does not have any mechanisms in place to evaluate and control degradation. Responsibility for ecosystem conservation is delegated by letting the logging companies elaborate their own management plans.

Under these circumstances, sustainability of primary forests within the reserves is threatened by impacts such as the size of areas under concession (currently exceeding 130,000 ha), habitat fragmentation due to road construction, and the doubtful activities undertaken by companies in reserves in the western part of the country.

Statement of Purposes

The main purpose of this thesis is to estimate changes in tropical rain forest landscapes and forest communities due to forest degradation caused by selective logging and indigenous shifting cultivation in the central sector of the Forest Reserve Imataca (Venezuela).

The achievement of the main objective is based on the following specific objectives:

1. To determine floristic composition and structure of selected undisturbed and disturbed forests regarding selective logging and indigenous shifting cultivation.
2. To recognize patterns of spatial configuration of selective logging and indigenous shifting cultivation, in order to locate degraded areas
3. To evaluate basal area as indicator of forest degradation in terms of changes in forest communities structure and biomass content
4. To evaluate normalized difference vegetation index (NDVI) as an indicator of forest degradation in terms of biomass changes in Landsat temporal data sets
5. To determine overlapping areas between both land uses and the actual area available for indigenous shifting cultivation as well as potentially conflictive areas
6. To evaluate the suitability of the landscape approach based on satellite imagery to monitor tropical forests degradation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

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SECTION I. BACKGROUND

1. General landscape characterization and evaluation

The research assumes that tropical forest landscape is a complex system of ecological and social components. Hence, its study demands an integrative approach. Research about landscape focuses on both, components which denote structures and the relationships among them, representing functioning.

Landscape concept has a huge variety of connotations, some of them related to physical features which are natural qualities of an area, mosaic of local ecosystems along a wide area, as well as heterogeneous zoning of homogeneous ecosystems (Forman 1995, Doing 1997, Müller and Volk 2001). Besides, landscape refers to a common cultural commodity ever changing, thus structure and functioning of a landscape are closely related (Antrop, 2000).

Even though an integrative approach is suitable for landscape processes analysis, the landscape concept is mainly structural while the ecosystem concept is more functional. Therefore, each landscape can be identified through a characteristic combination and distribution of different elements (Walz, 1999). Those elements or landscape components include land use, land cover, soil, morphology, hydrology, climate, geology, etc. (Volk and Steinhardt, 2001) and their combinations, which build the three-dimensional organization of earth surface (Chuvieco, 1995). Regarding ecosystems and biotic communities, structure means the distribution of energy, materials and species (Forman, 1995).

The term “landscape functions” refers to the capacity of natural processes addressed to produce goods and environmental services to fulfil human needs. Functional relationships between landscape attributes include interdependences among vegetation, soils, atmosphere, groundwater, fauna, etc. There are different groups of functions such as: production (economic functions), regulation (ecological functions) and habitat (social functions). (Doing 1997, Müller and Volk 2001).

Relationships among “natural” landscape components have been established along evolutionary processes following certain cycles; however it is doubtful if the same approach is suitable to explain processes in cultural landscapes (Doing, 1987).

Likewise, evaluation procedures of landscape have different implications, however “…the problem of landscape assessment becomes clear as it is always connected with anthropogenic interference in the natural balance. These interventions compel the assessment of ecosystems, which, in the natural sense, are actually free from values". Most of the methodological trends in evaluation refer to the following ones (Wiegleb 1997 cited by Müller and Volk 2001):

a) Analysis ("evaluation" of data)
b) Judgement
c) Sequencing (relative comparison)
d) Current/potential status (assessment in a more precise sense)

The analysis phase deals with descriptive ways according to specific targets, therefore analysis approaches vary, but most of them can be grouped as follows (Antrop, 2000):

a) Thematic or components analysis, this means studying different landscape components independently and finally to make a synthesis.
b) Regional or spatial approaches, which deal with area differentiation into landscape units, which are structured in a hierarchical and spatial way. The result is a chorological classification of the area and the description of different landscape types (Mitchell 1973, Zonneveld, 1995 cited by Antrop, 2000)
c) Landscape metrics, which consists of indicators whose purpose it is to obtain sets of quantitative data of different landscapes for grouping or differentiation. In addition, landscape metrics allow a monitoring of changes in landscape structure.

Furthermore, approaches such as the "transversal" proposes that evaluation procedures should focus on problem and process jointly, setting geographical and temporal contexts Thus, process, patterns, and indicators can be analysed together, as follows (Farina, 2000):

a) Processes (fragmentation, disturbance, landscape change)
b) Patterns (structure, mosaic configuration)
c) Bioindicators (biodiversity, animal behaviour)

Tools addressed to support these types of evaluation procedures are remote sensing, landscape metrics and GIS.

1.1. Changes in landscapes resulting from disturbance

Landscape variability, i.e., heterogeneity results from spatial variation in abiotic factors (parent material, relief, etc.) of ecosystems and interactive controls (disturbance and dominant plant species, etc.). Of those factors, natural disturbance causes spatial patterning at different scales; whilst human activities have become the main source of changes in ecosystems because they have altered the frequency and size of some natural disturbances such as fires, and have introduced new types of disturbance such as large scale logging, mining, etc. which can be measured by length of roads, amount of logged biomass and so on (Farina 2000, Chapin et al. 2002).

A disturbance has been described as a relatively discrete event in time and space, as well as a collection of processes that alter or impact on population, energy, and nutrient cycles (Chapin et al. 2002, Johnson and Cochrane 2003).

Even though the tropical rainforest bears a natural disturbance regime such as vegetation changes through the gap-phase succession; it does not cause degrading effects on the remaining forest such as those reported from logging, including stand impoverishment, forest replacement by degraded fire resistant vegetation, damage to trees, and so on (Lamprecht 1989, Attiwill 1994, Whitman et al. 1997, Jackson et al. 2002, Johnson and Cochrane 2003).

Though clearing forest due to traditional shifting cultivation, swidden agriculture or slash and burn is also a disturbance, it has existed for thousands of years and is not known to change biogeochemical cycles. Nevertheless, if population densities increase, hence land availability decreases and fallow periods are shortened or eliminated, then shifting cultivation leads to a degradation of forests (Attiwill 1994, Chapin et al. 2002).

Therefore it can be stated in tropical rain forests landscapes that disturbances mediated by humans become clear through the following general land use pattern (Johnson and Cochrane, 2003):

A →	B →	C
i. Subsistence agriculture	iii. Intensive agriculture	v. Area abandonment
ii. Logging	iv. Intensive forestry	vi. Land use conversion

Nowadays, most of the tropical regions remain in stage A, which gives them more chance for the maintenance of its primary forests and related biodiversity.

1.2. Tropical forest landscapes description and evaluation

Descriptions of tropical forest landscapes are normally based on different information sources such as floristic inventories, land use surveys, cultural features (settlements, home ranges, etc.), spectral patterns and change detection techniques.

The main objective of an evaluation of tropical forest landscapes often is to assess the susceptibility and the responses of forest to disturbance, and their capacity to meet environmental functions.

From a functional viewpoint, forests are relevant to regulation in climate dynamics and global biogeochemistry, and for the protection of global biodiversity (Waring and Running, 1998).

Estimations of tropical forest disturbance resulting from selective logging and shifting cultivation can be obtained using biomass changes as an indicator, even though this depends on the spatial scale and frequency of disturbance.

Nonetheless, deforestation processes are critical disturbances affecting primary tropical forests worldwide, because they threaten or break the close relationship between plants and animals. Some important effects of clearing are soil erosion, species diversity diminishing, and habitat changes. Deforestation assessment focuses on a quantification of logged forest lands and mosaics resulting from consecutive cuts (Farina, 2000). If the rate of harvesting continuously amounts to around 3 % $year^{-1}$ and this land is not returned to forest production after a short period of time, the global demand for wood will surpass production. In addition, at current rates of production there are already regions facing timber shortages, where importation or substitution have already begun (Waring and Running, 1998).

Periodic surveys on global forest resources, mainly on rain forests in pan-tropical regions (Africa, Latin America and Asia), estimate that the humid forest areas change are mainly due to clearing. Table 1 shows estimations from different institutions.

Table 1. Forest Lands Change in Humid Tropics.1990-1997 (million ha/year)

	FAO	TREES
Latin America	-2.7	-2.2 ± 1.2
Global	-6.4	-4.9 ± 1.3

Source: Achard et al. (2002)

Among types of forest change, the Food and Agriculture Organization of the United Nations (FAO) distinguishes the following categories:

- deforestation
- partial deforestation
- fragmentation
- degradation
- conversion to plantation
- afforestation.

Furthermore, FAO states that overall forest depletion during the last evaluation periods 1980-1990 and 1990-2000 mainly implies conversion of forest to small-scale or large-scale permanent agriculture (FAO, 2000).

In addition, the European Commission's research program TREES (Tropical Ecosystem Environment Observations by Satellites) estimated degradation rates of the world's humid tropical forests. According to TREES "… forest degradation means forest increasingly fragmented, heavily logged, or burned." (Achard et al. 2002). However, they did not include degradation stemming from processes such as selective logging.

TREE's results state that in Latin America the forest depletion rate between 1990 and 1997 has been as follows

Annual degraded area: 0.83 ± 0.67 million hectares

Brazilian Amazon and Guiana's sub region reach the following values:

Forest area in 1990: 420 ± 37 million hectares

Forest area change: -1.32 ± 0.74 million hectares/year

Both cited organizations consider clearing the main change factor in tropical forest, and they have also documented the growing influence of degradation processes on forests depletion.

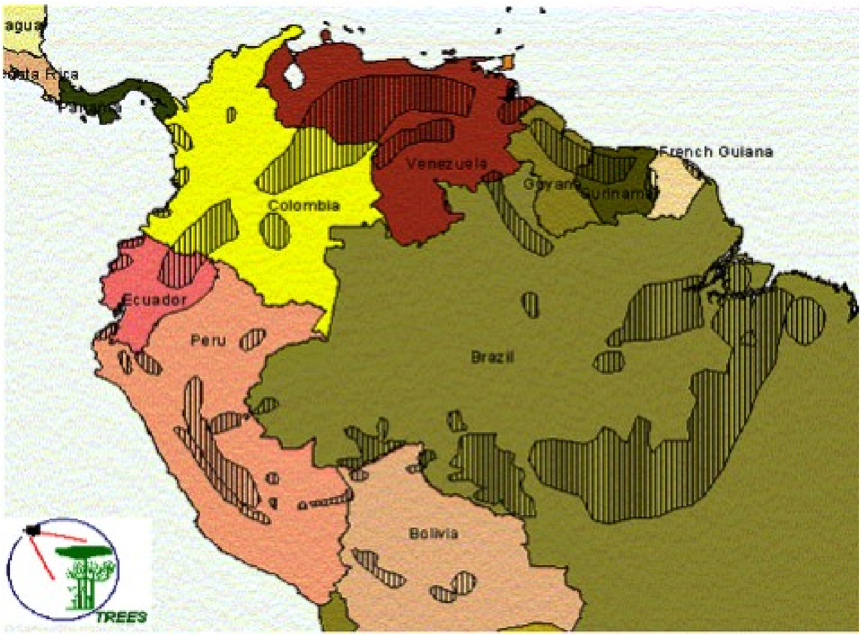
The Project Land Use and Land Cover (LUCC) a non-governmental research organization stated that “proximate causes” driving tropical deforestation and impact upon forest cover, can be grouped in three categories: agricultural expansion, wood extraction and expansion of infrastructure. LUCC’s approach subsumes not only forest conversion but also related types of degradation (impoverishment and fragmentation) under the concept of deforestation. Therefore, selective logging becomes a relevant deforestation cause (Geist and Lambin, 2001).

One of LUCC’s “driving forces” relevant in the current research is agricultural expansion, including two different categories such as traditional and colonist shifting cultivation, and wood extraction including commercial timber exploitation. Agricultural expansion also embraces private company logging that performs both selective harvesting and clear-cutting. Long term impacts due to selective logging for industrial purposes are scarcely documented so far, but they become increasingly relevant.

In South America, the Amazon basin is the most studied region with respect to deforestation and forest degradation. In fact, TREES identified forces from two general causes there: construction of roads and creation of new settlements along roads and rivers. Associated with these factors, “hot spots” or areas resulting from selective logging, mining operations, shifting cultivation, hydro-electric programmes, narcotics production and so forth had emerged as shown in Map 1 (Achard et al., 1998). Deforestation in eastern Brazilian Amazon is often an incremental process, which first step is usually logging. Fire is closely coupled to logging (Gerwin, 2002).

Regarding the forest landscape transformation, some typologies of spatial deforestation patterns have been described based on remote sensed images. They link landscape shapes to observed land use and land cover in order to get information about the following types of patterns: linear, insular, diffuse, and massive (Husson et al., 1995). Based on an interpretative approach of deforestation processes, an alternative typology suggests classes such as: geometric (large-scale clearings) corridor (roadside colonization), fishbone (settlement schemes), diffuse (shifting cultivation), patchy (urban areas with remaining forests), and island (urban suburbs). Among them the fishbone pattern is supposed to be regionally limited to the Amazon basin (Geist and Lambin, 2001).

In temperate forests, road nets have caused higher impacts in high-elevation landscape structure than logging. Therefore, roads play a key role in forest landscapes (McGarigal et al., 2001).



Map 1. Deforestation Hot Spots in South America
Source: TREE Project by Achard et al. (1998

1.2.1. Selective logging characterization and evaluation

With regard to tropical rainforest diversity, only few tree species are suitable for timber trade, hence commercial logging in tropical rainforests is selective. Logging operations are determined by forestry systems, according to theoretical cycles or time intervals that trees need to reach commercial size (stem diameter) (Haworth, 1999). The monocyclic system consists in taking out the entire stock of marketable timber in one single operation. Poly-cyclic systems refer to those where in each logging operation only a limited part of the marketable trees is taken out (Lamprecht, 1989).

Selective logging parameters include felling intensity in terms of removed individuals per area per year, varying at a regional scale. In the Venezuelan Guayana region the rate amounts to 1.5 to 3 trees per hectare or 3 to 5.3 cubic metres per hectare (CIAG 2000, WRI 2002) while in the Southeast Asia region, the intensity has risen to 72 trees per hectare. In the biggest part of the Amazonian forest, in contrast the intensity amounts to 3-5 trees per hectare.

Government technical supervision on forest concessionaire companies in tropical regions targets on getting information of exploitation intensity and harvested timber volume in order to collect taxes. Probably because industrial logging bears on legal contracts and follows management plans based on the sustained yield principle, which should be able to sustain the forest long term. Hence, official monitoring of selective logging in tropical forests is limited with respect to impacts detection and control.

On the other side, academic and NGO's field researches about effects of selective logging have reported chains of impacts, such as (Haworth, 1999):

- Disturbance on forest structure and regeneration
- Changes on habitats and supply of resources to fauna
- Social and economic impacts. Remarkable on forest-dwelling peoples
- Disturbance on the physical functions of the forests
- Induction of further damage

Despite the evidence to document those impacts, there is no standardized measurement or index to describe forest disturbance and damage intensity so far. Given that variables as injured trees, affected area, and volume of commercial timber damaged, are the most common to refer to logging impacts.

Regarding the disturbance on forest structure from selective logging for industrial purposes, stand damages caused by harvesting have been documented; for instance, throughout the 1980s in a former Brazilian Amazonian frontier, was applied an extraction rate of six trees per hectare which caused a damage rate of twenty-seven trees greater than 10 cm dbh, for each tree harvested (Verissimo et al., 1992). In eastern Brazilian Amazon, minimum values of severe crown damage per commercial tree felled were 4.5 trees, and 4.9 trees smashed to the ground. Every logged hectare caused 64 trees (≥10 cm dbh) damage. The mean area of all logging gaps was 166 m^2 and the total number of gaps was 108 (Johns et al., 1996). Impacts to the residual forest stand are substantial including 20-40% reductions in canopy cover and tree density (Gerwin, 2002); also in Venezuelan Guayana, roughly 20 – 30 % of the remaining mature trees became truncated or wounded (CIAG, 2000). As well in other Amazon frontier, most logging damage (55%) was concentrated in the canopy openings created in the felling process (Uhl et al., 1991).

Logging operations in the Amazon kill or damage 10-40 % of the living biomass of forests. These damages on many trees perforate forests but they are covered over by regrowing vegetation within 1 to 5 years. Furthermore, wide areas under primary forest turn into “cryptic” impoverished forest (Nepstad et al., 1999).

In Bolivia's humid forest, an area under logging rate of 4.35 trees/ha had an estimated average of 44 trees damaged for every tree extracted and 22 trees killed or severely damaged. Most common types of damages were uprooted stems, stems wounds, and bark scrapes (Jackson et al., 2002).

Fragmentation refers to the breaking up of a land type or habitat into smaller parcels, and results in increased light penetration and wind disturbance that changes the forest structure, microclimate and standing biomass (Forman 1995, Cochrane 2003). Related to commercial logging, road network triggers effects such as 25% ground area disturbance in the form of skid trails, logging roads, and log landings and an additional 25% in canopy openings due to tree felling (Jackson et al., 2002), furthermore deforestation of 30 m along main and 20 m in secondary roads; as well as, around 20 – 30 % removed or bare soils without conservation measures were reported in harvested areas in Venezuelan Guayana (CIAG, 2000).

Even in areas under silvicultural treatment (plantations, enrichment files, and remaining biomass improvement) there are common impacts such as natural regeneration removal, damages to the neighbouring vegetation and introduction of exotic species (CIAG, 2000).

The increase in fire risk is a meaningful factor stemming from logging, because it facilitates the spread of fire by disrupting forest canopy cover, thus allowing solar radiation to dry the humid forest floor and by providing large quantities of fine fuels in the form of residual logging debris (Gerwin, 2002). The combination of human access provided by logging roads and the forest damage caused by logging activities make logged forests extremely vulnerable to fire. This vulnerability may last for decades after the logging activities have ceased (Cochrane, 2003). Fire has the potential to transform large areas of tropical forest into scrub or savannas (Cochrane et al., 1999).

An integrative approach to evaluate tropical forests under selective logging should combine remote sensing techniques and ground-based work to assess local short-term ecological and social impacts.

However, satellite data in the optical spectral range tends to suffer from the presence of clouds; in fact, heavy cloud cover makes remote sensing of South America very difficult (Achard et al.1998, Wasseige and Defourny 2004). In addition, satellite imagery-based estimates of changes tend to systematically underestimate the extent of logged forest, because its visual clues can disappear from view during periods of time not well determined and because the remote sensing methods are not well developed yet

(Stone and Lefebvre 1998, Chan et al. 2003). The same problem affects the detection of indigenous settlements and production fields in Venezuelan Guayana, since available satellite images may have up to 20 % cloud cover (MARN, 2003).
Nonetheless optical satellite data gives a more synoptic view and allows an assessment of the area affected on a yearly basis, depending on cloud cover. Satellite images have been reported to be able to detect selective logging sites from 0.5 hectare (Stone and Lefebvre, 1998) or even smaller spots relying on sensor spatial resolution.

1.2.2. A remote sensing approach to evaluate selective logging and traditional shifting cultivation

The humanization process in terms of forest conversion into savannah is the last step of massive degradation. Detection in earlier stages can be achieved using spatial patterns that make elements such as plot deforestation, road networks, canopy gaps and fires visible.
Forest degradation refers to changes in forest conditions leading to permanent modifications in composition and structure (Sierra, 2000). Those effects are evident in remaining mosaics of log landings, roads, gaps, unaltered forest and injured trees due to harvesting operations. “Degraded forests are located in areas with a considerable human disturbance. These areas might include forest growing back from clear-felling resulting from either shifting cultivation or logging (secondary forest) or areas affected by pronounced selective logging” (Tottrup, 2004).
Selective logging, forest fires and other disturbances all result in significant changes in forest structure and canopy integrity (Matricardi et al. 2001, Wang et al. 2003).
Since traditional shifting cultivation also begins as plot deforestation and moves forward through burning, cropping and fallow cycles, monitoring to prevent degradation should focus on the vegetation growth and other spatial patterns already mentioned.
Remote sensed changes detection and monitoring techniques are based on the spectral response of vegetation; hence main bands for this target are in the optical domain red, near infrared (NIR) and mid-infrared. As well, patterns such as the “…concentration of large gaps and the linear features of the skid trial”; and the spectral difference between roads and forests are relevant features in logging detection (Metzger 2002, Wasseige and Defourny 2004).

However detection of differences in the forest is a complex task because the logged and unlogged forests sometimes have similar spectral characteristics. In these cases, spectral classification per-pixel is not suitable to separate them.

Forest canopy structure changes due to logging because of gaps created by for tree falling which produces changes in the forest canopy roughness and spatial heterogeneity. Therefore, texture analysis could be useful to increase the accuracy of logged forest classification (Chan et al., 2003). The effectiveness of textural filters has not led to conclusive results so far and need more research efforts (Stone and Lefebvre 1998, Chan et al. 2003, Wasseige and Defourny 2004). However, these techniques are increasingly used in studies addressing the differentiation between logged and non-logged forests (Matricardi et al., 2001).

Assessing forest canopy cover is one way of measuring forest degradation and recovery. In this sense, the linear unmixing model has been applied to map canopy cover in tropical forests in the Amazonian state of Mato Grosso, Brazil (Wang et al., 2003). The linear spectral mixing model, however, has also been providing good results with regard to the detection of deforested areas and logged forests in Brazilian Amazon (Spinelli et al., 2002).

Impacts associated with tree felling allow to estimate “influence areas” from nodal points, such as log landings in the Amazon which have around 180 m radius of potentially affected area (Souza and Barreto, 2000).

To monitor logging areas by means of satellite images a suitable approach should take into account both the extent and the intensity of the logging. The extent can be assessed by the surface drained by the logging trail network considering a buffer distance of e.g. 500 m from the trails. The intensity, i.e., the forest damage can be estimated by comparing the percentage of pixels that exceeds a given reflectance threshold compared to the percentage found in unlogged area (Wasseige and Defourny, 2004).

In addition, monitoring of shifting cultivation is based on temporal and spatial parameters such as agricultural use and abandonment rates, information available from satellite images (Metzger, 2002).

1.3. Indigenous people and territorial rights

Indigenous communities, peoples and nations, are those who have a historical continuity with pre-invasion and pre-colonial societies, who have developed in their territory, and who consider themselves different to the dominant society. They have decided to transfer their lands and ethnic identity to the next generations, in order to preserve their cultural patterns, social institutions and legal systems (UNO 1986 as cited by Posey 1999).

Indigenous people all over the world claim three fundamental rights: territories property and control, self-determination and self-representation through their own institutions. These rights are accepted in the framework of international civil rights, political and economic conventions such as the International Labour Organization (Conventions 107 and 169). As well, the Biological Diversity Convention (art. 8j) decrees indigenous and local communities' rights to preserve their traditional knowledge and to get profits from its utilization (art. 10c) (Colchester and Lohmann 1993, Valencia 1996).

In Latin America, national legislations in Brazil (1988), Colombia (1991), Mexico (1992), Paraguay (1992), Peru (1993), Bolivia (1994), and Venezuela (1999), have admitted indigenous peoples's rights.

The Venezuelan new Constitution assumes the modern paradigm of the coexistence of cultures; consequently, the Constitution contains more than 7 articles about indigenous rights and also orders the indigenous habitat demarcation throughout the country. Currently, ground demarcation and linked cartographic processes are ongoing (Mansutti, 2000).

According to Venezuelan law, ***indigenous habitat*** means "The whole space settled and used by people and indigenous communities, where they develop their physical, cultural, spiritual, social, economic and political life; which embraces cropping areas, hunting, fishing, gathering, shepherding, settlement, traditional ways, streams, sacred and historic places and others needed to ensure and develop their specific ways of life." (Venezuela, 2001).

1.3.1. Indigenous systems of tropical forest management

In general, one subsistence pattern common to Amerindian groups has been documented, based on horticulture, hunting, fishing and gathering. The outcome from these practices is a mosaic of vegetation patches, on several stages of reforestation, where people can get food, medicines, building materials, etc. according to traditional management and land use patterns (Lee, 1990). Nonetheless, traditional forest management systems are highly site-specific, diverse and ever changing, and generally promote and require the maintenance of forest structure and species diversity (Gomez-Pompa and Burley 1991, Laird 1999).

Tropical indigenous management systems include activities such as (Clay, 1988):

a) *Gathering* of wild plants, animals and inorganic materials. Posey estimates that the Kayapó Indians alone gather fruits from some 250 species of plants and nuts, tubers and leaves from hundreds of other species. Many indigenous groups eat ants, slugs and larvae from various beetles (Posey, 1983).

b) *Hunting* of animals provides to indigenous peoples a large portion of their food calories and, in many cases, most of their protein. As a management practice, indigenous peoples in Latin American tropical rain forests plant certain species of fruit and nut trees in their slash-and-burn farms to attract wild pigs, coati, macaws, parrots and other animals that they traditionally hunt.

c) *Fishing and aquatic resources use* are successful forms of indigenous resource management, using a number of species of fish, mammals, reptiles and vegetation that live in river systems of their areas.

d) *Swidden Agriculture and Agro forestry*

Swidden, or slash and burn agriculture is the system of alternating clearance of forest and a short cultivation period with a long fallow period during which the forest returns and soils recover. Agro-forestry systems mean the production that combines tree crops, cash crops, food crops and animals.

e) *Floodplain and river-bottom, drained fields*

This annual agriculture takes place on stream beds and seasonally flooded plains next to rivers, techniques to drain saturated soils by means of ditches are also applied.

f) *Permanent Agriculture*

This type of agriculture involves permanent, shifting cultivation and agro-forestry, these systems are gardens, chinampa, terraces and upgraded models of slash and burn agro-forestry.

In tropical rain forest, the spatial expression of land use and management systems mentioned above is a landscape differentiated in zones which are associated to the food production and the seasons or subsistence cycles (Meggers 1973 as cited by Brose 1998).

The landscape zoning as used by indigenous people is also shaped by their ecological systems of land use based on soil types, sensory energy intensity, environmental colours, smells, and plants and animals species, according with the Desana's classification in Colombia (Reichel-Dolmatoff, 1978 and 1990).

Another approach to tropical forest use links subsistence and production practices with ecological land features in order to analyse energy and protein consumption of indigenous Tukanos from Colombia (Lee, 1990).

1.3.2. Guiana indigenous settlement patterns

"Indigenous societies of the Guiana region in lowland South America so far are the Barama River Caribs, Akawaio, Maroni River Caribs, Panare, Piaroa, Ye'cuana, Pemon, Macusi, Wapishiana, Waiwai, Trio, Waiyana and Aparaí. They form a subculture that inhabits the Guiana Shield, surrounded by the Amazon River, the Rio Negro, the Casiquiare Canal, the Orinoco River, and the Atlantic Ocean. These peoples share features such as informal social and political organization, lacking of any common formal social grouping such as lineages, clans, age-sets, etc., small and short-lived settlements, among others" (Rivière, 1984).

The Guiana region has two traditional settlement patterns, one linked to forest ecosystems and other to the savannah. Regarding the pattern linked to forests, variations were observed on Barama Caribs such as a pattern of dual residence resulting from (i) trends in population concentration (in order to take advantage of public services) and (ii) subsistence relationships to the rain forest. It means that families tend to have one household in the big village and another one close to the forest (Adams, 1972). Nowadays, the dual pattern is consolidated, and represents the spatial reorganization of indigenous societies in Imataca (UNEG, 2000).

Since spatial features reveal important aspects of a culture, more information about settlement, households, and cropping field selection, results interesting.

Since settlement is a type of social grouping, it becomes a basic element of the social structure (Gillin, 1934); its physical dimension outlines the spatial pattern which in turn depends on household and field locations, distances between fields, village areas, land use and fallow periods. With regard to community features there had been reported population sizes ranging from 10 to 50 individuals, production fields circular or elliptical, and 3000 m2 in size, time period of settlement 7 years, and time of field use 3 years (Gillin 1934, Adams 1972, Rivière 1984).

Criteria about cropping field selection include good drainage, hilly relief, and soil white dirt (sand mixed with loam) or sand-clayey (Gillin 1934, Adams 1972).

1.3.3. Traditional Shifting Cultivation characterization and evaluation

The groups who practise traditional shifting cultivation (swidden or slash-and-burn agriculture) are not nomadic. They are located in one place, but move their plots over limited areas, using lands to which they have traditional rights, and return to the original plot after several years - anything between five to fifteen years. General steps of traditional shifting cultivation are (Jordan 1987, Indonesian Heritage 1996, CIAG 2000):

1. Cutting down of trees
2. Burning felled trees before the rainy season. The burned material increases soil fertility, for instance, ash provides potassium and improves the availability of calcium and magnesium
3. Planting begins immediately, before the ash bed is blown or leached away, and before the rains cause soil erosion.
4. Fast growing plants, emergence of weeds
5. Harvesting period
6. Abandonment of land left to lie fallow after harvesting for some years and its return to secondary forest, which in about ten years becomes closed canopy.

Indigenous land-use patterns and management practices in Latin American tropical rainforests depend on native plants (manioc, sweet potato, yam, arrowroot, cashew, pineapple, peanut, chilli pepper, papaya, avocado, guava, cacao and maize) that have a proven capacity to grow under local conditions (Alvim 1972 cited in Clay 1988).

Many indigenous groups that cultivate slash-and-burn plots employ a number of different methods of planting, which include using seeds, seedlings and cuttings. In addition, they leave a number of plants in the plot and allow them to regrow. Hence "…under the shifting cultivation system, the genetic pool of primary trees is retained, and from this pool comes the raw material for the successional processes." (Gómez-Pompa et al. 1972).

However, research results highlight that one critical factor of sustainability in traditional production systems implies maintaining low demographic pressure to be able to keep suitable fallow periods (Gómez-Pompa et al. 1972, Lee 1990).
The evaluation of traditional shifting cultivation in tropical forests landscapes deals with ground survey in production plots, fallows, indigenous habitat, together with the ecological features that shape landscape patterns.
Evaluation methods provide the opportunity to include socioeconomic survey data colleted at household level with remote sensing, aiming to understand the causes, processes, and impacts of land-use/land-cover changes (Lambin, 2003).

2. Changes in forest landscapes in Venezuela

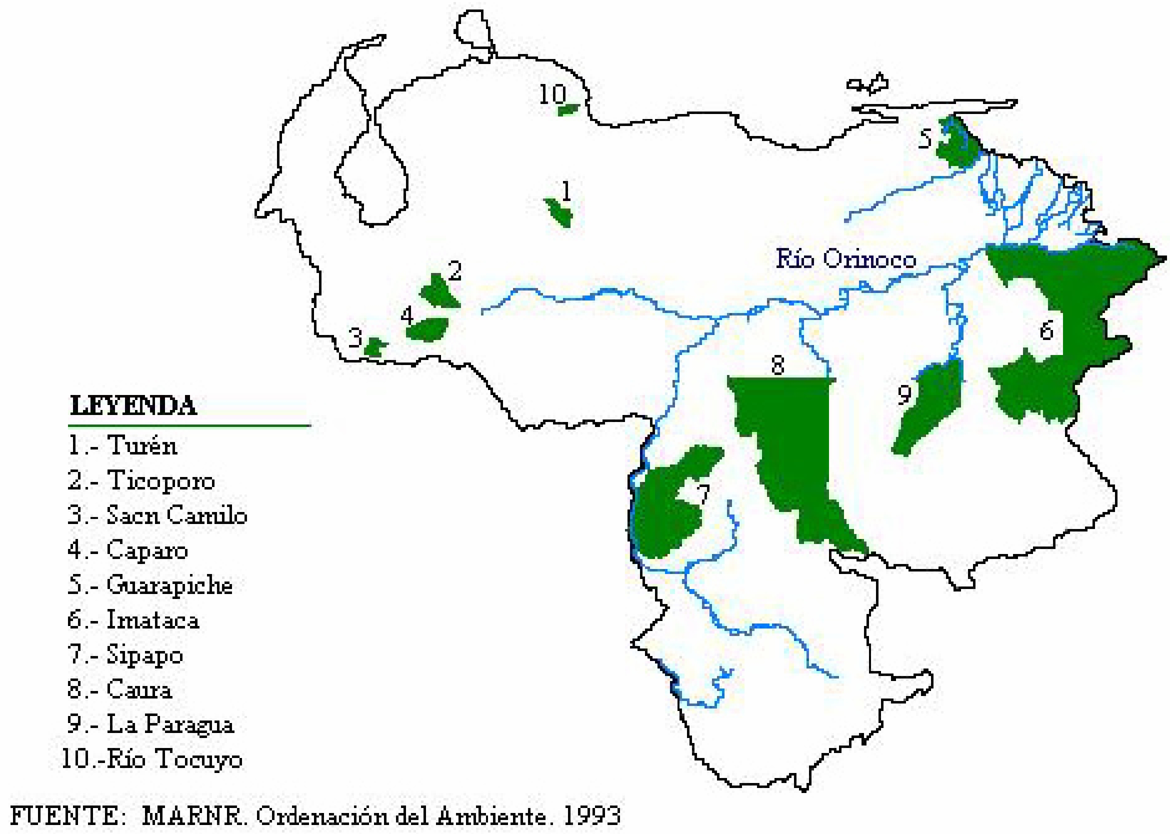
2.1. Forest depletion in the Northern Orinoco river basin: the colonization scheme of Western Venezuela forest reserves

Commercial logging in Venezuela started in the 1920s, by exploitation of the forests located in plains along Los Andes piedmont, which belong to the states of Portuguesa and Cojedes; after, as timber availability decreased logging moved towards the South to the state of Barinas, where it began in 1939. Subsequently, the Venezuelan government decided to keep forest allotments as wood suppliers to industry, thus ten forest reserves were created from 1950 on (Kammesheidt et al., 2001) as Table 2 and Map 2 show.

Table 2. Forest Reserves in Venezuela

Name	Area (ha)	Gazetted
1. Turén	116.400	1950
2. Ticoporo	187.156	1955
3. Caparo	181.143	1961
4. San Camilo	97.100	“
5. Imataca	3.640.899	"
6. El Caura	5.134.000	“
7. La Paragua	782.000	“
8. Guarapiche	370.000	
9. Sipapo	1.215.500	1963
10. Río Tucuyo	47.640	1969
Total	11.771.838	

Source: MARN (2000). Primer informe de Venezuela sobre Diversidad biológica. Caracas.



Map 2. Location of Forest Reserves in Venezuela

In spite of its long experience on natural forest management, the Venezuelan forest use and conservation politic have been unsuccessful in the northern part of the Orinoco River. A combination of unsuitable forest management mainly through commercial logging, farm owners concerns, peasant pressure and inadequate government control led to high deforestation levels and depletion of forest reserves along the foothills of the Andes (Rojas 1993, Kammesheidt et al. 2001, WRI 2002).

Nowadays there is no reliable or accurate figure of the total Venezuelan forestlands. In fact, government information does not coincide with the results from independent scientific projects conducted by international organizations like FAO, WRI and others. Discrepancies might be due to the fact that the government bases its figures on an estimation of former forestland and a calculation of deforestation rates. The Venezuelan government states that public forest reserves amount to 119.383,80 km^2 (13 % of the national territory), 8,6 % of which is located in the North and 86, 5% South of the Orinoco River (MARN 1986, Rojas 1993). Moreover, there are different estimations of forest losses in Venezuela. Some reports state that around 70 % of the northern forest reserves had been converted to cropping and cattle-ranching land-uses (Centeno 1988

cited by Rojas 1993); others state that between 1975 and 1988 more than one third of Venezuelan forestland in northern Orinoco became agricultural lands (WRI, 2002).
Regarding the social factors or “actors” taking part in the process, opinions differ between experts and the government. According to Franco (1987), the factors that had the biggest impact are the government lack of control, commercial farm owners, poor peasants, urban expansion and commercial selective forest logging.
Nevertheless, the government reports state that the main causes are the following ones: agricultural frontier expansion, illegal tree felling in natural forests, settlements in forest concessions, inadequate planning of mining land use and forest fires (WRI, 2002).

2.2. Forest exploitation in south of the Orinoco River

The process of forest destruction continues south of the Orinoco River partially in the same way as in the North, in spite of Venezuela’s seven laws and at least thirteen other legal regulations related to forest protection or mining control on forestland (WRI, 1998 and 2002).
A conspicuous issue south of the Orinoco River or Guayana Region which are traditional indigenous lands where former governments (from middle 1960 to 2000) gave grants to commercial concessionaries for a minimum of 30 years, in spite of the fact that these companies failed to manage the sustainability of the forest reserves north of the Orinoco River. One important factor in forest destruction has been selective logging because it has a weak technical basis. Critical aspects in Venezuela are (Ochoa, 1998):

1. the minimum cutting diameter value is not adapted to the growing patterns of local wood species
2. individual trees are selected as seed sources without knowledge of its reproductive cycles
3. trees are introduced into remaining forests without evaluation of their reproductive biology.

Furthermore, commercial logging was exempted in 1996 from the environmental impacts assessment study, a legal commitment on all industrial activities, because the government claimed that the identification of impacts and control measures were already included in the management plan. Conversely there is evidence of a chain of environmental impacts mainly around the timber cutting, timber dragging, forest tracks, log landings, and machinery maintenance activities which are in fact uncontrolled (Lozada and Arends 1998, Ochoa 1998).

According to the Organic Land Use Zoning Law (1983), every natural area under the national conservation system (ABRAE) must have specific regulations such as a zoning plan. However, on the national level only two of the eleven forest reserves fulfill this requirement. Legal weakness and loopholes allow forest damage in reserves without a zoning plan because in practice, land uses such as mining or cattle ranching are not strictly forbidden. A sound case of conflict on forestland use in Venezuela was the Decree 1850 on the Land Use Plan of Forest Reserve Imataca (FRI), proposal that confronted economic, social and political concerns and led to public struggles.

After nine years, in 2004 the government approved the Decree 3110 on the Land Use Plan of Forest Reserve Imataca (FRI), which provoked criticism because it did not introduce improvements on forestry systems, and conceded mining legal status into one forest reserve.

The official technical report supporting the new Land Use and Management Plan of Forest Reserve Imataca (Decree 3110, September 22nd 2004) carried out the land use survey, applying a classification system based on criteria such as expected products, machinery use and production practices, market oriented and labour intensity; which tried to estimate the order of importance into classes of use. Thus, mining came out the major land use class in terms of coverage percentage, followed by logging forestry.

The Plan concludes that forest selective logging currently in Imataca "… represents the less impacting land use on the ecosystem conditions" (MARN, 2003) while it does not mention the indigenous management systems, nor agriculture nor forestry. Instead of that, the plan refers to small subsistence units (conuco) highlighting that such agricultural use even in low extension represents a "threat" that deserves special attention (MARN, 2003).

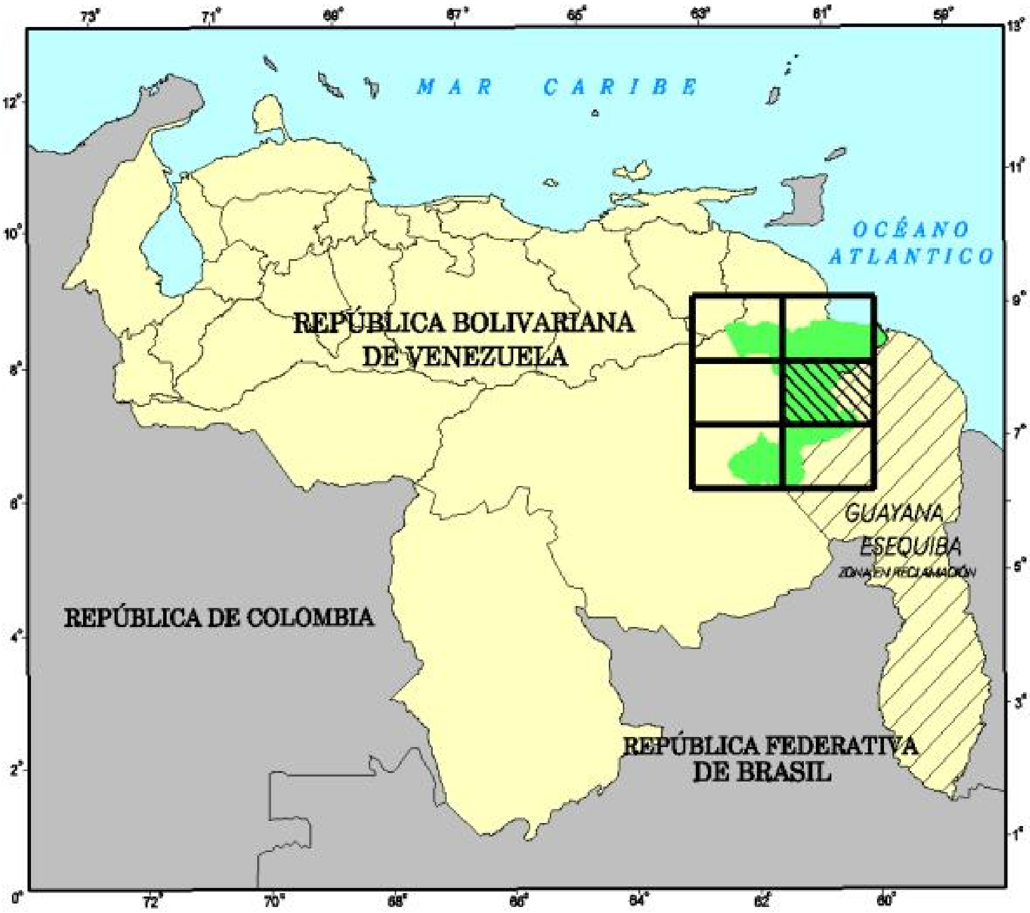
Former statements suggest that there has been no substantial change in the Venezuelan environment authorities regarding forest reserves management; in fact, commercial logging keeps its accepted rights, legally and socially almost without criticism, as happened in 1995 when Decree 1850 caused public controversy by focusing its attention only on mining.

Since the Land Use Plan assigns around 50% of the whole Forest Reserve Imataca to selective logging and not defines specific areas to indigenous shifting cultivation but mixed areas of logging or mining where indigenous “presence” is recognized, then it remains an ambiguous situation while indigenous land rights recognition seems to be unfeasible in the short-term.

3. The Forest Reserve Imataca (FRI)

The Forest Reserve Imataca (FRI) is a primary forest that covers 38.219,58 km^2, the first one in Venezuelan Guiana region to allow commercial logging in 1982. It was created in 1961 and enlarged in 1963, and is situated on Guiana Shield, an ancient geological formation composed of granite, quartz, lava, clay, and sands (Berroterán, 2003). FRI belongs to the Venezuelan national protected areas system (ABRAE), which corresponds to natural resources use type VI of the World Conservation Union (IUCN) categories. This means that this area is supposed to be a long-term supplier for the timber industry (WRI, 2002); this proposed use is conditional to the sustainability of its management.

The area selected for this research is central FRI, situated in the Parish Capital Sifontes, Bolívar State, representing one third of the Reserve, roughly 10.000 km^2. It stretches from 6°57’31.23” to 8°02’27.82” latitude north and 60°43’31.49” to 61°33’51.66” longitude west, as ilustrated in the Map 3 locating the relative situation of the study area. This location fits the worldwide reference system (WRS) path 233 row 055, and also radar imagery code NB20-4 (Radarsat).



Map 3. Central Forest Reserve Imataca
Source: IGVSB-Venezuela.

3.1. Physical features

The dominant climate in central FRI is humid without water deficit (no dry months). Main climate parameters range around following average values (Berroterán, 2003):

Annual rainfall: 1300-3000 mm

Annual temperature: 25-27 °C

Thermal oscillation: 2.5 °C

Relative humidity: 82%

Humidity index: 29

According to the Holdridge classification, the study area includes up to three "life zones" (TECMIN, 1987):

- In the western part of the area, there is a tropical dry forest strip (Bs-T) less than 400 m.a.s.l. (meters above sea level), representing 33.5% of the total area. Rainfall values range from 1250 to1500 mm and temperature averages from 25.5 to 26.7 °C

- In the east and in the hill foot of the Altiplanicie de Nuria in the northwest, there is a transitional zone between tropical dry forest and tropical wet forest representing 66.3% of the total area. It stretches from 400 to 600 m.a.s.l. Rainfall parameters range from 1500 to 1900 mm and temperature averages from 24.0 to 26.7 °C
- In the northwest, at the top of the Altiplanicie de Nuria up to 600 m.a.s.l. there is a small area with pre-mountain wet forest (Bh-P). Rainfall there ranges from 1300 to 1400 mm and temperature averages amount to less than 24 °C

The hydrographical network in central Imataca comes from the southern side of Imataca's Serranía where the Botanamo, Marhuani and Cuyubiní rivers originate. The drainage pattern is dendritic, seasonal variation of hydric regime is marked, and sometimes the rivers' main courses are interrupted in the dry season.

The Botanamo river basin spreads over 50% of the area formed by Corumo, Matupo, Hondo, and Guarampín rivers. The Marhuani river basin is situated in the South eastern part of the area and it is characterized by being long and narrow the hydro regime is permanent with large flows all year.

The study area is part of the Geologic Province of Pastora, whit an estimated age of 2800-2200 million years (Upper Archaeozoic to Proterozoic). The Pastora Province consists of Super Group Pastora, which in turn is made up by Cicapra, Yuruari and El Callao formations (CVG-TECMIN, 1987).

The Pastora Province is built of green rocks-granite associations named "greenstone belts", which main feature is a significant variety of intervals. In our case, the greenstone belt is a sequence of mafic-ultramafic and volcanic-sedimentary rocks that outcrops as green esquistos in the centre and southeast of FRI. They are related to gold mines and potential deposits of metallic and platinum polysulphuric deposits (USGS 1993 as cited by Villarroel et al. 2000).

The most important landscape types in the study area are mountains, hills, plains, and valleys; but hills are dominant. Altitude ranges from 50 to 250 m.a.s.l.

Mountains belong to the Guiana Shield, which general altitude is low. Typical relief forms are sierra, crest, beam and dike. The topography has steeped reliefs with slopes

(30-60 %). Igneo-metamorphic and meta-volcanic rocks such as gabbros and diabasas compose the bedrocks.

Mountainous landscapes are situated in the west, where a circular diabasa dike (Nuria high plain) can be found, and in the east, where a crest in meta-volcanic bedrocks arises.

Hills are the results of processes of erosion that led to slopes between 8 to 60% steepness. Hilly landforms are widely distributed in the study area and can be found in eight types differentiated by dissection level and topography slopes. In the north and southeast, landscapes formed by hills have few dissections and a rather steep topography (8-30 %). The Central zone hills have flatter slopes (8-16%).

Hills arise on different bedrocks such as igneous-metamorphic, meta-volcanic and sedimentary rock, among them granite, phyllites, diabase, meta-lavas, etc. Most frequent relief types are hills alternating with lowlands. Less common but still present are dike and colluvial fans. The major portions of hills are set in granite stones of the Supamo Complex.

The drainage pattern is generally dendritic of intermediate density; sometimes it may be parallel or rectangular (CVG-TECMIN, 1987).

Plains originate from the lowering of the original level but level differences arise in form of low hills and lowlands. Plains in the central area have low altitudes and a wavy topography (slopes between 8-16%). In the east and west, plains are also low with a soft topography (slopes between 4-8%). In addition, a plain of 200-500 m altitude with soft undulations in a circular diabase named Nuria high plain which is located in the northwest.

Most important bedrocks for these landscapes are granite, and in minor proportion meta-volcanic and meta-sedimentary rocks.

The drainage pattern is dendritic of a low density.

Valleys are the lowest land forms. They are generally situated along rivers, so in most cases they are of a long and plain shape. Relief types of this landscape type are meadows and flood plains, composed of non-consolidated material. Valleys distributed over the whole study area correspond to the hydrologic system. There are two types of valleys in the study area, one of them along main rivers such as Botanamo, Cuyubini, Guarampín, etc. from depositional origin. The second type can be found along Marwany River from residual-depositional origin (CVG-TECMIN, 1987).

The most frequent soil type in central FRI belongs to the order of Ultisols (Soil Taxonomy, 1975) on parent material from Pastora geologic formation. They developed in different bio- climates such as under forest macrothermic tropophic and ombrophic forests. The order is well represented in all landscapes types such as mountains, hills and plains. The widespread specific groups are distributed on hills, as example: Paleaquults, Tropaquults, Paleudults, Tropudults and Haplustults.

The main features of the local Ultisols are (CVG-TEMIN, 1987):

- Advanced pedogenesis development stage
- From moderate to very deep
- Brown to dark brown in surface and yellow to red at the bottom
- Texture franc at surface to clayey at the bottom
- Good drainage in upper areas and limited in lower areas
- Strong acidity to extrem acidity pH, low to very low cationic interchange capacity and low base saturation
- Poor natural fertility

Another widely represented soil order is Entisol, which exists on the same bio-climates as the former one but is restricted to mountains and scarped hills. Main features of this soil are:

- Low pedogenetic evolution stage
- Grey in surface and brown yellow at the bottom
- Variable texture, from sandy to clayey
- Excessively drained

The less frequently present order Inceptisol spreads mainly in alluvial flats and in valleys. It has moderated evolution stage, deep, brown, texture franc, and is well drained.

The so-called Ecological System is an integrative landscape classification, applied to zoning the Forest Reserve Imataca and applied to the new Imataca Ordering Plan decreed in September 2004.

The mentioned system is based on hierarchical categories such the ecological sub-region, mega ecosystem, macro ecosystem, geomorphologic landscape, relief, slope, parental material, soil, vegetation, and land use. From those parameters, vegetation (type and subtype), relief and soil, are converted to cartographic units (MARN-UCV, 2003).

According to this ecological classification system, the study area belongs to the following categories:

1. Guayana Shield ecological system

1.1. Sub-region Pastora – Nuria

1.1.1. Mega ecosystem Lomerios Bajos with Peniplanicies

1.1.1.1.Macroecosystems units 10, 23, 31

1.1.2. Mega ecosystem Lomerios Escarpados

1.1.3.1. Macro ecosystem units 24, 33, 35, 37, 39, 62

1.1.3. Mega ecosystem Lomerios de Cuyuni

1.1.2.1. Macro ecosystems units 10, 31, 33, 37, 38, 62, 81

1.2. Sub-region Peniplanos y Lomas del Cuyuní

1.2.1. Mega ecosystem Peniplanicie de Botanamo

1.2.1.1. Macro ecosystems units 23, 36, 60

1.2.2. Mega ecosystem Lomerios de Cuyuni

1.2.1.1. Macro ecosystem units 31, 33, 37, 38, 62, 81, 82

Of the more than 26 macro ecosystems, the following units are the more extensive and at the same time currently under forest logging: 23, 36, 31, 34 and 37. Their key features are summarized in Table 3.

Table 3. Central Imataca Mega ecosystems Features

Mega ecosyste	**Macro ecosys**	**Geomor Landsca**	**Relief**	**Slope**	**Parental material**	**Soil**	**Vegetation**	**Land use**
Lomerios bajos con peniplanicie	**23**	Low plain	Hill	0-4, 4-8	Granite, clayey meta-lava	Hapludults, Paleudults, Dystrudepts, Kandiudults, Kanhaplohumults, Kandihumults	Tropical rain forest tall and medium Seasonal evergreen forest	Forest logging Mining
	31	Medium, rough low hills	Low ridge	0-4 4-8 16-30 30-60	Andesitic lavas, medium sandy-clayey granite, clayey medium meta lava	Udorthents, Kandiustults, Haplohumults, Peleudults, Hapludults	Tropical rain forest tall and medium size	Forest logging Mining
Penillanura de Botanamo	**36**	Low rolling plain	Hill	0-4, 8-16	Clayey granite	Haplustults, Paleustults, Ustorthents, Kanhaplustults, Kandiustults, Kandihumults, Kandihudults	Tropical rain forest medium, tall size. Seasonal evergreen forest low and medium	Forest logging Mining
Lomerios escarpados	**34**	Steep low hills	Low ridge	30-60	Granite	Hapludults, Paleudults, Udorthents	Tropical rain forest tall	Forest logging Mining
	37	Steep medium hills	Low ridge	0-4, 4-8, 16-30, 30-60	Andesitic lavas, medium sandy-clayey granite, clayey meta lava	Ustorthents, Haplustults, Udorthents	Tropical rain forest tall, Seasonal evergreen forest medium	Forest logging

Source: modified from MARN (2003)

3.2. Biotic features

The Forest Reserve Imataca holds roughly 63.8 % of the botanical families, 36.4 % of the genera, and 14.9 % of the species of Venezuela' entire floristic richness. This high percentage in a poorly explored region that represents 3.6 % of national territory highlights an important potential of phyto-genetic resources (UFORGA-ULA, 2000).

In central FRI prevails primary forest of continuous canopy, with only few gaps in between, as well as general low human disturbance, then forest vegetation is the main landscape feature; its vertical profile and horizontal structure (three-dimensional canopy arrangement) are key factors to determine the landscape evolution.

In 1987 the regional natural resources inventory project identified in the Forest Reserve Imataca about 27 forests types or associations regarding (TECMIN, 1987):

- botanical composition
- humidity regime
- coverage density
- height.

When relevant, human disturbance was included as a complementary variable. According to inventory data, main vegetation formations were evergreen tropical rainforests (medium, high and very high) and evergreen seasonal forests (low, medium and high).

Central FRI has 92.3 % (815.285 ha.) of continuous forest cover composed of 69.3% (586.580 ha.) tropical evergreen rainforest (medium, high and very high) and 23% (228.705) of seasonal evergreen forest of low, medium and high height (Berroterán, 2003)

With respect to Central Imataca, Franco (1988) describes the vegetation as almost totally evergreen forest, ranging between medium and high size and density. Those forests are considered highly heterogeneous because they have average densities of 490 trees/ha, with about 300 species/ha. These values differ from data sampled some years later from the same area, which found tree density ranging around 490 individuals/ha, 120 species/ha and 63 m^3/ha yield (Ochoa, 1998).

Franco (1988) stated that the distribution pattern of forest types in Central Imataca is a function of the relatively stable relationship between the natural vegetation and the soils' hydro-regime. This relationship is established through topographic position and soil features, determining structural parameters of forest communities such as size and density. For instance the pattern indicates that sites under fast percolation where soil texture and depth have low water storage capacity tend to develop forest of medium size and density.

With regard to forest dynamics in Central Imataca, after seven years of measurements (1986-1993) Serrano (2002) got data on the species present, their growth rate, species abundance and dominance through monitoring of both undisturbed forests and forests that were disturbed due to selective logging. The results show that the gross growth rate in undisturbed forest amount to about 7,9 m^3/ha/year (2,6%); while the net growth rate in disturbed forest equals about 2,2 m^3/ha/year (1,1%). Furthermore, the average diametric growth rate is about 0.3 cm/year in undisturbed forest; and about 0.45 cm/year in disturbed forest. It is worth pointing out that growth rates depend on wood density. This means that high growing rates coincide with low density wood species.

3.3. Characteristics of the human population

The Forest Reserve Imataca population consists of indigenous dwellers, miners, peasant farmers, and forest workers (CIAG, 2000). According to the objectives of this thesis, only Kariñas indigenous and forest workers will be included as social actors in the analysis.

Kariñas settling in Central Imataca come from the same indigenous people that has been reported in east Venezuela, French Guiana, Guyana and Suriname (Amodio et al., 1991). Both groups, the Kariñas settling in the Bochinche and in the Barama River (Esequibo Territory) belong to the same Kariña Province (Adams, 1972).

The Kariñas are part of the Caribs linguistic family, and keep their social structure, that means, political and economic systems, establishments and relationships among communities (Morales and Arvelo Jiménez 1981, Morales 1989 mentioned by Berroterán 2003).

Their subsistence practices have not changed much during the last sixty years, they largely follow traditional land uses patterns and market integration remains extremely low. The Kariñas depend on the forest for subsistence, in particular with regard to the following activities (Grimmig, 1998):

1. Building and construction, with foundations of timber of different species, and palm roofs, also of different species

2. Production of arrows and bows of wood, vegetal fibres, and other plants
3. Manufacturing of “sebucan” and other baskets to process bitter yucca
4. Extraction of rubber gums, oils, fibres etc.
5. Hunting

However, the Kariña’s traditional settlement pattern has changed from highly dispersed to concentrated (Hernández and Foelster 1994 mentioned by CIAG 2000).

Likewise, a tendency towards a sedentary life and the growth of indigenous villages has been documented, implying an intensive use of forest resources (WRI, 2002).

The Census of Population and Indigenous Villages of 2001, registered 16.686 Kariña inhabitants in Venezuela; 3.973 of these inhabitants settled in Bolivar State (INE, 2003). In Central Imataca Parish Capital Sifontes (Bolivar State) there are 5674 indigenous, among them 865 Kariñas (INE 2004). Other indigenous people populating the remaining villages include Warao, Arawacos and Pemon. The population reached a growth rate of 8.5% between 1990 and 2002; this implies that it can be expected to double in 8 years. This phenomenon is likely to arise from the effects of a high birth rate and a low mortality rate. The migratory processes are the most dynamic in the whole reserve (WRI 2002, MARN 2003).

The settlements are concentrated in the Botanamo River basin, the northern part of the Cuyuní River and along the Tumeremo-Bochinche road.

On the other side, population related to the forest concessions is temporary staff who works during the inventory and exploitation periods. After these periods most of them leave, and just those remain who work with timber dispatching, maintenance of forestry research areas, and other routines. The concessions camps are autonomous in their operation because they depend on the headquarters of the company placed in urban centres. The forest technicians are an "expert community" that is devoted to the technical handling of the timber exploitation and does not consider the loss of the forests as their problem (Aicher, 1998).

3.4. Land uses

Traditional shifting cultivation and commercial logging land uses are both permitted in forest reserves in Venezuela. The former is granted in the Venezuelan National Constitution (Art. 119 and 120) since reserves had been established in ancestral lands.

The latter is allowed by The Forest Soil and Water Law (Art. 55) and the Nation Plan, which administrates the national system of protected areas (ABRAE).

In contrast, mining is incompatible with forest ecosystems and it cannot be reconciled with forest management objectives (Miranda et al., 1998). The mining use generates strong impacts on indigenous communities and the environment (Whiteman and Suckle 2002, Guimaraes et al.1999 cited by MARN 2003). Mining effects indicate a non-sustainable use in Imataca; hence mining use is not included in this research.

The cartography and land use areas measurement in the Forest Reserve Imataca (FRI) are based on a technical report used as the framework of the FRI Land Use Plan. This plan includes an integrated classification of vegetation and land use, assembling three information levels, (i) the grade of intervention in ecological systems (intervened and not intervened), (ii) the main land use classes and (iii) types of land use (MARN, 2003):

In intervened systems the following categories can be found:

i. Main land use classes: commercial forest, mining, agricultural, cattle ranching and services

ii. Types of land use: plantations, non-timber forest use, active mining, abandoned mining, shifting cultivation, electricity service, extensive cattle ranching and airport

Not intervened systems (type, sub type and vegetation class)

According to the previous classification system, not-intervened ecological systems cover roughly 92.3 % (815.285 ha) of the study area. They are continuous canopy forests such as:

- Evergreen tropical rainforests (medium, high and very high): 69.3 % (586580 ha)
- Evergreen seasonal forests (low, medium and high): 23% (228.705 ha)

Intervened ecological systems are forests under commercial logging, mining or agricultural use. Among them, the most extended land use is commercial logging representing 5.5% of the study area (54.795 ha) and distributed among five private forest companies.

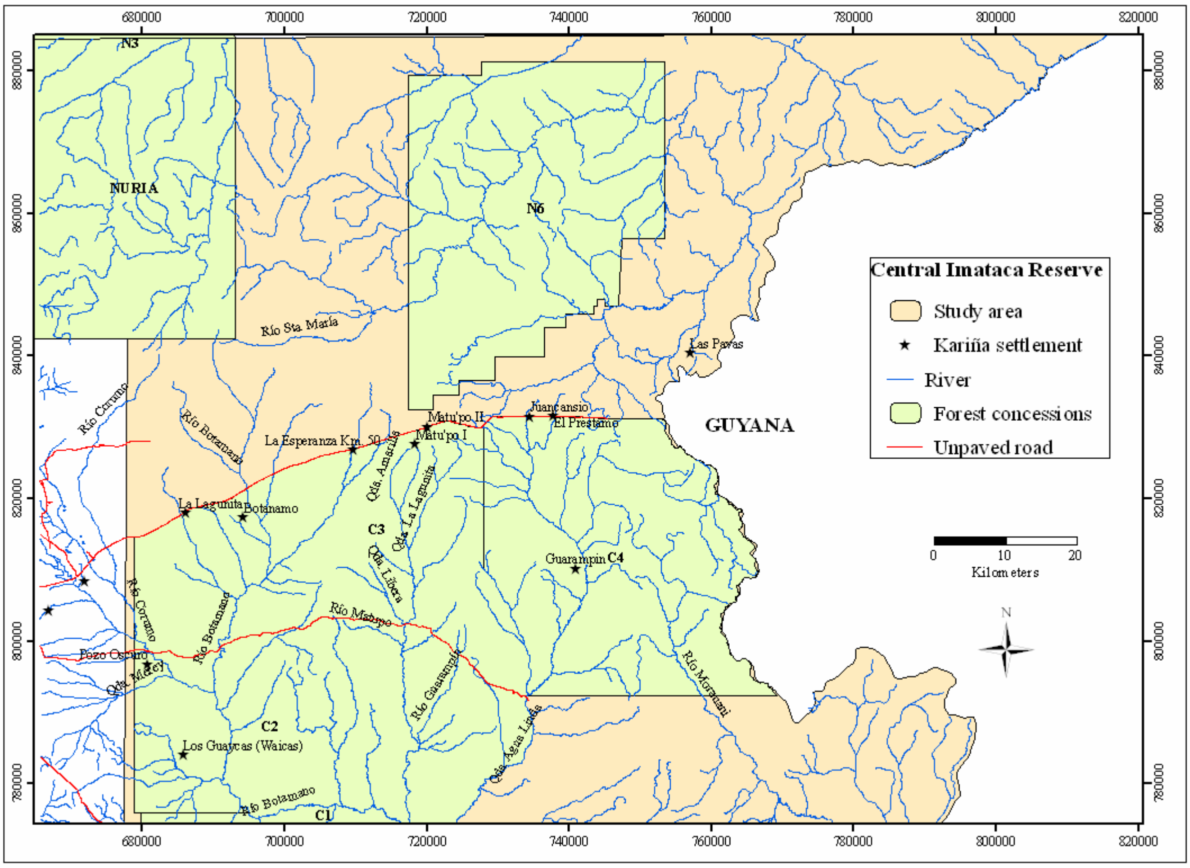
Mining activity is scattered and is carried out in 2.8% (27.541 ha) of the area. Active mining is situated in the west and the centre, along the river Botanamo and on the margins of the Tumeremo-Bochinche road, as well as in patches to the north and southeast of the Capital Sifontes Parish.

Active agriculture takes place in 30.9 ha. Plots are between 1000 – 3000 m^2 in size. There is evidence of mixed economy including crops for self-consumption, odd mining activities, and game selling from hunting, in order to buy products or services (Grimming personal conversation).

Even though land uses other than selective logging and traditional shifting cultivation are forbidden in Forest Reserves in Venezuela, mining, farming, and cattle ranching can be found in Imataca. The latter has often lead to conflicts, mainly because their areas sometimes overlap areas used for hunting, gathering, and/or farming areas (CIAG, 2000).

Therefore, relationships between logging companies or mining companies and Kariña settlements are rather conflictive. Huge numbers of conflicts have been reported, mostly because companies claim that settlements are located within concession areas. Known conflicts include for instance Matupo 1 settlement versus COMAFOR, PROFORCA and mining companies and Matupo 2 versus logging and mining companies (MARN, 2003).

Map 4 draws out the location of the study area where the mentioned land uses share the territory. The borderlines not marked in the map 4 to divide concessions C2, C3, and C4, follow the river and the unpaved road among them.



Map 4. Study Area Indicating Kariña's Settlements and Logging Concessions

3.4.1. Commercial logging land use

Commercial logging land use means of natural forest exploitation for industrial purposes, carrying out at least the following steps:

a) Build up of infrastructure (forest tracks, log landings, camps, etc)
b) Timber cutting
c) Timber dragging

This use is carried out by private concessionaries, i.e., companies according to the principle of selective logging (individual tree cutting) based on poly-cyclic system. Concessionaires exploit commercial species of high market value, promoting their overexploitation. It should be noted that in Central Imataca only 25 out of 120 tree species/ha have commercial value on markets (Ochoa 1998, CIAG 2000).

Venezuelan law demands for concession-holding companies to present a management plan based on the sustainable yield principle. These plans determine the timber quantities to be exploited every year, and all the technical operations to be done; in addition, they include specific requirements with regard to activities such as tree felling, silviculture, research, protection and industrial timber processing.

Since 1985 when concessionaire companies got forest lands allotments in the centre zone of the Forest Reserve Imataca, an amount of 511.820 ha were assigned, that means 68% of the total surface. Those concessions reported in the table 4 are the following ones

Table 4. Commercial Logging Concessions

Allotment	Company	Contract date	Area (ha)	Current state
C1	Maderas del Orinoco (MADERORCA)	03/11/1995 (25 years)	125.100	Inactive, under audit
C2	Corporación Forestal Guayana (COFORGUA)	Management plan preparation	130.000	Assigned
C3	Consorcio Maderero Forestal (COMAFOR)	03/11/1995 (30 years)	129.335	Active, developing plan 4° year
C4	Aserradero Hnos. Hernández	03/11/1995 (25 years)	125.000	Active, developing plan 4° year
Altiplanicie de Nuria	Maderas Nuria	28/12/1965 (? years)	171.720	Active, developing plan 4° year

Source: MARN-Dirección General del Recurso Forestal (2002)

To date, no government evaluation of company performance has been conducted, in spite of the fact that research reports had documented severe impacts resulting from commercial logging in Venezuela (Lozada & Arends 1998, Ochoa 1998, CIAG 2000, WRI 2002).

3.4.2. Traditional shifting cultivation land use

The Kariñas as the traditional inhabitants in Imataca, practice shifting cultivation or "conuco", i.e. a simultaneous agricultural production system (see Section 1.2.5).

Conuco consists of units of roughly one hectare with diverse subsistence crops and, frequently, also medicinal plants in different development stages that undergo cycles of about five years. A critical feature of shifting cultivation is the land abandonment after short times of use. Time under fallow allows forest recovery and is an important feature of traditional indigenous use (CIAG, 2000).

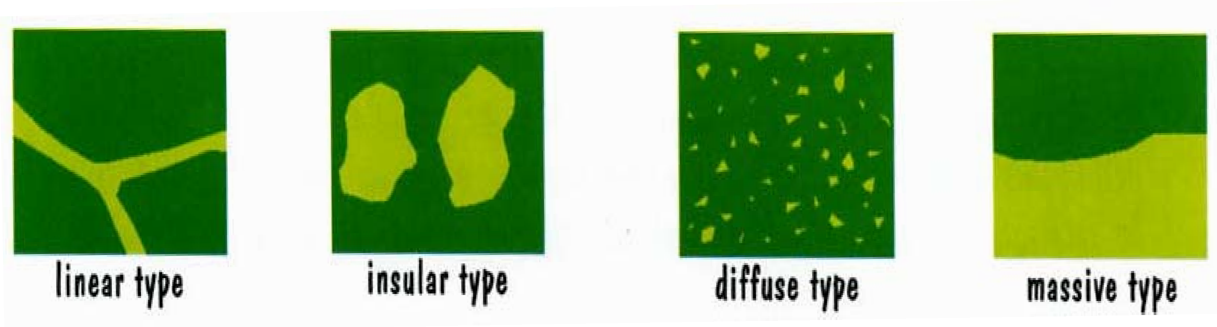
With regard to the Capital Sifontes Parish, it is worth pointing out that in 2002, 13 settlements were reported, representing around 400 families (per 5 persons). Every family cultivates roughly 0.5 ha, consequently at least 200 ha are under cultivation. Even if it is assumed that not necessarily all families open one conuco per year but every two years, 100 ha minimum should be detected in production. Accordingly, the 30.9 ha under conuco reported by the Zoning Plan (MARN, 2003) seems to be underestimated.

An accurate detection of traditional land use areas is increasingly relevant because official recognition of indigenous territory is an ongoing process based partially on evidence of former settlements close to secondary forest which indicates a recovery stage after forest disturbance.

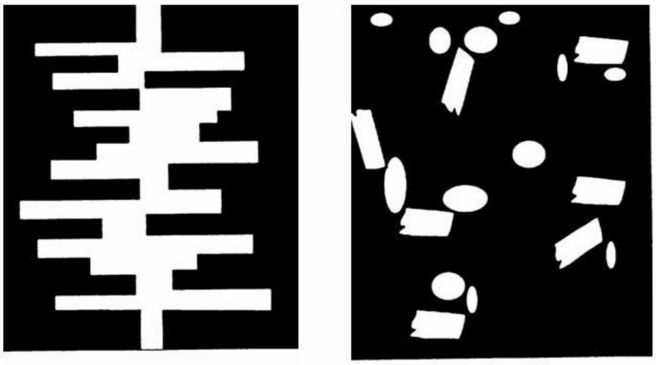
Furthermore some spatial configuration related to traditional subsistence agriculture has been reported, named diffuse pattern (European Commission 1995, Geist & Lambin 2001), which matches the Kariña land use.

3.4.3. Spatial patterns of land uses

Disturbances of tropical forests mediated by humans have been linked to land uses which may lead to spatial processes such as fragmentation, degradation, and others. The types of shapes resulting from those land uses include the following (Husson, 1995):



Typical spatial forms of commercial logging and shifting cultivation are basically the same or combinations such as (Geist & Lambin, 2001):



The previous patterns help to interpret processes in tropical forest landscapes that might be the first step in forest depletion. They could be considered a “forest non-forest interface” (Husson 1995, Geist & Lambin 2001).

SECTION II: METHODOLOGY

4. General field work methods

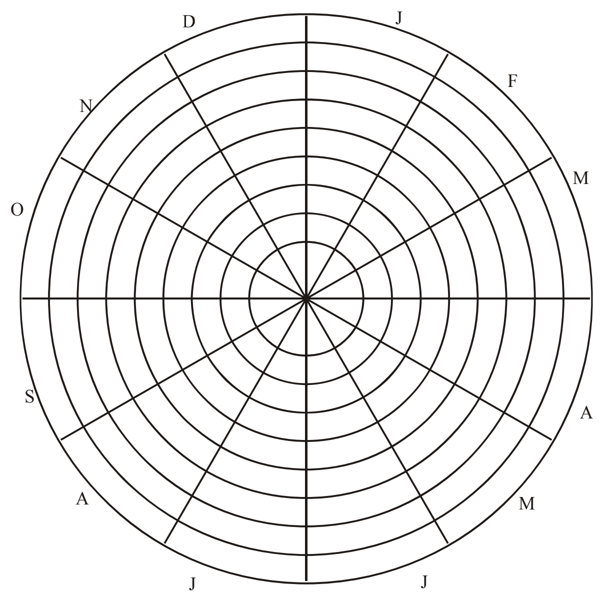
Preliminary field description of the landscapes structure (relief, hidrography, vegetation, soils) and survey of ecological zoning was used for indigenous communities and forest workers to develop daily activities.

Selection of pairs of sample plots according to the forest condition (undisturbed/ disturbed) deal with plots of old growth undisturbed forest, and disturbed plots from logging or shifting cultivation. Pairs of sample plots were located as uniformly as possible (outside left, right, and middle) in the study site.

4.1. Social survey method

The survey was carried out in indigenous settlements along the Tumeremo - Bochinche road, the unpaved 100 Km long way which crosses the study site from West to East. Interviews take place in households, as well as in cropping areas, visited to record plot's sizes and shapes, management practices, distance to settlements, and other traits. Economic information of land uses from surveys is plotted in a graphic known as the annual economic calendar.

The annual economic calendar is used to represent monthly production activities, such as cropping, fishing, hunting, and gathering. It is based on the knowledge that rainfall and drought cycles are the most relevant natural conditions to traditional food production systems. The calendar is a concentric circles graph partitioned in twelve months to mark out activities. The innermost circle shows rainfall periods and all other represent different production tasks.



Economic information comes out from interviews with indigenous community leaders (captains). It is important to highlight that the Kariña people do not speak Spanish and also do not seem interested in contact with strangers, even though every “conuco” owner agreed to answer questions related to the production system. Normally, only leaders and school teachers assume relationships with unknown people, and they are allowed to give information about community’s customs. Captains practice such control of information regarding traditional knowledge, as a defence mechanism against creoles selling of indigenous know-how.

Time periods allotted for cultivation, fallow, and secondary forest growth are not documented neither are precise. Same applies to landscape zoning oriented toward cultivation and harvesting of non-timber products. The forest management practices are not standardized.

The survey of forest companies land use and production systems refers to activities such as clear filling, woodcutting, stacked timber and forest roads network building. Commercial forest land use follows the “concession” scheme, it means that the companies have contracts with the Venezuelan government and they must fulfill out several financial, administrative and technical requirements.

4.2. Floristic inventory methods

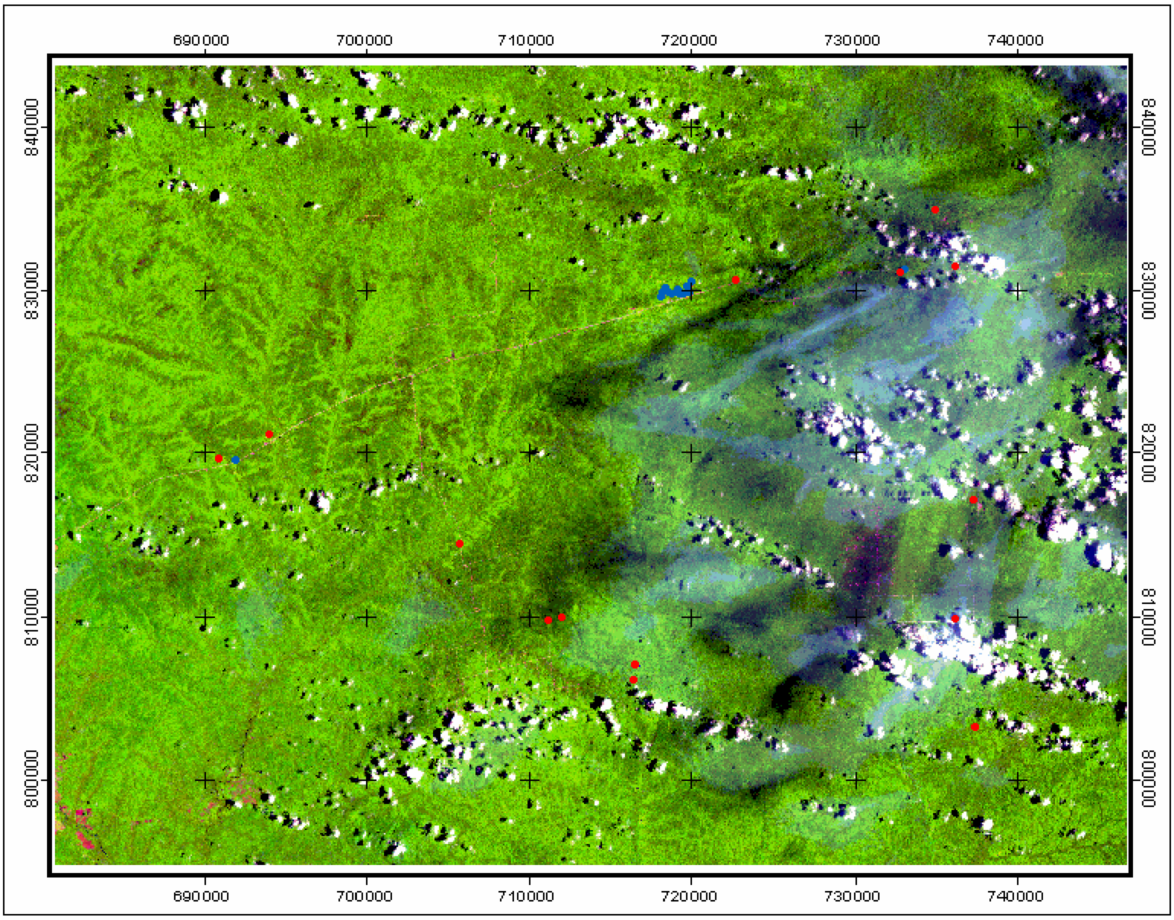
The field work lasted from September 15 to November 15 2002, in the central zone of Forest Reserve Imataca (FRI), Bolivar State in Venezuela.

The study area has one main road, which crosses central FRI and connects Tumeremo with Bochinche, villages located at opposite extremes of the Reserve; and also joins with the secondary network of commercial forestry concessions.

There were selected pairs of sample plots according to the forest condition (undisturbed/ disturbed), it means plots located in mature undisturbed forest, and plots located in forests disturbed by logging or shifting cultivation.

Pairs of plots were sampled as uniformly as possible (outside left, right, and middle) in the study site, even though the accessibility was also considered, given the hard conditions of transportation. Plots were located into the forest concession allotments and nearby indigenous communities, one group of 25 plots in undisturbed mature forest and other group of 16 plots in disturbed mature forest (Annex 1).

Map 5 locates floristic sample plots and inventoried indigenous cropping areas and fallows as well as forest concessions allotments, or yearly logged areas. The objective was to document production practices from both Kariñas and forest companies.



Map 5. Location of Sampling Plots (red dots) and Indigenous Conucos (blue).

We sampled "natural" communities in lowland forests, which are supposed to be heterogeneous, aiming to compare them with originally similar but disturbed communities. Statistical analysis of these forest communities dealt with floristic composition, structure and diversity as well known as heterogeneity measures.
"To analyze any set of empirical community data, the first thing you should do is to plot a species abundance curve" (Krebs, 1989). Then, to describe patterns of species abundance were plotted species vs. abundance curves, which allow us to illustrate differences in evenness and species richness (Magurran, 2004).
As statistical normal distribution cannot be assumed, we used nonparametric indices that made no assumptions about the underlying distribution of species abundances. Among them, were used the Shannon index that emphasizes the species richness

component of diversity, and the Simpson index, that focus on the dominance/evenness component (Magurran, 2004).

A set of empirical data was collected in 0.1 hectare rectangular plots (50m wide by 20m length) according with modified Whittaker methodology, including all trees up to 10 cm diameter at breast height (dbh), identified, and measured in the entire 0.1 hectare plot (Stohlgren, 1995). The methodology also suggested plot sub-sampling in order to measure smaller trees, shrubs and herbs, but this research did not require such data.

Floristic inventory variables were:

- Taxonomic identification (common name, specie and family)
- Circumference (cm)
- Height (tree trunk and total)
- Foliage orientation (north, south, east, west)
- Tree relative position in plot (coordinates x, y)

The floristic inventory result is the species list, and botanical samples of tree species, some of them identified and registered on the ground by Doctor Elio Sanoja; and the rest in the Orinoco Botanical Garden, Ciudad Bolivar (Venezuela) by Wilmer Díaz, the Garden's Curator.

Floristic inventory data is the input to other quantitative parameters calculation, such as:

- Species richness (S), the number of species recorded.
- Abundance (N), the number of individuals per specie recorded.
- Patterns of species richness and abundance in order to state curves
- Tree basal area (BA) is the cross-sectional area (over the bark) of each tree at breast height. Basal area is used as estimator of aboveground biomass.

http://sres.anu.edu.au/associated/mensuration/doborcir.htm

Equation (1) allows us the calculation of the basal area

$$BA = 0.0796\, c^2 \qquad \text{Eq. (1)}$$

c: circumference at breast height (dbh)

The result is given in metres squared (m^2) if *c* is expressed in metres.

Calculation and graphic representation of biomass spatial distribution, was based on ground data and vegetation index, which values were interpolated over the whole area. Maps of basal area, and vegetation index NDVI were created using the Kriging interpolation technique. This technique allows us to compute the local mean based on results of variogram modelling as input of this interpolation process. Kriging was performed using the program Surfer version 8 (by Golden Software).

4.3. Statistical Analysis

4.3.1. Cluster analysis to grouping forest types

Aiming to classify both forest conditions (undisturbed and disturbed) we carried out cluster analysis based on similarity measure of basal area content. Thus, each group was divided internally into groups according to a similarity matrix, then to get clusters we performed graphic analysis through the dendrogram to select more similar plots taking Pearson coefficient [r] > 0.4 as threshold value, because it enabled us to group reasonable amounts of plots and set a good correlation value.

Cluster analysis was calculated using the software STATISTICA '99. To begin the similarity matrix was computed, through 1-Pearson r coefficient, as measure of distance. Subsequently was performed an average linkage clustering named: unweighted pair–group method based on arithmetic averages (UPGMA) to produce a matrix of coefficients and its dendrogram or "joining tree".

4.3.2. Forest Species Diversity

Alfa (α) diversity describes the richness and evenness of species at a location when species abundances are estimated using a given method (Gore and Paranjpe, 2001). It is also, a heterogeneity measure that combines the richness and evenness components of diversity. Indices of Shannon-Wiener, Shannon Evenness, Simpson, and Simpson's Evenness, were selected to calculate diversity because they fit the following characteristics (Magurran, 1988 and 2004):

a) The Shannon-Wiener Index has moderate discriminant ability, moderate sensitivity to sample size and is biased towards species richness. The Shannon index is calculate by the equation:

$$H' = - \sum p_i \ln p_i \qquad \text{Eq. (2)}$$

p_i: is the proportion of individuals found in the *i*th species.

As in a sample the true value of p_i is unknown, it is estimated using its maximum likelihood estimator n_i /N.

The Shannon-Wiener Index values from empirical data usually falls between 1.5 and 3.5 and rarely surpasses 4, even if stated that H' does not seem to exceed 5 (Krebs 1989, Magurran 2004).

b) The Simpson Index (D) has moderate discriminant ability, low sensitivity to sample size and is biased towards dominance. It provides a good estimate of diversity at relatively small sample sizes. The Simpson's Index is calculated from the equation:

$$D = \sum p_i^{\,2} \qquad \text{Eq. (3)}$$

p_i: is the proportion of individuals found in the *i*th species

The form of the index appropriate for a finite community is:

$$D = \sum [n_i (ni - 1)/N(N-1)] \qquad \text{Eq. (4)}$$

Where n_i = number of individuals in the *i*th species, and N = total number of individuals.

The Simpson's Index is usually expressed as 1-D or 1/D, the complement or the reciprocal of its original formulation D, in this cases the value of the measure will rise as the assemblage becomes more even. (Magurran, 2004).

c) The Shannon Evenness (E) measure has poor discriminant ability, moderate sensitivity to sample size and is biased towards evenness. The Evenness (E) index is calculate from the equation:

$$E = H'/\ln S \qquad \text{Eq. (5)}$$

H': is the Shannon index

S: number of species

E is constrained between 0 and 1.0 representing a situation in which all species are equally abundant (Magurran 1988).

Further estimations of communities' species richness can be achieved by sampling and recording individuals and area data, addressing to plot a species accumulation curve and fitting it to an algebraic equation. Otherwise, species-individuals curve also enables to fit models to predict species numbers (Gore and Paranjpe, 2001).

Beta (ß) diversity is the variation in species composition between areas of alpha diversity. ß diversity is a measure of differences or similarities among ranges of habitats or samples regarding the species composition or abundances found in them. Considering species composition in two groups of forest communities such as undisturbed and disturbed, the fewer species that communities share indicates the higher ß diversity that can be expected (Magurran 1988). Variation in diversity as we go from site to site is termed as β-diversity. Low-βeta diversity means there is considerable geographic uniformity or similarity (Gore & Paranjpe, 2001).
Whittaker index β_W is a measure of βeta diversity between pairs of samples or adjacent quadrats along a transect, it takes into account presence or absence data. The index value ranges from 1 to 2. Calculation of the index comes from the equation (Magurran, 2004):

$$\beta_W = \overline{S7} \quad \alpha \qquad \text{Eq. (6)}$$

S: total number of species
$\overline{\alpha}$: average sample diversity
Subtracting 1 from the answer set the value between 0 to 1 scale.

The β-diversity of pairs of sites was also calculated using similarity coefficients. One similarity measure based on quantitative data is the Sorensen quantitative (C_N) index, based on species abundance, according to the equation (Magurran, 1988 and 2004):

$$C_N = 2jN/ Na + Nb \qquad \text{Eq (7)}$$

jN: the sum of the lower of the two abundances recorded for species found in both sites
Na: total number of individuals in site A
Nb: total number of individuals in site B

The Morisita-Horn (C_{MH}) index, as well a quantitative similarity measure, has been recognized not to be influenced by species richness and sample size (Magurran, 2004) therefore it was used in this research. The calculation uses the following equation:

$$C_{MH} = 2\sum (a_i \,.\, b_i) / (d_a + d_b) * (N_a * N_b) \qquad \text{Eq (8)}$$

Na: total number of individuals in site A

Nb: total number of individuals in site B

a_i : number of individuals in the *i*th species in A

b_i : number of individuals in the *i*th species in B

d_a and d_b are calculated using the following formula:

$$d_a = \sum a_i^2 / N_a^2 \qquad \text{Eq (9)}$$

Calculation of the Whittaker index (β_W) was done by hand, the rest of the mentioned diversities Alpha and Beta indices were performed using BIO~DAP (Ecological Diversity and its Measurements) a free program from Parks Canada (PHQ) and Fundy National Park.

Gamma (γ) diversity or accumulation refers to a landscape or other large area and often is expressed as number of species. γ diversity results from the combination of two diversity levels α and β, and it can be calculated as mean alpha diversity plus beta diversity (Gore & Paranjpe 2001, Magurran 2004).

4.3.3. Importance value index (IVI)

The climax adaptation number (Brown and Curtis 1952 cited by Krebs 1989) currently named index of value of importance (IVI) is an ordering technique that enables to classify samples based on their reciprocal relationship. The method consists in assigning categories of importance to each species into communities under evaluation, by addition of each relative abundance, frequency and dominance (basal area). Relative abundance is the percentage proportion of each species between the total numbers of trees multiplied by 100. Relative frequency of one species is obtained from the percentage of the sum of one species between the sums of the frequencies of all the species multiplied by 100. Relative Dominance calculates the proportion of one species in the evaluated total basal area multiplied by 100.

4.3.4. Structural Complexity Index

Structural Complexity Index (C_{HCI}) proposed by Holdrige et al. (1971) is a measure of ecosystem complexity, which deals with the calculation of relationships between mean tree height, basal area, density of stems, and species number, in one tenth (0.1) of a hectare plot. C_{HCI} allowed to compare forest types groups resulting from cluster analysis.

Since not all trees fit the equation requirements, to begin, it must calculate distribution of height frequency for each group type, in order to obtain classes and select the higher individuals to input to the C_{HCI} equation. The frequency distribution was performed using the program SPSS version 10.0 for Windows. The remaining parameters were taken without additional considerations.

$$C_{HCI} = HBDS/1000 \qquad \text{Eq. (10)}$$

H: mean tree height per 0.1 ha plot

B: basal area average per 0.1 ha plot

D: density per 0.1 ha plot

S: number of species per 0.1 ha plots

The higher values of C_{HCI} indicate the stands with most complex structure.

4.3.5. Principal Components Analysis

Principal Components Analysis (PCA) is a mathematical procedure to transform a set of correlated variables into a minor set of not correlated variables named principal components (Johnson, 1998), thus PCA enables identifying patterns in data sets, and expresses them in terms of similarities and differences (Smith, 2002). It means that the analysis reorders data, avoids redundant information, and provides compressed data.

Addressing the variability between undisturbed and disturbed forests, the PCA was applied jointly to all data sets including variables such as: height, basal area, density (number of tree per hectare), species density (number of species per hectare), complexity index, Shannon index, Evenness Shannon index, and Simpson index. The analysis set calculation of correlation matrix using the regression method, also it allows the graphic or scatter plot. The analysis has to be calculated using the program SPSS 8.0.

Next, was selected the Kruskal-Wallis nonparametric analysis of variance, in order to test each mentioned variable regarding the disturbance condition. The method uses Chi-Square test and significance level of $P<0.05$. Nonparametric methods are suitable when it cannot be reasonably supposed that the population source has a normal distribution, and also when the samples have unequal size. As well, the standard error is shown as bar chart for each significant variable. The calculations have to be performed through the program SAS.

4.4. Remote sensing methods

The study site was analysed using multi-spectral Landsat images (TM-4 and ETM) path 233 and row 055 from the Worldwide Reference System (WRS). Each scene covers 185 km in the west-east direction by 170 km in the north-south direction, overall amounting to about 31,450 km^2. The scene comprises the core area of Forest Reserve Imataca as well as surrounding areas. After reviewing 20 years of Landsat images series, only three images could be found: one TM 4 (23 November 1987), and two ETM (23 September 2000 and 13 September 2002), however their quality ranged from low (1987) to medium (2000 and 2002) due to the typical atmospheric noise in tropical latitudes such as haze, clouds, and shadows.

The first step of Landsat processing consisted in a radiometric correction to convert digital numbers (DNs) from the image data to spectral radiance (L_λ) and to Top of Atmosphere (TOA) reflectance (ρ_λ). Reflectance is defined as the ratio of reflected radiance and incoming irradiance.

$$\text{Reflectance } (\rho_\lambda) = \frac{\text{Radiance}}{\text{Irradiance}} = \frac{E_\lambda \uparrow}{E_\lambda \downarrow} \qquad \text{Eq. (11)}$$

The incoming irradiance is compute based on the position of the sun, time of year, time of day, latitude and longitude, etc. The units of spectral radiance are W/ (m^2 .sr. μm) watts per square meter per steradian (sr, unit of solid angular measure) per micrometer. The combined surface and atmospheric reflectance of the Earth was computed according to the following equation (Chander and Markham, 2003):

$$\rho_{TOA} = \frac{\pi L_\lambda . d^2}{Esun_\lambda . \cos \theta_S} \qquad \text{Eq. (12)}$$

Where:

ρ_{TOA} is the top-of-atmosphere reflectance;

L_λ spectral radiance at the sensor's aperture;

d earth-sun distance in astronomical units;

$Esun_\lambda$ mean solar exo-atmospheric irradiance;

θ_S solar zenith angle in degrees.

The earth-sun distance has to be deducted from tabular data using the image acquisition date and time. The solar exo-atmospheric irradiance was calculated using the Esun of DOY, an algorithm based in gain values from sensor (maximal radiance, minimal radiance), sun zenith and azimuth values.

DN to Radiance conversion (NASA 1998)

Radiance (L_λ) = {[Lmax – Lmin) / 255] x DN} + Lmin Eq. (13)

Where:

Lmax. radiance at which channel saturates

Lmin. minimum recordable radiance

The second step dealt with geometric correction, based on the Landsat TM-4 (1987) image orthorectified according to provider information. Thus, an image by image registration technique was applied on both ETM images (2000 and 2002) using the nearest neighbour 1st degree Polynomial technique, Root Mean Squared Error, RMS = 0.5, performed by the program Environment for Visualizing Images (ENVI) version 3.6 (Research Systems Inc., Colorado, USA).

The third step was image enhancement aimed at atmospheric noise removal (haze, clouds, and shadows masking). Procedures aimed at correcting atmospheric disturbances had been used with regard to the Brazilian Amazonian basin forests, where an automatic detection and measurement of selective logging was also the aim, (Matricardi, 2003). Procedures applied to improve images included the following:

a) Unsupervised classification ISODATA on Landsat all bands images, 20 classes, 10 iterations, 0.95 confidences. Resulting classes vary depending on the image quality that varied from 11 to 14 classes of atmospheric noise.

b) To set aside "noise" classes, post classification operations were applied such as combining classes and masking, until an image of two classes (noise: 0 and others: 1) could be produced

c) The previous image was overlapped on band 5 as a mask, to perform again unsupervised classification ISODATA, 20 classes, 10 iterations; followed by classes combining and masking to obtain an image of two classes (forest: 0 and non-forest. 1)

d) The forest–non forest image was textured using a texture variance 5x5 window.

e) The last textured image was filtered using a median filter to reduce noise

f) The filtered image pixel size was expanded (3x3 pixel window) to get only features of interest

g) On the previous image digital number (DN) values range of log landings (storage areas) and road networks were tested in order to get threshold values to mask all but log landings and road networks.

h) A mask was built from threshold values and converted to vector format to edit remaining noise in GIS

i) The log landings and road networks layer in GIS allows to calculate buffer areas around degraded forests

Since clouds and haze could not be removed entirely, the study area was subset in the following three sectors,

Central (C): 3153.3 Km^2

North West (NW): 1831.6 Km^2

South (S): 421.6 Km^2

In a fourth step normalized difference vegetation index (NDVI) was applied to the three mentioned subsets. NDVI is the ratio between red to near infrared bands, which values stretches from 0 to 1, from low to high biomass contents. The mentioned bands ratio is 3 / 4 in Landsat TM and ETM. The out coming values provide information about biomass through basal area distribution.

Given that the textural techniques tested on the Landsat ETM (2002) image produced only limited results, another approach to detect and estimate areas under forest degradation was tried to conduct a multi data comparison.

4.4.1. Vegetation Indices

A vegetation index is a radiation-based measurement, a ratio between the red and the near-infrared spectral regions that involves any relationship to biophysical variables, therefore is used to infer vegetation properties by segregation of vegetation radiation from other materials (Asner et al. 2003, Rencz 1999). However this desirable extraction of vegetation spectral purity is often unfeasible, then approaches like mixed pixel or sub pixel mixtures become suitable. An important case of pixel mixing occurs between soil and vegetation reflectance, which affects even forest canopy observations, because soil can contribute to the reflectance given that some wavelengths can penetrate the vegetation canopy. This relationship has been analysed through empirical observations of bare soils brightness in the frame of the red and near infrared spectral regions. Addressing to quantify the spectral mixture vegetation-soil, indices have been proposed, such as the Perpendicular Vegetation Index (PVI), the Soil Adjusted Vegetation Index (SAVI), and the Modified Soil Adjusted Vegetation Index (MSAVI), among others (Wang et al. 2003, Campbell 1996).

Since the evaluation of forest disturbance is one goal of this research, and also because a number of studies have stated that intensity of vegetation disturbance can be linked to changes of canopy structure, then disturbances such as selective logging can be assessed through canopy structure analysis techniques such vegetation indices (Asner et al., 2003).

In order to improve logging detection and to map canopy cover, it was applied a linear unmixing model based on the vegetation index domain. The vegetation index used was the Normalized Difference Vegetation Index (NDVI) to get estimations of canopy and soil fractions.

The canopy fractional cover (*fc*) equation is the following one:

$$fc = \frac{VI\text{-}VI\ soil}{VI\ canopy - VI\ soil} \qquad \text{Eq. (14)}$$

VI is the proxy variable for all types of vegetation indices.

VI canopy and *VI soil* are two endmembers empirically obtained from the ETM+ images by visually consulting of the image statistical information (Wang et al., 2003).

By substitution the equation turns out as:

$$fc_{NDVI} = \frac{NDVI - (\text{Soil endmember})}{(\text{Canopy endmember}) - (\text{Soil endmember})}$$

From Landsat (TM and ETM) images histograms, bands red (b3) and near infrared (b4), we got the following end member values:

Soil: 0.2

Vegetation: 0.65

The model takes original values of NDVI and scales them to 0 to 100 %, using as threshold the VI soil as 0% and the VI vegetation as 100 %. Further, the image was filtered to reduce atmospheric noise using the focal mean function, consisting of one

3x3 pixel window. The image was then post-classified to get classes of interest to mapping.

Image processing to performing the model was based in the ERDAS program by Leica Geosystems version 8.7.

4.5. Interpolation of basal area and NDVI by Kriging technique

The spatial distribution of basal area estimated from ground data collection and NDVI, vegetation index calculated on image Landsat ETM (2002), was carried out through the interpolation Kriging, a statistically based estimator of spatial variables. This technique creates a mathematical model used to estimate values across the surface. It provides estimated values unbiased and with minimal variance, from a set of sample plots either regularly or irregularly distributed. The Kriging interpolation calculates the semivariogram, the nugget effect (initial semivariance when the correlation typically is highest), the structural component or drift (spatial trend) and the anisotropy (FAO, 2001). The Kriging interpolation was performed using the program Surfer version 8 (Golden Software).

4.6. Visual interpretation

Visual interpretation and digitising of degraded areas on images Landsat TM and ETM, using band colour composites RGB 5-3-2, and 4-3-2, was other method used to identify selective logging, and indigenous shifting cultivation. Areas to perform visual interpretation were selected on screen and delimitated by one individual.

The scheme of categories adopted to carry out visual detection was:

i. obvious logging
ii. subtle logging
iii. shifting cultivation

The mentioned categories related to logging were suggested by Janeczek (1999) and Matricardi (2003) who state that obvious logging shows extensive canopy disturbance, road networks, and either spectrally bright or faded log landings. While subtle logging refers to areas where the mentioned features are dissolving, even differences in the forest canopy integrity can be observed.

Detection of shifting cultivation takes into account some spatial pattern features visible in a forest matrix, such as bare soil plots, and clustered rounded areas surrounding settlements along roads.

4.7. GIS - based methods

GIS-based data analysis was the research's last step since it enables the integration of landscape regional and local approaches. Former studies state that landscape changes began at local unconnected areas, where resources exploitation systems such as selective logging, have promoted disturbance on the remaining biomass and also over other landscape components like soils and rivers. As a consequence, the indigenous population is threatened since some areas devoted to their productive practices such as hunting, cropping, or fishing, became under private property regime, which introduces a disturbance factor already documented as social conflicts (UNEG, 2000).
Regarding estimation of forest degradation, the first step consisted of delimiting buffer areas based on distance radiuses, from log landings to surrounding logged areas. The tested distance values come out from empirical data, mainly recorded in ground truth and published data, threshold values ranged from 180 to 270 meters along roads. Then, having log landings as central points corridors were calculated along forest networks, as well as embraced forest areas were accounted as degraded forests.

Influence areas estimation of indigenous habitat stemmed from interviews with indigenous "captains" who stated as traditional territory areas between 5 to 20 kilometres from the Tumeremo - Bochinche road, towards North and South. The resulting polygons stretch variable surfaces.

Since the identification of landscape changes is the main goal of this research, and due to atmospheric noise, appropriate change detection is restricted to compare and subtract temporal data sets, estimations were performed based on overlapped polygons that came from visual interpretation on Landsat ETM images dated in 2002 and 2000.

The last analysis aimed at obtaining potential conflict areas resulted from overlapping the Land Use Plan (decreed in 2004) to areas under logging concession, and under indigenous shifting cultivation. It is noteworthy the inclusion of mining as allowed land use, since its harm impact to forest sustainability is common knowledge.

GIS analysis was carried out through the program ArcGIS 8.3 by ESRI.

SECTION III: RESULTS

5. Landscape approach to forest degradation

5.1. Spatial patterns of indigenous shifting cultivation and selective logging

The term “spatial pattern” refers to the overall shape of land use patterns. It results from spatial features such as plot distribution, sizes, edges, connectivity among plots and others. The pattern of indigenous shifting cultivation is named diffuse, disperse or discontinued (Geist and Lambin, 2001) because it is shaped by settlements representing the central place with respect to the surrounding farming plots.

The Kariña cultivation plots are interspersed in non-disturbed forest and fallows of various ages, they amount to 0.5 to 1 hectare, have a rectangular form and variable distances to each other. This kind of matrix is known as the diffuse pattern, which can be observed along the Tumeremo - Bochinche road, secondary roads, and even far away, into indigenous traditional lands, currently converted to private allotments then breaking the continuity of the pattern.

The study area embraces 14 Kariña settlements with approximately 1800 inhabitants, which represent 15 % of the indigenous population in Forest Reserve Imataca (MARN, 2003).

Selective logging in Imataca Central matches the fish-bone spatial pattern documented for tropical rainforests in the Amazon and South Asia. Figure 1 shows both spatial patterns detected in the study area for the two years of reference, 2000 and 2002.

Furthermore, selective logging patterns were classified as obvious and subtle types. The distinction was based on the visual appearance and brightness values recorded on satellite images, which imply different stages from disturbance to recovery while pioneer plant species grow up in the gaps that remained after logging operations.

Figure 1 shows two sub sets of Landsat ETM (23/09/2000) in the central zone of study area, drawing out two types of forest degradation resulting from the land uses under analysis.

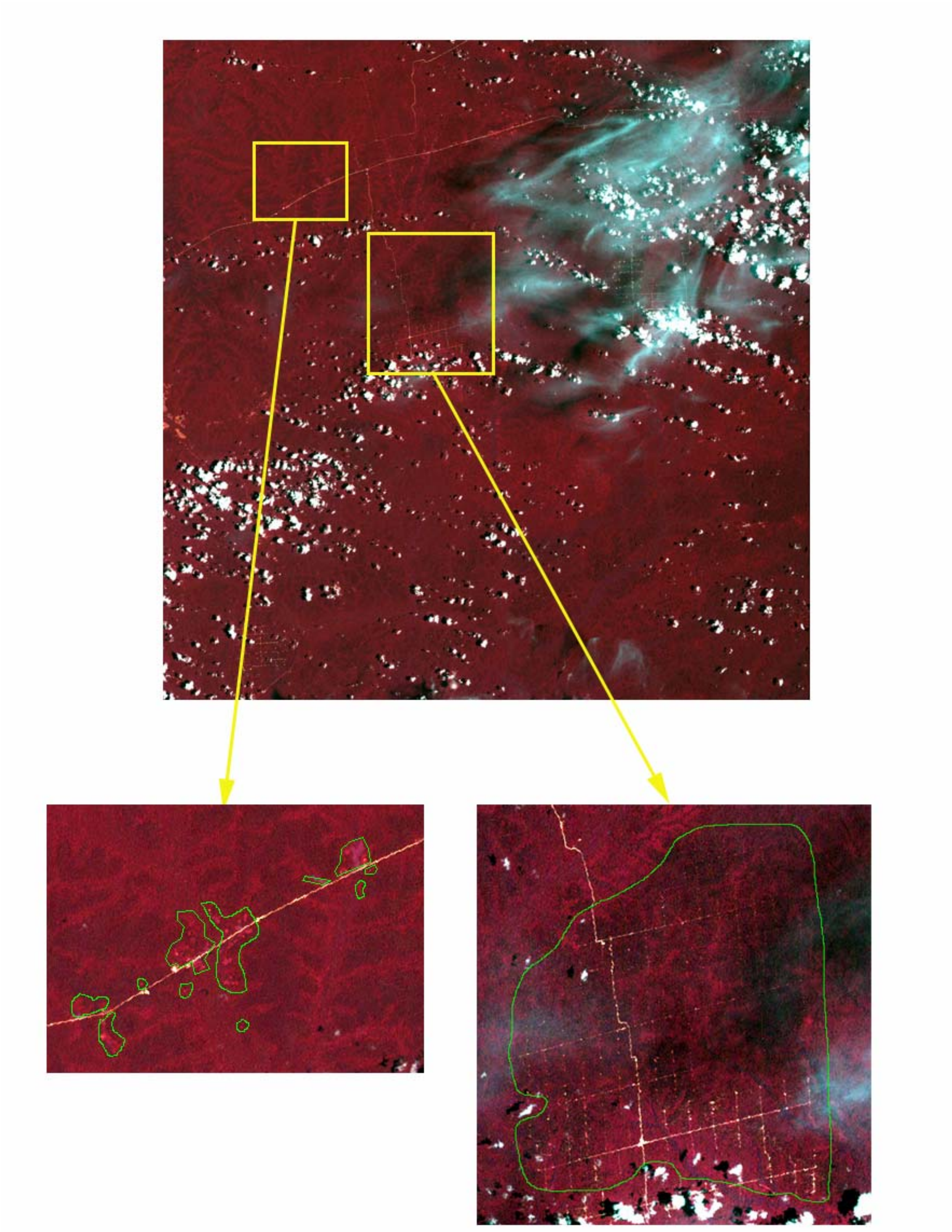


Figure 1: Indigenous Shifting Cultivation Plots (left) and Obvious Logging (right) in Imataca Central in 2000

As well figure 2 represents two sub sets of Landsat ETM (13/09/2002) one located in the centre and another in southern study area, both types of forest degradation result from analysed land uses.

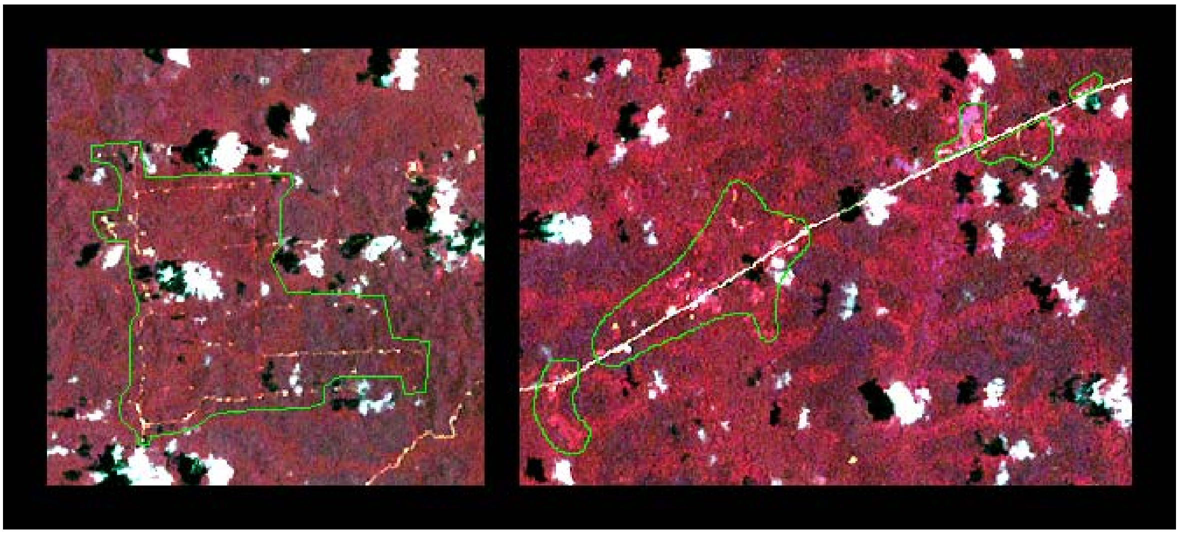


Figure 2. Subtle Logging at Southern (left) and Indigenous Shifting Cultivation (right) 2002.

Table 5 contains land cover values resulting from visual interpretation and automatic calculation by the ENVI program. It is worth pointing out that the Landsat ETM 2002 is affected by atmosphere noise (clouds, shadows, haze) impeding a suitable delimitation. Areas under obvious logging became smaller in only two years, while areas under subtle logging grew in a comparable proportion. This seems to make sense because logging features in tropical forests tend to disappear, and only some canopy changes related to colour brightness, roughness, and others remain, which eventually can be detected using textural methods on satellite images.

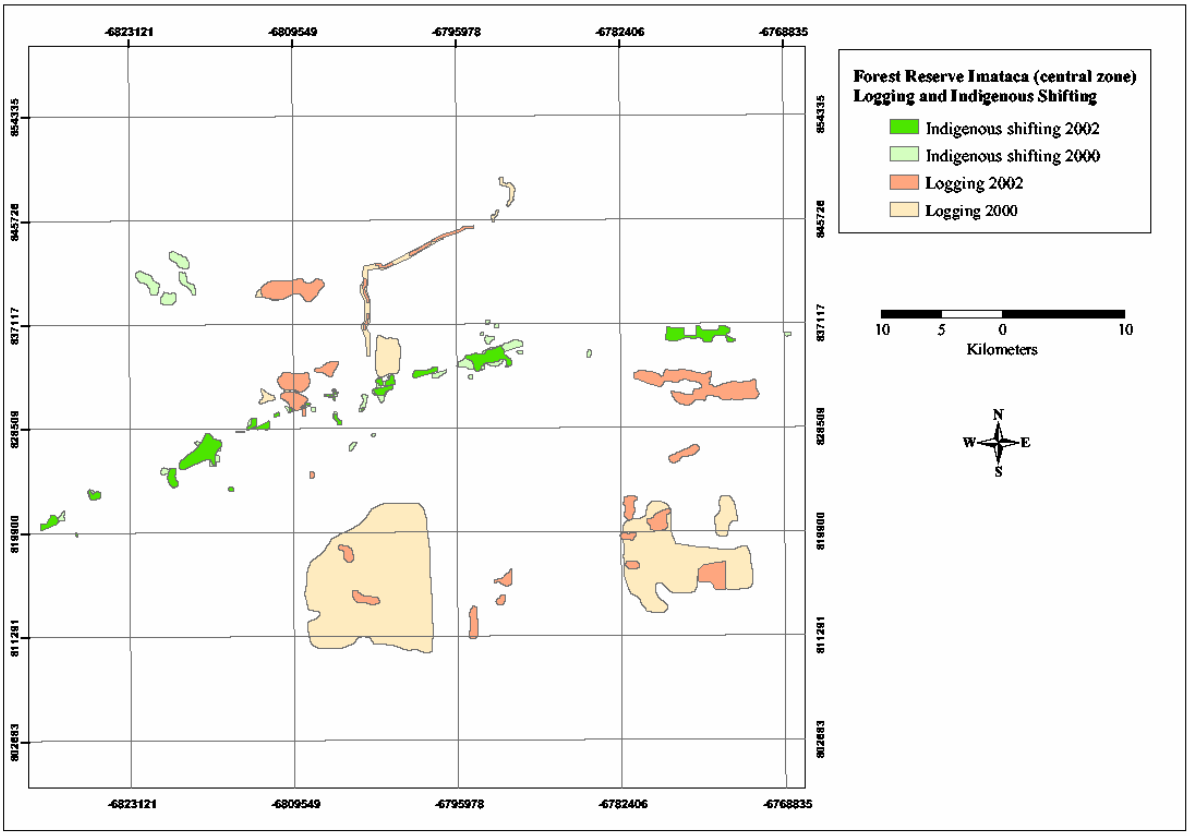
Table 5. Visual Detection of Areas (Km^2) Under Logging and Indigenous Cultivation

Subset	**2000**			**2002**		
	Obvious	**Subtle**	**Indigenous**	**Obvious**	**Subtle**	**Indigenous**
Central	162.8	12.6	22.4	15	27.7	19.1
North west	44	-	-	13	67.9	-
South	24.7	11.1	-	-	25.1	-
Total	231.5	23.7	22.4	28	120.7	19.1

Source: Landsat ETM images (p233r055 - 2000 and 2002)

Map 6 illustrates the spatial distribution of both studied land uses; selective logging is able to produce obvious landscape changes as exploited surfaces amount up to four thousand hectares per year. Consequently, these areas need an expanded road networks and other service facilities which then can be detected on the images.

On the other hand, indigenous shifting cultivation covers large surfaces where small communities last for relatively short time periods (around 20 years); after that period according to their tradition the whole territory including logging concessions belongs to them. Most of the Kariña settlements are located along Tumeremo – Bochinche road and surroundings.



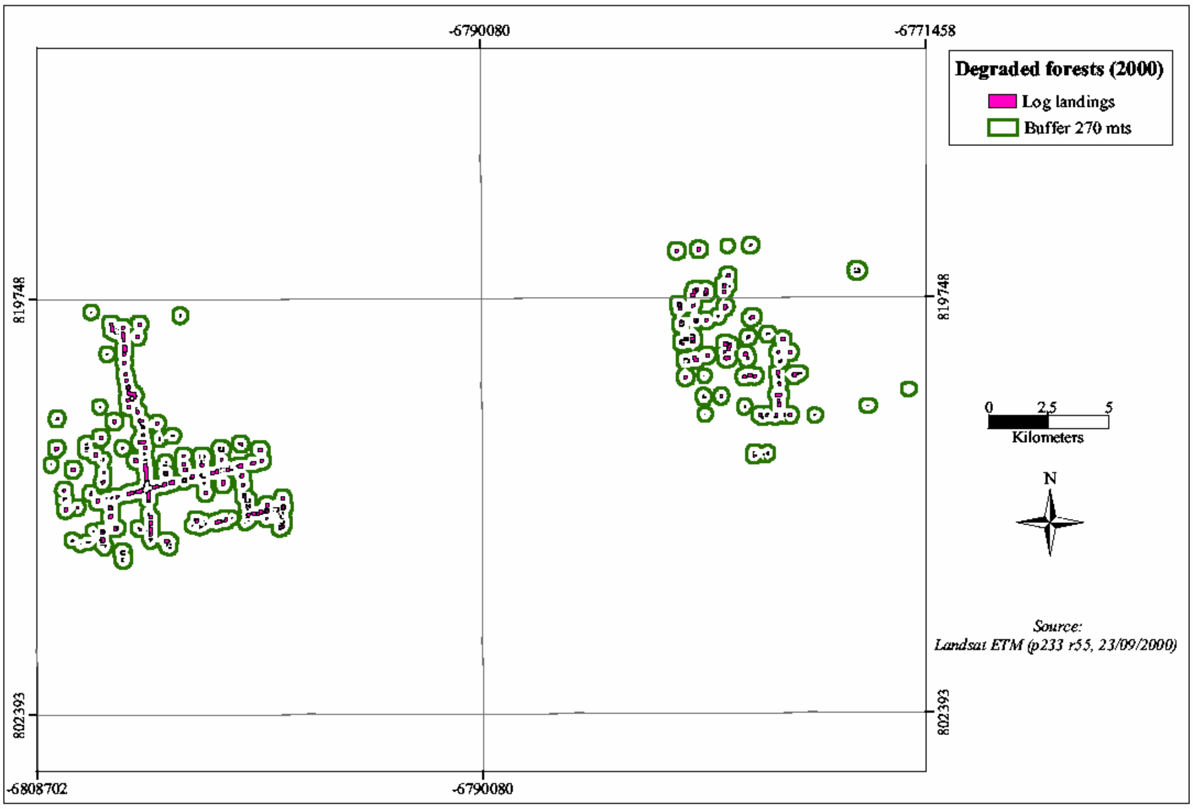
Map 6. Selective Logging and Indigenous Shifting Cultivation Areas in 2000 and 2002

Even though selectively logged forests keep most of the trees, damages on the remaining biomass have been reported stretching from 180 m to 500 m into the stand, depending on the exploitation rate. To estimate these areas of degraded forest we get sequential buffers of radiuses between 180 m to 270 m, taking as central point the log landings detected by textural automated analysis. Table 6 reports degraded forest areas between 62 and 92 km^2 of size calculated based on the image Landsat ETM (2000), which has less atmospheric noise. As masking and filtering were performed, even forest road networks and log landings could be detected. Maps 7 and 8 focus on logging areas where the detection produced the expected results.

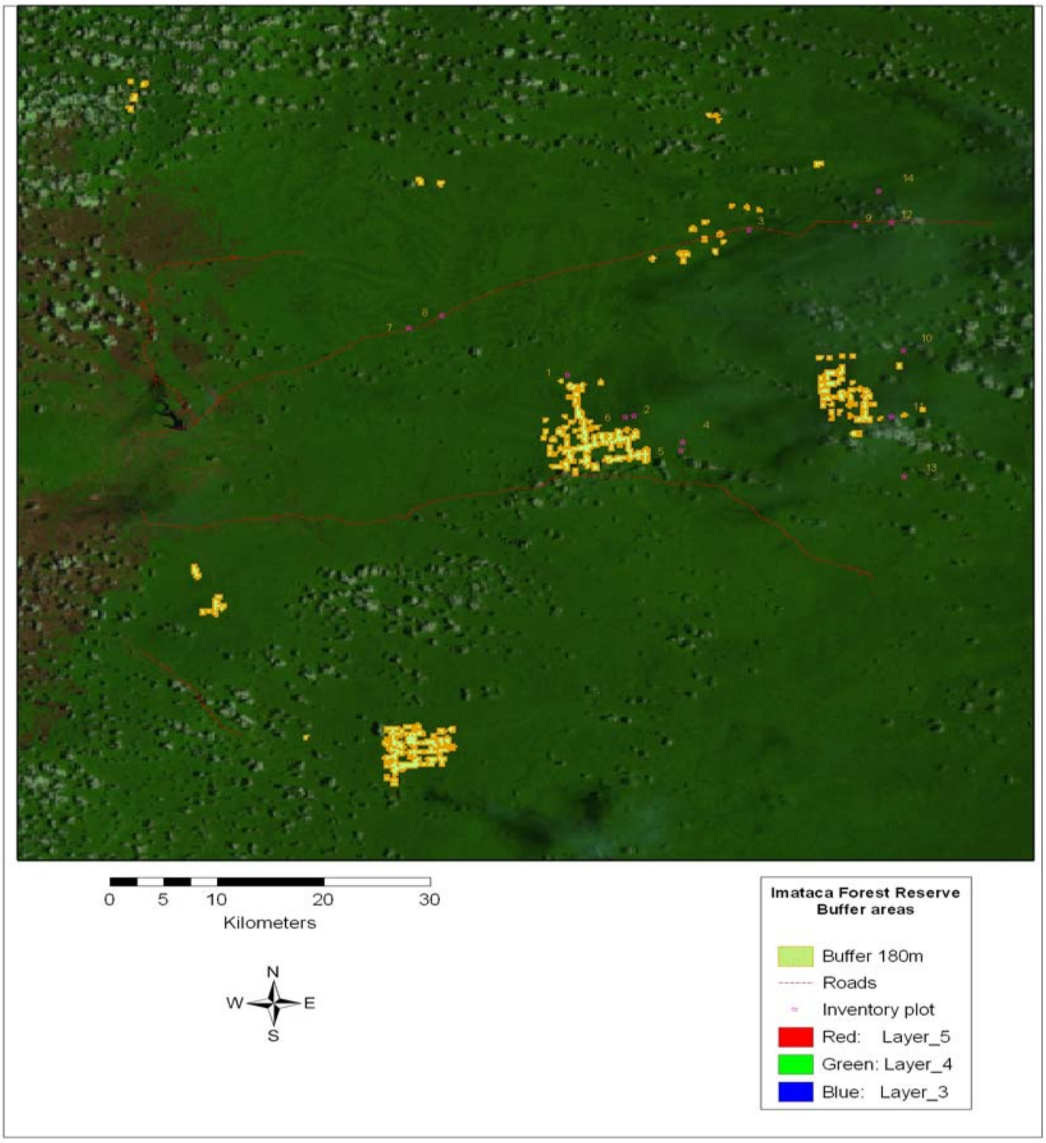
Table 6. Estimation of Degraded Areas from Logging Using Buffers

Forest Reserve Imataca-central zone			
Buffer 270 m	**Buffer 240 m**	**Buffer 210 m**	**Buffer 180 m**
9229,1 ha	8226,2 ha	7202,5 ha	6184,6 ha
92,3 Km2	82,3 Km2	72 Km2	62 Km2

Source: buffer areas on Landsat ETM (23/09/2000)



Map 7. Zoom of Major Buffer Area Based on Texture Analysis



Map 8. Overall Degraded Areas Including Minor Buffer Areas

5.2. Multi temporary estimation of the forest degradation

The multi-temporal assessment of forest degradation was based on the three available Landsat scenes from 1987, 2000, and 2002. It was carried out according to the fractional cover approach which applies use of vegetation index, in this case NDVI. Since the scenes were affected by atmospheric noise, the first noise class was eliminated, as well as two classes concerning soils were merged into one. Four forest types were used; three describing degraded forests, and one for undisturbed forests. The results about classes of forest degradation were merged as one class in the table 7; even they have drawn separately in the maps 9, 10 and 11.

Table 7. Forest Degradation Outcome of Fractional Cover Model (on NDVI)

Landsat TM 1987

Classes	Count	Area (ha)	(%)
Noise	1828591	148527,30	15,75
Noise and soils	1224775	99482,32	10,55
Degraded forest	3536051	287215,74	30,46
Undisturbed forest	5018486	407626,52	43,23
		942851,88	100,00

Landsat ETM 2000

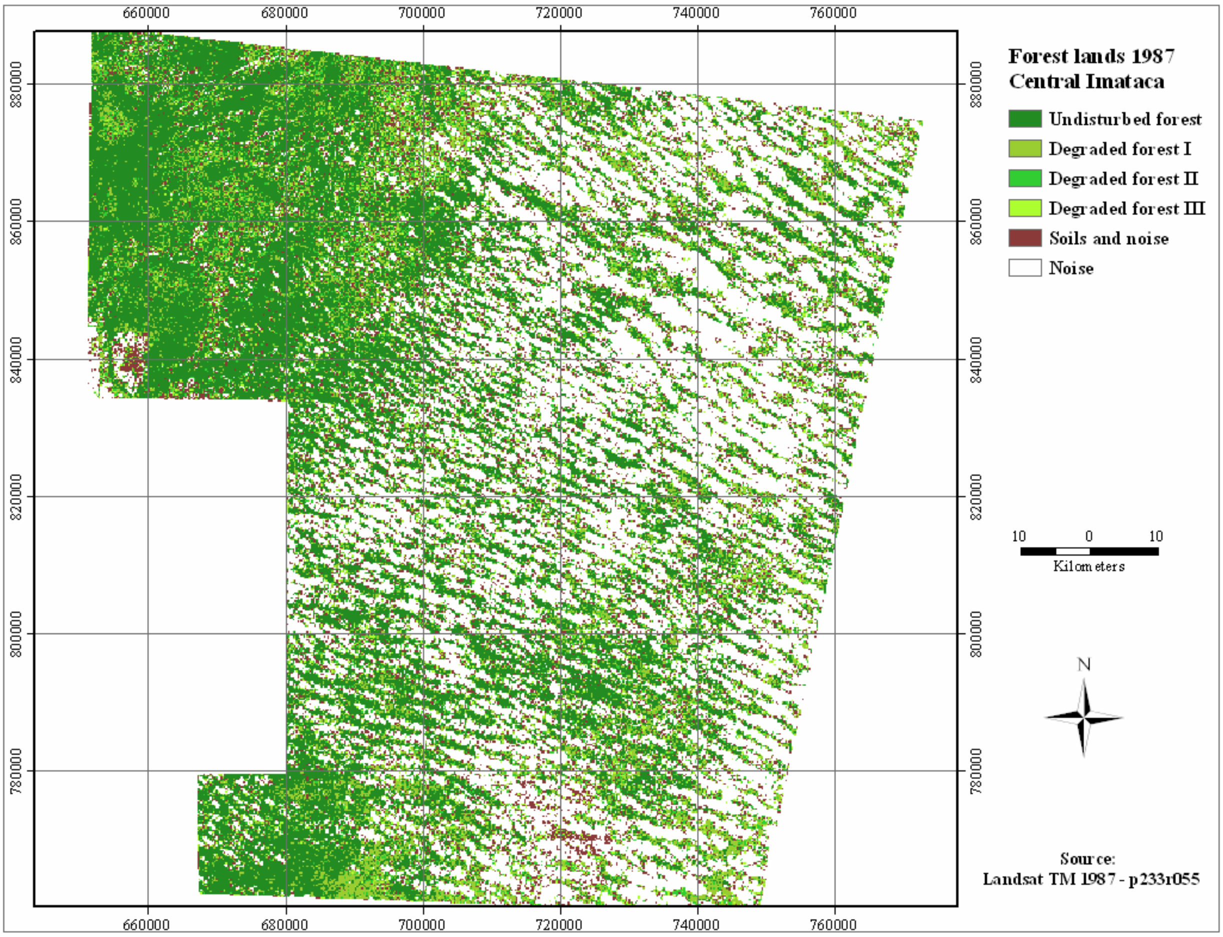
Classes	Count	Area (ha)	(%)
Noise	1385496	112536,90	12,02
Noise and soils	1717497	139503,69	14,90
Degraded forest	7986401	648695,41	69,27
Undisturbed forest	439875	35728,84	3,82
		936464,84	100,00

Landsat ETM 2002

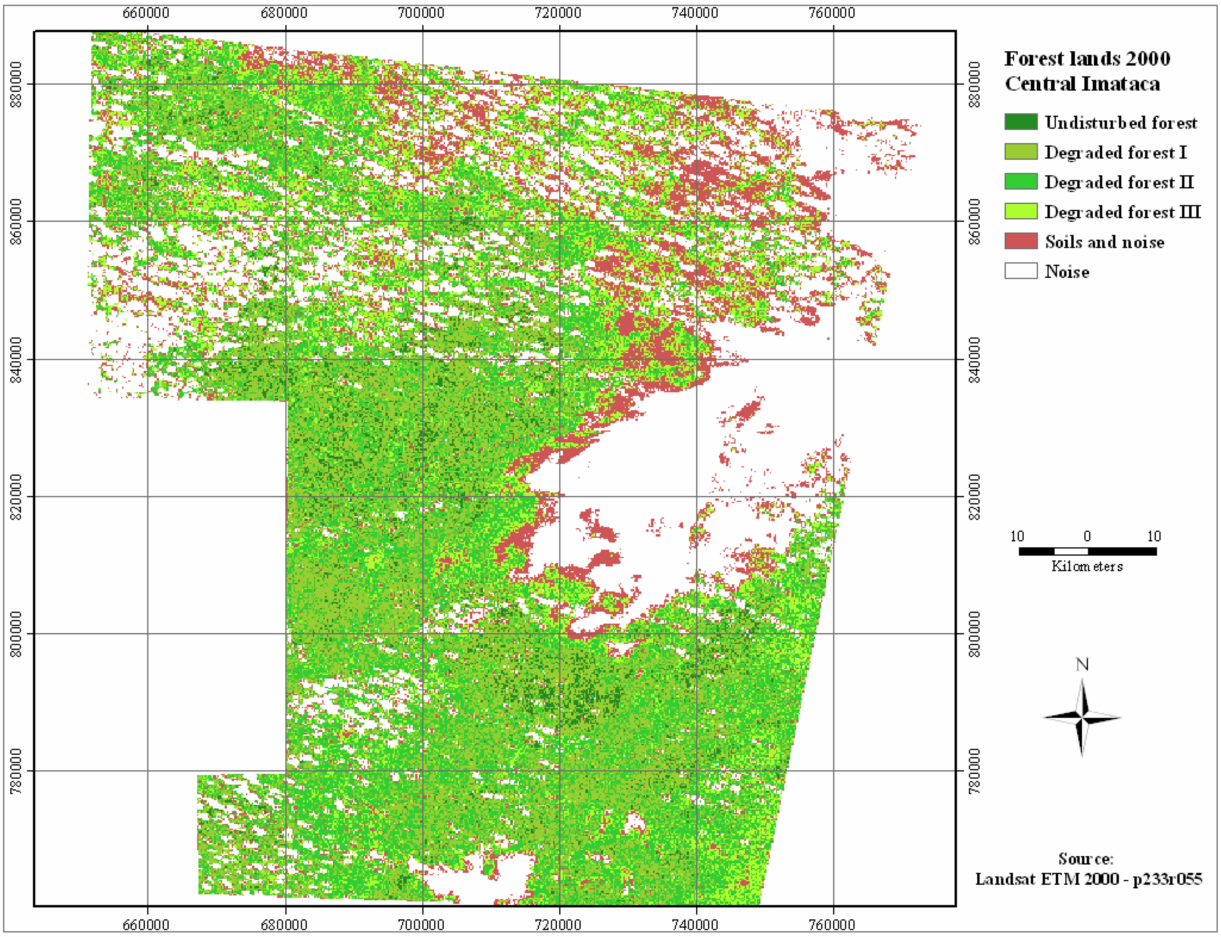
Classes	Count	Area (ha)	(%)
Noise	1118401	100656,09	10,02
Noise and soils	1063308	95697,72	9,53
Degraded forest	8370579	753352,11	75,02
Undisturbed forest	606027	54542,43	5,43
		1004248,35	100,00

Source: Landsat images 1987, 2000, 2002. Path 233, row 055.

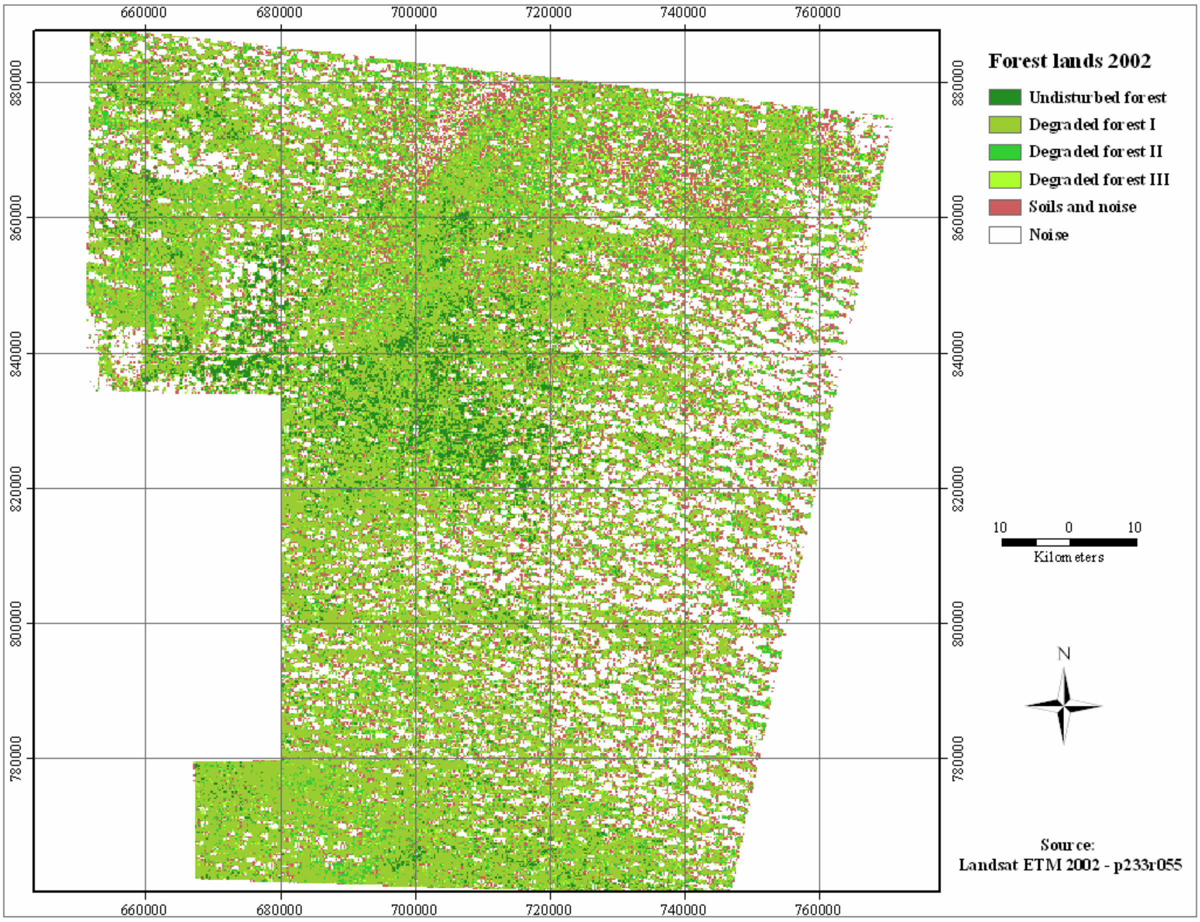
Maps 9, 10 and 11 display the spatial distribution of the degraded forests to each year of analysis. It can be observed that in 1987 the amount of undisturbed forest was high the opposite to images 2000 and 2002, meaning that free of cloud areas in 1987 were under natural undisturbed forest. The degradation distribution changed clearly during 13 years.



Map 9. Forest Lands Classes in 1987



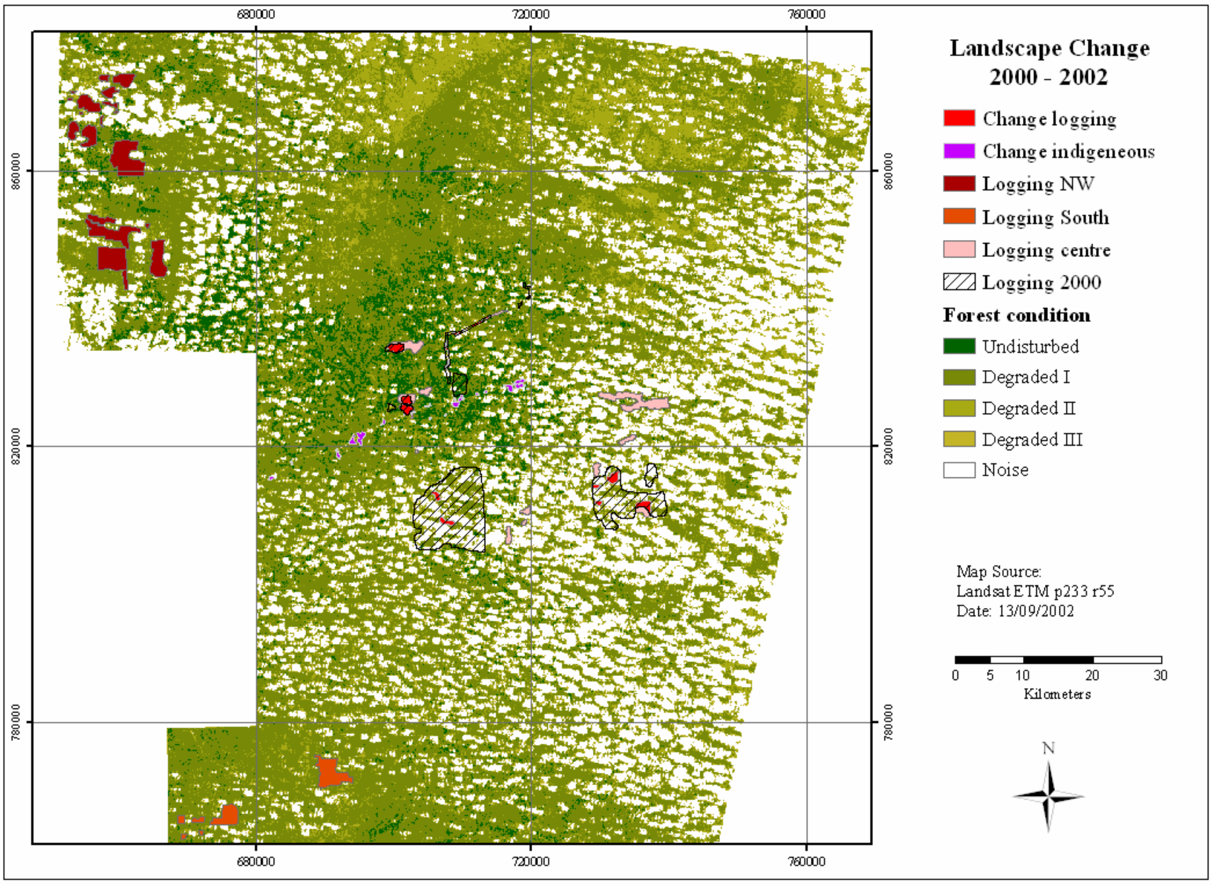
Map 10. Forest Land Classes in 2000



Map 11. Forest Lands Classes in 2002

Map 12 displays areas where landscape change was detected regarding selective logging and indigenous cultivation for a period of two years, from 2000 until 2002. The atmospheric disturbance did not allow automatic comparison by images subtraction, instead was overlapped the outcome of visual interpretation over the Landsat ETM image dated in 2002. We use as background, the image containing the forest degradation classes (Map 11) since it contains an estimation of such land uses effect.

As reference were plotted the logging areas in the middle of the study site detected in 2000, which highlights that logging traits tend to be less detectable relatively soon.



Map 12. Landscape Changes between 2000 and 2002

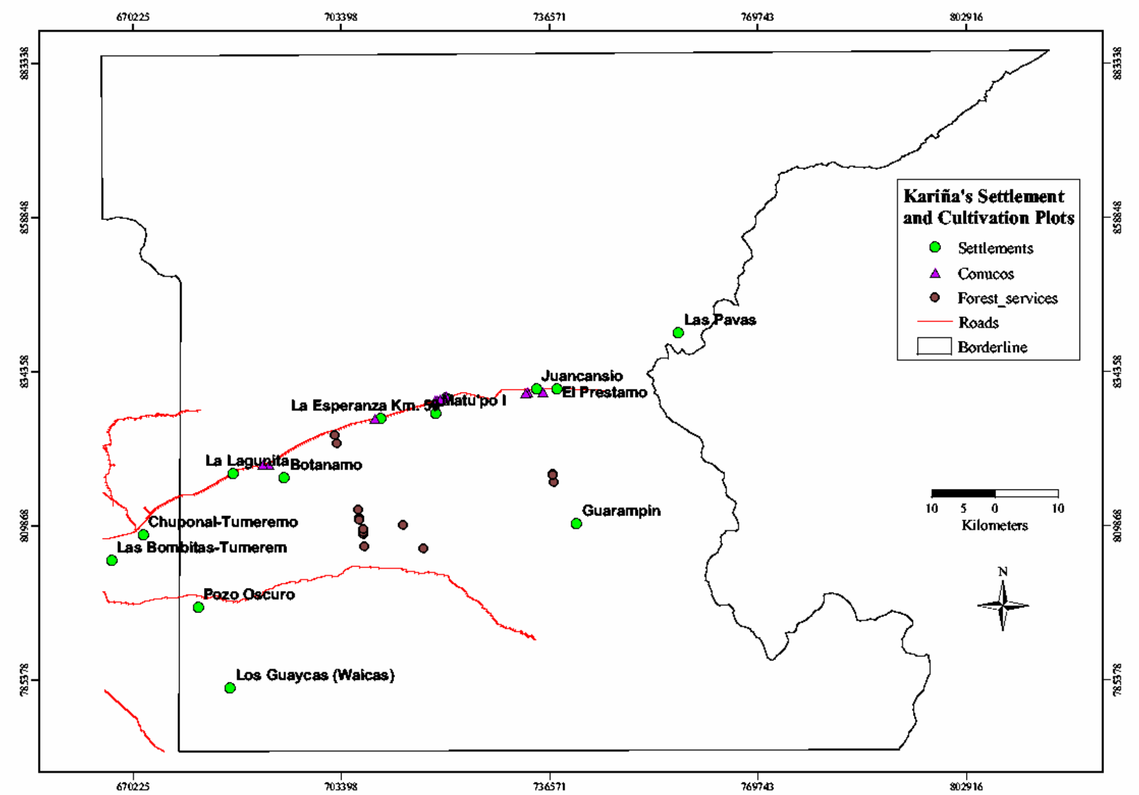
5.3. Indigenous shifting cultivation and selective logging land-uses

Description of indigenous and commercial forestry land-use comes out from interviews with community leaders and company managers. 18 indigenous production plots or *conucos* were visited and 5 households or *malocas* to register plots coordinates, size, shape, and agricultural practices. As well, we stayed in camps of forest companies, and went to service areas such as temporal camps, log landings (10 patios), cobblestone sources (2 sites) along secondary roads, and one machinery workshop.

Field work related to land uses characterization allowed two types of information, first, the Kariñas' food production system, settlement pattern, and landscape use. Second, the common production practices of logging companies, as well as, logistic tasks and silvicultural research projects. At that time, logging activities were stopped temporarily until new official exploitation permission was available.

5.3.1. Kariñas settlement and cultivation plots

Settlement and cultivation fields are plotted in map 13, where can be noted the roughly linear distribution of indigenous communities along roads.



Map 13. Kariña's Settlements and Cultivation Plots

In central Imataca 18 plots (conuco) were sampled, 9 of them on bare soil recently deforested, 4 under variable production stages, and 5 without age information. The oldest area under fallow had around 17 years, near the Botanamo settlement. Exploited surface was directly measured in 13 plots; the rest could not be measured. Conuco areas range between 1.3 and 0.1 hectare, in average 0.5 ha (Annex 1). Table 8 shows conuco locations, dimensions, and age.

Table 8. Conucos Dimensions and Age

Conuco N°	Place	Area (m^2)	Time (years)
1	Matupo I	11200	1
2	Matupo I	-	0
3	Matupo I	-	-
4	Matupo I	4422	-
5	Matupo I	10000	0
6	Matupo I	13000	0
7	Matupo I	4900	0
8	Matupo II	3000	-
9	Matupo II	1824	0
10	Matupo II	2848	3
11	Matupo II	2800	1
12	Matupo II	7500	0
13	La Esperanza	2700	0
14	Via Juancancio	-	0
15	Via Bochinche	1000	-
16	Via Bochinche	-	5
17	Botanamo	1400	0
18	Botanamo	-	-

Source: ground survey, November 2002

5.3.2. Indigenous agricultural site selection

Interviews with community leaders were performed in Botanamo, La Esperanza, Matupo I, Matupo II and Juancancio, settlements placed along the Tumeremo-Bochinche road, an unpaved way 100 Km long which crosses the study area from West to East. People were asked about agricultural site selection that implies their ecological knowledge about the relationships between crop-relief features, crop- soil properties, and other traits. Table 9 contains such information.

Table 9. Indigenous Agricultural Site Selection

Community	**Relief - Crop**	**Soil –Crop**	**Approximate soil taxonomy***	**Other physical trait**
Matupo I	Hills slope-high section is suitable for yucca (*Manihot esculenta)*, yam (*Dioscorea alata)* and mapuey (*Dioscorea trifida L.f)*. Hills slope-low section, for banana *(Musa paradisiaca)*, green banana, and ocumo *(Xanthosoma sagittifolium)*.	Sandy soil (dark colour) is suitable for yucca, and yam Clayey soil (red mud) favours banana, green banana, and ocumo	Oxic Dystropepts, Tropeptic Haplorthox, Typic Paleustults	Hills upper slope, tends to turn dry and plants wither. High and leafy trees indicate good land quality
Botanamo	Low areas are suitable for sugar cane *(Saccharum officinarum)* and ocumo *(Xanthosoma sagittifolium)*. High areas favour green banana	Sandy soil is suitable for yucca and sweet potato (*Ipomoea batatas)* Dark colour soil favours green banana	Tropeptic Haplorthox	Intermediate areas (slope-middle section) are inadequate for traditional farming (conuco)
Juancancio	Flat areas are suitable for cropping	Sandy soil is used for cropping Red soil does not allow seeds to grow	Plintic-Ultic Haplorthox, Ultic Haplorthox Ochraquox	Flat areas over sandy soil, are used to sow banana, yucca, green banana, maize (*Zea mays)*, mango *(Mangifera occidentale)* and papaya (*Carica papaya)*

Source: interviews with indigenous Captains, November 2002.

** adapted from Franco (1988)*

5.3.3. Annual economics calendar of land uses

5.3.3.1. Indigenous land use

The Kariñas' land use is the traditional shifting cultivation system that implies the cutting down of forest, burning fallen trees and the sowing of yucca, green banana, banana, maize, and yam among others plants. This established land plot (conuco) is used for production roughly for five years; afterwards the conuco becomes fallow and is left in recuperation for twenty or more years, and another new one is opened for food production.

According to the Kariñas tradition, each new family has the right of land to work on. Hence, the quantity of conucos under production depends on community growth as well as land availability, accordingly the Kariña's settlement changes of place with time. This temporary land use of small plot in the forests is a system of resources management because its exploitation intensity disrupts partially natural cycles; but remains ecosystem' rebuilt capacity. In fact, the present state of forest conservation in central Forest Reserve Imataca stems from former suitable indigenous land use systems.

In addition, hunting is a main activity developed along trails that cross areas where different natural resources are located. Hunting trails are also harvesting routes, so both activities are related.

Time periods allotted for cultivation, fishing, hunting, and forest harvesting of non timber products is represented in the annual economics calendar. The innermost circle shows two rainfall periods ranging between middle November to January and from May to August, so these are high water periods.

Most of the indigenous food production activities delivered throughout the year, as represented in the following economics calendar:

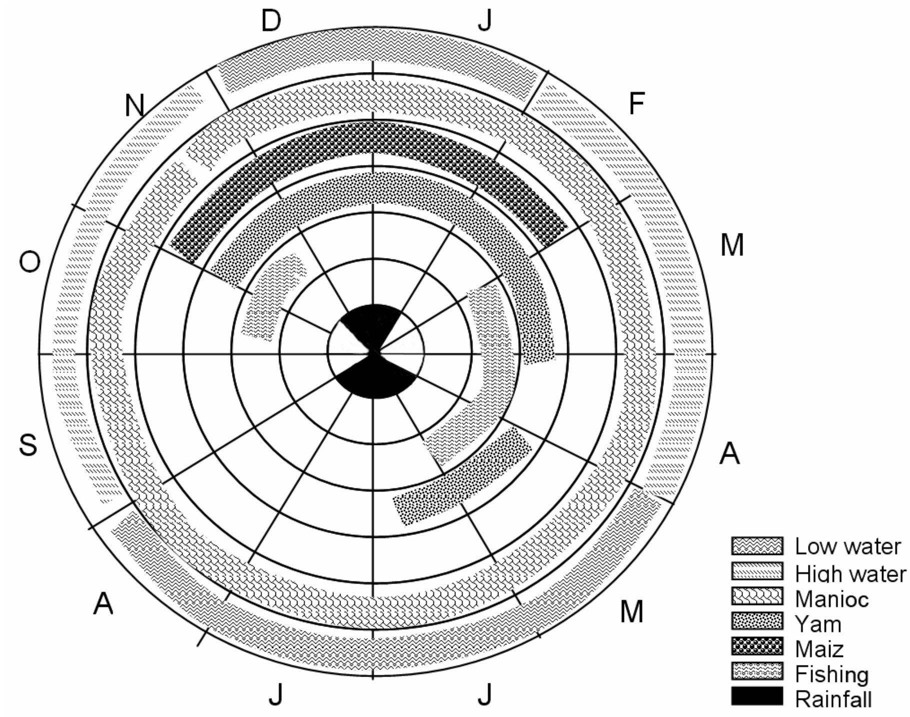


Figure 3: Economics calendar of indigenous production activities

As the calendar shows, main crops (short and semi permanent cycles) and related production activities are distributed as follows:

- Yucca (*Manihot esculenta*), green banana (*Musa paradisiaca x.*), banana, and sweet potato (*Ipomea batatas*) cultivation, begins mid November and remains the whole year
- Yam (*Dioscorea alata* y *D. trifida*) sowing time, starts in May and yields from December to March
- Maize (*Zea mays*) cultivation begins at the start of November and produces in February
- Fishing has two periods, from March to May and from mid October to mid November
- Hunting runs along the year as well as forest fruits harvesting

After setting up, each conuco produces for roughly 3 to 5 years alternating periods of cropping and gathering that rely on the family food demands. Depending on yields, a new conuco will be opened and old ones abandoned; therefore the indigenous production system states a sequential forest management system.

5.3.3.2. Commercial logging land use

Managers and technicians of forest companies, such as COMAFOR and Aserradero Hermanos Hernandez, were interviewed to get information about land use, social relationships, and other information they can provide from the commercial timber concessions beginning. Six logging concessions are placed in central Imataca, although currently two of them (Inproforca and Coforgua) are inactive because of legal constrains. The others are working on their management plans; the map 4 shows the logging companies located in Central Imataca.

Commercial forestry land use follows the "concession" scheme, which means that commercial forestry companies get rights of forest exploitation through contracts with the Venezuelan State. Hence, companies must fulfil financial, administrative and technical commitments, aimed at achieving sustained yield from the forest, through management plans; which are based on selective logging principles. Therefore, only "commercial" tree species and individuals up to 30 centimetres in diameter are allowed to be cut down. It entails all technical features about silvicultural treatments, road networks, logging, and transportation operations.

Commercial forestry production is supposed to begin yearly according to official permission, the activities are:

- Wood harvesting, every last quarter from December to March
- Log dragging, from mid September to May
- New secondary roads construction, from September to May
- Commercial inventory of the new compartment to be exploited next year, from May to August
- Maintenance tasks on main roads, from October to mid December
- Wood delivery to industry processing, over the whole year
- Seed sowing in breeding ground, from March to May
- Seedling trans-planting from breeding ground to the forest, from mid June to August
- Maintenance tasks on established research and silvicultural projects, from September to November

The following economic calendar describes the activities throughout the year:

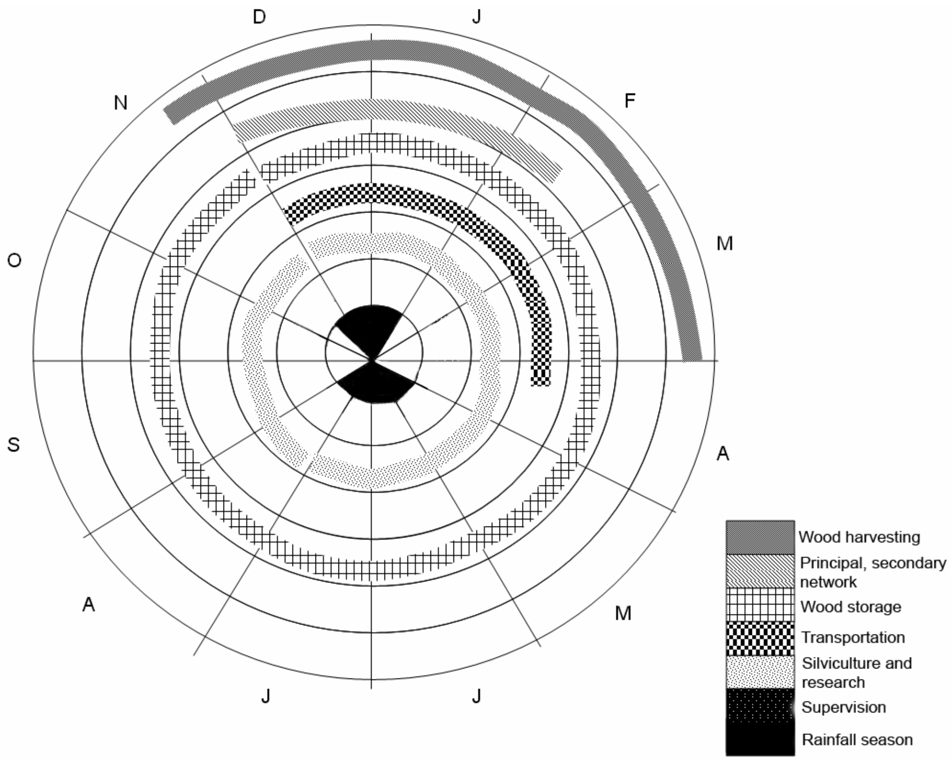
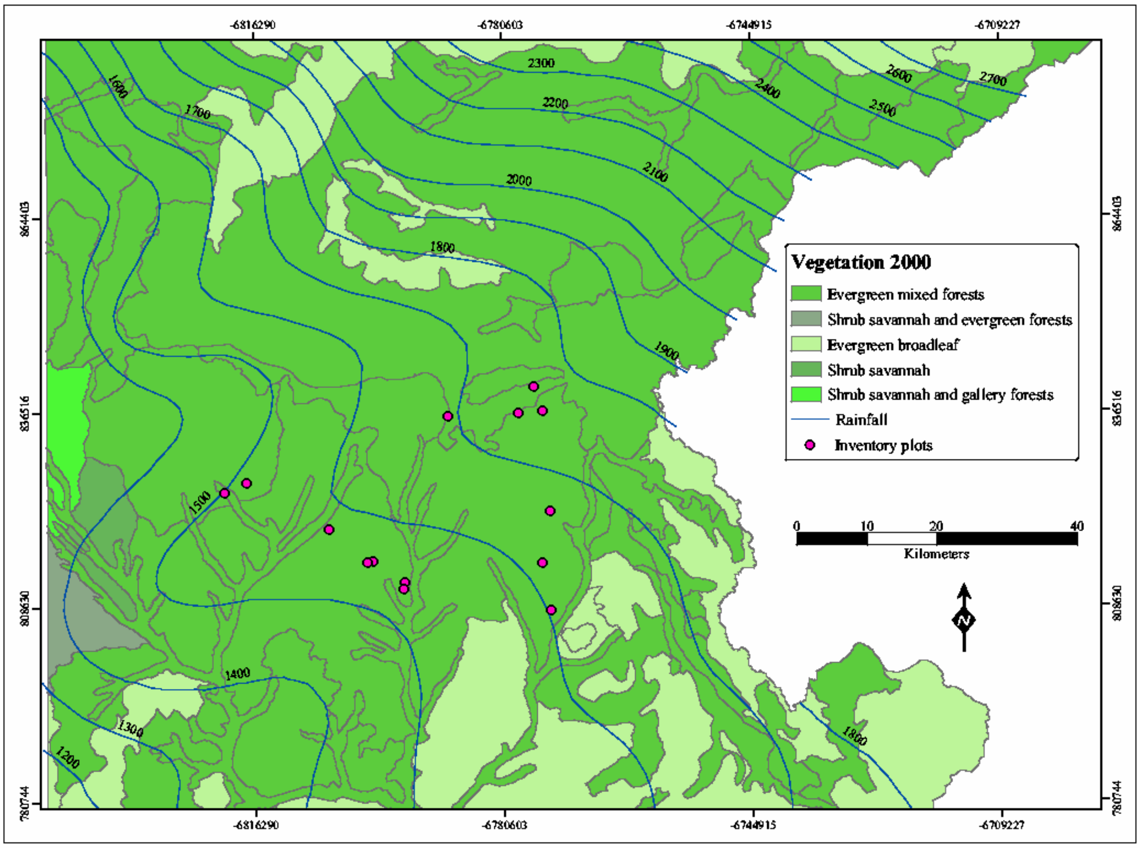


Figure 4. Economics calendar of commercial forestry production activities

In central Imataca 16 areas related to forest service were sampled, they are temporal log storage, machinery workshop, and workers camp, distances between log landings around 400 m. relying on the road network stated in the management plan. Annex 2 contents location of such areas.

6. A floristic approach to evaluating tropical rain forest degradation

The evaluation of tropical rain forests degradation on a local level was based on differences between tree communities with regard to floristic composition and structure. We selected samples from undisturbed and disturbed forests plots, distributed across areas of both commercial logging and indigenous shifting cultivation. Information about richness, abundance, dominance, frequency and vertical structure within communities was collected. Indices of species diversity, ecological importance, and communities' structural complexity were also calculated. Statistical analysis was performed to detect main variables that explain the variability between studied forests. As an indicator of aboveground biomass the content of basal area per plot was used. This allowed a classification of forests types. Since the normalized difference vegetation index (NDVI) represents an estimation of the aboveground biomass content (from satellite measurements) we explored correlations between both variables. The predictive capacity of the NDVI in the study area was tested as well. Map 14 shows vegetation formations updated to 2002 and the location of inventory plots.



Map 14. Vegetation Types (2002) and Inventory Plots in the Study Area

The statistical distribution of the data was tested using variance analysis (ANOVA). As the outcome indicates a non-normal distribution, cluster analysis was performed aiming at exploring the similarity between all sample plots with respect to their basal area (estimator of aboveground biomass). This step did not take into account the forest condition (undisturbed or disturbed) instead plots were grouped at random. The resulting groups showed no significant similarity in patterns.

Further processing consisted again in cluster analysis. This time, it was run separately for the two forest condition classes represented by both forests groups, 25 undisturbed and 16 disturbed plots. Similarities within the group were measured based on basal area.

Table 10. Forest Communities Features

Features	Overall	Undisturbed	Disturbed
Number of plots	41	25	16
Families	40	38	37
Genera	92	84	75
Species richness	122	104	93
Abundance (N)	1732	1101	631
Basal area average (m^2 / ha)	22.1 ± 8.86	24.36 ± 1	18.5 ± 5.2
Height average (m)	15.2 ± 4.46	15.1 ± 4.38	15 ± 4.67

Source: inventory data 2002

Table 10 shows information from the inventory which formed the basis of all further analysis that aimed at detecting significant differences as a consequence of the two different land use types.

6.1. Cluster analysis of forest types

Since tropical rainforest bears natural and human disturbance regime, changes from natural condition occur although their direction and magnitude are unknown, then grouping around key variables can help to detect such changes.

Cluster analysis between plots on each condition (undisturbed and disturbed) was carried out in order to examine the similarity in terms of biomass content through basal area as estimator. Forest types per plots regarding disturbance condition, 25 undisturbed and 16 disturbed were analysed.

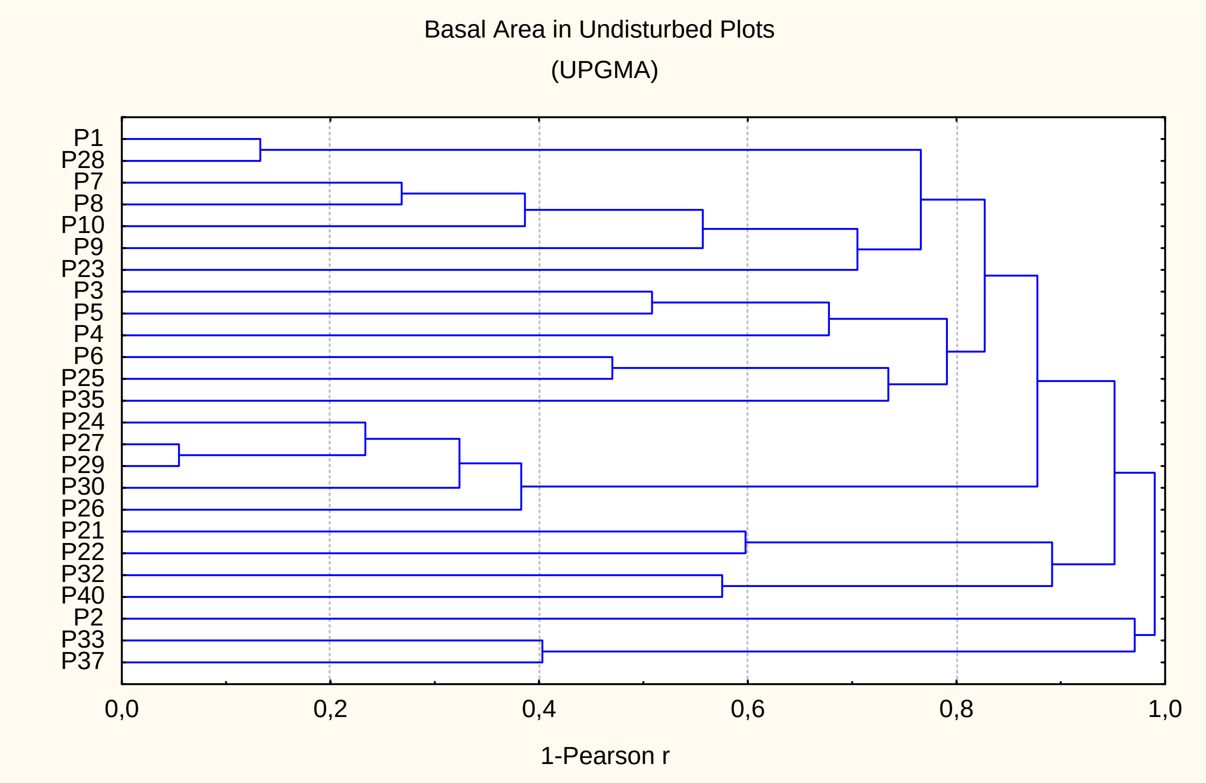


Figure 5: Basal Area Clusters in Undisturbed Plots

The dendrogram in Figure 7 draws out eight (8) clusters of 21 plots. Four plots were set aside from the analysis. Clusters contain roughly similar forest communities.

Table 11. Forest Types in Undisturbed Forests.

Forest types	I	II	III	IV	V	VI	VII	VIII
Plot N°	**1**	**7**	**3**	**6**	**24**	**21**	**32**	**33**
	28	**8**	**5**	**25**	**26**	**22**	**40**	**37**
		9			**27**			
		10			**29**			
					30			

Source: inventory data (2002)

The clustering procedure allowed an identification of eight (8) forest types, each constituted by different plots, distributed as indicated in Table 11 Forest types I, IV, VII, and VIII are constituted by spatially discontinuous plots, while the remaining forest types are represented by plots that are located contiguously.

In a subsequent step, 16 disturbed plots were clustered as shown in the dendrogram in Figure 8. These 16 plots form three (3) clusters containing eight plots (8) in total. The remaining eight (8) plots could not be grouped in a meaningful way; hence they were set aside from the analysis.

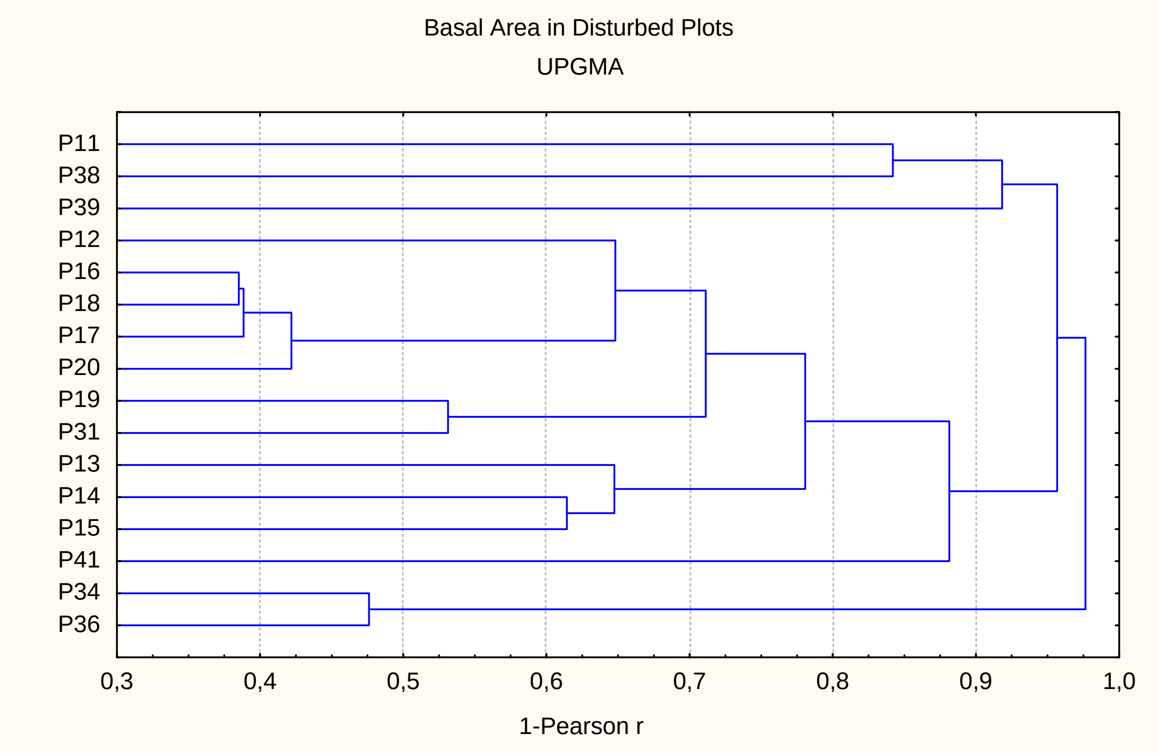


Figure 6. Basal Area Clusters in Disturbed Plots

Table 12 shows the cluster composition of the plots in disturbed forests Plots grouped in types I and II are located close to each other, whilst type III contains plots 34 and 36 which are located roughly 50 km away from each other.

Table 12. Forest Types in Disturbed Forests

Forest Types	**I**	**II**	**III**
Plots	16	19	34
	17	31	36
	18		
	20		

Source: inventory data (2002)

During the clustering procedure, 12 plots (29% of the original data) had been excluded from the analysis. This implies they had low correlation coefficient (Pearson) values and consequently a low similarity with regard to their basal area. This observation reflects that land cover in the study area is a mosaic of forest types varying according to the basal area and other not sampled variables, therefore the likely high natural heterogeneity is represented here only partially.

6.2. Floristic inventory

The survey covered 4,1 hectares distributed (a) along the Tumeremo - Bochinche road where most of the indigenous communities are located, and (b) in forest road networks in commercial forest concession areas. General floristic data of the total sample of 41 plots is shown in Table 13.

Table 13. Flora Inventory

Characteristics	**Undisturbed Plots**	**Disturbed Plots**	**Total Forest inventory**
Families represented	39	36	40
Shared families	35	35	
Non shared families	4	1	
Genera represented	83	75	92
Shared genera	66	66	
Non shared genera	17	9	
Genera absent	9	17	
Number of species	104	93	122
Shared species	75	75	
Non Shared species	29	18	
Species absent	18	29	

Source: inventory data (2002)

The data indicates the presence of 40 botanical families, 92 genera, and 122 species in 41 sampled plots. Table 13 also draws that undisturbed forests were home to specimens of 29 forest species that could not be found in disturbed forests, while disturbed forest featured 18 species which could not be found in undisturbed forests. Accordingly, natural forest communities hold around 25% more trees species than disturbed ones.

As data was gathered along spatially distant transects representing the forests conditions under analysis, we plotted three species accumulation curves, to visualise tendencies. Figure 7 shows the curves resulting from forests sampling transects. These transect were 500 meters long and 20 meters wide, and were each divided into ten sub-plots of 0.1

hectare. The Y-axis has a logarithmic scale in order to represent the curve's trend. The curves fit those reported for evergreen lowland forests in northern South America (Lamprecht, 1993).

An empirical curve is expected to show species accumulation increments with the number of individuals until they reach a plateau (Gore and Paranjpe, 2001). This development can be observed in Figure 7. Despite of the curves representing forest conditions that involve different species richness and abundances, they show similar tendency and fit linear equations reaching correlations coefficients higher than 0.9 in all cases.

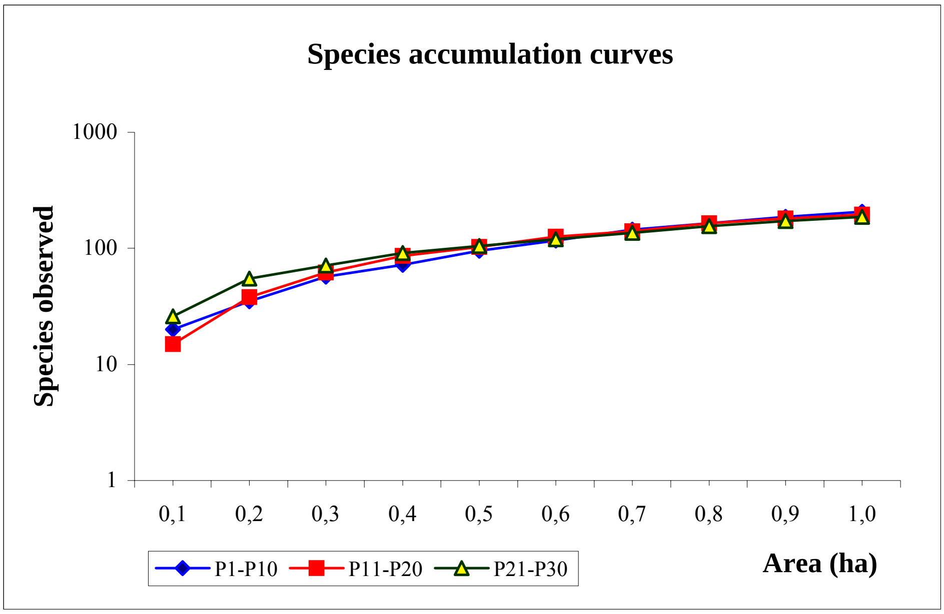


Figure 7. Transects of one hectare along undisturbed (P1-10 and P21-30) and disturbed (P11-20) forests

6.3. Floristic composition

In order to report the floristic composition of the forest communities, we had the support of the Orinoco Botanical Garden's Curator, and also of two taxonomists specialized in Imataca's flora, whose made the identification.

The family Mimosaceae was the most diverse group with 11 species, followed by the Fabaceae (7), Lecythidaceae (7), Caesalpiniaceae (5), Euphorbiaceae (5), Sapotaceae (5), Meliaceae (4), Sapindaceae (3), Burseraceae (3), Anacardiaceae (2), Sterculaceae (2), Chrysobalanaceae (2), among others (Annex 3). Of the 40 families found in the area, 35 are present in all plots; as well 66 genera and 75 tree species are shared by all plots. On the other hand, 26 tree species can be considered rare because they could only be found in one plot. Richness of tree species varies from 6 to 29 species per tenth hectare plot, while abundance ranges between 17 and 62 individuals per plot.

As a main concern this research seeks to detect differences between undisturbed and disturbed forests. Hence, woody species reported in undisturbed plots but absent in disturbed plots were grouped, as well as species found solely in disturbed forest. Likewise, woods specific weight, an important physical property regarding differential species growth, was included as a feature. After disturbance 27 species representing 22% of the original composition of woody species are missing as seen in Annex 4. Of these, 17 can be considered hardwood species (groups 3, 4 and 5). Six species belong to the softwood groups (1 and 2). According to Serrano (2002) in central Imataca around 50-60 % of forest biomass consisted of middle softwood to very hard wood. New species after disturbance include 9 hardwood and 7 softwood species, see the Annex 5. The latter observation suggests stands of different successional steps, forest heterogeneity, or low sampling data.

6.3.1. Abundance

A total amount of 1733 tree individuals up to 10 cm of diameter at breast height (dbh) were recorded, on average 425 trees per hectare. The most abundant specie was Alexa imperatricis (Fabaceae) with 115 individuals, followed by Eschweilera subgladulosa (Lecythidaceae), Carapa guianensis (Meliaceae) and Talisia guinensis (Sapindaceae).
Species abundance curves plot the relative abundance to the rank of “n” species from 1 (most abundant species) to n (most rare species). The communities of plants tend to contain few dominant species and many species that are relatively uncommon. Communities thus tend to be quite different from another (Krebs, 1989). The relationship between the number of species and the number of individuals tends to fit an exponential model. This is indicated for each group of forest plots (undisturbed and disturbed) in Figures 8 and 9, where each curve fits an exponential equation. Correlations coefficient grew up to 0.9 and high significance ($p<0.05$).

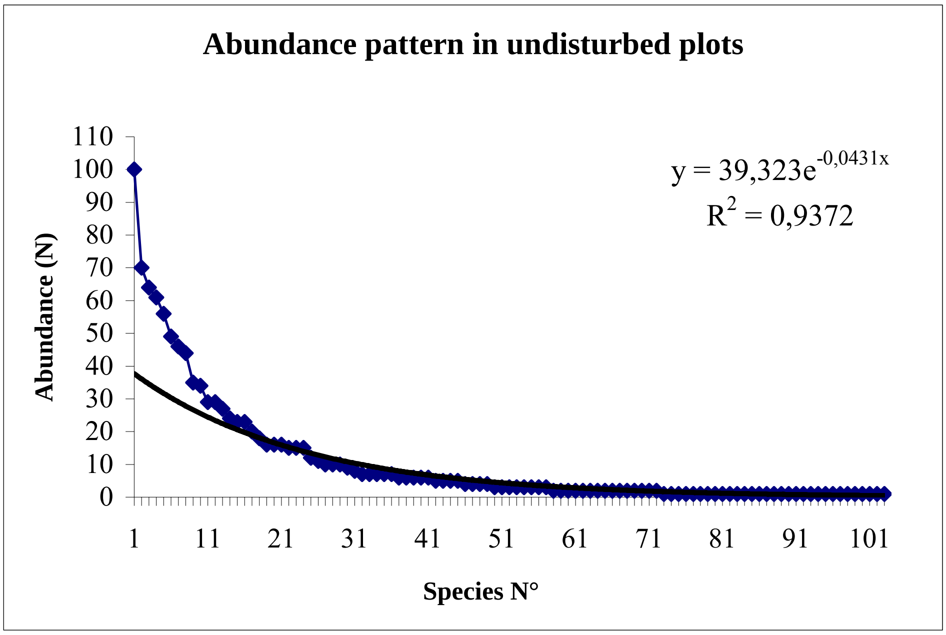


Figure 8. Species Abundance in 25 Plots of Undisturbed Forest

Figure 8 shows the abundance with regard to forest communities in undisturbed plots; they were assumed to represent the natural relative abundance. Twenty five (25) forest plots were assessed, and 1101 individuals of 103 species were found. The abundance pattern of undisturbed forest shows that 30% (31 species) of the species are represented by only one (1) individual in the whole undisturbed area, while 2% are abundant species (>70 individuals).

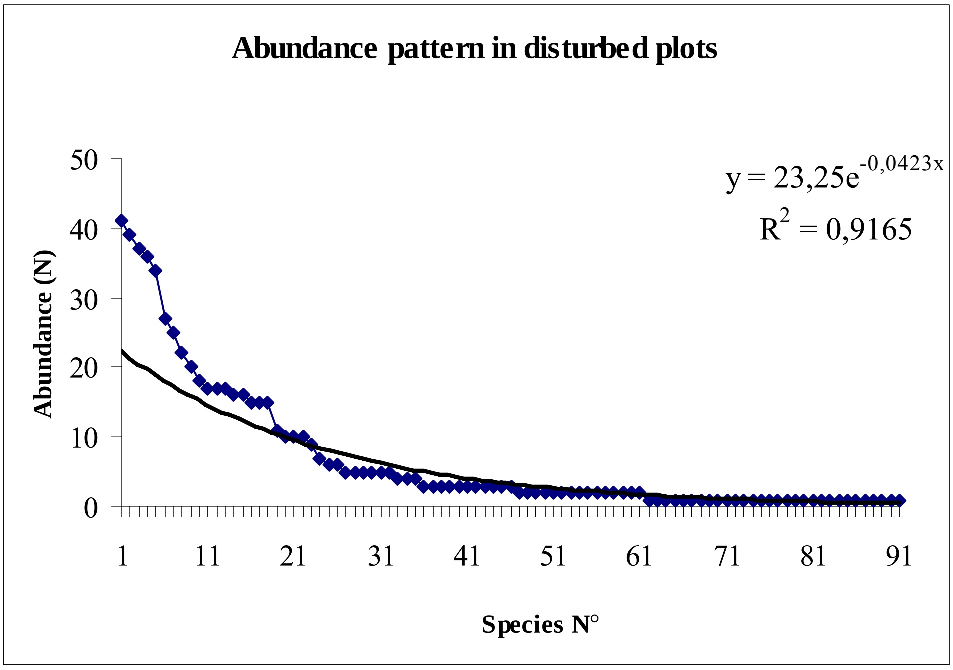


Figure 9. Species Abundance in 16 Plots of Disturbed Forest

Figure 9 shows the relative abundance of forest communities after logging or deforestation, in disturbed plots. Sixteen (16) plots were assessed and 631 individuals of 91 species found. Thirty two percent (29 species) of these species are represented by only one (1) individual found on these 16 plots, and 5% can be considered abundant species (>30 individuals). Disturbed plots have been affected by the reduction of both, common and rare species, even though proportionally the composition remains equal.
Evenness in disturbed plots tends to increase due to (i) the loss of rare species and (ii) the number of individuals diminishing. The distribution of data suggests that the decrease in rare species affects the community richness rather than abundance.

6.3.2. Frequency

Frequency refers to the number of plots where a certain species is present. This figure allows describing the spatial distribution of a species. A high relative frequency implies a rather homogeneous spatial distribution. Species of a high relative frequency tend to be similar to more abundant species (Cascante & Estrada, 2000).
In the study area, the relative frequency of woody species ranges between 0.13 – 3.7% across all plots. Only six species reach values above 3%, these include Eschweilera subglandulosa (Lecythidaceae), Protium neglectum (Burseraceae), Carapa guianensis (Meliaceae), Toulicia guinensis (Sapindaceae), Chrysothyllum auratum (Sapotaceae), Inga splendens (Mimosaceae). The remaining species show a variable relative frequency. Nevertheless 30% of the species are represented in only one plot, indicating a heterogeneous spatial pattern of forest composition.

6.3.3. Dominancy

Dominancy refers the taxonomic groups spatially more represented in the community expressed as basal area. Table 14 shows dominant species to forest types from cluster analysis. Families Anacardiaceae, Apocynaceae, Caesalpiniaceae, got more than 30% to one community; Meliaceae is dominant in three, and remaining community seems to be more heterogeneous.

Table 14. Floristic Relative Dominance in Forest Clusters Types

Cluster N°	Common Name	Species	Families	Dominance (%)
I-UD	Jobo	Spondias mombin	ANACARDIACEAE	43
	Clavellino	Pentaclethra macroloba	MIMOSACEAE	7
	Leche de cochino	Alexa imperatricis	FABACEAE	5
II-UD	Trompillo	Guarea grandiflora	MELIACEAE	14
	Guamo	Inga splendens	MIMOSACEAE	14
	Palma cucurito	Attalea maripa	ARECACEAE	10
III-UD	Guácimo	Guazuma ulmifolia	STERCULIACEAE	25
	Arahueque	Coccolaba sp	POLYGONCEAE	10
	Carapo blanco	Toulicia guinensis	SAPINDACEAE	9
IV-UD	Carapa	Carapa guianensis	MELIACEAE	37
	Hierrito	Licania densiflora	CHRYSOBALANACEAE	10
	Purguo	Manilkara bidentata	SAPOTACEAE	10
V-UD	Leche de cochino	Alexa imperatricis	FABACEAE	38
	Clavellino	Pentaclethra macroloba	MIMOSACEAE	9
	Guamo	Inga splendens	MIMOSACEAE	8
VI-UD	Purguillo	Pouteria egregia	SAPOTACEAE	16
	Hierrito	Licania densiflora	CHRYSOBALANACEAE	12
	Guatacare	Bourreria cumanensis	BORAGINACEAE	8
VII-UD	Canjilón amarillo	Aspidosperma marcgravianum	APOCYNACEAE	38
	Caramacate	Pirahea longepedunculata	EUPHORBIACEAE	25
	Caraño	Protium neglectum	BURSERACEAE	9
VIII-UD	Mora	Mora gongrijpii	CAESALPINIACEAE	33
	Baraman	Catostemma commune	BOMBACACCEAE	9
	Merecurillo	Pariani excelsa	CHRYSOBALANACEAE	8
1-D	Carapa	Carapa guianensis	MELIACEAE	27
	Caicareño	Clathrotropis brachypetala	FABACEAE	7
	Caraño	Protium neglectum	BURSERACEAE	5
2-D	Guamo colorado	Inga alba	MIMOSACEAE	15
	Carapo blanco	Toulicia guinensis	SAPINDACEAE	12
	Guácimo	Guazuma ulmifolia	STERCULIACEAE	12
3-D	Yagrumo	Cecropia sp.	MORACEAE	30
	Guamo morrocoyero	Inga heterophylla	MIMOSACEAE	16
	Cimaruba	Jacaranda copaia	BIGNONIACEAE	16

6.3.4. Floristic diversity

The concept of diversity joins the concepts of richness (number of species), abundance (number of individuals) and evenness (equitability). Diversity can be estimated using indices such as Shannon, Simpson, and others. Among them, the Shannon index is the most sensitive to changes of rare species in the community sample, while Simpson is most sensitive to changes of more abundant species (Krebs, 1989). Changes of diversity indicate impacts of disturbance on natural ecosystems. However the forest samples in this study generally show high diversity index values, leading to difficulties in detecting meaningful differences.

Tables 15 and 16 summarize values of species diversity per plot according to Shannon (H'), Shannon Evenness (E), Simpson (D), and Simpson's Evenness ($E_{1/D}$) Indices. Species diversity in sampling plots varies between 2.11 and 3.13 (Shannon H' Index); while the Simpson index ranges from 0.81 to 0.97. Evenness measured by Shannon varies between 0.79 and 0.96; and Simpson's Evenness ranges from 0.31 to 1.38. Major Alfa diversity values are highlighted in Tables 15 and 16. Most plots holding high index values remain under natural or undisturbed conditions.

Table 15. Alfa (α) Diversity Indices in Undisturbed Plots

Plot N	N° species	H' Shannon	Evenness Shannon	Simpson 1-D	Simpson 1/D	E 1/ D
1	20	2,75	0,92	0,94	17,37	0,87
P2	15	2,47	0,91	0,92	12,47	0,83
P3	22	2,77	0,9	0,93	15,07	0,68
P4	15	2,46	0,91	0,92	13,10	0,87
P5	23	2,94	0,94	0,96	24,15	1,05
P6	22	2,7	0,87	0,92	12,48	0,57
P7	28	3,12	0,94	0,97	29,57	1,06
P8	19	2,7	0,92	0,94	17,08	0,90
P9	22	2,94	0,95	0,96	27,04	1,23
P10	20	2,8	0,93	0,95	19,90	1,00
P21	26	3	0,92	0,95	21,69	0,83
P22	29	3,13	0,93	0,96	25,54	0,88
P23	16	2,24	0,81	0,85	6,68	0,42
P24	20	2,54	0,85	0,89	8,88	0,44
P25	14	2,25	0,85	0,88	8,53	0,61
P26	15	2,43	0,9	0,92	11,95	0,80
P27	16	2,2	0,79	0,83	5,97	0,37
P28	19	2,56	0,87	0,91	11,34	0,60
P29	17	2,14	0,76	0,81	5,20	0,31
P30	14	2,11	0,8	0,84	6,18	0,44
P32	19	2,6	0,88	0,92	12,00	0,63
P33	25	2,79	0,87	0,92	11,89	0,48
P35	25	3,05	0,96	0,97	34,44	1,38
P37	15	2,48	0,91	0,93	13,54	0,90
P40	13	2,22	0,87	0,88	8,41	0,65

Source: inventory data (2002)

Table 15 indicates two combinations of indices values. One features, as expected, rather high richness values combined with relatively low evenness figures, indicating communities composed by more rare species than common ones or vice versa. P21 and P22 (all in blue) are examples of this category. In contrast, some communities feature both high species richness and high evenness as can be seen in plots P7, P35, P5, and P9 (in orange).

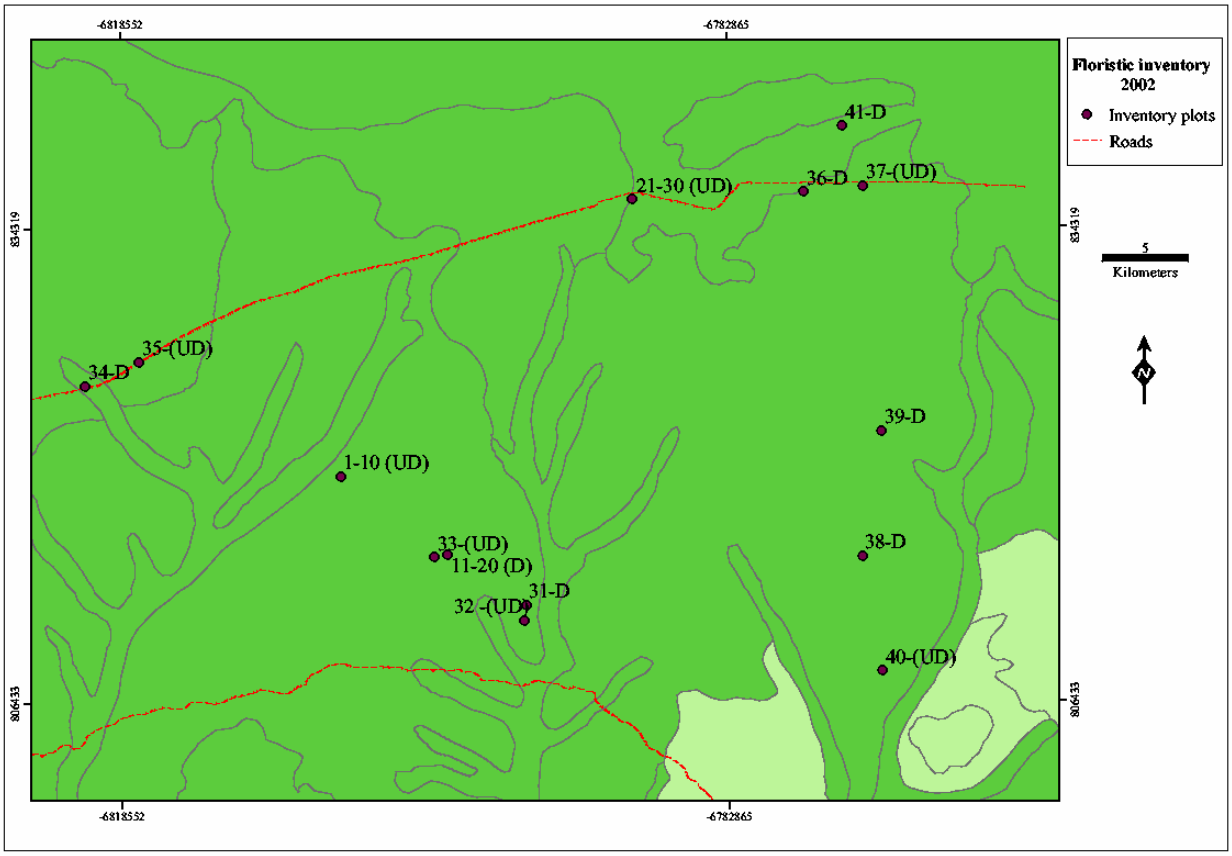
Table 16. Alfa (α) Diversity Indices in Disturbed Plots

Plot N°	**# species**	**H' Shannon**	**Shannon Evenness**	**1-D Simpson**	**1/D Simpson**	**E (1/D)**
P11	15	2,24	0,83	0,86	7,08	0,47
P12	23	2,86	0,91	0,94	17,55	0,76
P13	24	2,95	0,93	0,96	22,16	0,92
P14	24	2,92	0,92	0,95	19,95	0,83
P15	17	2,63	0,93	0,94	17,89	1,05
P16	23	2,87	0,92	0,95	19,30	0,84
P17	14	2,56	0,97	0,97	34,00	2,43
P18	24	2,78	0,87	0,93	13,78	0,57
P19	17	2,65	0,94	0,94	17,53	1,03
P20	14	2,34	0,89	0,91	10,57	0,75
P31	17	2,73	0,96	0,96	24,47	1,44
P34	6	1,58	0,88	0,79	4,72	0,79
P36	10	1,71	0,74	0,78	4,46	0,45
P38	15	2,3	0,85	0,88	8,29	0,55
P39	23	2,81	0,9	0,93	14,96	0,65
P41	19	2,79	0,95	0,96	24,00	1,26

Source: inventory data (2002)

Table 16 summarizes data on disturbed plots. Five plots have a relatively high number of species, more diversity and less evenness than the whole plots set as in the cases of P12, P13, P14, P16, and P18. On the other hand, the values shown by P17 and P41 imply less species but again relative high richness and high evenness. The last observation can be considered evidence of an unexpected outcome in logged forests that remain diverse and do not show any effects of disturbance.

Beta diversity (β) was calculated by comparing species composition and abundance data across sampling plots. Firstly, two transects of one hectare into undisturbed plots were examined, and subsequently, independent plots of one-tenth hectare each were spread across the sampling area. Indices use presence/absence data or species abundance data, respectively. Differences were measured between plots of the same forest type (UD: undisturbed or D: disturbed) located as far as possible from each other, and testing areas of interest namely into and nearby logging concessions and indigenous settlements as shown in map 15.



Map 15. Plots of Sampling used to β-Diversity Calculation

Table 17 indicates the location of plots in forest associations which are mixed with regard to cover canopy densities and geomorphologic features. Five vegetation types were sampled and examined to get β-diversity estimations based on comparisons of index values per plot.

Table 17. Location of Sampling Plots

Plots	Condition	Vegetation types
P (1-10)	UD	**B 4/7-1Pe**: evergreen mixed forest over plain relief
P (11-20)	D	Idem
P (31)	D	Idem
P (32)	UD	Idem
P (33)	UD	Idem
P (21-30)	UD	**B4/7-2Lo**: evergreen mixed forest over land hills
P (41)	D	Idem
P (36)	D	**B 4/2-1Pe**: evergreen mixed forest over plain relief
P (37)	UD	Idem
P (38)	D	Idem
P (39)	D	Idem
P (40)	UD	Idem
P (34)	D	**B 2/4-2Va**: evergreen mixed forest over valley
P (35)	UD	**B 2/8-1Pe**: evergreen mixed forest over plain relief

Table 18 shows the results for three indices. The P37 got high indices values compared to P32, P33 and P40. It is thus worth noting that distances between plots amount to up to 30 km. It should also be noted that the sampling of the plots situated in the East revealed a different floristic composition since these plots are stretched along the hilly lands along the border between Venezuela-Guyana. Within the sample of disturbed forests P34 got the highest β diversity because its dissimilarity to P38 and P41, which suggests a wide heterogeneity of forest mosaic.

From cluster analysis we got pairs of similar biomass content, which were compared with regard to β-diversity. For P32-P40 and P33-P37 we identified high beta diversity values according to Whittaker and Sorensen, but low ones according to the Morisita-Horn measure. This could mean that differences in sample size and abundance can be affecting Whittaker and Sorensen, and that the Morisita-Horn estimation is more reliable.

Table 18. Beta (β) Diversity Values

Undisturbed plots / Measure	**37-40**	**35-37**	**33-40**	**35-33**	**32-37**	**33-37**	**32-40**	**1-10/ 21-30**
β Whittaker (presence/absence data)	0,86	0,75	0,74	0,56	0,647	0,8	0,7	0,42
1- Sorenson (abundance data)	0,85	0,79	0,78	0,7	0,81	0,71	0,73	0,42
1- Morisita-Horn (abundance data)	0,84	0,80	0,78	0,76	0,88	0,39	0,65	0,42

Disturbed plots / Measure	38-41	34-36	34-41	34-38	31-41
β Whittaker (presence/absence data)	0,59	0,635	0,84	0,819	0,78
1- Sorenson (abundance data)	0,65	0,55	0,88	0,95	0,84
1- Morisita-Horn (abundance data)	0,49	0,37	0,82	0,94	0,84

Source: ground data (2002)

6.3.5. Importance Value Index (IVI)

The Importance Value Index (IVI) represents an evaluation of the ecological position that an individual species occupies in a forest community. The IVI reports a quantitative ranking of species from higher to lower importance status. Tables 19 and 20 show the IVI results in undisturbed and disturbed forests that can help to assess dominance among tree species and to compare types of forests.

Table 19. Importance Value Index in Undisturbed Forests

UNDISTURBED **Common name**	**Specie**	**Family**	**IVI**
Leche de cochino	*Alexa imperatricis*	FABACEAE	21,35
Carapa	*Carapa guianensis*	MELIACEAE	17,20
Carapo blanco	*Talisia guinensis*	SAPINDACEAE	12,67
Hierrito	*Licania densiflora*	CHRYSOBALANACEAE	12,27
Guamo	*Inga splendens*	MIMOSACEAE	12,07
Majaguillo	*Eschweilera subgladulosa*	LECYTHIDACEAE	11,36
Caraño	*Tetragastris panamensis*	BURSERACEAE	11,06
Clavellino	*Pentaclethra macroloba*	MIMOSACEAE	10,56
Canjilón amarillo	*Aspidosperma marcgravianum*	APOCYNACEAE	9,90
Arahueque	*Coccolaba sp*	POLYGONCEAE	8,70

Source: inventory data (2002)

Table 20. Importance Value Index in Disturbed Forests

DISTURBED **Common name**	**Specie**	**Family**	**IVI**
Carapa	*Carapa guianensis*	MELIACEAE	31,98
Yagrumo	*Cecropia putata*	MORACEAE	20,56
Clavellino	*Pentaclethra macroloba*	MIMOSACEAE	15,08
Caicareño	*Clathrotropis brachypetala*	FABACEAE	13,42
Caimito	*Chrysothyllum argeteum*	SAPOTACEAE	12,68
Guamo colorado	*Inga alba*	MIMOSACEAE	12,37
Carapo blanco	*Toulicia guinensis*	SAPINDACEAE	11,43
Guamo morrocoyero	*Inga heterophylla*	MIMOSACEAE	11,10
Caraño	*Tetragastris panamensis*	BURSERACEAE	10,86
Alatrique	*Cordia fallex*	BORAGINACEAE	10,29

Source: inventory data (2002)

IVI values are low in undisturbed forests and go along with relatively high number of species; while in disturbed forests IVI values increase which indicates that certain species become dominant and, at the same time, the number of species diminishes. Figure 10 illustrates these relationships between forest types. Whilst there are combinations that can be found in both forest types, the extreme ends are only represented by either disturbed (high IVI, low species number) or undisturbed forests (low IVI, high species numbers).

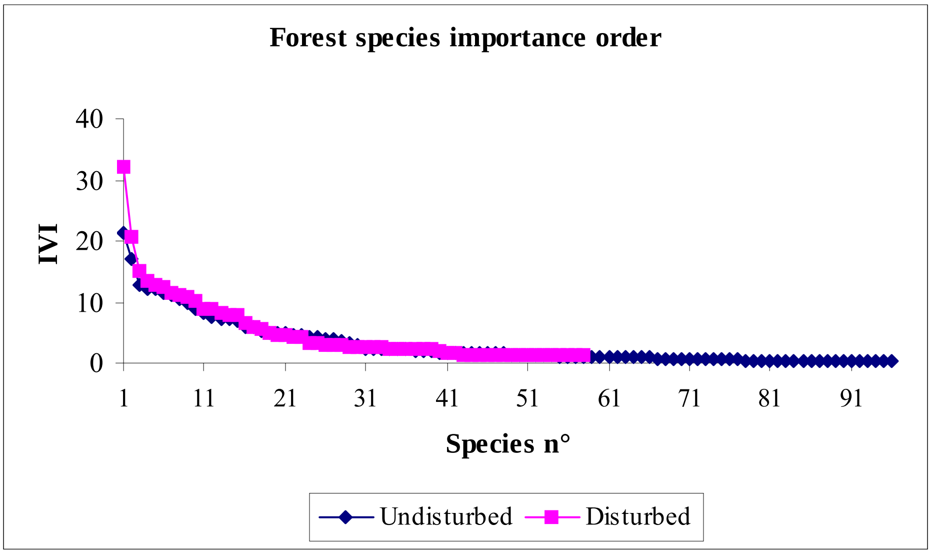


Figure 10. Forest Species Importance Order

6.3.6. Forests physiognomy

Forest stands physiognomy show two layers roughly defined by their height. The upper layer height ranges between 17 and 30 meters. Species present in this level are *Pariani excelsa* (Chrysobalanaceae), *Catosteainia comune* (Bombacacceae), *Cupania americana* (Sapindaceae), *Jacaranda copaia* (Bignoniaceae), *Spondias mombin* (Anacardiaceae), *Cedrela odorata* (Meliaceae), and others.

The layer below stretches between 10 and 17 m. Species present in this level are *Parkia pendula* (Mimosaceae), *Irga heterophylla* (Mimosaceae), *Eschweilera gratta* (Lecythidaceae), *Vitex capitata* (Verbenaceae), *Cordia fallex* (Boraginaceae), and others.

Few trees are less than 10 m tall and do not have sufficient spatial continuity to shape a layer.

The Holdridge complexity index (C_{HCI}) (Holdridge et al.,1971) allows an estimation of forest community physiognomy joining average values of tree features, such as height, basal area, density (number of tree per hectare), and species density (number of species per hectare).

Since not all trees fit the equation requirements, the distribution of height frequency must be calculated for each group type to obtain classes and to select the higher individuals as an input the C_{HCI} equation. Figures 11 and 12 show the height distribution of frequencies in groups.

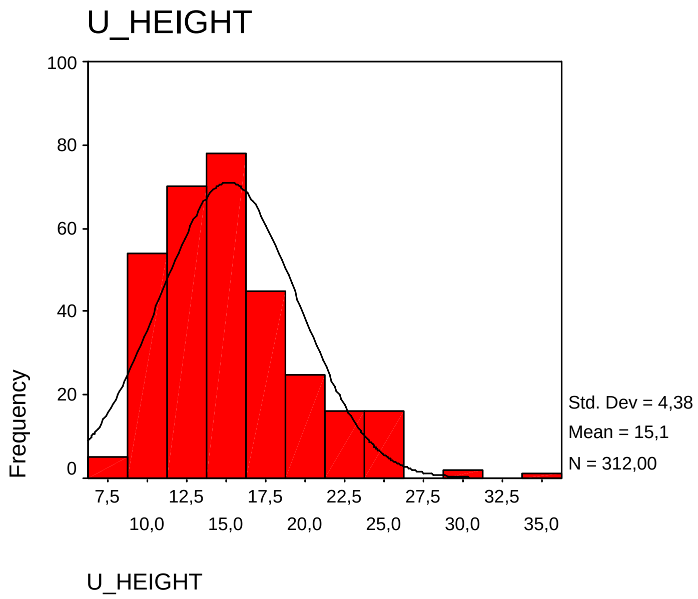


Figure 11. Height Frequency Distribution in Undisturbed Forests

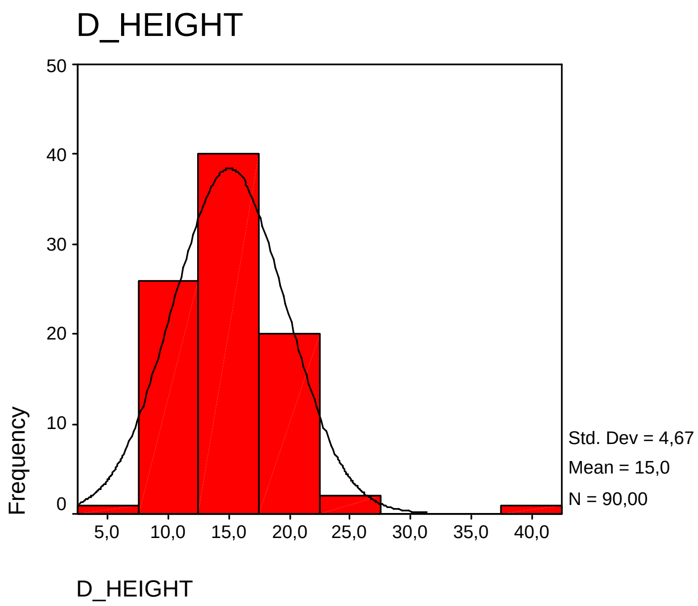


Figure 12. Height Frequency Distribution in Disturbed Forests

The Holdridge complexity index (C_{HCI}) was applied to compare vertical profiles of forest stands according to the forest condition. This is shown in Table 21, where undisturbed forests are grouped in eight clusters which are highly complex in structure, and disturbed forests are grouped in three less complex clusters.

Table 21. Structural Complexity Index (C_{HCI}) Values

Forest condition	Cluster n°	CHCI
Undisturbed	I	23,98
	II	37,40
	III	32,89
	IV	40,73
	V	33,96
	VI	55,00
	VII	116,16
	VIII	31,06
Disturbed	1	27,68
	2	8,81
	3	9,56

Source: inventory data (2002)

After calculating the indices new data is available, and along with the original data this enables us to carry out both univariate and multivariate analysis to explain the variability between the undisturbed and disturbed types of forest.

Statistic techniques applied included the Kruskal-Wallis nonparametric analysis of variance, and Principal Component Analysis (PCA). To perform the statistical analyses we used the following variables: height, basal area, density, richness, complexity index, Shannon index, Evenness Shannon index, and Simpson index, values are tabulated in (Annex 6).

6.4. Principal Component Analysis

The principal component analysis (PCA) is a multivariate technique that allows the identification of patterns within the given variables with regard to their similarities and differences. Table 22 shows eigenvalues of the principal components identified among the analyzed variables and the percentage of variance across the plot sample explained by these factors. Component one (1) explains 46 % of the variance, component two (2)

29 %, and component three (3) 14%, thus the three major components explain about 90 % of the variance within the total sample of plots.

Table 22. Eigenvalues of the Principal Components

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.706	46.325	46.325	3.706	46.325	46.325
2	2.335	29.184	75.509	2.335	29.184	75.509
3	1.148	14.350	89.858	1.148	14.350	89.858
4	.383	4.785	94.644			
5	.245	3.063	97.707			
6	.141	1.766	99.473			
7	3.576E-02	.447	99.920			
8	6.374E-03	7.967E-02	100.000			

Extraction Method: Principal Component Analysis.

Table 23 summarizes the eigenvectors and allows identifying main variables within each component. The first one includes variables related to floristic diversity, the second one variable related to biomass, while the third component represents a structural feature.

Table 23. Eigenvectors

Component Matrix [a]

	Component		
	1	2	3
HEIGHT	.335	.130	.876
BASALA	.622	.642	.239
DENSITY	.387	.747	-.338
RIQEZA	.900	1.127E-02	-.322
Complexity	.811	.517	7.470E-02
SHANNON	.902	-.324	-.199
EVENNESS	.604	-.689	.237
SIMPSON	.641	-.708	-7,07E-02

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

The bi-dimensional representation (Figure 13) of components C1 and C2 does not suggest significant differences between undisturbed (ND) and disturbed (D) plots, even though disturbed plots seem to be biased toward the low diversity area. This analysis did not enable any samples grouping neither a clear tendency.

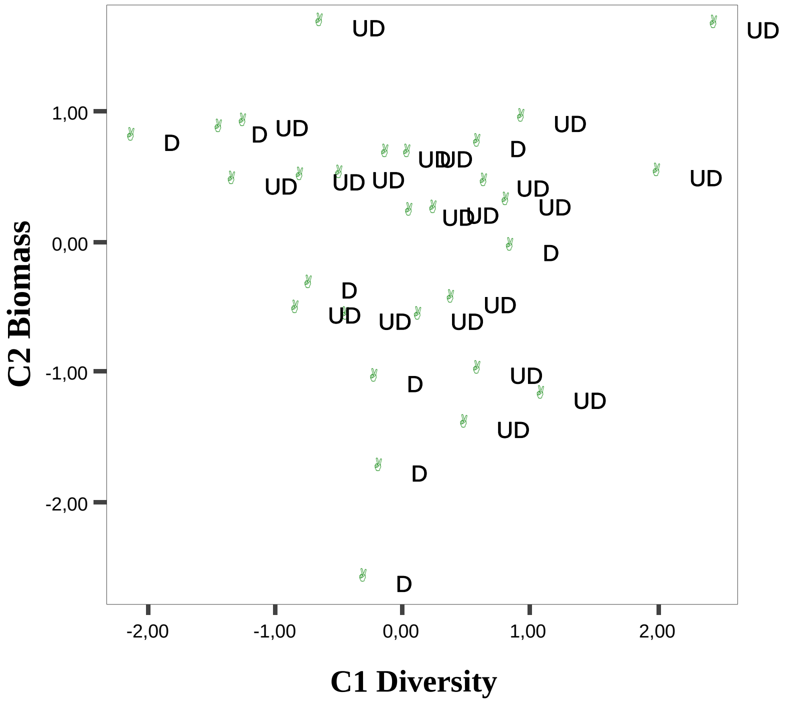


Figure13. Principal Component Analysis for undisturbed (UD) and disturbed (D) forest plots (C1 46% and C2 29% of variance)

The nonparametric analysis of variance using the Kruskal-Wallis test allowed identifying variables containing significant differences between forests conditions. The selected variables were basal area and the complexity index, which are represented in figures 14 and 15.

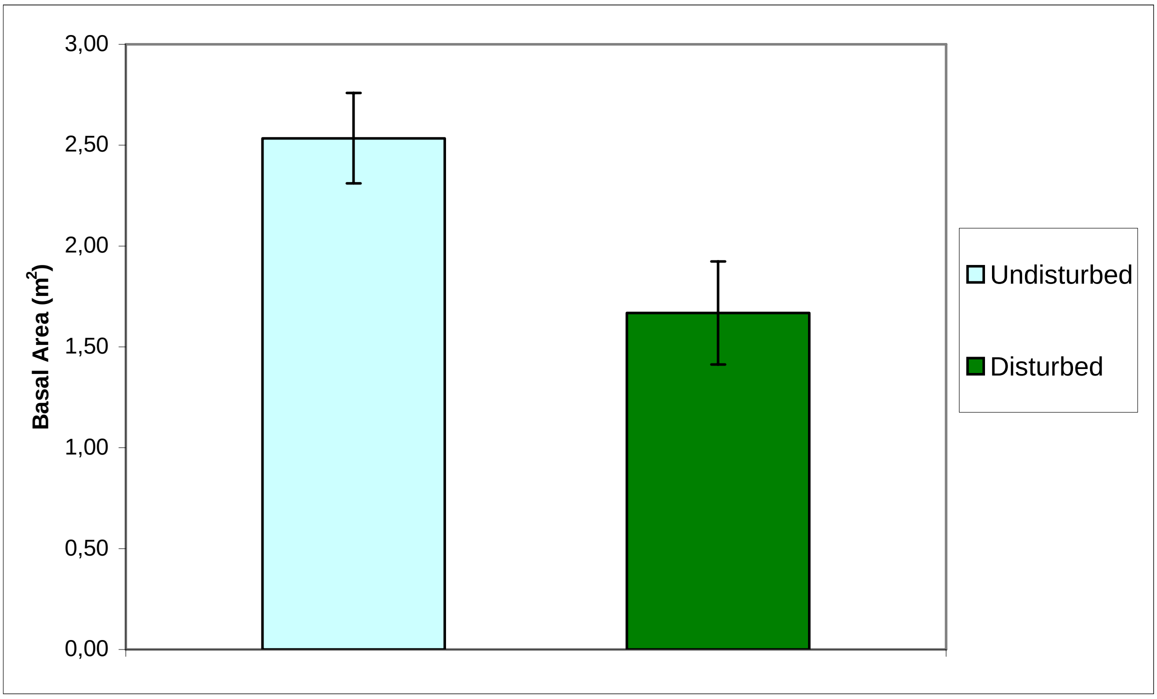


Figure14. Basal Area as significant variable to explain forest differences
Vertical lines on bars indicate the standard error

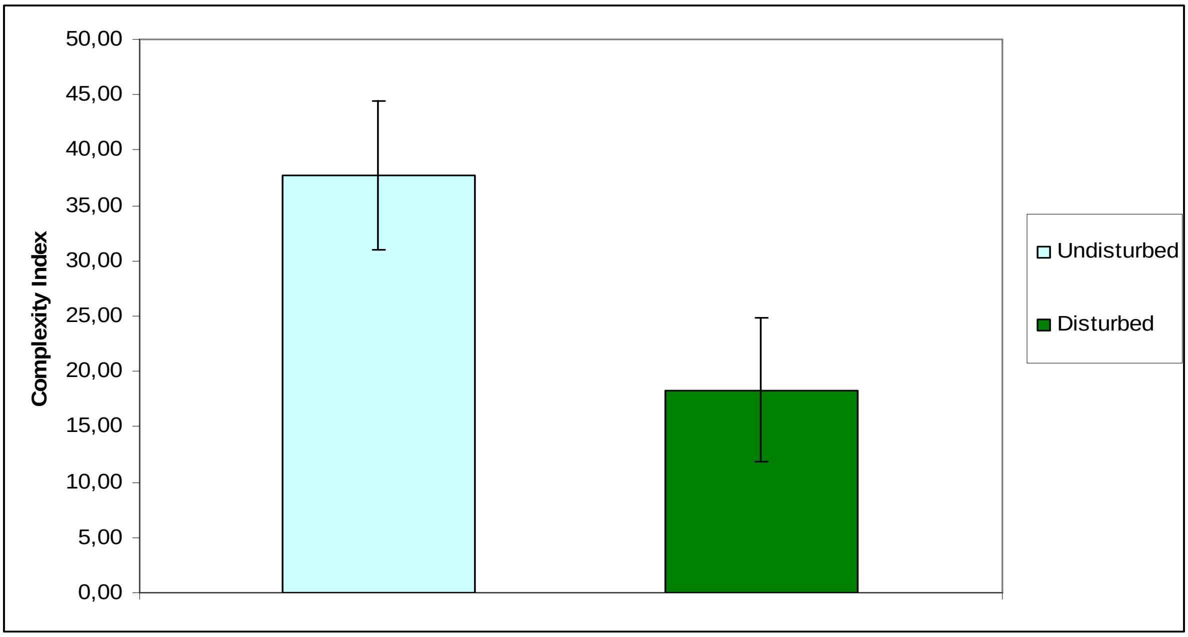
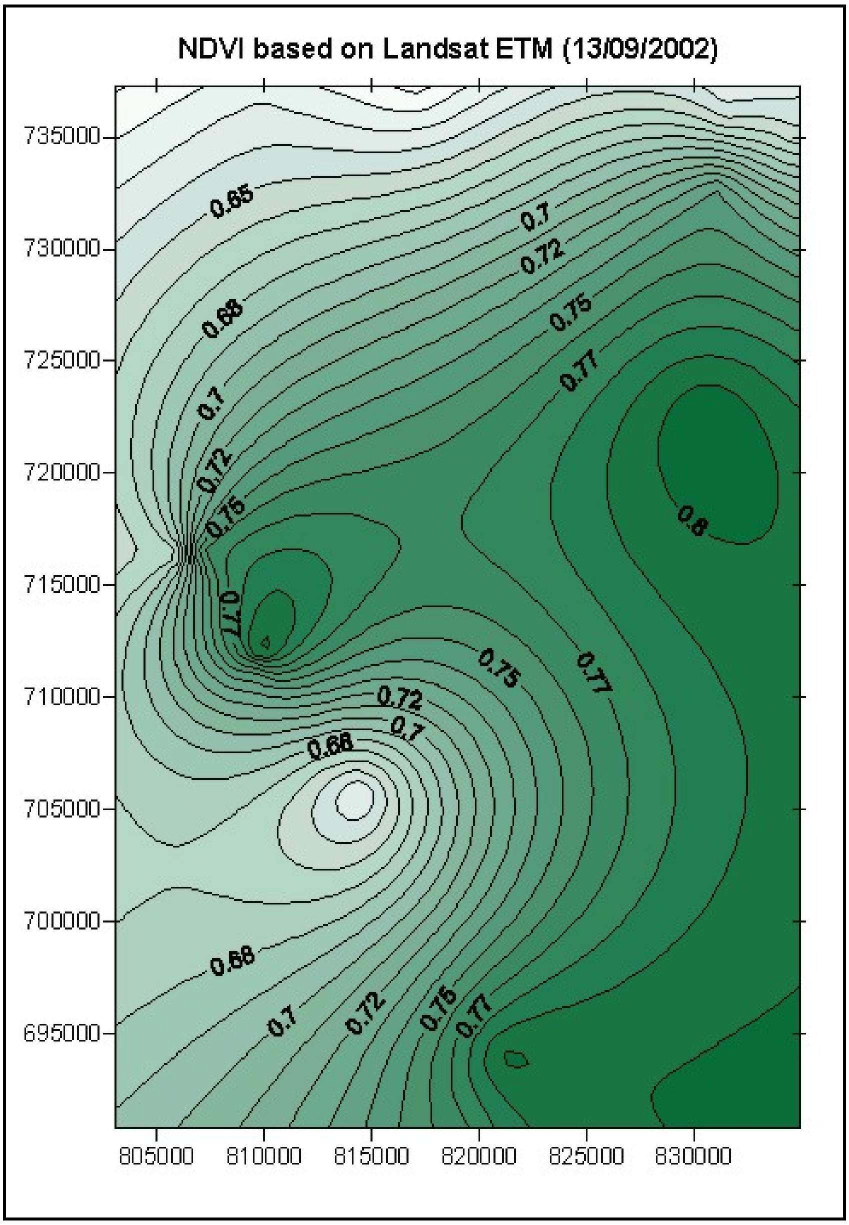


Figure15. Complexity index as significant variable to explain forest differences
Vertical lines on bars indicate the standard error

6.5. Linking data from remote sensing to data collected on the ground

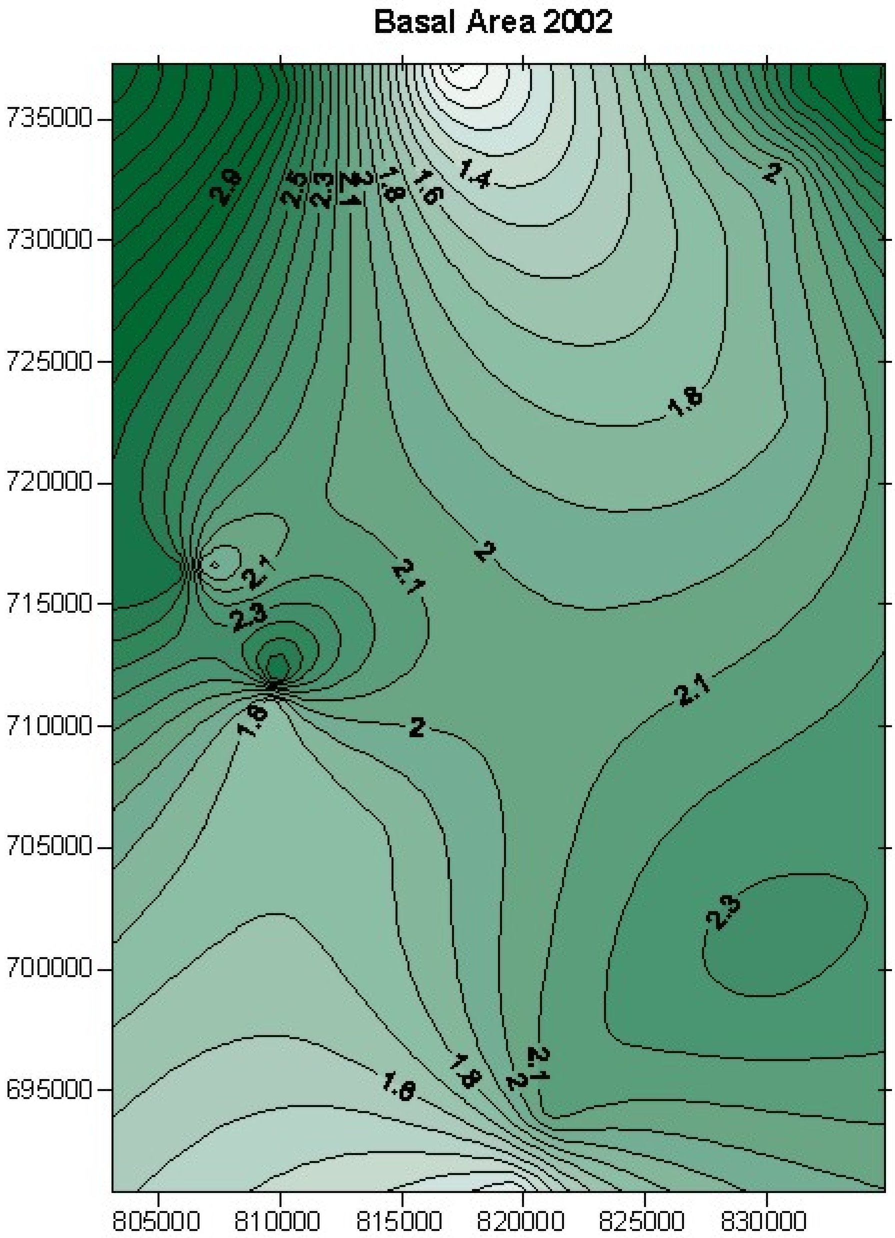
The spatial distribution of aboveground biomass in the study area was analysed by means of an interpolation of basal area values from two data sets: ground measurements in sampling plots, and averages of pixel values of the normalized difference vegetation index (NDVI) measured on Landsat ETM images. Maps 16 and 17 were created using the Kriging interpolation technique.

General NDVI patterns show descending values towards the north-western extreme, and increasing values on the East side, where belts spanning from the north east to the south east can be observed. The major concentration of high vegetation index values seems to be located around two nucleuses, one in the middle eastern and the other in the middle western extremes. Low index values core set up in the south-western area introducing a change of pattern.



Map 16. NDVI Calculated from Bands 3 and 4 of Landsat ETM Image (13/09/2002)

The distribution of basal area as calculated from ground data draws out high values in two northern areas located in the west and east where narrow belts shape a gradient from north to the middle, while a nucleus of low values arises in the northern centre. Another high value core appears in the south east, where gradual changes delineate a more homogeneous area.



Map 17. Basal Area (m^2/0.1 ha) Calculated from Ground Data Collection (October2002)

To illustrate the high variance of basal area (based on ground data) and NDVI (based on Landsat ETM) values, a histogram was drawn (Figure 16). It indicates that the NDVI stays almost constant while the basal area shows noticeable differences across sample plots. Table 24 contains the data for both variables that was used to draw the histogram. Correlations between basal area and NDVI were also computed but the outcome was statistically not significant ($P > 0.05$).

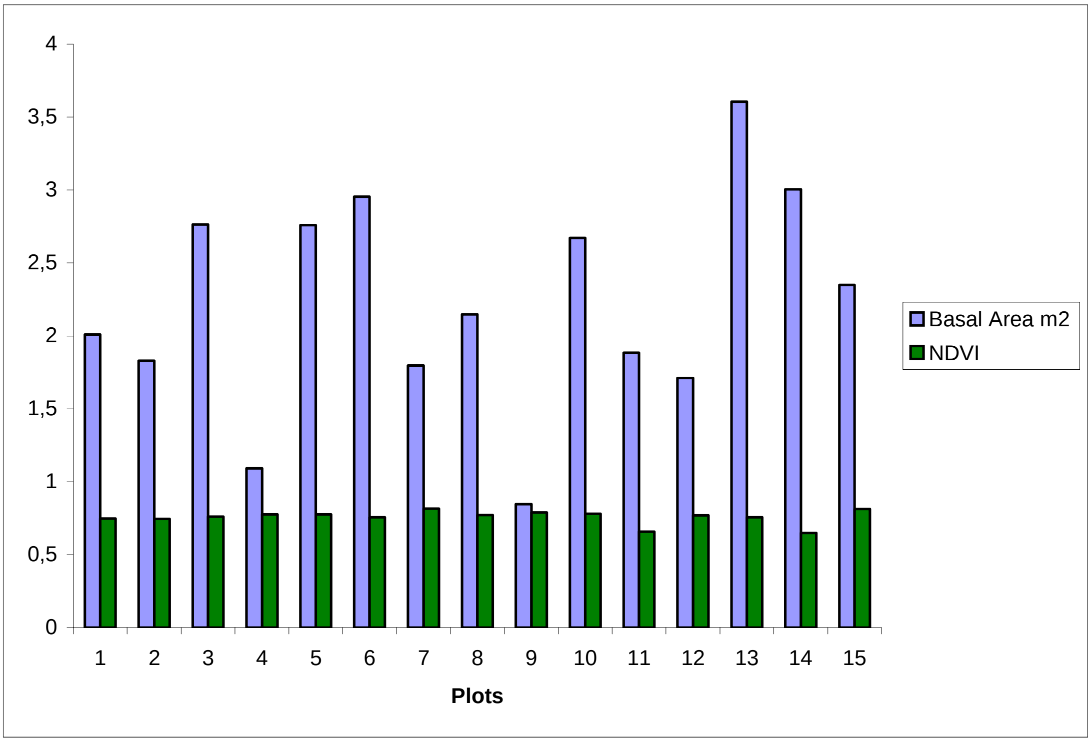


Figure 16. Basal Area and NDVI on Sampling Plots (2002)

Table 24. Basal Area and Vegetation Index (NDVI)

Name	BA_2002	NDVI 2002
P1	2,00879	0,74822
P2	1,83085	0,74478
P3	2,76347	0,76017
P4	1,09073	0,77642
P5	2,75843	0,77662
P6	2,95495	0,75682
P7	1,79797	0,81595
P8	2,14884	0,7715
P9	0,84573	0,78977
P10	2,67182	0,78103
P11	1,88558	0,65737
P12	1,71092	0,76975
P13	3,60468	0,75713
P14	3,00487	0,64837
P15	2,35	0,81303

Source: ground data (2002) and Landsat ETM (2002)

SECTION IV: DISCUSSION

7. The landscape focus and spatial patterns of indigenous agriculture and selective commercial logging of forests

Landscapes formed by tropical rain forests tend to be homogenous in appearance. As a consequence, interventions are not easy to detect, as the canopy continues to look intact in the sense that it maintains its three-dimensional appearance in spite of the disturbances. Moreover, visible evidence of landscape changes in forests tend to disappear after relatively short periods of time due to the favourable climatic conditions in the tropics, namely radiation and water availability, that stimulate the mechanisms of biological succession. Indeed, reported impacts on tropical forests in scientific publications regularly refer to deforestation, i.e. the permanent removal of vegetation layers.

The relatively high dynamics of the tropical atmosphere and the presence of clouds, haze, and other forms of vapour make a systematic observation of land cover difficult. For the study area e.g., only three Landsat images (Thematic Mapper and Enhanced Thematic Mapper) with a cloud cover of less than 30% within a period of twenty years were available. Auxiliary sources of information do not exist either, such as spectral libraries, i.e., data bases with measurement registers that serve as a reference when comparing data and calibrating models.

Depending on their intensity, signs of natural disturbances tend to disappear or to be covered after relatively short periods of time, whilst human activities of exploitation lead to more obvious alterations, and impacts on the forests themselves or soils tend to remain visible for much longer periods.

The spatial patterns analysed in this thesis refer to (i) traditional indigenous land use types such as shifting cultivation and the corresponding rotation of fallows and (ii) selective logging for commercial purposes based on concessions to forestry enterprises.

The indigenous people of Kariña are the traditional inhabitants of the central part of Imataca. They practice shifting cultivation whose spatial pattern consists of groups of deforested plots close to cultivated as well as to regenerating and fallow plots. These plots are grouped around a community or settlement, generally close to a road.

Figure 1 shows a satellite image that illustrates the spatial patterns of shifting cultivation and selective logging for commercial purposes. Indigenous use was detected though the identification of the pattern described above along Tumeremo-Bochinche road, an unpaved road that crosses the study area from West to East towards the North. A forestry company some distance away from the main road built a secondary road. Although the everyday life of the indigenous people and their use of the forests do not depend on the presence of roads, they make access easier and facilitate the transport of occasional agricultural surplus to markets.

Figure 2 shows the same area two years later. Areas of indigenous use still are being maintained and keep their spatial pattern without spreading to additional areas, although the demographic development of the Kariña is considered to be rapidly growing.

This observation suggests that deforestation in the context of plot establishment is a flexible process that depends on the actual need for additional agricultural areas rather than on a predefined quote of forest to be felled. Table 4 shows that in 2000 in the central sector of the study area, 22.4 square km were used according to indigenous land use techniques whilst in 2002 this area was reduced to 19.1 square km. However, it has to be noted that clouds affected the quality of the 2002 satellite images. Recently cultivated areas e.g., through shifting agriculture might thus have been left undetected. The Indigenous Census conducted in 2001 reported similar figures on the number of settlements within the community. This figure seems to confirm the estimates of agricultural areas based on satellite images.

Map 4 allows a comparison of areas under shifting cultivation with areas under commercial selective logging, visually identified on Landsat ETM images from the years 2000 and 2002. Only few changes within this period can be detected, though. The only difference with regard to the location of indigenous areas can be found where cultivation moved from the northern centre of the reserve, close to a former forest track, to the extreme east, close to the road Tumeremo-Bochinche in an area known as Juancancio.

In addition, an attempt was made to detect areas of former indigenous use far from the current settlements. As a reference, the fallow pattern was chosen, that is, groups of naturally regenerating areas in forests of different size and age structures. This approach did not produce significant results, probably because, as mentioned before, the Kariña communities in central Imataca had been relatively stable during the last 20 years. The penetration of forests over large distances served for hunting purposes and contributed

to family alimentation. Consequently, cultivating new plots at large distances from the community do not seem significant.
In general terms, to identify differences in the succession of tropical rain forests are a complex task even when aided by spatial patterns in remote sensing. Firstly, the structure of mature rain forest is heterogeneous. As a consequence, the spectral response tends to vary considerably. Secondly, the forest assimilates small openings in the canopy like any gaps caused by individual trees that have fallen down (gap dynamics). Thirdly, the spectral response of forests in certain phases of succession varies according to a number of other factors such as humidity contents, floristic composition, exposition, relief and soils.
The commercial exploitation of timber through concessions as carried out in central Imataca leads to a spatial pattern known as “fish bone”. This pattern resembles a network of perpendicular principal and secondary tracks built for timber transport (see Figure 1). Due to its rectangular form and its extension it can be found in relatively flat areas that lack stronger slopes such as the central sector of the study site. In the northwest sector, in contrast, the “Altiplanicie de Nuria” is located, which is an upland area with altitudes of up to 500 m. In these uplands, the tracks within the concession area formed a “fish bone” pattern in 2000. In 2002, however, a higher number of curvilinear axes were detected that served to extract timber in areas with more pronounced slopes. These relatively flat tracks are required to allow timber transport by the trucks used by the concessionaires. The weight of these vehicles compresses the soils and the traffic leads to a severe deterioration of the tracks that in turn enhance erosion particularly in steep sites.
Due to the fact the selective logging sites cover large areas and that the reflectance of these sites varies according to the time passed since their exploitation, two types of indicators for logging had to be distinguished: (i) the obvious and (ii) the subtle type. Figure 1 shows that in 2000, the obvious type was characterized by strong reflectance from the log landings and tracks. Figure 2 in contrast illustrates the subtle type predominant in 2002, with less intense reflectance and less well-defined tracks, which suggests an ongoing disappearance of the main traits of this spatial pattern.
The 2000 image shows a rather obvious pattern of selective logging. However the effects of haze affected it. To identify land cover different from forest and naked soil, the latter indicating tracks and log landings, the Short-wave Middle Infra-Red band was chosen and spectral filters applied. Textural analysis techniques were used to identify

and map selective logging from this filtered image. This procedure can be considered as relatively conservative as it does not capture neither exploited areas with very low reflectance nor riparian forests (Matricardi 2003).

The textural images served as basis to calculate the buffer areas with which the surface of the degraded forest was calculated, using distances of: 180, 210, 240 and 270 metres perpendicular to the roads and in the direction of the forest. The mentioned thresholds come from the field measurements reported for the Amazon Basin (Stone and Lefevre 1998, Souza and Barreto 2000, Matricardi 2003, Asner et al. 2004).

Map 5 is an enlargement of the 270m buffer area from which an area of 92.3Km² of degraded forest was estimated, while map 6 shows the general view of the degraded area estimated by the 180m buffer, which represents 62Km² of degraded forest in two concessions located in central Imataca area namely Hermanos Hernandez and COMAFOR. The values of degraded forest for all the buffer areas are shown in table 5.

The cloud cover over the forest's selective exploitation area in the Landsat images from 1987 and 2002 affected the textural analysis and made it impossible to obtain estimations of degraded forest for those dates.

Therefore to obtain the forest's general degradation estimates, the focus was placed on the analysis of spectral mixes, which decomposes the reflectance measurements in fractions to a sub-pixel level (Lu et al. 2004). This principle is the base model for the satellite-based canopy fractional cover based on the NDVI (normalized difference vegetation index) taken from applied satellite images to calculate two fractions: tree green canopy and bare soil. (Wang et al 2003).

Although the results of the Landsat images TM-1987 and ETM-2000 and 2000 are affected by atmospheric noise, the model served to detect three types of degraded forest and one class of undisturbed forest.

The detection of changes through image subtraction was not possible due to the changing cloud cover distribution. That means that the computer programs process the different cloud masses as if they were changes on the ground cover, which leads to errors in the calculations and interpretations.

Free cloud areas on map 7 (Landsat TM-1987) show undisturbed forest predominantly with 43%, while degraded forest occupies 30% (table 6). This image was used to observe the Northeast and the Southeast sectors where natural forest is predominant. Nevertheless, due to the relief and the solar exposure, areas under undisturbed forest show reflectance differences and were possibly classified as degraded forest.

Map 8 (Landsat ETM-2000) shows an area of 69% of degraded forest, while the undisturbed covers an area of around 4% (table 6). The undisturbed forests are found on the upper basin of the Botanamo River in the North part of the central area; also South of the Tumeremo-Bochinche road, forming round areas like riparian forests on the rivers that constitute the upper basin of the Guarampin River.

The areas for exploitation under logging concessions to the Northeast, centre and South show a variable spectrum of degradation although the natural forest matrix predominates. This distribution suggests changes in the structure and density of the undisturbed forest, which changed from being dominant in 1987 to being relatively sparse after thirteen years in 2000.

The areas under indigenous shifting cultivation on the North side of the Tumeremo-Bochinche road are dominated by undisturbed forest or in a low phase of degradation. They are spread within the matrix of the forest and do not conform to definite patterns in terms of degradation.

Map 9 (Landsat ETM-2002) shows undisturbed forest in the North of the central part of the study area occupying around 5% of the total area and confirms the predominantly degraded forest over 75% of the area, this distribution coincides partially with the one registered for the year 2000. The map allows us to see that over a period of two years, the obvious signals of forest commercial exploitation converted themselves in subtle, their reflectance is minor, possibly due to the effect of the succession which covers the openings in the canopy and the plant regeneration which covers the previously bare ground.

The areas under indigenous shifting cultivation have maintained the condition of being surrounded by less degraded forests, in the same way areas that had been deforested two years before, show currently vegetation cover and had been classified as degraded forest. In general the area under "conucos" seems to have remained stable.

It must be pointed out that the cloud cover allows the observation of different areas in each Landsat scene; under these conditions the superimposition of images has only relative use.

Nevertheless, just as a trial, a detection was tried out of an area under commercial exploitation, which was visible in the three images, and the result was that after fifteen years (from 1987 to 2002) the signs of degradation had almost disappeared.

The successful detection of the impacts of selective exploitation in tropical forests has also been the result of the fusion of high and medium resolution space images

(LANDSAT and IKONOS, SPOT and IKONOS, etc). With the aim of using this technology, the multi-spectrum bands were joined with the panchromatic band of the Landsat ETM, which transformed the spatial resolution from 30 to 15 metres on the fusion image. The result for the 2000 image was acceptable since it improved the possibility of seeing canopy gaps, however the spectral degradation of the image was notable, which makes this application void since it distorts previous treatments and classification results.

Due to the fact that the images IKONOS and others of high spatial resolution are not available for the study area and because of the high costs of contracting the taking of the images, the need to try other methods of evaluation of tropical forests based on multi-spectral images of medium space resolution (LANDSAT, SPOT) still continues.

8. Evaluation of the degradation of forest communities based on floristic composition and structure

The Venezuelan Guayana flora has low level of alien species i.e. highly intact flora and little disturbance (Berry et al. 1995). A well-documented estimation of species of vascular plants in the Venezuelan Guayana reported 9400 species representing two-thirds of the total vascular plants in Venezuela. In the frame of the hierarchical scheme of phytogeographic units in the Guayana Shield, the study site is located in the Eastern Guayana Province, composed of several evergreen lowland forest types (Berry et al. 1995). Among them, the inundated Mora forests from which some typical species were colleted, like *Mora gonggrijpii* (Caesalpiniaceae), *Catostemma commune* (Bombacaceae) and *Triplaris surinamensis* (Polygonaceae); as well, the greenheart forest represented by species of *Eschweilera* (Lecythidaceae) such as: *Eschweilera subglandulosa, Eschweilera chartacea,* and *Eschweilera gratta*.

The floristic information of the Forest Reserve Imataca is still incomplete, from estimated 2292 species only 1685 species had been properly registered; in the study site lack of botanical sampling was reported for the Serranía of Nuria and for Botanamo, Guarampín, and Matupo rivers, tributaries of the Cuyuni river basin. However from the ten most important floristic families in the Reserve, seven are represented in the study area. Regarding reported endemic species in the Reserve we found three of them, *Catostemma commune* (Bombacaceae), *Quiina indigofera* (Quiinaceae), and *Alexa imperatricis* (Fabaceae) (UFORGA-ULA 2000).

Since selective logging and indigenous shifting cultivation are the main land uses here, we explore how forests composition and structure are changing, because logging of big trees opens the canopy causing variations in microclimatic conditions and disturbances in the equilibrium of forest succession (Serrano 2002).

In order to evaluate forest degradation stemming from such land uses we registered floristic differences between undisturbed and disturbed forests, consisting of 5 families, 26 genera, and 47 species. The families were Arecaceae, Clusiaceae, Ebenaceae, Piperaceae, and Quiinaceae, all of them represented by one specie, furthermore Ebenaceae (1 genera, 8 species) and Quiinaceae (4 genera, 17 species) are part of families composed by few amount of genera and species in the Venezuelan Guayana.

Alpha α-diversity estimations matched only partially the expected pattern of high species richness and abundance are related to low evenness. We got three groups of plot, one followed the indicated performance, other got high values in all variables, and the last one showed values variability out of either model.

This turnover of taxonomic groups confirm the assertion that increases in species richness become after logging, in sites of previous similar composition, meaning significant floristic differences before and after logging, as reported to greenheart forest in Guyana. Hence, number of species has been considered not an appropiate measure for forest disturbance evaluation (Ek et al. 1997).

Abundance patterns were also considered to identify forest disturbances, as species represented by one or few individuals tend to disappear, whilst abundant species tend to become dominant. In the study area both undisturbed and disturbed forest had relative abundance around 33 % for rare species and 1 % for abundant species. However, disturbed ones had less total number of species and less number of individuals per specie, such differences point out depletion of rare species. It was confirmed through the importance value index (IVI) which values decreased to rare species but remained stable in dominance.

Previous result agrees with reported by Magurran (2001) who got high values of dominance by compare aquatic undisturbed and disturbed communities, regarding fish richness reduction, but might not explain such dominance (Magurran 2004).

Landscape diversity or β-diversity measurements were addressed to explore the floristic mosaic heterogeneity of forest community and environmental relationships involving them.

Set of plots used to estimate landscape diversity spread over broad surfaces where evergreen mixed forest over peneplains and hill-lands, are the dominant vegetation. Some plots are located parallel to the low mountains of the Serranía de Imataca in the borderline Venezuela-Guyana and have an amount to up to 30 km. Even though we did not follow an altitude gradient and instead we sampled lowlands forests two plots located in the "piedmont" reported the highest β-diversity. Likely because they benefit by the regional rainfall distribution growing up in direction west to east, hence water availability to vegetation rises meaningfully in this area.

Forest structure regards forest arrangement in the vertical plane determining the internal microclimates and the energy availability for the other organisms (Richards 1983). Tropical rain forests are structurally heterogeneous, therefore changes on this feature may lead to degradation processes, that is why we evaluated differences in two structure-related variables such as structural complexity and dominance (basal area) both variables statistically significant to our data. From the results it is worth pointing out that clusters of undisturbed forest highly complex in structure, showed less dominance regarding species composition. Whereas disturbed forests were low complex than undisturbed, and also they presented low dominance. The statistical evaluation coincides partially with the statement that biomass spatial variability could be more related to disturbance than to environmental factors such as soil fertility and soil variability, analysed in order to explain forest structure within sites (DeWalt and Chave 2004, Chave et al 2001).

9. Focus on the local indigenous agriculture and the selective commercial exploitation of the forest

The local approximation to the land uses was obtained through interviews, visits to local communities (households, school, medical centre), sampling in indigenous production units (conucos), forest units (compartimientos), mining units (corte); visits to forest service areas (camps, workshops, yards etc.) and a visit to the National Guard's border military camp.

Map 1 shows the Kariña indigenous settlements, the majority on the Tuemeremo-Bochinche road, where according to their chronology they have been for the past 15 to 25 years due to the migratory condition of their culture, which is a common characteristic of the peoples from the tropical forest.

The current settlement tendencies of the Kariña communities registered through the interviews, present two directions: the first shows that since the arrival of the wood exploiting companies, there is less land available to establish conucos because of the restrictions on land use, since the forest concessions are private property. In fact, the companies build camps, roads, log landings and other infrastructure within the forest, which reduces the habitat of the fauna. Also the noise produced by the spread of vehicles and heavy machinery, associated with the hunting practiced by the companies' staff, reduces the supply of wild fauna and increases the effort required by the indigenous communities to hunt, which is seen by the long walks needed to find animals.

As a result a sector of the population is organizing a move towards the North in the direction of the Orinoco Delta. Five family chiefs organized a trip in October 2002 towards the Delta (a three day walk) with the aim of opening a large community conuco that will allow them to move the families at short notice.

The other tendency shows that the Kariñas will not continue to migrate and are in favour of consolidating the current settlements, where there are schools, encouraging the building of wooden houses to replace the "malocas" which are made out of palms also to request the supply of drinking water and the construction of a sewerage network. They expressed that the government has the duty to provide them with tools like chainsaws, to cut wooden boards to be able to build houses. The Adventists pastors, teachers, and some members of the communities, the majority indigenous people subscribe to this tendency.

The argument to stop migrating is included in the political conjuncture that recognises the land rights of the indigenous communities that in these lands reside, as stated by The Constitution of the Republica Bolivariana de Venezuela. However, criteria expressed by the Ministry for the Environment (MARN) maintains that the government would recognise the collective rights of communities that have settled in specific locations and not collective rights to the whole ethnicity over extensive areas. This position denies the right for autonomy and the freedom of organisation of indigenous peoples, which is laid down in the constitution. Moreover, this vision does not seem to understand the role the tropical forest plays in the culture of the peoples that inhabit it.

The idea to discourage indigenous migrations forms part of a certain conception that is against the cultures that have their own organizational norms and that are resistant to the political and religious control.

Apart from the questionings, the mobility of the population forms part of the correct indigenous strategy of rotation of “barbechos” (land not cultivated for one year or more) that encourages the sustainable use of the tropical forest.

In central Imataca there are 13 Kariña settlements (Indigenous Census 2001, UNEG 2000, Grimmig 1998) from those, eight (8) inhabit low lying rolling plains with inclinations of between 0-8% and three (3) live on the middle hills with slopes of between 4-30%. This indicates that the selection criteria for agriculture described in table 2, refers basically to the flat areas and to the differences between the upper, middle and lower sections of the micro areas with low inclination slopes. The indigenous zoning from this areas is broad, considers few criteria in relation with environmental homogeneity of the area; it is based in the relationships crop-relief, crop-soil (considering texture and colour) and eventually water availability according to the relief. This suggests the existence of few zones with limitations for the traditional agricultural land use in the areas of the current indigenous settlements.

The production activities of the Kariña in central Imataca are illustrated in the economic calendar (figure 1) that contains the time distribution spent in agriculture, fishing and hunting. The sowing of manioc (*Manihot esculenta)*, banana (*Musa paradisiaca x*.), sweet potato (*Ipomea batatas*), ocumo (*Discorea alata y D. Trifida*) corresponds to the rainy season and the times of the corresponding high and low waters. Corn (*Zea mays*) is cultivated occasionally since the seeds are not easily available and are expensive. Fishing takes place twice a year, the first period lasts three months and the second one-month, four months in total, the supply of fish is low possibly because it is a high basin and some of the rivers are seasonal. Hunting takes place the whole year and although the animal population has decreased for the reasons given above, this activity provides a large portion of the nutrition of the Kariña people. From this comes the need to preserve the wholeness of the forest in its condition as habitat and fauna reserve for the sustainability of this people.

In central Imataca five (5) forest companies have concession contracts to extract wood in 681,155 ha. of natural forest, they occupy almost the entire area with a flat relief, soils with high to moderate fertility, good textures and easy accessibility.
The system of selective exploitation means to cut only commercial tree species with a diameter of at least 30cm at chest height, this activity takes four and a half months from mid-November until the end of March, time when the wood is transported out of the reserve. At the same time roads are constructed within the forest for a period of two and a half months, and the dragging of the logs to the yards or holding sites is carried out throughout the year, as can be seen on the forest economic calendar (figure 2). The exploitation activities and the construction of the support infrastructure is carried out with heavy machinery, which implies impacts over the ground and in a global way cause disturbances in the forest which stimulate its degradation although the intensity of the extraction varies from low to moderate, table 3 contains information over the forest services sites like camp sites, main and secondary yards, machinery maintenance workshops, etc. The sites shown on the map are located within the concessions COMAFOR and Hermanos Hernandez, on the South area of the Tumeremo-Bochinche road, they are marked C3 and C4 on map 2.

10. Legal Land Use Plan and Regulations for the Forest Reserve Imataca

The legal Plan and the Regulations for use were approved by Decree 3110 (7 September 2004) and established the following Legal Zones in the central sector of the Forest Reserve Imataca:

a. Forest management
b. Limited forest management
c. Special forest management with high presence of indigenous communities
d. Special forest-mining management.

The unit Special forest management with high presence of indigenous communities is a sub-zone located in the central area of the reserve in a sector of the Tumeremo-Bochinchito road. It is 289,560 ha. and represents 7.7% of the total area (República Bolivariana de Venezuela 2004).
The Plan defines as forest use the spaces with or without forest cover with the aim to take advantage of the wood producing and non-wood producing species (fibre, resin, gum, latex, palm, etc.)

The traditional indigenous agriculture use is known as “conuco” or a small unit for the production of diversified minor benefits, generally of between one and two hectares and worked with rudimentary procedures.

The mining use involves “... prospecting, exploration, processing, transformation, storage, transport and commercialisation of metal and non-metal minerals, including the installations associated to the mining projects according to the Law on Mines” (article 60).

It is worth noting the detailed description and the large number of different activities permitted for the mining and forest use, in contrast with the scarce conceptualisation and reduced opportunity for development given to the traditional use.

Also, the acknowledgment of the territorial rights of the Kariña people is still being discussed without the assignation of a concrete legal area, although in fact it is established as objective: to favour the presence and the cultural protection of the indigenous people and communities; it is established as regulation: to regulate the traditional activities, to provide forest plantations in degraded areas and to identify areas from which mineral resources can be taken advantage of, among others (article 6).

Although the Temporary Regulations for the Legal Plan include the possibility of revision and modification when the process of demarcation of the land for the indigenous peoples and communities is finished, this possibility seems remote given the slow pace of the demarcation process and that the Kariñas from central Imataca are not included in the programme for 2005 according to the allocated Presidential Commission.

The confirmation of the commercial forest management as the best alternative to the beneficial use of the FRI in accordance with the Legal Plan and the Regulations for Use manifests the extractive paradigm towards natural resources, as part of the State’s policies in the management of Venezuela’s forests.

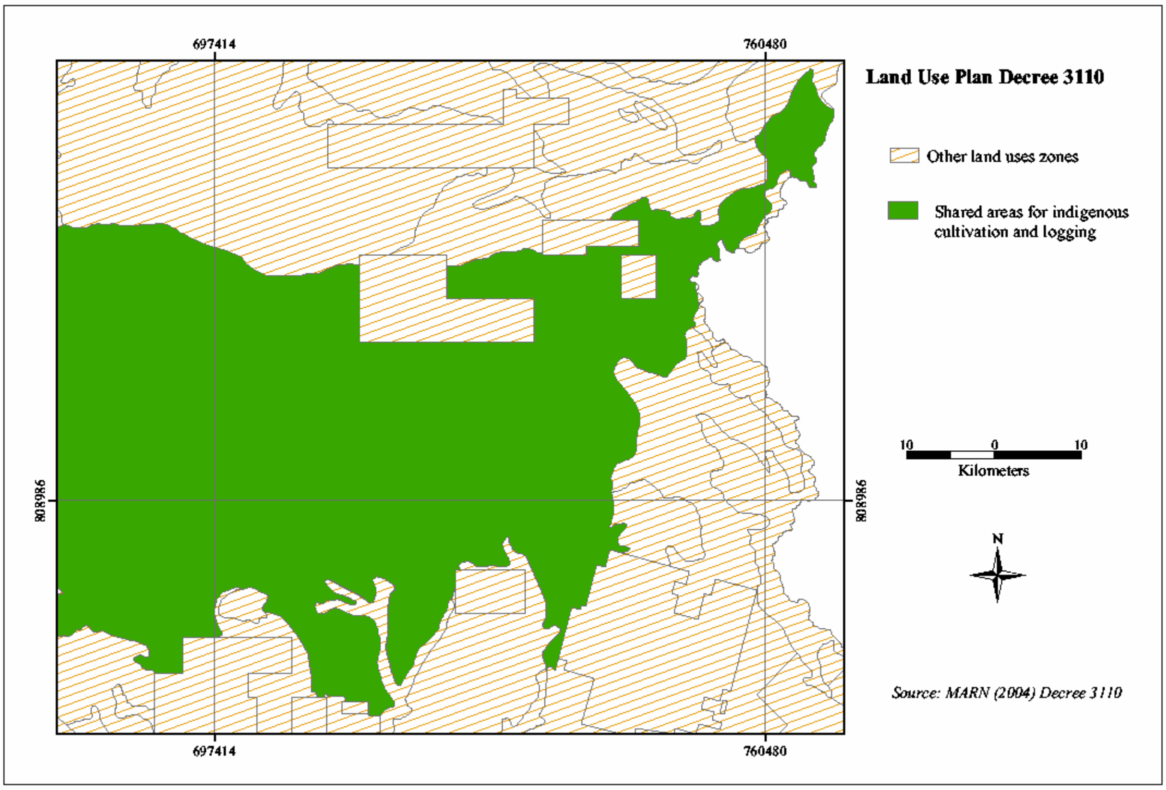
Table 25 shows the legal zones in central Imataca which are composed of two active forest concessions within the traditional area of the indigenous people, there is a third concession (COFORGUA) which has 127,276 ha. assigned although it has not yet began with the exploitation. In the same sector the Plan defines areas under mining contracts that is why the free area left for the use of the Kariña communities has been reduced dramatically.

Table 25. Legal Zones in Central Imataca

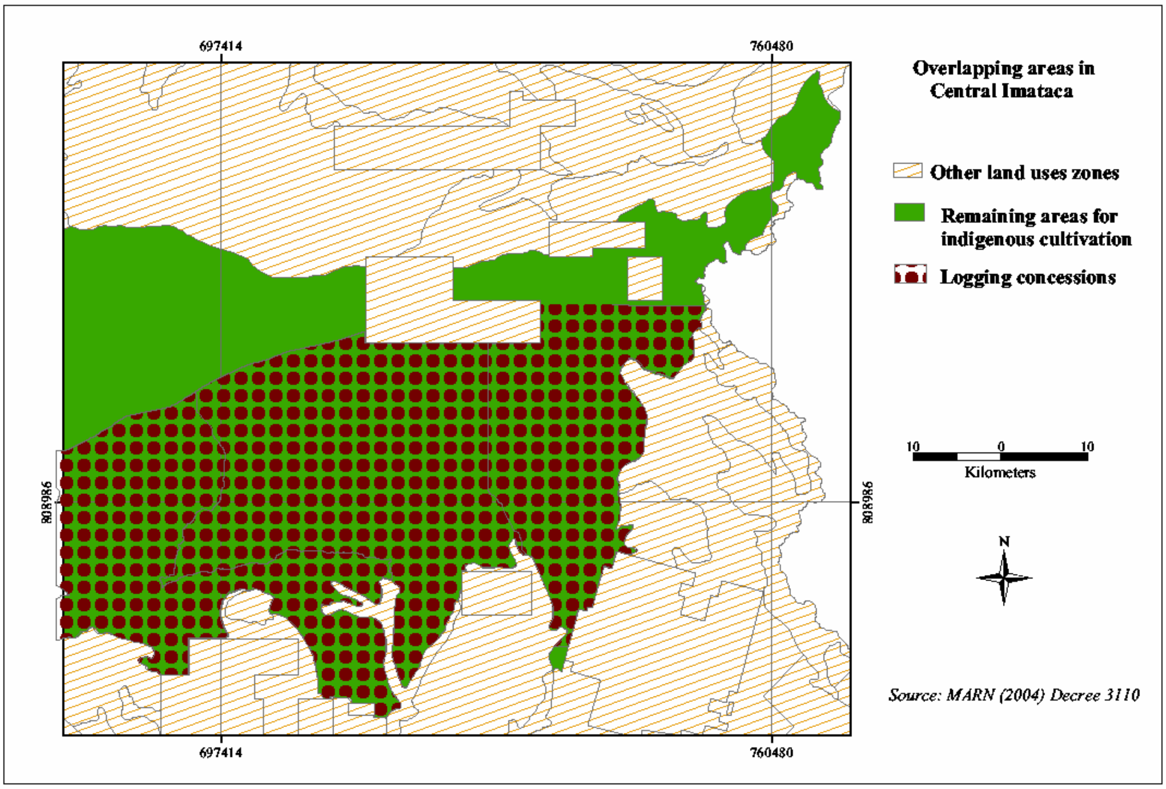
Legal Zone	**Area (ha.)**
Special forest management with high presence of indigenous communities	289,559
Area of overlapping occupied for Kariña communities and logging concessions C3 (COMAFOR), C4 (Hermanos Hernádez), C2 (COFORGUA)	202,403
Use of the Kariñas communities	87,156

Source: Decree Nr. 3110 from 7 September 2004 and Legal map of the Forest Reserve Imataca

Map 18 shows the shared area between both land uses and the Map 19 also shows the same area indicating the areas under logging contracts (valid until the 2025) and the reduced available area for the indigenous use.



Map 18. Area of Shared Logging and Traditional Land Uses Area



Map 19. Area under Logging Concessions and Restricted Traditional Land Use

Nevertheless, following on the process of participating democracy, which is gaining in the country, a change of direction has been proposed. The derogatory and controversial Decree 1,850 has reopened the debate over the convenience of maintaining the system of forest concessions for the exploitation of natural forests, taking as reference the degradation of other forest reserves in the Andean foothills. It is necessary to practice the social control to decide over the mining opening, practice, which has shown its highly degrading condition in the Guyana region and that, was the main objection to the previous proposed Plan.

From a strategic vision, the demarcation process of the indigenous territories constitutes a valuable opportunity to take on board the use and conservation of the FRI from a point of view of community management of the natural forests, and go from the rhetoric about the fundamental rights of the original peoples, to the practice of those rights.

There are successful experiences in tropical and sub-tropical countries about the community management of the forest, which viability was built from the process of confrontation business-communities, mediated by governments when the confrontations reached crisis levels.

In Venezuela the legal process of the FRI enjoys the legal context and the politicians' good will needed to make the sustainability of the use of the forest the reason for its management. From the success of the viable and sensible management forms depends the conservation of our extraordinary forests.

CONCLUSIONS

- Tropical forest degradation in Central Forest Reserve Imataca caused by selective logging and indigenous shifting cultivation was estimated for 2000 and 2002. The landscape estimation covered about 10,000 km^2, of which in 2000 roughly 70% were classified as degraded forests whilst 4% were classified as undisturbed forests. In 2002 about 75% were degraded forests whereas 5% were undisturbed forests. Since not the entire area was under land use, the estimation at the landscape level allowed a rough quantitative evaluation of general forest conditions. On the other hand, the estimation at the local level based on visual interpretation led to an estimate of 255 km^2 being affected by selective logging and 22 km^2 by indigenous shifting cultivation in the year 2000; whilst in 2002 these factors impacted on 149 km^2 and 19 km^2 respectively. These figures imply that most of Central Imataca was affected to some degree by forest degradation. In specific cases these impacts can be calculated through direct measurement supported by the spatial pattern of the respective land use type.

- The evaluation of the forest degradation was constrained by the usually strong noise in the tropical atmosphere, which affected both image quality and availability. This noise impeded a direct multi temporary analysis, since patterns of cloud and shadow were extremely variable across the dataset. Hence, further accurate evaluation of tropical forest degradation needs to be supported by both fine spatial resolution satellite images and ground data measurements.

- The differences among forest communities regarding floristic composition and structure in undisturbed and disturbed conditions were significant with regard to structural variables, namely basal area and structural complexity. This led us to identify a mosaic of eight (8) types of undisturbed forest, suggesting high natural heterogeneity, even though the lowland forests are expected to be more homogeneous. The remarkable landscape diversity (β-diversity) can be considered an evidence of such a forest mosaic, reflecting differences in floristic composition between the sampling plots.

- The evaluation of disturbances of the forest communities on a local scale was based on the floristic inventory data and represents temporary information. The detection of changes is restricted due to the scarcity of the reference data necessary to make comparisons. In this context, our results document the state of disturbance before the foreseeable increment in frequency and magnitude of such disturbances due to the mining use in industrial scale.

- The indigenous systems of forests management have been underestimated by being considered nonviable in market economy contexts, even though these do not degrade the resources and guarantee the permanence of tropical forests. The Venezuelan State adopted an industrial scheme and did not promote alternative forms of communitarian forest management, which would allow to maintain, to consolidate and even to develop sustainable systems of primary forest management. This conclusion can be drawn from the results of the recent land use territorial planning process in the Forest Reserve Imataca.

- According to the Legal Land Use Plan of the Forest Reserve Imataca, most of the central Reserve is under commercial logging use by legal contracts with the State. It means that the traditional territories of the Kariña are bearing degradation processes. What is more they have been reduced to a surface of 87,156 hectares. This situation is very likely to lead to conflicts.

- The landscapes approach was appropriate to evaluate the tropical forest degradation because the spatial patterns and the NDVI (Normalized difference vegetation index) allowed us to get a global estimate of forest conditions. Yet the expected correlation between NDVI values and the basal area turned out to be not significant. This result might not be reliable however, as cloud cover affects measurement accuracy on the satellite image.

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APPENDIX

Annex 1. Floristic inventory plots location

Locality	Comp.	Forest condition	Plots	Coordinates	Altitude (m)
Concession COMAFOR	C1	Not exploited, natural	10	7°21’50” N/ 61°08’12”W	145
“ “	C2	Exploited	10	7°19’16,2” N/ 61°05’13” W	230
	C2	Not exploited, natural	1	7°21’52” N/61°08’12 W	157
“ “	C4	Exploited	1	7°17’45” N/ 61°02’19” W	176
“ “	C5	Not exploited, natural	1	7°17’15” N/ 61°02’23” W	180
MATUPO (indigenous area)		Not exploited, natural	10	7°30’33,7” N/ 60°58’54” W	224
BOTANAMO (indigenous area)		Exploited	1	7°24’42,5” N/ 61°16’15,9” W	196
“		Not exploited, natural	1	7°30’58,1” N/ 60°51’08,3” W	193
JUANCANCIO (indigenous area)		Exploited	1	7°30’47,2” N/ 60°53’27,9” W	170
“		Not exploited, natural	1	7°30’58,1” N/ 60°51’36” W	193
Concession HERMANOS HERNANDEZ	C1	Exploited	1	7°23’12,3” N/ 60°51’40” W	178
“ “	C3	Exploited	1	7°19’17,6” N/ 60°51’40,1” W	174
“ “	C6	Not exploited, natural	1	7°15’40,2” N/ 60°51’08,3” W	193
Mine FANGOR		Not exploited, natural	1	7°32’35,3” N/ 60°52’09,8” W	160

Annex 2. Forest Service Areas

Point	**Type**	**Coordinates**	
		North	East
COMAFOR-CAMP	Main camp	702461	824307
PATPP2	Main log landing	707150	806685
PATPPA	Main log landing	707015	808575
PATS10	Secondary log landing	702699	822998
PATSE5	Secondary log landing	706184	812498
PATSE6	Secondary log landing	706327	811134
PATSE7	Secondary log landing	713229	810071
PATSE8	Secondary log landing	716489	806341
PATSE9	Secondary log landing	706349	810822
SAQUE GRANZA 1		706940	809333
SAQUE GRANZA 2		706971	808952
HERM. HERN. CAMP		737349	816821
Log landing 1/ v	Main log landing	737149	818233
Log landing 2/ v	Main log landing	737162	817972
COMAFOR - Road last point		716511	806104
COMAFOR-Machinery workshop	Main	705864	813155

Source: ground data collected in 2002.

Annex 3. List of woody species (DBH ≥ 10 cm) identified in 41 plots in tropical rainforest in Central Forest Reserve Imataca, Venezuela

Family	Species	Common name
ANACARDIACEAE	*Spondias mombin*	Jobo
	Astronium lecointei	Pata de zamuro
	Tapirira guianensis	Patillo
ANNONACEAE	*Rollina excucca*	Anoncillo
	Annona sp	Catuche
	Xylopia sp.	Fruta de burro
	Duguetia sp.	Yarayara amarillo
	Gutteria poeppigicena	Yarayara negro
APOCYNACEAE	*Aspidosperma excelsum*	Canjilón
	Aspidosperma marcgravianum	Canjilón amarillo
	Aspidosperma excelsum	Canjilón negro
	Aspidosperma megalocarpum	Hielillo
	Himathanthus articulata	Mapolo
ARECACEAE	*Attalea maripa*	Palma cucurito
BIGNONIACEAE	*Jacaranda copaia*	Cimaruba
	Tabebuia stenoedyx	Purguillo blanco
	Tabebuia serratifolia	Puy
	Jaracanda obtusifolia	San José
BOMBACACCEAE	*Catostemma commune*	Baraman
	Eriotheca globosa	Cedro dulce
BORAGINACEAE	*Cordia exalata*	Alatrique
	Bourreria cumanensis	Guatacare
BURSERACEAE	*Protium neglectum*	Caraño
	Trattinickia rhoifolia	Maro
	Protium crenatum	Sipuede
	Protium heptaphyllum	Tacamajaca
CAESALPINACEAE	*Peltogyne porphyrocardia*	Zapatero
	Hymenaea courbaril	Algarrobo
	Mora gongrijpii	Mora
	Bauhinia benthamiana	Pata de vaca
	Brownea latifolia	Rosa de montaña
CELASTRACEAE	*Guopia glabra*	Pilón lombricero
CHRYSOBALANACEAE	*Licania densiflora*	Hierrito
	Pariani excelsa	Merecurillo
CLUSIACEAE	*Garcinia*	Cosoiba
COMBRETACEAE	*Terminalia amazonia*	Pata de danto
	Terminalia guianensis	Pata de danto amarillo
	Terminalia sp	Pata de danto rosado

DICHAPETALACEAE	*Tapura guianensis*	Jabón
EBENACEAE	*Diospyros ierensis*	Carbón
ELAEOCARPACEAE	*Sloanea grandiflora*	Cabeza de araguato
EUPHORBIACEAE	*Hieronyma laxiflora*	Aguacatillo
	Chaetocarpus schomburgkianus	Cacho
	Pirahea longepedunculata	Caramacate
	Drypetes variabilis	Kerosen
	Mabea piriri	Pata de paují
	Croton sp	Sangre de drago
FLACOURTIACEAE	*Casearia guianensis*	Cafecillo
	Casearia arborea	Fruta de paloma
	Casearia rusbyana	Palma palmito
GUTTIFERAE	*Vismia cayennensis*	Lacre
	Tovomita calodictyos	Mangle
LAURACEAE	*Ocotea glomerata*	Laurel
LECYTHIDACEAE	*Gustavia augusta*	Burro muerto
	Eschweilera chartacea	Guacharaco
	Eschweilera subglandulosa	Majaguillo
	Eschweilera gratta	Majaguillo cacaito
	Eschweilera gratta	Pilón colmenero
	Lecythis davisii	Tinajito
	Couratari pulchra	Capa de tabaco
MELASTOMATACEAE	*Mouriri huberi*	Guarataro
	Miconia sp.	Saquiyá
MELIACEAE	*Trichilia propingua*	Biscochuelo
	Carapa guianensis	Carapa
	Cedrela odorata	Cedro amargo
	Cedrela sp.	Cedro rojo
	Guarea grandiflora	Trompillo
MIMOSACEAE	*Parkia pendula*	Caro
	Pentaclethra macroloba	Clavellino
	Inga splendens	Guamo
	Inga floribunda	Guamo camburito
	Inga sp	Guamo cinta
	Inga alba	Guamo colorado
	Inga heterophylla	Guamo morrocoyero
	Inga sp.	Guamo rebalsero
	cf. Cedrelinga catenaeformis	Pilón rosado
	Pithecellobium jupunba	Samán montañero
	Piptadenia psylostachya	Yiguire
MORACEAE	*Brosimum alicastrum*	Charo
	Ficus sp	Higo
	Cecropia sp.	Yagrumo

MYRTACEAE	*Eugenia patrisii*	Pendanga
	Calycorectes sp	Terciopelo
NICTAGINACEAE	*Torrubia cuspidata*	Casabe
QUIINACEAE	*Quiina indigofera*	Palma cola de pava
FABACEAE	*Diplotropis purpurea*	Congrio
	Alexa imperatricis	Leche de cochino
	Ormosia sp	Pericoco
	Andira surinamensis	Pilón
	Andira sp.	Pilón alcornoque
	Erythrina-mitis	Pionío
	Diteryx odorata	Sarrapia
	Pterocarpus officinalis	Cacú
	Clathrotropis brachypetala	Caicareño
	Lonchocarpus latifolius	Tocorito
PIPERACEAE	*Piper sp.*	Anicillo
POLYGONCEAE	*Coccolaba sp*	Arahueque
	Tryplaris surinamensis	Palo de maría
	Triplaris weigeltiana (Rchb.) Kuntze	Santa María
RUBIACEAE	*Duroia eriopila*	Conserva
	Guettarda sp	Punteral
RUTACEAE	*Fagara maritinicensis*	Bocsuo
SAPINDACEAE	*Toulicia guinensis*	Carapo blanco
	Cupania americana	Chaparillo
	Talisia cf. hexaphilla	Cotoperí
SAPOTACEAE	*Chrysothyllum auratum*	Caimito
	Pouteria caimito	Capure
	Pouteria sp	Chicle
	Pouteria venosa	Maspara
	Pouteria egregia	Purguillo
	Manilkara bidentata	Purguo
STERCULIACEAE	*Guazuma ulmifolia*	Guácimo
	Sterculia pruriens	Majagua
TILIACEAE	*Apeiba tibourbou*	Cabeza de negro
VERBENACEAE	*Citharexylum macrophyllum*	Totumillo
VIOLACEAE	*Paypayrola sp.*	Gaspadillo
	Paypayrola longifolia	Gaspadillo negro
VOCHYSIACEAE	*Vochysia tetraphylla*	Canelito blanco
	Erisma uncinatum	Mureillo

Annex 4. Species Absent in Undisturbed Plots

Common name	**Scientific name**	**Families**	**G R**	**p.e.b.**
Algarrobo	Hymenaea courbaril	CAESALPINIACEAE	5	0.821
Anicillo	Piper sp.	PIPERACEAE	?	
Cafecillo	Casearia guianensis	FLACOURTIACEAE	3*	
Canjilón negro	Aspidosperma excelsum	APOCYNACEAE	5	0.89
Caramacate	Pirahea longepedunculata	EUPHORBIACEAE	?	
Carbón	Diospyros ierensis	EBENACEAE	4*	
Catuche	Annona sp	ANNONACEAE	1*	
Chaparillo	Cupania americana	SAPINDACEAE	?	
Chicle	Pouteria sp	SAPOTACEAE	5	0.876
Cosoiba	Garcinia	CLUSIACEAE	3*	
Cotoperí	Talisia cf. hexaphilla	SAPINDACEAE	3*	
Guamo cinta	Inga sp	MIMOSACEAE	2	0.528
Kerosen	Drypetes variabilis	EUPHORBIACEAE	4	0.693
Mangle	Tovomita calodictyos	GUTTIFERAE	3*	
Palma cucurito	Attalea maripa	ARECACEAE	1*	
Pata de danto amarillo	Terminalia guianensis	COMBRETACEAE	4	0.727
Pata de danto rosado	Terminalia sp	COMBRETACEAE	4*	
Pata de vaca	Bauhinia benthamiana	CAESALPINIACEAE	3*	
Pericoco	Ormosia sp	FABACEAE	3	0.597
Pilón alcornoque	Andira sp.	FABACEAE	3	0.647
Puy	Tabebuia serratifolia	BIGNONIACEAE	5	0.967
Samán montañero	Pithecellobium jupunba	MIMOSACEAE	2	0.514
Sangre de drago	Croton sp	EUPHORBIACEAE	?	
Santa María	Triplaris weigeltiana (Rchb.) Kuntze	POLYGONCEAE	2	0.508
Yarayara amarillo	Duguetia sp.	ANNONACEAE	2*	
Yiguire	Piptadenia psylostachya	MIMOSACEAE	4	0.667
Zapatero	Peltogyne porphyrocardia	CAESALPINACEA	5	0.908

Source: Ground data (2002)

GR: groups of species based on basic specific weight
p.e.b.: basic specific weight
1: Light and softwood
2: Middle light and softwood
3: Middle heavy and hardwood
4: Heavy and hardwood
5: Heavy and very hard
Supposed group according to generic and ecological features

Annex 5. New Species in Disturbed Plots

Common name	Scientific name	Families	GR	p.e.b.
Aguacatillo	Hieronyma laxiflora	EUPHORBIACEAE	4	0.657
Cacú	Pterocarpus officinalis	FABACEAE	2	0.500
Canelito blanco	Vochysia tetraphylla	VOCHYSIACEAE	2	0.476
Capure	Pouteria caimito	SAPOTACEAE	5	0.760
Cedro rojo	Cedrela sp.	MELIACEAE	2	0.356
Simaruba	Jacaranda copaia	BIGNONIACEAE	1	0.320
Gaspadillo negro	Paypayrola longifolia	VIOLACEAE	2*	
Palma cola de pava	Quiina indigofera	QUIINACEAE	?	
Palo de María	Tryplaris surinamensis	POLYGONCEAE	2	0.508
Pata de danto	Terminalia amazonia	COMBRETACEAE	4	0.727
Patillo	Tapirira guianensis	ANACARDIACEAE	3	0.650
Pionío	Erythrina mitis	FABACEAE	3	0.597
Saquiyá	Miconia sp.	MELASTOMATACEAE	3*	
Tacamajaca	Protium heptaphyllum	BURSERACEAE	3	0.608
Terciopelo	Calycorectes sp	MYRTACEAE	3*	
Tocorito	Lonchocarpus latifolius	FABACEAE	4	0.699
Yarayara negro	Gutteria poeppigicena	ANNONACEAE	2*	

Source: Ground data (2002)

GR: groups of species according to basic specific weight
p.e.b.: basic specific weight
1: Light and softwood
2: Middle light and softwood
3: Middle heavy and hardwood
4: Heavy and hardwood
5: Heavy and very hard
* Supposed group according to generic and ecological features

Annex 6. Characteristics of Clustered Forests

Plots	Disturbance	Height	Basal Area	Density	Richness	Complex	Shannon	Evenness	Simpson (1/S)
1	UD	18,10	3,36	45	20	54,76	2,75	0,92	17,37
28	UD	13,05	3,02	50	19	37,51	2,56	0,87	11,34
7	UD	14,48	1,45	46	28	26,99	3,12	0,94	29,57
8	UD	16,61	1,99	37	19	23,19	2,70	0,92	17,08
9	UD	13,55	1,55	38	22	17,59	2,94	0,95	27,04
10	UD	14,13	2,17	46	20	28,17	2,80	0,93	19,90
24	UD	13,93	2,52	48	20	33,70	2,54	0,85	8,88
26	UD	10,13	1,47	39	15	8,71	2,43	0,90	11,95
27	UD	12,50	2,70	62	16	33,46	2,20	0,79	5,97
29	UD	12,13	1,58	46	17	14,96	2,14	0,76	5,20
30	UD	12,50	1,70	39	14	11,60	2,11	0,80	6,18
33	UD	18,80	2,95	50	25	69,44	2,79	0,87	11,89
37	UD	16,90	1,71	33	15	14,32	2,48	0,91	13,54
6	UD	16,61	2,40	42	22	36,84	2,70	0,87	12,48
25	UD	12,43	2,70	42	14	19,71	2,25	0,85	8,53
3	UD	15,17	2,82	52	22	48,96	2,77	0,90	15,07
5	UD	15,15	1,37	45	23	21,55	2,94	0,94	24,15
21	UD	16,98	5,69	56	26	140,65	3,00	0,92	21,69
22	UD	14,26	3,70	59	29	90,26	3,13	0,93	25,54
32	UD	16,10	2,76	40	19	33,75	2,60	0,88	12,00
40	UD	17,80	3,60	32	13	26,69	2,22	0,87	8,41
16	D	16,30	2,63	47	23	46,30	2,87	0,92	19,30
17	D	14,89	0,84	17	14	2,98	2,56	0,97	34,00
18	D	13,69	2,58	58	24	49,16	2,78	0,87	13,78
20	D	15,14	2,08	31	14	13,65	2,34	0,89	10,57
19	D	14,50	1,48	34	17	12,43	2,65	0,94	17,53
31	D	12,40	1,09	31	17	7,13	2,73	0,96	24,47
34	D	19,10	1,80	51	6	10,51	1,58	0,88	4,72
36	D	12,90	0,85	42	10	4,58	1,71	0,74	4,46

Source: inventory data 2002

LEBENSLAUF

Name	**Glenda Ysolina Rodríguez Aponte**
Geburtsdatum und -ort	29.10.1957 Puerto Cabello, Venezuela
Adresse	Albrecht-Thaer-Weg 26, App. 7 37075 Göttingen Deutschland Tel. 0551-2053581 / 397979
Staatsangehörigkeit	Venezolanisch

Heimatadresse

Abteilung für Mensch und Umwelt, und Zentrum für ökologische Forschung (CIEG) Nationaluniversität von Guayana (UNEG), Puerto Ordaz, Venezuela. 0058-286-9220192 / 9234786

Hochschulbildung

1976-1982	Studium der Geographie an der Universidad de Los Andes, Mérida, Venezuela
1998	Master in Umweltwissenschaften an der Universidad Nacional Experimental de Guayana, Puerto Ordaz, Venezuela
Seit 2002	Doktorandin am Institut für Geographie, Georg-August Universität, Göttingen

Berufliche Tätigkeiten

1978	**Wissenschaftliche Hilfskraft** an der Fakultät für Forstwissenschaften, Universidad de los Andes, Mérida, Venezuela
1979	**Studentische Hilfskraft** am Institut für Meteorologie an der Fakultät für Forstwissenschaften, Universität Los Andes
1983	**Geographin**: Sozioökonomische Studie zu Kleinbauern im Forstreservat Ticoporo (Barinas, Venezuela), Projekt der Fakultät für Forstwissenschaften, Universität Los Andes
1985	**Geographin** bei der Corporación Venezolana de Guayana, Puerto Ordaz
1987-1991	**Umweltwissenschaftlerin** am Institut für Arbeitssicherheit und Gesundheit der Venezolanischen Aluminiumschmelze (CVG-VENALUM) in Puerto Ordaz
1992-1996	**Wissenschaftliche Assistentin** am Abteilung für Mensch und Umwelt, Nationaluniversität von Guayana (UNEG), Puerto Ordaz

1999	**Koordinatorin des Postgraduiertenprogramms für Umweltwissenschaften** an der Nationaluniversität von Guayana (UNEG), Puerto Ordaz
1992-2000	**Universitätsdozentin** am Institut für Mensch und Umwelt, Nationaluniversität von Guayana (UNEG), Puerto Ordaz