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# Illegal Extraction of Forest Products in Laguna de Apoyo Nature Reserve, Nicaragua

J. K. McCrary[1,2], A. L. Hammett[2], M. E. Barany[2], H. E. Machado[1], D. J. García[3], and J. I. Barrios[3]

[1]*Basic Science Department, University of Central America, Apartado 69, Managua, Nicaragua.*
[2]*College of Forestry and Natural Resources, Virginia Polytechnic Institute and State University, Blacksburg, Virginia USA 24061*
[3]*National Agrarian University, Managua, Nicaragua. Corresponding author: jmccrary2@yahoo.com*

**Abstract.—Unregulated wood extraction has placed great pressure on many protected areas in Nicaragua. One example is the Laguna de Apoyo Nature Reserve, located on the edge of the most densely populated region in Nicaragua. Biomass extraction from this Reserve was principally for fuel wood (78%), followed by construction wood (13%) and other forest products (9%), the latter being dominated by broomsticks. Women and children, who accounted for 37% of the workforce involved in extraction activities, removed lower quantities of forest products per person than men. Although tree species richness in the reserve is still high, total wood extraction was estimated to occur at up to 50% of the maximum rate of biomass replacement by photosynthesis. Extraction rates were greater in areas with vehicular access. We conclude that the forested regions of the Reserve are under stress by heavy and irrational forest use, and recommend a community-based strategy to protect biodiversity and natural resource productivity that incorporates the promotion of sustainable harvesting techniques for fuel wood and non-timber forest products.**

**Keywords.—Forestry, sustainable resources, biodiversity, wood extraction**

## Introduction

Rising interest in the protection of forests and areas of biological value has led to a proliferation of protected areas in the developing world (WRI 1994). Nicaragua, for instance, includes 17% of its land surface area in a national system composed of 76 protected areas, most of them designated in the past 15 years. However, only seven of these areas are under active management by the Ministry of Natural Resources and the Environment (MARENA). Of the remainder, eleven receive minimal attention from MARENA (including Laguna de Apoyo Nature Reserve) and the rest are "paper parks" where wood extraction and other resource-use activities occur essentially without regulation or control (Sánchez 1999).

Multiple use forestry has become a conservation option for tropical forests and is touted by groups such as tour operators, environmentalists, coffee producers, and even lumber retailers. Multiple use policies, especially for the extraction of non-timber forest products (NTFP's), are often advocated to slow or halt the conversion of primary forest to agriculture or cattle pasture. The agricultural frontier in Nicaragua, eloquently described more than a century ago (Belt 1985), is still advancing in the northern and southeastern portions of the country (Maldidier and Antillón 1997; Faris 1999), although deforestation dynamics differ considerably among forests near populated areas in the Pacific region of Nicaragua. This paper discusses changes in use in the "internal forest frontier," which we define as a remnant forest in a densely populated and largely deforested zone, where special geographic and other factors promoted its continuance to the present, but whose biodiversity is subject to renewed threat due to changing political and socioeconomic conditions.

Our investigation was motivated by the apparent unsustainable forest product extraction in Nicaragua's remaining tropical dry forests. Although other studies of forest product use were performed in indigenous communities in remote parts of Nicaragua (Dennis 1988; Barrett 1994; Godoy 1994; Godoy et al. 1995; Coe and Anderson 1996) or among recently colonized areas in the classical agricultural frontier (Salick et al. 1995), we found little information to characterize the traditional relationships between the local Mestizo communities and the forests. The artisan and other forest-based industries abundant in the nearby city of Masaya, and intensive agroforestry tendencies in the area, suggest a potential historical connection to the uses of the forest found in the area of the Laguna de Apoyo Reserve (Hammett et al. 1999). Nonetheless, encroachment of urban lifestyles upon our study site and other forests in the Pacific region of Nicaragua, is certain to influence the types and quantities of forest products extracted. Hence, we hypothesize a recently altered, biologically unsustainable forest use pattern in the Reserve, based primarily in the increased extraction of fewer types of forest products (Godoy et al. 1995). We also test the validity of the hypothesis by van Buren (1990) that the mechanism of delivery of fuelwood is primarily through agricultural conversion of forested lands, particularly in the highly populated Pacific region.

## Materials and Methods

### *Study site*

The Laguna de Apoyo Nature Reserve (LANR), placed in the national protected area system in 1991 (Sánchez 1999), has a volcanic crater lake surrounded by a heavily forested cone interior (Fig. 1). The lake occupies 21 km$^2$ with maximum depth in excess of 200 m. The watershed, which constitutes the remainder of the reserve, is about 1700 ha, mostly steeply-graded closed tropical dry forest with 1200-1900 mm annual precipitation and 26-28 °C mean temperature (Salas 1993). The LANR contains one of the five largest dry forests remaining in Nicaragua. Tropical dry forest alternates between dry and wet seasons, and contains full-canopy broadleaf forest at maturity; this type of forest is among the least protected of the prominent life zones represented in Nicaragua, with only 5% inclusion into the protected area system (Gillespie et al. 2001). The LANR watershed has only one small year round in-flowing brook and no overland outflow occurs. The lake contains one described and several undescribed endemic species of fishes (Waid et al. 1999; McKaye et al. 2002).

The LANR is fewer than 15 km from two large cities, Masaya and Granada, and 35 km from Managua. More than 147 000 persons live in communities within 3 km of the Reserve boundary (INTA 1994). Urbanization of these communities, including water and electricity distribution, school and road improvements, has occurred recently. Approximately 70 impoverished families live inside the reserve.

### *Methods*

We made observations at five locations which we determined by preliminary observations to be the most important routes of movement of forest products across the reserve boundaries. We concentrated our observations at entrance 1, the principal entrance to LANR, which is a paved road allowing vehicular traffic into the crater (Fig. 1). The other four entrances (2- El Mojón; 3- Catarina; 4- Granada; 5- Diriá) are footpaths leading to towns or villages along the edge of the crater; they received limited monitoring in accordance with the extraction quantities seen during the preliminary observations. Observations of forest product extraction were made during the rainy season, from April 15 to November 20, 1999; products extracted were classified by product type (i.e., fuelwood, timber, and non-timber forest product-NTFP), species, number of persons and gender, exit location, time of day, and method of transport. Weights (wet weight at estimated 18% moisture), types, and species of forest products were estimated from brief visual analysis of the loads as individuals or groups exited the reserve. We confirmed weight estimates by weighing bundles of

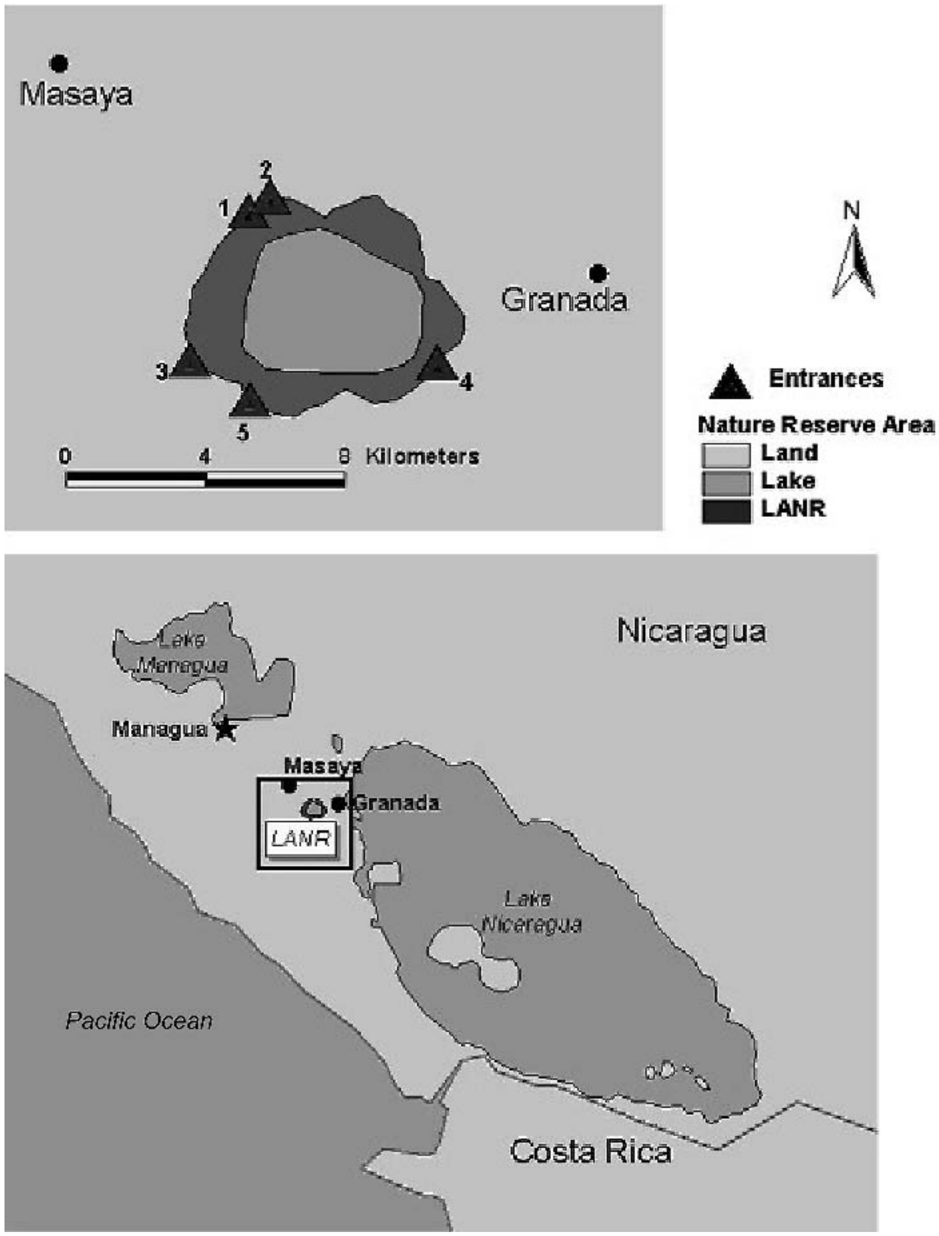


FIG. 1. Study area entrances at the Laguna de Apoyo Nature Reserve (LANR); 1-principal entrance; 2-El Mojón; 3-Catarina; 4-Granada; 5-Diriá. Source: The University of Texas at Austin.

wood to calibrate our "visual" method. Estimated weights were recorded to the nearest 0.5 kg for loads up to 10 kg, and to the nearest 2.5 kg for larger sizes. When more than one observer was present, a mean value of the estimate of each observer was taken. Means and standard deviations are reported for summed observations using an estimate of the within-groups variance (Pagano and Gauvreau 1993). Error values are reported as standard deviations. Statistical significance of observations and comparisons was determined using the appropriate $\chi^2$ or t test, to 95% confidence or greater (P < .05), except where noted otherwise. The following observations hours were taken at each entrance: 1- 219; 2- 23; 3- 34; 4- 10; 5- 72. The daily extraction by entrance was estimated by summing the extraction rates by hour of day.

During September and October 2000 we counted and measured the sizes and slopes of actively cultivated agricultural plots in the Reserve. According to the sector associated with the nearby communities served by the entrances, we considered villages associated with Masaya (entrances 1 and 2), Catarina (entrance 3), Granada (entrance 4), and Diriá (entrance 5). Only plots with lower than 10% canopy cover (tree canopy projection as a percentage of total field area) were included; a number of agroforestry plots were not included. Forest tree composition and wood quantities in the LANR were determined by taking random samples of approximately 1.8% of the forest area along a series of 12 transects 0.6 to 3 km long. Trees were sampled and standing wood volumes were estimated in 50 m × 50 m plots placed at 100 m intervals along the transect. Thirty hectares were surveyed for species in the reserve, and vegetation samples from each sector were accumulated over the period. Trees (stems at least 2.5 cm dbh) and forest products were identified by local technicians and confirmed in the National Herbarium in the University of Central America and in the herbarium of the National Agrarian University at Managua.

A notable difficulty of the survey method used for this study is the identification of the species represented by the material extracted. Few technicians can identify species based on a brief visual inspection of cut wood, a feat that becomes exponentially more difficult in a diverse forest. A reference collection of cut wood samples was made to facilitate field identifications, and local peasants well-versed in local woods were used as observers during the study.

## RESULTS

### *Fuelwood extraction*

Fuel wood was the most abundant forest product removed from the reserve (total averages 1767+/−270 kg/day; Fig. 2). Fuel wood extraction rates varied by hour of day ($\chi^2 > \chi^{2.05}$) at Entrance 1, where 60% of the extraction (Fig. 3) occurred. Peak hours of fuel wood extraction were found in the morning and in the afternoon, with very little extraction occurring outside daylight hours. We identified the species of 90% of the fuel wood biomass documented in the survey; among the 40 species represented, 42.1% of the mass belonged to *Gliricidia sepium*, *Guazuma ulmifolia*, and *Tecoma stans* (Table 1). Almost all of the wood extracted was freshly cut and green.

Men participated more in fuel wood extraction (28.9+/−1.2 men/day, 7.5+/−0.7 women/day, 11.0+/−1.3 children/day; Fig. 4), and they extracted more fuel wood per person on foot (27+/−18 kg/person) than women (15+/−11 kg/person) and children (8+/−5 kg/person). In the principal entrance, men used motorized vehicles, bicycles, and pack animals to remove fuel wood at greater rates per person (117+/−148 kg/person) than on foot. Women (22+/−16 kg/person; P < 0.10) and children (33+/−55 kg/person) also used vehicular transport in the principal entrance, but to a lesser extent and with less significant increases in loads. Almost all extraction in entrances 2-5 was by individuals on foot.

### *Timber extraction*

Timber removal totaled 299+/-37 kg/day and was significantly higher through the main entrance (138+/-42 kg/day) than the other monitored entrances (Fig. 2). Peak extraction hours from entrance 1 were early morning (0600 to 0700) and after dusk (1800

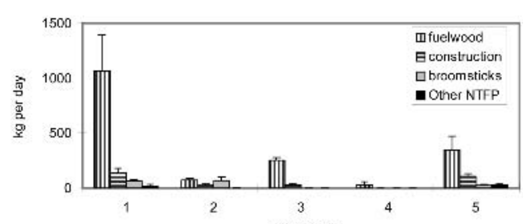


FIG. 2. Forest products extraction by entrance, Laguna de Apoyo Nature Reserve.

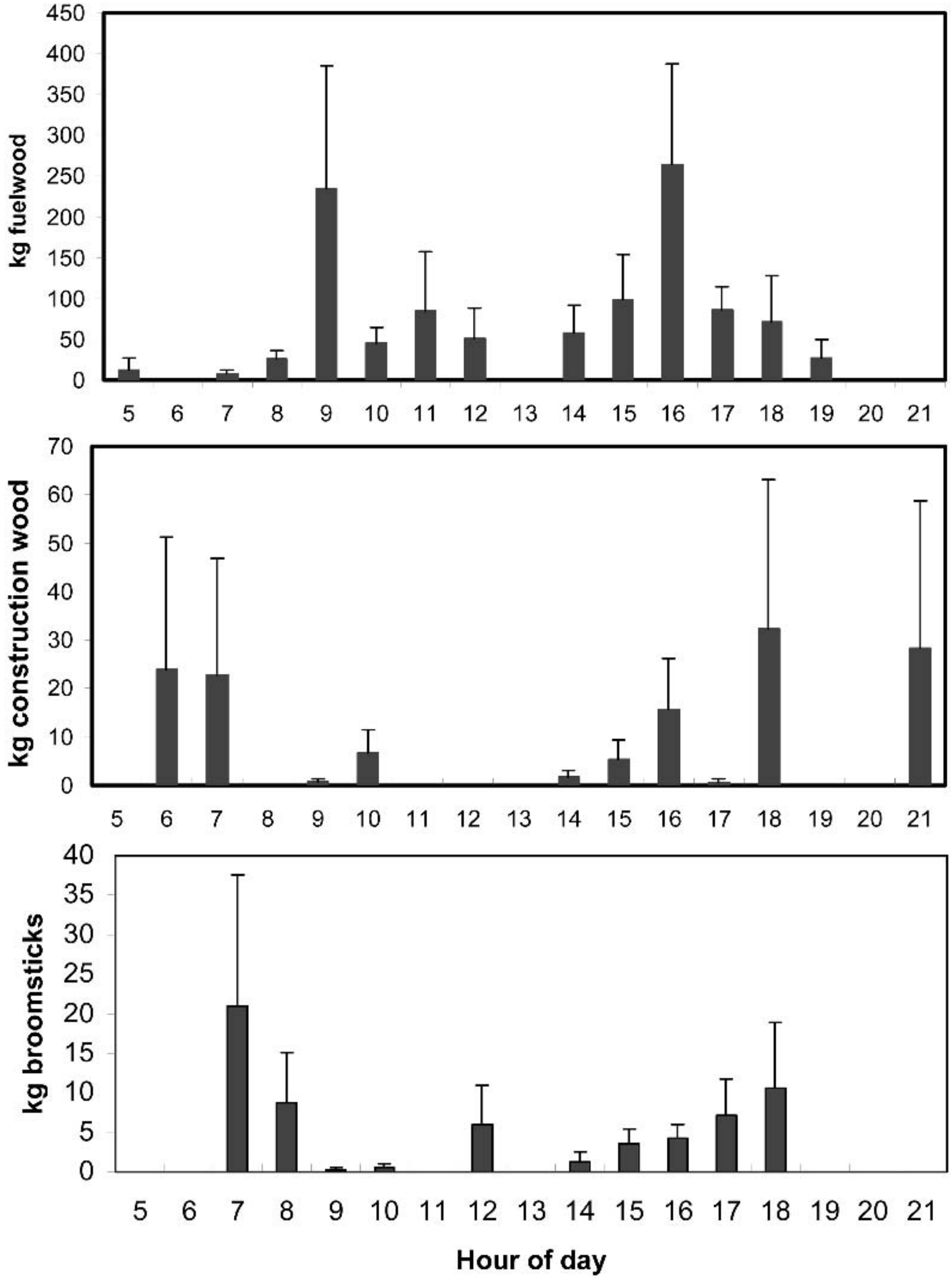


FIG. 3. Wood extraction for fuel, construction and broomstick from the principal entrance (#1), Laguna de Apoyo Nature Reserve, by hour of day.

TABLE 1. Tree specimens in Laguna de Apoyo Nature Reserve, with uses recorded in this report.

| Species | Family | Uses |
|---|---|---|
| *Bravaisia integerrima* (Spreng.) Standl. | Acanthaceae | |
| *Anacardium occidentale* L.* | Anacardiaceae | N |
| *Astronium graveolens* Jacq. | Anacardiaceae | |
| *Mangifera indica* L.* | Anacardiaceae | F,N |
| *Mosquitoxylum jamaicense* Krug & Urban | Anacardiaceae | F |
| *Spondias mombin* L. | Anacardiaceae | F,C |
| *Spondias purpurea* L. | Anacardiaceae | |
| *Annona purpurea* Mocinno & Sesse | Anacardiaceae | F,N |
| *Sapranthus nicaraguensis* Seem | Annonaceae | |
| *Lacmella panamensis* (Woods.) Markg. | Apocynaceae | |
| *Plumeria rubra* L. | Apocynaceae | N |
| *Stemmadenia donnell-smithii* (Rose) Woodson | Apocynaceae | |
| *Stemmadenia obovata* (Hook & Am.) K. Schum. | Apocynaceae | F,C |
| *Thevetia peruviana* (Pers.) K. Schum. | Apocynaceae | |
| *Thevetia peruviana* (Pers.) K. Schum. | Apocynaceae | |
| *Oreopanax capitatus* (Jacq.) Decne & Planchon | Araliaceae | |
| *Sciadodendron excelsum* Griseb | Araliaceae | N |
| *Vernonia patens* Patens | Asteraceae | |
| *Crescentia alata* H.B.K. | Bignoniaceae | |
| *Spanthodia campanulata* Beauv. | Bignoniaceae | |
| *Tabebuia chrysantha* (Jacq.) Nicolson | Bignoniaceae | F,N |
| *Tabebuia rosea* (Bertol.) D.C. | Bignoniaceae | |
| *Tecoma stans* (L.) Juss. Ex H.B.K. | Bignoniaceae | F,B |
| *Bixa orellana* L. | Bixaceae | |
| *Cochlospermum vitifolium* Willd. Ex Spreng. | Bixaceae | C |
| *Bombacopsis quinata* (Jacq.) Dugand | Bombacaceae | F |
| *Ceiba aescufolia* (H.B.K.) Britt. & Baker | Bombacaceae | |
| *Ceiba pentandra* (L.) Gaertn. | Bombacaceae | |
| *Ochroma pyramidale* (Cav. Ex Lam.) Urban | Bombacaceae | |
| *Cordia alliodora* (Ruiz & Pavon) Oken | Boraginaceae | F,C,N |
| *Cordia collococca* L. | Boraginaceae | |
| *Cordia dentata* Poir | Boraginaceae | F,C |
| *Cordia gerascanthus* L. | Boraginaceae | |
| *Bursera graveolens* (H.B.K.) Triana | Burseraceae | |
| *Bursera simarouba* (L.) Sarg. | Burseraceae | F,C |
| *Bauhinia ungulata* L. | Caesalpiniaceae | |
| *Caesalpinia violacea* (P. Miller) Standl. | Caesalpiniaceae | |
| *Cassia grandis* L.f. | Caesalpiniaceae | F |
| *Cassia siamea* (Lam.) Irwin & Barneby* | Caesalpiniaceae | |
| *Delonix regia* (Bojer) Raf.* | Caesalpiniaceae | |
| *Hymenaea courbaril* L. | Caesalpiniaceae | |
| *Senna atomaria* (L.) Irw. & Barn. | Caesalpiniaceae | |
| *Senna reticulata* (Willd.) Irw. & Barn. | Caesalpiniaceae | |
| *Senna skinneri* (Benth.) Irw. & Barn. | Caesalpiniaceae | F |
| *Tamarindus indica* L.* | Caesalpiniaceae | F,N |
| *Capparis frondosa* Jacq. | Capparaceae | |
| *Morisonia americana* L. | Capparaceae | |
| Unidentified | Caricaceae | |
| *Cecropia peltata* L. | Cecropiaceae | F |
| *Combretum farinosum* Kunth. | Combretaceae | |
| *Terminalia catappa* L.* | Combretaceae | |
| *Terminalia oblonga* (R.&P.) Stend. | Combretaceae | |
| *Licania arborea* Seem. | Chrysobalanaceae | |

F = fuel wood, C = construction wood, B = broomstick, N = other non-timber forest product, *exotic, established species.

TABLE 1. Continued.

| Species | Family | Uses |
|---|---|---|
| *Licania platypus* (Hemsl.) Fritsch | Chrysobalanaceae | |
| *Curatella americana* L. | Dilleniaceae | |
| *Diospyros nicaraguensis* Standl. | Ebenaceae | F,C |
| *Muntingia calabura* L. | Eleocarpaceae | |
| *Adelia barbinervis* Schlect. & Cham. | Euphorbiaceae | |
| *Croton* sp. | Euphorbiaceae | |
| *Euphorbia schlechtendalii* Boiss. | Euphorbiaceae | |
| *Hura polyandra* Baill. | Euphorbiaceae | |
| *Jatropha curcas* L. | Euphorbiaceae | |
| *Ricinus comunis* L. | Euphorbiaceae | |
| *Sapium macrocarpum* Muell.-Arg. | Euphorbiaceae | |
| *Dalberghia retusa* Hemsl. | Fabaceae | |
| *Diphysa robinioides* Benth. | Fabaceae | |
| *Dipterix panamensis* (Pittier) Record & Mell | Fabaceae | |
| *Erythrina berteroana* Urb | Fabaceae | |
| *Gliricidia sepium* (Jacq.) Stend. | Fabaceae | F,C,B |
| *Lonchocarpus minimiflorus* J.D. Smith | Fabaceae | F,C |
| *Lonchocarpus phlebifolius* Standl. & Steyerm. | Fabaceae | |
| *Machaerium* sp. | Fabaceae | |
| *Myrospermum frutescens* (Aubl.) Jacq. | Fabaceae | F |
| *Piscidia grandifolia* (Smith) Johnston | Fabaceae | |
| *Piscidia piscicula* (L.) Sarg. | Fabaceae | |
| *Platymiscium pinnatum* (Jacq.) Dugand | Fabaceae | |
| *Pterocarpus rohrii* Vahl | Fabaceae | |
| *Casearia corymbosa* H.B.K. | Flacourtiaceae | |
| *Gyrocarpus americanus* Jacq. | Hernandiaceae | |
| *Hemiangium excensum* (H.B.K.) A.C. Smith | Hippocrateaceae | |
| *Persea americana* Mill. | Lauraceae | |
| *Couroupita nicaraguensis* D.C. | Lecythidaceae | |
| *Byrsonima crassifolia* (L.) H.B.K. s.l. | Malpighiaceae | |
| Unidentified | Melastomataceae | |
| *Carapa guianensis* Aubl. | Meliaceae | |
| *Cedrela odorata* L. | Meliaceae | F,C |
| *Guarea glabra* Vahl | Meliaceae | |
| *Azadirachta indica* L.* | Meliaceae | |
| *Melia azedarach* L.* | Meliaceae | |
| *Swietenia humilis* Zucc. | Meliaceae | |
| *Acacia farnesiana* (L.) Willd. | Mimosaceae | |
| *Acacia hindsii* Benth. | Mimosaceae | C |
| *Acacia pennatula* (Shlecht.) Benth. | Mimosaceae | F |
| *Albizia andincephala* (J.D. Smith) B.&R. | Mimosaceae | |
| *Albizia caribaea* (Urb) B.&R. | Mimosaceae | F |
| *Albizia guachapele* (H.B.K.) Dugand | Mimosaceae | F |
| *Enterolobium cyclocarpum* (Jacq.) Grisev. | Mimosaceae | F |
| *Leucaena leucocephala* (Lam.) De Wit | Mimosaceae | |
| *Mimosa arenosa* (Schlecht.) Benth. | Mimosaceae | F |
| *Pithecellobium saman* (Jacq.) Benth. | Mimosaceae | F |
| *Pithesellobium dulce* (Roxb.) Benth. | Mimosaceae | F |
| *Pithesellobium oblongum* Benth | Mimosaceae | F,C |
| *Castilla elastica* Sesse. | Moraceae | F,C |
| *Chlorophora tinctoria* (L.) Gaud. | Moraceae | F |
| *Ficus benjamina* L.* | Moraceae | |
| *Ficus continfolia* H.B.K. | Moraceae | |

F = fuel wood, C = construction wood, B = broomstick, N = other non-timber forest product, *exotic, established species.

TABLE 1. Continued.

| Species | Family | Uses |
|---|---|---|
| *Ficus insipida* Willd. | Moraceae | F |
| *Ficus obtusifolia* H.B.K. | Moraceae | F |
| *Trophis racemosa* (L.) Urb. | Moraceae | |
| *Eugenia salamensis* J.D. Smith | Myrtaceae | F |
| *Psidium guajava* L. | Myrtaceae | |
| *Pisonia macranthocrapa* J.D. Smith | Nyctaginaceae | |
| *Schoepfia schreberi* J.F. Gmelin | Olacaceae | |
| *Ximenia americana* L. | Olacaceae | |
| *Piper tuberculatum* Jacq. | Piperaceae | |
| *Coccoloba caracasana* Meissn. | Polygonaceae | F,B |
| *Triplaris melaenodendron* (Bertol.) Standl. & Steyerm. | Polygonaceae | |
| *Karwinskia calderonii* Standl. | Rhamnaceae | |
| *Zizyphus guatemalensis* Hemsl. | Rhamnaceae | |
| *Calycophyllum candidissimum* (Vahl) D.C. | Rubiaceae | F,C |
| *Chomelia speciosa* L. | Rubiaceae | |
| *Hamelia patens* Jacq. | Rubiaceae | |
| *Citrus limon* (L.) Burm.* | Rutaceae | |
| *Zanthoxylum belizense* Lund. | Rutaceae | |
| *Allophylus oxidentalis* (Sw.) Radlkofer | Sapindaceae | |
| *Cupania dentata* D.C. | Sapindaceae | |
| *Melicocca bijugatus* Jacq.* | Sapindaceae | C |
| *Sapindus saponaria* L. | Sapindaceae | |
| *Thouinidium decandrum* (H.&B.) Radlk. | Sapindaceae | F |
| *Manilkara chicle* (L.) H.B.K. s.l. | Sapotaceae | |
| *Mastichodendron capiri var. tempisque* (Pitt.) Cronq. | Sapotaceae | |
| *Pouteria sapota* (Jacq.) Moore & Stearn | Sapotaceae | |
| *Quassia amara* L. | Simaroubaceae | N |
| *Simarouba glauca* D.C. | Simaroubaceae | F |
| *Solanum erianthum* D. Don | Solanaceae | |
| *Guazuma ulmifolia* Lam. | Sterculiaceae | F,C,B,N |
| *Sterculia apetala* (Jacq.) Karst. | Sterculiaceae | |
| *Jacquinia aurantiaca* Ait. | Theophrastaceae | |
| Unidentified | Tiliaceae | |
| *Apeiba tibourbou* Aubl. | Tiliaceae | |
| *Luehea candida* (Moc & Sesse ex D.C.) Mart. & Zucc. | Tiliaceae | |
| *Trichospermum mexicanum* (D.C.) Baill. | Tiliaceae | C |
| *Celtis iguanaea* (Jacq.) Sarg. | Ulmaceae | |
| *Phyllostylon brasiliensis* Capan. | Ulmaceae | B |
| *Trema micrantha* (L.) Blume | Ulmaceae | F |
| *Urera caracassana* (Jacq.) Griseb | Urticaceae | |
| Unidentified | Verbenaceae | |
| *Petrea volubilis* L. | Verbenaceae | |

F = fuel wood, C = construction wood, B = broomstick, N = other non-timber forest product, *exotic, established species.

to 2100), when significantly more timber was removed per hour than during 0800 to 1700 (Fig. 3). Seventeen species were extracted as timber, 46.8% of which belonged to *Cordia alliodora*, *Bursera simaruba*, *Cochlospermum vitifolium*, and *Pithecellobium oblongum* (Table 1). Only men (6.6+/−0.7 persons/day) participated in timber extraction (Fig. 4), and the quantity removed per person varied little with method of transport (36+/−41 kg/person on foot; 48+/−34 kg/person in vehicles; $P > 0.10$).

*Broomsticks*

Broomstick extraction to supply cottage industries in communities between Laguna

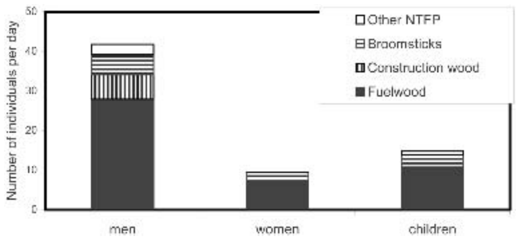


FIG. 4. Participants in forest product extraction.

de Apoyo and Masaya (Fig. 2) totaled 154+/−17 kg/day and occurred primarily at entrances 1 and 2. Extraction occurred mostly around 0700 and 1800 and was significantly higher than at low hours (1100 1300); extraction was not observed at night (Fig. 3).

Five species were extracted for broomsticks but over 90% of the extracted material belonged to *Guazuma ulmifolia*, *Gliricidia sepium*, and *Tecoma stans* (Table 1). Men (5.1+/−0.5 persons/day) exceeded women (2.0+/−0.6 persons/day) and children (3.0+/−1.0 persons/day) encountered with broomsticks (Fig. 4) and they were more efficient at this activity (20+/−16 kg/person) on foot than women (6+/−1 kg/person) and children (7+/−3 kg/person). Use of vehicles did not significantly increase the extraction quantities for men (27+/−19 kg/person; $P > 0.10$); women and children did not use vehicles.

*Other non-timber forest products*

A total of 46+/−18 kg/day of several other non-timber related products were extracted during the study. Seventy-five percent of this material passed through entrances 1 and 2 into villages on the north side of the Reserve while most of the remainder left through Entrance 5 into Diriá (Fig. 2). Most of the products were small wood items, bambo, fruits, seeds, edible snails (*Pyrgophorus coronatus*), wild game (armadillo *Dasypus novemcinctus*, paca *Agouti paca,* squirrel *Sciurus variegatoides*, deer *Odocoileus virginianus* and *Mazama americana*) fish (*Parachromis managuensis*, *Amphilophus citrinellus*, *A. zaliosus*, and *Gobiomorus dormitor*), structural fiber from vines, and medicinal products from leaves, bark and roots. Extraction of *Musa* leaves were not logged because they likely came from banana plantations. We observed mostly men involved in the extraction of these products (2.6+/−0.2 men/day; 0.1+/−0.1 women/day; 0.8+/−0.7 children/day; Fig. 4), and over 90% of our observations were of individuals on foot.

*Land clearing for agricultural use*

Forty hectares of land were under cultivation within the reserve, distributed in 179 plots ranging from 0.004 to 1.24 ha. Agriculture occupied 4.8% of the land associated with the Masaya municipality (corresponding to entrances 1 and 2), 2.3% of the land in the Catarina sector (entrance 3), 1.0% of the land in Diriá sector (entrance 5), and 0.9% in the Granada sector (entrance 4). Slopes of land under cultivation varied from 2% to 57%, with mean slopes similar in each sector (18.0-24.9%). Nine crops were found, plus much cleared pasture primarily in the Granada sector. Beans dominated the crops in Diriá sector (65% of cultivated land) and were important in Catarina sector (35%); broomstraw and beans occupied equal amounts of land in the Masaya sector (35% each). Other crops noted were maize, cassava, bananas, plantains, Napier grass, flowers, and two native varieties of squash (ayote and pipian).

*Forest arboreal evaluation*

We identified 147 species of trees at least to family level (50 families); the species considered native to the area constituted 136 of these, of which 130 were identified to species, in 111 genera representing 48 families (see Table 1). The most widely represented families in the reserve were Fabaceae (13 species present), Mimosaceae (12 species), and Caesalpinaceae (10 species). Arecaceae was not encountered other than cultivated in gardens. The quantities of wood in each sector of the reserve were estimated at the following: Masaya, 75 $m^3$/ha; Catarina, 145 $m^3$/ha; Diriá, 180 $m^3$/ha; and Granada, 55 $m^3$/ha.

## Discussion

### *Methodology of forest use assessment*

Investigations about forest use sustainability have prompted a variety of techniques to assess forest use patterns. The "questionnaire method" may provide information quickly and with little cost, but may be biased by ignorance, lack of interest, and intentional distortion by some interviewees (Shankar et al. 1998). The "consumption pattern" technique measures the quantities of fuel wood consumed in all activities in sample households of communities related to the forest (Shankar et al. 1998); this technique may produce useful information on use profiles in some circumstances but does not permit discrimination among potential sources of fuel wood and does not provide information on the extraction activity itself. Although Shankar et al. (1998) argued that the "footpath survey" method used in our study requires large numbers of observations to reach conclusions of scientific value (due to variations in collection activities on various time scales and difficulties in identification of all extraction routes and forest boundaries), this method provides direct information on forest use, including types of products and species, removal methods, and gender aspects.

We chose the "footpath survey" method because persons engaging in illegal wood extraction are not cooperative with interviewers due to the nature of their activities, some interviewees in fuel wood consuming homes bordering the LANR would not admit to using wood derived from the reserve, and because we wanted to document the extraction of all forest products from the reserve to create a more complete extractive use pattern. We also wished to obtain geographic, temporal, and gender profiles among all the important forest products extracted to create a more comprehensive view of the community relationship to this reserve, and to provide information vital to sound community-based management, which is lacking here and throughout Nicaragua.

### *Assessment of forest use*

Fuel wood cutting in the Laguna de Apoyo Nature Reserve, other than the gathering of dead wood, is illegal. However, the peak hours of fuel wood removal occurred during the day (Fig. 3), suggesting little enforcement of the law. Conversations with fuel wood cutters confirmed the lack of enforcement of sanctions. Fuel wood accounts for more than 75% of the mass of forest products extracted from the Reserve, a higher amount than that typically found in tropical forests (65%; FAO 1993). Nicaragua depends heavily on fuel wood as an energy source, constituting more than 50% of its total energy use, principally for cooking (Carneiro de Miranda and van den Broek 1996). Substantial fuel wood plantations for non-industrial use are absent, and this combined with the scarcity of sanctions against woodcutting in protected areas places great stress on natural forests (Ladrach 1996). This stress is heaviest in protected areas such as LANR, where large, poor populations have essentially free access to wood resources, and where a nearby ceramic industry consumes hundreds of thousands of kilograms of fuelwood each year (Lampmann 1995). Although there is great potential for conversion of underutilized nearby lands to managed fuel wood forests, the presence of open-access forests such as that in the Reserve hinders the development of a sustainable, managed supply of forest products.

### *Implications in forest composition and management*

The forested land of this reserve, although by no means "virgin", still sustains a high level of tree species richness, comparing favorably to tropical dry forest patches of similar or larger size in Nicaragua and Costa Rica (Gillespie et al. 2000; see Table 1). We contend that the high species richness of this reserve reflects a relatively sustainable use pattern, although the complete absence of palms and remarkably low abundance of fine woods suggests past excessive harvesting. In addition, fuel wood is obtained mostly by cutting directly from the forest, rather than as a by-product of land-clearing for agricultural purposes, as van Buren (1990) found to be typical in a national survey. In addition, much of the agricultural activity takes place on plots with slopes exceeding 30%, resulting in erosion, landslides, and increased sedimentation of the lake. Although there are no base-line data with which to compare, we consider that fuel wood cutting rates are presently far higher than in earlier historical periods.

To determine if the forest is being excessively burdened by product extraction, we attempted to estimate the rate of replacement of woody biomass by photosynthesis. Estimates of forest net primary productivities (sum of litterfall, herbivory, and aboveground biomass change) vary between 0.9 and 13.8 mt $ha^{-1}$ $yr^{-1}$. The aboveground woody biomass change component was 1.3 mt $ha^{-1}$ $yr^{-1}$ or 13% of the total net primary productivity in one study of a subtropical dry forest (Weaver 1996). For comparison, plantations of fast-growing eucalyptus in tropical dry forest life zones with irrigated sugar plantations on their borders, in what could be considered nearly ideal conditions, produce 4.9-6.4 dry mt $ha^{-1}$ $yr^{-1}$ of wood in Nicaragua (Carneiro de Miranda and van den Broek 1996). By extrapolation, we consider the aboveground biomass production rate in the Laguna de Apoyo Nature Reserve to lie between 1.3 and 2.7 mt $ha^{-1}$ $yr^{-1}$, most likely on the low end of the estimate given the rocky and steep soils of the Reserve. Therefore, the wood extraction estimated herein (0.55-0.65 mt $ha^{-1}$ $yr^{-1}$) is 20% to 50% of the maximum rate of replacement of woody biomass in the Reserve. Local rates of forest destruction would certainly exceed the maximum replacement rate, especially near entrances 1 and 2 on the north side.

Three factors make our estimates of forest products extraction conservative. First, many other access routes are used; along one we did not monitor, we encountered parts of two trunks of *Cedrela odorata*, freshly cut and converted to boards by chainsaw. We also detected the extraction of *Chlorophora tinctora* (a highly regarded wood for crafts) and *Bombacopsis quinata* (a prized construction wood) late at night via the main entrance. We observed several areas in the reserve which had been affected by cutting and forest product extraction, but the route for product removal was not one we monitored. Second, we did not monitor extraction beyond 22:00, although casual observations confirmed that nighttime extraction of commercial quantities of construction wood occur. Third, our work documented the rates of forest products extraction during the rainy season. We suspect that rates of fuel wood cutting are much higher during the dry season, when they are accompanied by fires set to remove brush, vines, and venomous animals, thus easing extraction procedures.

### *Social and gender aspects of forest use*

Removal of timber products by illegal "timber cruisers", although largely on foot and for personal use, was occasionally sighted on a commercial scale. Illegal construction woodcutters work in an organized fashion to avoid detection and carry semiautomatic arms to keep intruders at bay. Whereas individuals on foot with small loads of fuel wood are not prosecuted in Nicaragua, police at highway checkpoints stop suspected traffickers of timber and require permission documents. Thus, most timber is removed in the early-morning and late-evening to avoid police scrutiny.

Broomsticks supply a local cottage industry producing brooms for a substantial part of Nicaragua. The three species that supplied most broomsticks (*Gliricidia sepium*, *Guazuma ulmifolia*, and *Tecoma stans*) also provided almost half of the fuelwood and 8% of the construction wood. In addition, these species can be staked to form "living fences" and two of them have some recognized utility in furniture use. We recommend further investigation into the aspects of resource management of these species. The artisan broom industry, and other NTFP uses, suggests that there remains an important trend toward diversified forest use, influenced strongly by the historic roots of the community (Gould 1997) and the extensive artisan crafts industry in the area. The strong focus on a few forest products, however, supports the hypothesis of Godoy et al. (1995) that resource use specialization increases with increasing income; far fewer NTFP's were used here than in communities in that study because the communities adjacent to Laguna de Apoyo Nature Reserve enjoy many basic social services of urbanization and access to urban employment.

The gender roles in rural and forest-based informal economies in Nicaragua are little known. We found that the extraction of fuel wood and other products in the reserve is not regarded as "women's work." Women and children were particularly excluded from carrying construction wood, a task requiring physical strength, but often accompanied men in the process, carrying fuel wood gathered from the tree fall. Otherwise, women and children played important roles in many extraction activities, although more men generally participated and they carried greater quantities per person. While some of the materials extracted by women and children were for subsistence, others appeared to be income-generating.

Current policies which prohibit a wide range of extraction activities in protected areas are impractical. Such policies should recognize and even promote certain sustainable, traditional community uses. We suggest that the dynamics of forest use in LANR are qualitatively similar to those in other reserves with remnant tropical dry forest systems in Nicaragua. The biogeography and cultural reasons behind the continued existence of forests near populated regions should be considered in conservation plans throughout this region. Intervention is necessary to reduce pressure on wood inventories and to encourage the development of participatory management initiatives, including forest product extraction norms which are realistic in terms of the needs of local communities and sufficiently restrictive to protect the ecosystems therein and the environmental services that they provide.

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