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ECOLOGICAL SURVEY OF THE FLORA OF PORTO RICO

INTRODUCTION

This survey was made possible by the cooperation of the New York Botanical Garden and the Insular Department of Agriculture of Porto Rico. The authors wish to express their appreciation of the hearty cooperation of Dr. N. L. Britton, Director-in-chief of the New York Botanical Garden; Hon. C. E. Chardón, Commissioner of Agriculture and Labor of Porto Rico; Dr. Jaime Bagué, Assistant Commissioner of Agriculture and Labor of Porto Rico; Mr. F. A. López Domínguez, Director of the Insular Experiment Station of Porto Rico; Mr. Wm. P. Kramer, Chief Forester of Porto Rico. The authors also wish to express their thanks to Mr. Augusto P. Alvarez, Dr. José A. Antongiorgi, Hon. Charles Bahr, Mr. C. Z. Bates, Mr. Jorge Bird, Mr. Edmundo Colón, Mr. Rafael Colorado, Mr. Plácido Feliú, Dr. Arthur Hollick, Miss Clara Livingston, Mr. Mariano Mari, Mr. Juan Masini, Dr. Wm. R. Maxon, Mr. José I. Otero, Dr. B. E. Quick, Mr. Julio César Ramírez, Mr. Virgilio Ramos, Mr. R. A. Toro, Mr. R. A. Veve, Mr. Percy Wilson, and to many others through whose courtesy and assistance the field work was facilitated and made pleasant. The photographs were made by Rafael Colorado of San Juan.

The greater part of the field studies were made between January 16 and April 30, 1926, during which time the authors devoted practically all of their time to the work. The plans for the work were made largely by the senior author previous to the field work and the herbarium studies were made largely by the junior author after the field work was finished.

The results of this survey were first published by the New York Academy of Science in the Scientific Survey of Porto Rico and the Virgin Islands, Vo. VII, Parts 1 and 2 (February 1927). This is a popularized edition of this same work and is less extensive. The illustrations, with some few exceptions, are the same in the two publications.

Since the Island of Porto Rico includes some 3,400 or more square miles of territory, it was impossible to study all parts of it or to make statistical or experimental studies within the short period of four months allotted to us. Therefore, the time was devoted to the making of field studies of selected areas which are believed to be representative. The soil, climatic and other environmental factors have been noted, the dominant and secondary species listed so far as possible, their inter-relations described and the successional trends determined as far as possible from observational studies.

The appearance and structure of any plant association depends largely on the species present and the relative numbers of individuals of each. The species of almost all associations display a variety of forms and the preponderance of the individuals of any one form determines the general character of the vegetation. Most of the plant associations of Porto Rico, like those of other tropics, are composed of many species of the same vegetational form which therefore rank as codominant. Although any group of these species may produce the same ecological results, it is important to determine those which exert the greatest control on the environment, since the most abundant species are those best adapted to the existing physical environment. In the cat-tail sedge (*Typha-Mariscus*) association, in which two species constitute the greater part of the association, the determination of the dominant species is simple. In a mountain association which may be composed of a hundred arborescent species, the selection of the most abundant and most important can not always be accurately made by observation alone. Therefore, it is probable that future studies will show cases where the lists of species given are imperfect.

The discussions of the environmental factors have been based on publications of the United States Weather Bureau, the Reports of the Scientific Survey of Porto Rico and the Virgin Islands, on the geology and physiography of the area and our own observations. Since it has been impossible to make experimental studies, this work is primarily descriptive. The fact that a certain association as described grows under certain environmental conditions does not necessarily mean that the association is determined by those conditions. The primary cause of the association may depend on factors which are operative now or have been operative in the past. In deciding upon what appears to be the trend of succession, we have been guided by the recognized principles of ecology and the processes of physiography; also by the effective activities of vegetation so far as they could be observed in our field studies.

The great changes in the distribution of plant life and the destruction of the original growth over large areas which have resulted from the activities of man over a period of many years has made it impossible for us to do our work with accuracy and completeness. The dense population of Porto Rico has made use of almost all the available land for dwellings and agricultural purposes and the result has been the modification to a greater or less degree of the original plant associations as found in a state of nature.

Realizing the importance of accuracy in the determination of the species under discussion, we collected and preserved many specimens which have been identified; most of the flowering plants by Dr. N. L. Britton and Mr. Percy Wilson, authors of "The Botany of Porto Rico and the Virgin Islands", at the New York Botanical Garden; the grasses by Dr. A. S. Hitchcock of the U. S. Bureau of Plant Industry at Washington, D. C., and the ferns by Dr. Wm. R. Maxon of the National Herbarium at Washington, D. C.

The field work included studies on selected areas (see fig. 1) in all parts of the island. We were greatly aided in this work by the advice of Dr. N. L. Britton and by the personal guidance of Mr. William P. Kramer and Mr. C. Z. Bates.

Although Porto Rico has been visited by many botanists, the ecological studies have been very meager. The establishment of National and Insular Forest Reserves has led to a few valuable descriptive studies; Urban published on the phytogeographical affinities of the flora and also a flora of the Island; many expeditions from the New York Botanical Garden resulted in the publications on the Botany of Porto Rico and the Virgin Islands by Britton and Wilson; the geological surveys published by the New York Academy of Sciences and scattered ecological notes have all proved helpful in our work.

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GEOGRAPHY, PHYSIOGRAPHY AND GEOLOGY

Porto Rico is the smallest of the four islands known as the Greater Antilles and is the most eastern and most southern of that group. It is located between 17° 54′ and 18° 31′ north latitude and 65° 13′ and 67° 15′ west longitude and is well within the American tropics. The four islands, Cuba, Jamaica, Santo Domingo and Porto Rico which constitute the Greater Antilles and that crescent-shaped chain of smaller islands extending from the east of Porto Rico to South America, known as the Lesser Antilles, appear to be the tops of an enormous range of mountains. Many of these peaks show evidence of volcanic action and some few have been active within recent years. However, none of the peaks in Porto Rico shows any evidence of recent activity.

The ocean a short distance north of Porto Rico is approximately 7,500 meters (25,000 ft.) deep, while the Caribbean Sea to the south is approximately 4,500 meters (15,000 ft.) deep. The channels between Porto Rico and the islands on the east and west are 200 meters (600 ft.) deep. As to whether this range of mountains now represented by these islands was once the northern boundary of South America, the northern part of which subsided, thus forming the Caribbean Sea, is a matter of conjecture. However, it is evident that Porto Rico was once lowered until a considerable part was under water and then raised again.

The island is almost rectangular in shape and approximately 182 kilometers (113 miles) long by 66 kilometers (41 miles) wide with an area of about 8,900 square kilometers (3,425 square miles). It is almost rectangular in form and its greatest dimension is east and west. It is divided into north and south parts by an east-and-west mountain crest. This mountain range is crescents shaped and has its eastern terminus in El Yunque, which is about 1,060 meters (3,500 ft.) in height. Starting with El Yunque, this range extends to the southwest and then to the west with an elevation rarely exceeding 150 or 200 meters (500 or 600 ft.), for a considerable distance. It then rises abruptly to about 800 meters (2,500 ft.) between Cayey and Guayama. The range curves slightly to the northwest to the vicinity of Aibonito where the elevation is near 650 meters (2,000 ft.). From this point west the elevation is about 650 meters until we come to the vicinity of Adjuntas where there are several peaks which exceed 1,350 meters (4,000 ft.). Near Adjuntas, it divides into two ranges, the one extending west to Mayagüez, and gradually dropping to the sea level, the other extending northwest to near Rincón and gradually dropping to sea level. Smaller mountain ranges extend in a more or less north-and-south direction and subdivide the island into numerous fertile valleys. The crest of the main east-and-west range is about 10 or 12 miles from the south coast. Therefore, about two-thirds of the island is north of the crest, and about one-third south of it. The highest summits are in the vicinity of Jayuya, near the centre of the isalnd; Cerro de la Punta is the highest point in Porto Rico, reaching an altitude said to be 1,330 meters (4,492 feet). These ranges and elevations are shown on the map (Fig. 1).

That part of the main mountain range east of Aibonito is known as Sierra de Cayey and that part west of this point as the Cordillera Central. There is a third and smaller range which includes El Yunque and is known as Sierra de Luquillo in the eastern part of the Island. In fact, these three ranges may all be considered as part of a single main range. The table-lands on this main range are usually narrow, one of the widest of the tables lying between Cayey and Guayama. The north-and-south ranges are usually narrow and are known as *cuchillas* or knives. Small water falls, cascades and rapids are frequent, especially on the north side of the main ranges.

Geologically, the greater part of the island is of volcanic ([1]) origin with limestone deposits of a later period around the margins. The volcanic activity during the Cretaceous period covered the land deeply with tuffs, ashes and other volcanic ejecta. Some of this volcanic material fell into the waters of the Caribbean Sea and formed shale which was eventually elevated and formed the shale hills of the southwestern part of the island. During the early part of the Tertiary period, a considerable part of the island was submerged and the area above the water reduced to about two-thirds of its present size. Thick deposits of limestone were laid down during this period and raised above sea level by a later uplift. This elevation was greater along the north than along the south coast. The northern uplift is roughly bounded by a line extending from Loíza through Río Piedras, Corozal, Ciales and San Sebastián to Aguadilla. The uplift of the south side consists of a narrow strip. These

[1] More extensive studies of the geology will be found in the various reports of the N. Y. Academy of Science on the Scientific Survey of Porto Rico and the Virgin Islands.

extensive movements have been followed by other subsidences and elevations of less importance.

It will be readily seen that the central part of the island is composed largely of igneous materials, which on the north and south sides are covered by a coastal plain, formed during one or more periods of submergence. The long period of erosion has given rise to the peneplane and has cut many deep V-shaped valleys. The erosion has brought down great quantities of silt which has been deposited near the mouth of the rivers and has aided in the formation of the flat coastal plains and playas. Although the valleys of the island are the results of long periods of erosion, there is a surprisingly little wash or erosion at the present time. The steep slopes, many of them under intensive cultivation, wash so little as to attract the attention of the visitor. Berkey attributes this stability of the soil to three factors:

''One is the clinging character of some of the vegetation which tends to bind the soil together; another is the small range of temperature variations which reduces disintegration or disruptive tendencies to a minimum; and still another is the low content of inert or refractory materials, such as quartz, in the rocks whose destruction has furnished the soils; all of these factors favor the making of special tenacious soil.''

It will be readily seen that the coastal plain of the north side of the island is more extensive than that of the south coast. It extends the entire length of the north coast and at Lares extends inland to a distance of about 10 miles and to an elevation of about 1,200 feet. It is primarily a limestone shaly formation laid down during a period of subsidence and overlaps the igneous formations. A considerable part of it is characterized by the limestone hills which are called ''mogotes'', ''pepinos'' and ''hay stacks'' and by the sink holes of various sizes. The north coastal plain is in general more rugged than the south coast, due to the wind and wave action in forming a series of sand-dune zones. West of Quebradillas the coast line is formed by very abrupt limestone cliffs with an occasional trace of the San Juan sand-dune formation. The old consolicitated dunes can be traced along the entire north coast of the Island except for the extreme eastern part, but are not continuous. The most prominent dune forms the point or promontory on which El Morro stands. From San Juan westward, it can be traced easily, sometimes forming a coast line and sometimes forming rocks or small islands near the shore. It is especially prominent from near Barceloneta to near Arecibo, forming a pronounced ridge which separates the Caño Tiburones from the sea. The Arecibo lighthouse is on the extreme western end of this ridge. In most places the sea appears to be wearing this line of sand dunes away, but in some places there is evidence of rebuilding due to the action of the wind and the binding power of the vegetation.

West of Arecibo the sand dunes of the San Juan formation are very prominent but are pretty generally covered with fresh sands which gives the appearance of new dunes. The action of the vegetation in holding these new deposits of sand in place is very evident. West of Camuy, these consolidated dunes are much less prominent. Two isolated developments of this formation are found at Cape Rojo at the extreme southwest corner of the island.

Just south of the sand-dune formation we find rather narrow recent marine or fluvial deposits. The sand dunes are most prominent east of Arecibo, gradually disappearing west of that city. South of this, in the part east of Arecibo, we find the Arecibo limestone formation which is dissected into mogotes, pepinos or hay stack hills. This limestone is very white and weathers into numerous holes. Decaying vegetation collects in these holes, decomposes into soil and supports a dense thicket of vegetation. Sink holes are numerous in this region but not so conspicuous as in the western part of the island. Going west from Arecibo the Quebradillas limestone becomes more and more prominent and is characterized by conspicuous sink holes, lost rivers and caves. West of Quebradillas the coast line is characterized by high cliffs, extending to Aguadilla. The west coast of the island is characterized by alternating high limestone cliff formations and low playas lying at the mouths of the rivers. The south coast line west of Ponce is very similar to that of the west end of the island. Between Ponce and Guayama lies a very distinct coastal plain, averaging about four miles in width and never more than 300 feet in elevation. In many places the coast line resembles the coast line along the eastern end of the island, but coral reefs are more highly developed than at other places. There are also large deposits of silts and extensive growths of mangroves. The coastal plain includes extensive areas of salt marsh lands, some of which have never responded to cultivation. East of Guayama, high cliffs are prominent except where interrupted by the valleys. Many of these valleys are broad and fertile and used extensively for agricultural purposes, especially cane growing. The mouths of many of the streams of this region are choked with sand bars which in some cases have given rise to rather extensive swamp areas.

There are several small lakes in the coastal region, but none in the elevated part of the island. Back of the consolidated sand dunes between Barceloneta and Arecibo is the "Caño Tiburones", a brackish marshy region which has been partly reclaimed and planted to sugar cane. It is connected with the sea at the lighthouse just east of Arecibo. "Laguna Tortuguero," near the coast of Vega Baja and Manatí, is a very similar formation, but does not have any connection with the sea. There are other low areas of smaller size in this region which may represent swamp or lake regions of the past. Some of the small, low areas just back of the sand dunes and west of Arecibo are in reality small canales. West of Quebradillas there is to be found the formation of sand bars at the mouths of the rivers which if undisturbed may result in the future development of conditions very similar to the "Caño Tiburones."

There are 40 or 50 streams which are designated as rivers and several hundred small streams. The longest rivers are on the north side of the island. During dry periods they may appear to be of little importance but heavy rains in the mountains change them to dangerous torrents in a very short time. They are not navigable but are valuable as sources of water supply and for power. Most of the rivers on the south coast are dry for the greater part of the year, but occasionally become dangerous torrents as the result of rains in the mountains. These rivers are formed by the union of the small streams which are present in the numerous valleys. There are said to be nearly 1,500 of these small streams. It will be readily seen that the conditions are especially favorable for the rapid run off of the water resulting from the very heavy rainfall. However, in the limestone regions, sink holes and underground drainage are very prominent. The islands of Vieques and Culebra are geologically the same as the eastern part of Porto Rico.

GENERAL PRINCIPLES OF THE DEVELOPMENT AND STRUCTURE OF VEGETATION, AS APPLIED TO PORTO RICO

A. Development of the Flora of Porto Rico

Volcanic rocks of the Cretaceous age are the oldest formations contributing to the surface of the island at this time. The rich flora of seed plants over the face of the earth during the Cretaceous period is shown by the fossils found here and in other parts of the world. There is no reason to believe that the volcanic activities were continuous or that they prevented the migration of plants to Porto Rico or the formation of forests. There have probably been some minor volcanic activities and various changes in level since the close of the Cretaceous period but no evidence that the entire Island has been submerged or that the phanerogamic vegetation has not been continuous. There appears to be but two sources of the Island flora; migration from other regions and evolution within the Island.

The immigration of plants to Porto Rico is independent of the present relation of the island to other islands of the West Indies. If Porto Rico at some time in the past was physically connected with the other islands, plants would naturally have migrated overland. If the island has been separated from other lands from its earliest geological history, plant migration would have been retarded but not prevented. However, the entrance of plants into Porto Rico appears to have been continuous from the Cretaceous period to the present and the future will see many additions to our Island flora.

The most rapid immigration of plants into Porto Rico began with the coming of man. The Caribs are known to have traveled from island to island and no doubt carried many plants with them. The coming of the Europeans marks the beginning of a new period of plant immigration which resulted in the introduction of our most important agricultural plants and many weeds. Many of the weeds have never spread beyond the limit of human influence and are to be found on farms, roadsides and waste places. The same agencies that brought plants to Porto Rico have also taken plants from Porto Rico to other parts of the world, especially to the neighboring islands.

Botanists are still ignorant as to the details of the time and place of the origin of the great majority of the known species of plants. Fossils from the Cretaceous and Tertiary periods show great similarities in families and genera but the species are very generally distinct. The evidence indicates that as a result of the evolutionary agencies, the majority of the early species have become extinct and have been replaced by species of recent origin. Although the evidence is not so clear in Porto Rico as in other parts of the world, there is no reason to believe that the Porto Rican flora has been any exception.

From the many possibilities of migration and evolution, it is evident that the species of Porto Rican plants may be divided into a number of categories as follows:[1]

[1] From Plant Ecology of Porto Rico.

A. Species common to Porto Rico and other parts of the world:
   1. Originating elsewhere by evolution and reaching Porto Rico by immigration.
   2. Originating in Porto Rico by evolution and reaching other lands by immigration.
   3. Originating both in Porto Rico and in other lands by evolution from common ancestral stock.

B. Species endemic to Porto Rico:
   4. Originating elsewhere by evolution, reaching Porto Rico by immigration, and becoming extinct in the original habitats.
   5. Originating in Porto Rico and not at present colonized in other lands by immigration.

Our present knowledge of the geological history of the West Indies and their floras is not sufficient to enable us to assign many plants to their places in this scheme but future studies of the morphological character, geographical distribution, and ecological behavior of the species will add much to our knowledge of the history of the vegetation of Porto Rico.

B. Plant Migration

Each species, whether established in Porto Rico by evolution or by immigration from some other part of the world, has the entire area of the island available for future migration and colonization. The ability of a species to migrate depends on the structure of the organs or parts by which it migrates and their ability to utilize the various agencies for their movement. The capacity of a species to migrate is very generally underestimated. Some species, especially agricultural plants and weeds, are carried by commerce. They may travel very rapidly over very large areas and are frequently accompanied by other species of plants of little or no value to man. Heavy fruits come to rest within a short distance of a parent plant and travel very slowly. The majority of species lie between these two extremes. *Vernonia cinerea* (L) Less. is a good example of the first; its seeds are produced within few months and are easily carried by the wind. The jácana (*Lucuma multiflora* A. DC.) is a good example of the second; its large fruits fall to the ground and require many years to produce a second generation. Therefore, we would expect the former to migrate more rapidly than the latter, but the jácana may possibly be carried by some agency to distant points and give origin to new foci of distribution. It is well known that seeds are frequently carried for long distances by storms, by water, by birds, by mammals and by other agencies. If the fruit of the jácana comes to rest not more than 20 meters from the plants and it requires 10 years to grow and produce a second generation of fruits, it will require 80,000 years for the species to extend its range the length of Porto Rico, but accidental distribution of its seeds to a greater distance by fruit-eating birds or mammals will bring about the same result in a much shorter period of time.

It is evident that some species may have been introduced into Porto Rico many times and in many places, and that species arising by evolution may have appeared in groups and over considerable range. In either case the time required for occupying the area would be very short as compared to starting with a single individual. It is also reasonable to suppose that some species may have come into Porto Rico or been evolved so recently that they have not had time to extend their ranges to the limit.

Evolution and immigration have probably been continuous from the Tertiary and possibly from an earlier period to the present and it is possible that they have been fully as active at one time as another. This means evolution and immigration over a million years or more. Since a species may complete its migration in a few centuries, it appears that most of our plants have had sufficient time for their complete migration over the Island. However, our field studies show that many native species of the Luquillo Mountains are not known elsewhere; the rocky summit of "El Yunque" has at least three endemic species. This is not due to the lack of migration but the failure of the seeds to establish themselves in new sites or to natural barriers between suitable sites. The former is more important in Porto Rico that the latter.

Each species requires a more or less definite combination of conditions for the germination of its seeds and growth of the plants. These conditions involve soil, soil water, atmospheric moisture, temperature, light, air movements and very often association with certain other organisms. If the variations of any one or more of these factors exceed the tolerance of the plants, the seeds fail to germinate or the young plants fail to reach maturity. Therefore, each combination of environmental characters makes possible the growth of certain species and excludes others.

The differences in the flora of two widely separated localities with apparently similar environments may be due to obscure environmental differences or to the failure of species to migrate over or through natural barriers. It is not always possible to determine this from field observations. This is illustrated by the flora of "El Yunque'' and ''Cerro de la Punta''. These peaks appear to have similar environmental conditions although the latter has less wind, less rainfall and a drier and possibly a slightly cooler atmosphere. The vegetation is similar but two of the four characteristic species of shrubs and low trees on the summit of ''El Yunque,'' have not been found on ''Cerro de la Punta''. The environmental differences do not appear to be sufficient to exclude the two species from ''Cerro de la Punta,'' but between these two peaks there is a gap of about 70 kilometers in which conditions are not suitable for the growth of these two species. Therefore, it is not possible at the present time for them to migrate slowly across the intervening country from one point to another. It may be that the conditions never have been favorable for them to migrate from one point to another but it is possible that they may at some future time appear on ''Cerro de la Punta.'' There are many other cases in Porto Rico, but definite explanations are impossible with our present incomplete knowledge.

However, there are many cases in the island in which the nature of the inhibitory factors is very evident. Common ferns of the genus Dicranopteris are characteristic of the mountainous regions of the central parts of the island. Their spores are readily carried by the winds and new plants start promptly in new and favorable locations. Their normal habitat is on the rocks and cliffs of the forests, but they immediately invade the newly made banks of the roads. There can be no doubt that the spores are carried by the wind every year to the limestone hills north of the mountain range, yet the plants do not grow in these locations, and it is very probable that this is due to unfavorable soil conditions.

The llume palm (*Gaussia attenuata* (Cook) Beccari) is characteristic of the limestone hills or *mogotes* of the north side of the island. The tall, slender trees of this species are scattered over the summits of many of these hills and young plants may be found on the hills throughout this region. A few individuals of this species are also present on the limestone hills of the southwestern part of the island which indicates that it has the ability to migrate. Its absence from many of the limestone hills or mogotes appear to be due to the difficulties of migration rather than to environmental differences.

It will be readily seen that the origin of the flora of any habitat is very complicated as is well illustrated by the flora of these limestone hills or mogotes. A mogote is usually occupied by about 200 species of flowering plants, more or less, and the great mass of the seeds of these plants do not migrate to any great extent, although there is, no doubt, more or less migration between the hills every year. The result is that the hills are now occupied by floras which are essentially the same. The *Dicranopteris* ferns and other species undoubtedly migrate to these hills to a greater or less degree but do not become established because of the unfavorable environments.

C. The Environment

In the preceding pages we have emphasized the fact that in most cases the presence or absence of a species cannot be determined by a single environmental factor, but that a number of factors are usually involved, some of which are favorable and some unfavorable for the species. A plant rarely, possibly never, grows where all the factors are most favorable for its growth but under a combination of factors some of which may be unfavorable for its optimum growth. A great number of environmental combinations exist in Porto Rico. They consist of variations in rainfall, ranges of temperature, velocity of wind, character of soils, intensity of light and many other factors. Erosion, base leveling and rock decomposition are changing the habitats of the plants; destroying or changing old habitats and making new ones.

To the physical and inorganic changes must be added the changes brought about by growing plants themselves, which are working continuously and gradually changing the physical and chemical nature of the soil, producing humus, and modifying the wind, light and atmospheric humidity. In the older parts of the Island where the physiographic and vegetational processes have been active for many thousands of years, each change of the environment has been followed by corresponding changes in the plant life, which have in turn resulted in other changes of the environment. The environment in some of these places has come to a state of relative stability and the plant life will probably remain very nearly stable for many years to come. The environment in other places is changing rapidly and each change is followed by a corresponding change in the plant life which becomes a part of a new environment and which may tend to retard or accelerate future changes. In still other but rather limited areas, new sites for plant life are forming and starting on what may be long cycles of change or may be destroyed after relatively short periods of existence.

Each of these many habitats in Porto Rico has certain environmental factors which the vegetation cannot materially change.

These factors are temperature regulated by broad climatic conditions; rainfall regulated by same broad climatic and physical agencies; wind regulated by the location and topography. However, the stable factors are a small part of the environment which is otherwise subject to great modification by the plant life. The larger plants intercept and reduce the light which is so necessary for their own seedlings and for many smaller species. They also modify the wind currents and increase the atmospheric moisture and thus reduce transpiration. They modify the soil both physically and chemically by their roots and by the accumulation of decaying material. It will be readily seen that plants not only modify the environment but become a part of it. However, the influence of plants is extremely variable, ranging from a minimum on the sand dunes and along the coast generally to a maximum in the mountain forests, but is ever present and every acre of land in Porto Rico demonstrates these interactions through long periods of time which in some cases may extend back to the Cretaceous period.

The physical and vegetational features of the environment are so important in the development of the present plant life of the island, that the destruction of its original vegetation by man is usually followed by new associations of plant life. Abandoned fields that were formerly in forest are soon covered with a dense growth of ferns. The removal of the natural growth around the *mogotes* is followed by an abundance of the various species of *Piper*. The flooded mangrove swamp are an exception to this rule in that they regenerate themselves very soon after cutting. The explanation of all this cannot be definitely given until we have more exact information which we trust will come with future studies. However, we believe the inferences which we have made in many cases are justified by our observations.

In the following description of the plant life of Porto Rico, the leading features of the environments are given for each type of vegetation, but we will discuss the broader features of temperature and rainfall in this place.

Porto Rico is well within the tropical zone, is surrounded by water and almost constantly under the influence of the trade winds, which are mostly from the east and northeast, and which tend to reduce the fluctuations in temperature. In this connection it should be remembered that there are four kinds of temperature variations: (1) a daily variation with a minimum shortly before sun rise and a maximum shortly after noon; (2) a variation from day to day in which warm and cool days may alternate; (3) a seasonal variation depending on length of day and altitude of suns; (4) a variation from year to year. In Porto Rico, the range of temperature during a single day is very seldom more than 20°F. at the coast and 30°F. in the mountains. The variations in mean temperature from day to day is seldom more than 5°F. The difference between the warmest and the coolest month of the year is from 5° to 8°F. The variation from year to year is not more than 1°F. The average annual temperature for the coastal plains over a period of twenty-four years is 78°F. and for elevations of 2,000 to 3,000 feet is 72°F. The extremes of temperature during this same period were a minimum of 41°F. in the higher elevations and a maximum of 94°F. in the coastal regions. These variations in temperature are so slight that it is doubtful if they have any influence on the distribution of plant life. (Fig. 2.)

The altitudinal variation in temperature is accompanied by changes in the plant life. Many species of the coastal region do not ascend much above sea level. Good examples of this are the bucar (*Bucida buceras* L.) which is quite common on the south coast and the cóbana (*Stahlia monosperma* (Tul.) Urban) of the east and west ends of the island. The sierra palms (*Euterpe globosa* Gaertn.) appear in the Luquillo Mountain at about 600 meters (2,000 ft.) and in the Central Cordillera at about 900 meters (3,000 ft.), extending to the highest points. However, the variations in temperature from lowest to highest points is so gradual and the boundaries between the *sierra* palms and ridge forests so abrupt that temperature cannot be considered the sole factor in fixing their distribution. In general, it may be said that a species of plant can grow and reproduce in extremes of temperature to which it is not subject in its natural range, and therefore, that there are factors other than temperature, which tend to fix the range. (Fig. 2.)

The atmosphere of these regions is ladened with moisture practically all the time. The moisture-laden winds sweeping in from the east and northeast, are checked by the mountains, and the hot air from below forces them up until they come in contact with the cooler strata of air above. The cool air causes a precipitation of moisture and heavy rainfall. Dense clouds form with very great rapidity and heavy rains follow at any time during the greater part of the year. These rainfalls are local, sometimes covering small and sometimes large areas, but are far more abundant on the north than on the south side of the mountain range. The most frequent and the heaviest rainfalls are in the highest mountains. (Fig. 3.)

The effect of the heavy rainfall is to be seen on both soil and vegetation. The deep valleys and gorges with their very steep sides are the results of the heavy rainfall and and runoff. The soil is very cohesive and does not erode, even on the cultivated hillside, as rapidly as one would suppose. (See page 8). This makes agriculture possible on the slopes of 30 to 40 degrees. The lack of rainfall is equally evident on the south side of the principal mountain range.

When we realize that an annual rainfall of 80 inches or more is generally necessary for the formation of a true rain forest in the tropics and that an annual rainfall of 40 inches will usually fail to support a vegetation more luxuriant than desert scrub, it will be readily understood that the amount of annual rainfall is of the greatest importance in determining the character of the plant life and its distribution in Porto Rico.

The mesophytic vegetation is dominant on the north side of the principal mountain range and for a short distance south of it, where the change to xerophytic scrub is remarkably abrupt, a distance of one to three kilometers frequently resulting in a very marked change in the general character of the plant life. The rainfall, the atmospheric humidity and possibly some other factors are responsible for this sudden and most remarkable change in the plant life. The relationship of temperature and humidity to altitude is well known. As the air currents rise and pass over the mountains from north to south, they become cooler and a part of their moisture is precipitated as rain; as they descend on the south side they become warm and relatively dry, which affects the transpiration of the plant life of that region. This condition and the reduced rainfall favor the development of a xerophytic vegetation. Unfortunately there are no records to show the comparative evaporation of water from free surfaces on the two sides of the mountain range.

The xerophytic types of plant life may also be favored on the south side by the frequent and long droughts. The observation station at Potala reports 88 periods of drouth of more than ten days each, and with an average of 21 days during the nine years from 1914 to 1922. Some of these periods were 80 days in length and in the best year for plant growth there was a drouth of 28 days. It is very evident that a normal mesophytic vegetation cannot develop under these conditions unless there is an unusual amount of soil water to compensate for the low rainfall. We cannot assume that this complexity of environment always favors directly the growth of certain species at high altitudes. It may act indirectly by preventing the growth of certain species and thus leave more available space for the growth of those species that can grow under the existing conditions. But if some factors such as the lowering of the temperature is unfavorable for, or eliminates certain species, then the remaining species will produce a large number of individuals. This is illustrated by the sierra palm zone of the Luquillo Mountains, which are located on the northeast corner of the Island where there are high winds and rainfall as compared with the corresponding zone in the Central Cordillera. The xerophytic nature of the vegetation of the southern coast of the Island has already been mentioned and it appears that the temperature is a contributing factor in this region. The daily temperatures are higher than on the north coasts and the plants are exposed daily to a greater isolation and drier atmosphere and to a higher temperature.

In summarization we may say that the important climatic features of Porto Rico, such as rainfall, atmospheric humidity, wind and temperature have a distinct relation to the topography; that they exert an influence on the distribution and grouping of species in distinct associations; but that no one of them alone enables us to make a satisfactory explanation as to the nature of the distribution of plant life in Porto Rico. The relative importance of these various factors in the distribution of plant life cannot be determined except by careful experimentation.

D. The Plant Associations

Plant ecology may be broadly defined as a study of the relation between the plant and its environment, and the term environment as including every factor that influences the plant when growing in its natural surroundings. These environmental factors are reflected in the many variations in the structure and behavior of the plant, excluding those features inherited from proceeding generations. These environmental effects are here grouped under three general heads as follows:

(1) The environmental influences control the structure and behavior of the plant to some extent. The shape of the leaf of a plant is inherited but the size, thickness, amount of chlorophyll, number of stomata and structure of the vascular bundles may vary with the amount of light and water. All plants of a particular environment do not necessarily present the same structural characters as a result of the environment, but many species do show the same structural characteristics, which gives the vegetation a more or less uniform appearance.

(2) No species of plant can grow in all, or even a majority of the available types of environment and each species has a certain range of environment within which it can grow and reproduce. Therefore, the areas in which a more or less definite environmental complex is repeated, tend to be occupied by the same species. Furthermore, the plants of any particular area tend to modify the environment for themselves and for the other species, so that there arises an interrelationship between the species. The result is a very definite grouping of plants which resembles the social and political organizations of man. These groups are known as plant associations. The field of plant ecology includes the study of these plant associations, their characteristics, their mode of development, their relationship to the environment and their relationship to each other in both time and space.

(3) The various environments affect and control the distribution of all species on the face of the earth. All the individuals of any species require essentially the same environments and the species is restricted to the part or parts of the world where these environments exist. However, the species does not necessarily exist in all parts of the world where the environments are favorable. The study of the distribution of a species and of the environmental agencies which led to its distribution is known as plant geography or phytogeography. Ecological studies show that many species of plants do not occupy all the available parts of the earth. Some species are restricted by impassable barriers and other are still migrating.

An ecological survey deals with the various plant associations of a region, the species of which each is composed, their characteristics and general appearance, their relationships to the environments and their relationships to each other in time and space. It does not include a study of the structure and behavior of the individual plants, or the geographical distribution or classification of the larger groups.

There are few phenomena of plant life more evident than the fact that the vegetation of a region is not uniform and that gradual variations from one type of vegetation to another are unusual. The vegetation of a region is usually divided into associations, each occupying a small or large area and very uniform in general appearance. These associations may be repeated but the transition from one type to another type is usually abrupt and often readily distinguished by an untrained observer. This is well illustrated by the swamp vegetation of the north coast of Porto Rico, where there are hundreds of acres covered with pure growths of mangle. On the land side of these mangle growths are found equally pure but smaller growths of a bracken fern or cat-tails, but they do not mingle with the mangle growths. Neither do the ferns and cat-tails mingle.

The formation and maintenance of these associations depend on migration and environment. Many seeds and spores of many species of plants must necessarily be carried into each of these pure associations every year but they do not grow. If a new swamp should be formed, the seeds and spores of many species would be carried into it and nature would select those suited to the environment. However, it should be remembered that the plants themselves will modify the environment. They shade the ground, reduce the light and thus prevent the growth of species which require a maximum of light. The leaves and twigs decay and increase the available humus and this modifies the amount of available soil water. Thus the environment is gradually changed by the plants themselves.

The general appearance of any plant association depends on the number of species represented, their size, color, form and other characters. Some of these species which are similar in size and appearance may out-bulk the others and determine the general appearance of the whole association. This is well illustrated in the mangrove swamps which include three species, very much alike in size and general appearance. Beneath the larger plants will usually be found many smaller plants which could be removed without changing the general appearance of the association. Of course the species with the most numerous and largest individuals will exert the greatest influence on the environment. They are dominant species.

In Porto Rico such environmental factors as temperature, light and rainfall vary gradually from place to place and the same is usually true of the soils; but the changes in plant life are usually very abrupt. Therefore, it will be readily seen that it is not always possible to explain the transition in vegetation on a physical basis alone. It appear that they must be explained to some extent by the influence of vegetation on the physical environment. That is, the gradual variation of the environment may become abrupt as a result of the different reactions of two unlike sets of species. This is well illustrated by the brackish waters of a Porto Rican lagoon in which there is no abrupt variation between the fresh and the salt waters but in which the circulation is restricted by the density of the vegetation and other environmental factors. There we find a sharp line between the mangroves and bracken fern of the saline waters and the cat-tails of fresh waters near the shore.

The environments of plant life are always changing. The lakes, ponds and swamps are usually becoming shallower as a result of the soil being carried into them by streams following the heavy rains and by deposits of muck formed by the vegetation. The soil of the hills and mountains is being washed away by rain and the underlying formations of soil and rock exposed. In every case, the change of environment makes possible greater or less changes in the plant life. Some plants die as a result of the change and new species are introduced by migration. Therefore, any plant association can have but a limited duration in any one place. Eventually the original species disappear and their places are taken by new ones which are better suited to the new environments. This change of vegetation is known as succession.

It is very evident that the lifetime of any plant association is dependent on the rapidity of the changes of the environment. This is well illustrated by the coastal and mountain plant associations of Porto Rico. The sand dunes of the north coast are continually changing and each change is followed by new associations, which in time are again destroyed and replaced by others. In the mountain regions the environments are more stable and the changes in plant associations so slow that the associations are almost permanent. It is not likely that any great natural changes will occur in these regions unless there should be some great geological activities such as uplifts or depressions. It is useless to speculate on the past or future of such associations.

In conclusion we must repeat that plant associations are the basic units of plant life; that they are the results of immigration and environmental selections and that the length of their duration depends on the rate of environmental changes. It is the purpose of an ecological survey to record and described these associations, to correlate them with the environments, to interpret so far as possible their past histories and to predict so far as possible from the existing evidence their future history.

The survey of the plant life in Porto Rico indicates the presence of a large number of different plant associations. Some of these occupy large areas and were probably continuous before they were partly destroyed by man. Some cover small areas and are scattered and frequently isolated. Some have had a precarious existence because of the changes in their environments. Some do not show evidence of any changes except those brought about by man. Some are the results of the activities of man in cutting, burning, clearing and agriculture. The past history of the associations of short duration can be traced with reasonable degree of accuracy, and their futures may be predicted with some degree of certainty. The study of the history of associations of long duration is much more difficult.

The many plant associations of the limited areas of Porto Rico make some system of classification necessary. We have, therefore, designated three primary groups which are geographical and based on the broad features of soils and climates. They are as follows: (1) The plant life of the northern coastal regions which are of limestone or alluvial soil and have heavy rainfall. (2) The plant life of the central mountain regions in which the soils are mostly volcanic and over which the rainfall is heavy. (3) The plant life of the south coastal region in which the soils are diverse and the rainfall low.

In the central mountain regions there are five major plant associations and practically no evidence of successional relationships. In the two coastal regions there are many associations which we have grouped according to their successional relationship. The Island also shows many secondary associations in which the changes are due to the activities of man. In some cases the larger plants have been cut for fuel and nature permitted to proceed in her own manner. In others the original vegetation has been removed for the promotion of agriculture and the native vegetation now restricted largely to waste areas and roadsides. These have been omitted from these studies.

An ecological survey of Porto Rico is necessarily very incomplete because of the extensive development of agriculture and the density of rural population. Some associations were found in the natural or semi-natural state in but a single locality; similar habitats which might have supported the same or similar plant life being under cultivation. These cases led us to believe that the original vegetation was uniform, and therefore we have described these individual stations as typical of the original condition. In other cases we can only refer to the natural vegetation as extinct.

NOTE: For the convenience of those readers who may not be familiar with ecological terms we insert the following definitions:

Hydrophytes are plants which grow in water or saturated soil. *Xerophytes* are plants which grow under more or less arid conditions. They frequently exhibit structures adapted to the conservation of their water supply. Plants living in sea water, or in soil impregnated with salts, frequently have a xerophytic aspect and are known as *halophytes*. *Mesophytes* are plants which live under average conditions of water supply, and include the great majority of the species of Puerto Rico.

A *successional series* is a sequence of plant associations, following each other in time on the same area of ground. The successional series may be *mesarch*, *xerarch*, *hydrarch* or *halarch*, depending on the mesophytic, xerophytic, hydrophitic, or halophytic nature of the first association in the series.

VEGETATION OF THE NORTHERN COASTAL PLAIN

A. General

That part of Porto Rico lying north of an irregular line drawn through Loíza, Río Piedras, Corozal, Ciales, Lares and Aguadilla was submerged during the Tertiary period and covered by a thick deposite of limestone. Since that time it has been alternately elevated above the sea and submerged. Each elevation above the sea must have been followed by the establishment of plant life and each submergence by its destruction. The character of this old plant life and its distribution are subjects for future investigations. Each elevation above sea level must have been followed by erosion and soil formation and these same agencies are in operation today; sometimes hastened, and sometimes retarded by the presence of plant life.

The highest point of the coastal plain at the present time is about 400 meters (1,300 feet) above sea level and is no doubt the oldest part of this formation. The plant life of this highest part probably completed its development as a mesophytic forest long ago, but its destruction by man makes it impossible to do more than approximate its nature. This forest reached a temporary climax and a mesarch series of successions may be traced to the climax forests of the low lands.

The elevation of this area has varied during post-Tertiary times but the general tendency has been towards emergence, and new land along the coast has been made available for the plant growth. The vegetation of these new coast lands is hydrophytic at the margins of the lagoons and along the streams; halophytic in salt marshes and mangrove swamps; and xerophytic along the sandy beaches and on the sand dunes. Three succesional series which are correlated with the above may be traced; hydrarch, halarch or xerarch; all culminating in the climax forest of the lowland. (Fig. 4.) This climax forest has been removed and the land used for agriculture; most of the intermediate series have also been changed by the influence of man; therefore, it is impossible to study the complete series. Furthermore, the periods of subsidence were probably accompanied by a reversion of the usual successional series but we have no method of determining whether the intermediate stages have been the same for both elevation and submergence. The recent demands of a dense population for fuel, building materials and land for agricultural purposes have resulted in many changes in the vegetation and in many secondary successions.

B. The Mesarch Successional Series of the Limestone Hills

The limestone strata of the north coastal plain may be divided into five geological series; the Quebradillas and Cibao series which show little erosion except the rolling surfaces and the steep-sided ravines with streams at the bottoms; and the Arecibo, Los Puertos and Lares series which show extraordinary amounts of erosion, which have resulted in a characteristic hill formation known as pepinos, mogotes, or haystacks. The area of the Quebradillas and Cibao series has been very generally utilized for agriculture.

The mogotes of the Arecibo, Los Puertos and Lares series are more or less rounded or elliptic in outline (Fig. 5) with steep, sometimes precipitous slopes and sharp or ridge-like summits. They may be in close contact or separated by small valleys which are drained through sink-holes. Hundreds of these mogotes varying from 15 to 100 meters in height are the most prominent features of the landscape between San Juan and Arecibo. Older belts of mogotes are prominent between Arecibo and Lares. The limestone of which these mogotes are composed is eroded into sharp points and edges and into deep crevices and pockets (Fig. 6) which hold the accumulations of decaying plants and develops into a rich soil. The soil is thin, but deep crevices hold enough to give a footing for plants and the result is a dense vegetation which sometimes includes large trees that have escaped the ax. The soil in the valleys between these mogotes is deep and rich and is extensively used for agriculture. The soil in the middle of these valleys has been leached by the heavy rains for so long and accumulations of decaying plants have been so great that it is usually acid, while the newer soils at the bases of these mogotes, which have been recently formed from limestone, are usually alkaline. Pineapples growing in the alkaline soils generally show chlorosis. Sugar cane, citrus fruits, tobacco and vegetables are also grown in these soils.

Both surface and subterranean erosion are still active. Rain water may be carried away by surface streams or may flow into the many crevices and pits which are constantly enlarging and being filled with soil. There are many caves, some of them of considerable size throughout this region. Fallen blocks of limestone at the bases of the mogotes show that the processes of disintegration are still active. Many of the intervening valleys are not drained by surface streams but through sink-holes. Most of these are filled with soil but some of them are open, deep, of large size and subterranean streams my be heard at the bottom. Open sink-holes and lost rivers are most common near the western end of the north coastal plain. Although the rainfall of the western part of the north coastal plain is less than that of the eastern part, it is sufficient to support a mesophytic forest and it is probable that the plant life of recent time was of that type.

The San Juan formation is a narrow strip of the low limestone hills extending, with occassional breaks, from a short distance east of San Juan to a short distance west of Camuy. It is composed of calcareous sand held together by an organic cement derived from decaying vegetable matter. This has been developed from a series of fixed dunes in comparatively recent times. It is seldom more than one kilometer in width, or more than 50 meters in height. The old fortress of El Morro at San Juan and the lighthouse at Arecibo are on the highest points. This formation is much less prominent east of Arecibo than west of that city. The subterranean erosion in this formation is unimportant but the surface weathering as a result of the activities of the water is very evident and apparently rapid, although Indian carvings in some of these caves must be more than 400 years old. The original sharp outline of the major part has been softened with time and covered with a layer of soil which supports a limited agriculture, but the few remaining thickets resemble those of the limestone mogotes a short distance inland so closely that it is reasonable to suppose that the original plant life of the two was essentially the same.

1. THE MESOPHYTIC FOREST

The original mesophytic forest of both the limestone mogotes and the San Juan formation has been destroyed or greatly modified. It is impossible to approximate its ecological character from the few remaining mature trees, as they are species of no economic value, such as: almácigo (*Elaphrium simaruba* (L.) Rose), cupey (*Clusia rosea* Jacq.), jagüeys (*Ficus laevigata* Vahl and *F. Stahlii* Warb.), and the llume palm (*Gaussia attenuata* (Cook) Beccari) which is so characteristic of this part of the Island. It is probable that the entire coastal plain of the north was covered with a very uniform forest before the coming of the white men.

Murphy, in his discussion of the forests of Porto Rico (26), also refers to the destruction of this original type of forest, and states that moralón (*Coccolobis grandifolia* Jacq.), aceitillo (*Simaruba tulae* Urban), capá amarillo (*Petitia domingensis* Jacq.), bay-rum tree or malagueta (*Amomis caryophyllata* (Jacq.) Krug. & Urban) and the granadillo (*Buchenavia capitata* (Vahl.) Eichl.) are reported to have been very common on the limestone hills, together with other species of large trees.

This forest was the last of the successional series which started soon after the elevation of the north coastal plain above the sea. It passed through unkown stages in its development and probably existed as a temporary climax for thousands of years, keeping pace in growth and changes with the erosion of the land surface.

2. THE SECOND-GROWTH THICKETS

The rapid increase in population and the utilization of the most available land for agriculture has resulted in the destruction or modification of the mesophytic forests and a secondary succession of the present thicket associations on the Arecibo, Los Puertos and Lares upland limestone. All this has resulted in a modification of the environment, increasing the amount of light available for the development of the ground flora, increasing the wind exposure which is accompanied by increased transpiration, increasing the removal of soil by surface erosion, decreasing the accumulation of vegetable mold, decreasing the amount of soid water and increasing surface evaporación. Although these changes in environment have probably not yet caused the extermination of many species, they have certainly led to considerable change in the numerical proportions of a large number of individual. Species which prefer shade and a moist air have decreased in abundance, while those which prefer sunlight have increased. Numerous additional species, mostly weeds, have been quick to immigrate into the region. Nor are the changes in environment and vegetation as yet complete. A continually increasing population makes greater demands on the thickets for fuel, gradually reducing their density; and the foraging of goats will dobtless help towards the complete extinction of many species and their replacement by grass or weeds. The vegetation of the hills nearer to town already shows the effect of excessive cutting and grazing.

At the present time, the hills appear from a distance to be forested, but upon closer examination, this cover is found to be a dense thicket of shrubs, among which are found large individual trees of worthless species. The tall, slender llume palm (*Gaussia attenuata*

(Cook) Beccari) is endemic and characteristic of these hills and a few individuals are also to be found on the limestone hills of the southwestern coast. The trunks are so slender that they are almost or quite invisible from a distance and the crowns of five or six leaves each appear to float in the air like huge birds. The much-branched and crooked trunks of the almácigo (*Elaphrium simaruba* (L.) Rose) are common and very conspicuous during their leafless period. The llagrumo (*Ceropia peltata* L.) with its coarse ungainly stems and large leaves with the white undersurfaces is also conspicuous and characteristic. The jagüeys (*Ficus Stahlii* Warb. and *F. laevigata* Vahl) with their dense leafy crowns and the cupey (*Clusia rosea* Jacq.) with its dark green foliage stand in contrast to the proceding but attract less attention unless seen on the profile of the hills.

At the present time, practically all the land in the valleys between these limestone hills is under cultivation or in pasture but at the bases of the hills there are narrow zones composed of many weedy species intermixed with large herbaceous plants, shrubs and small tress. The most abundant shrubs are higuillos or Pipers, the most common being the higuillo (*Piper aduncum* L.) Other more or less conspicuous species are camasey (*Miconia laevigata* (L.) DC.), rabo de ratón (*Duggena hirsuta* (Jacq.) Britton), Santa María (*Osmia odorata* (L.) Sch. Bip.), with the large herbaceous basquiña (*Pothomorphe peltata* (L.) Miq.) and *Critonia portoricensis* (Urban) B. & W. The most common weedy herbs are the lengua de vaca (*Elephantopus mollis* HBK.), and Margarita silvestre (*Bidens pilosa* L.).

Above this lowest zone is a dense thicket (Fig. 6) of shrubs and small trees, usually from 3 to 5 meters in height which extends to the top of the hill. This thicket includes a large number of species but so scattered that no group appears to be predominant. Our observation led us to believe that the most abundant species are: garrocho (*Quararibaea turbinata* (Sw.) Poir.), higuillo (*Piper amalago* L.), laurel roseta (*Nectandra patens* (Sw.) Griseb,) the hueso (*Picramnia pentandra* Sw.), cenizo or espinosa (*Zanthoxylum martinicense* (Lam.) DC.), hoja menuda (*Eugenia procera* (Sw.) Poir.), caracolillo (*Trichilia pallida* Sw.) and the shrubs *Psychotria pubescens* Sw. and *Acalypha portoricensis* Muell. Arg. The most conspicuous of these is the cenizo or espinosa which has very prominent, stout, conical thorns on the trunk. The cupey trees (*Clusia rosea* Jacq.) may start directly in the soil or many grow epiphytically on the rocks and trees for a long time, sending out long aerial roots which may cling to its support or swing free in the wind. They are frequently suspended from the face of the cliffs and resemble long vines. The supporting trees are frequently destroyed, leaving the cupey standing as an independent tree. The Palo de María (*Calophylum antillanum* Britton) with its smooth glossy leaves of unusual venation the jácana (*Manilkara nitidia* (Sessé & Moc.) Dubard, the malagueta (*Amomis caryophyllata* (Jacq.) Krug & Urban), and the guayabacoa or sebucan (*Rheedia acuminata* (Spreng.) Tr. & Pl.) are very conspicuous. The shruby azota caballo (*Malpighia coccigera* L.) and the encinillo (*Drypetes ilicifolia* Krug & Urban) have peculiar holly-like leaves with spiny teeth. Another characteristic shrub of this and other parts of the island is the poisonous guao (*Comocladia glabra* (Schult Spreng.) which also has spiny leaves. The guano (*Ochroma pyramidale* (Cav.) Urban) is a tree with peculiary lobed leaves, and the shrub *Curcas hernandifolius* (Vent.) Britton with its lobed leaves are also very characteristic. One of the most prominent is the muñeco, (*Dendropanax arboreum* (L.) Dcne. & Pl.), a tree with very conspicuous, crowded, compound leaves composed of broad leaflets. The spiny trunks of palma de coger (*Bactris acanthophylla* Mart.) and espinosa (*Anthacanthus spinosus* (Jacq.) Nees), are conspicuous but not abundant. The gesneriad (*Pentarhaphia albiflora* Dcne.) is a wide-branching shrub of one of two meters growing very commonly in the crevices of the cliffs.

The entire thicket contains a tangle of vines. Some of the most prominent are the true zarza (*Acacia riparia* HBK.) which is very stout and thorny, pringa-mosa (*Tragia volubilis* L.), in which both stems and leaves are armed with stinging hairs, liana uñada (*Bactocydia Unguis* (L.) Mart.), bejuco de sopla (*Elsota virgata* (Sw.) Kuntze), dungey (*Smilax coriacea* Spreng.); bejuco de mona (*Cissampelos Pareira* L.), bejuco de costilla (*Serjania polyphylla* (L.) Raldk.), bejuco de prieto (*Hippocratea volubilis* L.), bejuco de toro (*Stigmaphyllon tomentosum* (Desf.) Ndz.) and *Exogonium repandum* (Jacq.) Choisy. The vine-like grass *Lasiacis sorghoidea* (Desv.) H. & C. is also abundant.

The epiphytes were probably abundant in the primitive forests but are comparatively few at the present time and are usually found on the exposed ledges of rock. One of the most striking in the flor de culebra (*Anthurium acaule* (Jacq.) Schott) which has bright green leaves a meter or more in length which grow in large rosettes. The calabazón (*Philodendron Krebsii* Schott.) climbs the trees and droops over the cliffs. The thick succulent climbing stems of gungulén (*Vanilla Eggersii* Rolfe) with their thick green leaves are also quite common. The erizo (*Pitcairnia angustifolia* (Sw.) Redoute) occurs in masses on the rocky ledges and several other species of bromeliads in sterile condition were observed, most commonly on the jagüey and cupey trees.

The herbaceous plants are decidedly subordinate both in number of species and in number of individuals in each species. The largest is the bijao or narciso (*Alpinia aromatica* Aubl.), which reaches a height of more than two meters. The plants of *Zamia latifoliolata* Preneloup are more common although not abundant. They are very widely distributed and frequently become abundant in new clearings. The shade-loving grases carruzo (*Ichnanthus pallens* (Sw.) Munro) and prenda de oro (*Pharus glaber* HBK.) are common but do not form dense growth. The yerba maravilla (*Ruellia coccinea* (L.) Vahl) is made conspicuous by its scarlet flowers. Madre selva (*Pilea microphylla* (L.) Liebm, yerba de culebra (*Pilea nummulariaefolia* Sw.) Wedd.), yerba de medio real (*Peperomia rotundifolia* (L.) HBK. and *P. magnoliaefolia* (Jacq.) A. Dietr.) are more or less common on the shaded cliffs. There are two common ferns and a number of other species that are met with less frequently. The most common are *Polypodium phyllitidis* L. and *Adiantum cristatum* L.

This type of vegetation is practically the same over the scattered hills and limestone bluffs of the Quebradillas formation. There is less variation from hill to hill than from the north to the south slope of the same hill. The limestone strata dip about five degrees to the north and this slight inclination probably helps to maintain a better supply of moisture on the north side, which also has a somewhat less direct exposure to the sun during the greater part of the year. The north side of a hill usually supports a denser growth of shrubs, bromeliades, aroids and ferns. The leaf mold is deeper and the general appearance mesophytic. The shrub growth of the south side is more open and contains more of a tangle of grasses (*Lasiacis*) and the true zarza (*Acacia riparia* HBK.) which are semi-xerophytic. The north side of the exposed cliffs will be covered with a dense mass of vegetation while those of the south may be almost barren. A continuation of human interference will result in a greater reduction of the plant life to weedy species not relished by goats or other domestic animals.

3. THE RED CLAY-LOAM PLAINS

Along the north side of the belt of limestone hills, are many valleys of varying areas and great undulating plains. The soil is a red clay loam. These lands are very generally under cultivation, mostly to citrus fruits and pineapples, although there is a considerable acreage of cane, some tobacco, vegetables and a few bananas. In some areas the pineapples grow well but in others they are more or less chlorotic, especially near the bases of the hills. It is well known that the lime in the soil causes a chlorotic condition of pineapples unless there is an abundance of humus. Chemical tests of this soil show that the character of the pineapples is a good index as to the condition of the soil. In general the soil of these valleys is acid except at the bases of the hills where it is alkaline. It is probably a mixture of disintegrated limestone and volcanic soil brought down from points farther south with the decaying vegetation. The leaching of the lime from the surface layer and the accumulation of decaying plants very quickly produce an acid condition.

4. THE FORESTS OF THE LOWLAND WHITE SANDS

Areas of white sands between the limestone hills and the ocean are frequent along the north coast. They are supposed to be the result of disintegration of the hills and are designated as the Arecibo sands. They are most extensive between Manatí and Dorado but are found as far east as San Juan. They are very generally cultivated, the most important crop being sugar cane. The only extensive development of natural vegetation was found on the estate of Miss Livingston, west of Dorado. Our description was prepared from a study of plant life of this estate (Fig. 7).

The land occupied by this forest is flat, level and very little above sea level and has few small depressions and streams. A slight elevation on the sea shore, formed by wind-borne sands is covered with a beach thicket. The soil is composed of white, calcareous sands of unknown depth. The surface is covered with a thin layer of humus, fallen twigs and leaves, which gives a brownish stain to the underlying sands for a distance of two or three decimeters. The surface is thoroughly shaded and very moist. The upper layer of soil is filled with feeding roots. The trade winds do not penetrate the forest more than 50 meters and the conditions are especially favorable for a mesophytic forest.

The dominant trees are only about 20 meters in height; the lumbermen having left a very few veterans. There has been no complete removal of forest and therefore trees of all ages from the few veterans to seedlings of less than one year are to be found. There are few shrubs and still fewer herbs. There are two species of trees of special interest because of their size and abundance; the mamey (*Mammea americana* L. and the Santa María (*Calophylum antillanum* Britton) both of which reach heights of 20 meters (60 ft.) and have trunks of approximately one meter in diameter. There are numerous small trees and seedlings forming about one-half the ground flora. Muñeco (*Dendropanax arboreum* (L.) Dcne. & Pl.), is ever present but its slender trunks rarely exceed 10 meters in height. Cupey (*Clusia rosea* Jacq.) is conspicuous because of its semi-epiphytic habit, the presence of its long, stout, aerial roots and the color of its leaves. Almácigo (*Elaphrium Simaruba* (L.) Rose) is abundant, malagueta (*Amomis caryophyllata* (Jacq.) Krug & Urban) is common and attains a height of 20 meters. The royal palm or palma real (*Roystonea borinqueña* Cook) is very generally found in the low wet places. Small trees of pomarosa (*Jambos Jambos* (L.) Millsp.) are very abundant along the trails, frequently forming thickets. Other species of trees sufficiently prominent to be mentioned are the aquilón (*Laugeria resinosa* Vahl), the cenizo (*Zanthoxylum martinicense* (Lam.) DC.), sapote de costa (*Manilkara duplicata* (Sessé & Moc.) Dubard), guayabota (*Diospyros ebenaster* (Retz.), higuerillo (*Enallagma latifolia* (Mill.) Small), the corozo palm (*acrocomia aculeata* (Jacq.) Lodd.), the shrubby yaita (*Gymnanthes lucida* (Sw.) and avispillo or laurel (*Nectandra coriacea* (Sw.) Griseb.).

Seedlings of large trees are quite numerous but the frequent cutting prevents the development of a forest. The most abundant shrub is the bejuco de berraco (*Chiococca alba* (L.) Hitch.) and the second in abundance is *Piper citrifolium* Lam. Other more or less prominent shrubs and small trees are rasca-garganta (*Parathesis serrulata* (Sw.) Mez), hoja menuda (*Eugenia monticola* (Sw.) Urban), cafeillo (*Casearia guianensis* (Aubl.) Urban), palo moro (*Psychotria undata* Jacq.), higuillo de limón and (*Piper Amalago* L.). The vines and viney shrubs are few in number but the most prominent are: the thorny escambrón (*Pisonia aculeata* L.), bejuco de garrote (*Rourea surinamensis* Miq.), gungulén (*Vanilla Eggersii* Rolfe), uña de gato (*Bactocydia Unguis* (L.) Mart.) dungüey (*Smilax coriacea* Spreng.) and bejuco de toro (*Stigmaphyllon tomentosum* (Desv.) Ndz.). Epiphytes are few and consist mostly of sterile Bromeliads; the small orchids *Ionopsis satyroides* (Sw.) Rchb., *Beadlea cranichoides* (Griseb.) Small, and *Liparis elata* Lindl.; the ferns, *Polypodium phyllitidis* L., *P. lycopodioides.* L. and *Nephrolepis exaltata* (L.) Schott. are rare. The two low grasses *Pharus glaber* HBK. and *Ichnanthus pallens* (Sw.) Munro are quite common.

The slight depressions previously mentioned contain a thin layer of wet muck, resulting form the decay of the plants, but the only changes in the forest are due to an increased number of royal palms (*Roystonea borinqueña* Cook) and thickets of pomarosa (*Jambos Jambos* (L.) Millsp). Some few of these depressions contain a little muddy water and support growths of eneas or cat-tails (*Typha angustifolia* L.).

There are no evidences of physiographic changes in progress at this time, with possible exception of the small depressions, which might result in further changes in the plant life. There is no certainty that this is the true climax association of the region, because the continued leaching of the lime and increase in humus might result in another succession, with the following vegetation possibly the same as the extinct forest which at one time occupied the alluvial plains of the region.

5. SECOND-GROWTH THICKETS OF THE WHITE SANDS

The removal of the forest from practically all of the white-sand plains has resulted in a shrub thicket over that area. Special attention was given to this type of thicket as found along the south shore of the Laguna Tortuguero. The surface of this region is level, frequently broken by shallow ravines which are occupied by intermittent streams during the rainy reasons. The soil is a pure white sand with a relatively small amount of humus. The result is a low water-holding capacity, high surface evaporation and a rapid run-off of surface water; all of which tend to produce a xerophytic environment which has its effect on the plant life.

The thickets are not continuous but alternate with open places. They are most highly developed in the ravines, are from 3 to 5 meters in height and almost impenetrable. The high, open places are mostly barren but support a limited growth of the low shrubs and herbs. (Fig. 8.)

Of the trees and shrubs in this formation, the most common is the icaco (*Chysobalanus Icaco* L.). It is a bushy plant, one to two meters in height, or sometimes higher or with the lower branches resting on or near the ground; under favorable conditions, plants of various ages grow close together. The second in abundance is the tree, maricao (*Byrsonima spicata* (Cav.) DC.), which is tall, erect and rather slender. The next in importance is rama menuda (*Myrcia splendens* (Sw.) DC.), which is a bushy shrub or small tree with a glossy dark foliage. Other shrubs and small trees of these thickets are tintillo

(*Randia mitis* L.), Santa María (*Calophyllum antillanum* Britton), camasey (*Miconia racemosa* (Aub.) DC. and *M. prasina* (Sw.) DC.), maray maray (*Ecastophyllum Ecastophyllum* (L.) Britton), cafeíllo cimarrón (*Casearia sylvestris* Sw.) cerezo (*Myrcia cerifera* L.), canela (*Acrodiclidium salicifolium* (Sw.) Griseb.), hoja menuda (*Myrcia citrifolia* Aubl.) Urban, and *Taonabo peduncularis* (DC.) Britton; all of which at this time have about the same height and bushy form. The llagrumo (*Didymopanax Morototoni* (Aubl.) Dcne. & Pl.) is not abundant but is conspicuous because of its large leaves with bronzed lower surface. The occasional thickets of corozo palm (*Acrocomia aculeata* (Jacq.) Lodd.) are quite prominent.

The vines are neither abundant nor distinctive. The most noticeable are the dunguey (*Smilax coriacea* Spreng.), bejuco de sopla (*Elsota virgata* (Sw.) Kuntze), bejuco de mona (*Cissampelos Pareira* L.), and *Cissus erosa* L. C. Rich. There are no epiphytes. There are practically no herbaceous plants under the upland thickets but in the moister places at the bottom of the ravines are found scattered individuals of altea (*Nepsera aquatica* (Aubl.) Naud.), grasilla (*Setiscapella subulata* (L.) Barnh. and *Xyris Elliottii* Chapm.

In the flat open places there is a characteristic shrubby and herbaceous vegetation consisting of a sparse growth of araynillo (*Ascyrum hypericoides* L.), hediondilla (*Chamaecrista diphylla* (L.) Greene), matraca (*Crotalaria retusa* L.), *Mitracarpus portoricensis* Urban, *Portulaca pilosa* L. and *Cladonia rangiferina* L.

This region has undoubtedly been cut over many times for fuel and the resulting change in environment probably accounts for the presence of so many species not found in the Livingston forest (page 32). This change in environment has been so great that many of the original species have given way to others better suited to the new conditions. Of these new arrivals, the icaco (*Chrysobalanus Icaco* L.) has the advantage because of its proximity, adaptation and efficiency of its edible fruit for migration. Therefore, it has become the dominant shrub. The history of these thickets will probably end in the near future through the utilization of the land for agriculture. If undisturbed by man, the accumulation of humus followed by the better conservation of soil moisture might result in the re-establishment of a normal forest association.

6. REVERSIONARY SUCCESSIONS ON THE SAN JUAN FORMATION

The changes in elevation of the northern coast line within recent time have exposed the San Juan consolidated sand dunes to the direct action of the sea. The result is a rapid erosion and modification of the second-growth thicket coverings which are passing through a reversionary successional series in which the plants will eventually be destroyed. Although these successions are logically a part of the mesarch series, they also indicate a possible stage in the history of the xerarch series as the plant life associated with them is so closely akin to that of the coastal sand dunes in its environment, dynamics and specific composition. Therefore, we will discuss their organization under the xerarch series.

SUMMARY

The north coastal plain was originally covered with a limestone deposit and the higher parts were covered by man and replaced by the thickets now found on the limestone hills. However, much of this limestone strata has been reduced by erosion to a base level which is covered with white calcareous sands which also supported a normal mesophytic forest that has been almost entirely destroyed by man. Part of this plain is under cultivation and part has been subject to repeated cutting for fuel. The forest association was followed by a thicket association of a different specific composition.

C. The Xerarch Series of the Sand Beaches and Sand Dunes

Subseries A.—Beaches and Beach Thickets

The conditions for the development of sand dunes is most ideal along the north coast and south along the eastern end of the Island as far as Fajardo Playa, a region which has a free exposure to the trade winds, except in the sheltered coves to the west of the headlands of the San Juan formation, where the force of the trade winds is greatly reduced, and on the northeastern part of the Island, where an adequate supply of sand seems to be unavailable. Under these conditions the sandy beaches rise gradually to a height of one or two meters above sea level and then pass into flat, sandy plains, or they come into immediate contact with the volcanic hills of the Cretaceous age. In both cases we find three zones of vegetation: (1) a beach association composed of scattered herbaceous species, (2) an association of shrubs forming a semi-xerophytic shrub association, and (3) an almost unknown association, probably of forest which was beyond the influence of the sea and which has been destroyed so that the land might be used for agriculture; it is probable that the sandy maritime plains were originally covered with a forest similar to that of the white-sand plain, and that the older hills were covered with a different type of forest of a different genetic history, which was in geographic contact with but not related to the thickets.

1. THE BEACH VEGETATION

The narrow strip of exposed beach, lying between the water and the edge of the thicket is usually from 5 to 10 meters in width and is partly covered by herbaceous species, which are destroyed at irregular intervals by the excessive wave action. Therefore, the flora consists of species that can be very quickly re-established from seeds or vegetative parts or from plants that trail down from the higher thickets. The most prominent are the two vines, bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.) and mato de la playa (*Canavali maritima* (Aubl.) Thou); the shrubby *Chamaesyce buxifolia* (Lam.) Small; the true herbs mostacilla de mar (*Cakile lanceolata* Willd.) O. E. Schulz.), and botón blanco *Borreria verticillata* (L.) Meyer the grass matojo de playa (*Sporobolus virginicus* (L.) Kunth) and the three sedges *Fimbristylis spathacea* Roth., *Kyllinga peruviana* Lam. and *Remirea maritima* Aubl. It will be readily seen that the plants are engaged in a continuous struggle for the possession of the land in which it is impossible to gain a permanent hold. The plants are destroyed by every storm and new ones develop in a short time. The number of individuals of each species and their location depends primarily on the dispersal and germination of seeds and vegetative parts.

2. THE BEACH THICKETS

The lower margin of the beach thicket marks the upper limit of the ordinary storm-wave action. The most conspicuous species is the shrubby uva de playa (*Coccolobis uvifera* (L.) Jacq.) which is usually most abundant, ranging from low shrubs to small-sized trees, depending on exposure or protection from the wind. The icaco (*Chrysobalanus Icaco* L.) is second in importance and usually farther back from the shore and more protected from the wind. The associated species are the shrubs borborón (*Scaevola Plumierii* (L.) Vahl), cariaquillo de Santa María (*Lantana involucrata* L.), tintillo (*Randia mitis* L.) añil (*Indigofera suffruticosa* Mill.), the vine mato azul (*Guilandina crista* (L.) Small; and the herbs matraca (*Crotalaria retusa* L.), zarzabacoa enana (*Stylosanthes hamata* (L.) Taubert) and margarita (*Bidens pilosa* L.).

An excellent example of the wide beach thicket was studied at kilometer 36 east of Mameyes. At the lower margin the number of species is few and individuals usually not more than one meter in height; but in passing to the higher levels both the number of species and the heights of the individuals increase, some of them attaining as much as 5 meters. The thickets also become dense and almost impassible.

The jayajabico (*Erithalis fruticosa* L.) is the most abundant shrub but other common and characteristic shrubs and small trees are the wattle (*Eugenia axillaris* (Sw.) Willd.), the cachimba (*Rauwolfia tetraphylla* L.), the bálsamo (*Citharexylum fruticosum* L.), the azúcares (*Jacquinia Barbasco* (Loefl.) Mez), *Ernodea littoralis* Sw., palo moro (*Psychotria undata* Jacq.). One of the most striking plants of this formation is the alelí (*Plumiera alba* L.) with its slender branches projecting above the surrounding vegetation. The whole thicket is interlaced by a tangled mass of vines such as mato azul (*Guilandina crista* (L.) Small), the dunguey (*Smilax coriacea* Spreng.), the bejuco de costilla (*Serjania polyphylla* (L.) Radlk.) and the pega palo (*Distictis lactiflora* Vahl) DC.). The development of this thicket is accompanied by the gradual disappearance of the pioneer shrub and small tree growths of *Coccolobis*, *Chysobalanus* and *Scaevola* to which we have previously referred. At a distance of 50 meters from the ocean we meet with a tree growth consisting largely of roble blanco (*Tabebuia pallida* Miers), almácigo (*Elaphrium simaruba* (L.) Rose) and tortugo amarillo (*Sideroxylon foetidissimum* Jacq.), which indicates a completion of the transition from a beach to a forest environment. The land back of the thickets has been utilized for pasture but the few remaining trees indicate that the area was originally occupied by a mesophytic forest, which we believe was similar to that of the forest on the white sands near Dorado (see page 32).

At Dorado, the narrow beach is bordered by a very narrow zone of beach thickets in which the uva de mar (*Coccolobis uvifera* (L.) Jacq.) is the dominant species. The narrow zone is in close contact with the mesophytic forest but several thicket species, such as cachimba *Rauwolfia tetraphylla* L.) and jayajabico (*Erithalis fruticosa* L.), are prominent near the shore. At Mameyes the presence of young trees of roble blanco (*Tabebuia pallida* Miers) near the thickets may indicate an attempt of the forest to establish itself closer to the shore.

The sand of the thickets appears to be stabilized as far as the front margin, and the variations in heights of the individual plants appear to be due almost entirely to the action of the wind. Each shrub is slightly taller than those in front of it and nearer the shore which results in a gradual slope from one meter to the height of a mature forest. Young trees occupying advanced positions under the shelter of the thickets cause a steeper pitch and if undisturbed the thicket zone would become narrower and narrower until it would occupy a very narrow strip between mesophytic forest and shore as at Dorado. The removal of the forest at Mameyes, followed by the repeated cutting of the young trees of the thicket for fuel has resulted in a comparatively wide thicket zone with a gradual pitch on the surface.

It appears that the beach thickets are very similar to the dune thickets so far as their component species are concerned, but lead to different successional results. At Fajardo Playa the thickets are intermediate in composition between the beach thickets just described and those of the mangrove swamps. They occupy a habitat intermediate in environment between that of the sand beaches and the coastal swamps, and will be discussed later (see pages 56, 63.

Subseries B.—The Sand Dune Vegetation

There are two entirely different types of sand dunes in Porto Rico, dependent primarily on their ages. The younger series, of recent development, consist of loose calcareous sands. They are typical sand-dune formations and move freely under the influence of the wind unless held in check by a covering of plants. The older series consists of sand which has been consolidated by an organic cement into a limestone rock, commonly known as the San Juan formation. This formation is continuous for the greater part of the distance from San Juan to Arecibo, the two highest points being the San Juan promotory on which the El Morro fortifications are located and the promontory on which the Arecibo lighthouse is located. In some places this formation stands as a wall protecting the land form the encroachments of the sea; in other places the sea has broken through. Small islands of this same formation which have resisted the action of the sea indicate that the formation was much more extensive in the past and that the shore line was farther out. In some cases the waves have worn caves in this formation and Indian carvings which must be 400 years or more old indicate that the disintegration is rather slow.

The San Juan formation consists of two or possible three parallel series. The farthest inland is the older and averages about one kilometer in width and about 20 to 50 meters in elevation above the sea.

The contours are rounded and flattened by erosion and deposits in the valleys. The youngest or coast series is narrower, lower, steeper and the summits shaped as might be expected in a comparatively recent formation. This series is in contact with the sea at many points and shows the effects of wave action. At some points the sea has broken through (Fig. 9) and occupies areas between the old and the newer series and at some points the outer or newer formation has been completely destroyed.

The active dunes are composed of sands which have washed ashore and been carried inland by the wind. This sand was probably derived from the disintegration of the old San Juan formation. When the old and new series are intact, they are separated by narrow valleys of fertile soil which are very generally used for agriculture.

The history of these dunes may be summarized as follows:

(1) At some time in the past the general level of the land was lower than at present and the sea extended inland as far as the region now occupied by the inner series of consolidated dunes. Large dunes were then formed and consolidated into the present inner series of the San Juan formation.

(2) An elevation of the land caused the sea to recede to the north and permited the formation of a new but smaller series of dunes which in turn were consolidated into our present outer series of the San Juan formation.

(3) This was followed by a subsidence of the land which brought the sea into contact with the outer or new series and resulted in its partial destruction which is now in progress. The sands resulting from this destruction are now being used in the formation of the active dunes.

It is impossible to predict with any degree of certainty the future changes in this region. A future subsidence will result in the complete destruction of the outer dunes and allow the sea to attack the inner series. If the present level is maintained, the present active dunes will become consolidated. If the land is elevated, the outer series will be preserved, the active dunes will become consolidated and a new series of active dunes will be formed.

The active dunes are of very little agricultural value except for the growth of coconuts which is rather uncertain under these conditions. On the other hand, the dunes frequently encroach on and destroy agricultural lands. Many small homes with their small plantings of yautía, sweet potatoes and tobacco are located on the lee side of these active dunes where they are protected from the wind and the sea. Small plantings on the crests of these dunes are invariably protected by wind breaks constructed of palm leaves or other materials. The inner series are very generally under cultivation; cane being grown on the richer soils while the poorer are used for grazing and minor crops. The valley lands between the inner and outer series are very generally planted to cane unless they are so low as to permit the entrance of the brackish water, when they support good growths of coconut palms.

The history of the sand dunes whether active or old is very closely connected with the plant life upon them and nearly all stages can be observed at the present time. As soon as an active dune becomes quiet, the plant life attempts to cover it, moving from the land side to the sea, until it comes into direct contact with the destructive force of the wind and wave. The result is a further stabilization of the sand which is soon covered by a growth of thicket shrubs. This tends to a further stabilization of the sand and the formation of a forest association. Any change, such as a subsidence of the land, which enables the sea to attack and destroy or partly destroy this formation, results in a reversion of this series and the forests give way to thickets which finally disappear leaving a more or less barren shore line which disintegrates under the action of the wind and waves.

The mechanics of a dune formation may be briefly summarized as follows: The wind tends to carry the loose dry grains of sand and to cause a general leveling of the surface, but any obstruction which tends to reduce the velocity of the wind, also reduces its carrying power and causes it to drop its load of sand behind the obstruction. The result is the formation of a dune limited in height by the height of the obstruction and the force of the wind. If the obstruction be a plant which can withstand these forces of nature, live and grow, the dune will rise gradually so long as the force of the wind is strong enough to carry sand to its top.

However, the development of the sand dune is usually more complicated than we have indicated. The increase in height is necessarily accompanied by an increase in breadth and plants are necessary for the protection of its slopes. But the establishment of plants is not easy and sometimes the dunes are destroyed by the wind and wave before they are completed. As the dune increases in height, the force of the wind at its summit is also increased and sand is blown over the top and falls on the lee side. Plants vary greatly in their ability to live under these adverse conditions and the dunes vary in size with the character of the plants which are continually trying to cover them. The dunes of the north coast of Porto Rico seldom exceed fifteen meters in height. The small dunes tend to unite and form long ridges, parallel to the shore. Any break in the plant life of such a ridge dune, either by nature or by man, permits the wind to attack the structure and start disintegration. If this break is not closed, more and more of the vegetation will be destroyed, and a gap formed through which quantities of sand will be carried to start a new dune on the lee side of the old one.

Sand dunes vary greatly in general appearance, in size, in topography and in the plant life which covers them. The beach may be broad or narrow, the dunes large or small, isolated or united, the sand motion variable and the plant life of different species. Sometimes the plant life appears to have the advantage in this continuous warfare with the winds and waves, covers the dunes and extends to the limits of wave action. Sometimes the wind and wave appear to have the advantage and the plants may give way or maintain themselves with difficulty. Sometimes the wind and the waves undetermine large trees and cause them to fall, and at other times the wind carries the sand in such quantities as to bury shrubs and trees and to threaten small buildings and gardens.

A study of this apparent chaos of topography, plant life and wind action, reveals certain fundamental principles and radically different types of environment which are subject to variation and change from time to time. The most important types of environment are: (1) The type within the limit of salt water which prevents the growth of land plants. (2) The type resulting from the deposition of sand by the wind, such as are found on the lee side of every cluster of plants and opposite every break in a dune; here we find such plants as can withstand partial burying and grow as rapidly as the sand accumulates and trailing vines which maintain their anchorage while their long stems ride over it. (3) The type in which the sand is removed by the wind and the vegetation consists of old individual plants which were established before the excavation started. (4) The type in which the surface of the sand is stationary and the mass effect of the many species of plants is to maintain its stability.

The variations in the amount and general appearance of the vegetation on these sand dunes is due to the variations in these four types of environment. The force of the wind and the rapidity of the movement of the sand will naturally influence the number of species and the number and size of the individual plants of each species. The vegetation will necessarily be sparse and limited to those species which can endure the unusual stress of wind and sand.

1. THE BEACH VEGETATION

The shore of the north coast throughout the Tertiary formation had a sandy beach of varying width which is occasionally broken by the headlands of the San Juan formation and by the estuaries of the many rivers. The plant life of this beach is practically the same as that previously described, except that it is somewhat more sparse as the result of greater wind and wave action, which has reduced the number of plants to the minimum. In many places no plants are to be found below the margin of the dune thickets and in other places the number is small. Probably the most outstanding plant is the yerba de sal (*Philoxerus vermicularis* (L.) Nutt.) (Fig. 10) which is usually established closer to the ocean than other plants. Its prostrate, red, fleshy stems spread over the sands and it is an important factor in the building of small dunes. Associated with it on the beach are the bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.), rooted above the beach and trailing down over it; and the grass matojo de playa (*Sporobolus virginicus* (L.) Kunth), which migrates along the beach by means of shallow rhizomes. There was also scattered individuals of the herbaceous mostacilla del mar (*Cakile lanceolata* (Wild.) O. E. Schulz) and *Diodia maritima* Thonn. The shrubby *Chamaesyce buxifolia* (Lam.) Small is rare.

2. THE *COCCOLOBIS UVIFERA* DUNES

A little above the zone of wave action, the sand is comparatively quiet and several types of dune-forming plants are to be found. One of the first is the shrubby *Chamaesyce buxifolia* (Lam.) Small; another is the herbaceous *Diodia maritima* Thonn., and the sedge *Remirea maritima* Aubl., all of which tend to hold the moving sand and start small dunes which may attain the height of one to three meters. The lee side of these small dunes is favorable for the uva de playa (*Coccolobis uvifera* (L.) Jacq.) which is the most important dune former of this region. Its extensive root system holds the sand and the shade of its broad leaves prevent surface evaporation to some extent and thus holds the sand which is blown under the thicket. Under the protection of this plant, the dunes grow rapidly and frequently unite into ridges (Fig. 12). The spread of this plant gradually forces out many of the pioneer herbaceous plants. Although some other plants have the same habit they are much less important as dune-formers. Some that may be mentioned are: the shrubby borborón (*Scaevola Plumierii* (L.) Vahl.) and icaco (*Chrysobalanus Icaco* L.), both of which are more abundant and more important in other habitats. The tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.) is common and forms tangled spreading mats three meters or more in width. When protected by the shade of the Coccolobis it grows slender and erect and is soon forced out.

The establishment of the dune is usually followed by a growth of uva de playa (*C. uvifera*), which very rarely reaches its maximum height of 15 meters in the dune environment. Its shade and fallen leaves help to hold moisture and increase the organic content of the soil. Therefore, a new environment is formed in which we find an increase in both number of species and indviduals. Among the latter are the vines noyo (*Ipomoea dissecta* (Jacq.) Pursh), dunguey (*Smilax coriacea* Spreng.), bejuco de costilla (*Serjania polyphylla* (L.) Radlk and the false guaco (*Mikania congesta* DC.). The most characteristic herb is the lirio (*Hymenocallis declinata* (Jacq.) M. Roem.). The introduced species, the cocuisa (*Cordyline guineensis* L. Britton) and the bruja (*Bryophyllum pinnatum* (Lam.) Kurz), are frequent and often form large patches where the shrubs have been removed. Various other species come in from the cultivated grounds near the dunes. Certain other shrubby and arborescent species also appear to a greater or less extent with the uva de playa; the most common are the icaco (*Chrysobalanus Icaco* L.), the roble blanco (*Tabebuia pallida* Miers), the palo de María (*Calophyllum antillanum* Britton), the palo de burro (*Capparis flexuosa* L.) and the escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.). None of these attains a large size or surpasses the general level of the uva de playa because of the exposure to continuous winds which checks the growth at a uniform level of about one meter. The vine species of the more exposed situation, such as the bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.) and the mato de playa (*Canavali maritima* (Aubl.) Thou.) trail over the occasional exposed places in the thickets where they are often associated with batatilla (*Ipomoea stolonifera* (Cyrill.) Poir). Here the first colonizers are the shrubs (*Diodia maritima* (Thonn) the sedge (*Remirea maritima* Aubl.), the shrub (*Chamaesyce buxifolia* (Lam.) Small) and the vines batatilla (*Ipomoea stolonifera* (Cyrill.) Poir), bejuco de playa (*I. Pes-caprae* (L.) Roth.) and the mato de playa (*Canavali maritima* (Aubl.) Thou.).

3. THE LEE-SLOPE THICKETS

The lee side of the growing dunes has a considerable protection from the winds and is favorable for many plants. One of the first arrivals is the herbaceous *Diodia maritima* Thonn., the sedge (*Remirea maritima* Aubl.), the shrub (*Chamaesyce buxifolia* (Lam.) Small.), the vine batatilla (*Ipomoea stolonifera* (Cyrill) Poir) and scattered trailing individual of such plants as bejuco de playa (*I. Pes-caprae* (L.) Roth.) and mato de playa *Canavali maritima* (Aubl.) Thou.). As the dune approaches the maximum in size and the lee side becomes stabilized, this sparse growth develops into a dense thicket in which the uva de playa (*Coccolobis uvifera* (L.) Jacq.) is usually the most prominent although it is occasionally replaced by other species. The stabilization of the lee slope leads to the conservation of the soil moisture, the addition of organic material and thickets which are taller, denser and composed of more species than the thickets of the ridges. The uva de playa which does not exceed a meter in height on the ridge, rises to the level of the ridge where its progress is checked by the force of the wind. (Fig. 11). In fact the entire association of the lee side of the dunes tends to grow to a greater height than the same species growing in exposed places, and some new species, such as mangle botón (*Conocarpus erecta* L.), ventura (*Ichthyomethia piscipula* (L.) Hitchc.) and the shrubby jayajabico (*Erithalis frutcosa* L.) are introduced. The almendra (*Terminalia Catappa* L.) Fig. 13) is used extensively for windbreak and its seedlings are usually to be found in considerable numbers on the lee slope of these dunes. They mingle to some extent with the uva de playa and become most abundant where the original vegetation has been destroyed. This species is also influenced by the wind; it seldon rises above the crest of the dunes and when exposed to the force of the wind shows a much greater branch development on the south than on the north side. With the growth of the thickets, the vines persist but herbaceous plants are reduced in number or disappear. When the shrubby growth is removed, the herbaceous weeds from neighboring fields and gardens come in very promptly.

4. THE DUNE FORESTS

It is difficult to trace the later development of these dune thickets, as they are cut over as soon as the new growth is large enough for fuel. However, it appears that the natural introduction of forest species would gradually overcome the uva de playa and its shrubby association and give rise to a mixed forest. Some of these species are: the conspicuous almácigo (*Elaphrium simaruba* (L.) Rose), the cenizo or espinosa (*Zanthoxylum martinicense* (Lam.) DC.) and the maray-maray (*Ecastophyllum Ecastophyllum* (L.) Britton). Intermingled with these are to be found the vines, mato azul (*Guilandina crista* (L.) Small) and bejuco de toro (*Stigmaphyllon tomentosum* (Desf.) Ndz.). There are also scattered plants of *Zamia latifoliolata* Preneloup. Most of these species are represented in the second-growth thickets of the limestone hills and there is reason to believe that the stabilized dunes of the San Juan formation were originally covered with a mesophytic forest similar to that of the older limestones.

The dune history may be summarized as follows: When the sand near the beach becomes sufficiently quiet to support plant life, it is more or less completely covered by the pioneer herbaceous species which soon give way to thickets of uva de playa. As the environment improves, new species are added, leading ultimately to a mixed forest. The occupation of the windward side of the dune by plant life is less complete than the summit and lee side because of its greater exposure to the wind. It is in these exposed places that the uva de playa will persist and that we find such plants as the grass, matojo de playa (*Sporobolus virginicus* (L.) Kunth) and the yerba de sal (*Philoxerus vermicularis* (L.) Nutt.) as the outpost plants in space just as they were the first plant in time.

5. SECONDARY SUCCESSIONS ON THE DUNES

Many dunes are destroyed before reaching maturity, sometimes by the removal of the sand when there is not enough plant life to hold it and sometimes by the too rapid deposition of sand. When a mature dune is completely occupied by plant life it is quite permanent unless a subsidence of the area exposes it to the action of the waves, or the vegetation is removed by man or other agents. A well-worn path across the top of a dune may permit the removal of sand by the wind and cause the undermining and destruction of the plant life. The destruction of a dune by the wind results in a new dune on the lee side of the old one. Every stage of destruction and construction can be observed along our north coast. In a few cases in which the destruction is caused by wave action, the attack is at the base of the windward side of the dune, resulting in low, steep cliffs of sand held in place by the roots of uva de playa and favoring the growth of the yerba de sal (*Philoxerus vermicularis*

(L.) Nutt.). In most cases the destruction starts with a break in the plant life on the crest of the dune. The sand is removed from this break and poured over the lee side where it forms an active lee slope. The break widens and the plants on its sides are undermined, but the action is retarded by the uva de playa and its associated species. If this continues the old dunes are completely destroyed and new ones formed slightly farther from the shore (Fig. 14). In these cases the moving sands frequently bury the old dune thickets. Some few species are able to withstand this action to some extent, such as the tree Santa María (*Calophyllum antillanum* Britton). The bejuco de costilla (*Serjania polyphylla* (L.) Radlk.) is also resistant and is frequently found twining over partly buried thickets. The mato de playa (*Canavali maritima* (Aubl.) Thou.) appears to thrive under these conditions and is found rooting at the edge of the lee slope and trailing over it. A grass (*Cenchrus carolinianus* Walt.) and some other herbaceous species are less frequent.

The rapid removal of the sand in front of a break results in a flat beach which is nearly or entirely devoid of plants. It is difficult to determine whether the small dunes on these flats are old or new. However, the old dunes are usually recognized by the uva de playa and other plants which are larger than is necessary to hold the small amount of sand and which indicate that the dunes are decreasing in size; while the young dunes are occupied by small plants. The uva de playa being the most common species of the stabilized dunes is very naturally the most common on the disintegrating dunes, although other plants are also present. They are the shrubs, clavelón de playa (*Borrichia arborescens* (L.) DC.) and borborón de playa (*Scaevola Plumierii* (L.) Vahl.) and the tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.). Even though such dunes are being destroyed by erosion on the windward side, they continue to collect sand in their lee and that area of deposition is at once occupied by the sedge (*Remirea maritima* Aubl.), the herb (*Diodia maritima* Thonn.), the bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.) and other plants of the habitat. In one case a plant of cariaquillo de Santa María (*Lantana involucrata* L.) was noted, a species which is most abundant on solid limestone.

All these activities in dune formation must be regarded as temporary. They may overrun fields (Fig. 15) and destroy plant life but they are finally stabilized. Eventually the supply of sea-sand is exhausted in a particular locality, the dune ridges protect the territory on the lee side and vegetation is stabilized. The compound series of dune ridges along our north shores indicates that dune formation, destruction, and reformation and recapture by vegetation has occurred repeatedly in the past.

6. THE VEGETATION OF THE SAN JUAN CONSOLIDATED DUNES

The sand under the dense thickets tends to become firm and solid and there is reason to believe that this is the first step in the consolidation into limestone by means of an organic binder. It is probable that the San Juan formation (Fig. 9) started in this manner although many thousands of years were required for its completion, and the vegetation of prehistoric time may have been quite different from that of today.

The consolidation into the San Juan formation must have been preceeded by a stabilization of sand dunes and must have been dependent on the vegetation of that period. It also appears that the plant life of the limestone rock and that of the stabilized dunes must have been similar. The thin soil of the San Juan limestone of today is the result of the disintegration of that formation into a sand which has been modified by leaching and by the addition of organic material. This soil is practically the same as that of the newly stabilized dunes. The plant life of the new and old dune series is very similar but the additional species on the San Juan dunes indicates a greater and larger stabilization of the soil and a greater accumulation of organic material.

The agencies which have had some influence on the plant life of the crest and sides of the dunes attain their greatest efficiency in the intervening valleys where erosion from the slopes has formed a deep, rich soil. It is practically impossible to tell the nature of the plant life of these valleys and slopes before it was removed by man and the land utilized for agriculture. However, two summits unfit for agriculture are still occupied by remnants of the original vegetation, although they have been cut over repeatedly.

The present vegetation is a dense thicket of shrubs, young trees and vines with a few herbs, in which the shrubby icaco (*Chrysobalanus Icaco* L.) is by far the most abundant, forming almost impenetrable thickets around the margin and in all parts of this area. A few plants of the uva de playa (*Coccolobis uvifera* (L.) Jacq.) still persist in the more exposed places where it is difficult for other plants to get a foothold. Many other species which are characteristic of the active dunes show the similiarity in environmental conditions but many additional species also accur. Among the more common are such trees as palo de María (*Calophyllum antillanum*

Britton), palo de burro (*Capparis flexuosa* L.), roble blanco (*Tabebuia pallida* Miers), and limoncillo de monte (*Calyptranthes Sintenisii* Kiaersk.); the shubby berenjena de playa (*Solanum persicifolium* Dunal); the vine pega palo (*Distictis lactiflora* (Vahl) DC.), the chew stick or soap stick (*Gouania lupuloides* (L.) Urban) bejuco de costilla (*Serjania polyphylla* (L.) Radlk.), the bejuco de palma (*Trichostigma octandrum* (L.) H. Walt.), the aguinaldo de blanco (*Jacquemontia nodiflora* (Desv.) G. Don.) the herbaceous botón blanco (*Borreria verticillata* (L.) Meyer), the carmín (*Rivina humilis* L.), the maya (*Bromelia Pinguin* L.), and the bruja (*Bryophyllum pinnatum* (Lam.) Kurz). These herbs are most common around the margin and the madre selva (*Pilea microphylla* (L.) Liebm.) and (*Clavenna tetandra* (L.) Standl.) and other herbs are also quite common. The tall trunks of the almácigo (*Elaphrium simaruba* (L.) Rose) are conspicuous on the summits and jagüey (*Ficus laevigata* Vahl) and cupey (*Clusia rosea* Jacq.) are common on the shady north slopes where the conditions are decidedly mesophytic. The two most common vines are the gungulén (*Vanilla Eggersii* Rolfe and calabazón (*Philodendron Krebsii* Schott). The viney pitalaya or night-blooming cereus (*Hylocereus trigonus* (Haw.) Safford) is common on the trees and the flor de culebra (*Anthurium acaule* (Jacq.) Schott) forms large clumps on the exposed ledges. The striking similarities of these fragments and the thickets of the limestone hills indicate that they represent the same original association which was a mesophytic forest now completely destroyed. It represented the temporary climax of both the mesarch and xerarch successional series.

7. DISINTEGRATION OF THE SAN JUAN DUNES

As previously stated, there were two, possibly three, series of consolidated dunes of the San Juan formation. As the result of a subsidence the second is now in contact with and partly below the level of the sea, and is being disintegrated into sand. This is followed by a retrogressive succession in the plant life. Along the lee front of the outer ridge, clearing and pasturing, aided by the effect of the salt-laden atmosphere, have reduced the original forests to mere thickets, composed largely of thorny species. The most common species in these localities are the tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.) which forms dense mats; crowded thickets of cariaquillo de Santa María (*Lantana involucrata* L.) and uva de playa (*Coccolobis uvifera* (L.) Jacq.); and tangled masses of the vine, mato azul (*Guilandina crista* (L.) Small). Other shrubby and small-tree species which are more or less common are the coscorran (*Elaeodendrum xylocarpum* (Vent.) DC.), the alelí cimarrón (*Plumiera alba* L.), the espinosa (*Anthacanthus spinosus* (Jacq.) Ness.), the ventura (*Ichthyomethia piscipula* (L.) Hitchc.), the sereno (*Gundlachia corymbosa* (Urban) Britton, the icaco (*Chrysobalanus Icaco* L.) and *Argythamnia candicans* Sw. They are aggregated into dense and almost impenetrable thickets, seldom more than one or two meters high and tangled with vines of pega palo (*Distictis lactiflora* (Vahl) DC.), bejuco de costilla (*Serjania polyphylla* (L.) Radlk.) and bejuco de toro (*Stigmaphyllon tomentosum* (Desv.) Ndz.) The small open places between the thickets are carpeted with a thin sod of grama blanca (*Stenotaphrum secundatum* (Walt.) (Kuntz) and also colonized by numerous weedy species.

Towards the top of the ridge, where there is a full exposure to the wind, many of these species disappear. The wattle (*Eugenia axillaris* (Sw.) Willd.), persists as a small tree or shrub; the sereno (*Gundlachia corymbosa* (Urban) Britton) is the most common shrub and one colony of lirio (*Hymenocallis declinata* (Jacq.) M. Roem.) was noted; the vine, mato azul ((*Guilandina crista* (L.) Small) was rare or entirely absent. The summits of these ridges, where the bases are exposed to the sea, frequently show fissures parallel to the sea, indicating lines along which blocks of stone will be broken off.

The outer slopes are in direct contact with waves which are undercutting and changing them into steep or vertical cliffs (Fig. 16). Caverns are excavated and fissures formed through which the spray shoots to considerable height. Projecting cliffs fall into the sea and are ground into sand. The whole effect is one of disintegration. This process is very evident to the most casual observer but it is also evident that it must be very slow as is indicated by the presence of old Indian carvings in some of the caverns.

The effect on the plant life is evident. Many species disappear, the strongest surviving longest. The flat pockets of sand which are seldom reached by the salt spray support a limited plant life consisting of the two vines bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.) and mato de playa (*Canavali maritima* (Aubl.) Thou.) and the grass, matojo de playa (*Sporobolus virginicus* (L.) Kunth), all of which decrease with the increase of salt water on the lower levels. Seedlings of *Sporobolus virginicus* and dwarfed plants of bellorita (*Erigeron bellioides* DC.) appear even in the small pockets but at the lower level they are quickly destroyed by the salt water. The shrubby uva de playa (*Coccolobis uvifera* (L.) Jacq.), icaco (*Chrysobalanus Icaco* L.), borborón (*Scaevola Plumierii* (L.) Vahl) and clavelón de playa (*Borrichia arborescens* (L.) DC.), which cling tenaceously to the small fissures on the side of vertical walls, become smaller in size and fewer in number at the lower elevations, where the sea water strikes them more frequently, and eventually cling only to crevices on the lee side of the walls. Clavelón de playa (*Borrichia arborescens* (L.) DC.) seems to extend farther toward the ocean than any other species.

Breaks in the San Juan formation may be seen at many points along the north coast. They range from a few meters to a kilometer or more in width and some of them are very old. When these breaks are cut low enough for the penetration of sea water a more or less semi-circular bay (Fig. 9) is formed on the land side. The wind sweeping though these breaks causes some destruction of the plant life on the lee side of the dune ridge (Fig. 17). Salt water dashing over the summits of the lower ridges also aids in the work of destruction. Under these trying conditions the uva de playa (*Coccolobis uvifera* (L.) Jacq.) Fig. 18) and clavelón de playa (*Borrichia arborescens* (L.) DC.) appear to be the hardiest species. But even here each layer of sand is occupied by that small but sturdy pioneer grass (*Sporobolus virginicus* (L.) Kunth) and by the shrubby temporana (*Suriana maritima* L.). However, the whole process is that of destruction of the rock and the vegetation.

9. SUMMARY

The sands deposited on the beach by the waves are carried inland by the winds. The xerophytic plants start a xerarch successional series which stabilizes the moving sand into dunes. This growth is characterized by the uva de playa (*Coccolobis uvifera* (L.) Jacq.) and associated species. This reduces the exposure to the wind, conserves moisture and adds organic matter to the sands, and thereby favors the incoming of other species and the formation of dune thickets. Occasional breaks in the dunes lead to the destruction of some of these thickets and the reversion of the plant life to the original pioneer stage. Eventually this dune formation is consolidated into limestone and covered with mesophytic forest. Submergence of the land exposes this formation to the waves which results in a greater or less destruction of both rock and vegetation. The forests are reduced to thickets which are finally destroyed. The sand which is formed as a result of this disintegration is washed ashore, blown inland and contributes to the formation of new dunes. The natural tendency of the plant life is towards the formation of a mesophytic forest and this will be hastened by elevation of the coast and retarded by submergence.

C.—Subseries the Vegetation of Icaco Cay

This cay is a small island a few kilometers from Fajardo Playa and is the only cay that we visited. It is composed of exceptionally white pure limestone with a beach of very recent sand deposit. The plant life is very different from that of the mainland and is probably typical of the many similar islands in this vicinity. Its flora has already been studied by Britton (9).

The island may be described as made up of flat-topped, irregular hills which do not exceed 30 meters above sea level. These hills are the result of erosion and include at least three undrained depressions and many sinkholes. The rainfall is light, probably not more than 40 inches per year, and the drainage largely into the sink holes. The very thin soil is mostly in pits and crevices of the limestone. The western end of the Island is a flat shelf about two meters above sea level and is covered with a thin layer of sand. The lee side has a sandy beach but the windward side is abrupt. The exposure to the influence of the high trade winds is reflected in the plant life.

The sandy beaches support a zone of uva de playa (*Coccolobis uvifera* (L) Jacq.) and other species which are usually associated with it. The original vegetation of the flats near the beaches has been removed and many coconut palms planted. Presumably it was similar to the beach thickets previously described but the older parts may have been covered with xerophytic forest. On the windward side the uva de playa thickets consist of a narrow strip at the foot of the hill.

The largest of the undrained depressions (Fig. 19) previously referred to, contains salt or brackish water and is surrounded by a narrow interrupted zone of mangroves, *Rhizophora mangle* L. being the predominant species. The other two large depressions lie above the sea level and one of them is occupied by the low herbaceous barilla (*Batis maritima* L.) and the border zone composed of mangle botón (*Conocarpus erecta* L.); the other is completely filled with mangle botón. In both cases the conditions favor the leaching out of the salt and the maintenance of moisture by drainage from the surrounding hills. These conditions are favorable for a vegetation similar to that of the limestone hills of the mainland and the begining of their association is already seen in the presence of jagüey (*Ficus laevigata* Vahl).

The limestone hills of the cay are covered with a xerophytic chaparral (Fig. 20), usually not more than two meters in height, which shows the effect of the high trade winds. The cariaquillo de Santa María (*Lantana involucrata* L.) is the dominant species, and is associated with small numbers of other microphyllous shrubs. Among these are the corcho (*Pisonia subcordata* Sw.), the escambrón (*Randis mitis* L.), the manto (*Rhacoma Crossopetalum* L.), the alelí cimarrón (*Plumiera alba* L.), the escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.), azúcares (*Jacquinia Barbasco* (Loefl.) Mez), *Jacquinia Berterii* Spreng., *Croton betulinus* Vahl, *Argythamnia candicans* Sw., *Wedelia calycina* L. C. Rich., *Chamaesyce articulata* (Aubl.) Britton, the trees espinosa (*Anthacanthus spinosus* (Jacq.) Nees) and *Bumelia obovata* (Lam.) A.DC.; the cacti, sebucán or dildo (*Cephalocereus Royeni* (L.) B. & R.), sebucán (*Leptocereus quadricostatus* (Bello) B. & R.) and tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.) There are few vines such as aguinaldo de costa (*Jacquemontia jamaicensis* (Jacq.) Hall. f.) and babiero amarillo (*Urechtites lutea* (L.) Britton); but the herbaceous vegetation is almost entirely wanting.

Along the summit of the limestone hills and fully exposed to the trade winds is a dense thicket of wind-swept, one-sided shrubs and small trees of bejuco inglés (*Capparis cynophallophora* L.), palo de burro (*Capparis flexuosa* L.), coscorrón (*Elaeodendrum xylocarpum* (Vent.) DC.), palo bobo (*Pisonia subcordata* Sw.) (Fig. 21), azúcares (*Jacquinia Barbasco* (Loefl.) Mez) and lirion (*Strumpfia maritima* Jacq.) (Fig. 22).

In conclusion we may say that the two most striking features of the vegetation are the results of the low rainfall and the high winds. The former tends to cause a dwarfing of the plant life and the latter to give a more or less uniform level and a one-sided growth.

D. The Hydarch Series of the Lagoons and Estuaries

1. THE RIVERS AND PLAYA LAND

The many rivers of the north side of Porto Rico are subject to great variations in the amount of water. Their courses through the narrow valleys of the mountains and limestone hills are tortuous. After passing the last series of hills they flow at nearly sea level and broaden into estuaries. The swift currents of the mountains are greatly reduced and a considerable part of the load of eroded materials is deposited. This action through long periods of time and sometimes favored by elevations or subsidences, has resulted in the formation of extensive areas of alluvial soils or playa lands, known as the Arecibo silt loam. These lands are seldom overflowed and there is reason to believe that they were made by submarine, littoral deposits. If so, the first plant life following their uplift above sea level was probably a halophytic vegetation of mangroves. Continued elevation accompanied by a leaching out of the salt made possible a successional series reaching a climax in a mesophytic forest.

This forest has been destroyed, but Mr. E. D. Colón, who has seen the last fragments in the vicinity of Barceloneta, tells us that it included the Santa María (*Calophyllum antillanum* Britton), the roble blanco (*Tabebuia pallida* Miers) and many other species. A few trees of these two species still exist in the vicinity. At the present time, the rivers of this region flow through deep channels and there does not appear to be any succession leading to a forest. The quiet waters of these streams contain small colonies of the two types of flor de agua (*Castalia ampla* Salisb. and *Piaropus crassipes* (Mart.) Britton). At the edge of the stream is a fringe of amphibious vegetation composed of the arrow leaf (*Sagittaria lancifolia* L.) and the eneas or cat-tails (*Typha augustifolia* L.). Thickets of the tall grasses caña de india (*Phragmites Phragmites* (L.) Karst.) and caña cimarrona (*Gynerium sagittatum* (Aubl.) Beauv.) are conspicuous but scattered features of the plant life. These playa lands are very rich and very fine for agriculture, especially the growing of sugar cane.

2. AQUATIC VEGETATION OF THE FRESH-WATER LAGOONS

Many fresh-water lagoons and swamps are characteristic of the north coast. They may be the results of the sand dunes which have obstructed the natural drainage or they may be the result of a subsidence which has drowned the mouths of certain rivers and caused the water to collect in the lowland back of the dune ridges. Laguna Tortuguero (Fig. 24), which covers an area of about 4 by 1½ kilometers to the northwest of Manatí, is the largest of these lakes and the one to which we gave special attention.

The quiet waters of these lagoons and the small drainage ditches of the swamp support dense colonies of flor de agua (*Castalia ampla* Salisb.). In the shallower waters nearer the shores are frequently found smaller colonies of *Nymphoides Humboldtianum* (HBK) Kuntze. The lechuguilla de agua (*Pistia Stratiotes* L.) and flor de agua (*Piaropus crassipes* (Mart.) Britton) also occur in some places. *Ceratophyllum demersum* L. and *Potamogeton fluitans* Roth are the most common floating plants.

The cat-tail or eneas (*Typha angustifolia* L.) frequently forms colonies sometimes of many acres. The sedge *Mariscus jamaicensis* (Crantz) Britton is also abundant, forming pure colonies at the shore line or mixing with cat-tails. Very few other plants are associated with these two dominant species but a few plants of the aquatic fern (*Blechnum indicum* Burm.) are scattered among the cat-tails. The cat-tails and sedges are rapid formers of the black mud soil which gradually rises above the water level. They may extend for some distance above water level and probably were originally in contact with the shrub or even the mesophytic forest associations of the playa lands. However, it is impossible to determine this point at present as all the playa lands now are under cane cultivation. In fact this crop is extended as far into the lagoon as specially selected varieties can be grown successfully.

3. THE MUD-BANK VEGETATION

The destruction of the cat-tails and sedges at the margins of the marshes is followed by a secondary association of several mud-loving species (Fig. 25). The soil is always saturated and no species has become dominant in this new association. In fact this association is very likely to be overrun in a short time by the cat-tails and sedges which tend to re-establish themselves.

The predominant species of these mud-banks are slender, erect sedges of which the most abundant is the junco de espiga (*Eleocharis interstincta* (Vahl) R. & S.). Other common sedges are *Fimbristylis complanata* (Retz.) Link, *Rynchospora cyperoides* (Sw.) Mart.), *Eleocharis caribaea* (Rottb.) Blake and a few others of similiar habit. Previous to the establishment of the sedges and between the clumps after establishment are many herbs, such as the creeping yerba de culebra (*Bramia Monnieri* (L.) Drake) with its conspicuous bluish-white flowers. *Hydrocotyle verticillata* Thunb. and the yerba de clavo (*Centella asiatica* (L.) Urban) have similar habits but are less frequent. Scattered plants of cat-tails are also common.

4. THE SAND-BANK VEGETATION

The thickets of the white sands of Laguna Tortuguero have already been described. The land occupied by these thickets slopes abruptly to the mud banks and wet sandy beaches which differ greatly in their plant life. The vegetation of the mud-banks is related successionally to the marsh vegetation of the lagoon but the vegetation of the sandy beaches consists of sparse groups of species which represent migrations between the two types of plant life which have no successional relations.

In the open sun in such localities, there is a scattered covering of clumps of the sedge *Scleria hirtella* Sw. and junquito (*Fimbristylis diphylla* (Retz.) Vahl) the shrubby herb yerba de ciénaga (*Aeschynomene sensitiva* Sw.) and occasional plants of various weedy species such as *Vernonia cinerea* (L.) Less. In the shade of the overhanging thickets, the vegetation is even sparser, and the commoner species include such herbaceous plants as yerba de San Martín (*Sauvagesia erecta* L.), camasey de charco (*Acisanthera Acisanthera* (L.) Britton), grasilla (*Setiscapella subulata* (L.) Barnh and *Setiscapella pusilla* (Vahl) Barnh.), *Xyris Jupicai* L. C. Rich, and the orchid *Ibidium tortile* (Sw.) House.

5. THE BEACH THICKETS

The shrubby thickets which lie between the wet beach and the dry sands at Laguna Tortuguero contain an interesting group of species. The water table is well below the surface but the soil moisture is maintained by capillarity, which gives a distinct mesophytic environment. The shrubby growth of these thickets attains a height of from one to five meters and many individuals would soon grow into trees if it were not for the repeated cutting of these areas for fuel. The icaco (*Chrysobalanus Icaco* L.) is the commonest species and grows abundantly on the higher and drier places. The camasey (*Miconia prasina* (Sw.) DC. and *M. racemosa* (Aubl.) DC.) are next in abundance. Other shrubs and trees of importance are the corazón (*Annona glabra* L.), the palo de cucubano (*Guettarda scabra* (L.) Lam. the hoja meñuda (*Eugenia monticola* (Sw.) DC.), badula (*Icacorea guadelupensis* (Duch.) Britton), the escambrón (*Randis mitis* L.) and *Clidemia hirta* (L.) D. Don. The most common vines are the maray-maray (*Ecastophyllum Ecastophyllum* (L.) Britton) and the chiggernit (*Tournefortia hirsutissima* L.). A fern (*Odontosoria aculeata* (L.) J. Smith.) is also quite common. Some of the plants of these thickets are no doubt invaders from neighboring semi-xerophytic thickets, while others indicate a tendency towards a succession by the extinct lowland forest.

6. SUMMARY

The hydrarch series of associations is correlated with the usual physographic process of soil formation and is represented by a series of associations differentiated largely by depth of water table and partly by nature of the soil. The deeper water is occupied by submerged and floating plants, the shallower water by a marsh association of cat-tails and the mariscus sedge, and the land above the water by a mesophytic forest. Temporary associations follow the disappearance of marsh plants on exposed beaches, or appear between the marshes and the adjacent forests of another successional series. The climax vegetation has been completely destroyed.

E. The Halarch Series of Coastal Swamps

There is every gradation from the seashores exposed to wave and wind where the sand and shingle forms beaches and dunes to the seashores protected from wind and waves. Most of the north coast of Porto Rico is of the former type. However, there are many places of the latter type, which are of two general kinds: (1) The banks of the river estuaries where the salt water is brought in by the tide and produces a saline condition for a considerable distance up stream. (2) The breaks through the dunes which have permitted the sea to overflow the low lands of the lee side, producing more or less extensive salt-water or brackish swamps, lagoons or bays depending on area and depth of water. In the largest of these, such as San Juan harbor and the lagoons east of San Juan, the depth of water may be considerable, but their land-locked position minimizes the effect of the waves. Their formation starts a series of successions which proceeds to a climax through intermediate stages depending on the variations in the salinity of the water.

Most of the swamps of the north coast are of this type and show certain fundamental similarities in their plant life, the variations depending on the differences in area, depth of water, salinity and age of the swamps under consideration. The larger areas show broad expanses of uniform plant life which sometimes covers hundred of acres, while in the smaller areas each plant association is limited. In the large, deep areas of open water, the halophytic vegetation is confined to narrow marginal zones. In the very saline waters the vegetation is distinctly halophytic while in the comparatively fresh water the halophytes are restricted to the shore line and are replaced by associations of the hydrarch series a short distance from the water. In general, the nature of the plant life depends on depth and salinity and the area occupied by each association on the gradient of ground surface; a gradual gradient producing uniform conditions over a large area, with similarly extensive development of each association, and a sharper gradient restricting the various associations to narrow zones parallel to the margin. There are three well-marked associations of this series in Porto Rico and it will be necessary to discuss the relationship between these associations and others of the xerarch and hydrarch series.

1. THE MANGROVE ASSOCIATION

The typical pioneer vegetation of such shores in the tropics is the mangrove or manglares composed of several species representing the first stage in the series. There are several species of mangrove belonging to widely different families. The common name applied to all of them is not due to any taxonomic relationship but to a similarity of habitat and behavior. The mangroves are a distinct ecological unit and not a taxonomic group and most of the features which they possess in common are correlated with their environment. The most remarkable of these features is vivipary. In most species, regardless of their taxonomic relations, the seeds germinate before falling from the tree. As a result of the organic contact between parent and offspring the seedlings reach a large size before they fall from the parent. They are either planted by falling into the mud or they drift until anchored in shallow water by the growing hypocotyl. This habit is well illustrated in the common mangle (*Rhizophora mangle* L.). The germination of the seed is followed by a comparatively slight enlargement of the cotyledons and a very conspicuous growth of the long, fusiform hypocotyl which may attain a length of two or three decimeters and a diameter of two or three centimeters. These young plants remain attached to the parent plant for a year before falling into the water where they are easily anchored in the mud in an upright position. They may be anchored near the parent or carried by a current for a long distance. When once established they also develop prop-roots. Sometimes these prop-roots grow from branches as much as five meters above the water. These roots eventually reach to the water and mud and form a tangle and covert the colony into an almost impassible thicket. The mangle bobo (*Avicennia nitida* Jacq.) and some other species produce specialized roots which grow vertically upward into the air. These roots are known as pneumatophores and function in the transportation of oxygen.

The leaves of the mangroves are also fairly constant in shape and structure. In our Porto Rican species they are elliptical, or nearly so; smooth, dark green, thick, and assume a more or less vertical position. All of these characters appear to be correlated with the physiological factors of their environment.

The mangroves are exceptionally good land builders. Their crowded stems, aerial roots and numerous pneumatophores retard or stop the movements of the sea waters and the suspended material is dropped among them. Since these plants are confined to still waters, the suspended materials are mostly silt and clay which results in deposits of mud. The falling leaves and twigs decay and add organic matter, thus making a black mud. With the accumulation of soil, the plants are forced seaward, the rate of progress depending on the depth of the water.

In Porto Rico we have four species of mangrove (Fig 26); the common mangle or mangle zapatera (*Rhizophora mangle* L.), the mangle blanco (*Laguncularia racemosa* (L.) Gaertn.), the mangle bobo (*Avicennia nitida* Jacq.) and the mangle botón (*Conocarpus erecta* L.). As previously stated, the common name of "Mangrove" refers to their ecological and not to this taxonomic relationship. The first three are of the greatest importance and are limited to the mangrove swamps. The fourth is smaller in size, comparatively unimportant in the swamps and more abundant in other habitats. These various species differ in their salt requirement: the common mangle (*R. mangle* L.) requires the highest concentration and is found very close to the ocean. The mangle blanco (*L. racemosa* (L.) Gaertn.) and mangle bobo (A. *nitida* Jacq.) are associated with it but are most abundant on the land side where the concentration is less. The mangle botón (*C. erecta* L.) also grows on the land side of the swamps but extends inland and into habitats which are free from salt water. The first three also require an abundance of free water and thrive only in a saturated soil, while the fourth will thrive in much drier conditions. Therefore, it is most abundant in the drained swamps and on the landward margin and is sometimes found on sand dunes and limestone rocks.

Ordinarily, the mangrove swamps consist of pure stands of the first three or of all four species with no secondary species but a reduction in salinity leads to the incoming of other species, such as the cadillo de ciénaga (*Malache scabra* B. Vogel) which grows to a height of two meters and forms dense thickets in the narrow channels (Fig. 23) of the swamps. The mahoe (*Pariti tiliaceum* (L.) St. Hil.) is a widely branching shrub or small tree, as much as five meters high and is occasionally found growing in the open places among the mangroves or extending over the channels. The palo de hoz (*Drepanocarpus lunatus* L. f.) G. F. W. Meyer) is a stiff, thorny, sparsely branched shrub attaining a height of five meters and arching out into the open sunlight above the canals.

The mangroves are an important source of fuel and their high economic value is fully recognized. They occupy hundreds of acres at sea level which cannot be drained except by the most expensive methods and yield a regular annual income. After cutting, they re-establish themselves easily and quickly.

2. THE ACHOSTICHUM ASSOCIATION

One of the most familiar types of vegetation along the north coast is the tall fern (*Acrostichum aureum* L.), growing in long zones or in irregular patches (Fig 27), which may be of several acres in extent on the landward margins of the mangrove swamps. This soil is usually somewhat drier because of its full exposure to wind and sun and always less impregnated with salt. The fern grows in crowded masses a meter or more in height and forms an almost pure stand, secondary species being missing or so few in numbers as to be of no ecological importance. The position of this association in the successional series is not clear. Its great abundance and uniform development in so many different localities and the regularity of its position in close contact with the mangroves, but in slightly drier or less saline environment, leads to the conclusion that it normally follows the mangrove. However, there are reasons, based on general ecological experiences or actual conditions in Porto Rico, for considering it as a temporary or secondary development. This fern thrives exceptionally well in mangrove swamps which have been cut over for fuel and in which the new growth in seldom more than five meters in height. In fact it is frequently found growing in the cleared portion of swamps where the mangroves have failed to re-establish themselves. The succession of a forest type of plant life by a herbaceous type, except as the result of some catastrophe, is unusual and not to be expected in Porto Rico where the climatic conditions of the north shore favor the development of a forest. Furthermore, young mangroves frequently grow in abundance around the margin of the fern association, where the sharp transition line, indicates that the succession at the present is proceeding in another direction.

Acrostichum aureum L. (Fig. 28) is physiologically adapted to the salty or brackish soils of the mangrove swamps, as few other herbaceous species are adapted. It produces enormous numbers of microscopic spores which are no doubt widely distributed over the coastal plain every year but seldom grow in any locality other than the high, open places of the mangrove swamps where they have a good light exposure and do not come in direct contact with the salt water. Under ordinary conditions it grows as scattered individuals and does not form an association, but if the mangrove trees are cut out over an area slightly above sea level, the very place where they are most likely to be cut because of working conditions, this fern forms a dense association. Its density retards the invasion of the mangroves except around the edge, where the ferns can be gradually shaded out by the overhanging branches thus permitting the mangroves to advance slowly and eventually reoccupy the entire area.

3. THE *PTEROCARPUS OFFICINALIS* ASSOCIATION

The only forest of palo de pollo (*Pterocarpus officinalis* Jacq.) is located not far from the shore of the Humacao Playa. Although it does not come in direct contact with the typical mangrove swamp, we consider it as representing the next stage in the halarch series. The small rivers of this section come to sea level at a considerable distance from the present shore line. The small bays into which they originally emptied are completely filled with a black soil. We have reason to believe that these swampy seashore plains were at one time active mangrove swamps. With the filling of these small bays and swamps and the development of these flat alluvial plains, sandy beaches were also formed. At this point, the beach is about 500 meters wide and is about one meter higher than the alluvial plain farther inland. The tides run up the rivers about one-half kilometer where contact with fresh water results in the partial damming of the streams and a reduction of the salinity above that point. However, their influence is still shown by the scattered mangrove trees along the banks.

The reduced salinity as a result of the distance from the sea and the fresh water from the streams produces ideal conditions for a succession from the mangroves because the germination of the seeds and their future growth will be checked by the change in environment and new species will be enabled to invade the territory. Such appears to be the history of the Pterocarpus forest. There is a deep black muck with the surface slightly above sea level, always wet and soggy and usually treacherous under-foot. The muck is shallow near the margins as indicated by the sand turned up in the planting of coconuts. This superimposed muck has undoubtedly been formed in a swamp of mangroves, or possibly of other plants, after the formation of the sand bars on the shore side. This muck is no doubt increasing as a result of the flooding by the rivers during the rainy periods and accumulation of vegetable matter.

The palo de pollo (*Pterocarpus officinalis* Jacq.) is the dominant tree (Fig. 29) and in fact almost the only tree of this swamp, although there are a few others such as the royal palm (*Roystonea borinqueña* Cook) and a very narrow zone of mangroves (*R. mangle* L.) along the rivers. The trees have been repeatedly cut for fuel and the coppice growth consists of three to six slender trunks from each stump which rarely exceed 20 meters in height and are usually less than 5 decimeters in diameter. The old stumps have exceptionally fine buttress growths; in some cases, the roots are four times as long as high, fairly thin at the base but with curved upper edges and sometimes branching distally. They may extend outward as much as five meters from the base of the tree. Traces of newly developed buttresses may be found as much as five meters above the ground and the size of the system is very much out of proportion to the size of the trunk; one tree only three decimeters in diameter at four meters above the ground had a buttress development 25 meters in circumference.

In addition to the royal palm (*Roystonea borinqueña* Cook) there are a few individuals of two other tree species in this association but they are always small. They are the escambrón (*Drepanocarpus lunatus* (L. f.) G. F. W. Meyer), with its slender trunks one decimeter in diameter and about 10 meters in height, and a few young trees of cupey (*Clusia rosea* Jacq.) which are anchored in the tops of the trees or grow as independent plants. The shrubby cadillo de ciénaga (*Malache scabra* B. Vogel) grows in small thickets and as isolated individuals throughout the forest and attains a height of four meters. The bejuco of guajanilla (*Paullinia pinnata* L.) is abundant, climbing to the tops of the trees, looping from tree to tree and festooning the trunks. Some of the other plants worthy of mention are the bejuco de Santiago (*Aristolochia trilobata* L.), the paralejo velludo (*Banisteria laurifolia* L.), bejuco de prieto (*Hippocratea volubilis* L.) and *Stigmaphyllon puberum* (L. C. Rich) A. Juss.

The irregular surfaces of the Pterocarpus buttresses and the accumulation of debris upon them forms a most excellent environment for epiphytic plants which are very numerous. The largest and most common is the flor de culebra (*Anthurium acaule* (Jacq.) Schott) with its dense masses of roots and large rosettes of long leaves which in turn shelters the young of its own species and *Peperomia glabella* (Sw.) A. Dietr.). The large fern (*Polypodium decumanum* Willd.) is common and a few individual plants of the fern (*Nephrolepis biserrata* (Sw.) Schott) are found on the stumps of the *Pterocarpus*. The night-blooming cereus or pitajaya (*Hylocereus trigonus* (Haw.) Safford) is occasionally seen in the higher trees. The fern *Acrostichum aureum* L. grows as isolated plants or in small colonies wherever the light is sufficient.

Some cuttings have been made along the margin for the purpose of planting coconuts and these places have been quickly occupied by an exceptionally dense growth of the fern *Acrostichum aureum* L. (Fig. 28). The fronds reach a length of more than three meters and are closely interlaced in every direction. In the next outer zone which is planted to coconuts we find a carpet of the yerba de culebra (*Bramia Monnieri* (L.) Drake) and *Nelsonia brunellioides* (Lam.) Kuntze.

4. THE CLIMAX FOREST

The Pterocarpus forest has followed the decrease in salinity which was unfavorable for the mangrove growth. This decrease will continue with the increase in deposits of alluvium which raise the land higher and higher above the influence of the tide until the environment is similar to that of the playa lands of the north coast. Therefore, we have reason to believe that if undisturbed by man, the extinc tforest of the playa would eventually succeed the Pterocarpus association.

5. INTERMEDIATE VEGETATION AT FAJARDO PLAYA

We have previously called attention to the wind and wave action of the north coast which causes the formation of sand dunes, the exclusion of vegetation from the wet fore-shore, and the initial stage in the xerophytic plant life of the dunes. There must be every possible intermediate stage between the environment and plant life of such a coast and the quiet shores which are inhabited by the mangroves. The reduction of the wave action results in the deposition of finer materials and plant life becomes possible at lower levels. The salt content of the soil becomes higher, the lower plants increase in number and the initial vegetation becomes more and more halophytic. At Fajardo Playa the off-shore islands reduce the wave action sufficiently to permit the growth of mangroves at the water edge and gives us an intermediate stage of environment. The waves are strong enough to carry up and deposit the fine sands but it is not blown into dunes; and becomes less and less saline with the increase in distance from the shore. The beach has a very gentle slope and is almost completely covered with the common mangle (*Rhizophora mangle* L.), the mangle blanco (*Laguncularia racemosa* (L.) Gaertn.) and the mangle bobo (*Avicennia nitida* Jacq.). A little farther back, this growth is intermingled with the uva de playa (*Coccolobis uvifera* (L.) Jacq.), the chamiso (*Dodonaea viscosa* Jacq.) and the tachuelo or karrebesu (*Pictetia aculeata* (Vahl) Urban) forming dense thickets about 6 meters in height but with little herbaceous plant life (Fig. 30). Still farther inland, *R. mangle* disappears, *L. racemosa*, *A. nitida* become less abundant and the mangle botón (*Conocarpus erecta* L.) appears in quantity; uva de playa (*C. uvifera* (L.) Jacq.) and the tachuelo (*Pictetia aculeata* (Vahl) Urban) continue. The last three become the dominant species over a large area extending a considerable distance from the beach. Other common species are the escambrón (*Randis mitis* L.), the escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.), the manto (*Rhacoma Crossopetalum* L.), the ucarillo (*Ginoria Rohrii* (Vahl.) Koehne.), the abejuelo (*Colubrina Colubrina* (Jacq.) Mills.) and the zarza vine (*Mimosa Ceratonia* L.).

This thicket is frequently cut over for fuel but the environment and the plant life are so similar to that of the thickets at Mameyes (page 70) that we believe that this area was formerly covered with a mesophytic forest, which was probably the equivalent to that of the white sands previously described. It is probable that the halarch series which depends on the salinity may be replaced, in a more sandy soil, by members of the xerarch series and the plant life carried to a corresponding conclusion.

6. VEGETATION OF THE CAÑO TIBURONES

This is the largest swamp on the north coast. It occupies an area of about 20 kilometers in length by three kilometers in width and extends from Arecibo on the west to Barceloneta on the east. Its natural outlet is into the Arecibo river at the western end but an artificial drainage system has been opened into the Manatí river at the east end. Much of this area is below sea level and none of it rises more than a few decimeters above the tide. The gradient is too slight for successful drainage and the opening of ditches and canals has facilitated the entrance of tide water and carried the salinity some distance into the interior. The salinity varies from place to place owing to the slow diffusion of salt water through the dense vegetation. Each rise of the tide tends to increase the salinity and each rainfall to reduce it. The removal of the vegetation in places and the exposure of the soil has tended to increase the salinity at the surface by the rise of the water from below and the deposition of salt by evaporation, to that the surface of the soil is frequently whitened by saline incrustations.

The soil is a very black muck formed by the accumulation of silt and the decomposition of decayed swamp vegetation. The water-table is a little above or very little below the surface and the salinity increases from east to west. The character of the vegetation over the eastern two-thirds of the swamp indicates that the soil water was originally fresh or very slightly saline and that of the western third indicates a salinity resulting from the tide water coming in through the Arecibo river. The soil is rich in organic matter but poor in minerals, especially potash.

When viewed from the hills on the north side of the swamp it can be readily seen that the eastern end is level and completely covered with a dense growth of narrow leaved sedges, grasses and cat-tails and a few isolated shrubs and small trees. Over the western fourth the plant life is quite different, consisting of a dense growth of a dark-green fern with scattered but numerous trees. At the extreme western end, the trees become still more numerous, and finally grade into a forest separated by strips of fern. The whole area is intersected by artificial canals and ditches of open water.

These three associations cover almost all of the western part of the swamp. A fourth swamp forest association originally existing at the eastern end has been destroyed and the land is now used for the growing of sugar cane. A fifth association has developed in the canals and drainage ditches and a sixth type which can scarcely be dignified as an association appears on the low ridges of the earth excavated in the digging of canals and on the ridges constructed in attempts to increase the area for growing cane.

The cat-tail sedge association (Fig. 25) covers most of the eastern three-fourths of the swamp and consists of a dense mass of narrow-leaved hydrophytes growing so close together that very few other plants can grow beneath them. There are three dominant species; the eneas or cat-tails (*Typha angustifolia* L.) is the most important and covers hundreds of acres with an almost pure stand; the sedge known as serrucho (*Mariscus jamaicensis* (Crantz) Britton) is second in quantity and grows in solid masses, attaining a height of two or three meters; and the caña de india (*Phragmites Phragmites* (L.) Karst.), which forms thickets at wider intervals and attains a height of four or five meters. Scattered individuals and small colonies of secondary species are also present. The most common is the shrub salvia (*Pluchea odorata* (L.) Cass.) which is one or two meters in height, and is tall enough to bring its leaves above the general mass of foliage. The falso guaco (*Mikania congesta* DC.) and an *Ipomoea* climb over the taller plants and secure the necessary light exposure. Growing in small open places are the arrow-leaf *Saggittaria lancifolia* L., the sedge junco de espiga (*Eleocharis interstincta* (Vahl) R. & S.), the herbaceous *Hydrocotyle verticillata* Thumb., the sedge *Dichoromena colorata* (L.) Hitchc., the yerba de culebra (*Bramia Monnieri* (L.) Drake) and other species of the mud association.

About three kilometers from the western end, the above vegetation is replaced by masses of the large fern (*Acrostichum aureum* L.) which grows in an almost pure association over hundreds of acres. This fern, which is characteristic of brackish water, grows in large clumps and its numerous fronds attain a length of two or even three meters. These plants grow in such dense masses that there does not appear to be any typical secondary species. There are some scattered individuals of the thorny legume, palo de hoz (*Drepanocarpus lunatus* (L. f.) G. F. W. Meyer) with ascending, sparsely branched stems rising above the general level. It is more abundant in this association than in the mangrove thickets farther west. Scattered individuals of mangle botón (*Conocarpus erecta* L.) also rise above the ferns. A few plants of the *Typha-Mariscus* association of the eastern part of the swamp persist here, including small colonies of the dominant species and patches of caña de india (*Phragmites Phragmites* (L.) Karst.), but these are always more abundant on the low ridges than elsewhere. The opening of the numerous ditches and canals (Fig. 31) has formed areas standing water so nearly fresh that several fresh-water hydrophytes have appeared. The most common is the flor de agua (*Castalia ampla* Salisb.). Associated with it are scattered colonies of *Potamogeton fluitans* Roth and *Ceratophyllum demersum* L.

The term terreplén is used to designate the low flat ridges formed by the earth thrown up in dredging or in making roads. They are 3 to 6 decimeters above the normal level and very few swamp species can grow on them. This is especially true where deep cutting has brought the underlying limestone soil to the surface. The vegetation on these terreplén is very sparse even after a lapse of 16 to 18 years. The common salvia (*Pluchea odorata* (L.) Cass.) has become established on the terreplén and in more abundant than in the swamp where it must compete with the cat-tails and sedges. The chief vegetation is composed entirely of adventitious weedy species, among which the herbaceous botón blanco (*Borreria verticillata* (L.) Meyer) is most abundant. Other species are the maray-maray (*Ecastophyllum Ecastophyllum* (L.) Britton), the herbaceous escobita (*Scoparia dulcis* L.), the shrubby berenjena cimarrona (*Solanum torvum* Sw.), the palo de María (*Calophyllum antillanum* Britton), the jagüey (*Ficus laevigata* Vahl), the corazón (*Annona glabra* L.), the malvavisco (*Corchorus hirtus* L.) and the herbaceous manzanilla (*Wedelia trilobata* (L.) Hitchs.).

If the plant life of this swamp had been undisturbed by man, it is probable that it would lie in the following order from west to east: mangroves, ferns, cat-tails and swamp forest. The geologic and physiographic history of this region indicates that the swamp started near the Arecibo river and extended eastward as a result of the submergence of the land. This does not necessarily mean that the swamp forest also started at the western end and moved eastward, giving way to the plant life in the west and traveling with the formation of the swamp. On the contrary we believe that the first swamp vegetation was a mangrove association on the margin of the young swamp. Mangroves are plants of quiet salt water, with means for rapid dispersal, and would naturally start wherever the conditions were favorable.

As the swamp increased in size, the mangrove thickets also increased and served to break the tide and reduce the mixing of the salt water with fresh water flowing in from the east. In this area of quiet water, ranging from brackish to nearly fresh, the other three associations became established as narrow zones. As the swamp increased in size due to a slow submergence, all the associations spread over larger areas. The cat-tails spread most rapidly and finally dominated the greater part of the swamp. The early stages in such a formation may now be seen at Palma's Altas where a small mangrove swamp is being established. In the San Juan harbor, we find a variation in this history; the water is deeper, there is a greater exposure to tides, and the steeper gradient of the surrounding land has led to a greater development of mangroves and a reduction of the cat-tail, sedge and fern association.

The transition at this time between the mangroves and the Acrostichum, and between the Acrostichum and the Typha-Mariscus associations is not caused by a similarly sharp transition in the salinity of the water. That decrease is gradual from west to east and should produce an equally gradual change in the vegetation if it were the one decisive factor in the environment. Furthermore, the range of tolerance of typical plants is greater than exists in the areas occupied chiefly by them; scattered plants of cat-tails are found in the mangrove zone, ferns are found among the cat-tails and even very close to the canals in which we find such typical fresh-water plants as the flor de agua (*Castalia ampla* Salisb.). The abrupt changes are due to the plants themselves; both the cat-tails and the ferns covering certain areas so completely that mixtures are difficult. It appears probable that the dense growth of these two species produces shading which prevents the germination of seeds and spores. The explanation is certainly true for the mangroves.

Evidence for the prediction of future changes, provided this swamp should be undisturbed by man, is very slight. At this time it is very evident that there are more colonies of ferns in the cat-tail-sedge association than the reverse, which may indicate that the ferns are advancing to the east. It is also conceivable that the isolated mangrove plants among the ferns may, if undisturbed, develop into thickets and progress eastward to the limit of their fresh-water toleration. It may be that the entire fern area was recently covered with mangroves which have been destroyed by repeated cutting for fuel.

The great swamp is almost entirely surrounded by cane fields which have been extended to the limit of cane toleration for saline soil. Attempts have been made to extend these fields by throwing the soil into flat ridges separated by channels but the rise of salt by means of capillarity and its accumulation in the surface soil by evaporation have been disastrous for the growing of cane and in many cases have resulted in abandonment of these ridges. In these abandoned areas the channels are quickly taken by the cat-tails and sedges to the very edges of the ridges. The yerba de culebra (*Bramia Monnieri* (L.) Drake) and other plants of the mud-bank association grow on the edges of the old cane beds. The surface of the ridges are taken by various weed species, especially the herbaceous *Wedelia trilobata* (L.) Hitchc. These muck soils are among the best in Porto Rico for cane growing and their reclamation is a question of time. Their location near sea level makes drainage by ordinary methods impossible but it is very probable that other methods will be devised (Fig. 32).

7. SUMMARY

The mangrove swamp is the pioneer association of the halarch series. The accumulation of soil reduces the salinity and it is succeeded by the *Pterocarpus* forest, which is in turn succeeded, under natural conditions, by the climax forest. The removal of the mangroves leads to the development of a fern (*Acrosticum aureum* L.) association. In places intermediate in environment between mangrove and uva de playa associations, these two species make a mixed growth. In the larger lagoons more remote from the ocean where the water is fresh or slightly brackish, the associations belong to the hydrarch series.

VEGETATION OF THE CENTRAL MOUNTAIN REGION

The plant life of the northern coastal plain of Porto Rico coincides quite accurately in distribution with the geology and physiography of the region, but the plant life of the southern coast, which is more or less xerophytic in nature, not only covers the coastal plain but extends up the mountain slopes and over the volcanic soils, reaching its northern limit along a line determined by rainfall and humidity. Therefore, that part of the island lying between the coastal plain on the north and the line just referred to on the south does not include all the ancient volcanic mountain region. On the north, this area extends as far as the Tertiary region; on the west and east to the sea shore, except for small areas of recent maritime or fluvial deposits; on the south to the limits of adequate rainfall. In general, this southern boundary may be designated as a line extending from the Panduras Ridge south of Yabucoa, westward along the southern side of the range at an altitude of about 450 meters (1,500 feet) to Cabo Rojo.

The most important environmental characters of this mountain region, on which the plant life primarily depends, are abundant rainfall, high atmospheric humidity and soils derived from the decomposition of ancient rocks, which are mostly acidic in nature. From this region south until we reach the coastal plain, the soil is practically the same but the rainfall is deficient. The northern boundary coincides with the geological boundary of the north coastal plain and is independent of altitude. At the north-east corner of the island, near Fajardo, the plant life of the mountains descends to sea level. At Lares it reaches is lower limit at about 400 meters (1,200 ft.) above sea level at a point where the Tertiary formations reach their highest altitude. The southern boundary is determined by rainfall and not by geological character of the soil and is fairly well correlated with elevation above sea level; the general altitude being 450 meters (1,500 ft.) gradually dropping to sea level at the eastern and western ends of the Island.

The transition from the plant life of either the northern or southern coastal region into the plant life of the central mountain region can be seen along the insular roads that cross the island from north to south in many places. On the north side we have an abundant rainfall both in the moutains and on the coastal plain and the transition is marked not so much by general appearance of certain species as by species which are restricted to one or the other of these regions. To the casual observer, the most conspicuous of these is a very common roadside fern (*Dicranopteris pectinata* (Willd.) Underw.), which grows in large masses along the highways (Fig. 33), especially on the shady banks. It is restricted to the old soils of the mountain region and is an excellent soil indicator. The beautiful fern tree (*Cyathea arborea* (L.) J. E. Smith) (Fig. 34) is also an important soil indicator but less abundant and more likely to extend beyond the soil limitation best suited for its growth. It is more or less common in elevations above 200 meters (650 ft.) and is one of the most attractive features of the landscape. They are not so abundant in the fully developed forests as in the thickets along the small brooks and steep slopes. The finest specimens are observed above 500 meters (1,500) feet).

Although there are many species that live on both the north coastal plain and the central mountain range, the plant life of the two regions is composed primarily of different species. One of the most common species that attracts attention from the highways is the terciopelo (*Heterotrichum cymosum* (Wendl.) Urban), a tall shrub or low tree of the high altitudes. Another is the llagrumo (*Didymopanax Morototoni* (Aubl.) Dcne. & Pl.), with its tall slender trunks and large leaves which are dark green above and brown beneath.

The southern limit of the mountain vegetation (Fig. 35) is determined by rainfall, atmospheric humidity, insolation and wind. Its exact location is irregular, depending to some slight degree on soil and topography. The south slope ravines tend to collect moisture from the run-off and seepage and are less exposed to the drying influence of the sun and wind. Therefore, the mesophytic plant life of the mountains extends to a lower level in these ravines while the xerophytic plant life of the plain extends to a higher level on the ridges between them. This distribution of plant life can be readily seen from the mountain roads which alternatively cross these two types of vegetation.

In the low lands at the eastern and western ends of the mountain mass we find areas of alluvial soils and maritime deposits in which the vegetation is not related to the mountains proper. It has already been discussed in connection with the northern coastal plain and consists of low sand dunes and mangrove swamps with small areas of *Pterocarpus* forest and second-growth thickets. The greater part of the land is utilized for agricultural purpose in the growing of sugar cane, coconuts and other crops.

There is a considerable variation of soil within this central mountain region but the most widely distributed surface rocks are tuffs, shales and conglomerates with some andesites, diorites, granites, porphyries and serpentines. A careful study would probably show some relationship between these soils and the plant life but it was impossible for us to do more in the alloted time than note a few species which appeared to be localized on the serpentine soil. The more common and dominant tree species and the general composition of the plant life does not show any relation to the geology of the region.

The rugged character of the country has already received consideration. Practically all of the available land is now used for some kind of agriculture, but the narrow valleys and precipitous hillsides still show some native vegetation although they have been cut over for building material and fuel or used for pasture to a greater or less degree. Large areas in the higher elevations are used for growing coffee and have been planted to shade trees of guama (*Inga laurina* (Sw.) Willd.) and guaba (*Inga Inga* (L.) Britton) which give the appearance of a natural forest. Diseases of the coffee plants have resulted in the abandonment of many estates which eventually revert to the native forest, but it is doubtful if any of these secondary forests have yet reached such a condition that they can be used to illustrate the original mountain vegetation.

The Luquillo Forest Reserve at the eastern end and the Insular Forest near Maricao at the western end contain many large individual trees and colonies of valuable economic species and there is evidence that the cuttings which they have received from time to time have not been so extensive as to seriously interfere with the general composition of the plant life. At some other points, notably near Adjuntas and Jayuya, the mountains rise above the limit of successful coffee growing and are occupied by fragments of the original forest which have been modified to some extent by cutting. These mountain forests originally extended to sea level at both eastern and western ends of the Island but these lower altitudes have been almost completely deforested. A few small areas, very much marred by selective cutting, remain at Ceiba and Humacao and have given us some data for this survey.

It is extremely difficult to characterize definite plant associations from a study of these widely separated tracts, some of which have been very much modified by man. However, we believe that there were five major associations of the mountain region as follows: (1) mountain forests of the low elevations, (2) the moist tropical forest, (3) the rain forests of the Luquillo Mountains, (4) the Sierra palm forests, and (5) the mossy forest.

1. THE MOUNTAIN FORESTS AT LOW ELEVATIONS

The forests of the central mountain range originally descended to very low elevations and possibly to the sea level at points near the eastern and western ends of the Island. East of San Juan the coastal plain is narrow or interrupted and even at Río Piedras the rolling hills of the Cretaceous age rise almost from sea level. From

Canóvanas east and south to Maunabo the mountains descend to the ocean except where broken by the playas (Fig. 36) or the many small rivers. At the western end of the Island, geological formations of the same age, and subject to similar interruptions, occupy the coast line from near Aguadilla south to Cabo Rojo.

Owing to the utilization of the lower hills for agriculture, the native vegetation is almost entirely limited to small zones along the streams, fence rows, roadsides, and small thickets on rocky outcrops and slopes too steep for agriculture or pasture. These small areas give a very imperfect idea of the composition of the original forest. The best remaining areas of the original forests are near Ceiba. One of these was in virgin condition until recently when the most valuable trees were removed. It is now a dense jungle of young trees. Near this place one small area of flat ground contains a few trees of cobana (*Stahlia monosperma* (Tul.) Urban), which is almost extinct in many parts of the Island; also a few trees of bucar (*Bucida Buceras* L.) and ceiba (*Ceiba pentandra* (L.) Gaertn.). The cobana usually has a crooked bole branching a short distance above ground into a low round head. A few individuals are known at other places along the south coast. These species indicate a considerable degree of ecological similarity between the two regions of the Island, notwithstanding the great variation in the amount of rainfall. This similarity is also indicated by the shrubs which grow along the landward side of the mangrove association, such as the palo de burro (*Capparis flexuosa* L.), the bariaco (*Krugiodendron ferreum* (Vahl) Urban), the coscorran (*Elaeodendrum xylocarpum* (Vent.) DC), the jiba (*Shaefferia frutescens* Jacq.), as well as such common vines as the bejuco de costilla (*Serjania polyphylla* (L.) Radlk.), the zarza (*Acacia riparia* HBK.) and *Gouania lupuloides* (L.) Urban, all of which are found also in the arid southern coastal plain.

Scattered trees of the original forest on the hills indicate that its general height was 20 to 30 meters, but give no idea of its density or the relative number of species. The arborescent species observed included the tamarindo cimarrón (*Acacia muricata* (L.) Willd.), the almácigo (*Elaphrium Simaruba* (L.) Rose), the cobana (*Stahlia monosperma* (Tul.) Urban), the jiba (*Schaefferia frutescens* Jacq.), the tachuelo (*Pictetia aculeata* (Vahl) Urban, the bucar (*Bucida Buceras* L.), the bejuco inglés (*Capparis cynophallophora* L.), the corcho (*Torrubia fragans* (Dum. Cours.) Standley), the palo de muñeca (*Cordia glabra* L.) and the *Capparis coccolobifolia* Mart., and tea (*Amyris elemifera* L.). The almácigo, which is so worthless that is not cut, is the only one that reaches the normal height. The others are limited to small trees seldom more than 10 meters in height, straight, erect and densely crowded into an almost impassable thicket. Associated with these trees and frequently nearly equaling them in size, is an assemblage of shrubs, including palo de burro (*Capparis flexuosa* L.), escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.), escambrón (*Randia mitis* L.), the alelí cimarrón (*Plumiera alba* L.), granadillo (*Eugenia ligustrina* (Sw.) Willd.), hoja meñuda (*E. monticola* (Sw.) DC.), quiebra hacha (*E. pseudopsidium* Jacq.), burro blanco (*Capparis portoricensis* Urban), *Neea buxifolia* (Hook. f.) Heimerl, *Eugenia cordata* (Sw.) DC., and *Psychotria pinularis* Sessé & Moc. There are also a few under-shrubs, such as *Argythamnia candicans* Sw., *Ditaxis fasciculata* Vahl, *Catesbaea parviflora* Sw. and the añil falso (*Benthamantha caribaea* (Jacq.) Kuntze.). Among the vines, the grass (*Lasicacis divaricata* (L.) Hitchc.) is very abundant and forms large tangled masses on the taller vegetation. Other abundant vines are the liana uñada (*Batocydia Unguis* (L.) Mart.), the bejuco de costilla (*Serjania polyphylla* (L.) Radlk.), the dunguey (*Smilax coriacea* Spreng.) and *Gouania lupuloides* (L.) Urban. Here again the strong floristic affinity to the arid woodlands of the southern coast becomes apparent although the general conformation of the plant life is different.

Farther back from the coast near Ceiba, the same type of plant life is essentially repeated although selective cutting has reduced the number of tree species and changed the composition of the forest. Here as at the coast, the bucar (*Bucida Buceras* L.), the almácigo (*Elaphrium Simaruba* (L.) Jacq.), the tachuelo (*Pictetia aculeata* (Vahl) Urban) are the common species. The bálsamo (*Citharexylum fruticosum* L.) and palo bobo (*Pisonia subcordata* Sw.) are additional species of xerophytic affinity, while malagueta (*Amomis caryophyllata* (Jacq.) Krug & Urban) and cenizo (*Zanthoxylum martinicense* (Lam.) DC.) indicate a mesophytic tendency. This mesophytic tendency is also illustrated by the herb, bijao (*Alpinia aromatica* Aubl.) and by the two ferns *Dryopteris subtetragosa* (Link) Maxon and *Dryopteris pedata* (L.) Fée.

A similar plant life exists at Humacao although more severe cutting has greatly reduced the number of tree species, which have been replaced by a greater development of shrubs. *Miconia Thomasiana* DC. is especially abundant. Most of the trees and shrubs are sclerophyllous, which is probably the result of a decrease in rainfall and atmospheric humidity.

It is extremely difficult to give any satisfactory discussion as to the character of the original forest from a study of these few, much-modified fragments. The only remaining species of full size is the worthless almácigo (*Elaphrium Simaruba* (L.) Rose), which is of no ecological significance. The xerophytic tendency of many of the species and their occurrence on the arid southern side of the Island is noteworthy, but they may have formed a small and very unimportant part of the original forest. It is reasonable to suppose that the original forest may have been distinctly mesophytic and that the clearing followed by exposure of the soil to wind and sun resulted in the establishment of the xerophytic species listed above. It is very probable that if undisturbed by man, they might shelter and encourage the return of a normal mesophytic species.

2. MOUNTAIN FOREST AT HIGHER ALTITUDE

The central mountain range above the low altitude forests which we have just discussed was originally covered with a luxuriant forest of an exceptionally large number of species. Gifford has placed its lower limit at about 150 meters and its upper limit as indicated by the few remaining fragments must have been about 600 meters (2,000 ft.) in the Luquillo Mountains and about 900 meters (3,000 ft.) in the Central Cordillera. Therefore, it covered the greater part of the mountain region, since the mountains rise above 900 meters in very few places. Its range was practically the same as that of successful coffee cultivation. It also covered the San Lorenzo and Cayey valleys which are now utilized in the growing of tobacco and also several areas now used for other crops.

This original forest has been almost entirely destroyed. The aborigines probably cleared small areas for their crude agriculture but Murphy believes that the most rapid destruction did not start until the nineteenth century when there was a demand for land for the growing of coffee. Beginning at about this time, there was a rapid increase in population, which has not yet ceased, and which increased the demand for building material and fuel and later led to the utilization of practically all of the available land for agricultural purposes.

Fortunately, a few areas escaped this period of destruction. The largest area includes several thousand acres of what was originally crown land which was set aside by the United States Government as the Luquillo Forest Reserve. This region shows no indication of having been cut over and used for agriculture but many valuable trees were evidently removed. A second area of considerable size lies south of Maricao and comprises the Insular Forest Reserve. There are some other privately owned small tracts on the higher slopes of the Central Cordillera in the valley of Jayuya and Adjuntas but they have been modified by selective cutting or lie above the limits of the region of the Sierra Palm or mossy forests.

At many places there is a second-growth forest development following the abandonment of coffee cultivation, but the dominant species are the guamá (*Inga laurina* (Sw.) Willd.) and the guaba (*Inga Inga* (L.) Britton) which were used for coffee shade, with a mixture of the more mobile species of trees and undergrowth. If undisturbed, there will be gradual migrations which will tend towards the re-establishment of the original forests, but this will probably require centuries for its completion.

Many apparent forest areas can be seen from the highways but they are mostly coffee plantations in which the guamá and guaba dominate. Most of the region is composed of steep hillsides and narrow valleys mostly occupied by cities, villages, pasture lands and various kinds of agriculture. The royal palm is common and there are many second-growth thickets containing llagrumo (*Cecropia peltata* L.), grayumo or llagrumo macho (*Didymopanax Morototoni* (Aubl.) Decne. & Pl.), tree ferns (*Cyathea arborea* (L.) J. E. Smith), cupey (*Clusia rosea* Jacq.) and a few species of *Piper* and *Miconia* (Fig. 34).

Fragments of the original mountain flora are still to be seen throughout the region. The common fern (*Dicranopteris bifida* (Willd.) Maxon) grows in masses on the recently made road banks. The shrubby terciopelo (*Heterotrichum cymosum* (Wendl.) Urban) and the several species of *Miconia* furnish shade for woodland ferns and many delicate plants. *Begonia decandra* Pav. and *Hillia parasitica* Jacq. (Fig. 37) are occasional; epiphytic orchids bloom on some of the trees and the introduced raspberry or fresa (*Rubus rosaefolius* Smith) grows in great abundance in many places.

The wide-spread destruction of this original forest made it necessary for us to restrict our studies almost entirely to the Luquillo Forest Reserve, the Insular Forest Reserve at Maricao and the region around Jayuya. The most superficial study shows that these tracts differ ecologically and that these differences are due primarily to variations in rainfall and atmospheric humidity. The Luquillo Mountains near the northeast corner of the Island have an altitude of about 1,050 meters, are fully exposed to the moisture-laden trade winds from the northeast and have the highest rainfall of any point on the Island, amounting to probably 350 centimeters (140 inches) or more per year. Droughts are unknown and there are few days without rain. Cloudiness is above the average and the vegetation is frequently drenched with condensed moisture. These conditions give rise to the development of a true rain forest. At Maricao the rainfall is less than 250 centimeters (100 inches), sunny days are more frequent, and droughts occasionally last long enough to have some effect on the forest. The natural vegetation approaches the type described by Schimper as a monsoon forest. There is no well-defined dry season but the abundance of vines and epiphytes and less luxuriant growth justify its classification as a moist tropical forest. Forests of this type probably extended originally over most or possibly all the central mountain range of the upper altitude, except the Luquillo Mountains which were covered by the rain forest to which we have referred.

A. The Moist Tropical Forest

When this forest is viewed from above, it is seen to be composed of trees of various heights and color, with a mottling of mosaic shades of green due to difference in species and age of foliage. There are very few trees with trunks of a meter or more in diameter, the crowns are narrow and sparcely branched and the bark on most species smooth. Many trunks show a pronounced basal flare. One of the most striking environmental features is the scanty development of humus. The ground is covered with a thin layer of leaves and twigs and a very thin layer of humus below which the soil is stained black for a few centimeters. This is probably due to the gradual fall of leaves throughout the year, the rapid oxidation of organic matter, and its rapid removal by the heavy rainfall. There are many tree species and very few individuals of each, which are usually widely scattered throughout the forest. It was impossible to make any statistical studies in the short time available for the work but we have made use of the information on this phase of the subject which was given us by Mr. W. J. Kramer and Mr. C. Z. Bates of the Forest Service.

The two most conspicuous tree species are the jácana (*Lucuma multiflora* (A. DC.) and the guara-guadillo (*Guarea ramiflora* Vent.); although large individuals are not common, their seedlings are very abundant. Other species that attract attention are the cenizo (*Zanthoxylum martinicense* (Lam.) DC.), which has a trunk covered with stout conical thorns; the cupeys (*Clusia rosea* Jacq. and *C. Gundlachii* Stahl) with their peculiar semi-epiphytic habit; the two llagrumos (*Didymopanax Morototoni* (Aubl.) Dcne. & Pl. and *Cecropia peltata* L.), with their large leaves which are brown above and white below, the moralón (*Coccolobis grandifolia* Jacq.), with its very large almost circular leaves; the cojobana (*Piptadenia peregrina* (L.) Benth.), with its peculiar foliage resembling the North America hemlock; isolated individuals of the sierra palm (*Euterpe globosa* Gaernt.), and scattered plants of the two tree ferns (*Cyathea arborea* (L.) J. E. Smith and *Alsophila aquilina* Christ) in places where the cover is not too dense. The straight, tall trunks makes it impossible to study the foliage at a distance. Some of the other trees that are worthy of mention are: the guaraguao (*Guarea Guara* (Jacq.) P. Wilson), the granadillo (*Buchenavia capitata* (Vahl) Eichl.) (Fig. 38); the laurel roseta (*Nectandra patens* (Sw.) Griseb.), the malagueta (*Amomis caryophyllata* (Jacq.) Krug & Urban), the gongolí (*Dendropanax laurifolium* (E. March.) Dcne. & Pl.) the hueso blanco (*Mayepea domingensis* (Lam.) Krug & Urban), the palo de dajao (*Ixora ferra* (Jacq.) Benth.) the palo de aceite (*Tetragastris balsamifera* (Sw.) Kuntze), the cieniguillo (*Myrcia deflexa* (Poir.) DC.), the cacaillo (*Meliosma obtusifolia* (Bello) Krug & Urban), the maricao (*Byrsonima spicata* (Cav.) DC.), the achiotillo (*Alchornea latifolia* Sw.), the palo blanco (*Drypetes glauca* Vahl) and *Nageia coriacea* (L. C. Rich. Kuntze.) Species of the native Erythrinas may be seen for a long distance in the neighboring forests when in bloom. This forest was originally the habitat of the satinwood or aceitillo (*Simaruba tulae* Urban) which is now almost extinct.

The distribution of these trees shows very little relation to topography, soil or soil moisture, although *Piptadenia peregrina* (L.) Benth. and *Nageia coriacea* (L. C. Rich.) Kuntze are more abundant near the bottoms of the valleys. Nearer the settlements, this valley location is occupied by thickets of the introduced poma rosa (*Jambos Jambos* (L.) Millsp.) In a few clearings and at the edge of the forest, *Miconia prasina* (Sw.) DC. and moral (*Cordia sulcata* DC.) are abundant. The majority of the smaller trees, ranging from 3 to 10 meters in height, are of the common species, but the muñeco (*Dendropanax arboreum* (L.) Dcne. & Pl.) and the jacanillo (*Petesioides pendulum* (Urban) Britton) are regular constituents of this layer.

Most of the numerous shrubs are in reality young trees such as the guara-guadillo (*Guarea ramiflora* Vent.) and the jácana (*Lucuma multiflora* A. DC.) which are very abundant everywhere, and the gongolí (*Dendropanax laurifolium* (E. March.) Dcne. & Pl.), which occur in scattered patches. One of the most common true shrubs is the gesnerad (*Pentaraphia albiflora* Dcne.), which grows in rocky ledges. The rasca garganta (*Parathesis serrulata* (Sw.) Mez) the galán del monte (*Cestum laurifolium* L'Her). the icaquillo (*Hirtella rugosa* Pers.) and *Psychotria grandis* Sw. are occasional.

Dense growths of the climbing bamboo-like grass (*Arthrostylidium sarmentosum* Pilger) and to some extent the grasses *Lasiacis divaricata* (L.) Hitchc, and *L. sorghoidea* (Desf.) H. & C. climb over the undergrowth. The high-climbing calabazón (*Philodendron Krebsii* Schott.) is common; gungulén (*Vanilla Eggersii* Rolfe) occurs at wider intervals; and the bejuco de palma or pega palma (*Marcgravia rectiflora* Tr. & Pl.) is also abundant.

The epiphytes are not very abundant; the most conspicuous being the flor de culebra (*Anthurium acaule* (Jacq.) Schott.) which grows in large rosettes on horizontal branches, in crotches of trees, on exposed rocks, stumps and occasionally on the ground. *Hillia parasitica* Jacq. is common, frequently two or three meters in height and with snowy flowers. Small orchids and ferns are common on the rocks, logs, stumps and occasionally on the trunks of living trees. Among the most common of the ferns are *Polypodium latum* (Moore) Sodiro, *P. pectinatum* L., *Elaphoglossum apodum* (Kaulf.) Schott., and *Asplenium cuneatum* Lam. The orchids *Spathiger rigidus* (Jacq.) Small, *Lepanthes selenipetala* Rchb. f. and *Pleurothalis ruscifolia* (Jacq.) R. Br. are also common. The same habitat is shared by *Columnea tulae* Urban and such epiphytes as *Tillandsia tenuifolia* L., and several sterile bromeliads grow on the trees.

The herbaceous ground flora is very scanty or absent. Three species appear to be well adapted to the dense shade and are much more abundant than the others. They are the yerba maravilla (*Ruellia coccinea* (L.) Vahl) and the two delicate grasses *Ichnanthus pallens* (Sw.) Munro and *Pharus glaber* HBK. Occasional plants of the tall achicoria cimarrona (*Tupa robusta* (Graham) A. DC.) and colonies of *Alpinia antillarum* R. & S. grow along the bottoms of the ravines. *Meibomia umbrosa* Britton, *Gesneria pauciflora* Urban and several ferns such as *Blechnum occidentale* L., *Dryopteris Brittonae* Slosson and *Nephrolepis rivularis* (Vahl) Mett. also occur.

There appear to be very few individuals of the smaller, secondary species but this is probably due to their wide intervals rather than their scarcity. Their seed production and migration are certainly sufficient to provide a much larger number of individuals and a more general distribution. The limiting factor is light; each plant from the highest tree to the lowest shrub reduces the amount of light available for those below and makes growth of the smaller plants more precarious. This law applies to their own seedlings and the mortality among the tree seedlings must be exceptionally high. The epiphytes germinate at higher levels and the vines attain high levels by their rapid growth.

As a result of this reduced light, many secondary species are represented by few individuals except at the edge of the forest and along the trails and roads where there is a maximum amount of light. Among the most characteristic species of shrubs in such places are *Tamonea macrophylla* (D. Don.) Krasser, *T. guianensis* Aubl., *Miconia prasina* (Sw.) DC., *M. laevigata* (L.) DC., *Calycogonium Krugii* Cogn., *Vitex divaricata* Sw., *Piper scabrum* Sw., rama menuda or hoja menuda (*Myrcia splendens* (Sw.) DC.), *Psychotria undata* Jacq., *Erythroxylon rufum* Cav. *Pentaraphia albiflora* Dcne. and *Parathesis serrulata* (Sw.) Mez. Among the herbaceous species we find *Sauvagesia erecta* L., *Nepsera aquatica* (Aubl.) Naud., and *Tontanea herbacea* (Lam.) Standl.). Ferns are abundant and include *Cyathea arborea* (L.) J. E. Smith, *Polypodium Plumula* H. & B., *Dicranopteris bifida* (Willd.) Maxon, *Adiantum tenerum* Sw., *Odontosoria aculeata* (L.) J. E. Smith, and *Hemitelia horrida* (L.) R. Br.

B. The Rain Forest

The tropical rain forest of the Luquillo Mountains is another high-altitude forest and extends to about 600 meters (2,000 ft.), but the original vegetation is intact in only a few places where it has not been subject to selective cuttings to a greater or less degree. The prevailing tree growth is now lower than normal and the best individuals of the most valuable species have been removed. Most tree species of the original growth, with some exceptions such as the tabanuco (*Dacryodes excelsa* Vahl), were scattered and therefore, the sporadic cutting has not resulted in a complete destruction of the forest.

A bird's-eye view of the rain forest shows a solid blanket of green interrupted by the higher cliffs, the small irregularities of the country being concealed. This green blanket presents a mosaic of several shades, varying with the species and the light. From a closer view the crowns are seen to be of various heights, and rounded or spreading. Among the most conspicuous species are the tree ferns (*Cyathea arborea* (L.) J. E. Smith) with their pale green flat tops, the ungainly llagrumo (*Cecropia peltata* L.) which shows flashes of white as its huge leaves are inverted by the wind, the llagrumo macho (*Didymopanax Morototoni* (Aubl.) Dcne. & Pl.) and the occasional Sierra palm (*Euterpe globosa* Gaertn.). Every shade of green, every form of crown and every size of leaf is represented.

As the eye travels up the mountain side, these features blend into a general mosaic, the form and heights of the crowns become less distinct, and the colors merge although the white flashes from the llagrumos are visible from a long distance.

The soil of the rain forest is a red or yellow plastic clay of a variable depth, overlaid by a thin layer of humus and a thicker layer of fallen leaves and stems. The trees stand close together and the general height rarely exceeds 20 meters and the diameter rarely more than 30 centimeters (1 foot), although there are some few trees with diameters 1.5 meters (5 ft.). The general aspect resembles that of the moist tropical forest and the component species are similarly widely scattered. The tabanuco (*Dacryodes excelsa* Vahl.) (Fig. 39) is an exception, in that it grows in small colonies.

The number of tree species is large, each represented by scattered individuals. Mr. W. J. Kramer ranks the valuable species in order of their abundance and importance as follows: the tabanuco (*Dacryodes xecelsa* Vahl) (Fig. 39), the sabino (*Magnolia splendens* Urban), the guamá (*Inga laurina* (Sw.) Willd.), the guaraguao (*Guarea Guara* (Jacq.) Wilson), the ácana (*Manilkara nitida* (Sessé & Moc.) Dubard), the roble blanco (*Tabebuia pallida* Miers), the ortegón (*Coccolobis rugosa* Desf.), *Miconia tetrandra* (Sw.) D. Don. and gaimitillo (*Micropholis garcinifolia* Pierre). Other species that were observed by us are the moca (*Andira inermis* HBK.), the granadillo (*Buchenavia capitata* (Vahl) Eichl.) (Fig. 15), the hueso blanco (*Mayepea domingensis* (Lam.) Krug & Urban), the guayabota (*Eugenia Stahlii* (Kiaersk) Krug & Urban), *Coccolobis pirifolia* Desf., *Croton poecilanthus* Urban and *Cedrela odorata* L. The latter is now nearly extinc. Still other species are mentioned by Gifford, including *Ternstroemia luquillensis* (Krug & Urban) Britton, stated by him to reach a diameter of eight feet and probably the largest tree in this respect in the forest; *Myroxylon Schwaneckeanum* Krug & Urban, the caracolillo (*Trichilia pallida* Sw.), the palo de gallina (*Alchorneopsis portoricensis* Urban), the aguacate cimarrón (*Hufelandia pendula* (Sw.) Nees.) the palo de dajao (*Ixora ferrea* (Jacq.) Benth.), the cacaillo (*Sloanea Berteriana* Choisy), the cacao bobo (*Meliosma Herberti* Rolfe), the maricao (*Haemocharis portoricensis* Krug & Urban), as well as several others which from their vernacular names cannot be associated with a species. Four species, llagrumo macho (*Didymopanax Morototoni* (Aubl.) Dcne. & Pl.), the llagrumo proper (*Cecropia peltata* L.), the tree fern (*Cyathea arborea* (L.) J. E. Smith) and *Clibadium erosum* (Sw.) DC., which behave ordinarily as forest weeds, grow in the small clearings and sunny places.

Young trees are abundant under the larger ones and are scattered like their parents. There are very few true shrubs, the most conspicuous being *Palicourea riparia* Benth., which grows to a height of two to four meters. It is most common on the lower levels along the trails where it gets the maximum sunlight. The guao (*Comocladia glabra* (Schultes) Spreng.) and the basquiña (*Pothomorphe peltata* (L.) Miq.) grow well in the deep shade. The camaseys (*Miconia prasina* (Sw). DC., *M. racemosa* (Aubl.) DC. and *Mecranium amygdalinum* (Desr.) C. Wright) colonize open places along the trails. The two shrubby species of galán de monte (*Cestrum macrophyllum* Vent. and *C. laurifolium* L'Her.) and the shrubby rabo de ratón (*Duggena hirsuta* (Jacq.) Britton) are less abundant.

The most conspicuous of the lianas are the bejuco de palma (*Marcgravia rectiflora* Tr. & Pl.) and bejuco de rana (*M. Sintenisii* Urban), the former being the more abundant. They are widely distributed and it is difficult to distinguish them in a sterile condition. They have already been referred to as inhabitants of the moist tropical forests but they are more abundant and larger in the rain forest, reach their maximum in the Sierra palm forests a little above the rain forests and extend to the highest peaks. The bejuco de palma and bejuco de rana are especially interesting because of the peculiar differentiation of the juvenile and adult stages. Seeds of these two species are produced most abundantly in the Sierra palm forests and are widely distributed over that region and the two lower forest They germinate freely on moist rocks, stumps, logs, earthy mossy banks and other places. The juvenile stages are abundant and are characterized by leaves which are closely appressed to the substratum to which the plant clings by means of its aerial roots. The leaves are sessile, ovate-oblong, blunt at the apex, cordate at the base, 1 to 4 centimeters long, crowded or almost overlaping on the short internodes. In this stage it resembles a small climbing aroid more than its own adult stage. Under favorable conditions a lateral branch grows out from the substratum, develops internodes two to three times as long as those of the juvenile plant and leaves which are narrow, oblong, obtuse at the base, and sharply acute or acuminate at the apex. This branch grows over tree trunks 3 to 10 meters in height and forms huge masses 2 or 3 meters in diameter. If a part of this adult plant is broken and falls to the ground, it is very likely to grow and give rise to a juvenile branch like the original juvenile plant.

The second vine in importance is the rasca garganta or calabazón (*Philodendron Krebsii* Schott), a large aroid which climbs to a height of 10 meters. Several other aroids including the guinda (*Anthurium scandens* (Aubl. Engler) climb but do not attain such large size. True epiphytes are not abundant. *Hillia parasitica* Jacq. trails over the lower tree trunks and is conspicuous by its flower branches and snowy white flowers.

The heavy rainfall and the saturated atmosphere favor the development of many small herbaceous plants which are distributed through the forest and grow in great abundance along the trails where the removal of the shrubs and young trees reduces the competition. The root system of these plants is small and poorly developed; some of them will flourish on moss banks, the rough bark of trees and in rock crevices. Even smooth rocks that are covered with a very thin layer of mosses will be occupied by numerous small herbs. It is very probable that the great majority never come to maturity but the seedling process is continuous and the rocks are never without cover if there is any possible chance for the young plants to gain a root hold. It will be readily seen that under these conditions, it is impossible to distinguish with any degree of certainty the ground plants, rock plants and true epiphytes; in fact the same species may be found behaving in all three ways within a very short distance.

The most abundant of the herbaceous plants belong to the genera *Pilea* and *Peperomia.* Of the latter genus yerba de medio real (*P. rotundifolia* (L.) HBK.) is especially conspicuous, covering tree trunks to a height of a meter or more with a close mantle of small orbicular leaves. *P. emarginella* (Sw.) DC. has this same habit. Among the larger species are: *P. robustior* Urban, *P. alata* R. & P., *P. magnoliaefolia* (Jacq.) A. Dietr. and *P. glabella* (Sw.) A. Dietr. The species of *Pilea* are also plants of deep shade and grow in thin soil or on rocks but do not have the climbing or epiphytic habit of some of the Peperomias. The most common are *P. inaequalis* (Juss.) Wedd., and *P. obtusata* Liebm., but the following are also found: *P. repens* (Sw.) Wedd., *P. Krugii* Urban, *P. Parietaria* (L.) Blume, and *P. semidentata* (Juss.) Wedd.

Associated with the *Pileas* and the *Peperomias* are many other herbaceous plants such as the yerba maravilla (*Ruellia coccinea* (L.) Vahl.), which is abundant and conspicuous because of its scarlet flowers; yerba de San Martín (*Sauvagesia erecta* L.) and the altea (*Nepsera aquatica* (Aubl.) Naud.), which are abundant along the trails; the woodland grass (*Ichnanthus pallens* (Sw.) Munro) and *Stethoma verticillaris* (Nees) Britton. There are also scattered plants of three small orchids (*Cranichis muscosa* Sw., *Prescottia oligantha* (Sw.) Lindl. and *Physurus plantagineus* (L.) Lindl.), which occur as scattered individuals. The pata de gallina (*Lepidagathis alopecuroidea* (Vahl) R. Br.) and tibey parasitico (*Columnea tulae* Urban) are of occasional occurrence in such places.

There are a few taller species each represented by a few individuals. They are the yerba de plata (*Rolandra fruticosa* (L.) Kuntze) and *Hypitis atrorubens* Poit., which are abundant but far less conspicuous than bijao (*Alpina aromatica* Aubl.) with its tall flowering stems and achicoria cimarrona (*Tupa robusta* (Graham) A. DC.); tangled masses of grasses belonging to the genus *Lasiacis* and the scrambling sedge (*Scleria canescens* Boeckl.), which obstructs the trails with its sharp edged, cutting leaves, are common and frequently abundant.

The ferns are exceptionally luxuriant and range in size from the tree fern (*Cyathea arborea* (L.) J. E. Smith) and *Hemitelia horrida* (L.) R. Br. to the very small ferns a few centimeters in height. Small members of the genus *Polypodium* climb over the tree trunks; mats of the Selaginellas cover the ground and clay banks; and masses of *Dicranopteris bifida* (Willd.) Maxon grow in many places. The others species most likely to attract attention are *Dryopteris reticulata* (L.) Urban, *D. deltoidea* (Sw.) Kuntze, *Polypodium lycopodioides* L., *P. chnoodes* Spreng., *P. loriceum* L., *Polybotrya cervina* (L.) Kaulf., *Nephrolepis rivularis* (Vahl) Mett., *Alsophila borinqueña* Maxon, *Hemitelia horrida* (L.) R. Br., *Hypolepsis repens* (L.) Presl, *Odontosoria aculeata* (L.) J. Smith, *Oleandra articulata* (Sw.) Presl, and *Vittaria filifolia* Fée. *Lycopodium cernuum* L. is common; *L. linifolium* L. grows as an epiphyte, and *Selaginella Krugii* Hieron. forms small mats on the forest floor.

A number of species, some of them of considerable size and others of special interest to botanists are not known outside this rain forest. Some of them have been collected but once and are not well represented in herbaria. Therefore, it is reasonable to suppose that a careful exploration of this region will result in the rediscovery of some of these species and the discovery of additional ones.

3. THE SIERRA PALM FOREST

Climbing above the rain forests or the moist tropical forest and into the Sierra palm forest, we note the first distinctive change in the plant life in the massing of the Sierra palms (*Euterpe globosa* Gaertn.) at and above an elevation of about 600 meters (2,000 ft.). This species, which is represented in the rain forest by scattered individuals, now becomes the dominant species. Its lowest altitudinal limit is in the Luquillo mountains; in the Central Cordillera, its lowest limit is about 900 meters (3,000 ft.). This variation is probably due to rainfall, atmospheric humidity, wind exposure, temperature and other agencies. The transition from rain forest to palm forest is usually sharp and always far more abrupt than any possible change in the climatic conditions. It appears that the Sierra Palm is better adapted to the higher altitudes than some of the more common species of the rain forests and that its abundant seed production, high germination and close control of its environment prevents any considerable mixing of other species. It is an excellent illustration of ecological dominance, being most abundant and almost the only component of the forest layer, and determining by its environmental control the secondary species associated with it.

The Sierra palm forest forms an almost continuous zone around the Luquillo Mountains at an elevation of about 600 meters (2,000 ft.). A little above this continuous zone, the palms alternate with the mossy forest, the palms occupying the more sheltered ravines. The areas occupied by the Sierra palms may be described as a series of triangles which are united at their bases, their apices extending almost to the summits. On the Cerro de la Punta of the Central Cordillera, near Jayuya, the Sierra palm forest starts at about 900 meters (3,000 ft.) and extends almost to the summit which is about 1,350 meters (4,400 ft.), the highest point in Puerto Rico.

The fact that the palm forests of these two regions differ in altitude by about 300 meters (1,000 ft.) and are very generally located in the sheltered ravines, indicates that they are controlled by meteorogical conditions and that the wind exposure is more important than the variations in temperature.

The transitions from the rain to the Sierra palm forest is sharp and well defined, a very complete change taking place within a very few meters. The transition between the palm forest and the mossy forest may be sharp and well defined or broad and poorly defined, depending on the topography of the region. On the eastern or windward slopes it is usually sharp and well defined, while on the slope where the wind exposure is less, it is usually broad and poorly defined, the dominant species of the two forests mingling.

The Sierra palm forest is easily recognized at a considerable distance by the form and size of the leaves and at a still greater distance by the pale green uniform color of the foliage. It is very conspicuous when seen from one of the highest summits which gives a bird's-eye view of large areas of mountain slopes and shows with great clearness the distribution of the palms in the ravines and in small colonies growing in the shelter of some minor peaks.

The Sierra palm has a straight, erect, cylindrical trunk, which is rarely more than 1.5 decimeter (6 inches) in diameter and 10 to 15 meters (30 to 45 feet) in height, and pinnate leaves, which are 2 to 2.5 meters in length and form a dense shade. The globose fruits are a little more than a centimeter in diameter and are produced in great abundance. Reproduction appears to be retarded by the reduced light but is always sufficient to maintain a pure stand of mature trees. The establishment of other species, either from the rain forest below or the mossy forest above, is very much hindered by fallen leaves which tend to smother the vegetation beneath them. Therefore, the palm forest is very open and free from undergrowth (Fig 40). However, there are occasional specimens of the llagrumo (*Cecropia peltata* L.), the tree fern (*Cyathea arborea* (L.) J. E. Smith) and *Clibadium erosum* (Sw.) DC., all of which are common weed trees of the rain forest. There are also a few individuals of cupey (*Clusia rosea* Jacq.), capá cimarrón (*Cordia borinquensis* Urban), hoja minga (*Cananga Blainii* (Griseb.) Britton), achiotillo (*Alchornea latifolia* Sw.), the hueso blanco (*Mayepea domingensis* (Lam.) Krug & Urban), the guaraguao (*Guarea guara* (Jacq.) P. Wilson) and *Miconia tetrandra* (Sw.) D. Don The shrubs are usually very poorly represented. *Psychotria Berteriana* DC. is the most abundant and attains a height of 6 meters, *P. uliginosa* Sw., *P. maleolens* Urban, *Duchartrea Sintenisii* (Urban) Britton and cieneguilla (*Daphnopsis Philippana* Krug & Urban) are smaller in size and less frequent.

The bejuco de palma (*Marcgravia rectiflora* Tr. & Pl.) and the bejuco de rana (*M. Sintenisii* Urban), which have been described as inhabitants of the rain forest, reach their best development in the Sierra palm forest. There are also a few climbing aroids and the climbing bamboo (*Arthrostylidium sarmentosum* Pilger). The species of epiphytic bromeliads that are found in the rain forest are much more abundant in the palm forest. *Hillia parasitica* Jacq. is abundant to an altitude of about 750 meters (2,500 feet). *Peperomia rotundifolia* (L.) HBK. is abundant on the bases of the palm trunks. The number of ferns is reduced but many species of the rain forest persist, including *Struthiopteris exaltata* (Fée) Broadh., *Hymenodium crinitum* (L.) Fée., *Polypodium asplenifolium* L., and *Vittaria remota* Fée, which grow most abundantly along the trails.

The herbaceous plants are reduced both in number of species and number of individuals. The most common and conspicuous is the begonia (*Begonia decandra* Pav.) (Fig. 41) which finds its optimum environment in this forest and grows abundantly wherever the light is sufficient. Clumps of the lengua de vaca (*Anthurium dominicense* Schott) are frequent and conspicuous, and the achicoria cimarrona (*Tupa robusta* (Graham) A. DC.) is common and large. Other species of this forest are *Peperomia alata* R. & P., *Sauvagesia erecta* L. *Crantzia ambigua* (Urban) Britton, *Physurus plantagineus* (L.) Lindl., *Carex polystachya* Sw., *Alsophila quadripinnata* (Gmel.) C. Chr., *Scrophularia minutiflora* Pennel and *Lycopodium cernuum* L.

4. THE MOSSY FOREST

Those portions of the Luquillo Mountains lying above the palm forests are more or less covered by an association known to the foresters as the ridge type and designated by Murphy as the hurricane type. A much better name is mossy forest because of its strong ecological resemblance to similar types of this name in other tropical regions. It occupies the peaks and descends along the more exposed wind-swept ridges (Fig. 42) to an elevation of about 700 meters (2,300 feet). It occupies a corresponding position on the Cordillera Central but descends to very little if any below 1,000 meters (3,300 feet).

In the Luquillo Mountains, this forest occupies the position of the highest rainfall and highest atmospheric humidity. Throughout practically the entire year, the peaks are wrapped for a considerable part of the time in fog or cloud which raises the humidity nearly or quite to the point of atmospheric saturation, resulting in rainfall almost every day and to a very great reduction of sunshine. These clouds collect during the night and cover the mountains at an elevation of 600 meters (2,000 feet). During the day the clouds are formed on the eastern slope and, driven by the winds, they ascend and cross the ridge, enveloping the peaks in cold mist or in drenching rains, and finally moving west where they are evaporated under the tropical sun.

As a result of the high rainfall and atmospheric humidity, the soil of the mossy forest is very generally water-soaked and the plants almost constantly dripping with moisture. The soil is usually thin and in many places the forest floor consists of irregular rocks separated by wet muck and covered with fallen leaves, dead twigs, superficial roots and prostrate stems.

The trade winds which blow almost constantly over the peaks of the Luquillo Mountains are so moist that it is doubtful if they affect the water relations of the plant life seriously but they do have a very pronounced mechanical effect, so that in the most exposed portions the trees are limited in height to about three meters and the tops are kept at a very uniform level.

The temperature is also considerably reduced. Although we have no exact records, it is reasonable to asume that the temperature of the rain forest is about six degrees lower than at sea level, that of the mossy forest 7 to 11 degrees, and that of the peaks of the Cordillera Central as much as 14 degrees.

The four important environmental conditions of the mossy forest appear to be low temperature, high wind exposure, water-soaked soil and an atmosphere of high humidity, frequent fog and mist and heavy rainfall. The wind appears to be the most important factor in differentiating the mossy forest from the palm forest; the former being limited to the summits and to the winds-swept ridges and the latter to the ravines.

The net result of the environmental influences has been the segregation at these high altitudes of a most interesting and distinct flora, few species of which are found in other associations. The few mossy forests of Porto Rico are on the higher elevations and well separated from each other by valleys. This conditions has led to a considerable endemism. The Luquillo Mountains are noted as being the only station for a large number of species; but the Cordillera Central, although less fully explored, also contains several endemic species and is the only known Porto Rican habitat for several other species.

Four species constitute the bulk of the arborescent vegetation: the organillo (*Weinmannia pinnata* L.), the granadillo (*Ocotea spathulata* Mez.), the roble de sierra (*Tabebuia rigida* Urban) and the *Eugenia borinquensis* Britton, none of which occur in the rain forest, except possibly as rare and widely isolated individuals. They are widely distributed at all altitudes of the mossy forest and probably constitute 75 per cent of the dominant species. The species of secondary importance are tortugo prieto (*Ravenia Urbani* Engler), *Calycogonium squamulosum* Cogn., *Miconia pycnoneura* Urban, *M. pachyphylla* Cogn., *M. foveolata* Cogn., *Ceratostemma portoricensis* (Urban) Hoerold, *Petesiodes yunquense* (Urban) Britton, *Thibaudia Krugii* Urban and Hoerold, *Ilex Sintensii* (Urban) Britton, cupeillo (*Clusia Krugiana* Urban), *Grammadenia Sintenisii* (Urban) Mez, *Meeranium amygdalium* (Desr.) C. Wright and capá cimarrón or muñeca (*Cordia borinquensis* Urban) and many less numerous species. The bejuco de rana (*Marcgravia sintenisii* Urban) and the bejuco de palma (*M. rectiflora* Tr. and Pl.) are abundant and constitute a striking feature of the vegetation.

At the lower limit of the mossy forest, (Fig. 43) at an elevation of about 700 meters (2,300 feet) these species grow into trees of 8 to 12 meters in height but differ from those of the rain forest in having crooked trunks, more branches and a greater abundance of mosses, *Selaginella* and various epiphytes. With the increase in altitude and greater exposure to wind, the size of the trees is generally reduced. At 900 meters (3,000 feet) the trees on the exposed ridges (Fig. 44) seldom exceed 4 meters in height, while on the wind-swept summit of El Yunque there are large areas of dwarf forest, composed of the same species but not more than two meters in height, and at the very edge of the forest on the rocky promontory, (Fig. 45) *Miconia foveolata* Cogn., *Ilex Sintenisii* (Urban) Britton, *Ceratostemma portoricensis* (Urban) Hoerold, *Eugenia borinquensis* Britton, and roble de sierra (*Tabebuia rigida* Urban) are reduced to not more than one meter in height.

On the lower limits of the mossy forests, the larger size and spreading habit of the trees leads to rather open spacing. On the upper limits the trees are smaller and densely crowded until on the summit (Fig. 46) of the Luquillo peaks, they form dense thickets of crooked nearly interlacing stems, through which vision can seldom penetrate more than 3 to 5 meters. At the lower limit the crowns of the trees are more or less rounded but on the upper limits the exposure to high winds cause the crowns to be level or flattened until at the summit they present an almost perfectly smooth expanse of dense foliage, over which the only contrast is caused by the occasional plants of epiphytic bromeliads and orchids which project above the general level. The close relationship between the wind exposure and the size of the trees is well shown at any ledge of rock; the plants on the lee side growing to a greater height than those on the windward side but not rising above the general level of the wind-drafts from the windward side.

One of the most characteristic features of this forest is the luxuriant growth of mosses and *Selaginella Krugii* Hieron. At the lower limit the trunks of the trees are covered to a height of 3 or 4 meters with a layer of moss and a considerable part of the forest floor is carpeted with mosses (Fig. 47). At the upper limit, the ground is completely covered with dense mats of *S. Krugii* which climbs the trees to a height of a meter. Above the *S. Krugii* the trunks are completely covered with a dense coat of several species of mosses and hepatics which extends to the smaller twigs and conceals their actual size and the character of their bark so that they all have the same appearance. The leaves are also frequently covered with growths of these same hepatics. Under these conditions, the differences between terrestrial and epiphytic habits are of little importance and most of the secondary species grow indiscriminately on the ground or on the sides of the trees.

The development of the two species of Marcgravia is especially interesting; the juvenile plants grow very abundantly as epiphytes. Some of the mature plants bloom as epiphytes while others are terrestrial and produce long stems two or three centimeters in diameter which scramble through and over the forest at a considerable height. Another noteworthy epiphyte is *Psychotria Grossourdyana* (Baill.) Urban which produces delicate pendant or ascending plants on the dominant trees, resembling an epiphytic ericad in habit quite unlike the commoner species of the genus.

The ferns are very common, the larger ones growing on the ground while the smaller ones grow indiscriminately on the ground or as epiphytes. The common species are *Struthiopteris polypodioides* (Sd.) Trev., *S. Underwoodiana* Broadh., *Cyathea pubescens* Mett., *Diplazium L'Herminieri* Hieron., *Alsophila borinqueña* Maxon, *Polypodium trifurcatum* L., *Lycopodium tenuicaule* Underw. & Lloyd, and various species of *Hymenophyllum* and *Trichomanes*. The lengua de vaca (*Anthurium dominicense* Schott) and a few species of bromeliads are abundant as epiphytes. Delicate plants of *Pilea yunquensis* (Urban) B. & W., *P. Krugii* Urban, *Peperomia hernandifolia* (Vahl) A. Dier. and *Pleurothallis crassipes* Lindl. are common. The grasses (*Arthrostylidium sarmentosum* and *Isachne angustifolia* Nash) grow in the open places. Plants of yerba de maravilla (*Ruellia coccinea* (L.) Vahl.), yerba de San Martín (*Sauvagesia erecta* L.), bijao (*Alpinia antillarum* R. & S.), common begonia (*Begonia decandra* Pav.) and *Stethonia verticillaris* (Nees) Britton, grow along the trail.

The abundant rains prevent the accumulation of soil on the rocky peaks except in the crevices and pockets of the rock, so there are practically no shrubs, although the typical species grow over the edge of the rock, on the lee side (Fig. 48). The grasses and sedges (Fig. 50) are most common and are represented by *Isachne angusti-*

folia Nash, *Arthrostylidium sarmentosum* Pilger, *Machaerina restioides* (Sw.) Vahl, *Rynchospora cyperoides* (Sw.) Mart., *R. Bruneri* Britton and *R. luquillensis* Britton. The small fern *Psilogramme portoricensis* Maxon, the larger fern *Struthiopteris lineata* (Sw.) Broadh and *Cyathea pubescens* Mett. grow in crevices in the rock while *Selaginella portoricensis* A. Br. grows on the sheltered ledges. *Setiscapella subulata* (L.) Barnh. and *S. pusilla* (Vahl) Barnh., common plants of the coastal plain, grow in pockets of wet soil and are excellent illustrations of the wide distribution of seeds. The small orchid *Octadesmia montana* (Sw.) Benth., and the endemic herb *Mikania pachyphylla*[1] Urban are rare on exposed rocks, while *Pitcairnia angustifolia* (Sw.) Redoute is fairly abundant.

The mossy forest association occurs on the higher peaks of the Cordillera Central (Fig. 49) but is very different in many respects from that of the Luquillo Mountains. The influence of the wind is very much reduced, the shrubs are neither bent to the south nor shorn to an even surface but are erect and have rounded crowns. The mosses are reduced to a thin layer on the sheltered trunks or absent and the Selaginellas are completely absent. The bromeliads are few and inconspicuous. The less rigorous environment is shown by the presence of many shrubs of the rain and moist tropical forests and by the more luxuriant development of herbs.

Of the four characteristic trees of the Luquillo mossy forest, only two, the granadillo (*Ocotea spathulata* Mez) and the oreganillo (*Weinmannia pinnata* L.) are present. The roble de sierra (*Tabebuia rigida* Urban) of the former location is replaced by the closely related roble de colorado (*T. Schumanniana* Urban). *Eugenia borinquensis* Britton is lacking. The bejuco de rana (*Marcgravia Sintenisii* Urban) and the bejuco de palma (*M. rectifolia* Tr. & Pl.) are abundant. *Miconia pycnoneura* Urban, *Palicourea alpina* (Sw.) DC. *Haenianthus obovatus* Krug & Urban, mata de pez (*Lasianthus Moralesii* (Griseb.) C. Wright), *Ceratostemma portoricensis* (Urban) Hoerold, *Psychotria Grossourdyana* (Baill.) Urban and cupeillo (*Clusia Krugiana* Urban) are present in both regions. Endemism is illustrated by *Persea portoricensis* B. & W., *Ilex Cooki* B. & W., *Didymopanax Gleasoni* B. & W. and possibly by a species of *Xolisma* which appears to be undescribed. The rare shrub *Ilex Riedlaei* Loes. also grows here and this is the lone Porto Rican station for *Torralbasia cuneifolia* (C. Wright) K. & U. Several other species

[1] Careful search during April 1926 disclosed but a single small specimen, possibly the sole remaining plant of the species.

of the Luquillo association were not seen but may be present. The plant life of the lower moist tropical forest is represented by *Hillia parasitica* Jacq., cucubano (*Rapanea ferruginea* (R. & P.) Mez), *Urceolaria exotica* Gmel., *Ocotea floribunda* (Sw.) Mez and cupey de altura (*Clusia Gundulachii* Stahl).

The ferns are numerous and include *Odontosoria uncinella* (Kunze) Fée, *O. aculeata* (L.) J. Smith, *Polypodium sectifrons* Kunze, *P. loriceum* L., *Histiopteris incisa* (Thunb.) J. Smith, *Struthiopteris polypodioides* (Sw.) Trev., *S. lineata* (Sw.) Broadh., *Elaphoglossum rigidum* (Aubl.) Urban, *Rhipidopteris peltata* (Sw.) Schott. *Hymenophyllum lineare* Sw., *H. crispum* HBK., *Trichomanes rigidum* Sw., *T. crispum* L., and a species of *Dicranopteris* which is apparently undescribed and endemic to this region, where it forms conspicuous clumps on the peak.

The dominant shrubs are sparser, and the herbaceous plants and under shrubs more abundant than in the Luquillo Mountains. The two grasses of the former region *Isachne angustifolia* Nash and *Arthostylidium sarmentosum* Pilger are common. Other common plants are *Lisianthus laxiflorus* Urban, *Crantzia ambigua* (Urban) Britton, *Pilea yunquensis* (Urban) Britton, *Peperomia tenella* A. Dietr., and *P. hernandifolia* (Vahl) A. Dietr. The orchids are represented by *Amphiglottis secunda* (Jacq.) Britton, *Octadesmia montana* (Sw.) Benth., *Pleurothallis crassipes* Lindl., *Ornithidium coccineum* (Jacq.) Salisb. and *Jacquinella teretifolia* (Sw.) B. & W.

Since each of the preceding five types of forest is largely the result of a definite set of factors such as temperature, rainfall, atmospheric humidity and wind, which are very stable and not subject to variation brought about by the plant life itself, successions between these types is not in progress at the present time and they may all be regarded as climatic climaxes.

VEGETATION OF THE SOUTHERN COASTAL PLAIN AND ADJACENT FOOTHILLS

A. General

The differences between the plant life of the northern and southern portions of Porto Rico are fundamental and apparent to any observing person. The plant life of the north side is easily differentiated into many associations of very different appearance and composition but form's a connected whole and its distribution coincides exactly with the Tertiary coastal plain, the principal environmental factor being the nature of the underlying soil and rocks, while the climate has only a very broad general effect. The south coastal plain is much smaller in area, the volcanic rocks of the Createaceous age coming down almost to the Caribbean sea for about half the length of the Island. The typical plant life covers the Tertiary rocks and extends far up into the central mountain mass. The soil is a subordinate environmental factor, the low rainfall (Fig. 3) being of primary importance. Many species and a few plant associations extend over the various soils regardless of whether they are volcanic, limestone, shale or fluvial outwash.

The abrupt transition from the mesophytic climate and vegetation of the central mountain mass to the xerophytic climate and vegetation of the southern foothills and coastal plain is very evident and can be readily seen in driving from Cayey to Guayama. Leaving the military road at Cayey which is about 400 meters (1,200 feet) above sea level, the road ascends quickly to about 800 meters (2,400 feet), winds along the mountain side and over table lands, gradually descending to within 10 kilometers of Guayama, at which point the elevation is about 650 meters (1,900 feet). From this point to Guayama the descent is very rapid and the transition from mesophytic to xerophytic vegetation equally rapid, there being a very striking change in the general appearance and component species within a distance of about three kilometers. The nature of this change in plant life has been discussed in a preceding part (page 71). The same transition in plant life may be seen on the roads north of Yauco, Villalba and Coamo and south of Adjuntas, sometimes abrupt and sometimes gradual, depending on the location of the roads with reference to the surrounding hills. The presence of the mesophytic species of the mountain in moist spots at low levels and of the xerophytic species of the coast on exposed cliffs at high altitudes indicates that the change in vegetation is not the result of temperature but of moisture.

The transition between the mesophytic and xerophytic regions is less abrupt along the roads which follow the shore line passing through Mayagüez on the west and Humacao on the east. Along the latter road, the fragment of the mountain forest near Humacao, which is in a region of high rainfall, already shows a considerable number of sclerophyllous species. Descending along the southern slope of the Panduras ridge into Maunabo, the transition is completed and from that point west along the coast, the plant life is distinctly xerophytic. At the western end of the Island the typical mesophytic vegetation of the Mayagüez region is continued to the north slope of the limestone ridge between San Germán and Lajas and almost to Sabana Grande, but a reentrant of xerophytic vegetation occupies the southern slopes of the Maricao mountains to the north.

Geographically, the southern region of Porto Rico lies to the south of an irregular line passing along the southern front of the mountains at an altitude of about 300 to 400 meters (1,000 to 1,500 feet) from the Panduras ridge on the east to a point northwest or north of San Germán, thence returning at a lower level to Sabana Grande, and then west again along the crest of the Lajas range of hills to the ocean south of Cabo Rojo. South of this line, the principal types of land, measured by differences in plant life, rather than by their geology, are the mountains of volcanic origin, the lower shale or limestone hills of the Cretaceous or Tertiary age, and the large outwash plains and valleys of alluvia. Several small tracts of fresh-water marsh, of sand or shingle beach and mangrove swamp are of secondary importance.

Successional processes within the whole area have, in general, been very much retarded and in some environments almost suppressed. The great physiographic processes of erosion, base-leveling and beach formation by which the environments of the north side have been changed are of much less importance on the south side, due to the short rivers, low run-off and a shore line which is protected from the force of the trade winds. The biotic process of soil accumulation and humus formation inland are retarded by the sparseness of the vegetation, due to low rainfall and atmospheric aridity. But the strips of mangrove are constantly building new land along the shore.

Although erosion by water and wind are continuous and the physiographic effects can be observed along the south coast, their activities are here so slow that in most cases there is no evidence of plant movements or of adjustment of boundaries between different associations. A halarch series beginning with the mangrove swamps and culminating in a xerophytic forest, is well defined. Parts of a hydrarch series exist along the lagoons between Guánica and Boquerón and along some of the rivers. An old xerarch series of ancient development has been completed as far as a temporary climax over the arid rocky coastal hills, and a succession from it to the climax forest of the lowlands may be inferred. There are a few isolated illustrations of a xerarch series on beaches and in coastal thickets. The mesarch series of the northern shore is naturally not represented in the arid region, but traces of it may be discovered in the more nearly mesophytic vegetation of the limestone hills at San Germán. Still another successional trend is exhibited in the foothills of the central mountains mass, where erosion and base-leveling are gradually leading to the replacement of the hillside xerophytes by the climax association of the alluvial plains. Almost every association shows the effect of pasturing or repeated cutting, leading to the development of secondary successions and followed in some cases by the reestablishment of the original vegetation. The general successional relations of the vegetation, together with a few more important secondary associations, are shown diagrammatically in figure 51. Murphy has given a good general account of the forest conditions in this part of the Island and mentions the effect of repeated cutting, burning and pasturing, but without attempt to segregate the various component associations.

B. The Halarch Series of Coastal Swamps and Salt Flats

One of the outstanding topographical features of the south shore are great level tracts of alluvial land, lying adjacent to and but little above the sea. Their origin dates back to an early period of partial submergence, during which the present alluvial lands lay beneath shallow bays of the ocean. The streams from the north carried in large amounts of eroded material and gradually built up deltas. The mangroves slowed the action of both streams and waves and thus causing the suspended materials to settle. With the gradual elevation of the land, the deltas were built farther to the south and the older portions were left above the sea level. The whole process of succession of alluvial soils may still be seen. It involves a pioneer association of mangroves at the edge of the land, a climax association of forest on these older parts of the delta which are removed from the influence of salt water, and one or two intermediate associations of small size.

1. The Mangrove Association

We have already indicated that the mangrove swamps of the north shore are limited to the sheltered bays, lagoons and estuaries where they are protected from the action of the waves. Around the eastern end of the Island they come down to the open ocean in many places as is well illustrated at Fajardo Playa; at Ceiba Playa they grow in the water of the open bay, and along the south shore generally they grow in the protected shallow waters with mud bottoms. Comparatively recent changes in the level of the north coast have resulted in the formation of large land-locked lagoons, coastal swamps and estuaries in which grow hundreds of acres of mangroves. On the south shore the bays are usually deep and surrounded by steep, rocky shores, the river estuaries undeveloped, and the mangroves more widely distributed but not so large nor of such great commercial importance. The best associations are in front of the great alluvial deposits but there are considerable growths on the small islands.

The composition of the mangrove associations of the north and south shores do not differ materially. The four mangrove species are found in both and the secondary species are few in number. The common mangle (*Rhizophora mangle* L.) is the pioneer species and extendes farthest from the shore and into the salt water. It is the first to appear in the open water offshore, where it builds up small islands, which are occupied by it alone for a long time before the incoming of other plants. Mangle blanco (*Laguncularia racemosa* (L.) Gaertn.) and mangle bobo (*Avicennia nitida* Jacq.) follow just back of the common mangle, while mangle botón (*Conocarpus erecta* L.) again forms the interior zone and extends farthest inland and onto the dry land.

Conditions on the land side of the mangrove swamps are in most cases essentially different from those of the north shore. The climate of the north shore is rainy, the supply of ground water abundant, the transitions from salt water to brackish water, and from brackish to fresh water swamps is gradual. The plant life varies primarily with the salinity of the water; and the succession of vegetation is from the mangrove to the Pterocarpus forest or to the cat-tail-sedge association of the hydrarch series. On the south shore, such a transition is exceptional, because of the arid climate, and the succession passes directly from the wet halophyte environment of the mangrove to the xerophytic habitat of the interior. This involves two fundamental changes in the environment, a decrease in the water-content of the soil and a decrease in the amount of salt dissolved in the water.

2. THE BATIS-SESUVIUM ASSOCIATIONS

This association consisting almost entirely of two small herbs is found on a belt of land just back of the mangrove swamps, where there is not sufficient water for the mangroves and where the amount of salt is too great for the growth of the climax forest. This association consists of almost pure growth of barilla (*Batis* *maritima* L.), verdolaga rosada or yerba de vidrio (*Sesuvium Portulacastrum* L.) and a few individuals of other species. The soil is usually a yellowish-brown loam, showing that the alluvial deposits have covered the black muck soil which was formed during the preceding growth of mangroves.

These two species have about the same vegetation character; they usually grow prostrate on the ground, although the barilla becomes ascending to as much as 5 decimeters when in dense patches and the verdolaga sometimes scrambles over bushes and stones to the height of nearly a meter; both have thick fleshy leaves adapted to water storage, which is characteristic of other plants in similar environments. They do not grow mixed to any extent but attain their best development in pure patches of as much as an acre in area. The verdolaga appears to prefer the drier soils and frequently grows on land which is somewhat higher than that occupied by the barilla. It also appears to require less salt and extend much farther inland than the barilla and frequently becomes a common secondary species on the shoreward margin of the climax forest.

Associations of these two species are conspicuous features of the plant life in many places along the entire south shore. They are easily distinguished from a distance by the pale, yellowish-green color of the barilla and the dark-green or reddish tints of the verdolaga rosada. In the best development of this association, the growth of the dominant is so heavy that secondary species are rarely present. In the thinner patches a few plants of the erect pega pollo (*Commicarpus scandens* (L.) Standley), the prostrate cotorra de la playa (*Heliotropium curassavicum* L.) and the minute red-leaved *Portulaca quadrifida* L. also occur (Fig 52). Isolated depauperated shrubs of mangle botón (*C. erecta* L.) and more rarely of the mangle blanco (*L. racemosa* (L.) Gaertn.) and mangle bobo (*A. nitidia* Jacq.) are sometimes present. The common sea-shore grass matojo de playa (*Sporobolus virginicus* (L.) Kunth) frequently forms a dense sod and indicates the succession to the climax forest.

These two species may also grow in a narrow zone at the edges of mangroves just below the xerophytic forest of the hills of a steep, rocky coast. In these places, the two halophytes may actually grow over patches of the tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.) but the contact is exceptional (Fig. 53).

Since these species are sun-lovers, it is difficult to understand how this herbaceous association has persisted between the two arborescent associations, the mangroves on the one side and the climax forest on the other. It may be that they represent a recent development or secondary succession and occupy ground from which the mangroves have been removed for fuel. If so, this association is analogous in its successional relations to the fern (*Acrostichum aureum*) association of the north coast, filling in on relatively dry ground the place taken by the latter on the wet soils. However, we did not observe any indication of its succession by the mangroves.

3. THE SALT FLATS

Near the village of Montalvo, southwest of Guánica, there are extensive areas of alluvial soil almost or entirely destitute of plant life (Fig. 52). These areas are distributed along the shore for a distance of about two kilometers and are sometimes as much as 300 to 400 meters wide. Their elevation is very little above sea level and although the tides do not cover them, the wheels of vehicles crossing them frequently sink a few centimeters into a muddy soil. They are bordered on the shore side by a narrow strip of the Batis-Sesuvium association and terminate in a slightly elevated beach which is occupied by thickets of the xerarch series.

Similar desert tracts are also found to the northeast of Central Aguirre, where there are areas 50 to 100 meters across without a single plant and areas of several acres with a very small amount of vegetation which usually occupies irregular patches. The soil is a yellow-brown silt, apparently a fluvial deposit; it is said to be usually hard and cracked, but at the time of our studies it was moist and smooth after a rain of the preceding night. These areas are bordered on the south by a well-developed mangrove forest of the usual type and separated from it by a narrow tension zone. The small amount of plant life on these areas is limited to depauperated, gnarled, prostrate mangroves (Fig. 54), the most abundant being the mangle botón (*C. erecta* L.); but mangle bobo (*A. nitida* Jacq.) also occurs. Around almost every mangrove, and in some spots between them are rounded patches of almost pure growths of barilla (*Batis maritima* L.) or verdolaga rosada (*Sesuvium Portulacastrum* L.) or sometimes mixtures of the two, in which case the barilla usually occupies the center. On the margin of these flats there is a narrow and interrupted zone of the Batis-Sesuvium association and the tract is bounded by a slightly higher terrain which is occupied by the climax forest.

The development of these two types of salt flats appears to be very much the same and they can doubtless be referred to the same causes. We believe that they are of artificial origin, caused by the removal of the original mangrove vegetation and the subsequent concentration of the salt at the surface by soil capillarity and surface evaporation, to a point beyond the tolerance of any plants in the local flora.

4. THE CLIMAX FOREST

This forest consists of bucar (*Bucida Buceras* L.) and associated species and originally covered all or practically all of the delta and alluvial deposit back of the mangrove and Batis-Sesuvium associations. The largest single expanse of alluvial plains extends along the shore from Guayama to Ponce, a strip about 70 kilometers long by 1 to 6 kilometers wide. Another large area about 33 kilometers long and about 4 kilometers wide, occupies a depression extending from Yauco to Boquerón between the Lajas range and the coastal hills. Smaller areas border most of the small rivers near their mouths. The soil survey of the Arecibo-Ponce area, records two types of alluvial soils; the Ponce sandy loam and the Ponce loam. They consist of water-washed particles in which the silt and fine sand predominant, are fertile and comprise the best of the cane lands of the southern shore. Almost all of these soils are used for cane growing although the arid climate makes irrigation necessary.

The entire southern range of foothills of the central mountain range is subject to continuous erosion by the numerous small streams which flow down the steep southern slopes. The lower coastal hills are eroded at a lower rate than the higher hills due to the lower rainfall. One result of this erosion is the reduction of some of these lower valleys to base level. These valleys are limited in area and occur only along a few of the larger rivers, such as the Yauco and Guayanilla, where the narrow interrupted belts of alluvium lie along the streams for a few kilometers. It is evident that the vegetational histories of the deltas and valleys are different; the one being derived from the semi-xerophytic vegetation of the foothills and the other from the halarch successional series. The present plant life, however, is essentially uniform throughout and constitutes the climax association of the region.

The original vegetation has been almost completely destroyed, but traces which remain are sufficient to show that the dominant tree of the association was the bucar (*Bucida Buceras* L.). At the present time, this is the most common tree of the pastures and roadsides and along the fence rows through this region. Most of the mature trees now standing are from 10 to 15 meters in height with ocassional individuals of 25 meters. They branch at a height of 3 or 4 meters and produce broadly spreading crowns, suggesting a growth development after the cutting of the original forest. Large trees of ceiba (*Ceiba pentandra* (L.) Gaertn.) with their huge trunks, relatively small crown's and frequently buttress roots, occur at wider intervals. Other common trees along the roadside and irrigation canals are the moca (*Andira inermis* HBK.), the algarroba (*Hymenaca Courbaril* L.) the *flamboyant* (*Delonix regia* (Bojer) Raf.), the guácima (*Guazuma Guazuma* (L.) Cockerell), the ben (*Moringa Moringa* (L.) Millsp.). The higuero (*Crescentia Cujete* L.) is abundant in cultivation. The escambrón (*Randia mitis* L.), the basora (*Varronia angustifolia* West), are common shrubs. The grass known as horquetillo (*Chloris radiata* (L.) Sw.) and the shrub *Chamaesyce articulata* (Aubl.) Britton are abundant ground plants. The bucar trees are very generally infested with the nidos de gungulén (*Tillandsia recurvata* L.) which also grows on insulated wires (Fig. 55) in the towns and cities of the south coast between Guayama and Ponce.

The contact of the bucar forest with the Batis-Sesuvium association is usually marked by a zone of the sea shore grass matojo de playa (*Sporobolus virginicus* (L.) Kunth.) which is somewhat halophytic on the south coast. It forms a loose sod adjacent to the Batis-Sesuvium zone and extends back under the trees as scattered colonies and individuals. The barilla (*B. maritima* L.) is rarely found under the trees but mats of verdolaga rosada (*S. portulacastrum* L.) and scattered plants of cotorrera de la playa *Heliotropium curassavicum* L.) and small plants of mangle botón (*C. erecta* L.) are abundant for half a kilometer back into the forest. The seaward limit of the bucar is apparently fixed by the salinity of the soil (Fig. 56.)

Land of this region when cleared and put to pasture very soon reverts into a thorny thicket if not given proper attention (Fig. 57). The most common of these thorny plants are the escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.), the palo de burro (*Capparis flexuosa* L.) the flor de mayo (*Parkinsonia aculeata* L.) and other similar thorny or inedible species which rapidly convert the pasture into a jungle of shrubbery. Intermixed with these are such cacti as the sebucan (*Cephalocereus Royeni* (L.) Britton and Rose.), the sebucan or pitajaya (*Leptocereus quadricostatus* (Bello) Britton & Rose.) and the tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.).

Another interesting reversion is in progress southwest of Yauco, where the lack of sufficient water for irrigation has lead to the abandonment of many acres of cane land. Here the ground is first captured by weeds, among which are to be found the margarita (*Bidens pilosa* L.), the yerba de papagallo (*Blechum Blechum* (L.) Millsp.), *Lippia reptans* HBK, and *Wissadula periplocifolia* (L.) Presl). Shrubs follow very quickly; among which are the basora (*Varronia angustifolia* West), the cariaquillo (*Lantana Camara* L.), the aroma casha (*Vachellia Farnesiana* (L.) W. & A.), the escambrón (*Randia mitis* L.), and algodón de seda (*Calotropis procera* (Ait.) R. Br.). These are followed and very soon overtopped by small trees of bucar (*Bucida buceras* L.), the tachuelo (*Pictetia aculeata* (L.) Urban.), the palo de hedionda (*Lonchocarpus latifolius* (Willd.) HBK.) and the calambreña (*Coccolobis venosa* L.). This thicket averages about 5 to 8 meters with many young bucar about 10 meters in height.

The bucar forest not only tends to re-establish itself as the dominant tree after cultivation but also appears as the normal succession of both hydrophytic and xerophytic plant life as will be shown later. There is very little reason to doubt its climax nature, although well developed examples of the association were not seen.

5. SUMMARY OF THE HALARCH SERIES

The mangrove vegetation is widely distributed along the south shore and has been an important factor in the building of the river deltas and flat alluvial areas. It is ecologically the same as the mangrove association of the north coast. The soil back of the mangroves is dry and saline and usually covered with the Batis-Sesuvium association but in places where the salt concentration appears to be unusually high it is completely barren. The climax forest of bucar (*Bucida Buceras* L.) grows well wherever the salinity is not too great and tends to re-establish itself after cultivation and pasturage.

C. The Hydrarch Series of Lagoons and Marshes

The hydrophytic plant life of the south coast is poorly developed. Narrow zones of eneas or cat-tails (*Typha angustifolia* L.) fringe the irrigation canals and occupy small areas of marsh land where the natural drainage is poor, but the only area of any consequence is in the alluvial valleys between Yauco and Boquerón. Our studies were made in this last section and in the small marshy areas between Salinas and Guayama.

The Yauco-Boquerón valley appears originally to have been an inlet of the sea which extended from Guánica Harbor to Boquerón and isolated the present range of coastal hills from the mainland. This shallow valley was probably filled by a continuous deposition of alluvium which was no doubt aided by an extensive growth of mangroves which still persist in a large swamp at Boquerón. The floor of this valley after its elevation above the sea level was not flat but contained many small depressions in which water accumulated from surface drainage of the hills to the north and south and formed lagoons. The eastern lagoon, not far from Ensenada, is now dry; the western one, south of Lajas, has a few acres of open water.

It is commonly reported by the people living in that section, that the level of the water in these lagoons has varied greatly for many years, depending on the amount of affluent water and on the amount removed by pumps for irrigation. Fields which are said to have been under water a few years ago are now (1926) dry and large areas of cane land have been abandoned for want of sufficient water for irrigation. Therefore, these lagoons not only show the hydrophytic vegetation of the region, but also the successional stages which leads to the establishment of the climax forest. It is reasonable to suppose that a series of years of heavier rainfall, or a change in the source for irrigation water for local agriculture, may cause the lagoons to be filled again and reverse the present sucessional series.

South of Lajas, the floor of this great valley appears to be perfectly level, but there is a slight slope to the middle of the lagoon which does not exceed eight decimeters in depth. The soil is alluvial but the black color near the lagoon indicates the accumulation of a considerable amount of decayed vegetable matter. The lagoon has no definite shore line and its margin cannot be definitely fixed. A change of one centimeter in the level of the surface will probably cause a change of a meter in the position of the shore line. During the dry season of 1926 the shore line receded about ten meters between February 25 and April 16, the dates of our two visits. It is very evident that under these conditions, zones of plant life, such as are usually found on the margins of ponds, cannot be established and maintained.

The most conspicuous species is the eneas or cat-tails (*T. angustifolia* L.) which grows in almost pure culture and is separated from the shore by a zone of open water. Outside the cat-tail zone are small colonies if the tall slender rush-like sedge, junco cimarrón (*Cyperus articulatus* L.) and the similar but smaller sedge (*Eleocharis interstincta* (Vahl) R. & S.). The lechuguilla de agua (*Pistia*

Stratiotes L.) grows in large floating mats which may be several meters across and are frequently attached to the cat-tails. These mats also contain considerable mixture of the shore grass matojo de playa (*Sporobolus virginicus* (L.) Kunth) and smaller quantities of other plants. This grass sometimes makes a sod so dense that it is used as a nesting place for water birds. The herb *Persicaria punctata* (Ell.) Small, grows as a common secondary species on these mats and the shrub *Sesban Emerus* (Aubl.) Urban is occas asionally found (Fig. 58.)

The open water is crowded with floating plants of *Ceratophyllum demersum* L. and a few unidentified species; also by many isolated plants of lechuguilla de agua (*P. Stratiotes* L.), which are driven from shore to shore by the wind and frequently left stranded by the receding water. In this new habitat they root in the mud and bloom freely. *Lemna perpusilla* Torr. is also common and closely associates with the lechuguilla de agua. The flor de agua (*Castalia ampla* Salisb.) grows and blooms freely in the open water near the shore, and when the water recedes it continues to grow and thrive on the mud flats. Under this latter condition the marsh plants appear quickly and would soon displace them if they were not checked by the rise of water during the next rainy period.

The lagoon is surrounded by a broad, rather indefinite zone of herbaceous plants and a few shrubs but the composition of this zone has undoubtedly been modified by grazing. The most common plants are those which have been avoided by the grazing animals. They are the shrubby *Lippia reptans* HBK, which is abundant, the herbaceous *Persicaria punctata* (Ell.) Small which grows in large patches, *Echinodorus cordifolius* (L.) Griseb which grows in small patches or as isolated individuals and the sedges junco cimarrón (*Cyperus articulatus* L.), *Eleocharis nodulosa* (Roth.), Schultes and *E. mutata* (L.) R. & S. which are quite common. There are also isolated plants of *Pluchea purpurascens* (Sw.) DC. and a species of *Marsilea* forms small mats on the ground.

Outside this last zone of hydrophytes, the herbaceous vegetation consist of grasses and weeds with many scattered trees of bucar (*Bucida Buceras* L.) (Fig. 59) which indicates that the land was originally covered with the climax forest. The abandoned cane lands near the lagoon are reverting to the bucar forest.

The Guánica lagoon which lies several kilometers to the east and not far from salt water at Ensenada, is now (1926) completely dry. Its site is surrounded by abandoned cane lands which have been invaded by weeds and shrubs, the first step towards the re-establishment of the climax forest. The slope of the ground is very slight, as in the Laja's lagoon, and there is no evidence of a deeper depression to mark the site of the old lagoon, but the density of the plant life increases towards a point which we believe was the deepest part or center of the old lagoon. Early collections from this locality include several plants with marked halophytic tendencies and it is probable that the water's of the old lagoon were slightly brackish. This condition is indicated by the present plant life which includes halophytic herbs, such as cotorrera de la playa (*Heliotropium currassavicum* L.), verdolaga rosada (*Sesuvium Portulacastrum* L.), *Portulaca quadrifida* L. and the shrub *Lippia reptans* HBK., which are still quite abundant. Other shrubs are the basora (*Varronia angustifolia* West), the escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.) and the escambrón blanco (*Volkameria aculeata* L.). The most conspicuous small trees are the flor de mayo (*Parkinsonia aculeata* L.), the mesquite (*Prosopis juliflora* (Sw.) DC.), and the bucar (*Bucida Buceras* L.). The xerophytic character of this environment is shown by two cacti, the sebucan (*Cephalocereus Royeni* (L.) B. & R.) and the ohulago (*Opuntia repens* Bello), which grows in mats. The plant life of the whole area is a sparse thicket in which herbaceous species occupy most of the surface.

There are a number of interesting small areas of hydrophytic plant life just back of the mangrove swamps between Salinas and Guayama. In this region there is a gradual decrease in salinity of the water from the shore inland and the plant life is arranged in four zones (Fig. 60) which are irregular in width and space relations. As the mangrove builds the land farther into the ocean, it is followed by the fresh-water environment and the accumulation of alluvial deposites which transform the marsh into dry land. The four zones of plant life follow in regular order and represent a successional series similar to that of the Caño de Tiburones (page 64) where the initial stages belong to the halarch series and the following associations to the hydrarch series. Hewever, there is this marked difference: the final stage is the xerophytic bucar (*Bucida Buceras* L.) forest.

The first zone is the mangrove swamp. The second zone is an association of the eneas or cat-tails (*T. angustifolia* L.) which grow in patches and are mixed with the shrubby *Pluchea purpurascens* (Sw.) DC. and the viney *Vigna repens* (L.) Kuntze. The soil under the cat-tails is black and shows the effect of decaying vegetable material. Where the cat-tails have been destroyed by pasturing, these mud banks are taken by the herbaceous *Bramia Monnieri* (L.) Drake and the shrubby *Lippia reptans* HBK. The third zone consists of scattered individuals of the shrubby *Pluchea purpurascens* (Sw.) DC., the *Vigna repens* (L.) Kuntze, and dense masses of the sedges *Fimbristylis spadicea* (L.) Vahl, and *Cyperus laevigatus* L. *F. spadicea* is dominant under natural conditions, but when destroyed by grazing animals, *C. laevigatus* becomes abundant and forms a loose sod. The fourth zone occupies the dry ground at the edge of the marsh which was originally occupied by the climax forest. In this fourth zone younger bucar (*B. Buceras* L.) are quite common. The shrubs are represented by aroma casha (*Vachellia Farnesiana* (L.) W. & A.), the basora (*Varronia angustifolia* West), the escambión (*Randia mitis* L.), the viscid mallow (*Bastardia viscosa* (L.) HBK.) and acacia (*Leucaena glauca* (L.) Benth.), which are scattered in the narrow thickets along the fence-rows. The herbaceous plant life is composed mostly of pasture grasses, with occasional mats of *Evolvulus glaber* Spreng. and *Achyranthes polygonoides* (L.) R. Br.

The two hodrophytic areas together present a complete series of associations, including submerged plants, such as *Ceratophyllum demersum*, floating *Pistia stratiotes*, anchored *Castalia ampla*, a marsh association of *Typha angustifolia*, an outer hydrophytic association of *Fimbristylis spadicea* and the climax forest of *Bucida Buceras*. The series may be continuous as in the lagoon at Lajas, or the latter part of it alone may appear and follow the initial stages of the halarch series.

D. The Xerach Series

Subseries a. Beaches and Coastal Thickets.

We have already called attention to the fact that sand dunes are very poorly developed along the south coast of Porto Rico. However, there are many places where the configuration of the shore has favored the building of sand beaches and a few points where small stones have been carried down by the river during periods of flood and built up into small stretches of shingle beach. We have not attempted to analyze the physical conditions accompanying the formation of these two types of beach but it is worthy of note that they may border on the open water of the Caribbean Sea or be separated from the sea by a zone of mangroves or salt flats. In most cases they lie in front of an area of alluvial land, and their plant life shows a transition to the north both geographically and successionally, into the climax forests of *Bucida buceras* L. In other cases, beaches have been formed along rocky limestones or shale shores and the plant life lies in direct but non-successional contact with the xerophytic forests described below under Subseries b (page 106). Again, as at Boquerón, beaches have been formed in front of tidal marshes, which have been developed into mangrove forests. In all cases, their plant life resembles the corresponding associations of the north shore, but is marked by the presence of many species which are of xerophytic character.

The pioneer plant life which first appears on the upper beach consists of scattered trailing plants of bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.) and the mata de playa (*Canavali maritima* (Aubl.) Thou.), creeping rhizomes with small leafy tufts of the common shore grass matojo de playa (*Sporobolus virginicus* (L.) Kunth), young plants of the shrubby escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.), the shrubby aroma casha (*Vachellia Farnesiana* (L.) Wight & Arn.) the flor de todo el año (*Catharanthus roseus* (L.) Don), and a few other species. All of the above species are small and depauperate and are frequenty destroyed by wave action. Occasionally small mats of tuna brava (*Opuntia Dillenii* Ker-Gawl.) Haw.), and ohulago (*O. repens* Bello), are developed from joints that are washed down from the thickets above and are left stranded on the upper beach. All of these plants have a temporary existence, are destroyed by waves and replaced by new growths. The plant life of this zone is subject to great variations in density of species from one beach to another.

On the sands or gravels of maritime origin which lie above the upper beach we find the beach thickets. This zone varies in width with the beach deposites and is sometimes as much as 200 meters wide. On its northern or landward margin, the soil changes to one of alluvial deposits and the plant life merges into the climax bucar forest. This narrow strip has but little agricultural value but it gives spaces for homes for many people and the thickets provide a poor pasture for cattle, goats and pigs. As a result of the pasturing, the growth of thorny or otherwise inedible species is favored, and the thickets are largely composed of such plants.

Among the more common species of trees are the guayacán or lignum vitae (*Guiacum officinale* L.) which attained a height of 10 meters and has a broad, spreading crown with dark-green foliage, the corcho (*Torrubia fragans* (Dum.-Cours.) Standley), and *Pisonia albida* (Heimerl.) Britton which are about equally tall. The cucubano (*Coccolobis laurifolia* Jacq.) is cut repeatedly for fuel at a height of 5 meters. The bucar (*Bucida Buceras* L.) is also quite common. The most abundant shrubs are the thorny species, such as the aroma casha (*Vachellia Farnesiana* (L.) W. & A.), the jugo (*Rochefortia acanthophora* (DC.) Griseb.), the escambrón (*Randia mitis* L.), the arboreous *Bumelia obovata* (Lam.) A. DC. and *Argythamnia candicans* Sw.; but the most abundant of all is the escambrón colorado (*Pithecellobium Unguis-cati* (Mart.) DC.). The thornless shrubs are the bejuco inglés (*Capparis cynophallophora* L.), the palo de burro (*C. flexuosa* L.), the bejuco de palma (*Trichostigma octandrum* (L.) H. Walt.) and the arborescent prieto (*Tabebuia heterophylla* (DC.) Britton).

One of the conspicuous features of the plant life is the large number of suculent plants such as the sebucan (*Cephalocereus Royeni* (L.) B. & R.) which reaches a height of 5 meters and the sebucan (*Leptocereus quadricostatus* (Bello) B. & R.) which is two or three meters high and widely spreading; the tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.) which is abundant and grows in mats; the ohulaga (*O. repens* Bello.) which is small, prostrate, and abundant and readily distributed by its fragile joints which are broken off and scattered far and wide by the animals; the maya (*Bromelia pinguin* L.) and the corita (*Agave missionum* Trel.) which is made conspicuous by its tall flower-stalks and clusters or orange-colored flowers.

The vines are represented by the liana uñada (*Batocydia Unguis* (L.) Mart.), the pega palo (*Distictis lactiflora* (Vahl.) D. C.,) the bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.), *Stigmaphyllon lingulatum* (Poir.) Small, and *Banisteria purpurea* L. The shore grass matojo de playa (*Sporobolus virginicus* (L.) Kunth) persists for only a short distance from the shore. The most common species in the true thickets are the pega pollo (*Commicarpus scandens* (L.) Standley), the berenjena de playa (*Solanum persicifolium* Dunal) and the peronia (*Abrus Abrus* (L.) W. F. Wight).

As the sandy beaches become covered to a greater and greater depth by the alluvial deposits from the north, the thicket association is succeeded by the climax bucar (*B. Buceras*) forest. However, this succession may be indefinitely delayed as a result of some of the beaches lying higher than alluvial plains, in which case the fully developed thicket is probably similar to the forest of the limestone coastal hills.

Subseries b. The Coastal Hills

1. GENERAL

The coastal hills of the southern side of Porto Rico fall into two geological series. an older of Cretaceous and a younger of Tertiary origin. The former underlies all the hills between the Ponce limestone and the central mountain mass and consists of tuffs and shales which are of volcanic origin and were deposited under waters of the Cretaceous ocean, and of small beds of limestone which were deposited in clear water during periods of volcanic inactivity. The amount of limestone is small but most conspicuous in outcrops in the hills between Juana Díaz and Villalba. We regret that the limited time available for this work made it impossible for us to study the flora of this region. The Ponce limestone represents the latter and is deposited mostly near the present shore from Ponce west to Ensenada.

The shales and tuffs are calcerous in nature and the hills formed by them are usually weathered into a thin soil full of fragments of rock. On the limestones, the formation of a soil by weathering has been very much limited and great surfaces of bare bed-rock are exposed. The plant life of the hills has mostly been destroyed or very much modified by cutting, pasturing, and to some extent by agriculture, and persists in relatively good condition only on the very arid and sterile hills of the Ponce formation, especially in the Guánica Insular Forest.

Just west of Yauco, there is a small isolated area characterized by serpentine rock and near Maunabo at the eastern end of this district the igneous rock comes down to the water's edge. The plant life of these two areas, at this time, does not differ materially from that of the Ponce limestone. Therefore, we will first give a description of the plant life of the Ponce formation in the Guánica Insular Forest, where it is preserved in its most nearly natural condition, and later make comparisons with the plant life on the shales, serpentines and tuffs in other parts of the region.

2. THE XEROPHYTIC FOREST OF THE PONCE LIMESTONE

The Ponce limestone occupies a narrow crescent-shaped area extending from Juana Díaz west and southwest to the shore of Guánica harbor. The northering boundary may be marked approximately by a line running about three kilometers north of Ponce, one kilometer south of Peñuelas and Yauco from which point it turns to the southwest. The same limestone also occupies the peninsula on the west side of Guánica harbor, with a length of 6 kilometers from east to west. It again appears northeast of Cape Rojo, and forms a belt along the shore about 8 kilometers long by 2.5 kilometers wide. It comes down to the sea in steep hills and promontories in the last two areas, also between Guánica harbor and Guayanilla bay, and again in a few places between Guayanilla and Ponce. Its widest development is between Guánica and Guayanilla and west of Ponce.

The general topography of this region is that of rolling hills rising to a height of 150 meters (500 feet) above sea level, usually with long, gentle slopes and few cliffs. These few cliffs and other rock exposures are due to the interpolation of harder strata in the softer limestone. The white or pale yellowish-gray limestone is heavily eroded and pitted into numerous pockets and crevices. Many large blocks of stones are completely separated from the solid, underlying rock, and emit a metallic ring under foot. Ravines and canyons are poorly developed and the drainage is mostly by percolation. A little coarse soil is collected in pits and crevices but large areas of bare flat rock are exposed. Humus has not been formed but in many places the surface is covered by a thin layer of dried leaves and twigs.

The climate of this region is the most arid of any part of Porto Rico and its xerophytic nature is intensified by the general absence of soil, so that the surface dries very quickly following every rain. Tree growth is possible only by the penetration of the roots into the deeper fissures in the rock. The scanty growth of taller plants intercepts very little sunlight and shade-loving plants are absent. Full exposure to the wind increases transpiration and emphasizes the xerophytic nature of the environment, but the physical effect of the wind is of little importance. One-sided trees are not common, even on slopes facing the ocean, but they do occur on the larger capes and promontories, as at La Parguera and south of Ensenada.

The hills of Ponce limestones that are not used for agriculture, are covered with a thin forest and a dense growth of microphyllous shrubs and practically no herbs (Fig. 61). During the dry season the general appearance is that of a low, rather crowded thicket about 2 to 4 meters is height, in which a majority of the shrubs are either leafless or with persistent leaves which are brown and curled by long droughts. Projecting above this growth are many almácigo trees (*Elaphrium simaruba* (L.) Rose) with their wide branches, rounded tops and red, glistening bark, and a less number of bucar (*B. buceras* L.) trees with their dense crowns. There are also a considerable number of bejuco inglés (*Capparis cynophallophora* L.), jagüey (*Ficus laevigata* Vahl.), *Amyris elemifera* L. and *Pisonia albida* (Heimerl.) Britton. The guayacán or lignum vitae (*Guiacum officinale* L.) and prieto (*Tabebuia heterophylla* (DC) Britton) are rare. The almácigo (*E. simaruba* (L.) Rose) is undoubtedly the

the most common tree and forms the ground work of the arborescent vegetation, in which the less abundant trees of other species form isolated spots of green. The sebucan or dildo (*Cephalocereus Royeni* (L.) B. & R.) is very abundant growing to a height of 8 meters and adding to the xerophytic aspect of the plant life.

The shrub layer is made up of a great many species, of which Santa María (*Lantana involucrata* L.), cucubano (*Coccolobis laurifolia* Jacq.), and huevo de gato (*Helicteres jamaicensis* Jacq.) appear to be the most abundant. Other common species are bertonica afelfada (*Moluchia tomentosa* (L.) Britton), adormida (*Croton rigidus* (Muell. Arg.) Britton) fire bush (*C. lucidus* L.) cuero de sapo (*Exostema caribaeum* (Jacq.) R. & S.), basora (*Varronia angustifolia* West.), escambrón colorado (*Pithecellobium unguis-cati* (L.) Mart.), cotorra (*Ricinella ricinella* (L.) Britton), granadillo (*Eugenia lingustrina* (Sw.) Willd.) arguilo (*E. buxifolia* (Sw.) Willd.), jibo (*Schaefferia frutescens* Jacq.), chicharrón (*Reynosia uncinata* Urban), bálsamo (*Citharexylum fruticosum* L.), alelí cimarrón (*Plumiera alba* L.), bariaco (*Krugiodendron ferreum* (Vahl.) Urban), coscorrán (*Elaeodendrum xylocarpum* (Vent.) DC.), guao (*Comocladia dodonaea* (L.) Urban), barbasco (*Canella winterana* (L.) Gaertn.), *Salvia sessiliflora* (Sw.) Willd., *Hypelate trifoliata* Sw., *Samyda dodecandra* Jacq. *Adelia Bernardia* L., *Jacquinia Berterii* Spreng., and *Tournefortia microphylla* Bert. Most of these shrubs are without leaves during the dry season, but when the leaves are present they are usually small, rounded, leathery and dark green. Leafy plants stand is sharp contrast with the prevailing brown or gray color which is characteristic of most of this vegetation.

The cacti are represented by large specimens of the two sebucans or dildos (*Cephalocereus Royeni* (L.) B. & R. and *Leptocereus quadricostatus* (Bello) B. & R.) which are abundant and 3 or 4 meters in height; also by great mats of tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.) which are less conspicuous but equally abundant and by ohulago (*Opuntia repens* Bello) which covers some places. The less common plants are pitajaya (*Hylocereus trigonus* (Haw.) Safford) which hang from the larger trees and many colonies of the conspicuous melón de costa (*Cactus intortus* Mill.) attaining height of 6 decimeters. The corita (*Agave missionum* Trel.) with its flowering stems about 6 meters in height is one of the striking features of the landscape.

The vines are represented by a few individuals, such as the bejuco de costillo (*Serjania polyphylla* (L.) Radlk.) which appears to be the most abundant, the dunguey (*Smilax coriacea* Spreng.)

and the gungulén (*Vanilla Eggersii* Rolfe). The epiphytic nidos de gungulén (*Tillandsia recurvata* L.) is very abundant and green bunches of pata de gallina (*Phoradendron chrysocarpum* Krug & Urban) are occasional. There are very few herbaceous plants during the dry season, but small plants of *Portulaca halimoides* L. and yerba de pollo (*P. quadrifida* L.) can be found growing in small pockets in the rocks. There are also a few grass plants (*Uniola virgata* (Poir) Griseb) and isolated plants and small colonies of *Zamia portoricensis* Urban are scattered over hill tops.

Our study of this region was made in April when the only blooming plant was the single specimen of the purple-flowered leguminous shrub, the retama (*Corynella pauciflora* DC.). It appears that the many plants which were leafless at the time of our visit, put forth their new leaves and that many herbs become more or less prominent during periods of rainy weather.

The plant life which we have just described occupies the hill tops and upper slopes. About halfway down the southern slope towards the ocean, and at an altitude of about 80 meters (250 feet) lies a narrow zone characterized by a very remarkable development of epiphytes, The shrub flora is less developed but represented by the same species as are found on the hill tops. The bucar (*B. buceras* L.), the almácigo (*E. simaruba* (L.) Rose), the bejuco inglés (*Capparis cynophallophora* L.), and the tea (*Amyris elemifera* L.) are the most common trees. Many of the larger bucar trees branch from the base and in some cases the large basal limbs lie on the ground. The alelí cimarrón (*Plumiera alba* L.) attains a height of 6 to 8 meters and the freely branching cupey de altura (*Clusia Gundlachii* Stahl.) attains a height of 5 meters and forms a thicket of tough, inflexible stems and twigs. The same six species of cacti previously referred to are present and larger. The melón de costa (*Cactus intortus* Mill.) is represented by hundreds of plants; mats of tuna brava (*Opuntia Dillenii* (Ker-Gawl.) Haw.) grow several meters in diameter and 2 meters in height; while the sebucan (*Cephalocereus Royeni* (L.) Britton & Rose) attain a height of 10 meters. All trees and the larger cacti are drapped with barbas de ucar (*Dendropogon usneoides* (L.) Raf.) forming festoons a meter or more in length and growing so luxuriantly as to almost conceal the branches and in some cases they appear to injure the plants on which they grow. In fact, this growth of barbas de ucar is so dense that visibility seldom extends beyond 10 meters in any direction and under some of the low branching bucar trees is even less. The nidos de gungulén (*Tillandsia recurvata* L.) and a sterile bromeliad are very abundant on all trees. The larger cacti, and the epiphytic cactus pitajaya (*Hylocereus trigonus* (Haw.) Safford) are common, while masses of fallen bromeliads almost cover the ground in some places. Even the orchid (*Encyclia papilionacea* (Vahl) Schechter) is epiphytic on the cacti. We have no theories as to the possible environment conditions determining the location of this remarkable zone of epiphytes, except that it may possibly be due to atmospheric conditions. The arborescent flora is the same as that found at higher levels and the smaller number of shrubs may be due to the dense shade cast by the trees and their loads of epiphytes. The belt is said to extend along the hillside at the same level for a considerable distance, although its width probably does not exceed 10 meters in altitude.

Below this belt of epiphytes, the plant life has the same specific composition and general appearance as on the hill tops. The guao (*Comocladia Dodonaea* (L.) Urban) becomes very common, while other common species are manto or maravedí (*Rhacoma crossopetalum* L.), lirio (*Strumpfia maritima* Jacq.) and *Krameria Ixina* L. These and other species common to this locality come down almost to sea level and are separated from the water by a very narrow rocky beach, full of rocky fragments. The common plants of this beach are barilla (*Batis maritima* L.), bejuco de playa (*Ipomoea Pes-caprae* (L.) Roth.), and mangle blanco (*Laguncularia racemosa* (L.) Gaertn.) which grow adjacent to the bucar, sebucan and guao. There is no successional relation between them, and will not be unless a future change in elevation brings about a readjustment of the boundary.

In most other places, the plant life of the Ponce limestone has been partly destroyed by cutting and consists almost entirely of shrubs. Good examples of this shrubby growth may be seen along the shore road from Ponce to Guayanilla. Additional species observed here and which no doubt grow in parts of the Guánica forest are *Catesbaea paviflora*, Sw., lechecillo (*Croton discolor* Willd.), *Stenostomum acutatum* DC., *Bumelia Krugii* Pierre, *Turnera diffusa* Wild., and *Osmia sinuata* (Lam.) B. & W., the viney *Stigmaphyllon lingulatum* (Poir) Small., the orchid (*Tetramicra elegans* (Hamilt.) Cogn.) and the grass *Uniola virgata* (Poir) Griseb. On the hills south of Ensenada, the corita (*Agave missionum* Trel,) is very abundant.

3. THE VEGETATION OF THE SHALE HILLS

These shale hills form a belt about 2 kilometers wide extending from near Ensenada at the east to the coast south of Boquerón and have an average height of about 150 meters (500 feet). The sides are steep or gently sloping, with little exposed bedrock. The soil is thin, hard, coarse in textures and mixed with numerous fragments of rock. On a few of them the original plant life is in fairly good condition and essentially the same as in the Guánica Forest but in most cases trees and the shrubs have been removed in order to make pasture.

The trees on these hills are rarely more than 10 or 15 meters in height (Fig. 62). The bucar (*Bucida buceras* L.) is much more abundant than any other species. Others that should be mentioned as common are retama (*Trichilia hirta* L.), carubia (*Xanthoxylum monophyllum* (Lam.) P. Wilson), guácima (*Guazuma guazuma* (L.) Cockerell), guayacán or lignum vitae (*Guaiacum officinale* L.), hediondilla (*Leucaena glauca* (L.) Benth.), tea (*Amyris elemifera* L.) and cucubano *Coccolobis laurifolia* Jacq.). The abundant growth of shrubs includes cotorra (*Ricinella ricinella* (L.) Britton), guao (*Comocladia dodonaea* (L.) Urban), algodón de seda (*Calotropis procera* (Ait.) R. Br.), palo de vaca (*Bourreria succulenta* Jacq,), espejuelo (*Sarcomphalus reticulatus* (Vahl.) Urban), huevo de gato (*Helicteres jamaicensis* Jacq.), escambrón colorado (*Pithecellobium Unguis-cati* L.), palo de burro (*Capparis coccolobifolia* Mart.) roseta (*Machaonia portoricensis* Baill.) yaiti (*Gymnanthes lucida* Sw.), jiba (*Schaefferia frutescens* Jacq.), *Jacquinia Berterii* Spreng., *Rondeletia pilosa* Sac., *Thyana portoricensis* (Radlk.) Britton, and *Stenostomum lucidum* (Sw.) Gaertn.

There are very few cacti under the shade of the shrubs or forests, probably due to lack of light, but they are abundant on the adjacent hills, where the trees and shrubs have been removed. The melón de costa (*Cactus intortus* Mill.) grows in colonies that are sometimes conspicuous at a distance and the ohulaga (*Opuntia repens* Bello) becomes a serious pest in the pastures. The larger species of *Cephalocereus* and *Leptocereus* are rare. The nidos de gungulén (*Tillandsia recurvata* L.) is abundant everywhere and the barbas de ucar (*Dendropogon usneoides* (L.) Raf.) is well developed on the bucar trees (Fig. 63) in the sheltered valleys. Herbaceous species are rare in the thickets.

Plant life of the type just described occupies all of the north side of the coastal range of hills as seen from the road between Ensenada and Lajas. A few of the hillsides still have a few forest trees, more have been reduced to shrubby thickets and may have been cleared and replaced by pasture with a few scattered bucar trees. The same plant life also occupies the uncultivated hills of the Lajas range from Boquerón east almost to Yauco. Over this entire area, there is a dense population and much of the land is used for agriculture, while the remainder has been cut over repeatedly for fuel. As a result, the arborescent growth is represented by a few small trees while many introduced weeds have come in. On one of these hills south of Lajas, the most common shrubby species are: cafeíllo (*Casearia guianensis* (Aubl.) Urban) which grows two to four meters in height, cariaquillo (*Lantana camara* L.) and the escambrón (*Randia mitis* L.). The trees are small and include the following species: almácigo (*Elaphrium simaruba* (L.) Rose), cupey (*Clusia rosea* Jacq.), jaguey (*Ficus laevigata* Vahl.), cenizo (*Zanthoxylum caribaeum* Lam,) and *Z. monophyllum* (Lam.) P. Vilson. Other common shrubs are basora (*Varronia angustifolia* West.), caracolillo (*Casearia decandra* Jacq.), galán del monte (*Cestrum laurifolium* L'Her.(acacia pálada (*Leucaena glauca* (L.) Benth.), higuillo (*Piper aduncum* L.), guava blanca (*Cupania Americana* L.) and *Psychotria undata* Jacq. The desmanto (*Acuan virgatum* (L.) Medic.), a thorny, scrambling plant is common. There are no cacti. The influence of man on the plant life is shown by the irregularity in size of the trees and shrubs, the frequent coppice growths and the many herbaceous weeds.

Lajas stands at the northern boundary of the xerophytic region and several plants of mesophytic tendences appear on the hills in the vicinity. The presence of the cupey (*C. rosea*) and the absence of cacti is significant of this transition in the plant life near this place.

On a hill a few kilometers west of Yauco, geologically similar to the preceding, but away from the proximity of a mesophytic environment, the arborescent species include the almácigo (*Elaphrium simaruba* (L.) Rose), the palo anastacia (*Trichilia hirta* L.), and only a few bucar (*B. buceras*) trees which are always the first to be removed from these hills. The most common shrubs are cariaquillo (*Lantana Camara* L.), escambrón colorado (*Pithecellobium unguis-cati* (L.) Mart.). Other common shrubs are tachuelo (*Pictetia aculeata* (Vahl.) Urban), cuero de sapo (*Exostema caribaeum* (Jacq.) R. & S.), ceboruquillo (*Thyana striata* (Radlk.) Britton). jiba (*Schaefferia frutescens* Jacq.), adormida (*Croton rigidus* (Muell Arg.) Britton), *Stenostomum lucidum* (Sw.) Gaertn. f., *Guettarda elliptica* Sw. and *Forestiera segregata* (Jacq.) Krug and Urban. The vines such as bejuco de costilla (*Serjania polyphylla* (L.) Radlk.), liana uñada (*Batocydia unguis* (L.) Mart.), and desmanto (*Acuan virgatum* (L.) Medic.) are well distributed. The nidos de gungulén (*Tillandsia recurvatum* L.) is abundant; *Zamia portoricensis* Urban and sebucan *Cephalocereus Royeni* (L.) B. & R. are present. This hill has not been pastured but the best trees have been removed. The shrubs show a great similarity to those of the Ponce limestone. (Figs. 64, 65).

4. VEGETATION OF THE SERPENTINE HILLS

The Geological Survey of the Ponce district mentions two small serpentine outcrops: one in the coastal range of hills west of La Parguera and one a few kilometers west of Yauco. Our studies were confined to the latter. The serpentine at this point underlies a low, rounded hill which was originally covered with forest, but which has been cut over repeatedly and used for pasture with the usual effects on the plant life. The few remaining trees are mostly bucar (*Bucida Buceras* L.) and almácigo (*Elaphrium Simaruba* (L.) Rose). The most abundant vegetation at this time consists of thickets of cacti and shrubs; and almost every species found here was also found on the Ponce limestones or shales of the vicinity. The most common cacti are the two sebucans (*Cephalocerus Royeni* (L.) B. & R. and *Leptocereus quadricostatus* (Bello) B. & R. (Fig. 64), the tuna brava (*Opuntia Dilenii* (Ker-Gawl.) Haw.), the ohulaga (*O. repens* Bello) and the melón de costa (*Cactus intortus* Mill.) Fig. 65). Other plants with well developed water-storage structures are the corita (*Agave missonum* Trel.), the alelí cimarrón (*Plumiera alba* L.), the maya (*Bromelia pinguin* L.) and the shrubby *Pedilanthus angustifolius* Poir. The most common shrubs are the roble de colorado (*Tabebuia haemantha* (Bert.) DC.) escambrón colorado (*Pithecellobium Unguis-cati* (L.) Mart.), guao (*Comocladia Dodonaea* (L.) Urban), adormida (*Croton rigidus* (Muell. Arg.) Britton, roseta (*Machaonia portoricensis* Baill.), granadilla (*Eugenia ligustrina* Willd.), guayabacoa (*Rheedia acuminata* (Spreng.) Tr. & Pl.) and *Jacquinia Berterii* Spreng. The vines and epiphytes are represented by pega palo (*Distictis lactiflora* (Vahl.) DC.), pitajaya (*Hylocereus trigonus* (Haw.) Safford) and *Banisteria purpurea* L., *Osmia sinuata* (Lam.) B. & W. None of these have been noted by Britton and Wilson as characteristic of the serpentine rocks and we are of the opinion that serpentine is of little or no importance as an environmental factor in this part of the Island.

5. THE VEGETATION OF THE CAPE MALA PASCUA

We did not examine the plant life of the outcrops of the Yabucoa Point, respectively south and east of Maunabo at the southeastern corner of the Island; but the Cretaceous tufts which appear in the same region bear the usual xerophytic vegetation, with some differences in specific composition due to distance.

The promontory of Cape Mala Pascua (Fig. 66) descends abruptly to the sea from a height of nearly 200 meters (600 feet). Most of the forest has been removed but the remaining fragments indicate that the dominant trees were probably bucar (*Bucida bùceras* L.), guácima (*Guazuma guazuma* (L.) Cockerell). palo anasta cia (*Trichilia hirta* L.), jaguey (*Ficus laevigata* Vahl.), corcho (*Pisonia subcordata* Sw.), carubio (*Zanthoxylum monophyllum* (Lam.) P. Wilson), ceiba (*Ceiba pentandra* (L.) Gaertn.). The most common shrubs are cafeíllo (*Casearia guianensis* (Aubl.) Urban) which grows in almost pure stands; cotorra (*Ricinella ricinella* (L.) Britton) which grows in dense masses and to a height of 6 meters; escambrón (*Randia mitis* L.) which grows to a height of 2 meters and *Psychotria pinularis* Seese & Moc. which grows in matted thickets to a height of 1.5 meters and shows the effects of the wind. Acacia palada (*Leucaena glauca* (L.) Benth. grows abundantly along roads. Other shrubs worthy of mention are prieta (*Tabebuia heterophylla* (DC.) Britton), bejuco de palma (*Trichostigma octandum* (L.) H. Walt.), bálsamo (*Citharexylum fructicosum* L.), palo de burro (*Capparis flexuosa* L.), roble guayo (*Bourreria succulenta* Jacq.) and bariaco (*Krugiodendron ferreum* (Vahl.) Urban). All of the above have been mentioned previously in connection with other developments of this same association and are sufficient to show the general uniformity of this xerophytic type across the full length of the southern shore. An interesting feature of this promontory is the presence of San Bartolomone (*Sebesten rickseckeri* (Mills.) Britton) which is 2 or 3 meters in height and has snowy red flowers and very thick rough leaves, and also the shrubby *Malphighia Shaferi* B. & W. with leaves which are covered on the lower surface with appressed easily detached stinging hairs. The former has been known only from Vieques, Culebra, St. Thomas and Tortola; the latter has therefore been considered endemic to Vieques.

Intertwined with the above shrubs we find many vines such as the true zarza (*Acacia riparia* HBK.) reaching a diameter of 5 centimeters; the smaller bejuco de costilla (*Serjania polyphylla* (L.) Radlk.), *Banisteria purpurea* L., *Stigmaphyllon lingulatum* (Poir) Small, and *Gouania lupuloides* (L.) Urban. Cattle avoid the steeper parts of the hillsides which permits the growth of many shrubs and herbs such as *Justicia periplocifolia* Jacq., *J. sessilia* Jacq. *Hyptis* *pectinata* (L.) Poir), and *Dolicholus reticulatus* (Sw.) Millsp. The presence of a single plant of cupey (*Clusia rosea* Jacq.) indicates the proximity of the more mesophytic conditions.

6. GENERAL RELATIONS AND SUCCESSIONS

The preceding description is based on a study of seven separate areas of xerophytic forest or thicket, extending over more than a hundred kilometers of space. In five of these the plant life has been very much modified by man, in one there is somewhat less modification and in one, the Guánica Insular Forest, it is in practically natural conditions. Therefore, it cannot be expected that the flora of the seven areas should show a great degree of homogenity. The number of species noted by us as reasonably common and of ecological importance in these areas ranges from 18 on the Ponce limestone near Tallaboa east of Guayanilla Harbor to 63 in the Guánica Insular Forest. The species noted from a single area only range from 4 on the shale hill to 34 on the promontory south of Maunabo. They constitute 59 per cent of the whole at Maunabo, due to isolation and the proximity of the mesophytic forest of the mountains, and in the other six areas vary from 17 to 30 per cent. The other species of each area, vary from 13 to 44 in number, appear also in other places, and the community coefficient between any two areas averages 11 per cent. It is lowest between the comparatively close areas of La Parguera and Tallaboa and greatest between Guánica Insular Forest and the serpentine hill at Yauco, in which the underlying rock is quite different. The coefficients between the isolated area at Maunabo and the other six average 9 per cent, showing that the large number of peculiar species in that isolated locality is after all of little geographic significance. We are, therefore, led to the conclusion that under natural conditions all of these rocky hills of the southern coast were populated by essentially the same type of vegetation, that the discrepancies which then occurred were caused primarily by geographic isolation and by proximity to or distance from a more mesophytic environment, and that the present differences are caused by clearing and pasturing.

The xerophytic character of the environment is clearly shown by the prevailing form and habit of the plants. Tropophilous species are abundant dropping their leaves during the dry season and producing a new crop with the beginning of the rains. The habit is well illustrated by many of the shrubs and especially by a great number of characteristic trees of almácigo (*Elaphrium simaruba* (L.) Rose). The low rainfall, the irregularity of the rains and the low-water-holding capacity the stony soil probably explains the relatively small number of water-storage plants which are well illustrated by the cacti, corita (*Agave missionum* Trel.), bruja (*Bryophyllum pinnatum* (Lam.) Kurz) and *Portulaca quadrifida* L. The majority of the species are well adapted to the arid conditions by their small, thick, leathery leaves. An anatomical study of such species would probably show many interesting devices to reduce the loss of water.

The dominant trees arranged in order of their importance are the almácigo (*Elaphrium Simaruba* (L.) Rose), bucar (*Bucida buceras* L.), tea (*Amyris elemifera* L.) and *Pisonia albida* (Heimerl.) Britton. Other common species of this association are the roble guayo (*Bourreria succulenta* Jacq.), the sebucan (*Cephalocereus Royeni* (L.) B. & R.), the cucubano (*Coccolobis laurifolia* Jacq.), bálsamo (*Citharexylum fruticosum* L.), guayacán (*Guiacum officinale* L.), espejuelo (*Krugiodendron ferreum* (Vahl.) Urban), cotorra (*Ricinella ricinella* (L.) Britton, jiba (*Schaefferia frutescens* Jacq.), palo anastacia (*Trichilia hirta* L.) and carubia (*Zanthoxylum monophyllum* (Lam.) P. Wilson.

The association is now in a state of temporary climax and no successional processes are actively in progress. Erosion is proceeding at a very slow rate. Unless other agencies supervene the hills will be reduced to a base level and the present plant life followed by the climax bucar (*B. buceras* L.) forest of the lowlands.

7. THE SEMI-MESOPHYTIC VEGETATION OF THE SAN GERMAN LIMESTONE

We have already called attention to the region of copious rainfall which extends south of Mayagüez along the west coast of the Island, so that a part of the coastal plain from Cabo Rojo east almost to Sabana Grande is characterized by a mesophytic vegetation, and various species have been able to establish themselves here and there among the xerophytes of the neighboring hills. Almost all of the mesophytic area is now under cultivation and the natural plant life is chiefly confined to narrow canyons and steeper hillsides. Even these hillsides are very generally used for pasture and the best illustration of the normal plant life occurs on some of the hills of San Germán limestone between the towns of San Germán and Lajas. These hills are unusually steep with many exposed ledges and vertical cliffs. The limestone is white in color, broken into numerous fragments, and very much eroded into pits, sharp points and knife-like edges. Its general appearance is very similar to the mogote or hay-stack hills of the north coast. The soil, above the talus slopes at the base, is restricted to thin deposites in the crevices and on the ledges.

The plant life, is similar in its general features, to that of the xerophytic hills of tuffs and shales in the same vicinity and already described (Fig. 68). The almácigo (*Elaphrium Simuraba* (L.) Rose), is the most common tree and grows in abundance over the upper slopes and tops of the hills. It is usually heavily infested with nidos de gungulén (*Tillandsia recurvata* L.). The bucar (*Bucida buceras* L.) is second in abundance. Beneath these trees is a loose thicket of various xerophytic shrubs, including the jiba (*Schaefferia frutescens* Jacq.), palo de burro (*Capparis flexuosa* L.), bariaco (*Krugiodendron ferreum* (Vahl), Urban), cotorra (*Ricinella Ricinella* (L.) Britton), cucubano (*Coccolobis laurifolia* Jacq.), cupey de altura (*Clusia Gundlachii* Stahl.), and *Zamia portoricensis* Urban (Fig. 69).

The effects of the mesophytic climate is shown by the presence of certain other species which are common on the mogotes or haysstack hills of the north shore, some of which were not noted by us in any other locality on the south side of the Island. The most conspicuous are the llume palm (*Gaussia attenuata* (Cook) Beccari which is common on the tops of the hills and in the thinner soils. Other species of this category are cupey (*Clusia rosea* Jacq), gungulén (*Vanilla Eggersii* Rolfe), flor de culebra (*Anthurium acaule* (Jacq.) Schott.) the shrub (*Curcas hernandifolius* (Vent.) Britton) and the pitajaya (*Hylocereus trigonus* (Haw.) Safford).

E. The Vegetation of the Lower Mountain Slopes

The abrupt transition between the mesophytic plant life of the central mountain region and the semi-xerophytic plant life of the lower slopes of the south side have already been mentioned (page 92). A short distance south of the water shed which extends the length of the Island, the whole aspect of the country changes. Along the upper part of this water shed, the plant life is primarily forest, either in fact or in superficial appearance; while below, it consists of grass-covered hillsides (Fig. 66) with many scattered trees and narrow strips of shrubs and trees along the bottoms of the valleys. The hills have sweeping, rounded contours and are separated by narrow valleys of the steep gradient. The plant life of these hills is brown during the dry season, except for the mango trees which retain their dark-green color. At this season the general aspect of the landscape is very similar to the summer appearance of parts of

California. The charm of the broad panoramas is enhanced by the open park-like country, and the views from any of the many highways are among the finest in Porto Rico.

From a botanical standpoint, the country is not so satisfactory. Originally this region was probably covered by relatively thin, open forest, which has been completely destroyed, so that neither characteristic species nor associational boundaries can be determined with accuracy. Most of the land is in pasture with some few small tracts under cultivation. The original native vegetation is restricted to the roadsides and to narrow zones of trees and shrubs which spring up along the beds of the streams and arroyos. In a few places, these zones broaden out into thickets or small groves, but they are always composed of second-growth trees of small size and cannot be be considered fair examples of the original normal plant life of the Island.

Along the Cayey–Guayama road, the transition from mesophytic to a xerophytic plant life is mostly accomplished within three or four meters. The zone of transition lies chiefly between altitudes of 300 and 500 meters (1,000 and 1,600 feet) and xerophytic plant life is fully established below 300 meters (1,000 feet). The character of this transition, and its relation to ridges and canyons, have been discussed in our treatment of the mesophytic forest of the mountain (page 92) and needs no repetition.

The most common trees of this region are those which have been conserved for their fruits, for shade, for living fence posts or for other uses when mature. They are the bucar (*Bucida buceras* L.), guácima (*Guazuma guazuma* (L.) Cockerell), almácigo (*Elaphrium simaruba* (L.) Rose), corazón (*Annona reticulata* L.), higuero (*Crescentia cujete* L.) ceiba petandra (L.) Gaertn.), and the mango (*Mangifera indica* L.). Other species of secondary abundance are the algarroba (*Hymenaea Courbaril* L.), acacia pálida (*Leucaena glauca* (L.) Benth.), Campeche or logwood (*Haematoxylon campechianum* L.), palo anastacia (*Trichilia hirta* L.), flor de mayo (*Parkinsonia aculeata* L.), flamboyant blanco (*Bauhinia monandra* Kurz.), moca (*Andira inermis* HBK), calambreña (*coccolobis venosa* L.) and caimito de perro (*Chrysophyllum pauciflorum* Lam.). The rare endemic tree known locally as palo de tortuga (*Phlebotaenia Cowellii* Britton) is more abundant in this region than elesewhere in Porto Rico.

A large number of shrubs grow along the roadside, the most abundant being the basora (*Varronia angustifolia* West.), maíz pelado (*Comocladia Dodonaea* (L.) Urban), cotorra (*Ricinella ricinella* (L.) Britton), bálsamo (*Cithrexylum fruticosum* L.), roble colorado (*Tabebuia haemantha* (Bert.) DC.), bejuco de palma (*Trichostigma octandrum* (L.) H. Walt.) tachuelo (*Pictetia aculeata* (Vahl.) Urban), roble guayo (*Bourreria succulenta* Jacq.), escambrón tintillo (*Randia mitis* L.) and *Proustia Krugiana* Urban. Vines are abundant in the thickets and the most common are bejuco de sopla (*Elsota virgata* (Sw.) Kuntze), bejuco de costilla (*Serjania polyphylla* (L.) Radlk.), *Gouiana lipuloides* (L.) Urban and *Stigmaphillon lingulatum* (Poir.) Small. The bicornis (*Andropogon bicornis* L.) is the prevailing native grass on the hillsides. The herbaceous species are mostly weeds, including *Iresine Celosia* L. and bruja (*Bryophyllum pinnatum* (Lam.) Kurz.). The nidos de gungulén (*Tillandsia recurvata* L.) is abundant below and altitude of 300 meters, especially on the bucar (*B. buceras* L.) trees.

A comparison of species listed above with those of the climax forest of the region shows an extraordinary degree of resemblance, and leads to the conclusion that they represent and extension of the bucar (*Bucida buceras* L.) climax association of the foothills. The presence of this type of plant life on the foothills is primarily a matter of aridity, and we have no evidence that the boundary between it and the mesophytic forest above is in process of successional adjustment. It is obvious that continued erosion of the foothills tend to reduce them to a base level and thereby to produce the physiographic climax upon which the plant life is usual and best developed.

F. Summary

The plant life of the south shore is ecologically simple in comparison with that of the northern shore. In a few areas only do the dynamic physiographic processess of beach formation or soil accumulation or humus formation, result in well-marked successional series. These proceed from mangrove swamps, through reduction in water-content and salinity of soil, or from fresh-water lagoons, through reduction in the water supply, to the climax forest. Over most of this region dynamic changes have come nearly or quite to a standstill, and the plant life is in a climax or sub-climax condition. The climax forest, no longer existing in a natural condition, was apparently dominated by *Bucida buceras* L. and occupied the fertile soils of the foothills and the alluvial coastal plains. The sub-climax occupies the arid coastal hills of shale, serpentine and limestone, and is characterized by a group of species in which *Elaphrium* *simuraba* (L.) Rose is most abundant. Throughout this region, the most important environmental factor is water-supply.

THE INFLUENCE OF AGRICULTURE ON THE ORIGINAL PLANT LIFE OF PORTO RICO

It will be readily seen that the plant life of Porto Rico, as it was when the first white settlements were made on the Island, has been greatly modified by activities of man. This was to be expected; man always destroys vegetation in order that he may make use of products of nature and in order that he may utilize the land in accordance with his wishes. If nature has been prolific, man does not stop when his own needs are supplied but usually destroys wantonly, forgetful that a time will come when he will need many products of nature that are no longer available. Porto Rico has been no exception and has suffered from the avaricious and destructive spirit of man.

The conditions are such that Porto Rico has been and probably will remain an agricultural country. Therefore, the removal of the natural growth of plant life has been largely for the supplying of the needs of man and for the purpose of bringing the land under cultivation. Unfortunately, the methods have in many cases been wasteful and the island would be much richer today if some of the natural resources had been conserved. The destruction of the plant life has been so great some of the original plant associations have been completely destroyed while others can be traced only from small remaining fragments. The realization that many of these fragments would soon be removed and this phase of the natural history forever lost, induced the authors to make this survey at this time. We have traced the history of the plant life so far as possible in the short time alloted to the work and have discussed so far as possible its relation to the environmental agencies. It now appears to be worth while to give a brief discussion of the agriculture that has followed this destruction of the products of nature.

The early land policies of Spain appear to have been very liberal. Large grants were made to the grandees and to the soldiers of fortune and small grants of little more than 170 acres to settlers. However, the settlement of Porto Rico was very slow and by 1830 the Spanish Government had disposed of only about one-half of the land of the island. Following that date. There was a rapid increase in population with a corresponding rapid increase in the utilization of the land, so that by 1898, the date of the Spanish

American War, nine-tenths of the remainder had been disposed off in various ways. By the treaty of Paris, Spain ceded to the United States Government, the Crown lands, estimated by Murphy at 147,971 acres, of which 7,400 acres were swamp. Practically all of these lands with some few additional acres, which have reverted in default of taxes, are now owned by the United States and the Insular Governments. The utilization of the lands in 1928, 1900 and 1911 are shown in Fig. 70 which we have adopted from Murphy **(26)**. The fact that in 1828 less than 4 per cent of the area was under cultivation and that in 1900 less than 13 per cent, indicates that the agricultural exports of the Island were very limited. However, the destruction of forests was probably greater than is indicated by the percentage under cultivation or in use for pasture. It appears that the forest was frequently destroyed for growing of crops and that after three or four years, the land was abandoned and new clearings made.

The great increase in population which began early in the nineteenth century naturally led to the removal of the forest over large areas in order that the land might be used for cultivation of crops that were becoming important for export and for the support of the increasing population.

Sugar cane is the most important crop on the Island. It was introduced early in the fifteenth century and has increased with the increase in population. Sugar is now about one-half or possibly a little more of the island export. It grows best on the rich alluvial soils which made necessary the clearings of practically all of the lowlands around the coast and in the valleys, except the swamp areas that were too low for satisfactory drainage (Fig. 71). In recent years sugar cane has been grown extensively on the hills but it is doubtful if the area can be increased to any great extent except by the draining of a few remaining swamps.

Coffee is the crop of second importance and although it is grown to some extent at elevations of not more than 35 meters (100 feet) the great commercial crop is grown on the volcanic soils at elevations ranging from 300 to 800 meters (1,500 to 2,500 feet). The limiting factors appear to be soil, rainfall and wind. The difference in the crop is very noticeable in passing from volcanic to limestone soils. High rainfall is necessary and this limits its production on the south side to the very high elevations and to the moist ravines. Strong winds are injurious and this appears to have been a factor in keeping it from going to higher elevations in the Luquillo Forests and in the vicinity of Jayuya. Coffee is a shade-loving plant and it would at first appear that its cultivation would not necessarily require the removal of the forest. However, it requires an open shade which is furnished by the guaba (*Inga inga*) and the guamá (*I. laurina*) and it grows especially well under these two species. This has resulted in the removal of the major part of the original forests over the regions indicated and the extensive planting of these two species (Fig. 72). In some parts of the Island the plantations have been abandoned, probably as the result of the ravages of root diseases of the coffee, and area gradually reverting to the original conditions.

The cattle industry is quite extensive but not large enough to supply the needs of the Island. It occupies extensive areas of pasture land, much greater in proportion to the value of the industry than any other phase of agriculture. These pasture lands are most extensive in the semi-arid region of the south side of the Island between Guayama and Ponce and between the sea and the line of rainfall near the crest of the central range. There are also rather extensive pasture lands on the north coast west of Arecibo. In other parts of the Island small areas too rough for cultivation are used for pasture and the dairy interest utilizes small areas suitable for other purposes in the vicinity of the cities.

The fruit industry is primarily along the north coast starting a short distance east of San Juan and extending to a short distance west of Arecibo. This industry consists mostly of citrus fruits and pineapple which are grown in the small valleys and over the low hills. The pineapple thrives best in volcanic soil and extends well to the south in the vicinity of Corozal. This crop also thrives on soils of limestone origin provided the lime has been well leached out or provided there is a high humus content. The leaching of the lime and humus accounts for the growing of this crop on the lower parts of the coastal plain. Oranges grow extensively without cultivation over the western part of the Island and pineapples are grown in the vicinity of Lajas. Aguacates, mangos and guavas grow without cultivation throughout the greater part of the island and can be grown extensively when the market makes it profitable to do so. In fact, the growing and preserving of some of these fruits may solve the problem of the more profitable utilization of some of the semi-arid lands of Porto Rico. Coconuts are grown along the coast, the most extensive plantings being around the eastern and western ends of the Island and in favorable locations along the south coast. It is doubtful if this industry can be increased with profit to any great extent. (Fig. 73).

Tobacco is grown most extensively in the Cayey and Juncos valleys, especially the former which is given over almost entirely to this crop. The soil and climate of this region appears to be especially favorable for the growing of this crop although small plantings are to be found in other parts of the Island, especially along the north coast (Fig. 74).

Cotton is a minor crop grown extensively in the regions of low rainfall along the northwest coast and to some extent along the western half of the south coast (Fig. 75). This cotton is the sea-island variety and the industry can be materially increased.

The native vegetables for local consumption are grown throughout the Island and to some extent for the northern markets. The most important vegetable-growing district for export coincides with the fruit growing region of the north coast, east of Arecibo.

It will be readily seen that all of these industries have made necessary the removal of the vast forest which covered practically all the Island at the time of its discovery by Columbus. Hills and other regions which cannot be used for agriculture are cut over repeatedly in order to meet the needs of the growing population for fuel. The result is that there are very few fragments of the original plant life, aside from the high mountain region to which we have referred. The great value of most of the land for agricultural purposes will prevent reforestation to any great extent and reforestation will not mean restoration to original conditions at the time of the coming of the white men. However, there are many regions of Porto Rico that can be reforested to an advantage, and all the higher elevations should be under Government ownership or control so that the water may be conserved to the greatest good to the greatest number of our population.

COMMON NAMES

This list of common names was prepared from information obtained from many sources. The cross reference numbers following the names will enable the reader to learn when a plant is known by two or more common names.

1. Abejuelo—*Colubrina colubrina* (Jacq.) Mills. 8.
2. Abrojo—*Cenchrus echinatus* L.
3. Acacia—*Leucaena glauca* (L.) Benth. 4, 124, 285.
4. Acacia pálada—*Leucaena glauca* (L.) Benth. 3, 124 285.
5. Acana—*Manilkara nitida* (Sessé & Moc.) Dubard. 316.

6. Aceitillo—*Simaruba tulae* Urban.
7. Achicoria cimarrona—*Tupa robusta* (Graham) A. DC. 161.
8. Achiotillo—*Colubrina colubrina* (Jacq.) Mills. 1.
9. Achiotillo—*Alchornea latifolia.* Sw. 327, 458.
10. Adormida—*Croton rigidus* (Muell Arg.) Britton. 275.
11. Aguacate cimarrón—*Hufelandia pendula* (Sw.) Nees. 152, 452.
12. Aguacatilla—*Meliosma herberti* Rolfe. 101.
13. Aguinaldo blanco—*Jacquemontia nodiflora* (Des.) G. Don.
14. Aguinaldo de costa—*Jacquemontia jamaicensis* (Jacq.) Hall.
15. Alelí cimarrón—*Plumiera alba.* L. 167, 559.
16. Algarroba—*Hymenaea courbaril* L.
17. Algodón de seda—*Calotropis procera* Ait. R. Br. 416.
18. Almácigo—*Elaphrium Simaruba* (L) Rose.
19. Almendra—*Terminalia catappa* L.
20. Almendrón—*Dipholis salicifolia* (L.) A. DC.
21. Altea—*Nepsera aquatica* (Aubl.) Naud.
22. Amarat—*Acacia muricata* (L.) Willd.
23. Angela—*Moringa moringa* (L.) Millsp. 76, 321.
24. Anguila—*Eugenia buxifolia* (Sw.) Willd. 29.
25. Añil—*Indigofera suffruticosa* Mill.
26. Añil (falso)—*Benthamantha caribaea* (Jacq.) Kuntz.
27. Aquilón—*Laugeria resinosa* Vahl.
28. Arayanilla—*Ascyrum hypericoides* L.
29. Arguilo—*Eugenia buxifolia* (Sw.) Willd. 24.
30. Aroma—*Lasianthus moralesii* (Grisseb.) C. Wright. 397.
31. Aroma—*Vachellia farnesiana* (L.) W. & A. 32,
32. Aroma casha—*Vachellia farnesiana* (L.) W. & A. 31.
33. Arrayán—*Myrica cerifera* L. 158.
34. Arrayán—*Rapanea ferruginea* (R. & P.) Mez. 196, 375.
35. Arroyo—*Meliosma obtusifolia* (Bello) K. & U. 98, 168, 169, 279, 280.
36. Avispillo—*Nectandra coriacea* (Sw.) Griseb. 335.
37. Avispillo—*Turpinia paniculata* Vent. 642.
38. Avispillo—*Phoebo montana* (Sw.) Griseb.
39. Avispillo—*Margarita nobilis* L. 629, 654, 659.
40. Avispillo—*Mayepea caribaea* (Jacq.) Kuntze.
41. Azota caballo—*Malpighia coccigera* L.
42. Azúcares—*Jacquinia barbasco* (Loefl.) Mez. 49.
43. Babiero amarillo—*Urechtites lutea* (L.) Britton.
44. Badula—*Icacorea guadalupensis* (Duch.) Britton. 374.
45. Badula—*Rapanea guianensis* (Aubl.)
46. Bálsamo—*Citharexylum fruticosum* L. 465, 493.
47. Bálsamo—*Hamelia axilaris* Sw.
48. Bambú trepador—*Arthrostylidium sarmentosum* Pilger.
49. Barbasco—*Jacquinia barbasco* (Loefl.) Mez. 42.
50. Barbasco—*Canella winterana* (L.) Gaertn. 133.
51. Barbas de úcar—*Dendropogon usneoides* (L.) Raf.
52. Bariaco—*Krugiodendron ferreum* (Vahl.) Urban. 223, 467, 647.
53. Bariacao—*Trichilia triacantha* Urban. 683.
54. Barilla—*Batis maritima* L. 593.

55. Basora—*Varronia angustifolia* West.
56. Basquiña—*Pothomorphe peltata* (L.) Mig.
57. Batatilla—*Ipomoea stolonifera* (Cyrill.) Poir. 633.
58. Begonia—*Begonia decandra* Pav.
59. Bejuco de berraco—*Chiococca alba* (L.) Hitch.
60. Bejuco de buey—*Banisteria laurifolia* L. 484.
61. Bejuco de costilla—*Serjania polyphylla* (L.) Radlk. 632.
62. Bejuco de garrote—*Rourea surinamensis* Miq. 664.
63. Bejuco de guajanilla—*Paullinia pinnata* L. 66.
64. Bejuco de inglés—*Capparis cynophallophora* L.
65. Bejuco de mona—*Cissampelos pareira* L. 485.
66. Bejuco de palma—*Paullinia pinnata* L. 63.
67. Bejuco de paloma—*Trichostigma octandrum* (L.) H. Walt.
68. Bejuco de palma—*Marcgravia rectiflora* Tr. & Pl. 488.
69. Bejuco de playa.—*Ipomoea Pes-Caprae* (L.) Roth.
70. Bejuco de prieto—*Hippocratea volubilis* L.
71. Bejuco de rana—*Marcgravia sintenisii* Urban.
72. Bejuco de Santiago—*Aristolochia trilobata* L. 105, 483.
73. Bejuco de sopla—*Elsota virgata* (Sw.) Kuntz. 313.
74. Bejuco de toro—*Stigmaphyllon tomentosum* (Desf.) Ndz.
75. Bellorita—*Erigeron bellioides* D. C.
76. Ben—*Moringa moringa* (L.) Millsp. 23, 321.
77. Berenjena cimarrona—*Solanum torvum* Sw.
78. Berenjena de playa—*Solanum persicifolium* Dunal.
79. Bertonica afellfada—*Moluchia tormentosa* L.
80. Bicornis—*Andropogon bicornis* L.
81. Bijao—*Alpinia aromatica* Aubl. 419.
82. Birijí—*Eugenia monticola* (Sw.) DC. 300.
83. Borborón—*Scaevola plumierii* L. 84, 183.
84. Borborón de playa—*Scaevola plumierii* L. 83, 183.
85. Botón blanco—*Borreria verticillata* (L.) Meyer.
86. Botón de oro—*Volkameria aculeata* L. 216.
87. Botón de oro—*Melampodium divaricatum* (L. C. Rich.) DC.
88. Botoncillo—*Conocarpus erecta* L.
89. Botoncillo—*Borreira ocimoides* (Burm.) DC.
90. Botoncillo—*Gnaphalium portoricense* Urban.
91. Botoncillo—*Dichromena ciliata* Vahl.
92. Bruja—*Byrophyllum pinnatum* (Lam.) Kruz.
93. Búcar. *Bucida buceras* L. 577.
94. Burro—*Capparis coccolobifolia* Mart.
95. Burro blanco—*Capparis portoricensis* Urban.
96. Cabai nagte—*Randia mitis* L. 215, 218, 459, 573.
87. Cabo de hacha—*Trichilia hirta* L.—328, 409, 442, 523 656, 692.
98. Cacaillo—*Meliosma obtusifolia* (Bello) K. & U. 35, 168, 169, 279, 280.
99. Cacaillo—*Slonaea breteriana* Choisy. 103, 415, 536.
100. Cacaillo—*Octoea leucoxylon* (Sw.) Mez.
101. Cacao bobo—*Meliosma herberti* Rolfe. 12.
102. Cacao rojo—*Sarcomphalus recticulatus* (Vahl.) Urban. 648.
103. Cacao roseta—*Slonaea berteriana* Choisy. 99, 536, 415.

104. Cachimba—*Dendropanax arboreum* (L.) Dcne. & Pl. 418, 450.
105. Cachimbos—*Aristolochia trilobata* L. 72, 483.
106. Cachimba—*Rauwolfia tetraphylla* L. 441, 473.
107. Cachimba—*Palicourea crocea* (Sw.) R. & S.
108. Cachimba—*Psychotria pubescens* Sw.
109. Cadillo de ciénaga—*Malache scabra* B. Vogel.
110. Cafeíllo—*Casearia guianensis* (Aubl.) Urban.
111. Cafeíllo—*Drypetes alba* Poit. 308, 481.
112. Cafeíllo—*Faramea accidentalis* (L. A. Rich.) 682.
113. Cafeíllo cimarrón—*Casearia sylvestris* Sw. 516, 550.
114. Caimitillo—*Micropholis garcinifolia* Pierre.
115. Caimito de perro—*Chrisophyllum pauciflorum* Lam.
116. Calabazón—*Philodendron krebsii* Schott.
117. Calambreña—*Coccolobis venosa* L.
118. Camasey—*Miconia laevigata* (L.) DC.
119. Camasey—*Miconia hirta* (L) D. Don.
120. Camasey—*Miconia prasina* (Sw.) DC.
121. Camasey—*Miconia racemosa* (Aubl.) DC.
122. Camasey—*Clidemia hirta* (L.) D. Don.
123. Camasey de charco—*Acisanthera acisanthera* (L.) Britton.
124. Campeche—*Leucaena glauca* (L.) Benth. 3, 4, 285.
125. Campeche—*Haematoxylon campechianum* L.
126. Caña cimarrona—*Gynerium sagittatum* (Aubl.) Beauv. 128, 637.
127. Caña india—*Phragmites phragmites* (L.) Karst.
128. Caña india—*Gynerium sagittatum* (Aubl.) Beauv. 126, 637.
129. Canario—*Allamanda cathartica* L. 628, 640.
130. Canela—*Acrodiclidium salicifolium* (Sw.) Griseb. 134.
131. Canela—*Ocotea wrightii* (Meissn.) Mez. 639.
132. Canela—*Persea krugii* Mez.
133. Canela—*Canella winterana* (L.) Gaertn. 50.
134. Canelillo—*Acrodiclidium salcifolium* (Sw.) Griseb. 130.
135. Canelillo—*Aniba bracteata* (Nees.) Mez.
136. Capá amarillo—*Petitia domingensis* Jacq.
137. Capá cimarrón—*Cordia borinquensis* Urban. 417.
138. Caracolillo—*Phlebotaenia cowellii* Britton. 140, 479, 641.
139. Caracolillo—*Casearia decandra* Jacq. 182, 188, 246, 443.
140. Caracolillo—*Phlebotaenia cowellii* Britton. 138, 479, 641.
141. Caracolillo—*Trichilia palida* Sw. 237, 238, 517.
142. Caracolillo—*Sabinea punicea* Urban.
143. Caracolillo—*Homalium racemosum* Jacq.
144. Cariaquillo—*Lantana camara* L. 546.
145. Cariaquillo de Santa María—*Lantana involucrata* L.
146. Carmín—*Rivina humilis* L.
147. Carruzo—*Ichnanthus pallens* (Sw.) Munro.
148. Carruzo—*Panicum trichanthum* Nees.
149. Carubio—*Zanthoxylum monophyllum* (Lam.) P. Wilson. 385, 538, 672.
150. Castilla—*Cynerium sagittaria* (Aubl.) Beauv.
151. Ceboruquillo—*Thyana striata* (Radlk.) Britton. 269, 508.

152. Cedro macho—*Hufelandia pendula* (Sw.) Nees. 11, 452.
153. Cedro macho—*Hyeronima clusioides* (Tul.) Muell.
154. Ceiba—*Ceiba pentandra* (L.) Gaertn.
155. Cenizo—*Xanthoxylum martinicense* (Lam.) DC. 225.
156. Cenizo—*Tetrazygia eleagonoides* (Sw.) DC. 666, 697.
157. Cerisa—*Cordia nitidia* Vahl. 673.
158. Cerezo—*Myrica cerifera* L. 33.
159. Chamiso—*Dodonaea viscosa* Jacq. 282, 652.
160. Chicharrón—*Reynosia uncintata* Urban.
161. Chicoria cimarrona—*Tupa robusta* (Graham) A. DC. 7.
162. Chiggernit—*Tournefortia hirsutissima* L.
163. Cieniguillo—*Daphnopsis philippiana* K. & U. 363, 507, 668.
164. Cieniguillo—*Myrcia deflexa* (Poir.) DC.
165. Cieniguillo—*Eugenia confusa* DC.
166. Cieniguillo—*Gomidesia lindeniana* Berg.
167. Cimarrón—*Plumiera alba* L. 15, 559.
168. Ciralillo—*Meliosma obtusifolia* (Bello) K & U. 35, 98, 169. 279, 280.
169. Cirnelillo—*Meliosma obtusifolia* (Bello) K. & U. 35, 98, 279, 280.
170. Clavelón de playa—*Borrichia arborescens* (L.) DC.
171. Cobana—*Stahlia monosperma* (Tul.) Urban. 501.
172. Cocorroncito—*Gyminda latifolia* (Sw.) Urban. 367.
173. Cocuisa—*Cordyline guineensis* (L.) Britton.
174. Cocuisa—*Furcraea tuberosa* Ait. 667.
175. Cocuisa—*Quisqualis indica* L. 689.
176. Cojóbana—*Piptadenia peregrina* (L.) Benth. 179, 498.
177. Cojóbana—*Piptadenia arboreum* (L.) Urban.
178. Cojóbana—*Acacia muricata* (L.) Willd.
179. Cojobillo—*Piptadenia peregrina* (L.) Benth. 176, 498.
180. Cojobillo—*Anneslia portoricensis* (Jacq.) Britton. 698.
181. Colaba—*Calophyllum antillanum* Britton. 243, 391, 470, 544.
182. Colorrerillo—*Caseria decandra* Jacq. 139, 188, 246, 443.
183. Coralillo—*Scaevola plumierii* (L.) Vahl. 83, 84.
184. Corazón—*Annona glabra* L.
185. Corcho—*Torrubia fragrans* (Dum.—Cours.) Standley, 362, 364.
186. Corcho—*Ochroma pyramidale* (Cav.) Urban. 262.
187. Corcho—*Pisonia subcordata* Sw. 189, 678.
188. Corcho blanco—*Casearia decandra* Jacq. 139, 182, 246, 443.
189. Corcho bobo—*Pisonia subcordata* Sw. 187, 678.
190. Corita—*Agave missionum* Trell.
191. Corozo palma—*Acrocomia aculeata* (Jacq.) Lodd. 254, 655.
192. Coscorrán—*Elaeodendrum xylocarpum* (Vent) DC. 277.
193. Cotorra—*Ricinella ricinella* (L.) Britton. 212, 224.
194. Cotorrera de la playa—*Heliotropium curasavicum* L.
195. Cucubano—*Coccolobis laurifolia* Jacq. 245, 585, 653.
196. Cucubano—*Rapanea ferruginea* (R. & P.) Mez. 34, 375.
197. Cuernocillo—*Helicteres jamaicensis* Jacq. 310.
198. Cuernocillo—*Morongia portoricensis* (Urb.) Britton.
199. Cuero de sapo—*Exostema caribaeum* (Jacq.) R. & S. 338.

200. Cupeillo—*Clusia krugiana* Urban.
201. Cupey—*Clusia rosea* Jacq.
202. Cupey de altura—*Clusia gundlachii* Stahl.
203. Desmanto—*Acuan virgatum* (L.) Medic. 669.
204. Dildo—*Cephalocereus royeni* (L.) B. & R. 551.
205. Dildo—*Cephalocereus nobilis* (Haw.) B. & R.
206. Dunguey—*Similax coriacea* Spreng.
207. Dunguey—*Dioscorea pilosiuscula* Bertero.
208. Emajagua—*Pariti tiliaceum* (L.) St. Hil. 361, 358, 366.
209. Encinillo—*Drypetes ilicifolia* K & U.
210. Eneas—*Typha angustifolia* L.
211. Erizo—*Pitcairnia augustifolia* (Sw.) Redoubte. 496.
212. Escambrón—*Ricinella ricinella* (L.) Britton. 193, 224.
213. Escambrón—*Drepanocarpus lunatus* (C.) G. F. W. Meyer. 469.
214. Escambrón—*Pisonia aculeata* L. 582.
215. Escambrón—*Randia mitis* L. 96, 218. 459, 573.
216. Escambrón blanco—*Volkameria aculeata* L. 86.
217. Escambrón colorado—*Pithecellobium unguis-cati* (L.) Mart. 533, 581.
218. Escambrón tintillo—*Randia mitis* L. 96, 215, 459, 573.
219. Escobita—*Scoparia dulcis* L. 220, 395, 432.
220. Escobita amarga—*Scoparia dulcis* L. 219, 395, 432.
221. Espejuelo—*Sarcomhalus reticulatus* (Vahl.) Urban. 102.
222. Espejuelo—*Dipholis sintenisiana* Pierre.
223. Espejuelo—*Krugiodendron ferreum* (Vahl.) Urban. 52, 467, 647.
224. Espinillo—*Ricinella ricinella* (L.) Britton. 193. 212.
225. Espinosa—*Zanthoxylum martinicense* (Lam.) DC. 155.
226. Espinosa—*Anthacanthus spinosus* (Jacq.) Nees.
227. Flamboyant—*Delonix regia*—(Bojer) Raf. 537.
228. Flamboyant blanco—*Bauhinia monandra* Kurz. 555, 588.
229. Flor de agua—*Piaropus crassipes* Mart.) Britton.
230. Flor de agua—*Castalia ampla* Salisb.
231. Flor de Culebra—*Anthurium acaule* (Jacq.) Schott. 297, 407.
232. Flor de mayo—*Parkinsonia aculeata* L. 478.
233. Flor de mayo—*Selenicereus pteranthus* L. & O., B. & R.
234. Flor de todo el año—*Catharanthus roseus* (L.) Don.
235. Forte Ventura—*Lonchocarpus latifolius* (Willd.) HBK. 466.
236. Fresa—*Rubus rosaefolius* Smith. 623.
237. Gai—*Trichilia pallida* (Sw.) 141, 238, 517.
238. Gaita—*Trichilia pallida* (Sw.) 141, 237, 517.
239. Gaita—*Exothea paniculata* (Juss.) Radlk. 256.
240. Gaita—*Samyda spinulosa* Vent.
241. Galán del monte—*Cestrum laurifolium* L'Her.
242. Galán del monte—*Cestrum macrophyllum* Vent.
243. Galba—*Calophyllum antillanum* Britton. 181, 391, 470, 544.
244. Garrocho—*Quararibaca turbinata* (Sw) Poir,
245. Gareado—*Coccolobis laurifolia* Jacq. 195, 585, 653.
246. Gia mausa—*Casearia decandra* Jacq. 139, 182, 188, 443.
247. Gongolí—*Dendropanax laurifolium* (E. March) Dcne. & Pl. 482, 680.

248. Grama blanca—*Stenotaphrum secundatum* (Walt.) Kuntz.
249. Granadilla—*Buchenavia capitata* (Vahl.) Eichl.
250. Granadilla—*Eugenia lingustrina* (Sw.) Willd. 471.
251. Granadillo—*Ocotea spathulata* Mez. 421, 643.
252. Grasilla—*Setiscapella subulata* (L.) Barnh.
253. Yagrumo—*Didymopanax morototoni* (Aubl.) Dcne. & Pl. 353, 354.
254. Grugrú—*Acrocomia aculeata* (Jacq.) Lodd. 191, 655.
255. Guaba—*Inga inga* (L.) Britton.
256. Guaracán—*Exothea paniculata* (Juss.) Radlk. 239.
257. Guácima—*Guazuma guazuma* (L.) Cockerell.
258. Guaco—*Mikania congesta* DC.
259. Guaco—*Mikania cordifolia* (L.) Willd.
260. Guadillo—*Guarea ramiflora* Vent. 266.
261. Guamá—*Inga laurina* (Sw.) Willd.
262. Guano—*Ochroma pyramidale* (Cav.) Urban.
263. Guano—*Arundo donax* L. 638.
264. Guao—*Comocladia glabra* (Schultes.) Spreng.
265. Guara blanca—*Cupania americana* L.
266. Guara-guadillo—*Guarea ramiflora* Vent. 260.
267. Guaraguao—*Guarea guara* (Jacq.) P. Wilson.
268. Guarema—*Picramnia pentandra* Sw. 307.
269. Guava—*Thyana striata* (Radlk.) Britton. 151, 508.
270. Guayabacoa—*Rheedia acuminata* (Spreng.) Tr. & Pl. 553.
271. Guayabota—*Eugenia Stahlia* (Kiaersk.) K. & U.
272. Guayabota—*Diospyros ebenaster* Retz. 278.
273. Guayabota—*Maba sintenisii* K. & U. 561.
274. Guayacán—*Guaiacum officinale* L. 348.
275. Guayacanillo—*Croton rigidus* (Muell. Arg.) Britton. 10.
276. Guayacanillo—*Guaiacum sanctum* L. 657.
277. Guayavota—*Elaeodendrum xylocarpum* (Vent.) DC. 192.
278. Guayavota—*Diospyros ebanester* Retz. 272.
279. Guayavota—*Meliosma obtusifolia* (Bello) K. & U. 98, 168, 169, 280.
280. Guayaroto—*Meliosma obtusifolia* (Bello) K. & U. 98, 168, 169, 279.
281. Guinda—*Anthurium scandens* (Aubl.) Engler.
282. Guitaran—*Dodonaea viscosa* Jacq. 159, 652.
283. Gungulén—*Vanilla Eggersii* Rolfe.
284. Haya-minga—*Cananga blainii* (Griseb.) Britton. 420.
285. Hediondilla—*Leucaena glauca* (L.) Benth. 3, 4, 124.
286. Hediondilla—*Chamaefistula antillana* B. & R.
287. Hediondilla—*Chamaecrista diphylla* (L.) Greene.
288. Hediondilla—*Peiranisia polyphylla* (Jacq.) B. & R. 525.
289. Higüera—*Crescentia cujete* L.
290. Higüerillo—*Enallagma latifolia* (Mill.) Small.
291. Higüerillo—*Citharexylum caudatum* L.
292. Higüerillo—*Vitex divaricata* Sw. 685.
293. Higuillo—*Piper amalago* L. 294.
294. Higuillo de limón—*Piper amalago* L. 293.

295. Higuillo de limón—*Piper aduncum* L. 303.
296. Higuillo de limón—*Margaritaria nobilis* L.
297. Hoja de costado—*Anthurium acaule* (Jacq.) Schott. 231, 407.
298. Hoja menuda—*Myrcia citrifolia* (Aubl.) Urban.
299. Hoja menuda—*Myrcia splendens* (Sw.) DC.
300. Hoja menuda—*Eugenia monticola* (Sw.) DC. 82.
301. Hoja menuda—*Eugenia lancea* Poir. 687.
302. Hoja menuda—*Eugenia procera* (Sw.) Poir.
303. Hoja menuda—*Piper aduncum* L. 295.
304. Hoja menuda—*Calyptranthes sintenisii* Kiaresk. 349.
305. Horquetilla—*Chloris radiata* (L.) Sw.
306. Huesillo—*Mayepea domingensis* (Lam.) K. & U. 309.
307. Hueso—*Picramnia pentandra* Sw. 268.
308. Hueso—*Drypetes alba* Poit. 111, 481.
309. Hueso blanco—*Mayepea domingensis* (Lam.) K. & U. 306.
310. Huevo de gato—*Helicteres jamaicensis* Jacq. 197.
311. Icaco—*Chysobalanus icaco* L.
312. Icaquillo—*Hirtella rugosa* Pers. 571.
313. Jaboncillo—*Elsota virgata* (Sw.) Kuntz. 73.
314. Jaboncillo—*Sapindus saponaria* L.
315. Jácana—*Lucuma multiflora* A. DC.
316. Jácana—*Manilkara nitida* (Sesse & Moc.) Dubard. 5.
317. Jacanillo—*Petesioides pendulum* (Urban) Britton. 511, 662.
318. Jagüey—*Ficus laevigata* Vahl. 326, 337, 634.
319. Jagüey—*Ficus Stahlii* Warb.
320. Jagüey—*Ficus urbaniana* Warb.
321. Jasmín—*Moringa moringa* (L.) Millsp. 23, 76.
322. Jasmín—*Jasminum grandiflorum* L.
323. Jayajabico—*Erithalis fructicosa* L.
324. Jiba—*Schaefferia frutescens* Jacq.
325. Jiba—*Erythroxylon brevipes* DC.
326. Jigüerillo—*Ficus laevigata* Vahl. 318, 337, 634.
327. Jobillo—*Alchornea latifolia* Sw. 9, 458.
328. Jobillo—*Trichilia hirta* L. 97, 409, 442, 523, 656, 692.
329. Jobo—*Spondias mombin* L.
330. Juzo—*Rochefortia acanthophora* DC. Griseb.
331. Junco cimarrón—*Cyperus articulatus* L.
332. Junco de espiga—*Eleocharis interstincta* (Vahl.) R. & S.
333. Junquito—*Fimbristylis diphylla* (Retz.) Val.
334. Karrebesu—*Pictetia aculeata* (Vahl.) Urban. 563.
335. Laurel—*Nectandra coriacea* (Sw.) Griseb. 36.
336. Laurel roseta—*Nectandra patens* (Sw.) Griseb.
337. Lechecillo—*Ficus laevigata* Vahl. 318, 326, 634.
338. Lechecillo—*Exostema caribaeum* (Jacq.) R. & S. 199.
339. Lechecillo—*Chrysophyllum bicolor* Poir. 636.
340. Lechecillo—*Croton discolor* Willd.
341. Lechecillo—*Chamaesyce prostata* (Aiton) Small.
342. Lechecillo—*Sapium laurocerasus* Desf. 660, 661.
343. Lechuguilla de agua—*Pistia stratiotes* L.
344. Lengua de vaca—*Anthurium dominicense* Schott.

345. Lengua de vaca—*Elephantopus mollis* HBK.
346. Liana fragante—*Distictis lactiflora* (Vahl.) DC. 436, 598.
347. Liaña uñada—*Batocydia unguis* (L.) Mart. 490, 579.
348. Lignum vita—*Guaiacum officinale* L. 274.
349. Limoncillo de monte—*Calyptranthes, sintenisii* Kiaersk. 304.
350. Lirio—*Hymenocallis declinata* (Jacq.) M. Roem.
351. Lirio—*Strumfia maritima* Jacq.
352. Llagrumo—*Cecropia peltata* L.
353. Llagrumo—*Didymopanax morotoni* (Aubl.) Dcne. & Pl. 253, 354.
354. Llagrumo macho—*Didymopanax morototoni* (Aubl.) Dcne. & Pl. 253, 353.
355. Llume—*Gaussia attenuata* (Cook) Beccari.
356. Madreselva—*Pilea microphylla* (L.) Liebm. 594.
357. Madreselva—*Leonicera japonica* Thumb.
358. Mahoe—*Pariti tiliaceum* (L.) St. Hil. 208, 361, 366.
359. Maíz pelado—*Comocladia dodonaea* (L.) Urban. 360, 506.
360. Maíz tostado—*Comocladia dodonaea* (L.) Urban. 359, 506.
361. Majagua—*Pariti tiliaceum* (L.) St. Hil. 208, 358, 366.
362. Majagua—*Torrubia fragrans* (Dum-Cours.) Standley. 185, 364.
363. Majagua brava—*Dapnopsis philippiana* K & U. 163, 507, 668.
364. Majagua que mona—*Torrubia fragrans* (Dum.—Cours.) Standley. 185, 362.
365. Malagueta—*Amomis caryophyllata* (Jacq.) K & U. 630.
366. Malagueta—*Pariti tiliaceum* (L.) St. Hil. 208, 358, 361.
367. Mala mujer—*Gyminda latifolia* (Sw.) Urban. 172.
368. Malvavisco—*Corchorus hirtus* L.
369. Malvavisco—*Malachra urens* Poit.
370. Malvavisco—*Malvastrum coromandelianum* (L.) Gracke.
371. Malvavisco—*Waltheria americana* L. 631.
372. Mamey—*Mammea americana* L.
373. Mameyuelo—*Manilkara duplicata* (Sesse & Moc.) Dubard. 549.
374. Mameyuelo—*Icacorea guadalupensis* (Duch.) Britton. 44.
375. Mameyuelo—*Rapanea ferruginea* (R. & P.) Mez. 34,375.
376. Mangle—*Rhizophora mangle* L. 380, 381.
377. Mangle blanco—*Laguncularia racemosa* (L.) Gaertn.
378. Mangle bobo—*Avicennia nitida* Jacq.
379. Mangle botón—*Conocarpus erecta* L.
380. Mangle Colorado—*Rhizophora mangle* L. 376, 381.
381. Mangle zapatero—*Rhizophora mangle* L. 376, 380.
382. Mango—*Mangifera indica* L.
383. Manto—*Rhacoma crossopetalum* L. 387.
384. Manzanilla—*Wedelia trilobata* (L.) Hitch.
385. Mopurito—*Zanthoxylum monophyllum* (Lam.) P. Wilson. 149, 538, 672.
386. Maray-maray—*Ecastophyllum ecastophyllum* (L.) Britton. 476.
387. Maravedí—*Rhacoma crossopetalum* L. 383.
388. Margarita—*Bidens pilosa* L. 694.
389. Margarita—*Browallia americana* L. 686.

390. Margarita silvestre—*Bidens pilosa* L.
391. María—*Calophyllum antillanum* Britton. 181, 243, 470, 544.
392. Maricao—*Byrsonima spicata* (Cav.) DC.
393. Maricao—*Haemocharis portoricensis* K. & U. 424.
394. Masa—*Tetragastris balsamifera* (Sw.) Kuntze. 456.
395. Mastuerzo—*Scoparia dulcis* L. 219, 220, 432.
396. Mato azul—*Guilandina crista* (L.) Small. 398.
397. Mato de peo—*Lasianthus moralesii* (Griseb.) C. Wright. 30.
398. Mato de playa—*Guilandina crista* (L.) Small. 396.
399. Mato de playa—*Canavali maritima* (Aubl.) Thou.
400. Mato mariposa—*Duggena hirsuta* (Jacq.) Britton 475, 512, 616.
401. Matojo de playa—*Sporobolus virginicus* (L.) Kunth.
402. Matraca—*Crotalaria retusa* L. 558.
403. Maya—*Bromelia pinguin* L. 497.
404. Melón de costa—*Cactus intortus* Mill.
405. Mesquite—*Prosopis juliflora* (Sw.) DC.
406. Moca—*Andira inermis* H. B. K.
407. Moca de pavo—*Anthurium acaule* (Jacq.) Schott. 231, 297.
408. Moco de pavo—*Amaranthus cruentus* L.
409. Molinillo—*Trichila hirta* L. 97, 328, 442, 523, 656, 692.
410. Molinillo—*Hura crepitans* L. 663.
411. Molinillo—*Leonotis nepetaefolia* (L.) R. Br. 635.
412. Moral—*Cordia sulcata* DC.
413. Moralón—*Coccolobis Grandifolia* Jacq.
414. Mostacilla del mar—*Cakile lanceolata* (Willd.) O. E. Schultz.
415. Motillo—*Slonaea berteriana* Choisy. 99, 103, 536.
416. Mudar—*Calotropis procera* (Ait.) R. Br. 17.
417. Muñeca—*Cordia borinquensis* Urban. 137.
418. Muñeca—*Dendropanax arboreum* (L.) Dcne. & Pl. 104, 450.
419. Narciso—*Alpinia aromatica* Aubl. 81.
420. Negralora—*Cananga blainii* (Grieseb.) Britton. 284.
421. Nemocá—*Ocotea spathulata* Mez. 251, 643.
422. Nemocá—*Octoea moschata* (Pavon) Mez. 675, 676, 677.
423. Nidos de gungulén—*Tillandsia recurvata* L.
424. Niño de cota—*Haemocharis portoricensis* K. & U. 393.
425. Noyo—*Ipomoea dissecta* (Jacq.) Pursh.
426. Ohulaga—*Opuntia repens* Bello. 427.
427. Olaga—*Opuntia repens* Bello. 426.
428. Olaga—*Malpighia fucata* Ker.
429. Oreganillo—*Weinmania pinnata* L.
430. Oreganillo—*Cynometra portoricensis* K. & U.
431. Oreganillo—*Eupatorium dolicholepsis* (Urban) Britton.
432. Orozuz—*Scoparia dulcis* L. 219, 220, 305.
433. Orozus—*Leptilon pusillum* (Nutt.) Britton. 684.
434. Orozuz—*Stemodia maritima* L.
435. Ortegón—*Coccolobis rugosa* Desf.
436. Pega Palo—*Distictis lactiflora* (Vahl.) DC. 346, 489, 598.
437. Palinguán—*Capparis flexuosa* L. 457.
438. Palmo de coyor—*Bactris acanthophylla* Mart., 644.
439. Palma de coyor—*Euterpe globosa* Gaertn.

440. Palma real—*Roystonea borinqueña* Cook.
441. Palo amargo—*Rauwolfia tetraphylla* L. 106, 473.
442. Palo anastacia—*Trichilia hirta* L. 97, 328, 409, 523, 692.
443. palo blanco—*Casearia decandra* Jacq. 139, 182, 188, 246.
444. Palo blanco—*Allophylus occidentalis* (Sw.) Radlk. 509.
445. Palo blanco—*Chione venosa* (Sw.) Urban. 671.
446. Palo blanco—*Drypetes glauca* Vahl. 587.
447. Palo bobo—*Pisonia subcordata* Sw.
448. Palo bobo—*Brunellia comocladifolia* H. & B.
449. Palo bobo—*Coccolobis diversifolia* Jacq.
450. Palo cachimba—*Dendropanax arboreum* (L.) Dene. & Pl. 104, 418.
451. Palo cachimba—*Psychotria brachiata Sw.*
452. Palo colorado—*Hufelandia pendula* (Sw.) Nees. 11, 152.
453. Palo colorado—*Taonabo luquillensis* (K. & U.) Britton.
454. Palo colorado—*Myroxylon schwaneckeanum* K. & U. 679.
455. Palo moro—*Psychotria undata* Jacq.
456. Palo de aceite—*Tetragastris balsamifera* (Sw.) Kuntz. 349
457. Palo de burro—*Capparis flexuosa* L. 437.
458. Palo de cotorra—*Alchornea latifolia* Sw. 9, 327.
459. Palo de cotorra—*Randia mitis* L. 96, 215, 218, 573.
460. Palo de cucubano—*Guettarda scabra* (L.) Lam.
461. Palo de dajao—*Ixora ferrea,* (Jacq.) Benth. 468.
462. Palo de gallina—*Alchorneopsis portoricensis* Urban.
463. Palo de gallina—*Acnistus arborescens* (L.) Schlecht. 649.
464. Palo de gallina—*Eleisine indica* (L.) Gaertn.
465. Palo de guitarra—*Citharexylum fruticosum* L. 46, 493.
466. Palo de hedionda—*Lonchocarphus latifolius* (Willd.) HBK. 235.
467. Palo de hierro—*Krugiodendrom ferreum* (Vahl.) Urban. 52, 223, 647.
468. Palo de hierro—*Ixora ferrea* (Jacq.) Benth. 461.
469. Palo de hoz—*Drepanocarpus lunatus* (C.) G. F. W. Meyers. 213. 391, 544.
470. Palo de María—*Calophyllum antillanum* Britton. 181, 243, 391, 544.
471. Palo de multa—*Eugenia lingustrina* (Sw.) Willd. 250.
472. Palo de muñeco—*Cordia glabra* L.
473. Palo de muñeco—*Rauwolfia tetraphylla* L. 106, 441.
474. Palo de muñeco—*Cordia glabra* L.
475. Palo de pelado—*Duggena hirsuta* (Jacq.) Britton. 400, 512, 616.
476. Palo de pollo—*Ecastophyllum ecastophyllum* (L.) Britton. 386.
477. Palo de pollo—*Pterocarpus officinalis* Jacq.
478. Palo de rayo—*Parkinsonia aculeata* L. 232.
479. Palo de tortuga—*Phlebotaenia cowellii* Britton. 138, 140, 641.
480. Palo de vaca—*Bourreria succulenta* Jacq. 531.
481. Palo de vaca—*Drypetes alba* Poit. 111, 308.
482. Palo de vaca—*Dendropanax laurifolium* (E. March) Dene. & Pl. 247, 680.

483. Panitos—*Aristolochia trilobata* L. 72, 105.
484. Paralejo—*Banisteria laurifolia* L. 60.
485. Parriera—*Cissampeles pareira* L. 65.
486. Pata de gallina—*Lepidagathis alopecuroidea* (Vahl.) R. Br.
487. Pata de gallina—*Phorodendron chrysocarpum* K. & U.
488. Pega palma—*Marcgravia rectiflora* Tr. & Pl. 68.
489. Pega palo—*Distictis latiflora* (Vahl.) DC. 346, 436,.
490. Pega palo—*Batocydia unguis* (L.) Mart. 347, 579.
491. Pega pollo—*Commicarpus scandens* (L.) Standley.
492. Pega pollo—*Alsine antillana* (Urb.) B. & W.
493. Pédula—*Cithrarexylum fruticosm* L. 46, 465.
494. Peronía—*Abrus abrus* (L.) W. F. Wight.)
495. Peronía—*Armosia krugii* Urban.
496. Piña de cuervo—*Pitcairnia angustifolia* (Sw.) Redoubte. 211.
497. Piñuela—*Bromelia pinguin* L. 403.
498. Piptadenia—*Piptadenia peregrina* (L.) Benth. 176. 179.
499. Pitajaya—*Leptocereus quadricostatus* (Bello) B. & R. 252.
500. Pitajaya—*Hylocereus trigonus* (Haw.) Safford.
501. Polisandre—*Staklia monosperma* (Tul) Urban. 171.
502. Pomarrosa—*Jambos jambos* (L.) Millsp.
503. Prenda de oro—*Pharus glaber* H. B. K.
504. Prieto—*Tabebuia heterophylla* (DC.) Britton. 693.
505. Pringa mosa—*Tragia volubilis* L.
506. Próspera—*Comocladia dodonaea* (L.) Urban. 359, 360.
507. Quemadora—*Daphnopsis philippiana* K. & U. 163, 363, 668.
508. Quiebra hacha—*Thyana striata* (Radlk.) Britton. 151, 269.
509. Quiebra hacha—*Allophylus occidentalis* (Cw.) Radlk. 444.
510. Quiebra hacha—*Eugenia pseudopsidium* Jacq.
511. Quiebra hacha—*Petesioides pendulum* (Urban) Britton. 317, 662.
512. Rabo de ratón—*Duggena hirsuta* (Jacq.) Britton. 400, 475, 616.
513. Rabo de ratón—*Casearia arborea* (L. C. Rich.) Urban. 651, 690.
514. Rabo de ratón—*Andropogon virgatus* Desr.
515. Rama menuda—*Myrcia splendens* (Sw.) DC.
516. Rama de perro—*Casearia sylvestris* Sw.—113, 550.
517. Ramoncillo—*Trichilia pallida* Sw. 141, 237. 238.
518. Ramoncillo—*Trophis racemosa* (L.) Urb. 691.
519. Rasca garganta—*Philodendron krebsii* Schott.
520. Rasca garganta—*Parathesis serrulata* (Sw.) Mez. 554.
521. Retama—*Corynella pauciflora* DC.
522. Retama—*Chamaecrista portoricensis* (Urb.) C. & C.
523. Retamo—*Trichilia hirta* L. 97, 328, 409, 442, 656, 692.
524. Retama—*Sabinea florida* (Vahl.) DC.
525. Retama prieita—*Peiranisia polyphylla* (Jacq.) B. & R. 288.
526. Roble blanco—*Tabebuia rigida* Urban. 530.
527. Roble blanco—*Tabebuia pallida* Miers.
528. Roble colorado—*Tabebuia schumanniana* Urban.
529. Roble colorado—*Tabebuia haemantha* (Bert.) DC.
530. Roble de sierra—*Tabebuia rigida* Urban. 526.
531. Roble de guayo—*Bourreria succulenta* Jacq. 480.

532. Roble de guayo—*Bourreria domingnensis* (DC.) Griseb.
533. Rolón—*Pithecellobium unguis-cati* (L.) Mart. 217, 581.
534. Rosa de ciénaga—*Ginoria rohrii* (Vahl.) Koehn. 578.
535. Roseta—*Macheonia portoricensis* Baill.
536. Roseta—*Slonaea berteriana* Choisy. 99, 103, 415.
537. Royal poinciana—*Delonix regia* (Bejer) Raf. 227.
538. Rubia — *Zanthoxylum monophyllum* (Lam.) P. Wilson. 149, 385, 672.
539. Rubia—*Rubia persicifoliorum* Dunol.
540. Sabino—*Magnolia splendens* Urban.
541. Salvia—*Salvia splendens* Sellow.
542. Salvia.—*Pluchea purpuracens* (Sw.) DC.
543. San Bartolomé—*Sebestén rickseckeri* Millsp.) Britton.
544. Santa María—*Calophyllum antillanum* Britton. 181, 243, 391, 470.
545. Santa María—*Thespesia populnea* (L.) Soland. 645, 681.
546. Santa María—*Lantana involucrata* L. 145.
547. Santa María—*Osmia odorata* (L.) Sch. Bip.
548. Santa María—*Vernonia albicaulis* Pers.
549. Sapote de costa—*Manilkara duplicata* (Sesse) Moc.) Dubard. 373.
550. Sarna de perro—*Casearia sylvestris* Sw. 113, 516.
551. Sebucán—*Cephalocereus royeni* (L.) B. & R. 204.
552. Sebucán—*Leptocereus quadricostatus* (Bello) B. & R. 499.
553. Sebucán—*Rheedia acuminata* (Spreng.) Tr. & Pl. 270.
554. Seca garganta—*Parathesis serrulata* (Sw.) Mez. 520.
555. Seplina—*Bauhinia monandra* Kurz. 228, 588.
556. Sereno—*Gundlachia corymbosa* (Urban) Britton.
557. Serrucho—*Mariscus jamaicensis* (Crantz.) Britton.
558. Sonajuelas—*Crotalaria retusa* L. 402.
559. Tabeiba—*Plumiera alba* L. 15, 167.
561. Tabeiba—*Maba sintenisii* K. & U. 273.
562. Tabanuco—*Dacryodes excelsa* Vahl.
563. Tachuelo—*Pictetia aculeata* (Vahl.) Urban. 334.
564. Tamarindo cimarrón—*Acacia muricata* (L.) Willd.
565. Temporana—*Suriana maritima* L.
566. Teiporana—*Mallotonia gnaphalodes* (L.) Britton. 674, 696.
567. Terciopelo—*Heterotrichum cymosum* (Wendl.) Urban.
568. Terciopelo—*Clidemia strigillosa* (Sw.) DC.
569. Terciopelo—*Miconia racemosa* (Aubl.) DC.
570. Terciopelo—*Abutilon commutatum* Schuman.
571. Teta de burra cimarron—*Hirtella rugosa* Pers. 312.
572. Tibey parasítica—*Columnea tulae* Urban.
573. Tintillo—*Randia mitis* L. 96, 218, 459.
574. Tortugo amarillo—*Sideroxylon foetidissmum* Jacq.
575. Tortugo prieto—*Ravenia Urbani* Engler.
576. Tuna brava—*Opuntia dillenii* (Ker. Gawl.) Haw.
577. Úcar—*Bucida buceras* L. 93.
578. Ucarillo—*Ginoria rohrii* (Vahl.) Koehn. 534.
579. Uña de gato—*Batocydia unguis* (L.) Mart. 347, 490.

580. Uña de gato.—*Martynia annua* L. 646.
581. Uña de gato—*Pithecellobium unguis-cati* (L.) Mart. 217, 533.
582. Uña de gato—*Pisonia aculeata* L. 214.
583. Uva de mar—*Coccolobis uvifera* (L.) Jacq. 584.
584. Uva de playa—*Coccolobis uvifera* (L.) Jacq. 583.
585. Uvillo—*Coccolobis laurifolia* Jacq. 195, 245, 653.
586. Uvillo—*Coccolobis portoricensis* (Urban) B. & S.
587. Varital—*Drypetes glauca* Vahl. 446.
588. Varital—*Bauhinia monandra* Kurz. 228, 555.
589. Varital—*Dipholis bellonis* Urban 695.
590. Ventura—*Ichthyomethia piscipula* (L.) Hitch.
591. Verdolaga—*Portulaca oleracea* L.
592. Verdolaga rosada—*Sesuvium portulacastrum* L. 620.
593. Verdolaga rosada—*Batis marítima* L. 54.
594. Verdolaguilla—*Pilea microphylla* (L.) Liebm. 356.
595. Verdolaguilla—*Pilea parietaria* (L.) Blume.
596. Víbora—*Angelonia angustifolia* Benth.
597. Víbora—*Dendropanax laurifolium* (E. March) Dene, & Pl.
598. Viuda—*Distictis lactiflora* Benth. 346, 436, 489.
599. Viuda—*Angelonia angustifolia* Benth.
600. Yaití—*Gymnanthes lucida* Sw.
601. Yerba de caña—*Lasiacis divaricata* (L.) Hitchc.
602. Yerba de ciénaga—*Aeschynomene sensitiva* Sw.
603. Yerba de clavo—*Centella asiatica* (L.) Urban.
604. Yerba de clavo—*Jussiaea angustifolia* Lam.
605. Yerba de culebra—*Bramia monnieri* (L.) Drake.
606. Yerba de culebra—*Caconapea stricta* (Schrad) Britton.
607. Yerba de culebra—*Piléa mummulariaefolia* (Sw.) Wedd.
608. Yerba de culebra—*Mecardonia procumbens* (Milld.) Small.
609. Yerba linda—*Peperomia rotundifolia* (L.) H, B. K. 612.
610. Yerba maravilla—*Ruellia coccinea* (L.) Vahl. 670.
611. Yerba de medio real — *Peperomia magnoliaefolia* (Jacq.) A. Dietr.
612. Yerba de medio real — *Peperomia rotundifolia* (L.) H. B. K. 609.
613. Yerba de plata—*Rolandra fructicosa* (L.) Kuntz.
614. Yerba de papagayo—*Blechum blechum* (L.) Millsp.
615. Yerba de pollo—*Portulaca quadrifidia* L.
616. Yerba pelada—*Duggena hirsuta* (Jacq.) Britton. 400, 475, 512.
617. Yerba de sal—*Philoxerus vermicularis* (L.) Nutt.
618. Yerba de sal—*Spartina patens* (Ait) Muhl.
619. Yerba de San Martín—*Sauvagesia erecta* L.
620. Yerba de vidrio—*Sesuvium portulacastrum* L. 591.
621. Zarza—(true)—*Acacia riparia* H. B. K.
622. Zarza—*Mimosa ceratonia* L.
623. Zarza—*Rubus rosaefolius* Smith. 236.
624. Zarzabacoa—*Chamaecrista diphylla* (L.) Greene. 658.
625. Zarzabacoa—*Meibonia purpurea* (Mill.) Vail. 665.
626. Zarzabacoa—*Meibomia supina* (Sw.) Britton.
627. Zarzabacoa enana—*Stylosanthes hamata* (L.) Taubert.

ADDITIONAL NAMES FOUND AFTER THE MANUSCRIPT HAD GONE TO PRESS

628. Allamanda—*Allamanda cathartica* L. 129, 640.
629. Amortiguado—*Margarita nobilis* L. 39, 654, 659.
630. Ausu—*Amomis caryophyllata* (Jacq.) K. & U. 365.
631. Basora prieta—*Waltheria americana* L. 371.
632. Bejuco de corrales—*Serjania polyphylla* (L.) Radlk. 61.
633. Bejuco de costa—*Ipomoea stolonifera* (Cyrill) Poir. 57.
634. Boislaglu—*Ficus laevigata* Vahl. 318, 326, 337.
635. Boton de cadeta—*Leonotis nepetaefolia* (L.) R. Br. 411, 688.
636. Caimito—*Chrysophyllum bicolor* Poir. 339.
637. Caña de castilla—*Gynerium sagittatum* (Aubl.) Beauv. 126 128.
638. Caña guava—*Arundo donax* L. 263.
639. Canelon—*Ocotea wrightii* (Meissn.) Mez. 131.
640. Cautiva—*Allamanda cathartica* L. 129, 628.
641. Caracolillo—*Phlebotaenia cowellii* Britton. 138, 140, 479.
642. Cedro hembra—*Turpinia paniculata* Vent. 37.
643. Cimarron—*Ocotea spathulata* Mez. 251, 421.
644. Coyure—*Bactris acanthophylla* Mart. 438.
645. Engaguilla—*Thespesia populnea* (L.) Soland. 545, 681.
646. Escorzonera—*Martynia annua* L. 580.
647. Espejueto — *Krugiodendron ferreum* (Vahl.) Urban. 52, 223, 467.
648. Espejueto—*Scarcomphalus reticulatus* (Vahl.) Urban. 102.
649. Galán arboreo—*Acnistus arborescens* (L.) Schlecht. 463.
651. Gia verde—*Casearia arborea* (L. C. Rich.) Urban. 513, 690.
652. Gitaran—*Dodonaea viscosa* Jacq. 159, 282.
653. Glateado—*Coccolobis laurifolia* Jacq. 245, 585, 653.
654. Gonglehout—*Margarita nobilis* L. 39, 629, 659.
655. Gru Gru—*Acrocomia aculeata* (Jacq.) Lodd. 191, 254.
656. Guaita—*Trichilia hirta* L. 97, 328, 409, 442, 523, 656, 692.
657. Guayacán blanco—*Guaiacum sanctum* L. 276.
658. Hediondilla—*Chamaecrista diphylla* (L.) Greene. 624.
659. Higuillo millo—*Margarita nobilis* L. 39, 629, 654
660. Hincha—*Sapium laurocerasus* Desf. 342, 661.
661. Huevos—*Sapium laurocerasus* Desf. 342, 660.
662. Jacanillo—*Petiesioides pendulum* (Urban) Britton. 317, 511.
663. Javillo—*Hura crepitans* L. 410.
664. Juan caliente—*Rourea surinamensis* Meg. 62.
665. Junquillo—*Meibonia purpurea* (Mill) Vail. 625.
666. Kre Kre—*Tetrazygia eleagonoides* (Sw.) D. C. 156, 697.
667. Magüey—*Furcraea tuberosa* Ait. 174.
668. Majagua quemadora—*Daphnopsis philippiana* K. & U., 163, 363, 507.
669. Manto—*Acuan virgatum* (L.) Medic. 203.
670. Maravilla—*Ruellia coccinea* (L.) Vahl. 610.
671. Martin Avila—*Chione venosa* (Sw.) Urban. 445.
672. Mopurito—*Zanthoxylum monophyllum* (Lam.) P. Wilson. 149, 385, 538.
673. Muñeca—*Cordia nitidia* Vahl. 157.

674. Nigua de Playa—*Mallotonia gnaphalodes* (L.) Britton 566, 696.
675. Nuez moscada—*Octoea moschata* (Pavon) Mez. 422, 676, 677.
676. Nuez moscada cimarrona—*Octoea moschata* (Pavon) Mez. 422, 675, 677.
677. Nuez moscada del País—*Octoea moschata* (Pavon) Mez. 422, 475, 476.
678. Palo bobo—*Pisonia subcordata* Sw. 187, 189.
679. Palo de candela—*Myroxylon schuwaneckeaum* K. & U. 454.
680. Palo de gungulin—*Dendropanax laurifolium* (E. March) Dcne. & Pl. 248, 482.
681. Palo de jaqueca—*Thespesia populnea* (L.) Soland 545, 645.
682. Palo de Toro—*Faramea occidentalis* (L. A. Rich) 112.
683. Palo de vaca—*Trichilia triacantha* Urban 53.
684. Pascueta—*Leptilon pusillum* (Nutt) Britton. 433.
685. Pendulo blanco—*Vitex divaricata* Sw. 292.
686. Pensamiento de pobre—*Browallia americana* L. 389.
687. Pitangueira—*Eugenia lancea* Poir. 301.
688. Quina del paeto—*Leonotis nepetaefolia* (L.) R. Br. 411, 635.
689. Quisqual—*Quisqualis indica* L. 175.
690. Rabojunco—*Casearia arborea* (L. C. Rich) Urban. 513, 651.
691. Ramon—*Trophis racemosa* (L.) Urban. 518.
692. Retamo—*Trichilia hirta* L. 97, 328, 409, 442, 523, 656.
693. Roble prieto—*Tabebuia heterophylla* (D.C.) Britton. 504.
694. Romerillo—*Bidens pilosa* L. 388.
695. Tabloncillo—*Dipholis bellonis* Urban. 589.
696. Te del Mar—*Mallotonia gnapholodes* (L.) Britton. 566. 674.
697. Verde seco—*Tetrazygia eleagnoides* (Sw.) D.C. 156, 666.
698. Zarza boba—*Anneslia portoricensis* Jacq. Britton. 180.

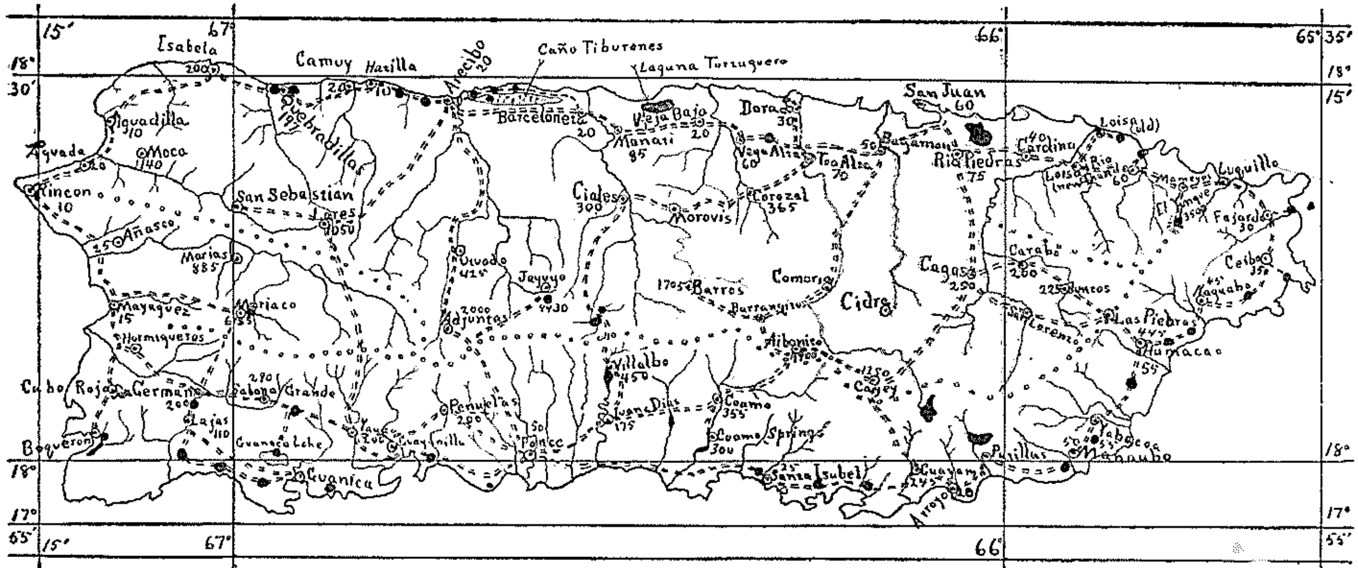

FIG. 1.—Map showing localities studied. The roads are indicated by == and the stops by • •. The crests of the mountain ranges are indicated by o o o o. The numbers refer to elevations in feet.

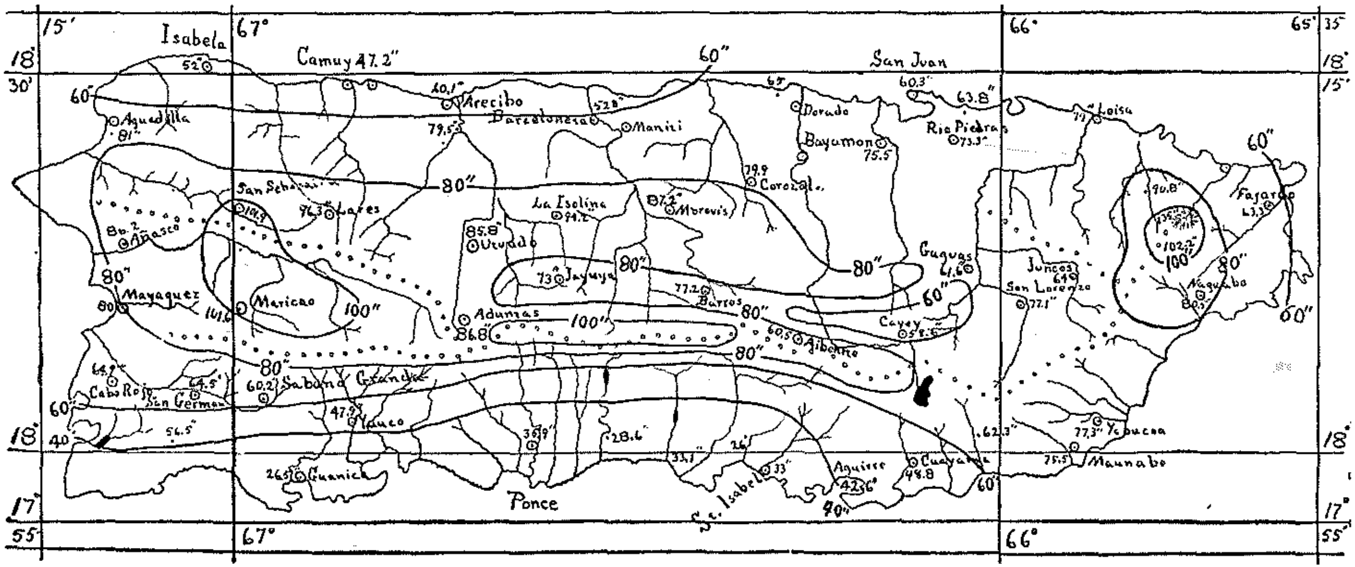

FIG. 3.—Map showing average rainfall in various parts of the island. Data obtained from the San Juan office of the U. S. Weather Bureau.

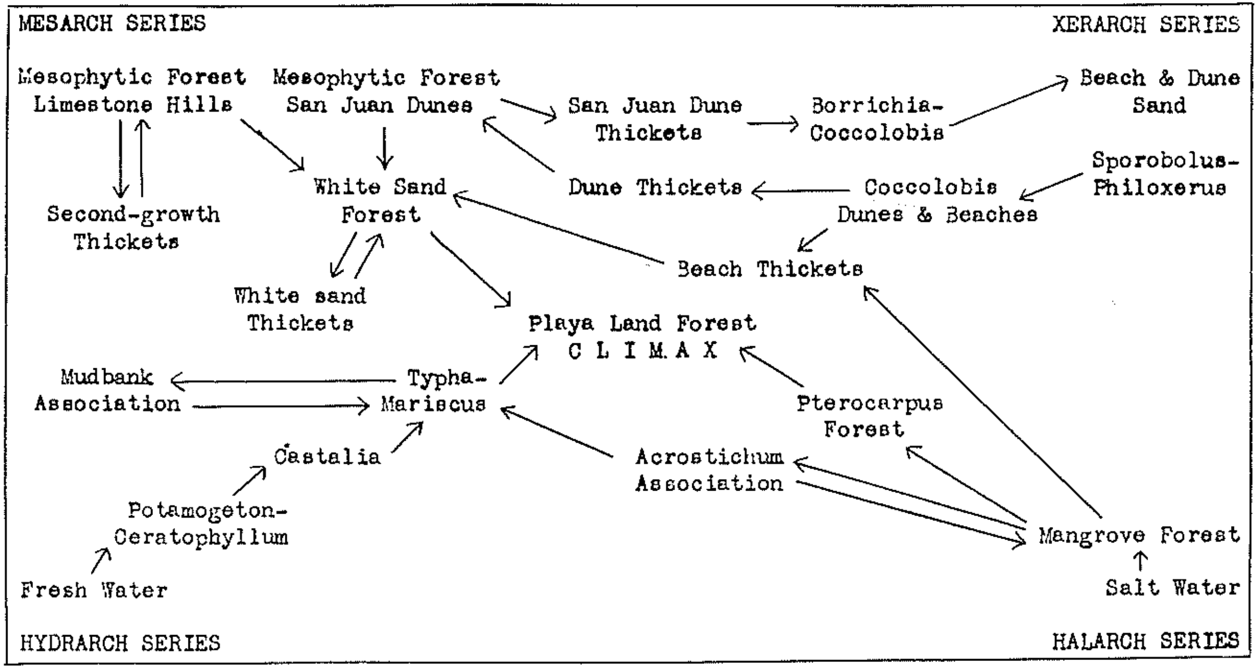

FIG. 4. The principal associations of the northern coastal plain of Porto Rico, with their successional relations.

Fig. 5. The mogotes or haystack hills. The slender llume palms (*Gaussia attenuata*) are almost invisible. Note the almácigo (*Elaphrium simaruba*) and the spreading leafy crowned jagüey (*Ficus laevigata*).

FIG. 6. Close view of a mogote or haystack hill. *Margaritara nobilis* at the extreme left; the moco de pavo (*Anthurium acaule*) at the extreme right; *Ipomoea* sp. trailing over the rocks in the center. Other plants are *Piper amalago*, *Nectandra patens*, *Erythroxylon brevipes* and *Acalypha portoricensis*.

Fig. 7. White sand forest at Dorado. The principal trees are: the muñeca (*Dendropanax arboreum*), the María (*Calophyllum antillanum*) and the *Mammea americana*.

Fig. 8. The white sand second growth thickets as seen at Laguna Tortuguero. These dense thickets are usually dominated by *Chrysobalanus icaco* but at this point the dominant is *Jambos jambos*.

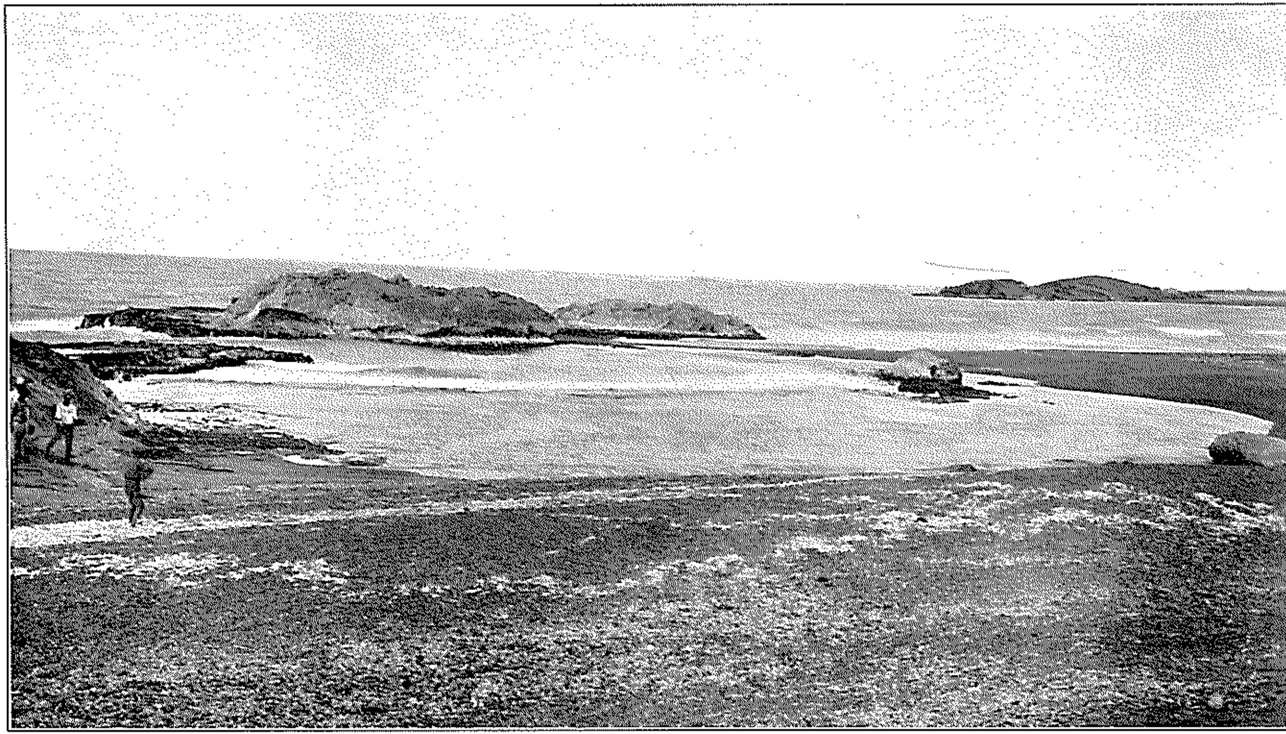

FIG. 9. Disintegration of the San Juan consolidated dunes. The sea has broken through and formed small semicircular bays on the landward side. Note the islands of this formation in the distance and the white patches of drifted shells in the fore ground.

FIG. 10. The yerba de sal (*Philoxerus vermicularis*) growing at the seaward margin of the dune vegetation; matojo de playa (*Sporobolus virginicus*) growing in the rear.

FIG. 11. Summit of a San Juan dune; the original vegetation has been reduced to a single wind swept thicket of uva de playa (*Coccolobis uvifera*) and a sod of *Stenotaphrum secundatum*.

Fig. 12. Dune vegetation near Barceloneta. This long dune is held by plant life consisting primarily of uva de playa (*Coccolobis uvifera*). Note the coconuts growing on the lee side.

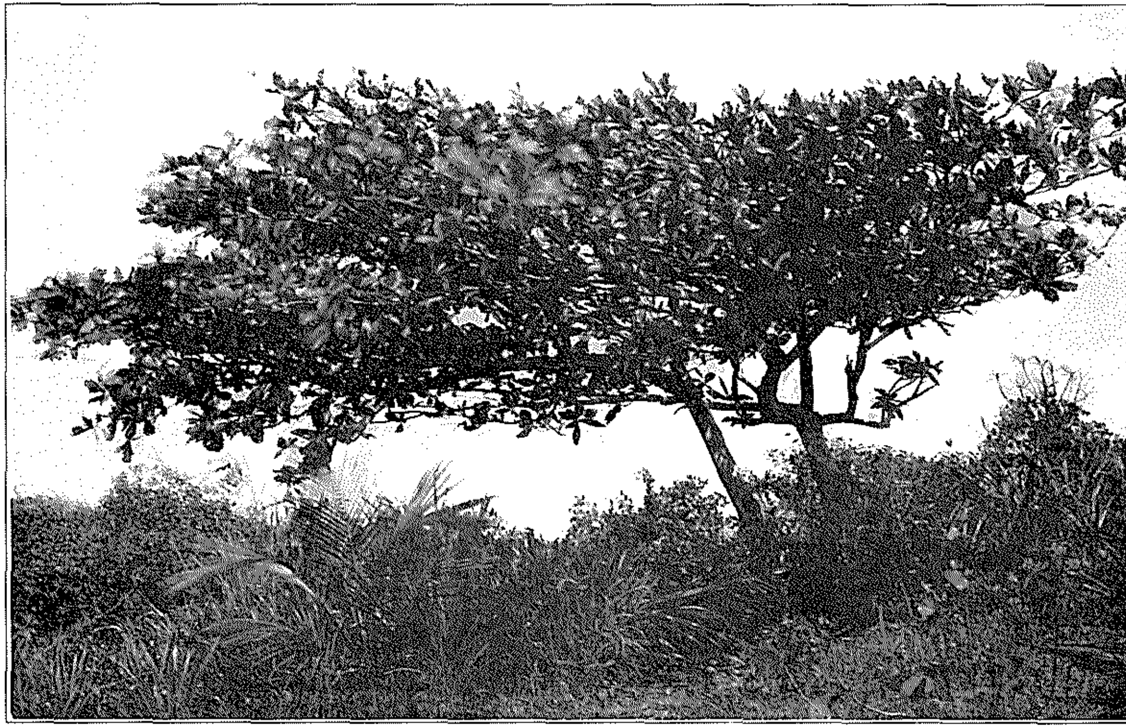

Fig. 13. Effect of wind on dune vegetation. The one sided tree (*Terminalia catappa*) is 5 meters high with a spread of 7 meters. Note the tabeiba (*Plumiera alba*) in the rear and at the right and the maya (*Bromelia pinguin*) below.

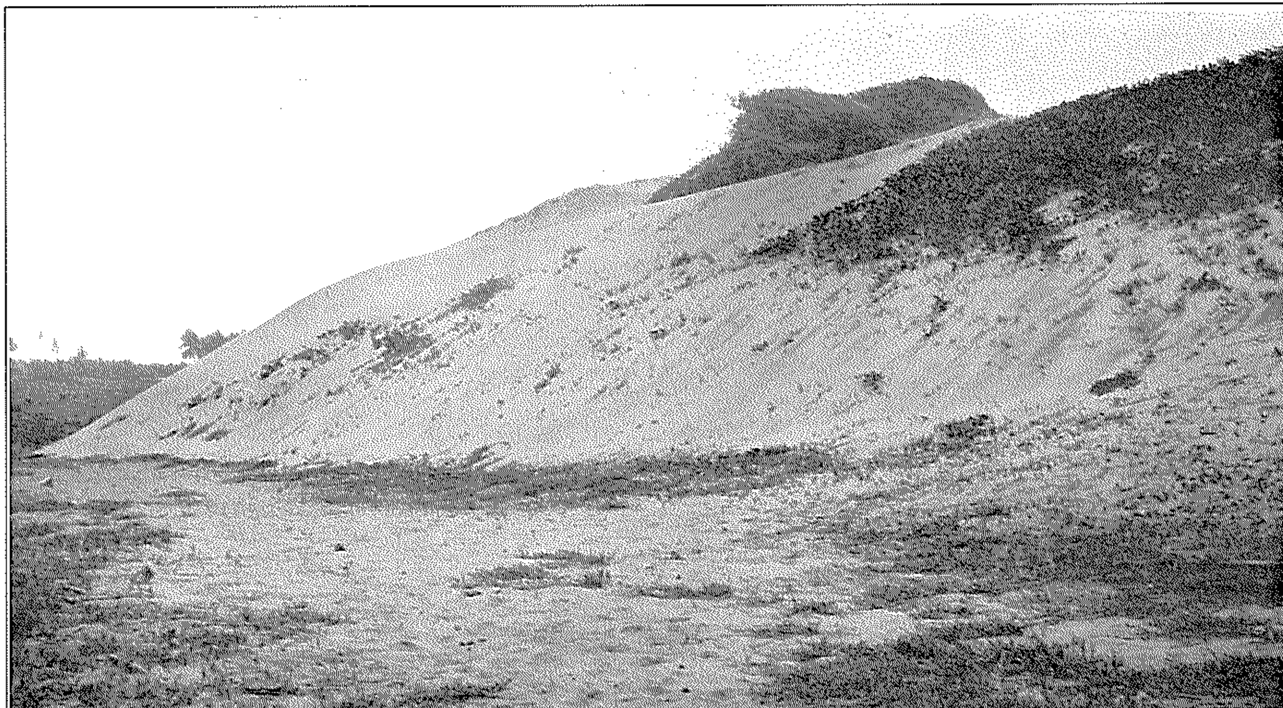

Fig. 14. Lee slope of an advancing dune west of Arecibo. The wind has broken through the series of dune thickets on the crest. The steep lee side is sparsely occupied by mato de la playa (*Canavali maritima*), matojo de playa (*Sporobolus virginicus*) and yerba de sal (*Phylloxerus vermicularis*) in the foreground.

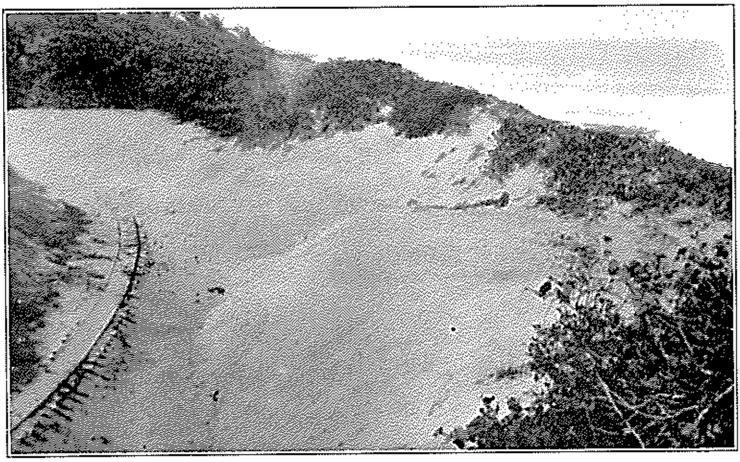

Fig. 15. A break in the dune vegetation permits the sand to blow through and cover a railway.

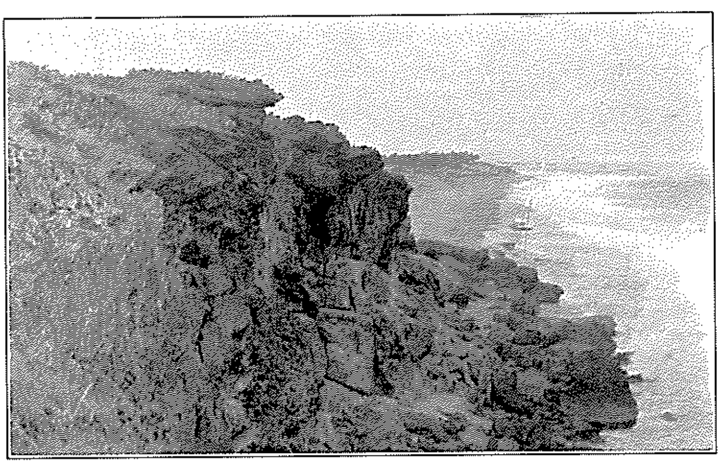

Fig. 16. Seaward face of a consolidated San Juan dune west of Arecibo, showing the undercutting by the sea and the destructive power of the wave action.

FIG. 17. Disintegration of the consolidated San Juan dunes. Note the matojo de playa (*Sporobolus virginicus*) on the sand in the foreground; the temporana (*Suriana maritima*) on the top of the cliff at the left; and the low thicket of uva de playa (*Coccolobis uvifera*) in the rear.

FIG. 18. Low thickets of uva de playa (*C. uvifera*) on the San Juan consolidated dunes.

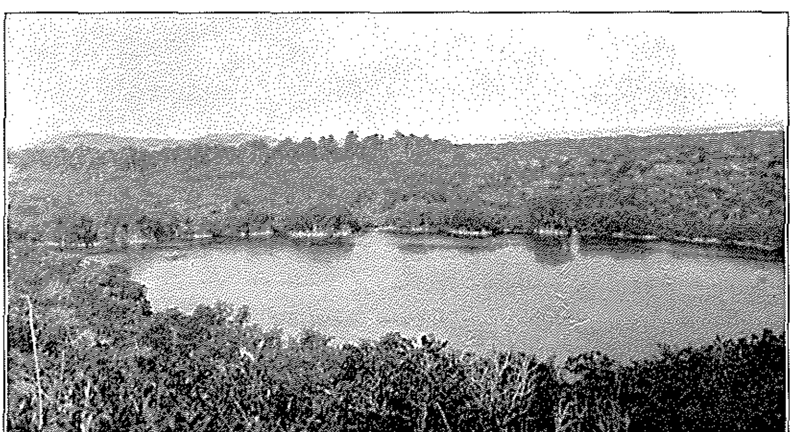

FIG. 19. Salt water pond on Icacos Cay, surrounded by an interrupted fringe of common mangrove (*Rhizophora mangle*).

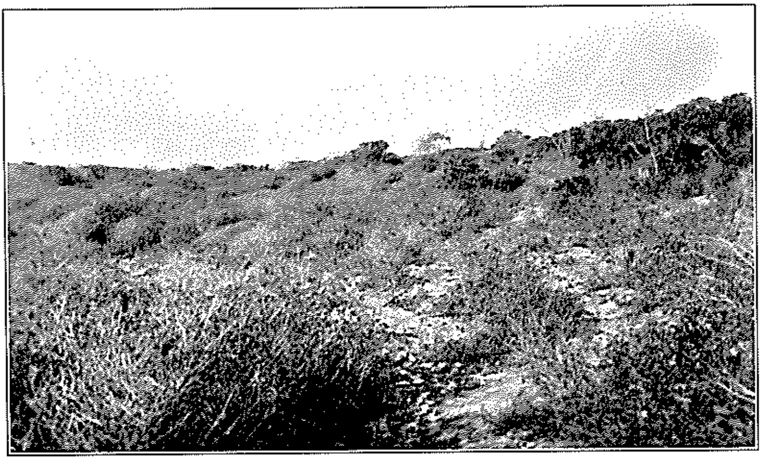

FIG. 20. Icacos Cay. The limestone plateau is covered by a xerophytic chaparral in which cariaquillo de Santa Maria (*Lantana involucrata*) is the dominant species.

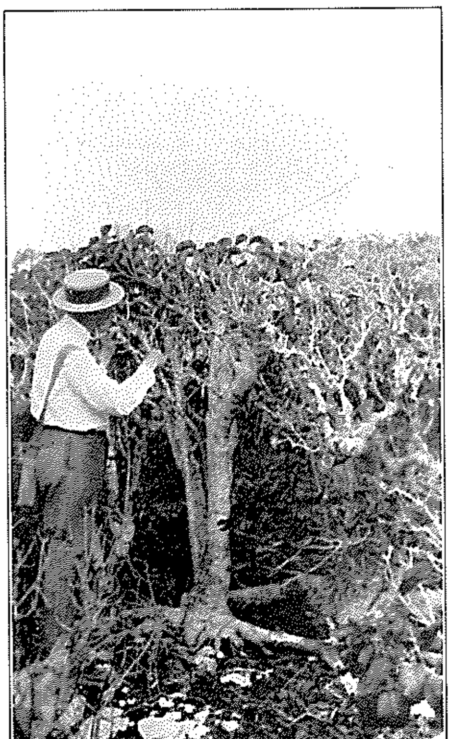

FIG. 21. Icacos Cay. Palo bobo (*Pisonia subcordata*) is abundant along the wind swept crest of the ridge. The vegetation is wind shorn and one sided.

FIG. 22. Icacos Cay. The vegetation of the wind swept ridge is xerophytic with several halophytic species. The single tall shrub is *Strumpfia maritima.*

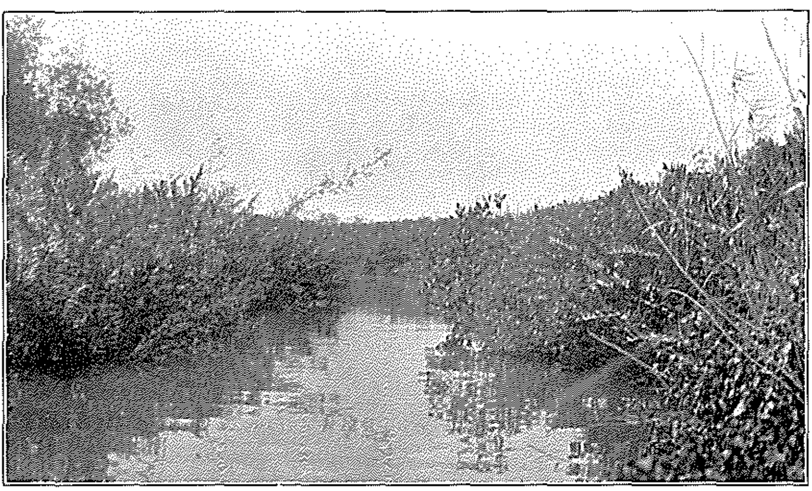

FIG. 23. Canal through the mangrove swamp of Caño Tiburones. Note the thicket of *Malache scabra* at the right and the ascending stems of *Drepanocarpus lunatus* at the left.

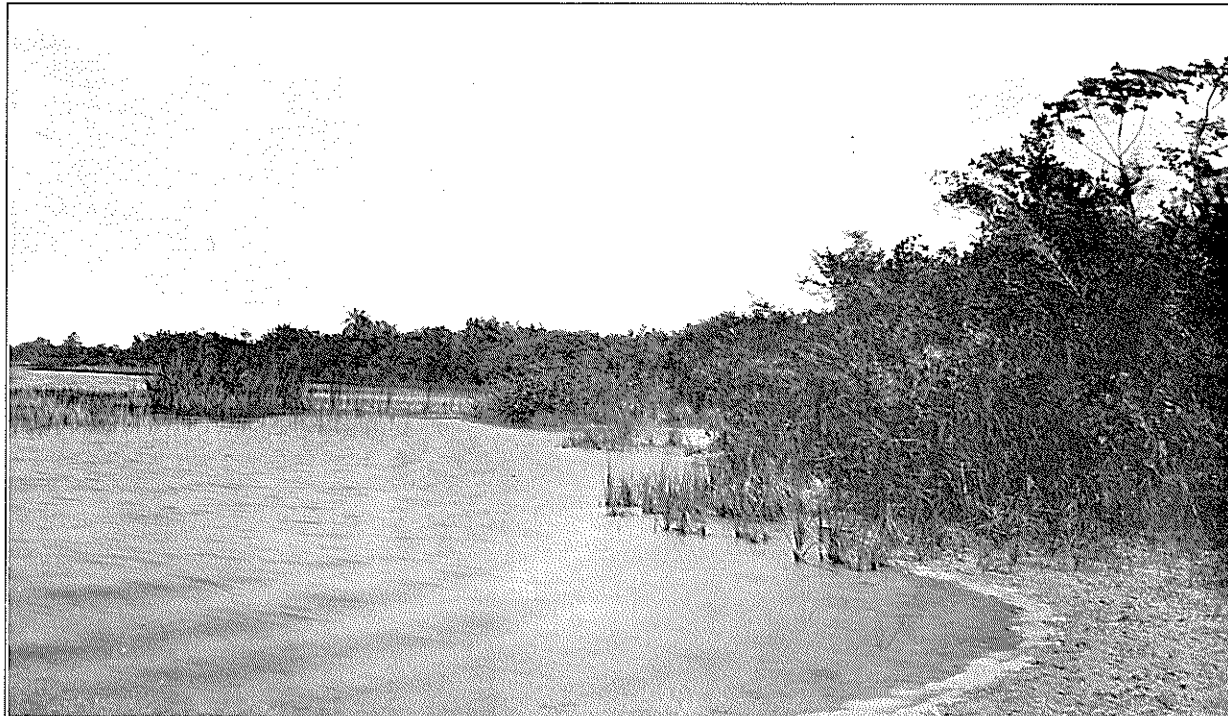

FIG. 24. Aquatic and shore vegetation, Laguna Tortuguero. The open water is occupied by cat-tails and Mariscus. A new colony of Mariscus is developing near the shore at the right. In the foreground a mud bank with scattered plants of *Bramia monnieri*. The shore thickets are dominated by *Chrysobalanus icaco* and *Ecastophyllum ecastophyllum*.

FIG. 25. Mud bank vegetation of Caño Tiburones. This association is composed of *Bramia monnieri* and *Eleocharis* sp. The Typha-Mariscus association forms the back ground.

Fig. 26. Mangrove vegetation east of Arecibo. Note the mangle blanco (*Laguncularia racemosa*) at the right; the tall mangle bobo (*Avicennia nitida*) in the center; and the common mangrove (*Rhizophora mangle*) in front.

Fig. 27. Acrostichum ferns and mangroves along road between Santurce and Bayamon. The ferns form an almost pure colony in the foreground over an area from which the mangroves have been cut.

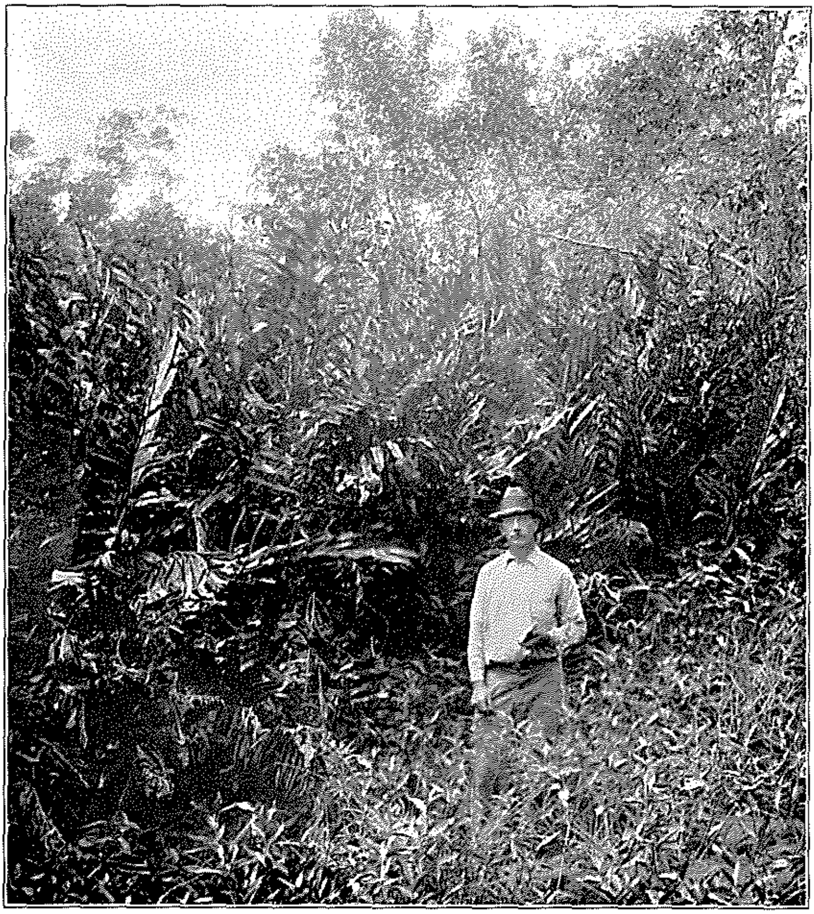

Fig. 28. Marginal growth of tall ferns (*Acrosticum aureum*) on the border of the palo de pollo (*Pterocarpus officinalis*) association at Humacao Playa.

FIG. 29. *Pterocarpus officinalis* association, Humacao Playa. The trees in the foreground measure 5 meters across the buttress. Many bejuco de palma (*Paullinia pinnata*) hang from the trees.

FIG. 30. Intermediate vegetation at Fajardo Playa. Note matojo de playa (*Sporobolus virginicus*) on the pastured foreground with uva de playa (*C. uvifera*) at the right. The thicket is composed of mangle boton (*Conocarpus erecta*). The ascending shrubs are escambron colorado (*Pithecel-lobium unguis-cati*).

FIG. 31. Drainage canal in Caño Tiburones. Water surface covered with flor de agua (*Castalia ampla*). *Scirpus olneyi*, *Sagittaria lancifolia* and *Acrostichum aureum* along the bank from righ. to left. The Typha-Mariscus association in the back ground.

FIG. 32. Reversion of cane land to swamp, Caño Tiburones. Mats of *Bramia monnieri* in the central foreground followed by colonies of *Eleocharis* spp. Typha-Mariscus association in the rear.

FIG. 33. Roadside vegetation of the central mountain region. The common fern (*Dicranopteris bifida*) and llagrumo (*Cecropia peltata*) in the center. The common fern (*D. pectinata*) in the right foreground.

Fig. 34. Second growth forest in the central mountain region. The conspicuous trees are; the llagrumo (*Cecropia peltata*), the tree fern (*Cyathea pubescens*) and the llagrumo macho (*Didymopanax morototoni*).

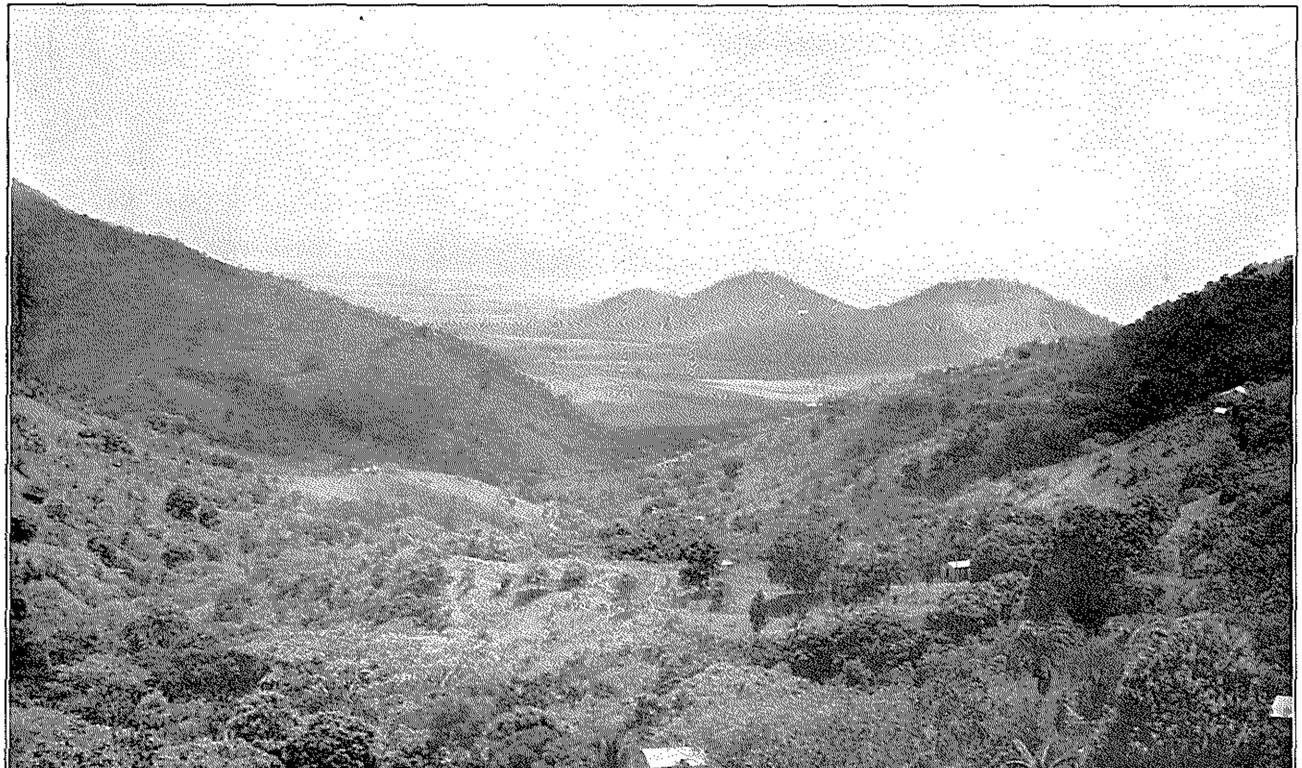

FIG. 35. Mountain landscape north of Guayama, looking southeast to the Caribbean. Xerophytic grasslands extend far up the ridges and second growth mesophytic forests extend down the ravines. The numerous scattered trees are mango (*Mangifera indica*) and jobo (*Spondias mombin*).

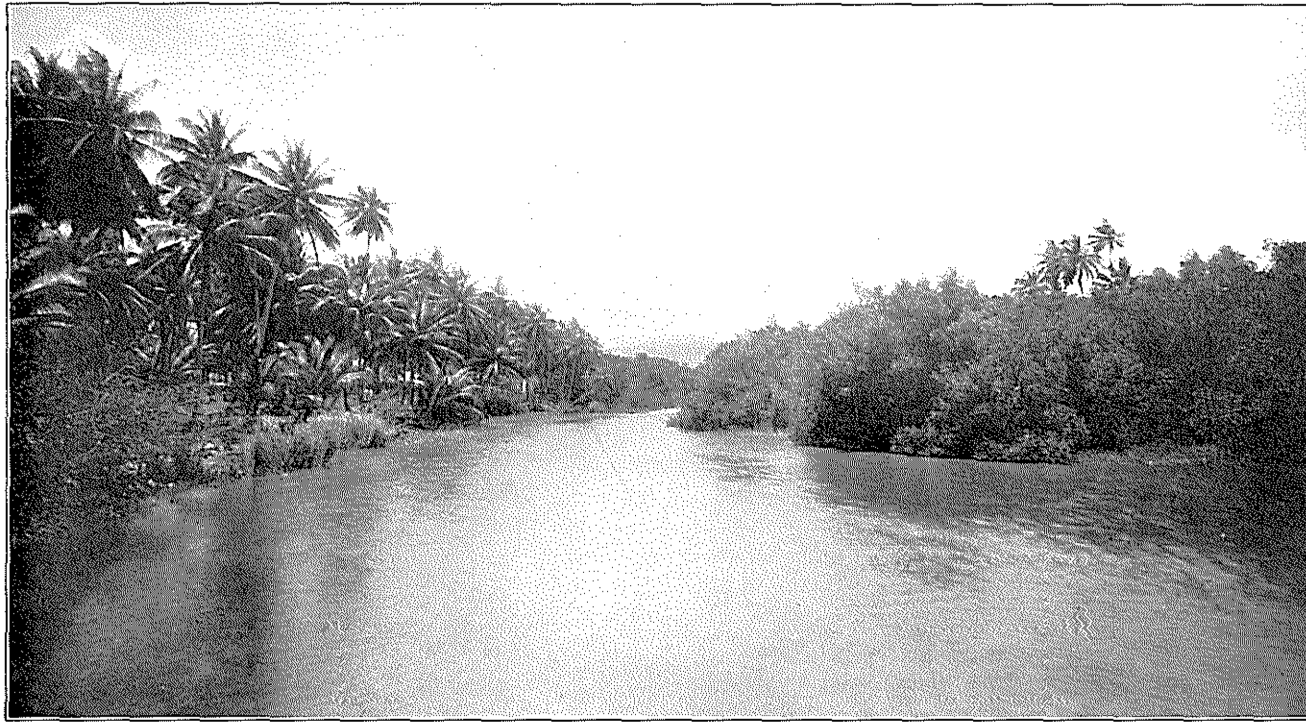

Fig. 36. Riparian vegetation at Naguabo Playa. The tidal river is bordered on the left by *Typha angustifolia* and other hydrophytes and on the right by the common mangrove (*Rhizophora mangle*) and by mangle bobo (*Avicennia nitida*).

Fig. 37. Roadside vegetation of the central mountain region south of Cayey, at an altitude of about 600 meters. *Peperomia glabella* in the central foreground; blooming plants of *Hillia parasitica* at left; long fronds of *Polypodium latum* in center with *Anthurium acaule* just above.

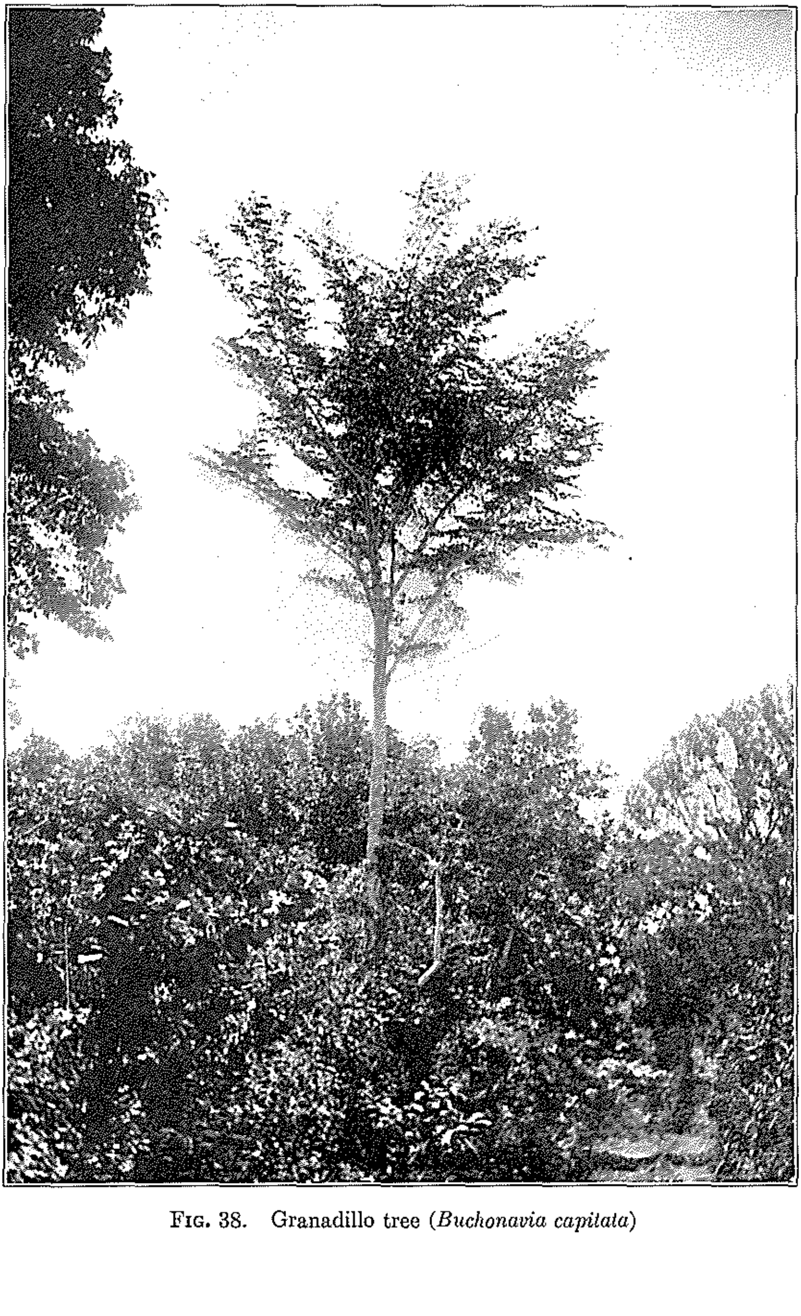

Fig. 38. Granadillo tree (*Buchonavia capitata*)

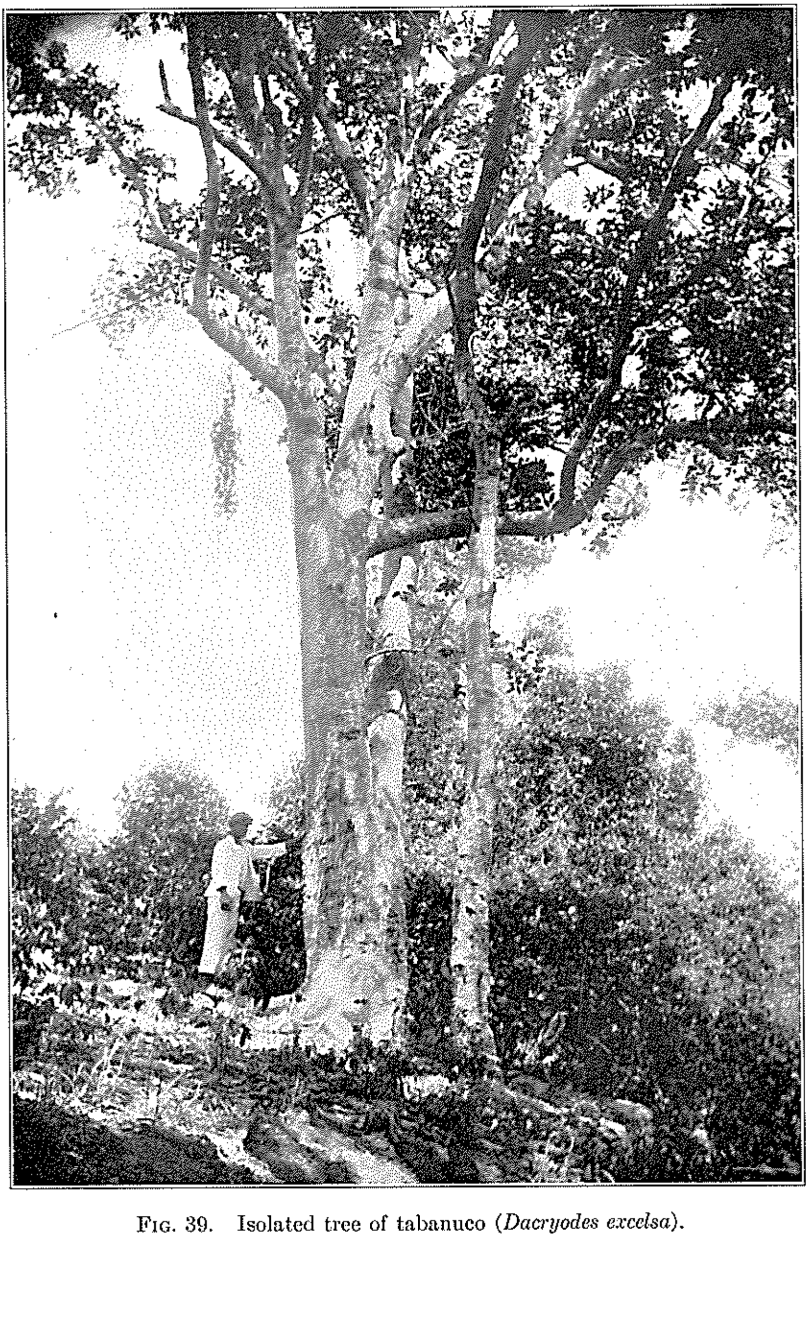

Fig. 39. Isolated tree of tabanuco (*Dacryodes excelsa*).

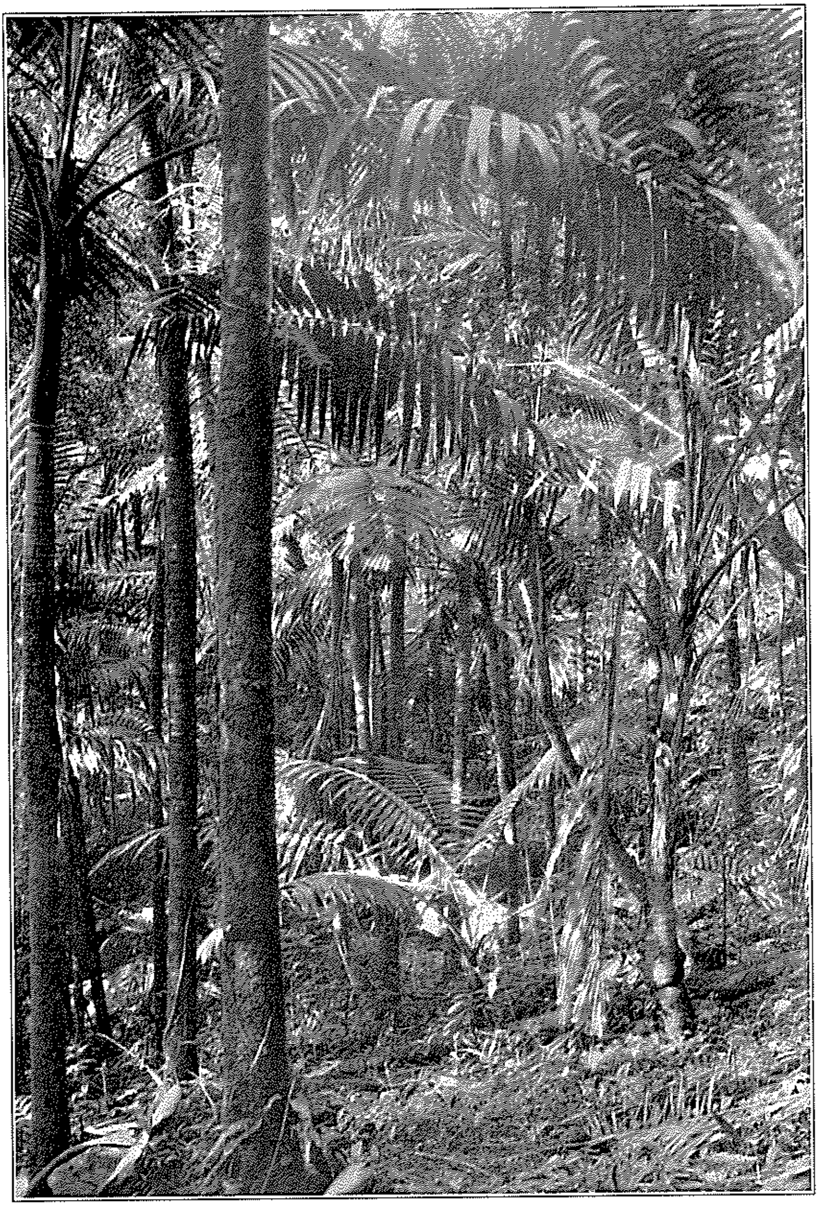

Fig. 40. Sierra palm forest, El Yunque. Palms of various ages dominate the vegetation. The ground flora is limited to palm seedlings and *Ruellia coccinea*.

FIG. 41. Open place in sierra palm forest, El Yunque. A colony of *Begonia decandra* occupies the center. The trunks of the palms are covered with moss, juvenile plants of Marcgravia, and a few large Bromeliads.

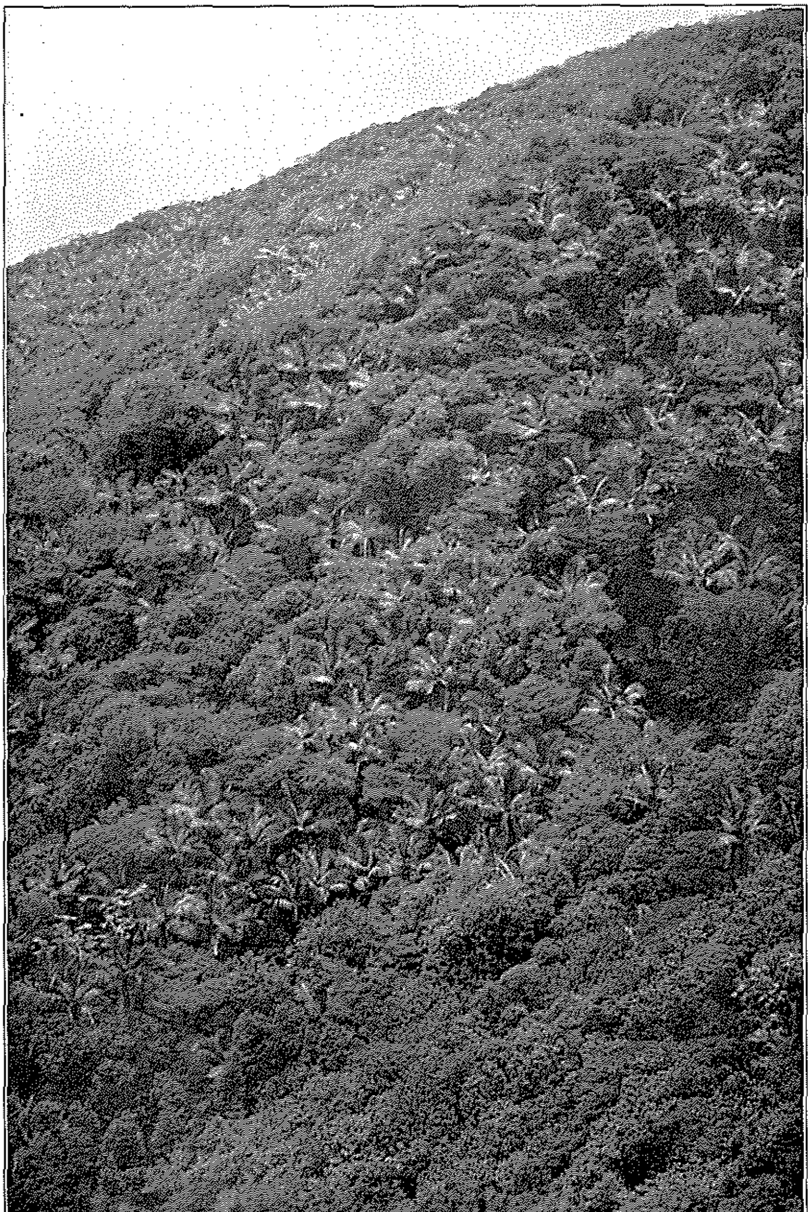

FIG. 42. Forests of the upper slopes of El Yunque at an altitude of about 1050 meters. The distribution of the sierra palms is in strips and patches and follows the contour of the land.

Fig. 43. Lower limit of mossy forest, El Yunque, Large trees about 10 meters high; epiphytic Bromiliads are conspicuous.

Fig. 44. Mossy forest along trail, El Yunque. *Ocotea spathulata* at upper left; *Tabebuia rigida* arching over the trail in the center; *Calycogonium squamulosum* at the right.

Fig. 45. Edge of mossy forest, summit of El Yunque. *Eugenia borinquensis* in the center; *Isachne angustifolia, Machaerina restioides* in the foreground.

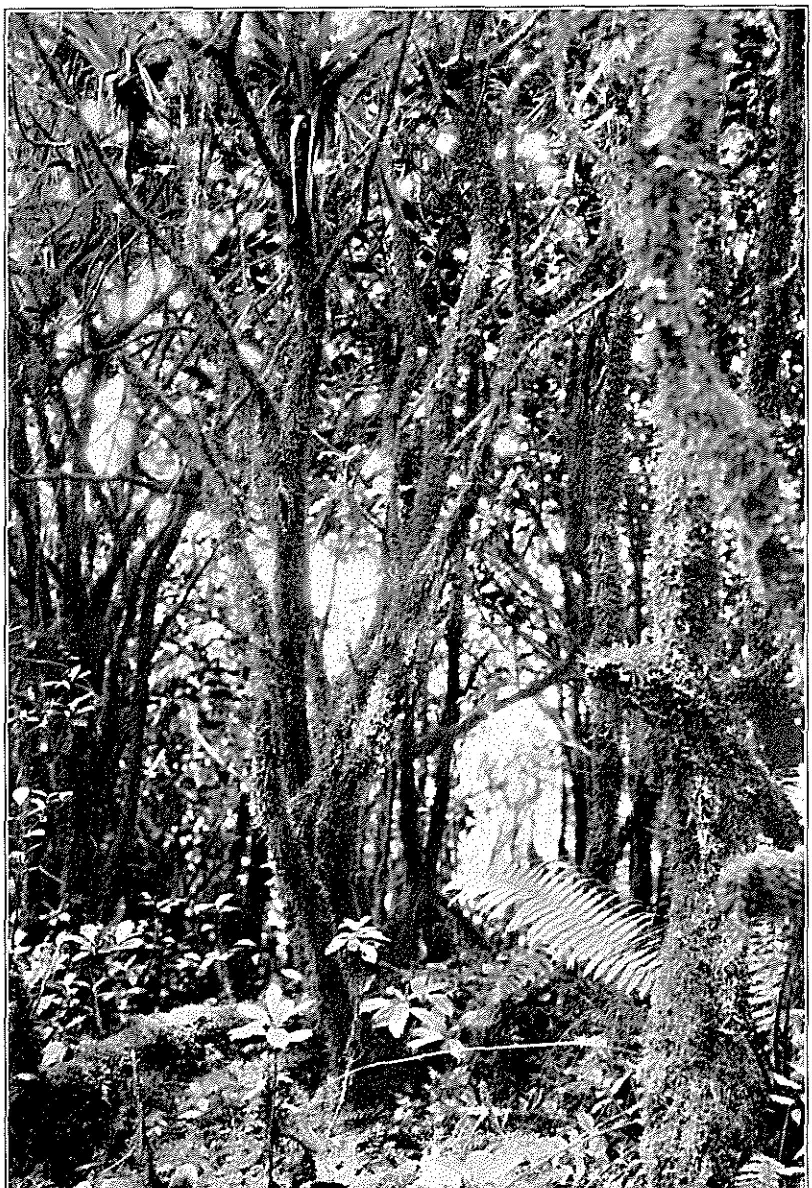

FIG. 46. Interior of mossy forest, summit of El Yunque. *Miconia pachyphylla* in central foreground and to left; *Tabebuia rigida* just back of center and to right.

Fig. 47. Interior of mossy forest, summit of El Yunque. The principal trees are *Tabebuia rigida*, about 4 meters high and *Miconia foveolata* in the foreground.

FIG. 48. Edge of mossy forest, promontory of El Yunque, altitude about 1050 meters. *Machaerina restioides* in the foreground; *Ceratostemme portoricensis* and *Arthrostylidium sarmentosum* on the rock; the round-leaved shrubs are *Eugenia borinquensis*.

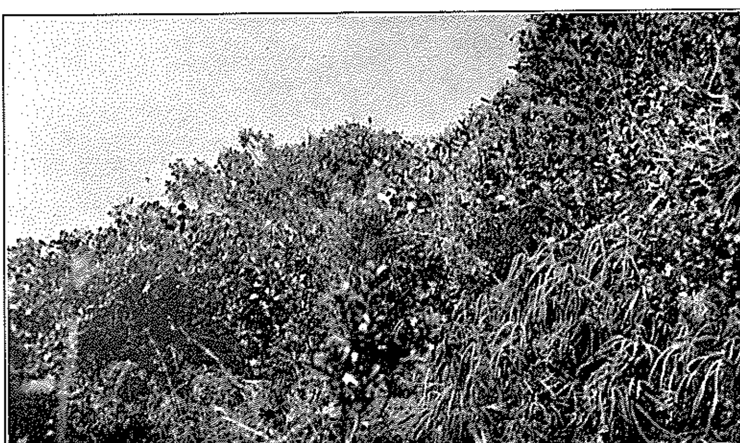

FIG. 49. Thickets of the mossy forest association, summit of the lower peak of Cerro de la Punta, altitude about 1300 meters.

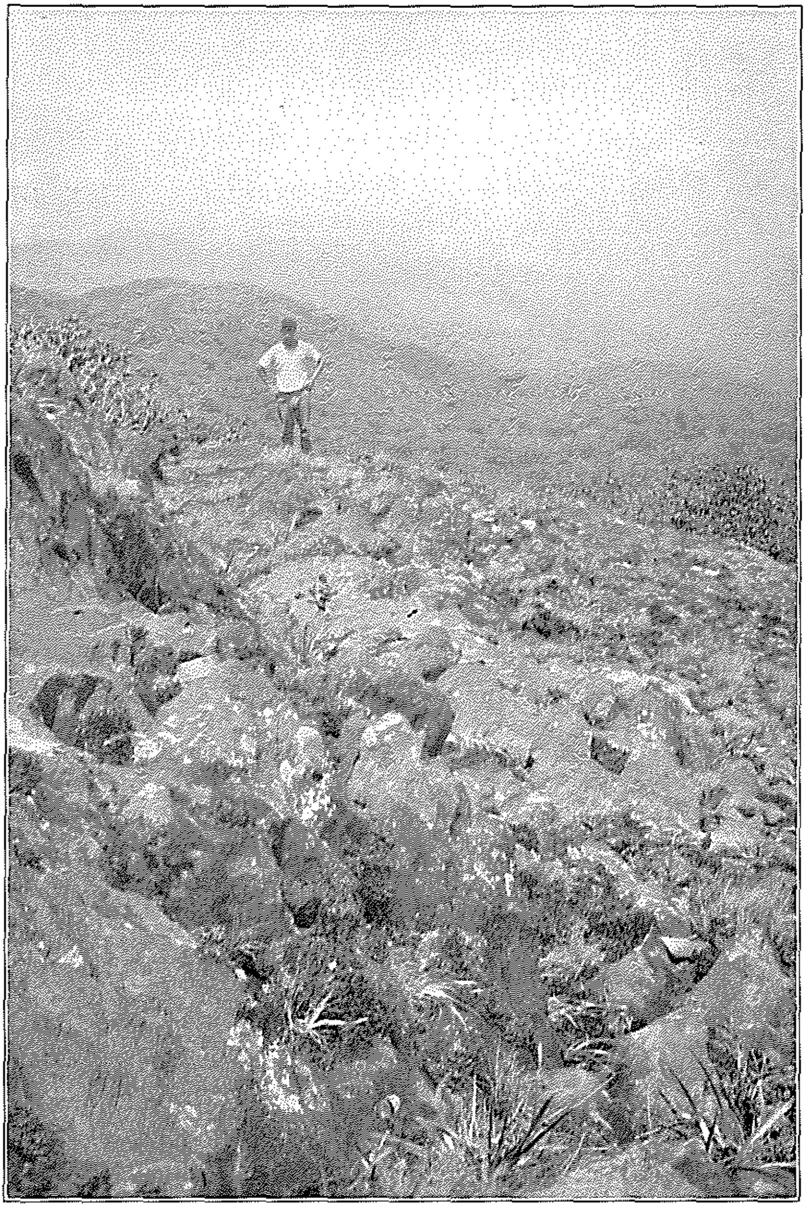

Fig. 50. Rock vegetation, summit of El Yunque. *Machaerina restioides* conspicuous in central foreground, growing on mats of mosses with smaller plants of *Scleria*.

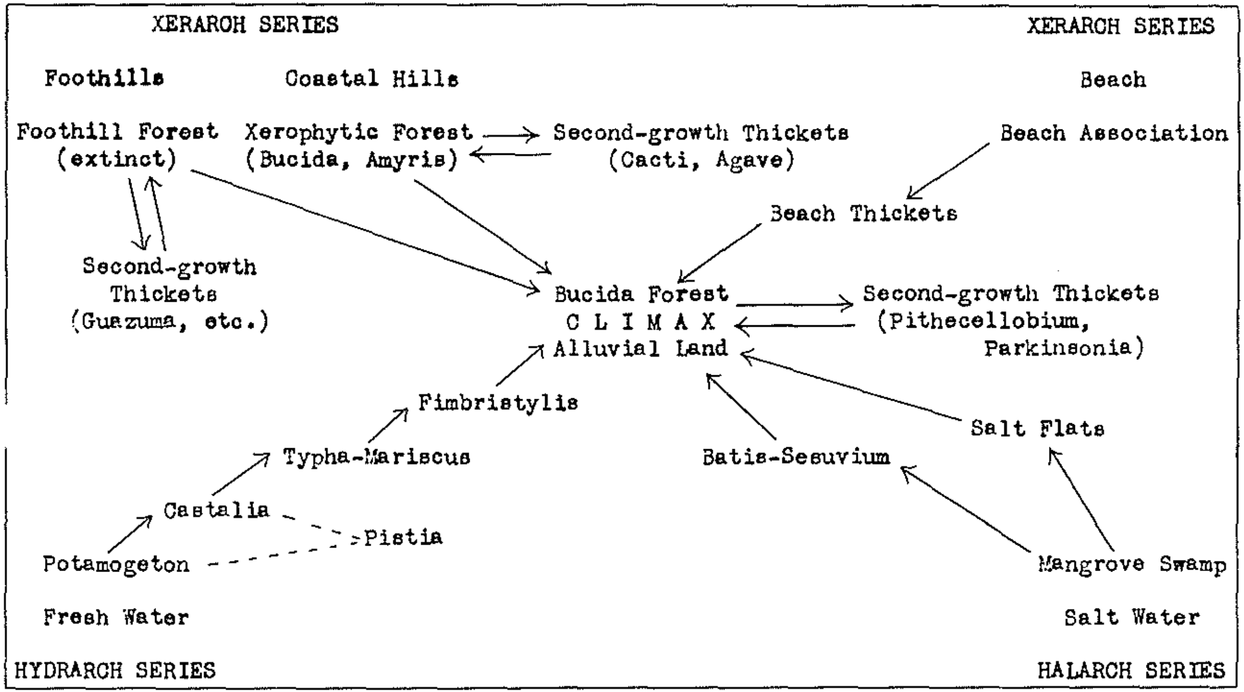

Fig. 51. The principal associations of the southern arid region of Porto Rico, with their successional relations.

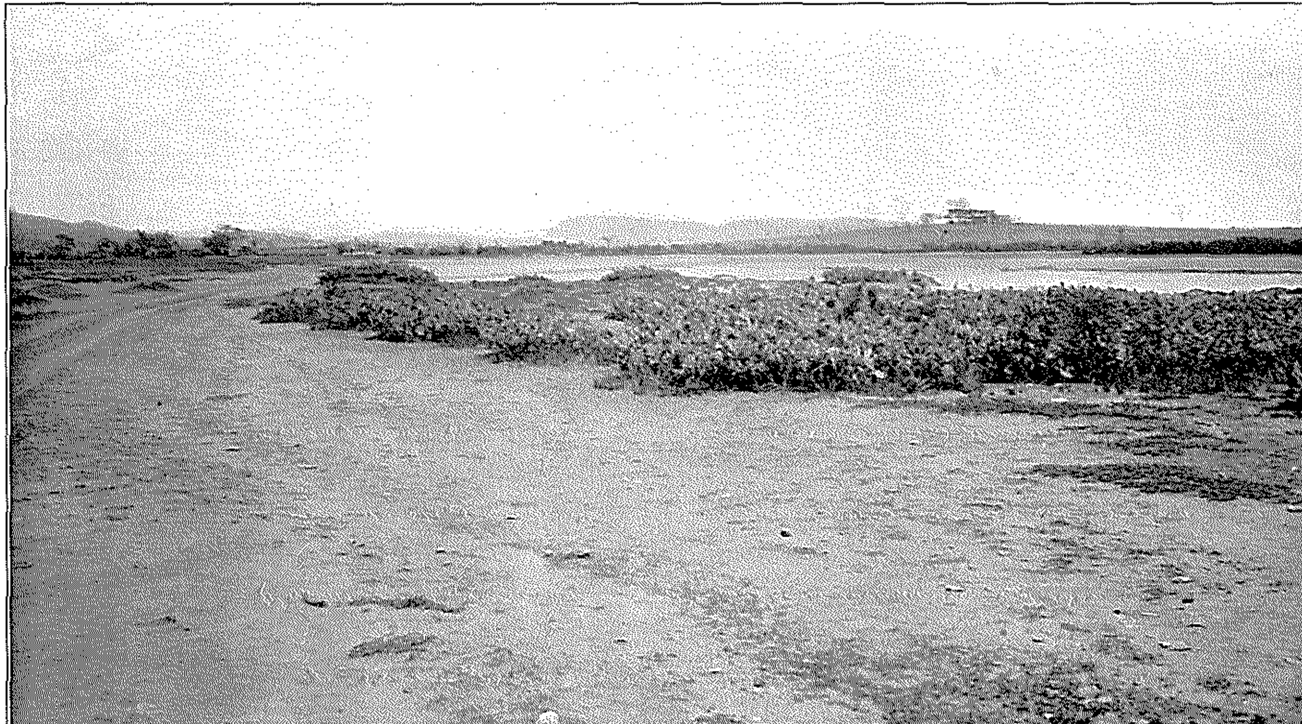

FIG. 52. Salt flats west of Guanica. The nearly bare foreground is sparsely occupied by small isolated plants of *Batis maritima*, *Sesuvium portulacastrum*, *Portulaca quadrifida*, *Heliotropium curassavicum*, *Commicarpus scandens* and *Opuntia repens*. *Opuntia dillenii* growing in the rear.

Fig. 53. Salt flats west of Guanica. The colony of *Opuntia dillenii* on slightly higher ground is overrun and surrounded by *Batis maritima* and *Sesuvium portulacastrum*.

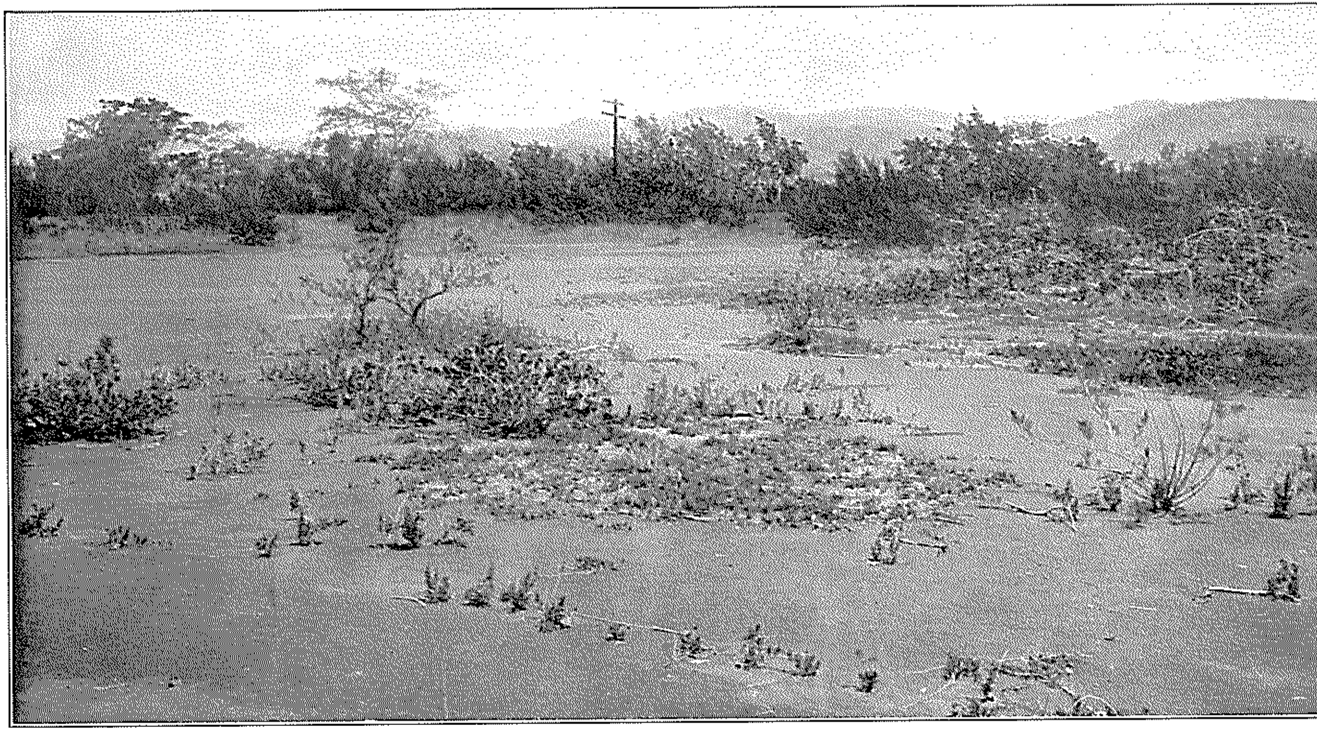

Fig. 54. Salt flats, Aguirre. A loose sod of matojo de playa (*Sporobolus virginicus*). Also the shrubby mangle bobo (*Avicennia nitida*) and small colonies of barilla (*Batis maritima*) and verdolaga rosada (*Sesuvium portulacastrum*). The transition to the bucar forest (*Bucida buceras*) is shown in the background.

FIG. 55. Nidos de gungulen (*Tillandsia recurvatum*) growing on insulated electric wires, Santa Isabel.

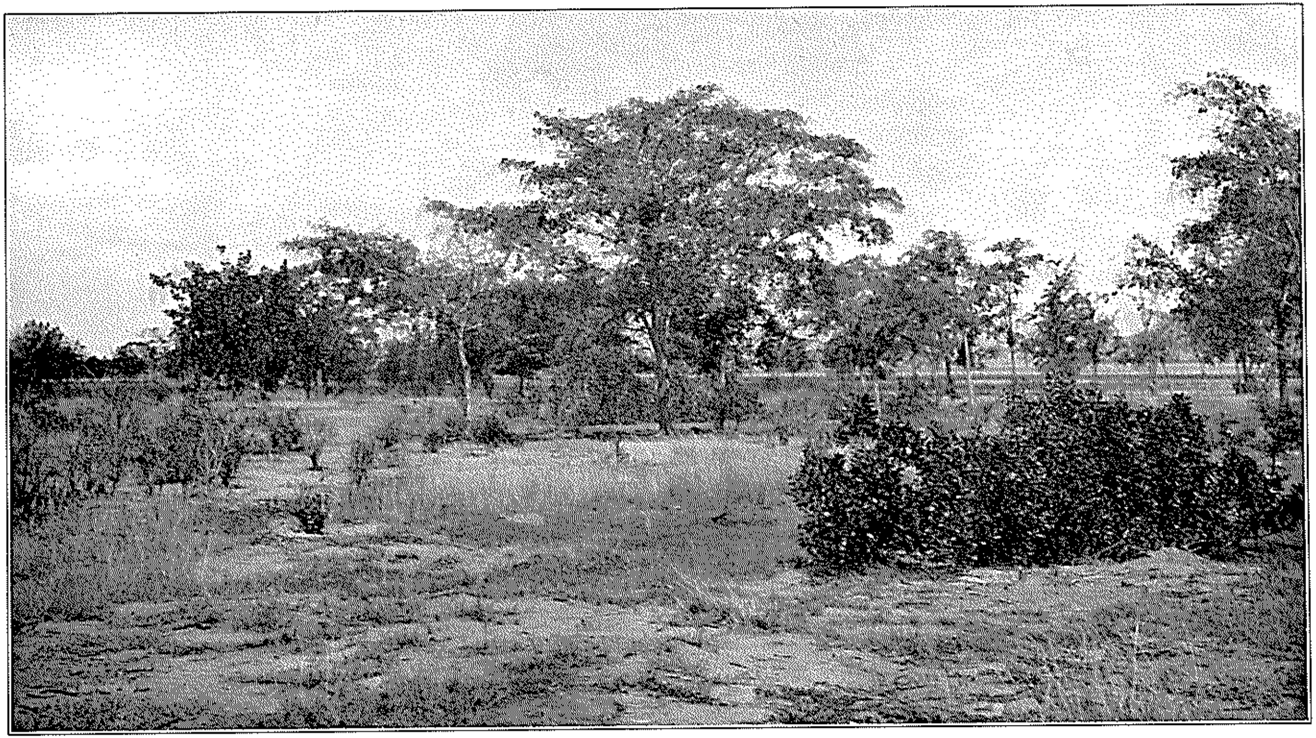

FIG. 56. Seaward margin of bucar forest (*B. buceras*), Aguiree. Mangle boton (*Conocarpus erecta*) at right; matojo de playa (*Sporobolus virginicus*) and horquetillo (*Chloris radiata*) in foreground. Also mats of *Sesuvium portulacastrum* and *Geliotropium currassavicum* in the foreground.

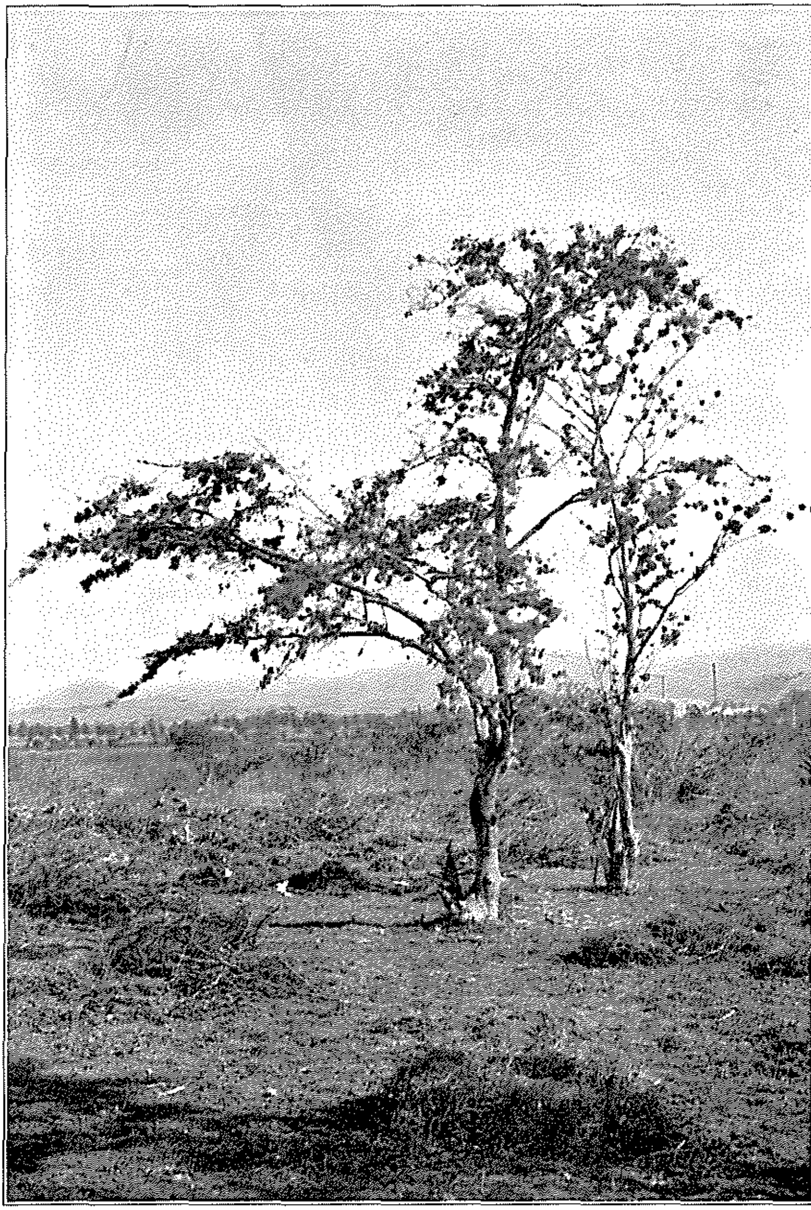

FIG. 57. Reversion of cleared pasture land to bucar forest (*B. buceras*) and thorn thicket near Ponce. The trees are heavily infested with nidos de gungulen (*Tillandsia recurvatum*). The thorn thicket is composed mostly of flor de Mayo (*Parkinsonia aculeata*) and escambron colorado (*Pithecellobium unguis-cati*) with various other species.

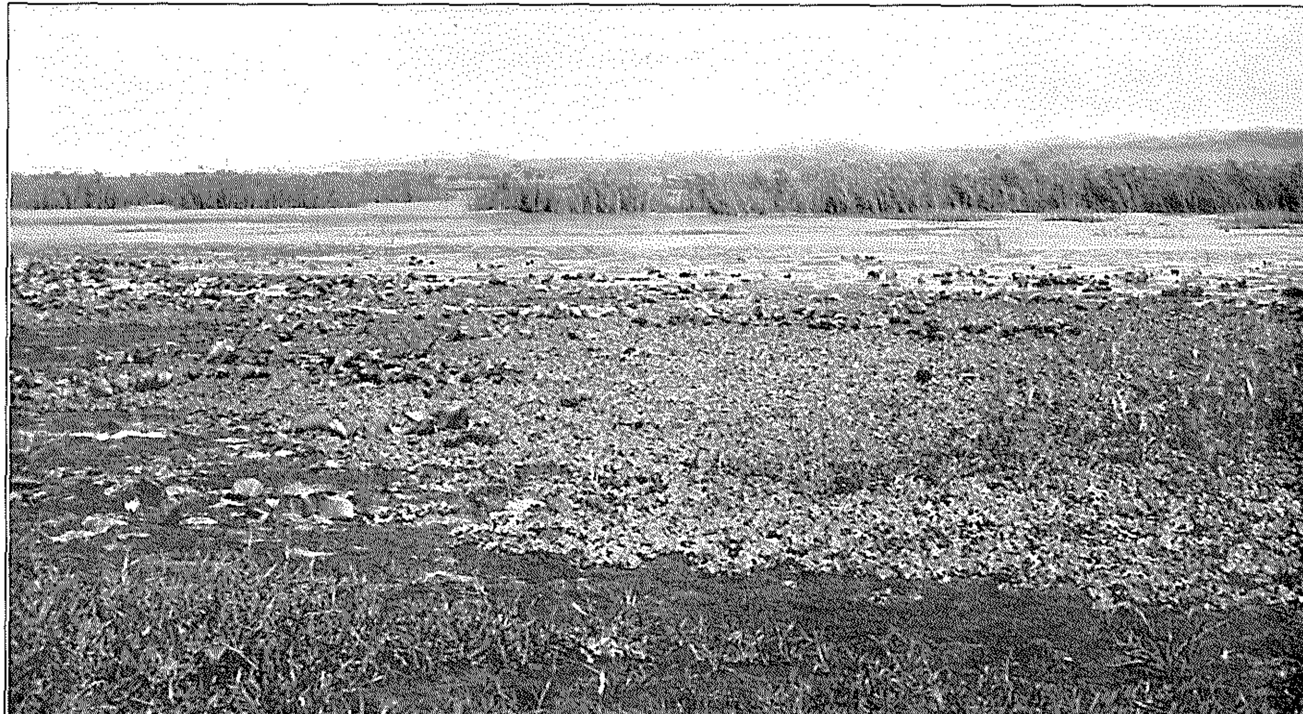

Fig. 58. Hydrophytic vegetation of the lagoon south of Lajas. The mud flats are occupied with masses of lechuguilla de agua (*Pistia stratiotes*) and flor de agua (*Castalia ampla*). The tall plants in the open water are eneas (*Typha angustifolia*).

FIG. 59. A large bucar (*B. buceras*) tree in cleared pastured land south of Lajas.

Fig. 60. Swamp vegetation near Aguirre. Four zones of vegetation are visible. The pastured foreground is occupied largely by *Cyperus laevigatus;* the next zone is *Fimbristylis spadicea;* the next is *Typha angustifolia* and the background is a mangrove forest.

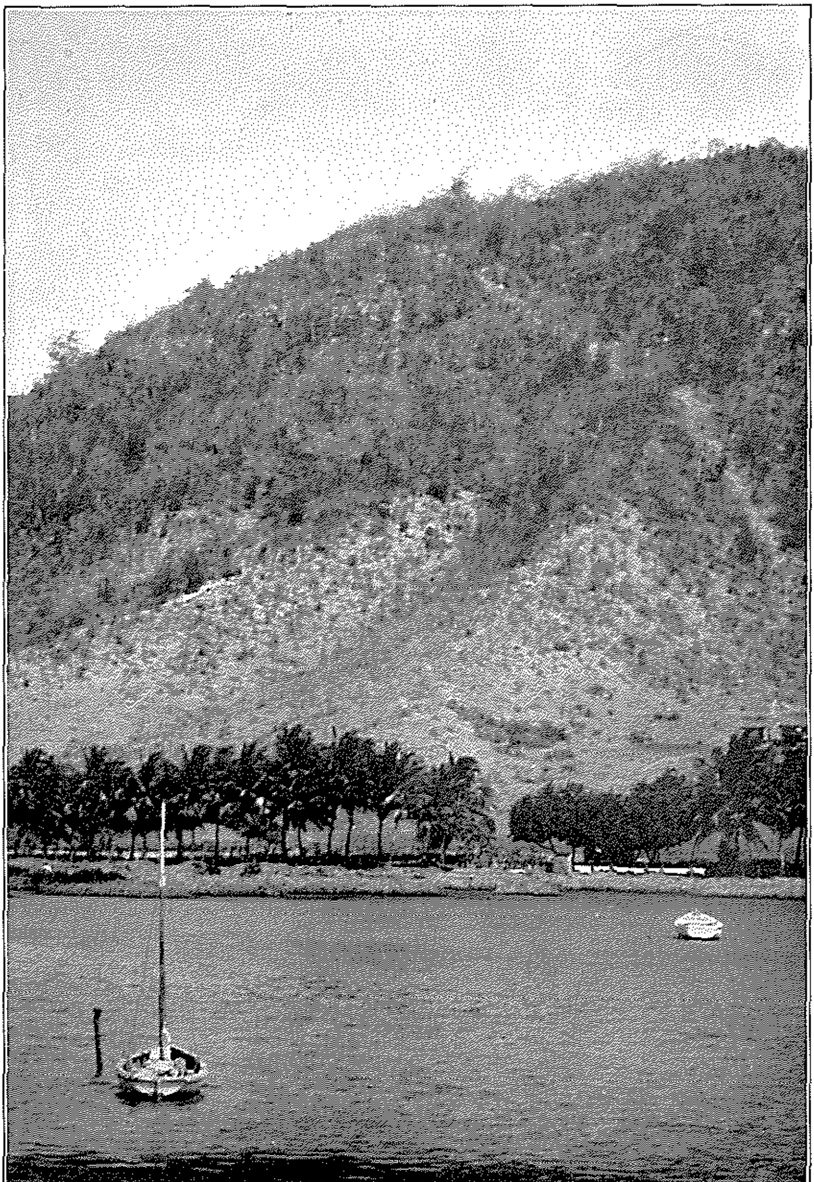

FIG. 61. Forest on Ponce limestone, east side of Guanica harbor. The xerophytic forest is composed of *Elaphrium simaruba*, *Amyris elemifera* and *Bucida buceras* and numerous other shrubs and small trees.

Fig. 62. Partly cleared forest on shale hills, La Parguera. *Amyris elemifera* in the center; *Eugenia rhombea* at right. The rocky soil and absence of herbs is characteristic.

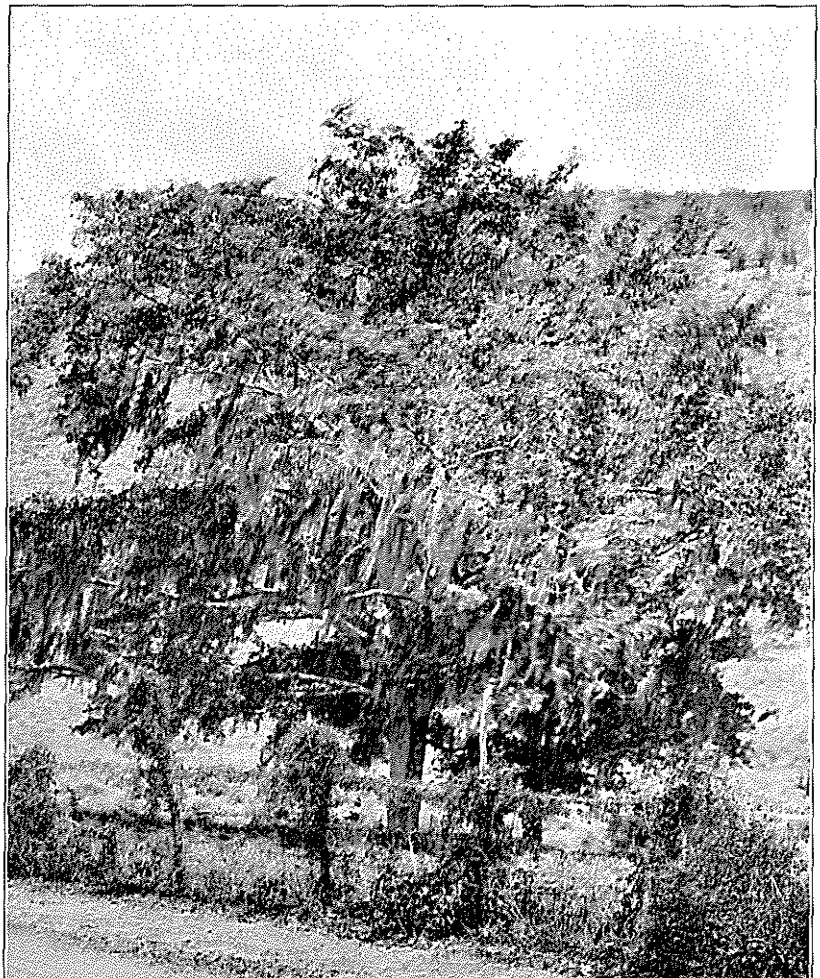

FIG. 63. Bucar tree (*Buceras buceras*) heavily infested with barbas de ucar (*Dendropogon usneoides*), near La Parguera.

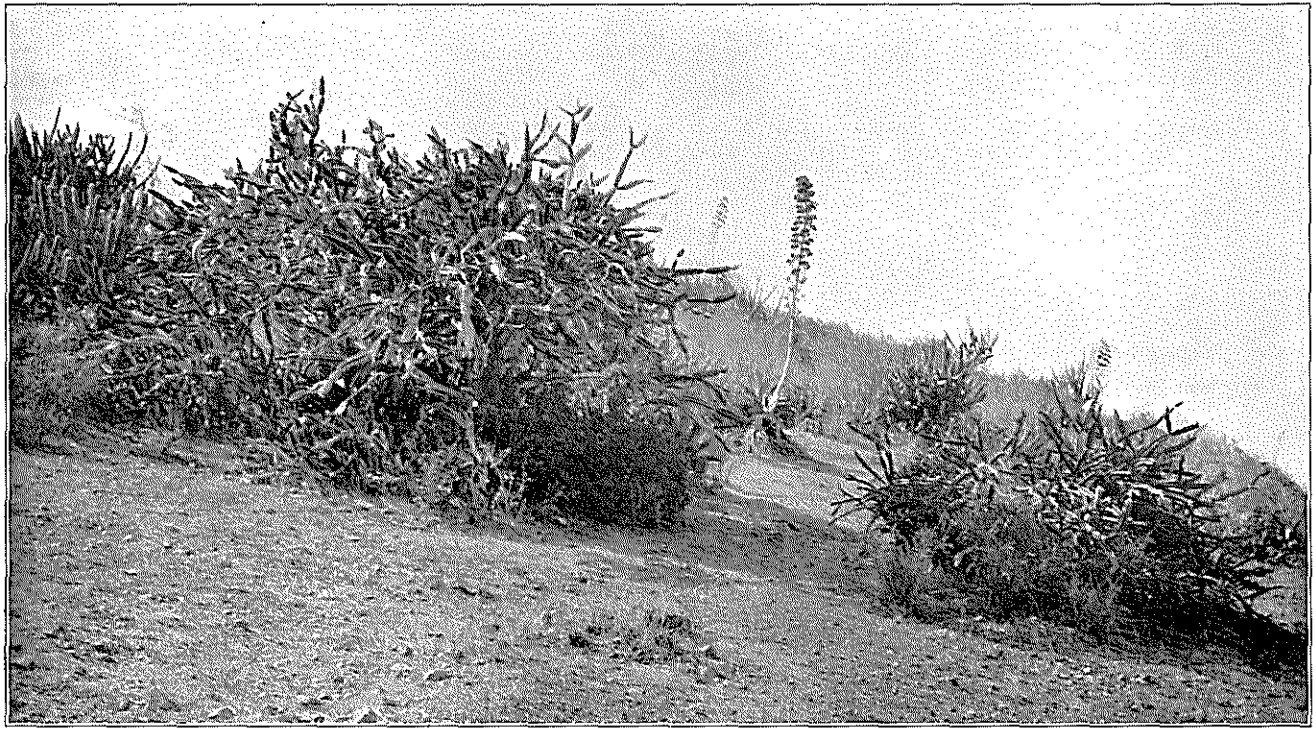

FIG. 64. Serpentine hill west of Yauco. Sebucan or dillo (*Cephalocereus royeni*) at the right; sebucan or pitajaga (*Leptocoreus quadricostatus*) at right and in center; small shrubs of *Pedilanthus angustifolius* in the right foreground and blooming plants of corita (*Agave missionum*) in the background.

FIG. 65. Serpentine hill west of Yauco. Melon de costa (*Cactus intortus*) and corita (*Agave missionum*) in the foreground. Tall stems of *Plumiera alba* and leafless shrubs of *Andrachne cunefolia* in the rear.

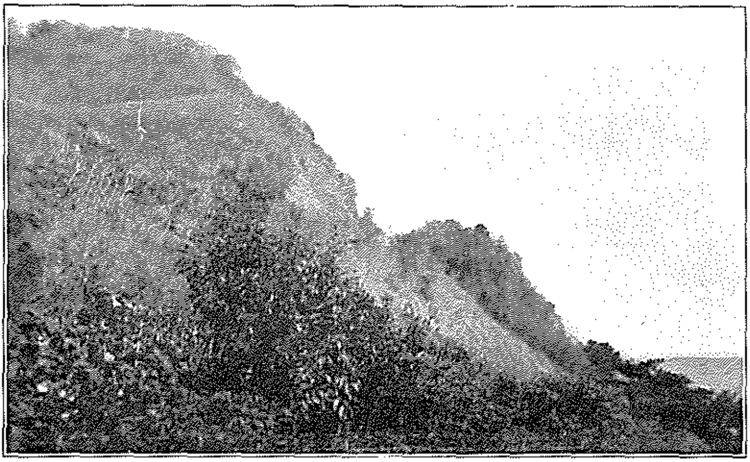

FIG. 66. Cape Mala Pascua, south of Maunabo. The vegetation is entirely xerophytic. The thickets on the summits are largely cotorra (*Ricinella ricinella*).

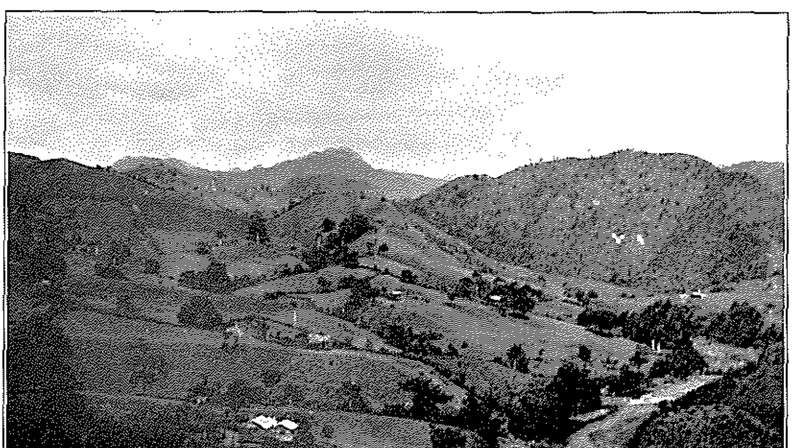

FIG. 67. Foothills of the central mountain range north of Yauco. Traces of the xerophytic forests persist on the hill at the right. Most of the land is in pasture with scattered mango trees (*Mangifera indica*) and jobo (*Spondias mombin*) and others.

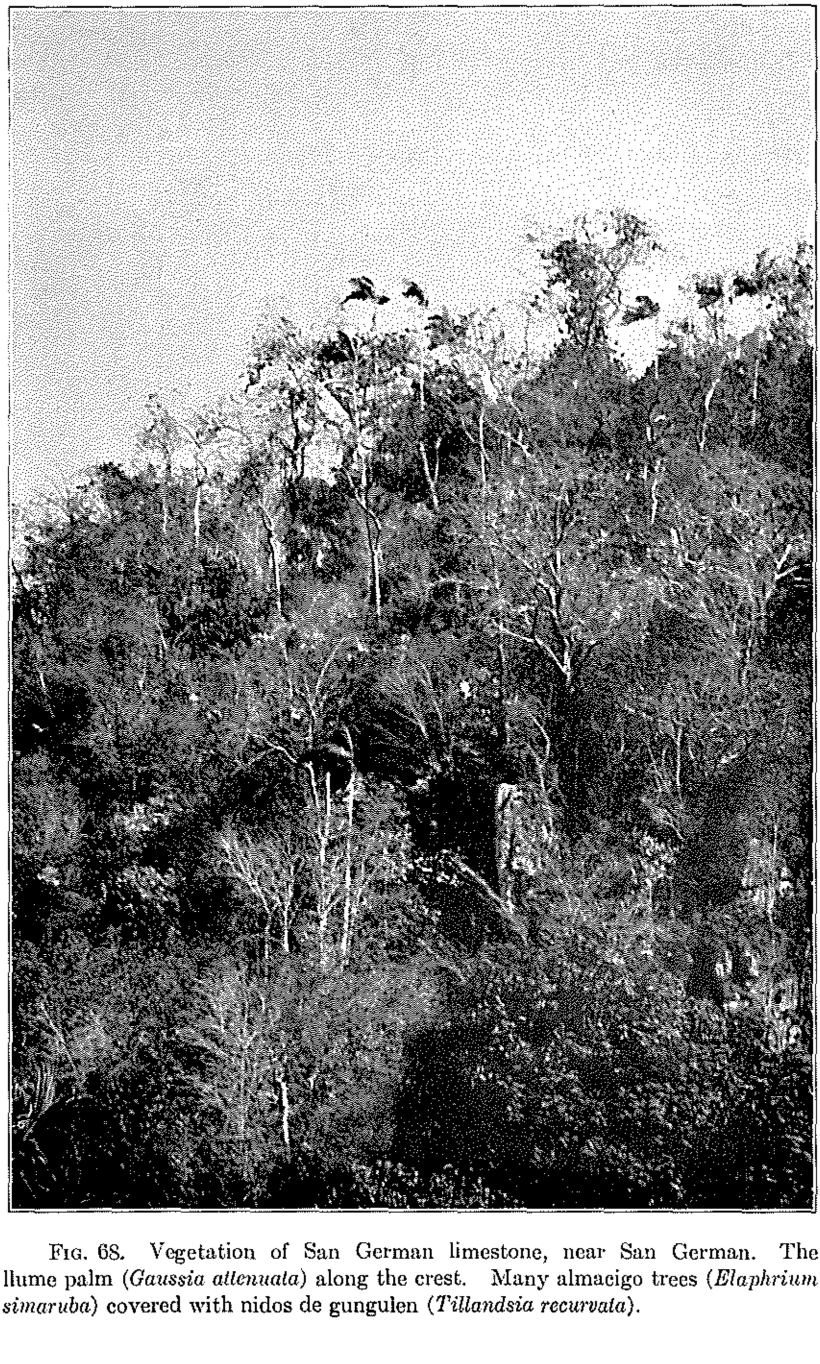

Fig. 68. Vegetation of San German limestone, near San German. The llume palm (*Gaussia attenuata*) along the crest. Many almacigo trees (*Elaphrium simaruba*) covered with nidos de gungulen (*Tillandsia recurvata*).

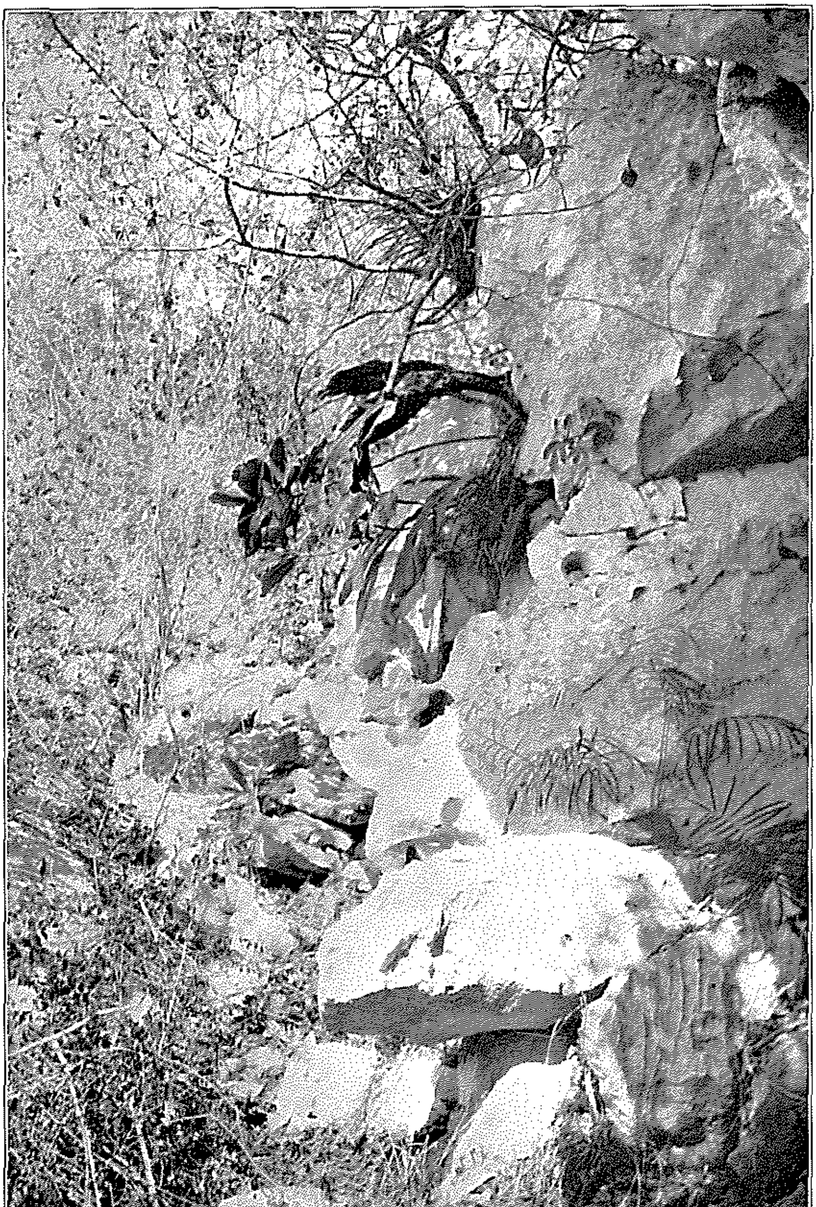

FIG. 69. Vegetation of San German limestone, near San German. *Zamia portoricensis* in the right foreground; *Anthurium acaule* and *Clusia rosea* in center; *Clusia gundlachii* and *Tillandsia* sp. at the top; with the vertical vines of *Serjania polyphylla* at the left.

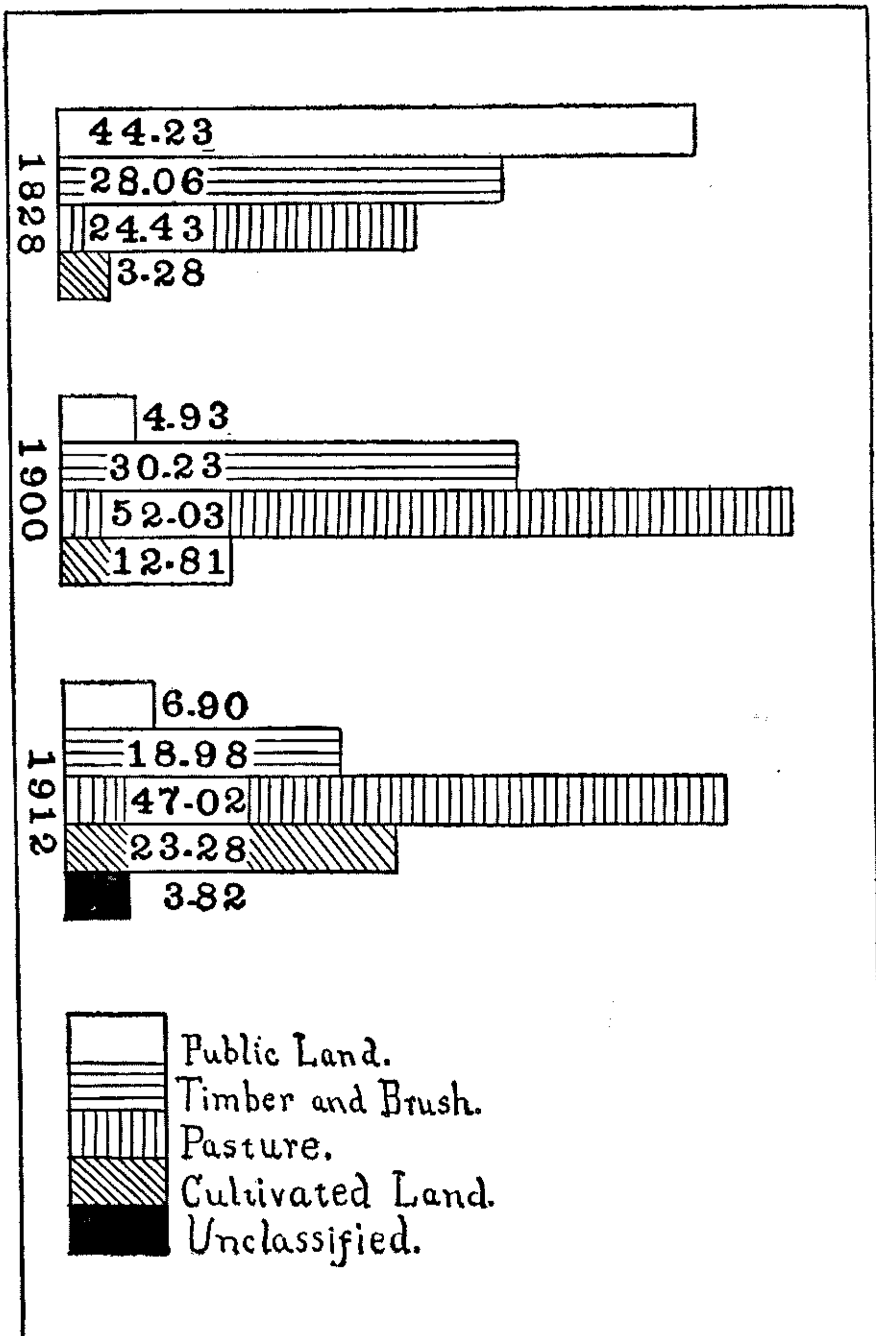

FIG. 70.—Showing the utilization of lands in Porto Rico. Adapted from Murphay.

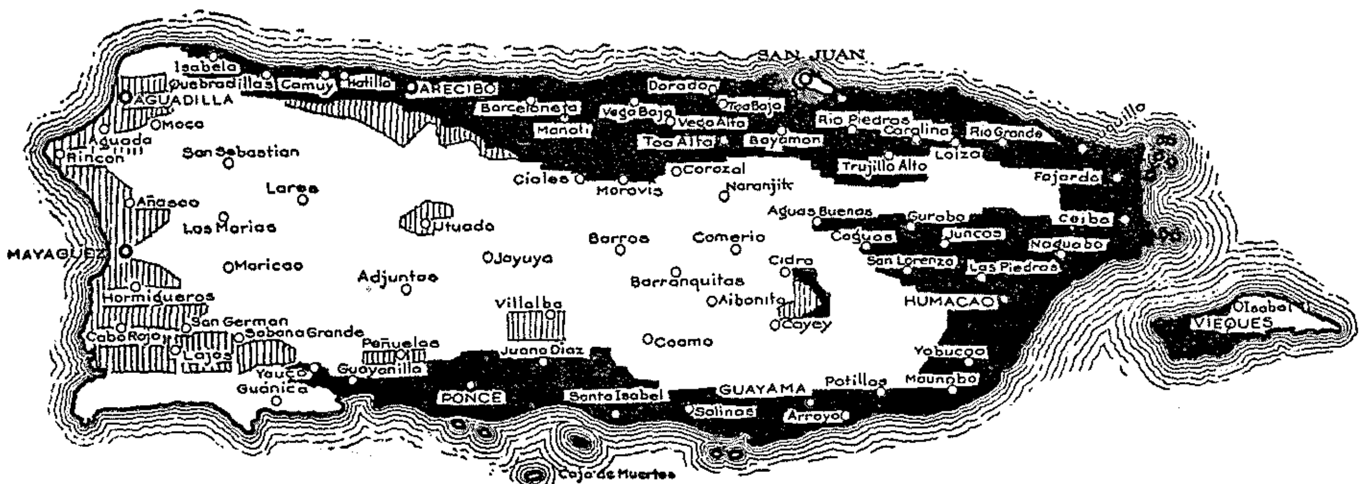

FIG. 71.—Showing the distribution of sugar cane. From the 1924–25 Annual Report of the Commissioner of Agriculture and Labor.

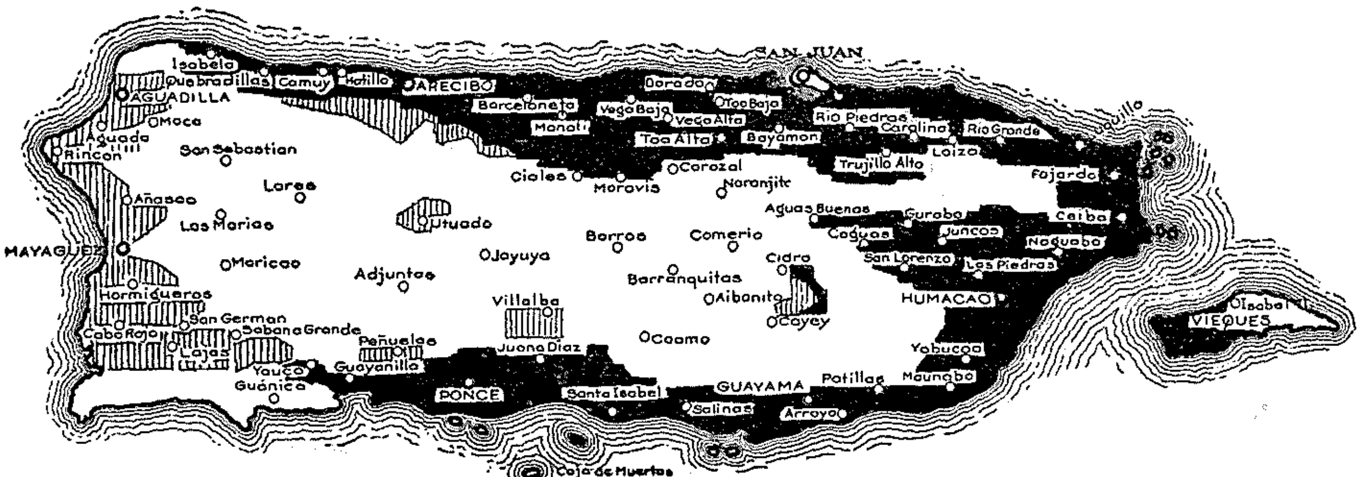

FIG. 71.—Showing the distribution of sugar cane. From the 1924–25 Annual Report of the Commissioner of Agriculture and Labor.

FIG. 72.—Showing the distribution of coffee. From the 192'–25 Annual Report of the Commissioner of Agriculture and Labor

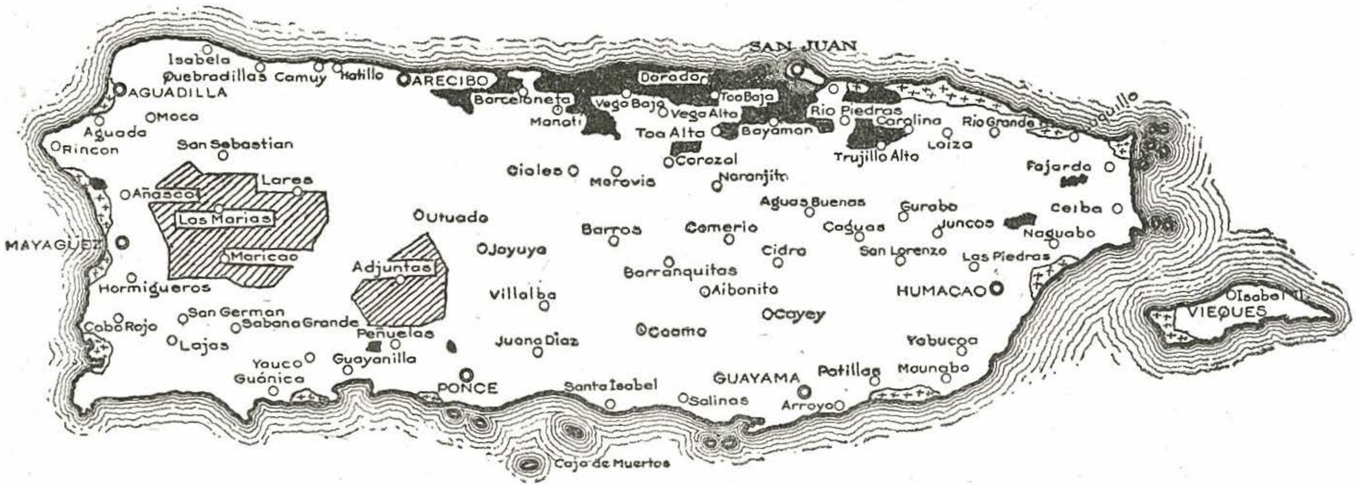

FIG. 73.—Showing distribution of the fruit industry. From the 1924–25 Annual Report of the Commissioner of Agriculture and Labor.