United States
Department of
Agriculture

Forest Service

Southern Forest Experiment Station

New Orleans,
Louisiana

Research Paper
SO-202
February 1984

Structure and Composition of Moist Coastal Forests in Dorado, Puerto Rico

Julio C. Figueroa, Luis Totti, Ariel E. Lugo, and Roy O. Woodbury

An Institute of Tropical Forestry Publication

SUMMARY

A survey of forest structure, species composition, and change in forest areas over a 44 year period was conducted on 39.5 ha of forest lands in Dorado, Puerto Rico, where H. A. Gleason and M. T. Cook had studied forest conditions in 1926. A total of 51 tree species were found in the study area. Six forest types were identified on white sands and poorly drained clay soil. The most complex forest was the 19.7 m tall old secondary forest with 32 tree species, 1,880 stems/ha, a basal area of 41.6 m^2/ha, and a complexity index of 493. Abandoned palm groves (5 tree species), a disturbed open forest with 9 tree species and dominated by *Hymenaea courbaril*, a Clusia-Zyzygium forest (11 tree species), and a young secondary forest with 19 tree species (also dominated by *H. courbaril*) were all undergoing succession towards the old secondary forest. This forest is considered to be the climax on white sands. In flooded soils, *Pterocarpus officinalis* and six other tree species form a climax swamp forest that has not changed in composition for the last 54 years. In terms of forest area, however, Pterocarpus and old secondary forests have been reduced by 30 percent and 79 percent, respectively. The primary cause of the changes in forest areas has been human intervention: direct, through cutting, and indirect, through changes in drainage conditions. The study forests, however, support four endangered plant species and an endangered bird species. Their social, scientific, and intrinsic values are significant.

Cover photo: *Isolated Pterocarpus forest trees in the Dorado golf course.*

Structure and Composition of Moist Coastal Forests in Dorado, Puerto Rico

Julio C. Figueroa, Luis Totti, Ariel E. Lugo, and Roy O. Woodbury

INTRODUCTION

In 1926, H. A. Gleason and M. T. Cook (1927) studied the moist coastal forests on property belonging to a Ms. Livingston, located just west of Dorado, Puerto Rico. They described in some detail what they termed "the forest of the lowland white sands," dominated by *Mammea americana* and *Calophyllum brasiliense.* These trees were up to 20 m in height and about a meter in diameter. Gleason and Cook reported that, due to clearing for agriculture, forests such as these had all but disappeared from the north coast of Puerto Rico. The estate of Ms. Livingston contained what they considered the only undisturbed remnant of this type. Fifty-four years later, in 1980, the U.S. Forest Service was asked by the new owners of this property to evaluate the condition of the forests in a 39.5 ha section (known as "Parcel F") that encompasses the forested areas visited by Gleason and Cook in 1926. Because of the importance of this forest type to the general understanding of forests in Puerto Rico's north coast, the U.S. Forest Service's Institute of Tropical Forestry agreed to conduct the study. An analysis that paralleled that of Gleason and Cook's was undertaken. Additional observations were made to describe, in quantitative terms, changes that have occurred since that time. This paper describes the results of the recent study and compares them with the observations made by Gleason and Cook.

SITE DESCRIPTION

The study site lies within the subtropical moist forest life zone (Ewel and Whitmore 1973), northwest of the town of Dorado on the north coast of Puerto Rico (fig. 1). Mean annual temperature is 25.4°C, and total annual rainfall is 1,688 mm (Álvarez 1982). Elevation ranges from 0 to 10 m above sea level. Deposited sands of both tuffaceous and calcareous origin (Roberts 1942), with varying drainage capacities, comprise the soils within the site (fig. 2):

- Cataño sand (well-drained phase). This soil is found in long narrow strips (some wider than 300 m) along the coastline. It is characterized by a 15 to 20 cm thick dark friable sandy surface layer underlain by a lighter colored calcareous layer. In the past, coconut plantations were grown on these soils.
- Cataño sand (poorly-drained phase). This soil is similar to the one just described, but because of its location (at low elevations close to lagoons or the ocean) the water table is within 45 cm of the surface and drainage is poor.

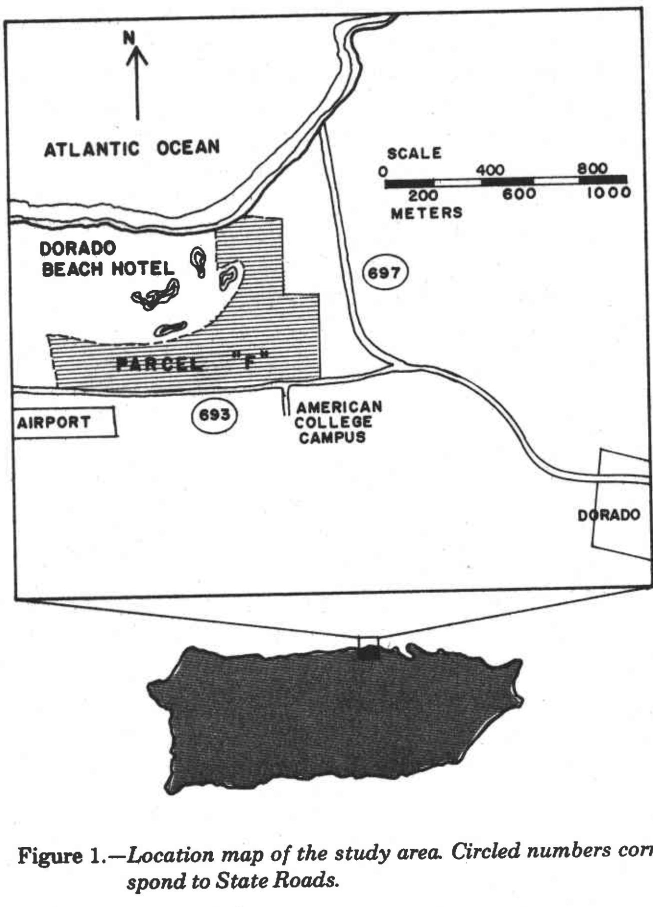

Figure 1.—*Location map of the study area. Circled numbers correspond to State Roads.*

Figueroa, Totti, and Lugo; Institute of Tropical Forestry, Southern Forest Experiment Station, USDA Forest Service, P.O. Box AQ, Rio Piedras, PR 00928. Woodbury, Department of Natural Resources, P.O. Box 5887, San Juan, Puerto Rico 00906.

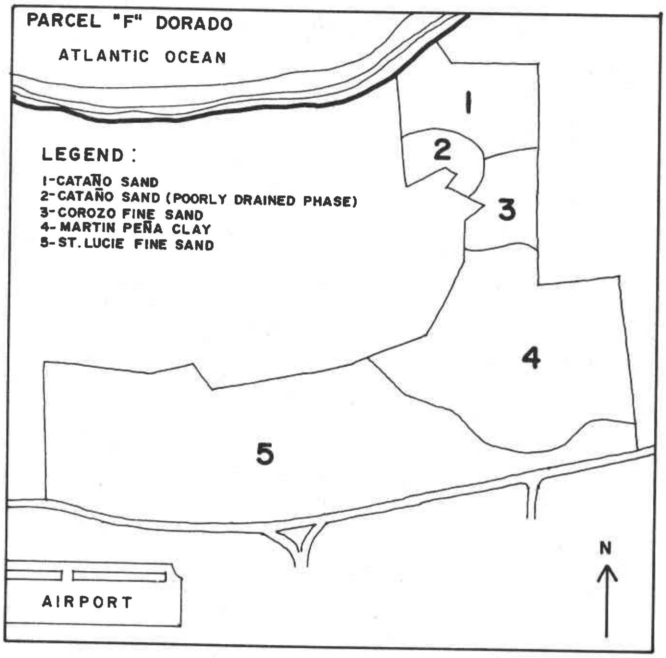

Figure 2.—*Soils map of the study area (Roberts 1942).*

- Corozo fine sand. This soil is landward from the previous two and is one of the most infertile soils of the coastal plains. It is well drained but extremely acid.
- Martin Peña clay. This soil is characterized by a dark plastic acid clay surface layer 20 to 25 cm thick overlying a layer of lighter colored, more compact plastic clay that gradually changes to substratum at a depth of 75 to 100 cm. This substratum is similar to the subsoil but less heavy and more compact. Martin Peña clays occupy low areas intermediate in location between the soils of the coastal lowlands and river flood plains. The water table is high, keeping the compact subsoil wet for considerable time periods throughout the year. As a consequence, there is practically no natural surface drainage, and internal drainage is restricted.
- St. Lucie sand. This soil is readily recognized by its nearly white surface color and dune-like relief. Its strongly acid, fine-sand surface layer changes very little in color, texture, structure, or consistency for depths of up to 4 m. In some places, though at considerable depths, this soil is underlain with material very similar to that found under Corozo fine sand. Though faintly developed in some areas, an organic hardpan layer is present throughout.

METHODS

The study consisted of three phases. First, a preliminary survey of species and tree communities was performed throughout the property to gain familiarization with the vegetation and the site. Next, 21, 10 × 10 m plots were placed randomly throughout the property. All individuals with a diameter at breast height (dbh) greater than 2.5 cm were indentified in each plot. Measurements of dbh and height were taken and the crown position noted. With these data, stand basal area, tree density, species importance values, and complexity index were calculated. The complexity index was calculated as the product of basal area, stand density, tree height (average of three tallest trees), and number of species (in 0.1 ha), divided by 1000 (Holdridge 1967). All species nomenclature is in accordance with that of Liogier and Martorell (1982). Aerial photographs obtained from the Puerto Rico Highway Authority were used to delineate forest types and study changes in coverage over 44 years, using photos for 1937, 1950, and 1981.

Table 1.—*Structure of six forest types recognized on the moist coastal white sands of Dorado, Puerto Rico (Parcel "F")*

Forest type	Study plots†	Number of species	Tree density∞	Basal area	Height‡	Complexity* index
			no/ha	*m²/ha*	*m*	
Abandoned palm grove	2	5	1600	32.6	12.3	32
Disturbed and open	2	9	1000	21.8	17	33
Pterocarpus forest¶	...	7	1680	44.6	19.0	100
Clusia-Syzygium	6	11	3200 (567)§	25.6 (7.0)	20.7	187
Young secondary	6	19	1833 (174)	29.0 (7.1)	19.3	194
Old secondary	5	32	1880 (299)	41.6 (5.3)	19.7	493

†All plots were 100 m² and all trees with diameter at breast height > 2.5 cm were considered.
∞Clumps were counted as 1 individual.
‡Average of tallest three trees.
*Complexity index = (no. of tree species) (tree density) (basal area) (height) (10^{-5}).
¶From Alvarez 1982.
§Standard error of mean is in parentheses.

Table 2.—*Relative values of tree density and basal area for the three most important species in each forest type of a coastal moist forest in Dorado, Puerto Rico*

Species	Tree density†	Basal area	Importance value‡
	percent		
Old secondary forest			
Manilkara bidentata	21	42	32
Lonchocarpus latifolius	6	11	9
Pisonia subcordata	8	4	6
Sub-total	35	57	47
29 other species	65	43	53
Young secondary forest			
Hymenaea courbaril	19	48	34
Bucida buceras	11	21	
Quararibaea turbinata	12	3	8
Sub-total	32	72	53
16 other species	68	28	47
Clusia-Syzygium forest			
Clusia rosea	28	81	55
Syzygium jambos	54	12	33
Ocotea leucoxylon	6	2	4
Sub-total	88	95	92
8 other species	12	5	8
Pterocarpus forest			
Pterocarpus officinalis	74	48	61
Bucida buceras	14	43	29
Calophyllum brasiliense	10	5	8
Sub-total	98	96	98
4 other species	2	4	2
Disturbed open forest			
Hymenaea courbaril	13	55	34
Syzygium jambos	42	10	26
Ocotea leucoxylon	21	4	13
Sub-total	76	69	73
6 other species	24	31	27
Abandoned palm grove			
Cocos nucifera	22	84	53
Lonchocarpus latifolius	42	10	26
Amphitecna latifolia	25	2	14
Sub-totals	89	96	93
2 other species	11	4	7

†Relative values of density and basal area expressed as percentages of the totals for each type.
‡Importance value = relative density + relative basal area divided by 2.
*From Alvarez 1982.

RESULTS

Six forest types were recognized in the study area in 1981 (table 1, fig. 3c). The groupings were selected for convenience and reflect stands that can be easily identified by their physiognomy as dictated by previous land use. However, we will refer to the traditional forest nomenclature in several locations in the text where such distinction is necessary. The structure and species composition of the six forest types mapped will be discussed according to their vegetation complexity, beginning with the simplest forest. Table 2 lists the dominant species on each forest type and their importance value.

Abandoned Palm Grove

This grove was once a commercial plantation and is now invaded by successional species such as *Lonchocarpus latifolius, Amphitecna latifolia,* and *Cordia laevigata.* Five tree species were found on the two plots established in this forest type. The grove was planted on Cataño and Corozo sands and had the shortest canopy height but a relatively large basal area. This area is notable because it supports the largest breeding colony of the endangered white-crowned pigeon (*Columba leucocephala*) on the north coast of Puerto Rico (Wiley 1979).

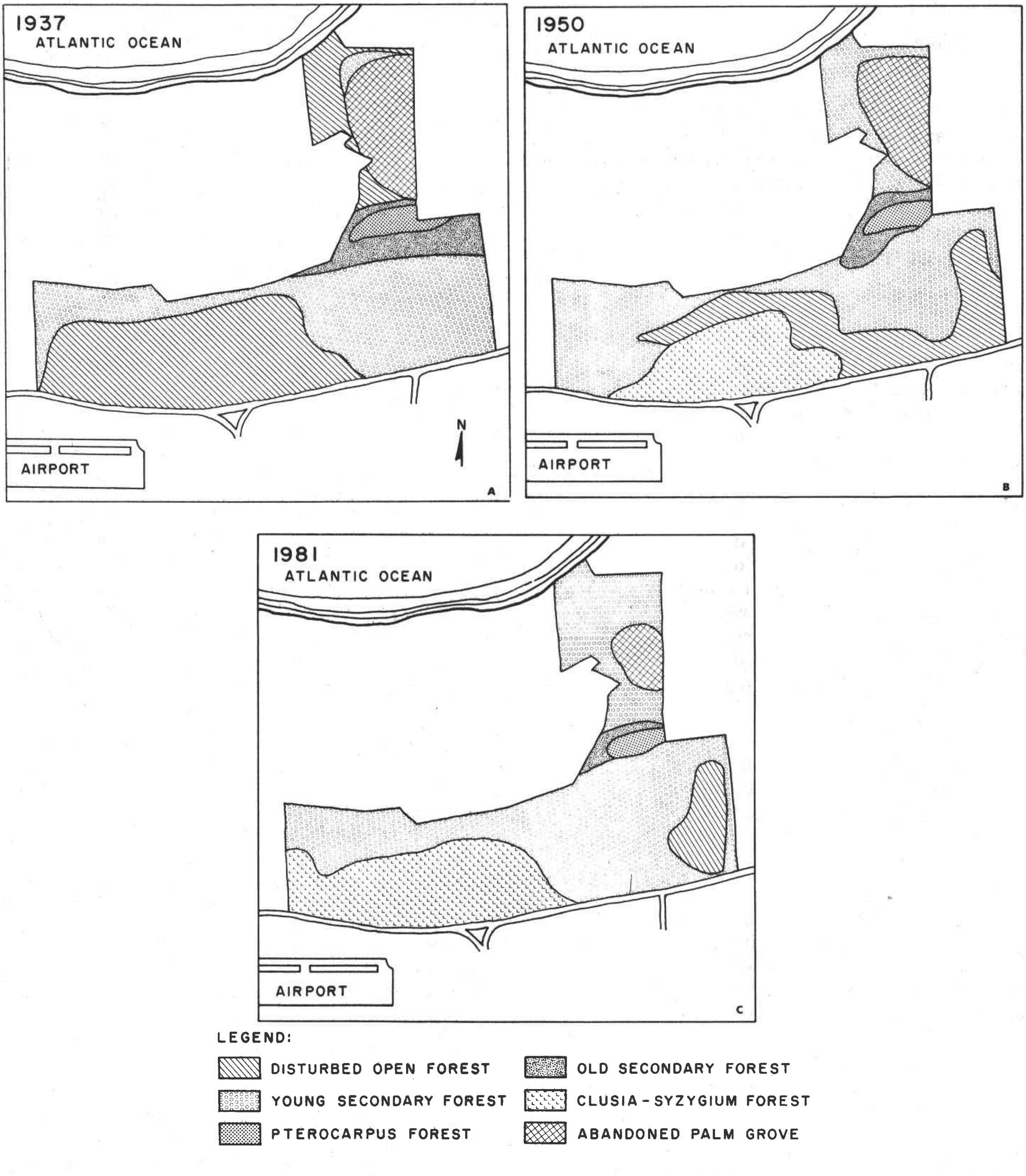

Figure 3.—*Maps of forest types in the study area corresponding to: (a) 1937, (b) 1950, and (c) 1981.*

Disturbed Open Forest

This forest is located on the southeastern portion of the property. Nine tree species were found in this forest type, dominated by *Hymenaea courbaril, Syzygium jambos,* and *Ocotea leucoxylon.* The forest tree density and basal area were 1,000 trees/ha and 21.8 m^2/ha. Canopy height was 17 m. This forest exhibited successional characteristics such as a high density of vines and wide open areas with few large trees.

Pterocarpus Forest

This forest wetland covers 0.7 ha of poorly drained Martin Peña clays. Seven tree species are found in this area, but only one species is dominant, *Pterocarpus officinalis.* Other species of importance were *Bucida buceras* and *Calophyllum brasiliense.* No experimental plots were established in this area, because this particular forest stand was studied in detail by Álvarez (1982).

Clusia-Syzygium Forest

This forest type was found as an uninterrupted block along the southern portion of the property. The forest is swampy, although it grows on Saint Lucie sands. The dominant species were *Clusia rosea, Syzygium jambos, and Ocotea leucoxylon.* The forest had a very high proportion of multiple stems, probably due to coppicing encouraged by past tree cutting.

Young Secondary Forest

Over half of Parcel F (23.9 ha) is dominated by this forest type. The dominant tree species were *Hymenaea courbaril, Bucida buceras,* and *Quararibaea turbinata.*

Old Secondary Forest

This was by far the most complex forest type sampled. It was found surrounding the Pterocarpus forest on Martin Peña clays. The forest is characterized by the presence of such species as *Manilkara bidentata, Lonchocarpus latifolius, Pisonia albida, Calophyllum brasiliense, Mastichodendron foetidissimum, Zanthoxylum martinicense,* and *Ocotea globosa.* Areas within this forest type were found completely covered by the herbaceous *Anthurium crenatum.* This is a unique forest and one of the two remaining examples of fairly undisturbed moist coastal forests in Puerto Rico. The other example is located in the Manati area, west of the study site.

Changes in Forest Area

In figures 3(a – c) and 4, we reconstructed the historical change in forest cover on the study site. In 1937 (fig. 3a) 90 percent of the property was in some degree of alteration (i.e. disturbed open, young secondary forest, and coconut plantation). The Clusia-Syzygium forest could not be detected in the photograph. Only 10 percent of the area was in natural forest. By 1950 (fig. 3b), the area of old secondary forest had decreased 46 percent and the area of Pterocarpus forest had been reduced by 10 percent (table 3). A Clusia-Syzygium forest replaced most of the disturbed open forest while the palm grove was invaded by secondary forest. Today (fig. 3c), young secondary forest covers 60 percent of the site and all other forest types have decreased in proportion. Construction of a golf course west of the study area has caused changes in drainage patterns resulting in serious declines of both the Pterocarpus and old secondary forests. On the southern portion of the site, the successional Clusia-Syzygium forest has continued to increase in area, partly due to impeded drainage in the area.

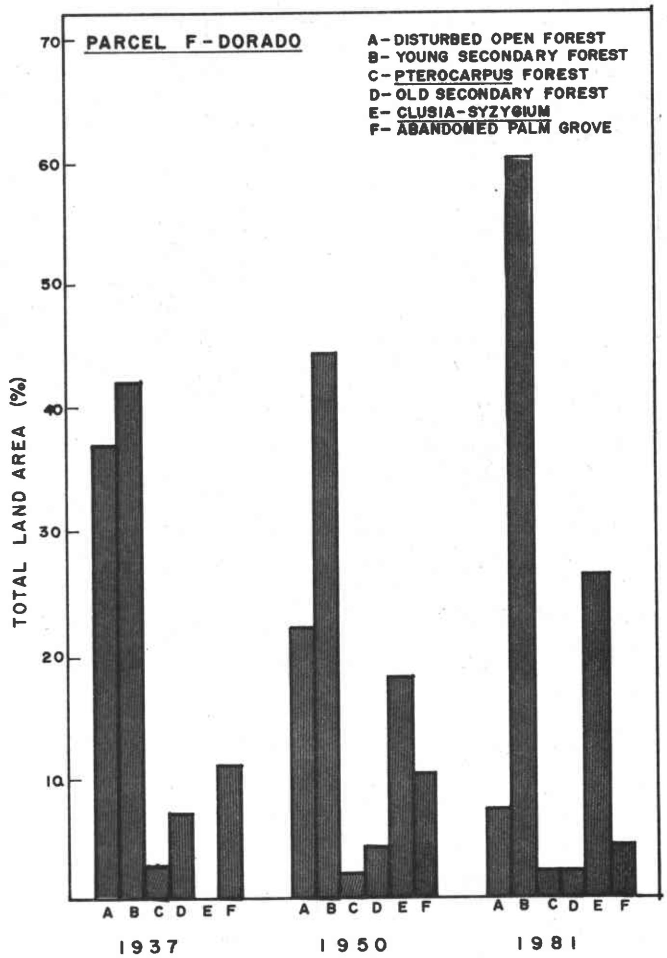

Figure 4.—*Changes in the proportion of total land area covered by each of six forest types in the study area.*

In summary, net changes over the last 44 years show an 82 percent decrease in disturbed open forest (replaced by the Clusia-Syzygium forest); a 30 percent loss of Pterocarpus forest, a 79 percent loss of old secondary forest, and an encroachment of 64 percent into the palm grove by young secondary forest.

Table 3.—*Temporal change in areal distribution by forest type in Parcel F, Dorado, Puerto Rico*

Forest type	Area†		
	1937	1950	1981
	ha		
Old secondary forest	2.8	1.5	0.6
Young secondary forest	16.5	17.2	23.9
Clusia-Syzygium forest	.....	7.4	10.1
Pterocarpus forest	1.0	0.9	0.7
Disturbed open forest	14.8	8.5	2.6
Abandoned palm grove	4.4	4.0	1.6

†Total area of Parcel F is 39.5 ha.

Table 4.—*Endangered plant species in the coastal moist forest of Dorado*

Forest type	Endangered species	Life form
Young secondary forest	*Cassia mirabilis* (E)†*	herb
Pterocarpus forest	*Sabicea cinerea*	shrub
Pterocarpus forest	*Epidendrum kraenzlinii* (E)	epiphyte
Old secondary forest	*Ficus stahlii**	tree

†(E) = Endemic.
*Observed on the property.

Species Relationships

Our survey of the arboreal vegetation was sufficient to typify species composition in the study site. All communities were sampled at an intensity sufficient to obtain a species-area curve with a flat asymptote (fig. 5). It is obvious from these curves that the richest forest stand was the old secondary forest followed by the young secondary forest. Table 5 contains a listing of all tree species encountered in the survey. Four presently considered endangered species were observed in the study site (table 4). It is clear from these results that the study area has a rich and unique assemblage of tree and other plant species. The old secondary forest supports 84 percent of all the species in the region. Thus, as already suggested by Gleason and Cook, the forest communities in Parcel F, with the exception of the Pterocarpus forest, are all part of one floristic assemblage that converges in a climax forest similar to the old secondary forest. This forest is known either as a moist coastal forest on white sands or as a coastal dry evergreen forest on silica sands.

DISCUSSION

Comparison With the Survey of Gleason and Cook

Not all of the species listed by Gleason and Cook in 1926 were sampled on the site in the present study. The extensive loss of mature forest area could explain why some were not encountered. The most significant changes, however, have been in the area occupied by the different forests. For example:

The original beach strand forest formation has been almost completely altered. Considerable time and lack of additional disturbance would be needed for this area to revert to its natural state. This beach strand formation that once included over 100 woody species, harboring trees over 10 m in height, was dominated by species of *Cassine, Coccoloba,* and *Morinda.* Today, young secondary forests occupy these locations.

The dry evergreen forest located next to the beach and north of the Pterocarpus swamp forest was a two-storied formation with strata at 10 and 20 m. This forest had several tree species that attained diameters of 1 m or more. Examples are *Bucida buceras, Calophyllum brasiliense, Mammea americana, Mastichodendron foetidissimum,* and *Manilkara bidentata.* Many smaller trees reached the upper canopy, such as *Lonchocarpus latifolius, Ocotea patens, O. globosa, Chione venosa, Zanthoxylum martinicense,* and *Cupania americana.*

The second story (10 m) was dominated by such trees as *Faramea occidentalis, Ixora ferrea, Eugenia biflora, Mouriri helleri, Casearia guianensis, Pimenta racemosa var. grisea,* and *Ardisia obovata.* Today, except for the area next to the Pterocarpus swamp forest, this area is mostly coconut grove and young secondary forest covered with *Cocos nucifera, Terminalia catappa,* and *Bucida buceras.*

The original coastal dry evergreen forest on silica sand was also disturbed. This forest was originally dominated by the following large upper story trees:

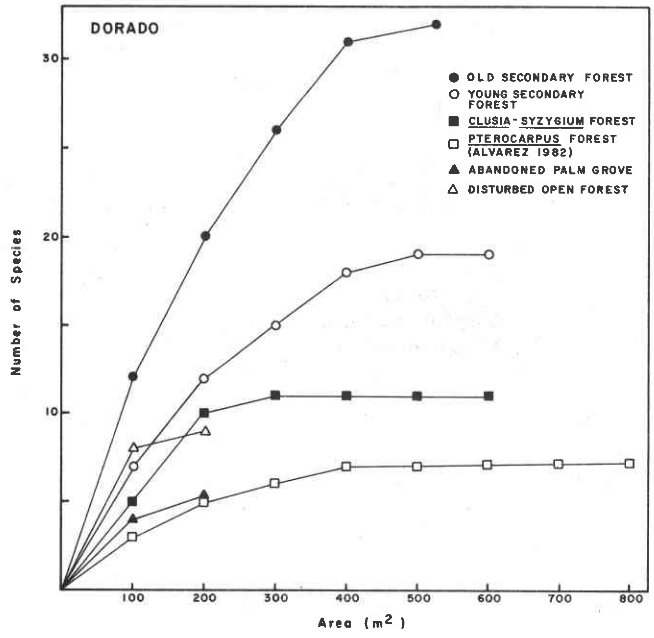

Figure 5.—*Species-area curve for six forest types in the study area.*

Hymenaea courbaril, Buchenavia capitata, Spondias mombin, Andira inermis, Manilkara bidentata, Ficus trigonata, Guapira fragrans, Cinnamomum elongatum, Ocotea floribunda, O. patens, O. globosa, Inga fagifolia, Guarea guidonia, and *Mastichondendron foetidissimum.*

The disturbed areas today contain mostly *Clusia rosea* and *Syzygium jambos*. The majority of these disturbed areas are in different stages of recovery as indicated by the following trees: *Myrcia splendens, Eugenia biflora, Myrciaria floribunda, Ocotea patens, O. globosa, Faramea occidentalis, Buchenavia capitata, Ardisia obovata, Chione venosa, Cupania americana, Montezuma grandiflora, Spondias mombin, Andira inermis, Byrsonima spicata, Zanthoxylum martinicense,* and other less common species.

The swampy Pterocarpus forest was and still is dominated by *Pterocarpus officinalis*. Co-dominant

Table 5.—*Distribution of all tree species tallied by forest type in the moist coastal forests of Dorado, Puerto Rico*

Species	Forest types					
	Secondary		Clusia-Syzygium	Pterocarpus†	Disturbed open	Abandoned palm grove
	Old	Young				
Alchornea latifolia Sw.			X			
Andira inermis (W. Wright) HBK.	X	X	X	X		
Amphitecna latifolia (Miller) A. Gentry*						X
Bourreria succulenta Jacq. var. *succulenta*	X					
Buchenavia capitata (Vahl) Eichl.	X					
Bucida buceras L.		X	X	X		
Bursera simaruba (L.) Sarg.*	X	X				
Byrsonima spicata (Cav.) HBK.					X	
Calophyllum brasiliense Jacq.*	X			X		
Calyptranthes sintenisii Kiaersk.	X	X				
Casearia guianensis (Aubl.) Urban*	X	X				
Chrysophyllum argenteum Jacq.	X					
Citharexylum fruticosum L.	X					
Clusia rosea Jacq.*			X			
Coccoloba diversifolia Jacq.	X					
Cocos nucifera L.						X
Cordia laevigata Lam.	X					X
Cupania americana L.*		X				
Dendropanax arboreus (L.) Decne. & Planch*	X					
Dendropanax laurifolius (E. March.) Decne. & Planch ex. Schneid.*	X					
Didymopanax morototoni (Aubl.) Decne. & Planch	X		X		X	
Drypetes alba Poir			X			
Eugenia biflora (L.) DC.	X	X				
Eugenia monticola (Sw.) DC.*	X		X			X
Faramea occidentalis (L.) A. Rich.		X				
Ficus citrifolia P. Miller				X		
Guapira fragrans (Dum.-Cours.) Little	X	X				
Guarea glabra Vahl.		X			X	
Hymenaea courbaril L.		X	X		X	
Inga fagifolia (L.) Willd.	X	X				
Licaria parvifolia (Lam.) Kostermans		X				
Lonchocarpus latifolius (Willd.) DC.	X					X
Mangifera indica L.					X	
Manilkara bidentata (A. DC.) A. Chev.*	X	X			X	
Myrcia leptoclada DC.	X				X	
Myrcia floribunda (West ex Willd.) Berg.		X				
Ocotea coriacea (Sw.) Britton*	X					
Ocotea globosa (Aubl.) Schlecht. & Cham.	X					
Ocotea leucoxylon (Sw.) Mez.	X	X	X		X	
Ouratea littoralis Urban			X			
Palicourea crocea va. *riparia* (Benth.) Griseb.*	X					

Table 5.—*Distribution of all tree species tallied by forest type in the moist coastal forests of Dorado, Puerto Rico—Continued.*

Species	Forest types					
	Secondary		Clusia-Syzygium	Pterocarpus†	Disturbed open	Abandoned palm grove
	Old	Young				
Piper aduncum L.*	X					
Pisonia subcordata (Sw.) ex Standl.*	X					
Pterocarpus officinalis Jacq.				X		
Quararibaea turbinata (Sw.) Poir.		X				
Randia aculeata L.*				X		
Roystonea borinquena O.F. Cook*‡				X		
Syzygium jambos (L.) Alst.*			X		X	
Tabebuia heterophylla (DC.) Britton*	X					
Trichilia hirta L.	X					
Zanthoxylum martinicense (Lam.) DC.*	X	X				
Total	32	19	11	7	9	5

†From Alvarez 1982.
*Also recorded by Gleason and Cook (1926).
‡Endemic.

species include *Bucida buceras, Roystonea borinquena,* and several fringe species such as *Andira inermis, Calophyllum brasiliense, Manilkara bidentata, Ardisia obovata, Ocotea leucoxylon, Coccoloba venosa,* and *Calyptranthes sintenisii.* The main impact on this forest has been its reduction in area rather than a change in species composition.

The Factors of Change

Many factors combine to cause vegetation changes such as those described. However, two can be singled out in the study site: 1) direct human intervention by cutting and replanting, and 2) indirect human effects mostly through changes in drainage. Direct human intervention was responsible for the destruction of the beach strand vegetation (through planting of the coconut grove) and most of the changes that occurred on the southern portion of the property near the road. These forces are no longer active, and the vegetation on these areas is in a clear process of recovery. But the speed of recovery is slow because the infertile soils present regeneration problems to the forest communities.

Changes in drainage are more subtle in their effect, but they nevertheless have played a significant role in reducing the area of both Pterocarpus and old secondary forests. The last extension to the golf course was particularly harmful in this respect (see cover).

In addition to these two major forces of change, it is evident that the area has been subjected to selective logging in the past. This has left its mark on the forest in a profusion of vines and an abundant number of sprouts and coppice growth in the surviving stumps.

Forest Values

It is obvious that the old secondary forest and the Pterocarpus forest cannot sustain much more human impact and still survive. These forest types are among the most endangered forest ecosystems in Puerto Rico. Their value rests in their limited representation elsewhere, high biological productivity, unique habitats, and outstanding floral composition. Because they grow in stressed environments (one is a wetland and the other grows on very nutrient-poor sands), they are also of unique interest to science and acquire enormous intrinsic and social value.

The young secondary forests and the Clusia-Syzygium forest represent two advanced stages of forest recovery in the region. Their species-area curves (fig. 5) and species composition (table 5) are clearly moving toward those of the old secondary forest. These forests will eventually reach a stature similar to the old secondary forest and their biotic value rests in their potential as well as their advanced stage of recovery. Topographically, they buffer the Pterocarpus and old secondary forest (fig. 3c) and may be very important as protective agents to the two endangered forest ecosystems. More research is needed on forest regeneration and water relations to be able to pinpoint the interrelationships between the young and old secondary forests. The presence of endangered and endemic species in these stands adds to their biotic value. Because of the harshness of the soils on which they grow, it is difficult to predict how long it will be before these forests reach full maturity. This also requires more research.

An open disturbed forest and coconut groves are the remnants of a time when intensive human activity regulated forest areas on the site. These groves will also become mature forests, but their recovery is many times slower due to the more complete modification of the sites by humans. Their value at the present is confined to soil protection and, of course, the support of wildlife, as is evident in the case of the white-crowned pigeon colonies in the coconut grove.

LITERATURE CITED

Álvarez, M. A comparison of the structure and ecology of *Pterocarpus officinalis* Jacq. forested wetlands in Puerto Rico. Rio Piedras, PR: University of Puerto Rico; 1982. 96 p.

Ewel, J. J.; Whitmore, J. L. The ecological life zones of Puerto Rico and the U.S. Virgin Islands. Res. Pap. ITF-18. Rio Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry; 1973. 72 p.

Gleason, H. A.; Cook, M. T. Plant ecology of Porto Rico. In: Scientific Survey of Porto Rico and the Virgin Islands. New York: New York Academy of Sciences; 1926: 1 – 173. Vol. 7, Parts 1 – 2 plus plates.

Holdridge, L. R. Life zone ecology. San José, Costa Rica: Tropical Science Center; 1967. 206 p.

Liogier, H. A.; Martorell, L. F. Flora of Puerto Rico and adjacent islands; a systematic synopsis. Rio Piedras, PR: Editorial de la Universidad de Puerto Rico; 1982. 342 p.

Roberts. R. C. Soil survey of Puerto Rico. Series 1936, No. 8. Washington, DC: U.S. Department of Agriculture, Bureau of Plant Industry and University of Puerto Rico Agriculture Experiment Station; 1942. 503 p.

Wiley, James W. The white-crowned pigeon in Puerto Rico: status, distribution, and movements. Journal of Wildlife Management. 43(2): 402 – 413; 1979.

Figueroa, Julio C.; Totti, Luis; Lugo, Ariel E.; Woodbury, Roy O. Structure and composition of moist coastal forests in Dorado, Puerto Rico. Res. Pap. SO-202. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. 11 p.

Changes in forest structure and area over a 44-year period in coastal moist forests in Puerto Rico show succession toward a single climax on white sands. A Pterocarpus forest has not changed and is considered a climax on flooded soils.

Keywords: Tropical forests, tropical succession, forested wetlands, Pterocarpus swamps.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984-769-089:13