THE WORLD BANK

ENVIRONMENT DEPARTMENT

Interdisciplinary Fact-Finding on Current Deforestation in Costa Rica

Ernst Lutz
Mario Vedova W.
Héctor Martínez
Lorena San Román
Ricardo Vazquez L.
Alfredo Alvarado
Lucia Merino
Rafael Celis
Jeroen Huising

September 1993

Environment Working Paper No. 61

INTERDISCIPLINARY FACT-FINDING ON CURRENT DEFORESTATION IN COSTA RICA

Ernst Lutz
Mario Vedova W.
Héctor Martínez
Lorena San Román
Ricardo Vazquez L.
Alfredo Alvarado
Lucia Merino
Rafael Celis
Jeroen Huising

A CATIE-World Bank Project
Funded by the Dutch Fund for the Environment

ACKNOWLEDGEMENTS

Ernst Lutz is senior economist in the Land, Water, and Natural Habitats Division of the World Bank's Environment Department. Mario Vedova is Co-Director of ProDesarrollo, a consulting firm in San Jose, Costa Rica. Hector Martinez is a forester and a free-lance consultant. Lorena San Roman is an ecologist and former director of the national museum in San Jose, Costa Rica. She currently is Vice-Chancellor of Research at the National University of Costa Rica. Ricardo Vazquez L. is an anthropologist with the National Museum of Costa Rica and lecturer at the University of Costa Rica. Alfredo Alvarado is a professor of agronomy and soils as well as Director of the Agronomic Research Center of the University of Costa Rica. Lucia Merino is a demographer, formerly with the Population and Environment Program of the Costa Rican Demographic Association. Rafael Celis, a resource economist, formerly Director of the Sustainable Agriculture Program at CATIE, is at present Co-Director of ProDesarrollo. Jeroen Huising did his Ph.D work on the Atlantico region and is currently a staff member at the Department of Surveying and Remote Sensing at the Wageningen Agricultural University in the Netherlands.

The authors are indebted to many individuals for their assistance during the course of the survey in Costa Rica. At the Bank, Mr. Binswanger, initially in his capacity as Chief of the Agriculture Division for Mexico and Central America and later as Senior Adviser for the Technical Department of the Latin America Region, has supported and commented on the work. His successor as Division Chief, Michael Baxter, also helped see this task through to completion as did Mohan Munasinghe and Colin Rees in the Environment Department. Susanna Hecht and James Shortle have provided useful specific comments on the initial drafts. During the review process in the Bank, many individuals have provided comments and suggestions including Bill Beattie, Luis Constantino, Robert Kirmse, Paul Knotter, John McIntire, Augusta Molnar, Jan Post, Robert Schneider, and Jeff Sayer. Linda Starke provided editorial assistance.

INTERDISCIPLINARY FACT-FINDING ON CURRENT DEFORESTATION IN COSTA RICA

Table of Contents

ABSTRACT

Rapid deforestation of tropical forests has received worldwide attention. Yet our understanding of the actual facts of deforestation tends to be limited, derived from satellite or aerial photographs or from case studies of limited representativeness. Suggestions for policy and project interventions are made in a context of limited information and considerable uncertainty. To reduce this uncertainty for at least one case, the World Bank and the Center for Tropical Agricultural Research and Teaching (CATIE) surveyed 52 deforestation sites distributed across Costa Rica to allow more accurate determination of important facts about deforestation.

Some of the key findings of the survey are:

- Selective logging is estimated to affect between 51,000 and 59,000 hectares a year, roughly 1 percent of Costa Rica's land area.

- Probably between 5,000 and 10,000 hectares of forestland a year are being converted to agricultural use through clear-cutting and clearing of previously logged-over areas. This represents some 0.1 to 0.2 % of Costa Rica's land area.

- The survey team found no evidence of clearing by burning, even though this is probably happening to a limited extent.

- Some forest plantations are being established, and there is some natural regeneration of forest in low-use or abandoned pastures. On a net basis, therefore, the loss of forest area is estimated to be small at present.

- Economic motives of owners of the forestland are the driving force behind most of the conversion and selective logging. The main objective is to realize the gains from the timber harvesting or from subsequent agricultural production or both. Forest clearing to establish a stronger claim to the land no longer appears to be a motive, as it was in the past.

- Environmental concerns tend not to be taken into consideration by the owners or the loggers who assist them when they are unrelated to on-site productivity benefits. Owners, and in particular those that are vertically integrated, seek to actively limit on-site damages.

- Smallholders squatting on public or private land seem to play only a minor role in current land clearing or logging. The survey data cannot answer the question whether smallholders have also played a minor role in the past.

- The large reduction in forested area during this century has reduced habitats for flora and fauna. Fortunately, it appears losses of biodiversity have been small so far. There are some threatened species, but the national park system, while needing

strengthening, should be able to preserve most of the country's biodiversity, which is one of the bases for the nation's important environmentally oriented tourism.

- Negative environmental effects on soils and water from land clearing and selective logging appear to be much smaller than sometimes asserted. The major sediment load comes from road construction. But under tropical conditions, dirt roads no longer used are generally covered by vegetation within months, thus sharply reducing erosion. Only a small part of eroded soil reached any waterways in the cases observed.

All but the last of these findings are specific to Costa Rica and should therefore not be generalized.

The findings of the survey present a more benign picture than is usually assumed. Given the dearth of empirical facts, hypotheses have sometimes been advanced that acquire the status of fact by dint of repetition. Some of these hypotheses dramatize a situation that helps raise awareness. The data here suggest that the impact of current deforestation in Costa Rica is less serious than sometimes alleged, in part because of past decisions to set aside large areas as national parks or reserves. But the findings are not a reason for complacency. Instead, we believe that they can be used to direct policy and regulatory interventions more intensively toward the areas and problems in Costa Rica where damage from current deforestation is most likely to occur. Also, fact-finding studies are encouraged elsewhere to provide a firmer information base for improved management.

INTERDISCIPLINARY FACT-FINDING ON CURRENT DEFORESTATION IN COSTA RICA

Costa Rica has a land area of about 51,000 square kilometers. The forested area has decreased from 85% in 1900 to 56% in 1950 and 29% in 1987. More than a quarter of the land area is part of national parks and reserves, whose forests in 1987 covered some 19% of the nation's land area.

Deforestation is a major concern in Costa Rica. However, despite a high level of awareness of this problem, information on the deforestation process has been sketchy. As a basis for improved natural resource management, the Center for Tropical Agricultural Research and Teaching (CATIE) in Costa Rica and the World Bank agreed to carry out a field survey in 1991-92 to determine key facts related to current deforestation in Costa Rica.

Study Objectives

The specific objectives of the study were to:

- Characterize forestry exploitation in Costa Rica (including clear-cutting), identifying those responsible for each operation.
- Identify damage to the environment due to forest exploitation, with an emphasis on soil, aquifers, and biodiversity.
- Determine the structure of prices for timber (in-stand, on landings or beside highways, at distribution sites and industrial plants).
- Estimate the participation of squatters in the deforestation process (with identification of the stages in which they participate), and their motivations and geographic origin.
- Identify the structure of land tenancy of the areas subject to exploitation or clear-cutting.
- Characterize the later use of cleared or exploited areas, and evaluate the environmental impacts of such practices (agriculture, livestock, agroforestry, forestry).
- Identify examples of sustainable use of primary and secondary forests in the different forest regions of the country.
- From a socioeconomic point of view, determine the motivations, relationships, and future options of people involved in forest exploitation.
- Quantify the area of selective exploitation and annual clear-cutting for the period in which satellite images are available.

Methods

The study was carried out by an interdisciplinary team that surveyed aspects such as forest management; impact on biodiversity; land use changes; costs of extraction, transport, and processing; and the social fabric behind deforestation. The team was composed of a specialist in economics (also the team leader), a forester, a specialist in agronomy and soils, an ecologist, and a social anthropologist. Between November 1991 and March 1992

the team visited 52 sites distributed in proportion to deforestation in each region during the last few years.

Initially, surveys were planned in 50 sites based on the results of analysis of available satellite images. But because Geographic Information System (GIS) data are not up to date and have other limitations such as cloud cover, an ad hoc methodology was devised for the study, based on data made available to the team on forested areas and volumes of timber authorized for exploitation in each forest region by the General Directorate of Forestry (DGF) for the period 1986–90. Table 1 shows the amount of forestland in each region and the distribution of the actual sample sites.

Table 1 Distribution of Forested Lands and Sample Sites in Costa Rica
(area in hectares; percentage)

Region	Protected	Unprotected	Total	Share of Total	Share of Sample
Dry Pacific Zone	41,400	40,920	82,320	5.6	8
E. Central Valley	159,309	35,171	194,480	13.2	0
Central Valley	5,120	3,260	8,380	0.6	0
W. Central Valley	39,920	31,040	70,960	4.8	0
Central Pacific	4,120	6,700	10,820	0.7	0
South Pacific	267,337	133,403	400,740	27.2	21
Northern Zone	70,050	148,610	218,660	14.8	38
Atlantic Zone	385,350	104,230	489,580	33.2	33
TOTAL	972,606	503,334	1,475,940	100.0	100

Source: DGF, Statistics Bulletin, 1990.

Between July and December 1991 the team leader and some team members, equipped with a four-wheel drive vehicle, made preliminary visits to various regions and contacted local officials and private-sector sources to find out where land clearing and logging were planned or going on. This was a lengthy process, as logging and land clearing is occurring largely in inaccessible areas, and pursuing leads was costly in terms of time.

Local DGF technicians were the most reliable source of information on sites. This may bias the results somewhat in favor of larger scale or legal logging and land-clearing activities. But the team believes that this bias is small for the following reasons:

- Widespread illegality does not occur in the sense that large areas are being converted without a permit or that much logging is undertaken without one; rather, at most sites for which permits were given, additional trees are being harvested illegally over and above the formally permitted volume.
- If large illegal logging operations or forest conversions were going on, it would be difficult to keep them secret because of the bulldozers, logging trucks, and crews needed to operate them.
- Given the reasonably good economic situation of the country, particularly in comparison with others in the region, the team believes that any squatting that is going on affects very small areas.

The team travelled to the 52 sites selected (Figure 1; see also Annex 1) and used questionnaires to interview farm owners, loggers, laborers, sawmill owners, transporters, and others involved in forest exploitation.1/ In addition, the team interviewed DGF officials from the headquarters of the Atlantic, northern, and southern Pacific regions and from the central headquarters, along with representatives from the following nongovernmental organizations: Association of Loggers of the Atlantic, Association of Forestry Producers of Agroindustry, Corporation of Forest Development of San Carlos, Union of Agroindustrial Producers of the Osa Peninsula, and Foundation for the Development of the Central Volcanic Mountain Range.

The study was limited by the following factors:

- Climate: the Atlantic and the northern zones of the country do not have a definite rainy season, although from November through February these zones receive the greatest amount of precipitation, which limits harvesting and extraction. This made it difficult to locate sites and the individuals who carry out the extraction operations.
- Legality of harvesting: the study attempted to identify specific cases of illegal harvesting, a practice that is difficult to detect since it is generally disguised through permits or legal authorizations. The team spent considerable time trying to locate this type of felling.
- Informants: the study intended to interview owners as well as persons exploiting the forest. In many cases it was not possible to locate the landowners themselves. The information obtained reflects the knowledge of the persons interviewed.

1/ The questionaire and the initial draft report, on which this Working Paper is based, were prepared in Spanish. A separate questionnaire was used for the socioeconomic survey.

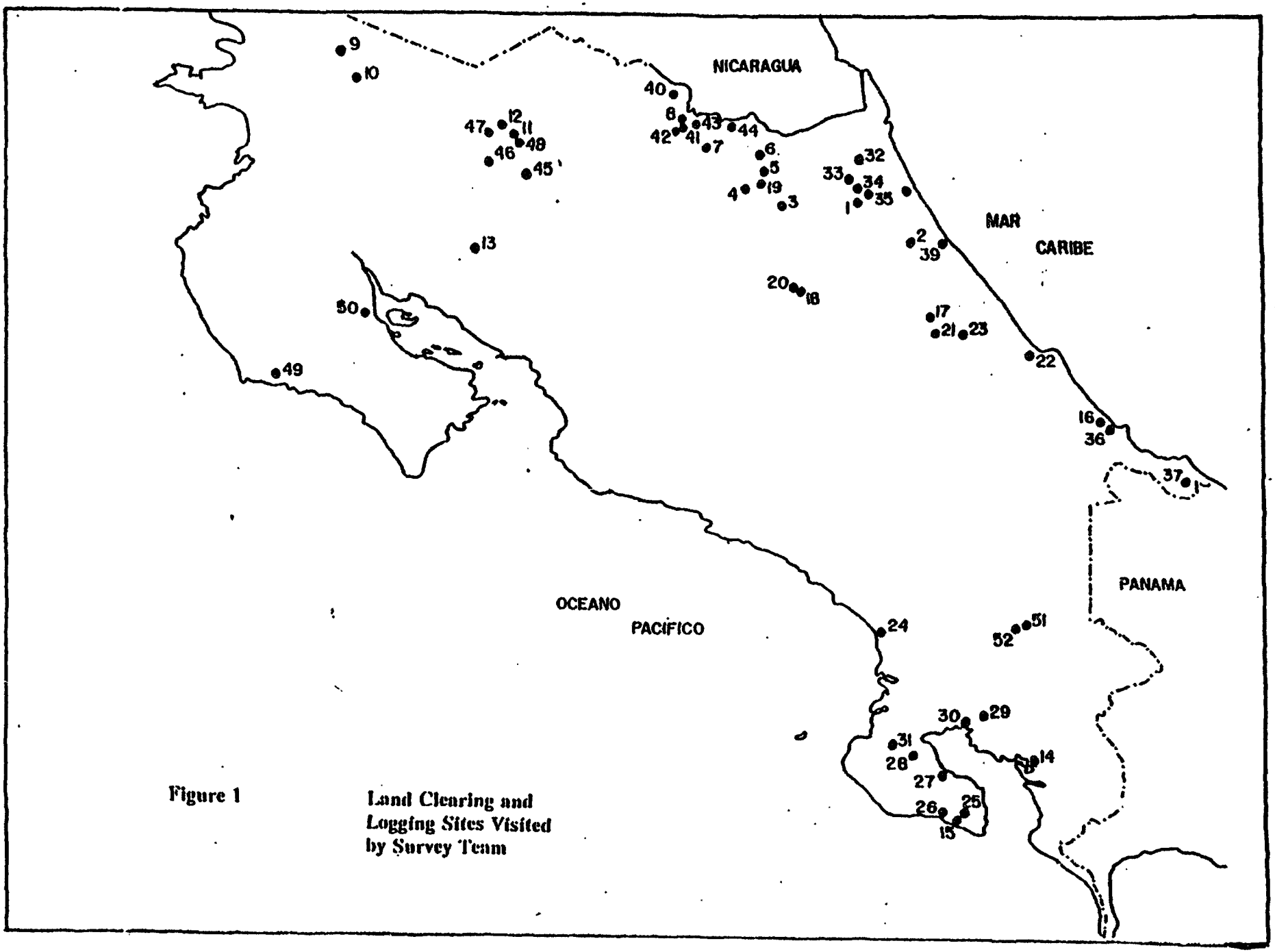

Figure 1 Land Clearing and Logging Sites Visited by Survey Team

Deforestation Estimates

Costa Rica does not have a continuous national forest inventory or monitoring system, nor a geographic information system that periodically updates changes in land use. Records on authorizations and cutting permits granted annually are available, but permits generally are not supervised in the field. Therefore, reliable national figures on the magnitude of deforestation or on affected areas are not available. The team used several approaches to produce such estimates.

Research on humid tropical forests indicates that felling one large tree produces a clearing of approximately 400 square meters (Oldeman, 1978). Given that on average in Costa Rica there are about five trees per hectare of more than 60 centimeters in diameter (Martínez, 1992), their cutting results in an affected area of about 2,000 square meters. When approximately 500 square meters for roads and loading docks are added in, the affected area totals approximately 2,500 square meters per hectare. This means that about 75% of the cover remains as intervened primary forest. When the total number of exploitable trees per hectare nears 10, the percentage of the disturbed forest can reach 50%.

The average volume per tree in the natural forest as well as in pasturelands is about 3.1 cubic meters. The DGF notes that trees from the natural forest have a volume of 3.16 cubic meters and those from other areas, 2.26. The total volume authorized for exploitation in 1992 was not significantly different from that authorized in 1990, approximately 650,000 cubic meters (DGF, 1991). Therefore, the total number of authorized trees felled in 1992 was about 207,000, which translates into an affected area of about 41,000 hectares.

The team estimates that:

- The clear-cut area ranges between 5,000 and 10,000 hectares per year (including about 500 hectares for banana cultivation), corresponding to 0.1–0.2% of national territory. In the past, some 30,000 hectares may have been converted a year.2/ The decrease can be explained in part by the fact that conversion historically occurred on land most suitable for agricultural use, and that the remaining forest lands are of increasingly marginal use for agriculture.
- The authorized change from primary to secondary forest, from secondary to logged-over secondary forest, or from tree stands to solely pastureland may reach 31,000 to 36,000 hectares per year, or about 0.6% of national territory. If, on average, overcutting in authorized sites amounts to 50%, and if cutting at unauthorized sites is 15%, selective logging could reach between 51,000 and 59,000 hectares per year, about 1% of national territory.

2/ Since our survey was completed, a government analysis of LANDSAT information for the period 1986 to 1992 found an average deforestation rate of 17,000 ha per year, which is broadly in line with our estimates.

Interviewees never mentioned that exploited forests were going to be used later for nonforestry purposes, which could be due to owners' fear that the information might be used by state agencies (DGF and others) to establish sanctions. Some indicated that in other sites, once valuable timber is extracted, forests would be "socolados" (understory eliminated) and later cleared for livestock production. This appears to happen infrequently, however.

In only three cases did small farmers solicit and receive permits to exploit the land and complete clearing. Banana companies also totally eliminate forest cover when converting the land for agricultural production. In these cases it can be concluded that all the area cleared is used for nonforestry purposes.

In the humid tropical forest areas, no fires in the natural forest (exploited or not) were registered, nor was information obtained on the use of this practice except in one case in which timber was burned to facilitate the clearing of land for banana production. In drier areas, this is commonly done on pasturelands and in early secondary forests to eliminate insects harmful to livestock, and the burning stimulates the formation of sprouts on pasturelands. It should be noted, however, that the dates of the study limited the observation of this phenomenon, which is more common in late March, April, and May.

An attempt was made to crosscheck the area figures with the total volume processed by the timber industry. But no reliable figures are available. A DGF estimate suggests that 900,000 cubic meters of logs are processed each year. If, on average, a tree produces a volume of 3.14 cubic meters, and if five such trees are being harvested per hectare, 900,000 cubic meters would translate into an area of about 57,000 hectares.

Four GIS methods were also used to assess national and regional deforestation between 1978 and 1986. (As noted, more recent satellite images for use at the national level were not available in part because of cloud cover.) Even correlating the land cover classes for the two years was difficult. The Defor-Refor method gave the lowest result: 19,000 hectares per year. The clump and sieve method, applying a threshold of 128 hectares, produced the highest estimate: 52,500 hectares annually. But it was difficult to say which estimate was the best one.

Logistics, Types, and Methods of Forest Intervention

An estimated 80% of the exploitable timber in Costa Rica comes from the natural forest. Exploitation is generally carried out in forests outside national parks or in "reserve zones," with authorized permits from DGF that not only permit tree-cutting but also regulate timber through transportation permits and tags placed by the owner or logger on tree trunks at the site of exploitation.

According to the Forestry Law (Law No. 7174 of 1990), all harvesting operations should be regulated through a forest permit. This is granted on the basis of a study by the forest owner that indicates the objective of the exploitation and the land use capacity of the land where the operation will be carried out. A DGF permit, in addition to the technical requisites mentioned, requires the timber owner to pay a forestry tax as well as municipal taxes.

Permits for the main categories of exploitation require a forest inventory as well as a management plan prepared by a professional. In practice, management plans are really "plans for cutting"; they are used to obtain permits but they tend to have a limited technical foundation that would allow them to be used to manage a forestry enterprise and assure a continued and sustainable yield from the forest.

Cutting of more than the authorized volume appears to be quite common, whether it be in the authorized site or nearby. This illegal cutting is hard to detect because it is generally hidden through the reuse of transportation permits and licenses for logs or through clandestine transportation to sawmills at night or during holidays, when there is less control on the highways.

In the field, DGF is generally viewed as excessively bureaucratic about granting licenses and permits, as favoring large producers over small ones, and as being too centralized, particularly when solving legal conflicts. On the other hand, those wishing greater control of extraction indicate DGF's effectiveness is limited by lack of technical personnel and budget.

The team identified three principal types of forest intervention:

- Clear-cutting to change the use of lands under forest cover (to banana plantations, production of subsistence crops, and pastures).
- Selective cutting of large, valuable trees in primary or secondary forest.
- Exploitation in pasture areas that contain patches of forest or individual trees cut by owners for extra income and/or to eliminate excessive shade.

Only the first type represents deforestation, since it results in the disappearance of the forest. The second type implies intervention in an existing forest that generally continues to remain a forest. This selective logging changes a primary forest into a secondary one or an existing secondary forest into a logged-over secondary one. Either of these can generally be selectively logged again after 15–30 years (even without any management, just through letting natural regrowth take its course). The third principal category—exploitation of trees on pasturelands—is the continuation of a process that already changed the land use earlier.

The survey confirmed that clear-cutting and selective logging are driven by economic interests. While loggers do play an important role, the principal actors are landowners who wish to obtain revenue from the sale of timber, to use the land for agriculture, or both. Environmental concerns tend not to be taken into account by the owners when they are not related to on-site productivity. The team noted that timber exploitation is generally carried out with care when the land is owned by integrated sawmill or other industrial operations, which are concerned about the sustainability of the operations.

In the past, government settlement policies also played a role in deforestation. The Institute of Land and Colonization (now the Institute for Agrarian Development, IDA) put "agricultural settlements" on national lands or private farms, and in some cases on forested lands, which forced farmers to eliminate the forest for "land preparation" and

titling. The banks granted credits only for agricultural activities, which in practice required the elimination of the forest.

Forest exploitation is generally carried out with equipment and machinery; in a few cases, the extraction is done with oxen. The felling is done with chain saws. The basic operations are clearing of the bole, determination of the direction of fall, and felling of the tree. Laborers called "sierreros" specialize in felling and preparing logs. These operators, when they own the chain saws, generally charge per foot of processed timber; if the logger owns the chain saw, the operator earns a daily or monthly salary.

Logs are prepared with a chain saw on the fall site by cutting the timber into sections of 8, 10, or 12 yards (6.6, 8.3, or 10.0 meters) and eliminating branches and deformations. The timber that is extracted from the felling site is hauled away by caterpillar tractors, oxen, or skidders. Caterpillar tractors, favored by 73% of those interviewed, disturb the soil structure, logs skidded directly by winch over the soil do damage, and trails 4–6 meters wide are cut to facilitate the movement of logs. The soil also becomes compacted by pressure exerted by the tractor.

Using skidders on rubber wheels, although it also requires the opening of roads and trails, causes less compaction. The entire log is not dragged over the soil, which reduces soil damage. Extracting timber using oxen, practiced by 14% of those interviewed, disturbs the soil the least. It is limited, however, by the weight (dimensions) of logs that can be skidded and the distance of the skid.

The major mode of transport from the landings or the forest is by truck, usually with double axle or greater. This means forest roads must be built and forest exploiters must avoid marshy sites, steep slopes, sharp curves, and the use of bridges or logging pontoons for water flow. The survey found that trucks with three axles (tandem) were used in 42% of the cases, flatbed trucks (trailer with two axles on the flatbed) in 31%, and other types of vehicles in 27%.

The species and trees selected are determined by several factors:

- The internal market for timber uses less than 20% of the species from primary tropical forests, as they are generally unfamiliar with other species and their technological properties.
- Prices are low for timber species that are unknown, white, or with little structural resistance.
- Sawmills often lack adequate machinery for processing small logs.
- The dimensions of the trees that can be harvested from the natural forest are legally restricted. Permits are only granted for trees that are more than 60 centimeters in diameter to breast height in the Atlantic and northern regions. Only trees of more than 80 centimeters can be harvested in the southern zone.

According to the survey, the most exploited species in the Atlantic zone are caobilla (Carapa guianesis), laurel (Cordia alliodora), and lechoso (Brosimun spp.); in the northern zone, caobilla and cedro (Cedrela odorata); and in the southern zone, caobilla and cristobal (Platymiscium polystachyum).

Even though the study team could not visit examples of forests managed under the concept of sustained yield, the literature reports some examples of research on sustainable silvicultural practices. Examples are the sites of Tirimbina in Siquirres, Limon (Finegan and Sabogal, 1988), and San Isidro of Perez Zeledón (Picado, W., personal communication, 1991). In high-altitude primary forests, CATIE in Turrialba is researching management practices for timber and charcoal production. Also, BOSCOSA (a conservation and agroforestry project in the Osa Peninsula) told the team it intended to initiate the management of a natural forest area, with the objective of obtaining a sustained yield of the area, in partnership with forest landowners of the region.

Groups Responsible for Logging and Land Clearing

In approximately 44% of the cases surveyed, the extraction of wood in natural forests was carried out by loggers; 33% was performed by independent sawyers contracted by landowners; the remaining 23% was done by landowners themselves.

Loggers. Loggers play a pivotal role in the extraction and marketing of timber. They actively seek extraction contracts that guarantee their own business survival, and that serve as a link between forest owners and timber purchasers. However, it would not be appropriate to blame loggers for logging and the deforestation problem since in most cases they carry out their activities at the request and with the consent of the owners of the forest. In some cases, logging companies and sawmill owners are logging their own land. (It is worth noting that in these situations they are more concerned about the technical excellence of the extraction than when they work on others' land.)

Loggers negotiate a price with the owner for standing timber and are responsible for all the work in extracting timber: opening or maintaining roads; felling and preparing timber; extraction from the forest to landings for loading or to a truck; and, in many cases, transportation to the areas where timber is used. They generally own the machinery and equipment necessary for extraction. In most cases, they pay for the right to exploit timber (through taxes to the DGF) and to use municipal roads, the cost of the permit, and municipal taxes, which then are deducted from the gross price of standing timber. One of the motivations for illegal cutting is that no taxes are paid on any additional volume extracted.

Loggers extract timber from sites authorized under permit A2 (for pasturelands in use or abandoned, or abandoned cacao plantations) or under forest management plans required by permit B2 (see Annex 2 for more details on the permit system). On small farms, with sites authorized for a change in land use (permit B1), the logger generally only extracts timber, while the owner provides the labor to clear and prepare the site.

The logger contracts with the owner of the forestland by volume removed, expressed in "pulgadas maderas ticas" (PMT).3/ The measurement appears to underestimate the

---

3/ This measures the volume commonly used in Costa Rica, which corresponds to a solid section of timber 1" x 1" x 4 yards = $(2.54 \text{ cm})^2 \times 3.35 \text{ m} = 0.002161 \text{ m}^3$. Therefore $1 \text{ m}^3 = 462.7$ PMT.

volume extracted. In none of the cases surveyed were logs measured using logging rules or traditional measurements based on mathematical formulas.

Aside from financial objectives, the loggers interviewed and the members of their crews also indicated individual motivations of a practical nature. For them, forest extraction work is gratifying because it entails overcoming challenging technical problems, team effort, and the know-how required in each step of the extraction process. As the research team could confirm, there is a high risk of accidents associated with timber extraction. Various informants told of fatal accidents at work. In two cases, those who died were family members of the loggers interviewed.

Logging activities and marketing are coordinated among families. This noncommercial relationship is typical among loggers, members of extraction crews, and sawmill owners. Twenty-three loggers were interviewed, 20 of whom worked from an early age alongside their fathers. In most cases, their fathers' businesses helped them obtain part of the original capital or machinery to work independently. Several brothers who work as a team in the same extraction site were interviewed, along with cousins who work together and a set of brothers who work separately. Also, some fathers and sons were linked in the business of exploiting and marketing timber.

The interviews indicated that loggers generally have had little formal, technical training in forestry. This might be because they began early to get practical work experience. In the current circumstances, formal, technical preparation is less important for loggers than other qualities they depend on to remain competitive: personal discipline, a nose for finding contracts, business instinct, and a good sense of logistics.

For methodological purposes, the loggers can be categorized into small, medium, and large. The small ones typically own saws, a bulldozer tractor, and a four-wheel drive vehicle for transporting personnel and supplies (gasoline, oil, food, and so on). They subcontract the transportation of logs to other enterprises.

Loggers in the medium range have all the necessary equipment: up to two tractors, a log carrier (skidder), and various trucks. For them, subcontracting is restricted to needing extra help because of time or weather constraints. Many of the medium-range loggers interviewed own farms with forests, which they exploit through management plans. Some have also reforested their farms with exotic and, less commonly, native species, mainly pochote (Bombacopsis quinata) and laurel (C. alliodora). They also consistently recognize that the natural regeneration of forests is environmentally the most beneficial silvicultural method.

The large loggers have integrated operations involving harvesting, transporting, and sawing. They have succeeded in expanding operations in order to guarantee the necessary raw material for their sawmills to function efficiently. The capital earned from those enterprises allows them to acquire large farms with primary and secondary forests. The data collected suggest that the large loggers continue to exploit other people's forests, if possible, in order to maintain their own reserves for the future.

One crucial need for loggers is sufficient extraction sites to guarantee the profitability of their operations. For that, strategies of search and contracting are employed. Various ways to search for exploitation sites were recorded: maintaining contacts in the local communities who inform them about possible contracts, or locating forested farms and approaching the owners to offer them services.

The most common strategy for obtaining contracts is to pay the forest owner in advance and get his signed receipt. The contractual agreement often includes provisions for the construction or improvement of roads or for other movements of earth on a farm with an extraction site. Getting this type of work done is attractive to the farm owner, and influences his decision on whether to agree to the exploitation. Sometimes the agreement is established verbally, but this can lead to problems when the logger does not complete the work as agreed.

Sawmill owners and contracted sawyers. Sawmill owners generally work in family businesses that span two or three generations and often still use original, obsolete machinery. They generally own farms with primary and secondary forest, and tend to have an interest in reforestation programs. Also, finances permitting, owners are interested in buying land to secure primary material in the future. This type of exploitation is carried out through the so-called management plans authorized by type B2 permits.

Two small, five medium, and four large sawmills were visited. The small ones are difficult to locate. They work with tree parts (branches and deteriorating parts of logs) that are not processed by other sawmills. Also included in this category are "resawyers" who edge and refine wastes produced by sawmills of greater range. The owner of a "resawyer" was in charge of one of the illegal logging operations registered.

Medium and large sawmill owners differ in that the medium-sized ones do not own extraction equipment (tractors, log carriers, and logging trucks). This also implies that the owners of large sawmills and the large loggers are essentially the same group of people.

Contracted sawyers are operators and owners of one or more chain saws who fell, cut, and process timber by the job. The cost of preparation depends on who owns the chain saws. When the worker does not own the machine, he charges the minimum legal salary or a similar amount agreed to with the owner or the logger; if he owns the chain saw, the price is agreed on for the volume prepared. Contracting by "task" (that is, by piecework or work carried out) does not favor the worker because he does not get paid if weather conditions prevent the work. Due to the risks of felling and extraction, everyone on the contracting crew is covered by workers' compensation, paid by the contractor.

Extraction by owners of portable mills occurs in forested areas of private farms and in national areas. Valuable trees are semiprocessed into planks and blocks directly in the forest. These sawyers generally have a license from the DGF to use rudimentary sawmills and chain saws, but they often do not have specific permits for work they do on their own account or for others. In the view of the team, they play only a minor role in the exploitation of Costa Rica's forests.

Forest owners. Most forest exploitation is carried out on private properties (owned by individuals, anonymous societies, or agroindustrial companies) or on land outside protected areas where the right to use has been granted by the Institute for Agrarian Development. It appears that in Costa Rica there is a relatively clear situation regarding land registration. During the survey, no struggles or conflicts about landownership were found.

Only on certain occasions is timber exploited in reserve areas or in refuges on farms that have not been compensated by the state. Ten percent of the farmers interviewed expressed an opinion about their expectations of state intervention. In areas surrounding the National Parks, where there are rumors of state action to protect reserves, farmers are eager to exploit their forests because they do not believe that they will be compensated. This is the reason for the accelerated exploitation of forests in the Osa Peninsula, where the possibility of extending the area of the Corcovado National Park has been mentioned. So expected public intervention of this type creates incentives for rapid extraction of timber.

Farms can be classified as small (up to 50 hectares), medium (50–100 hectares), or large (greater than 100 hectares). Medium-sized farms predominate. Farms owned by anonymous societies and agroindustry companies generally are large, while livestock farms are medium-sized and those of individual farmers vary from small to medium.

In areas suitable for banana production, there is no incentive to conserve forested areas, given the high opportunity cost of lands. Banana companies either buy up cleared land (in which case the owner sells, cuts, and contracts the transport of timber) or make a global purchase, appraising areas not suitable for banana cultivation at around 60,000 colones per hectare (about $460, at the February 1992 rate of 130 colones to the dollar) and computing a certain value for exploited saw-timber used on the farm, while using planks to build bridges, laborers' houses, and offices.

Owners of forestland sell timber to loggers for the following reasons:

- Need for short-term cash for subsistence or to pay for farm labor.
- Lack of capital for the timber permit, municipal taxes, and machinery needed for extraction.
- Little or no capacity to negotiate with sawmills or plywood factories, whether from lack of information or because the volume of timber is not of interest to these industries.
- Need for roads the logger will open so the farmer can transport other products (agricultural and livestock) later.

In 23% of the cases, it was found that the landowner carried out the work of extraction. Generally these are owners of large sawmills or companies. They own the machinery and equipment necessary for extraction and they contract workers by the job (or fixed salary). In other cases, banana companies or large private owners contract labor (by daily or fortnightly salaries, or by the hectare cut and chopped) to clear-cut the land and change its category of use.

In comparing place of origin with current residence, the survey showed great mobility of farm owners, as well as a single motive for migration. In all 22 cases interviewed, the owners of the forest were not native to the area of their farms; the fundamental reason they migrated was the search for land to use for their own agricultural and forestry activities. In nine of these cases, the owners were born in the same general region of the country; in the remaining 13 cases, they came from other regions. Migrations between regions occur principally from the central valley and the central Pacific toward the northern and Atlantic zones. There are only four cases registered, corresponding to the southern region and Guanacaste, which are divided equally between migrations within and among regions. Two forest owners interviewed were born in Nicaragua.

Illegal exploiters. Three sites were identified where forest exploitations were carried out without DGF permits: two of them corresponded to cutting and in situ sawing in order to market the timber; in the third, illegal felling was done to provide space for orange trees, and the timber was used on the same farm.4/

Squatters. In the past, some areas were deforested by squatters who were later settled there more formally by IDA. Traditionally, squatters (agricultural migrants or invaders of forestlands) have been mentioned as a part of the population responsible for deforestation. They may have played a significant role in the past, but during visits to the 52 sites only one such person was encountered near a logging site. He had arrived there approximately 10 years earlier, after land had already been exploited selectively by the landowner. In the view of the survey team, squatters have at present, little influence on the deforestation process.

Problems of Survival in the Forest Industry

The forest industry is facing various limitations on maintaining a supply of timber on a sustainable basis. The four basic problems are scarcity of remaining forest stands; high competition; limitations imposed by the DGF (that is, types of permits, periods of extraction, and volumes of felling); and an increasing number of state and private conservation areas with ecological, scientific, or tourism interests.

4/ The cases of cutting and in situ sawing took place in the northern and Atlantic zones. On one side, the timber from trees that were left on pasturelands. One exploiter was the owner of the farm and the other was a neighbor. Using a chain saw, the logs were turned into fence posts that were then skidded with oxen to the road. The exploiters were on that spot during the interview, waiting for someone to transport and sell the posts to a banana farm. They did this type of extraction to supplement their income. In the other side, the survey team witnessed the illegal logging. The farm owner led the exploitation, using a small sawmill not far from the extraction site and a truck to transport the timber. Working with him was an uncle, a brother, and a neighbor. The brother stood guard on the only accessible road to the site, to warn of any strangers. Logs were being cut with a chain saw to produced planks and fence posts to be sold to banana companies for infrastructure development on farms. According to the informants, who were interviewed on the site, this is common in the northern sector of the Atlantic zone.

All loggers and sawmill owners agreed about the strong competition for wood, and many said they intended to abandon their current occupation and switch to another business. There was a consensus that those most affected would be the smaller exploiters, since they generally do not own forests. But it is important to note that medium- and large-sized loggers face problems too. Informants interested in remaining in the forest industry agreed on the need to implement strategies that guarantee an adequate volume of timber for their enterprises. Among the strategies proposed are to operate with greater efficiency, to purchase primary and secondary forest, to purchase areas with regenerative capacity for forest species, and to reforest.

Three options mentioned are suitable for less competitive operations: specialized systems for extraction and sawing, reforestation projects, and contracts in the service sector. The first option applies, for example, to exploiters who use oxen. Their services would continue to be demanded by forest owners because oxen have a lower impact on vegetation and soils. Another possibility within the specialized systems in the case of timber processing would be to concentrate on sawing logs of small diameters. The second option would involve reforestation using the capital and knowledge accumulated by the exploiters as well as the incentives available for such activity. Finally, small loggers and transporters can use their equipment in activities such as land movements and carrying merchandise. For example, some loggers and transporters expect to transport products of agroexport companies between farms and ports of departure.

Joining a nongovernmental organization or a professional council has some advantages for forest exploiters, including the provision of technical assistance and extension programs, and having one day a week reserved for members to present permit applications to the DGF. There are also public relations benefits. Loggers and sawmill owners are concerned about their deteriorating public image. There were complaints that the national community and the media were creating an image that loggers and sawmill owners are the only ones responsible for the country's deforestation problem. Professional organizations help members argue that their work rests on a rational and responsible policy of forest exploitation based on management plans, that it is technically guided, and that there are obligatory quotas of reforestation based on the quantity of trees felled.

Relationship between Population Growth and Deforestation

Demographic pressure is often identified as the principal cause of deforestation, and reducing the rate of population growth is proposed by some as the best solution to the problem. Others identify political and economic factors as determinants of environmental deterioration, while a third group pinpoints rapid demographic growth combined with economic and social policies and the level of technological development as causes of deforestation and environmental deterioration. It is also argued that poverty and the unequal distribution of wealth in developing countries can accelerate the process of deforestation and environmental deterioration.

Costa Rica's population growth rate was among the highest in the world during the 1960s, at around 3.8% annually and it continues at a relatively high rate of 2.6% a year. It is often argued that the growth in population, the incidence of squatting in forest regions, and the short-term rate of harvesting or forest exploitation are related. Yet timber

harvesting requires heavy equipment, so can squatters—a group with scarce resources who live in marginal conditions—be identified as a prime factor in logging (Lutz and Daly, 1991).

Distribution of land and campesino settlements. The squatter movement and the consequent land invasions started when the laws of Precarious Occupants (1942) and of Lands and Colonization (1961) were proclaimed (Mata, 1991). The actions of legalizing and granting lands are carried out through the Institute for Agrarian Development (IDA), which attempts to resolve problems related to the patterns of land distribution and the conflicts caused by campesinos' efforts to gain access to land.

It is important to consider the differences among the programs of IDA, in particular whether an IDA action is in response to an initiative by squatters or whether it is the result of a previous state action. During its first seven years, IDA was mainly involved with granting lands that were considered "virgin" (Mora, 1991). About half the land that IDA distributed is suitable only for forestry (Matamoros, 1987) and is located in marginal areas (Mora, 1991). Matamoros (1987) indicates that the agrarian legislation in the past stimulated deforestation as a mechanism for recognizing "improvements" and facilitating the granting of titles on the occupied lands. At present, however, as noted earlier, the role of squatters in the deforestation process seems to be more an old stereotype than a widespread reality.

Lack of direct relationship. In the best empirical study to date for Costa Rica, Harrison (1991) analyzed the direct relationship between demographic growth and deforestation. She examined the spatial relationship between deforestation and patterns of population growth using correlation analyses, which, unlike regression analyses, require no assumptions about causality.

For the frontier region (the North, Atlantic, and South Pacific), her analysis shows no correlation between the increase in population density in absolute terms and percent loss of forest cover for 1950–84, 1950–73, or 1973–84. The same is the case for relative population density for 1950–73 and 1973–84. A significant negative relationship holds only for 1950–84. In the central region, the direction of the correlation is reversed: a relative increase in population is negatively correlated with a loss in forest cover for 1950–73, but positively correlated for 1973–84. For the Pacific region, none of the correlations are significant. These findings are in line with the results of Burgess (1991), who found in an econometric analysis of 54 tropical countries that, contrary to expectation, the relationship between population growth and deforestation was negative.

Effects of Logging and Land Clearing on Biodiversity, Water, and Soils

Effects on biodiversity. Costa Rica has a high diversity of flora and fauna. More than a half-million species are estimated to exist there, including approximately 800 species of birds, 228 mammals, 218 reptiles, 160 amphibians, 130 freshwater fish, and some 10,000 species of plants (9,000 of which are native to the area). It is expected that some 360,000 species of insects will be identified (Jiménez and Poveda, 1991; National Biodiversity Study, 1991). Endemic species are as follows: mammals: 8; birds: 6; reptiles: 17;

amphibians: 34; plants: about 10 percent. Identification of more species in neighboring countries may result in a decrease of endemic species but this is no reason for carelessness! The National Study on Biodiversity indicates that little or no research has been carried out in some areas of Costa Rica; the lack of information is more evident on fauna than on flora. So only "guesstimates" can be made of the extent of threatened species.

Currently between 1,000 and 1,200 species of plants (that is, about a tenth of the total) can be considered endangered (National Study on Biodiversity, 1991); eight tree species are being threatened. Thirteen mammal species are on the verge of extinction. It was recently reported that seven endemic species of fish from the continental waters and two coral species are in danger of extinction. Some bird species are no longer found due to the total or partial decrease in their population and the destruction of their habitats, with two species on the verge of extinction. A list of 37 species of amphibians and 36 species of reptiles found to be endangered or vulnerable has been published. With respect to the fauna, approximately 75% of the insect species are exclusive to the natural forest, so the decrease or disappearance of forest areas will significantly affect them.

Twenty-seven (52%) of the sites visited belong to very humid tropical forest, 14 (27%) to the very humid to basal premontane forest, 6 (12%) to the humid tropical forest, and the rest to life zones are represented only once. Timber harvesting is carried out mainly in ecological zones with annual precipitations between 2,000 and 8,000 millimeters, an annual average biotemperature greater than 17 degree Celsius, and ranges from very humid to prehumid.

Given that this study did not involve field inventories and measurements, indirect methods (field interviews) and research done by the ecologist in the field were used to estimate the effects of logging and land clearing on the environment. An arbitrary scale was assigned to evaluate subjectively the biodiversity in plants and animals as high, medium, or low. It was registered as high when people interviewed did not indicate an apparent decrease in the number of timber or animal species (especially hunted species). The medium value corresponded to a small decrease in species, while the low value was used when a substantial decrease in forest and animal species was indicated. Data were recorded on harvested timber on each site and on animal species that interviewees reported as common. Climatic data for each site were obtained from the closest meteorologic station.

Biologically diverse primary and secondary forests are found in the ecological zones where harvesting is carried out, based on what can be observed in the field, with 61% of the sites having high biodiversity, 12% with medium biodiversity, and 27% with low biodiversity. Of the sites visited, 31 (60%) consisted of primary forests; 14 (27%) were secondary forests, initial as well as advanced; and 10 (19%) were pasturelands, abandoned plantations (mainly cocoa), or isolated trees. Two sites had mangroves. In primary forests, plant species favor the development and maintenance of mammals. Secondary forests have more fruit species, which provides food for fauna, such as birds, rodents, and monkeys.

Management plans (found in 44% of the sites) do not include an ecological study of the forest or its dynamics including the effect of felling selected trees more than 60 cm. in

diameter. But what management plans have improved is the reduced harvesting of trees with good phenotypic characteristics, which could serve as producers of superior seed for natural regeneration or for forest nurseries.

In the 23 sites with management plans, local biodiversity can be decreased. The forest can be partially homogenized through selective harvesting of a few species to a degree that varies according to the type of harvesting (whether oxen or machinery, depending on size). In clear-cutting, on the other hand, such as harvesting trees for a change in land use during conversion to banana production, there is an almost total loss of biodiversity. In this case, the DGF recommends that a biologist-zoologist be present during harvesting, a precaution in many cases not followed.

Given current management plans, in which harvesting of main trees is based on their diameter, there is a tendency toward the loss of species and a decrease in the genetic diversity. Fortunately, actual losses appear to have been small so far, in part because of the sizable national park and reserve areas. So Costa Rica continues to be rich in biodiversity, which is important for its thriving ecologically oriented tourism.

Effects on water. The aquatic tropical systems of Central America have been studied in great detail. Little basic information exists on the geochemistry of the region, the chemistry of the water, and the aquatic biota (Pringle and Triska, 1989).

The water quality was assessed in each site. The reported degree of siltation or contamination (high, medium, or low) observed was registered to complement direct observations made by the team during field visits. Contamination was considered high if those interviewed reported that the water source was contaminated and there was a decrease in the number of fish; medium was used to indicate some contamination and some decrease in the number of fish; low was reserved for cases in which those interviewed had not observed any type of contamination or a decrease in the number of fish.

The negative impact of deforestation on water bodies is small. The sediment load near clearing and logging sites usually rises, but the increase tends to be temporary, as vegetation in general soon covers the soil.

Contamination of water was found in a few sites, but it was not directly attributable to deforestation. What affects water quality significantly are plantations for bananas and, on a smaller scale, other crops, as well as gold mining and similar activities. Specific studies would need to be carried out to determine the impact.

According to those interviewed, loggers in particular do not pay much attention to the water resources and sometimes do not know their names. Some farm owners, members of nearby communities, and persons linked to ecotourism, especially in areas with contaminated rivers, noted their concern about sources of water and expressed an interest in protecting and conserving forests.

Effects on soils. The soil is an integral part of the entire ecosystem and represents the base for all terrestrial communities. To study the soil, the predominant texture, taxonomic family, and percentage of inclination was indicated for each site visited, based on visual observation. Also, soil samples in the forest and the cleared areas were taken in the north, south, and dry Pacific regions. The sites contain ultisols and inceptisols. Little deterioration was found in connection with clearing activities, and in the case of harvesting on pastures, the soil had already stabilized. On-site inspection showed low degradation (in terms of soil compaction, loss of nutrients, erosion, and/or contamination) in 53% of the sites and moderate degradation in 40%, while only 7% of the sites showed severe damage. The field visits indicated that soil cover was usually reestablished within weeks of an intervention. The main damage to the soil occurs because of roads. But even these generally grow over quickly if they are no longer used.

Land Use after the Clearing of Forests

Land in Costa Rica during the period 1950–85 showed very slow increases for agricultural production (from 10% to 12%). Livestock areas increased from 18% to 43%. Forestland decreased from 85% in 1900 to 56% in 1950 and to 33% in 1985.

The study reconfirmed Pérez and Protti's findings (1978): the Atlantic, northern, and south Pacific regions have the greatest extraction of timber. Extraction in the dry Pacific zone and the Central Valley is minimal.

The land use capacity was determined using the U.S. system of agricultural classes, in which classes I to IV are related to agriculture, class V is reserved for livestock raising, classes VI and VII are for forests, and class VIII is for protection and wildlife. In the 29 sites visited by the agronomist (14 in the Atlantic region, 6 in the north, 8 in the south Pacific, and 1 in the dry Pacific), 28% were in areas with a good potential for agriculture (classes II, III, and IV), with the rest appropriate for livestock raising (class V), forestry (classes VI and VII), or protection (class VIII). Before the forests were cut, 13% of the sites were cultivated, 33% were occupied by pastures (in use or abandoned), and 54% were primary forest or selectively logged forest. After the extraction of timber, 10% of the sites continued under cultivation, 43% had been converted to pastures, and 47% became selectively logged forests. (See Table 2.)

In general, land use patterns conform to the land use capability (10-13% under cultivation versus 87-90% under pasture or forest), even though the tendency toward "pasturing" is maintained (33% previously and 43% after harvesting), a fact mentioned by Al'enburg, Hein, and Weller (1990).

The following changes in land use were observed: the planting of more than 10,000 hectares of Gmelina (Gmelina arborea) through reforestation programs in the southern region; the planting of some 20,000 hectares of orange orchards in the northern region; the expansion of banana cultivation in the Atlantic and northern regions (reaching 40,000 hectares at the end of 1992); and tourist development in the coastal regions. On a smaller scale, pasture grounds are also converted for cultivating pineapple (2,500 hectares) and

Table 2 Land Use Capacity, Actual Use and Use Before Logging

Sites	Land Class	Actual Use(a)	Former Use(a)	Degrad-ation(b)	Recommendations
Atlantic Region					
Linda Vista	VI	5	7	1	None
Linda Vista	VI	4	3	2	Introduce legumes
Canta Gallo	V	4	3	3	Drain for bananas
Canta Gallo	IV	4	6	2	Drain for bananas
Rio Tuba	III	3	2	1	Drain for bananas
Bribri	VII	5	7	1	Deforestation
Shiroles	VI	1	4	1	Perennials
Gandoca	IV	2	1	2	Intro. fodder legumes
Boca Parismina	VIII	9	7	1	None
Tortuguero	VIII	5	7	1	None
Penshurt	VI	2	2	1	Forest upgrade
Rio Hondo	IV	6	5	2	Cultivate perennials
Rio Costa Rica	VII	4 and 8	6 and 7	2	None
"La Macha"	VII	4	4	2	Deforestation
Northern Region					
Boca Tapada	VI	8	3	3	Mixed forest plantation
Boca Tapada	V	4	6	2	Intro. fodder legumes
"La Vega"	VI	4	7	2	Intro. fodder legumes
"La Vega"	IV	8	3	1	Mixed forest plantation
Venado	VI	4	4	1	Intro. fodder legumes
Pejibaye	VI	4	4	1	Intro. fodder legumes
Guatuzo	III	5	7	1	Intro. fodder legumes
South Pacific					
Puerto Cortes	VIII	5	7	1	None
Piru	VI	8	4 and 5	1	None
Cañaza	III	4 and 1	4	1	Intro. fodder legumes
Riyito	VI	4	1	2	Intro. fodder legumes
Las Gemelas	VII	8	6	2	None
Rancho Quemado	II	1	3	1	None
Helechales 1	VII	5	7	2	Manage forest
Helechales 2	VIII	5	7	1	Conservation
Other Regions					
Samara	VIII	5		1	Conservation

a. 1=Annual Crops; 2=Perennial Crops; 3=Tacotel (2); 4=Pasture; 5=Intervened Forest; (50%); 6=Intervened Forest (75%); 7=Primary forest; 8=Deforested; 9=Tourism.

b. 1=Low; 2=Medium; 3=High.

annual or biannual crops such as palm-heart (5,000 hectares), black pepper, roots, tubers, rice, and beans. Reforestation with native and other exotic species (except G. arborea) is just beginning, but people are starting to show interest in this, which in the short and medium term would affect land-use patterns. Fournier (1989) compares the advantages and disadvantages of natural regeneration and plantations, indicating that in the dry Pacific it is possible to recover the forest over 30 years by natural regeneration.

Field observations in areas where the forest was exploited 10 years ago indicated that in some cases old pasture or perhaps croplands present a reconversion of areas cleared of vegetation toward secondary forests. This indicates the process of secondary succession (brush, early secondary forest, late secondary forests), although it was not possible to quantify this change. Secondary forest areas do not appear to be of great interest currently for loggers. But they are used for other purposes (white wood or less valuable wood in the local market, fuelwood, and posts and timber for use on local farms).

In seven cases (13% of the sample), farms were located on forest reserve lands or buffer zones. In two of these cases the type of exploitation carried out corresponded to A2 permits (extraction of remaining trees on pasturelands), while in the other five it corresponded to the so-called management plans (B2 permits). In those cases, the government had declared the zone a reserve area or buffer zone and no compensation was paid to owners, so they continued with their normal productive activities. Asked about their motives for harvesting trees in areas that are supposedly forest reserves (especially in the Osa Peninsula), farmland owners pointed out that in the face of imminent prohibition of all forest activity, it was necessary obtain "something" (part of the products) from the forest, since the government later would not compensate them.

Finally, during the field trips, forest plantations were found in the southern zone as well as the northern and Atlantic zones, especially Gmelina (G. arborea) in the southern areas, where a project of Ston Forest is establishing a plantation of 10,000 hectares. Gmelina, laurel, and deglupta (Eucalyptus deglupta) also exist in the northern and Atlantic zones. In the dry Pacific, small plantations of Gmelina, teak (T. grandis), and pochote (B. quinata) were found. These reforestation projects have been financed through private initiative as well as through government incentives for reforestation.

Economic Aspects of Tree Harvesting and Processing

The value of forestlands depends on the potential use. The situation regarding land registry and farm taxes is relatively clear. Even in IDA settlements, registered farmers are allowed to sell their rights. The average national value per hectare is approximately 158,000 colones (US$1,200), which is strongly influenced by the high value of land in the banana zones. The value fluctuates between 60,000 colones (US$460) and 300,000 colones (US$2,300) in the banana zones.

Pricing of standing timber. Most farm owners interviewed (25 cases) had a fairly good idea of the price of standing timber as well as the value of their land. The gross price in current colones for a PMT (see footnote on p.9) of standing timber is approximately a tenth of the retail price of timber, and ranges from 5 to 15 colones (4–12¢ US) depending on the quality of the wood. The price is part of the contract between the owner and the

logger. The latter generally takes the responsibility for all the paperwork required for harvesting and transport. The price agreed on is the gross price, from which the costs of taxes, tariffs, roads, and other costs are subtracted to get the net price for the owner, which may be half as large. To compensate for the forest tax, which is 10% of the value of the harvest authorized by the DGF, and for other taxes, it is common to cut around 50% more than the stated volume.

Due to the remoteness of the harvesting sites of primary forests, there are incremental costs of skidding and loading. This helps produce a certain distribution of zones among loggers, as well as a market situation in which at most a few buyers exert a disproportionate influence on the purchasing of timber in remote areas. This depresses the prices paid to farmers.

Value of standing timber. The gross value per PMT for standing timber in early 1992 was as follows: softwood such as ceibo at 5.20 colones (4¢ US), semihard wood such as caobilla at 7.25 colones (6¢ US), and hardwood (fine woods) such as pochote at 15 colones (12¢ US). These figures refer to the contract between farm owners and loggers, and to the estimated volume of usable timber without the bark and scraps. It was observed that the prices paid on-farm varied in different zones, due mainly to the distances to sawmills, and that the costs of loading varied with the topography of the farm. Since the sawn timber market is very competitive, the costs of transportation and loading "penalize" the value of the standing timber.

The costs of access-road construction by loggers, the taxes paid in advance by loggers, the costs of the forest regency, the legal fees, and the fees for processing the permit are all deducted from the gross value agreed on by forest owners and loggers. Also, the requirement that a forester "regent" help lay out management plans and inspect the timber forest (at 7,000 colones per visit), together with the time it takes to process permits in DGF offices, weighs heavily on the gross income of the sale of exploitable timber. These costs may add up to 50% of the total contracted estimate. Existing skewed market situations further depress the gross values.

The contracted volume does not always correspond to the real volume extracted by loggers. There is likely an underestimation of 10% of the actual measured volume of wood because farmers are unfamiliar with the measurement of wood carried out with a rope ("mecate"), a technique that lends itself to confusion. According to the Technological Institute of Costa Rica (ITCR, 1988), the PMT underestimates around 30% of the exploitable volume of solid timber compared with other methods of volume determination that employ mathematical formulas ("Smalian," for example).

Costs of extraction. As noted earlier, exploitations are mainly carried out by a logger who uses chain saws for the felling and preparation of logs, caterpillar tractors or skidders for hauling off or minor transport, and trucks with three or more axles for major transport. Sometimes the logs are initially transported to a loading dock from which they are later taken to the sawmill. Rarely (only when dealing with medium-sized, highly valued timber) are oxen used for minor transport.

It costs approximately 1 colon (0.77¢ US) per PMT to use the chain saw, including the cost of an assistant. An additional 4 colones needs to be included for skidding and loading, while 10 colones per PMT must be added when a loading dock is involved. For skidding with oxen, which implies an investment cost in animals of 200,000 colones (US$1,540), loading costs approximately 1 colon per PMT. For skidding with a tractor to a river or a canal, the cost increases to 5 colones per PMT, while sawing it directly on the farm implies an extraction cost of 20 colones per PMT. Overall, the labor for preparing logs, skidding, handling at the landing, and loading onto trucks costs between 5 and 11 colones (4–8.5¢ US). The cost for handling at the sawmill is high and was not calculated in previous studies (Flores Rodas, 1985; WRI, 1991).

A "typical" logger generally owns chain saws, a caterpillar bulldozer, and a platform tractor, which altogether amount to a fixed capital investment of around 10 million colones (approximately US$77,000). He contracts sawyers and sometimes for trucks for transport to the mills.

Costs of transport and processing. The final transport by truck to sawmills is also calculated with PMT and costs 5–6 colones per 150 kilometers (approximately from the Atlantic Coast to San José) and 8–10 colones from the southern zone (where the Osa Peninsula is 300 kilometers from San José). Compared with other costs of standing timber and of hauling, loading, and docking, this is not as significant as discussed in other studies (WRI, 1991; Flores Rodas, 1985). Independent truck drivers point out that there is great competitiveness in this link in the chain of costs. Truck drivers and loggers interviewed claim that in addition, in municipalities and/or associations of community development force them either to pay a toll (peaje) for repairing roads or to return with stone and filling materials for road repair.

The forest industry employs about 2,000 people. Sawmill operators—an estimated 161 in 1988 (ITCR, 1988) and 125 in 1990 (DGF, 1990)—purchase approximately 60% of their timber from independent loggers even when the company owns forest reserves, since they prefer not to exhaust their own reserves. Large sawmills are increasingly trying to integrate vertically in order to secure a future supply of raw material. Sawmills on average buy softwood at 15 colones (12¢ US) per PMT, semi-softwood at 25 colones (19¢ US), and hardwood at 45–55 colones (35–42¢ US). These prices can vary slightly, depending on the source of the wood, due to transportation costs.

According to Flores Rodas (1985) and the ITCR (1988), most sawmills operate with low efficiency because they use old equipment and obsolete technology. That is probably due to the fact that their profits have historically been very good, which discourages improvements in efficiency (around 50%). Another factor in the low quality of sawmill equipment is that improvements would require a cumbersome and costly DGF procedure in order to reauthorize operation.

Wholesale sawn prices vary with the species and the volume acquired, ranging from 30 colones for softwoods to 90 colones for fine wood (23–69¢ US). Retail prices range from 42.50 to 140 colones per PMT (33¢ US to US$1.08) for finished wood. The greater proportion of the markup is added in the processing industry. It is interesting to

note that contrary to a previous study by Flores Rodas (1985), transport represents only 6% of the retail price.

The information compiled indicates that most of the timber is acquired by four groups: the free market located in San José, sawmill operators throughout the country, the Plywood Company, and exporters of finished products (furniture stores and the PORTICO Company). The last two purchasers also acquired raw material at the free market.

International Market. The export and import of timber in log form for commercial purposes is prohibited in Costa Rica (Forest Law, Art. 134, 1986). Therefore no official statistics on external trade for this item exist. International trade in sawn wood is allowed but is subject to regulations on thickness and length (Forest Law, 1986), and DGF authorization is required.

Costa Rican timber would be cheaper in the United Kingdom market than timber from Brazil but more costly than that from Africa. In consulting with local exporters of finished wood products, some questions were raised about whether the country could produce the amounts and the quality that would be required internationally.

BIBLIOGRAPHY

ALTENBURG, T., HEIN, W., and WELLER, J. 1990. El Desafío Económico de Costa Rica: Desarrollo Agroindustrial Autocentrado Como Alternativa. DEI, San José, Costa Rica, 394 p.

BURGESS, J. 1991. "Economic Analysis of Frontier Agriculture Expansion and Tropical Deforestation." Master's Thesis, University College, London. June.

DÜSZLELN, J. von. 1991. "Pesticide Contamination and Pesticide Control in Developing Countries." In Richardson, M. (ed.). Chemistry, Agriculture and the Environment. Royal Society of Chemistry, England. pp. 410–428.

FINEGAN, B. and SABOGAL, C. 1988. "El Desarollo de Sistemas de Producción Sostenible en los Bosques Tropicales Húmedos de Bajura: Un Estudio de Caso en Costa Rica." El Chaqui (Costa Rica) Vol. 18, pp. 16–24.

FLORES RODAS, J.G. 1985. "Diagnóstico del Sector Industrial Forestal." EUNED, San José, Costa Rica.

FOURNIER, L.A. 1985. "El Sector Forestal de Costa Rica: Antecedentes y Perspectivas." Agronomía Costarricense. Vol. 9, No. 2, pp. 253-260.

FOURNIER, L.A. 1989. "Importancia de la Reforestación en Costa Rica." Agronomía Costarricnese. Vol. 13, No. 1, pp. 127-133.

HARRISON, S. 1991. "Population Growth, Land Use and Deforestation in Costa Rica, 1950-1984." Interciencia. Vol. 16, No. 2, pp. 83-93.

INSTITUTO TECNOLOGICO DE COSTA RICA; MINISTERIO DE RECURSOS NATURALES, ENERGIA Y MINAS. 1988. Censo de la Industria Forestal. ITCR-MIRENEM, San José, Costa Rica.

JIMENEZ, Q. and POVEDA, L.J. 1991. "Arboles Maderables Nativos de Costa Rica." Contribuciones del Departamento de Historia Natural-Museo Nacional de Costa Rica. No 5. 32p.

LUTZ, E. and DALY, H. 1991. "Incentives, Regulations, and Sustainable Land Use in Costa Rica." Environment and Resource Economics. No. 1, pp. 179-194.

MATA, R. 1991. "Los Ordenes de Suelos de Costa Rica." In Vahrson, W. et al. (eds). Taller de Erosión de Suelos. Heredia, Costa Rica. pp. VII–VIII.

MATAMOROS, A. 1987. "Los Recursos Forestales. Borrador de Trabajo, Estudio Actual del Ambiente. San Jose, C.R." In Desarrollo Socioeconomico y El Ambiente Natural de Costa Rica: Situacion Actual y Perspectivas Futuras. Fundacion Neotropica, Editorial Heliconia, San José, Costa Rica.

MORA, J. 1990. "La Distribucion de la Tierra y los Asentamientos Humanos en Costa Rica." In Centroamerica y Los Problemas del Desarrollo en el Campo. FAO.

NATIONAL BIODIVERSITY STUDY. 1991. Ministerio de Recursos Naturales, Energía y Minas, Museo Nacional de Costa Rica, e Instituto Nacional de Biodiversidad. 188p.

OLDEMAN, R.A.A. 1978. "Architecture and Energy Exchange of Dicotyledonous Trees in the Forest." In Tomlinson, P.B. and Zimmermann, H.M. (eds). Tropical Trees as a Living System. Cambridge.

PEREZ, S. and PROTTI, F. 1978. "Comportamiento del Sector Forestal Durante el Período 1950-1977." AOPSA, San José, Costa Rica, 59 p.

PRINGLE, C. and TRISKA, F. 1989. "Spatial Variation in Phosphate Concentrations of Small-order Stream Draining Volcanic Landscapes in Costa Rica: Sources and Implications for Nutrient Cycling." In Phosphorus Cycles in Terrestrial and Aquatic Ecosystems. Scope-UNEP. Saskatchewan Institute of Pedology. pp. 70–83.

SADER, S.A. and Joyce, A.T. 1988. "Deforestation Rates and Trends in Costa Rica, 1940 to 1983." Biotropica. Vol. 20, No. 1, pp. 11–19.

SECRETARIA TECNICA DE RECURSOS NATURALES and DIRECCION GENERAL FORESTAL. 1990. Boletín Estadístico Forestal No. 4. San José, Costa Rica. DGF. 109 p.

WORLD RESOURCES INSTITUTE, U.N. ENVIRONMENT PROGRAMME, and U.N. DEVELOPMENT PROGRAMME. 1991. World Resources 1990–1991. New York. Oxford University Press. 463 p.

WORLD RESOURCES INSTITUTE. 1991. Accounts Overdue: Natural Resource Depreciation in Costa Rica. Washington, D.C. 110 p.

ANNEX 1: DETAILS ON METHODOLOGY AND SAMPLE SITES

Annex Table 1.1 Volumes of Cuttings Authorized by DGF in the Period 1986–1990, Per Forest Region

REGION	Volume of Timber Authorized (m^3) 1,986	1,987	1,988	1,989	1,990	TOTAL
Dry Pacific	24,296	31,039	46,582	23,233	22,075	147,225
E. Central Valley	6,587	4,650	5,953	8,407	16,800	42,397
Central Valley	7,162	4,748	5,787	5,074	143,25	37,096
W. Central Valley	5,041	5,511	6,184	4,979	7,990	29,705
Central Pacific	3,979	2,493	2,257	3,591	8,724	21,044
South Pacific	49,523	45,365	39,668	29,926	60,055	224,537
Northern Zone	246,391	133,941	163,724	243,226	266,658	1,053,940
Atlantic Zone	125,769	84,416	128,539	132,681	244,406	715,811
TOTAL	468,748	312,163	398,694	451,117	641,033	2,271,755

Source: DGF, 1990. Anuario estadístico.

Note: To help understand the increase between 1989 and 1990 in the table one needs to point out that during 1989 the past Forest Law was repealed and declared unconstitutional. In 1990 a new law was proclaimed. It facilitates better record keeping of the quantities authorized at the national level, and may explain the increase.

Annex Table 1.2 Calculation on the Distribution of the Sampling for the Study on Deforestation in Costa Rica

REGION	UNPROTECTED AREA[1]	TOTAL 86-90[2]	%[3]	N[4]	PROPORTION[5]	%[3]	N[4]	PROD. AREA[6]	N[4]
Dry Pacific	40,920	147,225	6	3	664,487	6	3	6,024	1
E. Central Valley	35,171	42,397	2	1	191,355	2	1	1,491	0
Central Valley	3,260	37,096	2	1	167,430	2	1	121	0
W. Central Valley	31,040	29,705	1	1	134,071	1	1	922	0
Central Pacific	6,700	21,044	1	0	94,980	1	0	141	0
South Pacific	133,403	224,537	10	5	1,013,429	10	5	29,954	6
Northern Zone	148,610	1,053,940	46	23	4,756,868	46	23	156,626	29
Atlantic Zone	104,230	715,811	32	16	3,230,752	32	16	74,609	14
TOTAL	503,334	2,271,755	100	50	10,253,372	100	50	269,888	50

1. Unprotected forest area in each region.
2. Total volume authorized in the period 1986-1990.
3. Percentage volume authorized in relation to the total.
4. Sampling size per forest region.
5. Volume authorized per factor for exploitation (Total volume authorized/unprotected area).
6. Volume authorized, emphasized for the unprotected area (in miles of ha. and m^3).

Annex Table 1.3 Location of the Selected Sites and Observations by Survey Team

Site	Municipality	Observations
01–Canta Gallo	Palmitas, Cariari	Logging on remaining trees in pasture
02–Lomas Sierpe	Pueblo Nuevo, Guacimo	Selective Logging with DGF permit in a farm near Tortuguero National Park; contract between a logger and the two co–owners of the primary forest
03–Finca Gavilan	Puerto Viejo, Sarapiqui	Clear cutting; wood chopped for fertilization; banana plantation preparation of COBAL, a subsidiary of United Brands, in a slightly logged forest.
04–Charco del Atlantico 1	Las Marias, Sarapiqui	Clear-cutting; Use and marketing of higher and lower quality woods; farm owned by logging company, surrounded by banana plantations; only slightly logged primary forest.
05–Finca Sol	Las Marias, Sarapiqui	Clearcutting with DGF permit in primary forests. Farm owned by a large logging company.
06–Cano Sardinal	Santa Elia, Sarapiqui	Logs taken from Las Marias area through the Sarapiqui River using a towing boat
07–Casa de Lata	Boca Tapada, Pital	Selective logging contracted by the landowner with a mill. It has a management plan
08–El Jardin	Coopevega, Cutris	Forest management with intervened forest plots and reforested plots
09–El Encanto	Dos Rios, Upala	Selective logging for 1992 in a secondary forest plot, which was intervened 30 years ago. Owner is an IDA settler

10-La Avalancha	Buenos Aires, Upala	Logging in a primary forest to be converted into pasture land. Some other areas within the farm show regeneration of forest.
11-Albata	Guayabito, Guatuso	Cutting of scattered remaining trees, without permit from the DGF, to make room for an extensive orange plantation. Farm is owned by a company (Albata)
12-La familia	Catira, Guatuso	Cutting of remaining trees and on-site milling with portable equipment. No DGF permit. Use of oxen to carry the logs.
13-Las Minas	Pitahaya, Abangares	Illegal logging in the Rio Abangares watershed, which shows pollution with mercury and cyanide spilled by gold mining
14-La Purruja	Golfito, Golfito	Cutting of secondary forest with permit from the DGF. Owner shows intention to take advantage of reforestation subsidies to replant.
15-Bosque Viejo	Rio Piro, Osa	Cutting of few trees from a primary forest preserved by the owner. Timber is processed in a small mill in the same farm.
16-Li Moc	Penshurst, Valle La Estrella	Cutting of cordia alliodora (laurel) trees from a cocoa plantation, where they were used as shade. Owner has permit from the DGF and management plan, which includes replanting with the same species. Use of oxen to transport logs
17-Rio Hondo	28 Millas, Siquirres	Selective cutting in intervened forest, with permit from the DGF. The owner's main activity is production of cocoa
18-Arjade	Rio Costa Rica, Guapiles	Selective cutting with permit from the DGF and management plan in a primary forest. The owner is also owner of a sawmill. He is also reforesting the farm.
19-Charco del	Las Marias, Sarapiqui	Clear-cutting in a farm acquired Atlantico by COBAL, a banana company. The former owner of the land contracted with a logger cutting and processing of timber, before

		COBAL would take possession of the property.
20-Aguas Mansas	Rio Costa Rica, Guapiles	Progressive cutting and in situ processing using chain saws. The owner obtained the forest from squatters who previously occupied the land
21-Israel Mora	Cimarrones, Siquirres	Cutting of remaining trees in a steep pasture plot. Only mature trees were authorized for cutting
22-GARGI	Bufalo, Limon	Selective cutting with permit from the DGF and management plan in a farm devoted to timber production
23-Barro de Olla	Rio Barbilla, Limon	Selective cutting in a former cocoa plantation, with permit from the DGF
24-Coopemangle	Coronado, Desembocadura	Selective cutting of del Rio Terrabamangrove, with permit from the DGF. The bark is used to produce tannine and the logs for production of charcoal
25-Coyunda	Rio Piro, Osa	Selective cutting with permit from the DGF and management plan in a primary forest. Reforestation with exotic and native species has taken place
26-Agua Buena	Agua Buena, Osa	Cutting of remaining trees in pasture plots, with permit from the DGF. The majority of the farm is still under primary forest.
27-Barrigones	Canaza, Osa	Selective cutting with permit from the DGF and management plan for primary and secondary forest. Cattle ranching is the main activity of the farm.
28-El Mentiroso	Rio Riyito, Osa	Selective cutting with permit from the DGF. The logger owns a truck and rents a caterpillar and additional transport. Dubious testimony, which makes this interview unreliable.
29-Las Gemelas	Chacarita, Golfito	Selective cutting with permit from the DGF. The logger owns the farm, and has a very well organized camp-site

30–Santa Cecilia	Mogos, Golfito	Selective cutting with permit from the DGF in a mildly intervened forest. The logger owns a farm with natural forest and reforestation near this logging site.
31–Aporreo	Rancho Quemado, Osa	Plan to clear-cut in order to establish a pasture plot. The logger had advanced money for the timber, but this type of permit was recently suspended.
32–Campana	Linda Vista, Cariari	Cutting and *in situ* sawmilling with chainsaw, without permit from the DGF. This is a mildly intervened forest. The farm is owned by a non-authorized sawyer. Cutting is done by purchase order from banana companies, which use the timber mainly for posts and planks.
33–Sociedad Vargas	Linda Vista, Cariari	This is a cattle ranch where clear-cutting and transport of logs is done by loggers hired by the landowner. Timber is sold to the plywood company and sawmills.
34–Casas Verdes	Palmitas, Cariari	Cutting of remaining trees in farms owned by banana companies. Extensive cutting took place about six years ago.
35–Hemingway	Canta Gallo, Cariari	This is a farm with pasture and secondary forest. Clear-cutting is performed in some plots to change use of land into banana plantation.
36–El Comendador Valle La Estrella	Tuba Creek	Cutting of remaining trees in a cocoafarm purchased by a banana company, with permit from the DGF. Use of oxen and bulldozer.
37–Corea	Gandoca, Sixaola	Cutting by a logger of remaining trees in pasture land, with permit from the DGF.
38–La Balsa	Boca de Parismina,	Cutting of remaining Tortuguero trees in pasture land. The farm still has land under secondary forest and crops. Logs are delivered to PORTICO, the company that claims to do sustainable logging, via the Tortuguero canals.

39–Betancour	Jaloba, Tortuguero	Selective cutting by landowner, who is also a logger, with permit from the DGF. Logs were transporte through the Tortuguero canals.
40–El Roble	Coopevega, Cutris	Cutting of remaining trees in pasture land, with permit from the DGF. The owner is planning to make a management plan for other parts of the farm still under forest cover.
41–Chamorro	Coopevega, Cutris	Selective cutting with permit from the DGF. The management plan was formulated by a forest engineer from CODEFORSA. The logger used to be a cattle rancher until 1989, when entered into the timber business.
42–El Carmen	Coopevega, Cutris	Selective cutting of remaining trees in pasture land, with permit from the DGF. The farm also has 100 reforested hectares.
43–Cano El Recreo	Boca Tapada, Pital	Selective cutting in primary forest, with permit from the DGF. The farm is possessed by the owner of a sawmill, who also owns harvesting equipment. A forest engineer is in charge of the field work.
44–Boca de la	Rio San Juan	Selective cutting in Curena Frontera Norteprimary forest. The site is located within the one-mile Costa Rican - Nicaraguan border conservation zone; nevertheless, this cutting was autho:ized by the DGF.
45–El Diamante	Venado, Guatuso	Cutting of remaining trees in pasture land, with permit from the DGF.
46–Pejibaye	Guatuso	Cutting of remaining trees in pasture land, with permit from the DGF
47–Numa	Buenavista, Guatuso	Cutting of remaining trees in pasture land, with permit from the DGF. The logger also participates in ecotourism activities.
48–Muerte	San Rafael, Guatuso	Cutting of remaining trees in pasture land, with permit from the DGF. This a very large ranch, devoted to fattening cattle.

49-Los Angeles	Garza, Nicoya	Selective cutting in a secondary forest, with permit from the DGF. Logging is performed on a hilly topography with clear forestry potential.
50-Salina	Puerto Jesus, Nicoya	Cutting of remaining trees, with permit from the DGF. Part of the timber is used as firewood in a neighboring salt factory.
51-Helechales	Potrero Grande,	Selective cutting in Coto Brus primary forest, with permit from the DGF. This site is located within what would be the buffer-zone of La Amistad National Park.
52-Lechoso	Potrero Grande	Selective cutting in Coto Brus primary forest, with permit from the DGF. This site is located within what would be the buffer-zone of La Amistad National Park.

ANNEX 2: TYPES OF EXPLOITATION AND PERMITS

Forest exploitation in Costa Rica is generally carried out on forestland situated outside national parks, but also in forest reserves through authorized permits from the Directorate General of Forestry (DGF) that permit tree-cutting and regulate transport.

Processing of Permits

The Costa Rican forest law has scheduled different stages in the processing of permits. For example, for 1992 the last day of July was established as a deadline for receiving the solicitation of permits at the regional offices of the DGF. During the subsequent months, the DGF informed the applicant whether the application had been processed or whether more documents were needed for processing. The documents that are lacking must be received by the last working day of August. During the months of September to November, the required inspections and evaluations are carried out, and the trees that are allowed to be extracted are marked. In December, applicants are notified about whether or not their requests have been approved. Beginning on December 31, permits for extraction and transport are granted to forestland owners. These permits authorize them to carry out the extraction, which must be completed before May 1. The month of May can only be used for transport of timber to the timber consuming areas.

In all cases, permits granted by the DGF indicate the quantity of taxable timber in cubic meters authorized for extraction. The quantity can also be expressed in total volume/area, or by volume and number of trees ("matas") to be extracted.

The Requirement of Management Plans

The granting of forest permits is regulated by the DGF based on a management plan that clearly indicates the purpose of the exploitation and the land use capacity on the site where it will be carried out. Such management plans generally require a professional forester's involvement. (In general, extraction permits on unforested lands that exceed 41 trees and are less than 400 m^3 (permits A2) must include a forest inventory carried out by a professional forester. Regarding permits B1 (located on lands suitable for agriculture and change of use), when areas for extraction are greater than 5 hectares, a forest inventory by a professional forester is required. Permits B2 (forest management plans in the natural forest) must be elaborated by a professional forester.)

Requiring the involvement of professional foresters is one of the mechanisms of control established by the DGF for the correct application of management plans and the replacing of extracted timber. According to the DGF's 1991 document on technical-administrative processing for the management and exploitation of the forest in Costa Rica 1990–1994, each management plan must include the provision of technical services by the technician who wrote up the plan, as defined by Article 104 of the Forest Law, which stipulates that such technician must prepare trimestral reports on the progress of the project and submit them to the DGF. The technician

responsible must be properly registered in the professional registry established by the DGF, as indicated in Article 54, clause "d," of the Forest Law.

Types of Permits in Survey Sites and Type of Trees Felled

According to informants interviewed (87% of the cases), the majority of the timber extracted from the forest or extraction sites involved permits obtained by owners of forestlands in accordance with the regulations of the DGF. It is notable that only in three cases was it clear that the extraction was carried without forest permits (Annex Table 2.1), while the majority of informants claimed that they had some type of permit. In the view of the team, illegal felling without permits on a large scale does not exist. Commonly, however, a greater volume is cut than is authorized, and transport permits and tags for the logs are reutilized and wood is transported at night and on weekends, when there is less control.

The three cases involved small trees. One extraction that occurred inside a citrus plantation amounted to 20 trees (40 m^3). In the second case, fallen trees and some standing timber (approximately 4), located on pastureland for extensive livestock production, were taken out. The third extraction involved a sawyer, the owner of forestland located in a reserve area, who works with the semiprocessing (squaring) of timber inside the forest because. As he indicated, the DGF had not granted the permit he had requested because all the documents required for processing the permit were not submitted.

At least three farmers interviewed during the field study stated that, faced with the difficulty in obtaining extraction permits for changing the land use by small farmers, a gradual approach was used. This is known in Costa Rica as "socola" ("clearing") involving the elimination of the understory in an area of natural forest, the planting of pastures and the gradual elimination, whether it be through ringing or simple felling of upper-crown trees. Later, a permit for extracting timber on pasturelands is obtained, which does not have the same requirements as a permit for changing the land use.

According to Annex Table 2.1, the majority of permits granted by the DGF correspond to selective exploitations in the primary forest (B2): 39%. As a consequence, it can be affirmed that the greater part of the timber used in Costa Rica comes from selective exploitations in the natural forest. In these cases, the most exploited species are: caobilla (Carapa guianensis), cedro (Cedrela odorata), cristobal (Platymiscium polystachyum), gavilán (Pentaclethra macroloba), fruta dorada (Virola spp.), botarrama (Vochysia hondurensis), roble (Tabebuia roseae), cocobolo (Dalbergia retusa), pilón (Hieronyma alchorneoides), ron-ron (Astronium graveolens), and lechoso (Brosimun spp.).

A2 authorizations, the next most numerous, correspond to the extraction of timber on pasturelands (seven cases) or on abandoned cocoa plantations (three cases), and represented 19% of the total interviewed. Generally, the timber extracted corresponds to species of high value, such as laurel (Cordia alliodora), chilamate (Ficus werckleana), and, on a smaller scale, cedro amargo (C. odorata) and guanacaste (Enterolobium cyclocarpurm).

Annex Table 2.1 Types of Permits Encountered During the Survey

Type	Atlantic	North	South Pacific	South Dry Pacific	Total	%
A2	5	5			10	19
A2-B2		1			1	2
B1	2	5			7	13
B2	8	5	6	1	20	39
B3			1		1	2
B5			3		3	6
Illegal	1	2			3	6
No Information	1	2	1	3	7	13
Total	17	20	11	4	52	100

Source: Field Survey

Permits for the change in land use (B1) are less common; these require a judgment on the land use capacity for the new activities. The interviews indicated that only 13% of this type of permits were granted to banana companies (four cases) or to small farmers (three cases).

One of the interviews corresponded to an organized group (Mangrove Cooperative, "Coopemangle") that processed and obtained a B3 permit for the management and exploitation of a mangrove area dedicated to harvesting trees, fuelwood, and charcoal. This group can count on the services of an international consultant (CATIE/IUCN) and the local university (UNAH) for executing the management plan.

The type B5 permit, which authorizes the harvesting of up to 10 trees in the natural forest, was not granted in 1992, and the cases reported correspond to permits granted during 1991. One of the persons interviewed claimed that the permit was revoked before he was able to extract the timber. As a result, he lost money that he had invested in obtaining the permit.

Types of Permits for Harvesting Timber and Other Forest Products

Type A permits. These permits are authorized in areas without forest cover (in areas currently used for agricultural production).

1.1 Type A1 permits. These are authorized for being processed and used within the same farm and as improvements. The maximum volume to be granted for each farm is 10 cubic meters per year. A maximum of two permits can be granted for a period of one year.

The selection, marking, numbering, and determining the cubic content of trees can be carried out by an authorized forest inspector for ensuring that protected areas are not affected.

In protected areas administered by the DGF, the complete processing for granting the permit can be carried out by the administrator of the area, when s/he is a professional forester or the equivalent, who in all case should send a copy of the permit granted to the corresponding Regional Forest Office.

1.2 Type A2 permits. These permits, by their nature, number of trees involved, and volume of timber to be harvested require greater utilization of machinery and equipment. They can be used on the same farm or for commercial purposes.

On lands suitable for forest production (Classes VI and above), processing of a maximum of 200 m^3 per farm each year is authorized. A maximum of two permits per farm can be granted without exceeding the volume assigned. As indicated by the Forest Law, there must be a regeneration of the cleared areas accepting the relationship of 20 trees planted for 1 tree harvested in the regeneration of the volume granted for those permits that allow cutting of less than 40 trees, where the selection, the marking, numbering, and volume determination of the trees for cutting can be carried out by an authorized forest inspector. For quantities greater than 41 trees, those interested in harvesting timber must have a forest inventory done by an authorized professional forester and clearly express the type of mechanisms used for regenerating the affected areas and other steps taken for maintaining an adequate forest cover of these areas. Forest regency would be required.

On lands suitable for agricultural production (Classes I-V), the processing of a maximum volume of 400 m^3 per farm each year is authorized. Greater quantities can be authorized with the approval of the DGF.

For such requests that consist of less than 40 trees, the selection, marking, numbering, and determining the cubic content of the trees to be cut can be carried by the authorized forest inspector. For harvesting more than 41 trees, those interested must have a forest inventory done by a professional forester or the equivalent.

1.3 Type A3 permits. These permits are authorized on municipal lands (parks and green areas) and other public institutions (schools, high schools, universities, parishes, etc.). The selection, marking, and determining the cubic content will be the responsibility of the DGF and can be carried out by a forest inspector, mainly to ensure that no protected zones are affected.

2 Type B permits. These permits authorize harvesting on natural forestland.

2.1 Type B1 permits. These are permits for harvesting in the natural forest located on lands suitable for agricultural production. They are granted when the land is proved suitable for agriculture, based on the methodology that is officially applied.

On forestlands suitable for agriculture production, where the owner has interest in extracting timber without converting the land, the DGF would offer the technical support for marking and determining the cubic content of trees through their forest technicians when the area

does not exceed five hectares. When intervention is required in areas greater than indicated, the owner must contract the services of a private technician to carry out the corresponding study.

When there is a desire to change the land, the verification of the study of land use capacity and inventory should be carried out by an authorized technician.

In protected areas administered by the DGF, changes in land use and clear-cutting are restricted to the maximum, since there is a desire to manage the remaining natural forest.

2.2 Type B2 permits. These permits are authorized for the management of the natural forest and the silvicultural treatment solicited should be fully justified for guaranteeing the permanence or increase of the resource of natural forests located on lands suitable for forest production, in which the regeneration of the areas intervened is obligatory. Changes in land use and clear-cutting are prohibited.

Forest management, whatever the area, should include technical forest services for the period indicated by the management plan. The technician acts as a forest regent.

All exploitation of the forest within a protected area administered by MIRENEM must be carried out through a management that has the objective of a sustained yield in an integral way for which, besides the aspects previously indicated, the acceptability of the property, the environmental impact that the exploitation implies, and the objectives that are pursued in the area will be considered. For exploitation within the protected areas administered by the DGF, consultation is obligatory and must be carried out through the Subdirectorate General of Forestry.

2.3 Type B3 permits. These permits are authorized for exploiting other products from the forest that are not timber for sawing, palmheart, and products from the thinning of plantations.

On lands inside the protected areas administrated by the DGF, authorization is required to transport the following products: vines, charcoal, fuelwood, varilla para puntales, ornamental plants, palm-heart, wool, and mangrove bark.

This type of permit will be processed and authorized by the administrator of the protected area with communication to the corresponding Regional Forest Office.

2.4 Type B4 permits. These permits authorize the harvesting inside forest areas for the construction of trails and roads for access to farms, population centers, or caserfos. They are only granted in the area corresponding to the right of way, which for rural roads is 14 meters wide.

The construction of access roads that affect forest areas will be restricted and will be oriented toward special objectives that will be evaluated carefully. The main considerations will be the importance of access and the possible damage it may cause.

2.5 Type B5 permits. These permits authorize exploitation of a maximum of 10 marked trees for each farm per year in the natural forest when the needed species is not found in the unforested areas. The construction of trails or the use of mechanical traction (chapulín, skidder, and caterpillar) are prohibited. The timber can be processed in the farm.

Trees must be marked and numbered, and the cubic content determined by an authorized professional forester from the DGF, and when possible should be marked in the periphery of the forest.

The request of a permit for cutting more than 10 trees must be processed as B1 or B2.

3 Type C permits. These permits authorize the harvesting of trees in plantations and windbreaks, located on lands suitable for agricultural production. They can be processed throughout the entire year.

ANNEX 3: POPULATION DYNAMICS

Costa Rica has the mortality rate of an industrial nation, with life expectancy of 77 years, while the birth rate resembles more those of developing countries. Between 1900 and 1950 the population increased from 304,000 to 862,000 inhabitants; in the subsequent 40 years the absolute growth was much greater, arriving at 3 million inhabitants at the end of 1990. This coincided with a significant decrease in forest area (Annex Table 3.1). It is this background that gives rise to the hypothesis of an inverse relationship between the growth in population and the forest cover.

Annex Table 3.1
Estimates on Population and ForestCover in Costa Rica for the Selected Years

Year	Population[1]	Ha. of Forest[2]
1950	861,800	3,400,000
1973	1,868,100	2,000,000
1977	2,087,000	1,790,000
1984	2,568,900	1,520,000
1987	2,790,635	1,475,940

Sources:
[1] CELADE, MIDEPLAN, DGEC, 1988. Estimaciones y proyecciones de problacion. San José, CR.
[2] Año 1950–84, promedio calculado por A. Mata con base en las fuentes: Fournier (1985), Junkov (1984), Perez y Protti (1977), Joyce (1969), Flores-Rodas (1985), Rodriguez and Varga (1988). Año 1987, Boletin Estadistico Forestal No. 4. DGF.

Population growth and migratory flows vary from one zone to another. In the country, the internal mobility of the population is high and is seen to be promoted by different reasons: hope for a better way of life and search for work or educational opportunities, among others. In Annex Table 3.2, it is possible to observe that in the Atlantic and Northern zone, the demographic growth is greater than in the other regions. This is part due to internal migration.

A study carried out by MIDEPLAN, CELADE, and the DGF (1987) divides the growth rate in the natural growth and the effect of migration for the intercensus period of 1973–84. According to the study, in the dry Pacific region, migration acts as a reducing factor of 58% in the natural growth of the population. At the other extreme, in the Atlantic region, the growth rate is accelerated by 45% due to migration.

Annex Table 3.2: Demographic Indicators Selected From the Forest Regions and Planning in Costa Rica Around 1980–85

	Rate of Growth		Net Rate of Migration	Average Number of Children (Fertility rate)	% Rural Population	Net Rate of Women's Participation	% of Literacy
	Total (a)	Natural (b)	(c)	(d)	(e)	(f)	(g)
Regions of Study							
Atlantic Zone	3.43	2.38	1.08	4.53	70	12.30	89
Northern Zone	3.37	3.21	0.15	4.37	87	15.60	87
South Pacific	2.33	2.44	-0.12	4.55	86	11.00	89
Dry Pacific	0.80	1.93	-1.13	4.14	73	12.60	90
Other Regions							
Central	2.43	2.34	0.08	3.14	44	24.50	95
Central Pacific	1.02	1.51	-0.50	3.65	64	14.60	89
Total Costa Rica	2.30	2.30		3.50	55	20.70	93

(a) Annual average for the period 1973–85, rate x 100
(b) Estimate for the period 1979–84, rate x 100
(c) Period 1979–84, rate x 100
(d) Average number of children for every woman
(e) 1984, rate x 100
(f) 1984, population in 10 years or more

Source: MIDEPLAN, CELADE, DGEC, 1989: Migracion interna per regiones, provincies y cantones 1968–1984 (a,b,c,f,g). CELADE, MIDEPLAN, DGEC, 1988: Estimaciones y proyecciones regionales de poblacion 1975–2000 (d); DGEC: censo de poblacion de Costa Rica 1984 (e)

It is important to analyze the migratory variable in relation to the economic activity of the regions since employment is one of the main motivations for migration (MIDEPLAN, CELADE, DGEC, 1989). In the period 1979–84, the dry Pacific or Chorotega region was described as having the highest index of emigration represented by a net rate migration of -1.3%. The region expanded its rice cultivation, which is highly mechanized, thereby requiring less labor. On the other hand, the Atlantic region, considered as the most attractive in terms of migratory flows (the net rate of migration equalled 1.08%) coincides with the region in which the most important economic activity requires a greater participation of labor: banana cultivation (see Annex Table 3.3).

Annex Table 3.3 Demographic Indicators and Agricultural Production of Forest Regions and Planning in Costa Rica Around 1980–85

Regions of Study	Net rate of Migration (1) (a)	% Agricultural in Immigrants (2) (b)	Distribution of Some Products Per Region (3) Banana (c)	Rice (d)	Cattle (e)
Atlantic Zone	1.08	66.5	76.1	7.8	7.8
Northern Zone	0.15	66.9	7.3	5.3	26.5
South Pacific	0.12	56.3	15.0	10.6	12.8
Dry Pacific	1.13	41.5	0.1	54.9	27.3
Other Regions					
Central	0.08	16.5	1.2	0.8	14.3
Central Pacific	-0.50	40.2	0.3	20.6	11.3

(1) Period 1979–84, rate x 100
(2) Period 1979–84, percentage of immigrants for every activity: agriculture, hunting and fishing
(3) 1984, percentages

Source: MIDEPLAN, CELADE, DGEC, 1989: internal migration per region, province, and central 1968–84: (a); calculated on the basis of the 1984 population census. DGEC (b); MIDEPLAN Control information system (c,d,e).

ANNEX 4: POSSIBILITIES AND DIFFICULTIES OF ASSESSING DEFORESTATION IN COSTA RICA WITH GIS INFORMATION

Studies of deforestation trends in Costa Rica have been conducted in the past, but many are outdated, referring to deforestation from before 1980. An update based on more recent satellite imagery was therefore attempted. However, for recent years insufficient scenes were available with an acceptable cloud cover percentage. So Landsat scenes from 1986 and 1987 had to be used. Results were compared with existing land cover data from 1978 to assess deforestation.

For one region, the Atlantic Zone, the spectral data for 1978 and 1988 were also available, aside from 1986 data. This made a comparison of forest cover between 1978, 1986, and 1988 possible.

The generalization entails the mapping of the set of original cover classes to a set of more general cover classes. In Annex Table 4.1 the general classes for the national and regional land cover inventory are given.

Annex Table 4.1 Land Cover Classes, 1986

Class value	Description
0	Background
1	Forest
2	Dense Woody Vegetation
3	Dense Secondary Vegetation, Plantation crops (e.g. Banana)
4	Scrubland and cropland
5	Grassland
6	Open Woody or Open Shrub Vegetation
7	Bare Soil and Built-up area
8	Waterbodies
9	Wetland vegetation (e.g. 'Yolillal'), Mangrove forest
10	Clouds
11	Shadow of clouds

For each Landsat-MSS scene, land cover is thus described in terms of these cover classes. For the land cover inventory of the Atlantic Zone a set of more specific land cover classes was applied.

Methods for Assessing Deforestation

Three methods were used to assess national and regional deforestation between 1978 and 1986.

(a) Through subtracting the 1986 total forest cover area from the 1978 total forest cover area. This method only considers map statistics and not the location of the forest areas. The method is referred to hereafter as comparing map statistics.

(b) Through the overlaying of both maps and identification of areas of change with associated type of land cover change. Because the comparison is on a per pixel basis (areas of 100 x 100m), the method is sensitive to the geometric inaccuracy of both maps. When the positions of the same forest area differ this will result in an area incorrectly classified as deforested. This requires clumping of pixel elements and subsequent sieving of areas smaller than a user specified threshold (the clump and sieve method). Two threshold values were defined: 128 and 320 hectares. Given a relative geometric accuracy of 400 meters, deforestation areas of 128 hectares might easily result as consequence of geometric error.

(c) Through subtracting the total area of reforestation from the total deforested area (defor-refor method). It departs from the idea that a relative error in the positioning of the forest areas leads to areas incorrectly classified as deforested and reforested. The drawback of this method is that difference in aggregation level between both maps will affect the results, because it may lead to areas wrongly classified as reforested.

For the Atlantic Zone the deforestation was assessed independently. This was done by comparing the statistics of the 1978 and 1986 land cover map of the Atlantic Zone. With respect to the deforestation zones it also involved the 1988 land cover map. The comparison of map statistics requires map correlation, because for each map a different set of land cover classes applies.

Correlation of land cover classifications is a rather difficult task because results might differ considerably as consequence of the different sensor characteristics of the satellite platforms. The sensors measure in different spectral wavebands and differ with respect to their resolution. It implies that the spectral characteristics of a cover type depends on the satellite platform used. This influences the classification and herewith also map statistics. These differences should be accounted for when comparing classification results. (For example, differences in pixel size imply that certain objects can be recognized in a scene with high resolution while they might not be recognized in a scene with lower resolution. An example is given by the lagoons and drowned valleys. They were recognized on the 1986 Landsat-TM scene and on the 1988 SPOT scene but not on the 1978 MSS scene. The forest area has to be corrected for the area of lagoons and drowned valleys in order to compare the different scenes.)

Another difficult element is cloud cover. Correction in cover percentages were made for cloud cover and shadowed parts, as well as the fringes of clouds, often (incorrectly) classified as one or another cover type.

National Deforestation from 1978 to 1986

The three above methods were used to calculate the national deforestation. The results are presented in Table 4.2

Annex Table 4.2
Deforestation in Costa Rica from 1978 to 1986 Applying Different Methods of Calculation

Method		Deforested area	Deforestation rate
1. Comparing map stat.		315450 Ha.	39400 Ha/Yr
2. Clump and Sieve	Sieving area < 128 Ha.	420449 Ha.	52556 Ha/Yr
	Sieving area < 320 Ha.	277509 Ha.	34688 Ha/Yr
3. Deforestation -	Reforestation	158512 Ha.	19814 Ha/Yr
Average		292980 Ha	36622 Ha/Yr

The Defor-Refor methods gave the lowest results. In part this may be due to the higher level of aggregation of the 1978 land cover map. The Defor-Refor number may represent an underestimate.

The clump and sieve method, applying a threshold of 128 hectares, produced the highest estimate. Applying a sieve factor of 128 hectares is considered rather low, given the geometric accuracy of 400 meters1/. One would therefore expect that it overestimates the deforestation area. The overestimation might be partly offset by the underestimation of deforested area as result of difference in aggregation level of both maps. On average the four estimates amount to 292980 ha or 36622 ha per year.

For comparison, data on deforestation of earlier periods are given (Annex Table 4.3).

1/ The CCT land cover map of 1978 showed some geometric inaccuracies (distortions) for which corrections were made in order to fit the map to the 1986 land cover map. The relative geometric accuracy of 400 meters resulted, referring to the error in positioning of the 1978 map with respect to the 1986 land cover map.

Annex Table 4.3 National Forest Area and Clearing Rates (1940–1983, based on Sader and Joyce, 1988)

Year/Period	Forest area (km^2)	Deforestation (ha^2/Yr)	Clearing rate (km^2/Yr/total area)
1940	34206		
1950	28642	55,600	1.1%
1961	23035	51,000	1.0%
1977	16154	43,000	0.8%

Regional Breakdown of Deforestation Figures

Forest cover and deforestation rate were calculated for separate regions as shown in Annex Table 4.4. The data show that the largest deforestation has occurred in the Zona Norte with an estimated minimum of 56,416 hectares over eight years and a maximum of 123,107 hectares. This is considered very high given the relatively small size of the region. Visual analyses revealed that deforestation mainly occurred along the San Carlos-Los Chiles road, concentrating around the villages of Concho and Boca Arenal. The Zona Sur (8) had a decrease in forest cover between 42,000 and 75,000 hectares in the period 1978–86. Deforestation has concentrated in the area connecting the Osa peninsula to the mainland, in the area south of city of Neily, and in the area stretching from Palmar Norte to Portrero Grande in the Coto Brus valley. Also, the Cordillera de Tilarán (5) showed a decrease in forest cover estimated between 23,000 and 31,000 hectares. Large areas of deforestation were observed in the area north of the cities of Miramar and San Ramon. The deforested areas corresponded to former spurs of the forest area covering the higher parts of the mountain range. Smaller deforested parts were encountered north of the village Bajo Caliente southeast of Tilarán and near Fortuna. The Zona Atlantica Norte (1) experienced deforestation estimated between 10,000 and 26,000 hectares. Deforestation has occurred as well in the agricultural frontier (to be specific in the area north of Ticaban and the Cerro Negro and the fringes of the Lomas de Sierpe') as well as in the agricultural areas, where remnants of the forest areas were cut (for example, areas corresponding to the settlement schemes of El Indio in the Nequev).

For regions 2, 6, and 7, ambiguous results are obtained, and those for region 4 are not usable because of high cloud cover in 1986. For the Cordillera Central (2), no deforestation was estimated given the negative values for deforestation (indicating 'reforestation'), applying the comparing map statistics and the Defor-Refor methods and the relatively low values obtained with the clump and sieve method. Areas indicated as reforested are due to errors in either land cover maps. The deforested area (clump and sieve method) represents less than 2% of the section area, which is within the error margin. Also, visual analysis of the resulting maps did not show larger deforested areas. In the Guanacaste region (6) a considerable deforestation area resulted when using the clump and sieve method, while the results of the other methods indicated a limited increase in forest area. The latter is probably the consequence of the strongly segmented forest area in this section, resulting in many small forest areas disregarded in the 1978 map. Part of the deforestation area indicated by the clump and sieve method must be due to the different mapping conventions. However, some parts

de seem to represent actual deforestation. These areas are near Cuajiniquil, in the neighbourhood of the village Portegolpe, and along the road of Carmona to Sta. Cruz. Contradictory results are also obtained for the Talamanca region (7). The areas indicated as deforested, as well as reforested, are rather small when compared with the total section area. The indication of deforested area is partly due to cloud cover and to difference in mapping conventions. One larger area, north of Buenos Aires

Annex Table 4.4 Area of Deforestation (1978–1986) in the Eight Regions

Area name	Total Area	Methods of calculation			
		Comparison Map Stat.	Clump & Sieve <128 Ha.	Defor-Refor <320 Ha.	
1. Atlantic Zone N.	396,624	25,566	27,827	13,820	10,071
2. Cordillera Central	349,069	-18,649	11,246	5,920	-23,410
3. 'Zona Norte'	418,183	123,107	77,812	56,416	80,972
4. North-West	540,371	93,939	55,944	35,154	24,819
5. Tilarán	214,114	31,131	32,093	23,590	30,037
6. Guanacaste	793,091	-2,972	74,777	50,317	-21,640
7. Talamanca	1,330,898	-12,037	67,364	41,274	-30,249
8. 'Zona Sur'	562,583	74,682	73,386	51,017	42,215

(on the Pacific slopes of the mountain range) shows actual deforestation, with other areas spread across the section. These are found around Palmares; in the Coto Brus valley; northeast of San Vito in the mountainous area against the Panama border; and in the hills south of Cartago, near Santa Maria. At the Atlantic side of the Talamanca region deforestation is only indicated in the Talamanca valley. Further assessment of deforestation in this part is hampered by the high cloud cover in the 1986 scene.

Limitations

Deforestation can be assessed with only a limited degree of accuracy for the following reasons:

- Land cover classifications themselves are generally not very accurate. For the 1986 ZAN classification, a 94 percent accuracy was obtained for the classification of forest. This is considered very high, but it required long preparation and extensive testing of the training statistics, and the classification was carried out in a restricted area, limiting the variation in land cover types. For the 1988 land cover classification, training samples were selected only in the ZAN. It resulted in large forest areas in the Zone Norte to be classified as dense woody vegetation, indicating that retraining of the classifier should be done when new areas are incorporated. The accuracy of the classification of the different scenes could not be determined because the accuracy of the forest cover maps is unknown.

- One evident source of error is the difference in the materials used, referring to the resolution and spectral characteristics of the imagery and level of aggregation of maps. It means that class definitions will not correspond for the different classifications, making the correlation between classification products necessary. Thereby an additional source of error is introduced. Especially with respect to the 1978 land cover map, the lack of information on the processing steps make the interpretation of results and the statements on the accuracy very difficult.

- Extrapolation of the results is required when no data are obtained for part of the area at issue as consequence of cloud cover or because only part of the area is covered by the scene. As regards the 1986 landsat-MSS, mosaic cloud cover was considerable for the extreme northwest area, the southern region (Zona Sur), and the Talamanca region. Clouds covered more than 10 percent of the total mosaic, influencing the accuracy of the final results.

- For countries with a humid tropical climate, like parts of Costa Rica, optical remote sensing platforms provide less opportunity for acquisition of good quality data. This is illustrated by the fact that 1986 is the last year for which a mosaic could be made with an acceptable cloud cover percentage.

For these reasons, different ways of calculating the deforestation have been applied. The results then indicate a wide range in which the actual deforestation may have taken place.

Deforestation Rates 1963–86

In Annex Table 4.5 data on forest cover and clearing rates are presented, based on the CCT and WRI report (1991) and on our own data. The deviating figures for 1986 are related to the interpretation of the class of dense woody vegetation of the 1986 land cover classification. A considerable area is classified as such. For correlation of the 1986 data to the data from earlier periods, the class dense woody vegetation was listed as secondary vegetation, given its smooth canopy surface in comparison to primary forest. However, the 1986 dense woody vegetation (DWVEG) area corresponds very well to 1978 forest area.

Annex Table 4.5 Deforestation Rates (1963–1986)
(based on CCT & WRI, 1991 and own data)

Year/Period	Primary Forest (km^2)	Secondary Forest (km^2)	Deforestation (km^2/Yr)	(% of nat. ter.)
1963	31,543	2,990		
1973	26,660	2,836	488	1.0%
1978	24,498	1,920	432	0.9%
1986	15,582	7,683[3]	[1]1,115	2.2%
			[2]394	0.8%

1. Deforestation when only considering primary forest. Method for calculating deforestation: comparing map statistics.
2. Deforestation when considering the total of primary and secondary forest. It is assumed to represent the more correct figures on deforestation.
3. Corresponds to the area of dense woody vegetation, which has a differently meaning than secondary forest.

When DWVEG is taken to denote forest vegetation, a yearly deforestation of 0.8 percent (or 0.9, depending on the calculation method applied) results. This is in agreement with the clearing rate of earlier periods.

When only considering the 1986 area classified as forest for the calculation of deforestation, a yearly decrease of 2.2 percent is obtained, representing a rather sudden and sharp increase in deforestation as from 1978. It would be in agreement with the 2.4 percent clearing rate for the

1977–83 period, calculated on the basis of data from the Sader and Joyce. However, it must be remarked that their 1983 forest cover information is based on another data source than used for the preceding four dates. Also, the figures for forest cover are very low when compared to the data listed elsewhere.

When 0.8% is accepted to represent actual deforestation, a decrease in clearing rate would be suggested. However, this decrease cannot be considered significant.