A SURVEY
OF THE
FOREST PLANTATIONS
IN THE
CARIBBEAN NATIONAL FOREST

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by

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January 11, 1947

Box 22
Río Piedras, Puerto Rico
January 11, 1947

Mr. Samuel T. Dana, Dean
School of Forestry and Conservation
University of Michigan
Ann Arbor, Mich.

Dear Sir:

The report "A Survey of the Forest Plantations in the Caribbean National Forest" is submitted as partial fulfilment of the requirements for the degree of Master of Forestry in the School of Forestry of the University of Michigan.

This work is part of the general survey of plantations in Puerto Rico. The writer was directly responsible for the field work and for the preparation of this report.

Yours very truly,

José Marrero

jm/ecm
Encl.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge his indebtedness to Frank H. Wadsworth, Silviculturist of the Tropical Forest Experiment Station, for his valuable help in drawing up the specifications and procedure of this study, and for his suggestions in the preparation of the report.

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The field personnel of the Luquillo and Toro Negro Divisions were very cooperative in the collection of the data.

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INTRODUCTION

Forestry has been less studied in tropical than in temperate climates. In the tropics information is needed in many phases of forestry work.

In Puerto Rico, reforestation had not been carried on an island-wide scale until the Civilian Conservation Corps and the Puerto Rico Reconstruction Administration initiated a forestry program in Federal and Insular forests during 1934 and 1935. Practically no research and little plantation establishment had been done previously. Formal research was not organized until 1939.

Over 20,000 acres of forest plantations established by the above organizations and lately by the Puerto Rico Emergency Program are in themselves the most abundant and readily obtainable source of information of forest regeneration in the island. These plantations have been established under a great variety of conditions, from low to high elevations, and from arid to very humid climates.

Although reforestation policies and technique have evolved upon recognition of the most obvious failures and through the findings by experimentation, no comprehensive report had been prepared putting together the great fund of information obtainable from a study of plantations. An intensive study should yield the following information of value to forest administration and research.

1. A permanent record and reference of plantation establishment.
2. A reliable estimate of the planting and plantation management job ahead with recommendations as made evident by the survey.
3. A clearer picture of regeneration and plantation management problems for use in planning research programs.

After a preliminary study of survey procedure during 1940, the survey was carried during part of 1944 and early part of 1945. Twenty thousand acres of plantations in the Caribbean National Forest and Insular Forests were surveyed by the research staff.

The report corresponding to the Caribbean National Forest is hereby presented as a partial fulfilment of the requirements for the degree of Master of Forestry in the School of Forestry of the University of Michigan.

GENERAL BACKGROUND

The Island of Puerto Rico.

Puerto Rico, the smallest of the Greater Antilles, has an approximate area of 3435 square miles. It lies within the torrid zone, on the way of the trade winds. This fact and the mountainous character of the island make a comfortable climate.

The island is almost a parallelogram, approximately 100 miles long by 35 miles wide, the longest dimension lying east and west.

The topography is characterized by a central mountainous core running east-west, surrounded by coastal plains of varying widths, most of them being narrow. The highest elevation, 4398 feet, is found in the Central Mountains.

In spite of its small size, the island shows a surprising variation of geologic and geographic features. Picó (8) divided the island into eleven geographic regions.

The records of over 10 years show an average temperature of 76° F. During the coolest months of winter the average is 73°F., and during the warmest months of summer, 79° F. Temperature differences between the warmer coastal plains and the sub-tropical climate of the mountainous interior affect the distribution of agricultural crops.

ENGINEER REPRODUCTION PLANT, THE ARMY WAR COLLEGE, WASHINGTON, D. C. 14619
1939

Rainfall is more important in crop distribution and is definitely influential in the distribution of forest tree species. There is a wide range in rainfall from an average of 26 inches in the arid southwest to about 188 inches in the Luquillo Mountains.

Economic Considerations.

Puerto Rico ranks among the most densely populated countries of the world. At present there are over 600 persons to the square mile, the greatest preponderance being rural. The total land area is approximately two million acres, or about 1 acre of land per capita. Of this land less than one-half acre is cultivated. This land-population ratio requires specialization in a few highly productive agricultural crops and a great intensity of cultivation to assure a high yield per acre.

At present the island depends upon a highly commercialized agriculture. The contribution of industries to the island's income has been small.

In very few other countries is there a greater need for the most suitable and intensive use of every acre of land. Although a maximum area needs to be under cultivation of agricultural crops, there is an undetermined percentage of the land whose highest use is forest production.

Statistics supplied by the Tropical Forest Experiment Station, based on the 1940 census are as follows:

	(Acres)
Government forests	74,804
Privately-owned forests	128,112
Coffee woodlands	175,890
Woodland pastures	148,487
Total	527,393

According to this census the total area of the island is 2,190,720 acres.

The stocking of the privately-owned forests and the woodland pastures is very low. Because of their poor condition, they are not contributing to the extent indicated by their area. The coffee woodlands produce a great portion of the fuel consumed. The government forests are under the most intensive management, and acre by acre are the highest producing forests.

The forests are necessary on steep lands under high rainfall for soil stabilization and retarding of run-off.

The production of forest products is the other main objective of the forests. The condition and extent of the island forests are such that the available timber is inadequate to supply the needs for wood and wood products. Thus, the bulk of the island's needs in both construction and furniture manufacture is imported. However, the yield of the existing forests is of great importance to the island for the production of fuel and agricultural needs such as fence posts, ties, etc. This materially reduces the importation of the latter products.

No suitable timber inventory has been made for the island. Teesdale and Girard (11) estimated the annual value of the fuel from all sources in 16.5 million dollars or roughly 16.5 per cent of the value of all imports. The labor involved in producing charcoal alone was estimated to provide approximately 1,400,000 man-days of work per year. The contribution of the forest in materials for the contruction of ox-carts, ox-yokes, tobacco sticks, fence posts, ties, rural houses, tool and broom handles, represents a saving of $150,000 in the value of imports.

A small but expanding furniture industry in the island consumes about 1,800,000 board feet annually, of which about 600,000 board feet are produced locally and the rest imported. This includes mostly high-priced wood such as mahogany or similar timber.

Since the island lacks coal, oil, and other possible material for fuel, it is certain that wood will remain the main source of fuel. The amount of fuel and timber used is increasing because of the fast population growth.

Teesdale and Girard (11) estimated that the forest drain is about 30 per cent greater than the growth.

The following statement is quoted from their report.

"The importance of greater production from all types of wooded areas is obvious, and suitable steps should be taken to increase the volume of wood grown per acre to prevent future shortage.

If there is any place where scientific forest management, good cutting practices, and bringing the forest lands into a state of maximum production is justified, it is Puerto Rico."

History of the Work.

The Caribbean National Forest consists of two divisions: the Luquillo, including most of the Luquillo Mountains on the northeast of the island, and the smaller Toro Negro Division located on the higher elevations of the Central Mountains, about 40 miles southwest of the former. The Luquillo Division, variously called the Luquillo Forest Reserve and later the Luquillo National Forest, was originated by presidential proclamation in 1903. Originally it included about 15,000 acres, 12,000 of which had been unclaimed by private owners, and 3000 acres which were transferred from the Insular to the Federal government. Subsequent land acquisition, especially after 1934, enlarged the division to a total of 25,251 acres. Large-scale planting work was initiated by such agencies as the Civilian Conservation Corps and the Puerto Rico Reconstruction Administration.

The area in need of artificial reforestation was expanded considerably after the acquisition program inaugurated in 1933-34. The original forest

was mostly well forested, but a great portion of the area obtained by acquisition consisted of open-degraded land. In the fall of 1931 experimental plantations were established in Del Valle, but the large-scale reforestation work was initiated in 1934. Between the years 1934 and 1942 a total of 3861.8 acres of plantations were established. An additional 64 acres were planted in 1945. Maintenance work including replanting has been done at varying intervals from the time of plantation establishment to the present.

The Toro Negro Division was acquired by purchase from private owners during 1935. It consists of 6001 acres of forest land located high on the summits of the Cordillera Central.

Planting work started in Toro Negro during 1933. A small plantation was established around Guineo Lake. Large-scale reforestation work started in Doña Juana during 1934. Planting and replanting continued at varying intervals to the present. Up to June 1945 a total of 1856 acres of plantations had been established in this division.

PROCEDURE

The data was obtained by interpretation of the condition of the stands and failed spots by personnel well acquainted with the history and condition of the plantations. Additional data was provided by temporary sample plots in those areas deserving more intensive study.

A preliminary study showed the impossibility of adapting randomized-sample survey techniques to plantations. This was the result of the great heterogeneity of the stands themselves and of most sites. Repeated replantings made with several species, plus rugged relief and great site variability, did not permit obtaining the required data from plots located at random. Results obtained from general reconnaissance, the study of

planting and nursery records, and from the study of purposely selected sample plots, were considered very adequate to form a basis for reliable conclusions. Results were qualified according to the methods used.

The reconnaissance consisted of going through the plantation, sampling the different sites, and taking data on site species relationships and complete notes as illustrated by form 2 of the appendix. It was not possible to make any hard and fast rule as to the number of "site studies". In the Luquillo Division, 52 site studies were recorded.

As site studies were made on every site and with every species present in good stands, all of the temporary growth plots were located where a site study had been already made.

Data was also obtained from one-fourth acre circular growth plots of 59 foot radius. The diameter of every tree inside the plot was measured at breast height. The average and maximum heights were estimated for each plot. The trees were classified as good (those of satisfactory form and vigor which could become part of the final crop) and poor trees which were those of poor form or attacked by insects, diseases, or otherwise unthrifty and of low vigor.

The analysis includes separate tabulation of the data from the growth plots and from the site studies for presentation in this report.

PHYSICAL FEATURES

Luquillo Division.

The Luquillo Division of the Caribbean National Forest comprises at present a total of 25,251 acres including the steeper portion of the Luquillo Mountains.

This range is separated from the Central Mountains and the Carite Range. The better known peak is El Yunque, 3496 feet, although El Toro, 3532 feet, and located more to the southeast, is the highest.

Numerous rivers originate in the area. The Mameyes River valley is the largest within the Luquillo Division. The Espíritu Santo and Río Grande are among the largest rivers on the northwest. The Mameyes, the Gurabo, Canovanillas and Fajardo Rivers have their headwaters in the range.

Geology and Soils: An intensive erosion since early geologic periods has produced a definite drainage pattern of rapidly ascending and numerous knife-edge ridges. The range is of volcanic origin, although a greater portion of its rocks are volcanic tuffs and shales formed by deposition of volcanic materials. On the southeastern part rocks are intrusives of the quartz-diorite type. The diorites, being crystalline igneous rocks, have produced coarse granular soils as evidenced south of La Mina recreational area. The topography is often precipitous. Upon weathering, the tuffs and shales have produced soils such as those of the Catalina and Los Guineos series which are high in clay and low in sand, and thus are heavy textured. The high rainfall and temperature have caused intense weathering and deep soils, although in steep slopes soils might be shallow.

Clearing of the forest and mismanagement of the heavy clays reduce the soil to a condition in which it is of little use, except for pastures of very low quality or forest.

The more open-textured, less-leached and better-drained soils of lower elevations include such series as Múcara, Picachos, and the deeper phases of Catalina. These stand cultivation better, although sometimes they are located on very steep slopes. As elevation increases, soils are heavier. The soils in the highest ridges and peaks have been classified as Rough Stony Land.

Climate: The location of the Luquillo Mountains as the first high range on the way of moisture-laden trade winds accounts for a high annual precipitation. The condensation of the moisture-laden trade winds causes

very frequent fogs at higher elevations.

Rainfall is well distributed, although it concentrates in the summer and fall. It decreases from high to lower elevations, and from east to west. The less humid period generally extends from the month of February to April. The rainfall records from four stations are shown in table 1, page 10.

At lower elevations and in the most exposed areas, short rainless periods during the winter months affect the result of planting operations.

Most of the temperature data refer to La Mina recreational area (2050 feet), which is higher than most of the plantations. The yearly average maximum and minimum temperatures for the period are 76.1° F. and 63.8° F. respectively. The highest temperatures are recorded from June to October, and the lowest from January to March.

The following is the monthly average for a six-year period in degrees Fahrenheit.

Table 2. Monthly Average Temperature for La Mina, Luquillo Division

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
66.9	66.6	67.2	69.0	70.0	71.4	72.0	72.7	72.6	71.9	70.4	68.4	69.9

Toro Negro Division.

The Toro Negro Division of the Caribbean National Forest has been roughly set up as a rectangle reaching El Alto de la Bandera on the west, the town of Villalba on the south, the town of Orocovis on the east, and an east-west line following latitude 18°15' to the north. While this outer limit contains over 100,000 acres, it was recognized at the time that probably not over 40,000 acres could or should be bought while it was admitted that purchases up to 30,000 acres would include all that is most important to acquire,

Table 1. Rainfall Data of Four Localities in the Luquillo Division

Locality and elevation	No. of years	Rainfall	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
La Mina	10	Monthly Average	14.05	11.9	7.26	8.78	20.99	17.86	13.17	19.59	15.76	19.66	21.19	17.96	188.17
2,050 ft.		Days with rain	24	19	17	17	24	23	24	24	23	24	24	26	269
Río Blanco 500 ft.		Monthly Average	6.02	5.21	4.30	4.93	11.50	10.33	9.38	11.27	12.20	12.19	12.23	9.90	109.46
	11	Monthly Average	11.09	8.64	7.83	8.62	15.49	14.14	11.62	13.84	15.04	13.42	16.27	13.19	149.09
1,800 ft.		Days with rain	25	20	20	23	26	26	27	28	27	27	26	28	303
Sabana 500 ft.	9	Monthly Average	8.21	3.37	6.54	11.27	14.94	13.75	14.56	11.14	12.24	13.94	16.23	9.36	135.55
El Verde 350 ft.	23	Monthly Average	8.10	5.25	5.48	5.21	7.30	7.68	11.46	8.68	10.34	7.51	10.33	10.42	97.66
		Days with rain	14	10	10	9	12	12	16	13	11	14	16	17	154

that is, land over 3000 feet elevation, and the steeper and rougher slopes in the 2000-3000-foot zone. Actually only 6001 acres, including the highest elevations in the island, are in government ownership, but it is expected that such area be rapidly increased by post-war acquisition.

Geology and Soils: Volcanic activity has been responsible for the rocks in part of the area. These are, according to Meyerhoff (6)"intrusive porphyries chiefly andesitic invading upper cretaceous, sedimentary, pyroclastic rocks and andesitic tuffs agglomerates and associated conglomerates."

Yellowish heavy clays are mapped as Los Guineos and Cialitos clays. However, in a limited area around Guineo Lake, there is a purplish-friable permeable clay known as Alonso clay. Toward the west, in the Utuado-Jayuya valley, granitoid intrusives, diorites and granites are in evidence.

Soils derived from granitoid rocks are known as Utuado loam. The latter are the best drained and more friable soils of any found in the area. The higher elevations to the west of Guineo Lake are mapped as containing Rough Stony Land.

Mucara soils, prevalent in the highlands to the east and to a less extent to the north and south, are included within the rectangle comprising the division. They occur east of Río Bauta and to a smaller extent south of Casa Blanca along the Toro Negro River, and a short distance north of the town of Villalba. Probably they will never be in government ownership since they are being cropped and are considered of agricultural value in spite of the very steep topography.

The southern streams have a precipitous descent toward the coastal plain less than ten 10 miles away. As a consequence, rivers are short and numerous to the south and larger north of the main divide. Among those rivers which rise in the division and flow south into the Caribbean Sea are: Portugués, Inabón,

Jacaguas, Guayo, Vaca, Descalabrado, and Coamo. To the north all go into the Arecibo and Manatí Rivers. The Caonillas Rivera, which supplies the largest hydroelectric project in the island, has its headwater in this division.

The rivers south of the divide are used for irrigating the dry but intensively farmed coastal plain. Two dams have been built within the division in the headwaters of rivers flowing north. The water has been tunneled south to a power house at Villalba at the base of the hills. Water is further collected to another dam on the Jacaguas River at a lower elevation, from where it is distributed through irrigation canals to the sugar cane lands. In addition, considerable water for irrigation is obtained from wells which are fed from the mountains.

Climate: As with other areas of the island, topography is influential in determining climate. In Toro Negro the climate is more comfortable than at the Luquillo Mountains as a result of a cooler temperature and a less humid environment.

Temperature data for two stations in the division are shown in table 3. The station with the lowest rainfall in Toro Negro is about 14 inches lower than the respective one in Luquillo.

The three rainfall stations in Toro Negro range from 83.38 inches at Matrullas (2300 feet) to 11.15 inches at Guineo Lake (3000 feet). The Toro Negro station located at 2250 feet has an average of 97.99 inches. There seems to be an appreciable reduction in rainfall from west to east.

Rainfall is well distributed throughout the year. The days with a measurable amount of rainfall range from 176 in the Toro Negro station to 236 in Matrullas, and 235 at Guineo. In the Luquillo Mountains there is a much larger range among the different localities.

May is the month of highest rainfall in both Guineo and Matrullas.

Table 3. Temperature Data of Two Localities in the Toro Negro Division

Locality and elevation	Temp. ° F.	No. of years	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Guineo Lake 3,000 ft.	Mean maximum	8-10	70.5	70.9	71.6	73.6	74.8	76.2	77.4	77.5	76.7	76.5	74.3	72.0	74.3
	Mean	3-4	63.3	61.9	63.0	65.3	67.4	69.5	70.3	70.2	69.9	69.4	67.6	65.1	66.9
	Mean minimum	3-4	55.6	54.7	55.7	57.2	60.0	62.2	62.6	63.2	62.3	61.9	60.2	57.9	59.5
Toro Negro 2,250 ft.	Mean maximum	6-7	74.7	74.6	74.8	75.2	76.2	78.6	80.2	80.7	79.5	79.0	77.3	75.6	72.2
	Mean	13-14	66.5	65.9	66.3	66.9	69.1	70.6	71.7	72.0	71.3	70.8	69.4	67.5	69.0
	Mean minimum	13-15	58.3	57.3	57.7	58.7	61.9	62.7	63.1	63.4	63.0	62.5	61.6	59.3	60.8

August, September and October approach or exceed 10 inches of rainfall. Average monthly and annual rainfall for Toro Negro is shown in table 4.

The Luquillo plantations are located at elevations between 500 and 2000 feet with the greater portion under 1000 feet. In Toro Negro, plantations are located between 2500 and 3500 feet.

No data of wind velocity and evaporation were obtained, but there is no doubt that the greater exposure of the Luquillo Mountains results in more persistent and stronger winds. This and the higher temperature increase the evaporation which should counteract somewhat the higher rainfall in Luquillo.

THE PLANTATIONS

Planting Objectives.

The objects of planting as visualized at present have been established by the forest planting policy. The following objectives are quoted from the planting policy of 1945.

"Forest planting is done in Puerto Rico (1) for timber production and (2) for watershed protection. The former is nearly always the chief objective, although on steep bare slopes with very poor soils in areas of high rainfall the latter may be the most important.

The final goal of planting is the establishment of a forest which is (1) all-aged, (2) composed of sawtimber and durable round timber species, and (3) capable of reproducing itself.

Sawtimber (primarily furniture woods) and durable round timber species are believed to be the highest yielding products of the forest. Fuelwood yield can always be maintained at a very high level on a by-product basis.

The desirability of a forest which reproduces itself is obvious. In such a forest none of the present heavy establishment costs need over be paid again. This stipulation requires that the species of the managed

Table 4. Rainfall Data of Three Localities in the Toro Negro Division

Locality and elevation	No. of years	Rainfall	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Guineo Lake	12	Monthly Average	4.37	5.24	5.42	6.84	17.52	7.81	6.92	12.36	14.88	15.78	9.25	4.76	111.15
3,000 ft.		Days with rain	19	16	17	18	24	19	17	20	22	24	21	18	235
Matrullas	9	Monthly Average	4.99	3.74	5.60	5.15	12.04	4.58	4.70	7.63	9.53	11.01	8.65	5.66	83.38
2,300 ft.		Days with rain	21	14	16	16	22	16	16	23	23	24	23	22	236
Toro Negro	29	Monthly Average	3.98	4.85	4.71	7.39	12.11	6.78	6.64	9.37	13.24	14.52	9.84	4.56	97.99
2,250 ft.		Days with rain	14	12	12	13	16	14	14	16	18	16	18	13	176

forest be sufficiently shade-tolerant to be able to reproduce themselves under natural forest conditions without liberation except for that provided by light periodic cuts.

The relative merits of mixed and pure stands have not been determined under Puerto Rican conditioms, but it appears that a mixed stand, being more natural, may prove more satisfactory."

General Description.

Luquillo Division: A total of 4,055,966 seedlings plus 44,690.3 pounds of seeds were used in a total of 3,925.8 * acres in which about 27 species were represented.

The land in process of reforestation had been divided for administrative purposes into planting projects as follows: El Verde, Pizá, Sabana, Coca Valley, Del Valle, and Ciénega Alta. Each project, in turn, was divided into plantations, following planting handbook procedure. In all, 54 different plantations were established. Gradually the original distribution of species was altered or completely changed by repeated replanting so that for this discussion the plantations were grouped by tracts or group of tracts. A map of the plantations is shown in page 16a.

The working plan recently proposed for Luquillo divides the area into ten working cycles which correspond to the original planting projects as follows:

Planting Projects	Working Cycles
El Verde	Espíritu Santo and Jiménez
Pizá	Espíritu Santo and Cacique
Ciénega Alta	Ciénega Alta and Gurabo
Del Valle	Hicaco
Tract 91	Fajardo
Sabana	Cristal
Coca Valley	Cristal and La Mina

* This figure might not agree with other reports. It includes actual area planted and does not consider plantations dropped or established in areas that had been dropped.

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
LYLE F. WATTS, CHIEF
T. W. NORCROSS, CHIEF, DIVISION OF ENGINEERING

CARIBBEAN NATIONAL FOREST AND PURCHASE UNIT

(LUQUILLO DIVISION)

PUERTO RICO

1945

Scale

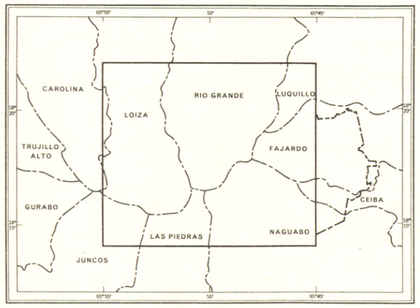
1 0 1 2 Miles

1 0 1 2 3 4 Kilometers

LEGEND

- National Forest boundary
- Main motor highway
- Good motor road
- Poor motor road
- Road not passable to motors
- Trail
- House, cabin, or other building
- Permanent bench mark and elevation
- Purchase Unit boundary
- Railroad
- Guard station
- Triangulation station
- 1304 Elevation point
- Land acquired or being acquired
- K14.2 Kilometer marker

Supervisor's headquarters at Rio Piedras



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COCA VALLEY PLANTATIONS

SABANA PLANTATIONS

DEL VALLE AND TRACT 91

Compiled at Washington Office from U.S.G.S. field sheets and quadrangles of P.R. based on aerial photographs and from Forest Service surveys, by S. Loiacono, January, 1945. Traced by F. E. Sizer.

Longitude west from Greenwich

The total area of plantations established is as follows:

Table 5. Total Area and Number of Plantations Established in the Luquillo Division

Project	Area in plantations (Acres)	Number of plantations
El Verde and Jiménez	180	3
Pizá	571	6
Ciénega Alta	1,525.8	26
Sabana and Coca	953	7
Del Valle	696	12
Total	3,925.8	54

The total amount of trees and seeds used up to June 1945 is shown below:

Table 6. Trees and Seeds Planted or Seeded in the Luquillo Division from Jan. 1934 to June 1945.

Species	Seedlings	Seeds
		Pounds
Albizzia lebbeck	46,150	
Andira jamaicensis	1,975	24,601.8
Byrsonima spicata	19,169	
Calophyllum calaba		12,660.2
Casuarina equisetifolia	121,770	
Cedrela mexicana	525,950	
Ceiba pentandra	5,500	
Cordia alliodora	344,685	
Dalberghia sissoo	60,920	
Eucalyptus citriodora	2,150	
Eucalyptus robusta	17,650	
Eucalyptus spp.	4,640	
Guarea trichilioides	63,891	
Hymenaea courbaril	3,900	544

Table 6. (Cont.)

Species	Seedlings	Seeds
		Pounds
Jambosa jambos	1,975	
Lucuma multiflora		6,384.3
Manilkara nitida	19,450	
Montezuma speciosissima	206,359	
Ocotea moschata		500
Petitia domingensis	191,105	
Sciacassia siamea	43,155	
Swietenia candollei	405,742	
Swietenia macrophylla	700,460	
Swietenia mahagoni	963,902	
Tabebuia pallida	232,625	
Tectona grandis	63.543	
Vitex divaricata	9,300	
Total	4,055,966	44,690.3

If the pounds are converted to the total amount of seeds, an additional 2,029,840 seeds are obtained. This makes a total of 6,085,806 seeds and seedlings. The total area in plantations is 3925.8 acres, but the area actually planted was figured at 2866 acres. The total amount of seeds and seedlings planted and replanted per acre equals 2123. Since planting and seeding was done at approximately 1000 per acre, it is evident that enough planting stock was used to plant the whole area twice. This is also shown when the total amount of planting material is figured separately for original planting and replanting. The total amount of seedlings used was 2,233,064 for original planting and 1,822,902 for replanting. The seeds used for

original planting and replanting were 20,235.4 pounds and 24,454.9 pounds respectively.

It would be difficult to trace low survival to any one factor or set of factors even if the evidence would have been present at the time of the survey. Results of planting are the consequence of a complicated series of events and conditions such as choice of planting sites, selection of species, time of planting, weather, quality of supervision, amount of knowledge, and experience back of the planting plan, etc. Survival is further discussed in the text.

Toro Negro Division: Except the highest section west of Guineo Lake which was well forested, the rest was in need of reforestation, especially the area between Guineo and Matrullas dams.

The technique and general procedure in this division has been similar to the one used in Luquillo, although the work at Toro Negro has been more intensive mainly because of a smaller area of plantations.

The original planting was followed by repeated replantings using several species. Some of the latest replantings have been done in land, which, until recently, had been cultivated by parceleros. Some of the land where tabonuco was harvested has been replanted lately.

Up to June 1945 a total of 3,090,265 seedlings and wildings plus 18,899 pounds of seeds had been planted or direct seeded. The total area of plantations is 1856 acres. About 28 species were planted in 29 different plantations.

The total area of plantations established in the different projects is as follows:

Table 7. Total Area and Number of Plantations Established in the Toro Negro Division

Project	Area in plantations	Number of plantations
	Acres	
Doña Juana	787	14
Matrullas	737	8
Guineo Lake	332	7
Total	1,856	29

The total amount of trees and seeds planted is shown below:

Table 8. Trees and Seeds Planted or Seeded in the Toro Negro Division from April 1935 to June 1945

Species	Seedlings	Seeds
		(Pounds)
Bambusa spp.	2,350	
Buchenavia capitata	200	
Calophyllum calaba		757
Cedrela mexicana	507,016	
Cordia alliodora	737,158	
Dacryodes excelsa	22,398	
Eucalyptus resinifera	10,800	
Eucalyptus robusta	80,910	
Eucalyptus rostrata	3,800	
Eucalyptus spp.	3,380	
Eugenia stahlii	6,500	
Guarea trichilioides	125,401	
Hymenaea courbaril	14	
Lucuma multiflora		15,293
Manilkara nitida	3,500	

Table 8 (Cont.)

Species	Seedlings	Seeds
		(Pounds)
Montezuma speciosissima	142,785	
Ocotea moschata	1,000	2,849
Petitia domingensis	10,010	
Sideroxylon foetidissimum	2,075	
Swietenia candollei	204,990	
Swietenia macrophylla	931,536	
Swietenia mahagoni	61,843	
Tabebuia pallida	42,200	
Tectona grandis	1,500	
Vitex divaricata	188,899	
Total	3,090,265	18,899

If the total amount of seeds is added to the seedlings and wildings, a total of 3,729,125 seeds and seedlings is obtained. The total area planted is 1856 acres; thus, an average of 2009 seeds and seedlings were planted per acre. Because of low original survival and prolonged replanting, a large amount of planting material was used per acre.

The same or very similar conditions operated in Toro Negro as in Luquillo so that the results obtained are comparable.

RESULTS

Site Factors.

Topography and Soils, Luquillo Division: The relation between the site and the various species planted is of decisive importance and was studied in detail.

CARIBBEAN PURCHASE UNIT

(TORO NEGRO DIVISION)

PUERTO RICO

1946

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
ENOS E. WAYNE, CHIEF
W. W. NORCROSS, CHIEF, DIVISION OF ENGINEERING

Scale

1 0 1 2 Miles

1 0 1 2 3 4 Kilometers

LEGEND

- Purchase Unit boundary
- Main motor highway
- Good motor road
- Poor motor road
- Road not passable to motors
- Trail
- House, cabin, or other building
- Permanent bench mark and elevation
- Railroad
- Ranger station (Report fires here)
- Guard station
- Triangulation station
- 1204 Elevation point
- Land acquired or being acquired
- Kilometer marker
- Electric transmission line
- Supervisor's headquarters at Rio Piedras

MATRULLAS PLANTATIONS

DONA JUANA PLANTATIONS

GUINEO LAKE PLANTATIONS

INDEX OF MUNICIPALITIES

UTUADO, JAYUYA, CIALES, OROCOVIS, ADJUNTAS, PONCE, VILLALBA, JUANA DIAZ, COAMO, PENUELAS

Compiled at Washington Office from U.S.G.S. field sheets and quadrangles of P.R. based on aerial photographs and from Forest Service surveys, by S. Loiseonno, June, 1946. Traced by F. E. Sizer.

Caution: The accuracy of this map in unknown, since compiled from sources of unknown accuracy.

Longitude west from Greenwich

B-3188-D 12-++

The heavy rainfall and the very broken topography of the Luquillo Mountains favor soil degradation. The heavy clays of Catalina and Los Guineos series after losing the top soil become a deep mass of nearly inert clay low in minerals, organic matter, and biological activity. Although losses by erosion are high in Mucara and similar soils, these soils rest upon rapidly decomposing rocks which constitute a reservoir of plant nutrients. These nutrients are gradually released and made available to plants. Mineral content is higher than in the Catalina and Los Guineos, and leaching and acidity are lower too.

Relief is the most striking factor affecting site-species relationships. Differences between concave and convex slopes have been recognized by farmers in their selection of sites for agricultural crops. R.C. Roberts(9 brought out this relation when referring to coffee. "In equal areas crop production generally is about four times greater on concave than on convex slopes. The soils on the concave slopes are higher in organic matter and have thicker surface layers than those on the convex slopes, owing to a gradual accumulation of soil and plant moisture."

S. E. Wilds (14) states: "Hill tops, ridges and similar elevated portions of topography receive much light and heat; they are exposed to the wind and their available moisture is at a minimum. The valleys and basins receive on the contrary a smaller amount of light and heat, but an abundance of moisture."

Probably run-off considerations and soil accumulation are more influential in site differentiation in this forest. Three different sites are distinguished. These are: (1) lower concave slopes and valleys, (2) uniform slopes, and (3) ridges or upper convex slopes.

They are best described by soil removal and deposition which is as follows:

Ridges - soil removal without replenishment from above.

Slopes - replenishment from ridge and soil removal to valleys

Valleys - deposition from above and little or no soil loss

Naturally, there are no sharp lines between the divisions which gradually fit into each other. The upper slopes differ little from ridges, and the lower part of uniform slopes are similar to valleys. In almost each acre, more than one type is represented. It is very difficult to estimate the area in each of the three sites. The acreage in each site was estimated as follows:

Site	Per cent	Area
Ridges	32	1256.1
Slopes	51.2	2010.2
Valleys	16.8	659.5

Slopes vary from 10 to 80 per cent but mostly between 20 and 30 per cent. The ridges range from 15 per cent upwards, mostly around 35 per cent. Valleys show a much narrower range from 5 to 30 per cent with the greater frequency between 10 and 15 per cent.

Clear cut differences were not obtained when sites were compared on the basis of annual growth in diameter and height. In part this was due to a difficulty in separating several ages in stands, but mainly to different degrees of soil deterioration. This fact introduces another variable in addition to the relief. The distribution of the 14 sample plots measured in the best stands is as follows: 3 in the ridges, 7 in the slopes, and 4 in the valleys.

Topography and Soils, Toro Negro Division: In the area occupied by plantations in the Luquillo Division, the difference between convex

and concave slopes was considered to be the most influential factor in site differentiation. In the Toro Negro Division, on the other hand, the effect of such topographical features is not so evident. Although the difference between valleys and ridges is also perceptible, soil degradation is accelerated by the removal of the forest cover, irrespective of topography.

Soils in Toro Negro consist predominantly of the yellow colored heavy clays of high elevations, particularly Los Guineos clay. The more open-textured soils like Alonso clay and Múcara are rather the exception. In Luquillo the plantations are located on the outer lower fringes of the range where there is a higher proportion of the light-textured more favorable soils.

In Toro Negro the same topographic features as ridges, slopes and valleys are evident, but the following two main sites are considered more influential: (1) severely degraded soils and (2) slightly degraded soils.

Variation in slopes is large, usually between 15 and 90 per cent.

The process of soil degradation mentioned before is reflected in the agricultural practices in Toro Negro. Hardly any crops that require open cultivation are grown. Even in the level areas, soils degrade very fast after the forest cover or the coffee woodland is removed. Since profitable cultivation with open-grown crops can hardly be expected to go beyond the fifth year, a considerable portion of the area is left as unimproved pastures. In many instances no attempt is made at cultivation after removal of the forest cover, and poor pastures follow the clearing of the forest.

This soil relationship seems to be responsible for the predominance of the coffee-type of cultivation at the higher elevations. This fact suggests a type of forest management with a minimum of soil disturbance and exposure as occurs with the natural-forest type of stand establishment.

The extent to which the artificial and parklike stands of Eucalyptus fit in the forest management of Toro Negro is hard to realize at present.

Exposure: No evidence was obtained that the kind of exposure affects the plantations enough to be noticeable.

Beard (2) considers that increased exposure to wind with higher elevation brings a corresponding increase in the evaporating ability of the air. A rise in elevation results in lowering the temperature and increasing rainfall, which gradually produces a state of physiological drought. This brings about a gradual lowering of the canopy, culminating in alpine woodland.

In the Caribbean National Forest there is sufficient humidity in excess of evaporation so that moisture is not a limiting factor.

The plantations to date have not been exposed to hurricanes. When this happens, it is probable that stands to the windward side will be more affected.

Drainage: Although the land being reforested is generally located on steep slopes, lack of drainage is a possibility because of two conditions.

(1) Very high rainfall

(2) Preponderance of heavy clay soils, some of which are underlaid by clay pans.

One of the most undesirable features of the heavy clay soils when the topsoil is removed by erosion, is their apparent lack of drainage. The same soils when under a forest cover, have adequate drainage, especially for seedlings and small trees. The difference in soil qualities obtained by the addition of a thin layer of the top forest soil is remarkable.

Survival examinations often showed water stagnation in the upper layer and roting of the stem and root system of the seedlings. Those species like roble, Eucalyptus, maría, etc. which are successful in degraded sites, apparently are tolerant to such lack of drainage in the uppermost layers.

Differential drainage requirements do not seem to be limited to the seedling stage. The artificial regeneration of Spanish cedar which so far remains an unsolved silvicultural problem, is recognized to have a strong connection with drainage and aereation of the root system.

It was also noticed that Dominican mahogany was thrifty only in the very well-drained Panduras soils in Del Valle. Capá prieto is a tree of very well-drained localities.

In general, drainage needs more consideration in the Toro Negro plantations than in Luquillo, because the plantations are located at higher elevations.

Ground Cover: Openings are not naturally found in the mesophytic forests. These are the result of continued disturbance of the forest growth to make room for agricultural crops or grazing. Sites without volunteer woody growth, or which were in grass at time pf planting, had been degraded through misuse and exposure. Evidence shows that only a few species can be established under such conditions. These species are maría, Eucalyptus, capá blanco, roble, and pomarrosa. María, roble, and pomarrosa do well in degraded sites and are able to compete successfully with weeds. Capá blanco and Eucalyptus require frequent weedings, especially the latter species which is very sensitive to weed competition. However, Eucalyptus grows so fast that in two years or so very little maintenance is needed.

Volunteer forest growth rapidly improves the soil and thus creates favorable soil conditions for tree growth. Also it maintains favorable humidity and reduces weeds and vines.

Climax species, which as a rule are more exacting, do not appear until the site has been improved by pioneer species.

The lack of appreciation of ecological succession resulted in the failure of climax species like mahogany, capá prieto, nuez moscada, when planted in open degraded sites. The majority of the species used in reforestation were climax species. The following species grow well when planted under forest conditions. Capá prieto, guaraguao, algarrobo, jácana, ausubo, nuez moscada, pomarrosa and broadleaved mahogany.

Guaraguao, ausubo, pomarrosa, and nuez moscada, are the most tolerant species in this group.

Trees growing under a canopy are usually of good form and the intermediate cuttings are provided by the natural stands. For this reason only enough trees of the valuable species need to be planted to assure the crop trees.

PLANTING PRACTICE

Planting Stock.

Nursery seedlings, seeds, wildings and transplants have been used in planting. María has been direct seeded with great success. Plantations established with roble and guaraguao wildings have had a very high survival. Transplants are now used with Eucalyptus and Casuarina.

Overgrown stock gives poor results, unless it is cut back to 1 or 2 inches. Good survival and growth have been obtained by cutting back large stock which have grown wide apart in the nursery, using such species as broadleaved mahogany, capá prieto, teak, higuerillo and guaraguao.

Planting Season.

The time of planting is generally determined by the rainy season. In both divisions rainfall is ample so that as a whole, lack of humidity is not a limiting factor.

Rainless periods as short as two weeks can affect the survival of plantations because of the rapid drying of the topsoil. Low survival may occur in a month of high total rainfall concentrated during one or two weeks. The significance of such short rainless periods is familiar to field men but can not be appreciated from the mean monthly rainfall. The cooler and more uniform climate of the Toro Negro Division permits practically year-around planting.

Wildings which can be held without getting overgrown can be planted during the periods of most favorable weather. Local nurseries close to the planting sites are also advantageous in this respect.

Ground Preparation.

When the role of volunteer trees of inferior species was less appreciated, ground preparation consisted of removing trees or saplings of inferior species. This was expensive and generally not necessary. An example of such specifications is shown in page 121.

The procedure now used consists in removing vines and allowing volunteer trees to grow. The introduction of better species is done gradually using the natural stand as a shelterwood.

Individual "coronas" for every tree are used with species grown in the open. Coronas are circular spots, 2 to 3 feet in diameter, which are kept free of vines and herbaceous vegetation.

Method of Planting.

The method of planting has not been changed. The pick-mattock is the tool universally used because of the heavy clay soils and the abundance of rocks and large roots.

Spacing is irregular because of broken topography, rocks, presence of natural trees, etc. In the open, trees are spaced 8 ft. by 8 ft. Underplanting is done at a considerable wider spacing at approximately 25 ft. by 25 ft.

Little is known about the mixture of species. More information is necessary before any type of mixture is recommended. It is undesirable to mix species of different rates of growth in alternate rows unless the slower grower is an understory species. The mixture of Dominican mahogany with more rapid-growing species has resulted in the elimination of the mahogany. This is evident particularly in Del Valle plantations.

As a result of heavy replantings using different species, plantations are well mixed.

Mixing by groups is probably the safest and most adequate procedure. It consists in planting the different species according to site requirements. Since sites are so variable, the stands will consist of more than one species, each planted in the site to which it is best suited. Different species will be planted in the ridges and in the valleys so that a plantation of any size will be mixed.

SURVIVAL AND GENERAL CONDITIONS OF PLANTATIONS

Survival.

The evidence of the direct causes of low survival was either lacking or masked by other factors. For this reason the specifications of the

plantation survey did not require the determination of the direct causes of survival.

It is considered that the most important factors contributing to a low survival were as follows:

1. Large scale work by relief organizations carried within a relatively short period of time.
2. Difficult and highly variable site conditions involving degraded sites and intense competition by weeds and vines.
3. Lack of research data and experience with the establishment of plantations of tropical hardwoods.

The knowledge about reforestation problems has increased with research and with the experience obtained in handling the plantations. A higher survival and thriftiness and more uniform stands are now obtained as a result of the following:

1. Great reduction in the number of species used. During a 10-year period over 35 species were used in this forest. The present planting policy requires the use of four species pending experimental trials in progress.
2. A better recognition of the site problems involved and the use of tree species accordingly.
3. The formulation of a planting policy based on results obtained to date. The time element is now more favorable since planting operations are small and can be planned ahead of time.
4. Reduction in the size of the planting crews. The large crews of relief workers have given place to small crews of permanent forest workers. Supervision of these crews

can be done more effectively than in the early days.

The circumstances mentioned above have required a long process of trial and error to arrive at the present knowledge of species and site adaptation.

The very heterogeneous site and cover resulted in very uneven and mixed stands where trees occur in all ages from one to eleven years.

The results obtained in the Caribbean National Forest show that as far as survival, the species can be divided in three groups as follows:

Table 9. Survival Classes of Different Species in the Caribbean National Forest

High survival 50-100%	Fair survival 25-50%	Low survival 0-25%
Ausubo	Albizzia lebbeck	Algarrobo
Capá blanco	Ash (Fraxinus)	Casuarina
Eucalyptus resinifera	Broadleaved mahogany	Ceiba
Eucalyptus robusta	Capá prieto	Dalberghia
Guaraguao	Cassia de Siam	Dominican mahogany
* Guayabota	Higuerillo	Eucalyptus citriodora
* Jácana	Pomarrosa (plants)	Maricao
Maga	Teak	Moca
* María		Negra lora
* Nuez moscada		Spanish cedar
* Pomarrosa		Tabonuco
Roble		Tortugo amarillo

* direct seeded

General Condition of the Plantations.

The following estimate shows the general situation of plantations in the early part of 1945. Every separate plantation or groups of plantations were considered individually. The degree of success was determined by the percentage of the area occupied by species known to have succeeded. This estimate did not consider the effects of natural regeneration. Because of this, many areas which are rated low by this classification or understocked, might have enough reproduction to make further planting

unnecessary. This estimate was done primarily to determine the results of artificial regeneration.

Table 10. Area Covered by Planting and Condition of the Different Projects

Forest units	Area in plantations	Area actually planted	Successful area	Percentage of successful stands
	Acres	Acres	Acres	
Luquillo Division:				
El Verde and Jiménez	180	180	50	28
Pizá	571	467	315	67
Ciénega Alta	1,525.8	989	343	34
Sabana and Coca Valley	953	815	445	55
Del Valle	696	415	175	42
Total	3,925.8	2,866	1,328	46
Toro Negro Division:				
Doña Juana	787	439	262	60
Matrullas	737	376	228	60
Guineo Lake	332	332	230	70
Total	1,856	1,147	720	63
GRAND TOTAL CARIBBEAN NATIONAL FOREST	5,781.8	4,013	2,048	51

PLANTATION CARE

Weeding and Maintenance.

When the survey was initiated, portions of the plantations were under combined agriculture and forestry use. This method of plantation maintenance consists in growing subsistence crops between the rows of trees. At that time it was important to find out how the two systems compared. Plantations maintained by forest service crews use the system of coronas.

The application of land utility classes to our land utilization policy plus the administrative difficulties of handling a large number of permittees have eliminated combined agriculture and forestry use

on the same area of land. Thus, the comparison between both methods of maintenance has lost a great deal of its interest and significance. The following facts are familiar to personnel directly in touch with plantation management.

1. Inter-cultivation with agricultural crops gives a decided stimulus to the early growth of the forest trees and probably increases survival. Some species like teak require clean cultivation for best results. In some projects a considerable saving was done in maintenance when a large area was maintained by parceleros. After the trees are out of the reach of the weeds, through cultivation of the soil might be harmful, especially if done close to the trees. Often the rapid growth and thriftiness of the intercultivated stands resulted from their location in the concave slopes and the most fertile sites.
2. At any time only fractions of the total area of the plantations were cultivated so it was always necessary to keep weeding crews in a larger portion of the plantations.
3. After the trees are 5 feet tall or over, there is some competition between the planted trees and agricultural crops such as bananas,
4. There is danger of severe soil erosion by cultivation of steep slopes.
5. Unlimited grazing of the parceleros' cattle and other animals might result in some harm to the plantations.
6. Since planting practices have changed so that maintenance expenses will be lower, there will be less need of cultivation even if it had shown to be successful. The plantation maintenance done at present consists only of vine and weed cutting around

each small tree plus vine removal from taller stands.

Pruning.

Pruning was done in the past but was soon discontinued because of defective work.

Because of low stocking, and therefore wide spacing, many trees of such species like capá prieto and maría have formed thick branches. In more dense stands hardly any pruning would have been necessary.

Unless growing close, capá blanco requires pruning.

Pruning should be done when branches are small and easy to remove. This operation is better done at frequent intervals in connection with maintenance work. The removal of live branches should be done gradually as excessive pruning can weaken the trees. Only the best trees, which have chances of becoming crop trees, should be pruned. Skilled and well-trained personnel should be used in this work.

Thinning and Liberation.

Although stands are about 10 years old, thinning is not yet considered necessary. This is the result of the occurrence of trees of different ages, the mixed and very heterogeneous stands, and of the low stocking.

Planting under faster growing natural trees requires that the more valuable planted trees be released from such competition. During the last two years a considerable amount of liberation from competition of volunteer trees has been done.

There is evidence of serious suppression of broadleaved mahogany in the Coca Valley plantations. Although liberation was done over most of the area, it was not done soon enough, and many trees were mishapen.

The most vigorous fastest growing crop trees suffer first and during a longer period. Fast-growing species like capá prieto, maga, and broadleaved mahogany in good sites require an early liberation.

COSTS OF ESTABLISHMENT AND MAINTENANCE

The average cost per acre for plantation establishment and maintenance is shown in table 11. The costs do not include overhead, but only the permanent supervision used directly in the field. Costs are based on labor wages paid in the Caribbean National Forest between the years 1935 and 1940.

Table 11. Average Cost Per Acre of Planting and Weeding in the Caribbean National Forest

Forest units	Cost of establishment	Cumulative cost at the end of 5 years: Establishment plus replanting	Weeding	Total
Luquillo Division				
Pizá	$28.49	$46.73	$28.13	$74.86
Sabana	29.03	32.80	28.18	60.96
Ciénega Alta	29.00	32.01	23.64	55.65
Del Valle	31.25	35.46	54.60	90.06
Coca Valley	30.26	33.56	40.69	74.25
Average	29.46	35.16	32.40	67.56
Per cent of total	43.60	52.04	47.96	
Toro Negro Division				
Doña Juana	24.14	27.60	36.51	64.01
Matrullas	17.99	35.46	24.30	59.76
Guineo Lake	28.08	40.63	39.40	80.03
Average	22.40	33.01	32.18	65.19
Per cent of total	34.36	50.63	49.37	
Caribbean National Forest				
Average	27.12	34.45	32.33	66.78
Per cent of total	40.61	51.59	48.41	

The costs shown in the table include only up to the end of the first 5-year period. The total investment is higher since in some plantations maintenance is still being done after 11 years.

Although the costs were uniformly high, there is some variation between the different planting projects. The serious vine problem in Del Valle and Coca Valley resulted in very high costs. Failure of the original planting in Pizá raised the cost of establishment and replanting.

In Ciénega Alta, maintenance during the first 5 years was less intense because of a larger area of plantations and maintenance of a considerable area of plantations by parceleros. In Sabana a large area was in second growth and degraded forest, so there was less planting and maintenance to do.

Costs were similarly high in the Toro Negro Division. The low cost of establishment in Matrullas was the result of a large area in coffee shade where little preparation was done previous to planting. Replanting costs were high because of a very low survival in the original planting. The existence of the coffee shade also contributed to low weeding costs. The parceleros maintained a large area of plantations.

In Guineo Lake and Doña Juana a greater proportion of the plantations are in the open; thus, they require more frequent weedings.

During the first 5-year period the cost of establishment was over 40 per cent of the total cost. This percentage gradually decreases after the fifth year since weeding expenses continued thereafter.

The average total cost per acre was $67.56 and $65.19 for the Luquillo and the Toro Negro Divisions respectively. The total average cost per acre was $66.78.

In the Luquillo and Toro Negro Divisions, weeding constitutes 47.96 and 49.37 per cent respectively of the total cost for the first 5-year period. The general average for the forest is 48.41 per cent.

The cost of the original establishment was divided as follows:

Table 12. Cost of Establishment in Per cent

Divisions	Planting stock	Ground preparation	Planting	Transportation	Other
Luquillo	7.63	67.49	21.00	1.34	2.54
Toro Negro	16.99	57.33	23.48	.50	1.70

Except for the higher cost of trees in Toro Negro, other expenses were similar. This difference is the result of the use of local highland nurseries where cost of seedlings is higher. Ground preparation constitutes up to two-thirds of the cost of establishment.

This work if repeated at present, will be more expensive because of higher wages. The following regeneration procedure has been found to be considerably less expensive:

1. Do not plant species which require continued weeding during a long period in open-weedy sites.
2. A large saving in planting and weeding is obtained when plantations are established under a shelterwood.

GENERAL DATA ON SPECIES

Albizzia lebbeck, albizzia, cassia amarilla.

Albizzia has been little used for reforestation. In other parts of the island its main use has been as a roadside tree. It was planted to fill in blanks mostly in degraded sites. Survival was good and trees were thrifty. It has shown ability to stand weed competition. Three-

to four-year-old trees were less than 1 inch d.b.h., and not over 5 feet tall.

Andira jamaicensis, moca.

Moca was planted as a complement to the nursery stock during the early years after the initiation of the planting program in 1935 and 1936. Direct seeding was done in mixture with other species as Dominican mahogany and cedar.

The germination was fairly good, but mice ate the tender seedlings thereafter until not much was left of the original sowings. Injury was highest in deforested sites. Wildings are found all over the plantations, but the concentration in any one part is low. It is hard to distinguish planted seedlings from wildings.

Growth has been exceptionally low. As a rule, trees were 5 feet or less in height at the time of the survey.

Although in poor sites seedlings were chlorotic, general results did not depend on the site.

In a few words, moca failed because of slow growth, poor shrubby form, and susceptibility to mice injury. It should not be considered for artificial reforestation. As it is favored in silvicultural operations, stands will contain a fair amount of trees. Young natural reproduction is found in good numbers because seed trees are abundant, but few trees usually reach adult size.

Bambusa spp., bamboo.

During 1944 and experimental plantation was established in tract 20 above 3,000 feet elevation. Over 2000 clumps of exotic species were planted. Although survival and thriftiness of the

common bamboo are very good in this area, the experimental planting failed. A long period elapsed between lifting and planting. Drying up of the clumps during storage and transportation was probably the cause of the poor results obtained.

Buchenavia capitata, granadillo.

Next to tabonuco, granadillo is probably the most abundant timber tree of good dimensions in the Toro Negro Division. Undoubtedly, its ability to sprout, and the fact that it is not in large demand, have contributed to its persistence. Some trees are known to bear fruits heavily, but they seem to do so at long intervals. During 1939 a group of 200 seedlings were planted close to the Doña Juana nursery in an open-degraded site. One tree was 1.9 inches in diameter and 10 feet tall after 6 years. It was thrifty and of very good form.

Bucida buceras, ucar.

Ucar was accidentally introduced in Doña Juana during 1937 from lower elevations. A few trees survived and have been growing well. On the average they were about 2 inches in diameter and 10 to 12 feet tall after 8 years. Form was good. Although this is a very promising species for lower elevations, it does not belong in the higher elevations.

Byrsonima spicata, maricao.

Maricao is abundant in second-growth stands and degraded forests. When open-grown, it is usually umbrella-shaped and of poor form. Trees are medium sized. Its wood is considered useful.

In the Luquillo Division maricao was planted on a limited scale, mostly in open-degraded sites. Survival was very low. It is regarded

as a difficult species to transplant. Six-year-old trees were 1 to 2 inches in diameter and 12 to 15 feet tall, very thrifty and of good form. The very good health of the trees in spite of the degraded site is striking.

During 1936 a few trees were planted in the Doña Juana nursery in a very degraded slope. Trees were 3 to 4 inches in diameter and 12 to 15 feet tall after 9 years. One tree had very good form, but the rest were poor and chlorotic.

No insects or diseases have been noticed.

In one instance, fruits which had been stored at ordinary temperature during one year produced abundant seedlings when direct seeded.

Calophyllum calaba, maría, Santa María.

Because of its ability to survive in degraded and tough sites and to compete with vegetation, maría has been widely used in plantations. It has shown adaptability to a wide range of conditions from the dry southwest to the humid areas at higher elevations. Direct seeding has been used with good results, except occasional low survival and a longer wait when seeds are used instead of plants. Occasional weeding is necessary until the trees overtop the weeds.

Seeding has been done more extensively in Pizá but it was done steadily in all projects until 1942.

Survival depends mostly upon germination percentage which varies with seed viability. In one study, germination was negligible the first time, but upon resowing, 72 and 66 per cent germination was obtained after 6 months and 1 year respectively. This difference

resulted from better seed quality and careful discarding of unsound hollow fruits.

Most of the maría stands were small to be worth measuring. The following data is from a stand measured in Pizá.

Table 13. Stand in María Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Pure, 5 to 8 years from seed		
1	76	32	108
2	176	44	220
3	64	-	64
4	28	4	32
Total	344	80	424

It is not easy to separate the different ages, however, it is certain that the 3-inch trees are from the 1936 sowing, and thus 8 years old. Average d.b.h. of the satisfactory or good trees is 1.20 inches. This is one of the largest stands with 81 per cent of good trees. The tallest trees were 20 feet high.

This site is a high windy slope of degraded Los Guineos clay. At time of the survey there was a 13-per cent windfall among seedlings 1/2 inch in diameter.

One stand in tract 91 located on a site better than the average was 6 to 8 years old and trees had an average diameter of 4 inches, and a maximum diameter of 6 inches. Average height was 20 feet and maximum height 25 feet.

Apparently growth speeds up (especially diameter growth) after the first 6-year period. The following average annual growth of maría gives some indications of this fact.

Table 14. Average Annual Growth of María

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Ridge	5	1	.1	.2	.6	1
	8	1	.25	.375	1.87	2.5
Slope	4	1	.12	.37	2.0	3.0
	5	2	.175	.3	2.2	3.0
	6	2	.21	.33	1.5	2.0
	8	1	.37	.44	1.88	2.55

In Del Valle, 13-year-old trees had an average diameter of about 5 inches. The largest trees were 8 inches in diameter and 35 feet tall. María trees are mixed with Honduras mahogany, maga, and capá blanco of the same age. María is the best of all because of its good form and thriftiness.

Because of the low survival of the original sowing in Pizá, the largest trees have grown wide apart and have formed thick side branches. When trees are close, the form is good.

Some pruning is necessary where stands are irregular and widely spaced. As a rule, no removal of overstory is needed as stands are for the most part in the open. Likewise, no thinning of plantations seems necessary for the near future.

During 1939, 757 pounds were direct seeded in Doña Juana and Guineo plantations. Survival was satisfactory, trees being up to 1 1/2 inches in diameter, and between 3 and 8 feet tall after 6 years. Trees are thrifty but not promising since they are surrounded by species which are more suitable for the locality.

No insects or diseases have been found which might be a limiting factor in growing maría. The leaves are commonly affected by galls but this does not seem to affect the health of the trees. The seed

crop is heavily affected by a weevil (not identified) which causes seed drop, and undoubtedly affects the quality of the seed.

Bats and nocturnal birds are very effective agents in the distribution of this species. They eat the rind, and in so doing, distribute the seed.

In the Luquillo Division, differently from all other forests in the island, trees suitable for sawtimber form a substantial portion of the total stumpage. Most of the plantations are of the long rotation lumber-producing species, so there is not enough room left for quick-growing short rotation crops and products like yokes, railway ties, house posts, etc. The land to be acquired in the future will be for the most part, badly cut-over and eroded so that a forest cover will have to be re-established. In order to have the necessary supply of a short-rotation crop in the future, degraded sites will be planted to roble.

Casuarina equisetifolia, Australian pine, pino.

Casuarina was not generally planted in government lands in the Luquillo Mountains until 1941 and 1942 when it was distributed to permittees. Private owners across the government boundary have established a few plantations at lower elevations and most of them have been successful. Results of planting in government lands are very variable. In general, it is believed that survival was low. Many trees became chlorotic and unthrifty. Trees did well along the lower part of the El Verde road and in some of the parcels.

The outstanding plantation was measured at Sabana during February 1945. It was established in a good site at an elevation of about 500 feet where all factors are very favorable. Land is agricultural, better than the average soil used in reforestation.

Survival was evidently very high. Planting distances are irregular and vary between 8 and 9 feet. There is not an exact date of planting, but 1937 is the most probable date, thus making the stand 8 years old. A total of 146 trees were measured and classified according to crown classes. Height varied between 40 and 55 feet. Average diameter was 5 inches.

Distribution of the diameters and classification of the crown classes from a .3-acre plot are shown in the following table.

Table 15. Diameter Classification and Crown Classes of Casuarina

D.B.H. class	Dominant	Codominant	Intermediate	Suppressed	Total
Inches					
2	-	-	-	3	3
3	-	-	4	7	11
4	-	2	29	2	33
5	-	29	20	-	49
6	15	16	1	-	32
7	16	-	-	-	16
8	1	1	-	-	2
Total	32	48	54	12	146

The stand had a basal area of 71 square feet per acre. The dominants and codominants account for over two-thirds of the basal area. The bulk of the stand lies between 4 and 6 inches in diameter. One-third of the stand is 6 inches or over. Very few of the stands in Luquillo will compare to this one. Casuarina is a desirable species to grow, but it can hardly be claimed that it belongs within the present boundaries of this forest. It has been very successful farther down along the coastal plain and large river valleys.

Cedrela mexicana, Spanish cedar, cedro.

Cedar was one of the first species planted from 1934-36 in most of the projects. It was used over a large area and failed in most sites.

As a rule, survival was 60 per cent or over during the first year, but rapidly declined until not many trees were left by the end of the second or third years. This might have been the result of weed competition, shoot borer attack, lack of adaptability, or a combination of the three. In heavy clay soils at El Verde, trees persisted for a long time in an unthrifty condition until they were cut down.

Investigators agree that the site is of decisive importance and that it is more a soil-moisture relationship.

In Puerto Rico this species has failed when planted indiscriminately, although occasional good trees are found scattered along roads and backyards. Small successful stands have been noticed in the drier northwest and less humid areas.

Cedar has met with some degree of success only in a small stand in Del Valle plantations. A small amount of trees remain in plantations 1, 2 and 3 in the extreme southeastern part. The soil is Picachos stony clay which is particularly poorly drained at this place. However, trees are growing in a very thin layer of soil resting over a bed of big boulders which gives a very effective drainage. Land slopes from 8 to 20 per cent. The site is not over 1000 feet in elevation. The closest weather station at 1800 feet registered an average of 149 inches of rainfall falling in 303 days. That is, air moisture is high, and soil moisture is ample. Trees were planted 8 years ago and had an average height of 20 feet and an average diameter of 5 inches. The largest trees were 25 feet tall and 9 inches d.b.h.

Trees are found in small groups in places of best drainage. The base of the trunk is raised over the general level of the soil. Some trees were actually lying over rocks. Trees are either mixed with the natural second growth which they have overgrown, or with capá blanco of the same age and size and with whom they seem to mix well.

The shoot borer is a serious insect pest. Its attacks become more evident in unthrifty stands.

Only a small group of trees remain in the old conversion project in Doña Juana. Site is very well-drained since it is precipitous. Soil is loose, dark colored, probably a Mucara clay loam. Trees looked healthy, and after 9 years were 3 to 3 1/2 inches d.b.h. and 20 to 25 feet tall.

In addition to the shoot borer, the foliage is heavily attacked by a leaf hopper, Dikraneura cedrela, which causes premature defoliation.

Large-scale plantings of cedar have been discontinued pending results of investigations, but it seems certain that whatever happens, large plantations scattered indiscriminately over a large area will not be repeated.

Cedrela odorata, cedro, cedro hembra.

Our native species of cedar occurs over a wide range in humid areas from low to high elevations. It has been so heavily exploited that only scattered young trees are found. Seed trees are scarce and, moreover, they produce less seed and at longer intervals than C. mexicana.

Native cedar was planted during 1944 on an experimental scale in tract 20 in Toro Negro.

Trees have been planted under different degrees of drainage. Some trees were planted on mounds similar to those used with citrus fruits. The Toro Negro plantings vary from chlorotic and unthrifty to very healthy.

Cedrela toona, cedro, cedar.

This species was introduced between 1928-29 from the East by the Forest Service and planted in a few localities. It was found in El Verde, planted by the former owner. There is no record of this planting, but it was done presumably in 1929.

This stand of Cedrela toona has attracted the attention because of the good thriftiness and better growth than either Spanish cedar and West Indian mahogany, all planted in contiguous degraded sites.

A group of 50 trees grown in three different locations were measured during August 1944, that is, about 15 years after planting. The size of trees varied considerably from 1.5 inches to 11 inches in diameter. Average d.b.h. was 6.1 inches. Height also varied between 15 and 30 feet, although a few were as small as 8 feet. Such variation is not easy to explain.

The distribution of the diameters and their basal areas is given in the following table.

Table 16. Distribution of Diameters With Basal Areas

D.B.H.	Number	Basal area
Inches		Square feet
1.5-2.5	5	.1418
2.6-3.5	9	.4630
3.6-4.5	6	.5244
4.6-5.5	9	1.2263
5.6-6.5	6	1.2005
6.6-7.5	5	1.3947
7.6-8.5	2	.6671
8.6-9.5	4	1.7501
9.6-10.5	0	-
10.6-11.5	4	2.6056
Total	50	9.9735

Trunks are more solid than those of Spanish cedar. A sample cut from a branch showed development of a pink-red color of the wood at an early age. The largest trees occur in depressions which seem to favor growth and thriftiness. Crowns are wide since trees are in the open. The trees must have been attacked repeatedly by Hypsipyla but results are much less in evidence than in the case of mahogany and Spanish cedar.

During March 1945 a small planting was done in tract 20 of the Toro Negro Division. Trees are adjacent to plantings of native cedar of the same age, so it will be possible to compare the behavior of both species. Early survival was 100 per cent.

Trees produce fruits more regularly and in larger amounts than other species of cedar growing in the island.

Ceiba pentandra, ceiba.

This species is widely distributed in the island as isolated trees at medium elevations, particularly in dry habitats. It was planted in small amounts in the Luquillo Division.

Plantings failed. Not enough information was obtained to determine the cause of low survival.

Since there are no possibilities for the production of kapok on a commercial scale in the island and the wood of ceiba is little used locally, it seems that no further trials with this species are justified.

Cordia alliodora, Spanish elm, capá prieto.

Capá prieto was found growing naturally in the Luquillo Division only in the lower part of Ciénega Alta and El Verde, and usually associated with Múcara soils. This seems to be a remnant from the

east-central section of Cayey-Aibonito where at present it grows naturally and in greater abundance. Capá prieto seems to avoid the areas of higher rainfall and do best in well-drained sites.

Marshall (5) reports that in Trinidad capá prieto grows best between 50 and 75 inches of rainfall, although it is found to a limited extent in rain forests. This seems to check with our natural distribution. It has done well even in the dry Guánica forest with 30 inches of rainfall, although in this place it was planted in a valley. It will be safe to limit plantations to well-drained sites.

Capá prieto has been planted practically in all projects of the Luquillo Division from 1936 to 1941. Trees are scattered. In the degraded clays of Pizá a sprinkling of thrifty trees of good form remain in the sites which previously had been in brush and were not degraded.

The following growth measurements were taken from two plots in the eastern part of tract 105.

Table 17. Stand in Capá Prieto Sample Plot - Slope

D.B.H.	Tree form and number per acre					
	Good	Poor	Total	Good	Poor	Total
(inches)	Mixed 6 years			Mixed 8 years		
1	8	20	28	-	4	4
2	32	40	72	20	32	52
3	72	-	72	48	-	48
4	28	-	28	28	-	28
5	-	-	-	12	-	12
Total	140	60	200	108	36	144

The 6-year-old stand is located on a Múcara slope, mixed with several other species. The average d.b.h. of the good trees was

2.79 inches. Average height was 22 feet, the tallest trees being 26 feet. The 8-year-old plot is located higher up on a moister site in Los Guineos soil. Average d.b.h. of the good trees was 3.5 inches. Average height was 25 feet, the tallest trees being 28 feet. The percentage of good trees was 5 per cent higher in Los Guineos clay (75%).

The latter stand is located in a parcel and has received very good care. In both plots capá prieto does not constitute over 40 per cent of the stands which are a mixture of planted and natural trees of about 10 different species. These stands are better stocked than the average.

Survival has varied from good to low although low survival has been more frequent. Poor nursery stock and heavy attack of leaf spot seem to have been contributing factors. Survival can be improved by the use of adequate planting stock, use of suitable sites, and planting of a smaller number of trees per acre under a shelterwood. In preliminary studies, stump planting has given very high survival.

In the Toro Negro Division capá prieto was planted in large amounts, especially in Matrullas. Survival was very low, particularly in the open sites in the ridges. It was better under the coffee shade trees. Survival varied from 15 to 50 per cent, but usually was closer to the lower figure. At Matrullas trees have made a good growth although a large percentage show lack of vigor, high leaf spot, and lace wing bug attack. One tree was found suffering from a canker like disease. Any other similar cases should be reported promptly since in Trinidad, canker is a limiting factor to the growth of this species.

The old conversion project in Doña Juana is the outstanding plantation in this forest. The soil is a loose clay loam of a dark color, of good texture, and quite stony, similar to Múcara clay loam.

The topography is precipitous. Growth and thriftiness have been very high in spite of an intense weed competition. Average height was 15 feet, the tallest trees being 30 to 35 feet after 8 years. Survival was 85 per cent one year after planting.

Table 18. Stand in Capá Prieto Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Pure stand, 8 years		
1	-	4	4
2	4	-	4
3	36	16	52
4	32	4	36
5	28	-	28
6	16	-	16
Total	116	24	140

The percentage of well-formed vigorous trees was exceptionally high. One tree was found affected by foot rot.

The growth rate from 10 site studies in the Toro Negro Division is shown in table 19.

Table 19. Average Annual Growth of Capá Prieto

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	7	6	.29	.46	1.52	2.53
Valley	8	4	.28	.41	1.61	2.61

The form is good in spite of very open stands but some pruning could be helpful. The occurrence of the best stands in the best-drained soils and in very steep slopes suggests that in high rainfall areas it requires effective drainage for best results.

So far it has been highly successful when underplanted in palm stands in heavy clays. Plantings 4 to 5 years old, at about 3200 feet elevation, had an average height of 8 feet although the tallest were 16 feet high. Average and maximum diameters were 1 and 3 inches respectively. Survival was very high and trees were thrifty.

Capá is growing well in the Guineo plantations above 3000 feet in very steep slopes of Alonso clay. The best trees are found in the lower slopes with deeper soils and more favorable conditions.

Unthrifty stands in good sites should be underplanted if no change takes place within the next two years as this condition may have been the result of poor nursery stock, poor planting, etc.

Capá does not show such a clear cut preference for good sites as broadleaf mahogany or maga, but should not be planted in degraded sites. Trees grow well in upper slopes and ridges, provided the soil has been kept in good condition by means of an overstory. In the Múcara sites the range of adaptability is larger, but even here it should not be planted in degraded slopes. The canopy should be gradually removed as capá is a light demander.

We are not in a position to make recommendations regarding mixtures. However, large concentrations of this species should be avoided to reduce insect and disease attack to which it is susceptible. Guaraguao and capá prieto seem to mix wëll.

The Spanish elm lace wingbug, Monanthia monotropidia, affects the leaves severely but its attack has not been critical. In exposed situations and during dry years, this insect may cause injurious defoliation. The leaf spot attacks the small seedlings and the nursery stock more heavily.

Capá prieto is one of the most desirable species for reforestation. Its range of adaptability is large, growth is rapid, form is good, and its wood is very widely used.

Dacryodes excelsa, tabonuco.

Tabonuco is still one of the most abundant species in the Caribbean National Forest.

Very little planting has been done as it requires to be transplanted with earth. Even with this, survival is low. A small area was direct seeded with poor results.

Small-scale plantings were done in 1936 in good sites along the Doña Juana River. Survival was rather low but the few trees left are very thrifty. They were 1 to 2 inches d.b.h. and 8 to 12 feet tall after 9 years. Average annual growth from site studies was as follows:

Table 20. Average Annual Growth of Tabonuco

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Ridge	9	1	.22	-	1.11	-
Valley	9	2	.17	.26	1.11	1.56

Tabonuco is sensitive to disturbances so that even old stands die off after hurricanes, logging operations, land clearing, etc.

It might be possible to increase stocking by underplanting second growth, palm stands, or degraded forests, but it is not known to what extent trees will eventually survive.

Dalberghia sissoo, Dalberghia.

Dalberghia was planted in the Luquillo Division as early as 1935. Site relationships were soon evident. In the heavy clays early failure

was definite both as to survival and thriftiness. In the Mûcara sites in El Verde and in tract 17, survival varied but a majority of the trees were thrifty.

The best stand is found in a valley in tract 17. The soil is fertile and humid but quite stony. Dalberghia grew rapidly and with great thrift until trees were over 4 inches in diameter. At this stage they were attacked by a disease whose outstanding sympton is a gum exudation. The exudation extends over most of the trunk but the injury is caused by a root rot. Trees were also attacked by the pin-hole weevil, although this injury might be secondary on diseased trees. The tallest trees were 40 feet high. Distribution by diameter classes follows:

Table 21. Stand in Dalberghia Sissoo Sample Plot - Valley

D.B.H.	Tree form and number per acre			
	Good	Poor	Dead	Total
(inches)	Pure stand, 8 years			
1	-	12	-	12
2	8	64	-	72
3	52	60	-	112
4	64	8	8	80
5	96	16	-	112
6	64	-	12	76
7	56	12	-	68
8	28	16	4	48
9	4	8	16	28
Total	372	196	40	608

The percentage of dead trees was low but practically the whole stand showed gum exudation and pin-hole attack so that they will probably die completely with time. Growth is very variable and there is a wide range in size. Sixty-five per cent of the living trees apparently were thrifty but they already showed gummosis. Trees have produced abundant root suckers.

Eucalyptus citriodora, eucalipto, eucalyptus.

A small stand was planted in the Doña Juana nursery about three years ago. The site is a poorly-drained and degraded clay. Growth has been slower than for E. robusta and trees are not as vigorous.

The average and maximum diameters were 2 inches and 3.8 inches respectively, with average and maximum heights of 12 and 20 feet respectively. Further observations will be necessary with this species at Toro Negro.

A few trees of E. citriodora planted five years ago in Pizá, had average diameters varying between 1 and 2 inches. However, one tree planted the same day was 11 inches in diameter. Height ranged between 30 and 45 feet. Shape was generally poor as stems are crooked.

Eucalyptus resinifera, eucalipto, eucalyptus, red mahogany.

In plantings of tract 19A in Toro Negro it had been originally classified as Eucalyptus spp. At present it is referred to as E. resinifera but this classification is not definite yet.

Survival was apparently high although trees were planted with bare roots.

Table 22. Stand in Eucalyptus resinifera Sample Plot -Slope

D.B.H.	Tree form in group of 54 trees		
	Good	Poor	Total
(inches)			
3	3	2	5
4	6	1	7
5	10	2	12
6	14	1	15
7	10	-	10
8	4	-	4
9	1	-	1
Total	48	6	54

Tree form and thrift are good to the extent that 90 per cent of the trees were classified as satisfactory. Trees are growing wide apart but they prune themselves very effectively. Also trees show less taper than E. robusta. Average and maximum heights were 40 and 55 feet respectively.

Stands are for the most part in loose open Alonso clay. Results were not very different in the heavy clays, although growth is affected by the quality of site. Trees are producing seeds in abundance.

Since the stand is open, undergrowth consists of ferns, brush and tall herbs which grow undisturbed. Growth has been fast, over 8 feet per year. The tender growth is subject to breakeage by wind in a high percentage of trees. No uprooting was evident. Eucalyptus has a well-developed root system, so the trees are well anchored.

Stands are not well stocked. A distance of 8 feet by 8 feet is adequate, provided a high initial survival is obtained. Replantings should be done soon so as to have a uniform stand which is important with highly intolerant species. Maintenance should be intensive during the first two years, after which, little care will be necessary. When working on timber rotations, thinnings will probably be needed by the fifth year if stands are close. The coppicing power is good. No insects or diseases have been noticed.

Eucalyptus robusta, eucalipto, eucalyptus, swamp mahogany.

This species of Eucalyptus has been extensively planted in the highlands in the last three or four years. It has been used to fill in blanks in degraded sites. Plantings in Toro Negro started in 1941 and have been continued to the present.

The growth of the following group of trees is typical. Site is poor and has been heavily grazed.

Table 23. Stand in Eucalyptus robusta Sample Plot - Ridge

D.B.H.	Tree form in a group of 66 trees		
	Good	Poor	Total
(inches)			
1	-	2	2
2	3	14	17
3	14	4	18
4	12	1	13
5	14	-	14
6	2	-	2
Total	45	21	66

Trees had an average height of 26 feet, the largest trees being 36 feet. Seventy per cent of the trees were classified as vigorous and of good form. The poor trees are those located in the worst sites or else affected by weed competition or by livestock. In spite of its location in an exposed situation, this stand has stood strong winds well.

The following stand, about 4 years old, is growing in alluvial soil along the Doña Juana River. Site has been cultivated and grazed.

Survival was high and the proportion of good trees was 90 per cent. In this site trees have grown better both in diameter and height than in the ridge. Average height was 30 feet, the maximum being about 40 feet.

Table 24. Stand in Eucalyptus robusta Sample Plot -Lower Slope

D.B.H.	Tree form in a group of 51 trees		
	Good	Poor	Total
(inches)			
1	-	1	1
2	5	3	8
3	13	1	14
4	17	1	18
5	9	1	10
Total	44	7	51

Behavior in a better site which had been in brush and where soil was in good condition is as follows:

Table 25, Stand in Eucalyptus robusta Sample Plot - Lower Slope

D.B.H.	Tree form in a group of 81 trees		
	Good	Poor	Total
(inches)			
3	1	1	2
4	7	2	9
5	28	1	29
6	17	-	17
7	14	-	14
8	9	-	9
9	1	-	1
Total	77	4	81

Average height was 40 feet with maximum of 50 feet. It is noticeable that 95 per cent of the trees were vigorous and of good form in spite of very wide spacing. Eleven per cent of the trees have been broken by winds at about one-third of their height.

Undergrowth consists of vines, grasses, and low brush, which grow ininhibited as a result of a light canopy.

Larger stands are very scattered and open since they originated from replantings in which only a small part of spaces were filled in. Solid replanting at 8 feet by 8 feet, disregarding poor trees of other species, would have been a better policy.

There seems to be variation in the form of E. robusta. Many of the old specimens become mishapen and ugly, showing a twisted trunk. Trees in these conditions are worthless, except for fuel. The same condition has been reported by Troup in India (12).

The literature shows that its wood is not outstanding but is useful for building, piling, wheel work and fence posts. In New Zealand it has been reported as non-resistant to wind damage. The

coppicing power is high.

Gummosis has been observed in a few trees, but gum exudation is probably normal. No injurious insects have been noticed.

So far no thinnings have been made since stands are widely spaced.

Since other species producing wood of wider utility have done well, it is suggested that future plantings should not be limited to E. robusta. Species such as E. resinifera, E. tereticornis, and E. citriodora should also be planted.

Eucalyptus rostrata, eucalipto.

Small amounts of seedlings were planted in the Matrullas Lake plantations. Because trees did not survive, there are not many indications regarding behavior of this species.

Eucalyptus spp., eucalipto.

Eucalyptus has been planted in the Luquillo Division in rather small amounts. Survival must have been low as the few trees found are scattered.

All species require full exposure since the seedling stage. Thus, trees must be kept free from competition.

In a poor site in Sabana a few 5-year-old trees of E. robusta and E. citriodora were 5 inches in diameter and the latter were 25 feet tall on the average, and at least 5 feet taller than the trees of E. robusta. E. citriodora not only had grown faster, but was more thrifty and of better shape. One tree similar to E. tereticornis or E. rostrata was about 40 feet tall and 6.7 inches d.b.h.

The role of Eucalyptus in Luquillo is not yet clear as results to date do not compare with those obtained in the Central Mountains. Lately, a few species have shown good early growth in experimental plantations at medium elevations. Lands to be acquired in Luquillo are located

at lower elevations where Eucalyptus is not so clearly superior. Thus, roble will be used in reforesting any extensive area of open-deforested lands.

Eugenia aeruginea, guasábara.

Occasional trees of guasábara are found in the Central Mountains. They are fairly straight and of good size. Wood is useful, especially when used in contact with the ground. During December 1944 a small amount of wildings were underplanted in palm stands close to the Doña Juana recreational area, both with and without soil. In spite of the small and spindly stock used, survival was high in both cases. Trees were very thrifty at time of examination.

Eugenia jambos, pomarrosa.

Pomarrosa grows naturally in the Toro Negro Division where the cool and humid environment is suitable. It is found mostly west of Guineo Lake but not usually in the high forest.

Its possibility for use in degraded sites has attracted the attention during the later years. It is capable of taking over most any site and produces a high yield of fuelwood per acre.

Pomarrosa has been planted on an experimental scale in low brush and pastures and underplanted beneath sierra palms. Results have shown that it can either be propagated by the use of seeds (broadcasting and direct seeding), or plants. The results of the use of wildings have not been consistent, and in some occasions a low survival has been obtained. Pomarrosa plants are sensitive to planting. A high survival has been obtained when underplanting sierra palm stands. The use of seeds is a sure method of propagation, yet seedlings are slow in getting above the height of the weeds and brush. This is considered a slow method.

It has been suggested as a good undergrowth species for the high ridges and exposed sites where only a low type of forest and sierra palm can grow.

Eugenia stahlii, guayabota.

Guayabota is one of the most common species in Toro Negro, especially at the higher elevations. Since it produces large fruits regularly and in large amounts, it was considered a desirable species to establish by means of direct seeding. A small plantation of 4.4 acres was established during the later part of 1936 in a very degraded site close to the Doña Juana River. Survival was high but growth has been unusually slow. On the average, trees were 1 inch in diameter and about 4 feet tall after 9 years. In the later part of 1944 an experimental underplanting of wildings under palm stands was done near the recreational area. Shortly after planting survival was very high and trees were thrifty.

Fraxinus spp., ash, fresno del Hawaii.

Planting stock was raised by the Forest Service in the early thirties from seed imported from Hawaii. This species is undistinguishable from F. americana or white ash.

Plantings were done in Luquillo, Toro Negro and Maricao Forests, and seedlings were distributed to different localities of the island.

During February 1933 a narrow section was planted around Guineo Lake. There is no record of the number of trees planted. No replanting was done after the first year.

Occasional examinations showed a good survival and thriftiness. The trees grew slowly and were heavily attacked by scale insects so that shoots repeatedly didd back.

During January 1945 a 1/4-acre plot was measured. This stand has received fairly good care.

The following amount of trees were obtained per acre.

Table 26. Stand in Fraxinus spp. Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Pure stand, 12 years		
1	-	12	12
2	4	60	64
3	80	72	152
4	60	36	96
5	40	4	44
6	16	16	32
7	12	-	12
8	4	-	4
Total	216	200	416

Growth has been relatively slow. After 12 years the bulk of trees were 4 inches or less in diameter. Average height was about 15 feet, the largest trees being 20 feet. The form is not good. About 50 per cent of the trees were marked as poor. Site is exposed and many trees are reclining.

The stand was affected by the hurricane of October 1943 and at least 15 per cent of the trees were removed because of wind damage. A very heavy pruning done in August 1944 might have slowed the growth.

The stands in the ravines and valleys of this plantation will probably be more successful.

The trees had shed foliage completely at time of examination in January. Trees along the road had the largest diameters but were short and seldom straight. This plantation is the most successful ash stand found to date.

Guarea trichilioides, guaraguao.

Planting was done first early in 1937 in the Guineo Lake plantations to fill-in very low survival of cedar and mahogany.

Survival was high but thriftiness varied. In the open-degraded sites seedlings got chlorotic and stunted. In the better sites, especially under a shelterwood, trees were 1 to 3 inches in diameter and 6 to 15 feet in height. Growth is variable, but in the better sites trees are generally thrifty. The form of trees is not good as it tends toward a short trunk and a heavy crown, although it might grow straight under forest conditions. The wood is useful and easy to work. It is one of the most common species in humid forests.

Another plantation was established using wildings during 1944. Site is very favorable and early survival was about 90 per cent. Wildings which had been cut back to about 2 feet at time of planting were healthy and vigorous. Some were 1 inch in diameter. The use of large stock is advantageous since trees outgrow the weeds sooner. The rate of growth has been medium to slow.

During 1939 and 1940 palm stands contiguous to the recreational area were underplanted. Survival was high. Trees were thrifty and were 1/2 to 1 inch in diameter and 5 to 10 feet in height when 5 to 6 years old. The growth of guaraguao as determined by site studies is shown in table 27.

Table 27. Average Annual Growth of Guaraguao

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	6	1	.25	-	2	-
Valley	4	1	.13	.25	1.50	2.50

Growth is slower than that of capá prieto, maga, and broadleaved mahogany.

Guaraguao is an understory species and thrives best under forest conditions. Thus, plantings in degraded sites in the open generally fail.

It should mix well with a faster-growing species like capá prieto since it is shade tolerant. More data about its silviculture is needed. The possibilities of raising seedlings in crude nurseries under an overstory should be investigated, since, if successful, it will be a cheap method of raising good planting stock. Wildings are found in coffee plantations and in secondary forests. They are not abundant as roble wildings, but it is possible to get moderate amounts.

Insects have not been observed attacking this species. Wildings are attacked by a circular leaf spot but this disease has not been important to date.

Hymenaea courbaril, algarrobo.

Algarrobo occurs at lower elevations in the Luquillo Mountains but it is not found within the government forests in Toro Negro. Algarrobo is a good coppicer. Because of this factor it is persistent in cut-over stands. It was direct seeded in tract 105 of Ciénega Alta where it occurs naturally. Survival was very low because mice ate the succulent leaves. Probably, weed competition contributed tc low survival.

As usual, growth has been slow. Average annual growth from site studies is as follows:

Table 28. Average Annual Growth of Algarrobo

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Ridge	8	2	.09	.2	.9	1.5

In poor sites, 8-year-old trees from seed were not over 2 inches d.b.h. and 12 feet tall. Trees are usually very thrifty and can thrive in poor exposed sites better than most hardwoods. Seedlings can be started under a canopy, but soon need full overhead light for best growth.

Tree form at first is vine-like, similar to other leguminous species, but after it reaches 6 to 8 feet in height a main leader is formed.

Algarrobo is generally free from insects and diseases. In some localities the attack of mice might be a factor against its artificial or natural regeneration.

It is a desirable species to grow at low elevations since it is a large tree, produces a valuable timber, and can be established by direct seeding.

Lucuma multiflora, jácana.

Jácana is a large tree of humid forests. It is found occasionally probably because of its large seed which is not easily distributed. The timber is not well known although it is considered good for construction.

It has been planted mainly to fill-in blanks or failed spots. It was used in a variety of sites from exposed Múcara ridges to wet heavy clays at higher elevations. It was also used for underplanting and for seeding in the open. Originally it was thought that jácana was suitable for use in poor sites, but it has been found that it gets yellowish and stunted in degraded sites. In better sites, especially under a shelterwood, it grows fairly fast and is exceptionally thrifty and vigorous.

Stands were small and no data was obtained from sample plots. Annual diameter and height growth from site studies were as follows:

Table 29. Average Annual Growth of Jácana

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	5	1	.4	.4	3	4
Slope	6	1	.5	.7	3.3	4.2

Five-year-old stands in favorable sites under a canopy were 1 to 2 inches in diameter and 10 to 20 feet tall. A six-year-old stand mixed with broadleaved mahogany and raised under a shelterwood had 79 per cent of good trees. Average diameter was 2.3 inches. Average and maximum heights were 20 and 25 feet respectively. This is better than the average stand. In good sites, jácana grows faster than maría, but slower than capá prieto or broadleaved mahogany. When growing in the open, trees have a tendency to fall down. This is a further reason for seeding under an overstory.

Survival has been fair to good, although at times germination has been slow. The fruits do not keep for long periods. Large amounts can be obtained under seed trees. Wildings have been used with good results under favorable conditions.

In the Toro Negro Division, large amounts of seed were direct seeded. Survival ranged from fair to good. Germination was high and small seedlings stood adverse conditions and weed competition fairly well.

In the open-degraded slopes trees got chlorotic but continued growing in all but the worst sites. In Toro Negro, growth has been slower than in Luquillo and follows closely the quality of the site. Stands 8-year-old from seed were on the average 1 inch in diameter and 12 feet in height with a maximum of 2 inches and 18 feet respectively. In open-degraded slopes trees of the same age were less than 10 feet tall. Probably, growth and thriftiness of these trees will improve

if sites are allowed to be taken over by second growth.

The growth rate of jácana as determined by site studies in Toro Negro is shown in table 30.

Table 30. Average Annual Growth of Jácana

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	6	7	.18	.35	1.11	3.33
Ridge	8	2	.17	.30	1.13	1.47
Valley	7	3	.18	.30	1.55	2.18

Jácana has shown to be unusually free from insects and diseases.

Magnolia portoricensis, jaguilla, burro.

This species, the counterpart of laurel sabino in the Central Mountains, apparently was abundant but has been heavily exploited. Trees are large. The seed had not been considered viable, but recent sowings made at Río Piedras and at the Galarza nursery have shown that small amounts of seedlings can be obtained. Growth in the nursery has been slow.

Manilkara nitida, ausubo.

Ausubo is one of the most valuable timbers of the island, and the one which has been more intensively exploited in the Luquillo Division. It is not found at the higher elevations of the Central Mountains, but is found on the southern slopes of the Cordillera and probably occurs at lower elevations on the northern slopes.

It is a wood of great beauty, very durable, and suitable for heavy construction. Mostly because of the failure to obtain seeds in the necessary amounts, it has been planted on a small scale. Ausubo is

shade-tolerant and does well under forest stands in the humid areas. It seems to prefer the favorable soil and humidity of dense shelterwoods.

An excellent survival was obtained under a high canopy in tract 48. Five-year-old trees had an average diameter of 2 inches and were 15 to 20 feet tall. Another stand of the same age showed very high survival, and diameter ranged between 1 and 2 inches. Average height was 20 feet. Trees in both stands were thrifty and of excellent form. This rate of growth is almost equal to that of jácana from seed and faster than that of maría from seed.

The stands look more natural than those of any other species. High survival, good growth, thriftiness, good form plus the value of the wood recommend it as a logical species for underplanting. Management of the natural stands will increase the stocking of ausubo considerably. Planting will only be necessary in those forests where seed trees or reproduction are lacking.

No pruning or thinning will be necessary for the present at the Sabana plantations, but the canopy should be opened up to allow better growth.

About 3500 trees were planted in Doña Juana in 1936. So far, trees have shown to be very well adapted to this site. They have stood competition well and are very vigorous. Nine-year-old trees were 2 and 2 1/2 inches in diameter, and 8 to 12 feet in height. The following average annual growth was obtained from site studies.

Table 31. Average Annual Growth of Ausubo

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	9	2	.2	.3	.8	1.6

Evidence indicates that it should be planted in favorable sites in Toro Negro.

So far ausubo has been free from serious insect and disease attack.

Matayba domingensis, negra lora.

Negra lora is fairly common and is a medium-sized tree in second-growth stands and in the high forests in the Central Mountains. It is used for small round timbers and for fuel. It is a very heavy seeder and is fairly abundant. Probably it is a slow grower.

During December 1944 wildings were planted experimentally under the palm stands close to the Doña Juana recreational area. Wildings were transplanted both with bare roots and with earth. Survival was low with bare-rooted wildings and fair when soil was used.

Montezuma speciosissima, maga colorada.

Maga is found naturalized at low elevations in the Múcara soils of western Luquillo where landowners grow it for shade and along fence lines.

It does better on the valleys and lower slopes. In eroded heavy clay soils, trees get chlorotic and stunted. Survival is generally high in favorable sites. The following plot was measured in a 45-per cent Múcara slope under cultivation.

Table 32. Stand in Maga Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 5 years		
1	-	8	8
2	56	56	112
3	132	16	148
4	24	-	24
Total	212	80	292

This is the best stand of this species in Luquillo. Trees were 4 to 6 years old, the average trees being 30 feet and the tallest 40 feet. The average diameter of the good trees was 2.9 inches. Spacing is close, which contributed to a good form. This stand represents a very good stocking which holds for most of the lower part of tract 105.

Measurements taken in another stand are as follows:

Table 33. Stand in Maga Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 6 years		
1	-	40	40
2	4	80	84
3	28	68	96
4	12	12	24
5	4	4	8
Total	48	204	252

This is a fertile humid Mûcara steep slope where maga and other species were raised with bananas and other food crops. The plot is close to the top of the ridge where wind action is strong. Trees were spaced about 10 feet apart. This fact, helped by the persistent winds, has brought about leaning of trees, production of side suckers and of several stems per tree. Although trees are vigorous and healthy, only 15 per cent of them were rated as good because of poor form. Most trees are of little use except for firewood or as cover. The average height was 20 feet, tallest trees being 30 feet.

The following stand is growing in a Mûcara slope in a good site.

Table 34. Stand in Maga Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 5 years		
1	4	80	84
2	96	176	272
3	100	132	232
4	4	32	36
Total	204	420	624

Trees had been raised under a tall canopy of Spondias and had not been cultivated. Although conditions are very favorable, only 33 per cent of the trees were rated as good because of poor form. Average and maximum heights were 15 and 20 feet respectively.

The data obtained in El Verde is similar to that of other sites in the Luquillo Division excepting the best sites in Ciénega Alta. A large number of the thrifty trees are useless for the production of timber. Unless trees are in a close stand and in a favorable site, trees form a wide crown and often lean over. This results in the production of water suckers and sprouts. In addition, the points where the side branches join the trunk swell-up producing a very irregular poor-shaped trunk. Many of the selected trees will probably develop into excellent specimens but they will be in the minority.

Since water sprouts are produced freely, pruning does not seem to be of great help.

The removal of an overstory is hardly needed as most plantations are in the open; however, it is necessary when good stands are shaded and suppressed. Maga should not be used for replanting. Stands in tract 105 should be improved by thinning and possibly by some pruning.

Results obtained do not warrant future extension of maga plantations or replantings in the Luquillo Mountains even in the most favorable sites.

Maga does not grow naturally in the Central Mountains, but a few stands along the Ciales-Villalba road at high elevations are doing well and an excellent small stand of large trees was found at about 3000 feet south of Jayuya.

In Doña Juana survival was high in the valleys but poor in the ridges. In Matrullas survival was very low. Similarly to its behavior in Luquillo, it has shown to require the deeper soils at the base of slopes and along the valleys for satisfactory growth. In Doña Juana the difference between the valleys and the ridges was evident at an early age and the good stands follow the edges of the creeks and the depressions.

The data in Table 35 show a stand which was originally mixed with Spanish cedar, but where now only maga remains.

Table 35. Stand in Maga Sample Plot - Valley

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Pure stand, 8 years		
1	-	28	28
2	20	64	84
3	120	48	168
4	52	12	64
5	16	4	20
Total	208	156	364

On the average, the trees were 8 years old and 25 feet tall, the tallest trees being 45 feet. Fifty-seven per cent of the trees were classified as vigorous and of good form. Stand is better than the average.

In Toro Negro good trees have well-formed trunks free from swellings or cankers. They are free from suckers and are pruning naturally very well. Trees have been also pruned artificially but there should be something else than the effect of pruning in producing such well-shaped

trees. The trees along the road where they get light from all sides are just as good. A more favorable light relation is probably one of the causes of the good form of trees. Many of the stands developed under a light canopy. Stands in good sites in Matrullas are just as good. Many trees are of excellent form, up to 4 inches d.b.h. and 35 feet tall.

The following table shows the average annual growth taken from site studies.

Table 36. Average Annual Growth of Maga

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	6	2	.35	.50	2.50	3.50
Valley	6	5	.39	.54	2.98	4.00

Figures show a very rapid growth especially in the valley. This is a better rate of growth than for most of the species planted at Toro Negro.

Thinning of defective trees does not have a high priority since many of them have been left behind and will be eliminated. Rapid growth, good form, and freedom from cankers and water sprouts, make the maga in Toro Negro as good as the best in the island. This suggests very strongly the existence of different strains or varieties. Form and vigor are probably hereditary characters.

Because of the passage of part of the life cycle of the pink cotton ball worm on this species, further planting was suspended until this point is definitely settled. Unthrifty trees in less favorable sites showed a high infection of leaf spot. Chlorosis is less generalized than in the limestone section. Fruits are a favorite food of the cotton stainer. No diseases have been observed.

Nectandra membranaceae, laurel amarillo.

Laurel amarillo is an aggressive species that invades pasture areas and brushland, especially in the El-Verde-Ciénega Alta section. It comes early during re-establishment of tree cover. Often it is well mixed with roble, but persists longer when such areas are taken over by taller and more light-tolerant species. Wood is not considered outstanding and is probably on the same level with other soft-wood laurels. Planting under a canopy was done on an experimental scale with good results. Still more information is needed regarding survival. Probably it survives well only when planted under a canopy. Its chief value will be its ability as an invader of grass and brushland. This will be possible if there are enough seed trees in the area.

Ocotea moschata, nuez moscada.

Nuez moscada has been planted in small amounts. The failure of seeding in Pizá was mainly the result of an unsuitable site. It does well under a canopy in forest-like conditions.

Fruits are produced in large amounts and germination is high. Direct seeding is very practical.

A few trees probably six years old were found under an overstory of Ingas and bananas at Ciénega Alta. Diameter varied between 1.2 and 1.7 inches and average height between 12 and 15 feet. Trees were thrifty, of very good form, and very successful. No injurious insects or diseases were noticed.

Three trees planted about 25 years ago were found on a high eroded ridge. On the average they were about 35 feet tall, 11 inches d.b.h., very thrifty, and of good form.

During 1945 an experimental seeding of 43 acres was done along the

Doña Juana River mostly under coffee shade. In addition, some filling-in was done in Guineo Lake plantations during 1938.

Germination was high at Doña Juana, but not so at Guineo. After two years, survival at the former place was 40 per cent. Stands are spotty. After more than 9 years, trees in the good sites at Doña Juana were 1 to 2 inches d.b.h., and 8 to 12 feet tall.

In Toro Negro growth has been slow. For a time, the attack of leaf roller was high and it was feared that it could become epidemic but lately conditions have improved. It is now believed that trees will grow well in spite of it. The following annual growth was shown by site studies.

Table 37. Average Annual Growth of Nuez Moscada

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Valley	9	1	.11	-	.89	-
Valley	9	2	.14	.20	.90	1.3

Because of very slow growth, results of this stand have not been impressive. Apparently, growth of this species is faster at lower elevations.

Nuez moscada is considered a good species for underplanting. It is easily established by direct seeding. Seed crops are produced regularly and in good amounts. Tree form is very good and its wood is rated very high locally. Large pure plantings should be avoided because leaf roller attack might become serious.

Petitia domingensis, capá blanco.

Capá blanco is not found naturally in the high elevations of the Luquillo and the Central Mountains. It is more common in the limestone

areas, but is fairly common at low and medium elevations all throughout the island.

Survival was generally high, and in most plantations about 60 per cent of the original trees were growing by the end of the third year. The trees are thrifty and show great ability to stand weed competition.

After roble and maría, capá blanco is the species doing best in poor sites. In such places it is poorly formed. It grows well in convex as well as concave slopes, although the form of trees is better in the latter. It seems better adapted to the more open soils like Múcaras and those derived from quartz-diorite. It should not be considered very seriously for the heavy clays in the high rainfall areas.

The stands shown in the table below were measured in a Múcara slope in both pure and mixed plantations. Slopes varied from 45 to 60 per cent.

Table 38. Stands in Capá Blanco Sample Plot - Slope

D.B.H.	Tree form and number per acre					
	Good	Poor	Total	Good	Poor	Total
(inches)	Pure stand, 6 years			Mixed stand, 6 years		
1	-	8	8	-	96	96
2	24	52	76	192	100	292
3	232	64	296	80	16	96
4	172	4	176	8	-	8
5	12	-	12	-	-	-
6	-	-	-	-	-	-
Total	440	128	568	280	212	492

In the pure stand, the percentage of satisfactory trees was 78 while in the mixed stand it dropped down to 58.5 per cent. Average d.b.h. of satisfactory trees was 3.45 inches and 2.38 inches respectively. Average height was less than 25 feet. The mixed plot was inferior

because of a somewhat poorer degraded site and the competition of teak. Teak is doing fairly well at this site, and being a more rapid grower than capá, has overgrown the latter both in height and diameter. As capá is intolerant, it has slowed up growth. In time, most of the stand will be eliminated.

The stand shown in the table below is in a favorable site over Panduras clay loam at Del Valle.

Table 39. Stand in Capá Blanco Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 6 years		
1	-	4	4
2	-	52	52
3	32	60	92
4	76	44	120
5	100	24	124
6	24	8	32
7	4	-	4
Total	236	192	428

There was 55 per cent of good trees with an average diameter of 4.5 inches. Average height was 20 feet. As far as diameter, this stand compares favorably with those on Múcara slopes. There was not much difference in height growth. Form is poorer because of greater distance between rows of trees. Trees are more vigorous.

Unless it grows with some degree of side shade, it is apt to develop a large round crown with several thick branches. This condition is especially so in the poorer sites. Taper of the trunk is pronounced.

If trees are properly raised in regard to stocking and amount of side shade, straight trees can be produced. This will be more so in good sites, in lower slopes, and valleys. Planting distance should not

be over 6 feet by 6 feet. Emphasis should be given to full stands early in the life of the plantation. As far as we know, capá blanco should not be mixed intimately with other species.

So far no thinning is needed since trees have more than enough space. The poor-shaped and less vigorous trees could be eliminated gradually in the future.

It is somewhat late to do pruning or to do it so that it might be of help. However, some good could be done to that part of the stand to be reserved as the final crop. The number of well-shaped trees could be increased by doing a moderate amount of pruning if work is not delayed.

Capá blanco is not usually found within the Toro Negro Division but did fairly when introduced. Growth has been rapid as shown by the following data obtained from site studies.

Table 40. Average Annual Growth of Capá Blanco

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	4	1	.38	.50	2	2.5

A good increment has been obtained especially in diameter growth. Trees have a very rapid taper.

So far no injurious insects and diseases have been observed and no trouble is expected in this respect.

Capá blanco does not seem to have the value or the timber-producing possibilities of capá prieto or ausubo, or the ability to grow in the worst sites like roble and maría. It is rather small, and logs of adult trees are knotty and of poor shape. It has been used in small sizes for special purposes because of its resistance to humidity, but

it has never been very important as a construction timber. Plantations have done very well in Del Valle where it has succeeded in spite of the very serious vine problem. Capá blanco should be planted only in Del Valle and surrounding tracts since it is capable of growing in spite of vines. It does not belong in the Toro Negro Division and should not be used there in future plantings or replantings.

Sciacassia siamea, cassia.

This exotic, used mainly as a fuelwood species, was planted in tracts 73 and 75 in Luquillo so as to get a quick cover and an overstory for the slower-growing Dominican mahogany. Rows were spaced 24 feet apart with three rows of mahogany between each two rows of cassia. Trees were spaced 6 feet in the rows.

The site of the 1936 plantation is a fairly good Catalina clay with a 30 per cent slope. Stand is mixed with a variety of native species. Since the Dominican mahogany did poorly and spacing between rows of cassia was wide, trees branched considerably. Survival was high. Fifty per cent of the trees were classified as good. Average diameter of good stems was 5.2 inches. Average height was 30 feet and maximum 40 feet. The distribution of stems follows:

Table 41, Stand in Cassia Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 8 years		
1	-	-	-
2	4	20	24
3	44	60	104
4	76	64	140
5	40	52	92
6	40	40	80
7	36	12	48
8	16	4	20
9	8	4	12
Total	264	256	520

Two- to three-year-old trees in open weedy slopes in Sabana varied between 1 and 2 inches in diameter, and 15 to 20 feet in height. Survival and thriftiness were high.

Cassia is better adapted to be planted by farmers in windbreaks and along the farm boundaries. In the forest it does not satisfy any special purpose, thus, it should not be planted except for some special purpose and in a small area.

Sideroxylon foetidissimum, tortugo amarillo.

This species is common in the dry coastal lowlands usually near the seashore. A small amount, 2075 trees, were planted along the Doña Juana River in 1938. Some trees were found during the last examination. They were thrifty, but only about 4 feet tall. Although these trees which were planted in a favorable site may grow to adult size, it is evident that they are out of place in the Central Mountains.

Swietenia macrophylla, broadleaved mahogany
Swietenia candollei, Venezuelan mahogany.

These two species will be discussed at the same time because they are undistinguishable for practical purposes.

Since 1936 planting was done in large amounts in almost every plantation and thus in many sites to which it was not adapted.

Broadleaved mahogany requires lower slopes and valleys for best results. In degraded slopes and ridges it gets stunted, and not being able to cope with shoot borer attack, it eventually dies off, or gets so unthrifty as to be of no value. It grows better in the heavy-textured soils probably this being a humidity relationship. In the more exposed less humid areas of El Verde and the lower part of Ciénega Alta, it has made an indifferent growth.

The following are growth measurements of a 13-year-old plantation.

This is one of the oldest mahogany stands in Luquillo. It was established in a lower slope which had been cultivated previously and evidently was somewhat degraded at time of planting. Results were as follows:

Table 42. Stand in Broadleaved Mahogany Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 13 years		
3	-	4	4
4	12	12	24
5	28	32	60
6	48	20	68
7	48	12	60
8	32	16	48
9	32	8	40
10	-	4	4
11	-	4	4
Total	200	112	312

The percentage of well-formed vigorous trees was 64. Probably this stand was more extensive at time of planting, but now occupies a terrace-like slope and follows the deeper soils along a creek. The average length of the first log is only 14 feet. The trees branched considerably and most trunks show characteristic irregularities and swellings above this point.

The following stand was established in Coca Valley.

Table 43. Stand in Broadleaved Mahogany Sample Plot - Valley

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 7 years		
2	-	28	28
3	56	92	148
4	156	32	188
5	80	4	84
6	20	8	28
Total	312	164	476

Average annual growth was 5 feet, the tallest trees being 45 feet. The figures are from one of the best stands located in colluvial terraces. Soils are fertile and classified as Fajardo and Torres clays which are friable soils washed down from above. Drainage is good because of a steep slope and very stony soil. The percentage of good trees is 66 in spite of suppression by overstory. Broadleaved mahogany seems to prefer humid areas and clays in environments very similar to coffee plantations.

Results from other stands in lower slopes and valleys are shown below.

Table 44. Stands in Broadleaved Mahogany Sample Plot- Valley

D.B.H.	Tree form and number per acre					
	Good	Poor	Total	Good	Poor	Total
(inches)	Mixed stand, 6 years			Mixed stand, 7 years		
1	4	-	4	-	-	-
2	8	56	64	-	120	120
3	80	52	132	132	148	280
4	60	8	68	144	56	200
5	12	-	12	52	12	64
6	-	-	-	4	-	4
Total	164	116	280	332	336	668

Average annual growth for the 6-year-old stand was 5 feet, and 4 feet for the 7-year-old plantation. Tallest trees were 40 feet tall. The percentage of well-formed vigorous trees was 60 in the younger stand, and 50 in the 7-year-old plantation. Both are located in good sites, but the older plantations have been suppressed by an overstory of second-growth trees, a fact which apparently retarded growth and contributed materially to a higher percentage of poor trees.

Survival of broadleaved mahogany is generally good. In a favorable site establishment is easier than for most species of hardwoods. The

shape and form are good. Trees tend to form a long pole, and in a suitable site do not branch until after they are 30 feet tall or so. Shoot borer attack, which is high, causes branching unless the tree is growing vigorously. When growing together with bananas, the leaves of the latter should be trimmed to prevent any pressure over the rapidly-growing leader. The overstory should be gradually removed not later than the fifth year.

Shoot borer attack and falling down of trees should not cause much worry in well-managed stands. Results show that a high percentage of trees get ultimately well anchored in favorable sites. However, it still remain to find out how the trees will stand strong winds and hurricanes. It is evident that broadleaved mahogany will not be planted to an extent comparable to the amounts used in the past. The sites to which it is well adapted will be in high demand for subsistence agriculture.

In the Toro Negro Division the two species were planted in most of the plantations and in a larger number than other species. Planting was started in 1936, but replanting continued up to 1941. It was done irrespective of sites. Survival was generally very low, especially in the open ridges and slopes.

The best 8-year-old trees in the good coffee sites in Matrullas were 3 to 4 inches in diameter, and 30 to 35 feet high. On the average, trees are smaller and spindly. In Doña Juana and Guineo, trees were poor, from 2 to 2.5 inches in diameter and 12 to 15 feet tall. Mahogany never was promising in these sites, but in Matrullas it had a good start in the lower slopes under coffee shade. Growth was rapid and the trees developed thrifty. The coffee shade was gradually removed to avoid suppressing the mahogany.

The last examination in January 1945 showed a discouraging situation.

Trees were weak, too tall for their small diameter, and had failed to develop a good crown. The few leaves left had an unhealthy light green color.

Windthrow has been very high and continuous. In the less favorable sites of Guineo and Doña Juana mahogany was considered a total loss. In Matrullas a small percentage of the trees can be expected to become crop trees, yet situation as a whole was discouraging.

Shoot borer is not considered the main cause for the poor condition of the trees. Many trees had been girdled by mice.

Since mahogany is doing better in similar sites at lower elevations, it is apparent that it is not climatically adapted to conditions of the Toro Negro Division.

Results do not justify further trials or plantings in Toro Negro.

Pure plantations should not be repeated. Introducing groups of mahogany into either the natural forest or in artificial stands in the most suitable sites is a safer and more natural procedure. Good points in favor of broadleaved mahogany are: ease of propagation, rapid growth, good form, and valuable timber of a high local demand.

Swietenia mahagoni, West Indian mahogany, Dominican mahogany, caoba.

Caoba was planted in larger amounts in Del Valle and Sabana plantations, although smaller amounts are found in the rest of the plantations. Very soon after planting, its poor showing was apparent.

Plantations in tract 36 in Del Valle developed very well upon a well-drained Panduras clay loam, but is being eliminated by the more vigorous and more rapid-growing capá blanco with which it is mixed. Survival was fair to low. In the humid climate of Luquillo, attacks

of leaf blight are prevalent. Being a slow grower, it stays for a long period within the reach of vines and suffers accordingly.

In Luquillo, no stand of this species has been successful, thus, none of the sample plots measured contained many good trees. The following data is based on estimated diameter and heights.

Table 45. Average Annual Growth of Dominican Mahogany in Sabana and Del Valle

Locality and site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
Sabana	Years		Inches	Inches	Feet	Feet
Ridge	8	2	.25	.38	1.13	2.20
Slope	8	1	.31	.44	1.80	1.80
Valley	8	3	.23	.31	1.50	2.00
Del Valle						
Ridge	8	2	.34	.44	1.90	2.10
Slope	8	4	.31	.44	1.60	1.80

Not much difference was evident among the different sites. Annual growth in diameter was good, yet increase in height was poor. Trees were stunted, about 15 feet high or less after 8 years. They were wide crowned, similar to orchard trees. Shoot borer attack was very high.

A stand in El Verde, planted during 1929, prior to the acquisition of that tract, is a good evidence of what can be expected under similar conditions.

Site is a degraded heavy Catalina stony clay of a rolling topography. Plantation was measured in 1944. The average height was about 18 feet, the highest trees being 25 feet tall. Trees had the same flat top appearance and were stunted, of poor form, and heavily attacked by shoot borer and leaf blight.

Diameter distribution in this stand is as shown in table 46.

Table 46. Diameter Distribution in Dominican Mahogany Stand

D.B.H.	Total number of trees
(inches)	Pure stand, 15 years old
1.5-2.5	7
2.6-3.5	7
3.6-4.5	12
4.6-5.5	13
5.6-6.5	12
6.6-7.5	6
7.6-8.5	1
Total	58

This plantation does not have much value, except as a shelterwood for other species.

In the better sites of Del Valle and in some parts of Sabana, counts showed from 10 to 30 per cent of well-formed trees which will probably make crop trees. Stands have been replanted with more successful species which are eliminating the mahogany. Little if any work in pruning or thinning will be necessary. Dominican mahogany should not be mixed with more rapid-growing species.

During 1936 Dominican mahogany was planted in Doña Juana plantations in mixture with Spanish cedar and jácana. Early survival was fair, but by the third year few trees were left and hardly any was seen at the time of the survey.

West Indian mahogany is not adapted to the high rainfall areas in Luquillo and the Central Mountains. It should be limited to the drier portion of the island where it grows well.

Tabebuia pallida, roble.

This species grows in the Luquillo Mountains, especially at the El Verde-Ciénega Alta section. Good stands are also found in Sabana

and Del Valle. In fact it grows well in the whole division when the favorable ecological conditions are present. It forms pure or almost pure stands by invading grasslands and degraded soils of hillsides and ridges. Roble is a small to medium sized tree. Usually it does not produce sawtimber, but special items in high demand in our rural communities.

Replanting started in degraded heavy clays during 1938. where previous plantations had failed. Smaller amounts were used in other projects. Cuttings were unsatisfactory as few did strike root. Survival of wildings has been exceptionally high.

Roble is a tree of slopes and ridges. In the valleys and lower slopes, conditions are favorable for more tolerant larger species.

Its seeding habit and adaptability to the worst sites makes it a very aggressive pioneer species. It does well in humid waterlogged sites.

The fact that wildings are so successful and that they are found in good amounts, greatly facilitates establishment of plantations. Most plantations are young, thus only one stand was measured. The following data was obtained from a stand growing in an eroded ridge in Los Guineos clay. Age from planting was estimated at 5 years.

Table 47. Stand in Roble Sample Plot - Ridge

D.B.H.	Tree form and number per acre
	Good
(inches)	Pure stand, 5 years
1	16
2	32
3	76
4	36
Total	160

Average height was 8 feet, the tallest trees being about 16 feet. The average diameter was 1.92 inches and all trees were classified as good.

Average annual growth was calculated for five different locations all in ridges.

Table 48. Average Annual Growth of Roble

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Ridge	5	5	.28	.41	1.60	2.04

Another stand in an equally eroded heavy clay was 12 to 15 feet tall with average and maximum diameters of 1.5 inches and 2.6 inches respectively. The age of the stand is 4 to 5 years.

For the present no thinning is necessary. In older natural stands thinning is usually done by means of sales. Roble is one of the easiest species to work with. Artificial stands will be important in the future.

In the Guineo Lake plantations a survival of not less than 80% was obtained. In Doña Juana, use of seedlings on an experimental scale gave a high survival and a few were about 6 feet tall two years after planting. Trees take about 6 months to resume growth after transplanting. Roble is not common at high elevations in the Toro Negro Division but grows well around Lake Matrullas. In this locality trees 15 inches in diameter and 45 feet tall were found.

Damage from insect and disease, if any, is not important. At lower elevations and where it is subject to artificial unnatural situations, along avenues and in backyards, trees get heavily attacked by a witch-broom. In Luquillo this condition has been noticed to a small extent, but does not seem to get serious or to affect the trees. A shoot borer is common but attacks are of little consequence.

Tectona grandis, teak.

Marshall (5) reports that in Trinidad, teak thrives in lands formerly occupied by semi-deciduous and rain forests with a range of rainfall between 50 and 100 inches, but mostly between 50 and 60 inches. It seems to require a well-marked dry season and a well-drained soil.

Unfortunately most plantings were small and very scattered. Because of these conditions, it was not possible to control weeds effectively as it is necessary for its best growth. Survival was very low, except in the vegetable garden in tract 105 and in Sabana. In both sites trees were kept free of weeds since cultivation was intense.

The Sabana plantation is located along a small stream in alluvial soils, but drainage is effective because of stoniness of soil. The plantation was 5 years old with average and maximum diameters of 4 inches and 6 inches respectively. Heights were 40 feet for the average, and 45 feet for the maximum. The stand is thrifty and the dominant trees are of good form. The smaller trees are branchy. Stand is close and teak is mixed with capá prieto, maría, and Dominican mahogany. Teak is clearly dominant.

In a steep shallow Múcara slope in Ciénega Alta, survival was very high. Teak was mixed with capá blanco. Seventy-three per cent of the trees were marked as satisfactory. Average diameter was 3.04 inches. Trees were six years old and 25 feet tall.

Table 49. Stand in Teak Sample Plot - Slope

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
(inches)	Mixed stand, 6 years		
1	4	28	32
2	16	54	70
3	236	12	248
4	32	-	32
Total	288	94	382

Contiguous to this stand, but in the valleys and lower slopes, trees had reached diameters up to 4.5 inches and heights up to 45 feet.

It is evident that growth in this plot has been slower because the soil is too steep and shallow. Teak was at least 3 feet taller than the capá blanco. The Múcara sites in the western part of Luquillo are probably climatically suitable since rainfall is not over 80 inches, and soils are well-drained. However, the sites which are good enough for teak will be in high demand for subsistence agriculture.

The two stands, one in each Sabana and Ciénega Alta, might need thinning of the poor-deformed trees in the near future. Growth should be observed closely.

So far no serious insects or diseases have been noticed. Teak has shown to be an exceedingly tough species. There are reports indicating that it stands hurricane winds exceptionally well.

About 1500 seedlings were planted in Doña Juana during 1938 and 1939. The few trees which survived were not much taller than at time of planting. Teak belongs to a less mesophytic forest at lower elevations. No further trials should be made at Toro Negro.

Triplaris americana.

This South American species has been introduced during the last 10 or 15 years. No large trees have been found. It is fast becoming popular as an ornamental because of its rapid growth, erect and graceful form, and showy pink red blossoms.

In forest lands it has been planted only as an ornamental around buildings. A group of 19 six-year-old trees back of the headquarters office at Sabana were measured and found to have an average diameter of 4.6 inches, being 15 to 22 feet in height. Trees varied from 2 to 7 inches in diameter. There is no record of this planting but probably

they were planted in 1938. Trees have received good care and kept free of weeds.

Since trees and shrubs in this genus have a tendency of being hollow, one tree was examined and found that all the trunk, about 4 inches in diameter, was solid except for about 1/8 inch in the center of the pith. If hollowness does not increase with age, it should not be an obstacle to timber production. A wood sample obtained was similar to pine.

This tree has been considered with possibilities as a plantation tree because it is well-formed, grows rapidly, and prefers openings in nearly pure stands. Preliminary data from other forest units show that its survival has been low and that a high percentage of the trees get unthrifty in the poor sites in which it has been planted.

Vitex divaricata, higuerillo.

Higuerillo is widely distributed in our humid forests from the coast to the higher elevations. It occurs sparingly but is of more common occurrence in the Central Mountains. It persists as scattered trees long after the forest has been cleared and large specimens are found isolated in clearings and pastures. Wood is considered very durable in the ground.

During 1938 higherillo was planted in small amounts in Pizá and El Verde. It has not been planted in Luquillo anywhere to the same extent as in Toro Negro.

Survival has been fair, but it is considered to belong to the class of trees that survive well. It is able to compete with weeds and has been planted in the open-degraded clay soils. In such sites its growth has been rather slow.

Sample plots were not measured. The following table shows the average annual growth from site studies in Pizá and El Verde.

Table 50. Average Annual Growth of Higuerillo

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Ridge	5	1	.2	.3	2	2.4
Slope	5	1	.3	.74	2.4	3
	6	3	.2	-	1.9	-
	8	2	.2	.31	2.4	3

Hardly any stand has reached 25 feet in height, even though the oldest trees are eight years old. Higuerillo has grown slower than capá blanco when planted together with it. Marshall (5) reports it as a fast grower in Trinidad, reaching a height of about 40 feet and a diameter of 6 inches in 6 years. However, in Trinidad they use better sites for planting and their variety might be a faster grower than ours.

Higuerillo is a strong light demander and needs at least full overhead light. It does well when planted in large openings in the forest. When intimately mixed with faster-growing species, it will probably be eliminated. Side-shade could be helpful in improving tree form. Trees branch somewhat, although not so much as capá blanco. Pruning is necessary and many trees could be considerably improved in this way.

There are no serious disease or insect pests, yet in some localities foliage is heavily attacked by a leaf roller. A mite causing swollen and chlorotic areas in the foliage is common when growing seedlings under shade.

Higuerillo does not seem to be a very desirable species to grow

in the Luquillo Division. It is a slow grower, and although it is growing fairly well in eroded poor sites, these can be utilized better by roble.

In Toro Negro, except at Guineo Lake, growth has been slow. A high percentage of trees are of poor form.

Survival has been good, considering the sites. A 9-year-old open grown stand in a degraded slope at Doña Juana had average and maximum diameters of 2 inches and 3.6 inches respectively, and average and maximum heights of 12 and 20 feet. When underplanted in sierra palm stands, 4- and 5-year-old trees were 1/2 inch to 1 inch in diameter and 5 to 8 feet tall, thrifty and of good form.

Best stands are found in the lower slopes of the Alonso soils where trees four years after planting were 1 to 2 inches in diameter and 8 to 12 feet in height.

No sample plots were established since trees were small. The following average annual growth is from site studies in Toro Negro.

Table 51. Average Annual Growth of Higuerillo

Site	Average age	Number of locations	D.B.H. growth		Height growth	
			Average	Maximum	Average	Maximum
	Years		Inches	Inches	Feet	Feet
Slope	5	7	.25	.38	1.63	2.17
Valley	4	1	.25	.50	2	3

It has shown capable of growing well when planted in the forests at high elevations among natural stands of Micropholis and similar species. It does well when underplanted under sierra palms if the stand admits enough light.

Vitex spp.

An introduced species of Vitex was planted in Pizá in 1938. Its

description checks well with that of Vitex parviflora from the Philippines. There are records of its introduction into the island by the Forest Service in the early twenties.

Adult trees in the Forest Service arboretum give heavy crops of seeds. Isolated trees have been found in other areas of the Luquillo, probably planted by former landowners from trees originated in the Forest Service.

This species is a very heavy seeder and is found close to the mother trees. Growth has been rapid, even in degraded heavy sites. Eight-year-old trees were 3 to 4 inches in diameter and 15 to 20 feet tall. Survival was high. Trees have been growing at a fast rate. In some parts of Pizá trees are unthrifty and heavily attacked by scale insects.

Trees are intolerant, and having grown in the open, produce a very wide crown similar to capá blanco. Growth is more rapid than with our native species and it is just as aggressive and adapted to poor sites.

It has ornamental possibilities as it produces large blossoms of lavender color flowers and heavy crops of grape-like fruits.

DISCUSSION AND RECOMMENDATIONS

Table 52 shows the area covered and the condition of the different plantations up to June 1945. The total area of the plantations is larger than the area actually planted, in this case 5781.8 acres. Within this larger area there is a certain amount of natural reproduction which adds very materially to the stocking of the areas, and which should be considered in sizing up the area that still requires planting in the open or underplanting.

Considering both the natural reproduction and the established plantations, the amount of stocking was estimated in June 1945 as follows:

Table 52. Amount of Stocking Including Natural Stands, Caribbean National Forest

Plantations	Condition of plantations			Total
	Well stocked	Understocked		
		Forested	Open	
	Acres	Acres	Acres	Acres
Luquillo Division				
El Verde and Jiménez	65	20	95	180
Pizá	467	29	75	571
Ciénega Alta	1,086.8	302	137	1,525.8
Sabana and Coca	525	261	167	953
Del Valle	260	328	40	628
Tract 91	15	48	5	68
Total	2,418.8	988	519	3,925.8
Per cent	61.4	25.1	13.5	
Toro Negro Division				
Doña Juana	454	61	272	787
Matrullas	350	277	110	737
Guineo	265	5	62	332
Total	1,069	343	444	1,856
Per cent	57.5	18.5	24	
Grand Total Caribbean National Forest	3,487.8	1331	963	5,781.8
Per cent	60.3	23.0	16.7	

The above table shows that 60 per cent of the total area of the plantations was considered well stocked. This is a total of 3487.8 acres made up of 2048 acres of plantations and 1438.8 acres of natural stands. That is, plantations have contributed with about 59 per cent to the well-stocked stands.

The effectiveness of the planting work can be appreciated by considering the fact that after planting an average of 2000 trees per acre, only 51 per cent of the area actually planted was considered successful. This was so after planting during 10 years in the same area.

A total of 2294 acres are in need of replanting. Considering the whole area of plantations, 23 per cent or 1331 acres were estimated to need underplanting, and 16.7 or 963 acres requiring replanting in the open. Some of this area was replanted during the latter part of 1945

and the whole of 1946 with roble, Eucalyptus, and maría. Thus, most of the area which at present is understocked, requires underplanting.

The terms "stocked" and "understocked" should be explained fully so that a good picture of the situation is obtained.

1. Well-stocked Plantations

Plantations in which planted trees of good form and satisfactory growth, or such planted trees together with natural reproduction of the better species, form, or with release could form, an 80 per cent to fully-stocked dominant stand. No replanting needed, nor underplanting in the immediate future. Part needing vine cutting and release.

2. Understocked Plantations

Plantations in which planted trees of good form and satisfactory growth, or such planted trees together with natural reproduction of the better species, do not form, nor with release would not form, an 80 per cent stocked stand. Replanting or underplanting, vine cutting, and release needed.

a. Forested. The satisfactory trees, either planted or natural, forming a minor part of a stand composed chiefly of poor trees, either planted or natural, which provides a complete canopy beneath which a shady forest environment exists. Part needing vine cutting, release, and underplanting.

b. Open. The satisfactory trees, either planted or natural, not within a closed stand, and therefore on a site where the soil receives little shade and there exists a prominent herbaceous cover. Part needing vine cutting and replanting.

Luquillo Division.

Management of Successful Plantations: It is necessary to make recommendations separately for the different sites such as lower slopes, uniform slopes, and ridges.

The following classification shows the adaptability of the different species in lower slopes and valleys.

Promising	Not promising	Not recommended
Ausubo	Ceiba	Albizzia lebbeck
Broadleaved mahogany	Dalberghia	Algarrobo
Capá prieto	Moca	Capá blanco
Jácana	Spanish cedar	Casuarina
Nuez moscada	West Indian mahogany	Guaraguao
		Higuerillo
		Maga
		María
		Maricao
		Roble
		Teak

The species listed as not recommended grow well in lower slopes but either they belong better in less suitable sites like maría and roble, or else they do not produce good enough timber like maricao and casuarina. Other species in this column like capá blanco, maga, teak, algarrobo, and guaraguao, although producing valuable timber, are not recommended for the best sites on this basis of results to date. Teak has done well in Múcara sites, but requires clean cultivation. Little is known about its future possibilities. Guaraguao has been underplanted with a high survival and good thriftiness, but the form of adult trees is not good. More information about higuerillo and capá blanco is also needed before recommending them for this site.

Of the species listed as promising, jácana might not produce one of the best timbers, but it has been very successful in the plantations.

Maga is not being recommended in view of its behavior in the rest of Luquillo although it has done very well in tract 105.

With the exception of the broadleaved mahogany in Sabana and Coca Valley, the capá blanco in Del Valle, and maría in Pizá, there is not a large area of one species in anyone of the older stands. Since stands are mixed in many different combinations, it will be necessary to consider more than one species at anyone time and place in silvicultural work.

Many of the best stands have been growing under a shelterwood of native species of low value. The gradual removal of these is being effected through sales. This work will have to be done continuously to avoid good trees of valuable species being suppreseed by natural trees of less valuable species. It is hard to lay any rules to be followed since no two groups of trees are identical. Enough of the shelterwood should be removed to allow uninterrupted growth to the plantation, but care should be exercised not to open the canopy excessively. This is especially so in sites where vine growth is heavy. The right balance should be maintained between the growth of the planted trees and the amount of canopy. When the plantation is poor it is preferable to replant with a more successful species and to do the improvement cuttings as required by the latter planting. Thinnings are hardly necessary at present. Stocking of planted trees is light so that good trees are not competing with each other.

Trees classified as poor will tend to remain behind or be eliminated by the best specimens so that there will hardly be need of thinning to favor crop trees. There are many stands of capá blanco in Del Valle, which, although very vigorous, are widely spaced and of poor form. Maga stands which are of good form and growing close in the lower part of tract 105 will need to be thinned out soon.

In cases in which there is competition between the planted trees it is hard to set down any rule as to which tree should be favored since there are different combinations. This is something to be judged on the ground.

Pruning should have been started earlier. Any work should be carefully supervised. When "machetes" are used as pruning tools, stubs are usually left after removing branches. It is preferable not to prune, rather than to do it incorrectly as this is conducive to fungous infections and defective trees. Capá blanco is the species most in need of pruning. Only the crop trees should be pruned, and even in this group of trees only those branches 1 inch in diameter of less should be pruned.

Little replanting should be required in the successful stands in this site. Many blanks are being filled by natural reproduction. Large openings should be filled with promising species, especially if wildings can be procured nearby or by the use of direct seeding.

Weedy vegetation such as melastomaceous shrubs, ferns, and other forms of ground cover should be encouraged and not removed in cleaning operations. In critical areas as in Del Valle and Coca Valley, vines still have to be cut regularly as they are able to choke large trees.

The uniform slopes contain the largest area of plantations, estimated to be about 50 per cent of the total area.

The adaptability of species to sites is as follows:

Promising	Not promising	Not recommended
Ausubo	Broadleaved mahogany	Albizzia lebbeck
Capá blanco	Ceiba	Algarrobo
Capá prieto	Dalberghia	Cassia de Siam
Jácana	Maga	Casuarina
María	Moca	Eucalyptus spp.
Maricao	Spanish cedar	Higuerillo
Nuez moscada	West Indian mahogany	Teak

There is not much difference in handling successful plantations in the valleys and in the slopes of ausubo, capá prieto, jácana, and nuez moscada when growing under a shelterwood. Capá blanco has done remarkably well in the slopes of Del Valle, irrespective of the conditions of the site. María, roble, and maricao will be more useful in those slopes

where the soil is worn-out.

The management of the promising plantations in the slopes should be as follows: In well-formed stands of capá blanco, it is mostly a matter of removing the overstory where present. Pruning, if done correctly and soon enough, will be helpful. Thinning of capá blanco is generally not needed at present.

Vine removal is important in Del Valle and in few other sites.

The artificial stands of roble are young and hardly need any care, except occasional vine removal. María is intolerant and will not grow well under an overstory. Pruning will be helpful as many trees have developed wide crowns. Thinning is not needed for the present. The maricao stands are too small to require any special consideration.

The group classified as not promising will be substituted, either by natural stands or by planting.

The management of the group of species classified as not recommended should be as follows:

The cassia stands in Sabana should be considered only as temporary. They should be treated as an overstory and removed as required by the understory of roble, maría, and a few good trees of Dominican mahogany. If the stands of the latter are not enough, an inexpensive replanting could be done with roble wildings. Unthrifty Dominican mahogany should be underplanted also.

The few successful stands of teak should be managed on an experimental basis. The management of the small successful stands of Eucalyptus, higuerillo, Albizzia, and Casuarina, is not important and should follow what is done in surrounding stands.

The ridges were estimated to include 32 per cent of the total area in plantations.

Most species do not do well, especially if the soil is degraded. Under these circumstances, maría and roble have been very successful in Luquillo. María will not be used in future regeneration in Luquillo, as roble fits in better in the present management plan.

Improvement of Poor Plantations: Management of poor stands in the best sites, that is, in the lower slopes and valleys is as follows:

In the maga stands the amount of underplanting with promising species will vary with the quantity of good-formed trees. There might be a majority of poor trees, but there might be enough good crop trees of maga or of other species so as to preclude the need of underplanting. The same holds for capá blanco. If not enough good trees are present, or if good natural reproduction is not coming in, it is a clear case of underplanting with promising species.

West Indian mahogany stands are poor, irrespective of site. Where it was planted pure, the canopy is usually open. The need of replanting in such stands will be determined by the stocking and the kind of dominating species.

Where a canopy is missing so that the site is overgrown with weeds and vines, replanting with roble is probably the most intelligent decision in spite the fact that roble is usually planted in the poorer sites.

New Planting: Practically no new plantations will be established irrespective of site until new areas are acquired.

Problems Remaining for Research: In the lower slopes and valleys the problems to be investigated are mostly those in connection with future growth. Permanent sample plots should be established in successful stands to measure growth and to study thinnings. The following stands are suggested for plot establishment.

1. Good broadleaved mahogany in Coca Valley and Sabana.

2. Maga and teak stands in the lower part of tract 105.

3. Capá blanco and mixed species in the lower slopes of Del Valle.

The successful Spanish cedar stands in plantations 1, 2, and 3, of Del Valle should be included in item no. 3.

Although many of the species planted at present survive well, there is need of an intensive study of survival with many species of hardwoods.

The research problems of the uniform slopes do not differ from those above.

Toro Negro Division.

Management of Successful Plantations: Recommendations are also made separately for the different sites. In Toro Negro two different sites were differentiated. The data given below refer to open-degraded sites. The results obtained with the different species in this site are as follows:

Promising	Not promising	Not recommended
Eucalyptus spp. Pomarrosa Roble	All other species	María

According to table 52, when all sites are considered, a total of 1069 acres were estimated to be well-stocked. The successful plantations in open-degraded sites include only the later plantings of Eucalyptus, most of the roble, part of the jácana, and a small part of the higuerillo.

Where the jácana trees are 4 feet or over, should be allowed to grow uninterruptedly. The growth of woody bushes and brush, and of tall ferns, should help the growth of trees and the rapid recovery of degraded sites. Unless vines are troublesome, cutting down the brush from plantations which are out of the reach of the brush, is poor silviculture. At this stage it does not pay to take care of jácana seedlings which are chlorotic and stunted. They should be replaced with the more successful species if

the blank spots are large enough to justify further planting.

The stands of small Eucalyptus should be weeded and replanted having in mind to raise well-stocked uniform stands. Roble needs less care than Eucalyptus. Three or four weedings should be enough. If higuerillo becomes stunted and unthrifty, the best practice will be to replant solid with Eucalyptus or roble. In good higuerillo stands, only occasional vine removal will be necessary.

The results obtained with different species in sites which were not degraded at time of planting are as follows:

Promising	Not promising	Not recommended
Ausubo	Broadleaved mahogany	Capá blanco
Capá prieto	Spanish cedar	María
Guaraguao	Teak	
Higuerillo	Tortugo amarillo	
Jácana	West Indian mahogany	
Maga		
Nuez moscada		
Tabonuco		

Eucalyptus and roble grow very successfully in this site, although usually they are planted in the degraded sites. The area of successful plantations includes promising groups of trees scattered over wide areas. The number and combination of species, stage of growth, need of liberation, and need of thinning and pruning, vary from place to place so that it is hard to set any rules for the treatment of these stands.

The successful but young stands of Eucalyptus and roble were still in need of weeding early in 1945. The older successful stands are composed of the following species: maga, capá prieto, Eucalyptus, and broadleaved mahogany. Maga and Eucalyptus were the only species approaching a condition where thinning would be needed. At the time of the survey the good stands of these two species were not crowded, but since they are growing fast, it is likely that some thinning might be needed within the next two years or so.

In Matrullas, Ingas which are shading good capá prieto trees should be removed. Removal of the overstory to favor mahogany should be done only in the case of thrifty and promising trees. When the mahogany was not good enough to establish its own cover, complete removal of the overstory resulted in site deterioration.

Bananas should be kept well thinned so that they do not get over dense and compete with good forest trees. Pruning does not seem very necessary.

Improvement of Poor Plantations: At the time of the survey the understocked plantations in Toro Negro were estimated as divided into 343 forested and 444 acres in the open. Since that time an appreciable amount of planting has been done with Eucalyptus and roble in the open-degraded sites.

The bulk of the forested but understocked stands was found in Matrullas. The stocking of plantations under a shelterwood of coffee shade trees was low. On the eastern side of the Matrullas dam, 67 acres were estimated to need underplanting, especially toward the end of the main lower trail where plantations, 3, 4, and 5 meet. The overstory was largely made of Cecropia under which, the survival of mahogany and capá prieto was slow. Capá prieto and ausubo are the best species to use here. Underplanting of this section should have a high priority since conditions are very favorable.

New Planting: New plantations will have to extend west of tract 20. Between this and tract 3 there is an area of about 3000 acres of mixed palms and such species as are found at high elevations. In some places there is only second growth. Regeneration of open-degraded sites should not be important in this area as it is practically all forested.

Problems Remaining for Research: The research problems to be investigated include both successful and poor plantations. In the successful plantations research has to do with the management of the best stands. The silviculture of the Eucalyptus should be investigated with special reference to thinnings and harvest cuttings. Sample plots should be established in the following stands.

1. Close Eucalyptus stands in Guineo.
2. Good maga stands in Doña Juana.
3. Stands of capá prieto and broadleaved mahogany either in Matrullas or Doña Juana.
4. Jácana stands in Matrullas.

The following points of underplanting require further study. (1) the most favorable type of cover, (2) when and how much of the overstory should be removed, and (3) with what frequency should the overstory be opened. Information about different degrees of species mixture, amount of trees to plant and frequency of underplanting, and the eventual relative position of the valuable species in the stand, is also needed.

Conversion of sierra palm stands to more valuable species is worth of study since this is an important type in the highlands. The optimum density of the palm canopy should be determined as well as the most economic methods of sierra palm removal. The tests of underplanting sierra palm started at Doña Juana and Guineo Lake should be closely observed and expanded if successful.

In the open sites it is not clear whether the expense of raising the Eucalyptus plantations is justified against the slower but sure method of allowing the natural succession to operate.

The natural succession of degraded lands should be studied so as

to obtain the necessary data. Information is needed on the process leading to the rapid degradation of the clay soils when the forest cover is removed.

SUMMARY AND CONCLUSIONS

Reforestation is one of the main activities of the forestry program in Puerto Rico. The evaluation of the work done since C.C.C. days was necessary as a basis for the planning of future work and for the most efficient management of the already established stands. An intensive survey of the 20,000 acres of plantations was conducted by the research staff with the cooperation of the field force during part of 1944 and 1945. Of this area, 5,700 acres are located in the Caribbean National Forest.

The survey was intended to obtain the following information of value to administration and research.

1. A permanent combined record of plantation establishment.
2. A reliable estimate of the planting and plantation management job ahead, based upon practices recommended as a result of the survey.
3. A clearer picture of regeneration and plantation management problems for use in planning research.

In line with the intensive use of land, characteristic of an over-populated island, maximum production is required from every acre of land. The best agricultural land is dedicated to an intensive form of agriculture which gives a relatively high yield per acre. There is an undetermined area of land whose highest use is for forest production. Forests are needed for the production of fuelwood, timber, and miscellaneous forest products. Soil Conservation surveys have shown that 60 per cent or more

of the area of the island is not suited for clean cultivation and should be maintained in pasture or woodland.

The Caribbean National Forest is composed of two Divisions: the Luquillo and the Toro Negro, located on the Luquillo and Central Mountains respectively. Although this is a relatively small forest, it is very important for timber production, for soil and watershed protection, and as a recreational area.

Lands within the National Forest being reforested are generally steep and located between 50 and 3000 feet elevation. At Toro Negro, the plantations are at an elevation about 1500 feet higher than at Luquillo. This land is all submarginal for agriculture. At the time it was acquired it was either deforested or covered with young second growth. Practically all of it had been degraded through improper farming.

Large-scale reforestation work was started during 1934 by the Civilian Conservation Corps. Other relief agencies such as the Puerto Rico Reconstruction Administration and the Insular War Emergency Program have also partially financed the program at one time or another. Between 1934 and 1945 a total of 5782 acres of plantations were established in the Caribbean National Forest, using more than 7,000,000 seedlings and wildings, and about 64,000 pounds of seeds (including planting material for replanting). About thirty different species were included.

Factors of site, as they affected the adaptability of species, determined to a large extent the success of the work. Degree of past erosion was one of the most important site factors. Eroded and degraded soils where the forest canopy had been long removed required different species and silvicultural treatment. Most of the valuable species of hardwoods require for proper early development the favorable forest-like conditions existing under a shelterwood. Little is yet known

here regarding the handling of the canopy and of the underwood for best regeneration by this system.

In the Luquillo Division, the site differences between concave and convex slopes evidently affected tree growth and the adaptability. Three sites were distinguished: (1) ridges, (2) uniform slopes, and (3) lower slopes or valleys. At Toro Negro, the heavy clays at higher elevations degrade very rapidly upon removal of the forest cover, even before accelerated erosion is evident. There, the degree of degradation is not so directly influenced by topography. The following site classification is considered more directly related to plantation success: (1) Severely degraded soils and (2) slightly degraded soils. The influence of other site factors such as exposure, drainage, and ground cover, are discussed. Planting stock, systems of planting, ground preparation, methods of planting, and maintenance after planting are described in detail. Detailed recommendations for the management of plantations are presented.

Survival has generally been low. However, natural reproduction has complemented artificial stands. Considering both volunteer growth of valuable species and plantations, 60 per cent of the total area is considered well-stocked. Of these, the planted trees make up about 59 per cent. The balance are from volunteer growth. Of the 40 per cent understocked, 23 per cent is now forested and 17 per cent is still open.

The cost of establishment and maintenance has been high because of heavy replanting and the long period of maintenance which has been required to get the plantations free from weed and vine competition. The high costs, low survival, and the long period of replanting and weeding, are the result of an improper approach to reforestation. The following factors are largely responsible.

1. Large scale programs carried out within a relatively short period of time.
2. Difficult and highly variable site conditions, involving degraded soils and intense competition by weeds and vines.
3. Lack of research data and experience with the establishment of plantations of tropical hardwoods.

The cost of the planting work is shown clearly by the fact that after more than 2000 trees per acre were planted (including replanting), only 51 per cent of the plantation area is now considered successful, about 10 years later. A total of 2294 acres is estimated to be still in need of replanting, roughly 40 per cent of the total area of plantations. The very heterogeneous site and cover conditions resulted in uneven and mixed stands with age classes from 1 to 10 or 11 years.

The average cost per acre during the first five-year period was $67.56 and $65.19 for the Luquillo and Toro Negro Division respectively. The total average cost per acre during this period was $66.78. The cost of plantation establishment averages $27.12, of which ground preparation makes up two-thirds. Weeding cost was 48.41 per cent of the total.

The high value and scarcity of wood products here justifies a higher investment in regeneration work than under a less intensive system. However, these costs may be considered excessive under almost any circumstances.

Work done at present is less expensive, not so much because of lower planting costs, but because of the following approach:

1. In open weedy sites the species planted are those requiring a minimum of subsequent weeding.
2. The use of any available shelterwood as a protection for the trees and to assist in the control of weeds and vines.

It is unfortunate that experimental plantations were not established

previous to the initiation of the planting work. In the absence of research, the establishment and management of the plantations has been done by trial and error. Puerto Rico is not the only place where early planting of tropical hardwoods has been costly or unsuccessful. Brooks (3a) reports the following in relation to similar work done in Trinidad.

> "Obviously the outstanding fault of the work of these earlier years lay in the failure to approach regeneration problems from an ecological standpoint. An attempt was made to force an artificial crop of two or three species on a clear-felled area, which formerly carried a highly mixed and complex crop, without any adequate knowledge of how such a drastic interference with natural conditions would affect the local climate and soil."

He describes the conditions of the resulting plantations as follows:

> "Extensive filling up of blanks was necessary in the second and third year after planting, together with constant expensive tending; growth of the crop was extremely slow and canopy was not formed for several years. The formation of a crop was a prolonged struggle and costs were naturally extremely high."

Beard (3) arrives at similar illuminating conclusions from intensive experimental work in the MacNair Ravine Sable Forest in Trinidad.

> "On really degraded sites ecological conditions have become so adverse and balances so upset that artificial methods may be demanding the impossible, demanding of the planted stock a tolerance which it cannot hope to possess. There is no certainty in artificial regeneration under such circumstances. It is invariable costly and if it fails the last state may well be worse than the first, due to the additional interference tendings have necessitated.

The additional time required by natural methods is surely of no consequence in forestry where rotations run to 60, 80, 100, or more years, and in any case the experience at MacNair has shown that this time lag is by no means as great as is generally supposed. Tropical forestry, in nearly every country in which it has been practised (and Trinidad is no exception), has suffered in its youth from a disease that has been called "planting measles", a fixed idea that it was necessary to start forming plantations at great speed all over the place, often without any previous research. After the wastage of much money the programme is revised in favour of less costly, more natural methods based on careful experiment."

APPENDIX

A - Brief Description of the Soil Types in the Caribbean National Forest.

B - Forest Types of the Caribbean National Forest.

C - Sample of Project Specifications of the Early Planting Work

D - Sample of Site Study Form Used in the Plantation Survey

E - Copy of the Last Planting Policy for Puerto Rico

F - Bibliography

BRIEF DESCRIPTION* OF THE IMPORTANT SOIL GROUPS OF THE CARIBBEAN NATIONAL FOREST

Name. Alonso clay

Origin: Residual from tuffaceous rocks, vesicular lavas, and agglomerates with cretaceous limestone influence.

pH: A - Acid
B - Acid
C - Acid

Drainage: Good

Profile characteristics: A - Horizon - 6- inch brownish-purple friable permeable clay

B - Horizon - From 5" to 20" or over there is a friable granular reddish-purple clay over weathered rock.

Adaptation and Other Characteristics: Zonal, Lateritic. Depth varies with slope. Very good for coffee. Plantations grow fast when soil is not degraded.

Name. Catalina clay
Catalina stony clay

Origin: Residual from andesitic tuffs and tuffaceous shales.

pH: A - Acid
B - Acid
C - Acid

Drainage: Good

Profile characteristics: A - Horizon - 0 to 6". Reddish-brown friable softly granular clay. Forms large clods when plowed, but breaks into fine granules after first rains.

B - Horizon - Upper subsoil ranges from 8" to 24" deep. Brownish-red or red friable heavy clay. Uniform red clay continues to 10 to 30 feet deep.

* Information obtained from Key to Soils of Puerto Rico, by J.J. Landrón and Juan Suárez.

Adaptation and Other Characteristics : All-around soil. Suitable for most any crop grown in the island. Red lateritic, low in calcium, phosphorus, and magnesium.

Name: Cialitos clay

Origin: Andesitic tuffs and tuffaceous shales.

pH: A - Acid
B - Acid
C - Acid

Drainage: Good to fair.

Profile characteristics: A - Horizon - 0 to 4" or 6" light grayish-brown or brownish-red friable, finely granular clay surface.

B - Horizon - Over yellowish-red or red medium heavy but permeable plastic clay. Becomes more friable at 20".

Adaptation and Other Characteristics : Coffee, bananas, pasture. Red lateritic. In places the lower subsoil has a tendency to have a mottled yellowish-brown and light brownish-red color.

Name. Fajardo clay

Origin: Outwashed from shale hills and Rfo Piedras soils.

pH: A - Very acid
B - " "
C - " "

Drainage: Fair. Gray phase poorly drained.

Profile characteristics: A - Horizon - 0 to 9". Brown or reddish-brown, granular, friable clay.

B - Horizon - 9" to 14". Heavier mottled deep red and brown rather compact clay. Below 14" to about 5 feet becomes distinctly mottled red, yellow and gray.

Adaptation and Other Characteristics : Good for sugar cane, citrus and pasture. Below 5 feet becomes less compact but distinctly mottled. Angular shale fragments present through entire profile.

Name. Los Guineos clay

Origin: Residual from andesitic tuffs and shales.

pH: A - Strongly acid
B - Strongly acid
C - Acid

Drainage: Good

Profile characteristics: A - Horizon - 0 to 6" or 8". Grayish-brown slightly granular medium plastic clay and 3 to 6 inches of brownish-yellow clay sub-surface.

B - Horizon - Abruptly changing to a red plastic permeable clay grading at 3 to 4 feet into a lighter red more friable clay.

Adaptation and Other Characteristics : Suitable for coffee, bananas, minor crops. The steep and stony phases used for forests and pastures.

Name. Múcara silty clay loam
Múcara silt loam

Origin: Residual from tuffaceous rocks with calcareous influence. Angular rock fragments present in B and C horizons.

pH: A - Neutral to slightly acid
B - Neutral
C - Neutral to alkaline

Drainage: Good

Profile characteristics: A - Horizon - 0 to 8". Dark brownish-gray or grayish-brown medium plastic clay, silty clay with crumb structure.

B - Horizon - 8" to 18". Yellowish-brown plastic clay or silty clay with tendency to gray and yellowish-gray

mottling in lower part.

Adaptation and Other Characteristics : Tobacco is the main crop. Minor crops are also extensively raised. Depth of soil varies greatly with slope and erosion.

Name. Panduras sandy clay loam
Panduras loam

Origin: Quartz diorite and granite

pH: A - Acid
B - Acid
C - Acid

Drainage: Good to excessive

Profile characteristics: A - Horizon - 0 to 6". Light brown, granular, gritty surface. Depth depends on slopes, and amount of erosion.

B - Horizon - 6" to 12" or 30". Mixture of loose gritty sandy loam and desintegrated granite over rock.

Ad

Adaptation and Other Characteristics : Pasture and trees. Also for minor crops and tobacco.

Name. Picacho stony clay loam

Origin: Dark colored andesitic igneous rocks

pH: A - Acid
B - Acid
C - Acid

Drainage: Good to excessive due to depth and relief

Profile characteristics: A - Horizon - 0 to 4". Light grayish-brown plastic silty clay loam or clay. Texture depends on slope and rainfall.

B - Horizon - 4" to 8". Yellowish-brown clay material with abundance of angular rock fragments. Depth to the rock varies from 3" to 14".

Adaptation and Other Characteristics : About 80 per cent in pasture and forest. Coffee on the best and deeper colluvial areas.

Name. Rough Stony Land

Origin: Dark colored igneous rocks and andesitic tuffs.

pH: A - Acid
C - Acid

Drainage: Good to excessive

Profile characteristics: Shallow stony soil too rough and broken for cultivation. Peaks above 3000 feet. Vegetation depends more on climate and soil.

Adaptation and Other Characteristics : High peaks with high rainfall. Vegetation is typical of Montane Rain Forest.

Name. Sabana silty clay loam
Sabana silt loam

Origin: Andesitic tuffs. More acid than Múcara. Higher rainfall than Múcara soils.

pH: A - Acid
B - Acid
C - Acid

Drainage: Imperfect to fair

Profile characteristics: A - Horizon - 0 to 8". Light brownish-gray or grayish-brown medium plastic with distinct crumb structure. Many stones and boulders on surface.

B - Horizon - 8" to 18". Light yellowish-brown or light brown plastic clay or silty clay that has a tendency to become mottled gray and yellowish-gray in lower part. Depth depends on slope.

Adaptation and Other Characteristics : About 80 per cent used for subsistence crops, the rest for pasture and sugar cane. Less desirable than Múcara.

Name. Torres clay
Torres silty clay loam

Origin: Washed from Cialitos, Catalinas, Yunes, and associated red and purple soils of the uplands.

pH: A - Acid
B - Acid
C - Acid

Drainage: Fair to good

Profile characteristics: A - Horizon - 0 to 6" or 8". Yellowish-brown or brown, slightly granular clay.

B - Horizon - 8" to 20". Red or brownish-red moderately compact silty clay, lower part streaked yellow and gray.

Adaptation and Other Characteristics: Red lateritic. Suitable for coffee, sugar cane and minor crops. Substratum is friable, reddish-brown or red gravelly loam or clay loam.

FOREST TYPES OF THE CARIBBEAN NATIONAL FOREST

The Luquillo Division contains the less disturbed areas of forests in the island, yet it is difficult to find any area which has not been culled of valuable species, like ausubo. The forests in Toro Negro have been disturbed to a much greater extent than those of Luquillo.

The vegetation types have been divided (following Beard's classification) into the Lower Montane Evergreen Rain Forest, the Montane Rain Forest, and the Elfin Woodlands. Wadsworth (12) set the limits of the Lower Montane Evergreen Rain Forest in Puerto Rico between 800 and 2400 feet. In the protected slopes of the Central Mountains, this type probably rises to about 3000 feet.

Holdridge (4) refers to it as the moist mountain type and calls it "a continuation of the moist lowland type with the addition of more species". The coffee woodlands are also located in this forest type. It has been estimated to include 39 per cent of the area of the Luquillo Division. It is composed of only one association, the Austamo, named for its three outstanding species in the Luquillo Division: Dacryodes-Sloanea-Manilkara.

The Lower Montane Evergreen Rain Forest consists of two layers, a canopy layer from 70 to 100 feet (Beard's Climax Vegetation in Tropical America) and a lower story of 10 to 50 feet. Individual trees in sheltered places might get to 120 feet.

Other species in this association are Buchenavia capitata, Tetragastris balsamifera, Guarea trichilioides, Homalium racemosum, Ocotea moschata, Didymopanax morototoni, Mayepea domingensis, Ormosia krugii. Among the smaller trees are several Rubiaceae,

Hedyosmum arborescens, Guarea racemiflora, Piper spp., tree ferns, etc.

This is the most important type in this forest because it supports the best stands, the best forest sites, and includes practically all the area of plantations.

Above this is found a wetter shorter forest, the Montane Rain Forest, Beard (2). This forest occurs at higher elevations, under a greater exposure and generally less favorable conditions. In the Luquillo Division it reaches to about 3000 feet, but it rises to higher elevations in the Central Mountains. Beard (2) considers its structure as typically rain forest, although the canopy is low to about 60 feet. Hardly any tree reaches 75 feet.

In the Luquillo Division only one association is included in the Montane Rain Forest. This association is the Sabne or Cyrilla, known for the two of its outstanding species, Magnolia splendens and Ocotea spathulata. In Toro Negro, Magnolia portorricensis is found instead of its counterpart M. splendens. Cyrilla racemiflora is dominant over large areas in the Luquillo Division. Other species are: Micropholis spp., Calycogonium squamulosum, Matayba domingensis, Tabebuia rigida, Tabebuia schumanniana, and Didymopanax gleasoni. There are several Eugenias. Tree ferns and composite shrubs are common in the understory.

Palm brakes of Euterpe globosa or sierra palm are indiscriminately scattered. This is a fast invader and takes possession of openings in the forest. Abundance of Bromeliads perched over the palms and trees is one of the typical features. In the higher elevations the tree vegetation is dwarfed, and although it includes many species found at lower elevations, it has been called the "Elfin Woodland" or "Mossy Woodland" because of its very striking structure. It is recognized

as a separate mountain formation. Much of the forest growth is 10 to 12 feet tall, and in the more exposed places just thickets about 6 feet in height. Important species are Clusia spp., Ocotea spathulata, Eugenia borinquensis, Tabebuia rigida, Calycogonium squamulosum, Cordia borinquensis, and dwarf sierra palms.

SAMPLE OF PROJECT SPECIFICATIONS FOR THE EARLY PLANTING WORK

PRRA Supervision
Forestry Division
Project Specifications

Camp No. _____
Forest Caribbean
Structural _____
Non-Structural _____

1. Project: Pizá Planting 26.124 205-4001.4.19[x]

[x] To be used on requisitions, payrolls, etc.

2. Location: Northern and western parts of tract #13 in the Luquillo Unit of the Caribbean, south of the town of Río Grande between the River Espíritu Santo and the Río Grande.

3. Purpose: To convert brush and pasture land to a stand of valuable hardwoods for the purpose of timber production and watershed production.

4. Description: This area comprises approximately 1200 acres of brush and poor pasture at an elevation of about 1000 feet above sea level. Soil is of heavy clay and rainfall in this region is abundant.

5. Specifications: Clear area of brush, grass and weed species leaving any valuable reproduction encountered. Plant Honduras mahogany in mixture with guaraguao, maga colorada or capá prieto in alternate rows with a spacing of 6' x 6'. Planting should be confined to the rainy season and all leaves trimmed from the seedlings before planting. Weed plantations at approximately two months, 6 months, 1 year, and two years after planting.

6. Estimated amount and cost of materials.

Species	No.	Cost
Honduras mahogany	600,000	$2,400.00
Guaraguao	200,000	800.00
Maga colorada	200,000	800.00
	First aid materials	200.00
	4 gals. white paint	9.20
	1 gal. black paint	2.00
		$4,211.20

7. Equipment:

400 machetes	$148.00
100 pick mattocks	87.50
burlap	20.00
	$255.50

8. Organization:

Project Superintendent

Clerk		Foreman	Timekeeper
	8	Subforemen	
	24	Leaders	
	376	Laborers	

9. Order of Work:

Clear areas of brush, grass and weed species.
Plant seedlings.
Weed new plantations when necessary.

10. Allotment:

Materials	$7,411.20
Equipment	255.50
Labor	60,000.00
Supervision	6,000.00
	$73,666.70

11. Duration of Work:

Clearing and planting, 4 months; weeding 2 years.

12. Man-Days:

60,000

13. Originated by:

14. Specifications prepared by:

15. Approved by:

16. Work started:

17. Completed to:

Date	Unit	Quantity	Remarks

Form TFU- 23

SAMPLE OF

FOREST PLANTATION SURVEY

Site study

No. 1 Date 1 - 15 -44

Unit Luquillo Project Ciénega Alta Plantation P-S-21

Location On the northern side of parcel no. 5 below the trail leading to the school.

Site Conditions

Soil A deep phase of Mucara of medium fertility

Topography Low slope at base of a steeper slope
(Ridge, slope, valley)

Slope 8 - 10 % Aspect North East

Shade Partial (dense, partial, open) Weeding Cult (Corona or cult) Parcel? Yes (Yes or No)

Remarks: Shade was partial at time of establishment but after two years was completely removed to allow full sunlight. Site had been under bananas and cultivated until trees no longer permitted cultivation.

Cultivation has not worn-out soil appreciably because of favorable slope and constant deposition from above. Maga was planted at the bottom with capá blanco above it. Both species need some pruning. Only maga needs thinning within the next year.

Species Dominican mahogany Av. Diam. 2.5 ins. Av. Ht. 10 ft.

Age 6 Years Max. Diam. 3 ins. Max. Ht. 12 ft.

General survival and conditions Dominican mahogany was planted pure spaced 6' x 6'. Maga and capá blanco replaced mahogany due to unthrifty condition. Mahogany is stunted and attacked by shoot borer and leaf blight.

Species Maga colorada Av. Diam. 3 ins. Av. Ht. 20 ft.

Age 4 1/2 Years Max. Diam. 3.5 ins. Max. Ht. 25 ft.

General survival and conditions Survival was high probably over 60 per cent. Trees are very thrifty and form is fair to good. Form seems to improve with a close spacing where survival was higher. Trees prune themselves when closely spaced.

Species Capá blanco Av. Diam. 2.5 ins. Av. Ht. 15 ft.

Age 4 Years Max. Diam. 3 ins. Max. Ht. 20 ft.

General survival and conditions Was replanted in the steeper part where some maga failed. Shade had already been removed so form is poor due to excessive branching. Trees are thrifty and growing well. There is room for some pruning although it would have been more desirable during the first two years.

Work Needed

Replanting No Pruning Some of the capá blanco

Weeding No Thinning Some of the poor-shaped maga trees.

Site for Growth Plot Yes

A FOREST PLANTING POLICY FOR PUERTO RICO - 1945

By Frank H. Wadsworth

Study of past regeneration work in the Caribbean, both in the field and in the records, has brought forth the great need for a stable planting policy. Such a policy cannot be as detailed as is possible on the continent where forestry is further advanced. For example no attempt should be made at this stage to pass final judgement on different tree species. Although the findings of the survey just described are based upon intensive study of many millions of trees planted on a wide variety of sites over a period of 20 years, and although the species recommended have made the best showing to date, no claim is made that research may not at any time find better species. Notwithstanding this and many other phases of forestry not yet fully understood here the adherence to the best policy which can at present be formulated will make possible much better orientation of planting work than in the past. As this policy differs in some respects from those of the continent an attempt has been made to explain it fully by describing in some detail the techniques to be used.

The Objects of Planting.

Forest planting is done in Puerto Rico (1) for timber production and (2) for watershed protection. The former is nearly always the chief objective although on steep bare slopes with very poor soils in areas of high rainfall the latter may be the most important.

The final goal of planting is the establishment of a forest which is (1) all-aged, (2) composed of sawtimber and durable round timber species, and (3) capable of reproducing itself.

A longer period will be required for the establishment of an all-aged forest than would be necessary for an even-aged forest. Nevertheless an all-aged forest is considered preferable for the following reasons:

(1) The removal of the bulk of the volume during a short period, as is necessary in even-aged stands even under the shelterwood system, cannot be done without so opening the forest that vine growth will become troublesome. Cutting of vines from a new stand or plantation is a job which experience has shown must be done at least annually for 10 years. Frequent light selective harvest cuttings in an all-aged forest on the other hand, may be made without this very undesirable result.

(2) The danger of soil erosion in mountainous areas with very high rainfall is great following heavy cuttings in even-aged stands but does not exist after light cuttings in all-aged stands.

(3) Indications are that an all-aged forest withstands hurricanes better than an even-aged forest. Hurricanes have visited the island during the past 40 years at the rate of once every five years.

Sawtimber (primarily furniture woods) and durable round timber species are believed to be the highest yielding products of the forest. Fuelwood yield can always be maintained at a very high level on a by-product basis.

The desirability of a forest which reproduces itself is obvious. In such a forest none of the present heavy establishment costs need ever be paid again. This stipulation requires that the species of the managed forest be sufficiently shade-tolerant to be able to reproduce themselves under natural forest conditions without liberation except for that provided by light periodic cuts.

The relative merits of mixed and pure stands have not been determined under Puerto Rican conditions, but it appears that a mixed stand, being more natural, may prove more satisfactory.

Planting for Forest Production.

The chief contribution of planting in Puerto Rico toward increased forest production is its provision for control of forest composition or in other words, assurance that certain desirable species will be represented.

The climax formation throughout Puerto Rico is forest, and thus it cannot be said that planting produces tree growth where it would not otherwise become established in time. Nor does planting greatly shorten this period. Almost any abandoned cleared area will become covered with brush within two to five years and a forest will develop soon thereafter. Some of the plantations here have not exceeded that rate of development, and had they not been cleaned once or twice annually the planted trees would have been smothered by volunteer growth.

In spite of the fact that forest planting in Puerto Rico does not serve these functions the planting of bare forest land solely to control the species in the forest which is to develop is economically justifiable on almost any site on the island. This justification of planting is believed to be much more important here than on the continent. Forests here are extremely complex, there being more than 500 native species within some 3,500 square-miles. As a rule the species of trees which invade abandoned cleared lands are inferior to those which might be successfully established by planting. They often are of species which, because of small size at maturity, inferior wood, or inherent poor form, produce nothing of value, or fuelwood only. Succession to a highly productive forest of the better native species is slow and, even with judicious silvicultural practices in effect, probably would require at least three rotations.

Thus it is seen that the immediate establishment on bare land by planting of the best species would advance forest production many years. However, bitter experience has shown that most of the species most desired in the well-managed forest are adapted only to a shady forest habitat with soil rich in organic matter and are not capable of becoming established on the exposed and degraded sites characteristic of abandoned cleared land. It is therefore almost always necessary to plant and to manage

during the first rotation other tree species which are better adapted but which yield less. If no adapted species could be found which would yield better products than fuelwood, planting should not be done, but instead the natural vegetation should be permitted to do the job. Such vegetation would become established rapidly without cost and usually produces at least fuelwood. Fortunately, however, good pole and tie species have been found which will survive on the worst Puerto Rican sites, and planting of these is recommended where the ability of better species to become established is in doubt.

Planting bare land at 8 x 8-foot spacing leads to an even-aged rather than the all-aged forest which is desired. Conversion to an all-aged forest can be accomplished gradually by spreading the harvest of the first crop over a long period. Light selective cuttings at five-year intervals which remove only the largest or poorest individuals will encourage reproduction of many ages and will eventually produce an all-aged forest. If the species planted were chosen for adaptability to an adverse site rather than high yield, as is generally necessary, introduction of better species may be made by gradually underplanting a small number of trees under the openings created by each of the several light cuttings of the canopy trees.

Planting is justified also in established forests, if they contain chiefly poor species, such as volunteer stands recently developed on formerly cleared lands. However, in accordance with Forest Service policy, this type of planting has lower priority than reforestation. Planting here may advance succession toward a forest of the better species by several rotations or may introduce exotic species superior to the best native species which might become established, regardless of time. If the existing cover, however poor the trees, is preserved to the extent necessary to maintain a forest environment the most productive species known to be suited to the site may usually be established immediately by underplanting without any intermediate planting of hardier, less productive tree species. For this reason a forested area, regardless of the species present, is much farther advanced toward high forest productivity than an open area on the same site.

Planting for Watershed Protection.

The greatest single advance which could be made in the conservation of the natural resources of Puerto Rico is the establishment of forest on steep lands under high rainfall. Recognition of the beneficial influence of forests in soil stabilization and retarding of runoff is seen in the location of the public forests of the island on the steepest lands and in the headwaters of important rivers. It is believed that when Puerto Rico's land is properly classified for its highest use the relative need for soil and water conservation will distinguish forest from non-forest land.

Planting trees is one way in which the needed protective forest cover can be established. However, planting merely to supply a forest cover is not generally justified because of the great rapidity, already described, with which most sites become covered with protective volunteer tree growth without planting. Thus it must be recognized that despite the great

protection value of the cover produced, except under the most extreme circumstance forest planting is done in Puerto Rico primarily to assure the productive, not protective capacity of the vegetation which becomes established. On no site in Puerto Rico need the establishment of a protective cover be the sole reason for tree planting, as trees which are productive as well as protective are adapted to even the most adverse sites of the island.

The Role of Natural Vegetation.

The generally low productivity of volunteer growth on abandoned cleared lands has been referred to. Such vegetation is not always a liability, however, and should be carefully considered for what it may be worth. When a volunteer tree of inferior species or poor form is hindering the development of a promising planted tree its value is clearly negative and it should be removed. When volunteer trees are not interfering with planted trees their presence is generally beneficial.

The most important contribution of volunteer trees is generally shade. Shade, regardless of the tree which provides it, maintains soil humidity during dry weather and produces an ideal environment for the establishment of better trees, either naturally or through underplanting. Also, side shade tends to train and prune the planted trees, producing clear straight boles.

Another important value of these volunteer trees may be in their present or potential wood products. If the trees are of good form, and are of the better sawtimber or post species and are not interfering with superior planted trees it is generally economic to incorporate them into the "plantation" and to carry them through the rotation. If because of their poor quality they will never serve for anything but fuelwood and their removal will not excessively open the canopy at a location where no promising advance reproduction exists they should be cut after they have attained merchantability.

The removal of undesirable volunteer trees can generally be done at a profit here if they are three or more inches in diameter. Such cuttings should be predicated upon silvicultural needs. Gradual removal in light cuttings will provide an ideal opportunity for the development of young underplanted trees beneath.

Plantation Care.

The compromise which must be made in planting on poor sites between high yielding species which are not well adapted and less productive species better adapted has already been mentioned. If, following planting on such sites, no care is given the trees conditions are so adverse that only a few species survive. Even if survival is high the trees will produce little for one or more of the following reasons: (1) slow early growth due to competition with weeds, (2) poor form which may result from damage caused by vines, (3) limbiness due to lack of pruning, and (4) early stagnation or reduction in growth due to crowding. If, on the other hand, weeding, vine cutting, pruning, and thinning are done when needed the adversity of the site is so ameliorated that a larger number of species can be expected to successfully become established, some of which may

produce better woods. Growth will be more rapid, and the quality of the timber produced will be higher. If the increase in yield will pay for the cost of the care needed the work is justified.

The mere fact that increased yield pays for the cost of plantation care does not establish a technique as satisfactory. The best practice is that in which the excess of increased yield over cost is the greatest. Thus among a group of equally high yielding species the best is that requiring least care. On the poorest sites the opposite approach is necessary; of those requiring least care which yields the most?

Weeding, the elimination of grass and herbs, has been found to satisfactorily serve its function if the grass or brush is cut down to one to three inches in height within a circle of 18 inch radius around the tree. When the trees are two feet taller than the general level of the surrounding grass or herbaceous vegetation weeding is no longer justified as its beneficial effect, while still existant, is considerably lessened thereafter. Cultivation of the soil is beneficial only at the time of planting and may be harmful thereafter. No rule can be set as to the number of weedings per year because of wide variation with site. It has never been necessary here more than 4 times during a year and generally twice is sufficient. Weeding is seldom necessary after the second year in good plantations.

Vine cutting, the elimination of vines from the planted trees, requires that the vines be carefully removed in order to avoid damaging the trees. The vines should not be merely cut but should be uprooted. No cutting of grass or herbaceous vegetation need accompany vine cutting. As with weeding, no rule can be established as to the number of cuttings needed per year. On some sites it is necessary three or four times. Vine cutting may on particularly bad sites be necessary occasionally throughout the first 10 years of the plantation. As vine cutting is costly in the aggregate, every effort should be made to control vine growth by maintaining sufficient shade to prevent it. Vines should be removed from volunteer trees as well as planted trees, as they often will spread from crown to crown.

Pruning and thinning have not been given adequate attention here in the past. Only small parts of plantations are in need of these treatments. No standards can be established on the basis of our present knowledge, but when research has discovered the best policies they will be put into effect.

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