United States
Department of
Agriculture

Forest Service

**International Institute
of Tropical Forestry**

ANNUAL LETTER
1997-98

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International Institute of Tropical Forestry
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Dear Colleagues:

With this Annual Letter we break a long-held tradition of publishing our annual report in both English and Spanish. We deeply regret this decision, forced on us by changing circumstances under which we operate at the Institute. On the positive side of the equation, we hope to be able to speed up the publication of the Annual Letter so that it reaches our colleagues in a timely fashion. As usual, the Annual Letter summarizes the key accomplishments of the Institute over the Fiscal Year and contains the list of publications over this time period. We also include reports of non-research projects such as our State and Private Forestry Program. We welcome comments and exchange of publications with all our readers.

Sincerely,

ARIEL E. LUGO
Director

ANNUAL LETTER

1997-98

INTERNATIONAL INSTITUTE OF TROPICAL FORESTRY
RÍO PIEDRAS, PUERTO RICO

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

INTERNATIONAL INSTITUTE OF TROPICAL FORESTRY ANNUAL LETTER

1997-98
Contents

ECOLOGICAL RESEARCH

Ariel E. Lugo
Ecologist

This fiscal year my publications involved long-term studies in Venezuela, studies on the ecological role of tree plantations and on mangrove wetlands, and various other activities.

LONG-TERM STUDIES IN VENEZUELA

One of the major uncertainties concerning the role of tropical forests in the global carbon cycle is a lack of adequate data on the carbon content of forest components. Our goal (Delaney and others 1997) was to contribute to filling this data gap by estimating the quantity of carbon in the biomass, soil, and necromass for 23 long-term, permanent forest plots in five life zones of Venezuela (table 1, fig. 1) to determine how C was partitioned among these compartments across a range of environments. Aboveground biomass C ranged from 70 to 179 Mg ha^{-1} and soil C from 125 to 257 Mg ha^{-1}, and

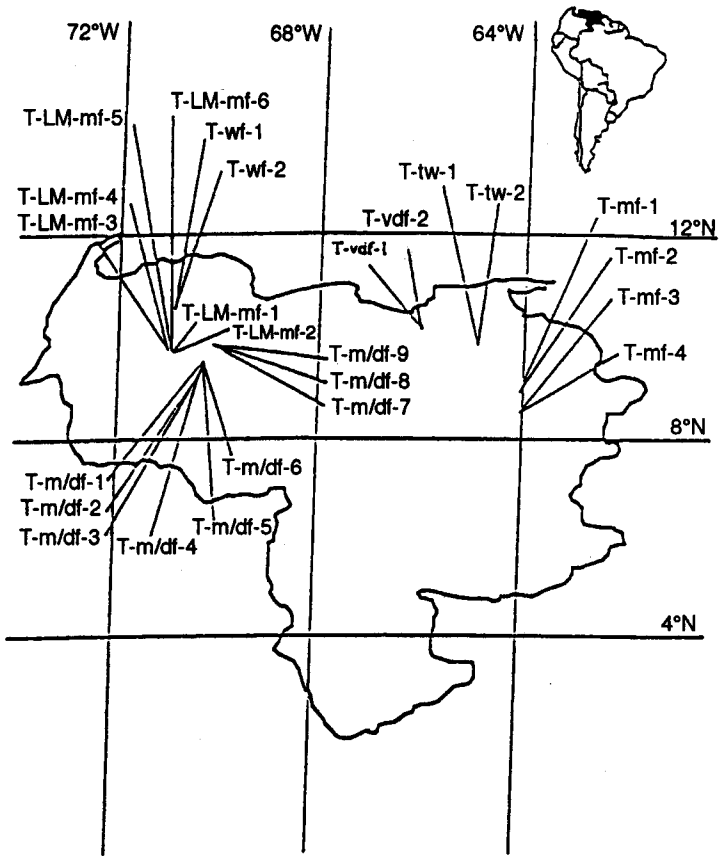

Figure 1. *–Location of long-term permanent forest plots sampled in Venezuela in 1994. T-tw = tropical thorn woodland; T-vdf = tropical very dry forest; T-m/df = tropical moist transition dry forest; T-mf = tropical moist forest; T-LM-mf = tropical lower montane moist forest; T-M-wf = tropical montane wet forest.*

Table 1. *–Description of long-term permanent forest plots sampled in Venezuela in 1994.*

Veillon plot number and (sample date)[a]		Life zone[b]	Latitude and longitude (°N/°W)	Average annual temperature	Annual rainfall (mm)	Elevation (m)	Soil textural class[c]
Cero El Coco	A.3	T-vdf-1	10/66	27.0	800	130	c-l
(6/13-15)		A.4 -2		27.0	800	130	c-l
Caimita	C.1	T-m/df-1	9.5/70	26.0	1500	150	c
(3/24-29	C.2	-2		26.0	1500	150	c-l
	C.3	-3		26.0	1500	150	c-l
	C.4	-4		26.0	1500	150	s-c-l
	C.5	-5		26.0	1500	150	c
	C.6	-6		26.0	1500	150	c
Ticoporo	C9T1	-7		26.0	1500	150	c-l
(4/19-23)	C9T2	-8		26.0	1500	150	st-c-l
	C9T3	-9		26.0	1500	150	st-c-l
Río Grande	DA.1	T-mf-1	9/64	25.5	2500	270	s-c-l
(6/5-10)	DA.2	-2		25.5	2500	270	s-c-l
KM92	G.1	-3		25.5	3200	210	s-l
(6/8-10)	G.2	-4		25.5	3200	210	s-l
Carbonera	MC.1	T-LM-mf-1	9.5/71	15.0	1400	2310	c-l
(3/9-5/12)	MC.2	-2		15.0	1400	2320	c-l
	MC.3	-3		15.0	1500	2430	c
	MC.4	-4		15.0	1500	2430	c
	MC.5	-5		15.0	1560	2450	l
	MC.6	-6		15.0	1560	2450	c
Mucuy	M.6	T-M-wf-1	10.5/71	10.5	2136	2640	s-l
(5/23; 7/26)	M.8	-2		10.5	1800	3000	st-l

[a]Sampling dates = month/day/1994.
[b]T-vdf = tropical very dry forest; T-d/mf = tropical moist transition dry forest; T-mf = tropical moist forest; T-LM-mf = tropical lower montane moist forest; T-M-wf = tropical montane wet forest.
[c]Based on the relationship between class name of a soil and its particle size distribution (% clay, % silt, and % sand): c = clay; c-l = clay loam; s-c-l = sandy clay loam; s-l = sandy loam; st-l = silty loam; st-c-l = silty clay loam (data from N. Bello Quintero, ongoing research).

they represented the two largest C components in all plots (table 2). The C in fine litter (2.4 to 5.2 Mg ha^{-1}), dead wood (2.4 to 21.2 Mg ha^{-1}), and roots (23.6 to 38.0 Mg ha^{-1}) accounted for less than 13 percent of the total C. Among life zones, total C ranged from 302 to 488 Mg ha^{-1}, and showed no clear trend with life zone. In three of the five life zones, more C was found in the dead components (soil, litter, dead wood) than in the live (biomass) components (dead to live ratios of 1.3 to 2.3); the lowland moist and moist transition to dry life zones had dead to live ratios of less than one. Results from this research suggest that for most life zones, an amount equivalent to between 20 and 50 percent of the aboveground biomass is located in necromass and roots. These results, coupled with reliable estimates of aboveground

Table 2. *–Mean (= SE, in parentheses), range of organic C density (Mg ha^{-1}), and range of percentage of total C in each forest component, in that order, in forest plots of five life zones of Venezuela.*

Life zone[a]	N[b]	Aboveground biomass	Soil	Fine litter	Dead wood	Roots	Total
T-vdf	2	70 (NE)[c]	233 NE)	5.2 (NE)	2.4 (NE)	33.4 (NE)	344
		67-72	196-271	5.2-5.2	2.1-2.7	32.2-34.6	310-377
		17.8-23.2	63.1-71.8	1.4-1.7	0.6-0.9	8.5-11.1	100
T-m/df	9	148 (19.1)	125 (8.3)	2.7-(0.3)	3.3 (0.4)	23.6 (3.1)	302
		80-256	73-153	1.6-4.0	1.2-4.3	13.0-40.9	200-414
		38.2-62.1	26.4-53.7	0.6-1.8	0.4-1.5	6.1-9.9	100
T-mf	4	179 (10.6)	160 (24.1)	2.4 (0.2)	16.7 (3.7)	28.6 (1.7)	386
		165-210	132-232	1.8-2.7	10.9-27.7	26.3-33.5	340-449
		39.1-52.1	35.4-51.6	0.5-0.7	2.4-7.8	6.3-8.3	100
T-LM-mf	6	173 (20.5)	253 (20.8)	3.1 (0.3)	21.2 (3.8)	38.0 (4.5)	488
		119-260	186-319	2.3-4.6	10.3-38.3	26.1-57.2	434-543
		25.6-49.4	35.3-65.9	0.4-0.8	2.2-7.8	5.6-10.9	100
T-M-wf	2	157 (NE)	257 (NE)	2.7 (NE)	17.2 (NE)	34.5 (NE)	468
		147-167	237-276	2.4-2.9	6.7-27.7	32.3-36.6	464-471
		31.7-35.3	50.4-59.4	0.5-0.6	1.4-5.9	7.0-7.8	100

[a]T-vdf = tropical very dry forest; T-m/df = tropical moist transition dry forest; T-mf = tropical moist forest, T-LM-mf = tropical lower montane forest; T-M-wf = tropical montane wet forest.
[b]N = number of plots.
[c]NE = not estimated, as N = 2.

biomass from forest inventories, enable more complete estimations of the C content of tropical forests.

Dead wood can be an important component of the carbon pool in many forests, but few measurements have been made of this pool in tropical forests. To fill this gap, we determined the quantity of dead wood (downed and standing dead) in 25 long-term (up to 30 years) permanent forest plots located in six different life zones of Venezuela (Delaney and others 1998). Downed wood was separated into fine (< 10 cm in diameter) and coarse (≥10 cm in diameter) classes, and three decomposition states (sound, intermediate, or rotten) (table 3). The total quantity of dead wood, averaged by life zone, was lowest in the dry (2.43 Mg ha^{-1}), reached a peak in the moist (42.33 Mg ha^{-1}) and decreased slightly in the wet (34.50 Mg ha^{-1}) life zones (table 4). Most of the dead wood in all plots was in the standing dead category (about 42 to 76 percent of the total). The decomposition state of dead wood in all plots was mostly rotten (45 percent) or intermediate (44 percent); there was little sound wood (11 percent). Turnover rates of dead wood generally ranged between 0.03 and 0.52 per year with no clear trend by life zone. The large amount of dead wood in some plots was equivalent to about 20 percent or less of

Table 3. *–Mean density (Mg/m-^{3}, with 1 SE in parentheses) of dead wood by diameter and decomposition class in six life zones of Venezuela.*

Life zone[a]	N	2.5-4.99 cm[c]	5.0-9.99 cm[b,c]	Sound[c]	Intermediate[d]	Rotten[c,d]
T-tw	2	0.29 (NE)	NW	NW	0.69 (NE)	NW
T-vdf	2	0.29 (NE)	0.70 (NE)	NW	0.59 (NE)	0.40 (NE)
T-m/df	9	0.24 (0.02)	0.22 (0.07)	0.42 (0.00)	0.37 (0.03)	0.25 (0.05)
T-mf	4	0.29 (0.05)	0.29 (0.11)	0.58 (0.02)	0.59 (0.03)	0.50 (0.13)
T-LM-mf	6	0.20 (0.01)	0.12 (0.02)	0.52 (0.04)	0.39 (0.03)	0.31 (0.01)
T-M-wf	2	0.19 (NE)	0.13 (NE)	NW	0.48 (NE)	0.32 (NE)

[a]T-tw = tropical thorn woodland; T-vdf = tropical very dry forest; T-m/df = tropical moist transition dry forest; T-mf = tropical moist forest; T-LM-mf = tropical lower montane moist forest; T-M-wf = tropical montane wet forest.
[b]NW = no wood in this category.
[c]NE = not estimated, as N = 2.

Table 4. *–Mean (1 SE in parentheses) and range of standing dead wood, total dead wood, percent aboveground tree biomass in dead wood, and dead wood turnover rate, in six life zones of Venezuela.*

Life zone[a]		Standing dead wood (Mg ha^{-1})[d]	Total dead wood (Mg ha^{-1})[d]	Percent of aboveground in dead wood[d]	Turnover rate per year[d]
T-tw	2/1[c]	1.4 (NE)	2.4 (NE)	18.3 (NE)	0.06
		0.13-2.74	0.65-4.2	4.1-32.5	
T-vdf	2	2.9 (NE)	4.8 (NE)	3.4 (NE)	0.20 (NE)
		1.99-3.73	4.19-5.35	3.1-3.7	0.18-0.22
T-m/df	6[d]	2.8-0.96	6.6 (1.00)	2.0 (0.51)	0.52 (0.17)
		0.0-11.4	2.45-13.90	0.69-3.61	0.12-1.21
T-mf	4	14.8 (10.6)	33.3 (7.48)	9.6 (2.5)	0.03 (0.01)
		0.0-45.2	21.80-55.31	6.2-16.8	0.01-0.06
T-LM-mf	6	21.3 (6.55)	42.3 (7.56)	12.4 (5.5)	0.13 (0.02)
		8.2-52.5	20.63-76.62	8.2-20.0	0.06-0.18
T-M-wf	2	26.3 (NE)	34.5 (NE)	10.6 (NE)	0.11 (NE)
		5.91-46.7	13.46-55.46	4.6-16.7	0.08-0.14

[a]T = tropical, tw = thorn woodland, vdf = very dry forest, m/df = moist transition dry forest, mf = moist forest, LM-mf = lower montane moist forest, M-wf = montane wet forest.
[b]The second plot in the thorn woodland was established in 1994; only one plot was used to calculate turnover time for this life zone.
[c]Plots T-m/df 7-9 were not used in this table because no long-term data were available.
[d]NE = not estimated, as N = 2.

aboveground biomass, indicating that dead wood can represent a significant amount of carbon in these forests.

ECOLOGICAL ROLE OF TREE PLANTATIONS

The proliferation of degraded tropical landscapes in need of rehabilitation, and the reduction of primary forest area have forced a close collaboration between ecologists and land managers. This collaboration has led to new paradigms of forest management (combined in the term "ecosystem management"), new insights into forest ecology through comparative ecological research, a more objective analysis of the ecology of tree plantations, and a better understanding of the ecological functioning of these ecosystems. Plantation forests can have the same functions as secondary forest stands. However, because of their species composition, structure, and management history, plantations can be more susceptible to disturbances than paired secondary forest stands. Plantations can be designed for maximization of particular outputs such as timber, or for specific land rehabilitation objectives such as protection of soils from erosion. Observations of plantation understories in Puerto Rico suggested that high species richness could occur under the shade of monocultural stands. This led to the hypothesis that reestablishment of tree species richness on degraded sites with arrested succession could be facilitated through plantings of tree monocultures. The approach was demonstrated experimentally in small plots and through observations at the landscape scale. Restoring tree species richness by planting tree monocultures works because the manager can match species to particular site conditions and thus overcome limiting factors that prevent the regeneration of species-rich forests on degraded sites. Once a forest canopy is established, microsite conditions change and wildlife is attracted. Animals are likely to disperse tree species from surrounding forest patches and regeneration of shade-intolerant species can be inhibited. Nine lines of research are suggested in Lugo (1997).

We published a synthesis of yield data on tropical tree plantations (Lugo 1998a). This work was part of the activities of the

Table 5. *–Retranslocation of nitrogen and phosphorus in mangrove forests at Jobos Bay, Puerto Rico (Retranslocation is the difference in nutrient content between mature and senescent leaves. The percentage of the nutrient content of mature leaves that is retranslocated is also given.)*

	Retranslocation			
	N		P	
Species and location	(mg cm^{-2})	(%)	(mg cm^{-2})	(%)
Salina				
Laguncularia racemosa	0.112	65	0.012	80
Avicennia germinans	0.204	62	0.017	84
Rhizophora mangle	0.165	65	0.009	78
Fringe				
Rhizophora mangle	0.082	59	0.005	73

research committee of Food and Agriculture Organization (FAO's) Latin American and Caribbean Forestry Commission.

MANGROVE WETLANDS

The status of knowledge and priorities for mangrove ecosystem research were reviewed in Lugo (1998b) for 11 topics: diversity of mangrove habitats; primary productivity; nutrient cycling; food chains; birds, fisheries and other wildlife; silviculture; response to stressors; restoration; basic biology; values; and changes in sea level. Data for nutrient cycling include publications up to 1986, and, for the other topics, up to 1990. Mangrove species show different rates of nutrient retranslocation when growing in contrasting conditions (table 5). Mangrove stands are believed to be an example of forest ecosystems that are resistant to invasion of alien species (Lugo 1998c).

OTHER ACTIVITIES

Sandra Brown and I (Lugo and Brown 1998) published a map of the biomass of the tropical forests of Brazil and developed a case for the feasibility of restoring tropical forests. Carleen Yocum and I (Yocum and Lugo 1997) edited the proceedings of the eighth meeting of Caribbean Foresters. This publication was dedicated to the management of protected areas.

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HISTORICAL PERSPECTIVE

Carlos M. Domínguez Cristóbal
Forest Historian

This report, covering the period October 1, 1997 through September 30, 1998, provides an overview of the research projects we have pursued as well as the other activities in which we have been involved. These have included participation in lectures, conferences, forums and seminars; as well as interaction with local and regional government and private sector agencies. We were also pleased to be nominated, for the first time, to become a member of the board of the "Asociación Puertorriqueña de Historiadores de Puerto Rico."

To help celebrate Earth Week, Social Studies Week, and Science and Math Week, and or other occasions as they arose, staff members gave talks in several public and private schools in Puerto Rico. The schools are as follows:

Eugenio María de Hostos High School (Mayàgüez),

Dra. Antonia Sáez Elementary School (Carolina),

Juan A. Corretjer Montes High School (Ciales),

Luis Muñoz Rivera High School (Utuado),

Francisco Morales High School (Naranjito),

Baptist School of Carolina,

Antilles High School (Fort Buchanan),

Bayamón Military Academy,

Carmen Sol Private School (Toa Baja).

The main topics of these talks were "The forests of Puerto Rico," "The presence of flora in our history," and "Flora as a recreational resource."

For the first time, forestry topics played a part in talks related to recycling. This occurred at the College of Agriculture and Mechanical Arts (Mayagüez) and at the Industrial Commission of Puerto Rico (San Juan).

We also participated in a course at the University College at Humacao (UPR). The course, "Problemática ambiental en Puerto Rico" [Environmental problems in Puerto Rico] included a lecture entitled "Presencia de la Flora en las plazas públicas de Puerto Rico" [Presence of flora in public squares of Puerto Rico].

Historically, our interactions with communities have been a vehicle for keeping in touch with the general public. Initiation of these occasions comes from the communities themselves. The following activities were undertaken within this framework:

- A preliminary inventory of trees and shrubs on the school grounds at Mariano Abril Junior High School, Guaynabo.

- Noches Borincanas Activity, an exposition and literature related to Puerto Rican forests, at Saint John School, Ashford Avenue, Condado.

- The second Agriculture Fair, with a lecture on "Presencia de la flora en los escudos municipales de Puerto Rico" [Presence of flora in the municipal shields of Puerto Rico], at the Georgina Baquero School, barrio Cubuy, Canóvanas.

- The forwarding of documents of natural history content to the Municipality of Culebra.

- A celebration of Earth and Environmental Week, with a lecture on "Presencia de la flora en nuestra historia:" [Presence of flora in our history] at Pfizer Pharmaceuticals Inc, Barceloneta.

Staff members participated in the following forums, symposia, and annual meetings:

- Fifth Annual Meeting of the "Asociación Puertorriqueña de Historiadores," at Interamerican University, Arecibo Campus.

- Scientific Research Symposium. Students participating in the course on scientific research at Luis Muñoz Rivera High School, in the municipality of Utuado, presented partial and final results of their ecological research on a secondary forest located at Caguana within the same municipality. The symposium was held at "Colegio Regional de la Montaña" (UPR) in Utuado.

- "The XVII Symposium on Caribbean Flora and Fauna" at Colegio Universitario de Humacao (UPR). We participated with a lecture on "The botanical garden of Puerto Rico, 1852-1949."

- First Environmental Forum, held in Bayamón and sponsored by the Community Resources Development Program in cooperation with the University of Puerto Rico (UPR) - Mayagüez Campus (Agriculture Sciences College and Agriculture Extension Service). We participated with a lecture on "History of our forests."

- A program entitled, "Our history and technology: forum between historians and engineers," sponsored by the Institute of Mechanical Engineers of the Association of Engineers and Surveyors of Puerto Rico.

We also participated, in a nonspeaking role, at the Puerto Rico Forestry Conference held in Ponce, Puerto Rico.

Staff interaction with several municipalities and members of the House of Representatives of Puerto Rico led to the generation of municipal legislation and to several proposals, some of which would affect Puerto Rican forests. These are as follows:

- The Municipal Assembly of Caguas selected their tree, flower, and bird (roble blanco, moriviví, and pitirre, respectively) as an integral part of their environmental education work.

- The Municipal Assembly of Ceiba discussed the selection of their municipal flower, *Pleodendron macranthum.* As on outcome of that discussion, initial work has begun to establish a small nursery in the municipality to propagate this endangered species. Their selection of the Ceiba *(Ceiba pentandra, kapok* or *silk-cotton-tree*) as the municipal tree, and the ensuing publicity, has led to recent plantings of this tree in urban areas of the municipality.

- The municipal tree, flower, and bird selection project is at different stages in several municipalities. Among them are Culebra, Morovis, Patillas, Juana Díaz, and Sabana Grande.

- House of Representatives Resolution 847 recommends expropriation of the private lands that form a part of the Valley and Trail of Parrots in barrio Galateo Alto of Isabela. The Resolution seeks to declare a natural reserve zone on this land and connect it to the Guajataca Forest. Public hearings have been held and a recommendation made for forest history studies; we have been an integral part of this activity. The effort continues, with new emphasis areas and studies.

Our staff assistance in forest history related studies has increased dramatically. Among the most significant are those at Cambalache State

Forest (by Aurea Berríos, Francisco Morales High School, Naranjito), Toro Negro State Forest (by Abeliz Rosado, graduate student at College of Agriculture and Mechanical Arts - UPR, Mayagüez Campus), and Caribbean National Forest (by Pedro Acevedo - New York Botanical Gardens).

Research in forest history motivated the following articles, which have been submitted for publication:

- "El inventario de los montes públicos de Puerto Rico, 1870," Acta Científica (Revista de la Asociación de Maestros de Ciencia de Puerto Rico [English title: Inventory of the public forests of Puerto Rico, 1870].

- "Presencia de la flora en las plazas públicas de Puerto Rico," Revista ICONOS (Revista de Comunicación del Colegio Universitario de Humacao, UPR) [English title: Presence of flora in the public squares of Puerto Rico].

- "El Jardín Botánico de Puerto Rico, 1852-1949," XVII Simposio flora y fauna del Caribe, Colegio Universitario Humacao, UPR [English title: The botanical garden of Puerto Rico, 1852-1949].

- "Panorama histórico forestal de Puerto Rico - desde la época indígena hasta 1975" [Forest history panorama of Puerto Rico - from indigenous time to 1975].

Among the projects that we have followed up on during this period are:

- Land use and tenure in the San Cristóbal Canyon.

- Forest toponymy in the names of barrios and towns in Puerto Rico.

- Municipal symbols: bird, flower, and tree.

- Presence of flora in the municipal shields of Puerto Rico.

- Flora (trees and shrubs) in the public squares of Puerto Rico (slides).

- Historic trees of Puerto Rico (slides).

Of the projects initiated, those with publication potential are the following:

- Forest legislature during the tenure of the Chamber of Delegates (1900-1917).

- Land tenure and use of present-day forested lands in barrio Sabana of Luquillo.

- Presence of flora in the festivals of Puerto Rico.

- Forest legislation index of Puerto Rico 1900-50. This project is being done at the University of Puerto Rico, Río Piedras Campus, Law School; the Institute of Puerto Rican Culture, General Archives of Puerto Rico; and the Legislative Library of Puerto Rico. It was initiated with the cooperation of Carlos Díaz Ochoa, a student at UPR, Río Piedras Campus, under the sponsorship of "Programa Pasaporte."

- Influence of roots in a biomass project with various mahogany species.

The following articles were published during this period:

- "La evolución del patrimonio público de Puerto Rico (el caso de los bosques, de la costa a la montaña." Acta Científica. [English title: Evolution of Puerto Rico's public heritage].

- "La Historia de la Sierra de Luquillo (Bosque Nacional del Caribe: parte 2)." Tiempo Libre. [English title: History of the Sierra de Luquillo (Caribbean National Forest, Part 2).

INTERNATIONAL COOPERATION

Frank H. Wadsworth
Research Forester

Institute staff offered technical assistance in St. Lucia, Mexico, Brazil, and Bolivia. In St. Lucia, we supported a mangrove development and utilization program of the Caribbean Natural Resources Institute in the interests of multiple development: integrating charcoal production with conservation of birdlife and ecotourism.

In Veracruz, Mexico, we participated in a workshop on forest restoration cosponsored by the Institute with SAMARNAP of Mexico and the government of Canada. The workshop was arranged through the Silvicultural Study Group of the Food and Agriculture Organization (FAO) North American Forestry Commission. Our contribution was a presentation on restoration of mine lands in Brazil. After the workshop, a subgroup visited Quintana Roo to explore the potential for local participation in forest conservation. One outcome is the Institute's support of a workshop within the region late this year to prioritize projects of this nature.

In Brazil, we supported the Tropical Forest Foundation demonstration of low-input logging at Paragominas by adding a demonstration of systematized, post-logging liberation of remaining trees for the next crop. Technicians were trained and some 800 crop trees were marked for liberation; half were treated. Technicians are following up to assure rapid elimination of competitors. Treatment costs are being carried by the Institute.

In Bolivia, the management planning required of some 80 concessionaires, with inventories and other practices of recent legislation, was reviewed in a search for greater efficiency and the possible introduction of post-logging silviculture under especially favorable situations. A presentation of the possibilities was made before concessionaires, government officials, and students. The activity was based and carried out with the cooperation of BOLFOR in Santa Cruz.

ISTF NEWS, the quarterly newsletter of the International Society of Tropical Foresters, was edited for the 19th year at the Institute. During the current year, 82 technical articles were briefed and presented, as were announcements of 61 new publications and 51 meetings and courses. Current distribution is worldwide and includes more than 1,500 dues-paying members.

A paper comparing tropical and temperate zone silviculture was presented by Institute staff at the meeting of the World Forestry Committee during the annual convention of the Society of American Foresters.

A book, "Forest Production for Tropical America," generated at the Institute, was printed in English by the U.S. Department of Agriculture, Forest Service in Washington. Written for the forestry schools of Latin America, its translation into Spanish is nearly complete. It is to be printed and placed on the web by the International Union of Forestry Research Organization (IUFRO) in Austria.

WATERSHED RESEARCH

Fred N. Scatena
Hydrologist

This year will be remembered by Hurricane Georges' visit to Puerto Rico on September 21, 1998. A few may also remember the International Symposium on Tropical Hydrology in San Juan and the addition of hot water to the Sabana bathrooms. Many more will recall the graduate theses that were completed on a wide variety of topics. These topics included the influence of riparian bamboo (O'Connor 1998), scale-dependent influences of riparian processes (Reed 1998), nitrogen cycling in the Luquillo Experimental Forest (LEF) (Eklund 1997), stream metabolism (Ortiz Zayas 1998), the effects of land use change on stream-channel morphology (Clark 1997), rainfall interception (Wickel 1997) and forest evaporation (Holwerda 1997). In addition to these recent publications, María Rivera of the Institute completed the most extensive bibliography of the Bisley watersheds to date (table 1).

In July of 1998, the Institute actively participated in the aforementioned International Symposium on Tropical Hydrology and Caribbean Water Resources, held in San Juan and sponsored by the American Water Resources Association. In addition to leading field trips to the LEF, Institute collaborators published four complete, peer-reviewed papers at the symposium. These papers included a regional study on flood estimation (Clark 1998), a study on the effects of drought on stream benthos (Covich and others 1998), an assessment of climate change in the Luquillo Mountains (Scatena 1998), and a comparison of water budgets of forested and agriculturally developed watersheds (Larsen and Concepción 1998). In a special session on climate change it was suggested that past climatic records, tree species distributions, and projections of future climate indicate that the LEF has become and will continue to become drier (Scatena 1998). Fortunately, the detailed micro-meteorological field work conducted by Hans Vugts and Michael Molen of the Faculty of Earth Sciences, Vrije Universiteit, Amsterdam, completed in June of this year, will provide invaluable information on the influence of land use change and climate in Puerto Rico and elsewhere.

The year also marked the completion of a study (Wang and Scatena, in press) on the regeneration of mahogany in LEF plantations, carried out at the Taiwan Forestry Research Institute. The 1- year study of natural mahogany regeneration was conducted in three plantations 8 years after they received different levels of hurricane- induced disturbance. Lack of seed rain and competition with pioneer species limited regeneration in the most severely damaged plantations. In the plantations that received moderate and low levels of damage, seed rain and regeneration were abundant and there was an inverse J-shape size distribution of mahoganies. However, even within these plantations, regeneration was inversely related to the density of pioneer species and the amount of coarse woody debris on the forest floor. The study suggests that mahogany is not competitive in areas that are colonized by pioneer species, but regenerates well in areas with moderate canopy disturbance.

Understanding the spatial and temporal scales of disturbance and environmental processes has been a major theme of watershed research at the Institute. Humid tropical forests are dynamic ecosystems that are affected by a wide array of environmental processes (fig. 1). These processes, which can range from episodes of mountain building that occur over millions of years and thousands of square kilometers, to variations in light intensity that occur over milliseconds and millimeters, have been reviewed in a forthcoming paper (Scatena, in press).

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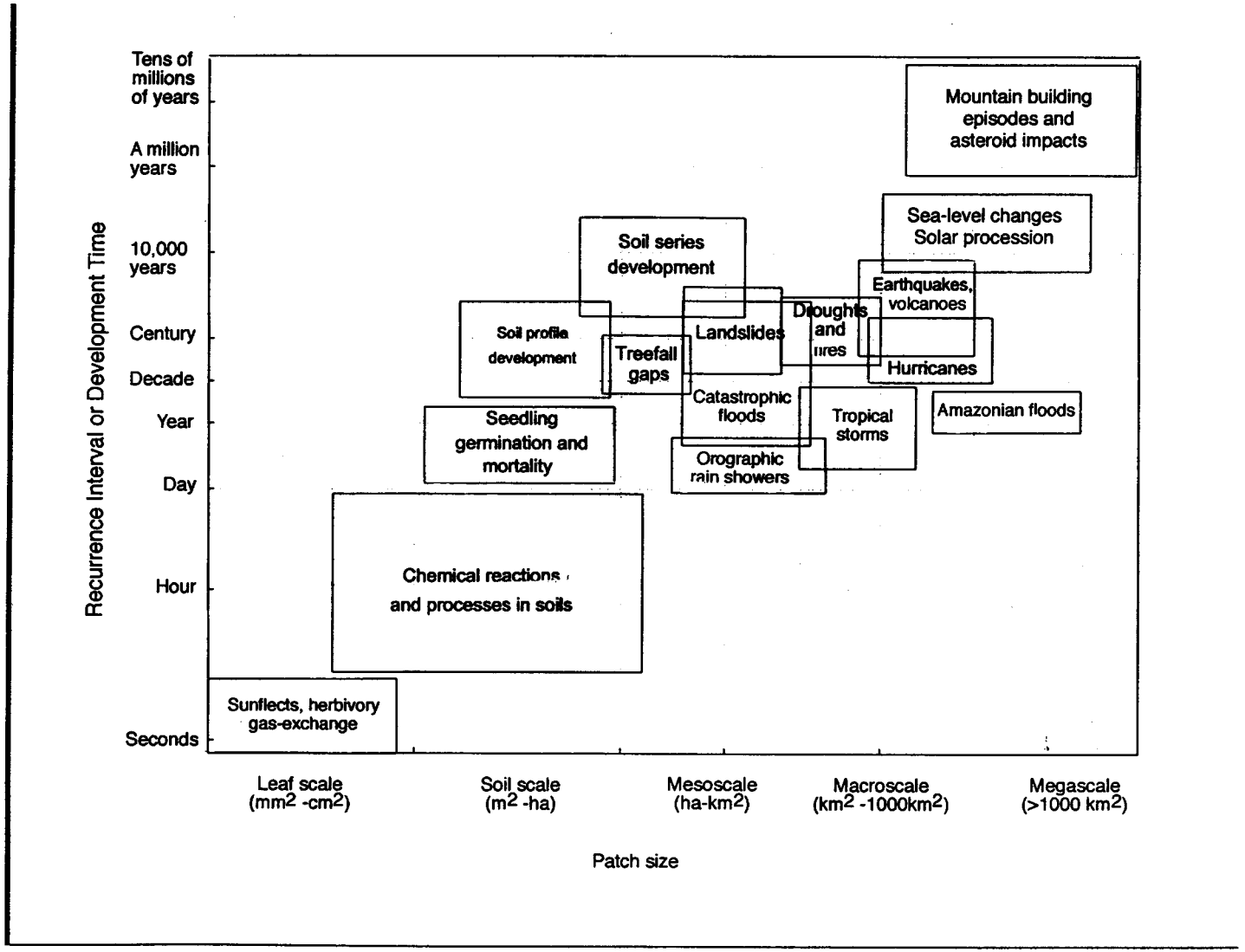

Figure 1. *–The spatial and temporal scales of environmental processes that affect humid neotropical forests; from Scatena [in press].*

THE DEATH OF A LUQUILLO GIANT

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On March 7, 1998, the Luquillo scientific community lost one of its oldest and most durable collaborators, the giant Colorado (*Cyrilla racemiflora*) tree at the El Verde radiation site. The tree apparently fell during the 16.6-inch rainstorm that battered the Sonadora watershed and caused extensive flooding in the Río Espíritu. Although the death of the giant has been attributed to this event, the uprooted stem was not discovered until for several weeks later when R.B. Waide and fellow researchers entered the area during a bird count.

During the past 3 decades, this stately tree has played a prominent role in research in the Luquillo Experimental Forest. Being located 5 m from the radiation center and having branches that overhung the source, the tree was directly irradiated with a 10,000 curie cesium source during the 1965 experiment (Odum and others 1970, Taylor and others 1995). More than half of its leaves were lost during the 3 months of irradiation. In addition, the trunk received severe radiation burns on one side and was scarred for the remainder of its life. Since the mid-1970's these scars have been the most visible evidence of the historic experiment; they have been viewed by hundreds of students and researchers. Despite the tree's defoliation and scarring, within 4 years most of its crown had recovered and the tree continued to grow for another 28 years. During the passage of Hurricane Hugo in 1989 the tree suffered branch and crown damage but remained a canopy dominant until it was finally uprooted in March.

Shortly after the discovery of the uprooted stem, the IITF inventory crew returned to the area to remeasure the trees within 20 m of the radiation plot and record the historic turnover event. During this survey, no *Cyrilla* regeneration was observed in the plot and the space occupied by the giant *Cyrilla* will most likely be replaced with a species common to the lower elevation, lower rainfall forests of the LEF. Could it be that the last lesson this giant is providing to us concerns climate change in the Luquillo Mountains?

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NITROGEN OXIDE EMISSIONS FROM TROPICAL AGRICULTURAL SOILS: AN INTENSIVE 3-YEAR EXPERIMENT IN COSTA RICA

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SUMMARY

Tropical forest soils are the largest known source of nitrous oxide (N_2O). Forest conversion to agriculture and pasture often results in large increases in the emission of N_2O. We measured about 20,000 N_2O fluxes over 3 years, using manual and automated chambers from two soils (clay, loam) on experimental farm plots converted from secondary forest in the Atlantic lowlands of Costa Rica. Here we show results from one of four plots for manual sampling, and one of four intensive periods from automated sampling. Forest soil emissions averaged 1-2 ng-N cm^{-2} h^{-1} N_2O. The process of clearing and burning resulted in a fivefold to tenfold increase in N O emissions. Annual and perennial crops were planted after the clearing. Emissions from unfertilized agricultural soils were generally less than, or equal to, forest soil emissions. Emissions from soils fertilized with nitrogen at recommended levels (>200 kg-N ha^{-1} per year) exceeded forest soil emissions by a factor of 2 to 5. Correcting for emissions of unfertilized soils, approximately 1 percent of the applied fertilizer was released as N_2O. This N_2O release from fertilization is similar to findings at temperate sites and is far lower than from some intensively farmed tropical sites. The global contribution of tropical agriculture to the atmospheric N_2O budget depends strongly on management, and thus may be amenable to control.

EXPERIMENT DESCRIPTION

We measured nitrogen oxide (NO and N_2O) fluxes and soil physical and chemical properties from secondary forest and derived agricultural plots at the La Selva Biological Research Station in Costa Rica (latitude 10° 24' N; longitude 84° 0' W). Four plots, approximately 1 ha each, on two soils [fluventic Eutropept (loam) and andic Dystropept (clay)], of secondary forest were cleared and burned between February 24, 1994 and April 13, 1994. Each 1-ha plot was divided into quadrants, of which two were planted with annual crops, corn followed by taro; the other two with a perennial crop, papaya followed by balsa. One quadrant of each crop type was left unfertilized, while the other was fertilized according to locally recommended practice. Data are shown for one plot on the fluventic Europept. Management practices are detailed in the upper panel of figure 1.

We made manual measurements of NO and N_2O emissions with four and eight chambers, respectively, randomly distributed in each quadrant over 3 years. NO emissions were measured with a portable Scintrex LMA-3 chemiluminescence instrument from dynamic vented chambers. N_2O emissions were determined based on syringe samples taken from static vented chambers and analyzed using ECD gas chromatography. Water-filled pore space was calculated from gravimetric soil moisture content and bulk density. We also used an automated chromatographic system with recirculating chambers for semicontinuous measurement of N_2O flux. Approximately five fluxes per day were measured at each of the eight chambers, distributed two per quadrant. A schematic drawing of our automated measurement approach is displayed in figure 2.

RESULTS AND DISCUSSION

Based upon manual sampling, we collected a 3-year sequence of soil-atmosphere nitrogen

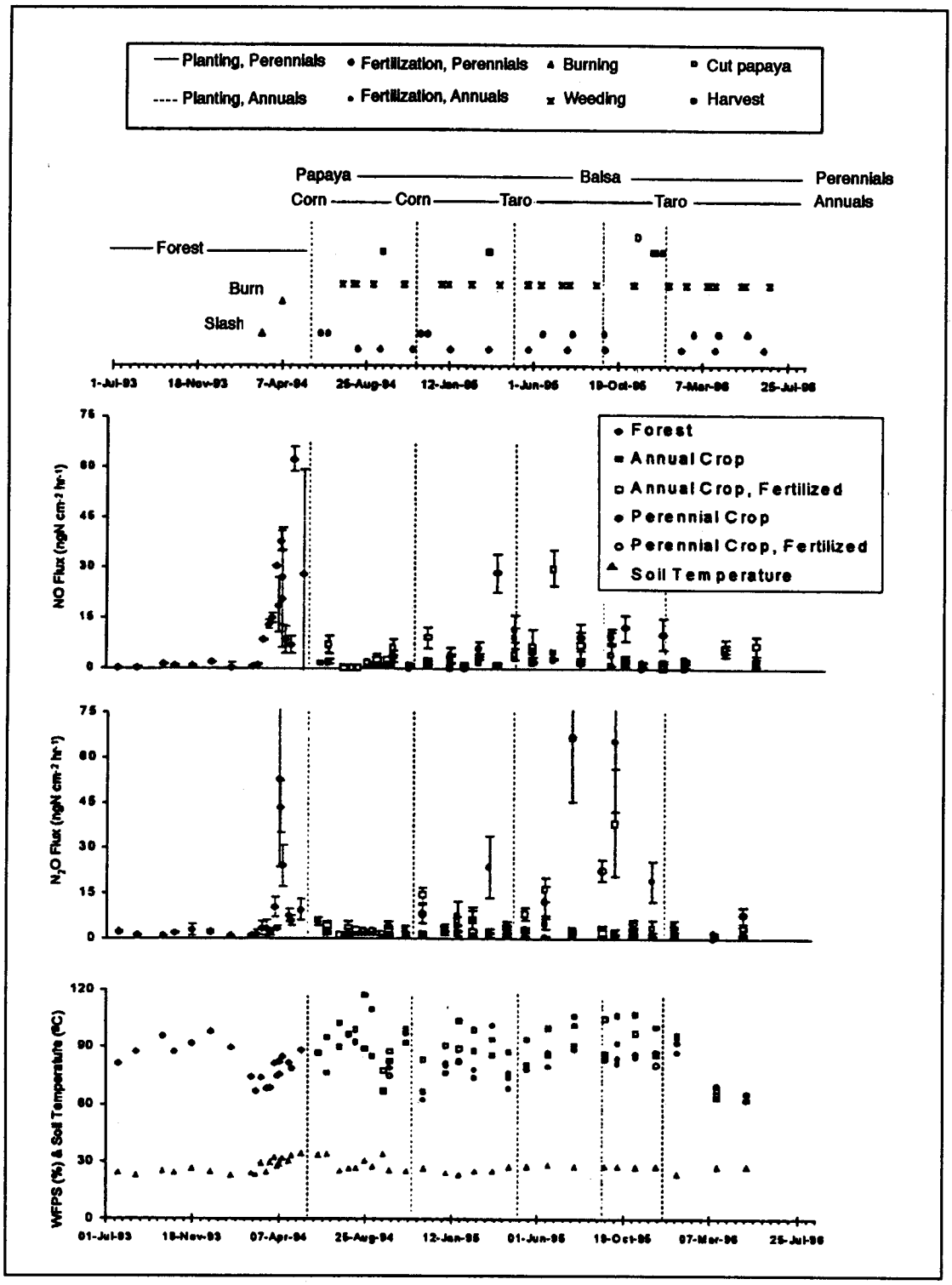
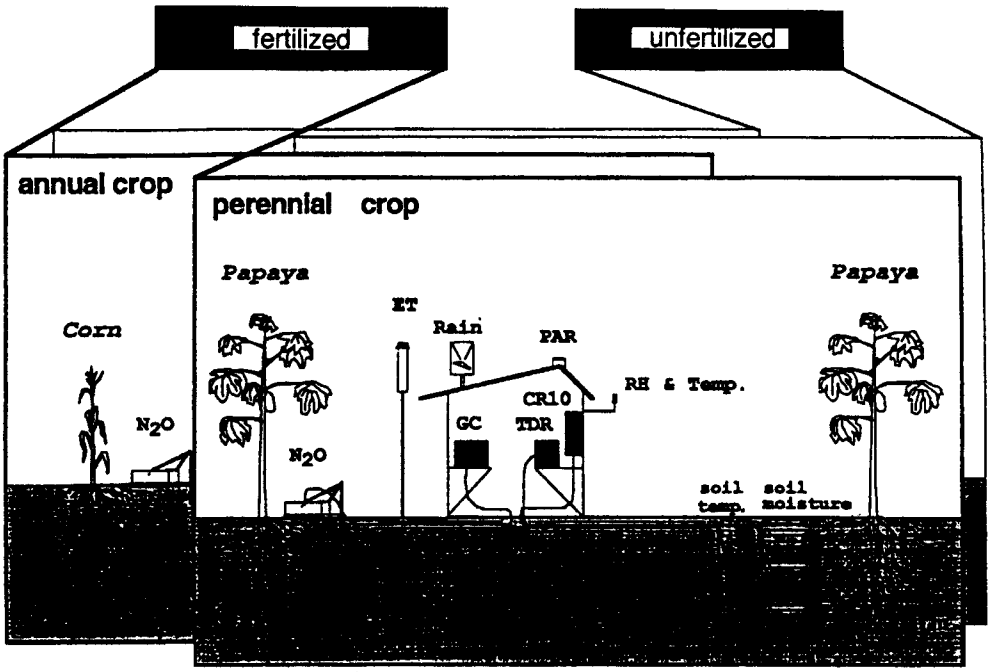


Figure 1. *–Farm management and manual sampling of nitrogen oxides, soil water filled pore space (WFPS) and soil temperature (2 cm depth).*



2. –*Schematic view of the Finca Eléctrica experimental design.*

oxide fluxes, and soil temperature and water-filled pore space (fig. 1). Over 2 years of agriculture, we collected automated data during four cropping periods on two types of soil. A selected period of intensive automated measurements covers a single corn crop (fig. 3).

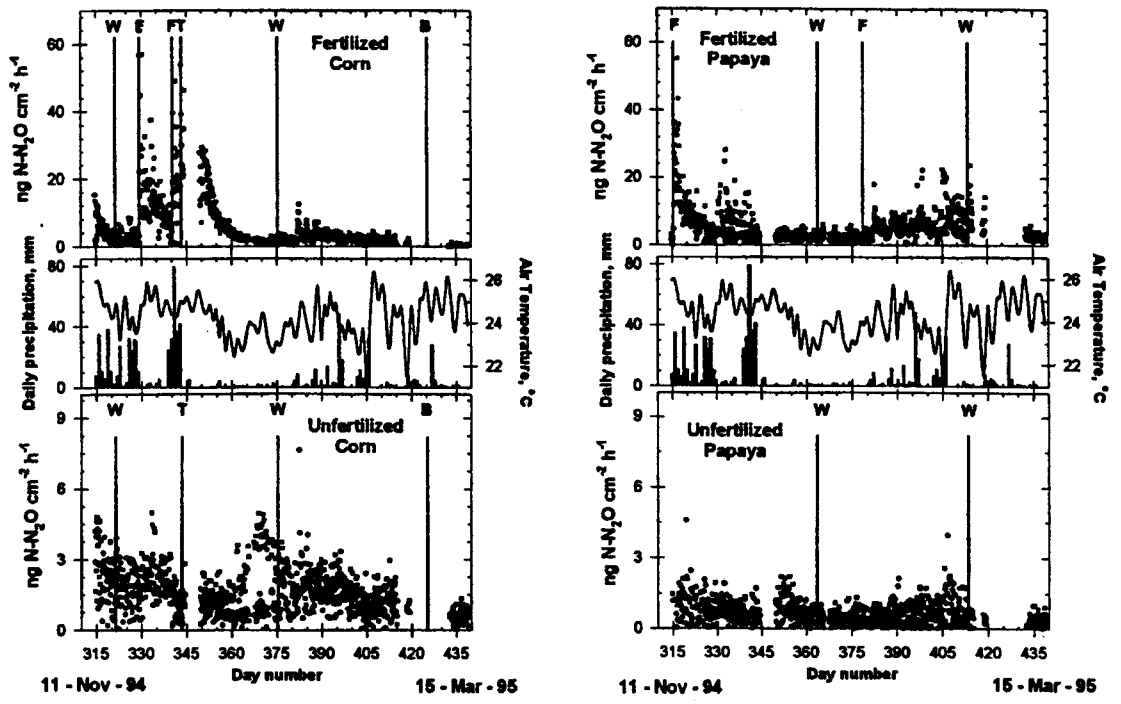
The two main controls on N_2O and NO fluxes were nitrogen availability in the soil and the soil moisture content. High fluxes were associated with high nitrogen availability. Clearing and burning of secondary forest vegetation or nitrogen fertilization increased nitrogen availability. High fluxes of N_2O and NO generally occurred within 2 weeks of fertilization.

The ratio of NO:N_2O was also controlled by nitrogen availability and soil moisture. In general, NO:N_2O ratios of less than 1 were found on fertilized plots when soils were wet. When unfertilized soils were relatively dry during the second taro crop, we found the highest ratio of NO:N_2O (4.8).

A partial nitrogen budget for the plots (table 1) shows that in general the annual crops took up nearly as much or more nitrogen from the field than was applied as fertilizer. In the case of perennial crops that received twice the fertilizer amendment (N-basis), biomass N was less or nearly equal to the amount of fertilizer N applied.

Crop uptake may have limited the nitrogen available to microbes that produce NO and N_2O. Total N oxide emission calculated for the full experimental period as a percentage of applied fertilizer N (corrected for underfertilized contribution) were 5.1 percent in the perennial crops versus 3.4 percent in the annual crops.

Mean N_2O fluxes for manual and automated chambers for the period of the second corn crop in the four quadrants were not significantly different (table 2). However, the temporally sparse manual sampling leaves wide error margins. Temporal variability appears to dominate over



3. *–Nitrous oxide fluxes (N_2O) daily precipitation air temperature from intensive automated sampling period, November 11, 1994 through March 15, 1995. The farm management events are labeled weeding (W), fertilization (F), thinning of corn seedlings (T), and bending of corn stalks before harvest (B).*

spatial variability. Comparison of daily values of N_2O flux for manual and automated sampling again showed similar values (table 3). We did not observe any perceptible diurnal signal in the N_2O flux.

- The current IPCC consensus estimate for the production of N_2O from fertilized agriculture suggests that, globally, approximately 1.25 $\pm$ 1 percent of applied fertilized N is lost as N_2O. Over the full 2-year cropping period, we found 1.8 percent (annual crops) and 4.0 percent (perennial crops) of applied N-fertilizer were lost as N_2O. Losses were greater for perennial than for annual crops, in part because the recommended fertilizer application was not matched to crop needs. N O fluxes observed in this study fall within the wide range of N_2O fluxes from N-fertilized agriculture in the tropics (Matson and others 1996, Veldkamp and Keller 1997, Matson and others 1998, Mosier and Delgado 1998, Veldkamp and others 1998). The challenge for future studies is to explain this wide range of responses among sites.

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Table 1. *–Nitrogen budget calculations based on manual sampling of nitrogen oxide fluxes and biomass harvests.*

Annual crop	Planting date	Harvest date	Fertilizer	Flux NO	Flux N_2O	Biomass N
			kg N ha^{-1}			
Corn - crop 1	27/5/94	22/894				
Unfertilized			0.2	0.5		
Fertilized			57.0	0.4	0.6	
Corn - crop 2	17/1194	18/5/95				
Unfertilized			0.4	1.3	62.0	
Fertilized			121.9	1.2	1.9	70.0
Taro - crop 1	8/5/95	9/1/96				
Unfertilized				1.4	1.2	170.2
Fertilized			72.9	3.9	5.2	226.6
Taro - crop 2	9/6/96		25/7/96			
Unfertilized				1.9	9.4	38.4
Fertilized			72.9	3.4	1.1	82.6
Total cropping period	790 days					
Unfertilized				3.3	4.3	
Fertilized			324.7	8.6	10.2	
Gas emission as percent of applied N *				1.6	1.8	
			Perennial crop			
Papaya	17/6/94	22/1195				
Unfertilized				3.5	1.7	148.6
Fertilized			430.3	8.5	20.9	253.0
Balsa	19/895	25/796				
Unfertilized				2.3	1.3	202.7
Fertilized			198.6	4.9	14.9	212.5
Total cropping period	769 days					
Unfertilized				4.8	2.4	
Fertilized			628.9	11.7	27.3	
Gas emission as percent of applied N *				1.1	4.0	

* Gas emitted as percent of applied N is calculated as $\frac{\text{Flux fertilized - Flux unfertilized}}{\text{N - Fertilizer applied}}$

Table 2. *–Average of manual and automated measurements of nitrogen oxide (N_2O) fluxes from November 11, 1994 through May 15, 1995.*

Crop	Measurement method	
	Automated	Manual
	(n=2)	(n=8)
Corn		
unfertilized	1.58 ± 0.43	4.34 ± 6.51
fertilized	5.45 ± 0.25	6.38 ± 3.02
Papaya		
unfertilized	0.54 ± 0.06	1.27 ± 0.54
fertilized	5.20 ± 2.0	5.49 ± 2.86

Table 3. *–Daily nitrogen oxide fluxes as measured at three points during intensive measurement period.*

Crop	28 Nov 94		4 Jan 95		25 Jan 95	
	Automated	Manual	Automated	Manual	Automated	Manual
Corn						
unfertilized	2.18 ± 0.31	1.61 ± 0.77	2.60 ± 2.30	2.00 ± 1.88	1.60 ± 0.09	7.44 ± 13.14
fertilized	13.78 ± 6.28	14.41 ± 6.81	1.67 ± 0.09	3.05 ± 2.22	3.56 ± 0.26	5.74 ± 4.52
Papaya						
unfertilized	0.83 ± 0.17	0.84 ± 0.51	0.51 ± 0.10	1.83 ± 1.36	0.67 ± 0.39	1.59 ± 1.68
fertilized	7.02 ± 4.96	8.25 ± 7.98	2.98 ± 1.04	3.80 ± 2.35	5.20 ± 1.20	3.98 ± 2.52

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FOREST RESEARCH

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Research Forester

Growth Rings and Phenology in a Rain Forest Tree

The growth phenology of four palo colorado (*Cyrilla racemiflora* L.) trees at 770 m in elevation in the montane forest of the Luquillo Mountains was studied intensively during 1989, and then semiannually through mid-1993, to determine periodicity of changes in xylem structure (Drew 1998). Bud-break and branch elongation in March 1989 were followed by earlywood xylem cell production in the lower stem in April and the onset of flowering in May. Leaf litterfall was greater between April and June, coinciding with peak branch growth and new leaf formation. Latewood xylem was produced in December. The general phenological pattern was synchronized among trees and over study years. Vessel diameter and density were monitored, along with thickness of earlywood and latewood, and the former were converted to vessel lumen area, a measure of xylem conductance capacity. Annual growth rings were formed with periods of earlywood and latewood production coinciding with traditional summer (rainy) and winter (dry) seasons, respectively.

Hurricane defoliation caused by Hugo in September of 1989 was followed by heavy flowering in 1990, a year of reduced branch elongation and annual xylem ring width, and was associated with maximum vessel lumen area, as was flowering in 1989 prior to the hurricane. Hurricane Hugo provided a perturbation that, through its elicited stress response, allowed for the demonstration of the interplay between flowering, branching, structural growth of xylem, and xylem function.

Forest Resources Inventory

The 1990 inventory of Puerto Rico's secondary forests showed an increase in forest land and better stocking with larger and higher quality trees than were evident in the 1980 inventory (Franco and others 1997). In the absence of commercial harvesting on the island, the number of trees in all diameter classes increased, resulting in substantial increases in sawtimber volume. Monitoring of Puerto Rico's secondary forests has shown recovery from past land uses on a regional basis and is providing information on their potential for future management.

Mahogany

Big-leaf mahogany (*Swietenia macrophylla* King) in Belize endured the Mayas for two millennia; Baymen loggers in the 17th, 18th, and 19th centuries; colonial forest administrations; two World Wars and a depression in the 20th century; and hurricanes throughout the entire period (Weaver and Sabido 1997).

Shipwrecked sailors-turned-loggers founded the country, implemented its first forestry rules, and established its dependence on mahogany exports as the main source of income. In the 1920's, the Forest Trust (later the Forest Department) implemented a diversified forestry program. The Department's annual reports provide a rare chronology of activities that include information on mahogany occurrence, silviculture, and research. Belize retains its mahogany resources; however, the country's role as a source of high-quality mahogany timber has been seriously eroded by past overcutting. Low population density, a colonial policy that

discouraged local agriculture and development, and 20th century attempts at mahogany silviculture and management have lessened the impact on the remaining mahogany resources. Recent national concern about the environment should lead to improved forest policy and management.

Hurricane and Forest Impacts

Hurricanes are regular phenomena in the Caribbean Basin during the late summer months. Numerous permanent plots, some established as early as 1943 in Puerto Rico, have shown several stages of recovery from past storms (Weaver 1998a). Among these are a growth stage of about 10 years with its rapid influx of secondary species. A building stage of about 35 years follows, during which competition among surviving trees reduces their numbers but continued growth on residual trees increases total stand biomass. Short-lived secondary species decline, and longer-lived, shade tolerant, primary species dominate. Finally, there is a mature stage, perhaps after 50 years, when maximum biomass is attained. Short-lived secondary species have largely disappeared, their numbers being maintained at low levels through gap dynamics. Stem ingrowth and mortality remain relatively low compared to earlier stages.

In 1983, 16 plots, stratified by topography and elevation, were established throughout the Cinnamon Bay Watershed on St. John, U.S. Virgin Islands (Weaver 1998b). Hurricane Hugo of 1989 passed southwest of the island and provided the first opportunity to assess hurricane damage on a watershed basis. About 10 percent of the watershed's trees died, including the tallest tree on nearly half of the plots. Several tree species showed statistical differences in their resistance to damage, regardless of other factors. Stem damage correlated with environmental factors (e.g., elevation, topography, and aspect) and paralleled biomass losses on the same plots.

Caribbean Basin Activities

Several forestry-related activities initiated in 1992 and 1993 (see Annual Letters 1992-93 and 1993-94) were reported in four countries of the wider Caribbean Basin (Weaver 1997a). In Grenada, the Institute cooperated with the local forest department and the Peace Corps on three separate projects. At Gran Bras Estate, 1.2 ha of mahogany planted in lines with 11-by 2-m spacing averaged 2.6 and 4.1 m after 1.5 and 2.5 years, respectively, with a survival rate of 95 percent (Frederick 1996). At Grand Etang, monitoring continues on permanent demonstration plots in lower montane and montane forests. These plots, set up to determine typical species composition and growth rates, and to serve as reference trees for wildlife investigators less familiar with the local flora, will be remeasured during 1999. At Morne Gazo (or Delice Hill), a nature trail was developed with interpretive signs highlighting local flora and avifauna. Morne Gazo is a unique 10-ha plot of government-owned, semideciduous forest that escaped cultivation.

In Antigua, the Institute, in collaboration with the Island Resources Foundation, worked with the local forest department and an advisory committee to develop a management plan for the Wallings Reservoir area. The plan contains information on property boundaries, vegetation, wildlife habitat, scenic viewpoints, and trails. Picnic sites were cleared near the reservoir and interpretative signs on flora, fauna, and the site's cultural heritage were devised for the trails. In Montserrat, the Institute, again in collaboration with the Island Resources Foundation, worked with the local forest department and the tourist board to clear a nature trail and install interpretative signs. Several multi-use tree species were also planted.

In the Dominican Republic, the Institute worked in conjunction with PRONATURA (a local Non Governmental Organization, NGO) and the Peace Corps to establish plantations. About 15 ha of recently abandoned farmland at three different sites were planted with six species: *Acacia mangium* Willd, *Eucalyptus deglupta* Blume, *Swietenia macrophylla* King, *S. mahagoni* Jacq., *Simaruba glauca* DC., and *Guarea guidonia* (L.) Sleumer. In Venezuela's Tipocoro Forest, the Institute cooperated with the Venezuelan Forest Service (SEFORVEN) to plant 20 ha of degraded secondary forest with *Cordia alliodora* (Ruiz & Pav.) Oken interspersed with occasional trees of *Swietenia macrophylla.*

Historical Reviews

Forestry has a long history in the Caribbean Islands, particularly, in Puerto Rico. The experience gained, implemented in recent years through numerous partnerships, involves research, inventory and monitoring, and resource management, and has been communicated through demonstration and educational activities (Weaver 1997b). Much of this history is documented in the 24 volumes of the Caribbean Forester, in 55 years of annual letters (reports) written by the Institute's staff, in forestry bibliographies, and in numerous issues of scientific journals as well as the proceedings of seminars, meetings, and conferences. Forest managers and researchers, not only in the United States but also in the international arena, have been the recipients of information on tropical forestry through the IITF's library and its program in international cooperation. Research at the Institute has involved species trials and plantations, rehabilitation and enrichment plantings, autecological descriptions of nearly 100 tropical tree species, forest inventories, and ecological studies (Weaver 1996).

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LONG-TERM AVIAN RESEARCH

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Research Wildlife Biologist

LONG-TERM STUDIES IN THE GUÁNICA STATE FOREST

The annual mist netting and banding of Guánica forest birds took place in January 1998, marking the 26th year of this long-term study. Survival and population dynamics of both migratory and resident populations have been analyzed and summarized (Faaborg and others, in press).

Mist-net sampling, coupled with a more intense nest study (Woodworth 1995) of the single-island endemic Puerto Rican Vireo (*Vireo latimeri*), have shown that this species may be in danger of local extirpation due to low reproductive success. Vireo numbers are declining, mainly as a result of avian brood parasitism by the Shiny Cowbird (*Molothrus bonariensis*) (Faaborg and others 1997, Woodworth 1997). However, dispersal of adults between breeding seasons is fairly low (Woodworth and others 1998). Some 7 to 29 percent of adult males and 13 to 25 percent of adult females changed nest territories. The median breeding dispersal distance of 12 birds (7 males, 2 females, and 3 of unknown sex) was 370 m (range: 110 to 560 m). Four fledglings dispersed a median distance of 490 m from their natal nests to breeding territories (range: 300 to 2,030 m). These data suggest a strong nest-site persistence and minimal natal dispersal distances, two common characteristics of insular passerines. The fact that the Puerto Rican Vireo is a fairly long-lived species (many individuals survive at least 9 to 13 years) may increase its chances of survival in the forest even in light of continued brood parasitism (Woodworth and others, in press).

PUERTO RICAN PARROT RESTORATION PROGRAM

In recent years, parrot biologists have expressed concern over an apparent increase in the number of Pearly-eyed Thrashers in and around active parrot breeding areas. Upon request from the U.S. Fish and Wildlife Service, Caribbean National Forest, and the Commonwealth's Department of Natural and Environmental Resources, thrasher monitoring program has begun in one of the main parrot breeding areas. To date, 6 months of data have been collected. Encouragingly, preliminary results (fig. 1) suggest that thrasher numbers are not elevated in the main parrot breeding area. Mean numbers of individual detections are similar to, and sometimes below, those in prime thrasher habitat (colorado forest). The October Palo Hueco mean is outside (i.e., higher than) the Icacos Valley limits, probably because Icacos Valley was harder hit by Hurricane Georges (September 21, 1998) than was the Palo Hueco area. Thrashers were most likely forced out of the Icacos Valley area in search of food, thus accounting for the decline in detections.

STATUS OF THE VOLCANICALLY THREATENED MONTSERRAT ORIOLE

The future of Montserrat's only endemic bird, the Montserrat Oriole (*Icterus oberi*) is largely dependent upon the frequency and intensity of the increasingly occurring stochastic disasters, e.g., hurricanes and volcanic eruptions, that continue to plague the tiny leeward island. In December 1997, after more than 2 years of

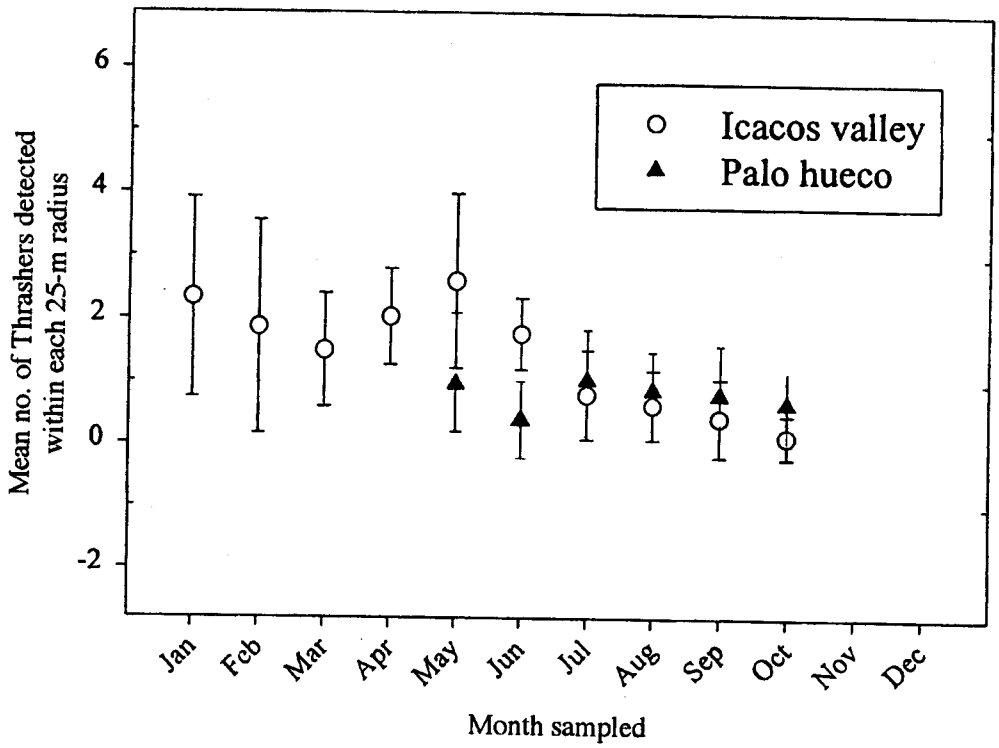

Figure 1. *–Comparison of 30 points sampled at Palo hueco (elevation 500 to 750 meters, x = 625 m) during a 6-month period (180 samples) in 1998, with 30 points sampled in Icacos valley (elevation 610 to 755 meters, x = 657 m) from January to October 1998 (300 samples). Error bars are ± standard deviation.*

periodic eruptions by a volcano on Chance's Peak (the highest mountain on Montserrat), an international effort was undertaken to quantify the oriole and other resident species' current distribution and population sizes. Using distance sampling to model oriole densities, it was estimated that *ca* 4,000 (95 percent "Cis" between 1,500 and 7,800) Montserrat Orioles have survived and are found in the Centre Hills. Nearly 80 percent of them remain in an area of only 8 km^2 and only some 5 km from the active volcano (Arendt and others, in press). Although the oriole's fate greatly depends on future hurricanes and volcanic activities in the region, a contingency captive-rearing program has been designed and put into place by the Jersey Trust (United Kingdom) and other international entities. Should an imminent catastrophe threaten the species, a well-trained international team of experts from different islands and the UK are well equipped and ready to retrieve and remove orioles if circumstances so warrant.

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WILDLIFE RESEARCH

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During the 1998 fiscal year we continued two field projects and published the results of several different studies. These activities are summarized below:

CURRENT FIELD AND COOPERATIVE RESEARCH PROJECTS

Movements, home range, and habitat use by the Puerto Rican Boa in the Luquillo Experimental Forest

We now are in the second year of a study of the endangered Puerto Rican Boa *(Epicrates inornatus)* using surgically implanted radio transmitters which enable us to use radio telemetry to locate and follow snakes in the Luquillo Experimental Forest (LEF). The snakes' locations are mapped and monitored by Global Positioning System (GPS). This enables us to quantify movements and determine the size of a boa's home range. In addition, habitat variables are measured wherever a snake is encountered in a tree, and compared with a nearby randomly selected site. This enables us to quantify the snakes' habitat use and differentiate "snake trees" from other trees in the forest. Information on habitat use may prove useful for reducing potential nestling predation on the endangered Puerto Rican Parrot, as well as for the management and recovery of this endangered boa.

During the 2 years of this study, our field staff have encountered more than 35 boas in the LEF, indicating that the boa is not as rare in the forest as originally thought. Approximately 15 snakes have been studied so far, with some individuals providing 12 to 18 months of data on their movements in the LEF. The radio telemetry work has shown that the snakes are very difficult to see even when we can locate the exact tree or ground site where one is residing. Thus the boa's presumed rareness in the LEF is more an indication of its arboreal habits (i.e., low detectability) than of low population density.

Phenology of some common fruits consumed by the Puerto Rican Parrot

We are now in the second year of a phenology study designed to monitor fruit production of the more common tree and vine species in the Palo Colorado forest of the LEF. The study involves monthly sampling of marked plants along trails at Caimitillo (10 species, 122 individuals) and Palo Hueco-Quebrada Grande (11 species, 144 individuals). The study is designed to characterize variations in fruit production to help us understand the behavior of Puerto Rican Parrots and to identify the most appropriate time to release them. The study was initiated in August 1996 and fruiting plants will be monitored for at least 5 years.

Density of Red-tailed Hawk Territories in the LEF

We supported a cooperative research project conducted by Helen Snyder and Clint Boal to test the hypothesis that Red-tailed Hawk densities had increased in the LEF since the 1970's, possibly as a result of changes in the forest resulting from Hurricane Hugo. Counts of Red-tailed Hawks obtained during parrot censuses had suggested an increase in number over the past 10 years. Yet, in the same period, counts of Sharp-shinned Hawks and Broad-winged Hawks had shown a decline.

These decreases in Sharp-shinned and Broad-winged Hawks were verified in separate censuses conducted by Dr. Carlos Delannoy (University of Puerto Rico, Mayagüez). The Red-tailed Hawk increases needed to be separately verified, primarily because of the potential threat to the endangered Puerto Rican Parrot. The Red-tailed Hawk is believed to be a major threat to adult and juvenile parrots, and any increase in densities would likely be detrimental to the parrot.

In the 1970's, Helen Snyder mapped territories of Red-tailed Hawks in the upper Mamayes drainage (Snyder and others 1987). In 1984, Santana and Temple [n.d.] mapped territories in the same area and found similar densities of territorial Red-tailed Hawks. Snyder and Boal returned to the area in January 1998 and replicated their earlier methods to map territories of the Red-tailed Hawks. Despite changes in canopy structure resulting from Hurricane Hugo, Snyder and Boal found the same number of territories as in the initial study in the 1970's and as later found by Santana and Temple. Moreover, they found that the territory boundaries were in almost identical positions as in the previous studies, despite the likelihood that the individuals were different. Snyder and Boal found that the smallest territory measured 0.6 km^2 and was located on the ridge northeast of El Yunque; the largest territory measured 2.0 km^2 and was located in the Icacos Valley. All studies have indicated that the densities of the Red-tailed Hawks in this part of the LEF are high, but there is no indication that Red-tailed Hawk densities have increased since the 1970's.

Publications

During collaboration with my IITF colleague, Dr. John Parrotta, it became apparent that animals, particularly birds and bats, played a critical role in dispersing seeds onto restoration sites in the tropics. Moreover, it was apparent that the abundance and behavior of animal seed dispersers could affect and even limit such seed dispersal (Parrotta and others 1997). These findings indicated that a review of the animal seed dispersal literature in relation to tropical forest restoration efforts would be a useful management tool. I provided such a review (Wunderle 1997), summarizing the characteristics of animal seed dispersal relevant to tropical forest restoration efforts and discussing their management implications. As summarized in the original abstract:

"In many tropical regions seed dispersal by animals is the predominant form of dissemination of propagules and has the potential to facilitate recolonization of native vegetation on degraded sites. The site traits relevant for attracting seed dispersers include availability of perches, the structural complexity of the vegetation and the presence of food resources, especially fruit, as an attractant. Tree plantations with these traits will be particularly attractive to animal seed dispersers, and therefore, will have higher seed rain than plantations lacking these traits. The efficacy of animal seed dispersal to restoration sites can be limited by the degree of isolation from a seed source, absence of animal seed dispersers in the region and by large seed size. In highly degraded regions, where seed sources may be isolated and animal seed dispersers in the region and by large seed size. In highiy degraded regions, where seed sources may be isolated and animal seed dispersers rare, restoration will require direct seeding or planting. However, even under the best of conditions with a full complement of animal seed dispersers and a nearby seed source, large-seeded species, because of their relative immobility, should be planted if a full return to primary forest is desired."

The results of our shade coffee research continue to appear in the literature. A summary of the conservation value of shade coffee to birds

was a popular article in Jamaica (Wunderle 1998a). In addition, we published a paper summarizing our foraging observations of birds in shade coffee plantations, which indicate that most of the foraging activity occurs in the shade overstory and not in the coffee bushes below (Wunderle and Latta 1998b). During the coffee studies we discovered a previously undescribed hybrid of Magnolia x Yellow-rumped Warbler, which adds to our understanding of the evolutionary relationships of migratory warblers (Latta and others 1998). Finally, we summarized our observations of aquatic birds made on the poorly seldom-studied Turks and Caicos islands during December 1998 (Walsh McGehee and others 1998).

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FOREST REHABILITATION AND RESTORATION RESEARCH

John A. Parrotta
Research Forester

Productivity, Nutrient Cycling, and Succession in Single- and Mixed-species Plantations

Tree growth, biomass productivity, litterfall mass and nutrient content, changes in soil chemical properties, and understory forest succession were evaluated over an 8 1/2 year period in single- and mixed-species (50:50) plantations of two nitrogen- (N_2) fixing species, *Casuarina equisetifolia* and *Leucaena leucocephala*, and a nonfixing species, *Eucalyptus robusta*. At the optimal harvest age for maximum biomass production (4 years), total aboveground biomass ranged from 63 Mg ha^{-1} in the *Eucalyptus* monoculture to 124 Mg ha^{-1} in the *Casuarina/ Leucaena* mixture, and was generally greater in the mixed species than in the single species due to increased productivity of the N-fixing species in the mixed stands. Total litterfall varied from 5.3 to 10.0 Mg ha^{-1} per year among treatments, or between 5.9 percent and 13.2 percent of net primary production. Litterfall production and rates of nutrient return for N, P, K, Ca and Mg were generally highest for *Leucaena*, intermediate for Casuarina, and lowest for eucalyptus. Again, these rates were usually higher in the mixed species than in the monospecific stands, due to differences in biomass productivity, but varied considerably depending on their species composition.

Total system carbon and nutrient pools (in biomass plus soils to 40 cm depth) for N, P, K, Ca, Mg, Mn at 4 years were consistently greater in the plantation treatments than in the unplanted control plots. Relative to the single-species plantations, these system pools were generally larger in the mixed-species plantations for C (-10 to +10 percent), N (+17 to +50 percent), P (-1 to +63 percent), K (-19 to +46 percent), Ca (-10 to +48 percent), Mg (+5 to +57 percent) and Mn (+19 to +86 percent). Whole-tree harvests at 4 years would result in substantial system carbon and nutrient losses, although these estimated losses would not exceed the estimated gains realized during the 4-year period of tree growth at this site. At 7 1/2 years, soil organic matter and effective cation exchange capacity were reduced in all plantation treatments relative to the control. Changes in soil nutrient content from 0 to 7 1/2 years were highly variable and not significantly different among treatments, although stands containing *Leucaena* generally showed higher rates of nitrogen and phosphorus accretion in soils than those containing *Eucalyptus* and/or *Casuarina*.

Natural regeneration of secondary forest tree and shrub species increased over time in all plantation treatments. A total of 24 native or naturalized forest species were recorded in the plantations at 8 1/2 years. Woody species abundance at this age was significantly greater beneath *Casuarina* than beneath either *Eucalyptus* or the *Eucalyptus/Leucaena* mixed stands. Species richness and diversity, however, were greatest beneath stands containing *Eucalyptus* and/or *Leucaena* than in stands with Casuarina.

Development of Floristic Diversity in 10-Year-Old Restoration Forests on a Bauxite- Mined Site in Amazonia

Patterns of plant and animal diversity were studied in a 10-year-old native species reforestation area at a bauxite-mined site at Porto Trombetas, western Pará State, Brazil. Understory and overstory floristic composition and structure, understory light conditions, forest

floor development, and soil properties were evaluated in a total of thirty-eight 78.5 m^2 plots located in the reforestation area at varying distances up to 640 m from the boundary with the surrounding primary forest. Wildlife surveys, focusing primarily on birds and bats, were also conducted to assess the role of seed-dispersing animals in regeneration of woody forest species within the plantations and colonization by primary forest species not included in the original reforestation.

Regeneration density, species richness, and species diversity (Shannon-Wiener index) for woody perennial species, vines, herbs, and grasses were strongly correlated with diversity of planted tree species and structural development parameters, degree of forest floor development, and soil pH. The better-developed, closed-canopy plots (>40 percent crown closure) were characterized by relatively well-developed litter and humus layers, more acidic soils typical of the surrounding primary forests, and a more diverse herb, vine, and woody perennial flora with a greater representation of primary forest species characteristic of late secondary forests. In closed-canopy plots a total of 125 tree, palm, and shrub species were counted (vs 34 in the more open canopy plots), of which 75 species are known to have been introduced by natural means from the surrounding primary forest (vs 11 species in the open-canopy plots).

Among the plantation plots, there was significant colonization by primary forest woody species up to 640 m away from the primary forest edge, although both abundance and diversity of colonizing species declined with increasing distance into the plantations. Smaller-seeded primary forest woody species dispersed by mammals and birds represented a higher proportion of the colonizing species compared with the larger-seeded species. These data are consistent with the results of the wildlife surveys, which indicated that most animal seed dispersal is provided by bats, that the most common frugivorous bat and bird species in the plantations feed on small-seeded plant species, and that birds and mammals that typically disperse larger-seeded tree species (such as toucans, trogons, tapirs, deer, and primates) are still rare in the reforestation area. These results suggest that while the reforestation program has been successful in creating a favorable environment for regeneration of native primary forest species, further management interventions, such as enrichment plantings, may be required to accelerate regeneration of large-seeded primary forest species.

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ACCOMPLISHMENTS DURING THE PAST YEAR

Sheila Ward
Ecologist

The manuscript "A Study of Twenty Provenances of *Swietenia spp.* in Differing Environmental Conditions in Puerto Rico and the U.S. Virgin Islands," by Sheila Ward and Ariel E. Lugo, was submitted for inclusion in the mahogany book. This paper examined genetic and environmental influences on growth, survivorship, and shootborer attack in a mahogany provenance trial that began in Puerto Rico in the 1960's. The paper aspects of this study were presented at the AIBS meeting in Baltimore, MD in August 1998.

Another paper, "Efectos del Ambiente y la Genética en la Variación del Crecimiento, Ataque del Barrenador de la Yema, Sobrevivencia, y Tamaño en 20 Procedencias de Caoba en Puerto Rico," by Sheila Ward and Ariel E. Lugo, was presented at the first International Union of Forestry Research Organization (IUFRO) Latin American Forestry Congress in Valdivia, Chile in November 1998 and included in the congress proceedings. This paper emphasized the practical implications of relative amounts of environmental and genetic variation for site selection, silviculture, and artificial selection of mahogany for tree improvement. Plans are also in the works to use the IITF mahogany provenance study to assess genetic diversity via molecular markers, as well as the genetic components of wood quality.

Last summer, I worked with two students, Rene Aguiñaga and Darlene Waterman, as part of the Forest Service initiative to increase workforce diversity. Rene and Darlene assisted me with a project to relate stand dynamics in long-term plots to land use history. Due to delays caused by Hurricane Georges, the Global Positioning System (GPS) assessment required for this project is still being carried out by the silviculture team technicians. In November, I gave a 2-day workshop on statistics for Institute technicians. Janet Rivera, Frank Wadsworth, and I have also initiated a key word index for the research files.

In November I was appointed the coordinator for three mahogany projects receiving funding from the U.S. Department of Agriculture Foreign Agricultural Service. One project is based at IITF; it concerns the development of long-term plots containing mahogany throughout the species' ranges. The second is being done in conjunction with Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Costa Rica; it concerns the genetic conservation of *Cedrela odorata*. The third, being done with ICRAF/INIFAP in Mexico, concerns the domestication of mahogany. I am the Principal Investigator on the IITF project (under a Cooperative Agreement with the Puerto Rico Conservation Foundation) to study plant development and implementation by Mr. Julio Figueroa), and an involved in the other two studies as the cooperating U.S. scientist. We hope to use these projects to develop a network for research and information exchange on mahogany.

RÍO SABANA WATER QUALITY PROJECT SUMMARY

Alexis Dinno
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Master's internship work sponsored by the IITF in the summer of 1998 pooled existing knowledge of the Río Sabana, and assessed water quality to provide a framework for resource planning and water quality management. The report documents water quality measurements made during the relatively low-flow period of mid-June to mid-August 1998. In addition, existing hydrological and water quality data were examined and developed into preliminary water and phosphorus budgets. These models and "snapshots" of water quality suggest relationships between current land use and water quality.

Temperature, pH, conductivity, and dissolved oxygen were sampled daily at seven points on the Río Sabana during the months of June, July, and August 1998. Measurements were taken using an Aqua-Check Water Analyzer model A51601, by O•I• Analytical, and the pH and DO sensors were frequently calibrated. The probe of the analyzer was consistently immersed at roughly a third of the river's depth, at reaches with steady downstream flow (i.e. not cross-current), that were relatively nonturbulent. Sample locations avoided areas of the stream congested with litter and other organic detritus, as well as mats of aquatic vegetation. All measurements were made between 6:00 a.m. and 3:00 p.m. These times correspond to the period of lowest DO and temperature readings (at dawn), and the point of peak temperature (conductivity varies inversely to temperature). Mean values for each sample site are recorded in table 1.

The following observations are apparent from existing data:

- The inverse relationship between conductivity and water stage suggests that periods of low flow are likely to see increased concentration of salts.

- Conductivity is inversely related to temperature. However, the variation in conductivity due to temperature is not as great as the variation in conductivity due to other factors, such as sewage or tidal inputs, or water stage.

- Conductivity (and therefore total ions) increases significantly with the addition of sewage effluent.

- There exists a diurnal fluctuation of DO, temperature, and conductivity. DO appears to correlate closely with daylight, implying phytotic activity.

- Temperature varies inversely with distance to the ocean.

- Dissolved Oxygen occasionally drops below EPA minimum levels of 5 milligrams per liter as far as 1 kilometer from the ocean.

The data support several conclusions relative to concerns about water quality on the more urbanized and frequently used segments of the river:

- The water quality of the river often fails to meet national environmental standards. Figure 1 illustrates the decline in DO

Table 1. *–Water quality and physical characteristics of sample sites.*

Name	Discharge area	Distance from mouth	Elevation	Temperature	Mean Metrics (n = 60)		Dissolved oxygen	Geologic unit
	ha	km	m	°C	pH	µS	ppm	
Oldfield	653	8.68	110	25.02	6.98	84.26	8.41	Qa
FSRS	788	8.44	100	25.08	7.11	96.50	8.49	Qa
USGS	1014	7.66	90	25.33	7.33	117.11	8.49	Qa
Ballfield	1284	4.94	20	25.99	7.58	127.24	8.56	Qa
Urbanization	1549	2.14	3	27.06	7.27	142.43	8.10	Qa
Route 3	1824	1.00	2	27.50	7.18	209.81	7.46	Qa
Estuary	3510	0.06	1	28.07	7.28	2107.82	6.38	Qb

Qa: Floodplain Alluvium (Holocene)-Chiefly unconsolidated, poorly sorted to moderately well sorted, commonly thick-bedded sand, gravel, and clay. In narrow stream valleys in and near mountainous areas; composed of boulders as large as 3 meters across and subordinate sand and pebbles. Forms piedmont plains in the valley of Río Fajardo quadrangle. As much as 35 meters thick.

Qb: Beach Deposits (Holocene)-Undivided, coarse- to fine-grained, moderately well to well-sorted sand, locally containing volcanic pebbles. Composed chiefly of calcium carbonate. South of Las Croabas composed of volcanic rock fragments ranging from boulders to sand in size, or calcium carbonate sand, or a mixture of these. Thickness ranges from 2 to 6 meters.

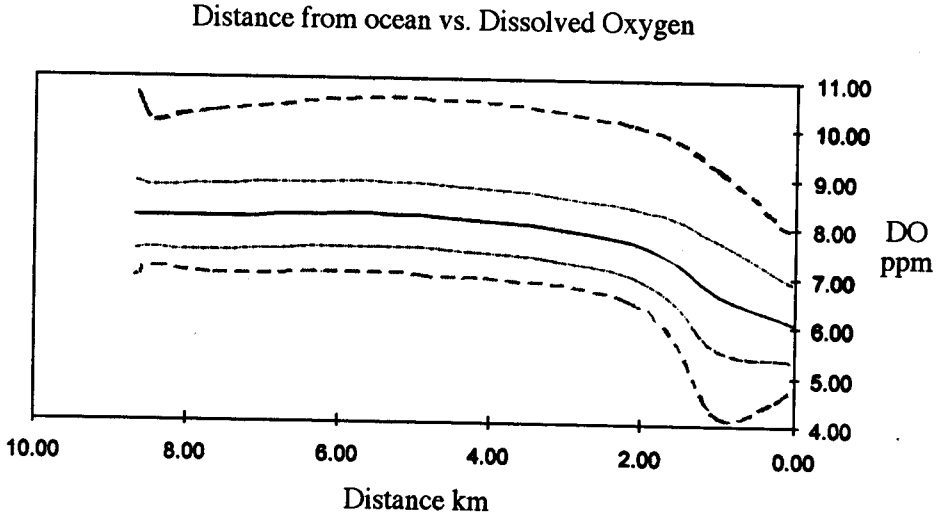

Figure 1. *–Distance from ocean vs. Dissolved Oxygen.*

between the sewage discharge and the river's mouth. The dashed lines represent the highest and lowest measured values, and the dash-dotted lines represent a single standard deviation above and below the mean (solid) line.

- Losses of habitat and of certain species within the river have been noted by local people who fish, net, and spear there, particularly in the first kilometer of the river (estuary).

- Health problems have been associated with water contact sports in the lower river.

COMPARISON OF STORM DAMAGE CAUSED BY HURRICANE GEORGES TO 24 SPECIES OF TREES

John K. Francis
Research Forester

Everyone residing in Puerto Rico on September 21, 1998 was affected in some way by Hurricane Georges. One of the most traumatic experiences during the storm was to witness the devastation of hundreds of thousands of urban trees. Not only will it take a number of years for new trees to grow and survivors to heal, but the government has had to spend huge sums for cleanup. Many have asked, "Would it not be better to plant species resistant to damage than to replant species that are doomed to be broken up in the next hurricane?" But which trees are resistant?

Most observations in the past have been only semiquantitative or confined to forest trees (Bates 1929, Lugo and others 1983, Wadsworth and Englerth 1959, Walker 1991). It is well known that tall trees are subject to greater drag (force of wind) than low trees. This suggests reducing height by pruning, or planting only low-growing species. Restricted rooting depth by compaction or water logging and restricted rooting on the sides by structures are well-known causes of tipping. Much of the tipping losses can be avoided by site analysis and careful planning before planting.

The question still remains, "Given equal environments, which species sustain greater damage and why?" In partial answer to the first part of the question, I offer the comparison given in table 1 for 24 species growing in proximity to each other and supposedly subjected to the same stresses. Please note that damage is only half of the story. *Spathodea campanulata,* for example, endured greater damage than any other species but it has apparently suffered only minimal mortality and the species has been able to rebuild its damaged crowns very quickly.

Table 1. *–Percent defoliation (Def.), crown loss (CL), and snap plus throw (S+T) of samples of 24 species of trees growing in or near the UPR Botanical Garden, Río Piedras, Puerto Rico as caused by Hurricane Georges.*

Species	Mean					
	D.b.h.	Height	Def.	CL	S+T	Number
			Percent			
1. *Swietenia mahagoni*	28.5	10.7	70.7	22.7	0	50
2. *Hymenaea courbaril*	38.0	17.3	89.6	40.6	2	50
3. *Calophyllum calaba*	34.8	15.2	77.3	41.0	6	50
4. *Pinus caribaea*	37.2	17.7	51.8	41.8	6	50
5. *Melaleuca quinquinervia*	26.6	8.8	52.4	43.2	10	39
6. *Dalonix regia*	36.3	10.9	70.2	43.8	2	49
7. *Lagerstromia speciosa*	48.5	11.5	77.0	44.0	2	50
8. *Terminalia catappa*	46.6	14.9	86.6	46.5	2	41

Table 1. *–(continued.)*

Species	Mean					
	D.b.h.	Height	Def.	CL	S+T	Number
9. *Tabebuia heterophylla*	23.7	10.3	73.2	47.4	4	50
10. *Cassia javanica*	43.9	10.5	87.7	47.4	10	31
11. *Casuarina equisetifolia*	54.0	20.6	62.0	49.8	4	50
12. *Pterocarpus macrocarpus*	76.4	20.7	94.5	50.7	6	50
13. *Bucida buceras*	33.6	13.4	80.7	50.7	2	50
14. *Enterolobium cyclocarpum*	113.6	17.5	87.6	50.8	9	33
15. *Mangifera indica*	64.5	12.6	66.8	51.7	2	50
16. *Clitoria fairchieldiana*	26.0	4.7	62.0	51.9	38	32
17. *Ficus benjamina*	68.6	9.1	56.5	52.5	30	50
18. *Schefflera morototoni*	16.4	10.1	91.3	56.4	30	50
19. *Albizia procera*	34.2	18.8	97.3	59.7	22	50
20. *Cecropia sherberiana*	24.5	12.7	94.5	60.6	24	34
21. *Sterculia apetala*	33.1	12.9	94.9	63.7	21	34
22. *Peltophorum pterocarpum*	38.6	15.4	89.5	65.6	12	33
23. *Senna siamea*	30.3	16.2	94.9	66.5	10	50
24. *Spathodea campanulata*	41.6	16.9	98.1	81.1	34	50

Notes on procedure: D.b.h. measured by diameter tape; height estimated prestorm; defoliation estimated from visualized normal leaf complement for that tree; crown loss is percentage of crown volume (space occupied by the envelope of limbs and twigs) lost based on a visualization of former crown volume; snap + throw is explain -not clear.

The answer to the question of why some species suffered more damage than others is complicated. Obviously, greater strength of wood in roots, trunks, and branches imparts resistance to tipping (because of root tearing), trunk snapping, and limb breakage. However, much breakage has been observed in some species such as *Casuarina equisetifolia* and *Clusia rosea* that possess great wood strength. The foliage of a tree is like the sail of a ship. In heavy storms, sailors strike the sail in order to save the mast and the ship. In like manner, a tree that easily defoliates can avoid most of the drag forces of the wind. Another factor is flexibility. Trunks and limbs that flex away from the wind cause a large reduction in cross-sectional area exposed to the wind, and thus reduce drag. As yet, the relative importance of these processes is unknown. To this end, I am collecting measurements of wood density (an indicator of wood strength), leaf retention strength, and resistance of branches to flexing of the same 24 species that were evaluated after the storm. I will then correlate these measurements with the damage data.

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STATE AND PRIVATE FORESTRY BRIEFING PAPER

Robin Morgan
State and Private Forestry

A Year in Review: Highlights from Fiscal Year 1998

Urban and Community Forestry

- Municipalities in Puerto Rico number 78, and 36 of these participated in some form of urban forestry activity, during FY1998. A total of 1,819 projects have been identified as contributing to forest health or function.

- Major damage was sustained by urban forests as a result of Hurricane Georges. A team from IITF worked with a team from the University of Florida to do some preliminary damage assessments at points around the island. The data are being compiled and will soon undergo statistical analysis.

Forest Stewardship Programs

- Three new Forest Stewardship Management plans were written this year, affecting 2,531 acres. The total number of these plans in Puerto Rico is now 20.

- The DNR Nursery at Cambalache was remodeled and production greatly increased to provide the trees necessary to support the agency's plan to plant 3.8 million trees in PR by the year 2000.

Forest Legacy Program

- The Secretary of Agriculture, U.S. Department of Agriculture, approved the Puerto Rico Forest Legacy Assessment of Need. Properties within designated Forest Legacy Areas that are in danger of conversion to nonforested land use are eligible for inclusion in the program. Conservation easements or outright fee simple purchases of the land are projects eligible for federal financial assistance.

Forest Health Management

- The Pink Hibiscus Mealy Bug has been positively identified in several places here in Puerto Rico. The extent of damage locally has yet to be determined, but major damage to ornamental and fruit trees occurred in St. Thomas and St. Croix, as well as other locations down-island.

Economic Action Programs

- Two major efforts were initiated to provide technical assistance and determine ways to create jobs and income utilizing natural resources. The results from these two efforts will be used to guide future funding assistance through Economic Action Programs, especially the Rural Development and Economic Recovery programs.

- A Forest Resource Specialist from Region 6 participated in a 2- week field visit to evaluate opportunities for jobs and income utilizing forest products in Puerto Rico and the USVI's.

- An ecotourism and business management professor from the College of Micronesia provided input into the creation of Puerto Rico as a destination location for Sea-Kayak Ecotourism.

Cooperative Fire Training

- Over 200 structural firefighters received training for the first time in wildfire conditions, including wildfire behavior; fire weather; and wildfire tools, equipment, and techniques.

Program	Recipient	Total award
Urban and Community Forest	PR DNER	$100,000
Urban and Community Forest	St Croix Env	10,000
Urban and Community Forest	VI Ag	100,000
Urban and Community Forest	U of FL	25,000
Urban and Community Forest	Greener PR	5,000
Urban and Community Forest	ISA Southern Ch	6,000
Urban and Community Forest	PR Science T As	8,000
Urban and Community Forest	Conservation Fndth	5,000
Forest Stewardship Program	PR DNER	75,899
Forest Stewardship Program	VI Ag	30,812
Stewardship Incentive Program	PR DNER	3,371
Forest Legacy	PR DNER	23,717
Forest Health Management	VI CES	15,908
Forest Health Management	UPR CES	15,908
Cooperative Fire	VI Fire	43,900
Cooperative Fire	PR Fire	67,564
Economic Action Programs	PR DNER	69,237
Economic Action Programs	Tabaiba	15,000
Economic Action Programs	VI RC&D	11,000

Appendix
Apéndice

A. Recent Publications of the International Institute of Tropical Forestry
(Numbers indicate reprints available for distribution).
Publicaciones recientes del Instituto Internacional de Dasonomía Tropical Forestal
(Números indican disponibilidad de separatas para distribución).

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