Fuelwood Supply for Managua, Nicaragua
Sustainable Alternatives for the Las Maderas Fuelwood Supply Region

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MITRE

Fuelwood Supply for Managua, Nicaragua Sustainable Alternatives for the Las Maderas Fuelwood Supply Region

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ABSTRACT

This is a preliminary investigation of the fuelwood supply for Managua, Nicaragua with particular emphasis on the supplies emanating from the area to the northeast of Managua around the town of Las Maderas. The study assesses the effect of fuelwood harvesting in this area, characterizes the commercial fuelwood industry active between Las Maderas and Managua and makes a preliminary estimate of the fuelwood supply and demand relationship between the Las Maderas region and Managua. The report includes a presentation and critique of potential sustainable alternatives for the Las Maderas fuelwood supply region including charcoal production and alternative forestry management techniques. The report concludes with a summary of the findings and recommended actions.

ACKNOWLEDGEMENT

The authors of this study wish to express their gratitude to key individuals at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and the Nicaraguan Instituto de Recursos Naturales y del Ambiente (IRENA) who provided the MITRE project team support in this study. In particular, we are grateful to Nico Gewald of CATIE, Costa Rica and Augusto Otárola of CATIE, Nicaragua who provided leadership and administrative support as well as useful suggestions in our research efforts. Paul Dulin of CATIE, Costa Rica, who accompanied the MITRE team throughout the Nicaraguan portion of this study, responded above and beyond all expectation as an informed guide, translator, research assistant, and most of all, insightful team participant. Many of the photographs in this document were a result of his quick photographic eye.

This study would not have been possible without the dedicated cooperation of the IRENA Fuelwood Project Staff under the direction of Miguel Reyes. The following IRENA staff members, formed the IRENA counterpart to the MITRE project team:

MAGALY URBINA
HUMBERTO BEJARANO
CESAR CORDOBA

The success of this project, in no small part, is dependent on the work and insight of these dedicated individuals. They provided the MITRE team constant attention and assistance during our two week stay in Nicaragua. Their expert knowledge of the Nicaragua fuelwood situation, the Las Maderas region and Managua itself is infused in the analysis and results of this report. Their patience, good will, and humor made all of the efforts of our Nicaraguan visit most enjoyable and meaningful.

Other individuals and organizations in Nicaragua were generous with their time and assistance, providing the MITRE/IRENA team with information resources crucial to the completion of this study. Their names and affiliations are listed in Appendix A.

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GLOSSARY

Spanish Terms

barrio	a geographically delineated neighborhood in Managua.
bolsa	a small sack measuring about 1.7 liters.
córdoba	Nicaraguan monetary unit.
empresario	directly translated as an entrepreneur - in the context of the Las Maderas region, the local name given to the fuelwood business operator.
leña	fuelwood
manojo	a bundle of 5 rajitas tied with thongs of bark.
marca	a stack of raja size fuelwood measuring approximately 2 meters wide and 1 meter high.
raja	a single piece of split round wood 10-15 cm in diameter and 70-80 cm in length
rajita	a single piece of split wood 2-3 cm in diameter and 70-80 cm in length.

Abbreviations

AAC	annual allowable cut
AID	United States Agency for International Development
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
cm	centimeter
CONARCA	Comisión Nacional de Renovación de Cafetales
C$	Córdoba
°C	degree Centigrade
DBH	Diameter Breast High
ft	feet
g	gram
ha	hectare
IRENA	Instituto de Recursos Naturales y del Ambiente
J	joule
kg	kilogram
km	kilometer
lb	pound
LPG	liquefied petroleum gas
MAI	mean annual increment
MT	metric ton
mm	millimeter

m	meter
NPP	Net Primary Productivity
ROCAP	Regional Office for Central American Programs (for AID)
R&D	research and development
S.G.	specific gravity
TJ	terajoule (10^{12}J)
yr	year

Currency Conversion

U.S. $1.00 = C$10.00 (official)

U.S. $1.00 = C$30.00 (approximate comparable value)

1.0 INTRODUCTION

Background

The demand for fuelwood in Nicaragua is substantial. Recent national surveys state that fuelwood accounts for 40 percent of the total energy consumption in the country (INE-1981). For the country as a whole, 61 percent of the total population uses fuelwood for cooking. Even in urban areas where incomes are higher and alternative fuels are available, 35 percent of the population cooks with fuelwood.

Managua, the capital city of Nicaragua, with a population of 615,000 in 1980, contains 42 percent of the total urban population of the country (INEC-1981). Although definitive fuelwood demand figures for Managua are not available, applying the national percentages to the Managua population, gives an estimate of 215,000 residents that use fuelwood for cooking.

Managua, similar to other Central American capitals such as Guatemala and Tegucigalpa, has a very active commercial industry centered on the supply, cutting, delivery, and marketing of fuelwood for Managua. Fuelwood is cut in the regions surrounding Managua, transported by truck to the city and sold as a commodity in markets and neighborhood stores.

Although the percentage of fuelwood users in Nicaragua has dropped somewhat over the past fifteen years, increases in international petroleum prices have made energy alternatives of liquefied

petroleum gases (LPG) and electricity difficult to afford. As these prices continue to rise and population continues to increase, it is expected that the demand for fuelwood will continue to increase.

These circumstances bring to bear the important national question for Nicaragua as to whether the supply of fuelwood for Managua is adequate to support the demand.

Central American Fuelwood Project

As part of the Central American Fuelwood Project sponsored by the Regional Office for Central American Programs (ROCAP) of the United States Agency for International Development (AID), the Centro Agronómico Tropical de Investigación y Enseñanza* (CATIE), is performing a number of survey, analysis, and demonstration programs throughout Central America to define and demonstrate effective programs for improving the fuelwood supplies in Central America. In its efforts in Nicaragua, CATIE has established a joint working relationship with the Nicaraguan Instituto de Recursos Naturales y del Ambiente (IRENA).

In relation to the Managua fuelwood supply question, CATIE and IRENA have focused on an area to the northeast of Managua in the region surrounding the small town of Las Maderas. This region is a major source of fuelwood for Managua and also the focal point for many of the small individual ventures in the fuelwood industry. The area is of major interest to CATIE because, with the structure

*Tropical Agricultural Research and Training Center.

of an existing commercial fuelwood industry, the Las Maderas region may hold a key for resolving similar fuelwood/deforestation problems in other locations in Central America.

Objectives of Study

The objectives of this study of the fuelwood supply to Managua from the Las Maderas region are:

- to assess the extent of deforestation in the Las Maderas region
- to characterize the operation of the commercial fuelwood industry operating out of Las Maderas
- to identify preliminary supply and demand relationships for fuelwood between the Las Maderas region and Managua
- to identify alternatives to insure a sustainable fuelwood supply and healthy commercial industry in the Las Maderas region
- to recommend actions to be taken

Time Frame of the Study

This study was performed over a ten-week period from October to December of 1981, with minor additions and revisions in early 1982. The MITRE team spent two weeks in Nicaragua for data collection and portions of the remaining weeks for analysis and documentation.

Clearly the short time frame of this effort precludes an in-depth analysis and well-substantiated conclusions. The goal of the effort from the authors' viewpoint is to provide initial insight, an indication of the nature and magnitude of the problem, and suggested directions for continued programs and investigations.

Contents of the Report

Section 2.0 of this report provides a word picture of the fuelwood system as it begins in Las Maderas and ends in consumption in the homes and cottage industries of Managua. Section 3.0 gives a summary of the economics of the current commercial fuelwood system. Section 4.0 provides an assessment of the demand for fuelwood in Managua. Section 5.0 follows with a more detailed look at the forestry, land use, and productivity aspects of the Las Maderas region. Section 6.0 provides a discussion of alternatives to the current Las Maderas/Managua fuelwood system. Finally Section 7.0 provides a summary of the conclusions and recommendations of the study. The reader interested in only an overview of this study, should proceed directly to this final section.

Five appendices provide additional supportive information for the study. Appendix A is a list of the individuals in Nicaragua who, in addition to the IRENA counterpart team, provided support to this study. Appendix B is a description of a set of tree samples MITRE took in the Las Maderas region. Appendix C presents a description of the soil characteristics of the Las Maderas region. Appendix D is a report written by Nico Gewald and Paul Dulin of CATIE describing their March 1982 measurements of vegetation in the region. Finally Appendix E is a listing of scientific and common names of dry forest shrub and tree species from the region.

Wood Moisture Content and the Presentation of this Report

The traditional forestry practice in wood energy analysis is to measure wood weight in oven-dry weight, that is, actual weight minus the weight of the entrapped water. For demand, transportation, and end-use energy aspects, knowledge of wood water content and the actual weight is more important than oven-dry weight. For this reason, in the demand related analyses of this report, Sections 3.0 and 4.0, 30 percent moisture wood weights are used. The wood supply sections of Section 5.0 and 6.0 use oven-dry measures of wood weight. The conclusion Section 7.0 converts all measures to 30 percent moisture weight so that meaningful supply/demand comparisons can be made.

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2.0 DESCRIPTION OF THE FUELWOOD SYSTEM

2.1 Fuelwood From the Las Maderas Region

Figure 2-1 shows a map of Managua and the Las Maderas fuelwood supply region. The village of Las Maderas is situated in the east center of the area. This village, located 51 kilometers northeast of Managua on the Pan American highway, is a focal point for the fuelwood cutting activity in Las Maderas.

The Las Maderas region covers approximately 680 square kilometers. As seen from the contours on the map, the terrain varies from flat in the southern and western areas to hilly in the northern and northeastern areas. The altitude varies from the 39 meter level of Lake Managua to about 600 meters for the hills to the north. Mountains rise to 1100 meters just to the north of the western portion of the region.

The entire region is quite dry, receiving about 1000 mm of annual rainfall (INEC-1981). The western lowland area around San Francisco Libre* appears to be noticeably dryer than the eastern and highland areas. Rainfall patterns match those of all of Central America with rains falling from May to October and practically no rain from November through April.

*Formerly San Francisco del Carnicero

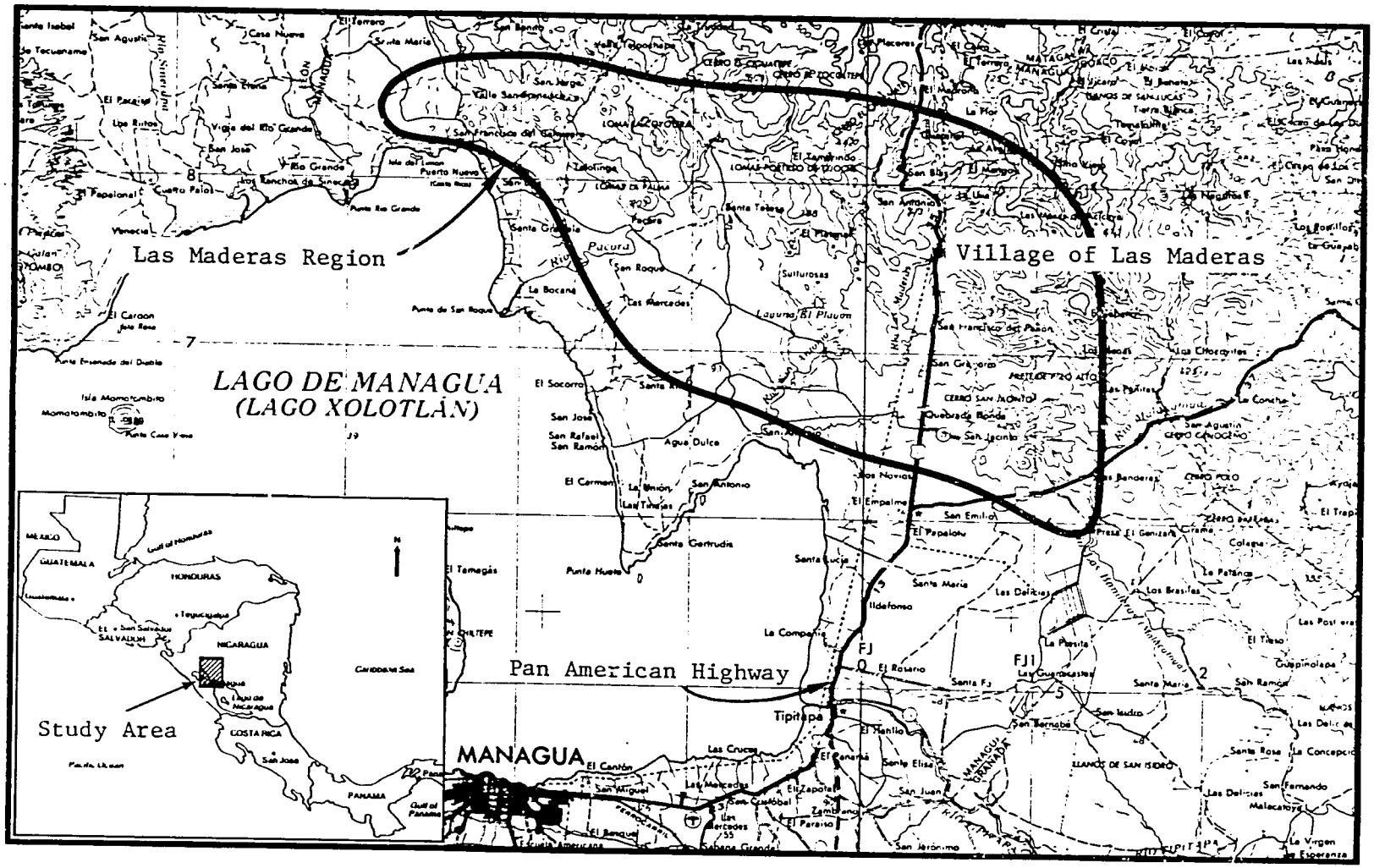


FIGURE 2-1
MAP OF MANAGUA AND LAS MADERAS REGION

Temperatures are uniformly warm throughout the year with daily temperatures ranging from average lows of 20-25°C to average highs of 30-38°C (INEC-1981).

The array of aerial photographs shown in Figure 2-2 give a perspective of the terrain, vegetation, and land use of the Las Maderas region. The area is primarily within the premontane dry forest ecological life zone (Holdridge-1967). The wooded savannahs are generally sparsely covered with trees and shrubs, more so in the flat than in the hilly areas. Denser woodlands are evident along the high mountains just to the north of the region.

Land in the Las Maderas area is primarily used for cattle grazing. Some open pasture is evident, especially in the plains to the south. More common however, cattle graze within the woodlands, feeding primarily on the ground cover growing between the trees.

The region contains a small amount of subsistence crop cultivation. Cultivated fields are often located near the tops of hills and often on slopes as steep as 100 percent. These higher areas appear to have soils with higher moisture retention capacities than those found in the valleys and flat lands. Fields used for cultivation appear to be temporary as evidenced by a large number of fields appearing today as pasture and exhibiting various levels of forest regrowth. The volcanic/clay soils of the entire region are marginal or unsuitable for profitable agricultural production.

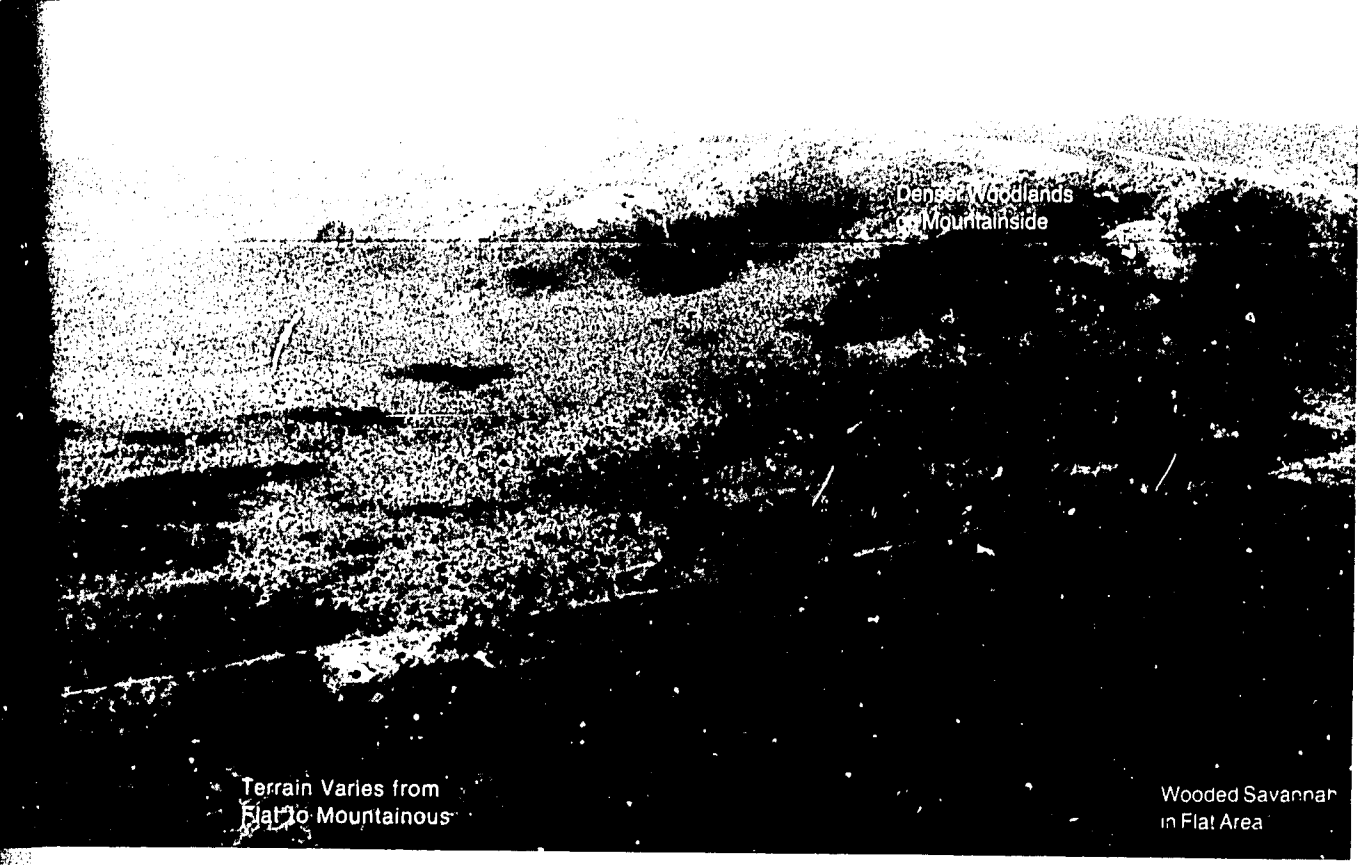


FIGURE 2-2
AERIAL PHOTOGRAPHS OF THE LAS MADERAS REGION

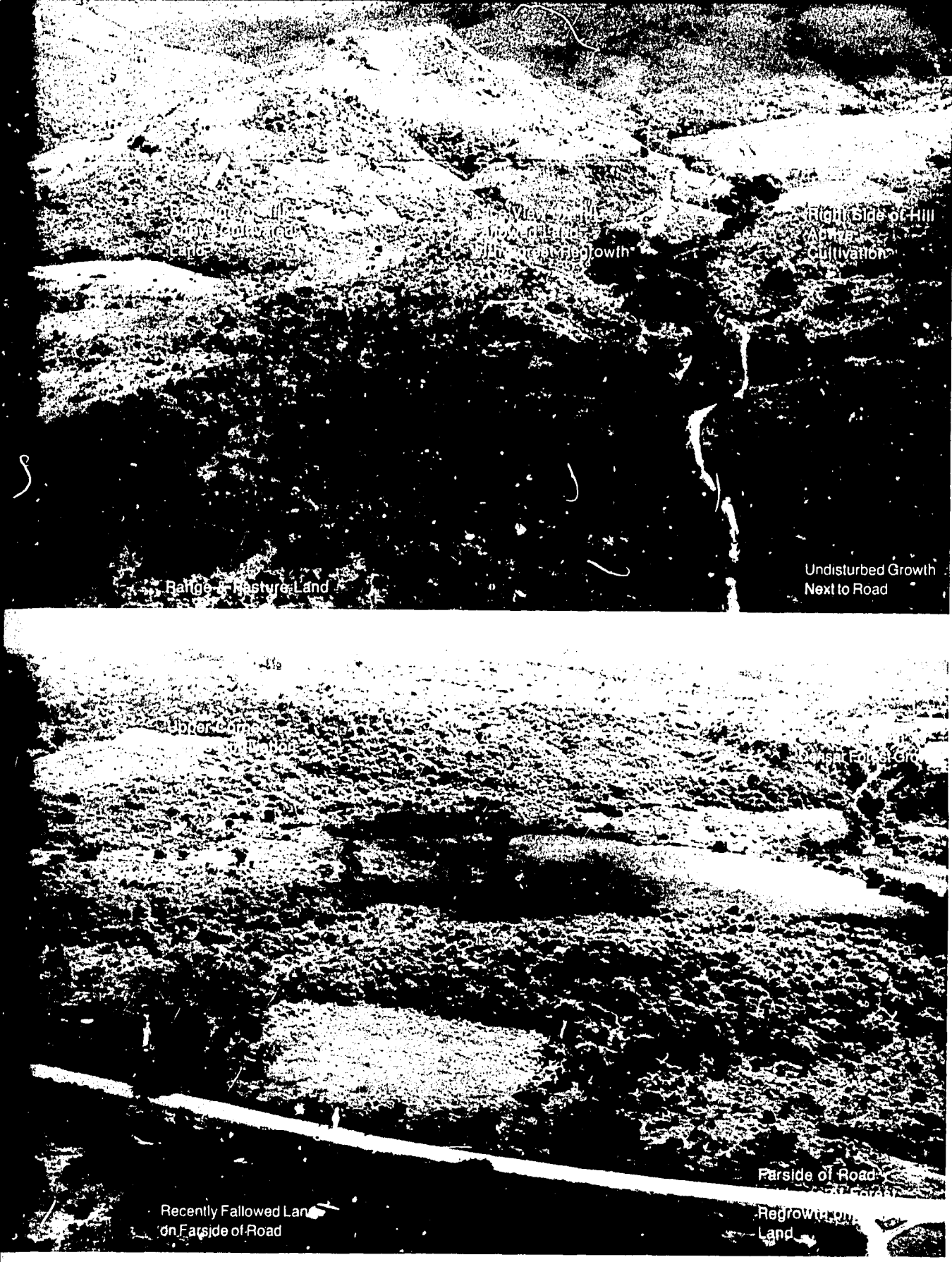


FIGURE 2-2 (Concluded)

The trees of the region are representative of dry tropical forests (see Figure 2-3), with broad, spreading, and flattened crowns with a maximum height of about 15 meters. The leaves are usually small, the foliage is sparse and species with thorns are abundant. Many trees have the ability to regenerate through coppicing. Legumes are especially prominent.

The incomplete crown cover for trees in the region allows for many varieties of grasses, herbs, and succulents in the understory during the wet season. The open areas lose this understory vegetation during the dry season.

The Las Maderas area shows evidence of extensive wood harvesting. Although there is no appearance of desertification as might be expected, almost all the forest stands are very young. Current growth in the forests of Las Maderas region appears to be less than six years old. It appears that because of vigorous natural reseeding and the extensive resprouting and rapid regrowth from stumps of cut trees, the forest has, at least for the present been able to maintain its regrowth capability.

The only paved road through the area is Route 1, the Pan American highway. Other routes delineated on the map of Figure 2-1 are primarily all-weather graded dirt roads. Access to most of the forest areas in the Las Maderas region where fuelwood is being cut however, is by narrow unimproved roads requiring four-wheel drive or truck capability. The extent of access of these roads to all

Typical Wooded Savannah

Typical Indigenous Species (Cornizuelo) in Wooded Savannah

Second Coppicing of Fuelwood Species

FIGURE 2-3
TREES OF THE LAS MADERAS REGION

the forest of Las Maderas region is not yet determined. Sample aerial photographs for 1968 for the region show many narrow paths criss-crossing the region. It was not determinable from the photographs to what extent many of these paths would permit vehicular traffic.

Although the Las Maderas region is frequented with torrential downpours during afternoon and evening hours of the rainy season, the lands of the region did not show significant erosional features at the time observations were made (October-November).

The Land Owners

As already noted, the lands of the Las Maderas region are owned and used primarily for cattle ranching. Although a survey of the size of cattle ranches was not made in this assessment, two ranches of moderate size measuring 2400 and 4100 manzanas were identified.*

Although some land owner/ranchers live on their own property, most are absentee owners, managing the ranch operation from nearby cities and leaving daily decisions to resident caretakers. Major cattle and land use decisions, however lie with these land owners. This includes the decisions on fuelwood cutting.

Clearly, the objectives on land use vary between individual landowners. However, based on information received from local Las Maderas resident caretakers, and a resident rancher/land owner,

* 1 hectare = 1.42 manzanas
0.7 hectare = 1.0 manzanas

decisions on timing, location, and extent of fuelwood cutting are based on land owner objectives for improving cattle production. As reported, the primary purpose of fuelwood cutting is to cut back sufficient foliage to permit the growth of grass for cattle grazing. Forests on cattle land are not clear-cut because of the need to provide shade for both the cattle and the undergrowth during the dry season.

The Empresario

The commercial fuelwood industry in the Las Maderas region is centered around the empresario, the local name given to the fuelwood business operator. Each empresario owns and runs his own fuelwood cutting operation, usually out of the village of Las Maderas. The capital equipment of the empresario is simply a truck, ranging in size from a pickup to as large as a 7 ton flat bed truck. The empresario arranges with land owners to cut fuelwood, hires fuelwood cutters and occasionally a truck driver. The empresario manages the entire fuelwood operation: cutting, delivery, and final sale in Managua.

The IRENA office in Managua has recently established a registration and permit system for fuelwood cutting in the Las Maderas region. The permits from January to August of 1981 show about 146 different individuals applying for permission to cut fuelwood in the Las Maderas region. It is unlikely that all of these individuals are separate empresarios. The MITRE project team conjectures

that several drivers, representing one empresario, apply for cutting permits in their own name.

It was reported verbally by local residents that about 30 empresarios work out of the village of Las Maderas.

The Cutting Operation

Fuelwood cutting begins early in the morning, shortly after day-break. The empresario collects the team of cutters and takes them to the area to be cut. Each cutter carries his own ax and machete. Cutters often work in family groups (all male) with older members handling the cutting and the young employed in the tying and stacking operation.

Selection and extent of tree cutting seem to be a combination of landowner direction and the desired efficiency of fuel cutters to cut the most fuelwood for the work expended. Tree trunks or sprouts less than about six cm in diameter will generally be left either as a directive of the rancher or because the fuelwood gained for the cutting effort is considered too small.

Figure 2-4 shows photographs of the tree cutting process. Felled trees and tree sprouts are trimmed and cut into 70 to 80 cm lengths. Branch and leaf wastes are pushed to the side and discarded. Large tree trunks are split into 10 to 15 cm diameter pieces called rajas. However, the majority of wood is split into 2-3 cm widths called rajitas. Moist bark stripped off of young branches is split into long thongs and used to tie rajitas into bundles (see

Splitting Fuelwood to Rajita Size

Bark Strips Used for Bundling of Manojos

FIGURE 2-4
THE CUTTING AND BUNDLING PROCESS

lower photographs in Figure 2-4). The manojo, a bundle of 5 rajitas, is the primary unit of residential fuelwood used throughout Las Maderas and Managua. Manojos and rajas are carried by the cutters to the side of the road for pick up by the truck. The maximum distance for carrying of cut fuelwood was reported by local cutters to be about 100 meters.*

The cutting operation ends around noon or 1:00 p.m. when it becomes too hot to work efficiently. On arrival of the empresario's truck, the day's fuelwood cut is recorded in rajas and manojos and stacked on the truck bed (see Figure 2-5). A typical day's work for a cutting team is 100 manojos. Although, the 5 ton truck shown in the photograph is carrying both rajas and manojos, this truck could carry approximately 1800 manojos separately.

The loaded truck and cutters return to Las Maderas where the fuelwood is either off-loaded into storage or is left on the truck for delivery to Managua the next or the following day (see Figure 2-6).

There is a seasonal variation that affects the quantity of wood harvested and the storage period. During the dry season (November through April), production is about double that of the wet season. Hence the storage time between harvesting and sale is longer than one to five days, due to the large quantity available.

*This gives an indication of the "depth" of cutting in progress relative to truck access in the region.

FIGURE 2-5
LOADING OF FUELWOOD

Storage of
Manojos in
Las Maderas

Manojos & Rajas
Ready for
Transport

FIGURE 2-6
FUELWOOD STORAGE IN LAS MADERAS

The two primary reasons for increased production in the dry season are the favorable weather conditions and the increased labor force available due to decreased cultivation during this period. Ranches and farms are also likely to require land maintenance (clearing for pasture) as well during this period to prepare for agricultural activity during the wet season.

Fuelwood Delivery to Managua

Fuelwood trucks leave Las Maderas early in the morning for sale of fuelwood in Managua. Riding each truck is usually one hired driver and an assistant. Occasionally the *empresario* drives the truck.

As shown in the map of Figure 2-7, the market for the Las Maderas fuelwood lies mostly in the eastern end of Managua. Fuelwood is sold to vendors in the large central markets, shown shaded on the map, to small neighborhood markets, and directly to users. Examples of each of these markets are shown sequentially in the photographs in Figure 2-8.

Rajitas, which are used primarily for residential cooking, are most often sold to vendors, either in the central or the neighborhood markets. It was estimated that only about 10 percent of the *rajitas* were sold directly on the street.

Rajas, which are used primarily in small cottage industries such as bakeries, are usually sold directly to these industries. Occasionally however, *rajas* may be found for sale in the markets.

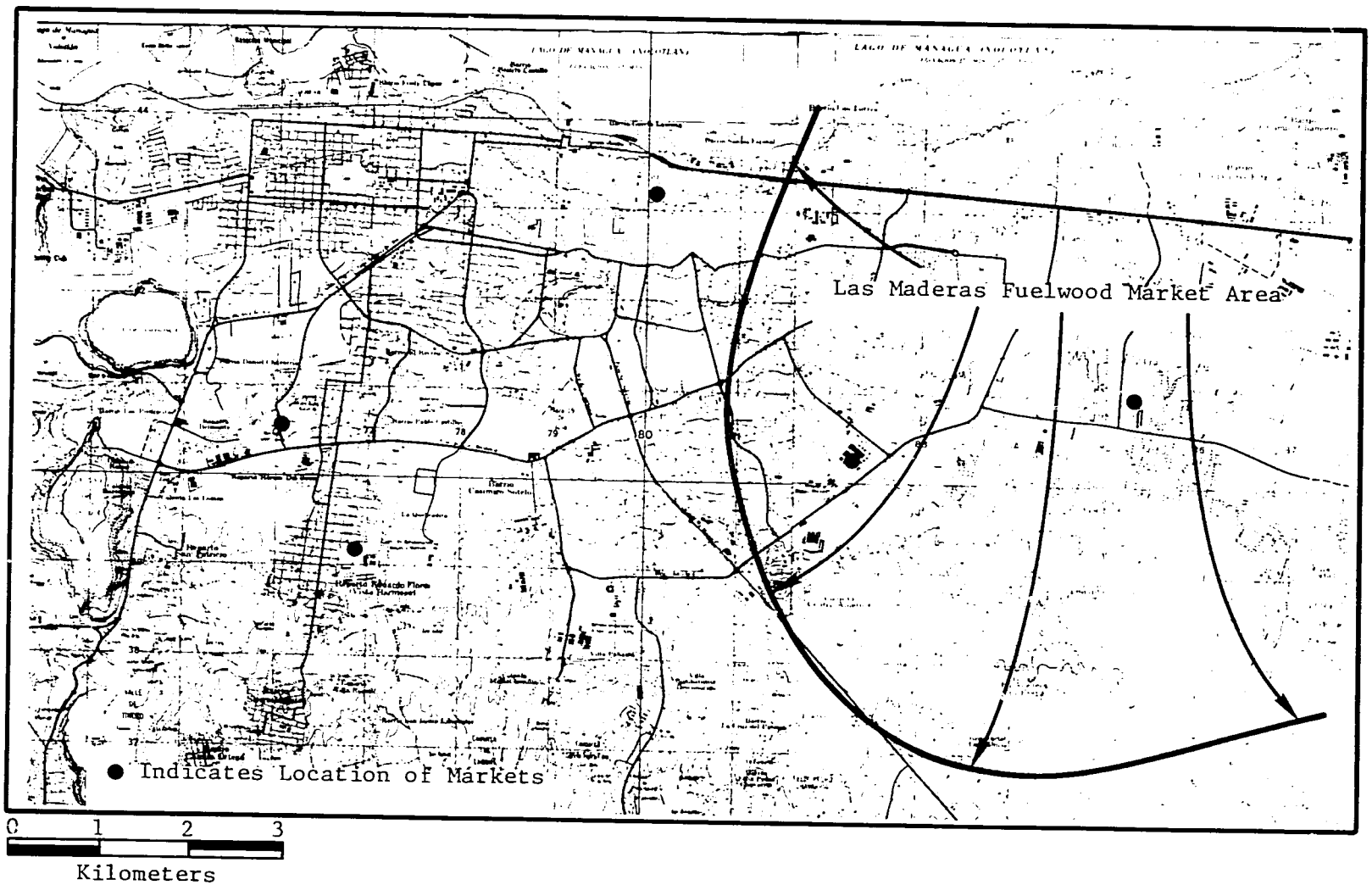


FIGURE 2-7
PRIMARY EASTERN MANAGUA MARKET AREA
FOR LAS MADERAS FUELWOOD

Fuelwood in the Central Markets

Fuelwood in Managua Barrio

Fuelwood Sales on the Street

FIGURE 2-8
FUELWOOD MARKETS

Sales in the large markets are made directly to the vendors. In these cases the fuelwood truck team makes a marketing visit directly to the vendor's location within the market. Sales to the neighborhood markets, commercial and small industrial establishments as well as to domestic users are made by driving through the barrio/neighborhood shouting "leña" (fuelwood) from the truck. All truck sales are usually completed by mid-morning.

There do not appear to be any prearranged sale agreements between market owners and truck drivers/empresarios for fuelwood supplies. Still, drivers have specific areas where they frequent, are known, and are most likely to sell.

Market owners generally buy fuelwood when inventories are low. Residential consumers, because of tradition and financial limitations, usually buy fuelwood on a daily basis to satisfy daily cooking needs.

The End-Use of Fuelwood

As described in more detail in Section 4.0, the use of fuelwood for residential cooking in Managua is strongly correlated to income level. City residents in the very lowest income levels use fuelwood almost totally for their cooking needs. As income levels rise, there is a pronounced trend to switch from fuelwood to charcoal and liquefied petroleum gas (LPG). Charcoal and LPG are preferred cooking fuels because of their handling ease and smokeless burning.

Typically, for each family in the lowest income class, two or three manojos are purchased and consumed daily. Fuelwood is purchased from neighborhood markets in most cases and in central markets if located near the home.

Typical residential use of fuelwood is shown in the photographs in Figure 2-9. Generally, each home contains a stove, either masonary as shown, or constructed from rudimentary open-topped metal containers. Fires are normally kept burning all day in these stoves, heating coffee, water, and providing the long consistent heat required for the cooking of the customary foods of rice and beans.

Although some stoves are attached to chimneys, most are not, and smoke from the wood fires clouds the cooking area (see the left hand photograph). Rajitas are burned from one end to the other in these stoves, being regularly pushed as necessary into the small fire area.

The amount of fuelwood used by consumers in higher income classes decreases as more funds are available to purchase charcoal and LPG. More funds available for transportation allows consumers to purchase fuelwood in central markets at prices generally lower than in the neighborhood markets. Higher income consumers also have the ability to purchase enough wood for several days. If the household normally cooks with LPG and/or charcoal then fuelwood will be commonly used once or twice a week to prepare customary foods that require a lengthy cooking time. Also, the increased financial

Open Fire Cinder Block Stove

Brick Stove with Chimney

FIGURE 2-9
TYPICAL RESIDENTIAL STOVES/FUELWOOD USE IN MANAGUA

resources in higher economic groups permit purchase of a wider variety of foods that do not require lengthy preparation.

2.2 Fuelwood From CONARCA* (Coffee Renovation Project)

Although this study was designed to investigate the fuelwood situation in the Las Maderas region, a sustainable supply of Las Maderas fuelwood is strongly affected by both the size of the fuelwood demand in Managua and the capability of other supply regions to meet their share of this demand. If other fuelwood supply regions were similar in nature to the Las Maderas region, their future impact on Las Maderas could be neglected in an initial study, assuming simply that each supply region will continue to provide its proportional share of Managua demand. This is not the case however. A significant fraction of Managua fuelwood demand is now being met by wood produced from the Nicaraguan Coffee Renovation Project (CONARCA).

The CONARCA project is located about 20 kilometers directly south of Managua in the hilly, productive coffee plantation district of Carazo. In an attempt to control the infestation of a coffee rust disease, the CONARCA project is cutting down the huge 50-60 year old trees of the region. Grown originally to shade the coffee plants, these trees** have grown to be so large that their excess shade has

*CONARCA is an acronym for Comisión Nacional de Renovación de Cafetales, The National Commission for Coffee Renovation.

**Primarily of the species *Gliricidia sepium* (Madero negro) and *Enterolobium cyclocarpum* (Guanacaste).

encouraged the moist conditions that promote the fungal disease. After razing an area of both trees and coffee plants, the CONARCA project is replanting the fields with new coffee hybrids, some of which are more tolerant of sunny conditions. They are also experimenting with different shading systems.

In the two years of operation, 5,000 manzanas (about 3500 ha) have been cut with the eventual target of 14,000 manzanas (about 9900 ha). The total amount of wood extracted to date has not been determined, but is of considerable size as may be seen in the CONARCA wood storage lot in the top photograph in Figure 2-10.

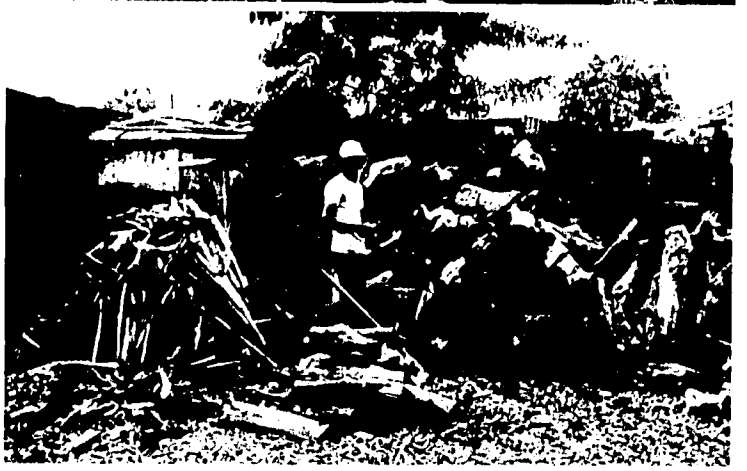
Although some of the CONARCA wood is being used by the government of Nicaragua for bridge construction and railroad ties, what appears to be a large quantity ends up as fuelwood both for direct fuelwood sale and also for charcoal production.

Very large trunk and branch wood is sold to consumers from the CONARCA wood storage lots. Wood used for energy consumption is driven to other staging areas where the wood is cut and split, and either used in charcoal production or transported to markets for sale as fuelwood. Based on interviews within Managua, the MITRE-IRENA team determined that very large quantities of CONARCA project wood appear as fuelwood in Managua.

The exact amount of fuelwood from CONARCA sold in Managua is not easily calculated. There is no system at CONARCA for documenting the quantities sold for fuelwood and charcoal and there is no system

CONARCA
Wood Storage
Area

Charcoal
Production
in Region
of CONARCA
Project



CONARCA
Wood
Being Split
for Fuelwood
at Market
in Managua

FIGURE 2-10
CONARCA WOOD/FUELWOOD UTILIZATION

in Managua that determines the origin of fuelwood supply. It was observed that quantities of wood from the CONARCA project were actually hauled to Las Maderas for splitting and binding and then carried back to Managua for sale.

Fuelwood users in Managua claim that the quality of most of the fuelwood from the CONARCA project is better than that of wood from Las Maderas. The wood is older, harder, drier, and burns with less smoke.

The supply of fuelwood from the CONARCA project will likely disappear in two to five years. It is very important that an accurate estimate be made of the amount of fuelwood from the CONARCA project reaching Managua today. This estimate will indicate the amount of increased fuelwood demand to be placed on Las Maderas and other regions supplying fuelwood for Managua in the future.

3.0 ECONOMICS OF THE FUELWOOD SYSTEM

3.1 Prices for Residential Cooking Fuels in Managua

The table below describes the October 1981 average prices of the primary residential cooking fuels in Managua:

TABLE 3-I
COOKING FUEL PRICES

	Market Price	Energy Price	
	(Cost/Unit)	In the Fuel (Cost/10^9 J)	In the Cooking Container (Cost/10^9 J)
Fuelwood	C$1.50/Manojo	C$45	C$300-C$750
Charcoal	C$2.50/Bolsa*	C$146	C$973
LPG	C$3.10/Pound	C$136	C$367

The price in the first column is the average market fuel price using units of measure typical for the sale of each fuel. The price in the center is the comparative energy price of each fuel.** On an energy basis, the price of charcoal and LPG is more than three times the price of fuelwood. The price on the right gives the comparative cost to obtain a unit of energy in the cooking vessel.***

*The bolsa is a small sack measuring about 1.7 liters.
**These energy prices assume the following:
- wood energy content (30 percent moisture) = 17.8 x 10^6 J/kg
- charcoal energy content = 36.8 x 10^6 J/kg
- LPG energy content = 61.3 x 10^6 J/kg

***Assumes the following cooking efficiencies:
- fuelwood: 6 percent (IRHE-1979) to 15 percent (Personal communication with ICAITI)
- charcoal: 15 percent (Openshaw-1980)
- LPG: 37 percent (IRHE-1979)

ICAITI (Instituto Centroamericano de Investigación y Tecnología Industrial) is currently assessing the relative efficiencies of fuelwood stoves as part of the Central American Fuelwood Project.

The costs of cooking with charcoal appear to be significantly higher than with either fuelwood or LPG. The low efficiency of wood versus LPG cooking virtually eliminates the advantage of the low fuel energy cost of fuelwood. This suggests that there may be a future trend toward greater LPG use in Managua if the price of LPG is maintained at its current level. The capital cost of LPG stoves, the limited availability of LPG tanks in neighborhood markets, the carrying weight of full LPG tanks, and of course, tradition in cooking practices may be the reasons why LPG is not used more extensively today in Managua.

3.2 Personal Income in the Commercial Fuelwood Industry

Figure 3-1 shows the breakdown of the market price of fuelwood within the commercial fuelwood industry. The breakdown assumes the fuelwood price of C$1.50 per *manojo* given in Table 3-I.

The landowner receives on the average about 7 percent of the market price of fuelwood. This amount of income is of secondary importance to the value of land clearance for grazing purposes. The typical agreement between the *empresario* and the land owner provides the owner with C$100 for every 1000 *manojos* harvested. This is an average. The highest owner price identified was C$150 per 1000 *manojos* for fuelwood of high quality (Madero negro).

The fuelwood cutter or cutting team working directly for an *empresario* receives about C$50 for the 100 *manojos* cut normally in a day. This amount represents about 33 percent of the final market cost of the *manojo*.

Land Owner	Fuelwood Cutter	Empresario	Market Operator
7%	33%	40%	20%

FIGURE 3-1
BREAKDOWN OF PRICE OF FUELWOOD WITHIN COMMERCIAL FUELWOOD INDUSTRY

The empresario markets his truckload of fuelwood at the highest bargained price he can obtain. Overall, prices range from C$100 to C$150 per 100 manojos. However, a typical sale price to markets is about C$120 per 100 manojos. This price provides the empresario with about 40 percent of the total fuelwood market price. The empresario must pay truck and driver expenses from these proceeds.

Prices to the consumer range from C$1.40 to C$1.75 per manojo. At the average market price of C$1.50 per manojo, the marke operator will average C$0.30 on each manojo sold, representing 20 percent of the final cost.

Table 3-II presents a breakdown of the estimated revenues, costs, and income to the empresario for one truck load of 1800 manojos cut in the Las Maderas region and sold in Managua. As outlined, the revenues of C$2160 are offset by estimated costs of C$1787 yielding a net income per trip of C$373.

What is particularly interesting about the income structure of the current system is its relationship to the question of maintaining sustainable fuelwood yields from the Las Maderas region. As noted in Section 2.0, the primary decisions on management of fuelwood harvests lie with the landowner. Fuelwood cutting decisions are controlled by an economic focus on cattle production, which has, in turn, provided a reasonable management of the forest resources. The land owner is now receiving only 7 percent of the final price of fuelwood. This low return maintains the focus of the profit motive of the landowner on cattle production.

TABLE 3-II

ESTIMATED EMPRESARIO REVENUE, COST, AND INCOME PER TRUCKLOAD

Estimated Revenue		C$2160	1800 manojos at C$1.20/manojo off the truck (5-ton)
Estimated Costs		C$1787	
	C$180		landowner at C$100/1000 manojos
	C$900		cutters at C$50/100 manojos
	C$100		truck driver
	C$75		driver's assistant
	C$411		operating and maintenance cost for 150 km trip at C$2.74/km; assumes diesel at C$22/gallon, 9.65 km/gallon, and 20 percent additional cost for tires, oil, and maintenance
	C$121		truck equity; assumes C$50,000 initial cost for used truck for 10 years at 12 percent; truck utilization 5 days/trip
Estimated Income Per Truckload		C$373	

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4.0 CURRENT AND FUTURE DEMAND FOR FUELWOOD IN MANAGUA AND FROM THE LAS MADERAS REGION

To determine the fuelwood yields required from the Las Maderas region, the MITRE team and the IRENA counterparts analyzed the current fuelwood demand in Managua. Through visits and communication with residents throughout the neighborhoods (barrios) and markets of Managua, the combined MITRE-IRENA team was able to define the approximate area currently supplied by fuelwood from the Las Maderas region. Through population statistics and forecasts and the results of a recent Managua residential energy consumption survey, the authors formed a preliminary estimate for the future fuelwood demand for the area of Managua that the Las Maderas region now serves. This estimate, in turn, provides a very preliminary idea of the level of pressure expected on the Las Maderas region to provide fuelwood in the next decade.

This section provides the details of this demand assessment.

4.1 Demand For Fuelwood in Managua

In April and May of 1980, the Forestry Section of IRENA conducted a survey of domestic fuel consumption in Managua (Riegelhaupt-1980). Although the survey was taken to obtain insight into the potential for substituting charcoal for fuelwood and LPG in Managua, the data obtained were most useful for this study.

The IRENA survey stratified eleven Managua barrios into four income groups; very low, low, middle, and upper. Homes from each of

these barrio/income categories were visited to gather data on residential fuel use.

In the current assessment on Las Maderas fuelwood use, the combined MITRE-IRENA team extended the original IRENA fuel use information to all of Managua. As the original IRENA study did not define the four income classes, the initial step in this study was to confirm the barrio types in each category and to assign a definition to each which could be used as a guideline to stratify all the remaining Managua barrios.

The MITRE-IRENA team assigned the following definitions:

- Very low income - Homes are constructed of rudimentary materials and usually have dirt floors. Neighborhood streets are narrow and unpaved.
- Low income - Homes are constructed with permanent materials; concrete floors exist in most homes. The neighborhood streets are wider with a greater frequency of pavement.
- Middle income - Homes are constructed of permanent materials and are larger than those of the lower income groups. Streets are wider and paved. The number of household amenities is visibly larger in in this group.
- Upper income - Homes are larger, constructed of permanent materials and equipped with all available household appliances. Streets are wide, paved and well kept.

The IRENA members of the team, based on their personal knowledge of the city, then assigned each of the Managua barrios listed in the

Nicaraguan 1980 Census (INEC-1981) to these income groups. The results of the original IRENA study could then be reasonably extrapolated to the rest of Managua.

Table 4-I shows the results of this extrapolation. The monthly energy use data from the original IRENA study are presented in the first column of the large block of data in the table. The second column converts the monthly data to annual data.

The small left hand box shows the results of allocating the 1980 Managua barrio population to the four income classes.

The Nicaraguan 1971 Census (BCN-1974) showed that the average household or family size in Managua was about six.* The assumption that this condition is similar today leads to the estimation of the number of households in each income category shown in the second column of the small box.

The remaining columns in the table are a result of multiplication of the number of households and the per household energy consumption. As seen, this procedure results in an estimate of 45 million manojos consumed by households in Managua in 1980. This corresponds to 103,000 metric tons** of fuelwood or an equivalent of 1831 TJ of energy.

*The Energy Balance study (INE-1981) surveyed urban household size for all of Nicaragua. The average size was approximately 5.7 persons per family.

**Wet weight basis at 30 percent moisture content.

TABLE 4-I

DEMAND FOR RESIDENTIAL COOKING FUELS
IN MANAGUA - 1980

Income Class	Population[1]	No. of Households
Very Low Income	40,713	6,786
Low Income	337,522	56,254
Middle Income	197,338	32,884
Upper Income	39,374	6,562
Total	614,947	102,486

Fuel	Income Class	Number of Manojos/ Month/ Household[2]	Number of Manojos/ Year/ Household	Number of Manojos/ Year/ (x 10^3)	Metric Tons/Year (x 10^3)	Energy Equivalent (TJ/Year)
Fuelwood (manojos)	Very Low Income	82.75	993	6,738	15.26	272
	Low Income	57.19	686	38,606	87.44	1556
	Middle Income	.18	2	71	.16	3
	Upper Income	-	-	-	-	-
	Total			45,415	102.86	1831
		No. of Bolsas/ Month/ Household	No. of Bolsas/ Year/ Household	No. of Bolsas/ Year (x 10^3)	Metric Tons/Year (x 10^3)	Energy Equivalent (TJ/Year)
Charcoal	Very Low Income	37.07	445	3,018	1.71	63
	Low Income	27.89	335	18,826	10.66	392
	Middle Income	30.35	364	11,977	6.78	250
	Upper Income	17.70	212	1,394	.79	29
	Total			35,215	19.94	734
		Pounds/ Month/ Household	Pounds/ Year/ Household	Pounds/ Year (x 10^3)	Metric Tons/Year (x 10^3)	Energy Equivalent (TJ/Year)
LPG	Very Low Income	9.32	112	758	.34	21
	Low Income	13.07	157	8,823	4.00	245
	Middle Income	28.59	343	11,282	5.11	313
	Upper Income	32.72	393	2,577	1.17	72
	Total			23,440	10.62	651

(1) INEC-1981

(2) Riegelhaupt-1980

Charcoal consumption is estimated at 19,900 metric tons per year or an energy equivalent of 734 TJ. At the maximum 35 percent efficiency of charcoal production in Nicaragua, this much charcoal requires 118,000 metric tons of fuelwood as raw material.

LPG consumption is estimated 10,600 metric tons per year or an energy equivalent of 651 TJ.

4.2 Demand for Fuelwood in Eastern Managua

The map shown previously in Figure 2-7 delineates the approximate demand area for the supplies of fuelwood from the Las Maderas region. As seen, this area covers the eastern part of Managua. This area was defined by the MITRE-IRENA team as a result of the interviews with market owners throughout the area.

Wood from Las Maderas can be found in small quantities in marketplaces in other portions of the city. This is not a result of a concentrated demand however. Trucks that have not been able to sell their supply in the traditional zone will drive throughout the city until their supply is depleted.

The fuelwood demand portion of the methodology described in the previous section for all of Managua was repeated for the *barrios* within the delineated area of eastern Managua. Table 4-II presents the results of these calculations. The region contains about 249,000 people or 40 percent of the population of Managua. The 1980 consumption in the region is estimated at 17 million *manojos* or 38,000 metric tons of fuelwood. This corresponds to

TABLE 4-II

DEMAND FOR MANOJOS IN EASTERN MANAGUA - 1980

Income Class	Population[1]	No. of Households	No. of Manojos/Year[2] ($x10^3$)	Metric Tons/Year ($x10^3$)	Energy Equivalent (TJ/Year)
Very Low Income	7,576	1,263	1,254	2.84	51
Low Income	136,665	22,778	15,628	35.40	630
Middle Income	93,892	15,649	34	08	1
Upper Income	10,866	1,811	-	-	-
Total	248,999	41,501	16,916	38.32	682

(1) INEC - 1981

(2) Riegelhaupt - 1980

37 percent of the total city consumption of fuelwood for cooking. The reduced percentage of fuelwood use is due to the fact that the eastern area of Managua is shown to have a smaller fraction of households in the very low income category and a large fraction in the middle income category. The highest use of fuelwood per household occurs in the very low income class.

4.3 Demand for Fuelwood from the Las Maderas Region

In translating the demand for fuelwood in eastern Managua to an estimate of the total quantity of fuelwood taken from the Las Maderas region, a number of factors need to be considered.

Just as there is no estimate of the quantity of Las Maderas fuelwood that finds its way to market places in the city outside of the eastern Managua area, there is also no estimate of the amount of fuelwood from CONARCA and other sources that enters eastern Managua. For the purposes of this study, we simply assume these two anomalies cancel each other.

The limitation of measuring fuelwood demand in manojos was dictated by the data available in the original IRENA survey. An active cottage industry throughout all of Managua commonly uses raja size fuelwood for its energy needs. A small amount of residential consumption of rajas also occurs. No estimate of the quantity of actual demand for this fuelwood was available or could be made in this study. Although a large portion of raja size wood does emanate from

the CONARCA project, some rajas are cut in Las Maderas and transported to Managua. (See photos in Figure 2-5 and 2-6). The only estimate that can be made of the amount of rajas cut in Las Maderas is based on the visual judgment of the MITRE team members in observing trucks delivering fuelwood from the Las Maderas region. We estimate that in addition to the harvest of rajitas, there is a 10 to 30 percent additional harvest of rajas. For a very rough and preliminary estimate, the total demand for the Managua portion of supplies of fuelwood from the Las Maderas region is estimated at 38,300 metric tons of rajitas plus 20 percent, that is, 7,700 metric tons of rajas, or 46,000 metric tons.

Finally, this quantity is increased again by 10 percent to account for the Las Maderas region fuelwood that is used in the Las Maderas region itself and for other demand areas outside of Managua. The local demand includes domestic use and the small amount of fuelwood that is used for charcoal production in the Las Maderas region. The final rough estimate of the 1980 fuelwood demand from the Las Maderas region is therefore 50,600 metric tons per year or 900 TJ energy equivalent. This production estimate is presented in Table 4-III.

The accuracy of the figures and the approach just presented is limited and therefore the results should be used with comparable caution. To assist the essential process of checking and refining these preliminary results in further studies, the authors identify

TABLE 4-III

1980 ESTIMATED FUELWOOD
PRODUCTION IN LAS MADERAS REGION

	Metric Tons ($x10^3$)	Energy Equivalent (TJ)
Demand for Manojos in Eastern Managua	38.3	682
Demand for Rajas in Eastern Managua	7.7	136
Subtotal	46.0	818
Local and Other Demand	4.6	82
Total	50.6	900

below those areas of potential error in this analysis which need to be reassessed.

- Survey of residential fuelwood use
  - confirm household size
  - survey more barrios
  - assess raja as well as manojo use
  - assess moisture and energy content of purchased fuelwood.
- Survey industrial and other non-residential uses of fuelwood in Managua.
- Confirm analysis results by cross reference to accurate fuelwood cutting permit data.*
- Assess the demand for Las Maderas fuelwood in Managua but outside of eastern Managua.
- Assess the amount of CONARCA fuelwood in use in eastern Managua, as well as other possible sources.
- Assess Las Maderas local and other fuelwood demand
  - charcoal production
  - other fuelwood markets outside of Managua
  - local fuelwood consumption

*The recently instituted IRENA fuelwood cutting and transport permit system shows that, from January through August of 1981, a total of 1,657,600 manojos were cut under permit in the Las Maderas area. Assuming a similar level of cutting for the four remaining months gives an estimate of 2,486,400 manojos for the year or approximately 5,600 metric tons annual production of manojos. This is significantly less than 38,300 metric tons annual manojo demand calculated in this analysis.

4.4 Projected Demand for Fuelwood in 1985 and 1990

Although changes in income strata and changes in price and availability of all the residential cooking fuels will affect the future use of these fuels, making the bold assumption that individual households in Managua continue to use fuel for cooking purposes in their present manner, the future demand for fuels will increase proportionately to population growth.

According to the 1980 Census (INEC-1981) the total population in Managua is expected to grow at an annual rate of 4.7 percent for the next ten years. The 1980 population of 614,947 would expand to 774,000 in 1985 and to 972,000 in 1990. This is approximately a 58 percent increase in population over a ten year period.

The assumption of growth in fuelwood use, based entirely on population growth, yields the projections of total consumption given in Table 4-IV. The current estimation of 45 million manojos (103,000 MT*) in 1980 is projected to grow to 57 million (129,000 MT) in 1985 and 72 million (163,000 MT) in 1990.

Table 4-V shows a similar projection for the fuelwood consumption in eastern Managua. Current 1980 consumption of 17 million manojos (38,000 MT) grows to 21 million manojos (48,000 MT) in 1985, and to 27 million manojos (61,000 MT) by 1990.

*MT = metric ton

TABLE 4-IV

PROJECTED ANNUAL DEMAND FOR MANOJOS
IN MANAGUA

Income Class	1980		1985		1990	
	Manojos ($x10^3$)	Metric Tons ($x10^3$)	Manojos ($x10^3$)	Metric Tons ($x10^3$)	Manojos ($x10^3$)	Metric Tons ($x10^3$)
Very Low Income	6,738	15.26	8,477	19.2	10,666	24.2
Low Income	38,606	87.44	48,572	110.0	61,111	138.4
Middle Income	71	.16	89	.2	112	.3
Upper Income	-	-	-	-	-	-
Total	45,415	102.86	57,138	129.4	71,900	162.9

Based on 4.7 estimated population growth (INEC - 1981).

TABLE 4-V

PROJECTED ANNUAL DEMAND FOR MANOJOS
IN EASTERN MANAGUA

Income Class	1980		1985		1990	
	Manojos ($x10^3$)	Metric Tons ($x10^3$)	Manojos ($x10^3$)	Metric Tons ($x10^3$)	Manojos ($x10^3$)	Metric Tons ($x10^3$)
Very Low Income	1,254	2.84	1,578	3.6	1,985	4.5
Low Income	15,628	35.40	19,662	44.5	24,738	56.0
Middle Income	34	.08	43	.1	54	.1
Upper Income	-	-	-	-	-	-
Total	16,916	38.32	21,283	48.2	26,777	60.6

Based on 4.7 estimated population growth (INFC - 1981)

Finally Table 4-VI shows the projection for total fuelwood consumption from the Las Maderas region, again, based on the 4.7 percent growth assumption. The estimated 1980 consumption of 51,000 MT (900TJ) grows to 64,000 MT (1100TJ) in 1985 and to 80,000 MT (1400TJ) in 1990.

TABLE 4-VI

PROJECTED FUELWOOD CONSUMPTION FROM
THE LAS MADERAS REGION

	1980		1985		1990	
	Metric Tons ($x10^3$)	Energy Equivalent (TJ)	Metric Tons ($x10^3$)	Energy Equivalent (TJ)	Metric Tons ($x10^3$)	Energy Equivalent (TJ)
Demand for Manojos in Eastern Managua	38.3	682	48.2	858	60.6	1079
Demand for Rajas in Eastern Managua	7.7	136	9.7	173	12.2	218
Local and Other Demands	4.6	82	5.8	103	7.3	130
Total	50.6	900	63.7	1134	80.1	1427

Based on 4.7 percent estimated population growth (INEC-1981).

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5.0 LAS MADERAS REGION FUELWOOD SUPPLY

A primary motivation behind this study was the need to understand the long term productive capacity of the Las Maderas fuelwood supply region and, in turn, to determine a sustainable level of fuelwood production in this area.

The ultimate and definitive answer to these questions can only be determined by statistically valid yield studies in the Las Maderas area itself. This process, although yielding the most reliable productivity information, requires time and resources, and fails to meet the need for early identification of potential forest degradation problems.

The approach taken in this study tries to bridge the time constraint problem of yield studies by estimating Las Maderas forest productivity, in major part, through the transfer of forest productivity information taken from other areas in the world that have very similar geographical and meteorological conditions to Las Maderas. Although some elementary sampling and measurements were made in the Las Maderas region, this latter data served more to complement the data taken from other sources and to provide additional data on species, stocking, etc.

This section describes the approach taken to estimate productivity. It includes:

- a description of the climatic, soil, and land-use characteristics of the Las Maderas region

- a literature review of fuelwood species productivity in other similar geographic locations
- a description of the field sampling performed by the authors and the project sponsors
- an examination of net primary productivity of seasonal (Rain-green) forests
- an estimation of Las Maderas annual fuelwood productivity.

5.1 Las Maderas Site Description

The Las Maderas Fuelwood Supply Area has been described generally in Chapter 2.0. It is located at approximately 12 North latitude and varies in altitude between 39 and 600 meters above mean sea level. The nearest shore of the Pacific Ocean is 70 kilometers away. The boundary of the 680 square kilometer area shown in Figure 2-1 was drawn with the help of IRENA staff to include all the area in which at least 90 percent of the fuelwood was harvested for sale in Managua. The area encloses all the major fuelwood cutting sites identified in the IRENA fuelwood cutting and transport permit applications for Las Maderas. The boundary was estimated based on this information; no effort was made to verify its location. In future studies the location of this boundary should be confirmed.

Table 5-I presents rainfall and temperature data for meteorological stations in and around the Las Maderas region. Precipitation is reported in monthly median and mean annual values for the life (average life of 22 years) of four meteorological stations. Temperature data in the table are average daily maxima and minima for each month for two stations.

TABLE 5-I

PRECIPITATION AND TEMPERATURE RECORD FOR LAS MADERAS AREA

MONTHLY MEDIAN PRECIPITATION (mm)

Station	WET SEASON May	Jun	July	Aug	Sep	Oct	Nov	DRY SEASON Dec	Jan	Feb	Mar	Apr	Sum of Monthly Medians	Mean Annual Precip-itation
Managua[1]	92	225	118	94	211	254	45	5	1	0	0	0	1045	1142
San Francisco Libre[2]	63	173	98	56	230	231	39	2	0	0	0	0	892	1127
Sébaco[3]	108	188	60	46	151	180	29	1	4	1	0	0	768	859
Panaloya[4]	18	88	160	109	130	227	217	13	1	0	0	0	963	1025

AVERAGE DAILY TEMPERATURES (°C)

Station		May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Managua[1]	Max.	37.0	34.9	35.9	36.2	35.5	34.4	35.0	35.7	36.1	36.6	37.4	37.9
	Min.	24.9	24.0	23.5	23.5	23.6	23.3	21.8	21.1	21.5	22.5	23.8	24.8
San Francisco Libre[2]	Max.	33.9	31.2	30.9	31.4	31.4	30.9	30.8	30.8	31.3	32.3	33.5	34.3
	Min.	23.4	23.1	22.6	22.4	22.5	22.2	21.1	20.2	21.5	20.6	21.5	22.5

[1]Station located 30 kilometers south of the Las Maderas Fuelwood Supply Region.

[2]Station located within Las Maderas Region.

[3]Station located 37 kilometers north of Las Maderas Region.

[4]Station located 16 kilometers north of Las Maderas Region.

Ref: (IRENA-1971)

Based on the information presented, the Las Maderas region mean annual precipitation ranges from 850 mm to 1150 mm, with virtually no rainfall occurring between December and April. Temperatures are quite uniform throughout the year, ranging from average lows of 20-25°C to average highs of 30-38°C.

It is interesting to note the variation in the precipitation data between the sum of the 12 monthly medians and the mean annual figures for each station. What this difference implies statistically is that each station occasionally has high monthly rainfall levels resulting in larger mean values over the years but not affecting the medians. The difference in precipitation means and medians for San Francisco Libre is pronounced.

Soil Description

A standard soil survey was made of the Pacific Region of Nicaragua in 1971 (IRENA-1971). Typing of soils is still being done by IRENA. Two photo mosaics that cover about 65 percent of the Las Maderas fuelwood supply region are now completed. From that source, MITRE estimated the proportion of the land in various soil series and in each of eight soil capability classes.

Soil Series

Eighty five percent of the land surveyed was classified into three soil series,* all of which are types of clay soils. Thirty five percent of the soils were vertisols and vertic soils which are

*Soil series EZ, SSJ, and V. See Appendix C for details.

fertile clays and clay loams. These latter soils are, however, very hard to work, crack widely (3 cm to 10 cm horizontally and over 1 meter vertically when dry) and some tend to be very stony. The vertic soils may be only suitable for forest use because their cultivation characteristics are so poor as to seriously restrict their use for cultivation.

Soil Capability Classification

The following description of soil capability classification is taken directly from the soil survey (IRENA-1971):

> "the capability classification is an interpretative classification made of soil mapping units or groups of mapping units primarily for agricultural purposes. The arable soils are grouped into capability classes according to their potentialities and limitations for sustained production of the cultivated crops that do not require specialized site conditioning or site treatment. Soils not suited to long-time sustained use for cultivated crops are grouped and classified according to their potentialities and limitations for the production of permanent vegetation, and according to risks of soil damage if mismanaged."

Table 5-II gives the percentage breakdown of the land areas of the Las Maderas region into eight soil capability classes used in the IRENA reference. A more detailed explanation of these soil capability classes is found in Appendix C.

Soil Productivity

The information in Table 5-II would lead one to believe that the dry forest area could not be very productive. Thirty six percent of the soils are unsuited for cultivation and fifty one percent are unsuited for cultivation or pasture. Eighty-seven percent of the soil

TABLE 5-II

SOIL CAPABILITY CLASES FOR LAS MADERAS REGION

Class	Description	% Area
I	No limitations on cultivation.	0.0
II	Few limitations on cultivation.	4.0
III	Moderate limitations on cultivation. Requires particular use and conservation measures.	1.7
IV	Severe limitations on cultivation. Demands very careful management and restricted crops.	3.7
V	Precludes cultivation unless structural changes are made to land.	0.0
VI	Unsuited to cultivation. Can be improved for pasture and range.	36.2
VII	Unsuited to cultivation and impractical to improve for pasture.	51.1
VIII	Unsuited for any plant production	3.3

can only be used for cattle grazing and woodland and three percent can not be used for any plant production.

These results do not mean that the soils in the Las Maderas region are not productive for perennial crops such as trees. The trees adapted to this life zone produce seed early and prolifically; most trees of the region coppice. Much of the area has over 1000 mm of rainfall yearly. This means that production (at somewhere near full stocking) could be slightly better than average sub-tropical dry forest experience.

Land Use Characteristics

The primary use of the lands of the dry forest area is agriculture. Whether crops or cattle are raised, most people depend upon farming to make a living. As a consequence, much of the fuelwood of the Las Maderas region is cut as a by-product of farming. For example:

- When an area of woodland is turned into a field in which a row crop is to be grown, fuelwood cutters will clearcut the existing woody vegetation. Fuelwood is produced from stems as small as 3 cm in diameter at the small end.

- When an area of woodland is managed for grazing, fuelwood tree species will be selectively cut so that enough light reaches the soil to encourage the growth of nutritious grasses and forbs. Enough trees will be left however, to provide adequate shade for cattle. If no harvesting were to take place in grazing land, some tree species would increase in stocking and eventually shade out the cattle forage. Therefore, woodlands that are used continuously for grazing are continuously thinned and the majority of these thinnings are used for fuelwood.

Some parts of the dry forest area are very rough (abrupt, rocky slopes) and of no use for agriculture. Trees on these areas are harvested to provide timber for local construction in addition to fuelwood harvesting. The fuelwood portion is often cut to a larger size (raja) than residential cooking fuelwood and sold to commercial users.

Land Use Determination

Methodology - MITRE sought to determine the land use of the Las Maderas region through the interpretation of aerial photographs. The latest available aerial photos were taken in 1968 (see Figure 5-1). These photos were procured from the Nicaraguan National Geographic Institute and interpreted along two flight lines to reveal the percent land use for four categories:

- cultivation
- managed grazing land
- wooded savannah
- woodland

Table 5-III presents the definition of these categories; each is discussed below.

Cultivation - The general cycle of land use in the dry forest area was introduced in Section 2.0. In places where land and local weather conditions in the Las Maderas region are suitable for cultivated farming, land is used to grow row crops (corn, millet) at least for the few years that it takes to utilize the natural soil

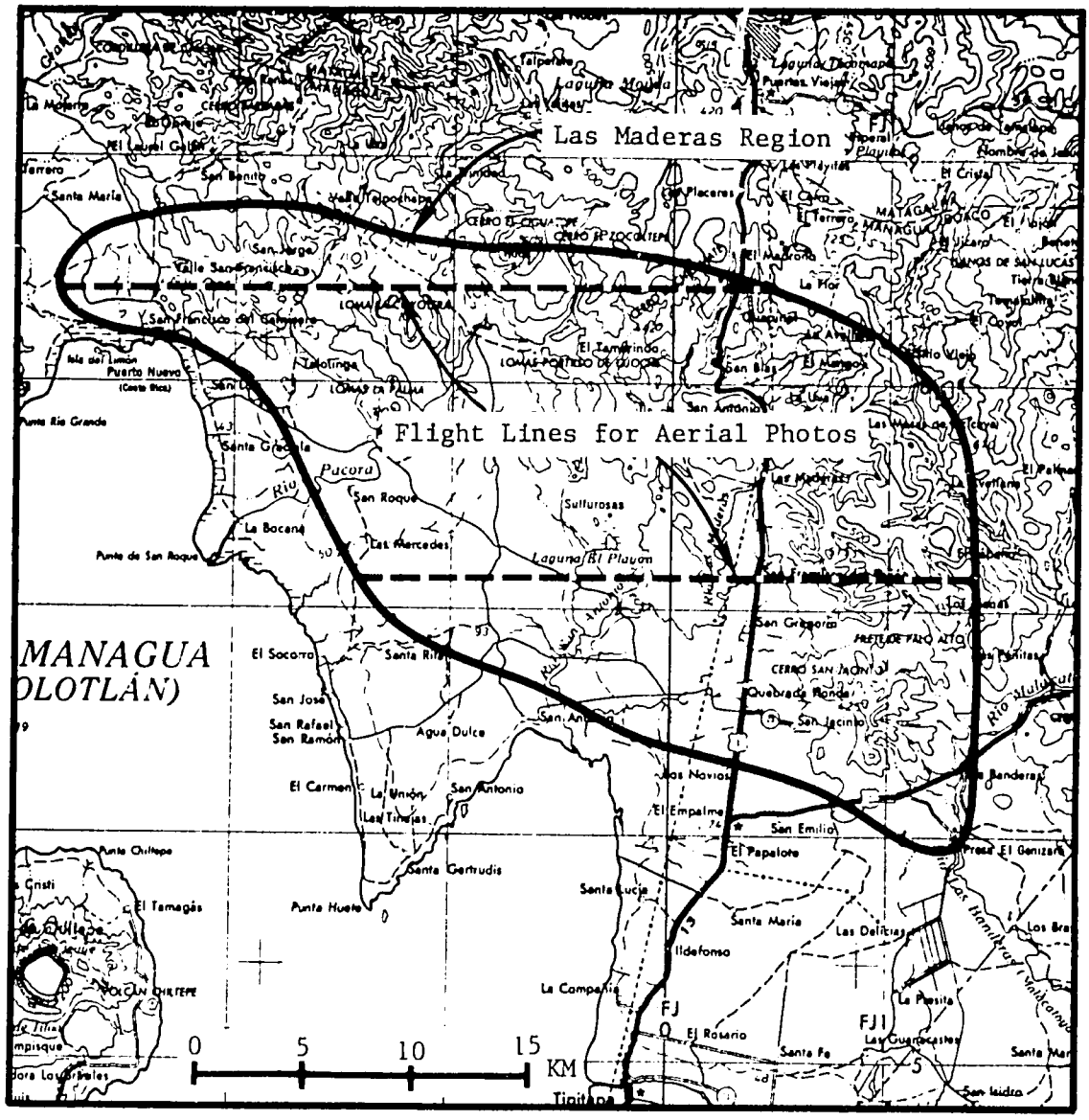

FIGURE 5-1
FLIGHT LINES FOR AERIAL PHOTOS SELECTED FOR SURVEY OF LAS MADERAS REGION

TABLE 5-III

LAND USE LEGEND*

Actively Used to Grow Row Crops or Cattle	
Cultivation	No tree cover: Evidence of cultivation identified the following ways: - clear cut border with adjoining land use or - alignment of plants in rows
Managed Grazing Lands	Tree cover less than 20 percent, but no evidence of row cultivation. Most of this area appeared to have been cultivated in the past and was abandoned to weeds and brush or has been used primarily for grazing with trees retained to provide shade.
Passively Used to Grow Trees	
Wooded Savannah	Tree cover more than 20 but less than 70 percent in which a variety of tree sizes could be seen, varying from large crowns to small, closely spaced trees. Extensively grazed.
Woodland	Tree cover in which individual crowns could be clearly seen but total crown cover exceed 70 percent. No evidence of grazing use.

*Used for aerial photo interpretation

fertility. If fertilizer is used, cultivation may continue much longer. In 1968, only 6 percent of the area appeared to be under cultivation. If the average cultivation time for one plot is three years, 2 percent of the 680 square kilometer fuelwood supply area is cleared of woody vegetation to create fields each year (1360 ha).

Managed Grazing Land - After cultivated land has been abandoned for that purpose and weeds begin to colonize, the land is used for grazing. Within a very short time, however, trees begin to seed from neighboring woodlands and maintenance in the form of tree cutting and burning must take place. If the purpose is to maintain the grazing lands, only a few trees will be kept for shade and grazing productivity will be maximized. Thirty five percent of the fuelwood supply area (a total of nearly 24,000 ha) is managed for grazing.

Wooded Savannah - Nearly thirty six percent of the land is used for extensive grazing in wooded savannah. Cattle are grazed on the land only during the dry season or extensively throughout the year. This may be because of the particular needs of the farmer/rancher or it may be the maximum carrying capacity of the land itself. The wooded savannah lands total over 24,000 ha and are probably the largest source of fuelwood as periodic forest thinning is needed to generate cattle forage.

Woodland - Occasionally, the land is allowed to revert to woodland because of abandonment, fallow, etc. Tree species that provide

their own soil nitrogen (leguminous) are commonly found in this category. It is suspected, however, that most woodlands are simply lands unsuitable for grazing or other uses or are otherwise inaccessible. In any case, woodland comprises 23 percent of the total or 15,640 ha from which the production of timber and fuelwood is the predominant use.

Discussion - Table 5-II presented previously, showed that only 9.4 percent of the total land area had soils capable of cultivation without serious conservation consequences. The land use analysis performed in this study showed actual cultivation on 6 percent of the land. However, a major portion of the land is not cultivated permanently but shifted into cultivation for perhaps a maximum of three years but then allowed to revert to pasture or fallow lands for an estimated period of 10 to 20 years. Were all cultivated land on this cycle, then based on actual use, and not the defined soil capability classes, 20 to 40 percent of the land would be considered as cultivated land. Moreover, as noted in the review of aerial survey data, some of the currently cultivated soils are on 15 to 30 percent slopes* and some on slopes greater than 30 percent. What is evident, assuming the validity of the land capability class definitions, is that farming of land unsuited for cultivation is common in the Las Maderas area.

*Soil Capability Class VI.

5.2 Examination of Dry Forest Productivity

The conventional methodology used by the forestry profession to estimate productivity is to survey the growth and stocking of a forest over a period of 10 to 100 years. A model of natural forest production can then be built from data representing all age classes - from juvenile growth to mature stands. Several important parameters can be quantified:

1. Rotation Age - The age at which a forest stand is mature and ready for harvesting. This may be defined as the age of the culmination of mean annual increment.

2. Mean Annual Increment (MAI) - The average annual growth in weight or volume of a forest stand. This is calculated by dividing the yield (in weight or volume) of the stand at any age by age.

3. Stocking - The number of trees per unit land area. For most forests, there is a theoretical "full" stocking level to which one may compare a measured stocking at any age.

4. Annual Allowable Cut (AAC) - The amount of wood that can be harvested each year from a given forest area without decreasing the forest's productive capacity. This is equal (in theory) to the MAI and is calculated by dividing yield at rotation age by age.

This last parameter, AAC, is the value to be calculated to define a level of sustainable fuelwood production for the Las Maderas region. The calculation of the stocking parameter is done to decide if improvements to forest productivity can be made by changing forest density. Together, recommendations can be made about the present and future expected forest productivity levels.

These concepts of forest growth are important to understand because, through their use, a reliable estimate of annual allowable

cut can be made. The use of the growth measurement methodology requiring repeated annual measurements however, is a long range project requiring much effort in administration and field survey.

Unfortunately, like most of the dry forest areas throughout the Americas, this area has not been inventoried or measured to determine growth rate. In lieu of current forest productivity measurements, three approaches were used to determine a credible estimate of MAI:

- Literature Review - After determining the characteristics of the Las Maderas site, the literature was searched to find productivity of sites similar to Las Maderas in other areas in the world.

- Field Measurements - Actual field measurements were made at selected locations in the Las Maderas area by the authors and by members of CATIE.* These measurements are not considered to have statistical significance for estimation of MAI for the Las Maderas region. However, they do provide insight into present growth, species composition, stocking, management practices, average age, desirable fuelwood species, etc.

- Estimation of Net Primary Productivity - An attempt was made to determine the theoretical Net Primary Productivity (NPP) of a typical dry forest site and adjust for fuelwood utilization of this production.

Each of these approaches is dicussed below.

Literature Review

In reviewing the literature, a screening process was employed to maximize the chances of matching sites. Data were considered only from sites described as follows:

altitude (0 to 600 meters)

*Nico Gewald and Paul Dulin.

latitude (0° to 20° North)

precipitation (less than 1300 mm)

length of dry season (at least 4 mos.)

natural forest competition (no tree plantation trial sites)*

Although a number of sites were found that passed the screening process, it was difficult to obtain sufficient data for a variety of reasons.

It was difficult to find yield numbers for the dry forest measured in volume or weight increments. The trees are so small that conventional volume tables, produced for measurement of logs or pulpwood, do not apply. Most of the dry forest never gets large enough to provide these kinds of products. In some cases, when basal area and height data were provided, the following formula was used to determine volume:**

Volume = Basal Area/ha x Mean Height x Form Factor

where:

Volume is the total tree volume per unit land area measured in m^3/ha.

Basal Area/ha is the total cross sectional area of wood (measured 1.3 m above the ground) per unit land area measured in m^2/ha.

Mean height is the mean tree hight measured in meters.

Form Factor (assumed to be 0.4) is the assumed ratio of actual tree volume to the product of tree basal area and height.

*Literature review for plantation trials is provided in Section 6.0.
**This formula was recommended by Nico Gewald, CATIE.

Another difficulty was to find growth measurements for natural forests. Most of the growth measurement was made on plantations created to te. the adaptability of exotic species. There appears to be no record of growth studies on any species of Acacia which is heavily represented in natural dry forest stands.

The average age of the dry forest in the Las Maderas area may be less than six years. However, when growth data for natural stands are reported, these stands are often much older. The problem is that the juvenile period of growth in the dry forest appears to be very short but growth during that period is very rapid. The rate of growth appears to slow drastically at 10 years or even before ten years and it may become negative before 20 years. Ariel Lugo* measured the biomass of a 50 year old stand and a ten year old stand in the tropical dry forest of Puerto Rico. The MAI of the 50 year stand was less than 1 MT/ha/yr and the ten year old stand was 2.5 MT/ha/yr. Assuming that leaves have a moisture content of 90 percent and the bole and branches have a moisture content of 50 percent, a MAI (biomass) of 2.5 MT/ha/yr corresponds to 5.43 green MT/ha/yr. MITRE's field study indicated that fuelwood makes up 43 percent of the green weight of the trees sampled. Using 50 percent moisture content for fuelwood, this green weight biomass productivity converts to a dry

*Conversation with Ariel E. Lugo, Tropical Forestry Institute, San Juan, P.R.

weight fuelwood productivity of 1.2 MT/ha/yr (approximately 50 percent of the biomass dry weight).

Jennings (Jennings-1979) surveyed the dry forest area in the Dominican Republic by applying an estimate of stand age she obtained from residents of the area to an inventory which she also conducted. The dry forest region in the Dominican Republic experienced average annual precipitation from 665 mm to 1014 mm, slightly less than the Nicaraguan dry forest area. Jennings reports a growth rate of 1 to 5 m^3/ha/year with an average of 2.9 m^3/ha/year.

A monograph on Prosopis juliflora (Felker-1979) reports production of mesquite from various studies in India and Pakistan. The rainfall was very low, 400 mm/yr and less, but growth of small, very densely planted plots in Pakistan ranged from 13 kg/ha/yr to 8000 kg/ha/yr. This range of data is not particularly useful, however, Felker reports that nine of these plots produced over 3 MT/ha/yr in timber volume at the age of 12 to 15 years.

R.H. Kemp (Kemp-1963, Kemp-1970) has reported about growth rates of savannah woodland in the Afaka Forest Reserve in Nigeria. The altitude of the reserve is 600 meters; precipitation is about 1300 mm with a five month dry season. Like much of the Las Maderas area, drainage at Afaka is imperfect. Measurement of growth of a stand of Isoberlinia doka and Monotes kerstingii with 50 year old specimens indicates something less than 1/2 m^3/ha/year (using the volume formula recommended by Gewald).

Although Kemp's analysis also showed that maximum volume growth of the natural forest would be reached on a long rotation (100 years or more), he also observed the growth of a nearby plantation of Cassia siamea. At 4 years, the basal area growth and the height of the Cassia siamea was equal to the 50 year old natural stand. However, height growth virtually stopped at this level, as if the characteristics of the site precluded growing trees taller than 4.5 meters. This characteristic may be shared with the Las Maderas site - early, fast height growth but early height limit reached as well. Also, it is likely that the slow, uniform growth rate of the natural stand that Kemp analyzed is a function of the genetic characteristics of the two species. The growth characteristics of Cassia siamea appear to be more similar to the species in the Las Maderas area than those of the Nigerian natural savannah forests.

Another publication, reporting on productivity at Afaka, Nigeria (Jackson, 1973) is more concerned with fuelwood production. He interprets Kemp's data, assigns an age of 50 years to the stand of Isoberlinia doka and Monotes kestingii and calculates a MAI of 0.43 m^3/ha/yr. Jackson analyzed a 70 year old stand of Isoberlinia doka and calculated a MAI of 0.59 m^3/ha/yr. Other 21 year old stands of coppiced Isoberlinia yielded 0.53 to 1.33 m^3/ha/yr. He suggests a MAI of the natural woodland in Nigerian savannah of 5 to 15 ft^3/acre/yr (0.32 to 0.95 m^3/ha/yr).

However, nearby plantation yields of Eucalyptus camaldulensis and E. grandis hybrid (suspected to be the same ones described by Kemp - 1970) reached 16 m^3/ha/yr for 3 and 6 years, respectively.

Field Measurements

The MITRE-IRENA project team took some measurements of typical fuelwood trees (see Appendix B) and recorded the green weight yield at maturity (rotation age varied from 2 to 3 1/2 years). Only one of the three samples was taken in a nearly fully stocked stand. The others were taken in managed grazing land with 100 to 400 trees/ha. It is estimated that fully stocked stands of this age might have 1400 trees/ha.

The two samples taken from managed grazing land show an average growth rate of 0.71 MT/ha/yr. The one sample taken in woodland represented a phenomenal growth rate of 6.9 MT/ha/yr. The soil in this area is clearly of agricultural quality and had been cultivated approximately 25 years ago.

Measurements of trees were also made by Nico Gewald and Paul Dulin at two of the three sites sampled by the MITRE-IRENA team. A copy of this report is included as Appendix D. Gewald estimated volume rather than weight yield. The volume estimate in the wooded savannah site is 8.5 m^3/ha/yr (7.65 metric tons/ha/yr; specific gravity of 0.9 is assumed). Gewald was reluctant to estimate volume in the other two sites, one of which he did not sample because of its degraded condition.

Estimation of Net Primary Productivity

Net Primary Productivity (NPP) estimation is an attempt to predict the annual plant yield for a given site. NPP is that part of the gross primary productivity of photosynthetic plants that remains after some of the carbohydrate material is used for respiration (Lieth-1975). If this measure could be determined and correct assumptions made about stocking and percent biomass produced by all the components, one could determine the capacity of a site for the production of fuelwood.

In the chapter on tropical terrestrial ecosystems (Lieth-1975) written by Peter B. Murphy, an attempt was made to determine the NPP of seasonal forest or raingreen forest - a term very descriptive of the Las Maderas dry forest. Table 5-IV shows four examples that were extracted from the literature and averaged to give a NPP estimate of 1620 $g/m^2/yr$ or 16 MT/ha/yr.

Experimentation has provided data (in a range from 1 gram to 10^6 grams of shoot system dry weight) that are used to determine coefficients for a regression which predicts root system dry weight:

$$\log RSDW = = -0.699 + \log SSDW.$$

Using this relationship to isolate the shoot system dry weight of 14.8 MT/ha/yr from the NPP value above, and assuming that about 50 percent of the aboveground dry weight of the tree can be used for fuelwood, the annual productivity of fully stocked raingreen

TABLE 5-IV

TOTAL ANNUAL NPP (OVEN DRY BASIS) IN TROPICAL RAINGREEN FORESTS

Ecosystem	Location	Approx. Growing Season (Days)	Annual Rainfall (mm)	NPP (g/m2/yr)	NPP (MT/ha/yr)
Dry deciduous forest	Varanasi, India 25°18'N	120	1040	1550	15.5
Seasonal forest	Ivory Coast 5°N	-	1500	1340	13.4
Mixed dry forest	Ibadan, Nigeria 7°26'N	-	1230	1140	11.4
Deciduous forest in Savannah	Calabozo Plains, Venezuela 8°48'N	-	1200	2460	24.6
		Mean Productivity		1620	16.2

forests is about 7.4 metric tons/ha/yr. This might be considered an upper bound for a natural woodland in the dry forest area.

Caution should be used in applying these results since the sample size is small, relations between the Nicaragua dry forest and the forests measured are not established and the ratio of fuelwood produced to aboveground biomass is not well known. However, the estimated NPP is very close to the maximum calculated productivity of the natural dry forest and encourges the acceptance of the field data.

5.3 Estimation of Productivity for the Las Maderas Fuelwood Supply Area

Table 5-V presents a summary of the productivity data for natural dry forests discussed in this section.

The top of the table shows the productivity estimates provided by Kemp and Jackson for the Nigerian natural savannah forest. As seen, the Nigerian data is based on stand ages of 21 to 70 years. These ages are not applicable to the young growth of the Las Maderas area, and in fact, all other indications suggest that MAI for tropical dry forests culminates before age 10. For these reasons, the MITRE project team feels that this Nigerian data has limited applicability in making productivity estimates for the Las Maderas region.

From the remaining productivity estimates, it should be noted that the MITRE data, taken directly from Las Maderas, is based on a crude sampling approach and that the upper range of the MITRE data and the Gewald estimate are based on sampling of high productivity

TABLE 5-V

PRODUCTIVITY ESTIMATES FOR
NATURAL DRY FORESTS

Source	Age	Volume (m^3/ha/yr)	Weight (MT/ha/yr)
Kemp	50	0.5	0.45
Jackson	21-70	0.32 - 0.95	0.29 - 1.20
Lugo	10	1.3	1.2
Jennings	2-3	1.0 - 5.0	0.9 - 4.5*
Felker	12-15	3.3	3.0
MITRE	2-3	0.8 - 7.7	0.7 - 6.9*
Gewald	3	8.5	7.6
NPP (Murphy)			7.4

*Assumed S.G. = 0.9

woodlands in the region. The NPP theoretical estimate, the Gewald estimate, and the upper range estimate for MITRE might be considered as upper limits for Las Maderas natural forest productivity and not considered as potential average productivity estimates.

From the data of Table 5-V, and the judgment of the MITRE project team in the comparison of this information with the actual conditions seen in Las Maderas, MITRE estimated ranges of dry forest productivity for each of the four land use categories described

earlier in this section. These ranges are presented in Table 5-VI under the title "Harvest Rate."

The low estimate given for the "Managed Grazing Land" category is based on the very low stocking of lands seen in this category relative to the typical stocking reported in the data sources. The conservative estimate given for the "Woodland" category is based on the concern of the authors that the high growth measured by both MITRE and Gewald in this category was taken from an area with fertile soils and based in large part on the species Gliricidium sepium which is not very common today in the Las Maderas region. Another consideration is that isolated woodland areas are also harvested for local construction lumber, poles, etc. which will not be available for fuelwood supplies.

The harvest rate ranges are multiplied by the areas calculated previously for each of the four land use categories and summed to give a range of Las Maderas Annual Productivity or Allowable Cut. In oven dry weight terms, this range is 74,000 to 127,000 MT and at 30 percent moisture, 106,000 to 182,000 MT.*

Commentary on Results

The annual supply estimate range given above is 2 to 3.6 times the estimated amount extracted from the Las Maderas region in 1980 (see Section 4.0). The implication that the supply for fuelwood

*Thirty percent moisture weight calculated for comparison with fuelwood demand figures in Sections 3.0, 4.0, and 7.0

TABLE 5-VI

ESTIMATE OF ANNUAL ALLOWABLE CUT
FOR THE LAS MADERAS REGION

Land Use Category	Area (ha)	Type Cut	Harvest Rate* (MT/ha)	Annual Production* (MT)
Cultivation (Fuelwood Harvested)	1,360	Clearcut	5.0	6,800
(No Fuelwood Harvested)	2,720	--	0	0
Managed Grazing Land	23,800	Selection	0.5 - 1.0	11,900 - 23,800
Wooded Savannah	24,480	Selection	1.0 - 2.0	24,480 - 49,960
Woodland	15,640	Selection	2.0 - 3.0	31,280 - 46,920
Total	68,000			
Range of Las Maderas Annual Productivity - Oven Dry Weight (MT)				74,460 - 127,480
Range of Las Maderas Annual Productivity - Weight at 30 percent Moisture (MT)				106,400 - 182,100

*Oven Dry Weight

greatly exceeds the demand in the area should not be misinterpreted. The fact that the age of the trees throughout most of the area visited by the MITRE/IRENA team was less than 6 years demonstrates the heavy cutting pressure being placed on the region.

First, the boundary of the Las Maderas region was drawn free hand with the help of the IRENA staff and information from fuelwood cutting permits. If the boundary of the region were moved "inward" only three kilometers, the total area of the region would be reduced by approximately 36 percent showing the sensitivity of the productivity estimates to the location of the boundary of the region. The actual fuelwood areas supplying Managua need to be delineated in greater detail in future studies.

Secondly, the question of access to the Las Maderas region was not resolved in this study. Although roads criss-cross the area, there was no confirmation of the question of non-uniformity of harvest in the region due to access limitation. This question needs to be analyzed in more depth. A new aerial photographic series of the area would be most useful.

Thirdly, assuming the reasonableness of the productivity estimation made above, the demands being placed on the Las Maderas area that the MITRE/IRENA team visited appear to be greater than what has been calculated. It was assumed that 90 percent of the fuelwood cut within the Las Maderas region was destined for Managua. This figure may be too high, implying a drain of wood resources to other areas or

for other purposes, or that the demands in Managua are actually significantly larger than has been calculated.

Finally, through more actual sampling in the Las Maderas region, the productivity estimates made above should be reevaluated.

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6.0 ALTERNATIVES FOR THE LAS MADERAS REGION

In this section we describe two possible options for future management and/or use of the Las Maderas fuelwood resources:

- Improved Forest Management
- Charcoal Production

We present a description of each of the options along with a discussion of the advantages and disadvantages of each.

6.1 Improved Forest Management

At the present time, fuelwood is being produced and harvested in the Las Maderas area primarily as a by-product of cattle grazing. The objectives of management are, for the most part, to produce food and shelter for cattle. Although the practice is an old one, it is only recently that a word has been coined to express the compound production of agricultural and forestry crops: agroforestry.

The reason that "agro" is the dominating force in agroforestry for the Las Maderas region is economics; there is more profit per unit land area to raise cattle than to use the land for other purposes. When the value of fuelwood increases relative to other goods in the economy (which it will likely do if fuelwood becomes scarce) profit will increase for the landholder practicing fuelwood management.

In spite of the present indicated excess of fuelwood supply over demand, as soon as fuelwood is no longer available from the

CONARCA project and population increases sufficiently, demand may increase past the supply ability of the present fuelwood production system.

Forest or woodland management is one option to increase the production of fuelwood. Within this concept there are three management philosophies which should be considered for application:

- Natural Forest Management
- Intensive Forest Management
- Agroforestry*

6.1.1. Natural Forest Management

Natural forest management is management of the natural forest so that the highest sustainable level of fuelwood production is reached with existing tree species. These are tree species that represent a major component of a stable ecosystem. The characteristics of this philosophy are:

1. The natural diversity of the established ecosystem is preserved as insurance against disaster or epidemic caused by a single predator or disease agent.

2. Any disruption of the established ecosystem that could have widespread and negative consequences is avoided.

3. Natural forest management requires relatively low level of economic inputs (low labor cost and little or no capital cost) which results in relatively low growth response (compared to intensive management) and a low level of risk.

4. Management of a natural forest is primarily a practice of fine tuning the forest growth. Typically, one tries to channel growth to trees with good form and minimize mortality due to competition between trees.

*Here considered as a well-defined scientific management approach.

If the present Las Maderas woodland area were to be managed for production of fuelwood instead of cattle, several changes could take place.

- It is possible that the forest is currently harvested rather unevenly; that portion closest to a road contributing more heavily toward the production of fuelwood than the more isolated areas. If this is the case, vehicle access should be provided to all areas on which fuelwood is produced, allowing regulation of harvest.

- The age of trees when they are now cut for fuelwood seems remarkably young-under 6 years. The age corresponding to the culmination of mean annual increment or financial maturity should be determined for the important fuelwood species in the Las Maderas area. When those ages are known, areas can be planned for harvest at rotation ages representing yield goals of a managed forest.

- As in managing for fuelwood and forage using the agroforestry philosophy, especially desirable fuelwood species can be encouraged by reducing competition. This can be done by employing local cutters to make improvement cuttings regularly. Spacing of the tree stand can be controlled the same way.

Although national forest management does provide opportunities for improving the forest productivity in the Las Maderas region, some parts of the wooded savannah and managed grazing regions may not contain sufficient soil moisture to support a dense tree crop. These lands may best be suited to production of cattle forage.

6.1.2 Intensive Forest Management

Intensive forest management requires plantations of trees selected for particularly desirable characteristics; e.g., high calorific value, fast growth, good pulping qualities. In intensive forest management:

- The natural forest is virtually eliminated because of poor productivity or because the desired product cannot be manufactured from the native species.
- The new forest is planted with species that have been selected or bred for specific, desirable qualities.
- Intensive methods of establishment and maintenance are employed to assure high production and elimination of competition.

There is very little of the Las Maderas area that does not support forest cover of some kind so that site preparation would have to occur before plantations could be established. Since most of the existing tree species sprout after cutting, there would also have to be provision for restricting competition until the plantation became established. These can be costly processes.

There are however, high yield species that are well suited to the production of fuelwood.* A review of literature revealed several of these species that have been tested under conditions similar to those found in the Las Maderas area. Table 6-I is a summary of the productivity found during these trials. In some cases, productivity was converted from weight or increment measurements because no volume estimates were reported. The footnotes to Table 6-I provide conversion information.

The "Sources" for Table 6-I have been chosen to represent as well as possible the conditions of the Las Maderas area.

*Some of these species are currently being grown at a CATIE sponsored test plantation near the village of San Francisco Libre.

TABLE 6-I

PRODUCTIVITY INFORMATION FOR TREE SPECIES GROWN IN DRY FOREST PLANTATIONS

SPECIES	YIELD (m^3/ha/yr)	AGE (yrs)	SOURCE	REMARKS
Acacia senegal	4-7	-	Webb-1980	short lived, 2-5 m height
	5	-	NAS-1980	13 m height
Acacia auriculiformis	5	15	NAS-1980	West Bengal, shallow soils
Albizia lebbeck	18-28	-	Webb-1980	Free draining soils
	5	10-15	NAS-1980	Damaged by browsing
Azadirachta indica	5-18	-	Webb-1980	
	2-21	8	NAS-1980	Used as cattle shade
	2-18[a]	8	Jackson-1973	Savannah zone of Nigeria
	9[b]	5	Gómez-1981	0.024 ha trial plot
Calliandra calothyrsus	5-20	1	NAS-1980	Indonesia trials-needs 1000 mm rainfall
Casuarina equisetifolia	6-18	-	Webb-1980	Prefers light textured, well drained soils
	20-25	8-12	HNEI-1977	S.G. = .9 to .98
	11-20[c]	7-10	NAS-1980	Grows poorly on heavy clays
Cassia siamea	20	10	NAS-1980	1000 mm rainfall; damaged by browsing; weeding necessary
(C. marginata and C. spactabilis may be more applicable to Nicaragua)	4-5[b]	4	Kemp-1963	stocking of 200 trees/ha is too high
Eucalyptus camaldulensis	3-26[b]	5-6	Gómez-1981	14 plots = 0.452 ha
	15-25	-	Webb-1980	
	2-11	15	NAS-1980	poor, dry sites
	17-30	7-10	NAS-1980	good sites
	13-27	-	FAO-1955	Israel
	16-44[ab]	3-6	Jackson-1973	Nigeria
Eucalyptus Teriticornis	7-14[b]	5-7	Gómez-1981	5 plots = 0.112 ha
	12-25	-	Webb-1980	Queensland, Papua New Guinea
Gliricidia sepium	7-8[d]	3	MITRE	La Concha, Nicaragua
	8.5[d]	3	CATIE	La Concha, Nicaragua
Leucaena leucocephala	30-40	3-10	NAS-1977	Hawaii (Salvador type)
Gmelina arborea	10-17[b]	5	Gómez-1981	3 plots = 0.084 ha
	20-35	5-8	NAS-1980	damaged by browsing S.G.= .42 to .64
	16-22	1-11	Jackson-1973	Nigeria forest/savannah transition
Prosopis juliflora	5-7	10-15	NAS-1980	150-750 mm rainfall
	3-5	-	Webb-1980	prefers well drained soils

[a] Production records kept in cords (128 ft^3 stacked volume). Jackson converted to solid volume by using 40 ft^3 solid to 128 ft^3 stacked volume.

[b] Volume determined by using the following formula:
Volume = mean height x basal area/ha. x 0.4 (form factor).

[c] Volume determined by using the following formula:
Volume (m^3) = oven dry weight (tons)/0.9 (S.G.)

[d] Natural forest data. Included here for comparison to show strong potential for Gliricidia sepium as a plantation species.

(Webb-1980) - From species trial data throughout the world, Webb has organized species by altitude, temperature and moisture requirements. All species selected from the Webb report were considered applicable in areas of 400 mm to 1000 mm rainfall, at 0-500 meters altitude, and where the mean annual temperature is over 24.5°C.

(NAS-1980) - The National Academy of Science publication, "Firewood Crops" is a comprehensive listing and description of tropical tree species suitable for fuelwood. The environmental requirements and peculiarities of each species are noted so the user may choose species on the basis of local requirements.

(FAO-1955) - This United Nations Food and Agriculture Organization publication is a silvicultural monograph of the Genus Eucalyptus with special emphasis on the requirements of establishing Eucalypts as exotics.

(Jackson-1973) - Jackson reviews natural and plantation production of several species adapted to Nigeria savanna conditions very similar to the Nicaraguan subtropical dry forest in latitude, rainfall, dry season and temperature.

(Kemp-1963) - Kemp reports on the growth in the same forest preserve as Jackson.

(NAS-1977) - This NAS monograph details all known requirements for establishing and maintaining plantations of Leucaena. Production data is primarily based on experience in Hawaii and the Phillipines.

(HNEI-1977) - The Hawaii Natural Energy Institute fuelwood investigated species that occur in Hawaii to determine appropriate yield for use in combustion. Casuarina equisetifolia was considered a dry site species.

(Gómez-1981) - Gómez wrote a Masters Thesis on the performance of those Nicaraguan plantations established by the British Forestry Mission starting in 1972. This is the only publication from which it is possible to obtain the results of tests of tree species grown in the same edapho-climatic region as the Las Maderas area.

(MITRE and CATIE) - Measurements taken of a stand of Gliricidia sepium by the authors (Appendix B) and by Gewald and Dulin (Appendix D) confirm that this species grows well even on undisturbed sites in the Las Maderas area. Although not plantation data, these results are promising for consideration of Gliricidia sepium as a plantation species.

It is clear that enough data exist to present a convincing case of increased yields to be gained from growing exotic species. Yields of 20 m^3/ha/yr and over have been reported for 9 of the 14 species adapted for dry forest conditions. Three species may be capable of yields over 30 m^3/ha/yr. This contrasts with natural dry forest maximum reported yields of 8 m^3/ha/yr (Table 5-V) in the unmanaged state. There is also a great deal of variation in yield even within a single species between provenances (E. camaldulensis, Gómez-1981). There is a great temptation to study other provenances and other

species to find the most suitable. However, the yield data appear to be derived from extremely small trial plots. It appears to be an appropriate time to review yield data and select a few species for a large scale operational, test - perhaps 100 hectares - large enough to experience representative effects of variation in micro sites and afforestation methods.

Afforestation Costs

The information on costs of testing, improvement, nursery construction, site preparation, etc., are not found as easily as yield data. The cost of converting land in the Las Maderas area to plantations is not known because no one has yet reported a similar site conversion attempt on a scale large enough to gather cost data. An estimate of the cost of creating and operating a 1000 acre (405 ha) energy tree farm in Hawaii has been reported by Brewbaker (Brewbaker-1980). However, the establishment and tending methods require the use of large machinery, herbicides, fertilizer, etc. This results in excellent growth but at a cost of $892 to $1660/ha/yr.

A preliminary assessment of the profitability of a dry forest energy farm in the Dominican Republic was made by MITRE in 1980. Production rates and costs of establishment, maintenance and harvesting were estimated. Although the establishment, maintenance and primary harvesting functions were expected to be done by hand, the harvesting system was designed for field chipping and transport

of chips in large trucks. Note that the establishment costs were formidable (Table 6-II) but maintenance costs were expected to be very low.

TABLE 6-II

ESTIMATED ESTABLISHMENT COSTS REQUIRED FOR LARGE SCALE ENERGY FARM

Production Element	Cost/[1] ha
Site Preparation	$ 74
Planting	$745[2]
Maintenance	$ 19

[1]1980 U.S. dollars

[2]Tree spacing at 1 m x 1 m.

Ref: (MITRE-1980)

Goor and Barney (Goor and Barney-1968) reviewed the costs of afforestation for several different arid zone regions and found great variation. Table 6-III is taken directly from their publication. Table 6-IV is an itemized list of afforestation costs by operation taken from data for plantations in the Middle East, where all operations are done manually. This analysis concluded that time spent for each operation varied greatly with the kind of soil, the degree of slope, road availability, the amount and species of vegetation

TABLE 6-III

COST OF AFFORESTATION IN DIFFERENT COUNTRIES

Country	Method of Planning	Man-Days per Hectare
Argentina	Mechanized + plants	150
Middle East	Manual labor	155
Spain	Plow (oxen + labor)	170
Brazil	Mechanized + plants	250
Mexico	Manual labor + plants	270
India	Manual labor + plants	300
East Africa	Manual labor + plants	450

TABLE 6-IV

COST OF AFFORESTATION

Operation	Man-Days per Hectare
First year:	
Clearing of land	15
Preparation of soil (pits, strips)	25
Planting, recruiting	15
First hoeing and weeding	25
Second hoeing and weeding	20
Fire lines, pads	5
Total	105
Second year:	
Recruiting	15
Hoeing and weeding (twice)	30
Firebreaks	5
Total	50

Ref: (Goor and Barney-1968).

growing on the site, efficiency of labor, techniques employed and the mechanical equipment used.

The choice between these first two philosophies, natural or intensive forest management, is ideally made by determining the costs of each and analyzing the benefits. Whitmore (Whitmore-1981) has reported that when this approach is used in Latin America, the use of plantations is often chosen only when the primary forest is either severely degraded or it has been eliminated. Regardless, an economic assessment of natural and intensive forest management should be persued for the Las Maderas area.

6.1.3 Agroforestry

A third philosophy of forest management that is gaining advocates in tropical regions rapidly and is being used in a somewhat ad hoc fashion in the Las Maderas region is agroforestry. As defined by King (King-1978) in an ICRAF (International Council for Research in Agroforestry) publication, "Agroforestry is ... a sustainable management system which increases overall yield of the land, combines the production of crops, (including tree crops) and forest plants and/or animals simultaneously or sequencially, on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population." Because of the high potential of this management philosophy the application of a more scientific approach to an already accepted concept may have the

greatest potential near-term impact for sustaining the future supplies of fuelwood from this region.

Agroforestry is employed to increase yields of feed and forage. In the Las Maderas case, leguminous trees provide shade for cattle grazing, nitrogen for forage production and a root mat to hold soil in place. Fuelwood production is incidental. There are other ways, however, to produce an agricultural crop and an energy crop simultaneously and increase total productivity.

In order for a different agroforestry system to be implemented, the land owner must receive more total benefits than were obtained from the old system. For cattle farmers, this means a system that will produce more forage and/or more fuelwood.

There are two fundamental ways to accomplish this:

1. Recognize those trees that are most valuable in providing forage and fuelwood and encourage their growth. This is simply fine tuning the present system and it would surely be helped by research that focused on maximizing profit to cattle/fuelwood producers.

2. Replace native species with exotics that provide the same types of benefits as do native tree species but at an increased productivity. The following relatively high yield species were described on Table 6-I: *Acacia senegal*, *Acacia auriculiformis*, *Azadirachta indica*, *Gliricidia sepium*, *Leucaena leucocephala*, *Prosopis juliflora*.

Gliricidia sepium is not an exotic. It is native to the moister portions of the Las Maderas area but is a fast growing legume that has a multitude of applications. *Gliricidia sepium* will provide shade and nitrogen when grown as a component of grazing land. It has

other uses, however, that make it an ideal species for the practise of agroforestry. Table 6-V outlines these uses and identifies other tree species that have multiple uses.

Trees and food crops can be interplanted for mutual benefit, too. Corn and millet demand high nitrogen nutrient levels which could be provided by interplanted Leucaena. When Leucaena provides too much shade, the trees can be harvested for use as fuelwood and allowed to coppice or can be cultivated in another area while the Leucaena is growing rapidly toward merchantability. Planting Eucalypts with beans or sorghum reverses the nitrogen processing from annual to perennial.

The Eucalypt gets the benefit of nitrogen and control of competition and the food crops get the benefit of leafy mulch and temperature moderation provided by the tree canopy. Even if the trees and food crops are not inter-cropped, they can be planted in strips and the tree branches can be lopped and placed on the soil; the food crops get the benefit of mulch and wind break.

Agroforestry systems are very site specific. Every landowner has slightly different needs or levels of needs and thus different systems are applicable. Once again, total benefits versus total costs will be instrumental in the landowners choice of systems. However, low cost is an important requisite as there is no present evidence, credible to the landowner, that scientific agroforestry is cost effective. As techniques of agroforestry are already practiced

TABLE 6-V

APPROPRIATE SPECIES

NAME	FOOD	FORAGE	FUELWOOD	TIMBER	CHARACTERISTICS
Acacia sp. (800 species)		X	X	X	A. albida-African species with valuable timing of leaf drop and pod maturation[4] famous for honey production - foliage provides forage and green manure yield of 400 to 600 kg of pods/ha[4] increases millet yields 500-600 percent[6] A. niloba-construction timber
Albezia lebbeck		X	X	X	foliage contains 30 percent protein[6] produces $5m^3$/ha/yr in 10-15 yr rotations[6] - 5166 kcal/kg calorific value[4] - very hardy
Cajanas cajan	X		X		leguminous cereal (22 percent protein)[6] produced 2 tons/ha of woody stalks for fuelwood
Casuarina equisetifolia			X	X	"best fuelwood in the world"[6] exceptional windbreak, very elastic, salt tolerant, prefers sand, grows poorly in clay[6] - strong, tough wood-posts, tool handles
Gliricidium sepium		X	X	X	seeds high in crude protein - foliage high in carbohydrates, over 20 percent protein[3] (however, it is reported that pods are used as rat poison)[3] - commonly used as living fence wood resistant to decay-fenceposts, etc.
Leucaena leucocephala		X	X	X	forage yield = 50 to 100 green tons/ha/yr[1] - fuelwood yield = 10 to 12 dry tons/ha/yr[2] - potential pulp and paper feedstock
Prosopis juliflora cineraria etc.	X	X	X		spiney, tap rooted tree - pods may contain 50 percent sucrose by weight[4] seeds may contain 35 percent protein by weight - flour may be made from pods good honey producer-up to 2000 kg/ha[4] very durable wood-fenceposts, door frames
Tamarindus indica	X	X	X	X	high sugar content in pod, pod pulp, leaves and flowers; leaves used for seasoning[6] seeds make livestock feed excellent fuelwood but slow growth; timber sold as Madeira Mahagony[6]

[1](Shih-1981)

[2](Lu-1981)

[3](Rostoski-1980)

[4](NAS-1979)

[5](Bene-1977)

[6](NAS-1980)

in Las Maderas, acceptance of other, more productive variations should be relatively easier than acceptance of intensive forest management. Research in pasture/fuelwood management is needed however, to understand the dynamics and trade offs of forage and tree production.

Another agroforestry aspect that should not be ignored is living fences. Tree species such as Gliricidium sepium and Casuarina equisetifolia have been used as living fences and regularly topped and pruned for fuelwood. Both species are adapted to the subtropical semi-arid life zone.

Perhaps one of the easiest agroforestry concepts to implement in the Las Maderas area would be production of fuelwood with forage through the use of species selected for the purpose. The easiest way to do this is to eliminate any non-fuel tree competing for space with a fuelwood tree during pasture maintenance. There are many desirable indigenous fuelwood species in the area (Appendix E).

Other trees could be planted that promise more rapid growth or are better forage producers. Leucaena leucocephala is an example of a fast growing fuelwood free with edible foliage and fruit. Prosopis juliflora is another. Other exotics that may apply equally well are described in (NAS-1980) and (NAS-1979).

6.2 Charcoal Production

From an end use standpoint, charcoal is more desirable than fuelwood as a residential cooking fuel. Charcoal burns hotter,

is not as bulky, and provides a fairly smokeless flame. Some users claim that a charcoal fire provides a desired flavor in the cooking of various foods. For other than the lowest of income classes, many residents in Managua are willing to pay the additional price for charcoal to obtain these benefits.

From a production viewpoint, the majority of charcoal for Managua is produced by the pit method. Wood is stacked tightly in an open pit in the ground, covered with grass and dirt, and pyrolyzed under the reduced air conditions to form charcoal. Charcoal is shoveled from these pits into sacks, delivered by truck to Managua and marketed in a fashion very similar to fuelwood.

Very little charcoal is produced from the Las Maderas region. Most charcoal comes from areas to the south of Managua where charcoal producers have more access to larger and harder woods. (See the discussion of the CONARCA project in Section 2.2.)

The effectiveness of charcoal production by the pit method is a result of many factors: the characteristics of the wood, its density, moisture content, the quantity of bark, the tightness of the stacking of the wood in the pit, the cooling caused by rains, and of course, control of the pyrolysis/charring process itself. This last factor is probably the most important. The traditional pit charcoal production process is more of an art than a science. The charcoal maker, through years of experience, knows from the color and density

of the smoke, the location and extent of the subsidence, what is happening in the charring process. He knows how to change conditions by altering entry air flow and collapsing the ground cover.

According to data obtained from both Nicaragua charcoal makers and from government professionals, the maximum yields of the pit charcoal production technique are 10 sacks of charcoal (totalling 1.2 cubic meters) for each marca of fuelwood (2.4 cubic meters stacked). This corresponds to approximately a 35 percent conversion efficiency on an energy basis (ratio of energy in charcoal to energy in original fuelwood).* This appears to be a target for the charcoal makers. How regularly this is obtained was not determined.

The pit process of producing charcoal requires one to two weeks (8-15 days from one source; 6-10 days from another). Newer processes based on above ground manufactured kilns can reduce this time requirement to 2-3 days (Earl-1974).

The Nicaraguan government through the offices of IRENA have established a charcoal research and development (R&D) program to study the effectiveness of these kilns and their applicability to Nicaragua.

To date, both the Missouri and the Mark V kilns (Earl-1974) have been tested in this ongoing program. Although the Missouri kiln was not successful, initial results from the portable Mark V kiln have been promising.

*On a weight basis, the charcoal will weigh about one-sixth of the original fuelwood weight (assuming 25 percent moisture).

The Nicaraguan charcoal R&D program has been focused on cost effective commercial production of charcoal from the large quantities of wood produced from the CONARCA project. The question arises as to whether a similar commercial charcoal production system based on above ground kilns would be applicable to the woods from the Las Maderas region. The question appears to have two important parts:

- Is a kiln-based charcoal production system cost effective as a commercial enterprise in the Las Maderas region?
- Does a commercial charcoal production system in the Las Maderas region enhance the capability of the region to provide sustainable fuelwood/charcoal supplies?

We treat each of these individually below.

Economic Aspects of Charcoal Production in the Las Maderas Region

Table 6-VI provides a preliminary estimate of the monthly revenues, costs, and income for a small charcoal producer in the Las Maderas region. The venture is based on a single Mark V portable kiln, two full time workers, and a 5 ton truck (identical to the one used in the fuelwood cost estimate in Table 3-II) used to transfer the kiln, transport workers, and to market the charcoal in Managua.

The process requires 20 marcas (30 metric tons) of fuelwood a month at an estimate of C$162 per metric ton of 10 cm diameter fuelwood. Each cycle of stacking the kiln, burning, and charcoal removal is assumed to take three days; eight production cycles occur each month. The 20 sacks from each run or 160 sacks per month are sold in Managua at the current average price of C$90 per sack. These

TABLE 6-VI

ESTIMATED MONTHLY REVENUE, COST, AND INCOME
FROM A LAS MADERAS SMALL CHARCOAL INDUSTRY

Estimated Revenue		C$14,400	160 sacks of charcoal (25 kg each) at C$90/sack
Estimated Costs		C$12,031	
	C$347		Mark V kiln at C$10,000 for three years at 12 percent
	C$4860		Wood costs - based on raja wholesale cost of C$250/120 rajas minus transportation cost estimated from Table 3-II at C$1080 per 5-ton truckload or C$238/metric ton
	C$3600		labor - 24 days at C$100/day 24 days at C$50/day
	C$737		Truck equity - C$50,000 initial cost for used truck for 10 years at 12 percent
	C$1972		Local Las Maderas region travel - 24 days at 30 km/day at C$2.74/km (see Table 3-II)
	C$515		Cost of Marketing Trip to Managua C$586 per trip x 3.99 metric tons per month production/4.53 metric tons full load
Estimated Monthly Income		C$2369	

assumptions, based on the combination of data from personal communications in Managua and (Earl-1974), result in the estimate of total monthly revenues of C$14,400 and costs of C$12,031, giving a monthly income of C$2369. This income estimate is very close to the empresario income estimate for the current commercial fuelwood industry in Las Maderas making 6-7 sales of truck loads of fuelwood in Managua per month.

These calculations also indicate a potential economic advantage of charcoal over fuelwood. A one month operation of the example charcoal system requires only one marketing trip to Managua, whereas the fuelwood operation requires 6 or 7. Because the distance between Las Maderas and Managua is relatively short, and the costs of the marketing trips are dominated by the costs of local Las Maderas travel, this a not a major factor. Should the distances between future fuelwood supplies and Managua markets increase, the economics of charcoal production relative to fuelwood production will improve.

Although the charcoal production cost estimates given here should be checked in continuing studies, the figures show that a portable kiln charcoal production enterprise is likely to be economically viable for the Las Maderas region. Of critical importance to be confirmed in continuing charcoal R&D in Nicaragua is whether the charcoal production of 20 sacks of charcoal (0.5 metric tons) from 2.5 marcas of fuelwood (3.75 metric tons of fuelwood with 25 percent

moisture) is actually obtainable using the typical fuelwoods from the Las Maderas region.

Energy Supply and Demand Aspects of Charcoal Production in the Las Maderas Region

The redirection of Las Maderas fuelwood production to charcoal production requires either a substitution of the new Las Maderas charcoal for the current supplies originating from other sources or an increase in the Managua demand for charcoal itself. The supply substitution appears to be unlikely, at least for the present, as long as the CONARCA project is a source of high quality, low price wood for charcoal production. A different situation is likely to occur when the CONARCA wood supply diminishes and the demand for other wood resources for charcoal production increases.

Secondly, increased demand for charcoal in Managua will occur if either prices of charcoal fall relative to other cooking fuels or if income levels increase to permit more substitution by preference of charcoal for fuelwood. Institution of advanced kiln systems with wood feedstocks produced by the CONARCA project should reduce production costs and could reduce the final market price of charcoal. This reduction will not encourage Las Maderas charcoal ventures without easy access to CONARCA project fuelwood.

From an energy perspective, converting Las Maderas fuelwood to charcoal production would significantly increase the demand on fuelwood resources from the area. At the maximum efficiency of 35 percent energy content of charcoal relative to the energy content of

the feedstock fuelwood, about 2.9 times the fuelwood is required to obtain the same energy in the form of charcoal than in the original fuelwood form. Unless the concentrated energy content of charcoal is needed for high temperature end use, the direct combustion of fuelwood is a much better use of energy resources.

If the Las Maderas region is currently near its capacity limits for fuelwood production, then a conversion from fuelwood to charcoal production would have most serious impacts on the ability of the region to provide cooking energy supplies to Managua and/or seriously deplete the forest resources of this region. This finding points again to the need to refine the Las Maderas forest productivity estimates outlined in Section 5.0.

7.0 RESULTS AND RECOMMENDATIONS

This section serves to integrate and summarize the results and recommendations of this assessment. The authors have selected a question and discussion answer presentation. The logic behind this is to provide the reader with insight into the thought process used to arrive at results and also to present the problems of conflicting data when they occur.

What is the Condition of the Forests in the Las Maderas Region?

The Las Maderas forests are better called woodlands because of their small size and generally low level of stocking. Most trees in other than streambeds or ravines appear to be young (and probably less than 6 years of age). This attests to the high level of pressure on the resource to provide cattle grazing conditions rather than a "hard" forest product (fuelwood, timber, etc.) Although stand age and stocking are low, the dry forest species sprout quickly and seed prolifically at a very early age thus guaranteeing stand regeneration.

In this context, obvious signs of neither forest desertification nor deforestation in the Las Maderas region have been found during the study. However, there is a trend towards less diversity as certain trees are selected by fuelwood producers, i.e., now madrono can hardly be found where once it was commonly found throughout its range.

What is the Condition of the Soils in the Las Maderas Region?

The soils are generally poor for agricultural purposes but adequate to support the requirements of the existing forest.

At issue is whether the high nutrient demands of a forest of juveniles will not deplete the nutrient pool of the shallow soils substantially quicker than would 20 year old forests. Very little evidence of erosion as a result of fuelwood harvesting was noted.

What is the Current Forest Management Practice in the Las Maderas Region?

The lands are used principally for cattle production with some scattered subsistence agriculture.* Except for the small amount of clearcutting to prepare new fields for crop planting, virtually all fuelwood cutting is a thinning operation. Landowners/ranchers cut back foliage to permit growth of grasses and forage for cattle grazing. Clearcutting is not done in order to maintain shade and tree forage for cattle, and to protect the shrub and grass undergrowth from scorching during the dry season.

This symbiosis between cattle and fuelwood production appears to be the key management element that is preserving the health and productivity of the forests in the Las Maderas region. Policies to encourage future sustainable fuelwood yields from the Las Maderas region must not neglect this symbiosis. The actual pattern of land ownership and the profitability of the cattle industry may be the most important factors in assuring future fuelwood supplies from the region in the context of the existing operation.

*The exact size of cattle production in the Las Maderas region could not be determined. This is an important factor for future assessment to be able to quantify the balance between cattle range needs and forest productivity.

What is the Supply and Demand Picture for Fuelwood for Managua and the Las Maderas Region?

This study estimates that the 1980 demand for fuelwood for residential cooking in Managua was 103,000 metric tons.* Although no data were available, based solely on what the MITRE-IRENA team could estimate from trucks supplying the Managua area, industrial use of fuelwood could increase the total by 20 percent, yielding a total fuelwood consumption in Managua of approximately 124,000 metric tons for that year.

Charcoal consumption in Managua in 1980 was estimated at 20,000 metric tons. At the maximum energy conversion efficiency of 35 percent obtained from the current charcoal production techniques, this consumption of charcoal required at least 118,000 metric tons of fuelwood as raw material.

Managua as a whole then consumed approximately 242,000 metric tons of wood for fuel in 1980.

MITRE estimated that in 1980 the Las Maderas region supplied Managua with 46,000 metric tons of fuelwood. With its own local fuelwood use and a small amount of charcoal production, the total production from the Las Maderas region was estimated at 51,000 metric tons.

*Except where noted, all fuelwood weights in this section are based on 30 percent moisture content.

At an expected population increase of 4.7 percent per year, this total demand on the Las Maderas region is projected to grow to 80,000 metric tons by 1990.

The estimation of current sustainable yield of fuelwood from the Las Maderas region is 74,000 to 127,000 oven dry metric tons or 106,000 to 182,000 metric tons at 30 percent moisture content. This estimated yield range is about 2 to 3.5 times the estimated 1980 production from this region.

The greatest impact to the present fuelwood supply and demand situation in Managua results from the large supply of fuelwood from the coffee renovation project (CONARCA) arriving in Managua as both fuelwood and charcoal. Should the project be terminated in 1982 as currently planned, this supply source would disappear within two years and would likely cause significant increased demand pressures on the traditional fuelwood supply areas such as the Las Maderas area.

Who Uses Fuelwood in Managua?

Direct fuelwood consumption for residential cooking is almost totally limited (99.8 percent) to the lowest income classes in Managua. These classes represent about 58 percent of the Managua population.

Residential charcoal consumption is fairly uniform across all income classes except for the highest income class which relies more heavily on liquified gas and electricity for cooking.

There are active cottage industries throughout Managua that use fuelwood. Bakeries, laundries and brick and tile manufactures are examples of these industries. Whereas residential users consume fuelwood purchased in small bundles (manojos), industrial users consume larger split log wood (rajas).

What is the Prospect for Sustainable Supplies of Fuelwood from the Las Maderas Region in the Future?

The evaluation of productivity reported in Section 5.0 was intended to be conservative because of the lack of site specific data. The estimates of productivity bracketed the present fuelwood demands identified by this study. However, several signs point to future sustainability problems:

1. There is no evidence of reserve forest capital in any part of the Las Maderas area. Virtually all trees seen by the MITRE-IRENA team appeared to be immature (no trees over age 6 could be identified positively.)

2. Land unsuited for cultivation (steep slopes) is used to grow row crops because of a lack of suitable arable land.

3. Future population increases will tend to increase pressure on all resources including crops and fuelwood.

4. At the present time CONARCA is furnishing a significant amount of fuelwood and charcoal to the Managua market. In a few years that supply will be exhausted and the Las Maderas area may be pressured to replace it.

Because of time limitations, the MITRE-IRENA team saw only the forest areas within reasonable access to roads. It is possible that forests are older and less disturbed in more isolated areas in the region. Study of aerial photos (1968), and the overflight of the

region did not disclose any obvious differences in forest density except for the high mountains outside of the area analyzed. Although truck access to isolated areas could not be determined by aerial photos, it was obvious that roads and trails criss-cross the entire area and that residents live and perform subsistence farming uniformly across the area.

Items recommended for closer study include:

- delineation of the boundary of the Las Maderas supply area
- cross-sectional sampling of forest productivity across entire region
- identification of road access
- identification of the extent of direct cattle browsing on forest regeneration

What are the Alternatives for Improving the Fuelwood Supply in the Las Maderas Region?

The alternatives assessed in this study were different forestry management techniques and charcoal production. As discussed below, although forestry management is a recommended option, charcoal is not.

Improved Forest Management

Three forest management options are available to improve the fuelwood productivity of the Las Maderas region:

- Natural Forest Management
- Intensive Forest Management
- Agroforestry

Natural forest management includes the development of improved forest access, more uniform and planned cutting over the entire region, and also the encouragement of desirable fuelwood species by thinning of tree competition. Intensive forest management includes the development of energy plantations, and the selection of species and management procedures most effective for energy plantations in the Las Maderas region. CATIE/IRENA are now testing the energy plantation concept and adaptability of species for this area. The last option, agroforestry, represents a forestry management approach which is a current topic of fuelwood research. Because the present control of Las Maderas fuelwood harvesting is in fact a type of agroforestry management, we suggest that emphasis be placed on assessing agroforestry management techniques that might be applied to enhance the current management system and improve the overall fuelwood productivity of the region.

Charcoal

Charcoal production in the Las Maderas region using portable kilns appears to be economically attractive as a small business venture. The major constraint to the charcoal option is again the supply of fuelwood. Requiring about 2.9 times the wood supply to make charcoal than to use the energy directly as fuelwood, the charcoal option is not recommended unless there is a substantial oversupply of fuelwood. Within the context of using the oversupply of wood from the CONARCA project, charcoal is a good option. For the

Las Maderas region, even assuming a high forest productivity, the supplies are not ample enough to justify large scale conversion to charcoal production.

What are the Recommended Actions to Be Taken to Improve the Managua and Las Maderas Fuelwood Situation?

1) The most important action to be taken by CATIE/IRENA relative to the Las Maderas region is to determine the productive capacity of the forest of the region with sufficient accuracy to permit good policy decisions in planning for future fuelwood production. This will require continued assessments of land use, soil quality, forest inventory and growth throughout this region.

2) More detailed species trials should be carried out and pilot fuelwood plantations should be initiated with well adapted species. Some of these pilot plantations should be considered as operational trials. These trials should be made to occupy areas large enough so that inferences can be made about establishment costs, and to account for survival and growth effects due to variations in soil and microclimatic changes. Concurrent economic studies should be carried out to determine the advantages and or disadvantages of intensive plantation management as compared to natural forest management and agroforestry.

3) An accurate fuelwood data system for the Managua region which tracks the production, transportation and consumption of fuelwood for both direct sale and for charcoal production should

be established. This system should encompass all of the fuelwood supply areas for Managua including both the Las Maderas region and the CONARCA project.

A separate project should be initiated to evaluate and monitor fuelwood moisture content to determine the effectiveness of fuelwood end-use consumption.

4) CATIE/IRENA should work to define policy options to encourage long term forest/pasture management procedures on the lands of the Las Maderas region. These practises should be assessed and implemented as needed.

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REFERENCES

Bene-1977 — Bene, J.G., et al., Trees, Food and People: Land Management in the Tropics, International Development Research Centre, Ottawa, Canada, 1977.

BCN-1974 — República de Nicaragua Censos Nacionales-1971, Banco Central de Nicaragua, Ministerio de Economía, Industria y Comercio, Managua, Nicaragua, 1974.

Brubaker-1980 — Brubaker, J.L., Editor, Giant Leucaena (Koa Haole) Energy Tree Farm - An Economic Feasibility Analysis For Island of Molokai, Hawaii, Hawaii Natural Energy Institute, University of Hawaii at Manoa, 1980.

Earl-1974 — Earl, D.E., Charcoal, Food and Agriculture Organization of the United Nations, Rome, 1974.

FAO-1955 — Eucalypts for Planting, FAO Forestry and Forest Products Studies, Food and Agriculture Organization of the United Nations, 1955.

Felker-1979 — Felker, P., Mesquite: An All Purpose Leguminous Arid Land Tree, New Agricultural Crops, AAAS Symposium #35:89-132, 1979.

Gómez-1981 — Gómez, D.A., Evaluación del Comportamiento de Ensayos y Plantaciones Forestales en Nicaragua, MS thesis, Universidad de Costa Rica, Costa Rica, 1981.

HNEI-1977 — Fuels from Biomass: Plants for Fuel, The Hawaii Natural Energy Institute, Technical Report No. 3, University of Hawaii, Honolulu, Hawaii, 1977.

Holdridge-1967 — Holdridge, L.R., Life Zone Ecology, Tropical Science Center, San Jose, Costa Rica, 1967.

INE-1981 — Balance Energético Nacional, Instituto Nicaragüense de Energía, Managua, Nicaragua, 1981.

INEC-1981 — Anuario Estadístico de Nicaragua - 1980, Instituto Nacional de Estadísticas y Censos, 1981.

IRENA-1971 — Soil Survey of the Pacific Region of Nicaragua, Instituto de Recursos Naturales, Managua, Nicaragua, 1971. (+IRENA supplements)

IRHE-1979 Estudio Sobre la Eficiencia de Las Cocinas, Instituto de Recursos Hidroelectricos, Panama, Panama, 1979.

Jackson-1973 Jackson, J.K. and G.O. Ojo, Productivity of Natural Woodland and Plantations of the Savannah Zones of Nigeria, Reprinted from the Nigerian Journal of Forestry, Vol. 1, #2, July, 1971 and reported as Research paper (Savanna Series) No. 20, Federal Department of Forest Research Nigeria.

Jennings-1979 Jennings, P., Dry Forests of the Dominican Republic and Their Energy Production Capacity, Proceedings, Biological and Sociological Basis for Natural Use of Forest Resources for Energy and Organics, Michigan State University, Ann Arbor, Michigan, May 6-11, 1979.

Kemp-1963 Kemp, R.H., Growth Rates and Regeneration of Northern Guinea Savanna Woodland, Department of Forest Research Technical Note No. 24, Nigeria, 1963.

Kemp-1970 Kemp, R.H., Trials of Exotic Tree Species in the Savannah Region of Nigeria, Research Paper No. 6 of the Savannah Forestry Research Station, Samaru, Zaria, 1970.

King-1979 King, K.S.F., Concepts of Agroforestry, International Cooperation in Agroforestry, Proceedings of an international conference sponsored by the International Council for Research in Agroforestry and the German Foundation for International Development, 1979.

Lieth-1975 Lieth, Helmut and R.H. Whittaker (Editors), Primary Productivity of the Biosphere, Springer-Verlag, 1975.

Lu-1981 Lu, C.M., et al., Biomass Production of Two-Year Old Spacing Trials and Plantations of Leucaena in Taiwan, Volume 2, Council for Agricultural Planning and Development, Taipei, Taiwan, Republic of China, 1981.

Lugo-1981 Lugo, A.E., R. Schmidt, S. Brown, Preliminary Estimates of Storage and Production of Stemwood and Organic Matter in Tropical Tree Plantations (draft report), 1981.

REFERENCES (Concluded)

MITRE-1980 Trehan, R.K., L.C. Newman, W.R. Park, The Potential for Energy Farming in the Dominican Republic: A Preliminary Analysis, MITRE Corporation MTR-80W105, McLean, Virginia, 1980.

NAS-1980 Firewood Crops, Shrub and Tree Species for Energy Production, National Academy of Science, Washington, D.C., 1980.

NAS-1979 Tropical Legumes: Resources for the Future, National Academy of Science, Washington, D.C., 1979.

NAS-1977 Leucaena: Promising Forage and Tree Crop for the Tropics, National Academy of Science, Washington, D.C., 1977.

Riegelhaupt-1980 Riegelhaupt, E., Encuesta Sobre Consumo Doméstico de Combustible en Managua (draft report), Managua, Nicaragua, 1980.

Rostoski-1980 Rostoski, J.P., et al., Woody Tropical Legumes: Potential Sources of Forage, Firewood and Soil Enrichment, Proceedings - Tree Crops for Energy Co-Production on Farms, SERI, November 12-14, 1980.

Shih-1981 Shih, W.C., et al., The Yields of Forage of Leucaena leucocephala in Taiwan, Leucaena Research Report, Volume 2, Council for Agricultural Planning and Development, Taipei, Taiwan, Republic of China, 1981.

Webb-1980 Webb, D.B., P.J. Wood, J. Smith, A Guide to Species Selection for Tropical and Sub-Tropical Plantations, Tropical Forestry Paper No. 15, Department of Forestry, Commonwealth Forestry Institute, University of Oxford, London, 1980.

Whitmore-1981 Plantations Versus Other Land Use Options in Latin America, Paper presented to the XVII IUFRO World Congress on Forest Environment and Silviculture, 1981.

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APPENDIX A

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APPENDIX B

A SAMPLE OF DRY FOREST PRODUCTIVITY

Introduction

In order to determine the capability of a site to produce fuelwood, some measure of forest growth must be known. Because this data could not be found at IRENA (Instituto de Recursos Naturales y del Ambiente), an attempt was made to sample trees from each life zone (defined by Holdridge, 1967) to determine biomass growth and fuelwood growth. Initially, it was intended to sample three age classes and three stand density classes as well. It was understood from the outset that the project did not include the design and execution of a statistically valid growth study and that the samples taken would simply give a rough approximation of growth.

There were two main problems with this approach.

1. It was very important to sample a representative or typical stand. There was no opportunity to establish representativeness by randomness. However, the choosing of sites that were truly typical required extensive site examination by a group consisting of two members of the MITRE team, two IRENA staff members and a local fuelwood cutter.

2. The growth variable of interest was "weight/ha/year." With this number, one could multiply by the applicable stand area and determine yearly production of fuelwood. Difficulty was experienced in finding owners or caretakers who could accurately reveal when a specific tree had last been cut for fuelwood. On two out of three samples a consensus of estimates had to be used. Because most of the trees that were merchantable were 2 to 4 years old, a mistake of only one year could have a large impact on the growth estimate.

Methodology

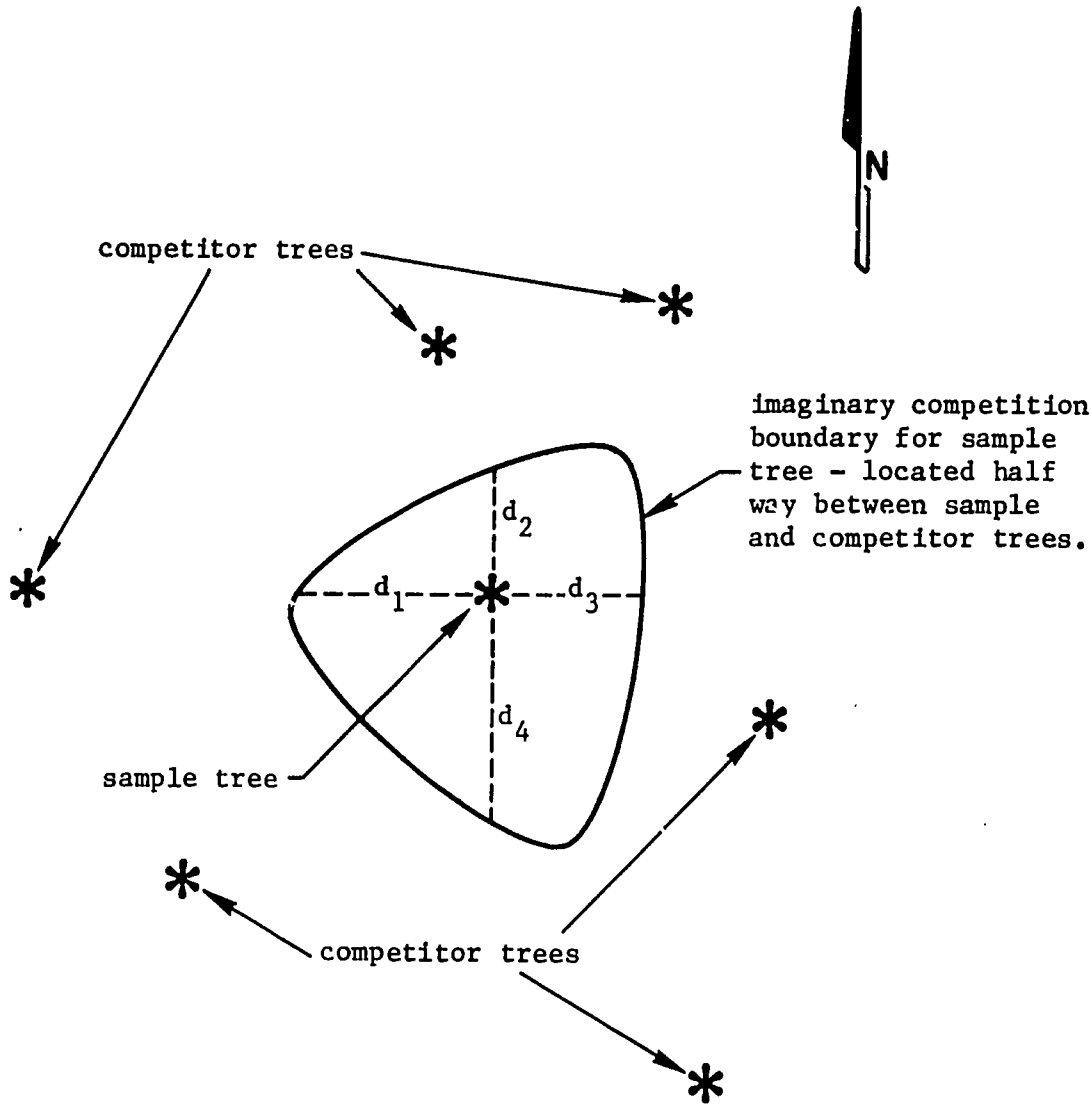
One day was spent familiarizing ourselves with the forest site near Las Maderas and two more days were spent identifying typical sites and collecting data. Since production of fuelwood was our greatest interest, we hired a local fuelwood cutter to cut sample trees into fuelwood.

When a representative tree was identified in a typical stand, the tree was photographed, cut into fuelwood and both the fuelwood and branches were weighed. The number of fuelwood units (manojos) produced was also recorded.

The area represented by this tree was estimated by systematically measuring the distance between the sample tree and several nearest trees which could be direct competitors for light, water and nutrients. An imaginary boundary was constructed halfway between the sample trees and the competitive trees. The distance was measured between the sample tree and the imaginary boundary at the cardinal directions (Figure B-1).

Each distance was considered a radius of the circle. Areas of four circles were summed and the average was calculated.

Another sample of all trees that occurred within a 10 m radius of the sample tree was taken. Each tree was identified by common name (later correlated with a latin name), origin (seedling or coppice) and use (fuelwood or not). Only trees that were likely to form part of a mature stand were counted. This measurement was



Area of space occupied by sample tree was estimated by $A = \frac{1}{4} \sum A_i$ where $A_i = \pi d_i^2$, ie. the average of areas of the four circles of radius d_i.

FIGURE B-1
MEASUREMENT OF "SPACE OCCUPIED BY SAMPLE TREE"

used to calculate stand density (Table B-I). As in much of this sampling procedure, judgement was exercised as to the likelihood of any tree becoming part of the mature stand.

Data Summary

A summary of the data collected by three growth samples is presented in Table B-I. Note the age distribution - two to three and one half years old. We observed some four to five year old stems but very rarely. Although there was only one coppice sample, most of the trees observed had been previously cut and were coppice growth (80 percent of the trees tallied to determine stand density at sample #1 were coppice growth).

There appears to be an inverse relationship of biomass production with spacing. This may result from dryer conditions at samples 2 and 3 or the fact that compaction of the soil in the pasture by cattle would lead to oxygen deprivation and greater moisture runoff or to the fact that the land was simply being managed more intensively at San Antonio and Las Pilas. This relationship could also be accounted for by species characteristics or a combination of the above.

TABLE B-I

SUMMARY OF DESTRUCTIVE GROWTH SAMPLES

	SAMPLE IDENTIFICATION		
LOCATION SITE	#1 LA CONCHA Old field grown up to fuelwood species. Cleared about 25 years ago	#2 SAN ANTONIO Wooded Savanna flat Vertisol	#3 LAS PILAS Wooded Savannah 5% slope Vertisol
Species	*Gliricidium sepium*	*Acacia costaricensis*	*Acacia* sp.
Regeneration source	Coppice-4 sprouts	seed	seed
Age	3 1/2 years	2 years	3 years
Maximum height (m)	7.5	5.9	5.2
Stump diameter (m)	9.5, 7.5, 8.5, 8.0	8.1	8.2, 9.0
Weight of fuelwood (lbs.)	160	31	36
Weight of remaining biomass (lbs.)	137	55	105
Number of *manojos*	21	5	6
Average weight/ *manojo* (lbs.)	7.6	6.2	6.0
Area occupied by sample tree (m^2)	15.15	35.72	62.55
Gross production of fuelwood (MT*/ha-yr)	6.86	0.99	0.43
Gross production of biomass (MT*/ha-yr)	12.75	1.75	1.27
Stand density (trees/ha)	1376	414	95
Fuelwood species (percent)	98	62	67

*Green weight converted to oven dry weight assuming moisture content to be 50 percent.

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APPENDIX C

SOIL CHARACTERISTICS

The attached Table C-I presents a summary of the soil characteristics in the Las Maderas region. Identification of the soil series and capability class was made by examining photomosaics of the Las Maderas region prepared for the Nicaraguan National Geographic Institute, map numbers 2953-2-A and 2953-2-B. Codes for the soil series and capability classes are taken from the Soil Survey of the Pacific Region of Nicaragua, Final Technical Report and Supplement. Percent areas were determined by line sampling across the photomosaic maps.

Table C-II is taken directly from IRENA, 1971, Soil Survey at the Pacific Region of Nicaragua. It offers the rationale for assigning soils to capability classes.

TABLE C-I

SOIL CHARACTERISTICS IN THE LAS MADERAS REGION

Soil Series	Capability Class	% Area	Rank by Area	Description: Slope	Depth	Texture	Other
C-b	IIe-4.2	2.8	12	1.5-4%	60-90 cm	clay loam	well drained
C-bp	IV	1.1					
C-c	III	1.1					
CV	VIII	1.3					
EZbp	VI	0.2					
EZcp	VIs-4	4.1	11	4-8%	40-90 cm	friable clay	stony, well drained
EZdp	VIs-4	4.9	8	8-15%	40-90 cm	friable clay	stony, well drained
EZep	VIIs-7	4.7	10	15-30%	0-40 cm	friable clay	coarse, very stony, well drained
EZf	VIIs-7	8.9	2	30-50%	0-40 cm	friable clay	coarse, very stony, well drained
GCcp	VI	1.3					
GCep	VII	1.2					
GCf	VII	1.0					
SN2a	II	0.3					
SN2b	II	0.7					
SSJa	VIII	0.2					
SSJap	VII	0.7					
SSJbp	VIII	1.6					
SSJcp	VIIs-3a	4.7	9	4-8%	0-25 cm	friable clay	rocky, slowly permeable
SSJdp	VIIs-3a	5.4	7	8-15%	0-25 cm	friable clay	rocky, slowly permeable
SSJep	VIIs-7a	6.2	5	15-30%	0-40 cm	friable clay	rocky, very coarse
SSJf	VIIs-7a	7.8	4	30-50%	0-40 cm	friable clay	rocky, very coarse
SSJff	VII	1.2					
SSJg	VIII	0.2					
TP3	VI	0.2					
TPp	VII	0.9					
TXa2	II	0.2					
TXw2	IV	0.5					
Va	VIw-2	5.4	6	0-1.5%	60-90 cm	heavy clay	vertisol, imperfectly to poorly drained
Vab	VIw-2	17.6	1	0-4%		heavy clay	vertisol, stony to poorly drained
Vb	VI	0.7					
V-C2	VIe-3	1.8	13	4-8%	40-90 cm	heavy clay	vertisol, stony, slowly permeable
VCa4	IVw-2	1.7	14	0-1%		heavy clay	vertisol, somewhat poorly drained
VCb2	III	0.3					
VCc	III	0.3					
VCd	IV	0.4					
Vpab	VIIs-5	8.5	3	0-4%	60-90 cm	heavy clay	vertisols, very stony, hardpan

TABLE C-II

DEFINITION OF SOIL CAPABILITY CLASSES

Class I

Soils in Class I have few limitations that restrict their use, and are suited to growing a wide range of crop plants. The soils are nearly level, and the erosion hazard is low. They are generally deep, well drained, and easily worked. They hold water well, and are either well supplied with plant nutrients, or are highly responsive to inputs of fertilizer. In this survey, extensive areas of Class I soils differ in some respects from Class I land mapped elsewhere in the world. Most Class I land in this survey has a slope of less than one percent, but on soils developed from volcanic cinders and ash, the erosion hazard is greater than on soils developed on most other kinds of parent material having similar slopes. One of the reasons for this is that the soil aggregates are so light in weight (bulk density generally less than one percent), that they are easily moved and transported by water, even though they are quite stable and the soils are readily permeable. The torrential rains that are common during the wet season, especially those in October, which occur after the soils are saturated, are apt to move the surface soil under clean cultivation on practically all slopes of more than three-tenths of one percent. Several areas of Class I land in irrigated areas of this survey would not be classified Class I elsewhere because of uneven microrelief.

Class II

Class II soils have some limitations that reduce the choice of plants, or require simple conservation practices. The limitations are few, however, and the practices are easy to apply. Limitations of Class II soils may be any one or a combination of the following: slopes of 1.5 to 4 percent; slight to moderate erosion; less than ideal soil depth; somewhat unfavorable soil structure, texture, or workability; slight to moderate quantities of salts or exchangeable sodium; occasional damaging floods; or moderately high water table conditions that occur for a short period during the growing season.

TABLE C-II (Continued)

DEFINITION OF SOIL CAPABILITY CLASSES

Class III

Soils in Class III have more restrictions than those of Class II, and when used for cultivated crops, the conservation practices are usually more difficult to apply and to maintain. Limitations may result from the effects of a combination of one or more of the following: slopes generally four to eight percent; moderate to severe water erosion; wetness due to flooding, high water table or imperfect drainage; moderately shallow effective depth of the soil; moderate moisture holding capacity; low fertility not easily corrected; moderate salinity or sodic conditions; or fine clay textures. Each soil in Class II can properly be maintained by one or more alternative combinations of use and conservation treatment, but there are fewer practical alternatives for the average farmer than are available for Class II soils.

Class IV

Soils in Class IV have severe limitations that restrict the choice of plants and or require very careful management or specific kind of management. Soils in Class IV may be well suited to only two or three of the common crops grown in the area, or the yields may be low in relation to inputs. Adaptability to cultivated crops is limited due to one or more of the following unfavorable features: slopes of 8 to 15 percent; shallow depth of effective soil material or root zone is 25-60 cm; unfavorable textures including coarse textures (sands and loamy sands), very gravelly textures of fine clay textures (40-60 percent 2-micron clay); moderate stoniness; wetness caused by somewhat poorly drained conditions, high water table, or flooding for moderately long periods during the growing season.

Class V

Land in Class V has restrictions that preclude growing the general farm crops, but the soil can be used for pasture, range, woodland, or wildlife and cover. The soils are nearly level and have severe limitations due to one or more of the following conditions: a water table at or near the surface during most of

the year; high accumulation of salts; high exchangeable sodium; and frequent flooding. The land that is used for pasture can generally be improved, and benefits from proper management can be expected.

Major improvements such as drainage, leaching of salts, replacing sodium with calcium in sodic soils, and construction of levels to prevent flooding would improve the soil so that the common or adapted crops could be grown. Generally, it was not possible for the soil mapper to determine the feasibility of drainage and reclamation of such land. This usually requires additional study by drainage engineers and agricultural economists. After the land is reclaimed, the capability classification may be upgraded.

Class VI

Class VI soils have limitations that make them generally unsuited to cultivation. Nevertheless, the physical condition of the soil is such that it is practical to apply range and pasture improvements if needed. These include seeding, fertilizing, and water control by use of furrows, drainage ditches, diversions, or water spreaders.

Soils are in Class VI because of moderately steep slopes, generally 15 to 30 percent, where erosion would be severe if cultivated crops were grown; shallowness, depth about 25 centimeters; coarse texture (sand); excessive wetness due to flooding or poorly drained conditions, or stoniness.

Some Class VI soils may be safely used for specialized crops, provided unusually intensive management is used. This is true in the Premontane Tropical Moist Forest life zone, where extensive areas of Class VI land are used for growing coffee in the shade of native trees. Specialized crops could be grown here and on many areas of Class VI land in other life zones. If the crop is planted on the contour, a good cover is established, and protective structures are used to control runoff and prevent erosion.

TABLE C-II (Concluded)

DEFINITION OF SOIL CAPABILITY CLASSES

Extensive areas of Vertisols are in Class VI because they are fine or very fine textured, and somewhat poorly or poorly drained. They have a high water table or are water saturated up to four or five months of the year, which greatly limits their agricultural use.

Most Class VI soils are used for grazing cattle during the rainy season, and for the first 8 to 12 weeks of the dry season until the pastures dry out.

Class VII

Soils in Class VII have very severe limitations that make them unsuited to cultivation and restrict their use largely to grazing, woodland, or wildlife. Where these soils are used for grazing, woodland, or wildlife, it is generally impractical to apply pasture or range improvements such as seeding, fertilizing, and water control. Soils are in Class VII because of one or more of the following continuing limitations: steep slopes, generally 30 to 75 percent; severe erosion hazard; wetness, shallowness, with depths less than 25 centimeters; very coarse texture; and stoniness.

Some soils in this class may be used for special crops under unusual management practices. In the Pacific Area, moderately extensive areas are used for growing coffee in the shade of native vegetation.

Class VIII

Soils and land types in Class VIII have limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or to esthetic purposes.

Soils and land types in Class VIII cannot be expected to return significant on-site benefits from management for crops, grasses, or trees, although area-wide benefits from wildlife use, watershed protection, or recreation may be possible.

Areas of rocky land, lava flows, sandy beaches, gravel pits, mangroves, and very steep land with slopes more than 75 percent are in Class VIII.

APPENDIX D

RESULTS OF FIELDWORK IN LAS MADERAS, NICARAGUA
(Prepared by Nico Gewald and Paul Dulin of CATIE, March 3, 4, 5, 1982)

Measurement Methodology

Three different sites were selected for a more detailed study of the existing vegetation. The first site, La Concha, located approximately 2 km west of km 57, Carretera Norte (Panamericana), is considered an example of the "woodland" landuse class. Another site, San Antonio, is under the "wooded savanna" landuse type. San Antonio is located at 10 km from the turn-off on the Carretera Norte along the road to San Francisco Libre. A third site, "Las Pilas" is 2 km west of the village of Las Maderas. At the Las Pilas site, stocking and species composition and soils were so poor that no measurements were taken. The site is considered a "degraded savanna."

In La Concha and in San Antonio a total of six rectangular plots of 20 x 25 m (three plots/site) were laid out at varying distances from access roads. All diameters at breast height of all the trees bigger than 3 cm were recorded to the nearest millimeter and sprouts and saplings smaller than 3 cm DBH were recorded as R (Resprout). The species were identified by their common names. Where trees had been cut, the diameters were measured at 20 cm from ground level and these diameters were extrapolated to diameters at breast height

(using a set of specific measurements on nearby trees of the same species where both diameter at 20 cm level and DBH were measured).

Due to the periodic selective thinning practices it was not possible to determine the age of the trees. Sample cross-sections have been cut to determine whether the species Gliricidia sepium has distinguishable annual growth rings. Other samples were taken to determine the moisture content and the specific wood density.

Results of Measurements

La Concha

The three sample plots in this site show a predominance of Gliricidia sepium. Although other species are present they mainly occur in the diameter classes smaller than 5 cm DBH, while the mean diameter of the normally distributed diameter classes of Gliricidia sepium attains values between 6 and 7 cm DBH. The results of the diameter-class distribution per plot and for the different species found are presented in Figure D-1.

The stocking varied between 3320 and 1880 trees and/or sprouts/ha including all species, and fluctuated between 1760 and 2040 trees and/or sprouts/ha of the species Gliricidia sepium only. Since site number two is periodically thinned for firewood production most of the "trees" originated from stumps. The number of original stumps was also recorded, and it was found that the number of sprouts increased with the decrease in the number of stumps per hectare. With 660 stumps per hectare an average of 3 sprouts/stump was found; where

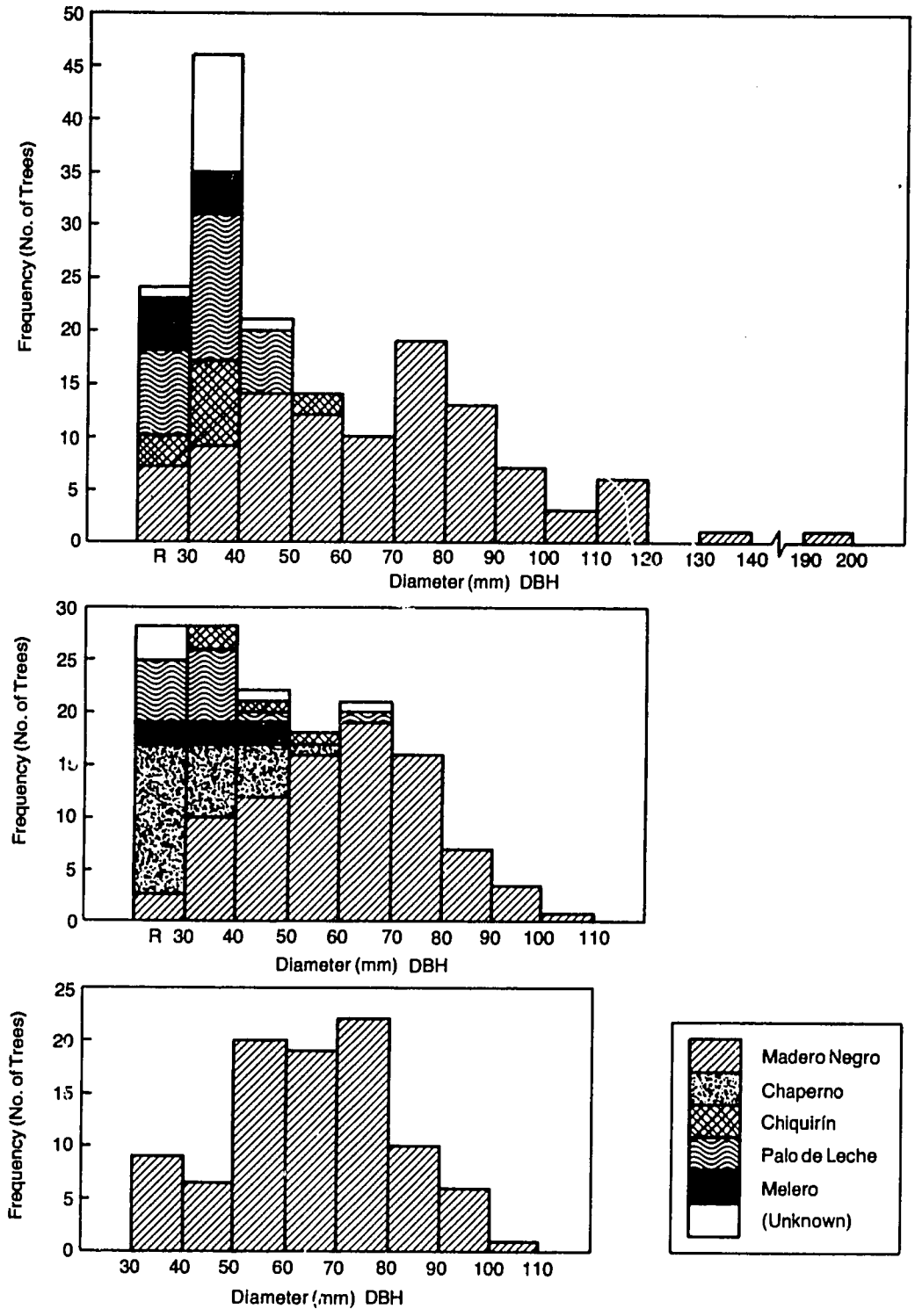

FIGURE D-1
DISTRIBUTION OF SPECIES AND DIAMETER CLASSES ON THREE TEST PLOTS AT LA CONCHA

the original density was 420 stumps/hectare 4.5 sprouts/stump were found and in plot number two, with 320 stumps/ha, 5.5 sprouts/stump were recorded. These data indicate that this species can reach full stocking in a relatively short period of time if planted at a spacing between 2 x 2 m and 2.5 x 2.5 m (1600-2500 trees/ha). In the case of Gliricidia in natural vegetation, densities as low as 320 trees/ha may reach full stocking if 4 to 5 sprouts/stumps are left to grow.

The basal area of the three plots varied between 6.7 and 10.0 m^2/ha of which Gliricidia sepium covered between 5.7 and 8.7 m^2/ha. This result is due to the greater occurrence of this species and its mean diameter which is higher than that of all other species.

An interesting case occurred in Plot Number one, where results of selective thinning practices were observed. From Figure D-2 it can be seen that a "high thinning" has been carried out, eliminating the trees with major diameters (over 7.0 cm DBH). From the total number of trees of this species nearly 40 percent was cut in a recent thinning. Converted to basal area, the thinning intensity rose to 62 percent of the original total basal area of this species.

Assuming that this thinning is carried out every third year (and that this is equal to total increment), then the estimated gross annual increment reaches a value about 8.5 m^3/ha/yr.

San Antonio

Despite the fact that the plots were located close to each other (50-100 m apart), species predominant in one or two plots hardly

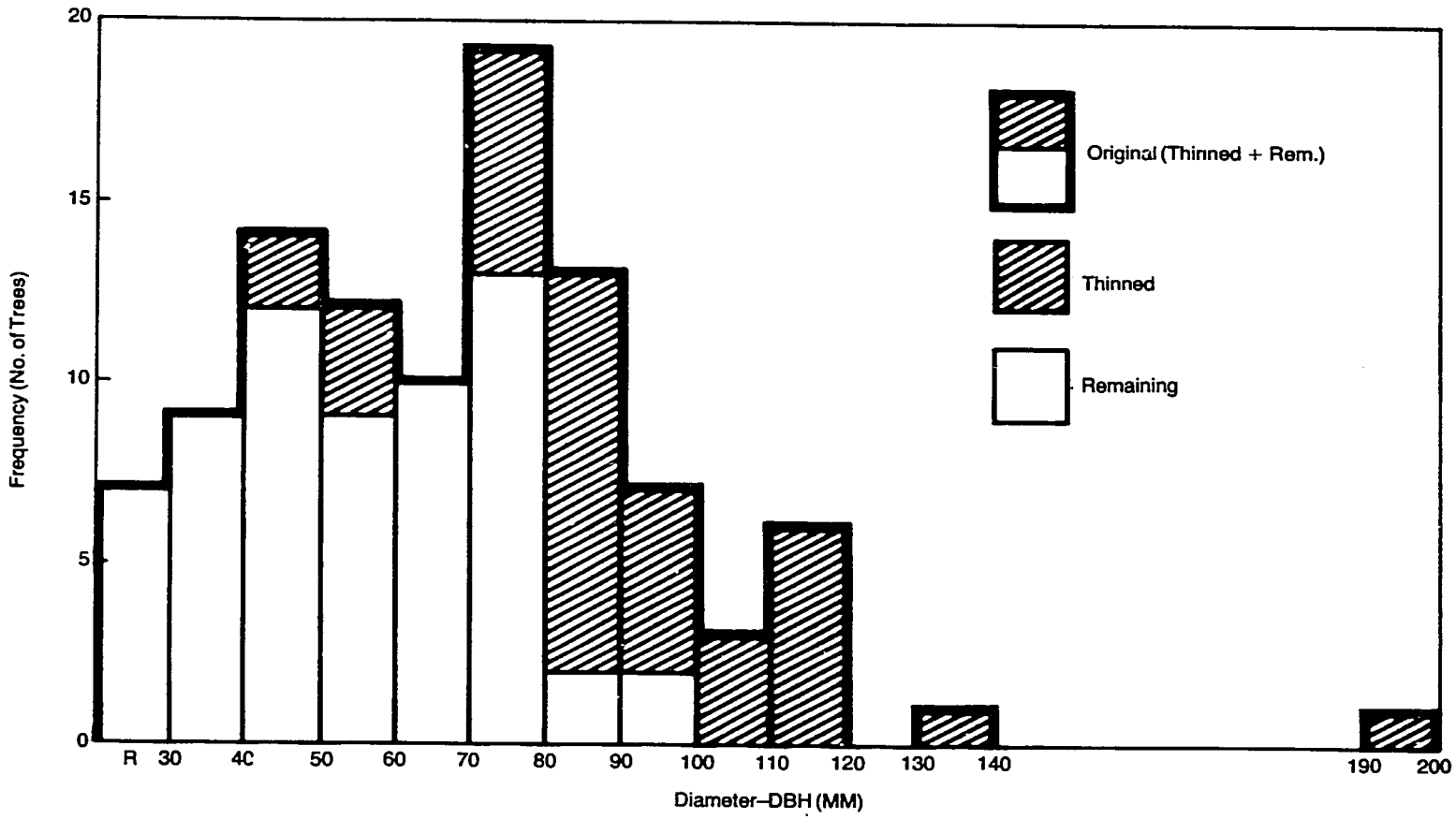

FIGURE D-2
DISTRIBUTION OF DIAMETER CLASSES OF ORIGINAL, THINNED, AND REMAINING TREES OF MADERO NEGRO IN PLOT #1-LA CONCHA

occurred in the other plot. Species which the plots had in common were Acacia costarricensis, "Chaperno" and Bursera sp. The diameter class distribution of each plot and for each species is presented in Figure D-3. As can be observed, not one single species had a normal diameter distribution. The stocking in the three plots varied between 460 and 540 stumps/ha. These stumps produced between 940 and 1120 trees and sprouts/ha. This figure is considerably lower than the numbers found in the plots in La Concha, in part due to the different species composition and possibly also partly due to the occurrence of fires which damage young sprouts and saplings. The species which showed the highest sprouting capability under these conditions were "tigüilote" (Cordia dentata) with more than 5 sprouts/stump in plot 2 and 3 and "Madroño" (Calycophyllum candidissimum) with an average of 4 sprouts/stump in plot number 2. It seemed however that fuelwood cutters were not considering tigüilote as a preferred species. Other species apparently not preferred for firewood were Bursera simaruba, Bursera spp., "Jocote monte" (Spondias), "Poró poró" (Cochlospermum vitifolium) and Crescentia alata.

Due to external influences caused by fires, cattle and firewood cutters, no approximation could be made about full stocking density.

The total basal area of the plots varied between 5.9 (plots 1 and 3) and 8.0 m^2/ha for plot number 2. In this last plot the basal area reached a relatively high value because of the presence of some isolated trees of Calycophyllum candidissimum, Acacia sp.,

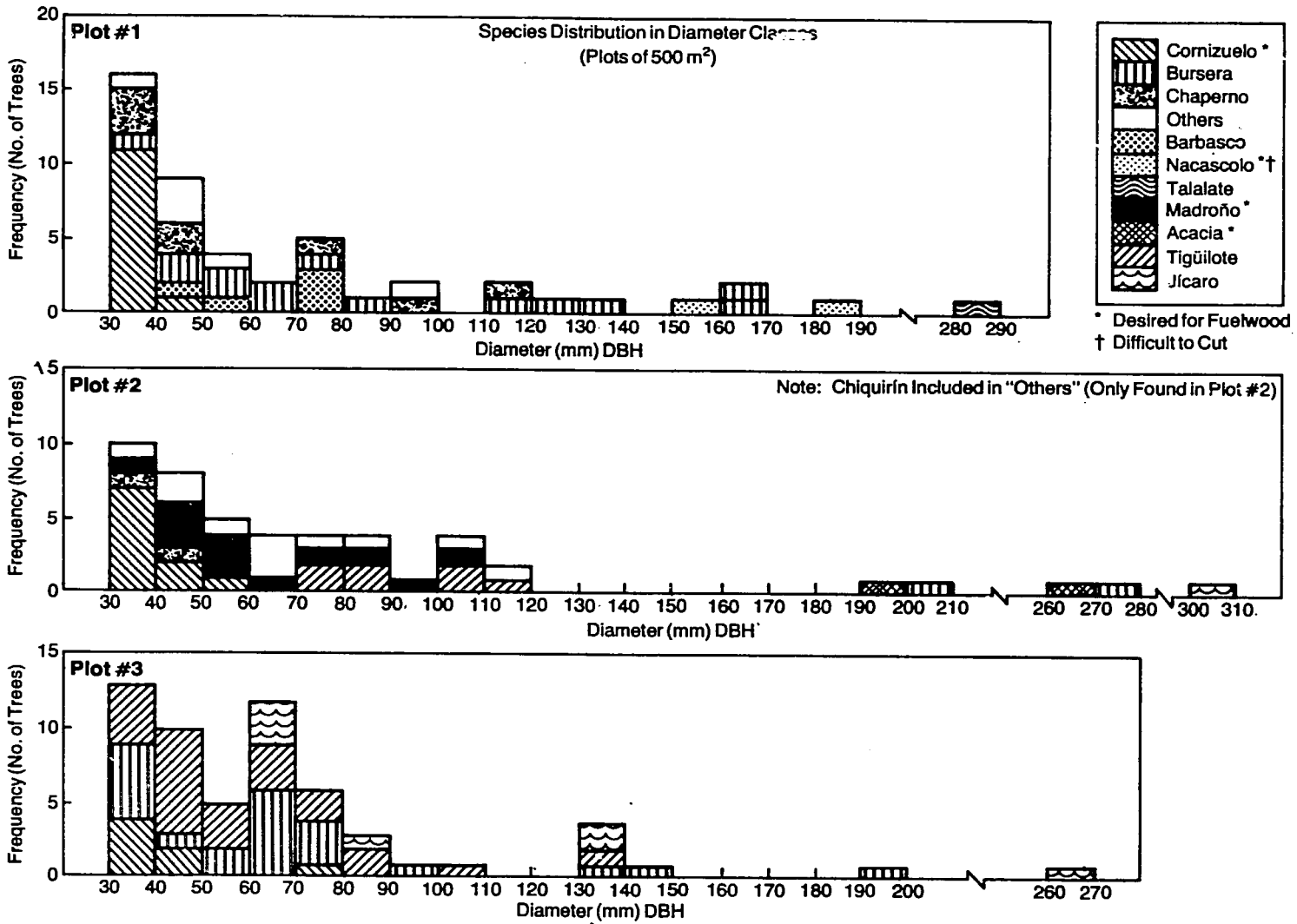

FIGURE D-3
DISTRIBUTION OF SPECIES AND DIAMETER CLASSES ON THREE TEST PLOTS AT SAN ANTONIO

Bursera sp and Spondias sp. Their basal area alone accounted for 73 percent of the total basal area of the plot. The low utility value of this vegetation is illustrated by the fact that no recently cut stumps were found in the plots that were 50-70 meters from the access road. Only in the plot at 100 meters from the roadside the bigger trees of Acacia and Calycophyllum had been cut, probably during the last 2-3 years. All of them had been cut leaving a stump of 1 to 1.5 m high, possibly in order to reduce damage to the trees by fires.

Standing volume based on species used for fuelwood was estimated at 0.25 m^3/ha in plot numbers 2 and 3, and reached a value of 9.9 m^3/ha in plot number 2. This illustrates clearly the low productivity of those areas in this site where useful fuelwood species were not present. More reseach is needed to determine whether the higher standing volume in plot number 2 can also be found in other areas further away from access roads. For the moment the available data do not permit a calculation of total standing volume, nor of increments of the vegetation in the land use class.

On-site Observation

During the fieldwork the following observation were made at the sites investigated:

La Concha ("Woodland"):

1. Cattle were present in the area even though forage was poor due to the high density of the stand.

2. There was not influence of fire at the site. Collection of litter from dry season leaf-fall was good with underlying

soils of obviously higher content of organic matter than in other sites.

3. Some management of the area, consisting of non-uniform elimination of undesirable species and thinning of smaller (less than 30 mmDBH) or excessive sprouts had been carried out in plot 3. Not known who was responsible.

4. Practices of agroforestry were noted, i.e.: intercropping with beans and corn after clearfelling trees (plot number 3).

5. Clearfelling was observed in and around plot number 3, a pure stand of Gliricidia, to over 100 meters from the access road, presumably because of improved access brought about by a clear understory (thinned and outshaded by crowns of Gliricidia).

San Antonio ("Wooded Savanna"):

1. Cattle present and more intensively grazed. Abundant jaragua (Hyperrhenia rufia) grass understory.

2. Seasonal burning was taking place during the field visit (March 4) with most understory grasses, forbs, etc., being consumed by the fires. Only scorching of bark and some crown damage was noted to more established trees and bushes (greater than 2 meters in height).

3. Soils noticeably poorer; vertisol-type with cracks from complete desiccation. Noted absence of organic matter in topsoil; little litter on ground. Fires consume what there is.

4. Stocking was less than in the woodland land use class (La Concha).

5. Species diversity (floristic composition) was found much poorer near access roads and improved with distance away from roads.

Las Pilas ("Degraded Savanna"):

1. Serious defoliation in this area; naked ground; little or no regeneration.

2. Soils of pure vertisol with obvious cracks to 1 meter in depth.

3. Little or no litter on ground; fire probably used but absence of fuel not congruent with the practice (vice-versa).

4. Stocking was observed as very poor and of few species of fuelwood utility.

5. Farmer mentioned a five-year rotation of fuelwood cutting; harvesting done approximately every two years with very poor yield per unit area.

6. Cattle present but noticeably little forage; poor carrying capacity.

Suggestions for Alternatives and Recommendations

Woodland:

1. Observations and investigations of *Gliricidia sepium* in combination with grazing (spacing, lopping).

2. Observations and investigations of *Gliricidia sepium* and intercropping (Taungya and intercropping after clearfelling).

3. Investigations into improved management of *Gliricidia sepium* (spacing, coppice management and thinning practices).

Wooded Savanna:

1. Trials with hardy species (natives and exotics).

2. Growth studies on understory vegetation management with and without fire and impact on fuelwood species (overstory) controlled fire experiment should also be carried out.

3. Soil studies into effects of fires.

4. Trials of improvement stocking with desirable species

5. Economic studies of optimal stand density/grassland combination (productivity studies).

Las Pilas:

1. Natural regeneration of vegetation for soil rehabilitation (in plots protected against fires, cattle and fuelwood cutters).

2. Trials with artificial regeneration of desirable native species.

General Suggestions

A complete aerial photograph survey should be carried out to determine with more precision the actual extension of the different land uses to better assess (fuel)wood production (present and potential). A new set of photos should be taken for the area. These photos could be compared with older photos to determine the dynamics of the land use and vegetative cover of the area.

Related maps should then be prepared, and permanent sample plots of 1000 m^2 should be installed in the different land use categories to study growth and external influences on growth and composition.

In the more important land use categories trials with mainly native species should be started (as mentioned before).

APPENDIX E

NAMES OF DRY FOREST SHRUB AND TREE SPECIES

The following Table E-I presents a listing of the scientific and common names of the dry forest shrub and tree species in the Las Maderas region.

TABLE E-I

KEY TO SCIENTIFIC AND COMMON NAMES OF DRY FOREST SHRUB AND TREE SPECIES

Scientific Name	Common Local Name
Acacia costaricensis	Cornizuelo
Acacia farnesiana	Aromo
Acacia sp.	Tepegüiste
Bursera excelsia	Caraño
Bursera simaruba	Jiñocuabo
Caesalpinia coriaria	Nacascolo
Calycophyllum candidissimum	Madroño
Casearia lanquitana	Cerillo, cerito
Cassia emarginata	Vainillo
Cochlospermum vitifolium	Poró - Poró
Cordia alliodora	Laurel
Cordia dentata	Tigüilote
Crescentia alata	Jícaro
Cupania dentata	Cola de pavo
Ficus glau escens	Copel
Gliricidia sepium	Madero negro, madre cacao
Guazuma ulmifolia	Guácimo
Gyrocarpus americanus	Talalate
Hamelia sp.	Papamiel
Jacquinia aurantica	Barbasco
Lonchocarpus sp.	Chaperno
Myrospermum frutescens	Chiquirín, chiquiriquín
Pisonea aculeata	Espino negro
Prosopis juliflora	Aguijoste
Santana camara	Cuasquito
Spondias sp.	Jocote (monte)
Tabebuia chrysantha	Cortéz
Tabernaemontana chrysocarpa	Cachito
Thouinidium decandrum	Melero

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