Journal of Vegetation Science 3: 407-416, 1992

Regeneration of tropical dry forests in Central America, with examples from Nicaragua

Sabogal, César

CATIE, Centro Agronómico Tropical de Investigación y Enseñanza, 7170 Turrialba, Costa Rica; Tel. +506 566431; Fax +506 561533

Abstract. This paper focuses on the management potential of natural forests in the tropical dry zones of Central America, particularly Nicaragua. Distribution and status of dry forest formations are reviewed. Two case studies from the Pacific coast of Nicaragua are presented to illustrate the disturbance created by traditional utilization, and to show the relatively high potential for natural forest management, with many of the tree species having economic value. Natural forest management, together with conservation and reforestation, is viewed as the main management option for the tropical dry forest areas. In spite of its importance, this option has received little attention or promotion from the governmental forestry sector.

Four complementary options which can be devised for silvicultural work in production forests are: encouragement of advanced growth of desirable tree species, inducement of natural regeneration, coppice management, and compensatory planting. These options form different strategies for rehabilitation of the production and conservation functions of the forest and may well be combined in the same area.

Research applied to better utilization of the forest resources should form an intrinsic part of rural development programs. Research work in tropical dry forest areas should focus on ecological, as well as socio-cultural and economical aspects related to the management options. Experimental sites are important enabling and securing long-term basic and applied biological research. They may also serve as units for demonstration, training and extension.

Keywords: Firewood species; Forest: primary; Forest: secondary; Silviculture; Timber species; Tree inventory.

Nomenclature: A. Grijalba (Herbario Nacional, Managua).

Introduction

Dry deciduous forests are the third major regional forest formation in the tropics (Lamprecht 1989), and the most threatened of all major lowland tropical forest types (Janzen 1988b). In Central America, they occur almost entirely as fragments and degraded patches, as a result of agriculture. However, dry forests represent an important source of firewood, timber and secondary (non-woody) products for the local population.

Options for management include strict protection and regeneration, habitat restoration and 'active' management for sustainable production of remaining forests. In this paper, attention is given to natural forest management for regenerating degraded dry forest stands.

Two examples from the Pacific coast of Nicaragua are described which illustrate the type and intensity of disturbance by traditional utilization of tropical dry forests, and show how research can contribute to the introduction of ecologically sound management practices for the sustainable utilization of forest.

Central American dry forests

Definition and distribution

Central America, ca. 485 000 km^2, extends from Panamá at 7° 15' N through Costa Rica, Nicaragua, Honduras, El Salvador and Belize to Guatemala at 18° N. According to Holdridge's (1971) life-zone classification, the dry tropical part of Central America includes four formations: Tropical Dry Forest, Tropical Very Dry Forest, Subtropical Dry Forest and Subtropical Thorn Woodland. These formations occupy 33 600 km^2, ca. 7 % of the region's land surface (Table 1); they are bound to an annual rainfall of 500 - 2000 mm, altitudes from 0 - 1000 m a.s.l., mean annual temperatures above 20 °C and a dry season of 4 - 7 months with < 50 mm rain (Dulin 1982; Martínez 1985). The dry zones in Central America extend mainly along the Pacific coast, around the Golfo de Panamá, in SW Panamá, a broad zone along the Pacific coast of Nicaragua, and El Salvador and the narrow Pacific lowland stretch of Guatemala. The proportion of dry zones varies in each country; Nicaragua has the largest proportion (Table 1). The Dominican Republic, although physically part of the Caribbean basin, is included here because dry formations are important in that country (Powell & Mercedes 1986).

Table 1. Areas (ha × 1000; % of the country's surface in brackets) of dry zones and forest formations in Central America and the Dominican Republic. After Martínez & Hughes (1987).

Country	Total Dry zone	TDF	TVDF	SDF	STW
Nicaragua	1225 (10.3 %)	564	–	661	–
Honduras	636 (5.6 %)	305	25	306	–
Guatemala	540 (4.3 %)	15	–	428	97
Costa Rica	375 (7.3 %)	375	–	–	–
Panama	366 (4.9 %)	289	–	77	–
El Salvador	222 (10.6 %)	222	–	–	–
Total	3364 (6.9)	1770	25	1472	97
Dominican Rep.	1090 (22.7)	–	–	990	100

Holdridge life-zones (P = precipitation):
TDF = Tropical Dry Forest 1000 < P < 2000 mm
TVDF = Tropical Very Dry Forest 500 < P < 1000 mm
SDF = Subtropical Dry Forest 500 < P < 1000 mm
STW = Subtropical Thorn Woodland 250 < P < 500 mm

Deforestation and status of the natural vegetation

Natural forest and woodland vegetation of the dry zones of Central America have been seriously degraded after more than 400 yr of human settlement (Janzen 1986). Land-use patterns have been and are traditionally dominated by an extensive export-oriented agriculture (cotton, sugar cane, banana) and subsistence crops (maize, beans, rice, sorghum), and extensive cattle ranching, the latter strongly promoted in the 1960's and 1970's (Martínez 1985; Janzen 1986, 1988b). Under extensive land-use the natural vegetation has been reduced to vegetation patches or 'habitat fragments' (Janzen 1988a).

Deforestation of dry forests still proceeds, as the socio-economical situation continues to decline (Anon. 1987a; Leonard 1986; Murphy & Lugo 1986). The main effects of this forest degradation appear to be:
- shortage of forest products, having effects not only on the local economies but also at the regional level of firewood;
- deterioration of the ecological functions of forests, causing problems of soil/wind erosion, alteration of the water regime and the soil fertility etc.;
- reduction of biodiversity, and negative effects on species reproduction, loss of the economic value of the impoverished vegetation and fauna.

The remaining mature forest consists of more or less original stands generally found in less accessible areas, intermixed with altered (successional) forest, and often conserved according to the owner's particular interest. These stands may represent < 2 % of the original dry forest on the Pacific coast of Central America (Janzen 1986).

Successional forest develops after abandoning of previously clear-cut mature or altered stands, used for agriculture. These secondary stands, called 'tacotales' in the region, are the main forest resource in many areas.

The floristics and structure of dry forests in the region are described in Taylor (1963), Holdridge (1971), Hubbell (1979), Witsberger, Current & Archer (1982), Hartshorn (1983), Janzen (1986), Pérez (1986), Anon. (1987b); for the Caribbean basin see also Powell & Mercedes (1986) and Murphy & Lugo (1986).

Case studies in Nicaragua

Nicaragua is the largest country in Central America, with a land surface of ca. 130 000 km^2 and a population of nearly 3 million, concentrated in the dry forest zone along the Pacific coast. The annual increase in population, 3.3 %, is one of the world's highest. The country has 37 510 km^2 of productive dense broad-leaved forests, of which 4640 km^2 (12.4 %) are dry semi-deciduous and deciduous (Fig. 1). The deforestation rate for the period 1976 - 1980 was 97 000 ha/yr (Anon. 1981). There are few studies of the country's dry forest resources (e.g. Taylor 1963; Begué 1966; Anon. 1987b), and there is little information on the species ecology, biology, silviculture and utilization; only some floristic surveys have been carried out, mainly for conservation purposes.

Nicaraguan dry forests have been intensively exploited and have traditionally provided timber for the domestic market and for export, e.g. *Swietenia humilis*, *Cedrela odorata*, *Bombacopsis quinatum*, *Dalbergia retusa*, *Guaiacum sanctum*. The primary dry forest has almost disappeared along the Pacific coast (Fig. 1).

Ca. 70 % of the Nicaraguans use firewood; this commodity represents about 54 % of the country's total energy consumption (cf. Torres & Ulmos 1990). Traditionally, firewood was also taken from the Pacific dry forests, but now secondary forest is the main source. Torres & Ulmos (1990) give the following figures: Secondary regrowth: 87 %; Degraded forest: 8 %; Riparian forest: 4 %; Other sources: 1 %.

Large-scale plantations in the region are still modest in size. Main tree species involved are the introduced *Eucalyptus* spp. and *Azadirachta indica*, and the indigenous *Leucaena leucocephala*, *Gliricidia sepium*, *Guazuma ulmifolia*, *Enterolobium cyclocarpum*, and *Pithecellobium saman*.

Chacocente

The Chacocente Biological Reserve, located on the south Pacific coast (Fig. 1), was established in 1983 by the Nicaraguan Institute for Natural Resources and

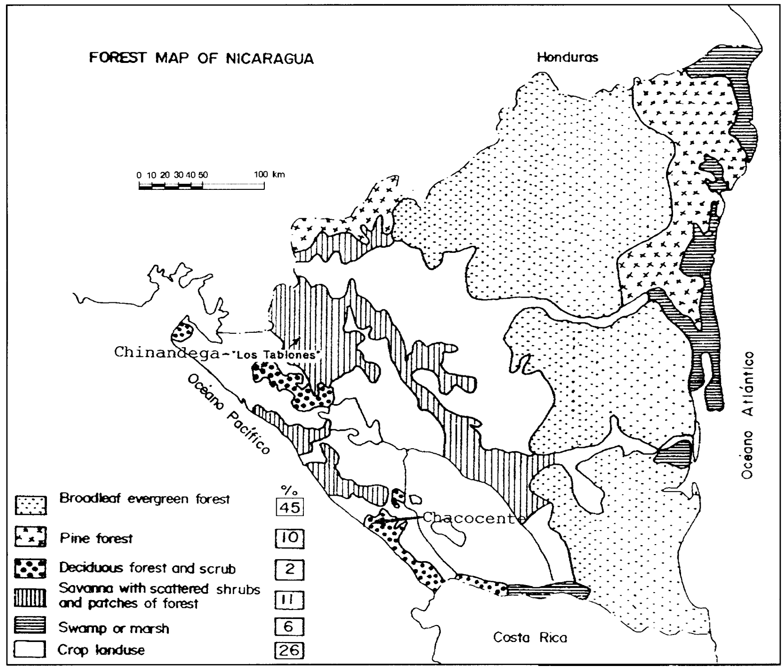

Fig. 1. Preliminary forest map of Nicaragua. Source: IRENA, Instituto Nicaraguense de Recursos Naturales y del Ambiente.

Environment (IRENA). Its size is >4700 ha, of which an estimated 1500 ha constitute the 'core' of one of the least damaged tropical dry forests along the Central American Pacific coast (Anon. 1987b). The Reserve includes also a well-conserved gallery forest along the main water course, Rio Escalante. Other vegetation types include shrubland and secondary forest on abandoned fields. Ca. 80% of the Reserve is considered as forestry land, and therefore unsuitable for other land uses than forestry production or protection (Anon. 1987b). Chacocente forests were selectively used for timber in the first decades of this century, when they were private property. Valuable timber species (see above) were exported.

About 150 families settled in both the Reserve and its 'buffer zone'. They practice subsistence agriculture, extensive cattle grazing, wood cutting for the construction of poles, for firewood and for commercial timber, hunting and honey gathering. The local people need more resources, but both funds and interest from the government are lacking; this is a typical situation.

In 1989 the Forestry School at the Agricultural University in Managua selected Chacocente as a research and training forest site for natural forest management. The project is being funded by the Swedish Agency for Research Cooperation (SAREC) with technical assistance from the Agronomic Tropical Centre for Research and Education (CATIE).

Site description

There are no climatic data for Chacocente. On the basis of climatic data from two neighbouring meteorological stations, Rivas and Nandaime, annual rainfall is estimated at ca. 1500 mm and the mean temperature is 26 - 27 °C. The altitude varies from sea level to ca. 300 m a.s.l. Three vegetation types were identified (Anon. 1987b): deciduous dry forest (70 % of the area), gallery forest and thorn- and beach forest. Soils occurring in the area are mainly Inceptisols and Vertisols (US Soil System). More open and lower forests are probably associated with the latter soil type.

Composition, structure and regeneration

A forest inventory undertaken by the Forestry School in nearly 1000 ha of the dry deciduous forest included 120 plots, each of 0.1 ha (size: 50 m × 20 m), systematically distributed over the study area (Sabogal 1989). Of all trees > 10 cm DBH species name, DBH, stem quality and crown position were recorded. Further, regenerating trees, defined as having a DBH between 2.5 and 9.9 cm, were recorded in two randomly selected subplots (size 10 m × 10 m) per plot. Finally, for young trees and saplings with a DBH < 2.5 cm and a height > 50 cm, a smaller sample was taken in 8 transects with 25 squares, each 2 m × 2 m, and placed in 8 randomly selected plots (Valerio in press). Additional data on site conditions were also systematically recorded in each plot.

115 species (trees > 10 cm DBH) were found in the 12 ha - not including unidentified species - (Table 2). Mean tree density *D* (*N*/ha) was 341, mean stocking (all stems) was 390/ha. The basal area *G* reached 14 m^2/ha.

Density distribution by diameter classes (Fig. 2) showed the typical 'reversed-J' type distribution, with a high proportion of small to medium size: 87 % of the trees (accounting for 55 % of the basal area) had a DBH < 30 cm. Canopy heights were between 15 and 30 m; distinct crown layers or strata could not easily be recognized.

Most of the tree species found in the inventory have one or more known types of local usage (Table 2). In order to simplify the analysis, tree species were grouped into broad categories, according to their major local usage. The resulting three groups (used in Table 3) are:
F: Firewood, species used mainly for firewood, but not for timber;
F/P is a subgroup of firewood and polewood species;
T: Timber, species used mainly for rural constructions, furniture, handicraft, etc., sawnwood and polewood;
O: Other species having non-woody products (tannin, fruits, forage, medicinal uses, living fences, etc.), and species without known (local) use.

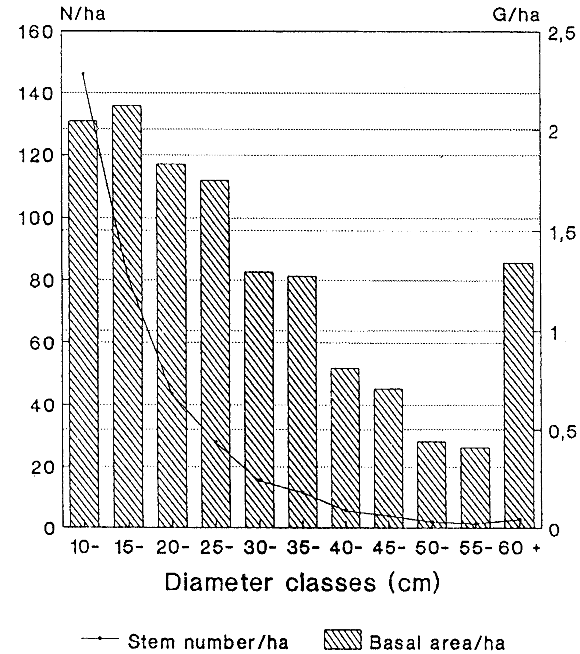

Fig. 2. Stem number (N per ha) and basal area (G, m^2/ha) distribution by diameter classes, all tree species. Chacocente dry deciduous forest, Carazo, Nicaragua.

Table 2. List of the main tree species and their usage of the dry forests Chacocente (Carazo) and Los Tablones (Chinandega) in Nicaragua. Usage categories: TI = timber (sawnwood); PO = polewood; FI = firewood; EF = Edible fruits, forage; ME = Medical use, tannins; LF = 'Living fence'.

Scientific name	TI	PO	FI	EF	ME	LF
Acacia costaricensis (Mimosaceae)			+		+	
Achatocarpus nigricans (Achatocarparc.)			+	+		
Albizzia caribaea (Mimosac.)	+		+			
Allophylus psilospermum (Sapindac.)			+		+	
Astronium graveolens (Anacardiac.)	+	+	+			
Bravasia floribunda (Acanthac.)			+		+	
Bursera simarouba (Burserac.)					+	+
Calycophyllum candidissimum (Rubiac.)	+	+		+		
Casimiroa sp. (Rutac.)	no usage known.					
Cassia grandis (Caesalpinac.)			+		+	
Chlorophora tinctoria (Morac.)	+	+	+		+	
Cochlospermum vitifolium (Bixac.)				+	+	
Cordia alliodora (Boraginac.)	+	+			+	
Cordia bicolor (Boraginac.)		+	+	+	+	
Cordia dentata (Boraginac.)		+	+	+	+	
Cordia gerascanthus (Boraginac.)	+	+	+			
Enterolobium cyclocarpum (Mimosac.)	+	+		+	+	
Gliricidia sepium (Fabac.)		+	+	+	+	+
Guaiacum sanctum (Zigophyllac.)	+	+				
Guazuma ulmifolia (Sterculiac.)			+	+	+	+
Gyrocarpus americanus (Hernandiac.)					+	
Karwinskia calderoni (Rhamnac.)		+	+	+		
Lonchocarpus minimiflorus (Fabac.)		+	+			
Luehea candida (Tiliac.)			+	+		+
Lysiloma sp. (Mimosac.)	+	+				
Myrospermum frutescens (Fabac.)		+	+	+		+
Pithecelobium dulce (Mimosac.)		+	+	+	+	
Spondias purpurea (Anacardiac.)			+	+	+	+
Stemmadenia obovata (Apocynac.)			+	+	+	
Swietenia humilis (Meliac.)	+					
Tabebuia ochracea (Bignoniac.)[1]	+	+	+	+		
Trichilia hirta (Meliac.)	+		+			
Ziziphus guatemalensis (Rhamnac.)		+	+	+		

Sources: Witsberger, Current & Archer 1982; Pérez S. 1986; Anon. (1987b); Mayorquin & Salinas 1989; Morales & Rueda 1989; Torres & Ulmos 1990. [1]ssp. *neochrysantha.*

48 firewood species (42 % of the total number of tree species) accounted for over 50 % of the tree density *D* and basal area *G*, while the 24 timber species (21 %) made up 19 % and 23 % of *D* and *G*, respectively. Timber species had a lower representation in the smaller diameter classes than the other groups (Fig. 3).

Table 3 summarizes some stand characteristics for 17 important tree species, arranged in order of decreasing value of the Importance Value Index (IVI) of Curtis & McIntosh (1951), defined here as the sum of relative density, relative frequency and relative basal area. *Gyrocarpus americanus*, a typical heliophyte of the dry deciduous forest (Taylor 1963), is the most important of them. Most species belong to the firewood group. They have wind-dispersed seeds, and generally reach only small to medium sizes. Four commercial species, listed separately, represent valuable timber species that were harvested in the past (a fifth, *Cedrela odorata,* was not recorded in the sample). These species are poorly represented in the forest.

Many species were found regenerating (i.e. present with DBH values between 2.5 and 9.9 cm) in the Chacocente forest (Table 4). Some of the 11 most important species were not found in the tree layer, e.g. *Erythroxylon havanensis* and *Acacia costaricensis.* 16 timber species accounted for only 12 % of the regenera-

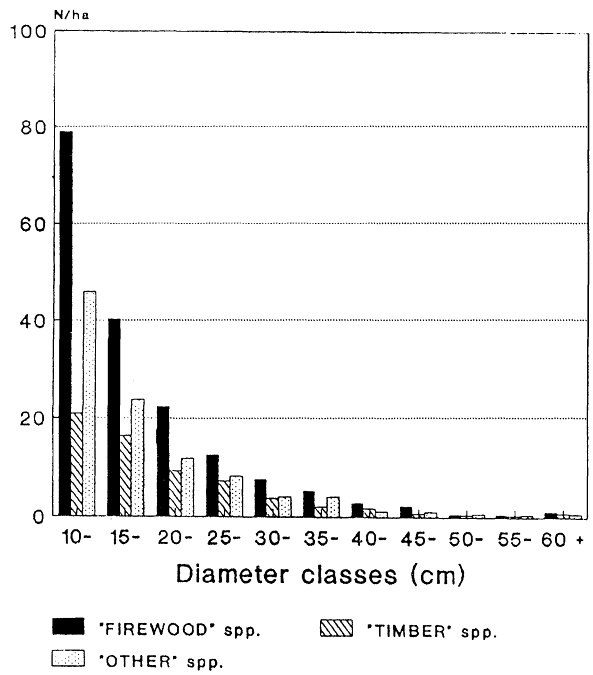

Fig. 3. Diameter class distribution (*N*/ha) by species-use groups. Chacocente dry deciduous forest, Carazo, Nicaragua.

tion density. *Tabebuia ochracea* ssp. *neochrysantha* was the most important species in this group. The valuable timber species were sporadically regenerating.

Tree species < 2.5 cm DBH and > 50 cm height accounted for 45 % of the 179 800 plants/ha present. The composition of this regeneration class (Table 5) was similar to that of the upper-size class, but the main species here, the small tree *Allophyllus psilospermum* (*Sapindaceae*) is not found in the higher classes.

Chinandega

In the western part of the Pacific coast of Nicaragua (Fig. 1), conversion of forest land to extensive cropping (cotton, sugar cane) and pastures increased markedly in the 1960s and continued after land was redistributed to cooperatives early in the 1980s. The mature forest was mostly reduced to small patches scattered in the plains. Now, secondary successional and savanna-derived woodlands dominated by *Crescentia alata* and shrub patches with *Acacia farnesiana* form the main wood resource.

An integrated binational development project, set up in the north part of Chinandega ('CHINORTE'), includes the management of existing forests owned by cooperatives of small farmers, inventories of production woodlots from selected cooperatives, investigations of the local usage of forest products (see Table 2) and a survey of existing markets for woody products.

Table 3. Stand characteristics (trees ≥ 10 cm DBH) for the dry deciduous forest site (12 ha) in Chacocente, Carazo, Nicaragua. UC = Usage category (see text); *D* = density (*N*/ha); *G* = basal area (m^2/ha); *F* = frequency (based on 120 0.1 ha plots); IVI = Importance Value Index = (*% D + % G + % F*)/3.

Species	UC	*D*	*D* %	*G*	*G* %	*F*	*F* %	IVI
1 *Gyrocarpus americanus*	O	40.5	11.8	1.60	11.6	99	5.3	9.6
2 *Tabebuia ochracea*[1]	T	17.6	5.1	0.57	4.1	70	3.7	4.3
3 *Lysiloma* sp.	F/P	8.6	2.5	0.89	6.4	55	2.9	3.9
4 *Stemmadenia obovata*	F	17.5	5.1	0.28	2.0	80	4.3	3.8
5 *Luehea candida*	F	12.7	3.7	0.50	3.6	68	3.6	3.6
6 *Gliricidia sepium*	F/P	11.5	3.4	0.65	4.6	48	2.6	3.5
7 *Allophyllus psilospermum*	F	13.1	3.8	0.39	2.8	65	3.5	3.4
8 *Achatocarpus nigricans*	O	16.0	4.7	0.31	2.2	38	2.0	3.0
9 *Calycophyllum cand.*[2]	F/P	5.7	1.7	0.67	4.8	39	2.1	2.9
10 *Myrospermum frutescens*	F/P	10.3	3.0	0.28	2.0	63	3.4	2.8
11 *Astronium graveolens*	T	6.9	2.0	0.48	3.4	46	2.5	2.6
12 *Lonchocarpus min.*[3]	F/P	13.5	4.0	0.26	1.9	36	1.9	2.6
13 *Bursera simarouba*	O	5.7	1.7	0.51	3.6	42	2.2	2.5
14 *Karwinskia calderoni*	F/P	6.9	2.0	0.40	2.9	43	2.3	2.4
15 *Guazuma ulmifolia*	F	7.3	2.1	0.35	2.5	39	2.1	2.2
16 *Cordia alliodora*	T	7.4	2.2	0.24	1.7	53	2.8	2.2
17 *Cordia gerascanthus*	T	9.9	2.9	0.22	1.6	37	2.0	2.2
Subtotal (17 species)		211.1	61.7	8.58	61.7	( )	49.2	57.5
Commercial species:								
Swietenia humilis	T	1.5	0.4	0.11	0.8	16	0.8	0.7
Dalbergia retusa	T	1.3	0.4	0.09	0.7	13	0.7	0.6
Hymenaea courbaril	T	0.3	0.1	0.05	0.4	3	0.2	0.2
Bombacopsis quinatum	T	0.5	0.1	0.03	0.2	5	0.3	0.2
Subtotal (4 species)		3.6	1.0	0.28	2.1	( )	2.0	1.7
Other species		127.1	37.3	5.13	63.8	( )	48.8	40.8
All species		341.8	100	14.01	100	120	100	100.0

[1] ssp. *neochrysantha*; [2]*candidissimum*; [3]*minimiflorus.*

The first forest reserve established here is 'Los Tablones', located in El Bonete, an area of 304 ha mainly on plain-alluvial Vertic and Vertisol soils, with ca. 1700 mm annual rainfall (5 dry months) and a mean annual temperature of 27.4 °C (Cáceres in press).

Due to frequent cutting (for timber, poles and firewoods), fires and grazing, the forest is mainly of a secondary nature. Bamboos (*Guadua* sp.) and vines are common in some more disturbed sectors of the forest.

39 species (trees ≥ 10 cm DBH) were found in a 6.2 ha sample (69 plots, 0.09 ha each) (Cáceres in press). Stand density *D* was 163/ha and basal area *G* 9 m^2/ha. 75 % of *D* and 65 % of *G* referred to trees < 30 cm DBH (Fig. 4). The stand structure was variable: a mosaic of forest patches and open woodlands, with trees concentrated in the height classes 6 - 9 m and 9 - 12 m (65 % of *D*). Firewood species made up 70 % of *D* and *G*, the remaining species were mainly timber species (Fig. 5). The diameter distribution of the timber species showed a bimodal distribution, where the greater trees repre-

Table 4. Density *D* (*N*/ha) and frequency *F* of regenerating trees from 2.5 - 4.9 cm DBH, 5.0 - 9.9 cm DBH, and 2.5 - 9.9 cm DBH (sum) in the dense dry deciduous forest in Chacocente, Carazo, Nicaragua. 60 10m × 10m subplots, 2 in each 0.1 ha plot. IVI based on *D* % and *F* % only.

	2.5 -	5.0 -		Sum			
Species	*D*	*D*	*D*	*D* %	*F*	*F* %	IVI
Stemmadenia obovata	77.5	62.5	140.2	13.5	42	7.2	10.35
Erythroxylon havanensis	69.2	29.2	98.3	9.5	36	6.2	7.85
Acacia costaricensis	44.2	20.0	64.2	6.8	29	5.0	5.60
Croton niveus	56.7	14.2	70.8	6.8	17	2.9	4.85
Tabebuia ochracea[1]	27.5	28.3	55.8	5.4	25	4.3	4.85
Lonchocarpus minimiflorus	20.8	17.5	38.8	3.7	22	3.8	3.75
Myrospermum frutescens	20.8	9.2	30.0	2.9	20	3.4	3.15
Casearia tremula	21.7	5.0	26.7	2.6	20	3.4	3.00
Achatocarpus nigricans	9.2	18.3	27.5	2.7	15	2.6	2.65
Cordia alliodora	14.2	8.3	22.5	2.2	17	2.9	2.55
Diospyros nicaraguensis	15.0	7.5	22.5	2.2	16	2.7	2.45
Subtotal (11 species)	376.8	220.0	596.6	57.6	-	44.4	51.05
Other species	244.9	193.3	438.4	42.4	-	55.6	48.95
All species	621.7	413.3	1035.0		-	100	100

[1]ssp. *neochrysantha*

sented remnants from the primary forest.

Table 6 summarizes the stand characteristics. *Guazuma ulmifolia*, a common species found in secondary regrowth (e.g. Taylor 1963; Hartshorn 1983), is the dominant tree species. Most of the important species are known to grow in sites with good soil water conditions, i.e. with a temporary high phreatic level.

Seedling regeneration appeared to be quite rare, particularly for timber species. An exception was *Enterolobium cyclocarpum*. On the contrary, common firewood species resprouted well.

Table 5. Density *D* ($N/100m^2$) of regenerating trees from 0.5 m height and up to 2.4 cm DBH in the dense dry deciduous forest in Chacocente, Carazo, Nicaragua. Sample area 800 m^2, 8 transects with 25 2m × 2m plots each.

Species	*D*	*D* %
Allophyllus psilospermum	12.5	15.2
Lonchocarpus minimiflorus	5.5	10.3
Chomelia spinosa	7.1	8.6
Casearia tremula	6.0	7.3
Croton niveus	5.5	6.7
Tabebuia ochracea spp. *neochrysantha*	4.7	5.8
Allophyllus occidentalis	4.4	5.3
Stemmadenia obovata	4.1	5.0
Diospyros nicaraguensis	3.9	4.7
Myrospermum frutescens	3.5	4.2
Subtotal (10 species)	60.2	73.1
Other species	22.1	26.9
All species	82.4	100.0

Table 6 . Stand characteristics for the dry deciduous forest in Los Tablones, Chinandega, Nicaragua. 69 0.09 ha plots. UC = Usage category (see text); For D, G, F and IVI, see Table 3.

Species	UC	*D*	*D%*	*G*	*G%*	*F*	*F%*	IVI
1 *Guazuma ulmifolia*	F	59.3	36.4	2.76	28.9	67	20.1	28.5
2 *Cordia bicolor*	F/O	15.0	9.2	0.38	3.9	32	9.5	7.5
3 *Bravasia floribunda*	F	12.4	7.6	0.79	8.2	18	5.4	7.1
4 *Cassia grandis*	F	8.4	7.2	0.69	7.0	29	8.7	7.0
5 *Enterolobium cyclocarpum*	T/O	9.7	6.0	0.77	7.9	18	5.4	6.4
6 *Ziziphus guatemalensis*	F	8.1	5.0	0.69	7.1	21	6.2	6.1
7 *Spondias purpurea*	O	9.7	6.0	0.47	4.8	22	6.6	5.8
8 *Pithecelobium dulce*	T/O	7.7	4.7	0.46	4.6	21	6.2	5.1
9 *Calycophylum cand.*[1]	F/O	4.2	2.6	0.46	4.6	18	5.4	4.2
10 *Albizzia caribaea*	T	4.0	2.5	0.52	5.3	15	4.6	4.1
11 *Pithecelobium saman*	T/O	4.2	2.6	0.43	4.4	15	4.6	3.9
12 *Coccoloba floribunda*	F	2.4	1.5	0.36	3.7	10	2.9	2.7
13 *Spondias mombin*	O	2.6	1.6	0.22	2.3	9	2.7	2.2
Subtotal 13 species)		147.7	90.9	9.00	99.1	-	92.1	90.6
All species		162.8	100	9.08	100	69	100	100.0

[1] *candidissimum*

Conclusions of the research

Tree species richness in the dry tropical forests investigated is relatively low and tends to decline with increasing stand disturbance. Tree densities, although variable, range within the normal values for primary stands in the tropical dry zone (e.g. Veillon 1983); basal area values, however, are well below those from unlogged stands, a clear result of former utilization.

Diameter distributions at the stand level (all tree species) are strongly determined by the high densities of small trees; this indicates good conditions for sustained production. Important commercial (timber) tree species, however, show irregular distributions. The spatial pattern of distribution is variable, as a result of variations in site conditions, mostly associated with water availability. It tends to be more complex in disturbed stands, where canopy disruptions create a patchy successional development. This offers better growing conditions for pioneer species, lianas and bamboos, and in general for the ground vegetation, depending on the extension of canopy disruption, and (past) disturbing factors.

Tree species with wind-dispersed seeds dominate both in the mature tree and regeneration stages. This can be linked to past disturbances in the stand, such as the removal of vertebrates; furthermore, wind-dispersed tree species are more resistant to the desiccating conditions of open sites (e.g. Janzen 1988a).

Seedling regeneration is mainly restricted to small and medium sized tree species. Commercially important timber tree species regenerate badly.

Current forest biomass is concentrated in firewood

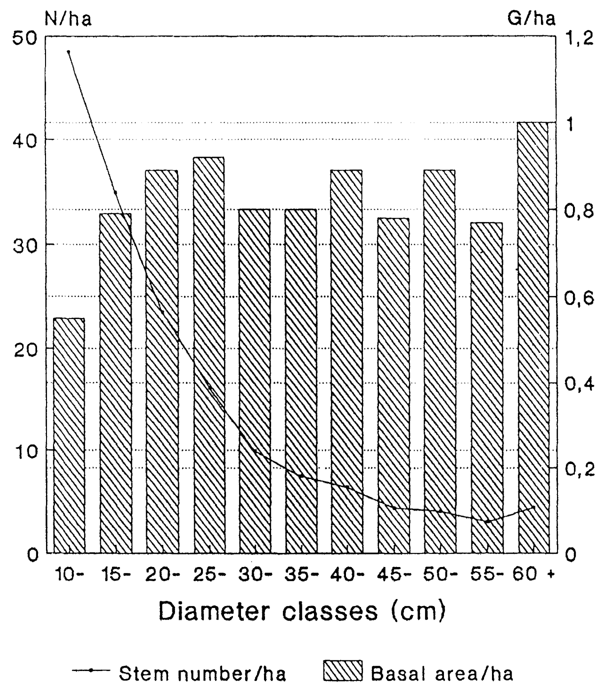

Fig. 4. Stem density (*N*/ha) and basal area *G*, m^2/ha) distribution by diameter class, all species. Los Tablones, Nicaragua.

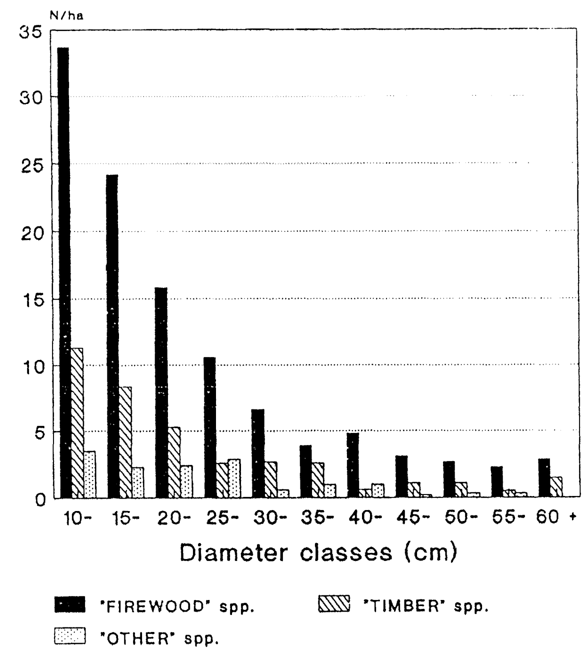

Fig. 5. Diameter class distribution (N per ha) by species usage category (see Fig. 3). Los Tablones, Chinandega, Nicaragua.

and polewood.

The two forests described are disturbed by human activities. Some general consequences of this over-utilization are: low productivity, loss of economic value, difficulties in securing adequate stocking, and uneven distribution of regenerating commercial species.

Discussion of management options

Management of tropical dry forests demands instant actions at the governmental (inter-institutional) level, giving priority to sound long-term land-use planning and effective training and development programs for better utilization of the existing forest resources. The main options are the 'traditional' ones of conservation, natural forest management and reforestation. Conservation, though not a management option for forestry, is an urgent strategy for long-term objectives such as biodiversity maintenance and ecosystem rehabilitation, (e.g. Lugo 1988; Janzen 1988a,b). However, conservation efforts in Central American dry zones - with the exception of Costa Rica - are few (e.g. Budowski 1982; Anon. 1987a).

Plantation forestry is increasingly supported and recognized as an option for the otherwise unproductive woodlands or abandoned agricultural and pasture lands. Intensive silviculture based on fast-growing and multipurpose tree species forms an important alternative to meet the needs for wood products at the farm, local and regional levels, and also contributes to alleviate the pressure on the remaining natural vegetation (Anon. 1986, 1991). It must however be recognized that existing plantations are not yet sufficient to meet the increasing demands (Anon. 1987a).

Natural forest management (NFM) is a land-use system aiming at the sustainable production of forest products, based on the regeneration potential of the existing vegetation. NFM facilitates production according to multiple-use objectives, combining biodiversity conservation, environmental functions and social services in the area (see Fig. 6). At the farm level NFM allows replenishment of forest assets, extending and diversifying farm productivity.

Natural forests also provide unique direct and indirect benefits that can not be adequately fulfilled by plantation forests (e.g. Palmer 1979; Evans 1982), as seems to be the case for some valuable tree species, medicinal plants, or recreation. In spite of the importance of natural forests for the local and regional economy, this option has received little attention or promotion from the governmental forestry sector.

Conservation, natural forest management for production and reforestation, can be viewed as alternative management options for the rehabilitation of Central American dry forest lands (Fig. 6). In general, the term ecosystem rehabilitation could well be used here to define the overall strategy needed. According to Lugo (1988), "through ecosystem rehabilitation, humans attempt to convert land that has been damaged by either human or natural perturbations to land that can have productive uses. Rehabilitation involves a mix of non-degradation, restoration and replacement strategies." The different strategies are required for each alternative case and for local conditions.

General guidelines for natural forest management

General guidelines for the implementation of silviculture and management in tropical (rain) forests, such as those prepared by Palmer (1986), Hutchinson (1988), Lamprecht (1989) and Anon. (1989), are valuable for dry forests. Depending on the regeneration status of the forest, the prevailing local conditions and the management objectives, four main options may be devised for silviculture in production forests:
(1) encouragement of advanced growth of desirable tree species; (2) inducement of natural regeneration, provided seed bearers of desirable species are available in the area; (3) coppice management, based on the re-sprouting capacity of desirable species; (4) enrichment planting with native species, as compensation for lacking or insufficient natural regeneration of commercially desirable species.

These different strategies may well be combined in the same area. Some of the silvicultural operations implied, e.g. removal of impediments, canopy openings, liberation, cleaning, thinning, may in fact serve more than one purpose.

Natural forest management faces several constraints as to its application in the American Tropics (Figueroa, Wadsworth & Branham 1987; Mergen & Vincent 1987; De Camino 1987; Dourojeanni 1987). Natural forests are not considered as perpetually productive assets; this negative thinking prevails, not only among the rural people, but also at the governmental level. Other general constraints for NFM are: a lack of trained manpower (at all levels) and of experiences in sustained NFM, institutional weakness, inadequate governmental control over the forests and the commercialization process of forest products.

In spite of these obstacles for natural forestry, much can be done if active work with land-owners is initiated and practical experiences are gained. Some relevant aspects that foresters should incorporate are:
-Acceptance of NFM by the landowners as a complementary low-input system. Management of production forests should be oriented to meet local needs and, where feasible, to external markets, thus having a quantifiable economic benefit for the forest-owner.

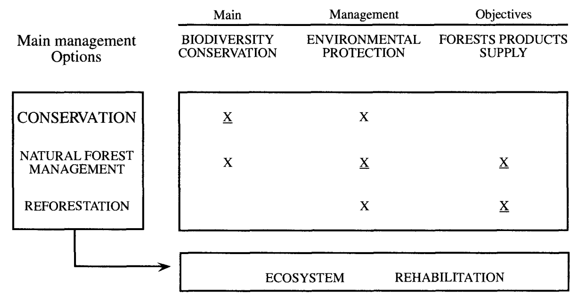

Fig. 6. Management options for tropical dry forest lands.

-A multiple-use approach for diversified production of woody and non-woody products, and for the indirect conservational benefits (e.g. Wadsworth 1979; De Camino 1987; Lamprecht 1989). These objectives should be reconciled with the traditional (detrimental) uses of the forest by the local residents.
- An effective control and regulation to counteract destructive biotic factors caused by human activities such as fires, overgrazing and irresponsible commercial logging, especially during the regeneration period. This should be done in consultation with landowners and the local residents.
- Integration of the local human population is assured only if the economic attractiveness of NFM is demonstrated. Educational activities are then needed for introducing the idea of NFM to the local residents, and convince them of the advantages of a better utilization of the forest resources. This requires well-designed training and extension activities. In addition, some kind of financial support such as credits may be needed for initial operations if there is any marketable product.

For the cooperative forests in Chinandega Norte, the main production objective should be production of firewood and polewood, both for local consumption and for commercial purposes (market in the city of Chinandega). This short- and medium-term management strategy should also aim at encouraging future regeneration to produce more valuable products, and at the improvement of their conservation benefits. Essential to the success would be the acceptance and effective application by the cooperatives of appropriate corrective measures, such as fencing, fire prevention and grazing control (Sabogal 1990).

Simple management plans for the first five years are envisaged for each cooperative, based on information from inventories and regeneration surveys, the cooperative's own objectives and limitations, and market prospects. The CHINORTE- program would provide the main support for the implementation of NFM, such as technical assistance and extension. Currently, regulation and control is run by the Program and by IRENA, mainly to regulate commercial cuttings and prevent burning in the natural vegetation.

Research needs

Relevant applied research is required to follow up the silvicultural work, as well as to improve local uses of the forest species (including non-woody products). This will be encouraged by the Program through universities and research institutions. These will also be actively involved in the training activities for local technicians and farmers. Research work in tropical dry forests has to focus on the ecological as well as on the socio-cultural and economical aspects related to the management options. Applied research on better utilization of the forest resources must constitute an intrinsic part of rural development programs and should be directly connected to the problems faced during the implementation of such programs.

Training constitutes a key issue and should include specific activities and operations in the field, as well as data processing and analysing (Berner 1990).

Research should be conducted primarily by local universities, where graduate teachers and non-graduate students can form interdisciplinary teams and benefit from training activities. In this process, governmental institutions, foreign universities and research institutes may play a role in providing the necessary inter-institutional linkages, technical and financial support.

Experimental areas are important in providing an appropriate (secure) 'working environment' for long-term basic and applied biological research. They may also be used for demonstration of natural forest management and for training and extension activities.

Some research topics relevant to the work are (see also Palmer 1986 and Hutchinson 1988) include:
- ethnobotany and autecology: phenological studies on flowering and seed production, dispersal and seedling establishment, of economically important tree species, preferably those which are ecologically important in degraded forests;
- resprouting capacity of economic trees, which respond to different management regimes;
- effects of the application of protection measures (e.g. fire and cattle grazing) in the regeneration/recovery process of the forest and effects of silvicultural treatments on the regeneration and growth of the forest;
- trial studies on enrichment planting: species, planting design, etc., and technological studies to improve species utilization.

Acknowledgements. The preparation of this paper was supported by the Swedish Agency for Research Cooperation with Developing Countries (SAREC), and the CATIE-AFN/SAREC Project. Bryan Finegan, Ian Hutchinson and Håkan Hytteborn commented on the paper and made useful comments and suggestions. My special gratitude to Karin Gerhardt for her encouragement and contributions to this work.

References

Anon. 1981. *Proyecto de evaluación de los recursos forestales tropicales (en el marco de SINUVIMA).* Los recursos forestales de la America Tropical. FAO, Roma.

Anon. 1986. *Proyecto Leña y Fuentes Alternas de Energia.* CATIE-ROCAP 596-0089. Informe final. CATIE, Turrialba.

Anon. 1987a. *Plan de Acción Forestal Tropical; Subregión Centroamérica y Panamá* FAO/CATIE. Turrialba.

Anon. 1987b. *Estudio de vegetacion Rio Escalante - Chacocente.* Documento interno, preparado por Angela Laguna. IRENA, Managua.

Anon. 1988. *Estudio basico de Chacocente.* Documento interno de base el Plan de Manejo del Refugio de Vida Silvestre de Chacocente; preparado por Margarita Moreno. IRENA, Managua.

Anon. 1989. *Management of tropical moist forests in Africa.* FAO Forestry Paper 88. Rome.

Anon. 1990. *Documento Base III Fase 1990-1994. Direccion General de Fomento Campesino y Reforma Agraria (MIDINRA)*. Cooperación Suiza al Desarrollo (COSUDE). Managua.

Anon. 1991. *Proyecto Cultivo de Arboles de Uso Múltiple (Madeleña).* CATIE/RENARM/ROCAP. CATIE, Turrialba.

Begué, L. 1966. Les fôrets du Nicaragua. *Rev. Bois Fôr. Trop.* 107: 15-26.

Berner, P. O. 1990. *Natural Forest Management Component.* Cons. Rep. to the USAID/Guatemala MAYARENA Project. March/April 1990. CATIE, Turrialba.

Budowski, G. 1982. The socio-economic effects of forest management on the lives of people living in the area: the case of Central America and some Carribbean countries. In: Hallsworth, E. G. (ed.) *Socio-economic effects and constraints in tropical forest management*, pp. 87-102. Wiley, New York.

Cáceres, O. In press. *Inventario forestal y proposicíon de alternativas silviculturales en un bosque seco de la región de Chinandega Norte, Nicaragua.* Trabajo de Diploma, Esc. Cienc. For., Universidad Nacional Agraria, Managua.

Curtis, J. T. & McIntosh, R. P. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology* 32: 476-496.

De Camino, R. 1987. *Consideraciones economicas en el manejo de bosques tropicales.* Doc. Conf. Manejo de Bosque tropical, Instituto forestal Tropical, Río Pedras, Sept.1986.

Dourojeanni, M. 1987. Manejo de bosques naturales en el tropico americano: Situación y perspectivas. *Rev. For. Peru* 14: 91-108.

Dulin, P. 1982. *Distribucion de la estacion seca en los países centroamericanos*. CATIE, Turrialba.
Evans, J. 1982. *Plantation forestry in the tropics*. Clarendon Press, Oxford.
Figueroa, J. C., Wadsworth, F. H. & Branham, S. 1987. *Management of the Forests of Tropical America: Prospects and Technologies*. Proc. Conference San Juan, Puerto Rico, Sept. 1986. Forest Service & University of Puerto Rico, Rio Piedras.
Hartshorn, G. S. 1983. Plants. In: Janzen, D. H. (ed.) *Costa Rican Natural History*, pp. 118-349. University of Chicago Press, Chicago.
Holdridge, L. 1971. *Forest environments in tropical life zones. A pilot study*. Pergamon Press, Oxford.
Hubbell, S. P. 1979. Tree dispersion, abundance, and diversity in a tropical dry forest. *Science* 203: 1299-1309.
Hutchinson, I. D. 1988. Points of departure for silviculture in humid tropical forests. *Commonw. For. Rev.* 67: 223-230.
Janzen, D. H. 1986. *Guanacaste National Park: Tropical Ecological and Cultural Restoration*. EUNED, San José, Costa Rica.
Janzen, D. H. 1988a. Tropical dry forests: the most endangered major tropical ecosystem. In: Wilson, E. O. (ed.) *Biodiversity*, pp. 130-137. National Academic Press, Washington, D.C.
Janzen, D. H. 1988b. Management of Habitat Fragments in a Tropical Dry Forest: Growth. *Ann. Mo. Bot. Gard.* 75: 105-116.
Lamprecht, H. 1989. *Silviculture in the Tropics. Tropical forest ecosystems and their tree species; possibilities and methods for their long-term utilization*. Deutsche Ges. f. techn. Zusammenarbeit (GTZ), Eschborn.
Leonard, H. F. 1986. *Recursos naturales y desarrollo economico en America Central. Un perfil ambiental regional*. IIED - CATIE. San José, Costa Rica.
Lugo, A. E. 1988. The Future of the Forest: Ecosystem Rehabilitation in the Tropics. *Environment* 30: 17-45.
Martínez, H. A. 1985. El problema de la Leña en las zonas secas de América Central. Necesidades de investigación. In: Salazar, R. (ed.) *Técnicas de producción en fincas pequeñas y recuperación de sitios degradados por medio de la silvicultura*, pp. 33-45. Acta de Simposio, 24-25.6.1988. CATIE, Turrialba.
Martínez, H. A. & Hughes, C. 1987. Manejo de vegetación secundaria en las zonas secas de América Central, México y el Caribe. In: *Investigaciones sobre las especies leñosas de uso múltiple para las zonas secas de América Central, México y el Caribe*. Doc. proyecto pres. al Taller IUFRO sobre Planificacion de la Investigacion Forestal en America Latina Tropical. Huaráz, Peru.
Mayorquin, M. & Salinas, B. 1989. *Estudio preliminar de la regeneración de especies forestales potencialmente productivas del área protegida de Chacocente, Carazo-Rivas*. Trabajo VIII Jornada Univ. Desarrollo Cient. Esc. Cienc. For., Inst. Sup. Cienc. Agropecuarias. Managua.
Mergen, F. & Vincent, J. R. (eds.) 1987. *Natural Management of Tropical Moist Forests. Silvicultural and Management Prospects of Sustained Utilization*. Yale University, New Haven, CT.
Morales, R. & Rueda de Morales, M. 1989. *Etnobotanica de las especies forestales en las comunidades Cantimplora y San Jacinto, Departamento de Rivas, IV Región*. Trabajo de Diploma. Esc. Cienc. For., Inst. Sup. Cienc. Agropecuarias. Managua.
Murphy, P. G. & Lugo, A. E. 1986. Ecology of tropical dry forest. *Annu. Rev. Ecol. Syst.* 17: 67-88.
Palmer, J. 1979. Funciones complementarias de los bosques naturales y las plantaciones. In: *Actas del Seminario Forestal CATIE-DDA; Proyectos forestales para el desarrollo rural de America Tropical*, pp. 83-86. CATIE, Turrialba.
Palmer, J. 1986. What the manager needs to know. In: Hadley, M. (ed.) Rain Forest Regeneration and Management. *Biol. Int. Spec. Iss.* 18: 5-10.
Pérez, S. D. 1986. *Plan de ordenación forestal del bosque seco tropical de La Pilarica, S.A.* Tesis Lic., Esc. Cienc. Amb., Universidad Nacional, Heredia, Costa Rica.
Powell, M. & Mercedes, J. 1986. *Composicion, estructura y estratificación de un bosque seco sub-tropical en Mao, Valverde, Rep. Dominicana*. Programa de Desarrollo de Madera como Combustible. ISA/COENER/AID. Nota Tecnica No. 25. Santiago, Rep. Dominicana.
Sabogal, C. 1989. *Planificación del inventario forestal en el área de investigacion del ISCA en Chacocente. Proyecto de Investigacion para el Manejo del Bosque Tropical Seco en Chacocente, Nicaragua*. Doc. Trab. No. 1. CATIE, Turrialba.
Sabogal, C. 1990. *Línea de Acción en manejo de bosque natural del Programa CHINORTE*. Informe de viaje. CATIE, Turrialba.
Taylor, B. W. 1963. An outline of the vegetation of Nicaragua. *J. Ecol.* 51: 27-54.
Torres Q., M.J. & Ulmos, V. 1990. *Extracción, comercialización y consumo de leña en Rivas*. Trabajo de Diploma, Fac. Rec. Nat. Amb., Universidad Nacional Agraria, Managua.
Valerio, L. In press. *Análisis de la regeneración natural en el bosque seco denso caducifolio de Chacocente, Carazo-Rivas*. Trabajo de Diploma, Escuela de Ciencias Forestales, Universidad Nacional Agraria, Managua.
Veillon, J.P. 1983. *El crecimiento de algunos bosques naturales de Venezuela en relación con los parametros del medio ambiente*. Inst. Silvicultura, Fac. de Ciencias Forestales, Universidad de Los Andes. Merida, Venezuela.
Wadsworth, F. H. 1979. Principles of management for sustained yield: evaluation and prospects. In: Chavarria, M. (ed.) *Simposio Internacional sobre las Ciencias Forestales y su Contribuccion al Desarrollo de la America Tropical*. San José, Costa Rica.
Witsberger, D., Current, D. & Archer, E. 1982. *Arboles del Parque Deininger*. Ministerio de Educacion - Direccion de Publicaciones. San Salvador, El Salvador.

Received 3 May 1991;
Revision received 1 February 1992;
Accepted 25 March 1992.