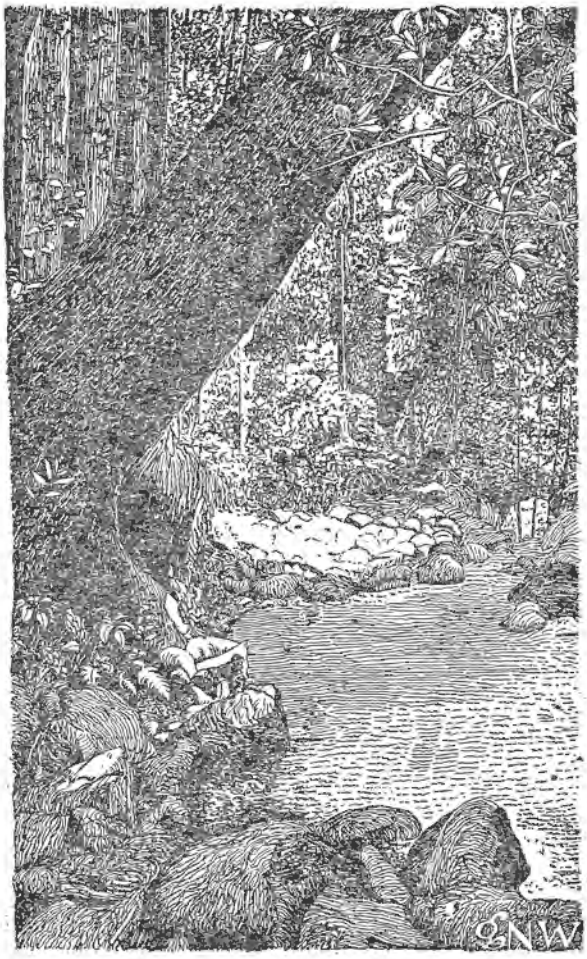
The Caribbean Forester



U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
TROPICAL FOREST EXPERIMENT STATION
RIO PIEDRAS, PUERTO RICO

VOLUME 11, NUMBER 3

JULY 1950

Caribbean Forester

El "Caribbean Forester", revista que el Servicio Forestal del Departamento de Agricultura de los Estados Unidos comenzó a publicar trimestralmente en julio de 1938 es de distribución gratuita y está dedicada a encauzar la mejor ordenación de los recursos forestales de la región del Caribe. Su propósito es estrechar las relaciones que existen entre los científicos interesados en la Ciencia Forestal y ciencias afines encarándoles con los problemas confrontados, las políticas forestales vigentes y el trabajo que se viene haciendo para lograr ese objetivo técnico.

Se solicitan aportaciones de no más de 20 páginas mecanografiadas. Deben ser sometidas en el lenguaje vernáculo del autor, con el título o posición que éste ocupa. Es imprescindible incluir un resumen conciso del estudio efectuado. Los artículos deben ser dirigidos al "Director, Tropical Forest Experiment Station, Río Piedras, Puerto Rico".

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The "Caribbean Forester", published since July 1938 by the Forest Service, U. S. Department of Agriculture, is a free quarterly journal devoted to the encouragement of improved management of the forest resources of the Caribbean region by keeping students of forestry and allied sciences in touch with the specific problems faced, the policies in effect, and the work being done toward this end throughout the region.

Contributions of not more than 20 typewritten pages in length are solicited. They should be submitted in the author's native tongue, and should include the author's title or position and a short summary. Papers should be sent to the Director, Tropical Forest Experiment Station, Rio Piedras, Puerto Rico.

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Le "Caribbean Forester", qui a été publié depuis Julliet 1938 par le Service Forestier du Département de l'Agriculture des Etats-Unis, est une revue trimestrielle gratuite, dediée à encourager l'aménagement rationnel des forêts de la région caraibe. Son but est d'entretenir des relations scientifiques entre ceux qui s'intéressent aux Sciences Forestières, ses problèmes et ses méthodes les plus récentes, ainsi qu'aux travaux effectués pour réaliser cet objectif d'amélioration technique.

On accepte voluntiers des contributions ne dépassant pas 20 pages dactilographiées. Elles doivent être écrites dans la langue maternelle de l'auteur qui voudra bien préciser son titre ou sa position professionnelle et en les accompagnant d'un résumé de l'étude. Les articles doivent être addressés au Director, Tropical Forest Experiment Station, Río Piedras, Puerto Rico.

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"The printing of this publication has been approved by the Director of the Bureau of the Budget (August 17, 1950)".

VOL. 11 - No. 3 JULY 1950

The Caribbean Forester

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Sumario

Estudiante Cubano Termina Curso de Entrenamiento en Materia Forestal en Puerto Rico

En junio del año en curso Arcadio M. Díaz Martínez, agrónomo graduado de la Escuela Forestal Pozos Dulces de Cuba, terminó seis meses de adiestramiento en dasonomía avanzada en la Región Tropical del Servicio Forestal en Puerto Rico. El Secretario de Agricultura de los Estados Unidos le había conferido al Sr. Díaz, quien es un empleado del Ministerio de Agricultura de Cuba, una beca para un año de estudios en el Servicio Forestal de Estados Unidos. El adiestramiento de este estudiante incluyó 6 semanas en un Centro de Orientación donde tomó cursos de inglés y de costumbres norteamericanas y tuvo ocasión de visitar sitios de interés en Washington, Distrito de Columbia y sus alrededores. Después recibió un mes de enseñanza en técnica forestal, familiarizándolo con la organización central y regional del Servicio Forestal de Estados Unidos; con los tipos forestales; especies forestales; clima; silvicultura; utilización; protección, ordenación; planeo de la ordenación; pastoreo; caza; hidrología y dasonomía privada.

El resto de los primeros seis meses lo pasó en el laboratorio de Productos Forestales y en los bosques del sudeste de los Estados Unidos. En el Laboratorio de Productos Forestales el señor Díaz participó en los estudios de las propiedades físicas y mecánicas y de la estructura de las maderas. También tuvo ocasión de probar diferentes métodos de preservación de madera, usando lo último en materia de preservativos. En los Bosques Nacionales de la Región Sur el señor Díaz abordó los problemas de administración forestal, ordenación de áreas de recreo, plantación y protección contra incendios forestales.

El señor Díaz pasó en Puerto Rico aproximadamente la mitad del año 1950, participando en varias tareas de oficina y de campo, relativas a administración forestal, ordenación e investigación en la Región Tropical del Servicio Forestal. El pasó tres meses entre los guardabosques de las diferentes unidades participando en la administración de áreas de recreo, en ventas de maderas y en la inspección de plantaciones. Con el Servicio Forestal Insular pasó una semana efectuando estudios similares y otra semana con el personal de campo de esa agencia, que estaba efectuando un inventario forestal de toda la isla. Durante otra semana el Sr. Díaz asistió al estudio de plantaciones, determinando la adaptabilidad de diferentes especies al medio estacional. Además pasó varias semanas con el personal principal de la Estación de Experimentación Forestal Tropical re-examinando cuarteles de ensayo, estudiando la mejora de rodales, la determinación de existencias, la preservación de postes y la construcción de tablas de volumen. Por espacio de dos semanas estuvo con técnicos del Servicio de Conservación de Suelos, aprendiendo los principios de clasificación de tierras y conservación de suelos. Al finalizar su curso de entrenamiento el Sr. Díaz preparó un informe para someter al gobierno de Cuba, recomendándole un programa de dasonomía pública.

Hasta la fecha, la Región Tropical del Servicio Forestal ha entrenado agrónomos de Cuba, Haití, Costa Rica, Venezuela y Bolivia. Estos cursos de entrenamiento están considerados como una función importante de esta oficina y esperamos que otras naciones aprovechen las ventajas de esta oportunidad.

Results of Forest Planting in the Insular Forests of Puerto Rico

JOSE MARRERO

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In a recent issue of The Caribbean Forester (9:85-213, 1948) a report on past forest plantings in the Caribbean National Forest was presented as a guide to future planting work. Upon completion of that study a similar investigation was carried out within the public forests of the Government of Puerto Rico. The results of this investigation are reported here. The same order of presentation has been followed, describing in order the enviroment, history of planting, methods of study, findings, and conclusions.

The Insular (as opposed to Federal) Forests of Puerto Rico cover some 45,000 acres, an area about 50 percent larger than that of the Caribbean National Forest. The planted area of about 16,000 acres is three times as large as in the Caribbean National Forest. Many different sites are included.

ENVIRONMENT

Nine distinct forest areas were studied. Environmental conditions vary so widely that each area is here described separately. The ecological descriptions include the use of Beard's (1) classification of vegetation.

CARITE

The Carite Forest contains about 6,300 acres in the southeastern mountains. It ranges in elevation from about 650 to about 3,000 feet. At Carite Reservoir at an elevation of 2,100 feet in the interior of the area the mean temperature is 72°F. and monthly means vary between 65° and 80°. The range in annual rainfall is from 65 to over 100 inches. At Patillas Reservoir, at 240 feet elevation near the south edge of the area the mean temperature is 76° and the monthly means vary between 71° and 86°F.

The parent rock is of volcanic origin, including andesitic tuffs and shales and quartz diorites. Most of the area is covered by deep, acid, heavy clay soil (Los Guineos and Catalina series) but a looser granular (Pandura) soil develops over quartz diorite. The soils of the southern slopes are shallow and less acid (Múcara).

The forest has at one time been removed from nearly all of the Carite Forest area. Small remnants of climax vegetation exist in remote areas. Cutting was partly for the timber but chiefly for farming. Large areas have since become reforested naturally. The forest types represented are montane thicket, lower montane rain forest, and evergreen seasonal forest.

GUAJATACA

The Guajataca Forest contains about 2,300 acres in the dry western limestone hills of the north coast. Its elevation is about 1,000 feet above sea level. Monthly temperature means range between 71°F and 82°F at nearby weather stations. Annual rainfall is between 70 and 80 inches. Evaporation is apparently much higher on the exposed tops of the hills than in the protected sinkholes between them. The parent rock is tertiary limestone. The topography is rough, consisting of numerous hills and sinkholes. The soils are mostly red or reddish brown clay (Tanamá series) from a few inches to 3 feet in depth. Other soil series are probably found in the bottoms of sinkholes. Soil depth varies with topography, since colluvial deposits accumulate on the lower slopes.

The forests of Guajataca have been cut and burned repeatedly. In 1935 when the area was taken over by the government the vegetation was chiefly low brush or grass.

Now small areas of secondary forest have developed on the north and west slopes. Most of the sinkhole bottoms bear coffee plantations. Apparently there was considerable variation between the forests of the hilltops and the sinkholes. The former may have been a dry evergreen forest, and the latter, evergreen seasonal or possibly lower montane rain forest.

GUANICA

The Guánica Forest contains about 7,000 acres of low hills along the southwest coast. Elevation ranges between sea level and about 500 feet. The mean temperature is about 77°F with a monthly range between 74°F and 79°. About 30 inches of rainfall are received in an average year. Severe droughts are frequent, chiefly from December to April. The southern edge of the forest is subject to sea blast.

The parent rock is tertiary limestone deposited when the area was beneath the sea. The topography is rolling. Except for beach sand the predominating soils are shallow clays (Aguilita and Ensenada series).

A short forest is found on most of the area. The canopy is generally only about 20 feet tall, although trees 50 feet tall are found in protected ravines. The shallow rocky soil and light rainfall have precluded cultivation of most of this area. Nevertheless the forest has been cut for fuelwood. Deforested areas were grazed until forest plantations became established. The original vegetation was probably deciduous seasonal forest.

GUILARTE

The Guilarte Forest comprises about 2,800 acres in the west central mountains. Elevation ranges between 2,500 and 3,950 feet above sea level. Monthly mean temperature ranges from 60°F to 75°F. A raingage located at 3,000 feet elevation near the area recorded 90 inches of rainfall annually. The mean for the forest is probably slightly higher.

The parent rock is of volcanic origin, chiefly andesites and shales. The dominant soils are yellowish heavy clays (Los Guineos and Cialitos) and grayish to purplish friable clays (Alonso and Múcara).

Remnants of forest remain within the area. They are of the lower montane rain forest and montane thicket formations. Secondary forests cover a large part of the more accessible areas.

MANGROVES

The public mangrove forests are located in protected estuaries and bays on all coasts of the island, near San Juan on the north, near Ceiba on the east, near Aguirre and Guánica on the south, and near Boquerón on the west. They aggregate about 8,200 acres. Climate is relatively unimportant. Mean temperature is at least 78°F and annual rainfall varies from 30 to 60 inches. All of the mangrove forest is subject seasonally to tidal inundation.

The soils are of biological origin, being dark peats and mucks derived from the deposition of plant remains. The soils tend to be more or less brackish.

The mangrove area is mostly forested since the saline soil is of little value for other uses. Nevertheless, the proximity of mangrove forests to coastal settlements has made them subject to repeated cutting. The removal of the best trees has tended to leave poorly formed, open, or brushy stands.

MARICAO

The Maricao Forest contains about 9,500 acres in the western mountains. It is generally steep and ranges in elevation from 500 to 2,000 feet above sea level. Mean temperature is about 72°F. Annual rainfall varies from 108 inches at 1,500 feet to about 80 inches at the southern edge of the forest.

The underlying rock is chiefly serpentine. It gives rise to soils of very low fertility and high in iron. Drainage is excessive. Shallow soils, averaging less than one foot in depth are designated Rosario silty

clay, and deeper soils to several feet in depth are designated Nipe clay.

The forest is generally scrubby, with only very small remnants of what might be considered primary vegetation. The timber was removed for farming. Secondary stands were burned over repeatedly before the area was put under protection in 1918. The original forest was probably not rain forest, but a drier evergreen type with numerous small-leaved trees.

MONA ISLAND

Mona Island is located about 45 miles west of Puerto Rico. It is about 6 miles long and 5 miles wide at the widest point, containing 13,600 acres of public forest land. Is is generally level, with a plateau about 200 feet above the narrow coastal plain. The average annual rainfall is about 40 inches. Most of this is received during the fall of the year.

The island is composed of tertiary limestone, and is covered by shallow grayish soils similar to the shallow phases of Ensenada and Aguilita stony clay. A strip of beach sand is of some importance on the southwest coast. Sandy and sandy loam soils on the coast range to 2 feet in depth.

About 85 percent of the island is covered by short forest generally less than 12 feet tall. Past land clearing for agriculture on the coastal plain has left some grassland areas. Most of the forest has been heavily culled for fuelwood. It probably belongs within the province of deciduous seasonal forest. On the exposed east edge of the plateau the vegetation is cactus scrub.

RÍO ABAJO

The Río Abajo Forest covers about 4,900 acres in the humid limestone hills of the central north coast. The topography is rough, with numerous sinkholes with steep walls. Elevation ranges from 500 to 1,400 feet above sea level. Reliable temperature data are not available, but it is known that the nights are cool, probably as a result of air drainage from the higher mountains to the south. Rainfall averages about 80 inches annually with a low of possibly 70 inches at the northern edge of the forest.

The parent rock is tertiary limestone of the Lares formation. The dark soils of the limestone hills are usually less than a foot in depth and are in the Soller and Tanamá series. In the few open valleys deep reddish clay soils are present (Camagüey clay loam and Dominguito, Moca, Lares, Río Arriba, and Cialitos clays).

The vegetation is considerably influenced by exposure and soil depth. Apparently that on the hill tops was originally dry evergreen forest, whereas an evergreen seasonal and possibly lower montane forest grew in the sinkholes. Drier conditions are evident near the northern boundary of the forest. Past cutting removed the forest cover from all but the least accessible and forested cliffs and hill-tops. The valleys have all been cleared and intensively cultivated for tobacco and food crops causing loss of most of the topsoil. On the lower slopes and bottoms of the sinkholes coffee and bananas have been produced. In the past, fire destroyed secondary growth on many of the hills. Protection from fire during the past 15 years has produced secondary growth on most of the slopes.

SUSUA

The Susúa Forest contains about 2,800 acres in the southwestern foothills. It has very rough topography and ranges from 500 to 1,500 feet in elevation. Temperature records are not available, but it is known that there is considerable variation between the hot afternoons and the coolness of the early morning. Rainfall varies considerably from the high northern edge of the forest to the lower southern edge. The average is probably about 60 inches annually. The dry season from December to March is very pronounced.

Like Maricao, the Susúa Forest is underlain largely by serpentine rock. Small areas of shales and tuffs are also present,

producing a silty clay soil (Descalabrado). All of the soils are shallow and excessively drained.

The vegetation was nearly completely destroyed for cultivation and grazing. Apparently the original stand was semi-deciduous seasonal forest, varying somewhat with exposure and soil depth. After fifteen years of protection part of the area is covered with low brush.

HISTORY OF PLANTING

Forest planting was started in the Maricao Forest in 1920 with the beginning of a large-scale program of introduction of exotic tree species and adaptability tests with native species. At Guánica planting began in 1922 and totalled 68,000 seedlings and 500 pounds of seed sown directly during the ensuing 10 years.

A second period of planting, from 1934 to 1941, was much more active than the first, and produced 12,600 acres of plantations. Unsuccessful earlier plantations were replanted also. Particularly significant to planting in this period was the purchase of large additional areas for public forestry.

From 1941 to 1949 the maintenance of the large area of existing plantations took most of the funds available for planting work. A small additional area was planted for the first time, however.

In summary, a total of about 16,000 acres were planted in the Insular Forests between 1920 and June 1949. A total of about 13,163,000 seedlings were planted and 91,230 pounds of seeds were sown. Forty-six different species of trees were included. The record of past planting appears in Table 1.

Table 1.—Planting Work Done in Insular Forests, January 1936 to June 1949.

Species	Total Number Seedlings	Seed, in lbs.
Albizzia procera	22,000	
Aleurites trisperma	800	
Andira jamaicensis		7,700
Avicennia nitida	44,000	730
Bambnsa sp.	8,000	
Bambusa tuldoides	1,000	
Byrsonima spicata	16,000	
Calophyllum calaba		55,800
Castilla elastica	200	
Casuarina equisetifolia	402,000	
Cedrela mexicana	545,000	
Cedrela odorata	17,000	
Colubrina ferruginosa	524,000	
Cordia alliodora	726,000	
Dacryodes excelsa	300	
Dalbergia sissoo	32,000	
Dipholis sintenisiana		260
Eucalyptus robusta	377,000	
Eucalyptus sp.	1,267,000	
Guarea trichilioides	256,000	
Guaiacum officinale	47,000	440
Haematoxylon campechianum	1,000	
Hyeronima clusioides	200	
Hymenaea courbaril		1,900
Inga punctata	3,000	
Laguncularia racemosa	167,000	2,500
Lucuma multiflora		8,900
Montezuma speciosissima	1,071,000	
Ocotea moschata		50
Petitia domingensis	674,000	110
Prosopis julifora		2,680
Rhizophora mangle		9,600
Samanea saman	1,000	
Sideroxylon foetidissimum	17,000	
Stahlia monosperma	100	
Swietenia candollei	1,019,000	
Swietenia macrophylla	1,593,000	
Swietenia mahagoni	3,955,000	520
Tabebuia pallida	25,000	
Tamarindus indica		40
Tectona grandis	228,000	
Tetragastris balsamifera	7,000	
Vitex divaricata	118,000	
Zanthoxylum flavum	500	
Zizyphus jujuba	200	
Total	13,163,300	91,230

PLANTING PRACTICE

Planting stock of various types has been used. Experience showed that most species can best be established using sturdy nursery stock. Overgrown nursery stock had to be used at times and was cut back for planting with good results for *Swietenia macrophylla*, King, *Cordia alliodora* (*R. & P.*) Cham, *Tectona grandis L.*, *Vitex divaricata*, Sw. and *Guarea trichilioides L.* Higher survival was obtained with potted seedings of *Swietenia mahagoni* Jacq. in dry acreas. Heavy-seeded

species, notably *Calophyllum antillanum* Britton have been sown directly in the field. *Casuarina* and *Eucalyptus* have been transplanted in the nursery to improve stock quality. Wildings of a few species have been used on a small scale.

Ground preparation originally consisted of cutting woody vegetation of inferior species. This proved expensive and to a large extent unnecessary. It was a particularly undesirable practice on adverse, exposed sites where protection was needed. More recently the volunteer trees have been left to grow, and narrow planting lines are opened with machetes. A small amount of underplanting has been done, leaving the canopy unchanged except to provide small openings above the planted trees.

Planting has always been done with pick-mattocks because of the heavy soils and the presence of rocks and large roots. The spacing, not always regular because of obstructions has varied bewteen 5 x 5 and 8 x 8 feet, averaging 6 x 6 feet. Underplanting has been done with wider spacings up to 25 feet. Plantings have generally been pure but as a rule have produced mixed stands where replanting was done with other than the original species. This was a result of increased knowledge concerning species adaptability.

PLANTATION CARE

A large investment in plantation care was found necessary subsequent to planting. Weeding has generally been done for from 2 to 4 years, and vine cutting has sometimes been done at least annually for more than 5 years. The length of this period of post-planting care has varied with the nature of the native vegetation and the rapidity of tree growth. In some plantations more weeding was done than was necessary, but more frequently plantation care has had to be periodically neglected because of fluctuations in appropriations from year to year. Weeding has generally consisted in freeing from vines and herbaceous vegetation a circular area of 2 to 3 feet in diameter around each tree or lines maintained free of vegetation along the lines of trees.

Pruning and thinning have been considered only in the older plantations. Early pruning proved undesirable in some plantations because of subsequent epicormic branching. The need for pruning has been avoided where possible by retaining densely stocked plantations. Thinning has been practiced on so small a scale as to hardly warrant mention. Only a few plantations are sufficiently large to need thinning. Liberation cuttings were made, however, in some areas where old coffee shade had been used as a shelter for plantation establishment. This work was generally not done until the planted trees had reached 10 feet in height.

PLANTATION COSTS

Planting costs varied widely with a number of factors. Nursery stock averaged about $3.00 per thousand trees. Potted stock cost about $8.00 per year thousand trees. Wilding stock averaged $4.50 or 3 man-days per thousand trees. Seed cost varied from $0.30 to $1.80 per thousand seeds.

Ground preparation was the largest single item of expense connected with planting. Costs of ground preparation averaged 13 man-days per acre, ranging to as low as 6 man-days per acre in the relatively open limestone hills and on dry sites with little vegetation.

Planting itself averaged about 10 man-days per acre but for direct seeding required only 3 man-days per acre. Replanting costs, which are a measure of the success of selection of species as well as of the planting job istelf, were high. In the humid moutain forests at Carite, and Guilarte, replanting cost about 15 man-days per acre, and reflects repeated replanting of poor weedy sites. In the limestone region of the north coast, at Guajataca and Río Abajo, replanting only cost 5 man-days per acre, a result of better species selection and less weed competition. In the dry forests of Susúa and

Mona Island where potted seedlings were used extensively replanting cost only 6 man-days.

Weeding is the most expensive item of cost in past forest establishment in the Insular Forests. Control of agressive native vegetation has required cleaning more than once each year for at least the first 5 years after planting. During these first 5 years weeding cost 42 man-days per acre in the humid mountains, 16 man-days in the limestone region, and 7 man-days in the dry areas.

Total costs for the 5 years average 77 man-days per acre in the humid mountains, 38 man-days in the limestone region, and 34 man-days in the dry areas. Of this total cost ground preparation and initial planting made up only 32 percent in the humid mountains, 46 percent in the limestone region, and 65 percent in the dry area. Weeding during the first 5 years made up 55 percent in the humid mountains, 42 percent in the limestone region, and 21 percent in the dry area.

Weeding costs were affected very materially by the character of the native vegetation. Tall bunch grasses such as guinea grass (*Panicum maximum*) must be cut back frequently while the plantation is young. The presence of herbaceous vines notably bejuco de puerco (*Ipomoea* sp.) greatly prolongs the period during which frequent weedings are necessary. The fact that the native vegetation in the dry areas is less agressive is seen in the lower weeding costs presented.

Costs of establishment at Guilarte are lower than elesewhere in the humid mountains because of the presence of a mixture of natural tree growth of partly acceptable species. These established trees assisted in the control of weeds and reduced the need of planting. It is significant that the higher cost of planting potted stock in dry areas was more than offset by lower weeding costs.

Planting in mangrove areas was generally cheaper than elsewhere. Total costs ranged between 3 and 8 man-days per acre except where it was necessary to remove the aggresive fern marunguey (*Acrostichum aureum* L.) This cost about 20 man-days per acre. Direct seeding and broadcasting were practiced, and no weeding was necessary.

Planting costs shown here are for the first 5 years. Total costs will be even higher, since vine cutting is necessary up to 10 years in some of the plantations of species not well adapted to the site.

OBSERVED RESULTS PRIOR TO THE STUDY

Results began to appear soon after the initiation of large scale planting in the Insular Forests. The planting sites, most of which had been abused by previous cultivation and were exposed and badly overrun by weeds and vines, proved unsuitable for the establishment of the better species of climax forests. The limitations of a large scale reforestation program carried on during a relatively short period and initiated with little previous experience resulted in failures in some areas. As a result, replanting costs were high. Lack of information concerning species-site relationships led in some areas to immediate failures or to weeding expenses which proved futile when the trees later died or were to be replaced by better adapted species. These and other findings led to the following major modifications of policy and practice.

1. All but the most aggressive species were eliminated from plans for planting or replanting exposed sites with degraded soils.
2. The better species were limited to the more favorable sites.
3. The number of species used was reduced and preference was given to native species.
4. Large-seeded species were sown directly at the planting site usually with a high survival.

5. On dry sites where high survival was difficult to attain, ball-of-earth planting was practiced, using tar-paper pots. Potted stock was produced in small nurseries near the planting site.
6. Individual planting crews were reduced to a size which could be adequately supervised. Local men were selected and trained.
7. The potentialities of natural reproduction were better appreciated. Cutting of natural tree growth prior to planting was minimized and many naturally established trees were incorporated into the plantations, receiving the same care as the planted trees.

METHODS OF STUDY

The objective of the study was to sum up all available evidence regarding the relationships between the different tree species planted and their environments. All plantations were examined to determine their present condition and the corresponding sites. The data of most value were those collected in fully stocked plantations. In such areas the species-site relationships were most evident, and growth could be accurately measured. Less information was available in areas of failure because evidence as to the factors responsible for the failure had generally been lost during the several years since planting. Nevertheless, much could be deduced by careful observation in such a large and varied area.

SITE CLASSIFICATION

The first requisite to the relating of observed results to site conditions was a classification of the planted areas with regard to the site factors which appeared to be of greatest significance to the fate of planted trees. The site factors are considered in four broad groups: climatic, physiographic, edaphic, and biological. The climatic factor of most significance in site differentiation is rainfall. Total annual precipitation varies from 30 inches at Guánica to over 100 inches at Maricao, Guilarte, and Carite. The different forest areas are related with regard to rainfall and humidity in ascending order as follows: Guánica, Mona Island, Susúa, Guájataca, Río Abajo, Maricao, Guilarte, and Carite. Rainfall is considered of comparatively little significance in the mangrove areas. The severity of drought is a more reliable index of moisture relationships than mean annual precipitation. Prolonged severe droughts occur annually at Guánica, Mona Island, and Susúa. Drought is of some influence also at Guajataca, Maricao, and the lower southern slopes of the Carite forests. The importance of temperature as a site factor is difficult to appraise since change in rainfall are of so much greater magnitude that the influences of temperature are obscured. The significance of temperature alone upon the relative results of reforestation work in different parts of the island is probably minor.

Physiographic factors such as slope, aspect, exposure, and topographic position affect tree establishment only indirectly as they influence microclimate and soil. They are grouped separately because of the difficulty of treating their effect separately as climatic and edaphic phenomena. Slope is of importance because of its influence upon soil losses by erosion, and upon water absorption and retention by the soil. Aspect is significant with respect to both the prevailing easterly trade winds and the position of the sun. These effects are most pronounced in the drier forests where evaporation is of major significance. Here the southern and eastern slopes tend to be the most adverse. Exposure, related to slope and aspect, is of importance also because of its relationship to evaporation.

Topographic position is a collective term which is probably the most important single site factor in the forests in the rough central mountains and limestone region. Generally valleys and lower slopes are better sites than upper slopes, concave slopes are better than

convex slopes, convex slopes are better sites than ridges, and ridges are better than peaks. This relationship is most pronounced in the sinkhole region. This relationship reflects differences in rate of soil erosion, the contribution of alluvial deposits, and exposure. A counteracting factor is soil drainage; which on certain heavy soils in rainy forest areas such as at Carite and Guilarte may make lower slopes superior to valleys for the establishment and growth of certain tree species. At Susúa and Maricao the effect of topographic position upon the vegetation is less pronounced than elsewhere apparently because of long uniform slopes.

The physical soil factors appear to be more important to reforestation than the chemical factors, although it is probably impossible to completely isolate the two. Loose rocky shallow soils tend to accentuate the effects of drought because of their poor water retention. Such soils are of significance to reforestation at Guánica, Guajataca, Río Abajo, Maricao, Susúa, and the drier southern edge of the Carite Forest. On the other hand, the heavier clay soils in the humid mountains are so poorly drained in the more level areas as to produce root decay in young planted trees.

The effects of modification of soils by past use or abuse can be as significant to tree establishment, at least temporarily, as the inherent physical or chemical properties of the soil. On the heavy soils of the Carite and Guilarte Forests in the central mountains, plantation sucess seems to be more directly related to the history of previous cultivation of the land than to any other factor, in spite of considerable variation in topography. Compacting and loss of topsoil and fertility through erosion and leaching are probably largely responsible for this relationship.

The biological site factors are the presence of insect pests and diseases and competition from natural vegetation. The importance of insect pests and diseases is not yet fully known since the plantations are all still very young. Insects and diseases tend to be

FIG. 1.—*View of lands being reforested in the Maricao highlands. Ridges are evident in the background, a small valley in the center and uniform slopes with a western exposure between them.*

more active on sites which for other reasons are adverse.

Weed and vine growth are important factors in all plantations but chiefly in the humid mountains. Reforestation of open weedy areas may become prohibitive except with the more aggresive species. Competition from arborescent native vegetation can also be an adverse factor. Properly utilized, however, it may serve to protect the plantation from excessive exposure and is a valuable complement to the planted trees. Shade from such an overstory may also control weed and vine growth.

The distinct sites on which forest planting has been done are here described briefly with reference to the more important site factors.

Carite

Climate humid to wet, topography rough, soils generally clays, and intense competition from weeds and vines. Topographic features are typical of the Central Mountains.

Site	Acreage Planted
Ridges	903
Uniform slopes	1,439
Lower, or concave slopes and valleys	480
Total	2,822

Guajataca

Climate humid, topography rough, soils generally shallow clays, over limestone, and weed and vine competition not intense. Here site factors are best expressed by topographic description, as follows:

Site	Acreage Planted
Hilltops	397
Lower slopes	1,278
Sinkhole bottoms	529
Total	2,204

Guánica

Climate dry, topography smooth to rolling, soils generally shallow, stony clays or beach sands and weed and vine competition slight. Plantations have been con-

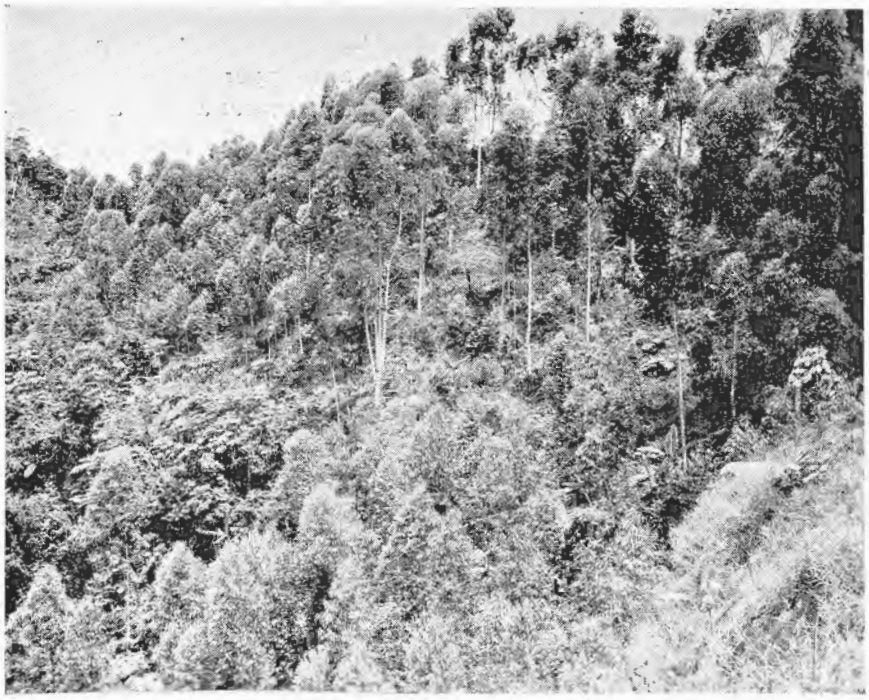

FIG. 2.—*A 7-year-old stand of eucalipto growing on a ridge at Guilarte. A younger stand is also growing on the slope, foreground.*

fined to valley bottoms and lower slopes and no sharp site differentiation is evident in the results to date. About 300 acres were planted.

Guilarte

Climate wet, topography rough, soils generally heavy clays or stony clays, and intense competition from weeds and vines. As at Carite, site differentiation is closely related to topography, as follows:

Site	Acreage Planted
Ridges	148
Uniform slopes	358
Lower, or concave slopes and valleys	197
Total	703

Mangrove

Climate humid, topography level, soils saline mucks or somewhat sandy and generally no weed or vine competition. Sites are differentiated by the soil level and its character. Areas adjacent to sandy soil (the sea side of lagoons) are different in productivity from those adjacent to the clayey soils toward the mainland. The soil washed into the mangrove is important to productivity, and is much richer on the land side of lagoons. In the only mangrove plantation where sites were classified the land side of the lagoon receiving silt or deposits includes 33 percent of the total area.

Maricao

Climate humid to wet, topography rough, soils very poor lateritic clay over serpentine and fairly intense weed and vine competition. These sites were differentiated, as follows:

Site	Acreage Planted
Valleys and lower concave slopes	299
Uniform slopes with northern or western aspect	1,441
Uniform slopes with southern or eastern aspect, upper slopes, ridges and degraded Nipe clay soils regardless of aspect	1,004
Total	2,714

Degraded soils had been created by excessive previous cultivation or repeated fires in soils of very low natural fertility.

Mona Island

Climate dry, topography level, soils sandy, shallow over limestone, and weed and vine competition slight. Only one site, the sandy seashore on the southeast coast, was planted extensively. Plantations there total 420 acres.

Río Abajo

Climate humid, topography very rough, and mostly shallow soils over limestone, weed and vine competition intense. Four sites are distinguished, as follows:

Site	Acreage Planted
Open valleys	715
Sinkhole bottoms	228
Lower slopes	182
Cliffs and upper slopes	879
Total	2,004

Little or no planting was done on the cliffs and upper slopes. Only about 42 percent of the total area was actually planted.

Susúa

Climate dry, topography rolling, soils very poor lateritic clays over serpentine and shales, except for the colluvial and alluvial soils along the streams, and weed and vine competition slight. The sites are differentiated as at Maricao, as follows:

Site	Acreage Planted
Valleys and lower concave slopes	232
Uniform slopes with northern or western aspect	840
Uniform slopes with southern or eastern aspect, upper slopes, ridges, and degraded Nipe clay soils regardless of aspect.	714
Total	1,786

PROCEDURE

The study began with a review of plantation records to determine the history of different plantations, kinds of stock, origin of stock, species, planting distances, weather, and other pertinent details.

The field work was carried out by a crew of two men, the leader being a trained forester. Both men were acquainted with the history of the plantations and local conditions. The first phase of the field work was a rapid reconnaissance of all plantations within a forest to determine general conditions and to find stands of significance in showing species-site relationships. In such areas a brief "site study" was made, consisting of a detailed description of the site and a few measurements of tree diameters and heights. These site studies concerned all species and all sites.

With the completion of the reconnaissance the site study data were reviewed to determine those areas which best indicate site capacities. Temporary quarter-acre circular sample plots were laid out, within which tree diameters were measured, heights estimated, and tree form was recorded, all to provide an indication of plantation development on an area basis at such locations. Trees classified as of "good form" are satisfactory to form a part of the final crop.

FINDINGS

This study was made so long after most of the plantations were established that the effects of different techniques could be appraised only where results were very marked. Much more information was available regarding the adaptability of different species to sites.

TECHNIQUES

The techniques studied were types of planting stock, spacing, mixture of species, weeding and vine cutting, pruning and liberation.

It was learned early that the seasonal nature of Puerto Rico's rainfall and the wide variation from year to year are of great significance to the success of forest planting. One rainy week during the dry season is generally insufficient to ensure success. Even planting during May, a generally wet month, is risky in the drier forests because June and July are usually dry. A rainless period as short as two weeks inmediately after planting may kill the trees. Planting should be discontinued a month or more before the end of the normal rainy season, which is usually in late December or early January.

The most favorable seasons for planting in the different forests are as follows:

Carite.—Early in May to late November, except at low elevation to the south (Patillas) where planting should be discontinued by the middle of November.

Guajataca.—Early in May to late in October.

Guánica.—Middle of August to middle of October.

Guilarte.—Early in March to late in November.

Mangroves.—Year around depending upon stock availability.

Maricao.—Middle of April to late in October.

Mona Island.—Early in September to late in October.

Río Abajo.—Middle of April to late in November.

Susúa.—Early in August to late in October.

May is a wet month on the south coast (Guánica and Susúa) but is normally followed by dry weather in June and July, so planting should generally be delayed until August at that location.

Planting Stock

Most plantations were established with bare-rooted seedling nursery stock from 18 to 24 inches tall. Australian pine (*Casuarina equisetifolia* Forst) and various species of Eucalyptus are exceptions in that they

produce poor stock if not transplanted in the nursery when from 4 to 8 inches tall. This transplanting improves both the root system and the crowns of the trees. Overgrown nursery stock of teca (*Tectona grandis L.*), capá prieto (*Cordia alliodora* (R. & P.) Cham.) and caoba hondureña (*Swietenia macrophylla* King) may be cut and planted with satisfactory results. Tabonuco (*Dacryodes excelsa* Vahl.), maricao (*Byrsonima spicata* (Cav.) DC.) and masa (*Tetragastris balsamifera* (Sw.) Kuntze) do not withstand bare-root planting well. Tabonuco has been successfully established when planted with a ball of earth around the roots. The use of tar-paper pots on dry sites such as Guánica, Susúa, and Mona Island has proven successful with Dominican mahogany (*Swietenia mahagoni* Jacq.), as previously described in this journal (12).

Wilding stock has been successfully used with guaraguao (*Guarea trichilioides L.*), roble (*Tabebuia pallida* Miers.), mangle blanco (*Laguncularia racemosa* L.), and guamá venezolano (*Inga punctata* Willd). Wilding stock, when obtainable, has been found generally more hardy than nursery stock, because of a better developed root system and the absence of succulent stems. Also wildings do not get easily overgrown as happens to nursery seedlings.

Large-seeded species can generally be best established by direct seeding. Many do not transplant well. Direct seeding has been successful with maría (*Calophyllum antillanum* Britton), jácana (*Lucuma multiflora* A. DC.), nuez moscada (*Ocotea moschata* L.) and pomarrosa (*Eugenia jambos* L.). Direct seeding of moca (*Andira jamaicensis* (W. Wright) Urb.) and algarrobo (*Hymenaea courbaril L.*) failed partly because of rodent damage to the seeds. Direct seeding of Dominican mahogany (*Swietenia mahogany* Jacq.) has been successful on limestone soils on the north coast but failed at Guánica, apparently because of drought. Seed of mangle blanco (*Laguncularia racemosa* L.) and mangle negro (*Avicennia nitida* Jacq.) were broadcasted, and the former species was successfully established by this method. Mangle colorado (*Rhizophora mangle* L.) is easily established by "planting" the long pointed radicles or extension of the embryo into the soft mud.

Spacing

The effectiveness of different spacings was judged on the basis of tree form and the rapidity of canopy formation. A spacing of 6 x 6 feet was most common and is generally satisfactory. A closer spacing of 5 x 5 feet was found desirable for maría (*Calophyllum antillanum* Britton), when planted on poor sites where canopy closure is slow and the trees tend to develop low branches. Eucalyptus and casuarina grow very rapidly and do not tend to form low branchy crowns so that a spacing of 8 x 8 feet appears to be satisfactory. Plantations of these two species will form a canopy in 3 to 4 years, yet early thinnings are not required.

Mixture of Species

Deliberate efforts to establish mixed plantations were rare and have not met with success. Inadequate knowledge as to the adaptabilities and growth rates of different species led to irregular stands in which one species outgrew the other. The result was open-grown dominants with large spreading crowns and suppression of the slower growing species to a degree which precluded development. Dominican mahogany (*Swietenia mahagoni* Jacq.) for instance, was soon completely suppressed by the spreading crowns of the less valuable but more rapid growing capá blanco (*Petitia domingensis* Jacq.).

No mixture has yet been found in which yield appears destined to exceed that of pure plantations. Nevertheless, all Puerto Rican plantations are so young that religious adherence to pure plantings is probably unwise. Conceivably a slow-growing tolerant species which is of high value for posts or poles could be successfully mixed with a rapid-growing intolerant of value for lumber.

The post species might be removed in thinnings at a greater profit than similar small trees of the lumber species many of which do not produce high quality roundwood.

On adverse sites the number of adapted species is so limited that natural succession begins with nearby pure stands of pioneer tree species. This same limitation governs reforestation and generally leads to the selection of one hardy, often shade-intolerant species for planting pure. Examples of such species are pino (*Casuarina equisetifolia* Forst.), maría (*Calophyllum antillanum* Britton), roble (*Tabebuia pallida* Miers.), and eucalipto (*Eucalyptus spp.*).

On better sites, particularly where a forest already exists and has produced a favorable soil condition and a protected environment, it appears desirable to follow nature in maintaining a mixed stand of species which form a part of or lie near the climax. Species such as capá prieto (*Cordia alliodora* (R. & P.) Cham.), caoba hondureña (*Swietenia macrophylla* King), nuez moscada (*Ocotea moschata* L.), and guaraguao (*Guarea trichilioides* L.) are in this class. They apparently can best be established by underplanting at a spacing of about 25 feet and leaving any natural vegetation around them which does not interfere with their development. Such a planting may lead to a pure stand when the trees are large, but only during the last few years of the rotation. At this time the ultimate result of mixed plantings can only be a matter of conjecture. This practice deserves early and intensive research.

Weeding and Vine Cutting

The high cost of weeding and vine cutting in the past was largely due to efforts to save plantations of species not adapted to the sites. Tree growth was slow, greatly prolonging the period during which weeding was necessary. Weeds and vines were generally not the primary cause of plantation failures but they were a contributing cause in that frequent weeding over a long period made plantation establishment prohibitive and if weedings are delayed tree seedlings might actually be smothered by vines and weeds. In a few locations badly overrun with such vines as *Dioscorea* sp. reforestation with most species might be a risky proposition.

Weeding and vine cutting costs have recently been greatly reduced as a result of better selection of species. On adverse open sites species such as roble (*Tabebuia pallida* Miers) and maría (*Calophyllum antillanum* Britton) are very aggresive and require only two or three weedings. On such sites less aggresive but very rapid growing species can also be established with a minimum of weeding. Pino (*Casuarina equisetifolia* Forst) and eucalipto (*Eucalyptus* spp.) are examples.

The more sensitive species, those which have required weeding over an excessively long period in past plantings, can be more cheaply established under a light forest canopy which prevents heavy weed growth yet provides sufficient light for the young trees. This technique does not eliminate the need for weeding, but reduces the task to two or three cheap treatments.

Pruning

Pruning has been done on only a very small scale. The study indicates that pruning will seldom be very necessary in Puerto Rico if plantations are properly managed. The reason is that dead branches are almost immediately consumed by termites and disappear. The control of form then is very largely a matter of spacing. Close spacing assures well formed trees with no low branches, almost regardless of species. Conservative thinnings need not produce epicormic branches. The number of malformed trees in a closed plantation is generally so small that they can all be removed in the first thinning.

Liberation

Liberation of plantations has been necessary in areas where the trees were es-

tablished at close spacing beneath a shelterwood. An outstanding instance is the caoba venezolana *(Swietenia candollei* Pittier) at Río Abajo, where large trees were eliminated by charcoal cutters or by girdling. Girdling, to be successful, requires removal of a ring of bark 6 inches wide. Bananas which had been interplanted had to be cut back repeatedly. A lesson learned was the importance of locating underplanted trees under the openings in the canopy so that a minimum of liberation would be necessary. Great care is needed in lowering a large tree through a planted understory of 10 or 15 foot saplings. Girdling of large trees in the shelterwood is used very often to reduce damage to the underplanted trees.

SPECIES ADAPTABILITY

Agathis australis (Lamb.) Steud, Kauri pine

A few trees planted in the open at Maricao on a lower slope in Rosario clay average 4 inches in diameter and 16 feet in height after 10 years. The largest tree was 7 inches inches in diameter and 20 feet tall. They are thrifty and of good form, and show promise for ornamental purposes.

Andira jamaicensis (W. Wright) Urban, Moca

Moca was direct sown over a large area at Carite on weedy degraded sites. It was a complete failure. Germination was fair but the seedlings made no growth and were finally dominated by competing vegetation. At Guajataca considerable mortality of seedlings was due to mice. Growth was slow also and the stand was very irregular. Growth was as shown in Table 2.

At Río Abajo moca was direct seeded in an open valley in a degraded soil. Survival was high after 4½ years but the trees were only 2 to 4 feet tall.

The failure of moca may well be largely due to an intolerance of the exposed degraded soils where it was sown. It appears to be a species of climax forests. Natural reproduction is common in closed stands, and moca should be accepted as a satisfactory species in secondary forest. Its growth, even under good forest conditions, is slow, however, so no further trials of artificial regeneration appear warranted at this time.

Avicennia nitida Jacq., Mangle negro

Both wildings and seeds of mangle negro were used in reforestation. Wildings gave very low survival. The results of broadcasting, which was done many years ago, are no longer evident. Mangle blanco (*Laguncularia racemosa* L.) is apparently of equal utility and regeneration has been more successful, so no further work with mangle negro is suggested at this time.

Aleurites trisperma Blanco, Tung oil

Plantations established at Maricao in a protected lower slope in Rosario clay have produced thrifty trees of good growth. At Río Abajo. Survival of potted seedlings was satisfactory and the trees outgrew contiguous forest tree seedlings of same age. Trees were thrifty but of a wide crown.

Table 2.—**Average annual growth of moca at Guajataca**

Site	Locations	Average age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Lower Slope	2	9	0.11	0.22	0.7	1.2

Byrsonima spicata (Cav.) DC., Maricao

Maricao has been planted on a small scale. Germination of the seed in the nursery is slow and erratic. A planting on a slope of degraded clay soils was growing slowly at Carite. In an open valley at Río Abajo initial survival was 60 percent, later reduced to 48 percent. The trees were thrifty, of good form, and 3 feet tall after 3 years. No insect or disease problems have been noticed. Further research is necessary to reduce mortality.

Castilla elastica Cav., Caucho

A small planting of caucho was made at Río Abajo in a valley bottom. Trees grow rapidly and produce abundant natural reproduction. Trees seem to require forested conditions, abundant moisture and good soil.

Calophyllum antillanum Britton, María

María has been widely used in reforestation because it is hardy, aggressive and it can be established easily by direct seeding. At Maricao it has proved to be the best species for exposed sites. Average annual growth there is shown in Table 3. A 27-year-old plantation has developed very well on degraded Nipe clay. The average diameter is 5 inches; the maximum 10 inches. The average height is 40 feet; the maximum 54 feet. A dense part of this plantation had attained 173 square feet of basal area per acre and is in need of a heavy thinning.

At Susúa 5-year-old plantations in the valleys and on the lower concave slopes average 1.5 inches in tree diameter, with a maximum of 2 inches. Average and maximum tree heights are 8 and 10 feet respectively.

At Guajataca maría was sown on all sites and the results to date are as shown in Table 4.

Table 3.—**Average annual growth of maría at Maricao**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Valleys and lower concave slopes	2	10	0.25	0.45	1.8	2.2
Uniform slopes with northern or western aspect	7	10	0.22	0.31	1.0	1.4
Uniform slopes with southern or eastern aspect, upper slopes, ridges and degraded Nipe clay	3	7	0.18	—	0.7	—

FIG. 3.—*A 21-year-old stand of maría after being thinned to a basal area of 80 sq. ft. per acre. Plantation growing on a concave slope in the Maricao highlands.*

Table 4.—**Average annual growth of maría at Guajataca**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Hilltops	8	6	0.36	0.43	1.6	2.2
Lower slopes	1	9	0.28	—	2.8	—
Sinkhole bottoms	2	6	0.43	0.56	2.9	3.9

Plantation development on a rocky upper slope exposed to the eastern winds at Guajataca is shown in Table 5. This 9-year-old pure plantation. The large number of poorly formed trees is partly due to the poor site but could have been lessened by closer spacing of this plantation. The trees were spaced 6 x 6 feet but many blank spaces resulted. Many trees are flat-topped because of the wind. A heavy pruning made some years ago resulted in epicormic branching since the stand is open.

Table 5.—**Development of maría plantation at Guajataca** Pure—9 years

D.B.H.	Tree form and number per acre		
	Good	Poor	Total
Inches	No.	No.	No.
1	8	28	36
2	152	180	332
3	124	76	200
Total	284	284	568

At Río Abajo establishment has been successful on the lower slopes. Plantings were very mixed and do not provide good growth data as yet.

In the southern part of the Carite Forest (Patillas) maría has proven better adapted to the lower rocky slopes than any other species tested. After 7 years maría trees were 2 to 3 inches in diameter and 12 to 15 feet in height. María is also growing well on the uniform slopes in the wetter part of the forest.

María sowings failed on Mona Island, apparently because the climate is too dry.

This species reproduces abundantly and is relatively free of insect pests and diseases. Its perpetuation after initial establishment should not be difficult.

Casuarina cunninghamiana Miguel, Pino

Of 8,800 trees planted on a degraded Nipe clay at Maricao in 1924 about 400 remained in 1945. They were from 2 to 5 inches in d.b.h. and 15 to 35 feet in height. This species looks more thrifty than an adjacent planting of *C. equisetifolia* Forst but it has never formed a closed canopy and seems unadapted to this poor site.

Casuarina equisetifolia Forst, Pino Australiano

Pino has been planted extensively only at Río Abajo, Maricao and Mona Island. The Río Abajo plantings have been confined to open valleys which had been degraded by farming. Survival has been satisfactory after an initial low survival. Replanting was done where necessary. Growth has been very rapid, the trees reaching 8 feet in height in 1 year. After 4 years the average d.b.h was 3 inches and the maximum was 5 inches. Average height was 30 feet. On the degraded red soils of the open valleys (Moca clay) pino rapidly improves the soil. Heavy needle-drop kills out herbaceous vegetation and forms a thick mat, beneath which the soil becomes more porous.

At Maricao on a degraded Nipe clay south slope 20-year-old trees averaged only 1 inch in diameter and 6 feet in height. The tallest trees were 25 feet in height but form was poor and the trees were chlorotic. The history of this planting is not well-known, but it is reported that fire swept through it at least once. Another 20-year-old planting on a west slope had an average diameter of 4 inches and an average height of 30 feet with maxima of 8 inches and 60 feet respectively. The trees were chlorotic and thin crowned. Both of these plantations are considered failures.

At Mona Island pino has grown very well on the beach sands. Planting was done with a ball of earth and planted trees were watered occasionally during the first few months. Twelve-year-old stands were 4 to 10 inches in diameter and 70 to 80 feet tall. Tree form is good everywhere except in one small area where a combination of saline soil and sea blast has killed back the upper limbs of the trees.

Cedrela mexicana Roem., Cedro español

Efforts to regenerate cedro español have been made throughout the Caribbean area with generally poor results (3, 4, 5, 6, 7, 8, 11). Between 1923 and 1929 about 140,000 seedlings were planted at Maricao. Still larger plantings were made at Maricao, Carite, and Río Abajo between 1935 and 1938. With the possible exception of a small stand at Maricao, these plantations were all complete failures, regardless of site. The remaining plantation at Maricao, ten years old is located on a lower concave slope on a loose stony Rosario clay. The trees average 5 inches in d.b.h. and 15 feet in height.

A clear explanation of the failure of cedar is not at hand. This species is not adapted to degraded soils and might be more successfully established by underplanting at a wide spacing, selecting carefully a favorable microenvironment for each tree.

Cedrela odorata L., Cedro hembra

Recent experimental plantings of cedro hembra indicate that this species is as sensitive to site as *C. mexicana*. On a lower slope at Río Abajo the largest trees in a 5-year-old plantation were 10 feet tall. Growth was variable. At this time it was believed that the trees had passed the usual difficult period of adjustment. On a well-drained uniform slope at Guilarte 3-year-old trees were 3 to 5 feet tall. Shoot borer attack is generally severe in the open, less so under a light shade. Widely spaced underplantings should be tested further.

Coccolobis grandifolia Jacq, Moralón

A 10-year old plantation on an exposed degraded Nipe clay ridge at Maricao averaged 9 feet in height, with the tallest trees 15 feet. Diameter varied between 1 and 2 inches. Form is good and the trees are thrifty despite the fact that this site is one of the most adverse in the island.

Colubrina arborescens (Mill.) Sarg. Avelluelo

Plantings made from 1937 to 1938 on the best sites at Río Abajo, Guajataca, Guilarte, Susúa, and Mona Island have all been disappointing. Survival was low, the trees grew slowly, and were of poor form. At Guilarte 6-year-old trees were 1 inch in diameter and 6 feet in height. Another plantation, however, made with seed collected at higher elevation near the forest, survived well and grew rapidly, the trees averaging 8 feet in height after 5 years. The trees were luxuriant with large leaves. Previous plantings had been made in all sites with seed from the dry forests at Guánica, where this species is only a small tree and probably a different species or variety. The superiority of the larger and faster growing variety had not been recognized at that time. Future plantings should be made with the larger type which is common in the more humid sections of the limestone areas.

Cordia alliodora R. & P., Capá prieto

Capá prieto is one of the most promising species planted to date. It was planted extensively on the better sites at Carite, Río Abajo, and Guilarte. Survival is generally low but the remaining trees are generally developing well. Capá prieto everywhere grows best on loose soils derived from diorites and shales. At Carite a plantation located on a uniform slope and established beneath mixed coffee shade attained an average diameter of 5 inches after 9 years. Average and maximum tree heights were 35 and 45 feet respectively. The trees were vigorous and of good form. They were liberated when 9 years old.

Capá prieto is native to Guilarte, and plantations there have developed well. The growth of a plantation at Guilarte is seen in Table 6.

Table 6.—**Average annual growth of capá prieto at Guilarte**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Lower slope	3	6	0.37	0.50	1.9	2.4

At Río Abajo 3-year survival was less than 40 percent. Plantings even on lower slopes gave high initial survival but died because of root rot and defoliation by the Spanish elm lacewing bug (*Monanthia montropidia*) (13) and leaf spot which was serious during dry years.

At Guánica an outstanding early plantation developed on a fertile soil in a valley. Trees planted in 1922 had attained an average diameter of 3.5 inches and a height of 15 feet in 10 years. Form was excellent and the stand was very thrifty.

Past experience shows the necessity of producing high quality nursery stock of capá prieto. Stock which is subject to leaf spot or is spindly cannot become established rapidly in the field. Cut back nursery or wilding stock the diameter of a pencil or more can give high survival and fast growth.

Capá prieto appears suited to underplanting. Preliminary tests indicate that it can make rapid early growth under light shade. Underplanting at wide spacing may reduce the severity of insect attack.

Cytharexylum fruticosum L., Péndula

Plantations of this species were established only on degraded Nipe clay at Maricao. One plantation which possibly had been subject to fire contained unthrifty trees which had died back several times. The largest trees were 1 inch in diameter, and heights ranged from 3 to 8 feet. Another 10-year old stand on a high ridge ranged from 2 to 10 feet tall and from 1 to 1½ inches in diameter. Recent experimental plantings on more favorable sites indicate that further trials would be desirable.

Dalbergia sissoo Roxb., Dalbergia

At Carite, one plantation, established on a slope in a degraded clay soil failed. Survival was low and the remaining trees were killed by weeds and vines or by a type of gummosis. Further tests with this species do not appear warranted.

Dipholis sintenisiana Pierre & Urban,, Espejuelo

More than 200 pounds of seed of this species were sown at Maricao in a dry exposed slope in Rosario clay. Little or no germination took place. Further study of this species is desirable.

Eucalyptus sp., Eucalipto

A species of eucalyptus until recently believed to be *E. resinifera* J. E. Smith is now in doubt. It is characterized by thin bark which peels off in long strips, leaving a smooth trunk. It has been identified as *E. kirtoniana* which is closely related to *E. resinifera* and has been named also as a variety of the latter.

This species survives and grows well in the mountains, even on adverse sites. Ten-year-old trees on a lower slope at Guilarte averaged 14.5 inches d.b.h. and 65 feet in height, somewhat larger than the trees of *E. robusta* with which they were mixed. Scattered open-grown trees of the same age growing on the edges of swamps in the open valleys at Río Abajo are up to 15 inches in diameter 50 to 60 feet tall. A few trees planted on degraded Nipe clay at Maricao have grown as rapidly as the more extensive plantation of *E. robusta* there.

FIG. 4.—*A 12-year-old tree of Eucalyptus sp. along a trail on a uniform slope at Guilarte*

Eucalyptus robusta Smith, Eucalipto

Eucalyptus robusta has proven to be one of the most rapid-growing species in the mountains. Survival is high and the trees are generally of good form. The tree is so shade intolerant that it self-prunes rapidly, and stands admit so much light that a dense understory develops, making difficult the perpetuation of this species but providing a good environment for underplanting.

A 22-year old planting on a uniform western slope at Maricao produced trees up to 17 inches in diameter and from 55 to 65 feet in height. When cut, this plantation sprouted vigorously. A four-year-old planting on degraded Nipe clay reached 1.5 to 3.5 in d.b.h. and 8 to 12 feet in height. The trees had clearly dominated weed growth.

At Carite on a uniform slope a 10-year old planting had produced trees averaging 8 inches in diameter. The basal area of this planting was 110 square feet per acre and a thinning was desirable.

At Guilarte this species proved to be one of the best for planting degraded soils on exposed ridges. On a lower concave slope a 10-year-old plantation had an average diameter of 13 inches and an average height of 55 feet.

At Río Abajo on an eroded red soil in an open valley beside a stream 5-year-old trees were 4 inches in diameter and 20 feet tall. Here this species grew much more vigorous-

ly than *E. alba, E. propinqua,* and *E. tereticornis.*

Fraxinus sp., Fresno

This species, possibly *F. americana,* was introduced from Hawaii. It was planted extensively on degraded Nipe soils at Maricao. Only a small area on a protected western slope has developed. After 10 years these trees have average and maximum diameters of 2 and 5 inches, respectively, and average and maximum heights of 10 to 20 feet. Most of the trees are of poor form, with wide spreading crowns.

Grevillea robusta Cunn., Roble de seda

Twenty trees were found in a 19-year-old plantation on a uniform western slope at Maricao. The largest trees were 9 inches in diameter and 35 feet tall. These trees were so heavily attacked by scale insects, that further planting is not recomended.

Guaiacum officinale L., Guayacán

Both direct seeding and planting of this species were attempted at Guánica. Direct seeding is not dependable because of low germination or death of young seedlings during dry weather. Planting with bare-rooted seedlings apparently failed because most of the trees were pot-planted. A 13 year-old plantation using potted seedlings established beneath a light overstory of *Leucaena glauca* has grown to an average height of 4 feet and a maximum tree height of 8 feet. The stand is vigorous in appearance and about 600 trees per acre remain. This growth is slow but the site is too adverse for most other species tested.

Guarea trichilioides L. Guaraguao

Plantings of guaraguao were limited to Carite and Guilarte where it is one of the most satisfactory species. It grows well when underplanted producing trees of good form and free from the shoot borer. Planting in the open generally fails. Average annual growth on a lower concave slope at Guilarte is as shown in Table 7.

Haematoxylon campechianum L. Campeche.

A plantation established in a protected valley at Guánica grew to an average diameter of 6 inches in 18 years. The trees were spreading and have not yet produced much dyewood. Natural reproduction is abundant, and the species may become a weed. No further testing seems warranted.

Hyeronima clusioides (Tul.) Griseb., Cedro macho

Cedro macho, one of the more attractive native furniture wood species, has not been widely planted because of low seed germination. Trees in a 10-year-old plantation on a degraded soil in an open valley at Río Abajo have an average d.b.h. of 3 inches and a height of 20 feet. Form is excellent. This plantation was established with pot-planted stock. The capacity of bare-rooted seedlings to survive is unknown.

Table 7.—**The average annual growth of guaraguao at Guilarte.**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Slope	3	5	0.28	0.41	1.9	2.8

Hymenaea courbaril L., Algarrobo

Algarrobo has been direct seeded at Susúa on a dry slope of Rosario clay and in the lower southern part of the Carite forest on a humid slope with clay loam soil. Survival was low and growth very slow. In both cases direct seeding was done in the open on a dry hot slope in Susúa and with severe competition from brush and weeds on Carite. Experimental direct seeding and planting under an overstory under more favorable conditions have been very satisfactory.

Laguncularia racemosa L., Mangle blanco

Plantings on mangrove soils subject to deposition of sand have failed, apparently because such sites are becoming more adverse for mangrove. On the land side of the lagoon where the deposition is chiefly silt and clay a very successful plantation was established at Piñones. Fern and grass growth was cleared and burned and wildings were planted. Survival was fair and at the end of 8 years the average diameter was 3 inches and many trees were being cut for posts.

Lucuma multiflora A. DC., Jácana

Jácana has been direct seeded in Guajataca and in the mountain forests of Guilarte. Germination is high and tree form is generally good. It is sufficiently tolerant to withstand underplanting. Jácana has proven adapted best to lower concave slopes. On exposed sites, especially where the soil has been worn out by farming, jácana becomes chlorotic and does not grow. In Guilarte seven-year-old trees on concave slopes were 1-1/2 to 2-1/2 inches in d.b.h. and 18 to 20 feet tall. This species proved capable of coming through a thick growth of Guinea grass on lower slopes at Guajataca.

Magnolia portoricensis Bello, Jaguilla

Planting of jaguilla has been limited by low seed germination. A plantation made in an open valley at Guilarte using potted seedlings shows the desirability of testing underplanting. Survival was high but the trees have grown only to 10 feet in 8 years and they appear to be making practically no growth. Their leaves are thick, yellowish and curled, indicating a need for shade.

Montezuma speciosisima Sessé & Moc., Maga colorada

Maga, which produces a termite-resistant furniture lumber, was one of the most widely planted species. The best plantations are located at Río Abajo in the sinkhole bottoms. A 5-year-old planting has an average diameter of 2.7 inches and an average height of 20 feet. After 9 years the same plantation averaged 3.6 inches in diameter and 58 square feet of basal area per acre. Diameter growth was clearly decreasing. The intolerance of the species was indicated by self pruning to ¾ of the stem height. On degraded soils in open valleys within the same forest maga becomes chlorotic and stops growing after about 3 years. The trees lack vigor and do not appear destined to develop properly.

Plantations at Guajataca were generally inferior to those at Río Abajo in spite of the fact that maga is native to the area. Survival was low due to greater exposure on most sites. In a sinkhole bottom, a 5-year-old widely spaced plantation trees averaged 3 inches in diameter and 20 feet in height.

At Carite in the lower river valleys at the southern edge of the forest the best 6-year old stands were 3 to 4½ inches d.b.h. and 18 to 25 feet tall. Many trees were of poor form.

Poor tree form has been a discouraging factor in maga plantations. Survival is high on good sites but after 3 or 4 years trees adjacent to a failed spot or other opening generally become limby. Pruning of such trees produces an abundance of epicormic branches and swellings on the bole. Objections have been raised to planting maga near cotton producing areas since the pink boll worm (*Pectinophora gossypiella*) may spend part of its life cycle in maga fruits

(13). The leaves and branches are sometimes heavily attacked by scale insects, often killing twigs and small branches and making the tree very unsightly.

Petitia domingensis Jacq., Capá blanco

Capá blanco was planted in all of the forests but the largest plantations were at Maricao, Susúa, and Guajataca. Twenty-year-old plantings on degraded Nipe clay at Maricao contained only a few shrubby trees. In a protected location the average d.b.h. was 4 inches and the average height was 18 to 20 feet. Growth in younger plantations on lower slopes in this forest was low. Nine-year-old trees in two locations averaged 0.07 inch in annual diameter growth and 0.6 foot in height growth.

At Susúa direct seeding failed and even planting was generally unsuccessful. In a valley bottom a 7-year-old plantation averaged 4 to 5 inches in diameter and 8 feet in height, with the tallest trees to 20 feet.

At Guajataca capá blanco has outgrown Dominican mahogany but the trees are generally poorly formed except on the lower slopes and in the sinkhole bottoms. Average annual growth is seen in Table 8.

At Río Abajo 7-year-old trees on a degraded soil in an open valley were 2 to 4 inches in diameter and 12 to 15 feet tall. In a sinkhole bottom an 8-year-old plantation averaged 3.5 inches in diameter and 30 feet in height. This is the best plantation in any forest.

At Guilarte 9-year-old open plantations on lower slopes were growing 0.35 to 0.65 inches in d.b.h. annually and 2.4 to 3.5 feet in height annually. The trees are poorly formed but vigorous in appearance.

Capá blanco generally survives well and competes satisfactorily with vines. Close planting is necessary to avoid branchy crowns. Mixed plantings have not been successful since the intolerant capá blanco must either dominate or it becomes suppressed and stops growing. In poor sites particularly in dry localities trees stagnate and are poorly formed. Capá blanco apparently should not be planted on sites sufficiently favorable for mahogany and other high grade furniture wood species.

Ocotea moschata L., Nuez moscada

Direct seeding of nuez moscada at lower elevations in Carite is very promising. A plantation established on a slope in a humid site of better than average fertility, reached an average diameter of 2 inches and a height of from 8 to 18 feet in 7 years. The trees are thrifty and of excellent form.

Prosopis juliflora (Sw.) DC., Bayahonda

There is some difficulty in separating planted from naturally established bayahonda since natural reproduction is generally abundant near plantations. A 20-year-old plantation established by direct seeding was found in a valley at Guánica. Diameters averaged 10 inches, with a maximum of 14 inches and the trees were about 15 feet tall. The trees were very thrifty, and spreading in form. A second planting, located on the

Table 8.—**Average annual growth of capá blanco in Guajataca**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Hilltops	1	7	0.43	0.71	2.1	2.9
Lower slopes	1	5	0.50	0.70	2.0	3.6

coastal sand at Guánica, had trees 10 inches in diameter and 15 feet in height after 19 years.

Direct seeding has generally resulted in incomplete stocking because of low germination. The pods are attacked by a Bruschid weevil while still on the tree so pods collected on the ground are generally heavily infested, with germination as low as 6 percent. Cattle like the fruits and contribute materially to the natural dissemination of this species.

Open-grown 20-year-old trees have been found to grow slowly, much more so than their average growth prior to that age. Bayahonda should apparently be managed on a 10-15 year rotation for posts or ties.

Rhizophora mangle L., Mangle colorado

Mangle colorado is best adapted to the margins of canals or the deeper areas on the exposed edge of the mangrove. On drier areas it does not compete well with mangle blanco (*Laguncularia racemosa* L.) or mangle negro (*Avicennia nitida* Jacq.). Seed is collected by boat, and the radicles are pushed into the mud. On a favorable site at Piñones trees 5 to 8 years old were 1 to 2 inches in diameter and 8 to 12 feet tall. Survival was high.

Mangle colorado should not be planted in areas subject to sand deposition. Such areas have apparently developed to a stage that is better suited to the other species. Burning of ferns proved a desirable practice where they were dense (9).

Sciacassia siamea (Lam.) Britton Cassia de Siam

A 5-year-old plantation established in a valley at Guánica averaged 18 feet in height. Most trees were forked. Stumps from some of the trees which were recently cut sprouted vigorously.

At Maricao on a lower slope of Rosario clay a 10-year-old plantation reached 10 inches in d.b.h. and 22 feet in height. Average d.b.h. and height was 3 inches and 20 feet respectively. Most trees were poorly formed and not promising.

Sideroxylon foetidissimum Jacq., Tortugo amarillo

A plantation established at high elevation at Carite is stunted and the trees are unable to compete with other vegetation. This species is probably better adapted for planting in the limestone region of the north coast where it is native.

Swietenia macrophylla King., Caoba hondureña

Caoba hondureña has proven unadapted to a large area of degraded soils which had been worn out by farming. Survival is generally high except in dry areas such as Maricao and Susúa. Shoot-borer attack may be severe on poor sites. The roots do not develop well on heavy wet soils with the result that many trees are blown over.

On protected sites with good soil caoba hondureña grows rapidly and with good form. The best site found for this species is the sinkhole bottoms at Río Abajo. On this site bananas or old coffee shade proved beneficial for the first few years. After 6 years trees average 3 inches in diameter and from 20 to 25 feet in height. After 10 years diameters averaged 4 inches and heights reached 40 to 50 feet. Heavy thinnings were made when the stand was 10 to 11 years old.

At Guilarte extensive plantings on degraded red clays have failed. The trees were spindly and were making no growth after about 10 years. A few trees located on protected concave slopes may eventually produce timber.

Failures also resulted from plantings on similar sites at Carite, Maricao, and Susúa. In the last two localities dry weather at time of planting contributed to a low survival. A few trees on lower concave slopes at Susúa averaged 3 to 4 inches in diameter and 12 to 15 feet in height after 9 years.

FIG. 5.—*An 11-year-old stand of Honduras mahogany on one of the best sites, a sinkhole bottom in Río Abajo, right after first thinning.*

Swietenia mahagoni Jacq., Caoba dominicana

Caoba dominicana is best adapted to the relatively dry areas along the northwest, southwest, and south coasts, within annual precipitation ranges of from 30 to 70 inches. Plantations have failed in the central mountains.

The best plantations in the Insular Forests are those established over serpentine or limestone parent material. Within these areas the trees grow best on protected lower slopes. Here growth is rapid and tree form is generally good.

At Guajataca tree growth has been as shown in Table 9. It is seen that at Guajataca a strong relationship to topography is not evident. Slopes facing the north or west produce taller trees than those exposed to the south or east. Soil degradation as a result of farming is most pronounced in the sinkholes, a fact which tends to offset the beneficial factors found in this protected location. Degradation apparently has an important influence upon growth, tree form, and shoot-borer attack.

Data from a quarter-acre sample plot in a 6-year-old plantation in a sinkhole bottom

Table 9.—**Average annual growth of caoba dominicana at Guajataca**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Hilltops	10	7	0.37	0.53	1.8	2.4
Lower slopes	2	8	0.43	0.57	2.5	2.9
Sinkhole bottoms	5	8	0.44	0.53	1.8	2.2

at Guajataca are summarized in Table 10. Table 10 shows 56 percent of the trees to be of poor form. This is due to shoot borer attack and/or site degradation due to previous cultivation of the soil.

At Susúa pot-planting was required for high survival (12). Growth is somewhat slower than at Guajataca yet this is by far the best species planted on most of the sites. A summary of growth at Susúa is shown in Table 11.

At Maricao plantations failed generally on degraded soils. Only in a few protected areas have the trees developed well. Even there, growth is slower than at Susúa. Growth rates at Maricao are summarized in Table 12.

Table 10.—**Six-year-old caoba dominicana plantation at Guajataca**

D.B.H.	Tree Form and Number per Acre		Total
	Good	Poor	
Inches	No.	No.	No.
1		8	8
2	32	120	152
3	192	188	380
4	60	24	84
Total	284	320	624

Table 11.—**Average annual growth of caoba dominicana at Susúa.**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Valleys and lower concave, slopes	8	7	0.33	0.45	1.6	2.0
Uniform slopes with northern or western aspect	11	7	0.27	0.41	1.3	1.7

Table 12.—**Average annual growth of caoba dominicana at Maricao.**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Valleys and lower concave slopes	1	18	0.17	0.28	1.00	1.22
Uniform slopes with northern or western aspect	2	8	0.19	0.28	1.25	1.56

At Guánica survival has been low because of prolonged drought. The use of tarpaper pots has given the best results to date. Low survival has resulted in widely spaced plantings and spreading tree crowns. One plantation 18 years old on a valley bottom had trees 12 to 16 feet tall and was just beginning to form a closed canopy. Shootborer attack had been heavy. A sample plot in this plantation is summarized in Table 13.

Table 13.—**Diameter distribution and condition of caoba dominicana tree at Guánica**

D.B.H.	Good	Poor	Total
Inches	No.	No.	No.
1	4	4	8
2	16	8	24
3	16	24	40
4	48	20	68
5	80	8	88
6	68	4	72
7	4	—	4
Total	236	68	304

Seventy-eight percent of the trees were of good form. Those of poor form are generally the largest. The smaller trees, some of which are replants have grown straight as a result of side shade from the larger trees. The average annual diameter growth at 15 years in this plantation is summarized in Table 14. The average growth rate compares favorably with plantations elsewhere on the island.

Table 14.—**Average diameter growth of caoba dominicana at Guánica**

Crown class	Trees	Average annual DBH growth
	No.	Inches
Dominant	5	0.32
Codominant	54	0.34
Intermediate	18	0.26
Total	77	Ave. 0.32

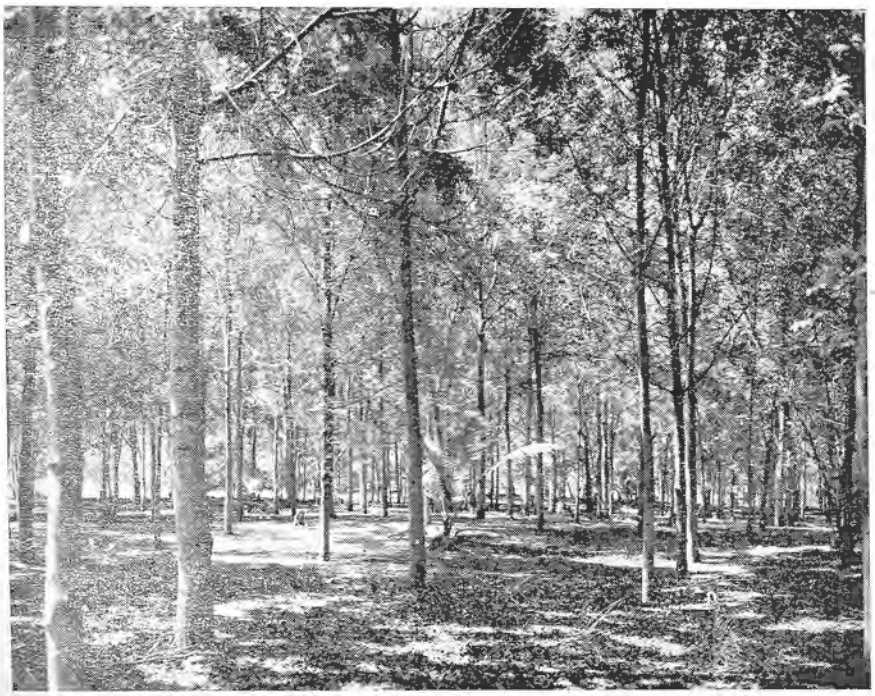

FIG. 6.—*A very successful 12-year-old plantation of caoba dominicana on the sandy coastal plain of Mona Island. Trees are unusually well formed.*

At Río Abajo where the soils are more highly leached because of higher rainfall the results of planting caoba dominicana have been very discouraging. Survival was low, never above 30 percent (using bare-rooted stock). After 7 years the trees are 2 inches or less in diameter and less than 10 feet tall. The trees look somewhat better on the warm east and south slopes. Shoot-borer damage is common but apparently is not the primary cause of failure.

At Mona Island the trees had to be watered until they became established. Seven-year-old plantations on the coastal plain are 4 inches in diameter and 15 feet in height. This is more rapid growth than on most sites in Puerto Rico.

Summarizing the experience with caoba dominicana, it may be said that degraded open areas should be avoided. Underplanting or interplanting with brush or other natural tree growth is desirable as brush or low forest offers favorable ecological conditions. A spacing of 20 feet each way can provide a closed stand purely of mahogany late in the rotation. Shoot-borer attack tends to be less in such plantings.

The worst pests of caoba dominicana are the shoot borer (*Hypsipila grandella* Zeller) (13) but its attack can be lessened as already described. Another less important insect pest is the apate borer (*Apate monachus*) (13). The leaf blight (*Phyllosticta swietenia* sp. nov.) (1) causes defoliation both in nurseries and in plantations, but is apparently of little importance to tree growth or survival.

Direct seeding of caoba dominicana has proven successful in the limestone region of the north coast where about 60 inches of rain falls annually. Preliminary tests failed at Guánica because of extreme drought. Further tests should be made under more favorable conditions since this practice greatly reduces costs when compared with pot-planting.

Tabebuia pallida Miers, Roble

Roble, a pioneer species which produces good posts and poles, has only been planted recently in the Insular Forests and plantations were still too small to provide growth data of value. On the lower edge of the Carite Forest on a degraded heavy clay slope the use of cuttings gave low survival but produced a few good trees. At Guilarte wilding stock has survived well and grown rapidly on severely eroded exposed slopes. This species merits more attention for reforestation of adverse sites.

Tectona grandis L., Teca

Teak was not planted extensively in any forest but a few trees are found in all forests except Guánica. Teak grows best on fertile, well-drained soils at low elevation, where it makes spectacular growth and produces well-formed trees. It has failed in the humid mountains. Young plantations require thorough weeding or intercultivation. No injurious insect attacks or diseases have been found.

At Río Abajo one of the best plantations is located in an open valley (Lares clay) in an area which had previously been cultivated for tobacco and food crops. After 7 years average d.b.h. was 4 inches and average height was 22 feet, and 75 percent of the trees were classified as of good form. After 11 years the average diameter was 4.8 inches and the average height 40 feet. The stand had a basal area of 90 square feet per acre and was thinned to 74 square feet. Another 10-year-old planting in the open valley near a stream had an average d.b.h. of 6.3 inches and an average height of 35 feet.

At the lower southern edge of the Carite Forest (Patillas) the best plantation found in the island is located on an alluvial soil. After 10 years these trees average 6 inches in diameter and 45 feet in height. Basal area ranges from 100 to 130 square feet per acre. Tree form is excellent. Nearby, however, on steep slopes 7-year-old trees average 2-½ inches in d.b.h. and 12 feet in height, and they are of poor form.

Teak appears to require better soils than Puerto Rico can afford to provide. Therefore, no great expansion of plantations of this species is to be expected in government

forests. In farms where better sites are available and where only few trees are planted it might become a popular species to grow on short rotations for posts and poles.

Tetragastris balsamifera (Sw) Kuntze, Masa

Only a very small area was planted to masa in the Insular Forests. This was on a favorable slope at lower elevations at Carite. All seedlings died, probably because this species does not transplant well without a ball of earth. Further study of this species is needed.

Vitex divaricata Sw., Higuerillo

Higuerillo, a durable construction timber species, was planted at Carite and Guilarte. At Carite very few trees remain, and these are not thrifty. At Guilarte survival was apparently about 40 per cent. Growth has generally been slow but it is sensitive to topographic position. Tree form is only fair, and there are no serious insect pests or diseases, although the foliage is occasionally attacked by a leaf roller. Table 15 presents growth data from a favorable site at Guilarte.

Zanthoxylum flavum Vahl Aceitillo

Aceitillo produces the most highly prized furniture wood in the island. Planting work has been limited by limited seed sources and very low germination. Small plantings were made at Guajataca in the sinkhole bottoms. Stock was transplanted with a ball of earth and survival was very high. After 11 years the average and maximum diameters were 2.5 and 4 inches respectively. Heights were 18 and 22 feet respectively. Judging by the thrifty appearance of naturally established trees, this species can be expected to grow well in the lower slopes of the limestone hills. Bare-root planting may also prove successful. The tree forms a small crown, and may be suited to underplanting beneath openings. Underplanting at wide spacing might prove to be the best use of the limited quantity of stock available. Naturally established trees at Guánica are being killed by an unknown disease.

CONCLUSIONS

The findings of this study lead to certain definite conclusions regarding the general condition of the plantations, the survival of the different species, the adaptability of species to various sites, factors responsible for losses, and desirable policies for the future. These conclusions are here presented.

GENERAL CONDITIONS OF PLANTATIONS

The plantations were classified in the field as to stocking, as a basis for estimates of future work. This classification is as follows:

1. Well stocked plantations.—Plantations in which planted trees of good form and satisfactory growth, or such planted trees with natural reproduction of the better species, constitute, or with release could form, an 80 percent of fully stocked dominant stand.

Table 15.—**Average annual growth of higuerillo at Guilarte**

Site	Locations	Average Age	D.B.H. Growth		Height Growth	
			Ave.	Max.	Ave.	Max.
	No.	Years	Inches	Inches	Feet	Feet
Lower slope	2	6	0.29	0.48	1.5	2.5

2. Understocked plantations.—All plantations not included in Class 1 above.

a. Forested. — The satisfactory trees, either planted or natural, forming a minor part of a stand composed chiefly of poor trees, which provides a complete canopy beneath which a shady forest environment exists.

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. The representation of each of these classes in the different forests is shown in Table 16.

The relatively large open areas at Guajataca and Río Abajo are the limestone cliffs and hill tops where plantings have failed and natural reforestation is low. Also included are some areas where farming is being permitted subsequent to planting failure, swamps, roads, etc. A large area of limestone cliffs and slopes is also reforesting naturally at Río Abajo. The large forested but understocked area at Guajataca includes mostly forested sinkholes in coffee. Unfavorable sites in exposed slopes and ridges in Susúa are being rapidly covered by natural reproduction.

PLANTING SURVIVAL

The different species varied widely in their capacity to survive the first year after being set out in the field. Bare-rooted seedlings of some hardy species survive planting well almost regardless of the site. Large-seeded species generally show the highest survival when direct seeded. Table 17 lists the species according to three broad survival classes, and is based upon all plantations and sites. Variable survival is often due to poor seed quality if direct sown or sensitivity to dry conditions.

Table 16.—**Stocking of Plantations in the Insular Forests**

Forest	Well stocked	Understocked		Total
		Forested	Open	
	Acres	Acres	Acres	Acres
Carite	1,923	654	245	2,822
Guajataca	1,321	576	307	2,204
Guánica	190	100	10	300
Guilarte	483	150	70	703
Mangrove (Piñones)	274	—	10	284
Maricao	2,021	653	40	2,714
Mona Island	379	40	—	419
Río Abajo	2,648	1,180	844	4,772
Susúa	994	792	—	1,786
Total	10,233	4,245	1,526	16,004

Table 17.—**Survival by Species**

High survival	Fair survival	Low survival
Aceitillo**	Algarrobo*	Aprín (direct seeded or planted)
Campeche	Bambú	Avelluelo
Caoba dominicana**	Caoba dominicana	Bayahonda*
Capá blanco	Caoba hondureña	Dalbergia

Table 17.—(Cont.)

High survival	Fair survival	Low survival
Cassia de Siam	Caoba venezolana	Espejuelo*
Cedro español[1]	Capa prieto	Mangle negro (wildings)
Cedro macho**	Guaraguao	Maricao
Eucalipto	Maga	Masa
Guayacán**	María*	Samán
Higuerillo	Moca*	Tabonuco
Jácana*	Pino	
Mangle colorado*	Pomarrosa	
Mangle blanco (wildings)	Tortugo amarillo	
Nuez moscada*		
Pomarrosa*		
Roble (wildings)		
Teca**		

* Direct-seeded
** Potted seedlings
1 High survival after planting is generally reduced considerably for lack of adaptability to many sites.

Overall survival and success in establishment can be further indicated by dividing the total number of trees planted and replanted by the area of plantations. Planting at the usual spacing of 6×6 feet requires 1,210 trees per acre. At 8×8 foot spacing the number per acre is 681. The success of potted seedlings on dry sites is shown by the low total number of trees planted, 629 per acre on Mona Island and 963 at Susúa. At Guánica, on the other hand, where bare-root planting was tried, a total of 2,999 trees per acre were required. The humid mountain forests of Carite, Guilarte and Maricao showed similar overall survival, averaging about 1,850 trees per acre. This indicates 50 percent replanting, part of which was the replacement of unadapted trees. Survival of bare-rooted planting was highest in the moist limestone forests. Broadcast sowing of mangle blanco and mangle negro in the mangrove required about 26,000 seeds per acre.

SPECIES ADAPTABILITY

The observations and measurements made in the plantations form the basis for conclusions as to the adaptability of the species planted to their respective sites. A summary of these conclusions appears in Table 18. Species listed as "promising" appear to be well adapted for planting on the site in question and will yield the best products obtainable from the site. Species listed as "doubtful" are less likely to form successful plantations either because adaptability is still in question, as indicated by poor form, low survival, or slow growth or because more valuable species can be raised as for instance eucalipto and roble in the lower slopes and valleys. Species listed as "unsuccessful" did not survive after extensive trials because they are either not adapted to the climate or soil, or are susceptible to attacks of insects, diseases or rodents; or if they survived produced very poor trees.

The adaptability of jácana, capá prieto and guaraguao is greater under a shade cover. In the open they require the best sites but under a forest canopy these species do well on slopes and even on ridges. The effect of diseases and insects is variable. Site factors at Río Abajo are generally favorable for capá prieto yet this species was not recommended because it here suffers from root rot.

The very dry weather of Guánica and Mona Island makes impractical the planting of species which although well adapted to the site suffer high transplanting losses. An example is caoba dominicana when planted bare rooted.

Region	Forest	Site	Adaptability of species		
			Promising	Doubtful	U
Central and Eastern Mts.	Guavate (North and West portions of Carite)	Lower concave slopes and valleys	Capá prieto Guaraguao Maga Nuez moscada	Caoba hondureña Caoba venezolana María Eucalipto Tabonuco Maricao Jácana Higuerillo Roble	Teca Motili Cedro Masa Tortu Caoba Dalbe Moca
		Uniform slopes	Capá prieto Guaraguao Nuez moscada María (only in lower Guavate) Jácana Roble Eucalipto	Higuerillo Tabonuco Maricao	Teca Motillo Cedro Masa Tortug Caoba Caoba Caoba Dalberg Maga Moca
		Upper convex slopes and ridges	Eucalipto María (only in lower Guavate) Roble	Tabonuco Maricao	Higueri Teca Motillo Cedro e Masa Tortugo Caoba v Caoba h Caoba d Dalberg Maga Jácana Guaragu Capá pr Nuez m Moca

Table 18.—(Cont.)

Region	Forest	Site	Adaptability of species		
			Promising	Doubtful	Unsuc
	Lower Patillas (Southern portion of Carite)	Lower concave slopes and valleys	María Maga Teca	Capá blanco Casuarina Guaraguao Eucalipto Higuerillo	Cedro esp Caoba dor Caoba hor Caoba ver
		Uniform slopes	María Eucalipto Capá blanco	Casuarina Guaraguao Maga	Cedro esp Caoba dor Caoba hor Caoba ver Teca Higuerillo
		Upper convex slopes and ridges	María Eucalipto	Casuarina	Cedro esp Caoba dor Caoba hor Caoba ver Maga Teca Higuerillo Capá blan Guaragua
	Upper Patillas (Eastern portion of Carite)	Lower concave slopes and valleys	Capá prieto Jácana	Roble Algarrobo María Eucalipto Maga Capá blanco Higuerillo	Cedro esp Tortugo a Caoba hor Caoba ver Caoba dor
		Uniform slopes	María Eucalipto Roble Capá prieto	Capá blanco Algarrobo Maga Higuerillo Jácana	Tortugo a Caoba hor Caoba ver Caoba dor Cedro esp

Region	Forest	Site	Adaptability of species		
			Promising	Doubtful	Un
		Upper convex slopes and ridges	María Roble Eucalipto		Capá b Caoba Caoba Capá p Algarro Maga Tortugo Higueri Jácana Cedro e Caoba h
	Guilarte	Lower concave slopes and valleys	Capá prieto Guaraguao Higuerillo Jácana Maga	Avelluelo Eucalipto Capá blanco María Roble	Teca Caoba h Caoba v Cedro e
		Uniform slopes	Capá prieto Guaraguao Higuerillo Jácana (avoid degraded sites) Roble Eucalipto	María Maga Capá blanco Avelluelo	Caoba h Caoba v Cedro e Teca
		Convex slopes and ridges	Roble Eucalipto	María Avelluelo	Teca Caoba h Caoba v Cedro e Maga Capá bl Higueril Guaragu Jácana Capá pr

Table 18.—(Cont.)

Region	Forest	Site	Adaptability of species		
			Promising	Doubtful	Un
Limestone areas	Río Abajo	Open rolling areas (This site includes a narrow valley of residual erodible red soils that have been intensely cultivated and is thus degraded and at present not suited to many species)	Teca María Casuarina Cedro macho	Capá blanco Maga Eucalipto (good along swamps)	Caoba Caoba Caoba Cedro Capá p Avellu Higuer Albizzi Guarag
		Bottom of sinkholes	Caoba venezolana Caoba hondureña Maga Guaraguao María	Capá prieto Capá blanco Eucalipto Cedro macho Casuarina Teca	Caoba Cedro Avellu higuer Albizzi
		Slopes (between bottoms and cliffs)	Cedro macho Capá blanco Guaraguao Maga María	Eucalipto Capá prieto Casuarina Teca	Caoba Caoba Caoba Avellu Albizzi Higuer Cedro
	Guajataca	Bottom of sinkholes	Aceitillo Caoba dominicana María Capá prieto Caoba venezolana Caoba hondureña Maga Guaraguao Teca Jácana Capá blanco	Roble	Moca

Region	Forest	Site	Adaptability of species		
			Promising	Doubtful	U
		Slopes (between bottoms and cliffs)	Caoba dominicana María Capá blanco Aceitillo	Teca Maga Capá prieto Jácana Guaraguao Roble	Caoba Caoba Moca
		Ridges (Top or cliffs separating sinkboles)	Caoba dominicana María Roble	Aceitillo	Caoba Caoba Teca Maga Jácan Capá Moca Capá Guara
	Guánica	Valley bottoms, flat soils and sandy soils along tbe the beach	Cassia de Siam Caoba dominicana Capá prieto Guayacán Bayahonda Casuarina	Campeche	Eucal Cedro Samá Aceiti María
	Mona Island	Sandy soils in coastal plain	Caoba dominicana Casuarina		Avell
Serpentine Areas	Maricao	Narrow river valleys and concave slopes, exposure not influential	Caoba venezolana Caoba hondureña Caoba dominicana María Maga Capá blanco Gnaraguao	Eucalipto Casuarina Dalbergia Jácana Péndula Algarrobo	Spani Fresn Cassi

Table 18.—(Cont.)

Region	Region	Site	Adaptability of species		
			Promising	Doubtful	Un
		Slopes with northern and western exposure	María Eucalipto	Capá blanco Guaraguao	Spanish Fresno Cassia Caoba Caoba Maga Casuari Dalberg Péndula Caoba Algarro Jácana
		Slopes with southern to eastern exposure, ridges and degraded high slopes and ridges and degraded phases of Nipe clay.	María Eucalipto		Cedro Fresno Cassia Caoba Caoba Caoba Dalberg Algarro Jácana Casuari Péndula Maga Capá bl Guaragu
	Susúa	Narrow river valleys and concave slopes, exposure not influential	Caoba dominicana María	Caoba venezolana Caoba hondureña Algarrobo Eucalipto Casuarina	Capá bl Bayaho Avellue

Region	Forest	Site	Adaptability of species		
			Promising	Doubtful	U
		Slopes with northern or western exposure	Caoba dominicana	María Caoba venezolana Caoba hondureña Algarrobo Eucalipto Casuarina	Capá Bayah Avellu
		Slopes with southern exposure high slopes and ridges and degraded phases of Nipe clay.	None of the species tried are satisfactory for this species growing satisfactorily on this site are c aceituna. Planting of these species has not been tes		
Mangrove swamps		Sandy soil on sea side of lagoons	Planting is not recommended.		
		Muck soils toward the land, constantly receiving fresh silt deposits.	Mangle blanco Mangle colorado (in the deeper water)	Mangle negro	

FACTORS RESPONSIBLE FOR LOSSES

Only 64 percent of the plantations are now considered well stocked, and some of these rely partly upon natural vegetation for their cover. Moreover, widespread replanting has been necessary. These heavy planting losses were caused by a combination of the following factors:

1. The use for planting of large crews required as an unemployment relief measure. Large projects were undertaken rapidly, without previous research.
2. Failure to recognize the significance of differences in climate and soil throughout the island.
3. Inadequate information as to the degree of degradation of farmed out soils.
4. The unexpectedly long period of plantation maintenance required before the planted trees, especially those not well adapted, dominated other vegetation. This factor involved difficulties of assuring continuity of funds for plantation care when these had to come from fluctuating annual appropriations.

The difficulties which have been met in reforestation in Puerto Rico seem to be the rule, rather than the exception. It is hoped that this report will help others to recognize the complexity of the problems involved in reforesting bare lands where no experimental precedent is at hand.

DESIRABLE POLICIES FOR THE FUTURE

The application of the findings of this study to future planting work in the Insular Forests calls for the following policies:

1. Plant the most promising sites first. Poor sites may never warrant planting, and they may reforest naturally.
2. Respect natural regeneration which is becoming established on open areas. It may be wisest to wait until it provides a complete cover and then, if necessary, to underplant better species. If not, merely interplant existing trees.
3. Plant only such areas as can be cared for with certainty. Do not understimate the cost of such care. Early weeding is generally necessary even with hardy species, and with others may be required for 5 years or more.
4. Use only the most promising species. A healthy forest of post species is superior to an unhealthy forest of sawtimber species.
5. Replant when necessary as soon as planting losses are known, preferably during the first year.
6. In dry areas confine planting to the rainy season and use potted stock as recommended. Small local nurseries are well adapted for these conditions.
7. Space field planting from 5 to 8 feet and underplantings from 20 to 25 feet.
8. Use wilding stock wherever obtainable.
9. Continue investigations of nursery practice, planting methods, adaptability of new species, light requirements for the development of underplanted trees, weed control by field crop intercultivation and thinning of plantations.

SUMMARY

A recent issue of The Caribbean Forester (9:85-213, 1948) described the results of reforestation carried out in about 5,800 acres of the Caribbean National Forest as a guide for future planting work. A similar study was carried out on about 16,000 acres within the public forests of the Insular Government. This report describes the results obtained in the Insular Forests.

Four broad regions are included within the Insular Forests:

Limestone areas—Río Abajo, Guajataca, Guánica and Mona Island. Forests with annual rainfall from 30 to 80 inches.

Mountainous Interior—Carite and Guilar-

te Forests, with annual rainfall of from 80 to 120 inches.

Serpentine areas—Maricao and Susúa Forests, with rainfall of 60 to 100 inches.

Mangrove swamps—Piñones, Ceiba, Aguirre and Boquerón Forests, where rainfall is of minor importance.

The original forests in these areas included mangrove swamps, dry evergreen forest, deciduous seasonal forest, evergreen seasonal forest, lower montane rain forest and the montane thicket formation.

Large scale planting was started in the Maricao Forest in 1920. However, most of the planting was done as a part of emergency programs between 1934 and 1941. To June 1949 a total of 13,163,300 seedlings and wildings and 91,230 pounds of seeds had been planted. About 45 different species were used.

Weeding has generally been necessary for from 2 to 4 years and vine cutting sometimes up to the tenth year. The vine and weed problem is most serious in the more humid areas. Weeding and vine cutting costs have been greatly reduced as a result of better selection of species.

Sites are variable within each forest, mostly because of differences in topography and in the degree of past land abuse. Site adaptability of the different species determined to a large extent the success of the work. The sites in each forest unit are described and the adaptability of all species tested is discussed in detail. The highest survival was obtained with potted plants, but their use is recommended only in the dry areas.

Acceptable natural reproduction has complemented artificially established stands so that 64 percent of the plantations are now considered well stocked. Of the remaining understocked area, 72 percent has a forest cover and 28 percent is still open.

The cost of establishment and maintenance was high because of heavy replanting and the long period of maintenance necessary. This was particularly so in the humid mountainous interior. Total costs for the first 5 years average 77 man-days per acre in the humid mountains, 38 man-days in the humid limestone areas and 34 man-days in the dry areas.

The factors responsible for losses were the following:

1. The use for planting of large crews required as an unemployment relief measure. Large projects were undertaken rapidly without previous research.
2. Failure to recognize the significance of differences in climate and soil throughout the island.
3. Inadequate information as to the degree of degradation of farmed out soils.
4. The unexpectedly long period of plantation maintenance required before the planted trees, especially those not well adapted, dominated other vegetation. This factor involved difficulties of assuring continuity of funds for plantation care when these had to come from fluctuating annual appropriations.

Based upon the findings of this study, a policy was drawn up for future planting work in the Insular forests.

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REVIEWS

An Index to the Termite-Resistance of Woods

Bulletin No. 85 of the University of Puerto Rico Agricultural Experiment Station bearing the above title and just completed by Dr. George N. Wolcott presents a summary of many years of research on this subject.

Several hundred woods of the West Indies, North America, Central America and northern South America are listed by common and scientific name with an index resistance number for comparison with other woods listed. The relative resistance of different woods was determined by the preference of the termites (*Cryptotermes brevis* Walker) under laboratory conditions.

This bulletin should be of great value throughout the large region in which this species of termites is of importance. The bulletin may be procured without charge from the Experiment Station at Río Piedras, Puerto Rico.

Indice de Resistencia a la Polilla de Algunas Maderas

El epígrafe anterior sirve de título en español al boletín número 85 publicado por la Estación Experimental Agrícola de la Universidad de Puerto Rico. Este trabajo que acaba de completar el Dr. George N. Wolcott presenta un resumen de muchos años de investigación sobre esta materia.

Esta obra enumera varios cientos de maderas de las Indias Occidentales, América del Norte, América Central y la parte norte de la América del Sur, con el nombre científico y el nombre común de las especies madereras, junto con un número de referencia que indica la resistencia de las maderas en comparación entre sí. La resistencia relativa de las diferentes maderas fué determinada a base de la preferencia de los termes (*Cryptotermes brevis* Walker) bajo las condiciones de laboratorio.

Este folleto es de gran valor a través de la vasta región donde el ataque de este termes asume caracteres de importancia. El folleto puede adquirirse sin costo alguno solicitándolo al editor de la Estación Experimental Agrícola en Río Piedras, Puerto Rico.

The Natural Vegetation of the Windward & Leeward Islands

By J. S. Beard, Oxford Forestry Memoirs No. 21, 1948

192 pp. Illus. Oxford University Press, London, 1949

This well illustrated work presents the results of 8 years of research by one of the most outstanding plant ecologists to ever enter Caribbean region. Dr. Beard presents a theory as to the origin of Lesser Antillean vegetation, a physiognomic classification of the important formations, and a description of the vegetation of the islands, based upon measured samples. Dr. Beard's classification has been perfected since he first presented it in 1944 and appears to be generally acceptable throughout the region. His descriptions of the forests should serve as a basis for forest conservation and additional ecological research. This work is an indispensable reference for plant scientists throughout the West Indies.

Reviews (cont.)

Forest Products of British Guiana

By D. B. Fanshawe,

Parts I & II. Forestry Bulletins Nos. 1 & 2

(New Series) Forestry Dept. British Guiana, 1948.

Forest Products of British Guiana is primarily the result of several years of research by the author in the interior of the colony. The magnitude of the task undertaken is indicated in the introduction, which states that approximately 1,000 tree species are known from the near interior. Bulletin No. 1 describes some 200 of the principal timbers. A large amount of taxonomic work was prerequisite to the completion of these bulletins. The descriptions are particularly valuable in that they include important notes as to tree size and form. The practicability of extracting the different species is shown very effectively in a tabulation of the average number of trees of each species to be expected per 1,000 acres, all segregated by the major geographic districts of the colony. Bulletin No. 2 describes minor uses of a large number of species many of which are common to the Caribbean area. The more important products listed are fibers, tannins, dyes, rubber, balata, chicle, resins, oils, fats, waxes, medicines, insecticides, and foods. Mr. Fanshawe is to be congratulated on a very extensive piece of work in a region where the vegetation is extremely complex and its utility has been little known. These bulletins should contribute materially in the development of British Guiana's forest wealth.

Timbers of South America

By R. P. Woods, 74 pp.

Timber Development Association Limited

75 Cannon St., London E. C. 4, 1949

This booklet is a handy reference of general information on nearly 100 of the more important timbers of South America. It brings together in brief form what is known regarding the description of the woods, their working qualities, and uses. The more common local names are also listed, as are the scientific names. Whereas this booklet is apparently published chiefly for the use of importers in England it should prove also of value in the countries where the timbers are found.