Series 1936, No. 8 Issued January 1942

Soil Survey

Puerto Rico

By
R. C. ROBERTS
United States Department of Agriculture
and party

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY
In cooperation with the
University of Puerto Rico Agricultural Experiment Station

For sale by the SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C. Price $3.25

This publication is a contribution from

BUREAU OF PLANT INDUSTRY

E. C. Auchter, *Chief*

Division of Soil Survey

Charles E. Kellogg, *Principal Soil Scientist, in Charge*

UNIVERSITY OF PUERTO RICO AGRICULTURAL EXPERIMENT STATION

F. A. López Domingues, *Director, 1931–38*

J. A. B. Nolla, *Director, 1938—*

Soils Division

J. A. Bonnet, *Chief*

Series 1936, No. 8 Issued January 1942

SOIL SURVEY OF PUERTO RICO

By R. C. ROBERTS, Division of Soil Survey, Bureau of Plant Industry, United States Department of Agriculture, and party [1]

Area inspected by MARK BALDWIN, Inspector, District 1

United States Department of Agriculture in cooperation with the University of Puerto Rico Agricultural Experiment Station

CONTENTS

	Page
Introduction	1
Island surveyed	2
Physiographic and geologic features	3
Mineral resources	15
Vegetation	17
Animal life	29
Population	32
Towns	36
Transportation	38
Education	40
Water supply	41
Farm buildings	42
Climate	47
Agriculture	59
Sugarcane (caña de azúcar)	67
Tobacco (tabaco)	84
Coffee (café)	94
Grapefruit (toronja)	103
Pineapples (piñas)	108
Coconuts (cocos)	117
Bananas (guineos) and plantains (plátanos)	120
Corn (maíz)	127
Sweetpotatoes (batatas)	129
Yautia, dasheen, or tania (yautía)	132
Name, or yam	134
Pigeonpeas (gandules)	137
Yuca (cassava)	141
Beans (habichuelas) and cowpeas (frijoles)	143
Cotton (algodón)	145
Oranges (chinas)	145
Mango	147
Avocado (aguacate)	149
Miscellaneous crops	149
Agriculture—Continued.	
Livestock	153
Soil-survey methods and definitions	166
Soils and crops	171
Soils of the uplands	183
Soils of the inner plains	249
Soils of the terraces and alluvial fans	264
Soils of the coastal plains	291
Soils of the river flood plains	312
Soils of the coastal lowlands	342
Agrología (suelos y cosechas)	358
Suelos de la altura	359
Suelos de las llanuras interiores	370
Suelos abancalados y de aluvión en abanico	373
Suelos de las llanuras costaneras	378
Suelos de los valles de aluvión	384
Suelos de los bajos costaneros	388
Glosario	390
Productivity ratings	391
Clasificación a base de productividad	412
Alkali and saline soils	414
Morphology and genesis of soils	421
The 20- to 25-inch rainfall belt	431
The 25- to 35-inch rainfall belt	434
The 35- to 45-inch rainfall belt	440
The 45- to 60-inch rainfall belt	445
The 60- to 75-inch rainfall belt	451
The 75- to 95-inch rainfall belt	467
The 95- to 160-inch + rainfall belt	481
Summary	484
Literature cited	492
Index	495
Map.	

INTRODUCTION

The detailed soil survey of Puerto Rico was started during the winter of 1928 and was continued each winter until its completion in 1936. The survey parties included from one to eight Federal men and from one to three insular men. The yearly average was a party of six. Usually the winter season started in January and finished in June. A soil survey (*16*) [2] of an area between Arecibo and Ponce was made in 1902, but since that time much additional knowledge of soils has been acquired, and it was deemed desirable to remap that area, in order that the map of the island might be consistent throughout. The original survey was neither so detailed nor so complete as the recently finished survey.

[1] The party included the following: James Thorp, L. R. Smith, C. C. Nikiforoff, A. E. Shearin, S. R, Bacon, O. C. Rogers, A. T. Sweet, Robert Wildermuth, Z. C. Foster, W. H. Buckhannan, T. E. Beesley. M. M. Striker, M. B. Marco, Ralph Leighty, Juan Juárez, Alfonso Reboyras, and V. M. Alexandrino. Division of Soil Survey, Bureau of Plant Industry, United States Department of Agriculture; and J. A. Zalduondo, D. A. Rodríguez, Jorge Landron, F. A. Villamil, G. A. Torruella, Octavio Reyes, Rafael Bird, and Ferdinand Méndez, University of Puerto Rico. The field work for this survey was done while the Division of Soil Survey was a part of the Bureau of Chemistry and Soils.

[2] Italic numbers in parentheses refer to Literature Cited, p. 492.

The purpose of the survey has been to take an inventory of all the land, determine the apparent productivity of the different soil types, and make a map of the island showing such cultural features as roads, trails, houses, schoolhouses, towns, railroads, bridges, canals, reservoirs, and cemeteries, and such natural features as soil types, streams, mountain peaks, lakes, and rock outcrops.

It was thought that, with a careful study of the soil types, better procedures for soil and crop management could be worked out in relation to the many soil types, so that higher yields could be obtained or production costs reduced. Most soil types have individual capabilities and requirements for fertilizers, kinds and varieties of crops, and cultivation practices; in fact, in many instances a special system of crop management is required for each soil, in order to obtain the maximum yields. By having a map showing the different soil types, the results of fertilizer experiments and the experiences of farmers can be classified, and the best crop and management can be found for each soil type.

This publication gives a brief description of Puerto Rico, its physiography, mineral resources, vegetation, climate, transportation, industries, agricultural statistics, soils, crops and their managements, and also the future possibilities of the crops now grown. A section on soils and crops, written in the Spanish language, also is included. For persons interested in the scientific aspects of the soils and their genesis, more detailed descriptions of the soils and a discussion of the soil-forming processes are made.

ISLAND SURVEYED

Puerto Rico is the smallest and farthest east of the four islands—Cuba, Jamaica, Hispaniola, and Puerto Rico—known as the Greater Antilles. It lies in the Torrid Zone between 17°55′ and 18°31′ north latitude and 65°39′ and 67°15′ west longitude. The latitude is about the same as that of the Sahara Desert and Bombay, India, and is slightly farther south than the southern tip of the island of Hawaii. The north-central coast of Puerto Rico is 1,400 nautical miles (1,610 statute miles) southeast of New York City, and the western part of the island is about 450 miles from the eastern point of Cuba. Ponce, on the south coast, is about 525 miles due north of Caracas, Venezuela. The island is bounded on the north and east by the Atlantic Ocean, which attains its maximum depth, 27,922 feet, about 75 miles to the north. On the south is the Mar Caribe (Caribbean Sea), which attains a depth of about 12,000 feet a short distance offshore. Canal de la Mona (Mona Passage) separates Puerto Rico on the west from the Dominican Republic, which occupies the eastern part of the island of Hispaniola.

Puerto Rico is nearly rectangular, as shown by figure 1. The greatest dimension, 113 miles (182 kilometers), is east and west, and the average width north and south is about 41 miles (66 kilometers). Including all the small islands under its jurisdiction, Puerto Rico has an area of approximately 3,435 square miles (8,896 square kilometers). The soil survey includes all the larger islands except Mona, which lies about 45 miles southwest of the mainland and has an area of about 20 square miles (52 square kilometers). The most important 2 of the 28 or more smaller islands belonging to Puerto Rico are Vieques and

Culebra. They have an area of approximately 57 square miles (148 square kilometers) and 11 square miles (28 square kilometers), respectively, and extend directly eastward from the mainland to

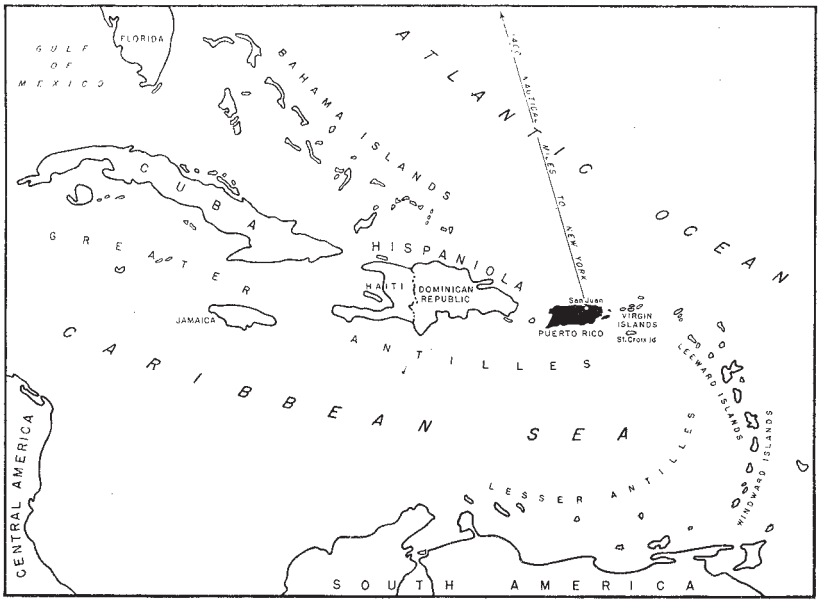

FIGURE 1.—Sketch map of the West Indies and adjacent regions, showing location of Puerto Rico.

Croquis de las Indias Occidentales y regiones adyacentes, demostrando la situación de Puerto Rico.

65°15′ west longitude. The total area of the soils mapped is 3,383 square miles, or 8,761 square kilometers.

PHYSIOGRAPHIC AND GEOLOGIC FEATURES

Puerto Rico may be divided roughly into three principal physiographic divisions, each having its own geologic relationships (fig. 2). The most extensive division consists of the complex mountain ranges which were eroded during Cretaceous time to an old, or peneplain, stage of topographic development. They were then submerged, and were overlapped during Tertiary time by the second division—the coastal plains. The sea level during that period fluctuated to such an extent that the coastal plains were exposed, eroded, and submerged, only to be exposed again and further dissected. The third division—the playa plains—includes land formed by sediments accumulated on the lower elevations during Quaternary time.

THE COMPLEX MOUNTAIN RANGES

If Puerto Rico were viewed from the air at a high elevation one would readily observe that it is divided into a northern and a southern part by an east-west mountain range, the crest of which is far to the south of a latitudinal line passing through the center of the island.

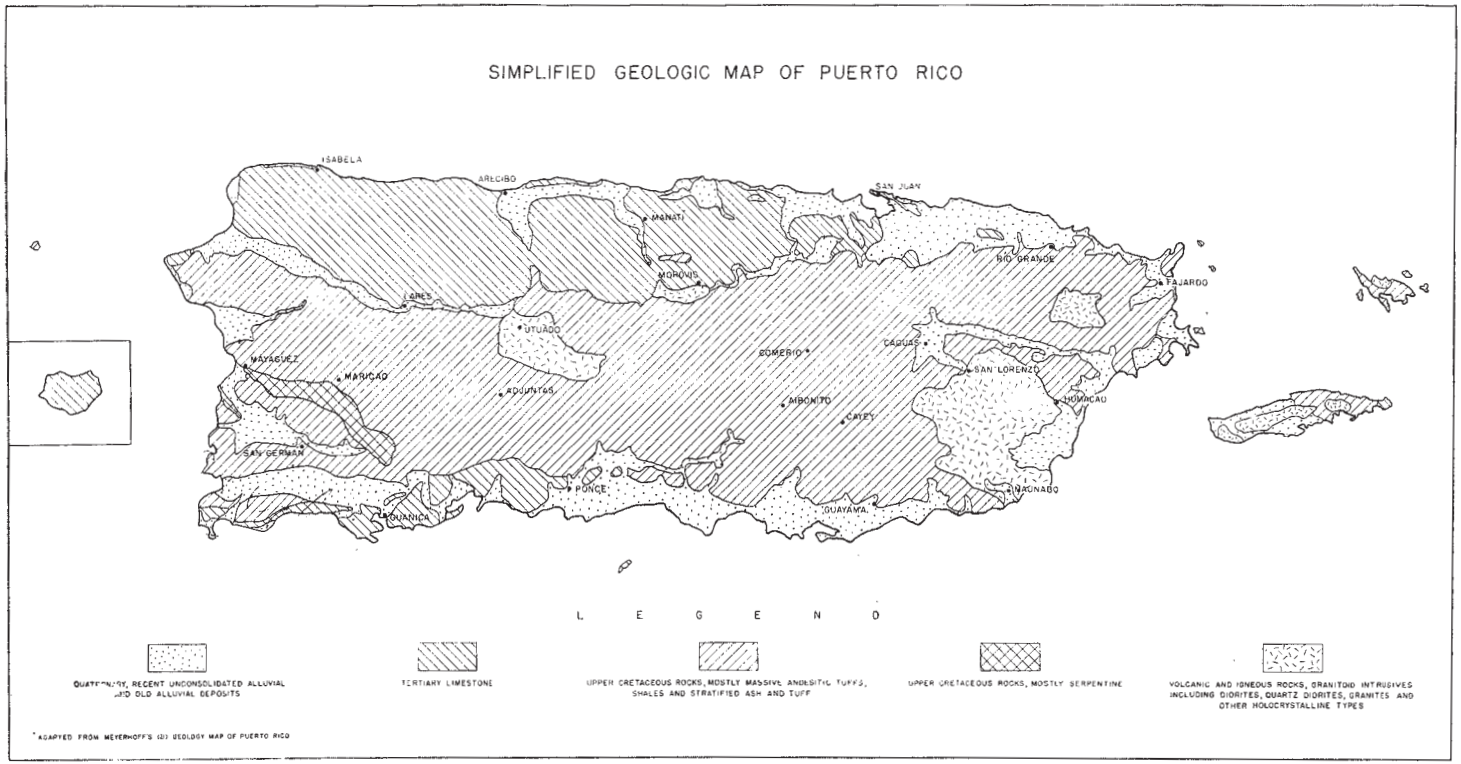

FIGURE 2.—The unconsolidated recent alluvial and old alluvial deposits largely comprise the playa plains. The areas occupied by Tertiary limestone comprise the northern and part of the southern coastal plains. The remainder of the island consists of complex mountain ranges and dissected plateaus of various rock types indicated in the legend.

Los llanos de la playa incluyen la mayor parte de los depósitos de aluvión recientes y viejos. Los llanos de la costa incluyen la mayor parte del área ocupada por la caliza terciaria. El resto de la isla constituye las cadenas montañosas complejas.

FIGURE 3.—Rain-forest vegetation in the Sierra de Luquillo; average annual rainfall about 130 inches. Soils are shallow and grayish brown on steep slope; on undulating areas they are grayish brown, underlain by light-red fairly permeable clay.

Vegetación en los bosques de las montañas de Luquillo; promedio anual de lluvia es alrededor de 130 pulgadas. Los suelos son poco profundos, de un color pardogrisáceo y en un declive escarpado. En áreas ondulantes el suelo es pardogrisáceo sobre una arcilla permeable de color rojo claro.

To the south of the crest the relief is rugged and is characterized by many steep-walled rock cliffs, abrupt high waterfalls, and jagged peaks. On the north side of the crest and extending to the coastal plain, the relief gradually becomes less rough, although there are many small waterfalls, cascades, rapids, and high mountain peaks. The main mountain range is known as the Cordillera Central in the west and Sierra de Cayey in the east. This chain extends in a northwesterly direction from Punta Yeguas (Yeguas Point) along the southeastern coast to a point near the Represa de Carite (Carite Reservoir) where the peaks attain a height of nearly 3,000 [3] feet. Thence the chain extends westward, skirting Cayey on the south, to the high rolling agricultural plateau at Aibonito. From Aibonito to a point

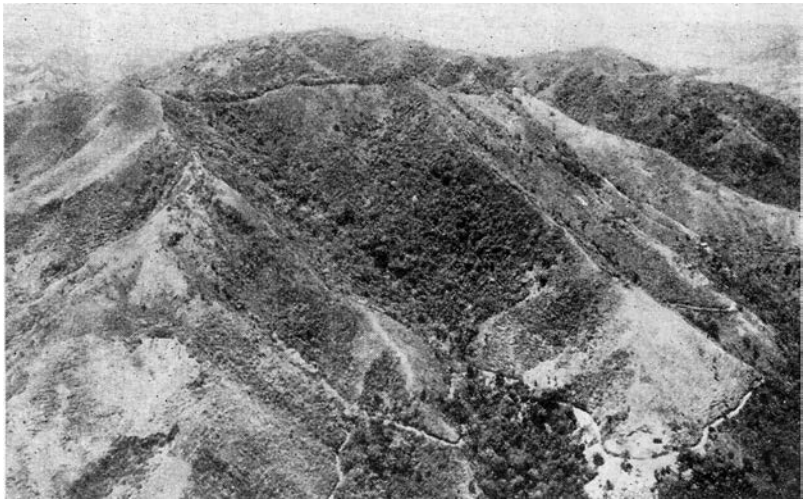

FIGURE 4.—Soil-covered slopes, ∧-shaped grass-covered ridges, and V-shaped forested ravines. The wind-protected southern and western concave slopes are better adapted to coffee, bananas, and oranges than are the wind-exposed ridges and the eastern and northern convex slopes.

Laderas cubiertas de suelo, montes en forma de ∧ cubiertos de yerba, y barrancas en forma de V cubiertas de bosques. Las laderas cóncavas al sur y al oeste protegidas del viento están mejor adaptadas para la siembra de café, guineos y chinas (naranjas) que aquellas convexas hacia el este y el norte, expuestas al viento.

west of Orocovis the peaks are numerous, steep, brush covered, and range in elevation from 3,000 to 3,300 feet. West from Orocovis to Monte Guilarte (Mount Guilarte) the range becomes more rugged, heavily forested, and more sparsely populated. Cerro de Punta, the highest peak (4,398 feet above sea level), is about 4 miles south of Jayuya and is near the center of this rugged area. From Monte Guilarte to sea level at Mayagüez the elevation gradually decreases, the relief becomes less rough, and more agricultural crops, especially coffee and oranges, are grown.

The less extensive chains of the complex mountain ranges consist of the prominent rocky, steep, sparsely populated, forest-covered Sierra

[3] All elevations are taken from a map (Porto Rico and Contiguous Islands under its Jurisdiction) published by U. S. Dept. Agr. Forest Service, R-8. (Revised by L. I. Neiman, 1935.)

de Luquillo (Luquillo Mountains) 2,500 to 3,500 feet high (fig. 3), in the eastern end of the island, and the less conspicuous lower highly eroded thickly populated grass- and minor-crop Atalaya range, culminating in Pico Atalaya (Atalaya Peak) in the northwestern part. In addition to these ranges, there are many smaller ranges separated by agricultural valleys and hills.

This extensive physiographic division is characterized by steep soil-covered slopes (fig. 4), ∧-shaped ridges, and V-shaped ravines that gradually change toward the coastal plains and interior valleys to gently rolling hills and sloping ravines. The hills and mountain ranges do not have a uniform definite trend as do the hills in the coastal plain along the northern coast, but they have been deeply dissected by a dendritic system of stream development, and many of the divides are separated by gorgelike valleys ranging from 500 to 1,000 feet in depth. Many excellent dam sites for hydroelectric plants occur along the rapid-flowing rock-bottom mountain streams (fig. 5).

FIGURE 5.—Rapid-flowing mountain stream, which affords excellent sites for dams for hydroelectric plants.

Torrente en un monte; sitio excelente para una presa de planta hidroeléctricas.

Practically all of the streams head in the area occupied by this physiographic division. Some of the rivers are very large, but none is navigable except for small boats. The largest waterways are the Río Grande de Loíza (Loíza River), Río de la Plata (Plata River), and Río Grande de Arecibo (Arecibo River). All these flow north to the ocean. The Río Culebrinas (Culebrinas River) flows west, following the limestone escarpment from a point near Lares to the western coast; and the Río Grande de Añasco (Añasco River) drains a large part of the west-central area. The streams flowing to the southern coast resemble the streams in the western plains of the United States, as they generally are dry many months of the year. Those flowing to the eastern coast are short but flow continuously. The beds of the larger streams, both in the humid and arid sections range from 100 to 175 feet in width, and the height of the banks ranges from 4 to 20 feet. Most of the stream beds through the uplands are strewn with large boulders, but only in the arid southern section are large boulders abundant in the stream channels throughout the river flood plains. During floodtime some of the streams discharge (*49, p. 26*) from 10,000 to 20,000 second-feet

of water. Even during the dry seasons, some of the streams in the humid area discharge from 250 to 1,500 second-feet.

Geologically, the complex mountain ranges are of volcanic origin, but not in the same degree as the ranges on the volcanic islands of Hawaii and Martinique. Meyerhoff (*31*) has written an extensive description of the geology of Puerto Rico. The most abundant and widely distributed rocks are volcanic tuffs and shales, many of which contain some igneous intrusive, generally andesitic in composition. The tuffs and shales contain a very small quantity of quartz. Therefore, the weathering of these rocks produces a soil that is high in clay, medium low in silt, and low in sand. The rocks have weathered to a depth ranging from 20 to 60 feet on level or rolling relief in areas of high rainfall. The development of the soil and the weathering of the rocks depend to a great extent on the character of the soil climate, which is the product of air climate and local conditions. The more

FIGURE 6.—Granite boulders strewn over the surface of Pandura loam, smooth phase. Making charcoal to the right on typical Pandura loam. Múcara soils in background.

Rocas graníticas regadas por la superficie del Pandura lómico, fase lisa. A la derecha haciendo carbón en un Pandura lómico típico. Suelos Múcara al fondo.

water and heat that penetrate to the rock, the greater the weathering process and the thicker the soil. Even in areas having very high rainfall, if the slopes are so steep that only a small quantity of water remains in contact with the rocks for any length of time, the soil is shallow. In fairly dry areas, if the surface is level or slightly depressed, the rock in general is weathered to a greater depth than on slopes in areas having a higher rainfall.

Granite ranks next in extent to tuffs and shales in the composition of the complex mountain ranges. It is localized chiefly in two rather large areas, one covering nearly 100 square miles in the vicinities of Juncos, Yabucoa, and Patillas, the other including about 30 square miles between Utuado and Jayuya. The larger area is characterized by two distinct separations, as follows: (1) Steep, eroded slopes with numerous smooth hard granite boulders, some of which are 20 feet in diameter, strewn over the surface (fig. 6). Some of the peaks in this area are nearly 2,000 feet high, but most of the land is below the

1,500-foot contour line. (2) The more rolling areas, which range in elevation from 250 to 1,000 feet and are rock-free, moderately eroded, but intensively cultivated. The small granite area near Utuado is characterized by short steep severely eroded stone-free cultivated hillsides and grass-covered knife-edged ridges, very few of which attain an altitude of more than 1,500 feet. Most of the granite rock in Puerto Rico is a coarse-grained quartz diorite that weathers into a friable well-drained and well-aerated soil that requires yearly fertilization. In most granite areas, the drainageways are U-shaped rather than V-shaped, as is characteristic in other areas of the island. Houses are numerous in these areas, especially so on those of more rolling relief.

In addition to the tuff, shale, and the granite igneous intrusions, a fairly large area of serpentine rock occurs in the west-central part of the island, extending from a point northwest of Yauco to the coast near Mayagüez. This rock produces soils that are less erodible than the products of other rocks, and most of the hills are conspicuous in that they extend above the surrounding land, forming high rounded ridges. Where soils from this rock occur, vegetation is scanty and there are very few houses. Extensive landslips and pronounced creeping occur on the steep slopes. The rock is smooth, like talc, and platy, and when an unusual quantity of rain falls, the rocks slide easily over the surface of each other, causing a part of the hillside to tumble down.

Another rock of the complex mountain ranges is the Cretaceous limestone which is conspicuous in the few areas in which it occurs, owing to the steep or precipitous relief and lack of stream channels. Water readily penetrates the limestone to underground streams. Soils derived from this rock are not well adapted to agriculture because they are rocky, shallow, and have unfavorable relief. The largest areas of this kind are east of Juana Díaz, near Lajas, in the vicinities of Cayey and Orocovis, and near La Muda.

Besides the above-mentioned rocks, conglomerates and agglomerates are associated with the tuffs and shales in many parts of the island.

COASTAL PLAINS

The coastal plains parallel nearly the entire coast line. They range in width from a maximum of 13 miles (21 kilometers) at Lares to nil at several points along the eastern and western coasts. On the north coast they include most of the area north of the towns of Loíza, Río Piedras, Corozal, Ciales, Lares, San Sebastián, Moca, and Aguadilla. On the south coast they are much less extensive. Here, they include a part of the area south of Boquerón, Lajas, Yauco, Guayanilla, Peñuelas, Juana Díaz, Baños de Coamo (Coamo Springs), and Guayama. On the east and west coasts they cover but a few square miles. Most of the coastal plains are confined to areas that were submerged during Tertiary time and covered by a thick deposit of limestone. Since that time there have been several fluctuations in sea level, causing the landscape to have a belted appearance.

The outstanding characteristic of the northern coastal plain is the horizontal east-west deposit of limestone, which develops into distinct topographic belts according to the composition of the limestone. This limestone area is a plateau in a youthful stage of dissection, so

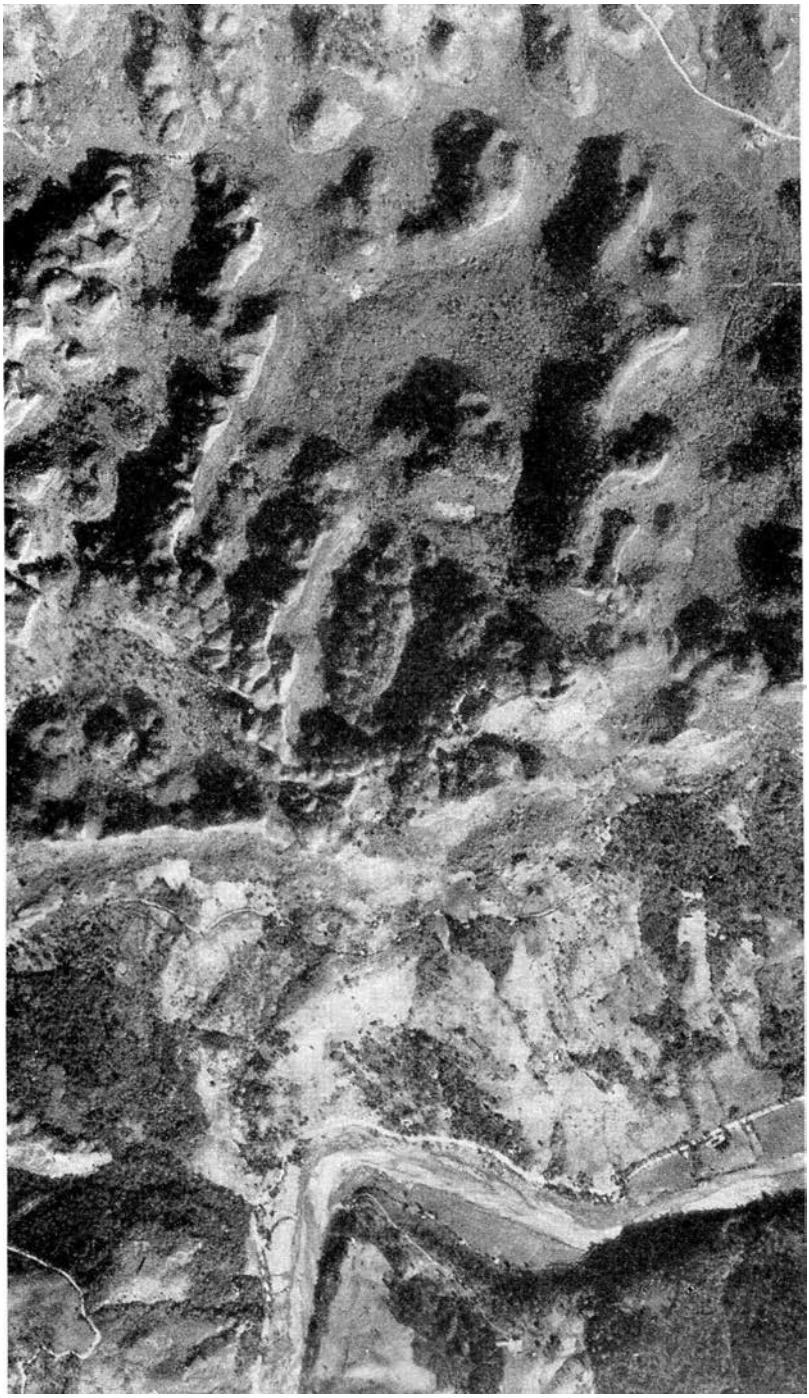

FIGURE 7.—See legend on page 11.

far as stream erosion is concerned, but the relief in some of the limestone belts is the roughest of the island, because the underground solution has caused sinkholes, caves, and numerous precipitous cliffs, making some areas nearly impossible to penetrate, even by foot. Both surface and subterranean erosion are still active. From a maximum elevation of about 1,500 feet near Lares, the northern coastal plain gradually slopes to sea level along the northern coast.

The most southerly belt of the northern coastal plain occupies an almost continuous narrow strip from a point near Corozal to a point near San Sebastián. This belt is characterized by comparatively pure calcium carbonate rocks and massive reef beds that have open porous textures, making it possible for the forces of erosion to form conspicuous high cone-shaped mogotes (haystacks) and long narrow pepino (cucumber-shaped) hills (fig. 7). Almost all of the pepino hills have a northeast-southwest trend and are about two-tenths of a mile long; none of them is very flat or broad on the top. Between the hills are numerous small long narrow undulating valleys. Drainage water makes its way to the small valleys and sinkholes, thence along underground passages to the few streams that have cut deep gorgelike valleys across this formation. Houses are fairly numerous in the small valleys, but only a few dot the hilltops. Trees are scarce except near dwellings and along the drainageways.

The southern limit of this belt has a very definite escarpment several hundred feet high (fig. 7). It is characterized by a nearly uniform east-west unbroken line, except where rivers flowing from the mountains have cut through the limestone formation, forming large triangular-shaped indentations with the apex pointing downstream and terminating in a gorge. The Ríos Guajataca, Camuy, Tanamá, Grande de Arecibo, Manatí, and Cibuco have cut through in this manner. The Río de la Plata terminates in a flood plain. Directly back of the escarpment, occurring from one end of the limestone areas to the other, and also in lowland valleys within the limestone section, are inner plains that range in width from a few feet to a mile or more. The soil contains considerable basal gravels and probably is derived from lower Tertiary shale. Wherever this material occurs there are many surface drainageways which abruptly sink where the material joins the limestone hills. In this area some of the land is nearly level, but most of the hills are dissected by drainageways.

North of the southernmost limestone belt is another limestone formation extending from the Río Guajataca eastward to a point south of Esperanza, thence from a point east of the Río Manatí to a point near Corozal. In this formation the steep mogotes are absent and the relief is rolling or undulating (fig. 8). The limestone is white and semicrystalline, with some chalky seams. All the rain water drains to numerous deep sinkholes, thence into the subsurface streams. Throughout

---

FIGURE 7.—Vertical aerial view of the southern escarpment of the north-coast limestone area along the Río Grande de Arecibo. The conspicuous long narrow pepino (cucumber-shaped) hills are gradually weathering into many cone-shaped hills. (Photograph taken by U. S. Navy.)

Vista aérea vertical de la escarpa sur del área caliza de la costa norte a lo largo del Río Grande de Arecibo. Las colinas largas y estrechas llamadas pepinos (en forma de pepinos), se están gradualmente convirtiendo en muchas colinas cónicas. (Fotografía tomada por la Marina de los EE. UU.)

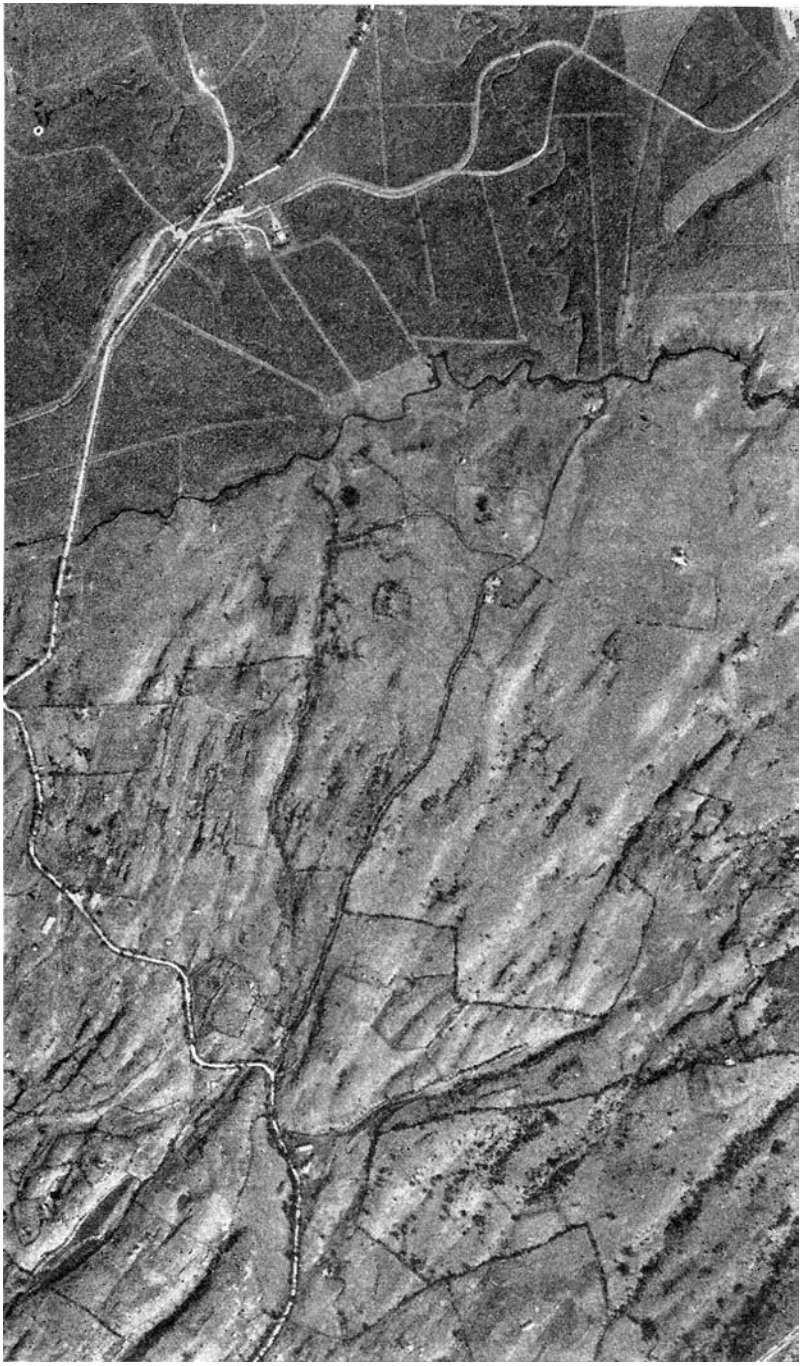

FIGURE 8.—See legend on page 13.

this limestone belt, houses are numerous and farms are small, few of them more than 10 acres in extent. There are very few trees throughout this area, except along fence lines.

Adjacent to this limestone belt on the north and extending to the west and east is another distinct limestone belt which extends from a point near Aguada north almost to Aguadilla, thence eastward in a narrow strip to the Represa de Guajataca (Guajataca Reservoir), thence in wider areas to Florida, Corozal, Toa Alta, and Central [4] Canóvanas. This belt is similar in relief and drainage to the southernmost belt, but it does not include so high a proportion of steep land and most of the hills have longer and more gentle slopes that are better suited for cultivated crops. Houses dot the hilltops and the narrow valleys.

The next limestone belt on the north, which extends from Aguadilla to Toa Alta, is characterized by spectacular, rugged, brush-covered mogotes and sinkholes. The general trend of the individual hills, or mogotes, is northeast to southwest. Drainage is effected through the numerous sinks, which in time may become united by the caving and dissolving of the adjacent limestone. Small dwellings are fairly numerous on the hills and valleys; they are located in many places without much regard to accessibility or nearness to the limited water supply. Foot and horse trails are the only means of travel through most of this country, and some of the rougher parts are hardly passable for the sure-footed small horses and mules.

The most northern of the large limestone belts is characterized by uniformly stratified beds of hard flinty limestone alternating with soft gray limestone. Most of the limestone rock of the mogotes in this belt is pitted with holes and has many irregularities (fig. 9); it is very dense and hard and will ring when hit with a hammer. Characteristic features of this belt are the long east-west chains of saw-toothed, jagged, tree-covered mogotes and the nearly level, densely populated rather wide valleys. This belt extends from the northwestern corner of the island to a point east of Loíza. From Bayamón to a point near Loíza only a few limestone hills are exposed. Some of them rise abruptly above the alluvial land and muck areas, where weathering of the limestone has been complete. In the northwestern part of the island this limestone belt terminates abruptly, forming high sea-girt cliffs. Most of this area has subterranean drainage, and consequently water for domestic purposes is scarce.

Fringing the northern coast at low elevations is another narrow intermittent belt of limestone. It is characterized by scattered ridges of calcareous sandstone that probably have been formed by a com-

---

FIGURE 8.—Vertical aerial view of the smooth grass-covered limestone hills in the foreground and the fields of sugarcane on the soils of the lower Tertiary plains, which abruptly join along the small stream. Land on one side of the stream is valued at $175 an acre and on the other side at $5. (Photograph taken by U. S. Navy.)

Vista aérea vertical; las colinas calizas cubiertas de yerba al frente y los campos de caña en suelos de los llanos Terciarios, se juntan abruptamente a lo largo del riachuelo. La tierra a un lado del riachuelo está valorada a $175 por acre y al otro lado a $5. (Fotografía tomada por la Marina de los EE. UU.)

[4] Central refers to a large surgarcane mill and adjacent land.

bination of a slight uplift of the shore line and the drifting action of the trade winds.

The coastal plain on the south side of the island has no definite limestone belts, but a large percentage of its area overlies Tertiary limestone, and it has a much higher proportion of old alluvial-fan material than the northern coastal plain. Most of the alluvial fans are in the east-central part or between Ponce and Patillas.

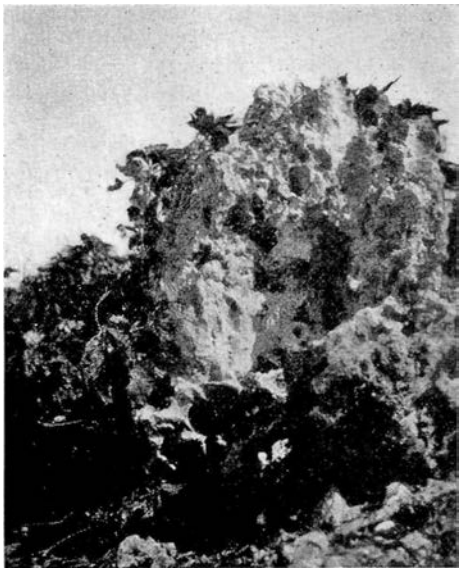

FIGURE 9.—Hard dense Tertiary limestone which weathers slowly, producing acid red soils of the Tanamá, Bayamón, and related series.

Piedra caliza Terciaria sólida y densa; esta piedra se desintegra lentamente y produce suelos rojos ácidos de las series Tanamá, Bayamón, y otras series relacionadas.

The limestone hills range from gently rolling to steep, and the many intervening plains or valleys are undulating and fairly wide. Most of the drainage of the limestone section is subterranean. The elevation of this area ranges from a few feet to more than 500 feet above sea level.

The largest area of the coastal plains in the eastern part of the island is near Ceiba. This is a broad nearly flat or undulating plain which is crossed by very few drainageways. Similar topographic positions occur in the intermountain valley east from Caguas, as well as in small areas on the west coast near Faro Cabo Rojo (Cabo Rojo Lighthouse), Boquerón, Puerto Real, and Joyuda. These areas range from a few feet to 100 or more feet above sea level. Most of them are densely populated.

PLAYA PLAINS

The playa plains include the level alluvial flood plains, the lagoon deposits, and the elevated beach sands. The flat alluvial flood plains occupy the largest area and comprise the most valuable agricultural land. They occur along all the streams but are most extensive near the mouths of the larger rivers. In a great many places the shape of the plain is triangular, with the apex pointing upstream. The alluvial deposits terminate abruptly against the upland hills. The soils are developed from transported material and, therefore, range in texture from coarse sands to clay. They occur at low elevations, generally not more than 10 feet above sea level. The land is so valuable that few houses are built on it. In most places natural drainage is supplemented by artificial drainage systems.

Nearly the entire coast line is fringed by a low, almost level, sandy beach, which ranges in width from a few feet to more than a mile. The coastal beach material consists of shells, coral, lime carbonate, and sand. In places sand dunes, a few of which are 20 feet high, occur

at or near the beach. In many places, depressions or lagoons, slightly below sea level, containing salt water or salt-marsh vegetation, occur inland a short distance from the dunes. Adjacent to the lagoons are old estuary clay or silty clay deposits which gradually merge, toward the rivers, with well-drained alluvial land. Many of the estuary deposits are only slightly above sea level and unless drained are under water several months of the year. The mouths of most of the streams emptying into the ocean are choked by sand bars, and these have helped to form the adjacent swamp areas.

Puerto Rico has several small natural lakes and a few large reservoirs. The lakes occur within the coastal lowland, and the reservoirs are located on the upland, most of them in the high mountains. The larger lakes are Lago Tortuguero, Laguna Cangrejos (Torrecilla), and Lago San José along the northern coast; Laguna de Guánica near the southern coast; and Lago Joyuda on the west coast. Lago Tortuguero, a fresh-water lake embracing an area of about 2 square miles, is the largest. All the other lakes are shallow and contain salty water, except Laguna de Guánica, in which the water is only brackish. As they have outlets to the nearby waters of the ocean, most of the lakes are affected by the tides.

Represa de Guajataca, the largest reservoir, is situated between the limestone hills of the coastal plains, and its waters are used to irrigate the land near Isabela. The water from all other reservoirs used for irrigation purposes is diverted to the south coast.

The island has many bays, some of which are well protected from the waves and have very quiet waters, with mangrove swamps extending to the water's edge. Puerto de San Juan (San Juan Bay) offers the finest harbor for ships.

MINERAL RESOURCES

Mineral resources seem to be limited in extent and value. Some of the rocks, especially the Cretaceous limestone, have high value as road-building material. This rock is hard, yet crushes fairly easily and has binding qualities superior to those of most of the other rocks. The semicrystalline Tertiary limestones are good for road material, but they are generally interbedded with chalky lime which is soon worn away when placed on a road and subjected to heavy traffic. The tuffs crumble too readily for road material, and the other volcanic rocks are either too hard for crushing or are not sufficiently indurated. Some andesites are used for road material.

Some of the chalk lime is used commercially for the liming of acid soils. Many thousands of acres in the interior could be greatly improved by an application ranging from 2 to 4 tons of lime to the acre. The addition of lime not only helps the physical condition of the soils, but it increases the yield of crops and probably improves the nutritive value of the grains and grasses produced. Almost any of the limestones occurring on the island is effective if it is finely ground. Some limestone, however, contains a fairly high content of phosphorus and therefore is more valuable as a soil amendment than are other calcareous rocks. The lime most commonly used comes from Cayo Icacos (Icacos Island), northeast of Fajardo. It is used on soils and for the sedimentation of impurities in the manufacture of sugar.

Some of the Tertiary limestone should make good building stone as it is rather easily worked into blocks and is fairly resistant to weathering.

The white silica sand, which occurs in large quantities near the line of the American Railroad Co. of Puerto Rico south and east of Lago Tortuguero, and in other areas along the northern coast from Santurce to the Río Camuy, may at some future time be used in the manufacture of glassware or sodium silicate.

The deep soils derived from serpentine rocks should have good possibilities for the mining of iron, chromium, and nickel, as they are very high in the first and moderately high in the other two minerals.[5] This kind of land (Nipe clay and Rosario silty clay) occupies 27,904 acres southeast of Mayagüez and near Punta Guanajibo.

Northeast of Juana Díaz, a deposit of manganese ore in Cretaceous limestone yields an annual production (*10, p. 5*) of about 2,500 tons.

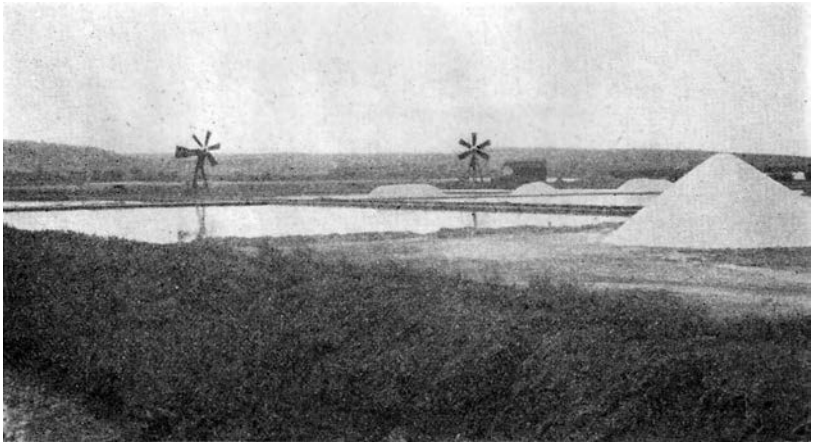

FIGURE 10.—Salt pans and piles of salt in the arid region along the south coast. Montones de sal y cristalizadores en la región árida a lo largo de la costa sur.

Other manganese deposits are south of Aguada, Adjuntas, and Corozal. Some magnetite has been found near Las Piedras. A few thin veins of lignite outcrop near San Sebastián, but they are not being developed. Some copper is mined south of Aguada, and placer gold mining has been carried on near Corozal for a number of years. Some gold has been found near Hacienda Catalina, Lares, Sabana Grande, and Guayama. A total of $100,000 worth of gold was mined between 1900 and 1932 (*10, p. 7*).

Sea water is evaporated to produce salt in fairly large quantities on the south coast adjacent to the sea. The quantity obtained annually depends on the size of the pans and the length of the rainless periods. The working season is during the winter and spring. In most places the water is pumped into the pans by large fan windmills (fig. 10). When the water has evaporated the salt is scooped into wheelbarrows and then dumped into piles until hauled by truck to local markets. This industry has been profitable during recent years, and the area devoted to it has greatly increased.

[5] Chemical analysis of a sample of Nipe clay appears on p. 475.

A small quantity of bat guano fertilizer is obtained from some of the caves in the Tertiary limestone, especially on Mona Island.

Several of the soil types, especially Catalina clay and Alonso clay, should make very good bricks. Indian pottery found on Las Mesas near Mayagüez is of good quality, indicating that Nipe clay also should be good for making bricks and pottery. The granite boulders in the Pandura soils should make very good building stone.

VEGETATION

Most of the present native vegetation undoubtedly is different from the plant life that existed during Cretaceous or even Tertiary periods. The introduction of plants into Puerto Rico, through the aid of man, probably was started by the Caribs and the Arawaks long before Columbus landed in 1493, and it has continued to the present time. The ever-changing environment has had its effect on the different species, as also has the destruction of the original forest, which exposed the soil, increased evaporation, and tended to make a drier soil climate. The second-growth vegetation was slightly different from the virgin trees, as it has had to be more drought-resistant in order to survive.

The native vegetation is very closely related to the soil climate. On droughty land, such as coarse sands, very steep hills, shallow soils, or very permeable soils, the vegetation in many places is more typical of a drier climate than that of the surrounding air climate. On the other hand, slight depressions, poorly drained soils, or swamps, even in arid regions, have a plant growth characteristic of a moist climate.

The names of the plants generally used throughout this report are those in most common use—some are English, and some are Spanish. The botanical names and the corresponding English and Spanish common names (taken mostly from Otero and Toro (*33*)) of nearly all of the plants mentioned are listed in table 1.

TABLE 1.—*Important plants growing in Puerto Rico*

Botanical name	English name	Spanish name
Acacia farnesiana	Casha	Aroma casha.
Achras zapota	Naseberry; sapodilla	Níspero.
Acrocomia aculeata	Corozo palm	Palma de corozo.
Acrostichum aureum	Acrostichum fern	Helecho.
Agati grandiflora		Gallito.
Agave americana	Centuryplant	Maguey.
Agave sisalana	Sisal hemp	Sisal.
Amomis caryophyllata	Bay rum tree	Malagueta.
Anacardium occidentale	Cashew nut	Pajuil.
Ananas sativus	Pineapple	Piña.
Andira inermis	Angelin tree; cabbage tree	Moca.
Andropogon virgatus		Rabo de ratón.
Annona reticulata	Custard-apple	Corazón.
Annona muricata	Soursop	Guanábana.
Arachis hypogaea	Peanut	Maní.
Artocarpus communis	Breadfruit	Palo de pan.
Athyrocarpus persicariaefolius		Cohitre blanco.
Avicennia nitida	Black mangrove	Mangle bobo.
Bambusa vulgaris	Bamboo	Bambú.
Batis maritima	Saltwort	Barilla.
Bromelia pinguin		Maya.
Buchenavia capitata	Yellow sanders	Granadilla.
Bucida buceras	Black olive	Húcar; úcar.
Cactus intortus	Turkscap	Melón de costa.
Cajanus cajan	Pigeonpea	Gandul.
Callisia monandra		Cohitre morado.
Calophyllum antillanum	Galba	Santa María; María.
Calotropis procera	Giant milkweed	Algodón de seda.

TABLE 1.—*Important plants growing in Puerto Rico*—Continued

Botanical name	English name	Spanish name
Caesalpinia sepiaria	Wait a bit	Zarzade cercas
Capparis coccolobifolia	Broad-leaved caper tree	Burro.
Capparis flexuosa	Caper tree	Palo de burro.
Carica papaya	Papaya	Lechoza.
Caryophyllus jambos (*Eugenia jambos*)	Rose apple	Poma rosa.
Castalia ampla	Waterlily	Flor de agua.
Casuarina equisetifolia	Australian pine	Pino Australiano.
Cecropia peltata	Trumpet tree	Llagrumo.
Cedrela odorata	Spanish cedar	Cedro.
Ceiba pentandra	Silk-cotton tree	Ceiba.
Cenchrus echinatus	Sandbur	Abrojo.
Cephalocereus royeni		Sebucán; dildo.
Chloris inflata	Mexican bluegrass	Horquetilla morada.
Chrysobalanus icaco	Coco-plum	Icaco.
Citrus grandis	Grapefruit	Toronja.
Citrus medica	Citron	Cidra.
Citrus sinensis	Orange	China.
Cladium jamaicense	Sawgrass	Serrucho.
Clusia rosea	Balsam fig	Cupey.
Coccoloba uvifera	Seagrape	Uva de playa.
Cocos nucifera	Coconut	Palma de coco.
Colocasia esculenta	Elephant ear	Malanga.
Colubrina reclinata	Nakedwood	Mabí.
Conocarpus erecta	Buttonwood	Mangle botón.
Cordia alliodora	Spanish elm	Capá prieta.
Cordia sulcata		Moral.
Crescentia cujete	Calabash	Higüero.
Crotalaria juncea	Crotalaria	Crotalaria.
Cucurbita moschata	Squash	Calabaza.
Cyathea arborea	Treefern	Helecho arborescente.
Cynodon dactylon	Bermuda grass	Grama; yerba Bermuda.
Cyperus giganteus		Junco de ciénaga.
Cyperus rotundus	Nutgrass	Coquí.
Dacryodes excelsa	Candlewood	Tabonuco.
Delonix regia	Flametree (royal poinciana)	Flamboyant.
Dendropogon usneoides	Spanish-moss	Barbas de úcar.
Dioscorea cayenensis	Yellow yam	Ñame de Guinea.
Dioscorea esculenta	Potato yam	Ñame papa.
Dioscorea rotundata	White Guinea yam	Ñame de Guinea blanco.
Dioscorea trifida	Indian yam	Mapuey.
Cassia occidentalis	Coffee senna	Hedionda.
Elaphrium simaruba	Gum tree	Almácigo.
Erythrina corallodendrum	Red-bean tree	Bucare.
Euterpe globosa	Mountain palm	Palma de sierra.
Ficus laevigata	Wild fig	Jagüey.
Fimbristylis diphylla		Junquillo.
Gaussia attenuata		Llume.
Gossypium barbadense	Cotton	Algodón.
Guaiacum officinale	Lignumvitae	Guayacán.
Guaiacum sanctum		Guayacán blanco; guayacanillo
Guarea guara	Muskwood	Guaraguao.
Hymenaea courbaril	West Indian locust	Algarrobo.
Inga vera		Guaba.
Inga laurina	Pomshock	Guamá.
Ipomoea batatas	Sweetpotato	Batata.
Laguncularia racemosa	White mangrove	Mangle blanco.
Lantana involucrata	Button sage	Santa María.
Laplacea portoricensis		Maricao.
Leptocereus quadricostatus		Sebucán; pitajaya.
Leptoglottis portoricensis		Zarzarilla.
Magnolia splendens		Sabino.
Mammea americana	Mammee apple	Mamey.
Mangifera indica	Mango	Mango.
Manihot esculenta	Cassava	Yuca.
Marcgravia rectiflora		Bejuco de palma.
Marcgravia sintenisii		Bejuco de rana.
Melinis minutiflora	Molasses grass	Yerba melado; yaraguá.
Meliosma obtusifolia		Cerrillo.
Mimosa pudica	Sensitiveplant	Sensitiva; moriviví.
Mimusops nitida	Bulletwood	Jácana.
Musa paradisiaca	Plantain	Plátano.
Musa paradisiaca sapientum	Banana	Guineo.
Nicotiana tabacum	Tobacco	Tabaco.
Ocotea spathulata		Granadillo.
Olyra latifolia		Carrucillo.
Opuntia dillenii	Pricklypear	Tuna brava.
Panicum purpurascens	Para grass	Malojillo.
Panicum maximum	Guinea grass	Yerba de Guinea.
Paspalum virgatum		Cortadero.
Pennisetum purpureum	Napier grass; elephant grass	Yerba elefante.
Persea americana	Avocado (alligator pear)	Aguacate.
Phaseolus vulgaris	Bean	Habichuela.
Philoxerus vermicularis	Saltweed	Yerba de sal.

TABLE 1.—*Important plants growing in Puerto Rico*—Continued

Botanical name	English name	Spanish name
Phragmites communis	Common reed	Caña de indio.
Pithecolobium unguis-cati	Blackbead	Escambrón colorado.
Prosopis chilensis	Mesquite	Mezquite.
Psidium guajava	Guava	Guayaba.
Pterocarpus officinalis		Palo de pollo.
Quercus thompsonii	Oak	Roble.
Randia mitis	Box brier	Tintillo; escambrón.
Rhizophora mangle	Mangrove	Mangle.
Roystonea borinquena	Royal palm	Palma real.
Rubus rosaefolius	Mountain raspberry	Fresa.
Saccharum officinarum	Sugarcane	Caña de azúcar.
Schizachyrium brevifolium		Serrillo dulce.
Sechium edule	Chayote	Tayote.
Sesuvium portulacastrum		Verdolaga rosada.
Sideroxylon foetidissimum		Ausubo.
Solanum tuberosum	Potato	Papa.
Spathodea campanulata	African tuliptree	Tulipán africano.
Spondias mombin	Hog plum	Jobo.
Sporobolus indicus	West Indian rush grass	Matojo.
Sporobolus virginicus		Matojo de playa.
Stenotaphrum secundatum	St. Augustine grass; running crabgrass.	Grama blanca.
Swietenia mahagoni	Mahogany	Caoba.
Tabebuia rigida		Roble de sierra.
Tamarindus indica	Tamarind	Tamarindo.
Terminalia catappa	Tropical almond (West Indian almond).	Almendro.
Theobroma cacao	Chocolate tree	Cacao.
Tragus berterionanus	Pricklegrass	Hincadora.
Typha angustifolia	Cattail	Aneas.
Tillandsia recurvata	Air plant	Nidos de gungulén.
Tripsacum laxum	Guatemala grass	Yerba Guatemala.
Triumfetta lappula		Cadillo.
Vigna unguiculata	Cowpea; black-eyed pea	Frijol.
Xanthosoma atrovirens	Yautia; dasheen; tania	Yautía amarilla.
Zea mays	Indian corn	Maíz.

Some of the most common plants that grow throughout nearly all parts of the island are flamboyant, maya, almendro, hedionda, Australian pine, bamboo, and such commercial crops as bananas, plantains, oranges, grapefruit, pineapples, sugarcane, tobacco, corn, beans, yuca, yautia, sweetpotatoes, mangoes, pigeonpeas, avocados, breadfruit, and papaya.

Among the tropical trees, flamboyant is one of the most beautiful. Its gorgeous firelike scarlet or purple flowers bloom from May to July. It grows readily from the dry sea-level areas of the south coast to the wet high areas of the mountain ranges. The maya, a barbed pineapplelike plant, often planted as a fence or as a boundary between small farms, thrives equally as well on the fairly strong "alkali"[6] soils as on the tropical rain-forest areas. The almendro is an ornamental deciduous tree which grows along most of the main highways. The nuts (Malabar almonds) ripen from July to August; they are edible. The hedionda is a low leguminous weed which seems to thrive throughout the island. Its seeds sometimes are mixed with coffee berries in preparing a hot beverage. It has not been long since the Australian pine was introduced, but it seems to be a tree as well adapted to the soils and climate of Puerto Rico as the maya. It is a fast-growing slender densely branched evergreen that is used as an ornamental tree along roadways and around houses, as well as a hedge which acts as a windbreak for fruit trees or other crops. It will grow on alkali land, if the concentration of salt is not much greater than 2

[6] The term "alkali" is used to indicate any harmful salt in the soil. Black alkali refers to sodium carbonate, and white alkali refers principally to sodium chloride.

percent, but none has been seen growing in the water-covered swamps. Many varieties of bamboo grow throughout the island. In the arid districts bamboo grows only along the edges of small ponds, and in the semiarid districts only along stream banks. Many of the bamboos are cut and used for fence posts, and some are used in the manufacture of furniture. The growing plant is used as a windbreak in some of the citrus groves, and it is also used on hillsides to help in the prevention of erosion. The commercial crops are discussed more fully under the section entitled "Agriculture."

Some plants are confined to rather narrow limits of environment, owing to the physical or chemical characteristics of the soil, to soil climate, or to elevation. Along the sandy beach, which fringes nearly the entire island, is a plant association consisting of matojo de playa, a low weedlike grass that migrates along the seaward side of the beach by means of rhizomes; yerba de sal, a prostrate fleshy red-stemmed plant tolerant to white alkali; and uva de playa which has broad leaves and an extensive root system. The height of the uva de playa

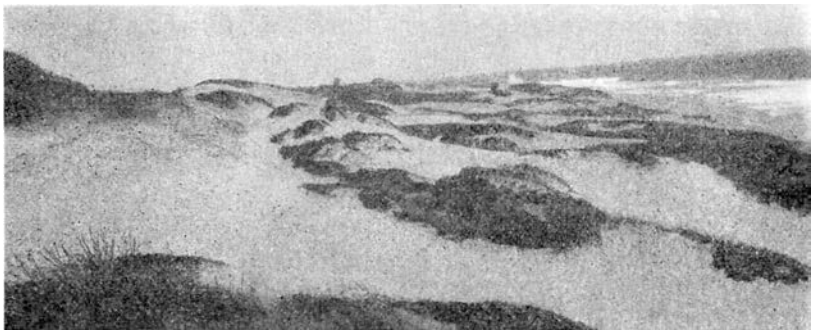

FIGURE 11.—Uva de playa and matojo de playa struggling desperately to stabilize the shifting sand dunes along the north coast.

Uva de playa y matojo de playa en lucha para estabilizar las dunas de la costa norte.

ranges from that of a nearly prostrate plant to that of a tall tree 8 inches in diameter. Generally, however, the plant is small, and its leaves are almost in contact with the soil. This helps to keep the sand moist and prevents the soil from blowing (fig. 11).

Closely associated with these drought-resistant sand-loving plant associations are plants that are resistant to salt water. In many places inland and parallel to the sandy coast are salt-water marshes and, in a few places, fresh-water swamps. The environment in these areas restricts vegetation to the water-loving or hydrophytic plants and alkali-resistant species. In some places the swamps extend to the quiet bays. In such places the plant nearest to the sea and that in the most salty water is the common mangrove, which has numerous strong aerial roots (fig. 12) that help to stop the agitation of the silt-laden water that pours into the swamps from the adjacent and far-away countryside. The silt and clay soon settle and thus build a mineral soil over the fast-decaying lower roots of the mangrove. Associated with the common mangrove but growing in areas having less concentration of salt, are the white mangrove, black mangrove,

and mangle botón. The last-named plant generally grows in dry climates and may be a considerable distance from the swamp, on alkali land. All the varieties of mangroves are important sources of wood for charcoal making. They quickly reestablish themselves and ordinarily are cut when 5 years old. At this age they produce from 15 to 20 cords of wood to the acre. Associated with the mangroves in wet open areas is a tall fern which grows to a height of 6 feet or more, and in many places the growth is so dense that it is impossible to penetrate it to any great distance. This fern is of little value, and it may crowd out stands of mangroves that have been cut over too frequently. Associated with this fern but now occurring in only a few places, such

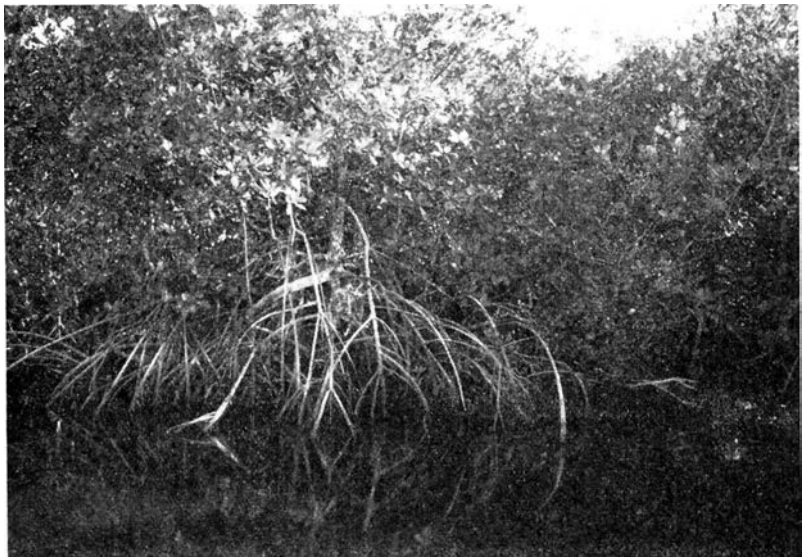

FIGURE 12.—Mangrove with its characteristic stiltlike aerial roots.
Mangles, nótese las raíces aéreas.

as in the swamp a mile west of Humacao playa, is the palo de pollo tree, a tree very similar to the common mangrove except that each stump has many slender trunks and an exceptionally large buttress. This tree also is used as a source of wood for charcoal making. Malojillo grows in many of the more open spaces in association with the palo de pollo, indicating that there is little or no harmful salt in the soil.

On the south and east coast, as well as on the coasts of the small islands, inland from the mangrove swamps, are two plants which indicate the presence of salt, namely, barilla and verdolaga rosada. Both are low bushlike shrubs; the former has pale-yellow stems and the latter dark-green or reddish-brown thick leaves. These plants nearly everywhere indicate that the land has about 3 percent of white alkali within the topmost foot of soil. These plants grow on better drained soils than do mangroves. They may grow even on well-drained sand if there is sufficient spray from the sea to maintain a high content of salt in the soil. In many places they grow in clusters adjacent to but slightly higher than the barren areas very high in alkali (fig. 13).

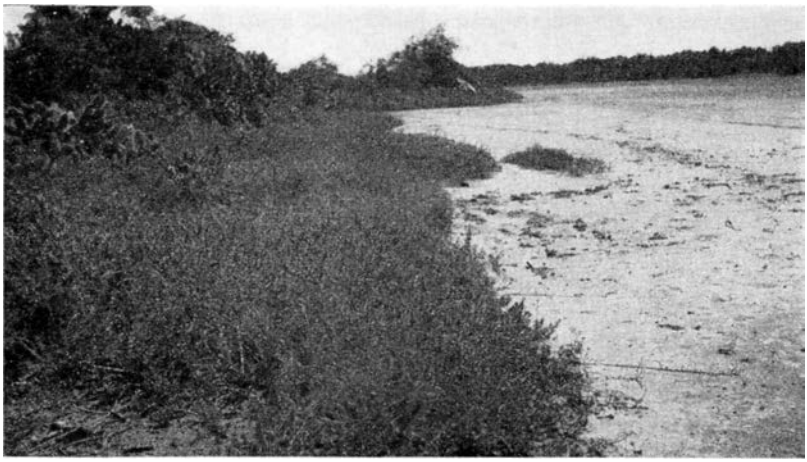

FIGURE 13.—Salt flats near Parguera. Barren areas have in excess of 3 percent of sodium chloride; barilla in foreground is on soil containing from 2 to 3 percent of salt; the tuna brava, or pricklypear (left), is growing on soil containing about 1 percent of sodium chloride.

Llanos salados cerca de La Parguera. Los eriales tienen más de 3 por ciento de cloruro de sodio; barilla crece al frente en suelo que contiene de 2 a 3 por ciento de sal; la tuna brava, a la izquierda, crece en suelo que contiene como 1 por ciento de cloruro de sodio.

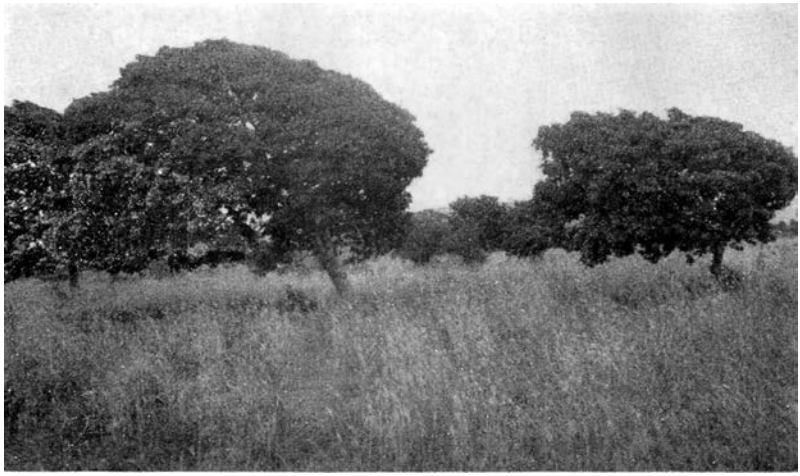

FIGURE 14.—Lignumvitae, or guayacán, trees, with a dense growth of Mexican bluegrass, or horquetilla morada. Note the effect of trade winds on the trees. Picture taken along the southern coast.

Árboles de guayacán o lignumvitae y horquetilla morada. Nótese el efecto del viento en los árboles. Fotografía tomada en la costa sur.

In general the salt content of the soil becomes less and less as the distance from the mangrove swamps increases, and the character of the vegetation changes accordingly. The most important plants a short distance from the mangrove associations are junquillo, a round-stemmed sedge, which nearly always grows on black-alkali land and

is therefore restricted to calcareous soils receiving a rainfall of less than 50 inches, and horquetilla morada (fig. 14), a fairly nutritious grass, which grows on both alkali and nonalkali land, as does the next important plant, Bermuda grass. These plants are associated on the wetter areas with junco de ciénaga, a tall coarse grass of little value. Cattail, sawgrass, caña de indio, and waterlily grow in brackish-water swamps in many parts of the island.

Associated with the Bermuda and horquetilla grasses in the arid sections are xerophytes, such as cacti and other drought-resistant plants (fig. 15). The most widely propagated cactus is the prickly-pear. It grows on Cabo Cabezas de San Juan near the Fajardo lighthouse, along the northwestern coast, and on Isla de Vieques (Island of Vieques), Isla de Culebra (Island of Culebra), and other dry islands, as well as in the large dry area extending from Guayama to the southwestern coast. In arid sections it grows on almost any soil, but in semiarid sections it grows either on very shallow permeable soils or on very sandy soils.

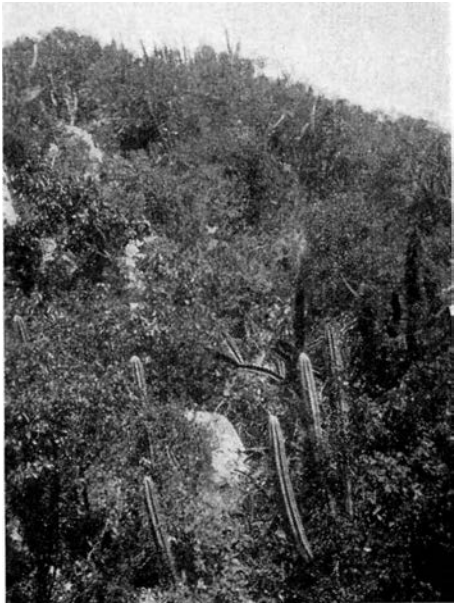

FIGURE 15.—Xerophytic vegetation on a steep limestone hill near Guánica quarry. Average annual rainfall about 30 inches.

Vegetación xerofítica en una colina caliza escarpada cerca de la cantera de Guánica. Promedia anual de lluvia—30 pulgadas.

Other cacti worthy of note are sebucán, or pitajaya, a many-branched bushlike wide-spreading cactus; sebucán, or dildo, a cactus shaped like a baseball bat; and the melón de costa which is nearly round (fig. 16). These cacti are numerous on the shallow soils of the limestone hills east of Faro Cabo Rojo to a point east of Ponce. They also grow on other hills in the semiarid sections, if they have not been removed in order to allow better grazing. Associated with the cacti are other thorny shrubs and small trees, such as escambrón colorado, tintillo, palo de burro, Santa María, mesquite, aroma casha, zarzarilla, and others. These are all of little value and are cut when the land is prepared for planting guinea grass, which is the most important pasture grass of the arid section. Several trees are more or less confined to the drier sections having calcareous soils. They are húcar (or úcar), algarrobo, tamarindo, almácigo, jagüey, lignumvitae, ceiba, and many species of acacia.

The húcar tree is confined to drier areas than are the other trees. It is used for building purposes, especially as sills, and also for fence posts. It is a gray-barked, spreading tree, often attaining a height of 30 feet. Many of these trees are nearly covered with Spanish-moss, especially in areas near Parguera and south of Baños de

Coamo. The algarrobo and tamarindo are conspicuous because of their dense spreading tops which make desirable shade for range cattle in the dry-land pastures. The tamarindo produces a substance around its podded seeds which is used in making a refreshing drink; it is also eaten raw or used as a dessert. The algarrobo produces a sausagelike pod which contains an ill-smelling but palatable substance that surrounds the seed. The almácigo is conspicuous by its shiny reddish-brown bark, wide open branches, and smooth limbs. It may grow in moist regions but is seldom seen in places where the annual rainfall is more than 65 inches. It is nearly valueless, even for charcoal.

FIGURE 16.—Melón de costa, or turkscap, growing on Ensenada clay, a shallow red soil derived from limestone. Annual rainfall about 25 inches.

Melón de costa, en Ensenada arcilloso, un suelo rojo poco profundo derivado de piedra caliza. Precipitación anual promedia alrededor de 25 pulgadas.

The jagüey, which has aerial twining roots, and the leguminous acacias have about the same climatic requirements as the almácigo; they grow in the eastern end of the island, in the northwestern part, on droughty soils in the more moist sections, and on the south coast. The lignumvitae at present is confined mostly to the drier parts of the island. It is a valuable and exceedingly hard wood. Unfortunately nearly all of these trees, as well as the other valuable trees, have been marketed, and few remain to propagate. The ceiba is common throughout the arid and semiarid sections. It is conspicuous, with its huge buttresses and sparsely branched giantlike trunk (fig. 17). The leguminous acacias are conspicuous along almost all the fence lines throughout the arid and semiarid sections. The air plant, with its ball-shaped matted structure, grows only in the arid or semiarid sections. It is prominent on many insulated wires, as well as on trees, cacti, and other vegetation of the south coast.

Inland from the arid or semiarid plant associations and below the rain forest, the vegetation consists for the most part of mesophytic plants or those that require a moist climate. This association includes the largest number of plants on the island, partly because there is a larger area involved. Growing within this area is the royal palm (fig. 18)—a magnificent symmetrical sentinellike palm that prefers

alkaline to acid soils but will grow on nearly every kind of soil, provided it has sufficient moisture. In some localities various parts of the royal palm are used. Its matured nutlike seeds (palmiche) are

FIGURE 17.—Giant ceiba tree growing on San Antón loam, one of the most productive soils in Puerto Rico. Sugarcane on this field produces from 70 to 90 tons an acre when the land is properly managed and irrigated.

Enorme ceiba en San Antón lómico, uno de los suelos más productivos de Puerto Rico. Este predio produce de 70 a 90 toneladas de caña de azúcar por acre, cuando se riega y se trabaja bien.

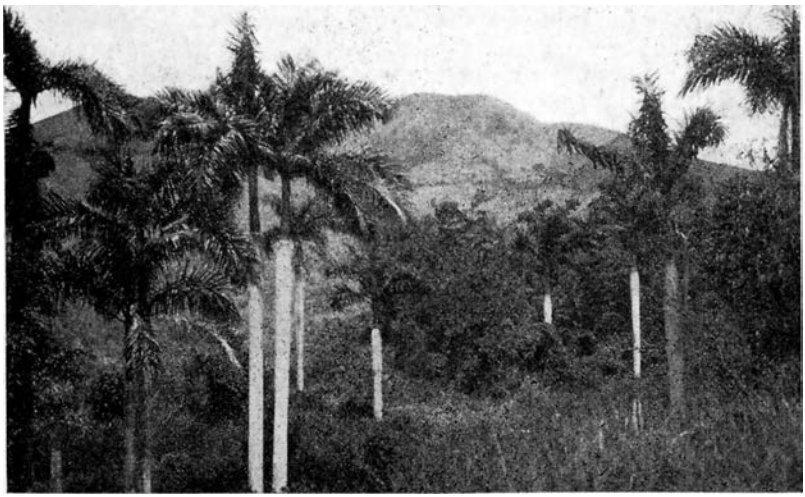

FIGURE 18.—The symmetrical royal palm that is used for many purposes.

La simétrica palma real se usa para muchas cosas.

nutritious and a favorite feed for hogs, as they contain nearly 6 percent of fat. Its bark is stripped off in long, narrow lengths (listones de la cortezas) and used as siding for the native houses. Its lustrous green leaves are used in the thatching of roofs or for covering coffee

seedbeds; some leaves are shredded and used in the making of chair seats. The racemes are used in the making of the locally used brooms. The leaf sheath, which is about 3 feet long and 20 inches wide, is used to cover roofs and walls, and it makes fairly good washtubs for the cleaning of clothes. The tigüero, or canoe-shaped palm sheath, is used as a convenient grain container, and, when the tree is cut, the cogollo, or bud, is used as a delicate salad which tastes very much like raw cabbage.

The llagrumo thrives in all moist areas and is very conspicuous on the abandoned coffee farms, on account of its ungainly stems and its large leaves, with white undersurfaces, floating in the breeze. It has a hollow fragile stem and is of very little value even for charcoal. The poma rosa, a bushlike tree which generally grows in moist acid soils, is used in basket weaving, for fence posts, for charcoal, and for roof tops for coffee seedbeds and nurseries. Its fruits are eaten by people and sometimes are fed to hogs. Associated with the mesophytic plants are many tropical fruit trees, such as jobo, corazón, guayaba, mabí, níspero, cacao, mamey, guanábana, citron, icaco, and cashew nut. The jobo is a deciduous tree that loses its leaves during winter, when it then presents a naked appearance, as all the limbs are nearly straight, smooth, and bare. It produces a plum-sized insipid yellow fruit during the summer and fall, which is relished by hogs and sometimes eaten by people. The corazón is a large tree having many branches, which, during the winter, produces heart-shaped grapefruit-sized solid reddish-colored slightly acid fruit. The guayaba, or guava, a semicultivated tree or bush, produces the pink-centered many-seeded walnut-sized fruit that is eaten raw or made into guava jelly or paste, some of which is exported to the United States. This bush becomes an obnoxious weed in many abandoned pastures. It readily develops a vigorous root system, and within 5 years, if not cut, an expenditure of about $5 an acre would be required to clear it from the fields. It grows on poor land nearly as well as on good land.

The mabí tree does not produce an edible fruit, but the bark is used in the preparation of a fermented drink. Sweetened water is added to an extract of the bark and allowed to ferment overnight. The níspero tree produces a fruit that is small, brown, sweet, and very high in sugar. It is relished by most people. The cacao tree was at one time important commercially, but at present a very small quantity of the seeds of the large ovate pods is gathered and prepared for market. The mamey is a dual-purpose tree; the thick smooth oblong leaves are used, especially in sandy soil, to protect young tender plants, such as tobacco, from the mole cricket, or changa. The fruit is sweet, yellow, and about the size of a coconut. The pulp is used raw, and some is made into a paste and consumed as a dessert. The guanábana produces a large somewhat pear-shaped fruit with soft rind, white fibrous pulp, and large black seeds; it is slightly acid; and the rind has many short fleshy spines. The fruit is eaten raw or as a dessert, and the pulp is made into drinks or sherbet. The citron grows in only a few groves, but it seems to be capable of producing a profitable commercial crop and in time probably will occupy a larger acreage than at present. Its requirements for soil and climatic conditions are similar to those of the grapefruit tree. The fruit is used in making candy. The icaco is a bushlike tree producing black, white, or purple plumlike fruit which has a large dark seed and a small quantity of sweet white

pulp that is eaten raw. This bush will thrive on droughty unproductive soils. The cashew tree grows in semiarid sections on droughty soil as well as within mesophytic plant associations. The nut is kidney-shaped and about one-fourth inch thick. The roasted kernel of the seed is of good quality and delicious, but it is seldom sold on a commercial scale. The pulp of the sour fruit is sometimes cooked for dessert. Some of the other associated forest trees are higüero, llume palm, cupey, jácana, bay rum tree, búcare, African tuliptree, many kinds of robles, moca, guamá, and guaba. The last three are used extensively as shade trees on the coffee plantations. The higüero produces a large oval gourdlike fruit (calabash) that is picked, dried, seeded, and used locally for water containers and cups. The llume palm presents an interesting sight when its tall thin cylindrical trunk and large pinnate leaves are fanned by the breeze. This palm prefers alkaline soils, and it grows only in the rugged limestone hills and in the rough land of Isla de Vieques. The cupey tree is conspicuous in the limestone section, as its long aerial roots resembling black ropes, swing far down over the cliffs. This tree usually grows as a parasite on other trees until its aerial roots become anchored in the soil. The jácana is a hardwood and is used for building purposes. The bay rum tree grows in moist as well as in semiarid sections. Its leaves are often gathered, brewed, and distilled, and the product is sold for making bay rum. The búcare, African tuliptree, and roble have striking blossoms which give the landscape added attraction. The leaves of the búcare, especially of the dwarf variety, make nutritious forage for livestock. The leaves, which are very high in protein, may be fed green or may be ground. This tree is used also as a support for the climbing vanilla plants.

The more common small plants in the moist sections are the many common ferns, sensitiveplant, fresa, and cohitre morado. The common ferns are very abundant along road banks and on idle land. Some species are very good indicators of strongly acid soil, low in plant nutrients. Ferns also extend into the rain-forest plant association. The sensitiveplant grows in many pastures and on many plantations. It is regarded as a weed. The fresas are more abundant at elevations of more than 1,500 feet than at the lower levels. The fresa berries are similar to raspberries, and they ripen throughout most of the year. They are gathered, and many of them are sold locally from the roadside. They are eaten fresh and used as dessert. Cohitre is similar to wandering-jew. Some varieties are used for hog feed. The cohitre morado is effective on the densely shaded coffee farms as a soil binder, thus helping in the control of erosion.

The most important grasses growing in the moist-climate areas are matojo, cerrillo, and St. Augustine grass. Matojo is a rank-growing bunchgrass that is eaten by livestock, but it seems to be low in nutritious constituents. The mountain matojo is used in thatching some of the bohíos, or mountain houses (fig. 19). Cerrillo ranks as a fair grass for livestock. It grows on many kinds of well-drained soils throughout the moist and semiarid sections. St. Augustine grass is considered the best upland grass. It not only is very nutritious, but it is one of the best plants for the control of erosion on the island, as it readily forms a thick mat and its long rhizome-stemmed foliage creeps over banks and over the sides of gullies, thereby helping to hold the soil in erodible places. It is used also on lawns.

As the rainfall increases there is a gradual change from the moist-climate plant association to the rain-forest vegetation, and thence to the moss vegetation of the areas having the highest rainfall, which are

FIGURE 19.—A bohío, or mountain home. Generally some subsistence crops, such as bananas, beans, yautias, yuca, pigeonpeas, and sweetpotatoes, are planted in the dooryard or nearby.

Un bohío. En general se encuentra algunos cultivos como guineos, habichuelas, yautías, yuca, gandules y batatas alrededor de la casa.

FIGURE 20.—Dense vegetation in the rain forest—treeferns, mountain palms, bananas, and many other plants—all striving for existence.

Exhuberante vegetación en un bosque—helechos arborescentes, palmas de sierra, guineos y muchas otras plantas.

the high wind-swept cool fog-laden peaks. Some of the most important plants of the rain-forest vegetation are (figs. 3 and 20) palma de sierra, or mountain palm, treefern, tabonuco, granadillo, sabino,

maricao, mahogany, and Spanish cedar. The mountain palm is similar to the royal palm, but it does not have so symmetrical an appearance and is more slender. It is used to some extent in building, the trunk being split into narrow strips for siding. The treefern is of value only in helping to prevent erosion, as it has a good root system and its leaves help to break the force of the rain. The tabonuco tree is valuable for its timber, and its resin is sometimes used in making torches. The granadillo, sabino, and maricao are used for building purposes. The mahogany and Spanish cedar are valuable woods for cabinetmaking. Neither tree is attacked by termites. Both grow in the moist sections as well as in the rain forest.

The moss association is confined mostly to the high peaks of the Sierra de Luquillo, where the precipitation is heavier than elsewhere on the island. The most common trees of this mossy plant association are roble de sierra and granadillo. On the high wind-swept peaks the trees, although mostly virgin, have a dwarfed appearance. They gradually increase in size with decreasing elevation. Those growing on the summits of the highest peaks range from 2 to 6 feet in height, but at the lower elevations they may attain a height of 30 feet. At the high elevations the branches are crooked and are so dense and interlaced that only a small amount of sunlight penetrates to the moss and sedge-covered shallow and nearly saturated rocky soil below. Many species of mosses and ferns are abundant. Most of the mosses grow on the branches of dead trees and on rocks. The bejuco de palma and bejuco de rana, two clinging vines, are abundant in moist climates and in the areas of highest rainfall. Orchidlike plants are conspicuous on the tree trunks in the high elevations and in the lower part of the rain forest. Many other plants grow throughout Puerto Rico, such as ornamental shrubs and flowers. Although many of them are very beautiful, most of them lack pleasing fragrance. Mushrooms and toadstools are rarely seen anywhere.

A valuable descriptive account of the plant ecology and plant distribution in Puerto Rico is given by Cook and Gleason (*12*).

ANIMAL LIFE

According to Danforth (*14, p. 18*), Puerto Rico does not have any indigenous land mammals; squirrels, skunks, minks, coyotes, alligators, or similar animals do not inhabit any part of the island. The most common animal is the mongoose (*Herpestes birmanicus*), which was imported from Cuba in 1877 for the purpose of destroying rats and snakes. The rats have not been controlled, there never were many snakes, and now the mongooses have increased so rapidly that they have become a nuisance. They inhabit all parts of the island and are destructive to chickens, lizards, and ground-nesting birds. Roof rats, house rats, and house mice are fairly numerous, especially in the congested parts of towns. The rats do considerable damage to sugarcane stalks and coconuts. Many of the coconut groves are protected with a 10- or 12-inch metal band placed around each palm at a height ranging from 4 to 8 feet above the ground (fig. 25). Bubonic plague, which is spread to human beings from infected rats, has appeared twice in San Juan and nearby cities.

Lizards are both prevalent and beneficial. They range in size from the 15- or 20-inch lagarto (*Ameiva exul*) to the 3-inch lagartija

(*Anolis poncemesis*). All the lizards are insectivorous and do incalculable good by destroying millions of flies, mosquitoes, and other insects. The lizards run about at will from the houses to the fields in all parts of the island. Several kinds of frogs have been imported and may be found in the wet areas adjacent to the coast as well as in the tropical rain-forest areas. The importation of the toad (*Bufo marinus*) has been one of the greatest benefits to the south-coast cane growers, as the toads have multiplied rapidly and have the white grub nearly under control by eating the May beetle (*Lachnosterna portoricensis*), the adult of the white grub.

Birds are not so plentiful as might be expected, owing in part to the destruction of the nests and young birds by hurricanes and in part to the density of the population, as boys and young men destroy the eggs and kill the birds. The greatest number of birds seem to be in the most sparsely populated areas, such as the arid southwest. Some of the most conspicuous birds (*14*) are the reinita, or Puerto Rican honey creeper; the mozambique, or grackle, that follows plows, catching grubs and other insects; the gorrión, or carib grassquit; the ruiseñor, or mockingbird; the pitirre, or gray kingbird; the golondrina, or barn swallow; the putilla, or killdeer; and the aura, or southern turkey vulture. Several species of doves and ducks are hunted and are relished by sportsmen. Herons are very numerous in the lagoons and mangrove thickets.

Bats are fairly numerous in the caves of the limestone section, especially on Mona Island. Bat guano is used as a fertilizer, but the quantity obtained now is much less than formerly.

There are many crabs along the coast. The most conspicuous are the large blue land crabs, or cangrejos (*Cardisoma quanhumi*), which are very numerous along the wet poorly drained coastal lowland soils. After the first few rains following a long dry season, thousands of crabs are caught and eaten by the people. These crabs do considerable damage to sugarcane, and poisoned bran must be placed near their holes in order to reduce their number as much as possible.

More than 1,400 different species of insects (*50*) have been identified on the island. These include many that are destructive to crops, such as the changa, or mole cricket (*Scapteriscus vicinus*), which does much damage in loose sandy soils, especially on level coastal plains, to the young tender crops, such as tobacco and minor crops; the white grub which causes much loss in the sugarcane fields on alluvial lands; the giant rhinoceros beetle, which attacks and kills young coconut palms; the sugarcane rhinoceros beetle, which at times feeds on sugarcane; the coffee-leaf miner, a small caterpillar that is very destructive to the coffee leaves; and the hormiguilla, a small ant that makes tunnels in living trees, especially the guamá one of the best shade trees for coffee. The damage caused by the pink bollworm has been one of the reasons for the small acreage devoted to cotton. The West India fruitfly has been a serious handicap to the fruit grower. Flea beetles do much damage to the tobacco plants in areas receiving less than 65 inches of annual rainfall. The corn earworm is a serious pest in both sweet corn and field corn.

Other important insects are the various species of termites, the polilla being very destructive to buildings of imported lumber. The comejen's large black "niggerhead" nest is very conspicuous on fence posts, trees, and even on the ground throughout the island. The

termite has social habits similar to the bee; its brittle vesicular nest, 1 foot or more in diameter, contains workers, soldiers, and a single royal pair.

Flies are not so numerous as might be expected, and very few enter the houses, although the windows and doors are usually open during the day. Mosquitoes are seldom seen during the daytime, except in a few swamps, but they are very numerous at night, and certain parts of the lowlands are infested with a fairly high proportion of malaria-carrying mosquitoes.

The number of deaths from malaria has decreased rapidly, owing to the work of the Department of Health of Puerto Rico and to the drainage work and studies on malaria by the Rockefeller Foundation.

Bees are not so common as might be expected. According to the 1935 census of the Puerto Rico Reconstruction Administration (*34*), 19,160 colonies were reported from 1,466 farms. The largest numbers of apiaries are in the mountainous sections, especially in the coffee districts. The exportation of honey during 1938–39 was 1,115,785 pounds, valued at $42,272, according to the Annual Book on Statistics of the Puerto Rico Department of Agriculture and Commerce.

The principal parasites affecting livestock are ticks, lice, flukes, tapeworms, and roundworms. The ticks and tick fever caused by the microparasites do incalculable damage to livestock. The loss of life is not great, but the vitality is sapped from the animals. A systematic tick-eradication program is now under way. Lice are prevalent among all animals in all parts of the island. Flukes are particularly obnoxious in the arid sections and in areas of calcareous or neutral soils, as their host, the snail (*Lymnaea cubensis*) (*48, p. 18*), is more prevalent on alkaline than on acid soils. The most favorable location for the snail is in wet or moist lowlands where the soils are neutral or calcareous. The flukes enter the livers of both man and beast. Tapeworms and roundworms are very common and serious parasites in many sections.

Visible effects of microfauna activity are noticed throughout all the soils. There seems to be more earthworm activity in the humid sections than in the nonirrigated arid or semiarid sections. The surface soils of the irrigated lands contain an abundance of worm casts, indicating the activity of numerous worms. However, the casts are not so plentiful as in the upland soils in the humid sections, especially in the Cialitos, Catalina, and related soils. The principal visible microfaunas are termites, white grubs, ants, fishworms, and nematodes, all of which play a very important role in mixing the plant residues and mineral part of the soil as it passes through their bodies.

The aquatic animal life in the waters near the coast, in the mangrove swamps, and in fresh-water streams includes fish, oysters, lobsters, corals, many kinds of mullusks, and sponges, The principal fish are el pargo, or lane snapper; macarela española, or Spanish mackerel; pargo rojo, or red snapper; el arenque, or herring; pámpano, or pompano; and salmonete blanco, or white mullet, of the salt-water and el dajao of the fresh-water streams. A large number of people make their living by seining fish along the coast. At times they catch barracuda, sharks, and manatees (or sea cows) in their nets.

The oysters are small and are gathered, not from beds but from the numerous mangrove roots. The lobsters are fairly numerous and are delicious. The principal corals along the beach are the fan

and brain corals. Many kinds of edible mollusks are gathered and eaten by the coast dwellers. The sponge most commonly seen is the finger sponge. Neither the sponge nor the mollusk industry is very important.

Domestic animals are discussed in the section on Agriculture.

POPULATION

Puerto Rico was discovered and named by Christopher Columbus in November 1493, or 127 years before the landing of the Pilgrims at Plymouth Rock. At that time the inhabitants were Indians, who have since disappeared. Puerto Rico remained Spanish territory until it was ceded to the United States by Spain in 1898. The present political status is that of a territory with certain legal limitations. The island is divided for governmental purposes into 77 municipal districts,[7] and these again into barrios.[8] The present inhabitants are for the most part either descendants of Spanish settlers or of Negroes brought in for work on the plantations. They are American citizens and have a right to vote at elections on the island and for Federal officials when residing in the United States.

According to the Federal census, the total population in 1930 was 1,543,913, or 454 people to the square mile. Of this number, in addition to the native-born Puerto Ricans, 3,585 were born in Spain, 2,160 in the United States, 367 in Central America and South America, 342 in France, and a few in other countries. Preliminary data of the 1940 census show an increase of 21.1 percent, to a total of 1,869,245, or 549.7 people to the square mile. The density of the population, which varies greatly from place to place, creates the most serious social and economic problems confronting the insular government. Few people build their homes on the good alluvial lands paralleling the larger streams, on the forest-covered soils of the high elevations, or on the pasture lands of the south coast.

The most densely populated parts of rural Puerto Rico (fig. 21) are on the shallow brown hill-land soils near Trujillo Alto and Rincón and south of Cabo Rojo, also from Hatillo (Hatillo) to Aguadilla on the soils derived from limestone (fig. 22), and on the soils along the north coast. In these areas there are more than 600 people to the square mile. This is a very grave situation, because most of the people depend almost entirely on agriculture for their support. A high proportion of the area of Puerto Rico consists of shallow, stony, steep, or submarginal land, and it is doubtful whether agriculture can support such a dense population and give the people a reasonable standard of living. Many people obtain part-time work in sugar centrals, tobacco-stripping shops, needlework shops, and other industries; but, even with this additional income, families are able to obtain only the bare necessities of life. Thousands of people of all ages are undernourished.

The large population has had its effect on the natural resources of the island, such as forests, soils, and fish. The great increase in population, which began more than 100 years ago, naturally has led to the removal of forests and the planting of both subsistence and major crops. Most of the timber has either been sold or is rapidly being

[7] The municipal district, or municipality, is an unsurveyed but somewhat definite land area averaging 44.6 square miles, or slightly larger than a township.

[8] The barrios are unsurveyed but fairly well recognized land areas about one-tenth the size of a municipality, or about 4 square miles.

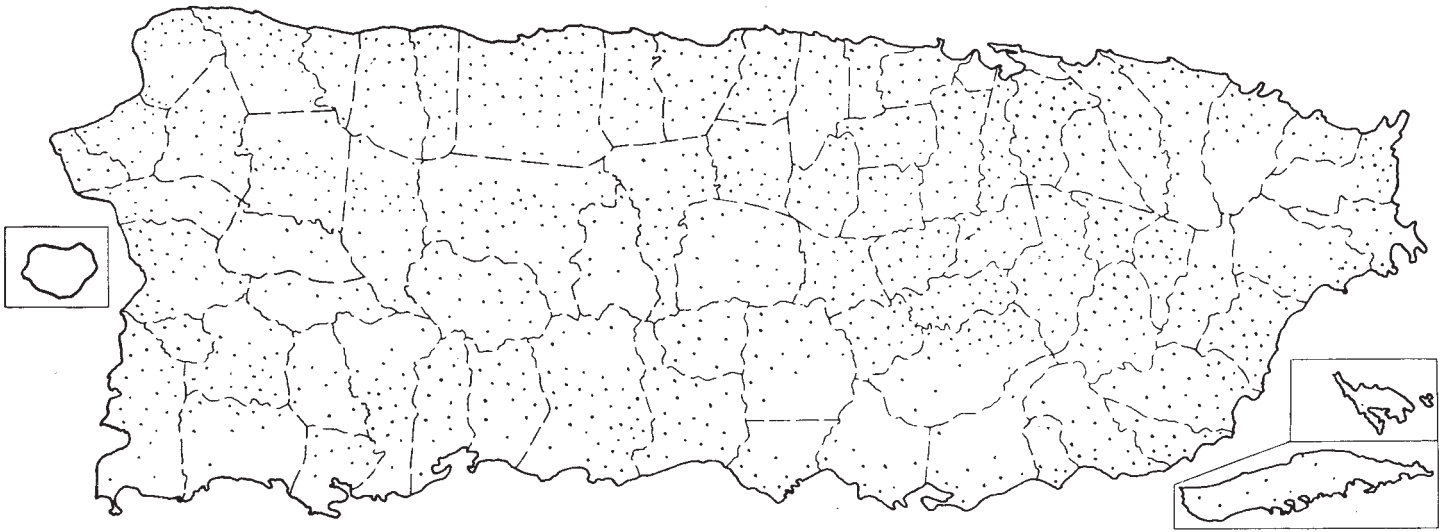

FIGURE 21.—Distribution of rural population in 1935. Each dot represents 1,000 people.
Distribución de la población rural en 1935. Cada punto representa 1,000 personas.

FIGURE 22.—Aerial photograph of about 600 acres in the irrigated district near Isabela. Approximately 800 people live in the 150 or more houses seen in this picture. Most of the soils are deep permeable red or yellowish-red Matanzas and Coto clays which are fairly well adapted to nearly every crop grown on the island. (Photograph taken by U. S. Navy.)

Fotografía aérea de cerca de 600 acres en el distrito de riego de Isabela. Aproximadamente 800 personas viven en las 150 ó más casas que se ven en la fotografía. Muchos de los suelos son arcillas Matanzas y Coto, profundas, rojas o amarillo rojizas y permeables y son bastante adaptables a casi cualquier cultivo de la isla. (Fotografía tomada por la Marina de los EE. UU.)

used for the making of charcoal, and this exploitation of the forest resources over a long period of years has nearly depleted the timber. According to Gill (*19, p. 133*), "probably 50 percent of Puerto Rico, or 1,000,000 acres, may be classified as true forest soil, but of all this only 110,000 acres still remains uncut. Eighty percent has been devastated." One reason so much of the land has been cut over is because the cutting has been unrestricted, with no provision made for reforestation. Fires never have and probably never will be a menace to either the forest or grass. A comprehensive and intensive forest program is needed immediately to make Puerto Rico self-supporting in wood requirements. Rapid progress in this direction has been made during the last 2 years, owing to activities of both the Federal and insular governments. At present (1940) about 186,155 acres are in forest, of which 26,010 acres are in the Federal forest reserve (Caribbean National Forest) and 40,000 acres are in insular forest land. The largest areas include some of each of the following: The rough, rugged mountainous areas, the mangrove swamps, and the shallow soils derived from serpentine and limestone in humid and arid regions, respectively.

The pressure of the increasing population forces the people to cultivate steeper and steeper land and a greater and greater acreage to the person, because returns to the acre are becoming less. With the exception of the soils of the alluvial lands, most of the cultivated land in humid Puerto Rico has been leached to such an extent that a deficiency of calcium, phosphorus, and magnesium seems to exist. A very low percentage of the owners of small farms [9] use fertilizer or manure to offset the loss of these necessary mineral elements. The plants produced, whether grain plants or grasses, do not have the maximum food value for the development of bones, teeth, and the physical well-being of the animals and people. Rickets, poor teeth, and poor health are common among some of the natives in the humid districts.

Livestock that have been grazed on grasses of the alkaline and semiarid districts have larger bone development, smoother hair, and better general appearance than those pastured in the moist mountainous districts where acid leached soils are dominant and the grass is tall and dense.

Sheet erosion has been reducing crop yields year after year on improperly used hill land (fig. 23). The combined destructive effects of leaching and erosion, in addition to the constantly increasing population, make an acute problem in land utilization. Probably one of the most effective measures for better land use is through the Puerto Rico Extension Service in directing the jibaros,[10] through their conuco [11] agriculture, to plant more strip crops with the contour of their land. Increasing quantities of fertilizer and lime must be used each year to restore the fertility that is lost by cropping and erosion, in order to increase or maintain the same yearly production of agricultural crops.

Few of the fresh-water fish become large before they are caught and used for food, and the only wild game left includes a few doves and ducks. Neither fish nor game is protected by strict game laws.

[9] According to the 1935 census of the Puerto Rico Reconstruction Administration (*34*), 27.9 percent of the improved land was in farms less than 50 acres in size.

[10] Jibaros refer to the tillers of small patches of land.

[11] Conuco agriculture refers to garden farming of small patches of several kinds of minor crops, such as pigeonpeas, beans, corn, yautia, yuca, bananas, and others.

Within the last few years the insular forest service has been stocking some of the streams with suitable kinds of fish. This should prove beneficial, but, owing to the large numbers of people, game laws cannot be made very effective, and it is doubtful whether fish or game ever will be very plentiful.

FIGURE 23.—Severe erosion on an improperly farmed hillside of Descalabrado silty clay, eroded phase, where the annual rainfall is sufficient to encourage the planting of crops, yet is not sufficient for the plants to make rapid growth which would check the force of tropical showers. The gardens to the right are properly farmed.

Fuerte erosión en una ladera de Descalabrado limo-arcilloso, fase erosiva, mal trabajada. La lluvia anual en este sitio es suficiente para la siembra de cultivos, pero no lo bastante para que las plantas crezcan rápidamente, y sirvan de resistencia a la fuerza de las lluvias tropicales. Los huertos hacia la derecha están bien trabajados.

TOWNS

San Juan, the capital and largest city, is on the north coast in the east-central part of the island. It is the location of the United States Army and Navy radio stations; other Army stations are at Borinquen

(near Aquadilla), near Vega Baja, and at Cayey. In 1940 the population of San Juan was 169,247. The business section and a part of the residential section are on an island connected to the mainland by bridges. Ponce, which is located near the center of the south coast, is the second largest city, with a population of 65,182 in 1940. Mayagüez, which is centrally located on the west coast, is the third city, with a population of 50,376 in 1940. Caguas, the fourth largest city, had a population of 24,377. It is situated in a mountain valley about 35 kilometers south of San Juan. The populations, elevation above sea level, approximate location, and principal crops and industries of the cities and larger towns are given in table 2.

TABLE 2.—*Data regarding principal cities and towns in Puerto Rico*

City or town	Population [1]		Increase or decrease in population	Elevation above sea level	Location	Principal crops and industries
	1940	1930				
San Juan	169,247	114,715	47.5	[2] 24.7	Northern coast	Commercial.
Ponce	65,182	53,430	22.0	[2] 51.5	Southern coast	Commercial, sugarcane.
Mayagüez	50,376	37,060	35.9	[2] 7.3	Western coast	Needlework, coffee, sugarcane.
Caguas	24,377	19,791	23.2	[3] 232.9	Mountain valley	Tobacco, sugarcane, subsistence crops.
Arecibo	22,134	12,863	([4])	[2] 27.3	Northern coast	Sugarcane, grapefruit, commercial, subsistence crops.
Río Piedras	19,935	13,408	48.7	[3] 78.7	do	Sugarcane, fruits.
Guayama	16,913	10,953	54.4	[2] 244.5	Southern coast	Sugarcane, livestock.
Bayamón	14,596	12,986	12.4	[2] 53.7	Northern coast	Sugarcane, grapefruit, pineapples.
Aguadilla	13,468	10,952	23.0	[2] 13.9	Western coast	Sugar cane, coconuts, commercial, needlework.
Yauco	9,985	8,607	16.0	[2] 104.1	Southern slope	Sugarcane, coffee, livestock.
Coamo	8,691	5,831	49.0	[3] 354.3	Southern valley	Livestock.
Cataño	7,924	7,044	12.5	[5] 20.0	Northern coast	Commercial.
Humacao	7,624	7,937	[6]—3.9	[3] 52.5	Eastern coast	Sugarcane.
Fajardo	7,108	7,322	[6]—2.9	[3] 32.8	do	Do.
Manatí	6,771	7,449	[6]—9.1	[2] 91.2	Northern coast	Sugarcane, fruits.
San Germán	6,446	5,636	14.4	[5] 244.3	Southern valley	Sugarcane, coffee, subsistence crops.
Cayey	5,622	5,953	[6]—5.6	[5] 1,300.0	Mountain valley	Tobacco, subsistence crops.
Vega Baja	5,409	4,784	13.1	[2] 28.9	Northern coast	Sugarcane, fruits.
Carolina	5,368	4,454	20.5	[3] 39.3	do	Sugarcane, subsistence crops.
Cabo Rojo	5,303	4,605	([7])	[2] 52.3	Western valley	Do.
San Lorenzo	5,181	4,916	5.4	[5] 200.0	Interior plain	Tobacco, sugarcane, subsistence crops.
Juncos	5,009	5,297	[6]—5.4	[3] 446.0	do	Sugarcane, tobacco, subsistence crops.
Sabana Grande	4,783	3,778	26.6	[5] 289.0	Southern valley	Sugarcane.
Yabucoa	4,542	3,841	18.3	[3] 52.5	Eastern coast	Do.
Utuado	4,430	4,758	[6]—6.9	[2] 442.6	Mountain valley	Coffee, tobacco, subsistence crops.

[1] Population data from the United States census.
[2] Elevations from U. S. Geological Survey.
[3] Barometric elevations by insular department of interior.
[4] Barrios Buenos Aires, Miramar, and San Luis were annexed to Arecibo town in 1937. The figure for 1930 is not, therefore, comparable with that for 1940.
[5] Approximate elevation.
[6] Minus sign indicates decrease.
[7] Pueblo Nuevo was organized from part of Miradero and annexed to Cabo Rojo town in 1932. The figure for 1930 is not, therefore, comparable with that for 1940.

Most of the larger cities are near the coast and adjacent to land that is well adapted to the production of sugarcane. Most of the inland mountain towns are small and generally have but one improved road leading to and from the town (fig. 24).

FIGURE 24.—The small inland town of Pueblito del Río which has but one automobile road and one oxcart road. Sugarcane is grown both on the alluvial lands and on the sloping hills.

Pueblito del Río, solamente tiene una carretera para automóviles y un camino para carretas. La caña se siembra en las tierras de aluvión y en las colinas.

TRANSPORTATION

Among the United States ports from which goods may be shipped to Puerto Rico are New York, Baltimore, New Orleans, Mobile, Tampa, Galveston, Houston, and San Francisco. Boats from other countries stop in San Juan harbor at frequent intervals. Ponce, Mayagüez, Aguirre, Fajardo, Arecibo, and other seacoast towns also have harbors where freighters pick up exports and leave imports. Passenger boats stop at Ponce, Mayagüez, and, at times, at some other ports. San Juan has connections with the United States by regular boat and airplane transportation, also by cable and telephone.

According to the Annual Book on Statistics for 1938–39, 22,607 motor cars are registered, of which 12,608 touring cars, 2,287 light trucks, and 2,073 heavy trucks, a total of 16,968 vehicles, are privately owned. There were 4,327 touring cars, 38 light trucks and 1,274 heavy trucks, or a total of 5,639 vehicles, under public ownership. This represents about 1 car for every 83 persons. Very few horse-drawn buggies and carriages are seen, and only a very small proportion of the rural inhabitants have saddle horses. Walking is the principal means of travel by day laborers and their families. Pedestrians throng the highways throughout the day and most of the night.

Lines of the American Railroad Co. of Porto Rico and other companies, subsidiaries of sugar mills, such as the Fajardo Development Co., or the Ferrocarriles del Este (Eastern Railroad), Fortuna Railroad Co., and Ponce & Guayama Railroad connect nearly all the coast towns, except those in the southeastern part of the island, from Arroyo to Yabucoa. Most of the lines have single tracks and are 1 meter wide. Owing to the rough terrain, the railroads do not cross the interior. They carry first- and second-class passengers, freight, and express, but most people travel by either bus or public cars, which ply between all towns, picking up and discharging passengers at any place along the road. The fare is about 1 cent a kilometer. All sugar centrals have a network of railroads throughout their holdings. Most of the railroads are very narrow gaged, and some of the tracks are removed

as soon as the crop is taken off the land. The towns and sugar centrals are connected by telephone and telegraph, but very few rural residences have telephones or free delivery of mail. During warnings

FIGURE 25.—A 15-foot highway along the coast. Note the metal bands on the coconut palms to keep the rats from climbing them.

Carretera de 15 pies de ancho a lo largo de la costa. Nótese las bandas metálicas en las palmas de coco para evitar que las ratas suban a las palmas.

of an approaching hurricane, news spreads surprisingly fast by verbal communication.

Hard-surfaced roads, or carreteras,[12] connect all the towns. Many of the secondary roads, or caminos, leading into the mountains or hilly country are impassable except by oxcart, saddle horse, or on foot. Thousands of the country homes, or bohíos, are reached only

[12] In Puerto Rico carretera is used to designate a hard-surfaced main-traveled automobile road; a callejón refers to an oxcart road, especially in the sugarcane fields; a camino refers to a second-class road; and a vereda refers to a footpath.

by foot and horse trails, which penetrate to all parts of the island. The trails zigzag up the steep rocky mountainsides then generally follow the ridge tops. The pack animals carrying coffee, tobacco, charcoal, bananas, and other crops on their way to towns, and returning with rice, beans, canned fish, and other provisions, have great difficulty in carrying comparatively light burdens through mud ankle deep or over the steep rock-strewn mountain slopes. Transportation in the mountainous districts is slow and expensive. Most of the first-class roads have the hard limestone as a base and a top dressing of tar, and, as there is no freezing or thawing to heave the underlying soil, the roads last for a number of years. Most of the roads, however, are only 15 feet wide (fig. 25), and, as a high percentage of all merchandise and products is moved with large trucks, they soon become uneven and require continual maintenance. Many of the secondary roads are made from crushed soft limestone which is soon worn away by the tropical downpours. On the large holdings of the sugar centrals, roads are numerous, and generally there is an oxcart road (callejón), around every 10 or 20 acres. Only the most important callejones are shown on the soil survey map, and many of the trails (veredas) are not shown.

EDUCATION

Every community has some public schools, but most of the isolated rural districts are very much handicapped by inadequate schools, both as regards number and size. Most of the schools in these districts have only four grades. In most of them the first-grade pupils attend for one-half of the day and the second-, third-, and fourth-grade pupils for the other half. Each teacher has about 60 children during the day. The 1935 census of the Puerto Rico Reconstruction Administration (*34*) shows that the average number of persons in a family is 5.4. Of the children between the ages of 7 and 13 years, 61.7 percent attend school, and of those between the ages of 14 and 15 years, 40.7 percent attend school. The census figures show that 35.1 percent of the people over 10 years old are illiterate.

The 54 districts that have established second-unit schools are very fortunate, as the schools under this system equal or are superior to schools in the United States, especially in regard to local needs, for instance, educating the children's taste for beneficial vegetables not commonly used by the families but which can be and are grown by the boys of the school on the 4- to 25-acre tracts of school land. Several teachers are employed at each of these rural schools. Domestic science, agriculture, manual training, and ceramics are some of the subjects taught besides the regular graded-school studies.

Spanish is the language of the people, but English is understood and spoken by all high-school students and many pupils in the graded schools. The University of Puerto Rico is located in Río Piedras. The enrollment for 1936–37 (first semester) was 4,306 students, of whom 1,492 were men and 2,814 women. The School of Tropical Medicine is in San Juan. The College of Agriculture and Mechanic Arts is near Mayagüez, where the enrollment in agriculture is about 200 and in engineering about 300 students. The Polytechnic Institute is at San Germán, and there are several denominational schools on the island.

Most of the municipalities have a county agricultural agent, and at present there are nine agricultural extension demonstrations farms,

locally called granjas. The average size is about 16 cuerdas.[13] The Agricultural Experiment Station of the University of Puerto Rico, having 185 cuerdas for agricultural purposes, is located near Río Piedras, and the irrigation substation, located west of Isabela, covers a total of 80 cuerdas in 3 farms on different soil types. The Federal Experiment Station has a total of 410 cuerdas in 2 separate farms and is located near Mayagüez. Valuable information in agriculture is obtained from all these stations and farms.

Every town has at least one church, which generally joins the plaza on the east, and a few churches have been built in the rural districts. As a rule, each town has only one cemetery, and there are very few in the rural districts. Less than 500 cuerdas are occupied by cemeteries in Puerto Rico. Several daily newspapers are published in San Juan and one or two in Ponce and Mayagüez. The papers are printed in the Spanish language, with the exception of one or two that have an English supplement. There are also several magazines published on the island, one of which is a scientific agricultural magazine. San Juan has two radio broadcasting stations, and broadcasting programs are heard from both Europe and the United States. The larger cities have public libraries, and nearly every town has a municipal hospital. San Juan has many clinics and hospitals and one Young Men's Christian Association building, the only one on the island.

WATER SUPPLY

In many places, especially in the rural districts, the water supply is insanitary and inadequate. In the northwestern part of the island, in the limestone area, underground drainage forces the people to use water caught in mudholes and depressions, especially after the limited supply of rain water caught from the eaves of the metal-roofed houses has been used. In irrigated districts the people use irrigation water. In the mountain areas any stream or spring water is used, regardless of its state of sanitation. The quality and quantity of water varies considerably from place to place. Probably the best water comes from springs originating in the serpentine rocks, such as those east of Mayagüez on Las Mesas. Within areas where granite rocks are dominant, surface water for drinking purposes is scarce during the dry seasons, and throughout all limestone areas most of the domestic water is obtained from the eaves of the metal-roofed houses. In areas where the dominant rocks are tuff and shale, the water supply is fairly good and usually abundant. Municipal water hydrants are located along many of the roads in the thickly populated rural districts where natural water is scarce. Most of the household water is carried in 5-gallon cans by the women, and often the water supply is from one-eighth to one-fourth of a mile down the mountainside from the house. Practically the only windmills or pumps in use are in pastures in the arid and semiarid districts. These wells provide water for people and for livestock. Water for the towns generally is piped from mountain streams through aqueducts, and in the larger cities it is chemically filtered with aluminum sulfate and treated with chlorine, but in the smaller towns it is filtered by settling and is treated only with chlorine. Typhoid fever and other water-borne diseases are disseminated by the insanitary water supply. Most of the household washing is done along the stream banks (fig. 26).

[13] A cuerda is equivalent to 0.9712 acre, or 42,305 square feet.

According to the data of the commissioner of health of Puerto Rico for 1937, the death rate per 100,000 population from diarrhea and enteritis was 482.4 people; from tuberculosis, 287.1; from pneumonia,

FIGURE 26.—Washing clothes along one of the shallow streams.
Lavando ropa en una quebrada.

187.8; and from malaria, 129.5. These five diseases accounted for 1,086.8 deaths per 100,000 out of a total death rate of 2,094.

FARM BUILDINGS

Many of the dwellings, or bohíos, are small and flimsy. Some are constructed with palms (fig. 19), either the leaves or sections of the outer trunk, and many are built from boxes and scraps of metal

FIGURE 27.—A hurricane shelter which could accommodate from 10 to 15 people, and a thatch-roofed house in right background.

Una tormentera para 10 ó 15 personas y una casa techada de yaguas a la derecha.

roofing. In general the dwelling has one or two rooms, with a lean-to for cooking. These homes afford only the bare necessities. The more well-to-do landowners have modern homes substantially built to withstand hurricanes, but at times even these are destroyed. Among the smaller dwellings there are a few hurricane shelters (fig. 27), but ex-

FIGURE 28.—Modern sugar central where both raw and refined sugar are manufactured. In the right foreground sugarcane is being loaded on oxcarts. Light streaks in sugarcane indicate areas of soil very high in lime, which condition causes chlorosis in the cane. Level soils are mostly Mercedita clay. Hills in background are used only for pasture.

Moderna central azucarera donde se fabrica azúcar cruda y refinada. A la derecha se carga azúcar en carretas. Los sitios claros en la caña indican áreas de alto contenido en cal, lo que causa clorosis en la caña. Los suelos llanos son principalmente Mercedita arcilloso. Los cerros al fondo se usan solamente para pasto.

perience has taught that their numbers are far too few to care for all the people during a storm.

The sugar centrals have many more modern buildings and equipment, the valuation of which ranges between $2,000,000 and $3,000,000 for the larger centrals (fig. 28). They have their own stores (tiendas), warehouses (almacén), and hospitals. The grapefruit growers have

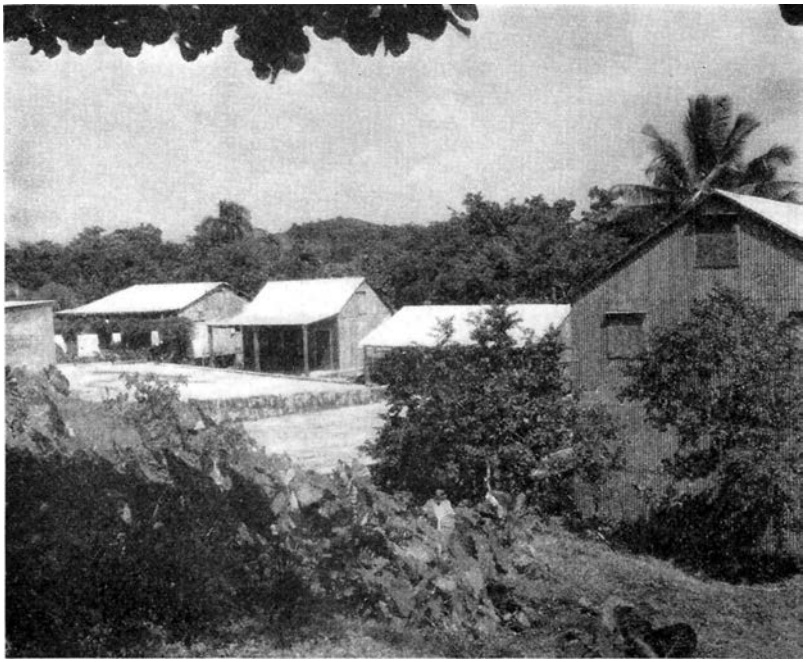

FIGURE 29.—Typical coffee finca. The concrete floors are glacis for drying the coffee. Building to right is the warehouse. The plants in the foreground are yautias.

Finca de café típica. Los pisos de concreto son glacis para secar café. El almacén está a la derecha. Yautías al frente.

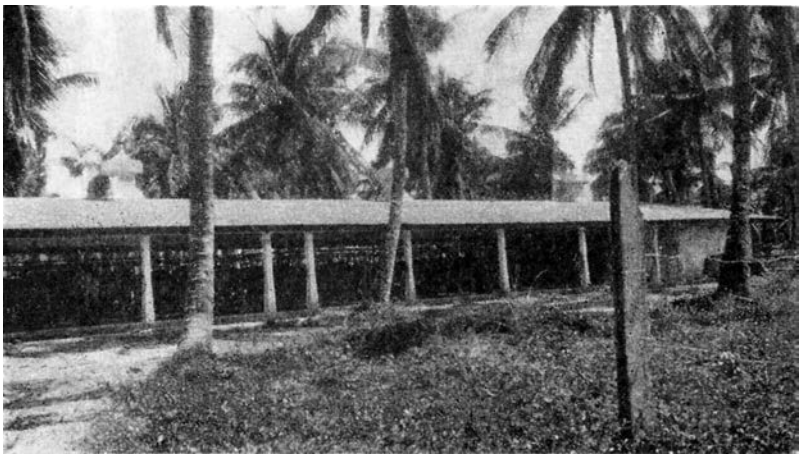

FIGURE 30.—Open-sided modern dairy barn.

Lechería moderna.

modern American homes, and many have a grading shed and possibly a packing plant. Most of the coffee growers have two-story square frame houses each with several additional small buildings for prepara-

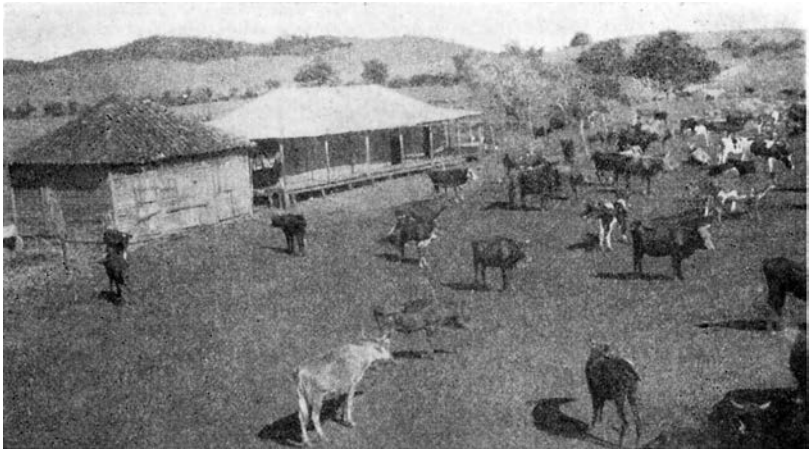

FIGURE 31.—Large cattle ranch in the arid southwest near Faro Cabo Rojo. The cows are milked once a day and also suckle their calves. About 1 gallon of milk is obtained from each cow. The feed consists entirely of guinea grass and a few other grasses.

Rancho de ganado en el suroeste árido de la isla, cerca del Faro Cabo Rojo. Las vacas se ordeñan una vez al día y también alimentan sus becerros. Solamente como 1 galón de leche se obtiene de cada vaca. La alimentación del ganado consiste de yerba de guinea y otras yerbas.

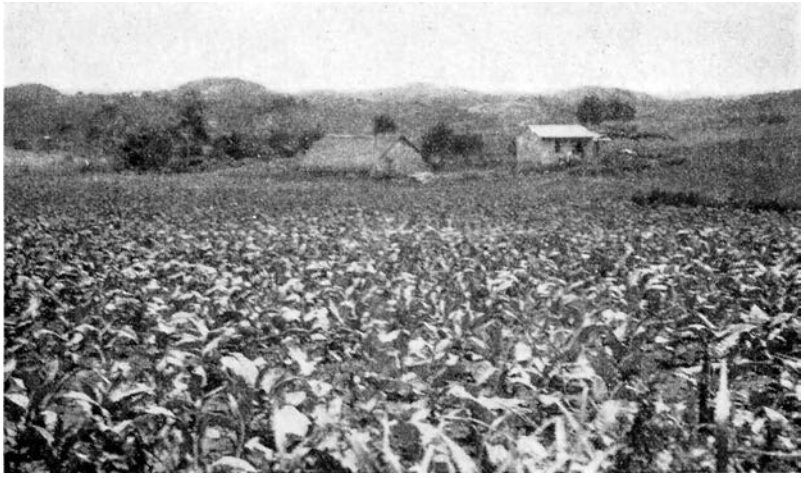

FIGURE 32.—Small tobacco farm in a limestone valley south of Isabela, on Sabana Seca sandy clay loam. Note the thatch-roofed tobacco barn and the small house.

Pequeña finca de tabaco en un valle calizo al sur de Isabela en Sabana Seca areno-arcilloso lómico. Nótese el rancho para tabaco techado de yaguas y la casita.

tion of the coffee (fig. 29). Many of the dairy farmers have modern dairy barns (fig. 30). The cattle ranches have substantial corrals but very few buildings (fig. 31). The tobacco growers have large tobacco barns but small houses averaging two rooms and a lean-to for cooking (fig. 32).

Charcoal is universally used for cooking and ironing. One seldom sees any outbuildings around the small farm dwellings. At night chickens and pigs stay under the houses which are elevated off the ground (fig. 33). Very few of the jibaros have storage sheds, and the crops grown are either consumed or sold immediately to the small rural stores nearby, which frequently sell some of these products back to the original seller at a later date. This does not apply to the more enterprising farmers, such as owners of sugarcane, citrus, coffee, or tobacco farms. Most of the commercial crops are sold a few months

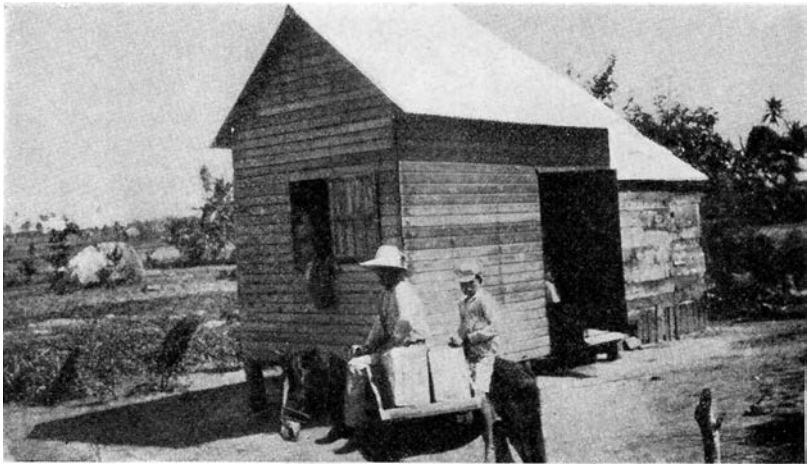

FIGURE 33.—Well-built farm dwelling elevated 1 or 2 feet from the ground for better ventilation. At night the doors and windows are closed. Poultry and small livestock stay under the house during rains and at night. Storage sheds are rarely seen. The 5-gallon cans are used as water containers. The water supply may be a mile or more away.

Casa de campo bien construída, elevada como dos pies de la tierra para mejor ventilación. De noche se cierra las puertas y ventanas. En tiempo lluvioso y de noche las aves de corral y otros animales pequeños duermen debajo de la casa. Rara vez se vé un almacén. Las latas de 5 galones se usan como recipientes de agua y la fuente de abastecimiento puede estar a una milla o más de distancia.

after they are harvested. Some of the centrals may store a part of their sugar in the hope of obtaining higher prices.

Most of the fences around grapefruit orchards, pineapple fields, and pastures are good; those around sugar central holdings range from fair to good; and those of most of the other farms are poor or lacking. The type of fence in most common use among the small landowners is formed by the maya, a thorny spreading plant from 3 to 4 feet tall. Many of these plants have a spread ranging from 6 to 9 feet. They make a very effective fence; but if allowed to grow unpruned, they cover too much of otherwise valuable land. Boundaries between the farms in the sugarcane, grapefruit, tobacco, and pasture lands generally are definite and distinct, but in the coffee and forest lands they are indefinite and hard to determine.

CLIMATE

Puerto Rico is less than 20° north of the Equator, rather small in area, and far from any large land masses. It has, as may be expected, a tropical, uniform, oceanic climate, and nearly ideal conditions exist for a heavy precipitation over most of its area. The moisture-laden northeast trade winds, over the warm waters of the ocean, blow almost continuously during the day and strike Sierra de Luquillo at right angles. The air is diverted upward where it expands because of less pressure at the higher elevations and is cooled below the dew point. Condensation then takes place, and generally it is followed by rain. As a general rule, the higher the elevation, the less the pressure, the cooler the atmosphere, and, therefore, the greater the precipitation, to a maximum at elevations ranging from 4,500 to 6,000 feet, but these high elevations do not occur in Puerto Rico. As the rain clouds move southwest across the island they gradually give up their moisture.

The highest peaks and the northern and eastern sides of the mountain ranges receive the greatest rainfall; the small islands, the southern side of the main island, the northwestern corner, the eastern shore line, and the interior valleys receive the least. The reason for the low rainfall on the small islands and the low eastern coast line is because such obstacles as mountain ranges are not present to lower the temperature of the wind as it passes. Often the weather will be clear on the eastern coast, yet clouds will form at about 9 a. m. on Sierra de Luquillo, from 3 to 5 miles away, and rain will fall throughout most of the day.

The southern coast is dry for two reasons: (1) The wind usually has given up much of its moisture before it passes the high mountain crest and there is none to fall on the low southern side; (2)—which is also the reason the mountain valleys near Caguas, Cayey, Adjuntas, Rincón, Jayuya, and Utuado are drier than the nearby hills—after the wind passes the high northern mountain ridges it blows down the steep southern slopes and becomes compressed and denser at the lower levels and so is warmed. It then can hold not only all the moisture it has, but can take up some through evaporation. The greater the evaporation, the drier the soil and the more sparse the vegetation. The northwestern corner of the island is drier than the interior because this area is to the north of the winds that have been cooled by any of the mountain ranges or peaks and the wind is warm and holds most of its moisture. Inland, for a mile or more, the entire north coast is dry for the same reason.

The average annual precipitation ranges from less than 30 inches in the southwestern part of the island to nearly 200 inches on the highest peaks in Sierra de Luquillo. Table 3 gives the rainfall, by months, at most of the United States Weather Bureau stations on the island. Table 4 gives the normal monthly, seasonal, and annual temperature and precipitation, as recorded by the Weather Bureau stations, at Fajardo, Río Piedras, and Isabela along the north coast; San Lorenzo, Aibonito, and Maricao, in the interior; and Maunabo, Ponce, and Ensenada along the south coast. These tables show that there are no definite seasons, but rather a rainy period from May 1 to November 1, inclusive, and a dry period the other 6 months. Throughout the winter, however, many showers occur, but the heavy torrential rains take place in the summer.

TABLE 3.—*Mean monthly and annual rainfall at a number of places in Puerto Rico based on all available records (1899–1928)*

Station	Length of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Yrs.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
SOUTH COAST AND ISLANDS														
Ensenada	27	0.72	1.17	1.22	1.98	2.78	2.17	1.75	2.70	3.75	4.02	3.34	1.11	26.71
Potala	21	.86	1.27	1.04	2.21	2.65	2.10	2.42	3.79	4.61	4.88	3.42	.99	30.24
Santa Isabel	28	1.04	1.01	1.11	1.62	3.45	2.62	2.85	3.52	4.46	5.93	4.10	1.97	33.68
Isla de Mona	11	1.05	2.32	2.44	2.09	3.15	2.75	3.36	2.97	4.38	4.22	4.06	2.14	34.93
Ponce	28	1.01	.99	1.44	2.08	3.06	3.46	2.97	4.16	4.97	6.45	4.05	1.22	35.86
Isla de Culebra	7	2.88	2.15	2.10	1.77	4.54	2.72	2.73	4.70	5.15	4.28	5.53	2.62	41.17
Aguirre	30	1.38	1.57	1.52	1.88	3.76	4.74	4.48	4.65	6.22	6.46	4.13	1.86	42.65
Isla de Vieques	30	2.95	2.53	2.21	2.68	3.53	3.96	4.24	4.55	6.12	6.26	5.77	3.35	48.15
Josefa	28	1.74	1.95	1.86	2.04	4.16	5.18	5.13	4.52	6.95	7.62	5.36	2.12	48.63
Guayama	18	2.11	2.37	2.04	2.17	4.34	5.11	5.19	4.52	6.91	7.23	5.52	2.46	49.97
Juana Díaz	30	1.07	1.71	2.10	3.50	4.63	4.51	3.87	6.08	7.24	8.65	5.08	1.80	50.24
Coamo	8	3.43	1.48	1.77	3.80	4.26	5.60	3.60	5.97	5.26	6.81	6.43	4.04	52.45
Peñuelas	21	1.58	2.69	2.04	4.19	4.90	4.15	4.82	6.10	6.99	8.56	5.85	2.07	53.94
NORTH COAST														
Camuy	16	4.03	2.92	3.25	3.32	3.74	2.49	3.53	3.78	4.56	4.67	6.85	4.36	47.50
Isabela	30	3.43	2.69	2.58	3.53	5.27	3.89	3.49	4.82	5.05	4.94	7.41	4.62	51.72
Arecibo	26	5.44	4.07	4.05	4.50	5.50	3.32	5.01	4.52	4.83	4.73	8.52	6.07	60.56
Barceloneta	14	5.77	4.64	3.52	3.75	5.50	3.17	5.88	4.31	5.47	5.03	8.40	5.36	60.80
San Juan	30	4.14	2.76	3.10	4.24	5.37	5.21	6.02	6.12	6.17	5.74	6.99	5.47	61.33
Cangrejo	8	4.67	3.78	2.39	3.98	5.83	5.59	6.47	4.54	6.34	7.28	7.86	4.99	63.72
Fajardo	30	3.50	3.01	3.11	3.71	5.40	4.96	5.88	5.54	7.30	8.34	8.64	4.86	64.25
Manatí	30	5.14	4.22	4.66	5.26	5.89	4.16	6.03	5.00	6.45	5.68	8.27	6.75	67.51
Dorado	21	5.45	4.19	3.94	4.67	5.69	4.65	6.68	5.95	6.15	5.38	8.92	6.21	67.88
Río Piedras	28	4.69	3.47	3.78	4.96	6.65	6.16	7.85	7.54	8.05	6.54	7.30	6.47	73.46
Bayamón	30	4.89	3.21	3.82	5.00	7.33	7.44	8.38	8.40	7.76	6.57	7.54	6.24	76.58
PROTECTED VALLEYS OF THE INTERIOR														
Cayey	30	3.21	2.83	2.90	3.47	4.44	5.64	6.22	6.58	6.60	6.37	6.26	4.13	58.65
Caguas	30	3.86	2.44	2.97	3.84	5.03	5.92	7.10	6.43	6.90	7.32	6.37	4.79	62.97
San Germán	30	1.96	2.65	3.52	6.49	5.59	4.31	5.79	7.45	7.39	9.05	6.86	3.19	64.25
Juncos	19	3.24	2.78	2.88	3.61	5.59	5.70	7.55	7.49	8.02	8.20	7.35	3.02	65.43
Cabo Rojo	22	2.15	2.98	3.84	5.36	5.55	4.57	7.64	7.94	9.04	8.75	5.73	2.80	66.35
Jayuya	20	2.25	2.20	5.53	7.26	6.38	3.95	6.02	5.89	10.37	8.10	7.02	2.45	67.42
Maunabo	30	3.70	3.27	3.45	3.24	5.86	8.22	7.15	7.10	9.50	9.81	8.55	5.00	74.85
Comerío Falls	22	6.63	4.53	4.85	5.78	5.70	4.52	7.91	8.29	7.69	6.70	8.57	7.11	78.28
Orocovis	11	5.63	3.15	5.89	4.93	9.37	4.13	7.35	4.58	8.34	8.93	8.98	7.68	78.96
Yabucoa	24	3.98	4.04	3.04	3.73	7.10	7.08	7.75	7.55	10.24	9.82	9.20	4.92	78.45
Utuado	15	3.72	1.85	3.64	6.94	8.19	7.86	6.47	7.68	12.75	10.24	7.66	3.89	80.89
INTERIOR														
Cidra	23	6.67	4.14	4.32	5.14	7.49	7.20	8.33	10.16	7.35	5.90	6.86	6.89	80.45
Coloso	30	2.13	2.09	2.97	4.90	9.92	12.20	9.37	9.99	10.30	8.32	6.79	2.60	81.58
Mayagüez	30	1.89	2.20	3.31	5.52	7.94	9.00	11.23	11.26	10.78	9.99	6.42	2.62	82.16
Carite Camp	18	4.79	4.94	4.73	4.70	6.57	7.55	9.63	7.61	9.12	10.38	8.17	4.71	82.90
Humacao	30	4.08	3.48	3.56	4.54	8.54	8.62	8.36	8.54	9.92	9.90	9.03	4.92	83.49
Guajataca	8	4.00	4.47	4.32	7.86	7.97	8.58	6.80	8.07	11.42	8.87	6.59	5.17	84.12
Añasco	21	1.52	2.90	2.82	5.63	8.71	10.15	11.63	12.21	11.05	10.47	6.26	2.84	86.19
Morovis	9	5.25	3.38	6.38	5.74	8.35	5.63	6.46	11.06	8.61	10.01	8.62	7.70	87.19
Toro Negro	18	3.88	4.39	4.57	8.43	9.02	6.64	7.48	7.54	13.01	14.50	10.90	4.64	95.00
Lares	24	3.26	3.60	4.39	9.16	11.74	9.99	8.46	9.26	12.23	12.32	8.79	5.03	98.23
Las Marías	17	2.75	2.61	4.72	6.49	12.37	10.66	9.34	12.14	13.24	12.37	8.97	3.72	99.38
San Sebastián	17	3.64	2.45	4.94	8.24	13.29	12.47	9.58	11.01	12.59	11.91	9.01	3.96	103.09
Maricao	18	1.92	3.14	4.65	8.36	10.77	9.18	12.75	13.40	13.26	15.80	9.37	3.68	106.28
Luquillo (La Perla)	9	8.21	3.37	6.54	11.27	14.94	13.75	14.56	11.14	12.24	13.94	16.23	9.36	135.55

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations*

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
FAJARDO, P. R. ELEVATION 30 FEET						
	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inches*
December	77.5	90	60	4.88	2.67	3.06
January	76.4	89	57	3.55	3.93	1.75
February	76.2	92	59	2.97	2.25	6.63
Winter	76.7	92	57	11.40	8.85	11.44
March	76.8	92	60	2.94	2.97	2.70
April	78.3	93	61	3.80	1.23	6.52
May	80.3	93	60	6.32	2.99	9.14
Spring	78.5	93	60	13.06	7.19	18.36
June	81.3	93	68	5.28	1.58	11.92
July	81.8	93	69	5.87	6.14	5.62
August	82.2	95	64	6.05	5.40	8.81
Summer	81.8	95	64	17.20	13.12	26.35
September	81.6	96	68	7.79	3.20	14.28
October	80.8	98	65	8.30	10.95	12.20
November	79.3	93	63	8.25	3.31	15.34
Fall	80.6	98	63	24.34	17.46	41.82
Year	79.4	98	57	66.00	[1] 46.62	[2] 97.97
RIO PIEDRAS, P. R. ELEVATION 75 FEET						
December	73.9	90	54	5.03	4.67	5.16
January	73.1	89	54	4.73	10.51	7.45
February	73.3	91	55	3.59	5.08	1.54
Winter	73.4	91	54	13.35	20.26	14.15
March	73.8	91	57	2.85	2.29	8.32
April	75.5	92	58	6.38	.69	4.82
May	77.7	93	62	8.87	3.96	12.20
Spring	75.7	93	57	18.10	6.94	25.34
June	78.8	93	63	5.76	3.17	9.86
July	78.8	94	63	7.08	4.04	17.38
August	79.1	95	58	6.13	6.33	6.56
Summer	78.9	95	58	18.97	13.54	33.80
September	79.6	95	57	7.59	4.46	8.82
October	78.9	95	64	6.91	4.10	11.82
November	77.0	94	62	7.89	4.84	12.89
Fall	78.5	95	57	22.39	13.40	33.53
Year	76.6	95	54	72.81	[3] 54.14	[4] 106.82
ISABELA, P. R. ELEVATION 275 FEET						
December	76.2	94	57	4.61	5.10	6.41
January	75.1	92	58	3.34	4.30	6.70
February	74.8	94	59	2.81	1.10	.29
Winter	75.3	94	57	10.76	10.50	13.40
March	75.7	94	59	2.87	1.50	2.64
April	77.0	96	60	3.36	3.00	4.70
May	78.5	97	62	6.40	1.95	15.89
Spring	77.1	97	59	12.63	6.45	23.23

See footnotes at end of table.

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations*—Continued

ISABELA, P. R. ELEVATION 275 FEET—Continued

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° F.	° F.	° F.	Inches	Inches	Inche
June	79.6	98	63	4.78	.85	5.67
July	80.4	96	65	3.97	3.30	11.87
August	80.5	99	65	5.15	1.90	9.17
Summer	80.2	99	63	13.90	6.05	26.71
September	80.3	99	63	5.60	3.00	16.80
October	79.7	97	60	5.42	6.80	7.14
November	78.4	96	60	7.02	3.10	6.22
Fall	79.5	99	60	18.04	12.90	30.16
Year	78.0	99	57	55.33	[5] 35.90	[6] 93.50
SAN LORENZO (VALDES FARM), P. R. ELEVATION 203 FEET						
December	74.6	92	53	4.95	0.95	3.29
January	72.9	90	54	3.51	2.70	2.45
February	72.9	92	53	2.39	2.75	4.88
Winter	73.5	92	53	10.85	6.40	10.62
March	73.6	93	53	3.14	2.48	2.74
April	76.2	93	57	3.43	2.06	11.25
May	78.0	95	53	9.23	3.89	17.77
Spring	75.9	95	53	15.80	8.43	31.76
June	78.8	94	60	6.55	2.66	10.23
July	78.8	94	64	6.76	9.78	9.10
August	79.4	103	63	7.56	6.00	4.81
Summer	79.0	103	60	20.87	18.44	24.14
September	79.0	101	60	10.00	6.47	20.97
October	78.1	96	60	8.06	5.28	15.27
November	76.3	97	58	7.93	3.08	18.97
Fall	77.8	101	58	25.99	14.83	55.21
Year	76.6	103	53	73.51	[1] 48.10	[2] 121.73
AIBONITO, P. R. ELEVATION 2,000 FEET						
December	69.4	85	49	4.44	2.40	2.64
January	67.9	89	43	3.74	3.65	5.51
February	67.8	88	43	3.13	1.05	2.21
Winter	68.4	89	43	11.31	7.10	10.36
March	68.6	89	40	3.45	2.95	1.95
April	69.9	88	45	3.82	2.95	3.45
May	71.9	92	48	6.00	5.15	6.10
Spring	70.1	92	40	13.27	11.05	11.50
June	73.4	90	49	4.16	1.05	3.72
July	74.4	90	52	5.21	2.40	16.62
August	74.8	90	52	6.10	2.47	15.47
Summer	74.2	90	49	15.47	5.92	35.81
September	74.1	90	51	6.54	5.20	8.34
October	73.2	92	50	7.53	3.09	19.43
November	71.6	91	50	6.43	4.05	8.18
Fall	73.0	92	50	20.50	12.34	35.95
Year	71.4	92	40	60.55	[7] 36.41	[8] 93.62

See footnotes at end of table.

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations*—Continued

MARICAO, ELEVATION 1,500 FEET

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° F.	*° F.*	*° F.*	*Inches*	*Inches*	*Inches*
December	70.9	89	50	3.72	3.05	1.60
January	70.1	88	50	2.20	2.30	2.80
February	69.7	90	48	3.02	.40	1.75
Winter	70.2	90	48	8.94	5.75	6.15
March	69.9	92	48	5.05	1.78	15.65
April	71.1	90	50	8.10	5.40	10.65
May	72.1	93	50	12.18	9.50	13.80
Spring	71.0	93	48	25.33	16.68	40.10
June	73.3	95	54	8.11	12.40	9.50
July	74.0	92	55	11.70	8.52	19.95
August	74.7	92	55	14.62	8.38	16.45
Summer	74.0	95	54	34.43	29.30	45.90
September	73.4	90	55	15.93	10.28	8.45
October	72.7	90	50	15.32	13.74	28.85
November	72.1	90	50	8.77	5.27	11.15
Fall	72.7	90	50	40.02	29.29	48.45
Year	72.0	95	48	108.72	[7] 81.02	[4] 140.60

MAUNABO, ELEVATION 50 FEET

December	78.0	93	61	5.48	2.30	8.47
January	76.3	90	59	4.53	8.14	1.60
February	76.7	93	58	3.33	3.89	2.62
Winter	77.0	93	58	13.34	14.33	12.69
March	77.0	93	57	3.26	1.10	.70
April	78.8	94	61	3.29	.60	5.50
May	79.8	95	62	7.27	3.39	13.93
Spring	78.5	95	57	13.82	5.09	20.13
June	81.1	96	62	8.31	4.68	17.70
July	82.2	95	68	7.35	4.15	9.55
August	82.7	96	62	7.56	4.60	14.90
Summer	82.0	96	62	23.22	13.43	42.15
September	81.8	95	66	9.58	3.82	13.95
October	81.1	96	65	9.86	10.75	15.15
November	79.6	94	61	8.31	5.20	9.55
Fall	80.8	96	61	27.75	19.77	38.65
Year	79.6	96	57	78.13	[9] 52.62	[2] 113.62

See footnotes at end of table.

TABLE 4.—*Normal monthly, seasonal, and annual temperature and precipitation at 9 Weather Bureau stations—Continued*

PONCE, ELEVATION 80 FEET

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° *F.*	° *F.*	° *F.*	*Inches*	*Inches*	*Inches*
December	77.0	91	57	1.17	0.97	0.10
January	75.4	90	57	1.05	.05	1.34
February	75.4	90	55	1.23	.56	.86
Winter	75.9	91	55	3.45	1.58	2.30
March	76.0	91	58	1.29	.54	.45
April	77.4	93	59	1.87	1.67	2.62
May	79.5	95	61	3.62	2.03	3.69
Spring	77.6	95	58	6.78	4.24	6.76
June	80.7	96	58	3.60	.89	7.74
July	81.0	95	58	2.73	.20	3.14
August	81.6	96	64	4.20	2.52	17.20
Summer	81.1	96	58	10.53	3.61	28.08
September	81.3	98	68	5.14	7.75	3.19
October	80.5	95	61	5.70	1.74	8.20
November	79.0	94	60	3.84	.87	10.20
Fall	80.3	98	60	14.68	10.36	21.59
Year	78.7	98	55	35.44	[10] 19.79	[11] 58.73

ENSENADA, ELEVATION 50 FEET

December	75.4	95	51	1.27	0.53	3.85
January	74.3	95	53	.84	.10	2.10
February	74.3	92	51	1.49	.18	.80
Winter	74.7	95	51	3.60	.81	6.75
March	75.1	100	52	1.43	.54	2.25
April	76.2	100	56	1.82	.93	.00
May	77.5	94	58	3.41	.32	7.70
Spring	76.3	100	52	6.66	1.79	9.95
June	79.0	99	58	2.40	2.00	3.90
July	79.3	95	60	1.71	.06	.70
August	79.6	98	60	3.01	.82	3.30
Summer	79.3	99	58	7.12	2.88	7.90
September	79.7	98	56	4.37	1.29	10.80
October	78.6	97	59	3.94	3.27	9.72
November	77.1	96	58	3.66	1.30	7.95
Fall	78.5	98	56	11.97	5.86	28.47
Year	77.2	100	51	29.35	[12] 11.34	[13] 53.07

[1] For 1926.
[2] For 1931.
[3] For 1920.
[4] For 1927.
[5] For 1923.
[6] For 1932.
[7] For 1913.
[8] For 1916.
[9] For 1930.
[10] For 1929.
[11] For 1909.
[12] For 1922.
[13] For 1933.

A rainfall of 30 inches in Puerto Rico is equivalent in effectiveness to about 15 inches in the United States. The high evaporation combined with high temperatures, low relative humidity, and constant winds tends to cause semiarid conditions even where the average annual rainfall is 45 inches. In San Juan the evaporation from a free water surface exceeds the precipitation, but in the moist mountain districts the precipitation probably far exceeds the evaporation. The evaporation is much higher in comparison to the rainfall during the dry winter than at other seasons, and, as crops grow throughout the year, irrigation is sometimes necessary even in areas having an average annual rainfall of 65 inches. Some of the soils, because of their permeable physical characteristics, require water at frequent intervals in order to insure maximum crop production. This is especially true with the red soils derived from limestone, which occur from Bayamón to Aguadilla. Extensive irrigation systems are in operation in most cultivated areas having less than 50 inches of rainfall, and some pumping plants have been installed for the irrigation of sugarcane and grapefruit in areas receiving an average annual rainfall of 68 inches.

The temperature, although tropical, is cooled during the day by the moisture-laden trade winds and at night by the land breezes that blow from the cool mountains to the coast. Mean monthly temperatures along the warmer dry coast towns range from about 75° F. in the winter to about 80° during the summer. Throughout the year the moist mountain areas are about 5° cooler than those along the coast. Extremes of temperature within 24 hours are very rare, except during hurricanes. The temperature seldom rises higher than 90°, and even in the highest, coolest parts of the island it seldom falls below 50°; at least there are no records of very low temperature. Fire is not needed in any of the homes, except for cooking and ironing. Frost is unknown, and rarely does one hear of sunstroke. Dense fogs occur only in the mountain valleys and on peaks.

The mild uniform temperature, low relative humidity combined with invigorating breezes, and the mountainous character of most of the island make it a very agreeable place in which to live. Sunshine occurs daily over most of the island, with the exception of a few days each year, and the ultraviolet rays of the Tropics are beneficial to plants, animals, and mankind. The high precipitation, however, has caused destructive leaching in many soils, and they are acid, low in bases, and lacking in plant nutrients. The plants produced from the leached soils do not seem to be so nutritious as those grown on neutral or alkaline soils high in bases.

The climate (*45, pp. 4–12*) is nearly ideal for a 12-month growing period for such tropical crops as coffee, sugarcane, pineapples, bananas, mangoes, coconuts, yautia, and yuca, but it is not so good for alfalfa and berries. Such crops as wheat, oats, barley, apples, and peaches are not grown. The imported dairy cattle, hogs, goats, and chickens suffer somewhat because of the climate, but oxen, horses, and mules seem to thrive. Sheep and beef cattle do much better in cooler climates. The climate has had very little direct effect on the distribution of most of the livestock and poultry, except turkeys which are much more prevalent in the dry hot areas than in the moist districts, because the drier areas are less favorable for the many harmful diseases that beset turkeys.

During the progress of the soil survey a rainfall map (fig. 34) of the island was compiled from rainfall data furnished by the United States Weather Bureau, owners of sugar centrals, and other landowners, as well as from information obtained from the correlation that exists between soil climate and the following: Plant species, growth of vegetation, soil erosion, soil color, soil development, elevation, and, to some extent, rural population.

There is very little noticeable correlation between the temperature and plant species, because there is only about 10° or 15° F. difference, for any length of time, between the coolest and warmest parts of the island. Such plants as wild raspberries, many kinds of flowers, and coffee grow better and produce higher yields in the cool mountains than on the warm coastal plain, but they are not limited to the cool mountains. Some of the mosses and vegetation on the highest peaks probably are restricted to the cool districts, but they are of minor importance. The quantity of rainfall, however, is the limiting factor for the distribution of many plant species. The sudden change in amount of precipitation is reflected so much in the native vegetation, that within a distance of a very few miles and a descent of a few hundred feet, one may pass from a luxuriant tropical rain forest to a shrub-covered desert.

The correlation that exists between plants and rainfall is in reality the relationship between plants and soil moisture, as is shown by the royal palms, which seldom grow on steep hillsides if the annual rainfall is less than 60 inches; but they will grow on level land if the annual rainfall is 50 or more inches; and they grow along drainageways if the annual rainfall is greater than 35 inches. Cacti and many of the thorny plants are confined mostly to sections having less than 40 inches of annual rainfall, but they grow abundantly in areas of higher rainfall if the soil is very permeable, droughty, and the relief steep, for instance, on some of the Rosario soils which are derived from serpentine and occur northwest of Yauco in a belt where the annual rainfall is more than 65 inches. The drought-resistant guinea grass grows abundantly in the valleys, but it ceases to grow on the adjacent hillsides having an annual rainfall of less than 30 inches, unless it has exceptionally good care. Coconuts will grow along the low coast regardless of the low rainfall, but they do not thrive on the hillsides unless the annual rainfall is greater than 40 inches. The húcar, or úcar, trees thrive either on hills or level land if the annual rainfall is 45 inches or less. The almácigo, tamarindo, algarrobo, and jagüey are conspicuous in almost all areas having an annual rainfall of 60 inches or less. This is also about the rainfall limit of barrilla and horquetilla grasses. The treeferns do not seem to grow in areas having less than 80 inches of annual rainfall, and generally with that rainfall they grow in the concave drainageways. The sierra palms are seldom conspicuous unless the annual rainfall is 100 or more inches. The characteristic moss vegetation of high peaks of Sierra de Luquillo requires more than 150 inches of rainfall annually.

Plant growth also is correlated with soil moisture. Sugarcane generally will be a failure when planted on steep hillsides, level sandy soils, or very impervious soils, in areas having less than 60 inches of annual rainfall. Low yields of sugarcane may be expected on level alluvial land in areas having less than 40 inches of annual rainfall, unless the land is irrigated. The valley south of Lajas, which has

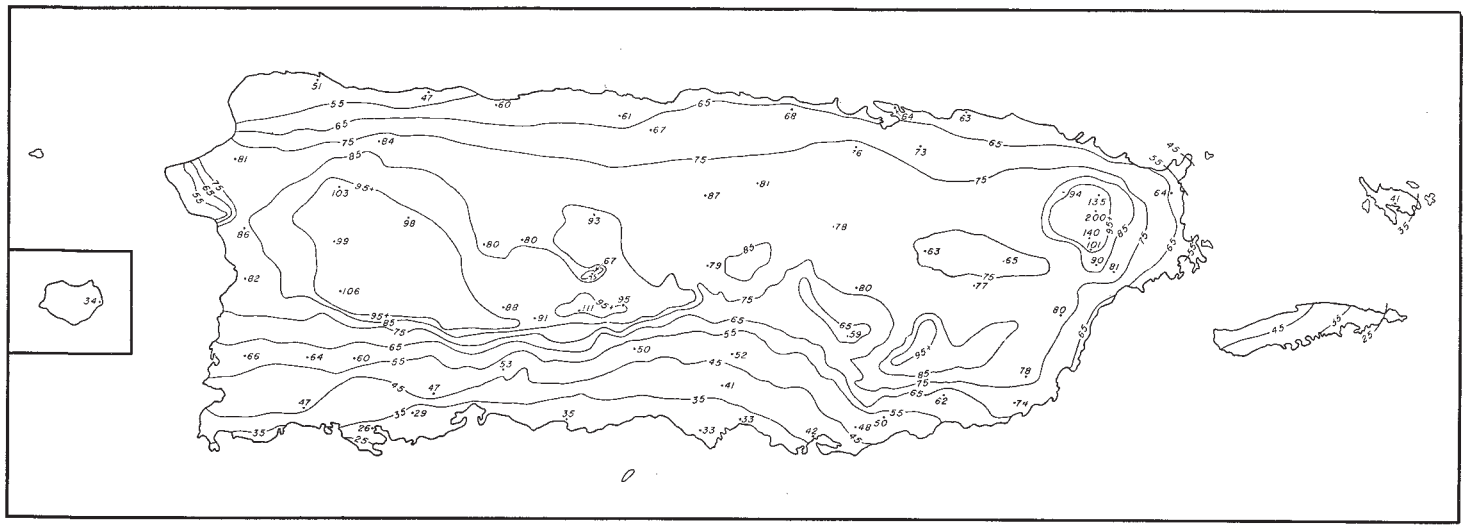

FIGURE 34.—Rainfall map of Puerto Rico, compiled from data furnished by the United States Weather Bureau, owners of sugar centrals, and other landowners, and from information obtained from the correlation that exists between soil climate and the following: Plant species, growth of vegetation, soil erosion, soil color, soil development, elevation, and, to some extent, rural population.

Mapa de precipitación pluvial de P. R. compilado de los datos suplidos por el Negociado del Tiempo de los EE. UU., las centrales y otros agricultores, también de información obtenida de la correlación que existe entre el clima del suelo y lo siguiente: especies de plantas, vegetación, erosión, color del suelo, desarrollo del mismo, elevación, y hasta cierto punto, población rural.

an average annual rainfall of 45 inches, produces fair yields of sugarcane on the low level lands, but the adjacent hills to the south will produce only such crops as corn, beans, grass, and pasture, which require less water. In the eastern part of the island, near Ensenada Honda de Fajardo, where the annual rainfall is about 60 inches, much of the sugarcane planted on the hillside will be a failure, unless the rainfall is above the average; but sugarcane generally will range from fair to good on the adjacent level alluvial lands, where the sugarcane roots can penetrate deeply and obtain a much greater supply of moisture than on hillsides.

The amount of rainfall varies greatly within short distances, especially in sections having mountain barriers and where the mean annual precipitation is less than 70 inches. The north side of a high or medium-high east-west ridge may receive 10 inches more rainfall annually than the south side. In many areas receiving annually from 50 to 60 inches of rainfall, the north side of a hill will be cultivated to corn, beans, tobacco, and gandules, or pigeonpeas, and the south side will be in pasture. It is of the utmost importance for the agriculturist as well as for money-lending agencies to know as nearly as possible the boundaries of the areas receiving less than 60 inches of rain annually, as this is more or less the critical moisture zone. The success or failure of many hundreds of people depends on whether or not they attempt hillside farming in areas having less or more than 60 inches of annual precipitation. A person may be deceived greatly by the general appearance of the drier country, if he visits it during the rainy season.

It is noticed that in sections having from 50 to 60 inches of annual rainfall, there is more serious soil erosion than in any other part of Puerto Rico. (See fig. 23, p. 36.) There may not be so much erosion within this area as in more mountainous areas, but the harm resulting from erosion is more lasting. Erosion is more serious within this belt than elsewhere mainly because the rainfall is sufficient to encourage hillside farming by small farm owners who plant clean-cultivated crops, such as beans, corn, tobacco, and pigeonpeas, yet not sufficient for plants to make a quick dense growth as in more moist areas. One of the main reasons that soil erosion is not more destructive on the steep hillside farms in the areas of high rainfall is because vegetation grows so quickly and densely that the force of the water is checked and the soil granules are bound together by the plant roots. The areas receiving less than 50 inches of rainfall annually support a sparse growth of vegetation, but the farmers do not attempt to cultivate the steeper slopes nor do they overgraze their pastures to such an extent as do farmers in the areas of slightly more rainfall. Erosion in the dry areas is due mostly to sudden, intense showers that fall at the termination of long dry periods, when the grass is short, or sparse, and much of the ground is exposed. Within a week's time after the spring rains start, however, the grass reestablishes itself so that destruction from rains during the rest of the rainy season is greatly reduced.

Very few data are obtainable on the intensity of the rains in different parts of Puerto Rico. The intensity of rainfall and wind as recorded by the Weather Bureau station at San Juan is presented in tables 5 and 6. These tables show that the greatest amount of rain falling in 24 hours was 10.55 inches and the heaviest downpour in 2 hours was 4.67 inches. This high intensity of rainfall is one of the serious

factors in causing soil erosion on the sloping lands. The intensity of rainfall is greater in some other cities than at San Juan.

TABLE 5.—*Extremes of precipitation and wind at San Juan (1899–1935)*

Month	Precipitation			Wind			
	Date	Year	Greatest in 24 hours	Date	Year	Direction	Highest velocity [1]
			Inches				*Miles per hour*
January	3	1934	4.52	21	1921	Northeast	[2] 43
February	23–24	1918	4.84	6	1931	North	40
March	4–5	1927	3.64	12	[3] 1921	East	38
April	7–8	1915	6.72	10	1915	do	35
May	1–2	1902	4.81	6	1928	Northeast	34
June	11–12	1919	5.26	16	1908	Southeast	40
July	6–7	1901	4.05	23	1926	East	51
August	8–9	1899	6.26	22	1916	Northeast	70
September	13–14	1928	8.50	13	1928	do	[2] 149
October	30–31	1927	3.87	9	1916	North	41
November	11–12	1931	8.06	28	1917	Northeast	40
December	13–14	1910	10.55	3	[4] 1934	do	40

[1] Corrected to true velocitiy.
[2] Estimated.
[3] Also in 1935, March 10, from the northeast.
[4] Also in 1935, December 7, from the northeast.

TABLE 6.—*Excessive precipitation at San Juan, 1899–1935*

[Maximum amounts for short periods]

Duration of downpour (minutes)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Maximum
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
5	0.48	0.45	0.56	0.58	0.79	0.50	0.44	0.57	0.56	0.48	0.44	0.50	0.79
10	.88	.83	.98	1.01	1.02	.76	.72	.89	.91	.80	.82	.89	1.02
15	1.17	1.10	1.20	1.32	1.08	1.05	.96	1.28	1.31	1.05	1.19	1.19	1.32
30	1.77	1.26	1.50	2.06	1.80	1.62	1.60	2.16	2.09	2.00	2.23	1.47	2.23
60	3.19	2.00	1.55	2.46	3.03	2.13	2.10	3.18	3.43	3.01	3.48	2.67	3.48
120	4.26	2.35	1.79	3.57	3.46	2.98	2.60	3.58	4.21	3.30	4.67	3.55	4.67

The correlation between soil climate and soil color and development is very obvious. In the driest part of the island, or the part receiving less than 25 inches of annual rainfall, the mature soils are brown, and they would be classified with the Brown soil group in the United States. The areas receiving from 25 to 35 inches of annual rainfall have chestnut-colored soils and are classified as Chestnut or Reddish Chestnut soils. The soils in a moister belt are very dark grayish brown and are classified with the Chernozem. This area has an annual rainfall ranging from 35 to 45 inches. Within the areas having an annual rainfall ranging from 45 to 60 inches, the soils having nearly black surface soils are classified as Prairie or Reddish Prairie soils. Most of the nearly level soils occurring within the area having an annual rainfall ranging from 60 to 75 inches have grayish-brown surface soils and leached layers above the subsoil. These soils are classified as podzolic soils. Most of the soils occurring on the level or undulating areas having an annual rainfall ranging from 75 to 90 inches are red and deep, and are classified as lateritic, but the soils on the slopes are shallow and brown. The soils in belts where the annual rainfall ranges from 90 to 110 inches are deep and red, even on 80-percent slopes, and are considered lateritic. In areas where the annual rainfall exceeds 110 inches, the surface soil has a gray cast, and the color

is similar to that of Podzol soils. Soils produced from limestone or rocks high in bases may be exceptions to the above; for example, the soils north of San Sebastián and Lares are nearly black, although the annual rainfall is nearly 100 inches. These soils are derived from a medium soft limestone and are classified as Rendzina. In the extreme northwestern and the southwestern parts of the island, the average annual rainfall is 50 and 30 inches, respectively, but the soils are red because they are derived from rather hard limestone.

In most areas a correlation exists between the rainfall and the acidity of the soils. If the average annual rainfall is below 40 inches the soils are strongly alkaline, they generally effervesce at the surface when treated with dilute hydrochloric acid, and they have a pH value of 8 or more. Within this rainfall limitation are most of the "black alkali" areas. This rainfall belt, as shown on the map, includes only a small percentage of the island. Most of the soils receiving from 40 to 50 inches of rainfall annually range from neutral to alkaline in the surface soil and have free lime in the subsoil. Most soils having from 50 to 60 inches of annual rainfall are neutral or slightly acid in the surface soil and slightly alkaline in the subsoil. Most of the soils receiving from 60 to 70 inches of rainfall annually are acid in the surface soil and neutral in the subsoil. In most areas receiving more than 70 inches of annual rainfall the soils are acid in both the surface soil and subsoil. In most places the more poorly drained soils are the most alkaline, as the calcium carbonate does not leach readily under saturated soil conditions. Muck and peat soils are exceptions, as they are generally strongly acid. In some places in the arid districts, the soils are acid because they are derived from exceptionally acidic rocks and are low in soluble bases; for example, the soil mapped as Mariana clay loam near Lajas. Other soils are acid in dry areas because they are very old and probably were leached of their carbonate under a more moist climate than now exists. In general, soils derived from soft limestone will be alkaline even if the annual rainfall is more than 100 inches, but if the limestone is very hard and weathers slowly the soil might be acid if the annual rainfall ranges from 40 to 50 inches.

There is no uniform correlation between elevation and rainfall, but throughout the island the heaviest precipitation occurs on the high peaks. Southward from the east-west mountain ranges, the rainfall decreases with decreasing elevation, but on the north, east, and west sides the total amount of precipitation at the same elevation varies.

Climate, especially the two extremes of rainfall, seems to be a factor in the distribution of rural population. In the arid islands and along the southern coast of the mainland, few crops, except the drought-resistant grasses, can be grown without irrigation. Such areas that are not irrigated are sparsely populated, because only a few people to the square mile can obtain a living. Subsistence crops are not grown successfully in the areas of high rainfall, which occur in the rough, rugged, fog-swept mountains at an elevation above 2,000 feet. Therefore, such areas are sparsely populated. The rural population is most dense in those municipalities that have the average climate, combined with soils, such as those of the Múcara and Cataño series, that are better adapted to subsistence crops than to other crops.

Climate probably has had some effect on the distribution of the races. On the hot sandy coast the proportion of Negroes is much

higher than that of whites, but in the cool high mountains there are very few Negroes.

Puerto Rico is in the region of the eastern Caribbean Sea where tropical cyclones take place, and these storms are dreaded from one season to the next. Between 1825 and 1935, 22 hurricanes caused great destruction on the island. The hurricanes generally occur between August and October, and the more severe ones have caused nearly $50,000,000 worth of damage and the loss of nearly 3,000 lives. The wind velocity may be more than 120 miles an hour, and the rainfall may exceed 20 inches for a 24-hour period. Some of the most destructive storms were: San Narciso, in 1867; San Ciriaco, in August 1899; San Felipe, in September 1928; and San Ciprián, in 1932.[14]

The crops most affected by storms are coffee, grapefruit, and sugarcane. The coffee growers suffer the greatest loss, as it requires 6 or 7 years after the shade trees have been destroyed before the coffee trees become profitably productive again. The loss of several successive crops, as well as the expense of planting new shade and coffee trees, is extremely heavy on the one-crop coffee grower. The grapefruit growers may lose 80 percent or more of their year's crop and possibly from 10 to 20 percent of their trees, but the next year the crop may be as large as the average. The sugar centrals undergo heavy losses of buildings, machinery, and railroads, in addition to the loss in sugarcane yields and to the low sucrose content of the cane, caused by the rapid growth of suckers as soon as the cane is blown over by the wind. After a storm the sugarcane is much harder to cut, as it is usually in a tangled mass.

In addition to the damage to property, loss of life, and loss in crop yields, the torrential rains occurring during and following the hurricanes do unestimable damage in washing the soil from the hills and either depositing it on alluvial flats or carrying it far out into the sea. Floods cause considerable damage to property, crops, and human life. Occasionally parts of the islands are affected by earthquakes.

AGRICULTURE

Puerto Rico always has been and probably always will be an agricultural island. When Columbus landed there nearly 450 years ago, some of the native Indians were gardeners and produced root crops to be used for a part of their diet. Today more than 50 percent of the farms are less than 9 acres each in area and are made up of small garden patches. The majority of the people have been gardeners for a long time, and, doubtless, with the rapidly increasing population, a much larger proportion of them will obtain a part of their living in the future by growing subsistence crops. For several hundred years the principal crops grown by the jibaro farmers or gardeners have been bananas, corn, sweetpotatoes, beans, yautia, pigeonpeas, yuca, and ñames. These subsistence crops are relished by all the native people and, supplemented with rice, fish, and coffee, constitute the main diet of the masses.

Although these crops are of vital importance to many thousands of people, the commercial prosperity of the island depends on the production and selling price of three main cash crops—sugarcane, tobacco, and coffee. These crops have been grown for many years, mostly by

[14] It is customary to name the hurricanes after a saint whose birthday is nearest to the day of the storm.

farmers owning large tracts of land. Table 7 gives the acreage of the principal crops grown, and figure 35 shows the types of farming practiced throughout the island.

TABLE 7.—*Acreage of the principal crops grown in Puerto Rico, in stated years*

Crop	1899 [1]	1903 [1]	1909 [2]	1901 [2]	1929 [2]	1935 [3]
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Sugarcane	72,146	112,416	145,433	227,815	237,758	245,154
Coffee	197,031	177,754	186,875	193,561	191,712	182,316
Bananas	69,380			[4] 52,206	[4] 128,339	[4] 61,786
Corn	18,093		56,640	58,785	70,217	49,820
Tobacco	5,963	18,414	22,142	39,068	52,947	45,720
Sweetpotatoes	37,109			31,457	47,616	36,947
Beans			20,652	34,907	40,902	31,470
Yautia	12,256				16,683	17,596
Coconuts	5,447	2,931	[5] 17,555	[5] 26,307	[5] 30,357	[5] 23,227
Pigeonpeas						15,954
Grapefruit			[6] 3,379	[6] 4,763	[6] 9,485	[6] 11,429
Rice	8,667		16,138	11,749	5,244	9,386
Ñames	2,098				5,186	7,966
Plantains				[4] 6,449	[4] 7,729	[4] 7,436
Yuca					6,072	6,846
Cowpeas						3,379
Vegetables					11,962	3,616
Pineapples			[7] 2,530	[7] 946	[7] 1,827	[7] 1,487
Cotton			1,425	2,760	10,282	934
Minor crops	[8] 49,836	[8] 201,036				

[1] See (*46, p. 17*).
[2] Federal census.
[3] From Puerto Rico Reconstruction Administration special census (*34*).
[4] Calculated on the basis of 625 plants to the acre. Many acres of these crops are interplanted with coffee. The same is true of oranges, which have not been included in this table.
[5] Calculated on the basis of 30 trees to the acre.
[6] Calculated on the basis of 70 trees to the acre.
[7] Calculated on the basis of 10,000 plants to the acre.
[8] The minor crops have not been separated.

Sugarcane was introduced 25 years after Columbus landed, and coffee plants were taken to the island about two centuries later. Tobacco has been grown for a long time but was not grown on a commercial scale until about 1880. The raising of cattle was an important enterprise during the early days. Pineapples and grapefruit were of little importance until occupation by the Americans. During the last 200 years there have been many fluctuations, both in the acreage and in the importance of the different crops, which will be fully discussed, crop by crop, in the latter part of this section.

The history of early land tenure in Puerto Rico, as in nearly all newly settled countries, is vague. Undoubtedly the island once was covered with dense forests which varied in density and in the size of trees from place to place according to the climate and soil. The clearing of the forests by Indians, in preparation of the land for their root crops, was confined mostly, but not entirely, to the land along the coast. The more peaceful Arawak Indians seldom dared cultivate land in full view from the sea, but confined their farming to concealed places along inland valleys and along the river flood plains a short distance from the coast. The early Spanish settlers practiced agriculture only on the coastal lowlands and river flood plains near the small settlements. Later, most of the land held by the Spaniards was in large grants, many of which included the good level alluvial lands that were soon planted to sugarcane. Now, with few exceptions, cane occupies all the best soils. Coffee and tobacco were planted on the steeper, more acid, and less fertile land.

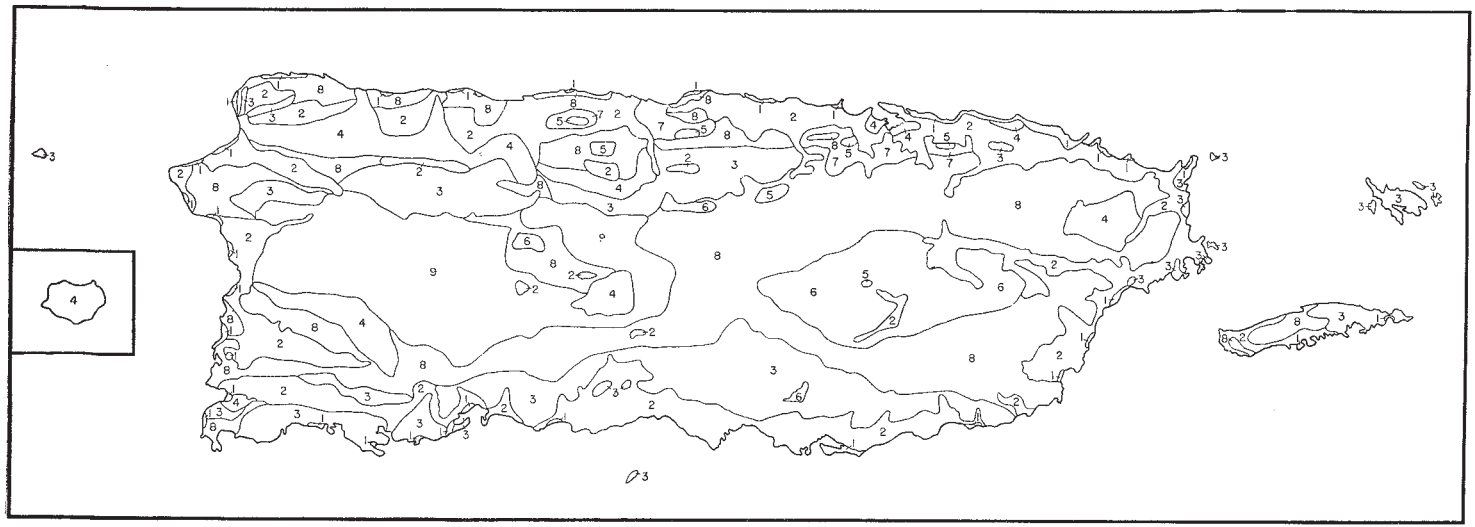

FIGURE 35.—Map of Puerto Rico, showing the different types of farming: 1, Coconuts; 2, sugarcane; 3, pasture and some subsistence crops; trees and some subsistence crops; 5, pineapples; 6, tobacco; 7, grapefruit; 8, subsistence crops; and 9, coffee.

Mapa de los siguientes cultivos en Puerto Rico: 1, Cocos; 2, caña de azúcar; 3 pastos y algunos cultivos de subsistencia; 4 árboles y algunos cultivos de subsistencia; 5, piñas; 6, tabaco; 7, toronjas; 8, cultivos de subsistencia; y 9, café.

FIGURE 36.—See legend on page 63.

Within the last 30 years most of the sugarcane estates and haciendas have been enlarged, and now many are owned by sugar centrals, many of which control from 1,000 to 10,000 acres. The best and most productive lands, therefore, are under the control of a comparatively few individuals or corporations. These lands, however, are efficiently and scientifically managed and now produce much higher yields than they did when they were held in small holdings and managed by the owners.

The coffee fincas always have been in large tracts, compared with the size of the minor truck farms. The tobacco farms range from very small to rather large. Tobacco is mostly grown by small farmers; 80 percent have less than 3 acres. From the beginning, the livestock ranches have included large tracts and probably will continue to do so. Owing to irrigation projects on the south coast, many large cattle ranches have been converted into checkerboard-patterned fields occupied exclusively by sugarcane (fig. 36). The average size of the commercial pineapple and grapefruit farms is about 200 and 100 acres, respectively, and their size has changed but little since they were started about 30 years ago. Many small farms have a few acres in pineapples or grapefruit.

The minor truck farms or gardens have changed considerably since the early days. At one time the most common practice of the jibaros was to cut the virgin trees, probably sell some timber but burn most of the limbs and branches on the land, then plant subsistence crops. This practice prevailed not only in the mountains but also on the better lands. In the olden times the jibaros had as large an acreage as they cared to cultivate even on the good alluvial lands. Later, when land became more valuable and sugarcane more important, the owners of the haciendas bought almost all of the level alluvial land, and the owners of the small tracts had to work for wages or buy other places on less desirable land. The owners of the haciendas, however, allowed the peon helper to have a small garden on the rich alluvial land. Gradually the alluvial land became too valuable for the production of subsistence crops, and the population increased so rapidly that the jibaros were crowded farther and farther into the steep mountainous country. As the jibaro family increased and married, the farm was divided and a part given to the sons or the farm products were shared with all members of the family.

At present these small gardeners live on steep hills where the soil is shallow or on very sandy level areas near the coast. In both situations the soils are poorly adapted for any of the main commercial crops, but, fortunately for the jibaro, they are fairly well adapted to subsistence crops. The hill land is steep, and, owing to much erosion, which is accelerated when clean-cultivated crops are planted, the surface soil becomes thin or is entirely washed away, but, as the subsoil and parent rock are soft and fairly rich in bases and plant nutrients,

---

FIGURE 36.—Checkerboard-patterned irrigated sugarcane fields on Machete clay loam and Machete clay, which formerly were range land for livestock. Note the modern sugar central in the lower left-hand corner and the old hacienda in the upper right-hand corner. (Photograph taken by U. S. Navy.)

Campos de caña en forma de tablero de damas, bajo riego en Machete arcilloso lómico y Machete arcilloso, y que antiguamente eran pastos. Nótese la moderna central en la parte baja a la izquierda y la antigua hacienda en la parte de arriba a la derecha. (Fotografía tomada por la Marina de los EE. UU.)

the crops produced are of a better quality and more abundant than those grown on the deeper, less eroded, more leached acid soils such as occur in the coffee districts. The shallow young soils can maintain their productivity better under the jibaros' system of farming than can most of the older soils. The jibaros rarely use fertilizer, and they frequently plant three or four crops on the same land year after year. When viewed from the air, these small irregular-shaped garden patches give the landscape an appearance of an intricate mosaic pattern.

Nearly all of the sandy soils along the coast that are used extensively by the jibaros for gardens are fairly good for root crops and other subsistence crops. Yields are seldom high unless fertilizers are used, but fair crops are obtained and help in keeping the people from starvation.

According to the 1935 census of the Puerto Rico Reconstruction Administration (*34*), the average-sized farm is 36.2 cuerdas. The average farm for each municipality ranged from 15.6 cuerdas in Aguada, where most of the land is in subsistence crops, to 1,001.1 cuerdas in Santa Isabel where most of the cultivated land is in sugarcane and the uncultivated land in cattle ranches. There are 52,790 farms on the island, 25,326 of which are between 3 and 9 cuerdas in size and only 335 are 500 cuerdas or more.

The average value of land and buildings per cuerda was $81.69 in 1935 and in 1920 was $74.80. Land values range from nearly $1,000 a cuerda for the very best irrigated land on the south coast to less than $5 for that on rough limestone hills in either the dry district on the south coast or in the haystack hill area on the north coast.

According to the 1935 census, 18.7 percent of the farms are operated by tenants, 4.6 percent by managers, and 76.7 percent by owners or part owners. Most of the tenant farms are rented on a cash basis, and some of the good sugarcane land rents at prices ranging from $10 to $30 an acre. The planter usually pays the taxes, which may be more than $5 an acre. Many leases of the cane land are for a period ranging from 10 to 20 years.

Very often sugar centrals advance money to the nearby colonos, or small farmers, who send their cane to be ground at the central's factory. The transaction is in the form of a contract. The sugar central agrees to grind the colono's cane and may advance him $20 or more an acre for the first year's planted crop and less for the ratoon crops. The centrals charge interest and usually exercise some control over the cultivation and management of the crop. The price paid to the colono usually depends on the percentage of sucrose in the cane. Many contracts specify that the cane grown by the colono must have at least the minimum sucrose content and purity required. If the cane does not reach the minimum requirement, the grower is not remunerated, as the cost of grinding equals or is greater than the value of the cane.

Buyers of tobacco and cotton often advance money to the planters of these crops. The Federal Intermediate Credit Bank makes crop loans for the production of coffee, tobacco, and other crops.

According to the Federal census, the amount of money expended for fertilizer, including manure, was only $911,412 in 1909, but nearly six

times that amount, or $5,697,465, was spent in 1919. In 1929, $5,401,-187 was spent by the 18,540 farmers reporting. This was almost one-eighth of the total value of all vegetable, field, and orchard crops for 1929. The municipalities expending the largest amount for fertilizers in 1929, ranking in the order named, are: Salinas, Humacao, Guánica, Arecibo, Caguas, Fajardo, Bayamón, and Cayey. All these municipalities, except Cayey, have a very large acreage in sugarcane. Arecibo and Bayamón have considerable acreages in fruits, and Cayey has a large acreage in tobacco.

The use of commercial fertilizer is general for such crops as sugarcane, grapefruit, tobacco, pineapples, ñames, and some vegetables. Very little is used for coffee, coconuts, corn, minor crops, and pasture. The municipalities using the greatest amount of fertilizer are those that have the largest acreages of sugarcane. Most of the fertilizer is purchased ready mixed, and about 600 pounds to the acre are used for cane, from 800 to 1,000 pounds for grapefruit and tobacco, and about 1,200 pounds for pineapples. The grades used are discussed under the agriculture of each crop. The potash salts for the preparation of the mixed fertilizers are imported directly from Germany, the nitrate of soda from Chile, and the sulfate of ammonia, calcium cyanamide, and calcium superphosphate are brought from the United States.

According to the Annual Book on Statistics issued by the Department of Agriculture and Commerce of the insular government, Puerto Rico imported, during the fiscal year 1938–39, a total of $75,684,719 worth of merchandise from the United States and $7,039,563 worth from foreign countries. Of the amount from foreign countries, more than $1,000,000 was expended for fish. The value of the most important items imported from the United States is given in table 8.

TABLE 8.—*Most important imports to Puerto Rico from the United States for the fiscal year ending June 30, 1939* [1]

Article	Value	Article	Value
Rice	$5,466,216	Lard, fat, and oils (edible)	$2,381,736
Cotton cloth	5,292,813	Electrical machinery and apparatus	1,998,305
Iron and steel manufactures	4,838,742	Silk manufactures	1,950,952
Cigarettes	3,491,023	Soap and toilet preparations	1,652,820
Meat products	3,442,501	Paper and manufactures	1,526,952
Leather manufactures (mostly shoes)	3,214,326	Cotton wearing apparel	1,468,182
Automobiles and other vehicles	2,827,406	Wheat flour	1,437,882
Lumber and wood products	2,805,340	Dairy products	1,344,463
Rayon and other synthetic fabrics	2,611,164	Fertilizers and fertilizer materials	1,328,755
Petroleum and products	2,535,032	Dried beans	1,327,670
Industrial machinery	2,415,740		

[1] Data taken from the following publication: DIVISION OF STATISTICS. DEPARTMENT OF AGRICULTURE AND COMMERCE. ANNUAL BOOK ON STATISTICS, FISCAL YEAR 1938–39. 222 pp. [1939]

In 1935 only five countries—United Kingdom, Canada, Japan, France, Germany—in addition to the Territory of Hawaii, bought more goods from the United States than did Puerto Rico.

Puerto Rico's position in United States trade is shown in table 9, taken from data of the United States Department of Commerce.

TABLE 9.—*Puerto Rico's place in export and import trade with the United States* [1]

[In thousands of dollars—i. e. 000 omitted]

Country	From the United States in—			To the United States in—		
	1935	1936	1937	1935	1936	1937
United Kingdom	$433,399	$440,122	$534,564	$155,282	$200,385	$202,771
Canada	323,194	384,151	509,508	286,444	375,832	398,539
Japan	203,283	204,348	288,378	152,902	171,744	204,202
France	117,013	129,457	164,311	58,107	65,288	75,663
Germany	91,981	101,956	124,166	77,792	79,679	92,644
Hawaii	78,925	85,744	104,181	98,696	125,537	130,138
Puerto Rico	70,052	86,352	90,044	87,726	103,952	102,859
Cuba	60,139	67,421	92,283	104,303	127,475	148,047
Philippine Islands	52,640	60,350	85,031	96,999	101,679	126,207
Italy	72,416	58,989	76,792	38,674	40,337	48,188
Argentina	49,374	56,910	94,173	65,408	65,882	139,123
Brazil	43,618	49,019	68,631	99,685	102,004	120,639
British Malaya	4,500	5,021	8,834	131,607	167,997	235,194

[1] From U. S. Department of Commerce, Summary of United States Trade with World, 1937, except data on Puerto Rico and Hawaii, which are from Monthly Summary of Foreign Commerce of the United States, December 1937.

According to the Annual Book on Statistics (1938–39) of the insular government, Puerto Rico exported a total of $86,486,570 worth of merchandise in the fiscal year 1939, of which $84,782,650 worth went to the United States (table 10). Of this amount $53,604,381 was for sugar. In 1936, Puerto Rico ranked seventh (table 9) among the countries shipping goods to the United States. The island led such countries as Brazil, Philippine Islands, Argentina, France, and China, but was led by Canada, United Kingdom, Japan, British Malaya, Cuba, and Hawaii. The percentage of Puerto Rico's world commerce that has been shared with the United States has ranged from 17.8 percent in 1896 to 95.3 percent in 1936.

TABLE 10.—*Value of shipments of most important merchandise from Puerto Rico to the United States in the fiscal year 1939* [1]

Product	Value	Total value	Product	Value	Total value
Sugar		$53,604,381	Oranges	$2,041	
Unrefined	$44,251,614		Pineapples	862,423	
Refined	9,352,767		Other fresh fruits	1,497	
Cotton manufactures		9,511,472	Prepared or preserved:		
Tobacco and manufactures		7,464,394	Grapefruit	170,466	
Unmanufactured:			Pineapples	142,533	
Leaf, stemmed	6,355,627		Other prepared or preserved fruits	15,507	
Leaf, unstemmed	217,868		Orange peel	1,147	
Stems, scrap, and trimmings	825,119		Linen manufactures		$2,605,893
Manufactured:			Alcohol		393,504
Cigars and cheroots	37,602		Coconuts in the shell		306,021
Cigarettes	26,985		Coffee		475,316
Other tobacco manufactures	1,193		For export	407,771	
Molasses		565,699	For consumption	67,545	
Fruits		1,352,609	Silk manufactures		2,661,282
Fresh:			Rum		3,194,849
Citrons	6,872		Buttons, pearl or shell		303,145
Grapefruit	110,612		Straw hats		235,634

[1] See footnote 15, p. 67.

According to the 1935 census of the Puerto Rico Reconstruction Administration, the leading enterprises, based on agriculture, and the number of persons employed in them are as follows: Cigar and tobacco

factories, 14,712; sugarcane mills, 16,162; and other food industries, 4,737. Agriculture employs 246,976 persons. The number of people, mostly women and girls, employed in the clothing and embroidery shops, is 19,857, and needlework and embroidery is done in the home by 50,371 persons. Although these are not agricultural industries, a large number of the employees are from the rural districts, as the farm women do piece work in their homes. The towns employing the largest number of employees are Mayagüez, San Juan, Ponce, and Arecibo.

On the farms visited by officials of the Division of Labor during 1930–31, a total of 30,714 persons were employed on sugarcane plantations, 5,851 on coffee plantations, and 5,202 on tobacco plantations. Wages are higher in the sugar mills and fruit industries than in the coffee or tobacco shops. Wages in the embroidery and needlework shops are slightly less than in the cigar factories. Wages range from 50 cents to $3 a day in the fruit industries and from 12 cents to $1.70 a day for women in the embroidery and needlework shops.

The farm land and buildings were assessed at $156,278,450 in 1935. Fifteen percent of the farms operated by full owners were mortgaged for $13,323,869, or 49.9 percent of their assessed value of $26,981,893. The public debt of the island is high; on June 30, 1933, it was $47,587,616.76, of which $17,872,122.22 was municipal debt and $29,715,494.54 was insular debt.

SUGARCANE (CAÑA DE AZÚCAR)

Sugarcane is the most valuable crop, and the manufacturing of refined and raw sugar is the most important industry. The climate, soil, and people are adapted to the production of this crop. It might be said that Puerto Rico is a sugar-bowl island, as nearly $54,000,000 of the $86,486,570 obtained for total exports in 1938–39 was from sugar, molasses, and alcohol. Generally speaking the yield and price of sugarcane is the barometer of prosperity for the entire island.

Sugarcane was first brought to the island from Haiti in 1515 (*16, p. 795*). For the first 32 years molasses only was manufactured. The first muscovado mill for the manufacture of sugar was built near Bayamón in 1548 (*17, p. 541*). At that time sugarcane was grown on the alluvial soils along the rivers Bayamón and La Plata. These soils are still producing sugarcane after more than 380 years of cultivation. They are now producing a higher tonnage than ever before, due to excellent varieties, good management, constant control of diseases and insects, fertilizer, and some irrigation. From all indications these soils will continue to produce good crops, if intelligently managed, for hundreds of years.

Many fluctuations have taken place in the industry since 1515. At one time in the seventeenth century, ginger was cultivated, almost to the exclusion of sugarcane. Later a royal decree prohibited the growing of ginger, and through governmental aid the sugar industry was established.

The production (*16, p. 795*) of sugar in 1581 was about 187 tons, and in 1828 [15] it had increased to 9,391 tons. For the next 20 years, there was a gradual increase to 52,089 tons in 1847. During the following 20 years, the production varied between 43,195 and 65,517 tons. In

[15] The Annual Book on Statistics for 1939-40 gives the yearly production of sugarcane from 1828 to 1939.

1879, a peak of 170,679 tons was reached. This high production was not exceeded until 1905, when 214,480 tons were produced. Since then, the yearly production has never been below 200,000 tons. In 1920, 485,077 tons were produced. With slight variations, production increased yearly until 1934, when an all-time peak of 1,103,822 tons was reached. Partly due to curtailment of the acreage, only 773,021 tons were produced in 1935, but an increase to 851,969 tons was made in 1939. The production in 1934 was almost one-half as great as that of Cuba and about 6 percent of the world production; in 1939 it was less than one-third of that of Cuba and 4.1 percent of the world production.

The value of exported sugar also has varied in different years, according to the amount exported and the price per ton. The value of the export sugar increased from $4,715,611 in 1901 to a high of $98,923,750 in 1920. The value fell to $35,224,038 in 1929 but increased to $53,604,381 in 1939. In 1935, sugar to the value of $47,837,144 was exported. Between 1901 and 1935 the price of exported sugar has ranged from $3.02 to $11.79 per 100 pounds. The price in 1939 was $2.84, the lowest yet recorded.

The number of sugar mills has varied considerably. In 1581, only 11 were reported on the island, but in 1879, 553 were grinding sugarcane (*16, p. 795*). In 1910 there were 41 modern mills, 14 old steam mills, and 91 ox mills grinding cane (*2, p. 15*). At present about 40 mills manufacture all the sugar produced on the island. In remote areas a few ox mills are still in use for grinding the sugarcane for locally used molasses.

According to the Puerto Rico Reconstruction Administration census of 1935 (*34*), the acreage in sugarcane has increased from 145,433 cuerdas in 1909 to 245,154 cuerdas, or 34.5 percent of the land from which crops were harvested, in 1935. This crop occupies a larger total area than any other crop grown on the island.

Figure 37 shows the distribution of sugarcane as recorded by the Puerto Rico Reconstruction Administration census of 1935. It may readily be seen that most of the sugarcane grows in the municipalities bordering the coast. The best soils for the production of sugarcane, such as those on the nearly level flood plains, terraces, and alluvial fans, occur within these municipalities. Owing to the good soils and valuable crops, roads, railroads, and towns are numerous along the coast. The production of sugarcane is limited largely to areas within a kilometer of a good road or railroad. Although sugarcane is grown throughout most of the island, unless the land is irrigated it is not grown on level areas receiving less than 40 inches of mean annual rainfall or on very steep land receiving less than 60 inches. In humid districts, much cane is grown on hills having 50-percent slopes. The municipalities having the largest acreage in sugarcane, ranking in the order named, are: Arecibo, Juana Díaz, Cabo Rojo, Loíza, Lajas, San Germán, Naguabo, Ponce, Guayama, and Salinas. In these municipalities the percentage of total crop land in sugarcane ranged from about 33 percent in Arecibo to 75 percent in Salinas. It is interesting to note that the acre yield is only three-fourths as great in the municipality of Arecibo as in the municipality of Santa Isabel. Most of the soils used for cane in the latter municipality are those of the San Antón, Santa Isabel, Fraternidad, and Aguirre series. In the Arecibo municipality cane is grown on less productive soils, such as

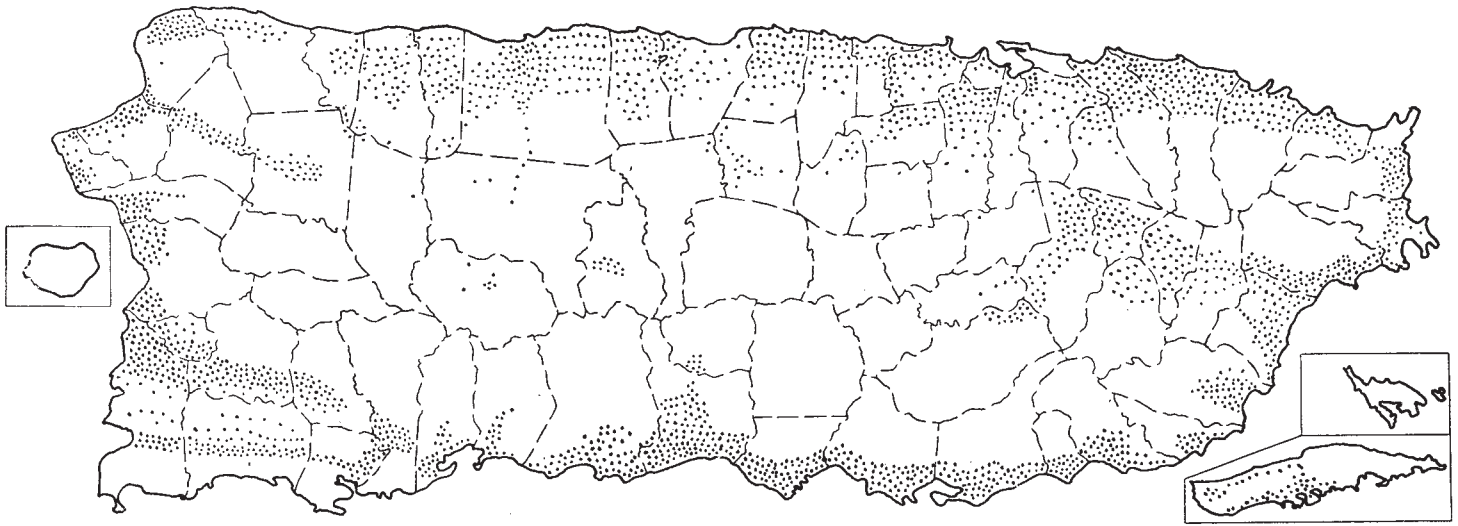

FIGURE 37.—Distribution of sugarcane in 1935. Each dot represents 100 acres.
Distribución de caña de azúcar en 1935. Cada punto representa 100 acres.

the Bayamón, Vega Alta, Sabana Seca, Espinosa, Coloso, and Toa.[16] Soils of the Coloso and Toa series are the most productive for sugarcane on the north coast, but they do not return such high yields as does the best soil along the irrigated southern coast.

Field observations and factory figures indicate that a higher yield of both sugar and sugarcane is obtained on the irrigated south coast than in any other large area on the island. This is because the low relative humidity along the south coast and a sufficiently regulated irrigation water supply, combined with level, deep, well-drained alkaline soils, make most favorable conditions for the growth of sugarcane. In addition, the soils have not been leached of mineral elements to so great an extent as have those in the areas of higher rainfall. Most of the soils of the south coast have been farmed for less than 40 years

FIGURE 38.—Excellent sugarcane.
Caña excelente.

whereas those in other parts of the island have been under cultivation nearly 400 years.

The best soils along the south coast, under favorable conditions and proper management, produce from 80 to 100 tons of sugarcane an acre, or from 10 to 14 tons of sugar (fig. 38). Here, some of the best land sells at prices ranging from $600 to $700 an acre. On the north coast the best land sells at prices ranging from $350 to $400 an acre, and a few irrigated areas sell for about $500 an acre.

Most of the land used for the production of sugarcane either is planted to this crop or is in process of preparation for it. The two planting periods are: Fall planting, or gran cultura, which is from July to November; and spring planting, or primavera, which is from January to June. Gran cultura crops grow for a period ranging from 14 to 22 months, averaging about 16 months, and primavera crops

[16] The soil series and soil types are defined in the section entitled "Soils and Crops."

mature within about 13 months. Both plantings will continue to produce volunteer, or ratoon, 12-month crops year after year, or until the fields are plowed. The tendency in the last few years is to give the sugarcane as long a period of growth as possible—that is, long ratoons and fall plantings rather than primavera plantings.

As gran cultura crops are planted in the rainy summer months and have a long period of growth, they outyield primavera crops by 15 or 20 percent. Usually primavera crops outyield the first ratoon crop by 10 or 15 percent. The succeeding ratoon crop yields from 5 to 10 percent less than the previous ratoon crop.

The proportion of each of these types of planting to the total area planted varies in different parts of the island and with the individual grower. In general, the farmers having a small acreage of sugarcane have a much larger percentage of their land in 2-, 3-, or 4-year ratoon crops than the large-scale operators. The sugar centrals on the south coast have a higher percentage of gran cultura plantings than those in any other part of the island. Along the south coast during average years, about 25 percent of the land is in gran cultura, about 35 percent is in primavera, and about 40 percent is in ratoons.

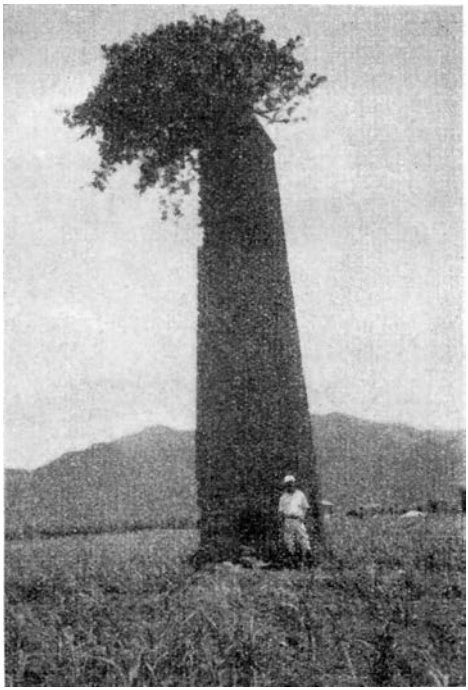

FIGURE 39.—The chimney—all that remains of an abandoned small sugar mill. La chimenea—todo lo que queda de una pequeña central abandonada.

On the level coastal plains, on such permeable soils as the Bayamón, Espinosa, Vega Alta, Coto, and Matanzas, the general practice is to grow a large proportion of ratoons and very little primavera plantings. In Isla de Vieques and semiarid districts, where the tonnage is low and very little fertilizer is used, five or six ratoon crops are common.

The sugarcane grower is interested primarily in obtaining the greatest acre yield of sugar at the lowest cost. Two of the most important factors in reaching this objective are efficient management and land suited to the growing of sugarcane. Efficient management includes efficiency in the sugar mills as well as in the canefields, and efficiency in the mills has increased manyfold since the time of small muscovado mills. In order to compete with other sugarcane-growing countries the small mills were abandoned (fig. 39), and large central mills were constructed (fig. 36). Each of the latter will grind the same quantity of sugarcane formerly ground by about 20 small mills in less than one-half of the time and with an increased sugar yield of more than 50 percent. The modern sugar-central factory is now developed

to a fine degree of perfection. The grinding capacity of the mills has increased from a season's grinding ranging from 20 to 1,000 tons of sugarcane in the first small mills to the 24-hour grinding capacity ranging from 1,000 to 4,000 tons in the present-day up-to-date mills.

Most of the canefields of the large sugar centrals are scientifically managed. They seem to be properly fertilized,[17] cultivated, and drained or irrigated if necessary. Excellent sugarcane varieties are grown, and continuous effort is being made to combat harmful insects, diseases, and weeds. Many of the owners of small sugarcane farms are not financially able to weed, fertilize, or manage their fields in the most efficient manner.

In order to compete successfully with the world's sugarcane-producing countries, Puerto Rico must economically produce a very high tonnage to the acre. The best way to do this seems to be on a

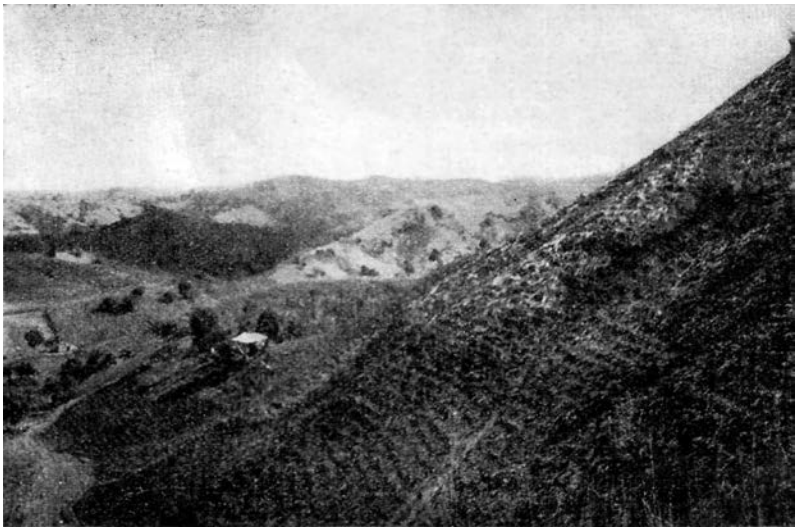

FIGURE 40.—Múcara silty clay loam on steep hillsides, used for the production of sugarcane. Yields are less than 18 tons an acre.

Laderas escarpadas de Múcara limo-arcilloso lómico sembradas de caña. El rendimiento es menos de 18 toneladas por acre.

large-scale production, with sufficient capital to invest in large quantities of fertilizer, machinery, and irrigation if necessary. Sufficient and contented labor at the proper time is another prerequisite for success in the sugar business.

Sugarcane can be grown successfully on many soil types, ranging from calcareous friable fine sandy loams to acid plastic clays and from medium-shallow steep soils of the uplands to the deep well-drained and poorly drained level soils of the river flood plains. Even the organic soils of the coastal lowlands produce fair yields, if the areas are well drained and fertilized. The acre yields, however, range from about 15 tons on the poorest soils (fig. 40) to more than 100 tons on the best soils, and the profits vary somewhat accordingly. According to Jensen

[17] Many of the large sugar centrals have their own scientifically planned fertilizer experiments and variety test plots on several of their most important soil types.

(*21, p. 32*), more than 50 percent of the sugarcane roots on dry-weight basis are in the first 8 inches of the soil, but sugarcane growing on soil having a depth ranging from 12 to 18 inches, such as the Múcara, Juncos, and some soils of the Colinas series, produce far lower yields than sugarcane produced on related but deeper soils, such as those of the Mabí, Santa Clara, and Camagüey series. The extensive development of the root system depends on the physical and chemical condition of the soil types, and without a healthy, well-developed root system the normal functions of the entire plant cannot operate at maximum efficiency.

The best land for sugarcane in Puerto Rico has a friable loam or silt loam surface soil, high in organic matter, neutral or alkaline in reaction, brown or very dark grayish brown, free from gravel or harmful salt, and granular, with a slightly heavier but friable alkaline subsoil beginning at a depth of 10 or 12 inches and continuing to a depth below 5 feet before any free water or gravel is reached. The surface soil is loose and porous and when cultivated forms an ideal seedbed. It can be worked under a fairly wide range of moisture conditions without harming its structure. The subsoil has enough silt and clay to prevent serious leaching of fertilizers or lime, yet it is not too heavy to interfere with the rapid penetration of roots. Water penetrates this soil rapidly and does not remain on the surface for any length of time. Owing to the slightly heavy subsoil, a high proportion of the percolating water reaching it is retained and is utilized by the lower roots of the cane. Soils of this description generally are flat. They allow the use of most kinds of modern machinery, and they are almost ideal for maximum agricultural utilization. Typical areas of Altura loam, Altura silt loam, San Antón loam, and San Antón silt loam have these characteristics, and when they are fertilized with from 300 to 400 pounds of mixed fertilizer and 300 to 400 pounds of ammonium sulfate, are properly managed, and have sufficient water, sugarcane will yield from 75 to 110 tons to the acre. Some of the other good soils for sugarcane on the south coast are those of the Machete, Fraternidad, Santa Isabel, Paso Seco, Vives, Coamo, Aguirre, and Guánica series. These soils have an acre yield ranging from 40 to 85 tons of gran cultura. The Ponceña, Moca, Dominguito, and Las Piedras soils occurring in the inner plains also are good soils for sugarcane. Most of the sugarcane on the north and west coasts is grown on the well-drained alluvial Toa and Estación soils, the imperfectly drained Coloso soils, and the poorly drained Palmas Altas soils. These soils when properly managed and planted to gran cultura yield from 40 to 60 tons to the acre. The yield of cane depends to a large extent on the management, fertilizer used, and especially the amount of rainfall during the critical period of ripening which, according to Davis (*15, p. 3*), is between December and February. The Coloso soils in the vicinity of Cabo Rojo and Filial Amor seem to be much more productive than the Coloso soils near Central Coloso or along the north coast. The difference in yields for the same soil in different parts of the island may be due to better management, more rainfall at the proper time, or to the fact that the soils have not been under cultivation for so long a time near Cabo Rojo as they have along the north coast.

A large acreage of the nearly level areas of such soils as Coto, Bayamón, Vega Alta, and associated soils in the northwestern part are in sugarcane. These soils produce from 20 to 45 tons of gran

cultura cane when they are properly managed. In the eastern end the best soils for the production of cane are those of the Fortuna, Viví, Yabucoa, Josefa, and Maunabo series. When these soils are planted to gran cultura and properly managed they produce from 30 to 50 tons to the acre. The interior hill lands, such as the Múcara, Alonso, Catalina, Río Piedras, Cayaguá, Utuado, and Colinas soils, produce from 18 to 30 tons of gran cultura. They require nearly as much fertilizer and weeding as do the soils producing 100 tons to the acre. It may readily be seen that the greatest profit is made from the cane grown on the best soils.

Such soils as the Nipe, Rosario, Tanamá, Pandura, Teja, Picacho, Yunes, Aguilita, San Germán, Descalabrado, Jácana, Guayabo, Corozo, Algarrobo, St. Lucie, Cataño, Meros, and Jaucas, the steep

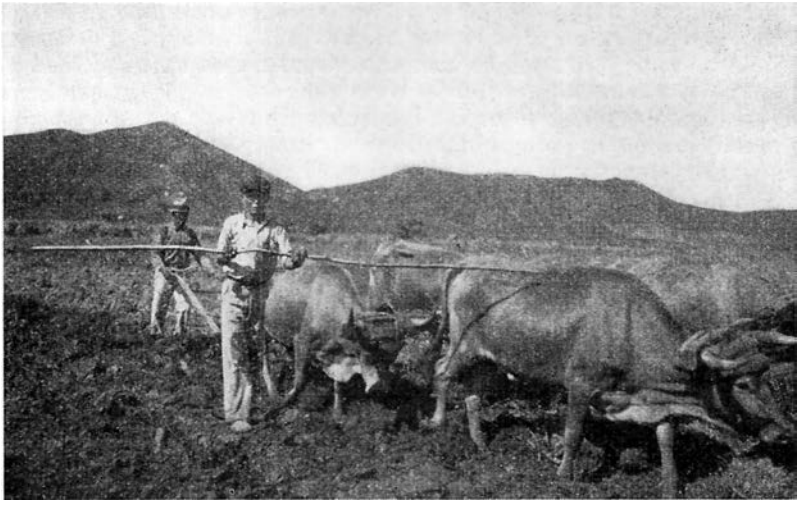

FIGURE 41.—Plowing land for sugarcane with oxen. Note how the yokes are attached to the animal's poll and forehead.

Arando con bueyes. Nótese los yugos en los animales.

phase of Soller, and coastal beach are not adapted to the production of a very high tonnage of sugarcane.

The Nipe and Rosario soils lack plant nutrients, and the Rosario soils are too steep for cultivation, as also are the Tanamá soils and most areas of the Pandura soils. The Pandura and Teja soils are low in fertility and are droughty. The Picacho and Yunes are too shallow and steep for the production of cane. The Aguilita, San Germán, Descalabrado, and Jácana occur in too dry a climate for the production of cane without irrigation, and the relief of these soils is unfavorable for irrigation. All except the Jácana soils are very shallow. The very sandy soils are too loose and low in fertility for profitable yields of sugarcane.

The method of planting and cultivating sugarcane varies considerably for soils having greatly contrasting characteristics. The clay soils are handled differently from the sandy soils, and the soils on steep hillsides are planted differently from those on level land. Poorly drained soils require more attention than well-drained soils. In

general the heavy-textured soils of the level river flood plains, alluvial fans, terraces, and inner plains are plowed twice, to a depth ranging from 12 to 18 inches. One plowing is at right angles to the other, and the land is harrowed after each plowing. At present more of the plowing of the large tracts is done by tractors than formerly. The use of tractors enables land to be in sugarcane that otherwise would be in pasture and hay for the work oxen. Most of the small farm owners still use oxen (fig. 41) and all plowing on hillsides and poorly drained areas is done by oxen. The rather steep hillsides, the permeable clay soils of the uplands, the coastal plains, and the sandy-textured soils are plowed only once. In some areas near the rivers the alluvial soils that are subject to overflow are not plowed at all, but furrows are made in which the sugarcane cuttings are planted.

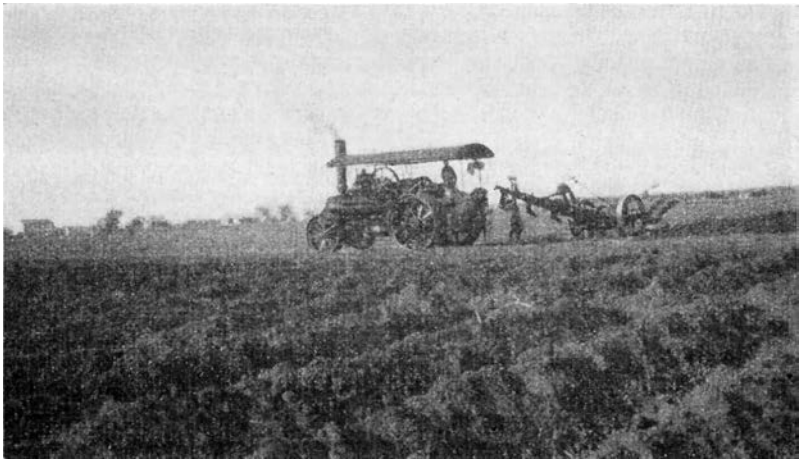

FIGURE 42.—A cable-gear plow making furrows in the soils of the alluvial fans along the irrigated south coast. Cane cuttings 10 or 12 inches long will be placed in the furrows and covered to a slight depth.

Haciendo surcos en los aluviones bajo riego de la costa sur para sembrar pedazos de caña de 10 ó 12 pulgadas de largo.

Within the last few years a specially constructed rotating plow—the gyrotiller—has been used. Foss (*18, p. 81*) states that, in 1935, 13 of these were in operation on the island. This plow does exceptionally good work in the churning of the soil to any desired depth not exceeding 2 feet. The soil is well churned and aerated yet not changed in position. This type of plowing should be very beneficial for those soils having heavy nearly impervious subsoils, such as the Sabana Seca, Santa Isabel, and Candelero soils, and the heavy-subsoil phases of the Vega Alta soils. Two sizes of gyrotiller are in use. The larger weighs 24 tons and has a 170-horsepower Diesel motor, and the smaller weighs 12 tons and has an 80-horsepower Diesel motor. The larger machine has an 11-foot plow width and the smaller one a 9-foot width. The cost of plowing with these machines ranges from $4 to $5 an acre. Other plows and tractors seen in many of the sugarcane fields are the large steam cable-gear plows (fig. 42) and various types of caterpillars.

On some of the heavy clay soils having compact subsoils, deep knifing or deep subsoiling is beneficial. This is a costly operation,

however, and should be practiced only in soils that will not run together after the first few rains. Such soils as those of the Santa Isabel, Sabana Seca, Candelero, and similar series are greatly benefited by such treatment. Such plastic soils as those of the Aguirre, Ponceña, Camagüey, Coloso, and similar series would be benefited for a short time only. Shallow knifing has proved beneficial on some of the shallow hill-land soils, such as the Múcara and Teja.

After the land is plowed and harrowed, it is ready to be planted. The sugarcane is planted either in furrows about 4 feet apart, in grand bank, or in shallow holes 4 feet apart. On the well-drained river flood plains soils, such as the San Antón, Toa, and Viví, and on the alluvial fans and terraces, both in the irrigated arid districts and in the humid districts, the sugarcane is planted in furrows. In the humid districts, drainage ditches are dug at intervals of about every 10 rows, and they are usually dry except during long wet periods. In the dry nonirrigated districts the furrows are deeper than in irrigated or humid areas, because it is necessary to plant the cuttings deep enough that they will be in an environment that is sufficiently moist to start germination. As the roots continue to grow to greater depth, they have, during droughts, a much larger area to drain than if the cuttings were planted at a slight depth.

On some of the deep upland soils, such as the Catalina, Cialitos, and Alonso, sugarcane often is planted in shallow holes 4 feet square and several sugarcane seed pieces are placed in each hole. The holes are not entirely filled with earth when the seed is planted, and they act as catch basins for sheet-erosion waters and help considerably in checking the speed and force of the flowing water. After sugarcane becomes a foot or more high, it is a fairly good crop for checking sheet erosion, even on steep hillsides.

Sugarcane seed for gran cultura planting is obtained from selected fields of young sugarcane stalks, about 8 months old, that are free from mosaic. Ratoon cane makes desirable seed. The sugarcane stalks are cut in pieces from 9 to 12 inches long, and they usually have two internodes and three nodes, or buds. Generally the leaf sheath is removed, except when the planting is made in sandy soils that are infested by the mole cricket, or changa. From 1½ to 3 tons of cuttings are required to seed an acre. The price of this seed ranges from $4 to $10 a ton, and the average price is about $7. Seed for primavera plantings is much less expensive, as this seed is obtained from a point near the tops of matured sugarcane stalks during harvest. The upper parts of the stalks contain every little sucrose; consequently they are of little value when ground for sugar. Cane seed of this kind sells at prices ranging from $2.50 to $4 a ton.

All the sugarcane is planted by hand. When planted in furrows, the seed cuttings are spaced from 6 to 12 inches apart in the bottom of the furrows in a single row, and one end of the cutting is covered with a few inches of soil. Some farmers plant two rows of cuttings about 4 inches apart in the bottom of the furrow and space the cuttings from 14 to 18 inches apart. In some parts of the island, as near Fajardo, entire sugarcane stalks are placed end to end in the bottom of the furrow and covered with a few inches of soil. The advantage of this method is (often) better germination and less opportunity for infestation by disease germs which may be on the cut

surfaces of the seed pieces. In the poorly drained river flood plains and coastal lowlands, on such soils as those of the Coloso, Fortuna, Palmas Altas, Aguirre, Yabucoa, and similar series, sugarcane is planted in grand banks. With this system of planting a ditch is dug on each side of every two, three, or four rows, depending on the amount of water to be drained away (fig. 43). Deeper cross ditches are dug at intervals ranging from about 20 to 40 feet. These ditches lead to larger drainage ditches and finally to the rivers. Most of the ditches are dug by hand, but some are made with a No. 90 plow. They are cleaned with a double moldboard plow or by hand. It is essential that the ditches be maintained at all times, in order to prevent the soils from becoming waterlogged. During long protracted droughts, the ditches can be blocked and the water table can be regulated to the best advantage of the growing crop. As lack of

FIGURE 43.—A modified grand-bank method of planting sugarcane on Coloso silty clay. None of the ditches is very deep.

Método de gran banco modificado en Coloso limo-arcilloso. Las zanjas no son muy profundas.

water is not a limiting factor on soils that are planted according to the grand-bank system, the sugarcane cuttings are planted in shallow holes.

The muck and peat areas planted to sugarcane require more complex drainage systems than do the mineral soils; in many places pumps are installed and dikes are built, in addition to the ditches necessary for the grand banks. This is because most of the muck and peat areas are slightly below the level of high tide.

In the permeable well-drained valley coastal plain soils, such as the Espinosa, Coto, Matanzas, Bayamón, and Vega Alta, sugarcane is planted in furrows, generally following the contour of the land, especially in the irrigated districts near Isabela. These soils are not only so permeable that drainage ditches are unnecessary, but in many areas lack of water is a limiting factor in crop production, and it is essential that the sugarcane cuttings be planted in furrows ranging from 10 to 15 inches in depth.

On the inner plains in such plastic soils as the Camagüey, Santa Clara, Ponceña, Moca, Mabí, and associated soils, sugarcane is planted in shallow furrows, although shallow drainage ditches are numerous. The naturally rolling relief is a very desirable feature for these soils, as a large proportion of the excess water is drained from the surface. In the few nearly level areas of these soils it is difficult to drain the land properly so that the sugarcane cuttings will germinate and develop a good root system. The character of the sticky plastic subsoil prevents excess water from percolating through it as fast as it should or as fast as the water penetrates the plastic but not so sticky poorly drained soils of the coastal lowlands and river flood plains. The drainage ditches, made either by hand labor or machines, are much more expensive than those made on other soils, because the soil sticks to shovels, plows, and other implements. Laborers refuse to work in this soil at the same price as in other lands, because of the harder and slower work.

On the medium deep soils of the uplands, such as those of the Juncos, Múcara, Río Piedras, Colinas, Cayaguá, and similar series, the progressive landowners use contour furrows, with numerous drainage ditches running zigzag down the hill. The bottoms of the ditches generally rest on rocks, so that gully erosion is arrested and does very little damage.

When the land is prepared for grand-bank plantings, from two to four pieces of sugarcane cuttings are planted on the banks in holes about 18 inches square and 6 inches deep. The holes are spaced from 40 to 60 inches apart, or about 2,000 to an acre. The seed pieces are planted by hand with a short-handled pick or hoe, and they are so placed in the ground that about one-half of the seed is exposed at an angle of about 30°.

The principal sugarcane varieties grown vary considerably in different parts of the island and on different soil types. B. H. 10 (12) is the dominant variety grown on soils of the river flood plains, such as the Toa, San Antón, Coloso, Yabucoa, Viví, and similar soils, regardless of the location or climate. If the sugarcane becomes badly infected with mosaic, however, the acreage of B. H. 10 (12) is reduced and that of P. O. J. 2878 and Mayagüez 28 is increased. P. O. J. 2878 is probably the second most commonly grown variety on these soils. A much higher proportion of this variety, however, is grown on the north coast than on the south coast. P. O. J. 2725 and P. O. J. 2878 are the principal varieties grown on the level permeable acid coastal plains, on such soils as those of the Vega Alta, Espinosa, Bayamón, and related series. Mayagüez 28 seems promising for these soils. P. O. J. 2878, B. H. 10 (12), and S. C. 12/4 seem to be the main varieties grown on the soils of the uplands, such as the Catalina, Colinas, Soller, and Múcara. Uba and S. C. 12/4 are the principal varieties grown in arid nonirrigated districts and by the owners of small tracts of land. In the northeastern part of the island probably 85 percent of the land in cane is planted to B. H. 10 (12) with S. C. 12/4, F. C. 916, and P. O. J. 2878 occupying most of the remaining 15 percent. In this area the average sucrose content is about 18 percent, the purity about 83 percent, and the yield about 11.5 percent. The number of tons of sugarcane produced to the acre in this area and on the alluvial soils of the north coast is about 31. Gran cultura averages about 40 tons, primavera about 35, and ratoons about 28. In this

area B. H. 10 (12) outyields S. C. 12/4 by about 10 tons to the acre. On the south coast on irrigated lands gran cultura averages about 65 tons, primavera about 42, and ratoons about 35. On the northwestern coastal plains the gran cultura plantings yield about 40 tons, the primavera 30, and the ratoons 25. In arid nonirrigated districts, such as on Isla de Vieques, most of the cane is ratoon S. C. 12/4, which yields from 15 to 25 tons to the acre.

Very little machinery is used in cultivation of the growing cane. The ratoon cane is plowed with a walking single moldboard plow, usually pulled by a mule. The plowing of the ratoons generally is completed within 2 weeks after harvest. First, the cane trash, or paja, is laid in alternating furrows by hand, the clean bank is then cultivated, and the trash is placed in the plowed furrow. The other row is plowed. During the plowing dead plants are replaced by new seed. In some fields that have been ratooned for many years, most of the growing cane consists of replants. The trash is burned in irrigation districts, in order to have unobstructed watercourses in irrigation. It is burned in many other areas also. Plowing is more difficult when the trash is not removed than when it is burned. Trash is usually burned in all areas subject to frequent overflow, as, if allowed to remain in the fields, it may be carried by floodwaters and piled on young cane, thereby killing the plants.

Almost all the weeding is by hand labor. Usually it is necessary to weed the cane several times before the plants are large enough to shade the ground and naturally keep the weeds under control. Some varieties of cane are far superior to others in this respect. Mayagüez 28 stools prolifically, and the cost of cultivation is much less than that of the erect canes with few stools.

Experiments with different fertilizer formulas seem to indicate that all the soils need a large quantity of nitrogen, less potash, and a small quantity of phosphorus. The red acid soils of the uplands probably need a larger quantity of phosphorus than the soils in the arid districts or the alluvial soils along the north coast. In most of the experiments with sugarcane, an application of phosphoric acid in excess of 90 pounds to the cuerda apparently lowered the gain in yields. The more common applications range from 150 to 250 pounds of ammonia to the acre, 30 to 90 pounds of phosphoric acid, and 100 to 200 pounds of potash. Fertilizer formulas vary among the different landowners; the most commonly used formulas contain from 14 to 16 percent of nitrogen, 8 to 16 percent of potash, and 4 to 8 percent of phosphoric acid. From 400 to 800 pounds of mixed fertilizer is used to the acre, and from 400 to 600 pounds of ammonium sulfate is used as a second application. All the fertilizer is distributed by hand labor, generally by women. On most farms the complete fertilizer is spread within a radius of 8 inches of the cane plants, from 1 to 2 months after the sugarcane is planted. The second application (ammonium sulfate) is applied in the same way 2 months later. The fertilizers are covered with a one-horse plow or with hoes.

So much sulfate of ammonia has been applied to the soils that in the humid districts an application ranging from 2 to 4 tons of finely ground limestone has given good results, especially in soil having a pH value of 5.8 or lower. Bonnet (*9*) states that ammonium sulfate should not be used as a source of nitrate for plants on Lares clay loam. Extensive experimental work should be started on the effect of lime

and the availability of the essential plant elements in the different soil series. In some soils the effect of lime may make certain fertilizers less available and thus prove detrimental.

Cowpeas are the principal crop used for green manure in the sugarcane fields, but even they are used on only a very small proportion of the land. Cowpeas grow rapidly and readily on almost all of the soils, provided the rainfall is sufficient. In general the crop is ready to be turned under within 3 months from the time of germination.

Filter-press mud, or cachaza, is applied to the soils which produce poorly. Only a small quantity of this is available during the grinding season, and, as several tons are applied to the acre, only a small area is treated each year. Cachaza should be beneficial for land on which sugarcane is affected with chlorosis. Table 11 shows the composition of a composite sample of filter-press mud collected from January 22 to February 1, 1912, at the South Puerto Rico Sugar Co.'s plant and analyzed by their chemists.

TABLE 11.—*Chemical composition of filter-press mud, or cachaza*

Content	Percent	Content	Percent
Moisture	61.78	Ash	10.89
Organic	27.33	Phosphoric acid (P_2O_5), equivalent to bone phosphate, 3.95 percent	1.81
Wax	2.77	Silica (SiO_2)	.42
Ammonia (NH_3), equivalent to nitrogen (N) 0.774 percent	.94	Fe_2O_3 and Al_2O_3	1.70
Sucrose	3.86	Lime (CaO)	4.13
Invert sugar	(1)	Magnesia (MgO)	(1)
Undetermined	19.76	Undetermined	2.83

[1] Trace.

So little stable manure is available that practically none is used in the sugarcane fields.

The sugarcane is cut exclusively with a machete by hand labor (fig. 44). The peons are very proficient in this work; they can cut from 2 to 8 tons a day, depending on the quality of cane and the ambition of the laborer. Wages for this work range from 50 cents to $1.50

FIGURE 44.—Cutting sugarcane by hand in the eastern part of the island.
Cortando caña en la parte este de la isla.

a day or from 20 to 35 cents a ton of cane. After the cane is cut it is gathered immediately and usually is either loaded on oxcarts or cars on portable tracks and conveyed to a loading station where derricks are used to transfer it to railroad cane cars or trucks, and it is then hauled to the sugar central. Some centrals have the cane hauled directly from the field to the factory in oxcarts and in small cars (fig. 45) which hold from 1½ to 2½ tons and are run on portable tracks. Usually the portable tracks are connected with a network of permanent tracks leading to the factory. In a very few of the nearly inaccessible hill areas, such as near Central Soller and Central Plata, sugarcane is carried on horses and mules from the field to the factory. Cane is not carried by water or gravity as in some parts of Hawaii.

Sugarcane harvest extends from December to July, and during this period the factories run day and night with the exception of 1 day a week, which is devoted to the cleaning and repairing of machinery.

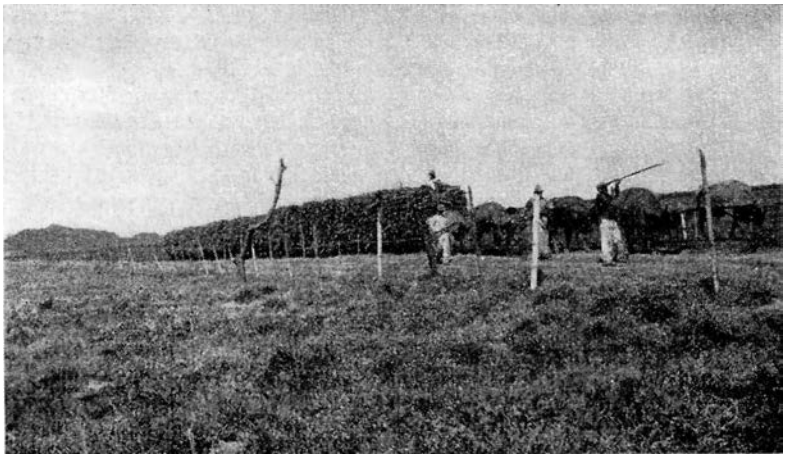

FIGURE 45.—Hauling sugarcane from the fields to the factory or to loading stations, where the cane will be transferred to larger cane cars.

Arrastre de caña de los campos a la factoría o a estaciones de carga para transferirla a vagones mayores.

During this season of the year, most of the laborers on the island obtain work, but during the rest of the year a high proportion of the sugarcane laborers are unemployed. Only a limited number of men obtain regular work in the canefields because weeding, ditching, and planting gran cultura cane is about the extent of the available work during the summer and early fall.

The pests and diseases most prevalent in the canefields are the sugarcane borer, white grub, mosaic, dry top rot, nematodes, yellow aphis, mole cricket, land crab, and rat. The sugarcane borer (*Diatraea saccharalis*) probably causes the greatest damage. It has spread throughout the island, but it is most damaging in gran cultura and primavera crops in the arid and semiarid districts. The white grub causes the greatest damage on the south coast but is also prevalent throughout the island. With the importation of the toad (*Bufo marinus*) and continued deep cultivation, the white grubs are not so

abundant as formerly. Mosaic has been brought nearly under control by the use of mosaic-resistant varieties of cane and the continual roguing by all progressive landowners, as well as the selection of good mosaic-free seed. Dry top rot is most severe in the poorly drained lowlands, and for its control drainage is essential. Nematodes and other soil organisms cause a small amount of damage to the roots. The yellow aphis is more noticeable on poor soils in dry areas where the cane does not have the vitality to resist the attack of the sucking insects. The mole cricket is destructive in the loose sandy soils, such as those in the Isabela district. Partial control is effected by leaving the cane sheath attached to the cane seeds. Land crabs are destructive to young cane on the coastal lowland soils and poorly drained river flood plains. These pests are controlled with a poison mixture of corn meal and phosphorus placed on or near their holes. Rats do considerable damage near ditches along the coast.

Weeds are not a serious pest to any of the commercial crops. The principal weeds in the canefields are coquí, cadillo, abrojo, rabo de ratón, cohitre blanco, moriviví, and the more common grasses, such as Bermuda, cerrillo, grama blanca, and malojillo.

Irrigation of sugarcane is very similar to irrigation of corn in the semiarid section of continental United States. Laterals laid out with the contours of the land convey the water from the large canals to the growing plants. The source of water is from mountain streams that empty into fairly large reservoirs and from deep wells. The wells used on the south coast for irrigation range from 40 to 750 feet in depth. Most of the shallower wells are grouped in a series including from 4 to 10 wells, 6 inches each in diameter, connected to a centrifugal pump located near the center of the series, in a concrete pit ranging from 10 to 30 feet in depth. Many of the pumps are operated by electricity. The deep wells are about 20 inches in diameter, and in general each one is operated by a motor above ground. The ells on the north coast range from 60 to 300 feet in depth. Some farmers pump the water directly from the river stream. In the Isabela irrigation district all the irrigation water comes from Río Guajataca, and most of the main-line canal is lined with concrete slabs, owing to the porous character of the permeable clay soils traversed by the canal. Along the south coast, the only parts of the canals and laterals that are lined have a gravelly or rocky substratum near the surface.

In order to eliminate inefficient night irrigation, small overnight reservoirs have been constructed along the south coast and in the Isabela irrigation district. The reservoirs range in size from small circular basins 20 feet in diameter to cisterns 300 feet square and 10 feet deep.

The number of irrigations necessary varies with the season, soil, and plantings. Along the south coast, in the average alluvial soil, such as typical San Antón loam or San Antón silt loam, when the annual rainfall is about 45 inches, an 18-month gran cultura crop requires about 25 irrigations, or about 13 acre-feet of water. The primavera crops require about 8 acre-feet and the ratoons only about 6 acre-feet. In the Isabela district the permeable Coto clay and related soils require considerably more water than the soils along the south coast or the alluvial soils along the north coast. In most parts of the island the cane is watered as soon as it is planted and is rewatered in a week if the weather is dry. The frequency of irrigation from then until maturity

of the cane depends on the rainfall, but the average period between irrigations is 15 days.

When the cane becomes large, irrigation is very difficult, as it is hard for the irrigators to penetrate the canefields. Many of the lower leaves of the cane must be removed, in order that they will not interfere with the flowing water, and such a procedure also makes it easier for the men to penetrate the rank high cane.

The sugarcane industry in Puerto Rico is more important than any other of the main commercial crops. The island is naturally ideal for growing sugarcane. It has a favorable climate, good soil, and good transportation service to the United States. The laborers are accustomed to working either singly or in groups in the fields. They often have to walk several miles over steep mountainous trails to and from work, sometimes starting on their journey at 3 or 4 a. m.,

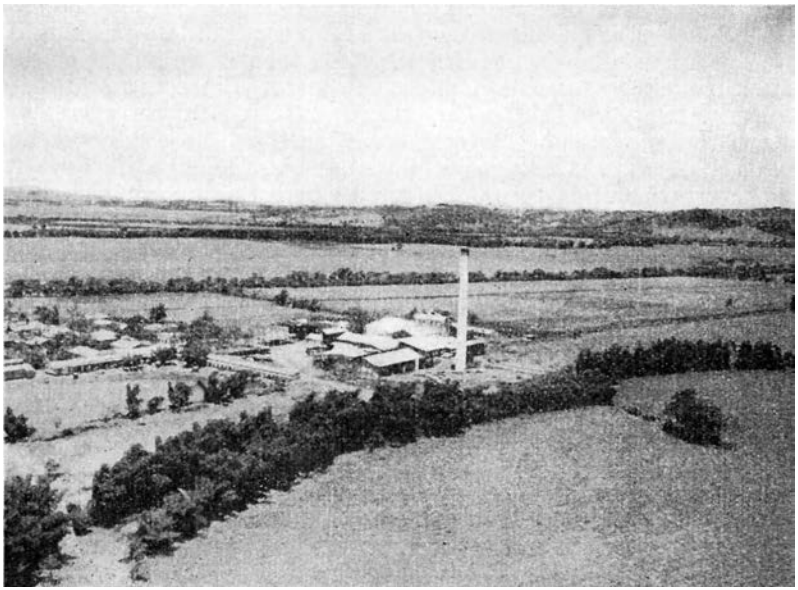

FIGURE 46.—A modern sugar factory with well-managed fields of cane on good productive Toa soils. Note the bamboo along the streams.

Moderna factoría de azúcar con campos de caña bien administrados en suelos productivos Toa. Véase el bambú al borde de los ríos.

because work means food. The summer, or idle period, is the lean season for the laborer. However, very few men will work 6 days a week, even if they are paid by the day or by piece work. They like to start work on Tuesday and finish the week on Friday.

The Puerto Rican sugar growers, in order to counteract the competition of sugar growers in other countries, have enlarged their holdings for the purpose of more efficient management. The sugar industry requires large capital, either from individuals, corporations, or efficiently managed cooperative associations. To equip a modern mill, a capital between $1,000,000 and $2,000,000 is necessary. This includes railroads, livestock, field and factory machinery, and buildings.

It is unreasonable to expect a landowner to finance his small farm and also have a small sugar factory, but it is possible for an energetic owner of a small farm to plant and harvest a crop of cane and sell it at a cooperative mill or a sugar central, at a profit, provided he is able to have his cane ground at the proper time. His acre yield and profit will be much less than if the same land were operated by a more efficient landowner having a much larger holding. For the owner of a small farm to make a success it is essential that he obtain credit at a very low interest rate.

Most of the best land for sugarcane belongs to large corporations (fig. 46) or is leased by them. This land is very efficiently managed, and under the present economic conditions, with the protective tariff on sugar, such land in cane yields from 15 to 25 percent greater returns than if it were in the other commercial crops now commonly grown in Puerto Rico.

The acre yields on the better soils probably can be increased provided the sugar producers continue their scientific studies in search of better varieties, better fertilizer practices for specific soil types, more efficient machinery, and more effective control of insects and diseases. Additional irrigation, either by pumps or from streams also should increase the acre yield. Several areas, such as those near Rincón, Aguadilla, Añasco, Cabo Rojo, the east coast, and a narrow strip along the northern coast would be greatly benefited by some irrigation.

TOBACCO (TABACO)

According to Barrett (*6, p. 254*), tobacco (known to the Arawaks as cohoba) was widely cultivated in the Antilles long before they were discovered by the Spaniards. It was chewed, smoked, and taken as snuff by the aborigines. Dorsey (*16, p. 796*) states:

> Tobacco is indigenous to the island, but in the earlier years of settlement its cultivation was interdicted, both by papal bulls and royal decrees, the latter issued in 1608. However, its cultivation was permitted by a special law passed in 1614. By this same law the sale of tobacco to a foreigner was prohibited on penalty of death and confiscation of property. Other stringent measures were enacted in 1777 and 1784, which by their very severity defeated their own purpose. In 1775 the crop reached 701,750 pounds. Production was large enough to permit of exportation in 1836 (4,954,200 pounds), but by 1838 had declined to half that amount. The maximum crop was that of 1880, when 12,000,000 pounds were produced. The crop of 1897 reached 6,250,000 pounds.

According to the 1938–39 Annual Book on Statistics, the production between 1921 and 1939 has ranged between 50 million pounds in 1927 and 6 million pounds in 1932, and the acreage has ranged from 81,900 acres in 1927 to 10,079 in 1932. The price received by the farmers since 1921 has ranged from 39 cents a pound in 1926 to 11 cents a pound in 1938. The production reported by the 1935 census of the Puerto Rico Reconstruction Administration was 31,254,288 pounds (*34*), or slightly less than that produced in Georgia in 1934, according to the 1935 Federal census. The area in tobacco as reported by the 1935 census of the Puerto Rico Reconstruction Administration was 45,720 cuerdas, or 6.4 percent of the harvested cropland. This was considerably less than the total area in tobacco in Georgia. Production has dropped since 1934, as the Annual Book on Statistics reports an area of only 18,688 acres in tobacco and a production of 11,688,384 pounds in 1939.

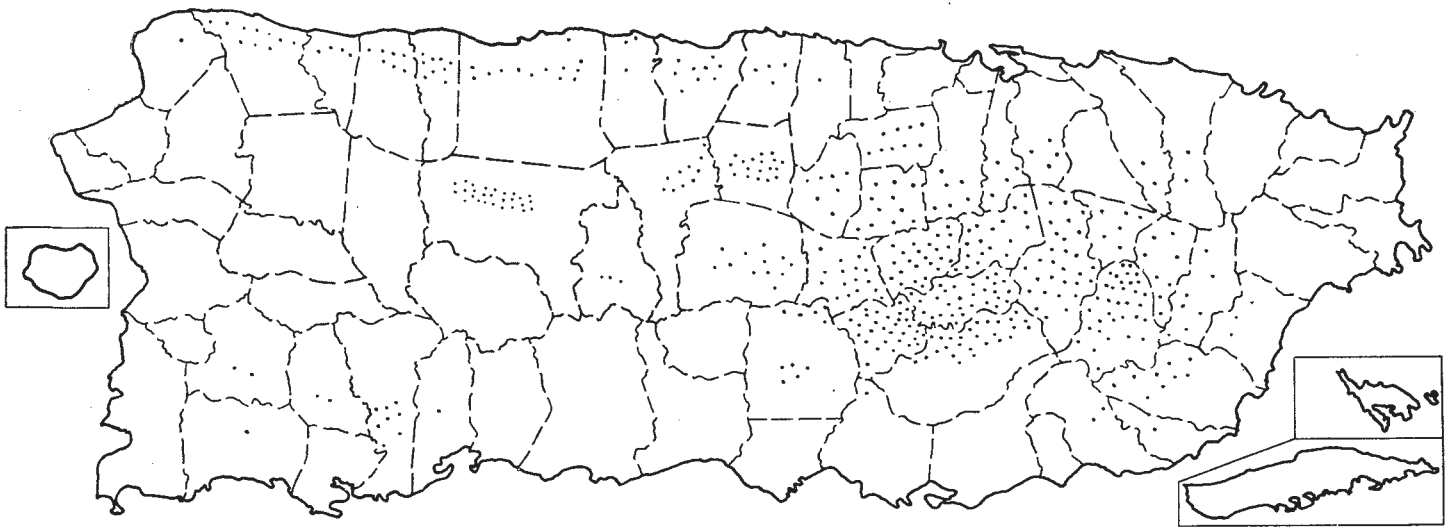

FIGURE 47.—Distribution of tobacco in 1935. Each dot represents 100 acres.
Distribución de tabaco en 1935. Cada punto representa 100 acres.

Between 1916 and 1931 the value of the export tobacco ranked second to that of sugarcane. Before 1916 it was exceeded by the value of both coffee and cane, and since 1932 it has been exceeded by cane and needlework. According to the Annual Book on Statistics (1938–39), $7,621,006 worth of tobacco was exported in the fiscal year 1939. Nearly the entire export crop is sent to the United States. Included in this total is $26,985 worth of cigarettes and $37,602 worth of cigars. The United States received all the cigarettes and almost all of the cigars. Puerto Rico imported $132,517 worth of leaf tobacco during the fiscal year 1939, nearly all of which came from the United States, with a small quantity from Cuba. During the same year, Puerto Rico imported $3,491,023 worth of cigarettes from the United States. The amount of money spent for imported cigarettes was more than one-third of the total export value of unmanufactured tobacco.

Compared with citrus or sugarcane, tobacco is a shallow-rooted crop. Therefore it will grow and produce fair or good yields on shallow

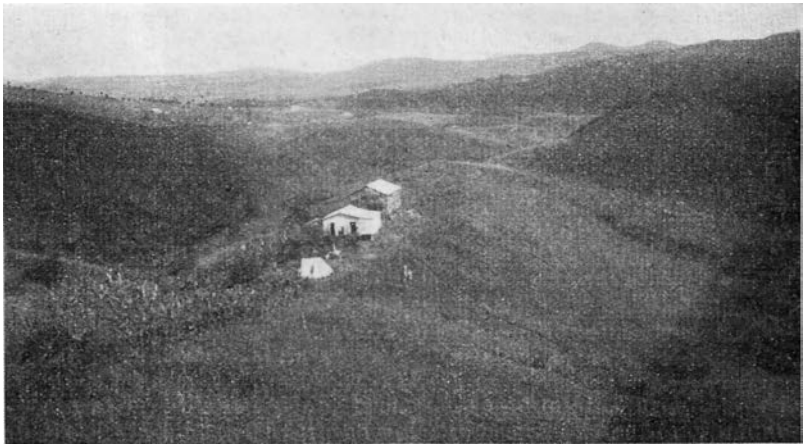

FIGURE 48.—Some of the soils used for tobacco near Cayey. The more rolling areas are Juncos clay, and the steeper areas are Múcara silty clay loam. In the foreground is a hurricane shed, a house, and a tobacco barn.

Algunos suelos sembrados de tabaco cerca de Cayey. Las areas más ondulantes son Juncos arcilloso, y las más escarpadas son Múcara limo-arcilloso lómico. Al frente, una tormentera, casa y rancho de tabaco.

soil or on steep hillsides. The best yields and quality are obtained on friable well-drained well-aerated soils that are neutral or alkaline in reaction, rich in plant nutrients, and situated at considerable distances from areas affected by the salt spray of the ocean. Tobacco is not well adapted to the strongly acid red soils of the uplands, as the acidity limits the supply of calcium and magnesium, as well as the availability of the phosphorus, and favors excessive solubility of aluminum and manganese. Areas of the Toa soils that are seldom overflowed are the most productive, but probably the largest acreages of tobacco are grown on the Múcara, Juncos, and related brown neutral soils of the uplands.

Figure 47 shows the distribution of the tobacco acreage in 1935, according to the Puerto Rico Reconstruction Administration census.

It may readily be seen that there are four tobacco areas. The heart of the largest is in the vicinity of Cayey. Tobacco in this area is grown mostly on the neutral friable rolling Juncos soils and on the neutral friable shallow very steep Múcara soils (fig. 48). To the east of Cayey tobacco is grown on the rolling granitic soils, among which the Las Piedras and Cayaguá are the most important (fig. 49). Northwest from Cayey considerable areas of Naranjito soils are used for the growing of tobacco. The best tobacco is produced in the vicinity of Cayey. The second most important area for the production of this crop is on the coastal plains in the vicinity of Isabela and eastward from that place to Vega Baja. The tobacco in the latter section is grown on the level or undulating soils derived from limestone, such as the Coto, Maleza, Vega Alta, and Bayamón soils and their shallow phases. All these soils occupy valleylike areas between limestone haystack hills. The third largest area is near Utuado, and the tobacco

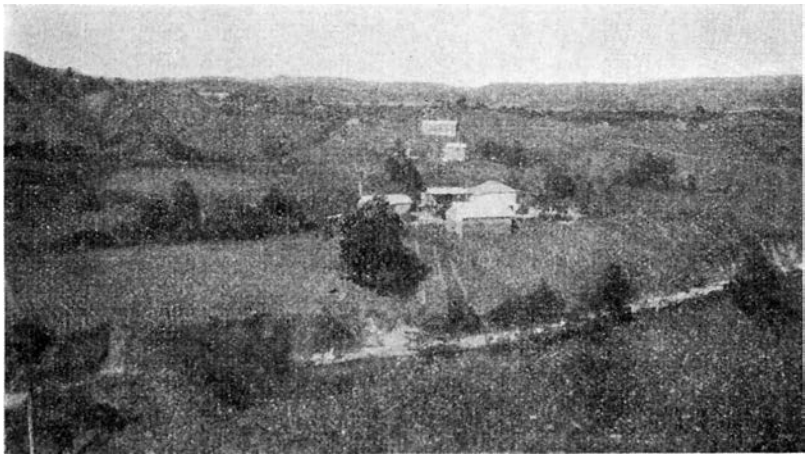

FIGURE 49.—Cayaguá sandy clay loam near San Lorenzo, used mostly for the production of tobacco, corn, and beans.

Cayaguá areno-arcilloso lómico cerca de San Lorenzo usado principalmente para tabaco, máiz y habichuelas.

grown is good-quality cigar-filler tobacco. It is grown on the Utuado and Jayuya soils which are derived from granite. The fourth largest area is near Sabana Grande on nonirrigated semiarid lands, and the tobacco returns low yields. It is grown in small patches, generally on low slopes or in valleylike positions.

The procedure in growing tobacco is very similar to that followed in the United States. Carefully selected seed of healthy, vigorous, good-quality, adaptable varieties is first planted in well-prepared seedbeds, which, generally, are small, gardenlike, banked beds located on well-drained alluvial soils or on gentle slopes near the bases of the hills, where the soil is friable, well drained, and fairly high in organic matter—all requirements of a good seedbed. About 1 acre of a well-prepared and productive seedbed is required from which to plant from 130 to 140 acres. Selected seeds generally are planted under the protection of cheesecloth (fig. 50), which helps to protect the young, tender plants

from insects, intense direct sunlight, and the beating effect of dashing rains.

The first seeds are planted in the beds during August, and generally a second planting is made early in September. The seedbeds are well fertilized. The plants are transplanted to the field during the last of October, November, and the first of December. They should be well protected from the sun during transplanting. They are set from 12 to 15 inches apart in rows spaced from 36 to 44 inches apart on well-prepared, weed-free, well-drained soils. In nearly all of the fields on slopes ranging from 40 to 100 percent, shallow ditches are dug around every plot (which includes about 900 square feet), giving the field the

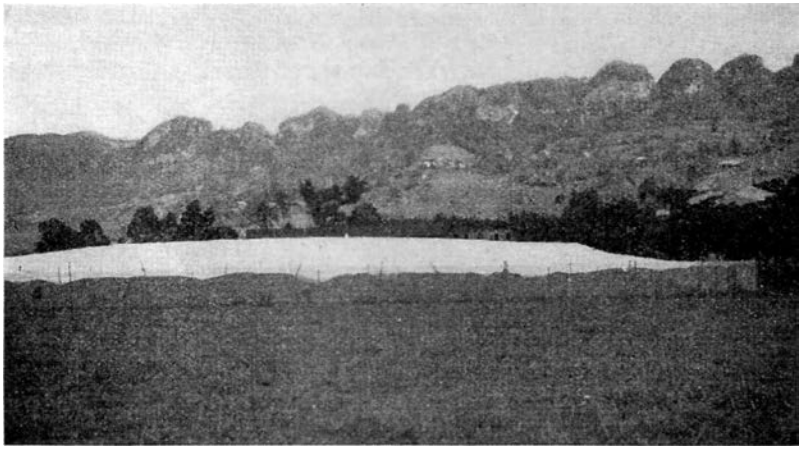

FIGURE 50.—Tobacco seedbed under cheesecloth near Ciales. Limestone escarpment in the distance.

Semillero de tabaco bajo toldo cerca de Ciales. Escarpa caliza a lo lejos.

appearance of a gridiron (fig. 51). These ditches enable the water to drain rapidly without causing serious loss of soil from the fields. The water travels but a short distance before it enters a ditch, and therefore it does not have time to develop much force to carry soil particles. This method seems to be the best of any tried for the prevention of serious erosion on the steep hillsides. Even with the many ditches, there is some erosion, but this must be expected when clean cultivation is practiced on hillsides having 80- to 100-percent slopes. There is only a small amount of gully erosion, however, as the bottoms of the ditches are bedrock.

For a good quality of tobacco, it is of utmost importance to use well-drained soils. Poorly drained soils are referred to by many farmers as "cold" soils for tobacco, and they produce tobacco of poor quality. Many of the sandy-textured soils produce a better quality of leaf than do highly fertile clay or silty clay soils. Salt spray as well as chlorides in the soil affect the quality.

Tobacco requires considerable quantities of readily available nitrogen and potash. The first application of fertilizer generally is made a few days before planting, at the rate of about 400 pounds to the acre of a 6–7–8 formula,[18] and a duplicate application is made about 30

[18] Percentages, respectively, of nitrogen, phosphoric acid, and potash.

days later. The fertilizer requirements for one soil type may or may not be the same as for another, and only by experience and experimentation can the best formula be obtained. The kind and quantity of fertilizer used vary somewhat for the different kinds of tobacco.

Land for tobacco is cultivated two or three times, depending on the weed growth. Generally all cultivation is done by hand, especially on the steep hillsides. Hoeings should be made with the contour of the land or up the slope rather than down the slope, as the latter practice tends to transfer the soil down the slope continually.

About 35 days after transplanting, the lower leaves of the tobacco plant should be removed, in order to increase the circulation of air

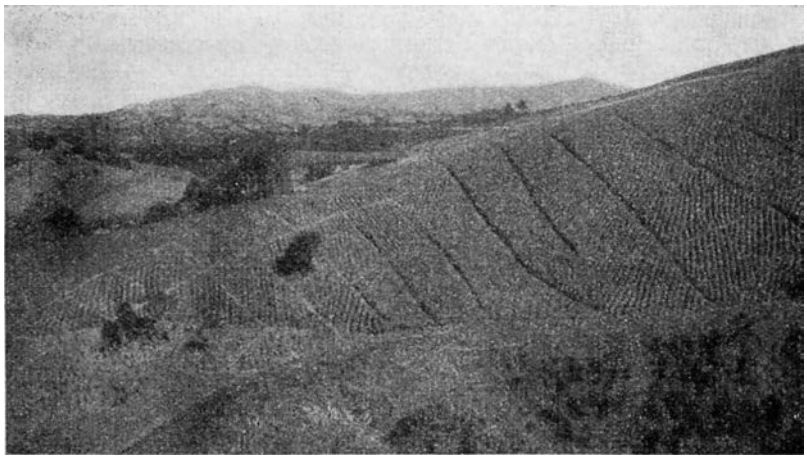

FIGURE 51.—Tobacco grown on Múcara silty clay loam having a slope ranging from 15 to 60 percent. Note the gridiron drainage ditches. The water travels but a short way before it enters a ditch and therefore does not have time to develop much force for carrying soil particles.

Tabaco cosechado en Múcara limo-arcilloso lómico con un declive que varia de 15 a 60 por ciento. Nótese las zanjas de avenamiento. El agua camina muy poco antes de entrar a una zanja y por lo tanto no tiene tiempo de desarrollar fuerza suficiente para transportar partículas de suelo.

The terminal bud is pinched off at this time or a week or two later, except from plants to be used for seed. The plant should be pruned, leaving from 12 to 16 well-developed healthy leaves. Any suckers that appear after pruning should be pinched off fairly near the axil.

Two methods are used in harvesting, which is done within about 90 days from the time the plants are transferred to the field. One is to cut the entire plant when the leaves are yellowish green or yellowish brown. The cut plants are allowed to wilt in the field, then are carried to the tobacco shed and hung bottom end up to dry on 6-foot sticks or bamboo poles that are suspended horizontally in racks one above the other in six or seven tiers. The drying process is very gradual, and the leaves and stems become yellowish brown and somewhat tough. The other method is to hand-pick the ripe leaves at three different periods, starting first with the bottom leaves, then the middle or best quality leaves, and finally the top ones. When the leaves are being transported to the barn they should be protected

from dust and sunlight. In the drying barns the leaves from the different parts of the stem are kept on separate racks.

The leaves are stored in the drying barn for a period ranging from 20 to 30 days, depending on the weather. The barns or curing sheds are built to protect the leaves from the sun, air currents, and excessive humidity. Many different kinds of barns are in use, but the most common type in the large tobacco-growing section near Cayey is a wooden well-constructed tight-roofed building from 36 to 120 feet long, 15 to 30 feet wide, and 15 to 30 feet high, with ventilation on all sides. The height should equal the width. Many tobacco barns in other districts, some of which are not more than 10 feet high, are thatched with palm leaves and covered with matojo grass. On some of the smaller farms the farmers cure their tobacco in their dwellings (fig. 52) or in open sheds or barns, most of which seem to be located

FIGURE 52.—Curing tobacco on the side of a dwelling.
Curando tabaco al lado de una casa.

without much regard to prevailing winds or exposure. They should be so placed that they could have, if necessary, a good draft throughout the building and should be located convenient to the tobacco fields.

Owing to a high content of moisture in the tobacco leaves, the drying process must be watched closely, in order that the best chemical changes may take place. The buildings must be closed during cold nights and rainy days, and at times charcoal must be burned, to provide sufficient heat during long wet periods. During clear dry days sufficient ventilation must be made by opening windows or doors.

When the midribs of the leaves are wrinkled and dry, the leaves have dried sufficiently to be removed from their supports in the drying barn and transferred to piles. This operation generally is done in the early morning when the leaves are moist and flexible and are less likely to be injured than if moved during the hot afternoon when they are dry and brittle. The stems, together with the leaves, are put in piles from 3 to 6 feet high, covered with banana leaves, and weighted with

rocks so that the plants will undergo a sweat. The length of time for the first sweat depends on climatic conditions and ranges from 1 to 6 days. The leaves are then stripped from the stem and separated, according to quality, in three grades and tied into bunches known as manillas. These are taken to the fermentation house for fermentation. The fermentation house, which generally is small, should have a wooden floor and very few windows, as air currents should be avoided. The different grades of leaves are placed in separate piles about 5 feet wide, 10 feet long, and 4 feet high, and are covered with sacks.

If the leaves have been removed from the stems in the field and classified when put in the tobacco barn, they are tied into packs when dried and also taken to the fermentation house and put in piles for fermentation. In order to obtain high-quality tobacco, the fermentation process must be watched closely, to see that the leaves in the piles have the proper moisture content and gradually heat to about 132° F., then gradually reduce to 80°, the temperature of the building. Tobacco generally is in fermentation for about 3 months, and during this time the piles may have to be opened, ventilated, and rebuilt many times, in order to keep the leaves from becoming too hot, glued to each other, or deteriorated in quality.

Most of the tobacco grown on the island is for cigar filler, although most of that produced near Isabela is used for chewing. A few years ago considerable cigar-wrapper tobacco was grown under cheesecloth cover, but this is not the present practice. Practically no green-leaved cigarette tobacco is grown, although the sandy-textured soils of the Bayamón and Maleza series and many other coastal plains soils should be adapted for this kind of tobacco if they were properly fertilized and the proper variety of tobacco planted.

The principal variety grown is Virginia Blanca, which can be harvested either by picking the leaf or by cutting the entire plant. It is used for cigar filler. The Gigante is grown to some extent in dry areas. The Connecticut Round Tip at one time was grown extensively under cover.

The principal disease affecting the seedbed is salcocho, or damping-off disease, which is controlled by spraying the soil with bordeaux mixture. The changa is destructive to young tobacco plants, especially in sandy soils. This pest is controlled by putting paris green and wheat flour around the tobacco stems or by encasing the young stems with mamey leaves. Flea beetles and certain worms, such as the gusano, gusano verde, pega pega, leaf miner, cuerudo, agrimensor verde, and tijerillas, are pests in the tobacco districts. Flea beetles are controlled by submerging the tops of the tobacco plants in lead arsenate solution before they are transplanted in the field. All the worms, except the leaf miner, are controlled by dusting the plants with lead arsenate.

Tobacco mosaic, black shank, leaf spot, and bacterial wilt are diseases attacking the plants. Mosaic and black shank are controlled by destroying the infected plants. There is at present no known control for leaf spot. Bacterial wilt is controlled by planting wilt-resistant varieties.

The farms in the tobacco-growing sections are of various sizes. In the Cayey district the average size probably is about 100 acres, about 45 acres of which are in pasture, 30 acres in minor crops, such as corn, beans, sweetpotatoes, and pigeonpeas, ranking in acreage in

the order named, 20 acres in tobacco, and possibly a small acreage in rice and coffee. The tobacco farms in the Isabela district are very small, probably averaging less than 15 acres each, with more than one-half of their area in pasture and almost valueless brush. Of the 7 or 8 acres in cultivated crops, corn probably occupies about 2½ acres, beans 1½ acres, sweetpotatoes 1 acre, and tobacco 1 acre; and the remaining acreage is divided among plantains, pigeonpeas, yuca, ñames, yautia, and other subsistence crops. The average size of the tobacco farms in the Utuado section is about 30 acres. Pasture probably occupies about 10 acres; corn, coffee, and tobacco about equal areas, or about 5 acres each; and the remaining 5 acres is used for the production of subsistence crops, such as sweetpotatoes, beans, yautia, and pigeonpeas. An average tobacco farm in the semiarid section along the southern coast includes about 40 acres. Probably 30 acres are in pasture, 5 in tobacco, and the remaining 5 in corn, beans, and other subsistence crops. At one time considerable cotton was grown on these farms.

It is rather questionable whether the average size of the tobacco farms will increase, that is, farms on which much of the income must be derived from subsistence crops, in order to insure a living. More net income to the acre is made on large tobacco farms than on small ones, but a small acreage of tobacco can be planted by nearly every farmer who plants subsistence crops in the tobacco-growing districts, and he will continue to do so even though the cash returns may be small. Subsistence farms undoubtedly will increase in number and decrease in size as the increasing pressure of the population forces people to cultivate the steeper hillsides.

The acre yield of tobacco is very similar to that in the United States. In the vicinity of Isabela, acre yields ranging from 400 to 600 pounds are common on the nonirrigated areas and from 700 to 900 pounds on the irrigated lands. This tobacco is used for chewing and is twisted in long ropelike pieces. It is sold in rolls of 25 or 30 pounds, at a price ranging from $18 to $24 a hundred pounds. Tobacco does not need nearly so much water as does sugarcane; therefore the farmers who grow tobacco are reluctant in using irrigation water, although it is available and increases the yield considerably, especially during very dry years. The production in the Cayey section ranges from 2,000 pounds to the acre on the good Toa and Estación soils to 400 pounds on the poorer grades of the Múcara soils. Most of the tobacco grown on average Múcara soils yields about 700 pounds an acre. The price for this tobacco is about $25 or $30 a hundred pounds. The yield, price, and quality of the tobacco grown near Utuado are comparable to those of tobacco grown near San Lorenzo, which are nearly as good as of that grown near Cayey. Production is low on the land in the semiarid section along the south coast, and it probably will continue to be low, owing to the frequency of dry years. Most of the land in this locality now used for tobacco would not be very well adapted for tobacco if it were irrigated, but it would be very good for sugarcane.

The general rotation practiced among tobacco growers is to prepare the land for such minor crops as corn, beans, or sweetpotatoes soon after the tobacco crop is harvested (fig. 53). The minor crops derive some benefit from the fertilizer applied for the tobacco and produce

an additional income. After these crops are harvested the land is prepared for the next crop of tobacco. The practice of producing tobacco on the same land year after year applies to the good level alluvial lands and the better grades of hill land. The steeper hillsides generally are planted to tobacco every 2 or 3 years and during the other years are in pasture or minor crops. In the vicinity of San Lorenzo considerable rice is planted after the tobacco has been harvested.

The future outlook for the production of tobacco is fairly good for ambitious, efficient young farmers, assuming that tobacco will continue to be protected by the tariff and that the island will not be forced to sell on the open market. The ever-changing economic conditions may in time be such that only small acreages will be devoted to tobacco in certain districts, but, owing to favorable climate, soils, and a crop which lends itself to small-scale farming, tobacco should continue

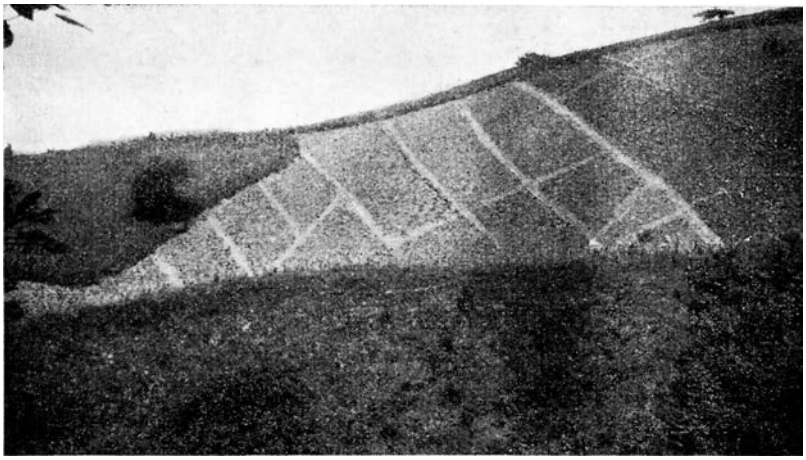

FIGURE 53.—Same area as that in figure 51. Picture taken a few months later. Corn, beans, and yautia are growing on land that was in tobacco a few months before.

La misma área de la fig. 51. Fotografía tomada unos meses más tarde. Siembras de maíz, habichuelas y yautía donde meses antes había tabaco.

to be the second leading commercial crop, and many thousands of laborers should obtain employment in the tobacco-stripping shops. Disputes between employees and employers which terminated in strikes have resulted in a curtailment of the acreage and a loss both to the employees and employers.

The quality of the tobacco should be improved, as the market favors a filler tobacco that has perfect combustibility and an agreeable aroma. The wrapper tobacco should contain a small quantity of nicotine and have a light color, fine texture, and small veins. The chewing, or roll, tobacco should contain considerable glutinous juice and be fairly sweet.

Living conditions could be improved on all the farms producing tobacco if more livestock were produced to supply a milk, cheese, butter, and meat diet to the people who now receive a very low percentage of protein in their food.

COFFEE (CAFÉ)

Coffee is believed to have been introduced into Puerto Rico in the eighteenth century by the French refugees from Haiti. The crop is produced on a low, diffusely branched small tree or shrub that is always green. The coffee tree has a soft gray bark and dark-green glossy

FIGURE 54.—Coffee berries are produced on the 1½- or 2-year-old growth of the lateral branches. (Courtesy of Office of Experiment Stations, U. S. Department of Agriculture.)

La uva del café se produce en las ramas laterales de 1½ ó 2 años de edad. (Cortesía de la Oficina de Estaciones Experimentales.)

oblong leaves. The blossoms are star-shaped, have white petals and yellow centers, and have both fragrance and beauty. The dull-green plump olive-shaped berries grow in clusters close to the stem in the axils of the leaves (fig. 54) and turn red when ripe. Most of them are

produced on the 1½- or 2-year-old growth of the lateral branches, although some are produced on the 3-, 4-, and 5-year-old branches.

At elevations ranging from 1,000 to 1,500 feet above sea level the coffee berries begin to ripen during September and October, or about 7 months from the time of blossoming. At elevations of about 80 feet, such as in the vicinity of Mayagüez, blossoming is advanced at least a month ahead of that at the higher elevations.

Each coffee berry contains two seeds, or coffee beans. The first berries picked are of poor quality. The main crop matures in October or November, depending on the elevation, and it is picked at intervals of about 15 days until all the berries have been gathered. The several ripenings correspond to the several blossomings in the spring. Only the ripe berries are picked, except at the last picking, when all the remaining berries are collected. The pickers, mostly women and children, strip the ripe berries from the branches, allowing them to drop into baskets, and, in turn, they are emptied into sacks which are carried when filled to the drying floor, where the berries are spread to dry overnight. In the morning they are sorted and taken to the hulling machine, or despulpadora, which consists either of one roller with many dull-pointed nails or the more modern disk-shaped machine. The machines may be turned by hand or by power, depending on their size. They remove the outer hull, or pulp, which falls to one side and is later used as a fertilizer. The coffee grains fall into a fairly large bin where they sweat or ferment for a period ranging from 8 to 12 hours. This process loosens the sweet sticky colorless substance called baba with which they are covered. The baba must be removed, and it is more easily washed off after the berries sweat for a few hours. During the washing process the poorer grains float and are strained off. After the water is drained away, the berries are taken to the dryer which usually is either a cement floor, called glacis, or consists of large shallow boxes, called correderas, that are mounted on tracks and can be pushed out in the sun during the day and put under shelter during rains and at night. The coffee is stirred occasionally, so that all the excess wash water will evaporate. When this operation is completed the coffee is said to be enjugado, or in a semidry condition. Every hundred pounds of this semidry coffee will make 46 pounds of cáscara seca, or dry coffee. To obtain the dry coffee, the natural water in the berry must be evaporated. This is done, in most places, by putting the berries in toldas, or square pieces of cloth, and placing them in the sun or directly on the glacis (fig. 29). It takes from 3 to 5 days to dry the berries. A hundred pounds of the dry coffee will make only 80 pounds of coffee ready to be roasted, as the yellow brittle outer covering must yet be removed. This may or may not be done on the farm. The coffee is sacked in 100-pound bags, and generally two bags are strapped to the back of a mule or a pony and thus conveyed to town or to the highway and then loaded into trucks to be taken to town where the coffee is sold or stored for future market. The wholesale dealer generally hulls, sorts, sizes, and polishes the coffee before he sells it. The price of coffee on the farm ranges from $10 to $24 a hundred pounds, depending on the supply, market demand, and quality. Coffee yields range from less than 50 pounds to more than 600 pounds an acre, depending on the soil, location, age and number of trees, condition of shade trees, management, and climate. The variety most commonly grown is *Coffea*

arabica (*29, p. 2*), and for high yields and long production it must be protected from the direct sunlight, although a medium amount of diffused sunlight is essential. Bananas and plantains are planted for temporary shade or until the permanent shade trees supply the coffee trees with enough protection from the sun. The trees commonly planted for permanent shade (fig. 55) are the guamá, on wind-exposed slopes and on high elevations, and the guaba and moca on medium elevations. The guamá is an excellent shade tree, but it is susceptible to injury from the hormigüilla, a small ant that migrates to the coffee trees from heavily infested shade trees. This insect bores tunnels in the coffee trees, thereby weakening the branches, causing them to be easily broken by the wind and during harvest. The guaba tree is preferred to the moca, as it is a fast-growing tree, is easily pruned, and does not scatter hundreds of prolific seeds as does the moca. Cutting the seedlings of the moca increases the cost of cultivation of coffee.

The shade trees should be spaced from 24 to 30 feet apart each way when they are fully grown, but they must be planted much thicker and some trees eliminated as they develop. The coffee trees should be planted about 9 feet apart. The height of the coffee tree should not be much more than 9 feet, in order that the crop may be gathered easily and also that many lateral berry-producing branches will be formed. The height of the coffee trees can be regulated to some extent by the number of shade trees planted to the acre and by pruning.

Coffee can be grown on the same land for many years. The coffee trees are fully grown at about 10 years of age, and they will continue to produce for another 10 years or more if they receive proper care. Each tree varies in yield in accordance with location, fertility, soil, shade, moisture, and vigor. Yields range from less than one-fourth pound to nearly 5 pounds a tree. Under favorable conditions and proper management the trees start producing 18 months after planting, but, as a general rule, very few berries are produced before the third year, and even under favorable conditions most trees do not produce more than one-half pound of berries each before they are 5 years old. The yields of coffee usually are higher every second year, partly because after a heavy production the trees have fed so heavily on the soil nutrients that nearly 2 years are required for the trees to obtain from the soil sufficient available nutrients to produce another good crop. The difference in yearly yields is not so noticeable if fertilizer is used each year. The production of coffee is much higher on concave slopes where the soil is richer and deeper than on the convex slopes. Coffee that will yield 50 pounds to the acre on convex slopes will yield from 300 to 500 pounds on concave slopes. Yields of coffee decrease with an increase in the slope of the land. Fairly high yields can be grown on 60-percent slopes, however, but yields are low on slopes ranging from 80 to 100 percent. Some of the best coffee farms are in Barrios Mameyes Abajo and Tetuán in the municipality of Utuado and in Barrio Frontón in the municipality of Ciales. Most of these farms are on slopes of 30 or 35 percent, and the soil is deep, is well drained, and is high in organic matter. Land values vary with location, road facilities, elevation, soil, degree of slope, extent to which erosion has taken place, and climate. At present (1938) land in good productive coffee trees, yielding about 400 pounds to the acre, is valued between $125 and $150 an acre. Land producing about 200 pounds

is valued at $80 or $90, and land producing only 50 pounds is valued at $40 or $50. Similar land in pasture is valued at about $30 or $40. The estimated cost of planting an acre of coffee trees is about $50.

FIGURE 55.—A coffee finca near Ciales. The shade trees are too close together and therefore form too dense a shade. Corn and some bananas in the foreground.

Finca de café cerca de Ciales. Los árboles de sombra están demasiado juntos y por lo tanto dan demasiada sombra. Maíz y guineos al frente.

Coffee of the best quality is grown at elevations of more than 1,500 feet above sea level, but, owing to the greater destruction from wind at high elevations, most of the coffee now grown is below an elevation

of 1,500 feet. At one time large areas of land above 1,500 feet were in coffee. At present the proportion of coffee grown at elevations above 1,500 feet is larger on the south side of the Cordillera Central than on the north side. This is especially true in the area north and west of Villalba. The coffee farms are of various sizes. A few include a thousand acres, many range from 10 to 20 acres, but most of them are between 100 and 200 acres. A 40-acre farm is about as large as can be handled efficiently by one man. The number of laborers required for an average 140- or 150-acre farm is about 20. The men are paid about 50 cents a day. Coffee pickers are paid from 5 to 7 cents an almud [19] which is about 5 gallons, or 20 liters. An average picker can gather from 4 to 6 almuds a day. Most of the pickers are women and children.

Usually each peon helper has the privilege of planting an acre or more to subsistence crops for his own use. He generally gathers all the bananas he can eat from his employer's land, and many employers permit the gathering of wood to be made into charcoal. It is customary for the peon helper to build his own house, or bohío, on his employer's coffee finca. The bohíos commonly are very crudely constructed one- or two-room structures with a lean-to for cooking. Only the bare necessities are in these bohíos. Most of the owners of coffee farms have a four-room house and several other buildings, such as sheds and places to wash and dry the coffee. Most of them do not attempt to produce other commercial crops, but they do gather and sell the sweet juicy mountain oranges that grow abundantly on their land. Owing to the excellent quality of these oranges, nearly all are sold on the local markets. The price is low, averaging from 25 cents a hundred during the fall and winter to $2 a hundred during the spring and early summer.

Coffee farmers have had many set-backs, owing mostly to destructive hurricanes, such as those in 1898, 1928, and 1932. Most of the farms are heavily mortgaged. Seven years after the hurricane of 1928, the value (*16, p. 120*) of the coffee exported from the island was $207,739, or only 3.4 percent of the value of that exported in 1919, an average year from 1911 to 1927. The coffee farms were so severely damaged by the 1928 hurricane that only a small proportion of the farmers began immediately after the storm to replant their coffee and shade trees. Many of those who did replant utilized only the most favorably located and least damaged parts of their farms and allowed the rest to grow up to brush and grass. Now nearly 60 percent of the total coffee area is either in grass, brush, or poor-quality trees. The proportion of idle and forested land is greater than land in coffee at elevations above 2,000 feet, but a higher proportion of the land is in coffee than is idle at elevations below 1,500 feet. This is because the winds were more destructive at the higher elevations. The proportion of idle land on the north and east slopes is greater than on the south and west slopes, because there is less protection from the winds on the windward sides of the hills and mountains. This can be seen readily in studying Puerto Rico's agriculture from an airplane. The most ideal location for a coffee farm is on the southwest slope of a half-cup shaped, gently sloping mountainside, at an elevation ranging from 1,500 to 1,700 feet, where the average annual rainfall is more than 84 inches and where the soil is not greatly eroded but is friable,

[19] 1 almud of coffee berries makes about 5 pounds of marketable coffee.

well-drained, deep, and contains about 3 or 4 percent of organic matter in the upper 8 inches. Coffee roots penetrate deeply. They are highly susceptible to stagnant ground water and cannot tolerate many floodings. Some of the necessary coffee roots develop only in the presence of humus, therefore the soil must be fertile. The water requirements for coffee are about the same as for cacao trees, slightly less than for sugar beets, but much more than for cotton, coconut palms, and corn.

Figure 56 shows the distribution of coffee trees in Puerto Rico as recorded by the Puerto Rico Reconstruction Administration special census for 1935. It may readily be seen that nearly all the coffee is grown in cool temperatures, at high elevations, and in localities where the average annual rainfall is greater than 80 inches. Exceptions occur, as a few small areas are in coffee southwest of Isabela, where the average annual rainfall is not more than 58 inches, and near San Germán, where it is 65 or 70 inches. Coffee grown in areas having less than 80 inches of annual precipitation produces low yields, and the leaves are attacked by the coffee leaf miner. According to the Puerto Rico Reconstruction Administration census of 1935, more than one-half of the total number of coffee trees growing on the island are in the municipalities of Utuado, Lares, Maricao, Las Marías, Adjuntas, Mayagüez, Ciales, and Jayuya. From 50 to 80 percent of the total farm land of these municipalities is planted to coffee. About one-fourth of the total farm land of the island was in coffee in 1935.

One reason that such a high percentage of coffee is grown in the municipalities mentioned is the scarcity of good roads. The only means of transportation from some of the farms is by mule or horse over narrow steep trails, and by such transportation it is easier and cheaper to transport coffee than most of the other crops grown. Also, coffee is not perishable and can withstand rather rough handling, which is a factor to be considered when transportation is made with pack animals.

The distribution of coffee trees coincides very closely with the distribution of the soils of four extensive upland soil series, namely: Catalina, Alonso, Los Guineos, and Cialitos. These are acid friable deep or fairly deep well-drained red or purple permeable clay soils, and they receive an average annual rainfall in excess of 78 inches. All are adapted to the production of coffee. The Alonso soils are considered the best, followed in order by the Catalina, Cialitos, and Los Guineos. In some places along the north coast, coffee is grown at elevations of less than 500 feet, on such land as Tanamá stony clay, colluvial phase, Tanamá stony clay, and associated soils derived from limestone. These soils are not considered good soils for coffee, and a high yield is very unusual. Coffee is grown on such land because the soil is of little value for other crops, partly because of its inaccessibility. The Lares, Torres, Toa, and the best Múcara soils are well adapted to the production of coffee, but, as sugarcane is a more profitable crop, only a small area is planted to coffee. Most of the Toa soils in the coffee districts are used appropriately for the coffee seedbeds.

Coffee trees should be planted at the rate of about 600 to the acre or from 8 to 10 feet apart, but on most of the coffee farms the trees are planted promiscuously over the farm, from 900 to 1,400 an acre, and often three or four seedlings in one place. The coffee seedlings should

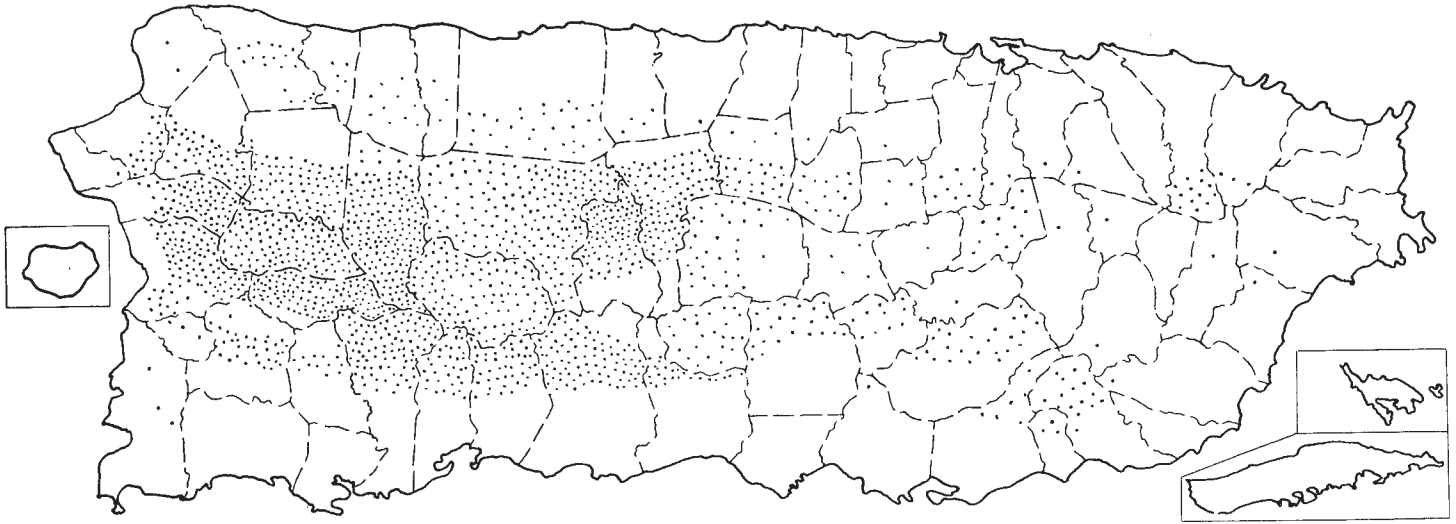

FIGURE 56.—Distribution of coffee trees in 1935. Each dot represents 100 acres.
Distribución de árboles de café en 1935. Cada punto representa 100 acres.

be transplanted from the nursery to the field at the age of approximately 1½ years, and the best time for planting them is just before the rainy season. The general practice is to plant the seedlings in holes about 18 inches square, and, on slopes, the plantings should follow the contours. For best production, coffee trees require diffused sunlight and good low-air circulation. It is best not to cultivate coffee land, especially that on slopes. At the beginning of the dry season, the grass and weeds near the coffee trees should be cut and all leaves and trash allowed to decay on the land. One of the most necessary procedures in handling hill-land coffee farms is to keep the surface soil from becoming low in plant nutrients or from being washed away by sheet erosion. This is best prevented by fertilization and by encouraging grass and cohitre morado to grow. Grass will not grow luxuriantly because most of the ground is shaded, but cohitre morado will grow very well, even on rocks, and it is a good plant for helping in the prevention of erosion. The coffee trees, as well as the shade trees, protect the land from erosion. Most land that has been in coffee for many years and properly managed has a 6-inch surface soil, but in much of the adjacent cultivated land the surface soil is only 2 inches thick, and in many places the subsoil is exposed.

Many farmers find it good policy to dig holes about a foot square and from 8 to 14 inches deep near most of the coffee trees, in order to prevent erosion. Digging the holes costs about $5 an acre. The holes are partly filled with manure or leaves to keep the tree roots from exposure, to add fertility to the soil, and to keep the soil moist. During rains, these holes serve to catch the flowing water and sediments and also to check the force of the water. The holes fill with soil within a period ranging from 2 to 4 years. Some farmers clean them and scatter their contents around the trees and others dig new holes, and the process is repeated.

Another good soil-conservation practice is to dig deep long pits along drainageways and hillside roads. The running water fills one hole after the other, but the force of the water is checked and some of the sediment has time to settle in each hole. In time these holes fill with sediments, after which their contents are scattered over the hillside from which they were washed.

The coffee trees should be fertilized at the rate of about 1 or 1½ pounds of mixed fertilizer, such as a 10–5–15 mixture, or about 5 pounds of manure, to the tree. The Federal experiment station at Mayagüez has had good results with a 7–10½–14 mixture. Some farmers use 100 pounds of ammonium sulfate and 200 pounds of potassium sulfate to the acre. A very small proportion of the farmers fertilize their coffee trees, but when fertilizer is used, it is generally applied in November and again in May or June. The production of coffee has varied greatly from year to year. In 1770, 728,025 pounds (*16, p. 796*) was produced. The market at that time was limited to Mediterranean ports. The production nearly doubled in the next 6 years, on account of the remission of taxes. Coffee did not hold an important place in the agriculture of the island until nearly 100 years later, when the United States took possession, at which time coffee was the most important crop, outranking sugarcane and all other crops by a wide margin. The hurricane of 1898, however, was so destructive to the coffee trees, and the impetus given the production of sugarcane by free trade was so great, that within a

very short time sugarcane was the leading crop. In 1850 the production of coffee amounted to 11,783,684 pounds, in 1870 to 17,416,762 pounds, and in 1897 to 51,710,997 pounds (*16, p. 796*). According to the Puerto Rico Reconstruction Administration census, the production was 53,209,362 pounds in 1919, only 7,331,877 pounds in 1929, owing to the severe hurricane in 1928, and 25,855,543 pounds in 1935. In the latter year the area in coffee represented 25.6 percent of the land from which crops were harvested.

In 1939 most of the coffee was exported to Czechoslovakia, Sweden, France, and the Netherlands, and some went to Switzerland and Italy. The value of export coffee ranged from $1,678,765 in 1901 to $9,034,028 in 1920 (*16, p. 120*). According to the 1938–39 Annual Book on Statistics, the value dropped to a low of $124,558 in 1933, reached a high of $1,169,684 in 1937, and fell again to $527,101 in 1939.

The future of the coffee industry is anything but encouraging. The exportation of coffee for the last 20 years has declined gradually, and during the last 6 years exportation has been so low that Puerto Rico has lost much of her European trade for this commodity. A very small quantity of Puerto Rican coffee is sent to the United States, and, therefore, nearly the entire exported crop enters the world market on a competitive basis. The coffee produced is of a mild excellent quality, but, because of the low acre yield, the growers must realize a very high price in order to make a profit.

In many areas within a kilometer of the main highways, sugarcane gradually is crowding out coffee. In some areas in the east-central part of the island, tobacco has been planted on the Múcara and associated brown shallow soils that once were fairly productive land for coffee but now, after a period ranging from 10 to 15 years of clean cultivation to tobacco and minor crops, these soils are so shallow that if coffee were planted, the crop would be a failure or very low yields would be produced. So far no crop has been grown on the island that will compete with well-cared-for coffee planted on the deep red acid Catalina and associated steep soils of the upland, which are in the high-rainfall areas. But even with good land, the successful coffee farmers will be those who take care of their own land, working it with their own families, and those who plant other crops adaptable to the soil, such as mountain oranges, plantains, bananas, vanilla, ñames, and yautia, and in addition have some livestock for consuming the grass grown on the land not suitable for coffee. Growers should have their own seedbeds, and immediately after a hurricane they should rebuild their farms. They will have to use more and more fertilizer, manure, and lime, as the years go by. In order to compete with other coffee-producing countries, which produce much higher acre yields, have less loss from hurricanes, and have cheaper land and labor, the farms must be well managed, the noxious weeds and vines must be cut, and the shade trees must be kept in good condition, in order that the losses from ants and diseases may be kept to a minimum. The coffee trees should be pruned systematically, and a continuous effort must be made to keep soil erosion at a minimum.

GRAPEFRUIT (TORONJA)

Puerto Rico had very few, if any, commercial grapefruit orchards before American occupation in 1898, but long before that date grapefruit was growing wild over the island. It is probable that the seeds were brought from land adjacent to the Mediterranean Sea.

The industry grew rapidly between 1900 and 1930, but since 1930 very few commercial orchards have been planted. According to the United States Customs Bureau, San Juan, P. R., $162,749 worth of grapefruit was shipped during the fiscal year 1910. In 1920 nearly 10 times that amount, or $1,332,742 worth, was shipped. According to the Annual Book on Statistics, $315,580 worth of fresh grapefruit and $591,136 worth of canned or preserved grapefruit, or less than 1 percent of the value of all exports, was shipped in 1937. These figures fell to $56,690 and $170,486 respectively in 1939. Most of the shipments are sent to New York City, but small quantities are sold in European markets, chiefly in England.

Most of the grapefruit orchards are owned and managed by continental Americans. The orchards range in size from a few acres to several hundred, but the average size of the commercial orchards is about 125 acres. Figure 57 shows the distribution of grapefruit trees, as recorded from data of the Puerto Rico Reconstruction Administration census of 1935. At that time there were 646,802 bearing trees and 153,120 nonbearing trees. The municipality of Bayamón had 150,207 trees, or about one-fifth of the total number on the island. Other municipalities ranking in number of trees in the order named are: Toa Baja, Manatí, Arecibo, Vega Baja, and Toa Alta. In these six municipalities are about 75 percent of the total number of grapefruit trees in Puerto Rico. From figure 57 it may readily be seen that over 90 percent of the trees are grown in the area between Arecibo and Trujillo Alto. Most of the soils in this area are derived from limestone, no part has an annual rainfall of less than 65 inches, and most of the area lies at an elevation of less than 300 feet, especially the land in grapefruit. Almost all the commercial orchards on the island are at elevations of less than 500 feet. Grapefruit growing in areas having an annual rainfall of less than 65 inches should be irrigated. Some growers irrigate in places where the average annual rainfall ranges from 70 to 75 inches.

The most common varieties grown in the commercial orchards are the Duncan or a variety resembling Duncan, the nearly seedless Marsh variety, and Triumph. Most of the growers have small nurseries, and the common practice is to bud grapefruit to grapefruit, or to rough lemon rootstock. Grapefruit trees under favorable conditions should start blooming at the age of 5 years and continue to bear until they are more than 35 or 40 years old. Maximum production is reached when the trees are from 9 to 12 years of age. As it takes more than 7 months for the crop to mature, the blossoms should appear in January, in order that the ripe fruit may reach favorable markets in August and September. At this time the price in New York is about $3 a box. During March it is often less than $2 a box. Locally grapefruit can be bought for $1 a hundred during March, April, May, and June, and $3 a hundred during August, September, October, and November. At times the price paid at the local canneries ranges from $4 to $12 a ton, which is from 20 to 60 cents a box. The season

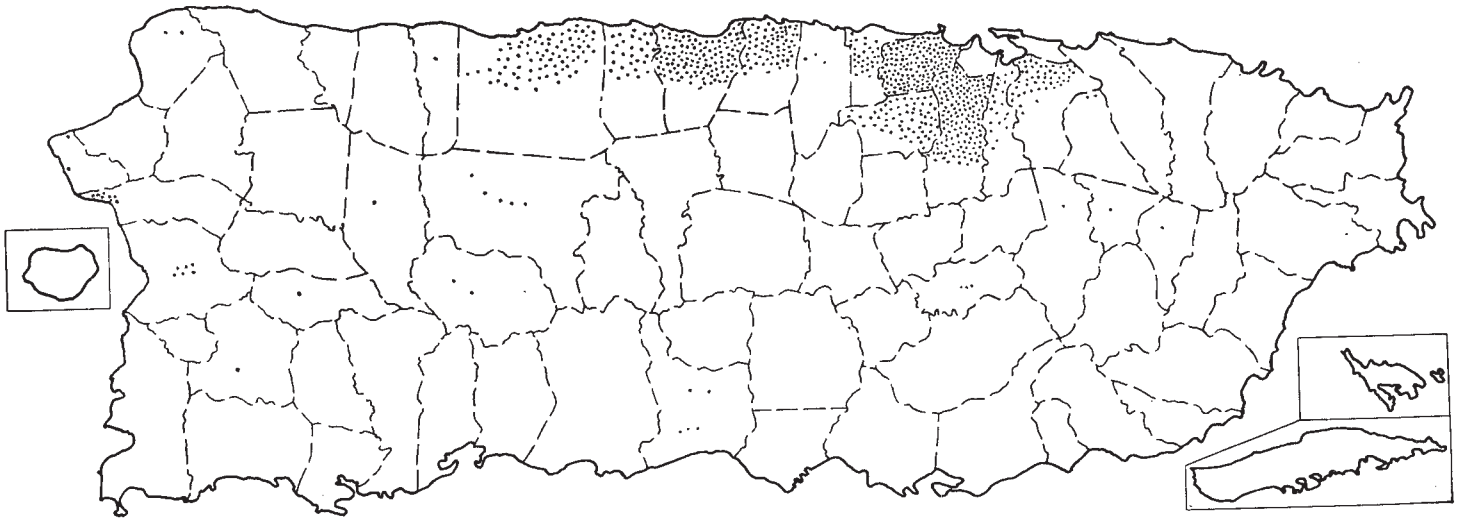

FIGURE 57.—Distribution of grapefruit trees in 1935. Each dot represents 1,000 trees.
Distribución de árboles de toronja en 1935. Cada punto representa 1,000 árboles.

for harvesting is between February and July. Some blossoms may appear between January and April, and it is not uncommon to see fresh blooms, small fruit 1 inch in diameter, and mature fruit on the same tree. A mature tree growing under favorable conditions may reach a height of 15 feet, have a radial branch spread from 12 to 15 feet, and have some roots that penetrate to a depth ranging from 10 to 12 feet.

The size, vigor, and production of the grapefruit trees depend on soil, climate, location, fertilizer, management, variety of tree, disease, and rootstock used for budding.

Grapefruit trees will grow on many soil types, but for a profitable crop during adverse times the land must either be nearly ideal for citrus or so fortunately situated that there will be little or no loss from hurricanes. For highest yields and longest periods of production, grapefruit trees require wind-protected areas in deep well-drained, well-aerated neutral or acid sandy-textured soils, such as the loamy sand and sandy loam types of the Maleza, Coto, Espinosa, Bayamón, Islote, and Vega Alta series, and the calcareous sand and loamy sand types of the well-drained Cataño series. The friable permeable clay soil of the best grades of the rolling to undulating areas of the Catalina and Alonso soils also are well adapted for grapefruit. The roots of the grapefruit trees can rapidly and easily spread and deeply penetrate all these soils, and, with sufficient water and fertilizer, rapid-growing trees are produced. It is unfortunate for the owners that many orchards have been planted on less favorable soils than those mentioned, such as the heavy plastic sticky clay soils of the Moca, Mabí, and Santa Clara series, in all of which internal drainage is too poor for the movement of both air and water, thereby causing the trees to be small and unhealthy; and soils like the Sabana Seca and the heavy-subsoil phases of the Vega Alta, in which the subsoils are too heavy and stiff for the roots to penetrate readily, thereby causing the trees to be stunted after they are 4 or 5 years old. Trees planted on the Corozo, Algarrobo, and St. Lucie soils are small, short, and produce low yields, as these soils are too infertile and too acid for grapefruit, and they also have an impervious layer at a depth ranging from 20 to 48 inches. Neither are the clay soils of the Bayamón, Coto, Vega Alta, Espinosa, and Almirante series very good soils for grapefruit, as they have too heavy surface soils and subsoils for the roots of the trees to penetrate as freely as they should to procure nutrients to form a large highly productive tree. Of the above-named soils, the lighter the texture the better the soil for grapefruit.

If the trees are planted about 30 feet apart, on a farm having Bayamón clay, Bayamón fine sandy loam, and Bayamón loamy fine sand, closely associated (as is very common), in about 15 or 20 years those on the loamy fine sand may be expected to be nearly three times as large as those on the clay, and the largest trees on the fine sandy loam will be about the size of the smallest trees on the loamy fine sand. The trees on the loamy fine sand will have nearly touched one another, shading nearly all the ground beneath, whereas only about one-half of the ground under the trees on the clay soil will be shaded, and other trees will have to be planted in order to have the total area shaded, thereby keeping down the cost of cutting the grass or the cost of cultivation. This difference in the growth of trees is not so apparent if the land is irrigated or if the average annual rainfall is above 80 Inches.

Production varies greatly according to the soil type. In one well-managed orchard a tree growing on Piñones clay was producing about 2 boxes of grapefruit a year, and not more than 100 feet distant on Bayamón loamy fine sand the production was 20 boxes to the tree, in fact one tree yielded 30 boxes.

The most prosperous looking orchards are those planted on sandy soils and favorably situated in relation to the wind. If the orchard is to be located on wind-exposed areas, good protection from the wind must be established before the trees are planted. The Australian pine is used extensively for this purpose, as it grows rapidly on almost any soil. A growth of 15 or 20 feet a year is not uncommon. In many places these trees are planted in hedges. Another permanent windbreak is the bamboo, which is desirable if a ditch is dug about 30 inches deep between the bamboos and the first row of grapefruit trees, as the roots of the bamboos are heavy water feeders and compete seriously with the grapefruit roots if they become intermingled. In many orchards leguminous crops are planted as protection from the wind, as well as for the fertility they add to the soil. The most common plants of this kind are crotalaria, pigeonpeas, and gallito (*25*). Some of the small circular valleys in the limestone hills are nearly as ideally protected from wind as is possible in Puerto Rico. Many of the limestone hills tower more than 100 feet above the level of the valley floor. Air circulation, however, in general is not so good as in more open and undulating land. Grapefruit trees grow better and are more healthy on slightly undulating land than on flat land or depressions, because of the better drainage and freer circulation of air. The trees cannot endure long if the land is under water for any length of time. Grapefruit trees planted on 30-percent slopes will grow if the soil is suitable, but it is noticed that the trees planted on the concave slopes are much superior to those on the tops of the hills or on the convex slopes. This is due to deeper richer soils and more moisture on the concave slopes, also to better protection from the wind, especially on the south and west slopes.

Good young productive orchards growing on loamy sand in well-protected locations having an average annual rainfall exceeding 75 inches or an economical irrigation system and good circulation of air are valued at $400 or $450 an acre. The same land in sugarcane would be worth not more than $60 or $75 an acre. The value of productive trees ranges from $5 to $9 each.

Grapefruit trees should be planted about 30 feet apart, or about 42 to the acre, in the loamy sands of the following soil series: Maleza, Coto, Bayamón, Espinosa, Cataño, and Vega Alta, and about 27 feet apart in Alonso and Catalina clay. They should be planted about 25 feet apart, or 70 trees to the acre, in sandy loams and loams of the first-mentioned soil series and about 20 feet apart if planted in the sandy clay and clay members of the same series. Each tree should be planted on an 18-inch mound of loose surface soil, in order to protect the tree from root rot. The newly planted trees should be kept watered, to enable the roots to become well established. In the irrigated districts near Isabela, in very permeable soil, a small basin about 6 feet in diameter is dug around each young tree and nearly filled with water. Small laterals spread the irrigation water over the land to the bearing trees. More of the owners of grapefruit orchards are installing irrigation pumps than formerly, especially near the coast

between Bayamón and Arecibo. Through the use of irrigation, the time of blossoming can be controlled better and the yield increased. Other things being equal, the sandier the soil texture the more frequent should be the irrigation and application of fertilizers, but the total quantity applied need not be greater than that for the heavy-textured soils.

Field observations indicate that it is not essential that the soil in grapefruit orchards be cultivated after the trees are more than 4 or 5 years old. After the trees are 5 years old, the grass and weeds should be cut at intervals and kept short during the dry season, but it is not necessary to hoe the land. This saves expense, the grass helps to stop sheet erosion, and the decaying grass roots and leaves are beneficial in enriching the soil. After the trees are large, their shade will kill almost all the undercover.

Fertilizer generally is placed around the tree within the spread of the branches. The formula most commonly used is 6–8–10. From 30 to 35 pounds are used for a tree producing 20 boxes of fruit, and from 15 to 20 pounds for a tree producing 10 boxes or less. The custom is to apply the fertilizer about December 1, again in February, and the third application in June. Young trees require much nitrogen for the formation of roots, trunk, and limbs; but the bearing trees require less nitrogen and more phosphoric acid and potash for the best quality of fruit.

The future of the industry is not encouraging, owing to the frequency of destructive hurricanes, uncertainty of favorable prices, and low yields from orchards unfortunately located on poor soils. Many orchards on the poorer soils are neglected, the grass and weeds are uncut, and no attempt is being made to check the ravages of diseases and insects. Ultimately this land will be planted to more productive crops, probably sugarcane or pineapples. The soils well adapted to grapefruit are producing as high or higher returns from grapefruit than they would produce from any other crop commonly grown. On such soils the yield is high and the quality of the fruit is good. The soil is easily handled and is becoming more fertile with use, owing to frequent applications of fertilizer and the use of adequate methods for the control of erosion.

Some of the growers of citrus fruit claim that grapefruit should be produced at a cost of about 25 or 35 cents a box and that the production should be from 10 to 15 boxes a tree for adequate profit. The average production of a bearing tree is probably about 5 boxes.

Very few acres have been planted to grapefruit trees during the last few years, and it is doubtful whether the acreage will increase within the next few years. There are several undeveloped areas on the island that would make very good land for grapefruit. One is a large area of Maleza loamy sand near Faro Cabo Rojo in the southwestern part of the island. This land should be irrigated. At present it is in guinea grass and corn. An area of Cataño sand and Cataño loamy sand is east of Loíza near the coast. This area also should have some irrigation if grapefruit is to be planted. It is now in minor crops, and some coconut palms are growing on it. Other good soils for grapefruit are the rarely overflowed areas along the north coast and the sandy-textured San Antón soils on the south coast. It is doubtful, however, whether grapefruit will ever compete with sugarcane on the high-priced valuable lands.

PINEAPPLES (PIÑAS)

According to Barrett (*6, p. 246*) the pineapple was almost certainly a native of Brazil, and very probably the Caribs or Arawaks took some to Puerto Rico before the sixteenth century. The Spaniards cultivated this crop to a small extent, and when the island was ceded to the United States the giant Cabezona variety had been developed and was grown in the vicinity of Lajas on the steep hillsides of the Mariana soils. Since that time other varieties, such as the Pan de Azúcar, or sugarloaf, Caraqueña, and Negrita have been grown to some extent in different parts of the island and have been used for home consumption. The principal commercial variety is the Red Spanish which is grown extensively on the soils of the coastal plain from Carolina to Arecibo.

The pineapple is related to the bromeliads and air plants, and it can absorb nutrient constituents through its leaf axils and long-barbed and barbless bayonetlike leaves that protrude from numerous whorls on the main stalk. It apparently is a stemless plant, as the leaves are produced at the surface of the ground. The height of the plant ranges from 2 feet in poor soil to 6 feet in very good soil. The fruit may weigh from 1 to 35 pounds, depending on the variety, soil, climate, and kind and quality of fertilizer used, but the average size of the commercial product is between 2 and 3 pounds. The fruit is produced near the center of the plant on a short bright-red stalk. The so-called fruit is an aggregate of many individual fruits with their fibrous juicy pulp surrounding the core. In some varieties each individual fruit has a number of seeds which can be used for propagation, but the most common practice is to plant slips or suckers. The slip resembles a miniature plant and is produced near the base of the fruit. A small crown slip is produced near the top of the fruit, and although this slip will grow when planted, it is rarely used for propagation. The suckers resemble the slips, but most of them are larger and are produced in the leaf axils. After one crop of pineapples is harvested, a second crop, or ratoon, is produced from a new plant resembling a sucker which is formed at the base of the main stalk in contact with the soil.

The pineapple is a very sensitive plant that responds to good management and good soil, but if the soil is too alkaline, too wet, too compact, or poorly aerated, the crop is very likely to be a complete failure. The pineapple plant is neither deep-rooted nor does it require large quantities of water. It grows best on acid well-drained permeable soils that contain considerable organic matter and are in positions where air drainage is good. The permeable clay soils, such as Catalina clay, Bayamón clay, and Espinosa clay, are slightly more productive than Bayamón sandy clay loam and Espinosa sandy clay. Mariana clay loam, Aguadilla sandy loam, and Sabana Seca sandy clay loam produce fairly good yields. Sabana Seca clay is slightly too heavy and compact for good aeration. The Cataño, Múcara, Colinas, and related soils are too alkaline. The Vega Baja and most of the alluvial soils are too wet.

The acreage in pineapples is relatively low compared to that in other crops, but the total value of the export crop is high. The 1935 Puerto Rico Reconstruction Administration census reports 14,872,929

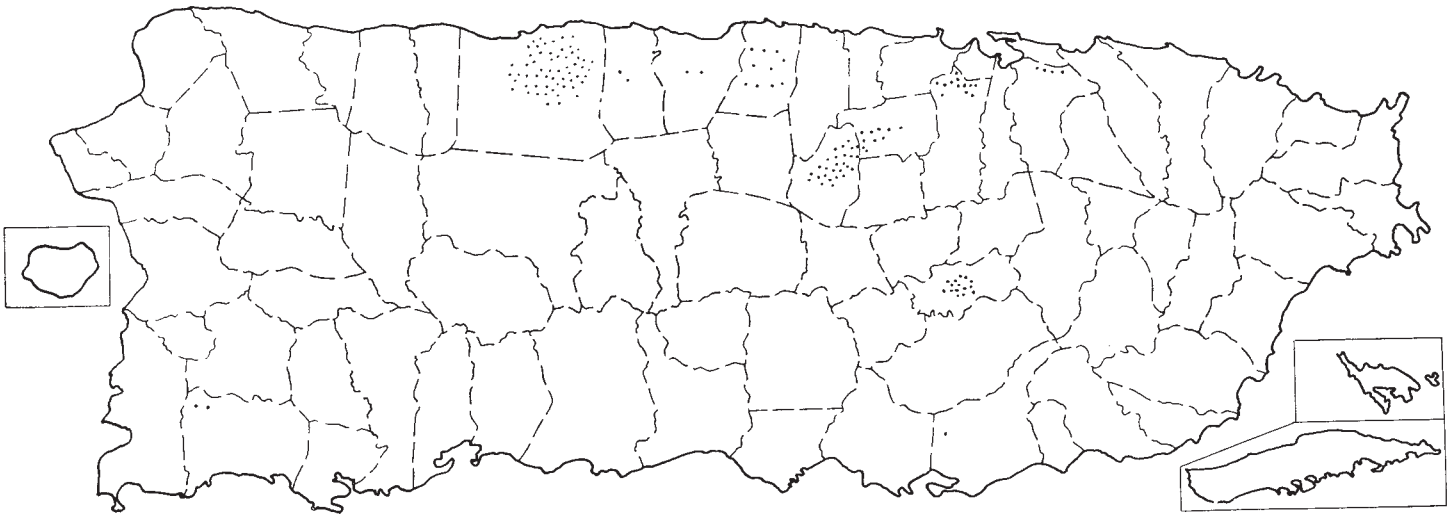

FIGURE 58.—Distribution of pineapple plants in 1935. Each dot represents 100,000 plants.
Distribución de plantas de piña en 1935. Cada punto representa 100,000 plantas.

plants on the island, of which 12,295,777 are bearing. On the assumption of 10,000 plants to the cuerda, only 1,487 cuerdas are planted to pineapples. From field observations this seems too small a figure. Figure 58 shows the distribution of pineapples according to the 1935 Puerto Rico Reconstruction Administration census. About 90 percent of the 14,872,929 plants grow in the municipalities of Arecibo, Corozal, Bayamón, Cidra, Vega Baja, and Toa Baja. Nearly all of the pineapples in the municipalities of Corozal and Cidra are produced on the Catalina, Cialitos, and Lares soils. Most of the pineapples in the municipality of Río Piedras are produced on Sabana Seca sandy clay loam. In the other municipalities mentioned, most of the plants are grown on soils of the Bayamón, Espinosa, and Vega Alta series. According to the 1935–36 Annual Book on Statistics,[20] the value of ex

FIGURE 59.—Pineapples growing on Bayamón clay. Four rows are planted to a bed, and the plants are set about 18 inches apart each way. Grapefruit trees on the other side of the road. Tanamá stony clay in the distance.

Piñas sembradas en Bayamón arcilloso. Cuatro hileras forman un banco, y las plantas están sembradas a 18 pulgadas entre sí. Al otro lado de la carretera, árboles de toronja. A lo lejos Tanamá pedrego-arcilloso.

ported pineapples before 1907 was less than $100,000 a year. Exportation gradually increased to $1,723,863 worth in 1915, gradually decreased to $479,461 worth in 1919, reached another peak of $2,278,449 worth in 1931, and again fell off. In 1939 the 463,860 crates exported were valued at $1.66 a crate, or a total of $862,423. Practically all of the pineapples exported were fresh, and nearly all of them were shipped to the United States. Puerto Rican pineapples are of good quality and bring a better price on the New York market than do those from Cuba.

A common procedure of planting pineapples in the nearly level Bayamón, Espinosa, or similar soils (fig. 59) is to have the soil in good tilth by plowing and harrowing at least once, if not twice, and then to plant either slips or suckers during the rainy season, between June and August. Some growers plant 60 percent of their land with suckers

[20] Annual Book on Statistics (1935–36), Government of Puerto Rico, Department of Agriculture and Commerce, Division of Commerce. [Mimeographed.]

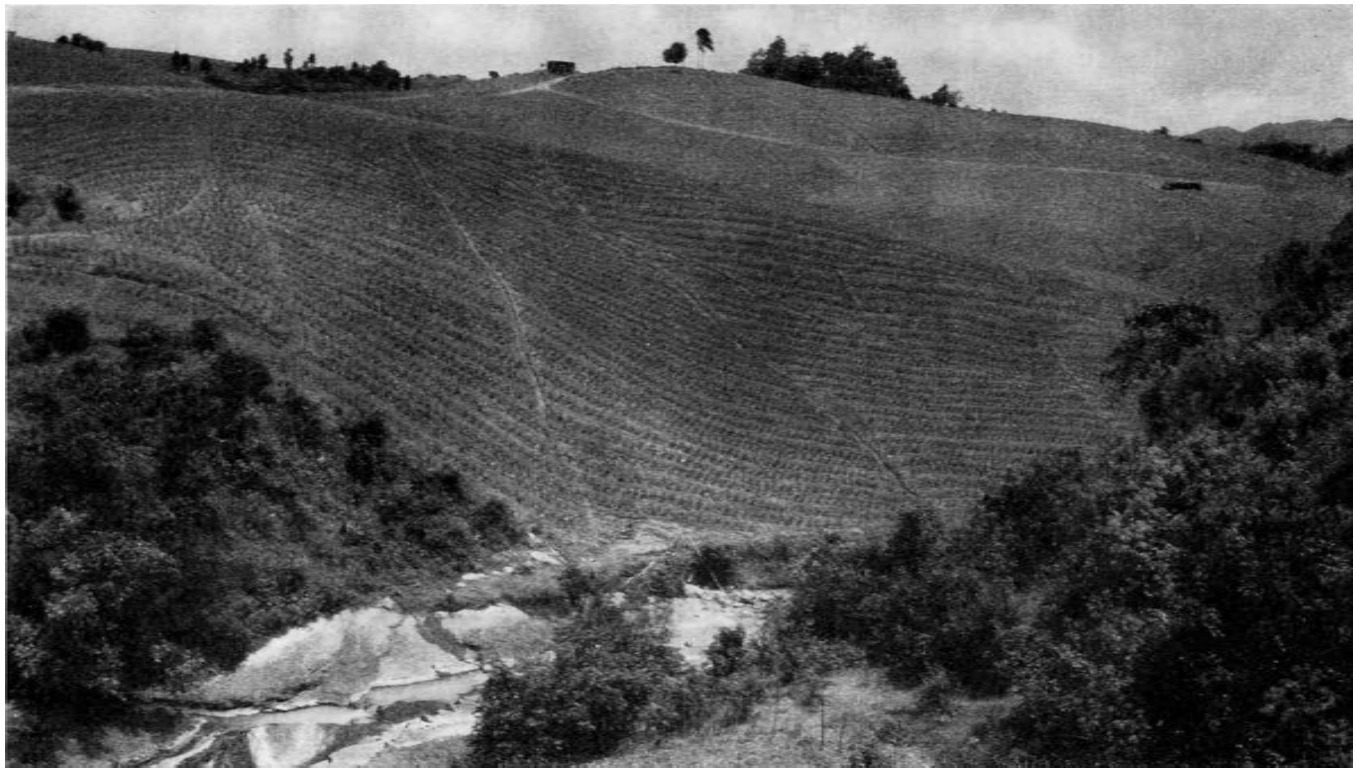

FIGURE 60.—Pineapples growing on Catalina clay near Corozal. Crisscross ditches are dug to facilitate the drainage of surplus water from the fields as quickly as possible. Owing to the permeability of the soils and lack of sand grains, there is very little gully erosion in the ditches.

Piñas en Catalina arcilloso cerca de Corozal. Zanjas de cruceta hechas para facilitar el avenamiento rápido del agua. Debido a la permeabilidad de los suelos y escasez de granos de arena, existe muy poca erosión barrancosa en las zanjas.

and 40 percent with slips. The slips generally make a larger plant, but the suckers are easier to plant, as they can be inserted in the ground at almost any depth, whereas the slips must not be set deeper than 2 inches. Both slips and suckers are planted 18 inches apart each way in four rows to a bed. The more permeable the soil, the shallower the bed. It requires about 10,000 slips to plant an acre. The slips or suckers should be vigorous, healthy, and mature. After they are pulled from the mother plant they can be placed in piles for several days before planting and still maintain their vitality.

On the Catalina, Mariana, and similar soils of the uplands three rows of slips or suckers are planted in beds about 6 inches high and 9 feet from center to center. Plants of the large Cabezona variety are set about 2 feet apart, but those of the Red Spanish variety are set the same distance apart as in the Bayamón and other coastal-plain soils. On the hillsides, numerous crisscross ditches (fig. 60) are dug to facilitate drainage of surplus water from the fields as quickly as possible yet maintain a minimum of water erosion. The water flowing across the field enters a ditch before it has time to develop sufficient speed and force to carry large soil particles. Owing to the lack of numerous sand grains and to the permeability of the soils, there is very little gully erosion in the ditches, although some of the ditches extend from the top to the bottom of the hill on slopes ranging from 45 to 70 percent. In the Mariana soils the bottoms of the ditches are bedrock, thus reducing any chance of serious erosion. In many fields it is possible to improve the prevailing planting practices by planting the pineapples with the contour of the land, rather than with the slope, and in many places it would be advantageous if some of the ditches were dug along the contour of the land, if there is no danger of the water overflowing the ditch banks and causing damage.

FIGURE 61.—A gully 2 or 3 feet deep made in Moca loam within 3 months' time. Grapefruit and pineapples planted in the same field.

Zanjón de 2 ó 3 pies de profundidad hecho en el término de 3 meses en Moca lómico. Toronjas y piñas sembradas en el mismo campo.

The steep slopes of the Moca and Lares soils planted to pineapples are very likely to become rather seriously eroded within a year after the crop has been planted. The soils of both series contain considerable sand grains and are plastic, especially the Moca. Both gully and

sheet erosion must be carefully guarded against if these soils are used for pineapples. Gullies from 2 to 3 feet deep (fig. 61) have formed on steep slopes of the Moca soils within 3 months' time. Owing to the wet plastic character of the Moca soils the pineapple beds must have considerable height, and this results in numerous rather deep ditches that are vulnerable to erosion.

Sheet erosion does not affect the yield of pineapples on the Catalina and related soils nearly so much as it does yields of other crops. With the application of rather large quantities of fertilizer, the production of pineapples on soils with a 6-inch surface soil is only slightly higher than on soils with a deep subsoil but with little or no surface soil.

The necessary cultivation in a pineapple field is to keep the surface soil from becoming hard and difficult for the plant roots, water, and air to penetrate rapidly to the subsoil. Weeds must be cut, but after the plant shades the ground very few weeds grow. Nearly all cultivation is by hand. A specially constructed hoe is used, one that has a blade set nearly parallel with the handle so that it can be used to cut the weeds or to stir the soil beneath the long bayonetlike crisscrossing leaves.

The kind and quantity of fertilizer applied at the proper time is most important and probably is the least correctly followed procedure in the growing of pineapples. Different soils need different fertilizers, and the correct quantities to apply can be determined only by long practice and numerous experiments. Some growers use from 1,500 to 3,000 pounds to the acre, applied in about equal quantities in July, September, and January. The formula seems to vary greatly with the different growers. The experiment stations at Río Piedras and Mayagüez should be consulted for the latest information regarding fertilizer formulas for different crops. Owing to the rapid progress that is being made in experimental work of this kind, the growers should keep in constant touch with new developments.

The pineapple crop generally is harvested between March and July, or about 12 months from the time it is planted, unless the plants have been "smoked," a process which hastens their maturity by about 2 months. The smoking process consists of the smothering of burning sticks beneath a canvas tent for a period ranging from 6 to 12 hours. The tents generally cover eight rows, or two beds (fig. 62), for a distance of 200 feet. Sometimes 2 or 3 acres are covered at the same time. The wood is placed in a pile about 2 feet square and is covered with green grass and soil. The advantage of this procedure is to get the fruit on an early and better market. The smoked plants produce ripe fruit during November and December. Smoking the plant prevents almost all of the slips from developing, and for that reason it is a disadvantage, as the buying of slips to start new fields is very expensive. Smoking is practiced in only a few localities and with the Red Spanish variety. The plants on the soils of the coastal plains are smoked during July and those on the uplands during October. The plants will flower within 30 days after being smoked, and the fruits ripen about 90 days later. The cost of smoking is about $25 an acre.

Harvesting consists of gathering the fruits as they ripen and carrying them in baskets (fig. 63) to trucks that haul them to packing sheds (fig. 64), where they are sorted, graded, and crated, and then (generally)

transported directly to a steamer in San Juan for shipment to United States markets. After the first crop is harvested, a second and third ratoon crop generally is harvested in the 2 succeeding years. Each crop outyields the succeeding crop by about 50 crates to the acre. The first crop on the Bayamón and related soils produces about 250 crates an acre, and the Catalina soils produce about 300 crates.

After the second ratoon crop, the field is plowed, and many farmers on the soils of the coastal plains plant crotalaria for 2 years, in order to assist the soil in building up its nitrogen content. The crotalaria is plowed under, and cane or minor crops occupy the land for a year, after which it is again ready for pineapples. On the Catalina soils many farmers replant the fields to pineapples as soon as the land is plowed. Many farmers on the Mariana soils rest the land a year before replanting to pineapples.

The pineapple plant seems to be similar to the maya plant in that it is attacked by very few pests or diseases. Mealybugs and ants

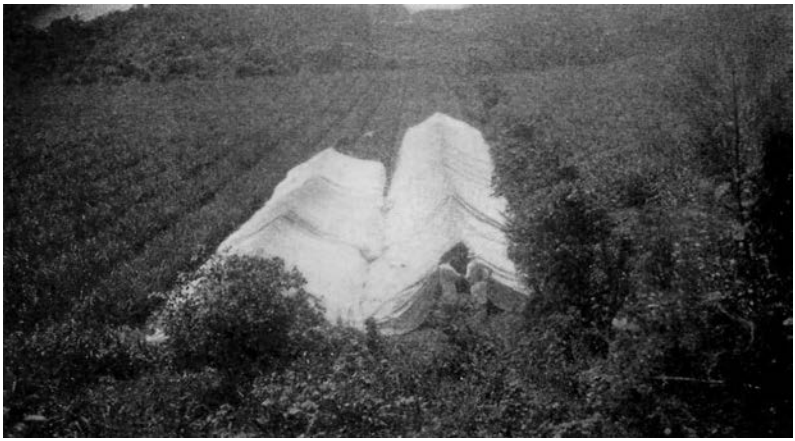

FIGURE 62.—Smoking a field of pineapples.
Ahumando un campo de piñas.

cause damage in some places. At times the fruit may be infected with black rot which frequently will destroy the center of a pineapple in 24 hours. Some growers paint the butts of the fruit with a commercial preparation of titanium trioxide for the control of black rot. A disease called gummosis affects the fruit in certain districts. The plants are sometimes affected with a chlorotic condition of the leaves. In the most severe cases the plants wither and die. In most places this condition is caused by a very high content of lime in the soil (fig. 65). It can be controlled, except where the pineapples are grown on limestone rock, by adding sulfur to the soil. This method is not economical, however, except in small spots. It is much better to choose land that is acid and adapted to pineapples. In many places the pineapples in narrow strips along the edges of roads surfaced with lime or along highways become chlorotic from the lime blowing directly on the plants or on the soil in sufficient quantity to increase the alkalinity beyond the point tolerated by pineapples. In many places, after heavy rains have washed the lime dust from the plant and leached

the lime from the immediate surface soil, the plants revive and again become green. In some fields where the soils are acid the plants become slightly chlorotic and the fruit becomes reddish pink and poor in quality, resembling the description given for the manganese chlo-

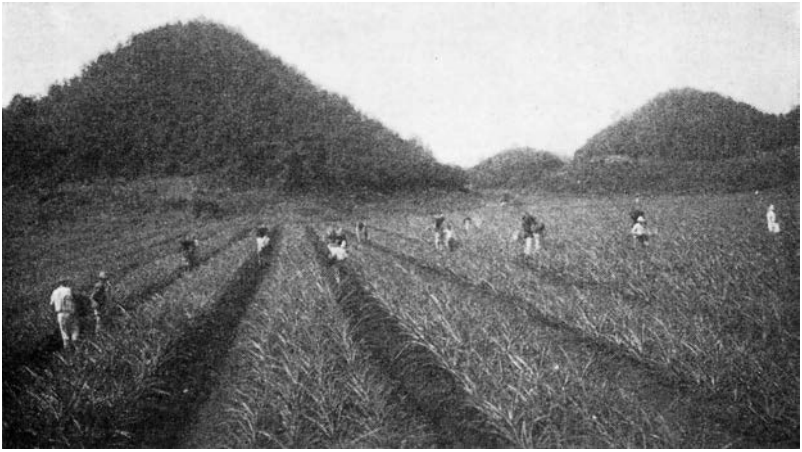

FIGURE 63.—Gathering pineapples on Bayamón clay.
Recogiendo piñas en Bayamón arcilloso.

FIGURE 64.—Pineapple field on Bayamón clay and a plant for packing both pineapples and citrus fruits.
Campo de piñas en Bayamón arcilloso y planta para empacar piñas y toronjas.

rosis of the pineapples grown on some of the soils high in manganese in Hawaii. Farmers have reported that this chlorotic condition, as well as that caused from lime, can be controlled readily by spraying the plants with iron sulfate.

The future possibilities for the production of pineapples are very promising for growers who have considerable capital and know the pineapple business. The production of pineapples on a commercial scale should not be attempted by an inexperienced grower, by a man

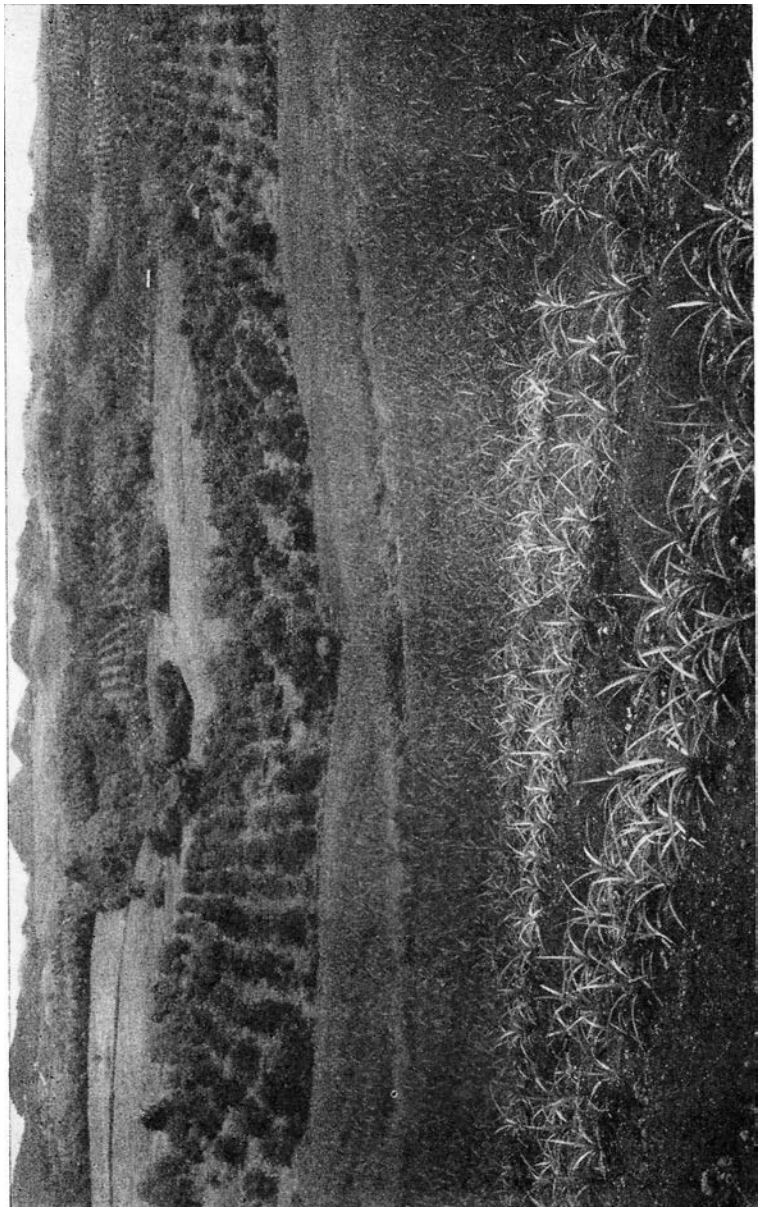

FIGURE 65.—Pineapples affected with chlorosis on a small area of Colinas clay loam. Grapefruit orchards in the distance on the Lares soils.

Piñas afectadas por clorosis en una pequeña área de Colinas arcilloso lómico. Huertos de toronjas a lo lejos en suelos Lares.

with small capital, or on a very small farm. Pineapples require more careful attention than any other commercial crop grown on the island. They are not necessarily hard to grow, nor do they require highly fertile soil, but the successful grower must know the habits of this

plant from the time it is planted until the fruit is sold. According to Henricksen, in El Libro de Puerto Rico by Fernández y García (*17, p. 609*), the cost of producing 258 boxes of pineapples an acre is $994.46. This includes 10,000 slips for seed at a cost of $200, cultivation, planting, fertilizing, interest on land and working capital, taxes, picking, packing, transportation to New York, selling commission, and other expenses. It may readily be seen that with such expense only those growers having considerable capital should attempt to plant this crop. A fairly large acreage is necessary in order to handle the crop more efficiently. On a large farm, slips and suckers for propagation can be produced; thereby the cost of buying slips is reduced. Packing sheds can be built on the large farms, to reduce the cost of crating and packing the fruit.

Considerable profit has been made in growing pineapples during the last few years; this has encouraged the growers to plant many acres. Probably very soon the increased production will lower the price and consequently lower the profit. The acre cost of planting and producing pineapples changes little throughout the years, but the price obtained for the fruit changes considerably. Competition is greater between the pineapple growers in Puerto Rico and Cuba than between the Puerto Ricans and Hawaiians. The canned-pineapple industry undoubtedly will increase in importance in Puerto Rico, and it will help in stabilizing a favorable market.

With the exception of the loss of packing sheds and other buildings on the pineapple farms, the growers of pineapples are not seriously affected by hurricanes. The hurricane risk, however, must be considered with every crop grown in Puerto Rico. Most of the growers of pineapples on all soils except those of the Mariana series, produce several different crops, such as grapefruit, minor crops, and sugarcane. Those on the coastal plains may have a patch of tobacco in addition to the other crops, and all these crops lessen the chances for complete crop failure. Most of the pineapple farms are about 200 acres in size.

COCONUTS (COCOS)

The coconut palm is one of the most picturesque trees along the sandy beaches of tropical countries (fig. 66). Its beauty is surpassed only by its usefulness. The nuts when green are filled with a colorless fluid which is one of the more popular refreshing drinks in Puerto Rico. Usually the coconut water, or agua de coco, is consumed directly from the nut with the husk attached; in recent years, however, the water is mixed with some carbonated water and sold in bottles. When the nuts are matured, a part of the fluid coagulates and forms the white oily meat that is used for desserts, confectionery, and the extraction of oil. The meat is relished by hogs, and when the price is less than $8 or $10 for a thousand nuts, many of the owners of coconut plantations consider it more economical to feed the nuts to hogs than to pay for the cost of gathering, grading, and transporting them.

The husks that protect the nuts are removed at the plantation by skilled laborers in much the same manner as the husks are jerked from ears of corn by a veteran corn husker. The coconut husker stands in one place, and, instead of having a corn hook or peg on his hand, he has a stationary perpendicular sharp-pointed iron bar that is firmly embedded in the soil and extends about 30 inches above the ground.

Each nut is brought down against the sharp metal point with a hard quick blow, then with a quick twist of the nut the husk is split and removed. From 1,000 to 3,000 nuts can be husked in a day by a good husker. The average price paid the husker is $1 for each 1,000 nuts husked. The husks are sometimes sold for the manufacture of brushes and coarse fabrics. The leaves of the coconut palm very often are used in the thatching of the native bohíos and sheds. The long slender erect unbranched trunks sometimes are used for fence posts or are sawed into boards. The lumber produced is fairly durable—more so than is generally supposed.

Coconuts were first taken to Puerto Rico about 1525 from the Cape Verde Islands. Their natural environment is the sandy beaches, and they readily became established. The area that is economically adapted to the production of coconuts is limited to a narrow sandy

FIGURE 66.—Coconut palms growing on Cataño sand along the north coast.
Palmas de coco en arena Cataño de la costa norte.

more or less continuous strip of land fringing the coast. The production of coconuts has never been very great, owing to the small extent of land that has the proper soil, climate, and elevation for a more profitable production of coconuts than of any other crop. According to the 1935–36 Annual Book on Statistics, the value of exported coconuts for the years 1902 to 1936 has ranged from a low of $12,720 in 1902 to a high of $1,142,412 in 1920. The value then declined to $152,055 in 1933, and rose slightly thereafter to $306,021 in 1939. Nearly all of the exported coconuts are sent in the shell to the United States. Practically no copra, or the dried meat of the coconut, is exported. The value of exported nuts has ranged from $20 to $45 a thousand. It was $20.36 in 1939.

According to the Puerto Rico Reconstruction Administration census, the number of coconuts harvested in 1910 was 15,568,000; in 1920, 24,608,000; in 1930, 12,003,000; and in 1935, 27,901,000.

Probably three-fourths of the nuts are exported. There were 157,621 bearing palms and 539,243 nonbearing palms in 1935. Assuming that an average of 50 palms are planted to the acre, 13,937 acres, or 3.3 percent of the harvested cropland in Puerto Rico, was in coconuts in 1935. This crop occupied the sixth largest acreage of the cultivated crops during that year.

Figure 67 shows the distribution of coconut palms, as recorded from data of the Puerto Rico Reconstruction Administration census of 1935. The municipalities having the largest number, ranking in the order named, are: Loíza, Carolina, Río Grande, Cabo Rojo, Isabela, and Humacao. These six municipalities produced more than one-half of the coconuts grown on the island. From figure 67 it may readily be seen that most of the coconut palms grow near the coast.

Coconuts grow better and produce higher yields near the sea at low elevations than they do inland at high elevations. For best production coconut palms require a well-drained fairly fertile loose sandy neutral or calcareous soil receiving more than 60 inches of average annual rainfall and being at an elevation of less than 300 feet above sea level. The best coconuts observed during the course of the survey were growing on Cataño loamy sand. Other soils well adapted to coconuts are the well-drained members of the Aguadilla, Cataño, and Meros series; soils of the Maleza, Guayabo, Río Lajas, Palm Beach, and Jaucas series; and coastal beach. Such soils as the sandy-textured types of the river flood plains would be even more productive than the soils just mentioned, but, as they return a high profit when planted to sugarcane, they are rarely planted to coconuts on a commercial scale. The sandy soils, such as the Corozo, Algarrobo, and St. Lucie, are only fair for the production of coconuts. Coconut palms seldom are seen at high elevations. Those that do grow in such places produce a fairly large number of nuts, but they are small and sell for a low price. Palms growing in areas receiving less than 40 inches of average annual rainfall and in which the roots cannot penetrate to ground water produce small nuts of low quality.

Coconut palms will grow at the water line along the beach, but where they are so near the water they are not very productive. They will be stunted or killed in almost all soils having a water table at a depth of less than 18 inches from the surface. They will grow very well if the water table is at least 30 inches below the surface. They can endure rather salty or alkali land; in fact, some experiments show that a small quantity of salt added to the tree roots is beneficial. Coconut palms were growing but not producing nuts on land having 0.9 percent of black alkali in the first foot of soil. Small poor-quality nuts were produced on soils having 0.6 percent of soluble salt, some of which was sodium carbonate.

The mature unhusked and unblemished nuts are used for purposes of propagation. Coconuts are not self-fertilized, and care must be used in the selection of seed to see that both parents are desirable as to quality and quantity of nuts produced. On most plantations the nuts are planted in checkrows about 34 feet apart at a depth slight enough to expose a part of the nut. In some places the seed nuts are first planted in beds and afterward transplanted to the field—in about a year. It takes about 6 months for the seeds to germinate. Very few plantation owners use fertilizer, and very little cultivation is necessary. Regardless of the age of the palms, the space between them

can be and often is planted with pigeonpeas, beans, sweetpotatoes, and yuca. These crops need cultivation, and they are sometimes fertilized, which also helps the coconut palms.

Generally the palms start producing when they are about 6 years old, and they continue to produce for many years. The nuts are harvested about every 2 or 3 months, and the yearly yield for a producing palm is from 40 to 60 nuts. Some palms, however, bear more than 200 nuts a year. An acre of productive palms will produce from 5,000 to 10,000 nuts a year. When the palms begin to produce, the nuts are in all stages of development. Some of the palms are more than 75 feet tall, and it is not easy work for the nut gatherers to climb barefooted to the towering, waving nut-laden crowns. Some of the coconut gatherers use a long slender bamboo pole that has a short sharp knife firmly fastened to one end in such a way that the blade points obliquely downward. A good pull severs the stalk and the nuts fall. Some of the nuts, especially the green ones, are cracked by the fall.

Coconut bud rot is the most serious disease of the palm. This fungus disease attacks and kills the terminal bud, and eventually almost all the leaves drop, leaving the trunk naked. Rats do considerable damage unless metal bands about 10 inches wide are fastened to each tree to a height ranging from 4 to 10 feet from the ground, to prevent the rats from reaching the nuts (fig. 25). The rhinoceros beetle also does considerable damage to young palms.

The chief varieties of coconuts grown are the Green and the Brown, which are produced on both the dwarf and the tall palms.

The future for the coconut-plantation owners is more encouraging than for most of the grapefruit growers. There is, however, considerable risk and uncertainty in the growing of coconuts. The tall palms are easy prey for the more severe hurricanes, and in some places the orchards are completely destroyed during one storm. It requires more than 6 years to reestablish a productive orchard. At present many orchards are still in a more or less abandoned condition from the effects of the serious hurricane of September 13, 1928.

Producing orchards sell for about $300 an acre. They are therefore assessed at a rather high figure, and when the orchard is only partly productive the profit from truck crops and the few nuts produced is used in paying taxes and interest. The expense of handling a productive orchard is low, and if the selling price is favorable good profits can be made.

BANANAS (GUINEOS) AND PLANTAINS (PLÁTANOS)

Owing to the similarity of bananas and plantains they will be discussed together. In Puerto Rico the bananas are about 10 times as plentiful as the plantains. Both are perennial herbaceous plants.

Bananas probably were introduced into Puerto Rico about the time of the first importation of coconuts, or about 1525. Some of the slave-trading ships undoubtedly brought bananas from northern and western Africa. Plantains and bananas are the most important food fruits on the island. Bananas can be purchased at any city market (fig. 68) or local roadside rural store at any time of the year for a very low price. The plantains are more expensive, but they are highly nutri-

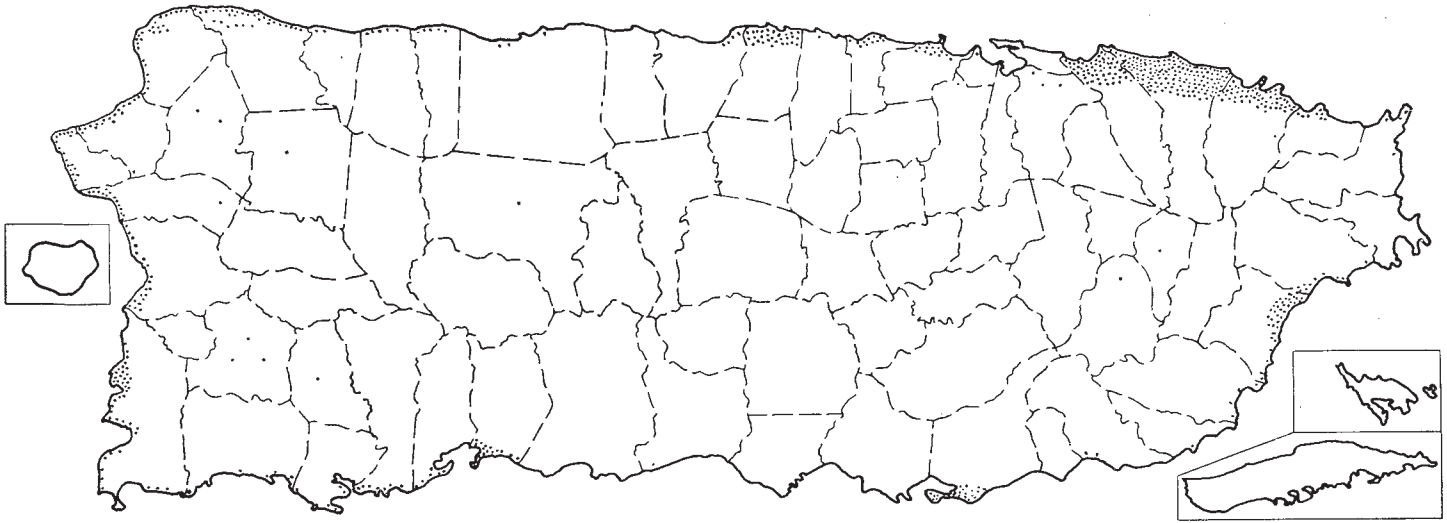

FIGURE 67.—Distribution of coconut palms in 1935. Each dot represents 1,000 palms.
Distribución de palmas de coco en 1935. Cada punto representa 1,000 palmas.

tious and one of the most wholesome fruits grown in Puerto Rico. They constitute an almost indispensable part of the diet of the jibaros.

The banana plant (fig. 69) is developed from an underground stem, or rhizome, called a corm, which sends out shoots that subsequently

FIGURE 68.—City market at Mayagüez.

Plaza del mercado de Mayagüez.

FIGURE 69.—Bananas growing on Catalina clay, where the mean annual rainfall is about 90 inches.

Guineos sembrados en Catalina arcilloso donde el promedio anual de lluvia es alrededor de 90 pulgadas.

develop to form the leafstalks, trunk, or stem. The leafstalk produces a crown of long, broad, umbrellalike leaves. Often, during tropical showers, the leaves are cut from the stalk and are used, especially by boys and girls, as umbrellas for protection against the rain. The entire plant is succulent and has a large area for transpiration.

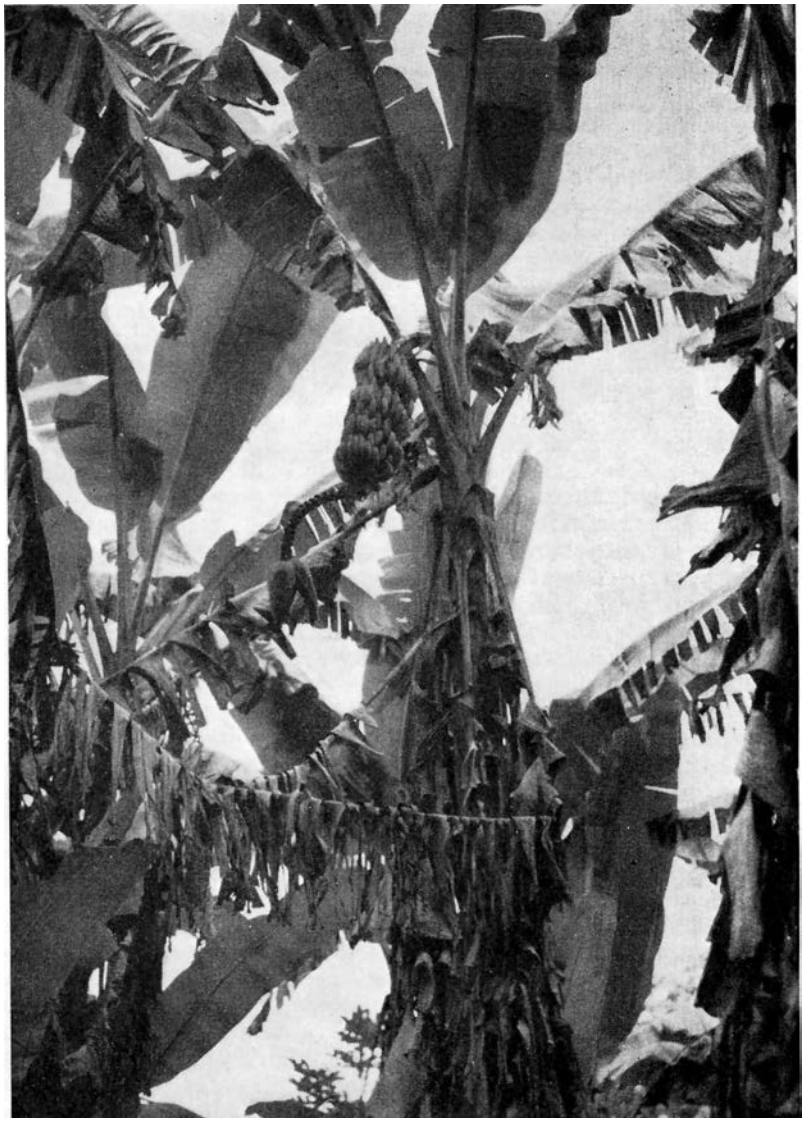

FIGURE 70.—The flowering stem is produced from the leafy crown, turns downward, and produces a bunch of bananas.

El tallo de flores es producido de la corona de hojas, se vuelve hacia abajo y produce un racimo de guineos.

The flowering stem is produced from the leafy crown, turns downward and produces a bunch of fruit (fig. 70), including from 100 to 200 fingers, or individual bananas. The plantain produces about 35 fingers to a bunch. The bunch is picked green and allowed to ripen in the market or store. The bunches are developed about 10 months from the time the buds appear, or when the plant germinates. After the bunch is gathered the stem, or trunk of the plant, is cut off from

1 to 3 feet from the ground. Fresh shoots or suckers will then appear, and a ratoon crop is produced.

Both bananas and plantains need considerable water, and for the most part they grow in areas of high rainfall. Coffee, bananas, and plantains very often are seen growing in the same district. Coffee is restricted to a narrower range of adaptation than the other two plants.

Figures 71 and 72 show the distribution of bananas and plantains, respectively, according to the 1935 Puerto Rico Reconstruction Administration census. The six municipalities having the greatest number of growing plants of bananas and plantains combined are Lares, Utuado, Orocovis, Adjuntas, Las Marías, Jayuya, and Maricao. The municipalities that lead in the production of bananas do not necessarily lead in the production of plantains. These muncipalities produce about three-fifths of the banana and plantain plants growing in Puerto Rico.

Both bananas and plantains are planted on nearly every soil type, and nearly every rural dwelling has a small patch near the dooryard where the soil is enriched by waste from the house. Yields vary greatly on the different soil types. For best growth and largest production, both plants require a deep, fertile, well-drained soil receiving an average of more than 80 inches of rainfall, well distributed throughout the year, or irrigation. The Catalina, Cialitos, Alonso, Utuado, and similar soils of the humid uplands are well adapted to these plants, and fair production is obtained on the concave slopes or the long, gentle slopes at the bases of the hills. In these areas the soil is much deeper, higher in organic matter, and generally is more moist than on the convex slopes or ridges. Such soils as those of the well-drained or slightly imperfectly drained river flood plains are the best for these crops, but the profit from either bananas or plantains on these valuable soils does not compare with the profit from sugarcane. Low yields may be expected from poorly drained soils, such as those of the Piñones, Coloso, and similar series, as well as from such shallow soils as the steep phases of the Soller, Colinas, Múcara, and similar soils.

The usual procedure for planting either plantains or bananas is to dig holes 18 inches square and about 10 inches deep, spacing them about 9 feet apart each way. The holes are unmolested for at least a week, in order that the soil may become aerated. Just before planting, some of the surface soil is put in the bottom of the holes, and one seed or cutting is inserted in each hole and covered with additional surface soil. Generally the hole is not completely filled artificially but is left open, in order to catch the beneficial run-off water and to act as a catch basin in the control of erosion. From 550 to 650 seeds are required to plant an acre. The seed used are either the sound suckers that protruded from the rhizomes, or fairly large slices containing one healthy bud or eye of a growing plant that has not fruited. Great care must be used in obtaining disease-free, vigorous seed. On most farms the seeds are planted over a period extending from February to August. The soil is cultivated only sufficiently to kill the weeds and to maintain a good tilth. Very few growers fertilize bananas, but some fertilize plantains, as they are more valuable and more profitable. The common practice is to place the first application of fertilizer in the hole with the seed, the second application around the plant 3 or 4 months later, and the third when the fruiting stem appears. The plant produces only one bunch, ordinarily within 11 months from the time of planting. Suckers appear, and the plant can thus survive.

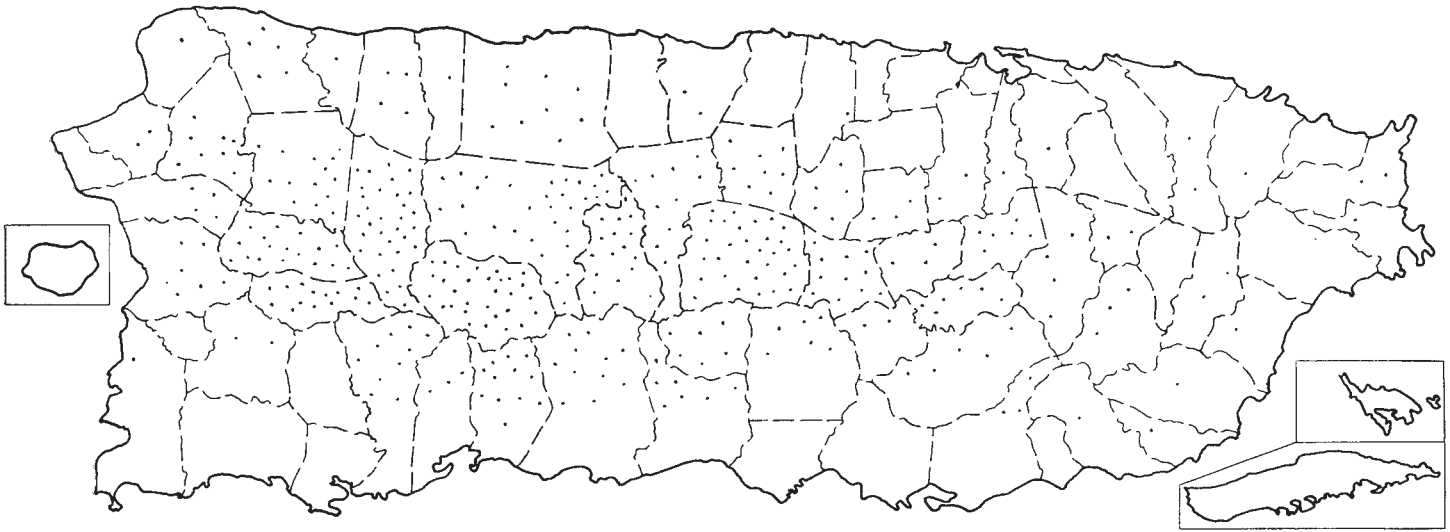

FIGURE 71.—Distribution of bananas in 1935. Each dot represent 100,000 plants.
Distribución de guineos en 1935. Cada punto representa 100,000 matas.

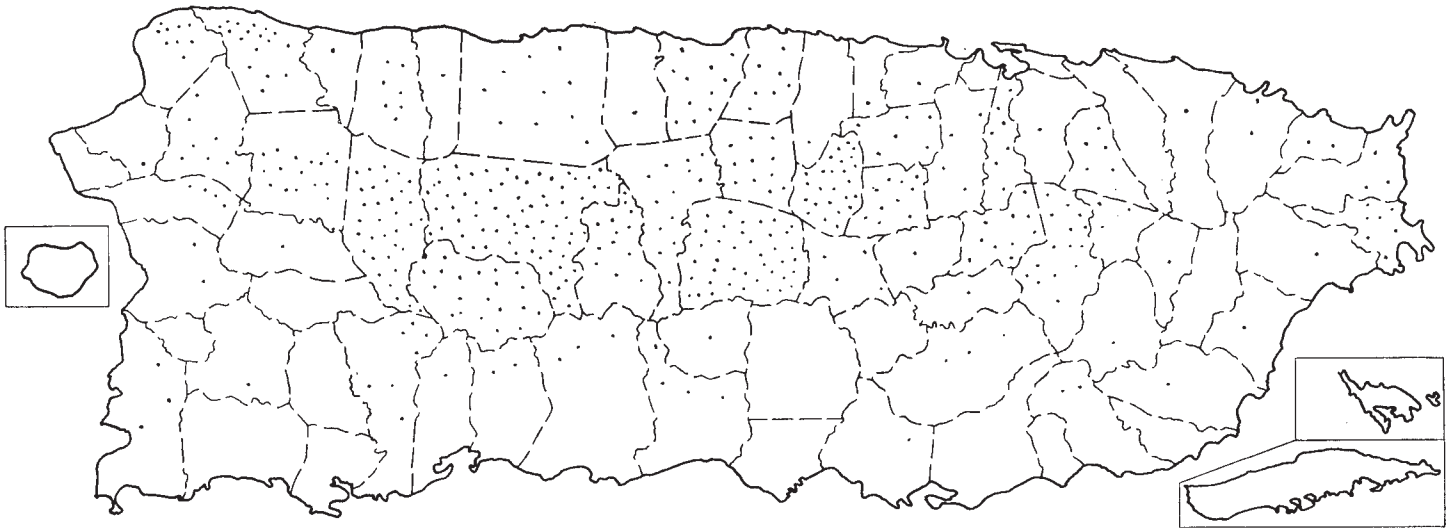

FIGURE 72.—Distribution of plantains in 1935. Each dot represents 10,000 plants.
Distribución de plátanos en 1935. Cada punto representa 10,000 matas.

The acreage in plantains has increased rapidly during the last few years, owing in part to the encouragement given by the Federal Land Bank to the owners of coffee farms, who are seeking to rehabilitate their land. Many small areas are available throughout the island for an increased acreage of both plantains and bananas, and these undoubtedly will be planted in the future. About 8,000 acres are now used in the production of bananas and plantains. Almost $80,000 worth of plantains were imported into Puerto Rico from the Dominican Republic during the fiscal year 1937.

Plantains sell for about 1 cent apiece and bananas for about 5 cents a dozen. Many different varieties of bananas are sold on the market.

The future for the production of bananas and plantains on a large scale is not promising. In order to make much profit on a large-scale production, large areas of well-drained alluvial land should be available, and in Puerto Rico nearly all of such land is now used for sugarcane which brings in greater profit than bananas or plantains under the present economic conditions.

Both bananas and plantains are subject to many diseases and to injury from storms. Probably they always will be important subsistence crops for local consumption.

CORN (MAÍZ)

Probably Puerto Rico has been producing corn for more than five centuries. According to the census of the Puerto Rico Reconstruction Administration for 1935, corn occupies the third largest area of all crops grown on the island. Corn from the 70,217 acres harvested in 1930 produced only 449,016 quintales (which amounts to 801,813 bushels) or about 11 bushels to the acre. Considerable areas that were in corn, however, also produced from 300 to 400 pounds of beans an acre at the same time, and many acres had produced from 600 to 800 pounds of tobacco during the same year.

In 1901 Puerto Rico exported 4,267 bushels of corn to Cuba and 1,843 bushels to the Dutch West Indies (*46, p. 67*). In recent years Puerto Rico has imported nearly one-fourth as much corn as the quantity produced on the island. During 1939, 321,645 bushels were imported, of which only 7,146 bushels came from the United States. Santo Domingo exports large quantities to Puerto Rico, especially from Puerto Plata. Recently the total value of corn meal imported has almost equaled or exceeded the value of imported corn.

Figure 73 shows the distribution of corn as recorded by the Puerto Rico Reconstruction Administration census of 1935. It may readily be seen that the largest acreage of corn correlates fairly closely with the area having the largest rural population. This bears out observations made in the field. Nearly every rural dwelling, except the ones located on land valuable for the production of sugarcane, has a small corn patch nearby, very often on very steep land as seen in figure 108. Corn is not grown on land that is well adapted to sugarcane or grapefruit, on irrigated land, or on the best soils of the island. The municipalities having the largest acreage in corn, ranking in the order named, are Cabo Rojo, Isabela, San Lorenzo, Yauco, Coamo, and Lajas.

The cornfields, with the exception of those in the southwestern part of the island, are small, are of irregular shape, and are managed en-

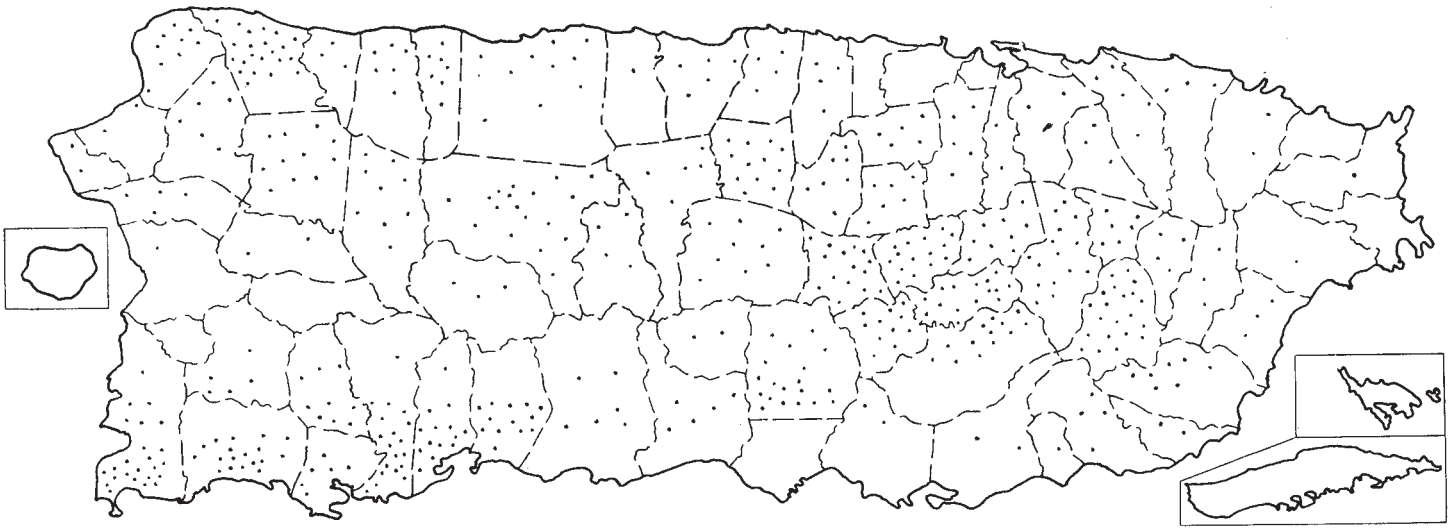

FIGURE 73.—Distribution of corn in 1935. Each dot represents 100 acres.
Distribución de maíz en 1935. Cada punto representa 100 acres.

tirely by hand labor. In the vicinity of Parguera and Peñuelas, the fields range in size from 5 to 30 acres and are more or less rectangular or square. Here some machinery is used in the preparation and cultivation of the land. These fields are owned and operated by owners of large ranches. In this district considerable areas of the Fraternidad soils that are not irrigated are planted to corn. The land is first plowed with oxen, then harrowed, and furrows are made about 4 feet apart. From 10 to 15 pounds of seed are planted to the acre. Seeding is done by hand, usually in September or October. The corn is harvested in March and April. The pickers, often from 6 to 10 in one small field, pick and husk the ears and throw them in piles on the ground. Later the ears are loaded into oxcarts and hauled to bins on the ranches. In this area the principal variety grown is Blanco de Cabo Rojo which yields from 20 to 30 bushels to the acre on the Fraternidad soils during favorable years and from 10 to 15 bushels on the more sandy soils, such as Maleza loamy sand and Guayabo fine sand. On many farms squash (calabaza) is planted between the corn rows. Very little fertilizer is used. Most of the corn grown here is consumed by the large dairy and range herds that are prevalent throughout this district.

Much of the corn produced in small fields in the humid sections is planted in holes, immediately following the last picking of the tobacco leaves, early in December. About four kernels of the native seed are planted in each hole, and the holes are spaced 3 by 2 feet. Beans frequently are planted between the corn rows, and both crops obtain some benefit from the fertilizer applied to the tobacco crop recently harvested. All cultivation and weeding is done by hand labor with hoes and short-handled pickaxes. Corn in the humid areas produces from 5 to 15 bushels to the acre, and most of it either is fed to chickens and pigs or is ground in small stone hand-operated mills for corn meal.

The native corn has small kernels and thick short cobs. The principal insects injuring corn are the corn earworm, cornstalk borer, and aphid. In some areas the cornstalk borer is the limiting factor in corn production. In the semiarid section near Parguera, giant milkweed and sandburs are the most troublesome weeds in the cornfields.

Corn always has been and probably always will be an important crop for the jibaros who grow subsistence crops. It fits in conveniently with their yearly crop rotation of tobacco, corn, and beans. The selling price of corn ranges from $1.25 to $2.50 a hundred pounds. The acre yield could be doubled easily in the humid section if better varieties of seed were planted and applications of fertilizer made. The adoption of better varieties of sweet corn also should be given more consideration than it has been given in the past. More sweet corn should be grown and consumed by the laboring classes.

SWEETPOTATOES (BATATAS)

When the Spaniards arrived in 1493, sweetpotatoes were grown fairly successfully by the Arawak Indians on the alluvial lands of the Yabucoa Valley and elsewhere. This plant probably came into Puerto Rico by way of the Venezuela-Trinidad route during early intercourse among the Indian tribes.

144038—41——9

This is the most widely planted root crop in Puerto Rico, and, according to the Puerto Rico Reconstruction Administration census for 1935, 36,947 acres, or 5.2 percent of the harvested cropland of the island, were planted to this crop. It rates sixth in acreage of all crops planted. The acreage of sweetpotatoes has varied in different years. There was a considerably larger acreage in 1929 than in either 1919 or 1935.

Figure 74 shows the distribution of sweetpotatoes according to the 1935 Puerto Rico Reconstruction Administration census. It may readily be seen that this plant is closely associated with areas where the rural population is dense (fig. 21). It is widely planted throughout the island, but the concentration seems to be greater in the municipalities of Isabela, Utuado, Arecibo, Cidra, Morovis, and San Lorenzo than in any other municipality. This crop, like many of the other subsistence crops, can be planted on almost any soil type at any time of the year in any part of the island, without complete failure. For best production, however, the soil should be reasonably fertile well-drained fairly deep loose sandy loam or loamy sand. A very good growth of vine is produced on rich alluvial loams, clay loams, and clays and on some of the heavy clay upland soils, but the best production is obtained on Cataño loamy sand, Maleza loamy sand, and similar soils. These soils produce from 6,000 to 7,000 pounds to the acre. The acre yields of other soils are as follows: Cayaguá sandy clay loam, 4,000 to 5,000 pounds; Alonso clay, smooth phase, 3,000 to 4,000 pounds; Utuado loam, smooth phase, 2,000 to 2,500 pounds; Sabana Seca sandy clay loam, 1,500 to 1,700 pounds; Múcara silty clay loam, 1,000 to 1,200 pounds; and Colinas clay loam, 800 to 1,200 pounds. It is not an unusual sight to see sweetpotatoes growing on Tanamá stony clay, where the only visible soil is in little pockets or crevices in the rocks. Such soil produces very low yields, but almost every bohío has a small patch of sweetpotatoes planted in the garden, even where the surface is almost all bare rock.

The selling price of sweetpotatoes is about 1 cent a pound, and they can be purchased at any of the city markets or at the rural roadside stores at any time of the year. They can be kept for a long time if properly stored in a cool dry place, preferably in the ground and covered with loose sandy soil.

The usual procedure for planting sweetpotatoes is to stir the ground to a depth of 6 inches with a walking plow or a hoe, then to make ridges about 6 inches high, 2 feet wide, and 3 feet from center to center. Either the stems of healthy plants or clean disease-free slices of the roots are used for seed. If the stems are used, pieces from 16 to 24 inches long are buried about 3 inches deep in the center of the ridges. The cuttings are spaced about 2 feet apart. If the roots are used, about 10,000 slices are needed to plant an acre. Sweetpotatoes may be planted at any time, but preferably during wet weather when the soil is moist. In the tobacco district near Cayey and San Lorenzo, the sweetpotatoes are planted after the tobacco is harvested. Very few farmers apply fertilizer to the sweetpotato crop, and little or no cultivation is necessary after the vines are large enough nearly to cover all the bare ground. This is a fairly good crop to prevent sheet erosion on steep hillsides, especially after the plants have attained a fair size.

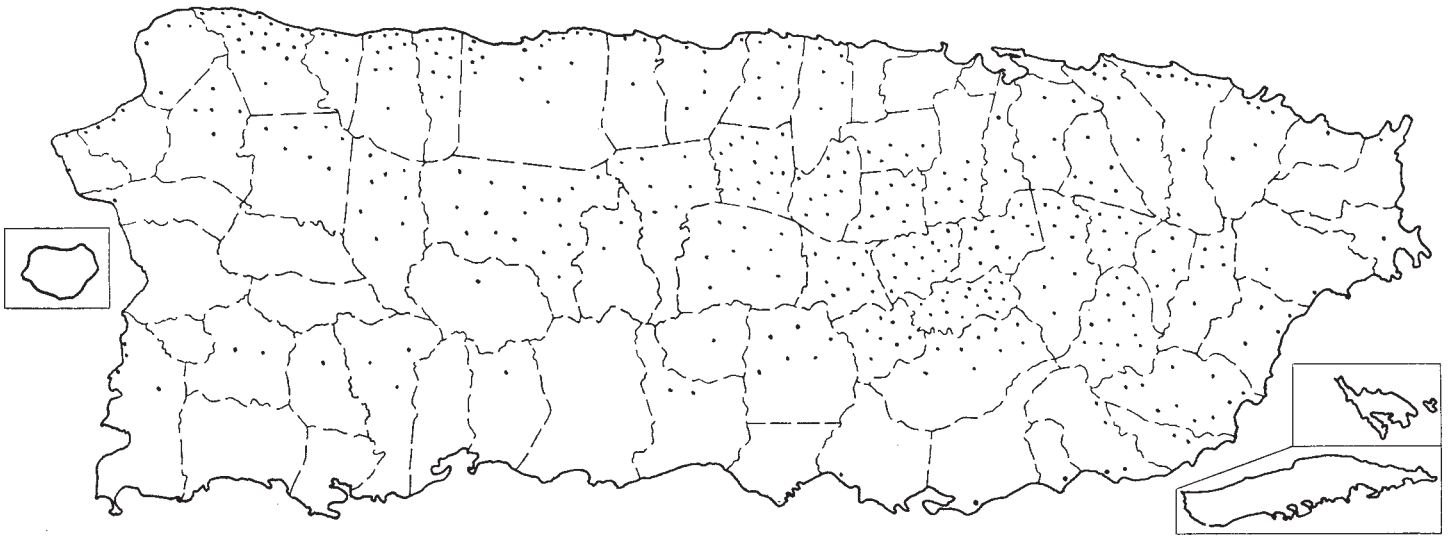

FIGURE 74.—Distribution of sweetpotatoes in 1935. Each dot represents 100 acres.
Distribución de batatas en 1935. Cada punto representa 100 acres.

The crop is harvested at a time ranging from about 4 to 6 months after planting, depending on the variety grown. The principal varieties are Key West(a white variety) and Mameya (a yellow variety).

Owing to the increasing population, the acreage in sweetpotatoes undoubtedly will increase. Sweetpotatoes are relished by nearly all Puerto Ricans, and, supplemented with other subsistence crops, are the staff of life for many thousands of people. Sweetpotatoes are easily and cheaply grown, and they do fairly well on land that is too poor for most of the other subsistence crops. Sweetpotatoes are fairly tolerant to "alkali" soils—more so than most other subsistence crops, except bananas.

Disease is not a limiting factor in the growth or production of sweetpotatoes, as they are comparatively free from pests and diseases. Yields would be greatly increased if the ground were properly fertilized with from 300 to 600 pounds of complete fertilizer, such as a 4–8–10 mixture, and if only pure or high-grade seed were used.

YAUTIA, DASHEEN, OR TANIA (YAUTÍA)

Yautias were grown successfully by the native Indians when the Spaniards landed in 1493. The yautia probably is one of the oldest cultivated crops of tropical America. Several species of uncultivated yautia (dasheen), commonly known as malanga, grow along the island's shaded stream courses and the moist areas at the heads of drains. The tubers of the cultivated varieties are nutritious and palatable when properly prepared. The entire production is consumed locally. Sometimes the large rootstock is eaten, as are also the leaves and rhizomes. The tubers are more or less cylindrical or oval and range from 4 to 8 inches in length. Different varieties have different shapes and colors—they may be white, red, or yellow. The tubers are prepared for eating in as many different ways as are potatoes. When the rootstocks are used, they generally are boiled. The young leaves are stewed as greens. Flour is sometimes made by grinding dried slices of the tubers. It may readily be seen that the yautia is a valuable plant for the poorer people. Fortunately the plant is not seriously attacked by insects or plant diseases, and it will grow and produce fair yields on nearly every soil type if the rainfall is sufficient. The production, however, varies considerably, according to soil and moisture conditions. For best results, yautias require a rather deep fertile medium heavy soil that is slightly poorly drained or receives a high yearly rainfall. On such soils as those of the Yabucoa, Coloso, and Fortuna series, the production ranges from 8,000 to 10,000 pounds to the acre. Yields on less desirable soils are considerably below 8,000 pounds. A production of 2,000 pounds is a good yield for such shallow soils as the Múcara, Tanamá, and Colinas. Such soils as the Catalina, Cialitos, Bayamón, and similar soils produce an acre yield ranging from 3,000 to 5,000 pounds. The sandy soils, such as the Aguadilla and Cataño, yield 4,000 to 6,000 pounds.

At any time of the year a small patch of yautias may be seen growing very close to nearly every rural dwelling in the humid and subhumid areas. The plants are planted promiscuously in many places along shaded ravines and moist spots, but on the hillsides the common practice is to dig 10-inch cup-shaped holes spaced 2 feet apart and to insert one or two small tubers or a part of the top of the old root-

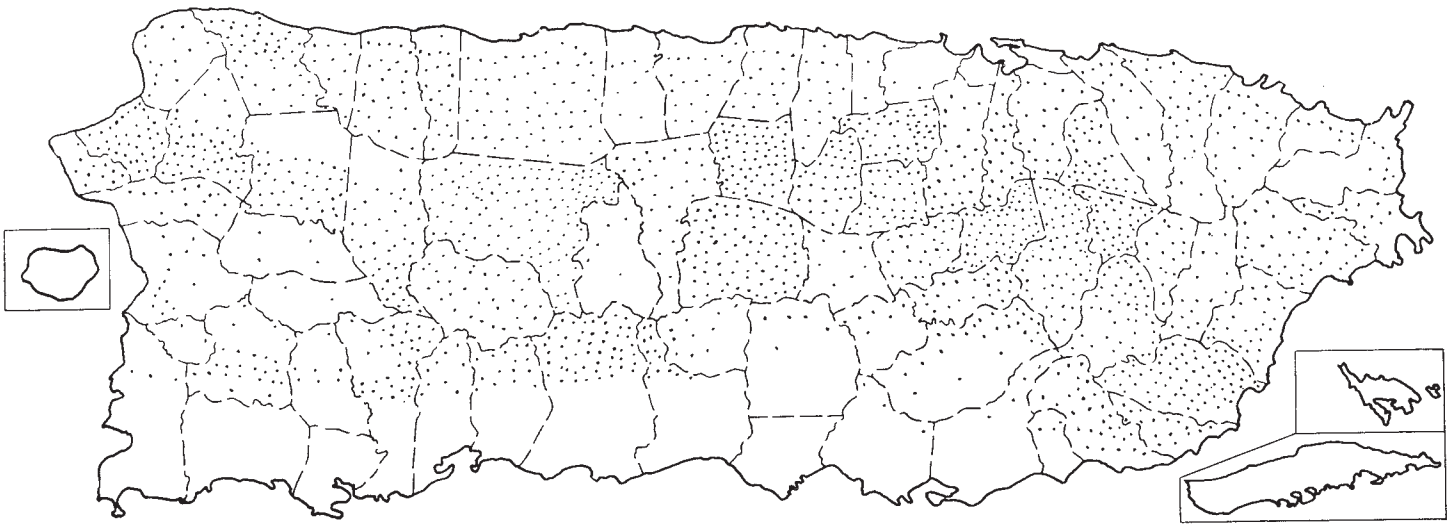

FIGURE 75.—Distribution of yautias in 1935. Each dot represents 10 acres.
Distribución de yautías en 1935. Cada punto representa 10 acres.

stock. The hole is then about half filled with soil. Wash from the hillsides eventually will fill the holes, replenish the organic supply, and add more moisture to the plant than if the plant were set flush with the ground. The holes serve as effective catch basins in preventing erosion as they check the force of the run-off water.

All cultivation is performed by hand labor, and very little fertilizer is used. Farmers who apply fertilizer use a 6–8–10 or 6–10–15 mixture, and about 1,000 pounds to the acre in two applications—the first 500 pounds after the first cultivation and the second 500 pounds about 5 months later.

Yautias are harvested from 8 to 12 months after the date of planting, depending on the varieties planted. The principal varieties grown are Blanca, Amarilla, Filipina, and Kelly. The Blancas probably are the most common, but the Amarillas are the most productive and the most preferred. The usual method of harvesting consists of pulling the leafstalk and digging the tubers that are not exposed, in much the same manner as potatoes are dug by hand labor. The composition (*4, p. 23*) of yautias compares favorably, especially in protein and carbohydrates, with that of either potatoes or sweetpotatoes. The fat content is less than in sweetpotatoes but greater than in potatoes. Yautias contain many more calories than potatoes but slightly less than sweetpotatoes.

Figure 75 shows the distribution of yautias in Puerto Rico, according to the 1935 Puerto Rico Reconstruction Administration census. It may readily be seen that this plant has a wider distribution throughout all the humid parts of the island than any other root crop.

The municipalities having the largest acreage in yautias are Utuado, Orocovis, Yabucoa, Morovis, Caguas, Aguas Buenas, and Arecibo. Most of these municipalities also have a large acreage in other subsistence crops. Generally speaking, soils and climate well adapted to coffee are also well adapted to yautias. Yautias, however, have a somewhat wider soil adaptation, as they grow very well on poorly drained soils.

The price of yautias is generally about $1.75 a hundred pounds. The price is usually less than that paid for ñames, corn, or pigeonpeas but it is greater than the price of sweetpotatoes and yuca.

The production of yautias in the future probably will be as high or higher than it has been in the past. According to the 1935 Puerto Rico Reconstruction Administration census, yautias occupied 17,596 cuerdas on the island, or 2.5 percent of the land from which crops were harvested in that year. They held the eighth place among the cultivated crops. As yautias thrive on imperfectly drained soils, it is possible that, with the use of excellent varieties and proper fertilizer, some of the poorer land on the coastal lowlands now producing low yields of cane can be utilized for this crop, thereby increasing the production of a crop that is consumed entirely on the island.

ÑAME, OR YAM

Ñames were introduced into Puerto Rico some time between the sixteenth and seventeenth centuries, and, owing to the favorable frost-free moist climate and deep soils, also to the fact that the roots are relished highly by the native people, the acreage rapidly increased. This is now one of the important root crops used for food by the Puerto Ricans, and nearly all the crop is consumed on the island.

The edible part of the ñame is the brown thick-skinned more or less cylindrical root, or tuber, which may weigh as much as 30 pounds. The interior of the ñame root is very similar to the potato, as it is white, firm, and starchy. It should be used when fresh. According to Kinman (*26, p. 12*), one of the most common varieties grown in Puerto Rico has more than 24 percent of starch in the fresh roots. Ñames have a high food value, and they are easily prepared in a number of different ways for table use.

The above-ground part of the plant resembles somewhat a very dense-leaved morning-glory vine. It requires an artificial support and may climb to a height of 8 feet.

Figure 76 shows the distribution of ñames in Puerto Rico. A very close similarity in area exists between the distribution of ñames and that of yuca. The production of ñames increased rapidly between 1929 and 1935, especially in the eastern part of the island. According to the 1935 Puerto Rico Reconstruction Administration census, the leading municipalities in which ñames are grown are Moca, Aguada, Yabucoa, San Sebastián, Isabela, and Utuado. The greatest concentration of land in ñames is along the highway between Moca and San Sebastián. This area receives a yearly rainfall ranging from 80 to 110 inches, and the soils in which the ñames are grown are red, acid, and fairly fertile, such as those of the Moca and Lares series. The smooth areas of the Catalina soils also are well adapted to ñames. In the municipality of Isabela the ñames are grown on the permeable deep Coto, Maleza, and Matanzas soils. Rainfall within this latter area is not sufficient for maximum production, and irrigation would increase the yield nearly twofold.

Ñames can be planted at any time during the year, but most farmers in the humid sections or within the irrigation districts prefer to plant during the winter and spring. In advance of planting, round-topped ridges about 5 feet apart and 1½ feet high are constructed, either with a plow or by hand labor. It is necessary to have fertile loose soil high in organic matter near the top of the ridge. Rather large seed pieces of good healthy ñames are selected for propagation. The seed pieces are very similar to the seed pieces of potatoes. Generally a 5- or 6-ounce cross section of a well-developed cylindrical root produces the highest yields. In many places the seed pieces are planted about 18 inches apart along the tops of the ridges at a depth of about 3 inches, and some growers prefer to plant them in hills spaced about 2 by 2 feet.

About 3 ounces of complete fertilizer, such as a 6–9–12 mixture, is applied in each hill about the time the seed germinates, and a second application of an equal quantity is applied about 4 months later.

The cultivation necessary is to keep the ridges in good loose condition and to destroy the weeds. These operations are accomplished with either a machete or a hoe. It is necessary for the growing vines to have a trestlelike support which often is made from post and wire.

At the time of the first harvest, usually about 8 months after planting, the soil is loosened and the large edible ñame root is severed from the crown. The void space is filled with loose fertile soil and many buds develop from the crown and produce a second supply of edible roots within about 4 months.

The main varieties grown are the Ñame de Guinea, Ñame Papa, Ñame de Agua, Ñame de Guinea Blanco, and Ñame de Mapuey.

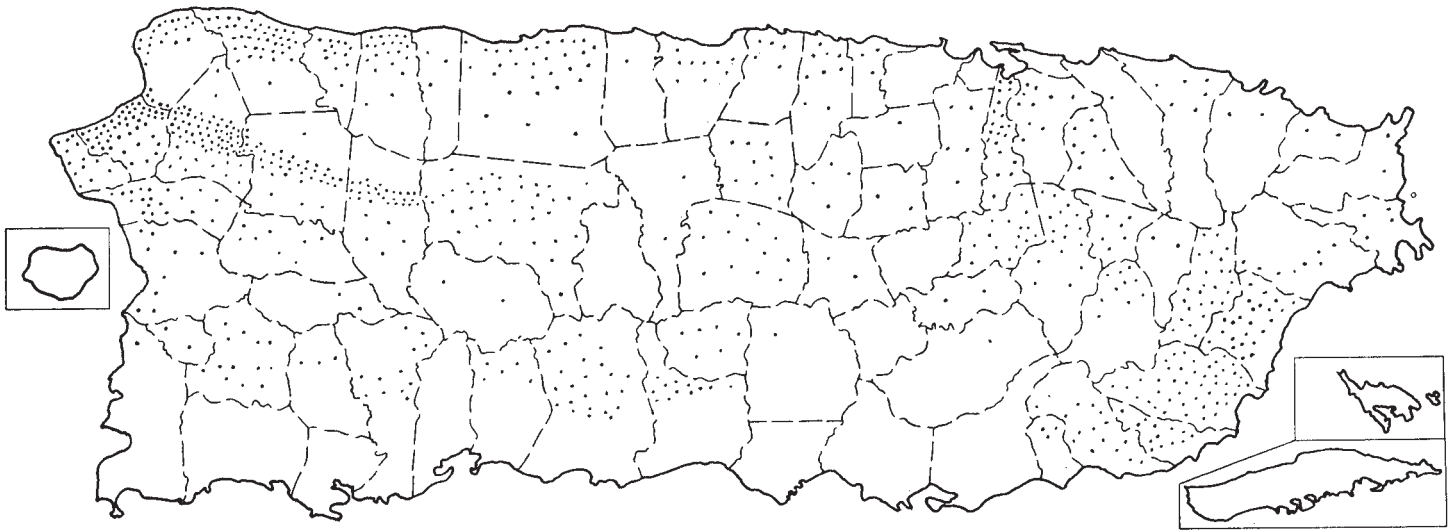

FIGURE 76.—Distribution of ñames in 1935. Each dot represents 10 acres.
Distribución de ñames en 1935. Cada punto representa 10 acres.

Ñames are practically free from insects pests and plant diseases, and this probably is one reason that they are so widely cultivated. They can be grown on many soil types in the humid areas, but by far the largest acreage devoted to their culture is on the well-drained deep acid soils such as those of the Moca, Lares, Fajardo, Catalina, Alonso, Cialitos, Bayamón, Coto, and similar series.

The production ranges from 8,000 to 12,000 pounds an acre on the Lares, Moca, Fajardo, and the better areas of the Catalina soils. The steep areas of the Catalina and Cialitos soils produce from 2,000 to 3,500 pounds an acre. The Coto, Bayamón, and similar soils of the valley coastal plains produce about 6,000 pounds an acre unless the land is irrigated or receives an average of more than 78 inches of rainfall a year. With irrigation, the yield is nearly doubled.

Ñames would grow very well on almost all of the well-drained alluvial soils, such as those of the Toa, Estación, and Viví series, but they cannot compete in profit with sugarcane on these soils. The best of these soils probably would produce more than 28,000 pounds to the acre. The shallow soils of the Múcara, Colinas, and similar series are not well adapted to the large roots of the ñame plants; therefore the production from these soils ranges from only 1,000 to 2,000 pounds an acre. Poorly drained soils of the coastal lowlands or river flood plains and the soils in the nonirrigated arid sections are not used for this crop. A very small area of the sandy soils of the coastal lowlands is planted to this crop, as these soils are only fair for the growing of ñames. The future of the production of ñames is very encouraging, especially for the grower of subsistence crops. As good ñame seed is rather expensive, the large tracts are planted by the more progressive landowners. Considerable extension work could profitably be made by giving advice and aid in fertilization, proper methods of planting, cultivation, harvesting, seed selection, and marketing of the ñames grown by the owners of small tracts.

The selling price of ñames ranges from $1 to $2.50 a hundred pounds, and the income to the acre from this crop is higher than that from any other crop commonly grown by the jibaros.

PIGEONPEAS (GANDULES)

The exact origin of the pigeonpea seems to be unknown. According to Sturtevant (*39, p. 125*), pigeonpeas were found in some of the Egyptian tombs of the twelfth dynasty (2200–2400 B. C.). It is not known when they were introduced into Puerto Rico; probably they came from Africa on some of the slave-trading boats. Pigeonpeas have been one of the leading protein foods of the Puerto Rican jibaros for many centuries. Numerous varieties are planted throughout the island; the most common are Gandul Blanco, New Era, and Gandul Guisante.

Pigeonpeas grow on tall slender perennial bushy shrubs that range in height from 4 to 10 feet, depending on the variety, soil, and climate. The seeds are produced in long slender rounded or flattened pods, and usually they are gathered before maturity and are prepared for cooking either alone or with rice. The fresh green seeds have a high nutritive value and are highly relished by the natives. The matured shelled peas, as well as the fresh green peas, can be purchased

in nearly every town market at any time during the year. The average price for a hundred pounds is about $2.50. This is more than the price of an equal quantity of corn, yuca, or yautia.

Nearly every rural home, as well as many city residences, has a small cluster of bushes in the dooryard or near the dwelling. Thus the needs of the family are supplied, and possibly there is some surplus for sale. Pigeonpeas are planted also in rows, in many places along the division lines of landowners, or as windbreaks in young grapefruit orchards. The plant is a legume and is sown by many farmers to enrich the soil, as the nodule-producing bacteria grow abundantly on the well-developed root system.

This plant, like most leguminous plants, prefers a neutral or alkaline well-drained deep soil for highest yields and best quality of seeds. Fortunately it produces fairly well on shallow neutral or very slightly acid soils, such as the Múcara, that occur in areas where the rural population is dense. Although pigeonpeas can endure long droughts, they will grow under a great variety of climatic conditions as well as on many kinds of soils.

Figure 77 shows the distribution of pigeonspeas as recorded from data of the Puerto Rico Reconstruction Administration census for 1935. The municipalities having the largest acreages, ranking in the order named, are Yauco, Isabela, Peñuelas, San Sebastián, Moca, Lares, Aguada, and San Germán. It may readily be seen that this crop is concentrated to a great extent in the extreme northwestern part and the southwestern part of the island. The land in these sections is either fairly dry or there is a considerable area of soil that is not very productive for cash crops, therefore minor crops occupy a fairly large acreage. The population also is very dense in these places, except in the extreme southern part. Only a small acreage is devoted to this crop on the red acid soil in the center of the island, where the rainfall is high. The pigeonpea, although a drought-resistant plant, will grow luxuriantly in humid sections on alkaline soils, provided the land has good surface drainage. It grows very well on the alkaline Soller soils in the vicinity of San Sebastián where the average annual precipitation exceeds 100 inches. In the same vicinity, pigeonpeas growing on the acid Catalina, Lares, or Moca soils do not have a healthy appearance and do not produce a high yield. The leaf growth in general is fairly dense on the plants growing on these soils, but they lack the bright green color noticed on plants growing on neutral or slightly alkaline soils.

In Puerto Rico the pigeonpea pod is used almost exclusively for human consumption. In other countries, especially Hawaii, both the plant and the pods are used with excellent results as forage for livestock.

Almost all of the pigeonpeas are grown in very small patches by the jibaros, and the general procedure is to loosen the ground with a hoe or pickax, then make square holes spaced about 30 inches apart in rows 3 or 4 feet apart. The planting season is from March to May, and the common practice is to place three seeds in each hole. About 5 pounds of seed to an acre are used. Only good clean seeds free from disease and injury by insects should be planted. The planted seeds are covered with soil to a depth of about 2 inches. Very few planters fertilize this crop, and the only cultivation necessary is to kill the weeds and keep the roots covered. Most of the land planted to

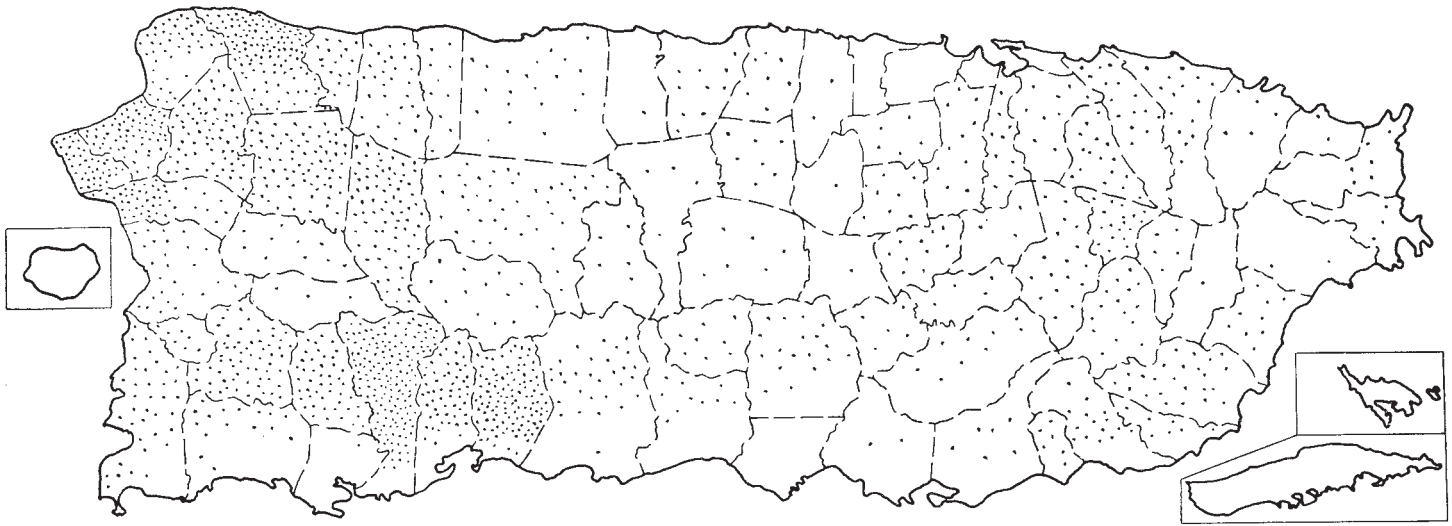

FIGURE 77.—Distribution of pigeonpeas in 1935. Each dot represents 100 acres.
Distribución de gandules en 1935. Cada punto representa 100 acres.

this crop has undergone considerable surface erosion, and much of the loose surface soil has been washed away from hills having more than 25-percent slope. Many patches of pigeonpeas are planted on 80- and 100-percent slopes.

Harvesting consists of picking the pods about 7 or 8 months from the time of planting and again in 6 or 7 months. The acre yield is very low compared with that in Hawaii. A yield of 300 pounds an acre is considered a good crop on such soils as the Múcara, Descalabrado, Colinas, and similar soils. From 150 to 200 pounds are obtained from acid red upland soils, such as the Catalina and Cialitos. The sandy Cataño and Aguadilla soils yield from 250 to 400 pounds. Lower yields are produced on the Sabana Seca soils and very low yields on the Corozo soils. Such soils as those of the Toa are the irrigated areas of the San Antón series probably would yield more than 4,000 pounds of shelled peas under proper management.

According to the 1935 Puerto Rico Reconstruction Administration census, 15,954 cuerdas, or 2.2 percent of the cultivated land from which crops were harvested, were in pigeonpeas in 1935. This acreage undoubtedly will increase in the future because: (1) The increasing population will need more food, which can be furnished by the palatable, nutritious, and easily grown pigeonpeas; (2) large areas of soils have lost, through leaching and continuous cultivation, essential plant nutrients, which eventually must be replenished by a cover crop, such as pigeonpeas; and (3) the installation of better canning factories and wider advertising of the value of canned pigeonpeas may be expected to increase the demand for them for export. According to Barrett (*5, p. 349*), pigeonpeas are high in iron and iodine. Owing to the large quantity of pigeonpeas consumed by the people of Puerto Rico it is possible that they obtain sufficient iodine to help prevent the growth of goiters. Very few cases of this disease were noticed on the island, but it has not been determined whether this is due to the large quantity of pigeonpeas consumed or to some other cause.

Pigeonpeas are relished by chickens and nearly all domestic animals. Krauss (*27, p. 34*) states that in Hawaii cattle fed wholly on pigeonpea pasture gained from 1½ to 2¾ pounds a day. The carrying capacity of a good field ranges from 2 acres to one head to 1 acre to one and a half head. It would seem that this plant should be used to much greater extent as a forage crop in the semiarid sections. It grows well on the Rosario and Nipe soils, two of the most infertile soils on the island. Such soils could be made more productive by growing this leguminous crop, and at the same time good pasture could be produced in places where only cacti and nearly worthless thorny bushes are growing now. The seeds of the pigeonpeas are relished by wild pigeons and other birds. The pigeonpea plant is an important source of honey, judging from the number of bees seen near the flowers.

Yields could be greatly increased by the use of fertilizer and by the control of insects and diseases. Very little attention has been given to the damage done by insects and diseases, but, judging from the number of inferior and shriveled pods in nearly every large cluster of bushes, the loss from fungus disease and insect injury must be great. Weevils are destructive after the seeds are gathered.

YUCA (CASSAVA)

Yuca is probably a native of Brazil and was imported into Puerto Rico many centuries ago. It was one of the main if not the main food crop of the Arawak Indians when the Spaniards discovered the island.

Although the yuca is a quasi-perennial plant, it nearly always is used as an annual. It is a shrubby, woody plant ranging from 4 to 10 feet in height. The stems are used for propagation. They are long, slender, and noded. The starchy tuberous roots are the only edible part of the plant. Several varieties of yuca are cultivated, but they commonly are referred to as either the "sweet" kind or the "bitter" kind. There is probably no botanical distinction between the two. The bitter kinds are used mostly for starch and tapioca flour, and the sweet ones are prepared for eating by boiling, baking, and frying. In some places the sweet yuca tubers are fed to livestock with very good results.

Some varieties, especially the bitter ones, contain considerable prussic acid which may be fatal if the tubers are eaten raw or after they have been dug for several days. Cooking the fresh tubers eliminates the danger of poison. Figure 78 shows the distribution of the yuca plant according to the Puerto Rico Reconstruction Administration census of 1935. This plant is fairly well distributed, and there is a concentration of plants in areas where the rural population is dense. The municipalities having the largest acreage in yucas, in the order named are: Isabela, Moca, Aguadilla, Camuy, and Loíza. All except Loíza are in the northwestern part of the island.

The yuca will grow and produce fairly good yields on a wide range of soil types and under diverse climatic conditions, but it cannot tolerate frost or waterlogged soils. The soils most commonly used for the growing of this plant and the average acre yields without fertilizer are as follows: Cataño loamy sand, 3,000 pounds; Maleza loamy sand, 2,800 pounds; Matanzas clay, 2,500 pounds; Vega Alta clay loam, 1,500 pounds; Catalina clay, 1,400 pounds; Múcara silty clay loam, 1,200 pounds; and Cayaguá sandy clay loam, 1,000 pounds. Similar soils produce accordingly. The level well-drained alluvial soils would produce considerably more than 8,000 pounds to the acre, but, as the land is more productive for cane, practically no yucas are grown on these soils.

The usual procedure for planting yuca is to loosen the ground with a hoe or with a walking plow to a depth of about 8 inches. Shallow furrows are then made, and fresh cuttings about 7 inches long of the middle part of sound stems having two or more eyes are inserted in the furrows in a slanting position and are covered with soil to a depth of about 4 inches. Some growers cover only about one-half of the cutting. The plants are spaced about 1½ or 2 feet apart in rows 4 feet apart from center to center. The planting can be made at any time during the year, but most farmers prefer to plant just before the rainy season. The young plants are cultivated frequently, but after they have grown to a fair size, the leaves and branches shade the ground, and weeds cannot thrive. Very few farmers use fertilizer on this crop.

The tubers are gathered with a hoe or a spade, from 8 to 10 months after planting. When the plant begins to flower, the tubers are considered mature enough for cooking purposes. The tubers to be used for food should be fresh. Considerable quantities are peeled, cut

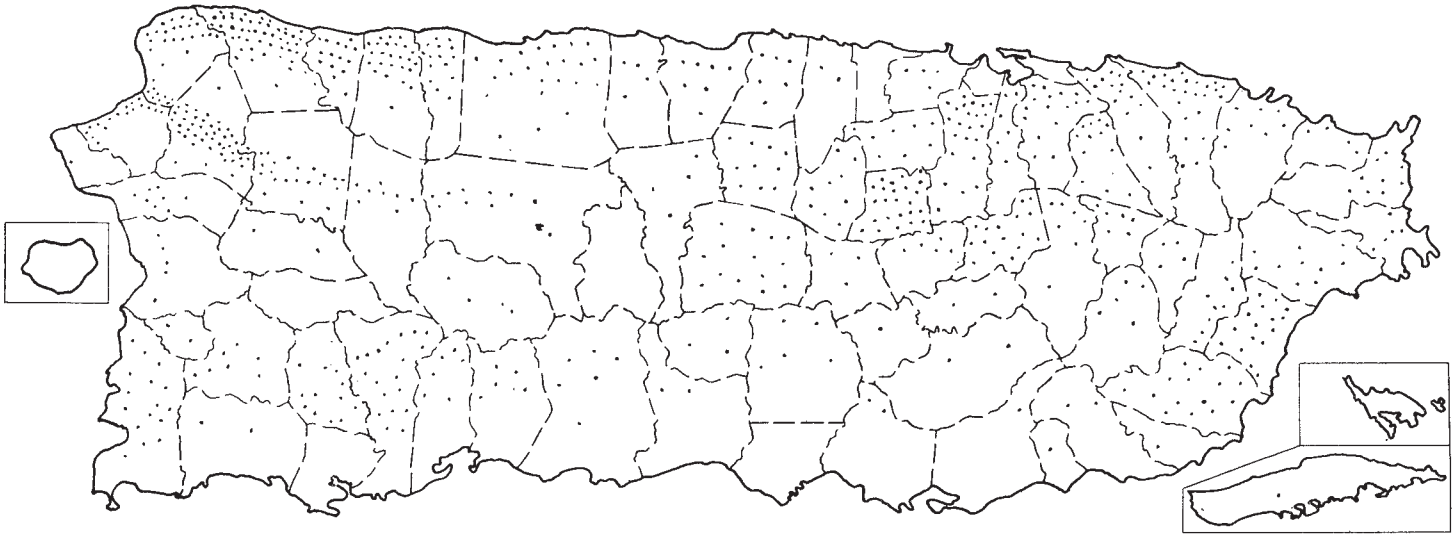

FIGURE 78.—Distribution of yuca in 1935. Each dot represents 10 acres.
Distribución de yuca en 1935. Cada punto representa 10 acres.

into slices 1-inch thick, sun-dried, and then pounded into a pulp and passed through a sieve. The flour part is used in making bread. Starch is made in much the same way at the individual homes. The tubers are thoroughly washed, scraped, and milled through a corrugated cylinder. The pulp is mixed with water, and the mixture passes over a trough with a sieve bottom. The trough is constantly shaken, and considerable water is poured on the mixture. The part that passes through the sieve is put in containers to settle, the water is poured off, and the residue, or starch, must be washed and rewashed before it is dried as a finished product.

According to the 1935 Puerto Rico Reconstruction Administration census, 6,846 acres were devoted to yuca in 1935, or slightly less than 1 percent of the total land from which crops were harvested. This acreage can be and probably will be greatly increased in the future, as the increasing pressure of population forces more land to be used for subsistence crops. Yuca is a palatable, nutritious, cheap food. It sells for about $1 a hundred pounds. As insect pests are not a limiting factor in the production of this crop, the growers are practically assured of a fair crop, regardless of where or when the crop is planted.

The possibilities of the yuca-starch industry are not so encouraging as is the growing of yuca for home consumption.

BEANS (HABICHUELAS) AND COWPEAS (FRIJOLES)

Beans have been grown in Puerto Rico for many centuries. They are handled in a manner very similar to that used in the United States. The beanfields are small, and in the tobacco districts the beans are planted in furrows after the tobacco has been harvested. On many farms corn and beans are planted in the same field. In many areas beans are planted at any time of the year.

Figure 79, compiled from information from the Puerto Rico Reconstruction Administration census, shows that beans are fairly uniformly distributed throughout the island, although the largest area is in the northwestern part. The municipalities having the largest acreages in beans are Isabela, Utuado, San Sebastián, Orocovis, Cayey, and Morovis. In 1935, 31,470 cuerdas were in beans, or 4.4 percent of the land from which crops were harvested.

The average acre yield is low, but beans are planted on many areas of very shallow soil that are poorly adapted to other crops and not well adapted to beans but which produce a higher profit when in beans than when in other crops. Very often beans on the shallow soils are affected by drought. Beans would be very productive on the well-drained alluvial soils, such as the Toa and Estación, but most of these soils are used for more profitable crops.

Puerto Rico should produce more beans, as it imports yearly about $1,150,000 worth, most of them from the United States. Beans are subject to many insect pests and plant diseases, but generally a fair crop may be expected, regardless of the kind of soil used.

According to the 1935 Puerto Rico Reconstruction Administration census, Puerto Rico has 3,379 cuerdas devoted to cowpeas. Some soybeans, as well as other cover crops, such as jackbeans, swordbeans, crotalaria, and many others, described by Kinman (*25*), are grown.

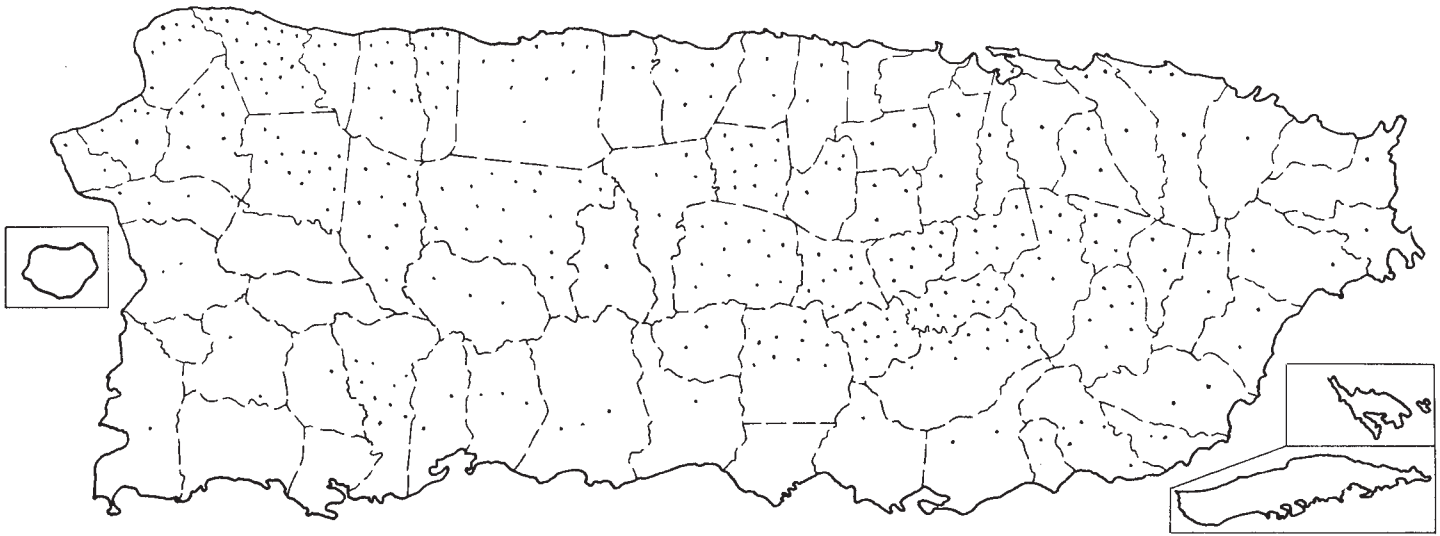

FIGURE 79.—Distribution of beans in 1935. Each dot represents 100 acres.
Distribución de habichuelas en 1935. Cada punto representa 100 acres.

COTTON (ALGODÓN)

Cotton has been grown in Puerto Rico since its early history. The acreage devoted to this crop, however, has varied considerably, owing to the price; during the period 1929–30 the value of exported cotton was about 4.1 cents a pound, and more than 10,000 acres were in this crop each year, but after 1931 the price dropped, the acreage decreased, and the only ginnery on the island suspended operations. Cotton from only 934 cuerdas was harvested in 1935, as reported by the Puerto Rico Reconstruction Administration census.

Cotton is grown only on the sandy soils in the semiarid northwestern part of the island and on the heavy clay soils in the arid and semiarid districts in the southwestern part. Near Isabela cotton is usually planted during January and February, and near Yauco some time in August.

An excellent quality of long-staple cotton is produced. Yields vary according to the soils and the moisture content during the growing season. Yields on Guayabo fine sand seldom exceed 400 pounds of seed cotton to the acre;[21] Guayabo fine sand, shallow phase, produces about 600 pounds; Sabana Seca sandy clay loam, about 800 pounds; Aguadilla loamy sand, about 1,200 pounds; and Fraternidad clay, about 600 pounds.

Land in cotton seldom is irrigated, even in dry years, and only a part of the producers fertilize the crop. The size of the cottonfields ranges from a fraction of an acre to 400 acres. Probably the majority of farms that produce cotton are less than 10 acres in area.

When cotton was a thriving crop, the ginnery furnished seed and fertilizer and advanced money on the crop to those growers who needed assistance.

The future of cotton growing is promising for a limited acreage. This crop can be produced on soils too sandy for other commercial crops, and unless cotton is planted on these soils most of the very sandy areas will be planted to grass. Yields of 1,000 or more pounds of seed cotton can be produced on some of the better soils in the vicinity of Isabela. The production of cotton furnishes work for many laborers, and any such crop or industry should be encouraged as much as possible, in order to relieve the pressing needs of the growing population.

The pink bollworm is a serious pest in the cottonfields, and constant effort will have to be put forth in order to keep destruction from this source to a minimum. The worm has many host plants on the island, which would be nearly impossible to eradicate.

ORANGES (CHINAS)

Oranges have been growing in a semiwild state in the mountains for many centuries, and at present only a few commercial orchards are in existence, although, according to the census of the Puerto Rico Reconstruction Administration, 1,858,284 trees were growing in 1935, of which 1,240,269 were bearing, compared with 663,943 bearing grapefruit trees. The production for the same year was 1,003,988 boxes of oranges and 883,388 boxes of grapefruit.

[21] One hundred pounds of seed cotton is equal to about 27 pounds of lint.

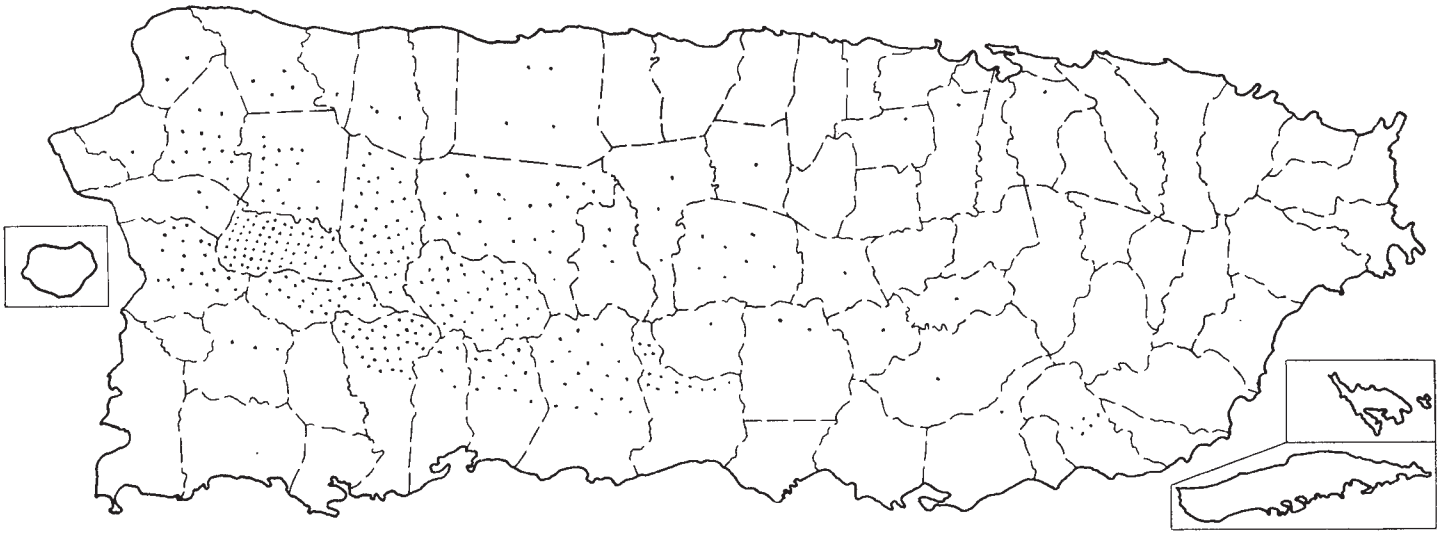

FIGURE 80.—Distribution of orange trees in 1935. Each dot represents 5,000 trees.
Distribución de árboles de naranja (china) en 1935. Cada punto representa 5,000 árboles.

Figure 80 shows the distribution of orange trees as recorded by the 1935 census. It may readily be seen from figures 80, 56, 71, and 72 that the municipalities having the greatest number of orange trees also have a very high number of coffee trees, bananas, and plantains.

In high elevations having a cool, damp climate, orange trees thrive much better than grapefruit trees. Soils well adapted to grapefruit are also well adapted to oranges.

The oranges produced are exceptionally juicy and sweet, and they should have a ready market in the United States. Owing to quarantine regulations, however, shipments during the last few years have fallen from nearly $1,000,000 worth a year between 1917 and 1929 to slightly more than $3,000 worth in 1939, according to the 1938–39 Annual Book on Statistics. The oranges are of much higher quality than the grapefruit grown, that is, compared with similar fruit in the United States.

The season for marketing oranges is from November to May, and during this time oranges may be purchased at nearly any street corner in any town at the rate of two or three for 1 cent. During the summer, when oranges are scarce, the price ranges from 2 to 3 cents apiece. On the farms the price ranges from 15 cents a hundred during the winter to $2 in summer.

In the mountain districts very little attention is given the trees other than gathering the fruit. Very few planters fertilize, spray, or prune the trees. The orange crop is more or less a side issue for the coffee planters.

The future of the production of oranges will depend to some extent on the continuation of the quarantine and the quantity of oranges that can be exported. Many more oranges could be grown than have been in the past, if the growers could realize enough profit to encourage systematic crop management.

Some sour oranges also are produced throughout all the mountain and hill areas. The trees are not numerous and are used only in grafting or budding in the grapefruit groves.

MANGO

According to Barrett (*6, p. 250*), the mango appeared in Puerto Rico about 1740, but very little interest was taken in this tree until 1905, when the United States Department of Agriculture took up the work of introduction in earnest.

The mango is a large, strong, symmetrical, widely branched tree that may grow to a height of more than 50 feet. The trunk withstands hurricanes, even though nearly all the branches may be destroyed. The tree endures many crude prunings by the inhabitants in collecting wood for making charcoal. The mango makes a very attractive ornamental tree for beautifying rural homes.

The fruit, which is more or less oval and weighs from 6 to 9 ounces, is produced during the winter or spring, depending on the elevation and temperature. It is smooth and has a bright-yellow color with some red splotches. The skin is tough and sticks tenaciously to the fibrous juicy flesh. The seeds are large and plump; they are nearly one-half as large as the whole fruit. Some varieties have a very pleasing sweet taste. Practically all the mangoes are eaten raw, but it is possible that in the future some will be canned. The sugar content ranges from about 10 to more than 18 percent.

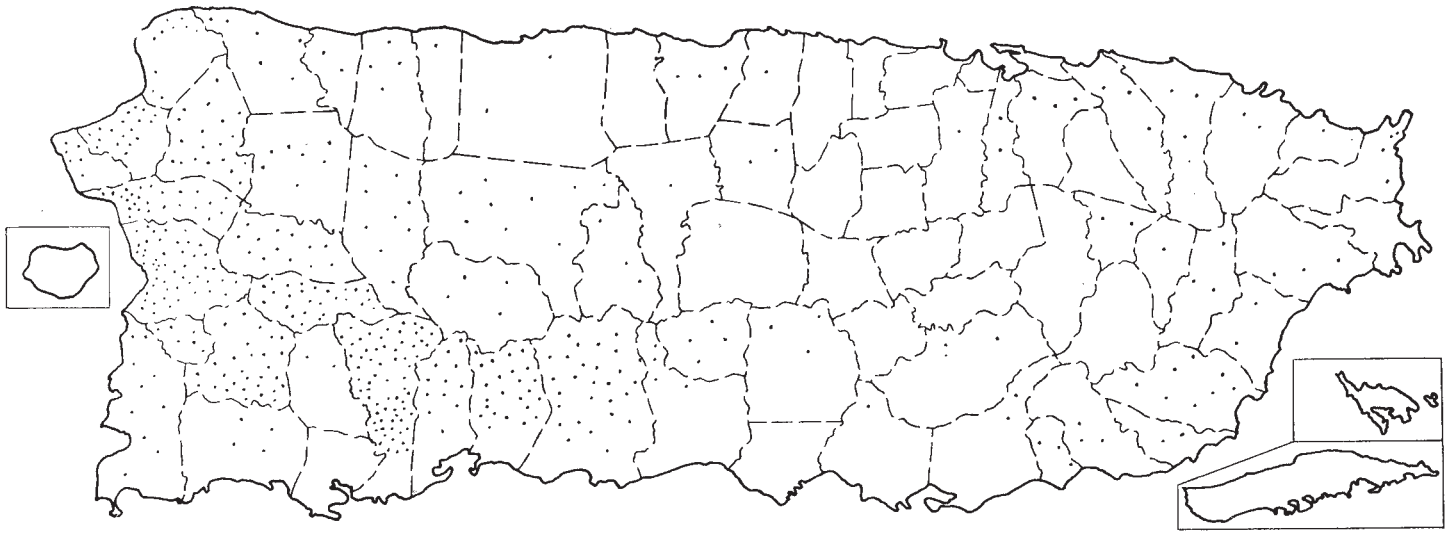

FIGURE 81.—Distribution of mango trees in 1935. Each dot represents 500 trees.
Distribución de árboles de mango en 1935. Cada punto representa 500 árboles.

Yauco, Mayagüez, San Germán, Ponce, Añasco, and Peñuelas have the largest number of mango trees. Figure 81 shows the distribution of mango trees, according to the 1935 Puerto Rico Reconstruction Administration census.

Although mango trees are distributed throughout the island, the most ideal locations for the production of high yields of good fruit are in areas where the average annual rainfall ranges from 45 to 65 inches. Such areas occur near Rincón, Cabo Rojo, Peñuelas, and other cities.

The fruiting organisms of the mango tree seem to be sensitive to high rainfall, because the production is very low in the humid areas, although the trees are large, plentiful, and have an excellent appearance. The frequency of tropical showers in the humid areas interferes with proper pollination of the flowers. The cold temperature of the higher elevations also may affect production. In very dry areas, most of the trees are not large and do not have a very good appearance. Mango trees seem to grow equally as well on the well-drained deep acid red soils of the interior uplands as they do on the thin brown alkaline soils on steep slopes in the semiarid sections. They do not grow very well on poorly drained or waterlogged soils.

Mangoes are not seriously affected with fungus diseases or by insects, and for these reasons as well as for the fact that they are adapted to almost any soil on the island, the yearly production could be greatly increased. The quality of the fruit produced could be improved to a marked degree through systematic planting and selection of varieties.

AVOCADO (AGUACATE)

The avocado, more correctly called aguacate, sometimes called alligator pear, probably was introduced from Mexico or Central America. Avocados are medium-sized trees having distinctly green-barked rather brittle open branches. The fruit resembles a pear in size and shape, and it has a green leathery skin and yellow soft oily flesh, from one-fourth to one-half inch thick, enclosing a hard seed. The flesh is nearly fiberless and contains from 10 to 30 percent of oil, from 1 to more than 4 percent of fat, and considerable vitamins. It has a very agreeable flavor and is one of the mostly highly prized tropical fruits. It generally is eaten as a salad with salt, vinegar, and dressing.

During August and September, large fresh avocados can be purchased in most of the city markets at 3 or 4 cents apiece. The season lasts from July to November.

Figure 82 shows the distribution of avocado trees according to the 1935 Puerto Rico Reconstruction Administration census. In that year 151,325 bearing trees produced 14,121,900 fruits, or about 100 fruits to the tree.

Avocados grow very well here, and the quality produced is excellent. The number of trees is increasing fairly rapidly, although there are no large commercial orchards.

MISCELLANEOUS CROPS

Some of the other important food crops grown are the papaya or lechoza, breadfruit, rice, potato, peanut, vanilla, lime, and lemon. The papaya may be seen growing in almost any back yard on any soil type. The cylindrical dark-green fruits are borne on short

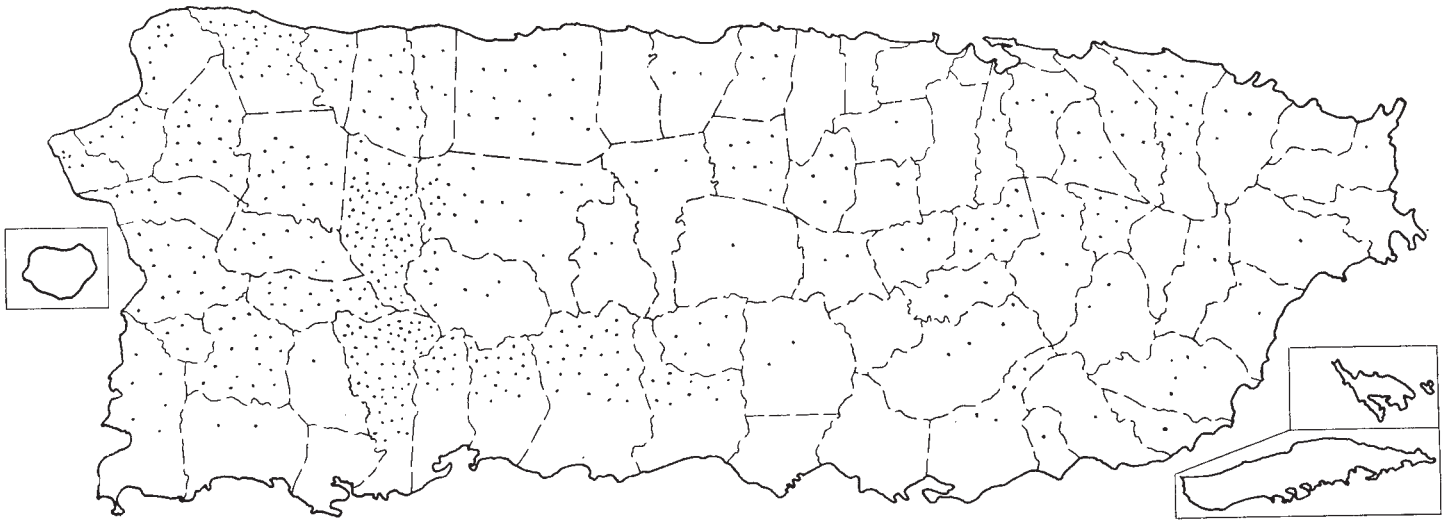

FIGURE 82.—Distribution of avocados in 1935. Each dot represents 500 trees.
Distribución de aguacates en 1935. Cada punto representa 500 árboles.

peduncles just below the leaves (fig. 83), and they turn yellow when ripe. They have a thin tender skin and yellowish-red pulp. Many of them weigh between 5 and 10 pounds each. The tree may live for several years and produce throughout each year. The male trees are sterile.

Breadfruit is widely grown throughout the island and produces an abundance of large rounded green wholesome fruit, which can be baked, roasted, or boiled, and then fried in thin slices. This fruit is relished by nearly all Puerto Ricans and is produced throughout a large part of each year. The breadfruit tree grows to a height of 25 or 30 feet on most soils. It has striking deeply incised rough leaves and is one of the most generous sources of nutriment that exist in the Tropics.

FIGURE 83.—The papaya, or lechoza, has yellowish-red pulp and tastes somewhat like a cantaloup.

La papaya o lechoza tiene una pulpa roja amarillosa y tiene un sabor parecido al del meloncillo (cantaloup).

Upland rice has been grown for a long time. According to the 1935 Puerto Rico Reconstruction Administration census, 9,386 cuerdas were planted to rice in that year. The largest total areas devoted to rice in 1935 were in the municipalities of San Lorenzo, Yabucoa, Corozal, Barranquitas, Morovis, and Orocovis. In the same year, 48,906 bushels were produced.

The 1938–39 Annual Book on Statistics reports that during the fiscal year 1939, 199,331,194 pounds of rice, valued at $5,466,-216, was imported; all lowland rice from the United States.

Rice is planted on the slopes of the Múcara, Cayaguó, and other soils in the spring, and it is harvested during the fall. It yields about 600 pounds to the acre without fertilizer. In places corn and rice are planted in the same field. The corn generally is harvested first. Rice will produce high yields on the alluvial soils or on the coastal plains soils, such as the Espinosa, but the profit derived from this crop is not so large as that derived from sugarcane.

According to the census of the Puerto Rico Reconstruction Administration, 13,683 bushels of potatoes were produced in 1935 from 680 cuerdas. Most of the potatoes are grown in the interior, where the climate is cool and only fairly moist. The leading municipalities in the production of potatoes are Cayey, Cidra, Adjuntas, and Yauco. The potatoes are of fair quality and sell for about 3 cents a pound.

A steadily growing quantity is imported from the United States. During 1939, according to the Annual Book on Statistics, the 48,854,159 pounds imported was valued at $367,350. The jibaros prefer yautia and sweetpotatoes to potatoes, and for that reason a very small acreage is planted to the latter crop.

Only 134 cuerdas were planted to peanuts in 1935. Most of this crop is grown on Aguadilla loamy sand and Aguadilla sandy loam near Aguadilla. The small Spanish variety is preferred. The peanuts are roasted, and many of them are sold in the plaza, a penny's worth at a time, by small children.

Vanilla is a promising crop for the humid and subhumid districts on the well-drained permeable soils fairly high in organic matter. The process of curing the beans has been greatly improved recently, and now a good quality of cured beans can be obtained by skillful growers who understand the proper methods of cultivation and processing. The more energetic growers can make large profits from a small acreage of productive vanilla plants. The Puerto Rico Reconstruction Administration census for 1935 reports the production of 27,911 pounds of vanilla from 69 cuerdas on 33 farms. This enterprise fits in nicely with the growing of coffee. On most coffee farms small acreages of fairly good land that support only a few coffee trees could be used advantageously for vanilla plants. Generally the coffee trees and shade trees are removed, and dwarf búcare trees are set out in rows about 6 feet apart. The vanilla cuttings are set out so that, as the vines grow they will be supported by the dwarf búcares. Within 3 or 4 years the vanilla plants will flower. They must be hand-fertilized—an operation that requires some skill. The pods ripen in the fall and must then be cured carefully. Root diseases are destructive to vanilla plants, and on many farms the plantation must be changed to another part of the farm after a few years of production.

According to the census of the Puerto Rico Reconstruction Administration for 1935 there were 3,860 lime trees not of bearing age and 9,549 trees of bearing age on the island. The largest numbers are in the districts best adapted to coffee, although many limes could be grown on the soils adapted to tobacco or sugarcane. The lime trees receive little or no attention, and the fruit is gathered and sold mainly for local consumption. Generally the price is high and the demand good. The quality of most of the limes is good, but it could be improved through better selection of trees and proper management. The number of lime trees could be greatly increased, and undoubtedly a good export trade could be established with American markets. The production was 8,294 boxes in 1935, which represents a decline of one-half from the production in 1920.

Lemons are of minor importance. The lemon trees are used mainly for grafting purposes on grapefruit farms, and the fruit seldom is seen on the market or used in the homes. Many large goat lemons grow in the mountainous districts, but these are seldom gathered.

According to the Puerto Rico Reconstruction Administration census of 1935, vegetables from 3,616 cuerdas were harvested for sale in that year. The vegetables sold in 1935, ranking according to area, were as follows: Tomatoes, peppers, onions, green beans, pumpkins and squashes, cabbages, eggplants, lettuce, okra, and cucumbers. The municipalities having the largest acreages in vegetables for sale during 1935 were Trujillo Alto, Carolina, and Gurabo. The produc-

tion of vegetables could be greatly increased, if the market justified an increase.

Vegetables grow very well on the Cataño and Aguadilla soils near the coast, and on the Lares soils on the terraces. They also grow well on Múcara soils and the coastal plains soils, such as the Coto, Maleza, Bayamón, and related soils.

A few years ago the production of vegetables was greatly increased in the irrigated district of Isabela, through the aid of the Vegetable Producers Association of Puerto Rico, Inc. This is a farmers' voluntary organization, and during the season of 1931–32, 61 percent of the tomatoes, peppers, cucumbers, string beans, and eggplants shipped from the island were produced in this district. In recent years, owing to low prices, only 8 to 10 percent of the shipments of these vegetables came from this district. Vegetables in this area are produced on soils of the Coto and Maleza series. Yields are very good, and the quality seems to be fairly good.

LIVESTOCK

According to Bagué in El Libro de Puerto Rico (*17, p. 627*) the first introduction of livestock into Puerto Rico was in 1502, when Yáñez, one of Columbus' captains, brought in a few goats and a drove of hogs. About 10 years later, Ponce de León brought from Santo Domingo a few head of cattle and horses, which had been introduced from Spain. In 1534, stallions, descendants from Arabian stock, were brought in from Andalucía, and some years later, other Arabian horses were imported. Undoubtedly, during the early days, some Narragansett pacers from Rhode Island were traded for molasses to some of the owners of sugar mills. Boats from New England took rum, flour, horses, and other products to Africa, where some were traded for slaves. The boats then sailed for the West Indies, where the slaves and the remaining products were sold or traded for molasses to make more rum.

Some of the slave boats were responsible for the introduction during the sixteenth century of the nutritious guinea grass from the West Coast of Africa. This grass and the introduced palatable malojillo grass from South America insured the stockmen abundant nutritious forage throughout the year. The numbers of livestock, especially cattle and horses, increased rapidly under these favorable conditions.

During the middle of the nineteenth century, some of the fine horses from Yabucoa Valley were sold for $1,000 each, and many owners of sugarcane land had fine saddle horses as well as beautiful well-matched driving horses. Most of the horses, however, at that time, were very similar to the ones now on the island, which are small wiry hackney-gaited sure-footed animals used principally for carrying large packs of coffee, bananas, charcoal, and other products down the steep rocky narrow mountain trails and slippery muddy roads to town—to return laden with rice, beans, fish, and other articles of food for the numerous small stores along the trails and roads of the interior. The sugar centrals, ranchers, and others still have fine saddle horses, but they also are small boned. Very few horses are registered.

The distribution of horses is fairly uniform throughout the island (fig. 84). The number has declined since 1910. The number of mules increased from 4,569 in 1910 to 5,827 in 1930 but decreased to 5,081 in

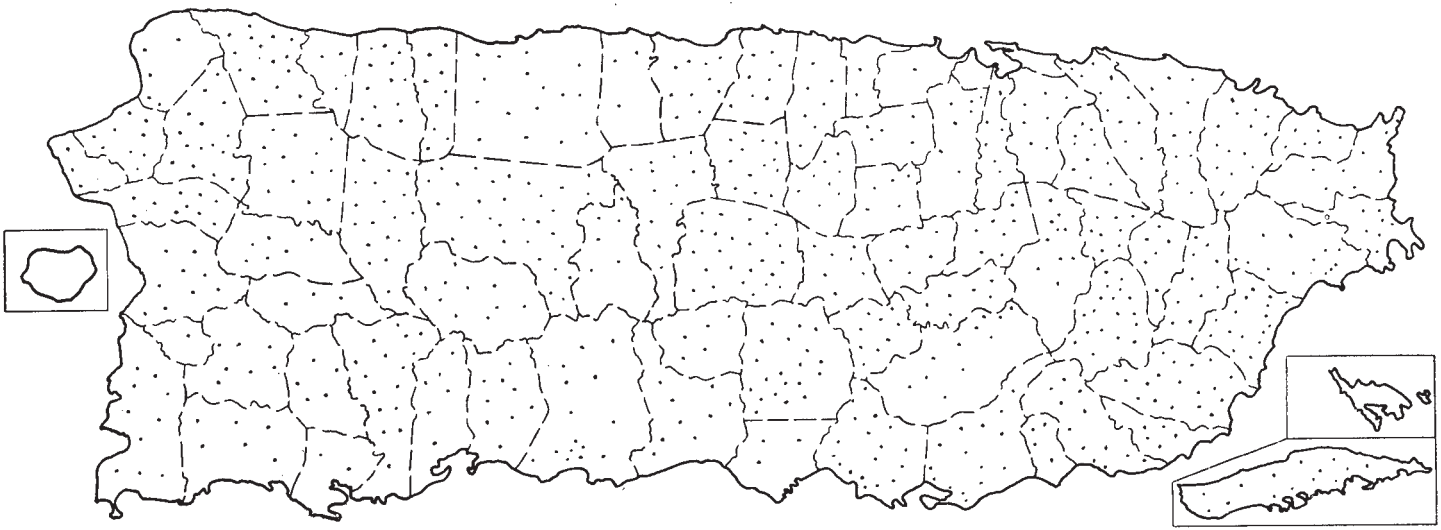

FIGURE 84.—Distribution of horses in 1935. Each dot represents 50 head.
Distribución de caballos en 1935. Cada punto representa 50 cabezas.

1935. Asses and burros are becoming more numerous. There were 2,653 reported in 1935. Only a few of the horses are castrated, owing in part to the danger of infection from the operation and in part to the greater endurance or stamina that stallions have over geldings. Nearly all of the horses are shod, especially those owned by sugar centrals. Very seldom are horses used for draft purposes, but many hundred are seen that have two large wicker baskets, or banastas, securely fastened to a harnesslike saddle, or aparejo, and hanging from both sides of their backs. Many different kinds of packsaddles are in use. Livestock, such as pigs, chickens, and turkeys, as well as all kinds of crops, are transported to market on horseback. Rarely is the western stock saddle seen, as the lightweight English riding saddle is preferred and is better adapted to the small gentle horses. The price of a good young saddle horse ranges from $75 to $125. The cost of pasturing a horse ranges from $1.50 to $2 a month. A few ranchers devote their entire time to the raising of horses, but most of the horses have been raised from colts born on the farms.

Mules are used fairly extensively for draft purposes, especially in the vicinity of Hormigueros, where they haul fertilizer and cane. Considerable areas of ratoon cane are cultivated with one-mule cultivators. Mules are used very extensively in carrying bags of coffee and charcoal from the coffee districts to towns or to highways, where trucks or public cars haul the products to market. Sacks of the coffee and charcoal are tied to the sides of the mules with sling ropes.

Cattle are by far the most important kind of livestock raised. According to the 1930 Federal census, the value of the 310,514 cattle reported, of which 296,235 were on farms, was $10,916,916. Horses, numbering 49,545, of which 42,120 were on farms, ranked second, with a value of $2,380,743. The Puerto Rico Reconstruction Administration census of 1935 reported 42,908 head of horses, of which 35,976 were on farms, and 280,433 head of cattle, of which 266,154 were on farms. The value of livestock is not given in the latter census. The number of cattle has been decreasing since about 1900. Steddom (*38, p. 512*) estimated the number to be 500,000 in 1899.

During the years between 1877 and 1883 and between 1901 and 1905, from 10,400 to 17,297 head of livestock were exported, at a value ranging from $280,932 to $576,577 (*46, p. 54*). Most of them were cattle. Since 1906, very few cattle have been exported, (1) because the island has had increasing demands for cattle, owing to the expansion of the sugarcane industry which required more work oxen (fig. 85) and to the increasing population which needed the beef animals formerly exported; and (2) because the number of cattle produced has been decreasing, partly because hundreds of acres of level fertile land along the arid and semiarid southern coast, formerly in large cattle ranches, have been converted into checkerboard-shaped fields occupied exclusively by sugarcane since 1908, when irrigation projects were developed. Grass still occupies most of the hills along the south coast as well as many of the steep hills throughout the island.

According to the 1935 Puerto Rico Reconstruction Administration census (fig. 86), the distribution of cattle is fairly equal throughout the island. Careful observations, however, show a much larger number along the arid and semiarid southern side and near large cities than in the interior. There are not many cattle in either the coffee or the tobacco districts.

The cattle have been selected for draft purposes for such a long time that they are docile, powerful, large-boned, thick-skinned animals with short hair, wide-spreading horns, and thick polls. Owing to the danger of tetanus following surgical operation, castration generally is performed by bruising the testicle or by rupturing the spermatic cord by torsion without cutting the skin. A pair of good young oxen sells at $75 to $125, and it costs about $1.50 to $1.75 to pasture an animal a month. Practically all of the animals have horns, as dehorning is not practiced. Nearly all of the oxen used on the main roads are shod. They pull heavy two-wheeled carts, plows, and other implements. A team of good oxen can pull from 2 to 3 tons of sugarcane on level, dry, dirt roads. Only one wooden yoke is used for each team. It rests on the polls of the animals and is lashed with a rope or rawhide to the base of the horns (fig. 41). The predominant color of the cattle is buff or light red, although some are black and others

FIGURE 85.—In Puerto Rico, cattle are considered beasts of burden, and they are selected and bred with that object in mind. Small boys ride on the yokes and assist in driving the oxen.

En Puerto Rico se considera al ganado como bestias de carga, y es seleccionado y criado como tal. Muchachos se montan sobre el yugo y ayudan a llevar los bueyes.

are dark red. There are very few roans or spotted animals. Of the cattle on farms in 1935, 72,029 were work oxen.

The Brahman or zebu cattle, which have been imported to a considerable extent from Texas within the last 15 years, are white or fawn-colored. They are faster walkers, stronger, and some farmers say that they are more resistant to tick fever than the so-called native cattle. Cows with from one-third to two-thirds zebu blood are said to give more milk than the native cows, and their calves are fatter and stronger than those from the native cows. These cattle, however, are more vicious and are hard to break in to work, also more difficult to keep in a pasture than are other cattle.

Most of the cattle ranches have some zebu (fig. 87) and some native stock. A one-third zebu and two-thirds native cross is recommended for draft purposes by many of the more progressive ranchers. The ranches along the arid southern coast are very similar to the ranches in Arizona, New Mexico, and some other Western States. All the land is fenced, however, as there is no free range. Some ranches

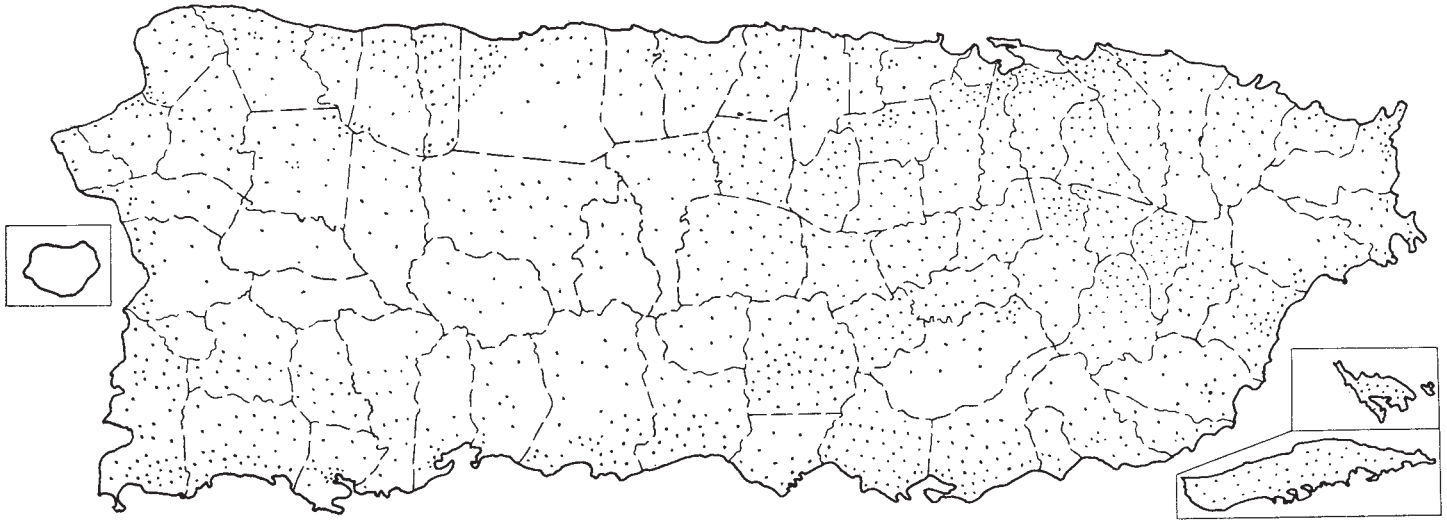

FIGURE 86.—Distribution of cattle in 1935. Each dot represents 200 head.
Distribución de ganado vacuno en 1935. Cada punto representa 200 cabezas.

support from 1,000 to 2,000 cattle on from 3,000 to 4,000 acres of pasture land that is fenced and cross fenced with three and four strands of barbwire. Posts from the native búcar, mabí, and jácana trees are set 6 or 9 feet apart. Regardless of the soil type, the posts rot a few inches below the surface within a period ranging from 5 to 10 years, depending on the kind of tree used. The búcar posts last about one-half as long as the mabí. Throughout the range land the large tamarindo and algarrobo trees are very conspicuous, with the livestock resting under their many spreading branches.

The common practice is to put about 50 cattle in a 50- or 60-acre pasture for several days, then change them to another pasture. The yearly carrying capacity of the land ranges from 2 acres a head on the level Fraternidad and Paso Seco soils to 4 or 5 acres a head on

FIGURE 87.—A herd of livestock on a cattle ranch north of Central Aguirre. Many of the animals have some zebu blood.

Ganado en un rancho al norte de la Central Aguirre. Muchos de los animales tienen sangre zebú.

the Aguilita, Ensenada, and Descalabrado soils. The capacity also varies considerably from year to year and from place to place, depending on the rainfall, the care of the pasture, and the kind of grass. An increased annual rainfall of 20 inches will nearly double the carrying capacity in districts receiving an average ranging from 30 to 40 inches. Pastures that have been freed of cacti, brush, zarzarilla (fig. 88), and guayacán blanco, or guayacanillo, have a higher carrying capacity than neglected fields. Zarzarilla spreads rapidly, and the animals that eat it seem to lose some of their hair and manes. The cost of destroying this weedlike bush, which grows in the arid and semiarid districts, is about $2.50 an acre. Guayacán blanco, or guayacanillo, grows on the shallow soils derived from limestone, in both the arid and humid districts. The pollen from this plant seems to irritate the eyes of the animals, and some ranchers have reported that it causes blindness in cattle.

The carrying capacity of the pasture land depends to some extent on the manner in which the livestock are handled. Cattle that are badly infested with ticks require a larger area over which to graze in

order to be in as good condition as are the nearly tick-free cattle. Ticks are a serious pest in all parts of the island, and a tick-eradication program is being initiated. Tick fever is sometimes fatal to imported dairy cattle. Most of the so-called native cattle and the zebu strains are more or less immune to tick fever, but the ticks do much harm to the animals by sapping their strength, which is of vital importance during the long dry periods when the pastures are overgrazed. In places along the southern coast, many hundreds of cattle die of starvation during a long dry season, such as that during the winter of 1930–31. Generally speaking, the first to die are those most heavily infested with ticks.

Tuberculosis among cattle also is prevalent but is not so serious as might be expected. A systematic tuberculosis testing and eradica-

FIGURE 88.—A badly infested guinea-grass pasture near Faro Cabo Rojo. Most of the brush is zarzarilla.

Yerba de guinea infestada, cerca del Faro de Cabo Rojo. La mayor parte de la maleza es zarzarilla.

tion program has been in progress for the last few years, under the direction of the United States Department of Agriculture, and it is hoped that all the range cattle, oxen, and dairy cattle on the island will soon be free of tuberculosis.

Most of the pasture in the arid districts has been planted with guinea grass, which grows from 2 to 8 feet high and seems to be much more nutritious than grass grown in the humid sections. Cattle raised in the arid districts are generally in better condition, have better health, and look better than animals born and raised on acid soils of the humid districts, where the grass is coarse and dense but less nutritious. Another important grass in the arid districts is Bermuda grass, which is resistant to alkali and salt. It is grown to a large extent on level lands near the coast that are subject to alkali. Bermuda grass is relished by the cattle much as it is in the United States. It and horquetilla (fig. 14), a fine-leaved slender grass, propagate naturally over the arid and semiarid districts. Horquetilla is fairly nutritious, but good stands of it very often are plowed under,

and guinea grass is planted. Bunches of guinea grass generally are planted in rows, often interplanted with corn, during the rainy season, and in some places the seed is planted. The seeds, however, may lie dormant in the soil for some time before they receive enough moisture for germination. After the guinea grass becomes large it will spread in the better soils, such as the Fraternidad, Paso Seco, and Yauco, but in the Aguilita, Ensenada, and similar soils, guinea grass grows only in the rows in which it was planted from 5 to 10 years ago. The guinea grass may become brown and dry during long droughts, but cattle will exist on the dead-appearing stems. Within a very few days after a rain, the grass in the previously brown baked pastures will become green and fresh. In some of the best

FIGURE 89.—Drawing water with oxen from an open dug well about 30 feet deep. The water is brought to the surface in a barrel, after which it is conveyed to a concrete trough.

Sacando agua de un pozo de 30 pies de profundidad. El agua es sacada a la superficie en un barril, después se echa en una canal de concreto.

pastures the cattle may be completely hidden by the tall dense guinea grass.

Water for livestock in the arid districts is drawn from dug wells (fig. 89) by hand and by windmill pumps. In many places the water is brackish, and additional salt for the animals is not necessary and is rarely seen near the corrals or in the pastures.

The grasses planted in the interior of the island for livestock are molasses grass, a prostrate twining fine hairy sweet-odored grass that is relished fairly well by livestock after they become accustomed to it; Guatemala grass, a rank-growing nutritious grass well adapted to acid soil in humid sections; and Napier grass (elephant grass), which resembles Japanese sugarcane in some respects. All the molasses grass is pastured, and after it becomes established it is an excellent grass for the prevention of soil erosion. It would be exceedingly difficult for water passing across a field of this grass to have sufficient force to wash soil particles from the intricately woven lower leaves and roots. The Guatemala and Napier grasses generally are cut by hand, made into bundles, and carried to the stables or corrals. In

this way enough hay can be gathered from an acre of most soil types to feed four or five oxen or dairy cows throughout the year. Other grasses of importance for livestock in the humid districts are grama or St. Augustine grass, cerrillo, and matojo. The so-called grama is superior to the other two and is an exceedingly good grass when grown on the alkaline soils, such as the Colinas, Soller, and Santa Clara. This grass also is good for the control of erosion, as its long runners securely anchor themselves to the soil and extend over gullies and on both sides of ditch banks, thus binding the soil in place. Cerrillo grows mostly in the subhumid districts, but it grows to some extent in the humid areas. It is considered a good grass for cattle or horses. Matojo grows in humid areas or on poorly drained soils. It is a rank-growing coarse grass of doubtful value for livestock. Although the animals eat it, it does not seem to keep them in good condition. It is also used in thatching houses, especially the roofs. Malojillo grass (fig. 90) probably is the most satisfactory grass on the island. It is a tall coarse grass that is always green. It is very palatable and an exceedingly heavy producer. Yields ranging between 7 and 8 tons to the acre are the average, and some fields have been said to produce 40 tons an acre during 1 year. This grass grows only on poorly drained soils or in humid districts. It would grow in the arid districts if the land were irrigated.

Most of the dairies are concentrated near the large cities, although many very large combination dairy and livestock ranches are in the arid districts. On some ranches from 100 to 200 cows are milked. The range cows are milked once a day and also suckle their calves. These cows give about 2 quarts of milk a day, and the strictly dairy cows give about 17 quarts a day. Many of the regular dairies have very good dairy cows and up-to-date equipment, but some dairies are neither efficiently run nor very sanitary. Milk costs from 12 to 20 cents a quart in the cities. The cost of feeding the dairy cows is very high, as most of the grain feed is imported from the United States. Malojillo grass is one of the main forage feeds, and it also is expensive. Nearly all of the main dairy breeds are represented on the island.

The number of sheep has declined rapidly since 1910. At that time, according to the Puerto Rico Reconstruction Administration census, 5,525 sheep were reported, but in 1930 only 3,259 were reported; and in 1935, 3,363. The constant hot weather does not favor the production of wool or a good quality of mutton. The largest numbers of sheep graze on the steep hills of the arid southern coast. The sheep are small, thin, straggly, and neglected. They roam about the pastures in small flocks and are restrained only when they attempt to enter a field of sugarcane.

The number of goats has decreased from 49,079 in 1910 to 36,478 in 1935. This is about the same as the number of goats in Utah in 1935. The climate and environment are well adapted to goats, and the number of these animals should be increasing instead of decreasing, as there are many hundreds of acres that are better adapted to the raising of goats than to anything else. Such soils as the Tanamá, Aguilita, San Germán, and many others could provide pasture for many thousands of goats. An increase in the number of goats would

FIGURE 90.—Rank-growing malojillo grass on Coloso clay in the eastern part of Puerto Rico. The hills in the distance are very similar to the hills in the prairie regions of continental United States.

Malojillo en Coloso arcilloso en la parte este de la isla. Las colinas a lo lejos son muy similares a las de las praderas de los Estados Unidos continentales.

give an additional needed milk and meat diet to the jibaros and their families. Goat and kid meat are relished by all classes of Puerto Ricans. Many kinds and colors of goats run loose about the island—from the city streets to the mountainsides. Most of them are in fairly good condition (fig. 91) and very active. It is unusual to see more than five in a flock, as most of the animals are owned by the jibaros who sell a part of their flock when they have more than two or three.

Hogs are fairly well distributed throughout the island (fig. 92). The number of hogs decreased from 103,041 in 1910 to 69,266 in 1930, and then increased to 79,508 in 1935. The last census shows that there are more hogs on the island than in any New England State except Massachusetts. In 1930 only 818 were registered. Most of them are of mixed breeding, and constant inbreeding has had its ill effects. The hogs are similar to the Tamworth bacon type, as they

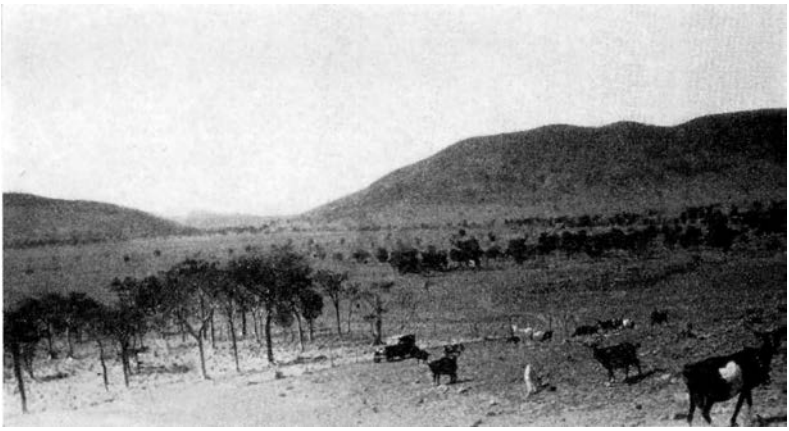

FIGURE 91.—Goats cropping the grass in the range land of Puerto Rico. The mean annual rainfall in this vicinity is about 40 inches.

Chivos pastando. El promedio anual de lluvia en esta vecindad es de 40 pulgadas.

are long, rangy, and thin with very little good fat meat. Most of them are red, but it is not unusual to see any ordinary color or combination of colors. Only a few hog ranches were noticed during the course of the survey. Generally the farmers have only one or two hogs each. The hogs may be confined to a pen but commonly are picketed to a small tree somewhere about the farm. Most of the hogs are marketed by leading them to town, but some are hauled on the bumpers of the public cars that carry both passengers and produce to and from town.

The hogs forage for themselves, living on roots, fruits, and nuts. Very few farmers feed much corn, and practically no mash or milk. Fortunately there are many nutritious nuts, such as the seeds of the royal palm and of the poma rosa, or rose apple, that are fairly abundant throughout the island.

According to the 1938–39 Annual Book on Statistics, $2,719,524 worth of pork and sausage and $2,373,103 worth of lard were imported from the United States during that fiscal year. This would indicate that a better quality of lard-producing hog should be raised.

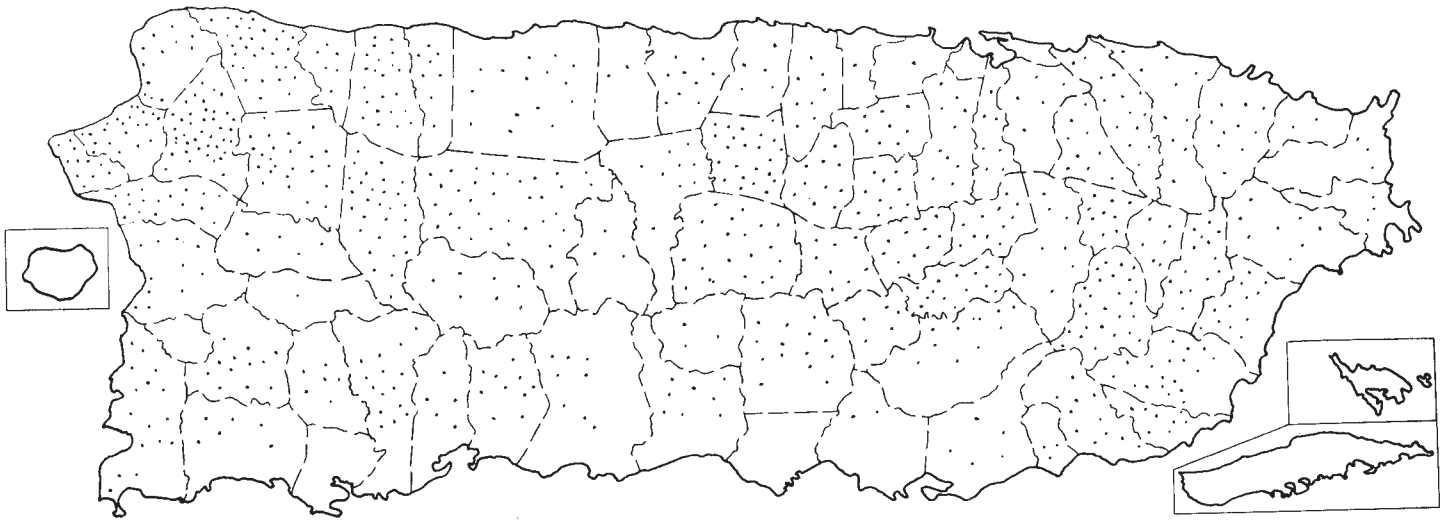

FIGURE 92.—Distribution of hogs in 1935. Each dot represents 100 head.
Distribucion de cerdos en 1935. Cada punto representa 100 cabezas.

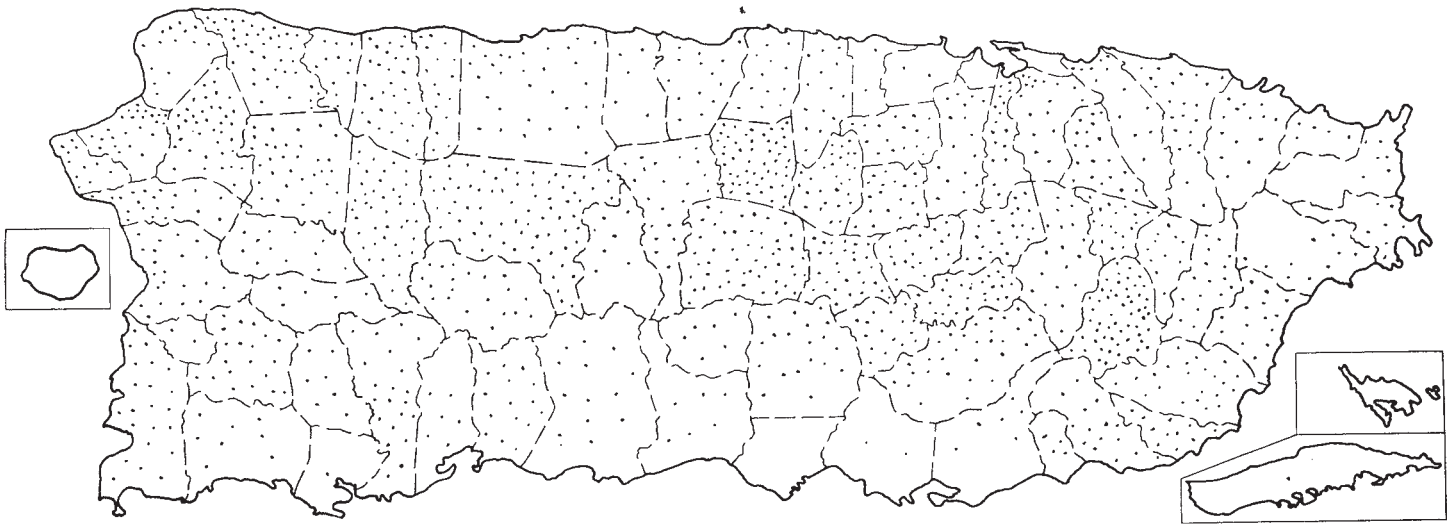

FIGURE 93.—Distribution of chickens in 1935. Each dot represents 500 chickens.
Distribución de aves (gallinas) en 1935. Cada punto representa 500 aves.

If as much advancement had been made in the production of corn as has been made in the production of sugarcane during the last 20 years, the hogs, corn, and, in fact, the island as a whole would be much better off today.

Nearly every rural family has a few chickens, but the average for 1930 was less than four chickens to a family. The distribution throughout the island corresponds fairly closely with the distribution of the rural population as can be seen by comparing figures 93 and 21. According to the 1935 census of the Puerto Rico Reconstruction Administration, the number of chickens on the island increased from 599,070 in 1910 to 684,448 in 1930 and decreased slightly to 667,749 in 1935.

Most of the chickens are a mixture of many breeds, but strains of the fighting cock or game bird probably are dominant, especially in many of the remote rural districts. They are good foragers and are active but are small and lean. They lay very small brown eggs that sell for about 15 cents a dozen less than eggs from the large breeds, such as the Plymouth Rock and Rhode Island Red. The Leghorn, Plymouth Rock, Rhode Island Red, and Minorca breeds seem to thrive, although undoubtedly they are less resistant to some diseases than the so-called Spanish chickens. Much improvement can be made in the poultry, both in regard to egg laying and meat production. The game birds receive more attention than any other livestock on the farm. They are exceedingly well groomed, fed, and trained. Cock fighting is legalized, and it receives more interest than any other form of amusement. Good fighting cocks sell at very high prices. Generally they are kept near the house, with one end of a string tied to a leg and the other end to a tree, stick, or rock.

Chickens do much better on well-drained soils having good circulation of air than on poorly drained soils. Many areas of very sandy soil, very rocky land, and soil low in fertility, that are not adapted to crops, make very desirable land for the raising of chickens. The Nipe, Corozo, and Aguilita soils, as well as the stony areas of many other soils, could be used advantageously for poultry yards. The island imports both poultry and eggs. During the fiscal year 1939, the United States sent to Puerto Rico 340,189 dozen eggs valued at $85,801, according to the 1938–39 Annual Book on Statistics.

Turkeys and guinea fowls are raised throughout the island. The largest numbers of turkeys are raised in the arid districts where diseases are not so prevalent. Guineas do well in nearly all districts and when killed and cooked are a favorite holiday food among the natives.

SOIL-SURVEY METHODS AND DEFINITIONS

The method used in making the detailed soil map of Puerto Rico was to traverse nearly all of the area in a car or on foot at intervals of one-fourth mile or less. The regular plane-table (fig. 94) survey method (*24, p. 37*) was used during the first two and the last winters. In 1931, the United States Navy took aerial photographs of approximately one-half of the area. These pictures were on a scale of about 1:10,000 and were used advantageously in the soil survey. Some of the aerial pictures were made into mosaics and reduced to a scale of about 1:40,000, and these were used in the field by covering them with thin pyralin paper, on which the soil boundaries, roads, and other features

were drawn. The method most generally used was one in which pyralin- or kodaloid-covered contact prints (fig. 95) were taken in the field, and on them was shown the location of the soil boundaries, streams, houses, and other features. Later the pyralins and koda-

FIGURE 94.—Soil surveyors making a detailed soil map by the regular plane-table survey method.

Técnicos de suelos haciendo un mapa detallado de suelos por el método de la plancheta.

loids were compiled, traced, reduced, and adjusted to a plane-table traverse of the main roads.

The soil was examined in many places to depths ranging from 3 to 6 feet, with a spade and an auger, in order to observe the variations of

FIGURE 95.—See legend on page 169 and table 12 on page 171.

the physical and some of the chemical properties of the surface soil, subsoil, and substratum. The surface soil and subsoil are referred to as the solum, and the substratum, in most instances, as the parent material. Collectively these terms include the soil profile. Like soils are combined into soil types, and their areas are delineated on a 1-inch to a kilometer scale map.[22] Careful attention has been given to the yields of crops growing on the different soil types and to the agricultural practices under which the yields were obtained.

The general features noticed in the examination of a soil are topographic position, drainage, parent material, native vegetation, apparent productivity, erosion, and crops produced. Careful observations are made of the color, texture (size of the individual soil grains), structure (arrangement of the soil grains into soil aggregates), and consistence (compaction, plasticity, or friability of the soil grains and soil aggregates) of the several layers of soil. The content of organic matter, roots, cracks, depth to lime, pH value, and other characteristics also are noted.

The different kinds of soil are grouped into series and types. The series is the broader group and may include one or more types. A soil series is a group of soil types that have certain physical and chemical properties in common. Some of the physical properties noted are the arrangement and thickness of the soil layers, or horizons, from the surface downward and color, consistence, and structure of the soil material; and some of the chemical properties noted are the relative amounts of organic matter, lime, and iron compounds present and the degree of acidity or alkalinity. The soil type, a subdivision of the series, is separated on the basis of texture of the surface soil. The series is given a geographic name, such as the name of the municipality or barrio where the soil was first mapped [23] and described, and this name, together with the name of the texture class, constitutes the name of the soil type. For example, a soil near Río Piedras, occurring on undulating or rolling uplands, having a yellowish-brown or reddish-brown acid surface soil and a plastic medium-compact mottled red, gray, and brown acid subsoil overlying fragmental shale, at a depth ranging from 26 to 36 inches, is classified in a series called

---

FIGURE 95.—Aerial photograph of about 400 acres of coastal plains in the vicinity of Vega Alta. In the field the soil-type boundary lines are shown on transparent pyralin or kodaloid paper that is fastened to the prints. The field data are transferred later to a plane-table traverse control map on a much smaller scale. This picture shows the density of rural dwellings, the large number of soil types, and from table 12 a correlation can be seen between soil types, land use, and plant growth. (Photograph taken by U. S. Navy.)

Fotografía aérea de alrededor de 400 acres de llanos de la costa en la vecindad de Vega Alta. En el campo los límites de los tipos de suelo son marcados en pyralina transparente o papel kodaloid que se coloca sobre la fotografía. Estos datos de campo después son transferidos a un mapa de control a una escala mucho menor. La fotografía muestra la densidad de las viviendas rurales, el gran número de tipos de suelo, y en la tabla 12 se puede ver una correlación entre los tipos de suelo y cosechas adaptables. (Fotografí tomada por la Marina de los EE. UU.)

---

[22] The published map is on a scale of 2 centimeters to a kilometer, or 1 : 50,000.

[23] Most of the soil series names occurring in this report and on the accompanying soil map are from geographic names in Puerto Rico, as these soils were mapped for the first time on the island. A few names have been introduced from the Virgin Islands, Cuba, and the United States.

Río Piedras, and if the surface soil is clay the type name is Río Piedras clay.

Río Piedras soils occur only on the uplands. Soils subject to frequent overflows, like the Toa and Coloso, occur only on bottoms, and soils of the terraces, like the Vía, occupy terrace positions only. Slight variations from the typical soil, in such features as relief, shallowness, or stoniness, frequently are described as phases. For example, an area of a soil type that has unusually steep relief may be designated as a steep phase of the typical soil.

The finer parts of all soils are composed of particles of different textural sizes, and these particles are grouped, according to size, under three principal heads, namely, sand, silt, and clay. The sand particles are the largest and are readily seen by the naked eye. The particles are rough, hard, gritty, and generally are noncoherent. Silt particles are microscopic in size and when wet are velvety to the touch, lacking the roughness of sand or the stickiness of clay. Clay particles are the smallest; some are so small that it is impossible to see them with a powerful microscope. Most of the clay particles when wet are plastic and sticky and when dried become hard and brittle. Different soils have different proportions of sand, silt, and clay, but generally every soil has some of each.

Soils have different characteristics, in part owing to the different proportions of sand, silt, and clay. Sand soils in general are comparatively unproductive and droughty, and their loose, open character causes them to drift readily when they are cultivated and unprotected by vegetation. The sandy loam soils contain more silt and clay than the sand soils and are, therefore, more fertile and have greater water-holding capacity. The loams are spoken of by many as the "all-round" soils and are, as a rule, adapted to a greater variety of crops than soils of other classes. Many of the sandy clay soils become very hard when dried, after having been wet a long time, as the clay particles have a cementing effect on the sand grains. The silt loam and clay loam soils are heavier in texture than the loams and require more careful management, in order to maintain good tilth, but for the most part they are strong soils and are suitable for many crops. The silty clay and clay soils contain more than 40 percent of clay, and many of them are very hard to work when wet, as the particles run together, and on drying, large hard clods are formed. At proper moisture conditions they can be handled easily, and they then form a good seedbed. Many clay soils absorb water very slowly and retain it a long time, as they have a large water-holding capacity, but some soils in Puerto Rico, containing more than 50 percent of clay, are friable, permeable, and do not retain moisture any better than sandy loams. Such soils have physical characteristics more like those of a loam than of a clay and are of common occurrence in the warm, moist Tropics. They have a high content of iron and alumina and a low content of silica. They are often spoken of as lateritic clays, and they have a lower capacity for the absorption of bases and retention of plant nutrients than do most other clays.

On the soil map that accompanies this report the areas occupied by the different soils are delineated according to soil types and phases. Each soil type and phase is shown by a separate symbol that corresponds to the soil legend. Table 12 gives a descriptive legend of a few soils that occur along the north coast. Land that is impregnated with

harmful quantities of salt is indicated on the map by a red boundary line. The concentrations of salt at specific locations are indicated on a percentage basis and are shown on the map.

TABLE 12.—*Descriptive legend for figure 95, showing correlation between soil types, land use, and plant growth in Puerto Rico*

Symbol	Soil type	Character of soil and principal land use
Ac	Almirante clay	Heavy brownish-yellow soil, poor for nearly all crops.
An	Almirante sandy clay	Do.
Bc	Bayamón clay	Deep red heavy-textured soil, fair for all crops.
Bs	Bayamón sandy clay	Deep red heavy-textured soil, fair for all crops, very similar to Bayamón clay.
By	Bayamón sandy clay loam	Deep red rather heavy textured soil, fair for sugarcane and pineapples.
Bf	Bayamón fine sandy loam	Deep sandy soil, good for citrus and truck crops.
Cz	Corozo fine sand	White coarse sand, very poor soil for all crops.
Ey	Espinosa sandy clay	Yellowish-red fairly heavy soil, only fair for most crops.
Eo	Espinosa loamy sand	Yellowish-red sandy soil, good for citrus and truck crops.
Sx	Santa Clara clay	Black heavy plastic medium deep soil, good for sugarcane.
Sk	Soller clay loam, hilly phase	Black heavy plastic shallow soil, excellent for grass.
Su	St. Lucie fine sand	Deep white coarse sand, very poor soil for all crops.
Ta	Tanamá stony clay	Shallow soil used only for brush.
Vf	Vega Alta fine sandy loam	Reddish-brown sandy soil, excellent for citrus crops.
Vl	Vega Alta loamy fine sand	Do.

The areas of the different soil types are outlined, although the distinction between any two adjoining soils is not everywhere sharply defined. In a few places, the soil boundaries do represent sharp changes, but in most places they indicate a transitional area between the two soil types. In many places the exact position of the boundary is an expression of the judgment of the man making the soil survey. The decisions of different fieldmen on any one unit or small tract may differ considerably, but in examining large areas, the results will be similar in most places. The soil maps should not be depended on entirely, without further field inspection, for the purchase or sale of individual farm units, but they should prove very useful as a guide for the purchase of land, establishment of fertilizer experiments, estimates of crop yields that may be expected from the soil types, and similar information.

SOILS AND CROPS

Many of the world's great soil groups are represented in Puerto Rico by some of the 115 soil series (including 352 soil types and phases) or one of the 6 miscellaneous land types. This is an unusually large number of soils for an area smaller than some of the western counties in continental United States. The factors responsible for soil development—climate, native vegetation, relief, age, and parent material—are extremely varied within short distances in Puerto Rico, and therefore a large number of soil types may be expected.

The average annual rainfall ranges from less than 30 inches in the southwestern part of the island to more than 200 inches in Sierra de Luquillo. The native vegetation ranges from the desert shrub type to the typical rain-forest type. The elevation ranges from sea level to 4,398 feet above on Cerro de Punta, south of Jayuya. The relief varies from level to precipitous. The age of the soils ranges from that of the recent alluvial deposits along streams and young soils on steep slopes to that of the very old soils developed on nearly flat remnants of ancient plateaus. The parent material has been produced, through the processes of weathering, from many different kinds of rock, such

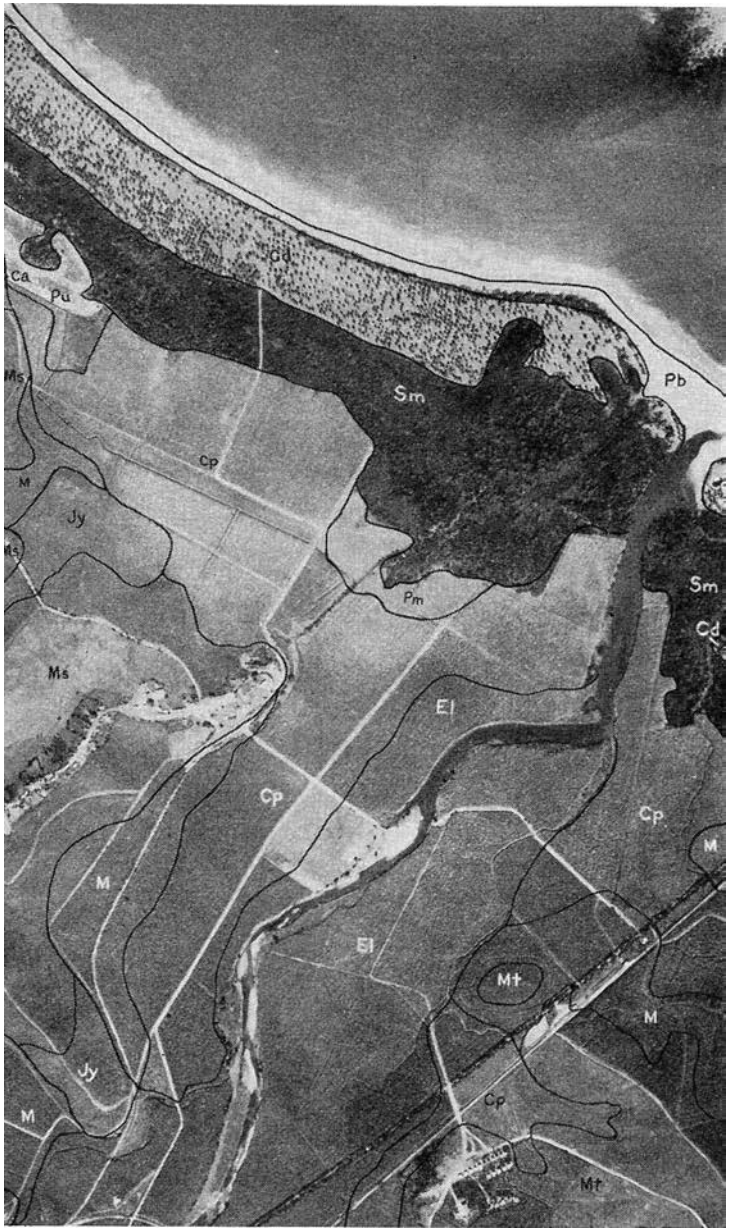

FIGURE 96.—See legend on page 173.

as Tertiary limestone, Cretaceous limestone, shales, tuff, volcanic ash, igneous intrusions, such as granites and andesites, and metamorphic rocks, such as serpentine, sandstone, and many mixtures of volcanic rock. These different rocks occur within different rainfall belts and many slope gradients, thereby greatly increasing the number of mappable soil types.

Some of the soils are similar to some of the soils in southern United States, but much larger numbers are similar to soils in more tropical countries, as Cuba, Santo Domingo, and the Virgin Islands.

As a discussion of the relationships between all the crops grown in Puerto Rico and all the soil types would be too lengthy, only the more important commercial crops will be discussed. The main crops are sugarcane, tobacco, grapefruit, bananas, pineapples, beans, sweetpotatoes, hay, corn, coffee, oranges, coconuts, yautia, plantains, yuca, pigeonpeas, ñames, and cotton.

If Puerto Rico were viewed from the air at a high altitude, one could distinguish readily several outstanding land forms that more or less encircle the island in ribbonlike bands, and each produces specific commercial crops (fig. 96). Beginning at any point along the coast and proceeding toward the interior, the most conspicuous correlation is that between the large coconut groves and small truck farms with the sandy coastal lowlands; the mangroves and salt-resistant vegetation with the swampy coastal lowlands; the level checkerboard-shaped fields of green succulent sugarcane with the nearly level river flood plains, terraces, and alluvial fans; a variety of crops with the smooth coastal plains; sugarcane with the undulating or rolling inner plains; and pineapples, tobacco, subsistence crops, coffee, bananas, oranges, forest trees, and grass with the rather restricted districts on the steep uplands.

If these several physiographic divisions or land forms are thoroughly studied, a definite cause will be discovered for the fact that farmers plant specific crops on certain types of land. In most places the determining factors for land use are climate, soil characteristics, relief, elevation, economic conditions, or a combination of these factors.

FIGURE 96.—Aerial view along Río Mameyes, showing ribbonlike bands of soil and the close correlation in land use. (The letter symbols are those used on the soil map to denote the various soils.) Palm Beach sand generally is barren or supports some xerophytic vegetation. Cataño sand generally is planted to coconuts intercropped with sweetpotatoes, yuca, and other subsistence crops. Nearly all of Saladar muck is covered with mangroves. Palmas Altas silty clay loam and clay are mostly in malojillo grass. The Coloso, Estación, and Mabí soils in general are occupied by sugarcane. Most of the Múcara and Juncos soils are in pasture and subsistence crops; many of the better areas near the road are in sugarcane. (Photograph taken by U. S. Navy.)

Vista aérea a lo largo del Río Mameyes, mostrando bandas de suelo en forma de cintas y la estrecha correlación en el uso de la tierra. La arena de playa generalmente es estéril con alguna vegetación xerofítica. La arena Cataño generalmente se siembra de cocos intercalados con batatas, yuca y otros cultivos de subsistencia. Casi todo el Saladar muck está cubierto de mangles. El Palmas Altas limo-arcilloso lómico y Palmas Altas arcilloso principalmente se siembran de malojillo. Los suelos Coloso, Estación, y Mabí se siembran casi exclusivamente de caña de azúcar. La mayor parte de los Múcara y Juncos están en pasto y en frutos menores; las mejores áreas cerca de la carretera a menudo están en caña. (Fotografía tomada por la Marina de los EE. UU.)

Most of the well-drained soils of the coastal lowlands, which form a discontinuous narrow strip fringing the coast, are nearly level, loose, sandy, and alkaline. These soils are preferred for coconuts and minor crops, such as sweetpotatoes, yuca, peanuts, and melons, because these crops are more profitably grown on the sandy soils than they are on the heavy clay soils or the poorly drained soils. Then, too, coconuts grow better and produce higher yields near the sea at low elevations than they do inland on high elevations. These sandy soils are too loose for profitable yields of sugarcane, too near the sea for good-quality tobacco, too low and too dry for coffee, and in general too alkaline for pineapples. Guinea grass and citrus trees would grow very well. Because these soils are so sandy and droughty, the principal native vegetation is xerophytic in character, regardless of whether the soil occurs in the humid or in the arid sections.

The poorly drained lands of the coastal lowlands include both organic and mineral soils. They occur adjacent to and inland from the beach or coast line. They have flat relief and are composed of soil having a high content of plastic sticky clay, muck, or fibrous peat. The elevation of these soils ranges from sea level to 2 feet above. Adequate drainage involves an expensive establishment of ditches, dikes, and pumps. The undrained organic soils in both the arid and humid sections are acid and salty, and they produce mangroves and other halophytic vegetation. The principal enterprise in these swamp areas is the making of charcoal from the native mangrove thickets that grow rapidly and readily, regardless of the salt content of the soils. The organic soils that have been adequately drained produce fair yields of sugarcane, but the content of sucrose in it is very low. Most of the mineral soils of the poorly drained coastal lowlands are adjacent to or closely associated with the organic soils. They are acid in the humid sections and calcareous in the arid sections. In the humid sections they produce fair malojillo grass, and when drained they make fair or good soils for the production of sugarcane. Most other crops, with the exception of rice, would be a failure on such land. In the arid sections, most of this land has a high content of harmful salt and produces nearly valueless alkali grasses and shrubs. A few areas have been reclaimed and are used for the production of sugarcane.

Although the river flood plains definitely lie adjacent to the stream channels, the alluvial material has been spread out to such an extent at the mouth of each river that a band of this material not only extends continuously for many miles parallel with the coast but inland from the coastal lowlands as well. About 90 percent of all the river flood plains are within 5 miles of the coast. Generally speaking, these soils of the alluvial lands are deep, nearly level, dark, and fertile. Those adjacent to the streams, for the most part, are more friable, better drained, and sandier than those occurring parallel with the streams (but a short distance away from them) and associated with the poorly drained mineral soils of the coastal lowlands. Most of the soils of the alluvial lands range from only slightly acid to calcareous. The most alkaline soils occur along the arid southern coast where the materials have accumulated from soil washed from the limestone, calcareous tuff, shale, and hills of related material where the rainfall has not been sufficient to leach the lime carbonates from the soil. The most acid and lightest colored alluvial soils occur where the soil

material has been washed from the acid, coarse-textured, grantic hills in the eastern and the west-central parts of the island.

The soils of the river flood plains are nearly ideal for the production of sugarcane, as, for high yields, this crop requires soil that is nearly level, fertile, deep, properly drained and that will respond to good management and fertilizers. Nearly 90 percent of the area of these soils is planted to sugarcane. Most of the other 10 percent is used for the production of malojillo grass, which is used extensively for hay by the dairy farmers. This grass is about the only crop that can compete with sugarcane on this high-priced, valuable, productive land. Other crops, such as rice on the poorly drained soils and citrus, tobacco, corn, and minor crops on the well-drained soils, would be productive but not so profitable as sugarcane, under present conditions.

Nearly the entire area of the soils in the arid sections is irrigated, and considerable areas in the humid sections receive some water from pumps.

Adjacent to the river flood plains, but on slightly higher elevations, are the soils of the river terraces and alluvial fans. These soils are composed of materials similar to the alluvial material of the river flood plains, but they are older, genetically more developed, and never flooded from stream overflow. They are nearly level and occupy rather large areas. The soils are deep and fertile, and most of the areas are readily accessible. These favorable factors, combined with sufficient rainfall or sufficient irrigation water, make them well adapted for the production of high yields of sugarcane, provided they are well managed and fertilized. More than 75 percent of their area is used for this crop, because more profit is made from sugarcane than from any other crop, under present economic conditions. Some areas that occur at high elevations and far from sugar centrals are used for coffee, which produces profitable yields when the crop is well managed and the price is reasonably high. A few areas in the arid sections are not irrigated and therefore are used only as pasture land.

The soils of the smooth coastal plains form a discontinuous strip ranging in width from almost nothing along the southern and southeastern coasts to more than 8 miles along the north-central and northwestern coasts. Most of these soils are derived from medium-hard Tertiary limestone, and they are generally red or reddish brown, friable, deep, fairly fertile, permeable, and acid. They occur in level or undulating areas and range in texture from sand to clay. Because they have a wide range in texture; are deep, friable, and well drained; and allow rapid penetration of plant roots, they are adapted to nearly every crop grown on the island. Even with good management, however, they do not produce such high yields as do the soils on the river flood plains, terraces, and alluvial fans. These soils have been leached of their bases and plant nutrients to much greater extent than the soils on the river flood plains and the terraces, because they are older, more permeable, and, for the most part, more acid. They respond fairly well to large applications of fertilizers. Most of the areas receiving less than 60 inches of annual rainfall are irrigated.

The most profitable and, therefore, the most common practice is to plant sugarcane and pineapples on the heavy-textured soil types and grapefruit, minor truck crops, and cotton on the sandy-textured types. Both sugarcane and pineapples will grow on the sandy soils, but yields are much lower than on the heavier soils. Grapefruit

trees for best production need a deep, friable, well-drained, and well-aerated soil. Therefore, the sandy-textured soils of these smooth valleylike coastal-plain areas are nearly ideal for grapefruit. Generally speaking, minor crops and cotton are not very profitable, but in many places they are more profitable than any other crop that can be grown on the very sandy soils. Large acreages of the soils of the coastal plains are planted to sweetpotatoes, yuca, ñames, melons, and other vegetables. Guinea grass and elephant grass produce fairly good yields on these soils.

Areas of the soils of the smooth coastal plains, occurring in the semiarid northwestern part of the island near Isabela and in the southwestern part near Cabo Rojo, are the least acid soils of this group, because the rainfall is insufficient to leach rapidly all the calcium that is returned to the soil from the decayed plant leaves which have received the calcium from the soil through the plant's lower roots. The soils in this area are too alkaline for the profitable production of pineapples, but they are desirable for tobacco, peppers, cucumbers, eggplant, and other vegetables. They require considerable irrigation water for high yields of all crops. Corn, melons, and guinea grass yield fairly well without irrigation.

The soils of the inner plains and colluvial slopes lie adjacent to the uplands, and they do not form so distinct a band as the coastal lowlands, as they are somewhat intermixed with the uplands. In a general way, however, they form an irregular noncontinuous belt between the uplands and the other physiographic divisions. The relief of these soils ranges from gently sloping to strongly undulating, and, therefore, external drainage is adequate in most places. Internal drainage is somewhat restricted in most of the soils because they have very plastic sticky surface soils and subsoils that do not favor rapid percolation of water. Therefore, they are not seriously leached of their bases and plant nutrients. The heavy subsoils have such high water-holding capacity that they generally feel moist except during protracted dry spells.

Most of the soils in this group occur in humid or subhumid sections, and only a few areas are irrigated. A harmful quantity of soluble salts is a limiting factor in crop production in a very small proportion of their total area.

All the soils of the inner plains and colluvial slopes are fairly deep, are fertile, and contain very few rocks. Sugarcane and malojillo grass are the crops best adapted for these soils. For high yields of sugarcane, from 800 to 1,000 pounds of fertilizer to the acre are added each year, and most areas require some artificial drainage. These soils are too heavy and too plastic for such crops as citrus, tobacco, and cotton.

The soils of the uplands occupy the interior of the island, and in a few places they extend to the coast. In areas having a high rainfall, most of the soils occur on steep relief and are for the most part red or purple, high in clay, acid, and only fairly fertile. Pineapples, a crop requiring an acid well-drained reasonably deep soil, are grown to considerable extent on the rolling and smooth areas of these soils, especially in the vicinity of Corozal. Coffee, a crop that requires more than 65 inches of average annual rainfall and that produces the best quality of berries at an elevation ranging from 1,200 to 2,000 feet, is grown exclusively on these soils. Forests occupy most of the land

above an elevation of 2,000 feet, because at that elevation the relief is so rough, broken, and the soils so exposed to wind that commercial crops cannot profitably be grown. Oranges, bananas, plantains, yautia, and ñames are grown throughout areas of these deep red soils of the uplands, because the plants require considerable moisture and grow better in deep permeable soils than in heavy, plastic, or shallow soils.

In the subhumid sections, the soils of the uplands are grayish brown or brown, neutral, friable, and fertile. Most of these soils are fairly shallow and occupy areas of steep relief. Tobacco, a crop requiring a well-drained friable soil not influenced by salt breezes, is well adapted to these soils, and large areas in the central and east-central parts of the island are planted to this crop.

Subsistence crops, such as beans, pigeonpeas, corn, and sweetpotatoes, are planted throughout all areas of the brown or grayish-brown neutral or slightly acid upland soils. These crops generally are grown by the jibaros, or peon farmers, who do not have funds for the purchase of fertilizer or lime, and, under this system of management, these soils are more productive than the deeper, more acid, and more leached red soils of the uplands. Sugarcane is often planted on the more gentle slopes within a mile of a good highway. Probably a higher proportion of the rural population lives on these extensive grayish-brown uplands than on the soils of any other group. The reason for this is due, in part, to economic conditions in the island. Sugarcane is by far the most important crop grown, and, for the highest efficiency in handling it and for largest yields, it must be grown on good soils and in large holdings. Therefore, most of the nearly level deep fertile soils are used for that crop. The land occurs in large tracts and is sparsely populated. The population is increasing at the rate of about 50 people to the square mile every 5 years. As the best land is used for cash crops, pressure of the rapidly increasing population gradually forces the jibaros and their families (fig. 97) farther into the hills and mountains onto the more or less shallow soils, where they plant some subsistence crops, in order to supplement the wages they receive from part-time work in sugar centrals, tobacco-stripping shops, needlework shops, and other industrial plants.

The soils of the uplands in the arid sections, as well as the most shallow soils in the subhumid and humid sections, are dark, shallow, and fertile. Most of these soils are alkaline, rocky, and have very steep relief. Owing to the shallowness of the soil, rockiness or steepness of the land, or dry climate, or a combination of these factors, these soils are suitable only for grass, brush, and trees. Large cattle ranches and few people are characteristic of the arid sections, and small farms with very small patches of subsistence crops and large acreages of pasture and forest are typical of the subhumid and humid sections.

When the soils were mapped, stress was laid, not only on the different physical characteristics of the soil profiles, but also on some of the chemical characteristics, such as acidity and salt content, which have a bearing on crop use. The relief was considered, and steep or smooth phases of soil types were differentiated, which required different use of the land from that employed on the typical soil.

144038—41——12

Very shallow alluvial soils underlain by gravel are shown as shallow soil phases, as these soils, when irrigated, may require more than five times as much water as the typical soil. Seriously eroded areas are shown as eroded phases.

The soils of some series, as Múcara, Catalina, Toa, Coloso, Fajardo, and Sabana Seca, occur throughout nearly all the humid parts of the island, and other soils, like the Dominguito and Juana Díaz, occur only in local areas.

The soils are arranged in several groups, based principally on the physiographic divisions in which they occur (fig. 98), and these

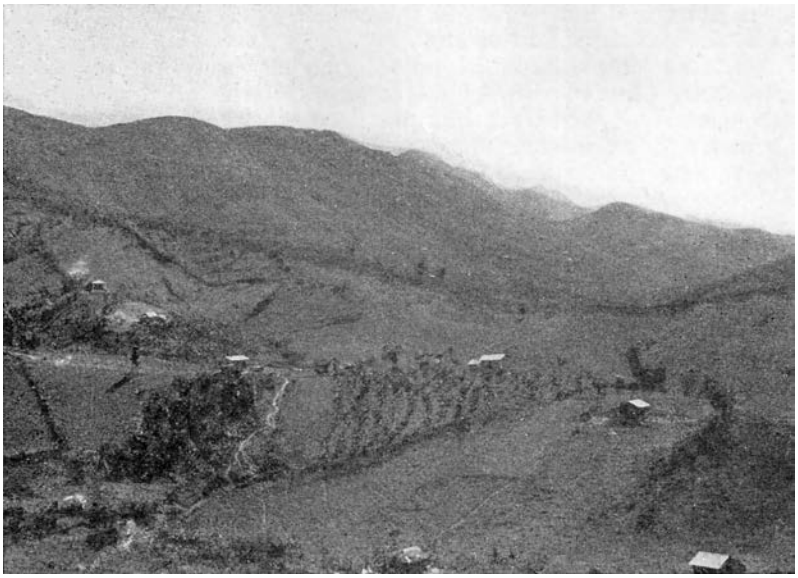

FIGURE 97.—Hundreds of families live on the shallow brown Múcara and related soils of the interior. The people plant subsistence crops, in order to supplement the wages they receive from part-time work in sugar centrals, tobacco-stripping shops, and other industrial plants.

Cientos de familias viven del suelo pardo poco profundo Múcara y de otros relacionados en el interior de la isla. La gente siembra frutos menores para suplementar los salarios recibidos de las centrales azucareras, despalillados de tabaco y otras industrias.

groups are subdivided on the basis of the soil characteristics that influence land use. The soils of the uplands have been placed in three subgroups, according to the depth to unconsolidated rock. These soils occupy nearly as much land as the combined area of all other soils. The relief of these soils ranges from rolling to precipitous; the largest acreage would be classified as very steep. Most of the coffee, oranges, bananas, vanilla, and the greater part of the tobacco and subsistence crops, as well as pasture grass, are grown on them. The soils of the inner plains occupy a small proportion of the total area. They have level, rolling, or sloping relief and are suitable for nearly all cultivated crops, but sugarcane occupies the largest acreage. The soils of the terraces and alluvial fans are divided into two subgroups, based on the compaction of the subsoils. These soils have

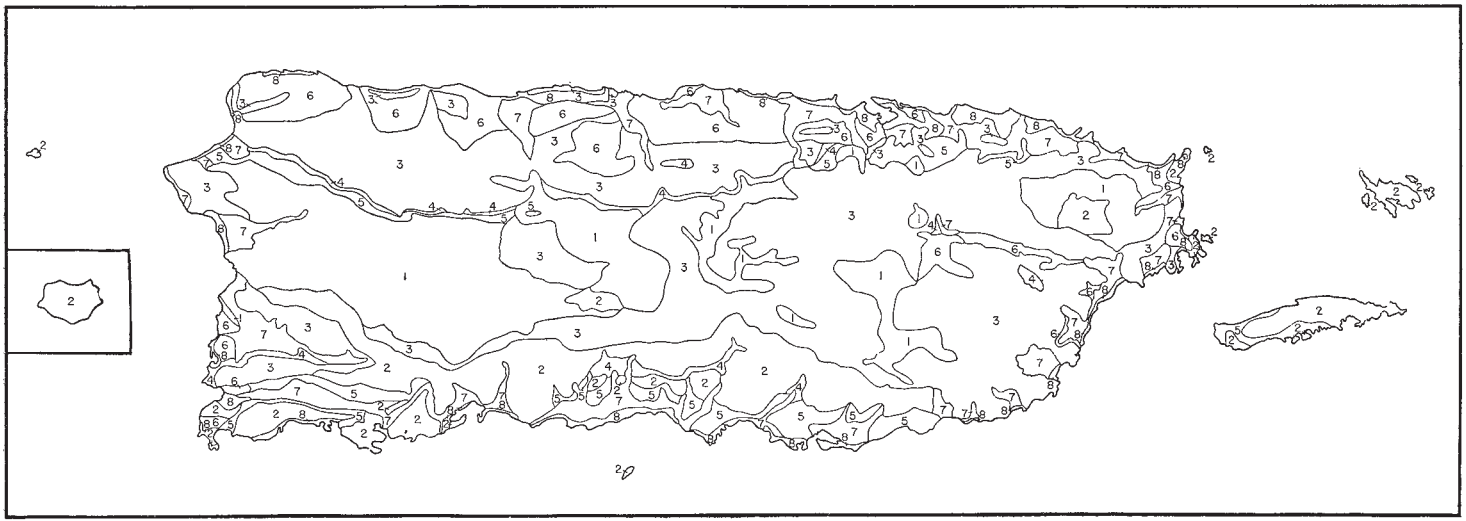

FIGURE 98.—Diagrammatic map of Puerto Rico, showing the approximate soil groupings and physiographic divisions: 1, Deep soils of the uplands; 2 shallow soils of the uplands; 3, medium-deep and some shallow soils of the uplands; 4, soils of the inner plains; 5, soils of the terraces and alluvial fans; 6, soils of the smooth coastal plains and, in places, some shallow soils of the uplands; 7, soils of the river flood plains; and 8, soils of the coastal lowlands.

Diagrama de Puerto Rico demostrando aproximadamente los grupos de suelos y divisiones fisiográficas: 1, Suelos profundos de la altura; 2, suelos poco-profundos de la altura; 3, suelos medio-profundos incluyendo algunos poco-profundos de la altura; 4, suelos de las llanuras interiores; 5, suelos abancalados y de aluvión en abanico; 6, suelos de las llanuras costaneras lisas incluyendo, en sitios, algunos suelos poco-profundos de la altura; 7, suelos de los valles de aluvión; y 8, suelos de los bajos costaneros.

nearly level relief and for the most part are high in fertility and are especially well adapted for sugarcane. The soils of the coastal plains are divided into four subgroups, according to the compaction of either the surface soil or the subsoil. These soils are fairly fertile and produce fair yields of nearly every crop commonly grown. They have level or undulating relief, and the majority of them are red or reddish brown. The soils of the river flood plains are divided into two subgroups, depending on the condition of internal drainage. Sugarcane, the most productive crop produced on these soils, occupies nearly 90 percent of their total area. They have level relief and are enriched frequently by silt-laden overflows which help to maintain their high fertility. The soils of the coastal lowlands are divided into three subgroups: Well-drained soils, imperfectly drained mineral soils, and imperfectly drained organic soils. Most of the land is level or flat, and the soils are fairly productive if they are not impregnated with salt or do not have a high water table. Nearly all of the coconuts and a large quantity of truck crops are produced on the well-drained areas of these soils. The organic and related soils include a very small proportion of the total area, and agriculturally they are not very important. Most of their area is in mangroves. Field observations are being made continually, regarding the use capabilities of each soil type; and this information, together with field notes on actual crop yields, as reported by farmers and experiment stations, combined with notes on the chemical and physical characteristics of the soil type, are the bases for the description of the soil types and phases discussed in the following pages. The accompanying soil maps show the location of the many soil types, and table 13 gives their acreage and proportionate extent.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Soils of the uplands			*Soils of the uplands*—Con.		
Catalina clay	38,336	1.8	Daguao clay, colluvial phase	1,728	0.1
Catalina clay, level phase	5,760	.3	Múcara silty clay loam	148,800	6.9
Catalina clay, steep phase	58,112	2.7	Múcara silt loam	6,528	.3
Catalina stony clay	11,968	.6	Juncos clay	31,360	1.4
Catalina stony clay, steep phase	4,672	.2	Sabana silty clay loam	18,368	.8
Cialitos clay	69,504	3.2	Sabana silt loam	8,192	.4
Cialitos clay, steep phase	131,840	6.0	Naranjito silty clay loam	11,136	.5
Cialitos clay, eroded phase	8,320	.4	Naranjito silty clay loam, smooth phase	3,392	.2
Los Guineos clay	52,416	2.4	Naranjito silty clay loam, colluvial phase	64	(1)
Los Guineos clay, smooth phase	18,112	.8	Río Piedras clay	9,472	.4
Alonso clay	17,344	.8	Río Piedras silty clay loam	192	(1)
Alonso clay, smooth phase	4,992	.2	Pandura sandy clay loam	15,680	.7
Alonso clay, colluvial phase	192	(1)	Pandura sandy clay loam, smooth phase	1,792	.1
Alonso clay, shallow phase	2,432	.1	Pandura loam	9,152	.4
Alonso silty clay loam	384	(1)	Pandura loam, smooth phase	21,824	1.0
Alonso silty clay loam, colluvial phase	128	(1)	Cayaguá sandy clay loam	7,424	.3
Malaya clay	512	(1)	Cayaguá sandy clay loam, steep phase	17,408	.8
Malaya clay, smooth phase	576	.05	Ciales clay loam	6,272	.3
Jayuya silty clay loam	4,096	.2	Ciales clay loam, smooth phase	512	(1)
Jayuya silty clay loam, steep phase	5,632	.3	Ciales loam	2,496	.1
Nipe clay	2,880	.1	Ciales loam, smooth phase	2,304	.1
Colinas clay loam	17,856	.8	Ciales loam, colluvial phase	64	(1)
Colinas stony loam	8,640	.4	Teja loam	1,984	.1
Colinas fine sandy loam	1,280	.1	Teja loam, steep phase	3,584	.2
Soller clay	5,632	.3	Teja loam, eroded phase	192	(1)
Tanamá stony clay, smooth phase	14,144	.7	Utuado loam	22,144	1.0
Tanamá stony clay, colluvial phase	9,408	.4	Utuado loam, smooth phase	3,200	.1
Plata clay	2,816	.1			
Plata clay, mixed phase	768	.05			
Daguao clay	2,752	.1			

See footnote at end of table.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*—Continued

Type of soil	Acres	Percent
Soils of the uplands—Con.		
Vieques loam	6,400	0.3
Vieques loam, undulating phase	1,472	.1
Vieques loam, colluvial phase	2,496	.1
Colinas clay loam, steep phase	20,544	.9
Colinas stony clay loam	6,400	.3
Colinas stony clay loam, steep phase	13,184	.6
Soller clay loam	3,456	.2
Soller clay loam, shallow phase	4,480	.2
Soller clay loam, hilly phase	20,672	.9
Soller clay loam, steep phase	33,024	1.5
Aguilita clay	9,600	.4
Aguilita stony clay	31,616	1.4
Aguilita stony clay, shallow phase	3,136	.1
Tanamá stony clay	89,600	4.1
Ensenada clay	768	.05
Ensenada clay, shallow phase	3,584	.2
San Germán clay	11,392	.5
Lajas clay	6,848	.3
Lajas clay, rolling phase	4,032	.2
Jácana clay	28,544	1.3
Descalabrado silty clay	49,344	2.3
Descalabrado silty clay, rolling phase	19,264	.9
Descalabrado silty clay, shallow phase	9,600	.4
Descalabrado silty clay, eroded phase	18,752	.8
Guayama clay	31,616	1.4
Guayama clay, colluvial phase	1,920	.1
Daguao clay, steep phase	896	.05
Múcara silty clay loam, steep phase	122,688	5.7
Múcara silty clay loam, shallow phase	44,352	2.0
Múcara silt loam, steep phase	20,928	1.0
Picacho stony clay loam	11,840	.5
Naranjito silty clay loam, steep phase	192	(1)
Yunes clay	3,712	.2
Yunes silt loam	960	.05
Mariana clay loam	6,400	.3
Juana Díaz clay loam	512	(1)
Juana Díaz silty clay	384	(1)
Rosario silty clay	22,208	1.0
Rosario silty clay, smooth phase	2,816	.1
Vieques loam, steep phase	3,584	.2
Rough stony land	10,624	.5
Soils of the inner plains		
Las Piedras clay loam	1,408	.1
Las Piedras clay loam, steep phase	576	.05
Las Piedras loam	1,344	.1
Mabí clay	22,784	1.0
Mabí clay, flat phase	4,416	.2
Moca clay	11,136	.5
Moca silty clay loam	3,136	.1
Moca silty clay loam, steep phase	128	(1)
Moca loam	1,024	.05
Dominguito clay	2,560	.1
Río Arriba clay	1,856	.1
Santa Clara clay	10,368	.5
Santa Clara clay loam	4,800	.2
Camagüey silty clay	2,560	.1
Camagüey clay loam	7,680	.3
Yauco clay	3,456	.2
Yauco clay, colluvial phase	1,792	.1
Ponceña clay	2,752	.1
Ponceña clay, eroded phase	512	(1)
Portugués clay	1,024	.05
Mercedita clay	1,920	.1
Barrancas clay	512	(1)
Barrancas silty clay loam	256	(1)
Pozo Blanco clay	320	(1)
Pozo Blanco clay loam	2,048	.1
Amelia clay	11,072	.5
Río Cañas clay	640	.05
Cabo Rojo clay	2,176	.1
Cabo Rojo clay, rolling phase	64	(1)
Soils of the terraces and alluvial fans		
Torres clay	3,520	0.2
Torres clay, steep phase	3,200	.1
Torres silty clay loam	1,216	.1
Vía silty clay	5,888	.3
Vía silty clay, broken phase	960	.05
Vía clay loam	1,664	.1
Vía silt loam	704	.05
Vía silt loam, broken phase	128	(1)
Lares clay	8,768	.4
Lares clay, steep phase	5,952	.3
Lares clay, red-subsoil phase	512	(1)
Lares silty clay loam	1,792	.1
Lares clay loam	4,288	.2
Lares sandy loam	1,088	.05
Fajardo clay	7,168	.3
Fajardo clay, gray phase	384	(1)
Fajardo clay, steep phase	1,408	.1
Humacao clay	1,408	.1
Humacao clay loam	896	.05
Humacao loam	1,856	.1
Humacao sandy loam	64	(1)
Mayo clay loam	64	(1)
Mayo loam	256	(1)
Resolución clay loam	256	(1)
Llave loam	1,472	.1
Llave sandy loam	704	.05
Arcadia loam	256	(1)
Coamo clay	6,464	.3
Coamo clay, alluvial-fan phase	320	(1)
Coamo silty clay loam	1,920	.1
Coamo silty clay loam, rolling phase	704	.05
Machete clay	960	.05
Machete clay loam	2,432	.1
Machete loam	64	(1)
Machete loam, steep phase	64	(1)
Vives clay loam	1,792	.1
Vives clay loam, colluvial phase	832	.05
Vives clay loam, steep phase	64	(1)
Vives loam	896	.05
Vives sandy loam	128	(1)
Fraternidad clay	11,072	.5
Fraternidad clay, shallow phase	64	(1)
Fraternidad clay, imperfectly drained phase	256	(1)
Fraternidad clay, colluvial phase	1,152	.1
Fraternidad clay loam	192	(1)
Paso Seco silty clay	5,120	.2
Paso Seco clay	1,344	.1
Paso Seco silty clay loam	3,136	.1
Paso Seco silt loam	192	(1)
Paso Seco loam	64	(1)
Fé clay	4,736	.2
Fé clay, imperfectly drained phase	2,176	.1
Santa Isabel clay	7,040	.3
Santa Isabel silty clay loam	3,904	.2
Santa Isabel loam	576	.05
Teresa clay	1,472	.1
Teresa silty clay loam	2,176	.1
Teresa loam	320	(1)
Candelero loam	1,536	.1
Candelero loam, shallow phase	704	.05
Candelero clay	64	(1)
Candelero clay, shallow phase	64	(1)
Candelero sandy clay loam	320	(1)
Candelero sandy clay loam, shallow phase	64	(1)
Candelero sandy clay loam, broken phase	128	(1)
Candelero sandy loam	1,408	.1
Soils of the coastal plains		
Sabana Seca clay	7,488	.3
Sabana Seca sandy clay loam	9,984	.5
Caguas clay	5,568	.3
Caguas sandy clay loam	256	(1)
Almirante clay	2,752	.1
Almirante sandy clay	3,584	.2

See footnote at end of table.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*—Continued

Type of soil	Acres	Percent
Soils of the coastal plains—Con.		
Almirante fine sandy loam	448	(1)
Vega Alta clay, heavy-subsoil phase	1,408	0.1
Vega Alta sandy clay loam, heavy-subsoil phase	1,728	.1
Vega Alta clay loam, heavy-subsoil phase	1,216	.1
Vega Alta clay loam, poorly drained phase	64	(1)
Islote clay loam	960	.05
Islote sandy loam	1,152	.1
Islote sandy loam, imperfectly drained phase	320	(1)
Coto clay, heavy phase	6,848	.3
Coto clay	4,672	.2
Coto sandy clay	1,600	.1
Espinosa clay	1,408	.1
Espinosa sandy clay	10,432	.5
Matanzas clay	3,072	.1
Matanzas sandy clay	320	(1)
Bayamón clay	2,176	.1
Bayamón sandy clay	2,112	.1
Bayamón sandy clay loam	1,344	.1
Vega Alta clay	384	(1)
Vega Alta clay loam	3,840	.2
Vega Alta sandy clay loam	1,472	.1
Vega Alta fine sandy loam	5,504	.3
Vega Alta loamy fine sand	2,624	.1
Espinosa sandy loam	2,368	.1
Espinosa loamy sand	2,560	.1
Coto loamy sand	256	(1)
Bayamón fine sandy loam	7,104	.3
Bayamón loamy fine sand	832	.05
Maleza fine sandy loam	1,152	.1
Maleza loamy sand	1,856	.1
Islote loamy sand	512	(1)
Islote sand	704	.05
Río Lajas sand	2,880	.1
Río Lajas sand, hardpan phase	128	(1)
Guayabo fine sand	2,624	.1
Guayabo fine sand, shallow phase	5,888	.3
Corozo fine sand	3,328	.2
Algarrobo fine sand	5,376	.3
St. Lucie fine sand	2,496	.1
Soils of the river flood plains		
Toa silty clay	2,176	.1
Toa silty clay loam	12,800	.6
Toa silt loam	11,584	.5
Toa silt loam, low-bottom phase	704	.05
Toa loam	5,632	.3
Toa fine sandy loam	3,776	.2
Toa fine sandy loam, low-bottom phase	3,968	.2
Estación silty clay	384	(1)
Estación clay loam	512	(1)
Estación silt loam	3,072	.1
Estación silt loam, low-bottom phase	320	(1)
Estación loam	2,752	.1
Estación sandy loam	1,152	.1
Riverwash	6,592	.3
Viví clay	128	(1)
Viví silty clay loam	128	(1)
Viví clay loam	384	(1)
Viví clay loam, shallow phase	64	(1)
Viví silt loam	128	(1)
Viví loam	3,904	.2
Viví loam, shallow phase	704	.05
Viví sandy loam	1,920	.1
Viví loamy sand	320	(1)
San Antón clay	1,088	.05
San Antón silty clay	960	.05
San Antón silty clay, shallow phase	192	(1)
Soils of the river flood plains—Con.		
San Antón silty clay loam	4,864	0.2
San Antón clay loam	2,240	.1
San Antón silt loam	3,904	.2
San Antón silt loam, shallow phase	1,088	.05
San Antón loam	5,952	.3
San Antón loam, shallow phase	3,392	.2
San Antón fine sandy loam	1,984	.1
Altura clay	128	(1)
Altura silty clay	384	(1)
Altura silt loam	576	.05
Altura loam	2,240	.1
Altura loam, shallow phase	1,280	.1
Coloso clay	11,712	.5
Coloso clay, poorly drained phase	6,720	.3
Coloso silty clay	14,976	.7
Coloso silty clay loam	2,816	.1
Coloso clay loam	576	.05
Coloso silt loam	4,096	.2
Coloso loam	832	.05
Fortuna clay	1,856	.1
Fortuna clay, poorly drained phase	832	.05
Fortuna silty clay loam	1,792	.1
Fortuna clay loam	1,408	.1
Vega Baja clay	192	(1)
Vega Baja silty clay	3,968	.2
Martín Peña clay	3,136	.1
Martín Peña sandy clay loam	2,176	.1
Talante clay	512	(1)
Talante silty clay loam	320	(1)
Talante clay loam	1,152	.1
Talante loam	1,728	.1
Talante sandy loam	832	.05
Talante fine gravel	128	(1)
Irurena clay loam	1,024	.05
Irurena loam	256	(1)
Yabucoa clay	384	(1)
Yabucoa clay loam	704	.05
Yabucoa loam	192	(1)
Josefa clay	2,688	.1
Josefa clay loam	256	(1)
Maunabo clay	704	.05
Maunabo silty clay loam	64	(1)
Maunabo clay loam	1,088	.05
Maunabo loam	896	.05
Vayas clay	640	.05
Vayas silty clay loam	1,664	.1
Vayas silt loam	1,024	.05
Vayas loam	320	(1)
Aguirre clay	9,344	.4
Aguirre silt loam	64	(1)
Guánica clay	5,696	.3
Soils of the coastal lowlands		
Cataño loamy sand	3,840	.2
Cataño loamy sand, shallow phase	1,344	.1
Cataño sand	6,848	.3
Aguadilla sandy loam	576	.05
Aguadilla loamy sand	2,880	.1
Aguadilla sand	960	.05
Palm Beach sand	1,152	.1
Coastal beach	1,600	.1
Dune sand	1,024	.05
Meros sand	3,968	.2
Jaucas sand	768	.05
Piñones clay	4,544	.2
Piñones silty clay	1,472	.1
Piñones sandy clay loam	1,280	.1
Palmas Altas clay	5,888	.3
Palmas Altas silty clay	128	(1)
Palmas Altas silty clay loam	192	(1)
Palmas Altas sandy clay loam	1,728	.1
Palmas Altas loam	448	(1)
Úrsula clay	1,088	.05
Cintrona clay	576	.05

See footnote at end of table.

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Puerto Rico*—Continued

Type of soil	Acres	Percent
Soils of the coastal lowlands—Con.		
Cintrona silty clay loam	3,840	0.2
Cintrona loam	704	.05
Serrano clay	6,976	.3
Serrano sandy clay loam	1,344	.1
Serrano loam	1,088	.05
Serrano sandy loam	256	(1)
Córcega sandy clay	1,408	.1
Córcega sandy clay, poorly drained phase	64	(1)
Córcega sandy loam	960	.05
Córcega sandy loam, poorly drained phase	256	(1)
Aguadilla sandy loam, poorly drained phase	448	(1)
Aguadilla loamy sand, poorly drained phase	448	(1)
Soils of the coastal lowlands—Con.		
Cataño loamy sand, poorly drained phase	128	(1)
Cataño sand, poorly drained phase	576	0.05
Meros sand, saline phase	256	(1)
Tiburones muck	6,848	.3
Saladar muck	8,000	.3
Saladar muck, shallow phase	1,152	.1
Peat	7,360	.3
Peat, shallow phase	1,280	.1
Piñones clay, peaty-subsoil phase	3,136	.1
Sinkholes	64	(1)
Reparada clay	2,560	.1
Total	2,165,120	

[1] Less than 0.05 percent.

SOILS OF THE UPLANDS

The soils of the uplands include such a large proportion of the center of the island that they may be referred to as the backbone of Puerto Rico. The soils in this division have a wide range in soil characteristics. They range from black to nearly white, from rich to poor, from acid to alkaline, from fine sandy loams to clays, from shallow to deep, and from young to old. The soil climate ranges from arid to humid and the elevation from near sea level to more than 4,000 feet above. This may seem too great a variety of conditions for one soil division, but by separating the soils within this division into three subgroups, on the basis of the depth of their profiles, it may be seen that a correlation exists between each of the three groups and the land use and crop adaptation.

DEEP SOILS OF THE UPLANDS

The deep soils of the uplands include 21 soil types and phases of the Catalina, Cialitos, Los Guineos, Alonso, Malaya, Jayuya, and Nipe series. These soils occur throughout the entire humid section of the interior, and they range in elevation from less than 100 to about 3,000 feet above sea level. All the soils in this subgroup, with the exception of the Jayuya soils, have been derived from fine-grained volcanic igneous rocks that have decomposed rapidly under the warm, moist tropical climate, thereby producing soils that are high in permeable clay and low in silt and sand. The soils are high in iron and aluminum content, and the silica content is low. All these soils are either red or purplish red. The surface soils are acid and friable and readily work to a good seedbed. The subsoils in general are very acid, heavy, but permeable, and are adequately drained. On a given rock the thickness of the subsoil and substratum increases with an increase in the average annual rainfall and also on the more gentle slopes.

Most of the soils in this group occur on steep hills, and numerous V-shaped drainageways dissect their entire area. Many of the soils are planted to clean-cultivated crops, regardless of the steepness of the slopes, and through improper management much of the surface soil is lost through erosion, although these soils are not susceptible to

erosion on ordinary slopes of 10 or 15 percent. After heavy rains, streams throughout areas of the cultivated steep hillsides soon become loaded with red and purple clay. As soil development is rapid, in many places it keeps pace with erosion. In the moist warm climate, vegetation grows rapidly, thereby keeping erosion to a minimum, except on the improperly cultivated hillsides. The run-off water on most farms has a steep but short course before it empties into grass-covered healed-over ravines or small rock-bottomed streams (fig. 99).

These soils, with the exception of the Jayuya and Nipe, have some large rocks on the surface and throughout the soil layers. Areas

FIGURE 99.—Typical stream in the humid section.
Río típico en la zona húmeda.

shown on the map with stone symbols and the stony soil types contain much larger quantities than the typical areas.

Physically, these soils are adapted to many crops, but, owing to a deficiency in such chemical compounds as lime, phosphorus, and magnesium, to their rough relief, high elevation, and in many places to their long distance from towns and highways (fig. 100), coffee, oranges, bananas, and timber are the principal crops. Citrus, pineapples, and sugarcane are important crops in the smoother lower areas adjacent to roads.

Based on their natural productivity, the Alonso soils are the strongest, followed in order by the Malaya, Catalina, Jayuya, Cialitos, Los Guineos, and Nipe. The latter soils are exceedingly low in productivity. The steeper the relief, the less productive and less desirable are these soils. In equal areas, crop production generally is about four times greater on concave slopes than on convex slopes. Coffee that yields 100 pounds to the acre on convex slopes yields from 400 to 600 pounds on concave slopes. The soils on the concave slopes are higher in organic matter and have thicker surface layers than those on the convex slopes, owing to a gradual accumulation of soil and plant remains that wash from the adjacent slopes. The concave slopes also

are better protected from the wind, and the soils have a higher content of soil moisture than those on the convex slopes.

The smooth phases of these soils are more desirable and are adapted to a greater variety of crops than the typical soils. Unless the level areas receive large quantities of fertilizers, they are, in general, less productive than the gently rolling areas, because they are leached to a greater extent, are more acid, and have slightly poorer internal drainage. The colluvial slopes are generally the most desirable areas of all the soils of this subgroup, especially if they occur below areas of Múcara or related alkaline soils, as the wash from the alkaline soils

FIGURE 100.—Typical view on Catalina clay. This soil is deficient in lime, phosphorus, and magnesium, and the crops produced apparently are low in nutritive value. Poor teeth and rickets are common among the people living on areas of this soil. This particular area has an average annual rainfall of about 90 inches and is about 4 miles from the nearest road. Coarse matojo grass in foreground.

Vista de Catalina arcilloso. Este suelo está deficiente en calcio, fosforo, y magnesio, y los cultivos producidos en él aparentemente son bajos en valor nutritivo. Dientes enfermos y raquitismo son corrientes entre la gente que vive en áreas de este suelo. Esta área tiene una precipitación anual de más o menos 90 pulgadas y está a más o menos a 4 millas de la carretera más próxima. Al frente, matojo.

tends to keep the red soils from becoming very acid, and the incorporation of freshly eroded material from the higher slopes increases the productivity of the red soils.

Catalina clay.—Catalina clay is one of the most extensive all-round farming soils in the uplands. It is one of the red friable clay soils distributed over the ridges and slopes in areas receiving more than 79 inches of average annual rainfall and where the most important soil-forming rocks are andesitic tuff and tuffaceous shale. This soil occurs in large areas south of San Juan, Corozal, and Morovis; south of Ciales; and east of Mayagüez and Añasco. The relief ranges from rolling to steep, but most of the hills are rounded, and gently sloping ravines intervene.

A cultivated field of Catalina clay ranges in color from red to light brown. Few of the large fields are uniform in color, because deep plowing and sheet erosion have exposed the red subsoil that lies below the original brown or reddish-brown surface soil, and the result is a heterogeneous color. Normally, the surface soil is light reddish-brown friable softly granular clay that forms large clods when plowed, but which soon slakes into fine granules after the first or second dashing tropical shower. The thickness of the surface soil, as well as the value of the land, varies with the relief. On the less valuable, steeper, more eroded slopes the surface soil does not average more than 4 inches in thickness, and when the land is plowed some of the subsoil is exposed. On the more rolling, more valuable, less eroded areas, the surface soil is generally about 8 inches thick. The upper part of the subsoil, ranging from a depth of 8 to a depth of 24 inches, is brownish-red or red heavy but friable slightly granular clay. Both the surface soil and the subsoil are penetrated readily by plant roots and percolating water, and as a consequence sheet erosion is less severe than on soils with more plastic subsoils, which absorb water more slowly.

The lower part of the subsoil, beginning at a depth of about 24 inches, is dark-red clay that is more friable than the material in the layers above. The uniform red clay continues to a depth ranging from 10 to 30 feet, before the parent rock is reached. This soil is acid in the surface soil and becomes much more acid with depth.

Mechanical analyses show that this soil is high in clay and low in sand and silt. The surface soil contains over 65 percent of clay; the subsoil, about 80 percent; and the lower substratum, about 70 percent. Catalina clay is friable, only slightly plastic, lateritic clay that does not crack greatly at extremes of moisture content, and it can be cultivated soon after a rain without harming its physical characteristics. It is not so friable as Nipe clay or Matanzas clay, which occur in both Puerto Rico and Cuba.

Catalina clay is fairly productive for a variety of crops. At elevations ranging from 1,000 to 1,500 feet, nearly the entire area is used for the production of coffee. Yields exceeding 400 pounds to the acre of dry coffee may be expected in normal years from well-managed coffee farms. The yields are highest on the concave slopes and near the bases of the southern and western sides of long sloping hills. This soil is well adapted to the growing of guava, guama, and moca trees for shade in the coffee plantations. It is considered one of the best soils for the production of coffee, because both the shade trees and the coffee trees grow rapidly, owing to the friability of the soil and its medium-high content of plant nutrients. The soil occurs only in areas having sufficient rainfall for the growing of coffee, and large areas lie at an elevation that is nearly ideal for this crop.

Other crops producing well on this soil at high elevations are bananas, plantains, oranges, and yautias. The trees of inferior quality growing on this soil are made into charcoal. The making of charcoal returns considerable income, but it is a poor practice so far as improvement of the natural resources is concerned.

At elevations below 500 feet, many acres of this soil are used for the growing of grapefruit trees. The soil, although high in clay, is sufficiently permeable for roots to penetrate deeply, and the trees produced have a wide branch spread, thus filling in the spaces between

the trees. This, in turn, shades the ground and prevents the growth of weeds. The common practice is to plant from 42 to 45 grapefruit trees to the acre, and the trees on this soil continue to produce to an old age. One 17-year-old orchard, under fertilization and proper management, is producing yearly from 11 to 20 boxes of fruit to the tree. Fertilizer is applied to this orchard at a rate of 1,500 pounds to the acre. The proportion of ingredients used is 1 ton of sulfate of

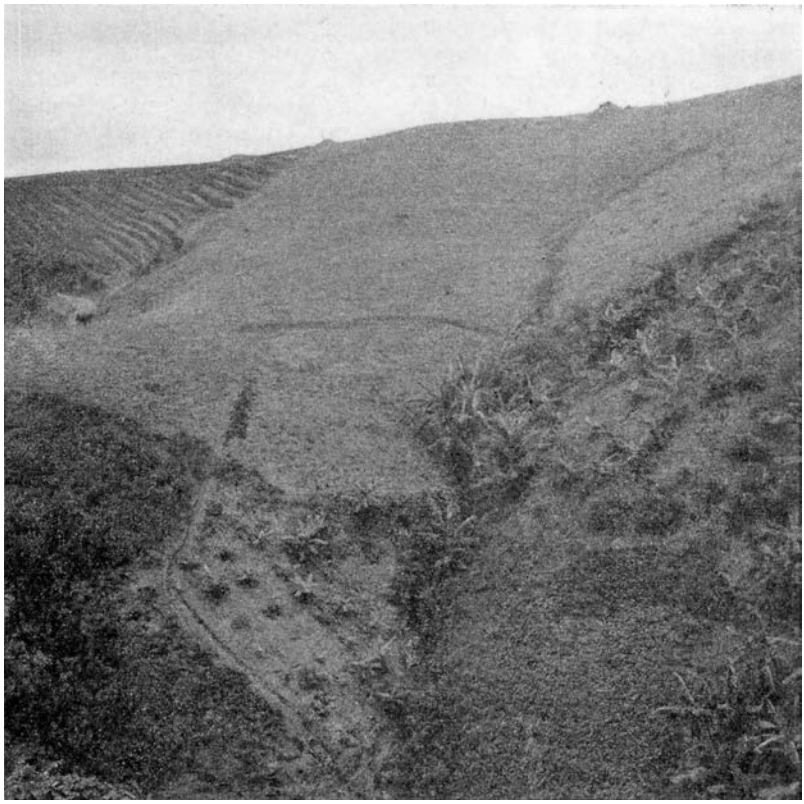

FIGURE 101.—Catalina clay along a highway near Corozal, where some fertilizer is used. Subsistence crops, such as sweetpotatoes, yautias, bananas, and pigeonpeas, planted on the 50-percent slope in the foreground. Pineapples and pasture in the background.

Catalina arcilloso a lo largo de una carretera cerca de Corozal donde se aplica algún abono. Frutos menores tales como batatas, yautías, guineos y gandules, al frente, sembrados en un declive de 50 por ciento. Piñas y pastos al fondo.

ammonia, 1 ton of acid phosphate, and one-half ton of potash. Two applications are made each year. Grass is grown in the orchards, in order to prevent erosion. The grass and weeds are cut with a machete at the beginning of the dry season.

Probably a larger acreage of this soil is planted to pineapples than of any other soil type on the island. On slopes (fig. 101) of 40 to 50 percent nearly as high yields are produced as on the undulating areas. In many places on the steep slopes the surface soil has been washed

away by erosion, but, with high applications of fertilizer, the subsoil of this soil is nearly as productive for pineapple as is the original surface soil. In many places, pineapples are planted in rows that run up and down the hills, but a much better practice is to plant with the contour of the land. This soil produces an average acre yield of about 300 crates of pineapples the first year, 250 crates the first ratoon, and 200 crates the second ratoon. The most common practice is to apply about 1,000 pounds of 6–8–10 fertilizer an acre in two applications. The largest acreage of pineapples planted on this soil is in the vicinity of Corozal and southeast of Morovis. The Red Spanish is the most important variety grown.

Sugarcane is often planted on this soil wherever it is within economical hauling distance from a sugar central. Sugarcane yields from 30 to 40 tons an acre gran cultura and 25 tons in ratoon cane. The P. O. J. 2878 variety does very well on this soil. In some places Mayagüez 28 produces very well, as it has very prolific stools. The common fertilizer practice is to apply the nitrogen in the form of ammonium sulfate but, as this soil is acid, probably sodium nitrate would be the better fertilizer to use (*9*).

American tomatoes and flowers, especially roses, grow very well, but such leguminous crops as beans and pigeonpeas do not produce very well as the soil is somewhat too acid.

Catalina clay, level phase.—Areas of Catalina clay in which the relief ranges from nearly level to slightly undulating are classified as Catalina clay, level phase. Most of this soil occurs on the high peneplain near Aibonito, in the terracelike area north of Cidra, and in a few areas south of Bayamón and Río Piedras. Owing to the nearly level relief, this soil has not been affected by sheet erosion, and the normal soil-forming processes have been acting unmolested on it for a long time. It differs from the typical soil, in that it has a thicker more acid surface soil and a slightly more compact lower subsoil layer, causing slightly restricted internal drainage, which is reflected by the mottled gray, reddish-brown, and red coloring of the normally red lower subsoil layer. This soil is leached of its plant nutrients to a slightly greater extent than is the typical soil. The farmers accustomed to using fertilizer prefer this soil to the typical soil for most crops, but those who do not use fertilizer consider this soil inferior to the more rolling areas.

Sugarcane yields from 40 to 50 tons an acre gran cultura, from 25 to 30 tons first ratoon, and from 20 to 25 tons second ratoon. Such high yields require the use of a large quantity of fertilizer. At the time of the survey one progressive farmer was using 1,000 pounds of 12–6–5 to the acre. The first crop of pineapples yields about 250 crates an acre, and the ratoon crops are much less. Other crops yield slightly less than on the typical soil unless they are more heavily fertilized. The large area north of Cidra is producing many kinds of truck crops, pineapples, sugarcane, and some grapefruit; and the area near Aibonito is largely in grass, coffee, and trees. Probably the largest acreage of this soil is used for sugarcane, and the rest is used for pasture, pineapples, minor crops, trees, and citrus.

Included with this soil on the map are several small areas, lying at an elevation of more than 2,000 feet, that are more poorly drained, lighter in color, and more acid than this soil. Most of these areas are used for forestry and the production of coffee. Trees are well

adapted to this included soil, but yields of coffee are low because of the high elevation and poor internal drainage of the land.

Catalina clay, steep phase.—Areas of Catalina clay that occur on slopes exceeding 50 percent are mapped as Catalina clay, steep phase. The color and soil characteristics of this soil and the typical soil are very similar. Soil of the steep phase has a slightly thinner surface soil because when the land is cultivated it erodes to a greater extent. The two soils are so interlaced in many places that the boundaries between them are drawn arbitrarily.

Catalina clay, steep phase, occupies large areas of the steep hills in the interior where the average annual rainfall is greater than 85 inches. Agriculturally, this soil is less desirable than the typical soil, and about 60 percent of it is used for pasture and trees; 30 percent for the growing of coffee, bananas, plantains, and oranges, and 10 percent for the production of minor truck crops. Yields in general are less than on the typical soil, but the concave slopes of this soil are more productive than the convex slopes of Catalina clay. This steep soil is considered good for the production of coffee, which yields 200 pounds an acre in favorable years on well-managed coffee farms. On many farms, however, only 30 or 40 pounds an acre are obtained.

This soil requires much more careful management than the less steep slopes in order to produce high yields of crops, as erosion is a factor that must receive serious consideration on any cultivated hillside having a slope ranging from 60 to 100 percent. Generally, the steeper the slope the less the yield. In many areas, land having a slope of more than 100 percent is planted to coffee which yields fairly well, but the coffee pickers must take precautions so that they will not fall down the hills. As might be expected, drainage is adequate or excessive. Nearly all of the streams throughout areas of the Catalina soils are continuous throughout most of the year, unless an unusual drought occurs. Most of the houses on this steep soil are located on the ridges of the hills, but many are on the concave slopes. Generally a few subsistence crops, such as sweetpotatoes, yautias, ñames, bananas, and plantains, are planted near each house. These plants produce very well, especially on the concave slopes and in places where refuse from the house is used as a soil amendment.

Pasture grass grows rank and coarse (fig. 101), but it has less nutritious feeding material than the grass in the dry sections. From 2 to 5 acres are required to pasture an animal throughout the year. The grass seems to grow about as well during the summer as during the drier, winter months.

Catalina stony clay.—Areas of Catalina clay that have an excessive number of rocks on the surface are classified as Catalina stony clay. Most areas of this soil are too stony for the profitable use of large farm implements, but cultivation by hand is carried on regardless of the rocks. Some of the rocks are more than 15 feet in diameter, but the majority are about 2 feet in diameter and are egg-shaped. When they weather, a veneerlike layer scales off. One of the largest areas of this soil is at the base of Sierra de Luquillo.

Catalina clay and Catalina stony clay are similar in color and soil characteristics. Owing to its high stone content, Catalina stony clay is used mostly for trees, coffee, and pasture and to only a small extent for cultivated crops. Tree production equals that on the

typical soil. These two soils are so intermingled in many places that no attempt is made to separate small areas of the stone-free soil from the stony soil, or vice versa.

Catalina stony clay, steep phase.—Catalina stony clay, steep phase, is the poorest soil of the Catalina series for all agricultural crops. It is used almost entirely for forestry. Trees grow very well, as the annual rainfall usually exceeds 90 inches, and the soil material is fairly deep, although it occurs on very steep relief. The depth to the unconsolidated rock is not quite so great as it is in areas of either Catalina stony clay or Catalina clay. Except for the thickness of the surface soil, this soil differs from the typical stony clay only in relief. In places rocks lie on the surface, and rock outcrops are numerous.

Agriculturally this soil is only slightly better than rough stony land. The cutting of wood for the making of charcoal is the main enterprise on this steep soil, especially after the virgin timber has been cut and sold.

Cialitos clay.—Cialitos clay is associated with Catalina clay and the related red and purple soils of the uplands. This soil is distributed over the entire area that is underlain by vulcanic tuffs and shale beds, where the average annual rainfall is greater than 75 inches. The soil occurs both on slopes and on the ridges of hills having less than 60-percent slope. It is similar in many respects to Catalina clay, but it has a lighter brown surface soil, a much heavier more plastic upper subsoil layer, and a lighter red lower subsoil layer. It is characterized by a light grayish-brown or brownish-red friable finely granular clay surface soil, which extends to the average depth of plowing, where it gradually changes to yellowish-red or red, medium heavy but permeable, plastic clay that swells and cracks to some extent when at the extremes of moisture content. At a depth of about 20 inches the soil is much more friable and is light yellowish-brown or light brownish-red clay. In places it has a tendency to have a mottled yellowish-brown and light brownish-red color, which indicates that internal drainage is not so good as in the Catalina soils, as, with the exception of the level phase of Catalina clay, they are not mottled.

This soil varies greatly within short distances. In places the subsoil is yellow, and rock fragments are present throughout all layers and even on the surface. In other places the surface soil is shallow, owing to sheet erosion. In some areas, the reddish-brown subsoil may continue to a depth of 30 inches before the friable yellowish-red lower subsoil layer is reached. In all places this soil is acid, becoming more strongly acid with depth. A plowed field may show many colors. In most places the eroded areas appear yellowish brown or reddish brown, and the noneroded areas are grayish brown. In virgin areas the surface layer is grayish brown or dark grayish brown. Trails through pastures appear red from a distance.

This soil occurs in large areas near Adjuntas in the coffee district, and south of Bayamón and Río Piedras. In the coffee district about 40 percent of this soil, including almost all of that on the concave and long gentle slopes, is used for the production of coffee. In such areas the yields are nearly as good as on Catalina clay. Most of the remaining 60 percent, including nearly all of the ridges (fig. 102) and convex slopes, is in grass which has low nutritive value. These latter areas have shallow surface soils and are not very productive unless heavily

fertilized. Sometimes sweetpotatoes, ñames, and yautias are planted. The areas south of Bayamón and Río Piedras are planted to sugarcane, citrus, and subsistence crops. Sugarcane produces about 30 tons to the acre when the land is sufficiently fertilized and well managed. Citrus does not grow so well as on Catalina clay. The pasture grasses grown on these lower lying areas, which have less rainfall, are better than those produced in areas of high rainfall. Generally, 1½ acres will pasture an animal during the year.

The area of this soil that is surrounded by limestone, between Ríos Tanamá and Grande de Arecibo, apparently is the remnant of higher land that was not covered with limestone during submergence or, if it were, the limestone has been completely removed. Most of this area is used for pasture and such subsistence crops as sweetpotatoes, ñames, and yautias.

In average years and with good management, this soil will produce acre yields of about 1,500 pounds of sweetpotatoes, 3,500 pounds of

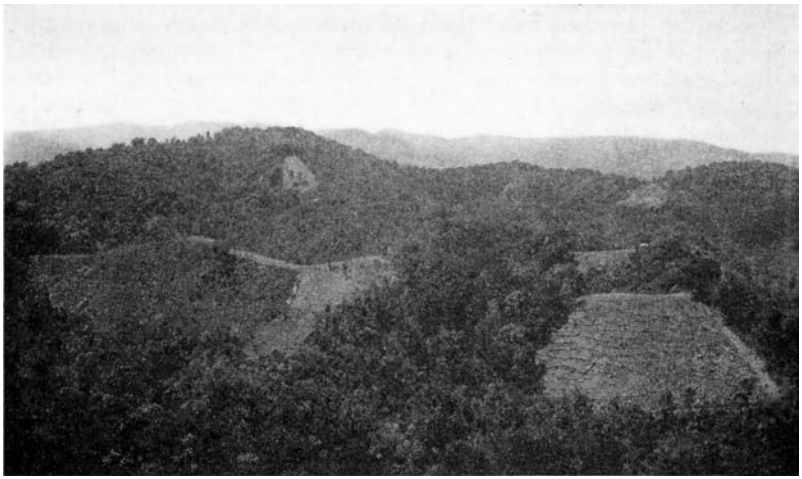

FIGURE 102.—Cialitos clay in the vicinity of Maricao. The ridges are cleared of timber, planted to subsistence crops for a few years, and then allowed to grow up to grass and eventually revert to brush.

Cialitos arcilloso en la vecindad de Maricao. La cresta de los montes ha sido despojada de bosques, sembrada de frutos menores por varios años y abandonada a pastos; luego se cubre de maleza.

ñames, 1,500 pounds of yautias, 250 pounds of beans, 200 pounds of pigeonpeas, 6 bushels of corn, and from 40 to 200 pounds of coffee.

Cialitos clay, steep phase.—Areas of Cialitos clay that occur on slopes greater than 50 percent are mapped as a steep phase of the typical soil. This steep soil has the same physical and chemical characteristics as Cialitos clay, but, owing to its relief, it is not so desirable or so productive. More than 50 percent of the land is idle or in pasture, and most of the remainder is in coffee. This soil is closely associated with the typical soil and is well distributed throughout all the humid sections where the parent material is dominantly tuff. It is one of the more extensive soils of the uplands, and the prosperity of future generations will depend to some extent on the manner in which this and related soils are managed. This soil requires fertilizer

and lime for best yields, also care in preventing loss from erosion when planted to clean-cultivated crops. Ñames and yautias are better crops for the prevention of erosion than corn, beans, and pigeonpeas. The holes in which the yautias are planted act as catch basins and retard the force of the running water. The mounds in which the ñames are planted also check the force of the run-off.

Some upland rice planted on this soil produces about 200 pounds to the acre. The rice generally is planted in March or April and is harvested within 8 months.

Areas of this soil shown on the soil map with stone symbols are much less productive than the typical areas.

Cialitos clay, eroded phase.—With the exception of Nipe clay, Cialitos clay, eroded phase, is the poorest deep upland soil. This soil probably is derived from intrusive volcanic lavas. The relief is hummocky, irregular, and steep. Many of the hills, especially those adjacent to deeply eroded foot and horse trails, have high vertical cliffs.

This soil is characterized by a 4- to 8-inch reddish-brown massive medium plastic strongly acid clay surface soil. It is underlain by red permeable massive strongly acid clay, which gradually changes to mottled red, yellow, and gray friable permeable clay having a lifeless ashy feel. This layer continues to a great depth. The mottled color seems to be due to the character of the parent material, as the soil does not have restricted drainage. The clay content of a representative sample gradually decreases from 77 percent in the surface layer to 50 percent at a depth of 4 feet, and the silt content increases from 17 percent in the surface soil to 41 percent at a depth of 4 feet. The pH value is 4.7 throughout the profile. This soil, according to chemical analysis of a typical sample, contains only 0.06 percent of potassium, 0.07 percent of phosphorus, 0.06 percent of magnesium, 0.12 percent of calcium oxide, and only 0.15 percent of nitrogen in the topmost 6 inches. The underlying layer also is deficient in plant nutrients. The unusually low content of important chemical compounds, combined with the acid reaction, probably is responsible for the low fertility of the soil. The total soluble salt content is low, as are also the chromium and selenium contents. The highest content of selenium occurs at a great depth. This soil is not eroded to the same extent as are many soils in the United States, but it is about as unproductive as the seriously eroded soils of the southern Piedmont.

Within the large area of this soil south of San Sebastián are many tax delinquencies and many unpaid farm mortgages. The farmers consider this soil nearly worthless. It is valued at a price ranging from $2 to $5 an acre, although nearby soils, such as Catalina clay and Múcara silty clay loam, are valued between $35 and $45 an acre. This area has been neglected for years because the small landowners have had no incentive to build up their land. Therefore, most of the organic matter has been used by crops or has been lost through erosion, and little or none has been returned to the land. Erosion, both sheet and gully types, has left its effect on this soil more than on any other deep soil in the humid parts of Puerto Rico. Most of this area is several kilometers from a good highway, which fact also has its effect in lowering the value of the land and makes liming and fertilizing very expensive.

More than 70 percent of the total area of this soil is either idle or in pasture. The grass produced is of low feeding value. Cows pastured on this soil do not give sufficient milk for their calves, even though one cow may have from 4 to 5 acres of grass over which to graze. The grass grows rank and dense, but it seems to contain very little nourishment. Generally the lower parts of the long gentle slopes are the only areas cultivated. In such areas, sugarcane, yautias, bananas, coffee, and plantains grow fairly well, if the land is fertilized. Liming and fertilizing of this soil probably would increase crop yields from 50 to 100 percent.

A characteristic feature of the soil is the presence of large black rocks which occur in isolated groups, both on the hilltops and on the slopes. Magnetic oxide of iron is conspicuous along most of the trails and roads, where a sorting of material has taken place during heavy rains. Gullies are numerous along most of the foot trails. The dominant vegetation, especially on acid-poor land, includes several varieties of wild ferns, matojo, and icaco. Coconut palms will grow, but they produce only a few small nuts.

Los Guineos clay.—Los Guineos clay is closely related to the Catalina and Cialitos soils, but it is developed at higher elevations where the weather in general is cooler, wetter, and windier than in areas of the other red and purple soils of the uplands.

This soil occurs on steep or very steep relief and is characterized by a 6- or 8-inch grayish-brown slightly granular medium plastic strongly acid clay surface soil and a 3- to 6-inch brownish-yellow clay subsurface soil that abruptly changes to red plastic but permeable strongly acid clay. This layer gradually gives way, at a depth ranging from 3 to 4 feet, to lighter red more friable acid clay. Some rocks are on the surface of this soil and throughout the soil layers.

Areas of this soil indicated on the map by rock-outcrop symbols are of low value except for forestry. The slopes in such areas generally are very steep, and stone and rock outcrops are so numerous that it is practically impossible to cultivate the land, except with hand implements. The rocks, which occupy a fairly high proportion of the total area, reduce the value of this soil for crops or even for trees.

Within areas of this soil are many small narrow strips adjacent to and at the heads of drainageways, that have a gray plastic sticky acid clay surface soil underlain at a depth ranging from 8 to 14 inches by mottled gray and rusty-brown plastic acid clay that has imperfect internal drainage. Surface drainage also is inadequate for most cultivated crops. Seepage water from higher land often collects on these imperfectly drained areas which are used for forestry and to a limited extent for the production of malangas and yautias.

Probably about 50 percent of the total area of this soil is used for forestry. The valuable trees are cut for timber, and the poor-quality woods are used for the making of charcoal, which is an important enterprise within this area. Probably about 30 percent of the land is used for the production of coffee. The quality of the coffee is better than that grown on the Catalina soils, but the quantity produced is generally less than that produced at lower elevations. In the growing of coffee, the risk of damage from hurricanes is greater than on the lower lying soils, such as the Cialitos and Catalina. Large tracts of Los Guineos clay at one time were in productive coffee plantations,

but at present, owing to the destruction of the coffee and shade trees caused by hurricanes, they are abandoned and produce only rank, coarse grasses of low feeding value and a variety of trees, some of which are valuable and others nearly valueless (fig. 103).

Los Guineos clay, smooth phase.—Areas of Los Guineos clay that have smooth or rolling relief are classified as a smooth phase of that soil. The smooth phase is much less extensive than the typical soil, but it occurs throughout almost all of the higher areas. Owing to its smooth relief, it has a deep surface soil, in places over 12 inches thick. The subsoil, especially in the more level areas, has a tendency to have a mottled gray, red, and brown color.

This soil is used more extensively for cultivated crops than is the typical soil, but probably more than 40 percent of its area is in grass. The main crops grown are tobacco, yautias, and coffee. All yields are low unless the land is carefully managed and heavily fertilized.

FIGURE 103.—Vegetation on Los Guineos clay. The vegetation is dense and grows rapidly, thereby keeping erosion to a minimum.

Vegetación en Los Guineos arcilloso. La vegetación crece espesa y rápidamente y mantiene la erosión a un mínimo.

Alonso clay.—Alonso clay is an extensive upland soil that is easily identified by its brownish-purple color. Most of it is derived from reddish-purple igneous rocks, but part of the material probably is derived from Cretaceous limestone, as many areas are closely associated with Cretaceous limestone outcrops. The soil occurs on hills having slopes ranging from 30 to 60 percent.

This soil has a brownish-purple friable permeable clay surface soil about 6 inches thick, underlain by friable granular reddish-purple clay, which rests on rock at a depth ranging from 20 to 60 inches, depending on the slope, amount of rainfall, and character of the rock. Generally speaking, the steeper the slope and the less the rainfall, the shallower is the soil. Alonso clay has characteristics similar to the very slightly plastic Catalina soils previously described and the nonplastic Matanzas, Nipe, and Maleza soils to be described later. Water penetrates this soil very readily, and very little rain is lost

through run-off unless the surface is very steep or the land is in clean cultivation. Plant roots are able to penetrate to the depth of the underlying porous rock, and in places they may penetrate it.

Alonso clay occurs in fairly large areas in the interior of the island, where the average annual rainfall ranges from 80 to 100 inches. Some of the larger areas are on both sides of Río Cialitos, southwest of Ciales, between Adjuntas and Maricao, and in other parts of the present coffee district. This soil is considered very desirable for the production of coffee. When properly managed, it yields from 300 to 600 pounds of coffee to the acre. Farmers prefer it to the red slightly more plastic Cialitos and Los Guineos soils for all crops. Coffee seems to grow faster on Alonso clay than on the other upland soils, but the life of the trees generally is not so long as on some of the other good coffee-producing soils. Most of this soil is planted to coffee, oranges, bananas, and plantains.

In many places this soil is not so acid as the Catalina or Los Guineos soils, and for this reason the Panama root disease of bananas is not likely to be so severe as on the more acid soils. Minor crops grow well.

Some areas, especially in Barrio Frontón in the municipality of Ciales, have a distinctly brighter reddish-purple color than is typical of this soil, but as crop use is the same, these areas were not separated on the map.

Alonso clay, smooth phase.—Areas of Alonso clay that have a slope of less than 30 percent are classified as Alonso clay, smooth phase. This soil has a purplish-brown friable clay surface soil that readily forms a fine-granular or mellow condition when cultivated. It is underlain, at a depth of about 8 inches, by a firm but friable brownish-purple granular clay subsoil that gradually changes to more friable looser purple clay, which, in turn, rests on porous rock lying, in most places, at a depth of more than 4 feet. In some places the depth to rock is more than 30 feet.

The mechanical analysis of a typical sample of this soil shows that the surface soil contains more than 81 percent of clay and 13 percent of silt, and that most of the remaining 6 percent is fine sand and very fine sand. The subsoil contains more than 91 percent of clay, of which 88 percent is composed of particles of colloidal size. The lower part of the subsoil contains less clay and more silt than the surface soil, but even below a depth of 4 feet, the clay content is more than 79 percent. All layers of this soil have many very fine disconnected tubelike channels that readily allow water to pass, as the character of the clay is such that when it becomes wet it does not swell to the extent of closing the tubelike channels. Such a soil allows water to penetrate rapidly to great depths, consequently the run-off is not great. Very little destructive erosion has taken place on this soil because absorption of water is rapid and the soil has neither a high content of silt, which may melt like sugar under a tropical shower, nor the abrasive effects of tons of sand flowing down the hillsides. In many places erosion barely keeps pace with the rapid decomposition and disintegration of the rocks.

The best areas of this soil probably are the most desirable all-round soils in the uplands (fig. 104). The land is easy to cultivate, does not dry out excessively during droughts, has a rather large water-holding capacity, and has a fairly high content of organic matter.

The average yearly acre yields of crops on this soil are as follows: Coffee, from 400 to 600 pounds an acre; grapefruit, from 400 to 600 boxes; pineapples, about 300 crates; beans, from 200 to 300 pounds; corn, from 10 to 15 bushels; and sugarcane, from 30 to 35 tons. Fertilizer is required for best yields, but this soil will produce better yields without the addition of fertilizer than the Catalina, Cialitos, and related soils. This soil occurs in areas closely associated with the typical soil, and nearly all of the land is planted to some productive

FIGURE 104.—Numerous subsistence crops growing on Alonso clay, smooth phase. The small irregular-shaped fields surrounding the jibaros' homes give the landscape an intricate pattern.

Frutos menores creciendo en Alonso arcilloso, fase lisa. Los campos en forma irregular que rodean las casitas de los jíbaros le dan al panorama un aspecto intricado.

crop. Probably more than 60 percent of it is in coffee, 20 percent in subsistence crops, and the remaining 20 percent about equally divided among sugarcane, pineapples, citrus, and tobacco.

Alonso clay, colluvial phase.—Areas of Alonso clay occurring near the bases of long gentle slopes on narrow strips adjacent to ravines and having a deeper surface soil than either Alonso clay or Alonso clay, smooth phase, are classified as Alonso clay, colluvial phase. As this soil occurs only in sections where the rainfall is high and the elevation above 500 feet, it is used mostly for the production of coffee and subsistence crops. Yields are better than on the typical soil. If properly fertilized, this soil would be as productive as or slightly more productive than Alonso clay, smooth phase, as it has a better surface soil with higher water-holding capacity and, therefore, higher natural productivity. Farmers prefer this soil to the typical soil, but as it is so closely associated with typical Alonso clay, the land use of the two soils is nearly identical.

Alonso clay, shallow phase.—Alonso clay, shallow phase, is the poorest of the Alonso soils. This soil not only is very shallow, but it also is very steep and may have many rocks on the surface. Most of

it occurs on hills having more than 60-percent slopes. Large areas are near Cialitos.

The physical and chemical characteristics of this soil are similar to those of the typical soil, but because it is so shallow it is more droughty, less desirable for deep-rooted crops, and, therefore, is used only for pasture and trees. Grass growing on this soil is considered slightly more desirable than that growing on the red soils of the uplands. The tree growth is about the same as on the Los Guineos soils.

In places where the parent rock is at or near the surface, some areas of this soil appear nearly white. This is true of the areas in the vicinity of Río Bucarabones.

Alonso silty clay loam.—Alonso silty clay loam differs from Alonso clay in that it has a lighter textured surface soil and occurs in areas having an average annual precipitation of about 70 inches. The largest area of this soil is adjacent to and south of Central Pasto Viejo. The total area is less than 400 acres.

This soil is characterized by a purplish-brown friable softly granular permeable silty clay loam surface soil ranging in thickness from 4 to 8 inches, depending on the steepness of the slope. The subsoil is brownish-purple or purple friable permeable massive clay resting on purple igneous rocks at a depth ranging from 18 to 24 inches. The surface soil is acid, and the soil becomes slightly more acid with depth. It occurs on hills with slopes ranging from 20 to 60 percent.

About 50 percent of the land is used for the pasturing of goats and cattle; the other 50 percent is planted to subsistence crops, such as sweetpotatoes, pigeonpeas, corn, beans, yautias, and yuca. The soil is well adapted to such crops, and good yields may be expected if precaution is taken to prevent erosion on the steeper slopes. Brush terraces and hedgelike terraces, made by planting guinea grass in narrow strips with the contours, should be beneficial. Crop yields are higher on this soil than on the associated Sabana soils.

Alonso silty clay loam, colluvial phase.—Areas of Alonso silty clay loam at the bases of the hills and along the concave slopes adjacent to the drainageways are separated as a colluvial phase of the typical soil. This soil has a deeper surface soil, subsoil, and substratum and a higher inherent natural productivity than the typical soil.

The total area does not greatly exceed 100 acres, of which more than 70 acres are in pasture and the remaining 30 acres in sugarcane and minor truck crops. Sugarcane is the most profitable crop that can be grown on this soil, but, as the soil occurs in such small areas, most of it is used for pasture in connection with the larger areas of the typical soil.

Malaya clay.—Areas of Malaya clay are readily identified by their purple color, in contrast to the brown color of the closely associated Múcara soils and the red color of the Río Piedras and Catalina soils.

Malaya clay is characterized by a dark brownish-purple friable granular permeable alkaline clay surface soil ranging from 2 to 10 inches in thickness, depending on the degree of slope. This layer is underlain by grayish-purple loose friable permeable alkaline clay that gradually changes to disintegrated purple vesicular rocks. Many calcite crystals are in the cavities of the rocks. The depth of the soil above the rock varies greatly within short distances. In places the rock is visible on the surface, and in other places it is below a depth of 30 inches. Rocks and rock fragments are strewn over the

surface to such an extent that most cultivation is done by hand. Seams of copper compounds are conspicuous in areas of this soil.

Malaya clay differs from Alonso clay in that it is derived from a volcanic flow or a succession of flows, and in most places it is alkaline or calcareous in the lower part of the subsoil, owing to calcite fillings in cavities and small cracks in the rocks and in the vesicular lava. The larger bodies of this soil occur on hills having from 20- to 60-percent slopes within a wedge-shaped area about 1½ miles south of Aguada. The lava flow must have spread out to the north and west for a distance of about 2 miles covering all the area, as nearly all the soil within this area is purple, with the exception of that on a few small shale hills, which have red clay soil. This area is thickly populated, and the houses are numerous on nearly every hill.

The steepest part of this soil is used mainly for pasture. Subsistence crops occupy the largest acreage of the cultivated crops grown. They do very well considering the small quantity of fertilizer the land receives. Sugarcane yields from 8 to 10 tons an acre, beans about 200 pounds, pigeonpeas 300 pounds, and corn about 300 pounds.

Malaya clay, smooth phase.—Areas of Malaya clay that are nearly level or have smooth relief are classified as Malaya clay, smooth phase. In cultivated fields, the surface soil, to a depth of 8 or 10 inches, consists of purplish-brown softly granular friable permeable clay with more than 60 percent of the particles of colloidal clay size. This soil, when wet, is mellow and works readily into a good seedbed. Large hard clods seldom remain intact for any length of time, as the first or second rain soon slakes them to small angular fragments or rounded soft granules. Nearly every granule has white pinhead specks on it. The subsoil, to a depth of 15 or 18 inches, contains less organic matter and is more compact than the surface soil. It ranges in color from purple to brownish purple and breaks into various-sized clods that feel slightly plastic when wet. Internal drainage, however, is good, and plant roots penetrate the soil readily. The upper part of the subsoil gradually changes to a lower lying layer of nearly the same texture and color, but the material is more friable. This layer continues below a depth of 10 feet before rock is reached.

In most places this soil is acid in all layers, but where it is adjacent to the typical soil it is neutral or alkaline. A few rocks lying on the surface are calcareous. Rocks are not so numerous as on the typical soil. This soil has only normal erosion, and very little water is lost through run-off, especially in places where the land is in crops or grass. In most places the slopes to the drainageways are gradual, and very few of the drains are V-shaped.

Nearly all of this soil could be cultivated profitably to sugarcane, coffee, pineapples, or many of the minor crops. In 1929 the two most important crops growing on this soil were sugarcane and beans. The sugarcane produced from 20 to 22 tons to the acre without fertilizer, beans about 700 pounds, sweetpotatoes 4,000 pounds, ñames 6,000 pounds, yuca 1,500 pounds, pigeonpeas 400 pounds, coffee 200 to 300 pounds, and corn 800 pounds.

This soil is considered nearly twice as valuable as the typical soil and has about the same value as Alonso clay, smooth phase.

Jayuya silty clay loam.—Jayuya silty clay loam occurs within the upland areas of the large granite area near Utuado and Jayuya, in those exceptional places where the relief is smooth and the mean annual

rainfall is sufficient for the soil-forming processes to produce a red soil.

This soil has a total area of only a few square miles, and it occurs only on the nearly level hilltops and the low rounded hills within areas of soils derived from granite and receiving from 80 to 100 inches of average annual rainfall.

In cultivated fields the 6- or 8-inch surface soil is brown or grayish-brown slightly plastic acid silty clay loam containing some gritty material. The subsoil to a depth of about 2 feet is medium-stiff red massive acid sandy clay or sandy clay loam, which gradually changes to friable red coarse-grained sandy clay loam or sandy loam. The parent material, lying at a depth ranging from 30 to 40 inches, is gritty quartz sand. The material in all layers is acid, and, because of the nature of the parent material, internal drainage is not restricted and does not interfere with crop production or cause a mottled condition in the subsoil.

This soil is not nearly so high in colloidal clay as the other soils in this group, but because it occurs within the same rainfall area and has a red color it is in the same group. It contains some gritty sandy material, and it erodes more seriously than the other permeable red and purple clay soils in the group. Many brush terraces are maintained throughout the fields of this soil.

Probably about 40 percent of the land is planted to coffee; 30 percent is in tobacco, beans, and corn; and 30 percent is in pasture and trees. Evidence of lack of nitrogen is not so noticeable in this soil as in the other soils derived from granite, but this soil requires large quantities of fertilizer high in nitrogen for the profitable production of most crops. Under favorable climatic conditions and good management the soil produces an average acre yield of about 100 pounds of coffee, 800 pounds of tobacco, 200 pounds of beans, or 15 bushels of corn. At least 2 acres of grassland are required to pasture a cow.

Jayuya silty clay loam, steep phase.—Areas of Jayuya silty clay loam that have a steep relief are designated on the map as a steep phase. This soil is slightly inferior to the typical soil for the production of cultivated crops, as the surface soil is shallower, owing partly to erosion and partly to less development of soil on the steep relief. The yield of coffee on a well-managed coffee farm on this soil is about the same as the yield on the typical soil. The unevenness and steepness of the relief is an objection in the cultivation of the land. A large proportion of the land is in coffee, especially the rougher parts, but the more favorable areas are used for the production of sugarcane, tobacco, and corn. Most crops produce less on this steep soil than on the typical soil.

Bodies of this soil are scattered throughout all areas of soil derived from granite in the vicinity of Utuado and Jayuya. This soil is more extensive than the typical soil. A large area surrounding Central Pellejas (see fig. 145, p. 483) is planted almost entirely to sugarcane which yields about 28 tons to the acre.

Nipe clay.—Nipe clay is easily identified because even when dry it stains clothing and flesh a purplish-red color. Buildings on this soil are stained red, especially the lower parts. The feet of horses and people treading across the land are stained with purplish-red colloidal clay.

Nipe clay is not only the most unproductive soil in this group, but it is one of the most unproductive soils in Puerto Rico, as well as in Cuba, where it occupies large mountainous areas. The largest areas in Puerto Rico are in the vicinity of Mayagüez, where the average annual rainfall is in excess of 80 inches. The relief of all areas of this soil is favorable for cultivation, as the soil occurs on high rounded hills and in flat tablelike positions. This soil is derived from serpentine rock.

The 5-inch surface soil of Nipe clay is dark brownish-red softly granular very slightly plastic neutral or slightly acid clay. The brown color is due almost entirely to organic matter, for the granules when crushed become very much lighter red. This material, although low in organic matter, contains from five to eight times the amount in the lower layers. Apparently owing to the presence of organic matter, this layer has a higher water-holding capacity than the layers below. A distinct boundary occurs between the surface soil and the subsoil, which consists of purplish-red nonplastic neutral clay composed of very small soft granules that crush readily to a fine mulch. This layer ranges from 15 to 20 inches in thickness. The material gradually changes to purplish-red loose friable soft and fairly granular nonplastic clay that continues to the serpentine rock, which, in places, lies at a depth of more than 30 feet. This soil, with the exception of the topmost few inches, has a dead appearance, and it feels more like a chemical compound than like a soil.

This soil has a number of characteristics peculiar to certain tropical soils called lateritic soils or Laterites. Very little change is noted in the physical properties from the surface to the underlying rock. The soil in all layers contains more than 71 percent of clay, in most of which the particles are of colloidal size. The clay particles are grouped in clusters and do not have the plastic nature of most clay but exhibit the physical properties of loam. Although water penetrates the soil rapidly, it is not retained so well as in most clay soils. This soil, when wet, is sticky and slippery, but it dries very quickly, and cultivation is seldom delayed for any great length of time after a rain. The soil, if worked when wet and the large clods turned over, slakes to small crumblike particles after the first or second rain.

As observed in a roadside cut, the soil shows little evidence of swelling or contracting at the extremes of moisture content. It dries to a great depth during long dry periods, however, and is considered more droughty than soils derived from shale or limestone. The native vegetation is typical of areas receiving much less rainfall. When the vegetation is removed and the land is idle, grasses and trees grow so slowly that it takes years to form a complete cover. Thus the soil is exposed to sheet erosion which becomes rather severe on this naturally nonerosive soil. The effect of the hot sun on the bare soil also is destructive, as the heat burns the organic matter in the soil and causes the material in the surface layer to become very hard, in places forming a firm crust. When cultivated, this layer is readily broken up.

Chemical analyses of this soil show that the silicon dioxide decreases and the aluminum oxide and iron oxide increase with depth to the serpentine rock. The content of phosphorus is very low, and that of potash is below the average for productive soils. The content of chromium and nickel is high, and possibly these substances have a

toxic effect on plant roots, thereby preventing normal growth. This soil has a higher content of iron than any other soil in Puerto Rico. Some layers contain more than 50 percent of iron oxide. In most of the layers, small black iron pellets, concretions, or perdigón are conspicuous, and in some places ironstones ranging from 2 inches to 3 feet in diameter are embedded in the soil at a depth of about 8 inches, unless erosion has washed the surface soil away, thus exposing the ironstones as well as thousands of smaller iron concretions.

This soil is used principally as grazing land. The grass produced is coarse, tough, and of little nutritive value. The most important grasses aré matojo, burro, cerrillo, rabo de ratón, cortadera, and carrucillo. Many ferns grow luxuriantly, but such trees as mango, mamey, and capá grow only fairly well. Mahogany and cedar grow slowly. Coffee trees grow fairly well on the concave slopes that receive an additional supply of moisture and organic matter from the surface wash of the adjacent slopes. Pigeonpeas and onions are two of the best minor crops now growing on this soil, since they withstand drought well and thrive in soils that are not too acid. One patch of onions on this soil produces from 7,000 to 10,000 pounds to the acre when fertilized with from 600 to 800 pounds of fertilizer an acre and when sufficient lime is applied to make the soil alkaline in reaction. The onions are planted in August or October. Pigeonpeas yield from 100 to 250 pounds to the acre.

Potatoes and corn are fairly well adapted to this soil, but yields are very low unless heavy applications of fertilizer high in phosphorus and potash are applied, in addition to large quantities of lime. The yield of sugarcane is very low, often not more than 15 or 20 tons, even with the use of fertilizer. The fields planted to sugarcane include many barren spots, ranging from 20 to 100 feet in diameter, where the sugarcane germinated but never attained full growth and in many places died.

This soil, although very high in content of clay, is well drained and should be suitable for poultry yards. Guinea grass will grow fairly well and would be much more nutritious than the grass now grown. This land is sparsely populated, and only comparatively few livestock graze on the wind-swept mesas or tablelands. Probably 80 percent of the land is idle or in poor pasture. Most of the other 20 percent is in sugarcane. Ultimately, it doubtless will be used as a source of iron ore, when richer deposits of iron in other parts of the world have been exhausted.

MEDIUM-DEEP SOILS OF THE UPLANDS

The medium-deep soils of the uplands include the hilly lands of the humid and subhumid sections, that have parent rock at a depth ranging from 1 to 2 feet below the surface.

Owing to the rather steep relief and thinness of the soil, the soils in this group are naturally better adapted for shallow-rooted crops, such as tobacco and subsistence crops, than for sugarcane and citrus. Some sugarcane is grown on the best parts of the land adjacent to main roads and near sugar centrals. Nearly all of the best-quality tobacco, most of the upland rice, and probably 60 percent of all the subsistence crops are produced on the soils of this group. The subsistence crops are mainly beans, corn, pigeonpeas, and sweetpotatoes. Probably a greater number of farmers derive either all or a part of

their income from these soils than from the soils of any other group. The success or failure of many thousands of people depends on the productivity of these soils (fig. 105).

The value of these soils depends on the degree of slope, the amount of surface soil lost by sheet erosion, and, to some extent, the number of years the land has been producing clean-cultivated crops without the addition of much fertilizer.

The requirements for successful management of farms on these soils are: The use of fertilizers, sound practices for the control of erosion, diversification of crops, and the raising of large numbers of livestock.

The soils in this group include 39 soil types and phases of 16 soil series. The Colinas, Soller, and Tanamá soils are derived from Tertiary limestone; the Plata soils, from lower Tertiary clay; the Daguao, Múcara, Juncos, Sabana, and Naranjito soils, mostly from massive

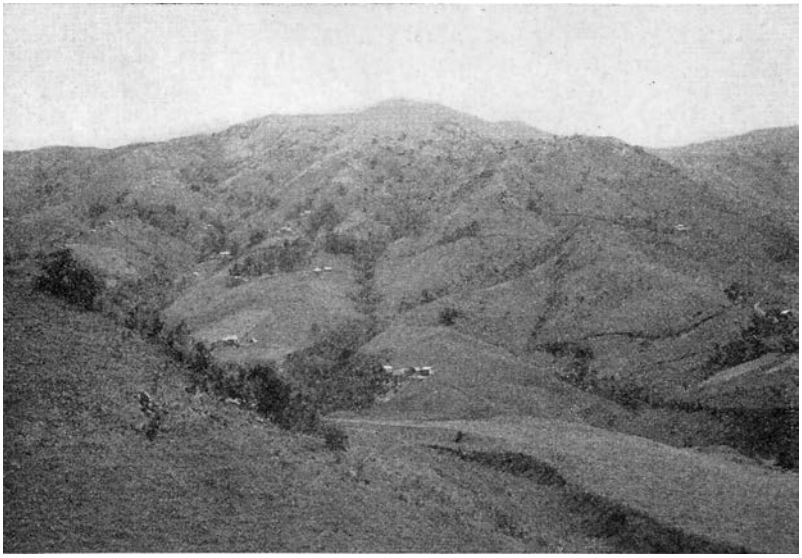

FIGURE 105.—The success or failure of many thousands of people in Puerto Rico depends on the productivity of the medium-deep soils of the uplands, such as this area of Múcara silty clay loam. Erosion is slight on ordinary slopes of 15 or 20 percent, owing to the rapid growth of plants. On slopes in excess of 40 percent, however, erosion is a factor that needs serious consideration.

El éxito o el fracaso de muchos miles de personas depende de la productividad de los suelos medianamente profundos de la altura, tales como esta área de Múcara limo-arcilloso lómico. La erosión es leve en declives de 15 a 20 por ciento debido al rápido crecimiento de las plantas. En laderas de más de 40 por ciento, sin embargo, la erosión es un factor importante.

tuffs, tuffaceous shales, and other volcanic rocks; the Río Piedras soils, from shale; and the Pandura, Cayaguá, Ciales, Utuado, Teja, and Vieques soils, from igneous rocks, mostly granite.

To facilitate the description of the soils in this group, those derived from the same or similar parent material will be discussed together.

Colinas clay loam, Colinas stony loam, Colinas fine sandy loam, and Soller clay are derived from soft or medium-soft limestone, and they are calcareous at a depth averaging about 20 inches. Soils of

some hilltops are calcareous at the surface. The best of these soils are the most productive soils in this group for sugarcane, and most of their area adjacent to the main roads is used for this crop. Soller clay is the best, and ranking with it are the best areas of Colinas clay loam. Sugarcane grown on these rolling or steep hills yields from 35 to 40 tons an acre gran cultura and from 20 to 35 tons in ratoon crops. It is not uncommon to grow six ratoon crops on these soils. In general the sucrose content in the cane grown on these soils is high, and very few of the cane stocks have suckers as is common on the wet alluvial lands. The main sugarcane variety grown is S. C. 12/4, but it is rapidly being replaced by P. O. J. 2878 and P. O. J. 2725, as the cost of cultivation is greater for S. C. 12/4 and it is more susceptible to mosaic disease than the P. O. J. canes mentioned. P. O. J. 2878 is a shallow-rooted cane, but when planted in these dense plastic clays and clay loams it does not uproot so readily as it does in the wet alluvial soils. Even when it does blow over, the soil is seldom wet enough for the nodes to germinate, start growing, and cause a loss of sucrose. Uba cane produces fairly well but is not recommended, as it is hard to cut and to grind. Mayagüez 28 appears promising for the most of the hill lands, as it can withstand drought well and closes in quickly, thereby reducing the number of cultivations necessary to kill the weeds. It is also a very prolific stooler. The fertilizer generally used on this land is 400 pounds to the acre of 12–6–8 at the first application and 400 pounds of ammonium sulfate at the second application.

Probably a larger area of these soils is in pasture than in sugarcane, but, because of the value of sugarcane, their use for pasture rates second in importance. Most of the permanent pasture land is covered with a thick stand of a mixture of fine-leaved cerrillo grass and a broad-leaved grama grass. Nearly all areas are free from weeds. From 1½ to 3 acres of land are needed to pasture an animal a year. The usual charges for pasturing animals is $1.50 a head a month. At this rate the yearly income would be from $6 to $12 an acre if the land were pastured the entire year, which is not unusual. The pasture land sells at prices ranging from $25 to $40 an acre. Grass grows better on the soils derived from limestone than on the soils derived from shale and tuff, provided they have the same rainfall.

Sweetpotatoes, pigeonpeas, corn, beans, and yautias are the main subsistence crops grown on these soils. The acre yields of the various crops are as follows: From 800 to 1,200 pounds of sweetpotatoes, from 300 to 600 pounds of pigeonpeas, about 10 bushels of corn, from 350 to 450 pounds of beans, and from 1,000 to 1,500 pounds of yautias.

In places where these soils are planted to crops requiring frequent cultivation, the surface soil erodes at a much more alarming rate than is realized by most landowners. It is true that these soils are now producing much higher yields, especially of sugarcane, than they did several years ago, although they have been in continuous cultivation. The increase is due to the selection of better varieties of sugarcane, better rate of planting, and better fertilization. Erosion starts on the top of the hill and gradually continues down the slope. The good original black surface soil is gradually being washed down the hill by sheet erosion. It is true that for some time the slopes gradually will produce better yields, but they are doing it at the expense of the soils farther up the hill, which are producing less and less as their surface

soil is removed by erosion. Near the top of the hill the surface soil is lacking in many areas, the subsoil is very thin, and, in places, the bare gray limestone is exposed. The sugarcane growing on these lime spots sometimes is affected with chlorosis. It is impossible for this thin soil resting on limestone to produce as much as the lower slopes that have a black surface layer more than 8 inches thick overlying a yellowish-brown plastic equally thick subsoil. When fertilized, these lime-exposed hilltops produce remarkably well, due to the friability of the soft limestone which allows the sugarcane roots to penetrate deeply. These soils produce even higher yields than the less eroded slopes of the Múcara and Río Piedras soils. If erosion is allowed to continue without check, in time the soil on the hills may become so thin that the land will be adapted only for pasture. Some of the steeper slopes of Soller clay already have been rendered nearly worthless by sheet erosion, owing to improper farm practices. Some erosion has taken place in the overgrazed pasture lands, but not nearly so much as in the sugarcane lands, and sugarcane lands are not nearly so eroded as lands used for the production of subsistence crops, especially pigeonpeas, beans, and corn. Strip crops, and plowing and planting with the contour, would help greatly to prevent erosion in these soils that have such plastic consistence that they absorb water slowly, making the run-off high.

These soils have an undulating or rolling relief and occur throughout the northwestern part of the island, extending from the coast to a distance of more than 8 miles inland. The elevation in this section ranges from sea level to 700 feet above, and the average annual rainfall ranges from about 50 inches near Isabela to more than 95 inches near San Sebastián. Most soils receiving from 70 to more than 90 inches of annual precipitation would be seriously leached of their plant nutrients, but as these soils are young and derived from soft limestone, the rainfall has very little leaching effect. In these soils the higher the rainfall the darker the soil and the higher the organic content. The quality and kind of grass vegetation changes but little throughout areas of these soils, but the quantity is much less in the drier areas than it is in the humid areas.

The drainageways in these soils are short, indefinite, and for the most part lead to subterranean channels. Only a very few streams cross areas of these soils, and water for domestic purposes is scarce, inadequate, and in many places far from the numerous houses that dot the hills. Some rain water is caught from the galvanized roofs of the houses.

The Tanamá soils are derived from a medium-hard Tertiary limestone that weathers so slowly that the soil produced is red, thin, permeable, and acid. Most of the two Tanamá soils included in this group are farmed by small landowners who plant coffee, bananas, tobacco, and subsistence crops. Yields are generally low, and a considerable acreage of these soils is adapted only for forestry, owing to prevalence of sinkholes and rock outcrops.

Although Plata clay and its mixed phase are closely associated with the shallow soils derived from limestone, they are derived from older materials and will be discussed separately.

The soils of the Daguao, Múcara, Juncos, Sabana, and Naranjito series are closely related. They have been derived from similar parent material, have about the same depth to unconsolidated rock, and are

adapted to about the same kinds of crops. They range in color from black to light grayish brown and in acidity from alkaline to strongly acid. Beginning with the Daguao soils, which are the most alkaline and darkest, the soils become less dark and more acid in the following order: Múcara, Juncos, Sabana, and Naranjito. The Daguao soils receive the least rainfall and the Naranjito soils the most, so, generally speaking, with increasing amounts of soil water the soils become more acid and more gray.

The soils occur in the subhumid part of the island between and east of the north and south limestone belts. The steep phases of these soils are included in the group of shallow soils of the uplands and are used predominantly for pasture, but the soils in this group are used extensively for tobacco, subsistence crops, and sugarcane. Where these soils are within a mile of a main-traveled road and not over 4 miles from a sugar central, a larger acreage of their area is planted to sugarcane than to all other crops (fig. 106).

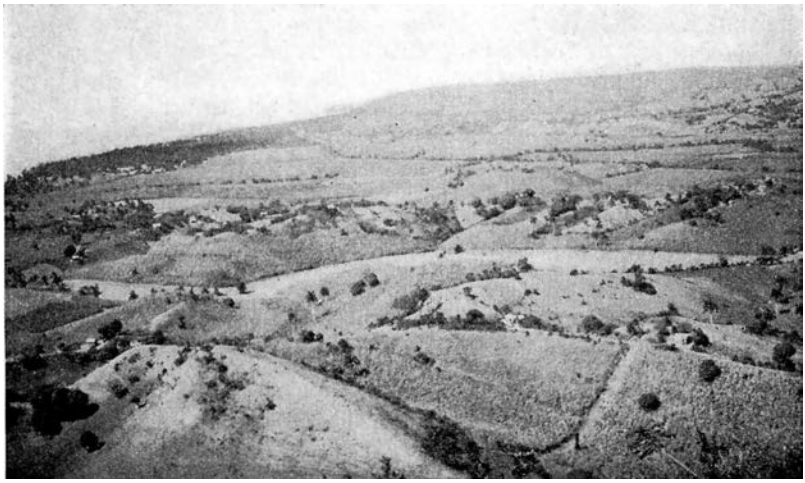

FIGURE 106.—Sugarcane growing on fairly shallow soils with steep slopes, within a mile of a main-traveled road in the western part of the island.

Caña creciendo en suelos regularmente poco profundos en laderas escarpadas, alrededor de una milla de distancia de una carretera principal en la parte oeste de la isla.

If the land is owned or managed by centrals, yields of sugarcane range from 25 to 35 tons to the acre, as the centrals properly weed and fertilize the land and also plant good varieties of cane. If the land is owned and managed by small landowners, however, the sugarcane seldom yields over 20 tons an acre and may yield as low as 12 tons, because the small landowners do not have the capital to buy fertilizer and properly manage this shallow land. Field observations indicate that under present conditions, with 3-cent sugar, this land should produce more than 12 or 15 tons of sugarcane to the acre, in order to return a profit to the owner. These soils are shallow to rock, and it is unreasonable to expect that the sugarcane roots will have sufficient room to secure enough plant nutrients and water for a high yield. Sugarcane roots, unlike tree roots, are unable to penetrate the rock

and, therefore, suffer for water during dry periods. On the Juncos soils and near the bases of the hills of the other soils, the depth to rock is much greater, and yields are noticeably higher.

Tobacco and most subsistence crops do not necessarily require deep soils for profitable production, therefore large acreages of the soils in this group are planted to these crops.

One of the most noticeable practices in farming these soils, especially for tobacco, is the digging of shallow narrow gridiron-shaped ditches (fig. 51) on the hillsides, regardless of the steepness of the slope. The bottoms of many ditches rest on solid rock, thus eliminating conditions favorable for a gully type of erosion. If any soil reaches the ditches, it is washed away, but, by having many small 20- or 30-foot squares surrounded by ditches, the water does not have a chance to collect much soil before it runs into a ditch. These ditches not only reduce erosion but they help drain the soil, making a more favorable growing condition for the tobacco plants.

The Río Piedras soils are developed from rocks of volcanic origin, largely tuffaceous shales, and they occur on hill slopes and ridges. Under weathering in a tropical climate, the rocks rapidly disintegrate forming soils with heavy clay textures.

The Pandura, Cayaguá, Ciales, Utuado, Teja, and Vieques soils are derived from granitic material and therefore have many characteristics in common. All are light colored, gritty, well drained, medium shallow, and susceptible to sheet erosion, and most of them are acid, coarse textured, and low in plant nutrients, especially nitrogen, but they are used extensively for crops, unless cultivation is impossible owing to the high content of rocks and boulders. Tobacco is the most important crop grown, followed in importance and acreage by such subsistence crops as beans, corn, and sweetpotatoes.

These soils occur on hills that range in elevation from 500 to more than 1,500 feet above sea level. The average annual rainfall ranges from less than 40 inches on the Vieques soils to more than 90 inches on some areas of the Pandura, Cayaguá, Ciales, and Utuado soils. The Teja soil receives about 70 inches of average annual rainfall.

The Cayaguá soils are the most productive, followed by the Utuado, Ciales, Vieques, Pandura, and Teja soils. The steeper the relief the less desirable is the soil and the more likely it is to be injured by sheet erosion.

These soils are the most seriously eroded soils from a topographic point of view. They are completely dissected with drainageways. Most of the drains are U-shaped and have a rather deep layer of sand, coarse sand, and fine gravel in the bottom.

The quality of the water throughout areas of these soils is good, but the quantity is not so great as in comparable areas of the Catalina and associated soils or of the Múcara and associated soils.

Colinas clay loam.—Colinas clay loam is easily recognized by two outstanding characteristics. It occurs on low rolling round-topped soft limestone hills (fig. 107), and it has a dark grayish-brown surface soil with many eroded spots exposing the white lime. It is fairly well distributed from the northwestern corner of the island to a point east of Toa Alta, a distance of about 51 miles. It is adequately drained because of its rolling relief.

The 4- to 7-inch surface soil ranges from grayish-brown to very dark grayish-brown granular clay loam. It is underlain by yellowish-

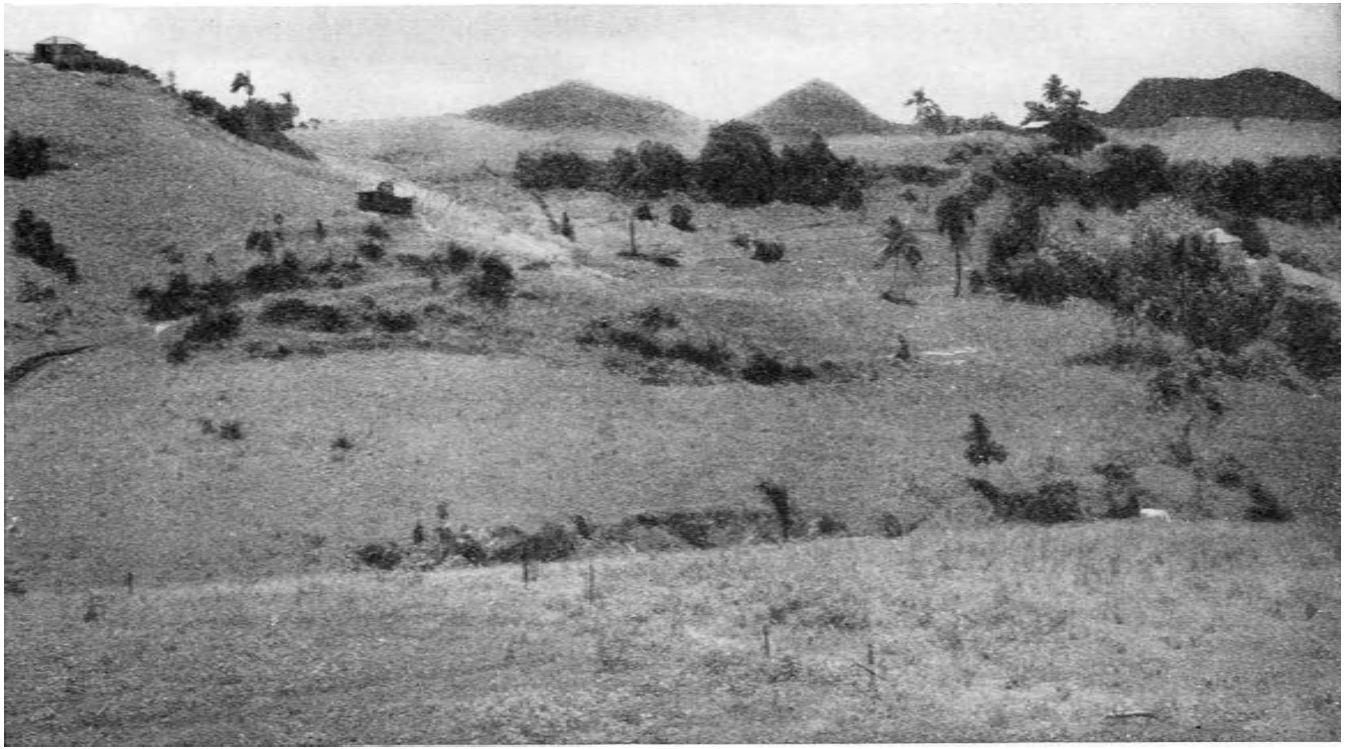

FIGURE 107.—Typical view of Colinas clay loam. These rolling round-topped hills receive about 80 inches of average annual rainfall, and erosion is rather severe on these plastic granular alkaline soils when the land is planted to clean-cultivated crops, such as beans, corn, and pigeonpeas.

Vista típica de un Colinas arcilloso lómico. Estas colinas de cima redonda reciben como 80 pulgadas de lluvia anualmente; la erosión es bastante fuerte en estos suelos alcalinos, plásticos y granulares, cuando se siembran de cultivos como habichuelas, maíz y gandules.

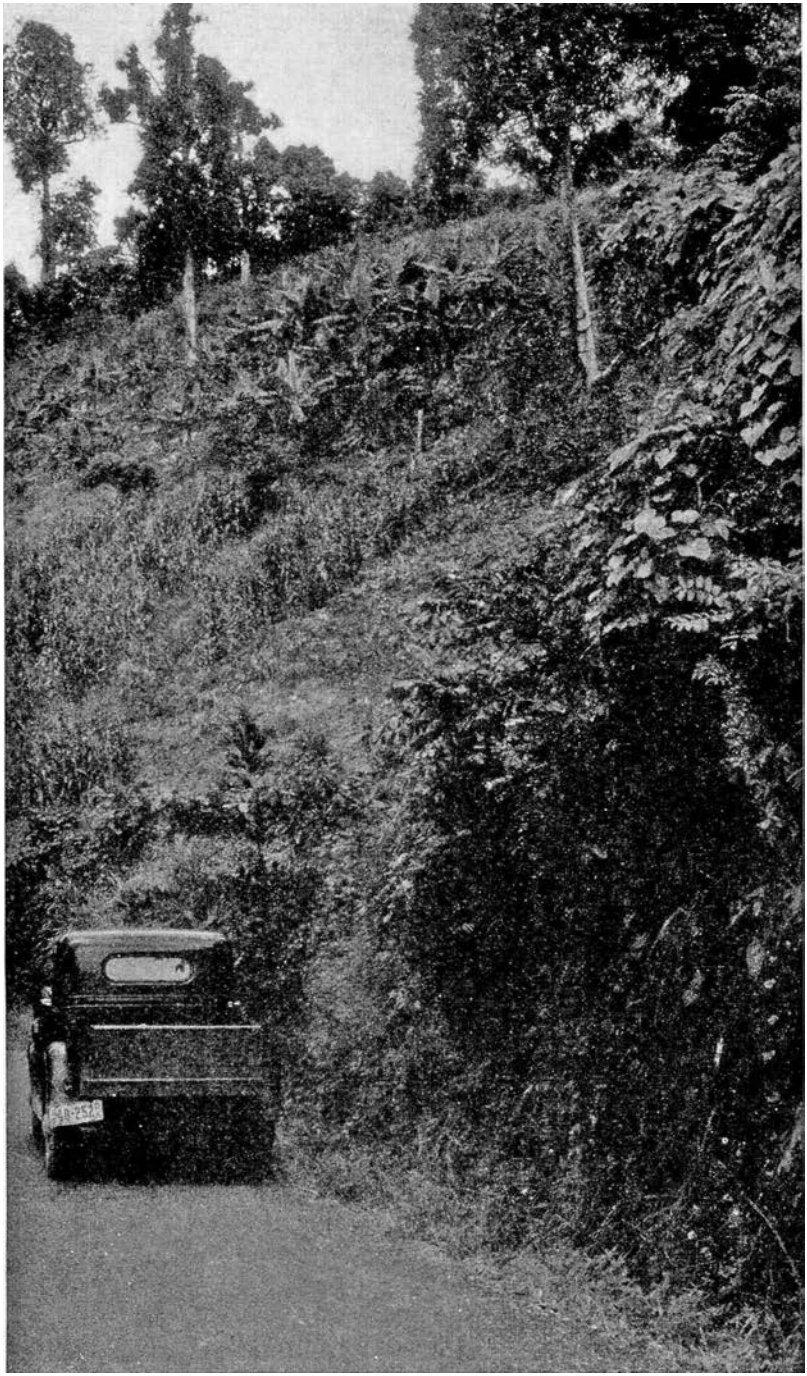

FIGURE 108.—See legend on page 209.

brown or light yellowish-brown clay loam which is slightly heavier and more plastic than the surface soil. This layer grades, at a depth of 12 or 14 inches, into light-gray soft limestone. The limestone becomes harder with depth, but in most places an auger can penetrate it to a depth of 20 inches. Plant roots, however, penetrate to much lower depths for a supply of moisture. This soil is alkaline from the surface downward, and in most places it is calcareous at a depth of 7 inches. In places it is calcareous at the surface, but such areas have been eroded and are distinctly noticeable on account of their light-gray color. They occur on top of the hills or ridges and on slightly higher irregular humps on the hillsides. These spots are not so noticeable if the land has always been in pasture.

Because of surface wash this soil gradually changes toward the base of the hill to deeper and better soils, such as Santa Clara clay and Camagüey silty clay, depending on the extent to which erosion has taken place. The boundary lines between any of these soils are changing gradually.

Nearly all of the land is cleared. About 50 percent of it is in sugarcane, 35 percent in pasture, and 15 percent in such subsistence crops as pigeonpeas, sweetpotatoes, beans, corn, and yautias (fig. 108). The yields produced are about the average for soils of this group.

Colinas stony loam.—Colinas stony loam occurs near the seacoast and probably has been influenced to some extent by the sands blowing from the beach. It has a very dark grayish-brown or black granular loam surface soil from 6 to 12 inches thick, underlain by a layer of grayish-brown loam or clay loam about 4 or 6 inches thick. This material grades into soft gritty limestone at an average depth of 14 inches. The soil material contains an abundance of small limestone fragments throughout. In places this soil may have only a 6-inch soil covering over medium-hard limestone rock. In other places, especially near Islote, the surface soil is slightly darker and more plastic than the average areas of this soil, and in this respect the Colinas soil resembles the Camagüey soils.

The better areas of Colinas stony loam are used for cultivated crops, especially tobacco in the Isabela-Camuy districts and sugarcane in the Islote district. Such minor crops as sweetpotatoes, corn, beans, and pigeonpeas are grown very successfully in all areas, with yields higher than the average for soils of this group. The more shallow areas are used for pasture, especially from Hatillo eastward. The pasture grass is good, but many fields are infested with weeds. This is uncommon for the soils of this group.

Colinas fine sandy loam.—Colinas fine sandy loam is easily distinguished from Colinas stony loam, as it is derived from a much sandier limestone and is, therefore, more sandy throughout. It occurs mainly in a few small areas, but a fairly large area is about 6 kilometers north of Morovis.

FIGURE 108.—Subsistence crops growing on Colinas clay loam having a slope of more than 60 percent. The crops are yautias, corn, and bananas.

Frutos menores o cultivos de subsistencia sembrados en Colinas arcilloso lómico con un declive de más de 60 por ciento. Los cultivos son yautías, maíz y guineos.

144038—41——14

This soil has a dark grayish-brown loose granular fine sandy loam or loam surface soil that gradually changes at a depth of about 5 inches to light yellowish-gray plastic sandy clay loam. In most places this layer is very thin and in some places may be lacking. When present it rests on fairly loose gritty gray limestone.

Agriculturally this soil is less valuable than Colinas clay loam, the soil it most closely resembles. The fine sandy loam occurs chiefly on rolling or steep hills, although a few small areas of colluvial soil or soil in valleylike positions have been included. The total area is only 1,280 acres. The land is used chiefly for pasture and to less extent for subsistence crops. Yields are similar to those obtained on Colinas clay loam. The better areas, especially those that are valleylike, produce fair sugarcane.

Soller clay.—Soller clay, which occurs on the low rolling or undulating hills in the vicinity of Central Soller, is the best soil of the Soller series. It has a very dark grayish-brown or black plastic dense granular clay surface soil from 4 to 7 inches thick, which, when dry, breaks into dense hard clods that require several rains in order to slake into fine granular particles. The subsoil is grayish-brown plastic clay that gradually changes to white loose calcareous marl of clay loam texture. In most places the marl occurs at a depth of 12 inches or less. In places, erosion has caused the marl rock to be exposed, thus reducing the value of the land from about $65 to $20 an acre or even less. Drainage is adequate, as the slope is sufficient to drain off excess water.

Road banks show that this soil contracts and expands greatly at the extremes of moisture content, as fairly wide cracks extend from a depth of 10 or 12 inches to the surface of the ground. In cultivated fields, cracks 1 or 2 inches wide may appear during dry periods following heavy rains. The soil is used almost entirely for the production of sugarcane, average acre yields of which are about 45 tons gran cultura.

Tanamá stony clay, smooth phase.—Tanamá stony clay, smooth phase, is an extensive soil derived from hard Tertiary limestone. It occurs in small limestone valleys throughout the north-coast limestone belt in less hilly areas than typical Tanamá stony clay. This soil is nonirrigable and is a very poor agricultural soil. The 4- to 8-inch surface soil consists of reddish-yellow or reddish-brown granular stony clay, and the subsoil is reddish-yellow or brick-red clay grading into hard limestone rock at a depth ranging from 8 to 30 inches. The average thickness of the profile to bedrock is probably about 15 inches. In places, the soil is not deep enough to develop a subsoil. It consists of brownish-red clay about 8 inches thick overlying loose small hard and soft limestone rocks. Numerous fragments of limestone are distributed throughout the soil, and limestone outcrops are fairly numerous (fig. 9).

Nearly all of this soil has been under cultivation at some time, but now a large proportion of it is in pasture. The principal crops grown are the shallow-rooted ones, such as onions, beans, sweetpotatoes, and tobacco. Tobacco, however, is grown only where the soil is more than 10 inches deep. In a few places sugarcane and coffee are grown fairly successfully. In dry seasons all crop yields are low, but during favorable years, yields are fair, about the same as on Colinas clay loam. Most farms on this soil range in size from 7 to 10 acres.

The income from the farm usually is insufficient for the owners to make a living, so they must obtain part-time work elsewhere. Owing to the shallowness and rockiness of the soil almost all of the field work must be done by hand, and if the land is plowed wooden plows are used to the best advantage. The surface soil is alkaline or slightly acid in reaction, and the subsoil in most places is acid.

Tanamá stony clay, colluvial phase.—Tanamá stony clay, colluvial phase, is a complex of the materials on the colluvial slopes of hills occupied by Tanamá stony clay and the material in the small irregular-shaped limestone valleys, sinks, and basins. The size of most areas of this complex ranges from 1 to 30 acres. The soils in the valleys may be any one of the soils derived from Tertiary limestone, but, as these valleys are so small and inaccessible, and no differentiation is made in their crop use, all are classified with Tanamá stony clay, colluvial phase.

Most of the soil is farmed by small landowners who plant coffee, bananas, tobacco, and subsistence crops in the valleys. Many of the sinks and small basins are used only for forestry, and the colluvial slopes produce only brush and trees. Most of this soil is so inaccessible and occurs in such small narrow strips that it adds very little to the value of the surrounding poor-quality Tanamá stony clay. Coffee is well protected from hurricanes in the small valleys. Since any material that is washed from the adjacent hills collects in the valleys, the soils in the lowest parts of the basins or valleys are much higher in organic matter than the surrounding soils.

This soil is about uniformly distributed throughout all areas of Tanamá stony clay, but on the soil map the areas between Ciales and Río Guajataca appear much more numerous than in other parts of the limestone section. This is because these areas include a larger proportion of slopes of Tanamá stony clay than is included in the other areas.

Plata clay.—Plata clay is derived from gravels and clays lying beneath the Tertiary limestone and therefore occurs on rolling rounded hills just south of the north-coast limestone escarpment and north of the south-coast limestone hills.

It is characterized by a grayish-brown or dark grayish-brown friable neutral clay surface soil 6 or 8 inches thick, containing many rounded quartz pebbles. The subsoil is yellowish-brown friable neutral clay loam containing much disintegrated gravel. At an average depth of 17 inches the material is firm but friable silt loam, neutral or alkaline in reaction and containing much gravel. This material continues to a great depth. In places, it is stratified with layers containing a large quantity of partly rounded rocks and rock fragments. In some places the soil is slightly mottled with gray and yellowish brown at a depth ranging from 6 to 17 inches.

About 50 percent of this soil is in grass, 30 percent in sugarcane, and the remainder in minor crops and coffee. The soil is considered superior to Múcara silty clay loam and about as good as Juncos clay.

Areas of this soil that have a considerable quantity of pebbles on the surface and throughout the profile are shown on the map with gravel symbols. These areas are more rolling, not so heavy, and lie nearer to the streams than the typical areas, and many of them are planted to sugarcane, which yields slightly better than on the typical areas.

Plata clay, mixed phase.—Plata clay, mixed phase, is readily identified by its variegated color. It occurs on steep slopes just south of the limestone escarpment, from Moca to Corozal, associated with the Colinas and Soller soils.

The 6- or 8-inch surface soil ranges from grayish-brown to black plastic waxy clay. It is underlain by plastic sticky clay having a peculiar banded mottled assortment of bright colors, mostly red, purple, gray, and brown. At a depth ranging from 30 to 40 inches, the material is about the same as that underlying typical Plata clay. In some places, lime carbonate occurs throughout the profile, owing to seepage of lime from the higher lying adjacent limestone soils. In most places this soil slopes toward the south, is well drained, and occurs in long narrow strips or small irregular-shaped areas, which are used for pasture, corn, and coffee. Crops grow very well, but because of its unfavorable relief more than 70 percent of the land is in pasture. The carrying capacity of the pastures is about 1½ acres for an animal a year. The rainfall is sufficient for nearly continuous plant growth.

Daguao clay.—Daguao clay is similar to some of the southern Prairie soils of the United States. It is a shallow nearly black soil of the uplands developed on rolling or hilly relief and derived from andesitic rocks having a green tinge. It occurs only in areas where the mean annual rainfall is between 55 and 65 inches. Most of it is in the eastern part of the island near Ensenada Honda.

The 6-inch surface soil when wet is nearly black granular plastic clay, but it becomes hard and cloddy when dry. Cracks 2 inches wide are common in dry fields. The upper part of the subsoil is reddish brown or brownish red, plastic when wet, and hard and dense when dry. The lower part of the subsoil is mottled brown and dark-gray plastic sticky clay resting on partly disintegrated rock at a depth ranging from 20 to 30 inches, depending on the degree of slope and the extent to which sheet erosion has taken place. On some of the steepest slopes, the disintegrated parent rock lies within 3 inches of the surface. The material in all layers is neutral or alkaline in reaction.

Nearly all of this soil has been used at some time for the production of sugarcane, which yields from 20 to 35 tons an acre during favorable years but less than 10 tons during dry years. Experience has shown that, under present conditions, owing to the frequent dry years, this soil is more productive for grass than for sugarcane. The grass produced is of very good quality, especially in areas that have been in grass for many years. At present, more than 50 percent of the land is used for pasture, the carrying capacity of which is about one animal to the acre during most of the year.

In places large boulders and rock outcrops are very conspicuous, and they reduce the value of the land.

Daguao clay, colluvial phase.—Areas of Daguao clay occurring at the bases of the hills and having much deeper surface soils and subsoils than typical are mapped as Daguao clay, colluvial phase. Agriculturally this soil differs from the typical soil in that it is better adapted to sugarcane and produces much higher yields year after year. It is very similar to Mabí clay, but it is slightly more alkaline in reaction and the subsoil is more reddish brown.

The soil occupies a very small area in the eastern part of the island. Probably 50 percent of the land is used for the production of sugarcane and the remainder for pasture.

Daguao clay, colluvial phase, is valued considerably higher than the typical soil, but it is more difficult to plow and prepare for sugarcane.

Múcara silty clay loam.—Múcara silty clay loam is the most extensive and most widely distributed soil in Puerto Rico. It occurs in nearly every part of the upland where the mean annual rainfall exceeds 65 inches. This soil is easily recognized by its dark-brown surface soil and light-brown shallow subsoil overlying tuffaceous rocks. In a well-managed cultivated field the surface soil is dark brownish-gray or grayish-brown medium plastic silty clay with a rather distinct crumb structure. This layer is underlain at a depth of about 8 inches by yellowish-brown or light-brown plastic clay or silty clay having a tendency to become mottled gray and yellowish gray in the lower part. In places, small angular fragments of partly weathered rocks are abundant in this layer. They become more abundant with depth. The depth to rock, as well as the thickness of each layer, depends on the slope. This soil occurs on hills having slopes ranging from 30 to 60 percent, and near the tops of the steeper hills the entire thickness above the rock is in few places more than 14 inches and in many places is less than 8 inches. In such localities, all layers are thin. Near the bases of the hills, or in places where this soil grades into Juncos clay, the parent rock may be nearly 3 feet below the surface. Throughout all layers of this soil, white hard specks are conspicuous, indicating that not all the minerals have become decomposed and therefore the soil has more or less of a reservoir of plant nutrients that are gradually released and made available to the plants. This soil is neutral or slightly acid in the surface soil and becomes more alkaline with depth. In some places, free lime carbonates occur in the rock seams. Here and there boulders and rock outcrops occur on the ridge tops and the steeper slopes.

Múcara silty clay loam is a well-drained soil, owing to the steepness of its relief. In small areas at the heads of drainageways and in a few small areas on flat ridge tops, however, drainage is inadequate for the production of good-quality tobacco. Such areas are spoken of as cold tobacco land, and the surface soil and subsoil are lighter gray than in the typical areas.

This soil is the most productive Múcara soil, and many thousands of people obtain most of their living from it. The numerous houses are on the narrow ridges, and the cultivated land is on the slopes. Throughout most areas of this soil are many small tobacco fields, some only a fraction of an acre in extent. Yields depend on the quantity of fertilizer used and the thickness of the surface soil. The average acre yields on this soil are: 800 pounds of tobacco, 1,200 pounds of sweetpotatoes, 400 pounds of beans, 1,200 pounds of yuca, 300 pounds of pigeonpeas, and from 10 to 15 bushels of corn. Other crops yield accordingly.

Múcara silt loam.—Múcara silt loam differs from Múcara silty clay loam in having a lighter textured surface soil and a slightly less heavy subsoil. All areas are well drained, even those at the heads of drainageways. This soil occurs mostly in the eastern part—from Ceiba to Carolina—and a few areas are in the western part.

Areas of this soil that have an unusually large number of stones and boulders on the surface are shown on the map with stone symbols; such areas are used only for pasture and trees. Some of the areas are very steep.

This soil occupies narrow ridges and the upper parts of long slopes. Some areas are used for grassland because their relief is unfavorable for the production of cultivated crops. Some of the more favorably situated areas, which are readily accessible, are used with adjoining soils for the production of sugarcane, but most of the land is used for subsistence crops. Yields are less than on Múcara silty clay loam.

Juncos clay.—Juncos clay is similar to Múcara silty clay loam in color, origin, and consistence, but owing to its smoother relief it has a thicker surface soil, more plastic subsoil, greater depth to parent rock, and is much more productive, especially for sugarcane. Nearly 90 percent of the land is cultivated to sugarcane.

This soil is characterized by a 7-inch dark grayish-brown semi-granular plastic sticky heavy clay surface soil. It is underlain by a 14- to 20-inch layer of yellowish-brown compact plastic sticky clay containing gray specks. Below this layer and continuing for another 10 inches, is a mixture of disintegrated rock and fine-grained yellowish-brown silty clay loam. Below a depth ranging from 30 to 40 inches are tuffaceous rocks.

This soil occupies the lower slopes and low rounded hills throughout the island, in association with the Múcara soils.

Sugarcane produces from 30 to 35 tons of gran cultura and from 20 to 25 tons in ratoon crops. P. O. J. 2878 and S. C. 12/4 are the most common varieties of cane planted on this soil. Subsistence crops and tobacco yield better on this soil than on Múcara silty clay loam.

Sabana silty clay loam.—Sabana silty clay loam differs from Múcara silty clay loam in having a lighter colored surface soil and subsoil, and it is more acid in all layers. In most places it occurs on rolling or steep hills associated with the Múcara soils but occupies areas receiving slightly more annual rainfall. There are many stones and boulders on most of the ridges.

On many of the more gentle slopes this soil has a plastic heavy subsoil, which retards the percolation of water, thereby causing gray spots to appear on the surface. Most of the concave areas or slight depressions have a distinct gray color, indicating that this soil is sensitive to underdrainage and that any abnormalities in the heaviness of the subsoil or additional accumulation of surface water will cause imperfect drainage, which, in turn, causes gray and rust-colored mottlings in the soil layers. On the ridges this soil is friable and well drained, but it is seldom more than 10 inches deep to bedrock. Most of the hills are rounded, and the ravines have sloping sides.

This soil is less desirable than Múcara silty clay loam for all agricultural crops. Probably 80 percent of the land is used for subsistence crops, and the remaining 20 percent is divided equally between pasture and sugarcane.

Sabana silt loam.—Sabana silt loam developed in the eastern part of the island, differs from Sabana silty clay loam in having a lighter textured surface soil and lighter colored more acid subsoil. The land use for these two soils is similar, and both produce about the same yields of crops.

Areas of this soil that have an unusual quantity of stones and boulders on the surface are shown on the map with stone symbols. Such areas are used only for pasture and trees, and many of them are very steep.

Naranjito silty clay loam.—Naranjito silty clay loam is associated so intricately with the Múcara and Sabana soils that in some places it is impossible to separate them. In general, the Naranjito soil occurs in areas receiving more rainfall than areas of either the Múcara or Sabana soils, and it is therefore more acid, has a lighter colored surface soil, and has a tendency to have a reddish-brown or brownish-red shallow subsoil over shale, tuffaceous rock, or in places igneous rock.

The surface soil of a cultivated field of Naranjito silty clay loam has a gray cloddy appearance, with some streaks of red clay that have been exposed, owing to sheet erosion or deep plowing. This layer is plastic, sticky, and strongly acid. It is underlain, at a depth ranging from 2 to 10 inches, depending on the slope and extent of erosion, by a layer that varies within short distances from reddish-brown to yellowish-brown acid plastic sticky clay, which becomes somewhat more friable at a depth of 20 inches and grades into unconsolidated parent rock at a depth of about 30 inches.

This soil is used for the production of minor crops, tobacco, and coffee, but yields are not so good as on the Múcara soils. Farmers not using fertilizer prefer this soil to the Cialitos or Catalina soils for tobacco and minor crops. A large proportion of the land is in pasture. Two acres are required to pasture an animal through the year. This soil occurs on slopes ranging from 40 to 60 percent. In places on the ridges and steeper slopes, there is a rather large number of boulders.

Naranjito silty clay loam, smooth phase.—Areas of Naranjito silty clay loam that have a slope of less than 30 percent are classified as Naranjito silty clay loam, smooth phase. This soil is slightly more desirable than the typical soil, and a larger proportion is in cultivation, especially to subsistence crops. Yields are higher than on the typical soil, and cultivation is usually done with a team of oxen instead of with hand implements, as is the practice on the typical soil.

This soil is associated with the typical soil and, therefore, occurs in areas of rather high yearly rainfall.

Naranjito silty clay loam, colluvial phase.—Areas of Naranjito silty clay loam that occur at the bases of the hills and have a much thicker surface soil and subsoil than typical Naranjito silty clay loam are mapped as a colluvial phase of that soil. Agriculturally the colluvial soil is much more desirable than the typical soil, because it receives the wash from the upper slopes and is therefore more fertile, has a higher water-holding capacity, and is much deeper to parent rock.

This soil is used mainly for subsistence crops, tobacco, and coffee, and areas near roads are used for sugarcane. Yields are about twice as high as those obtained on the typical soil, especially of such crops as sugarcane, coffee, and tobacco.

Río Piedras clay.—Río Piedras clay has a characteristic heavy plastic acid clay surface soil and subsoil, both of which contain various proportions of gray, yellow, and red. The surface soil is plastic and slippery when wet and hard and brittle when dry. There is no sharp line of separation between the soil and the underlying shale parent material, which in most places occurs at a depth of about

2 feet. This soil is acid in all layers. It occurs mostly in the vicinity of Río Piedras, but some areas are near Central Coloso and near Fajardo. Sugarcane, with yields ranging from 25 to 35 tons gran cultura cane, is the best crop grown on this land. Two acres are necessary to pasture an animal in favorable years. Yields of all crops are low, because of the low content of organic matter, strong acidity, and heavy plastic characteristics of all layers. The soil apparently is low in phosphorus. Owing to the plasticity, low fertility, sensitiveness to underdrainage, and susceptibility to erosion, the land requires very careful management.

Río Piedras silty clay loam.—Río Piedras silty clay loam occurs in a few small areas east of Fajardo, and they are very conspicuous, even from a distance, on account of their nearly white surface. A cultivated field has a very light gray or very light brownish-gray silty clay loam surface soil about 10 inches thick, which contains an abundance of small angular shale fragments. The subsoil is grayish-yellow heavy plastic clay mottled with yellow, gray, and red. This material rests on partly weathered shale at a depth of about 3 feet. Along some drainageways the material is composed largely of accumulated shale. This soil is very acid in all layers. The gray color is not caused by imperfect drainage but is due to the light color of the shale from which it is derived and to intense leaching under acid conditions.

This soil occupies sloping and steep hillsides. The less steep areas are used for the production of sugarcane, and the steeper areas are in pasture. Crop yields are lower than on Río Piedras clay. The land requires very careful management, as it is subject to erosion, difficult to cultivate, and low in fertility.

Pandura sandy clay loam.—Pandura sandy clay loam is readily distinguished from most of the other granitic soils, owing to the large number of granite boulders scattered on the surface (fig. 109). This soil occupies extensive areas on steep mountainsides as well as on lower steep hills in the southeastern part of the island near Yabucao and Maunabo.

This soil is characterized by a brown or light-brown granular friable acid gritty sandy clay loam surface soil about 6 inches thick, the thickness depending on the degree of slope and the extent to which erosion has taken place. The steeper the slope the greater the degree of sheet erosion and the thinner the surface soil. The surface soil is underlain by a mixture of loose gritty sandy loam and disintegrated granite of the quartz diorite variety, which gradually changes, at a depth ranging from 12 to 30 inches, to the parent rock.

As this soil is loose, friable, and sandy, it absorbs water rapidly and is excessively drained, but, owing to its occurrence in areas receiving a rather high monthly precipitation, crops produced on it do not suffer greatly from drought.

Owing to the steepness of the relief and the exceptionally high content of boulders, this soil is used principally for pasture and trees. The smoother rock-free areas are used advantageously for the production of minor crops and tobacco, which, when the land is sufficiently fertilized, produce crops comparable to those obtained on Múcara silty clay loam. Crops growing continuously on this soil for a number of years show evidence of lack of nitrogen. A characteristic feature of areas of this soil is the large boulders which are nearly concealed

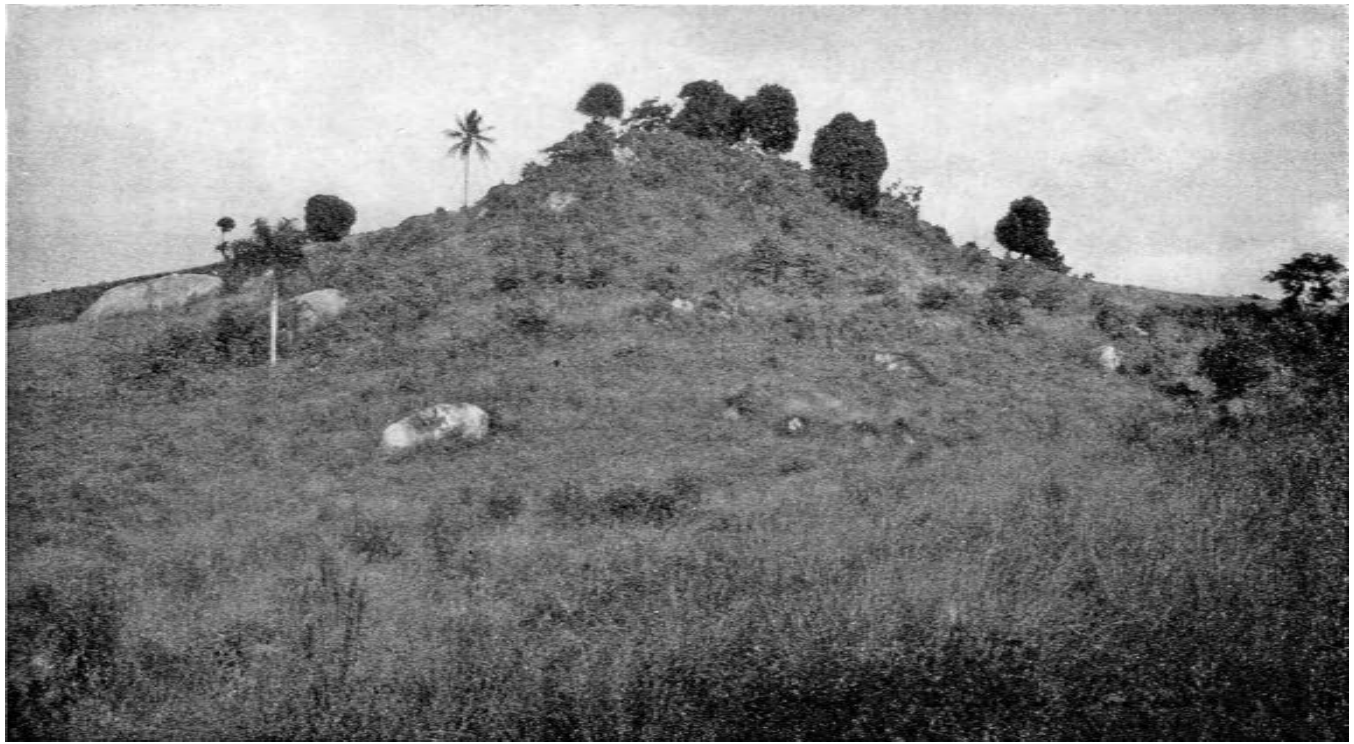

FIGURE 109.—Large boulders on Pandura sandy clay loam near Las Piedras. Mango trees on the right side of the hill.
Peñones en un Pandura areno-arcilloso lómico cerca de Las Piedras. Arboles de mangó a la derecha de la colina.

by banana and plantain plants. Some of the coffee trees are nearly hidden by the banana plants. Many of the areas in which boulders are numerous are shown on the map with stone symbols.

Pandura sandy clay loam, smooth phase.—Areas of Pandura sandy clay loam that have smooth relief, such as slopes ranging from 15 to 30 percent, are classified as Pandura sandy clay loam, smooth phase. The total area of this soil is only a small fraction of that of the typical soil.

Owing to the relief, this soil is more easily cultivated and has thicker layers than the typical soil. For these reasons, it is more desirable and generally sells at a higher price. A higher proportion of the land is in minor crops than in pasture or trees. Yields are about the same as on areas of Cayaguá sandy clay loam, steep phase, a soil the Pandura soil closely resembles.

Pandura loam.—Pandura loam differs from Pandura sandy clay loam in that it has a more loamy texture in all layers. It is less productive than Pandura sandy clay loam. In many places the two soils are closely associated, and the crop use is nearly the same for both soil types. The loam requires slightly more fertilizer than the sandy clay loam.

Pandura loam, smooth phase.—Areas of Pandura loam that have rather smooth relief are classified as Pandura loam, smooth phase. The total area of this soil is almost 22,000 acres.

This soil has a fairly thick surface soil and a thin subsoil above the same kind of parent material that underlies the typical soil. Owing to the relief and slightly thicker surface layer, this smoother soil is used mostly for the production of subsistence crops and to only a small extent for trees and grass. Yields are higher than on the typical soil. Cultivation is mostly by hand, as this soil, although smoother than the typical soil, is classified as rather steep.

Cayaguá sandy clay loam.—Cayaguá sandy clay loam is closely associated with the Pandura soils, from which it is readily distinguished by the presence of a small quantity of rocks or boulders on the surface and the less steep relief. In reality Cayaguá sandy clay loam is a complex of several different soils so intimately associated that they could not be separated on the map.

The 6- or 8-inch surface soil of Cayaguá sandy clay loam is light grayish-brown loose friable acid sandy clay loam that readily forms a good tilth when cultivated. Underlying the surface soil and continuing to a depth ranging from 14 to 20 inches is yellowish-brown, in places reddish-brown, rather heavy slightly stiff sandy clay, which gradually changes to loose coarse gritty quartz diorite material at a depth of about 30 inches. The compaction and depth of the subsoil varies greatly from place to place and within short distances. In concave areas or on very gentle slopes, the layers are thick, drainage is slightly impeded, and the subsoil is reddish brown and much more compact than on the convex slopes or the steeper areas. In the latter areas the layers are thin and the soil is friable and excessively drained.

This is one of the best soils for the production of tobacco in the San Lorenzo tobacco district (fig. 110), as it is well drained, warm, and friable. It requires larger quantities of fertilizer than Múcara silty clay loam in order to produce the same yield of tobacco.

The largest acreage of this soil is used for tobacco, followed by pasture, corn, beans, upland rice, sugarcane, and sweetpotatoes, ranking in acreage in the order named.

The principal variety of tobacco grown is Virginia Blanca, which yields from 500 to 1,200 pounds to the acre, depending on the quantity of fertilizer used, management of the land, and whether the crop is grown on concave or convex slopes. The best pastures have a carrying capacity of about 1½ acres to an animal, but the feed produced from this acid-leached nonfertilized soil is not so nutritious as that furnished from the grass growing on the Colinas or Descalabrado and related soils. Corn produces from 1,300 to 1,600 pounds an acre in fields from which tobacco has been harvested. The corn roots obtain the benefit of some of the fertilizer applied for the tobacco. Beans yield

FIGURE 110.—Cayaguá sandy clay loam south of San Lorenzo. Tobacco has been picked, and the land is now in corn and beans; a few months later it will be planted again to tobacco.

Cayaguá areno-arcilloso lómico al sur de San Lorenzo. El tabaco ya ha sido recolectado y la tierra está ahora sembrada de maíz y habichuelas; pocos meses después la tierra será sembrada otra vez de tabaco.

from 200 to 300 pounds to the acre. The common practice is to plant corn and beans together immediately after the tobacco is harvested. Upland rice yields form 600 to 900 pounds to the acre. Usually it is planted in March or April following tobacco and is harvested 5 or 6 months later. Sugarcane yields about 25 or 30 tons to the acre, sweetpotatoes from 4,000 to 5,000 pounds, yautias from 5,000 to 8,000 pounds, and yuca only about 1,000 pounds.

Throughout areas of this soil there is much evidence of lack of nitrogen, as the tobacco, corn, and even bananas have a pale-yellow color. The land is subject to erosion unless very carefully handled. The methods used to prevent erosion are brush terraces and gridiron-shaped ditches spaced about 20 feet apart.

Cayaguá sandy clay loam, steep phase.—The steep areas of Cayaguá sandy clay loam, occurring on both sides of the drainageways, are classified as Cayaguá sandy clay loam, steep phase. This soil occupies 17,408 acres and is used only for pasture. It includes not only the

steep slopes of the ravines but also narrow strips of level deep sandy material in the bottoms of the U-shaped drains, which are overflowed during rains but are dry and grass-covered during dry periods. A swamplike vegetation grows in some of the wet areas, but such areas are very small. The soil on the catstep slopes is friable, and the parent rock lies nearer to the surface than in the typical soil.

Areas of this soil are considered good pasture land, but it takes about 2 acres to pasture an animal a year.

Ciales clay loam.—Ciales clay loam is derived from granite. It occurs in large areas in many parts of the island. Some of the largest are near Ciales, Morovis, and Utuado. This soil occupies hills having slopes ranging from 40 to 100 percent, and it is characterized by a grayish-brown gritty granular clay loam surface soil about 4 or 6 inches thick, underlain by mottled red and yellowish-brown gritty sandy clay. In many places the subsoil would analyze gravelly sandy clay. The subsoil material breaks into small gravel, coarse sand, and single grains of sand and silt, and this is the most compact layer in the profile. It rests on decayed granite at a depth ranging from 8 to 20 inches. This soil is strongly leached and is very acid in reaction.

In most places, especially on the ridges, the soil is shallow and somewhat droughty. It requires barnyard manure or fertilizer to maintain its fertility, and erosion in most areas is serious unless the land is very carefully managed. Some areas of this soil near Utuado are used for the production of sugarcane, and the yields average between 25 and 30 tons an acre. The areas near Ciales are used mainly for pasture and subsistence crops, and the areas near Morovis mostly for subsistence crops and tobacco and to less extent for pasture.

Ciales clay loam, smooth phase.—Areas of Ciales clay loam occupying colluvial slopes and having rolling relief are classified as Ciales clay loam, smooth phase. This soil is very much less extensive than the typical soil, but it is more desirable and a higher proportion of it is planted to cultivated crops. Fertilizers are required for good yields and, even with the use of such amendments, the crops are often of a light-green color, showing a deficiency of nitrogen in the soil.

This soil grades so gradually into the typical soil that it is nearly impossible to separate the two, and, in many places, some areas of the smoother soil are included with the typical soil.

Ciales loam.—For the most part Ciales loam occurs in the vicinity of Patillas. This soil differs from Ciales clay loam in that it has a looser, more friable, and sandier surface soil. In other respects the two soils are the same, and the fertility of the two is about equal. The loam occurs in areas having less rainfall than areas of the clay loam, and therefore leaching has not been so great. Both soils, however, need fertilizer or manure in order to produce profitable yields.

Much of the land near Patillas is planted to sugarcane, but yields are low, especially during dry years. Yields of 15 or 20 tons of sugarcane are common during an average year when an application ranging from 600 to 700 pounds of fertilizer is used. Other areas of this soil are used for minor crops, pasture, and coffee.

Ciales loam, smooth phase.—The smooth phase of Ciales loam occurs on colluvial slopes and low rolling hills. It is associated with the typical soil and is considered more desirable for all cultivated crops. This soil has thicker layers and a slightly higher organic content than

the typical soil. Sugarcane growing on this soil seldom yields more than 30 tons an acre.

Ciales loam, colluvial phase.—Ciales loam, colluvial phase, occurs for the most part southeast of Patillas in the eastern part of the island. It is associated with Ciales loam and is used for the same crops, although it is more productive, and higher yields of all crops are obtained.

Ciales loam, colluvial phase, consists of material that is in part residual from granite rock and in part accumulated from surface wash and creep from upper slopes. This soil, owing to its depth and the continual wash from the upper slopes, is more fertile and more productive than Ciales loam. It is considered more desirable and sells for a higher price than typical areas of Ciales loam or Ciales loam, smooth phase.

This soil is used for the cultivation of tobacco, subsistence crops, and coffee, all of which yield fairly well when fertilizer or manure is added to the land.

Teja loam.—Teja loam is one of the poorest soils derived from granite in Puerto Rico, because both the soil and the soil-forming material are coarse and low in plant nutrients. During dry periods this soil is droughty, and during wet periods water percolates through the loose friable surface soil so fast that it carries plant nutrients with it. The subsoil is compact enough to prevent water from penetrating it as rapidly as it does the surface soil; therefore surplus water accumulates on the subsoil and eventually starts flowing laterally to some outlet or drainageway. Thus the lower part of the subsoil is deprived of needed moisture, and some plant nutrients are carried away by the drainage waters.

In a cultivated field this soil is characterized by a light-gray gritty granular light loam or sandy loam surface soil, from 4 to 8 inches thick, which is underlain by gray gritty compact sandy clay loam that is reddish brown in places. This layer is about a foot thick and rests on firm gritty coarse-grained more or less weathered quartz-diorite granite.

Areas of this soil have favorable relief for cultivation, but, owing to the characteristics of the soil material, caution must be used in farming the land, otherwise sheet erosion would be destructive. The largest acreage of this soil is used to supply the needs of several hundred people for subsistence crops, such as sweetpotatoes, beans, corn, and yautias. A few acres are used for the production of tobacco and sugarcane, but yields of all crops are low, even with the use of fertilizer. As the inherent natural productivity of the soil is low, much nitrogen must be added. Manure has more lasting effect than commercial fertilizers on this and related soils. Teja loam is valued at less than $20 an acre.

Teja loam, steep phase.—Areas of Teja loam that have hilly or steep relief are mapped as a steep phase. This soil is even poorer than the typical soil because of its steep relief, which is more favorable for the activities of sheet erosion in causing damage to the steep hills that are cultivated to minor crops.

This soil has a 2- to 4-inch gray gritty loam surface soil that rests on a thin compact sandy clay subsoil or directly on coarse gritty granitic material. On many of the ridges, the parent rock is exposed, and vegetation is greatly reduced. In grass-covered areas, the surface

soil is not only two or three times as thick is in cultivated areas but it is very much darker.

Most areas of this soil are used for pasture, which is inferior to that on the Daguao or Múcara soils.

Teja loam, eroded phase.—The eroded phase of Teja loam has a much heavier more plastic subsoil than the typical soil, because the original loamy surface soil has been removed by sheet erosion and the subsoil is exposed. The eroded soil is associated with the typical soil near the mouth of Río Candelero. The land is used principally for pasture and to less extent for minor crops. The relief ranges from rolling to hilly.

Utuado loam.—Utuado loam covers many square miles of rolling and very steep hills in the vicinity of Utuado. This soil is derived from rather fine-grained granite and occurs where the rainfall is sufficient to leach readily the bases and plant nutrients from the soil. Few granite boulders occur on the hilltops or slopes. This feature is in contrast to most of the granite areas.

This soil has a gray or light grayish-brown, friable, semigranular acid loam or sandy loam surface about 7 inches thick, underlain by slightly heavier slightly more compact similar colored loam or sandy clay loam, about 12 inches thick. This layer, in turn, gradually changes to the partly disintegrated granite rock.

This soil is excessively drained both externally and internally. Drainageways are numerous, and the area occupied by this soil is the most eroded section of the island. The slopes are steeper and the ridges more knife-edged than elsewhere. This soil is rather productive, however, and many thousands of people obtain a living from it by growing small patches of tobacco, beans, corn, and sweetpotatoes on their best land and pasturing a goat or two and possibly a cow on the poorest or steepest parts of their small tract. Some concave slopes are used for the production of coffee, which grows very well when the land is fertilized. The soil is low in plant nutrients, and heavy applications of manure or complete fertilizers should be used in order to maintain its fertility.

Virgin areas have a higher organic-matter content and a much darker and deeper surface soil than cultivated areas. All layers of this soil are acid, and the land would be benefited by the application of about 1½ tons of lime every 3 or 4 years.

Sheet erosion is partly controlled on this soil by crudely constructed brush and stick terraces built with the contours, also by the planting of hedgelike strips of guinea grass on the steep hillsides. The hedge is more effective after it becomes established, and it can be cut during certain seasons and used for cattle feed without losing its effectiveness.

Acre yields on this soil are as follows: Sweetpotatoes about 2,000 pounds, yautias about 1,500 pounds, beans about 400 pounds, corn from 300 to 500 pounds, and yuca from 400 to 600 pounds. Ordinarily yields are increased when the land is protected by properly constructed brush terraces.

Utuado loam, smooth phase.—Utuado loam, smooth phase, has physical and chemical characteristics similar to those of the typical soil, but the land is not so steep; therefore, it is considered a better agricultural soil and is more productive. Sheet erosion is less on this soil than on the typical soil, and a higher proportion of the land is in

cultivated crops. As it occurs in such intimate association with Utuado loam, the boundaries between the two soils are drawn arbitrarily in many places.

Vieques loam.—Vieques loam occurs only on the Isla de Vieques. It is derived from material similar to that underlying Pandura loam, but as it occurs in sections having much less annual rainfall, it is less acid and darker than the Pandura soil.

In a virgin area Vieques loam has a very dark grayish-brown or nearly black single-grained friable loam or sandy clay loam surface soil about 8 inches thick that contains an abundance of grass roots, is neutral or alkaline, and is rather high in organic matter. Many granite boulders are scattered over its surface. The subsoil, to a depth of 18 inches, is reddish-brown gritty sandy clay loam that is slightly plastic when wet. Underlying this layer, between depths of 18 and 30 inches, is partly disintegrated coarse-grained granitic material, which is slightly alkaline in reaction. This soil is well drained and easily cultivated, but at present, owing to the lack of rainfall, more than 60 percent of its area is in pasture, mostly of guinea grass, which is more nutritious than the grass grown on the Pandura soils. Sugarcane, tobacco, and cotton grow fairly well. The yield of sugarcane is low, except in exceedingly wet years.

Vieques loam, undulating phase.—Areas of Vieques loam that occupy positions having undulating relief are mapped as an undulating phase of that soil. This undulating soil is more desirable than the typical soil because of its more favorable relief and because more moisture is retained than in the typical soil.

Nearly all of this soil has been or is now planted to sugarcane. On account of the climate, the average yield is low compared to yields from similar soils in the mainland of Puerto Rico. Fertilizer, when applied to the nonirrigated soils in the dry sections, reduces rather than increases crop yields, because when the fertilizer is applied the plant roots do not need to penetrate to so great a depth in search of plant nutrients and, during the dry season, instead of being deep rooted and having a large area from which to obtain moisture, they are shallow rooted and die from lack of moisture. Planting the sugarcane in the bottoms of rather deep furrows is the common practice in such dry areas. A yield of 15 tons of sugarcane to the acre is considered a good yield on this soil for an average year. Guinea grass grows equally as well on this soil as on Vieques loam.

Vieques loam, colluvial phase.—The colluvial phase of Vieques loam is the most productive and most desirable soil of the Vieques series. It occupies an intermediate position between Vieques loam, undulating phase, and soils of the terraces and bottoms. Most of it is cultivated to sugarcane, which yields from 15 to 20 tons an acre. The remainder is in guinea grass which is productive and nutritious.

This soil is similar to Vieques loam, except that the surface soil is darker, more fertile, and slightly more acid. The depth to granite rock also is much greater, and, therefore, the water-holding capacity is greater than in the more shallow areas of the typical soil.

Vieques loam, colluvial phase, occurs only on the islands of Vieques and Culebra.

SHALLOW SOILS OF THE UPLANDS

The shallow soils of the uplands include 37 soil types and phases of 19 soil series, in addition to rough stony land. Their total acreage is greater than that of any other group of soils. The soils in this group occur throughout the entire upland part of Puerto Rico, and, as the group name implies, all are very shallow. Many are stony. The parent rock lies at a depth of less than 18 inches from the surface. These soils have a wider variation in relief and rainfall than the soils of any other group. The climate ranges from arid to humid, and the relief ranges from level to precipitous. Owing to the rockiness, shallowness, unfavorable relief, dry climate, or a combination of one or more of these features, grass covers from 60 to 65 percent of the area, trees occupy about 15 percent, brush about 15 percent, and subsistence crops and coffee only 5 to 10 percent.

In less densely populated countries most of the soils in this group probably would be classified as rough stony land and would be dis-

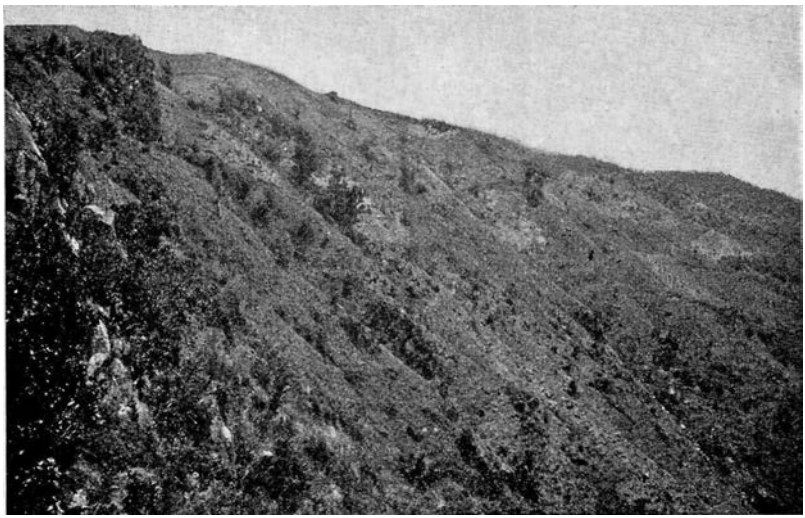

FIGURE 111.—Subsistence crops on Múcara silty clay loam, steep phase. In some places this kind of land would be classified as rough stony land and be described as nearly nonagricultural but the pressure of population is so great in Puerto Rico that many thousands of people farm these 60- and 80-percent slopes. Note the houses on the ∧-shaped ridge top.

Frutos menores en Múcara limo-arcilloso lómico, fase escarpada. En algunos sitios esta tierra sería clasificada como tierra quebrada pedregosa y descrita como casi inservible para la agricultura, pero la presión de la población es tán grande que millares de personas trabajan estas laderas de 60 y 80 por ciento de declive. Nótese las casas en la cresta del monte en forma de ∧.

cussed as having little or no agricultural importance. The pressure of population is so great, however, that many thousands of people are forced to live on these rough, rocky, steep (fig. 111) hills which have shallow soils, and they obtain a large part of their living by raising a few chickens, goats, pigs, or cattle. In favorable years they produce some subsistence crops from small patches of their best land. Owing to the large number of inhabitants and the high value of this land, more

careful separation was made of these shallow soils than ordinarily would be made.

This group includes soil types of the Colinas, Soller, Aguilita, Tanamá, and Ensenada series, all derived from Tertiary limestone; of the San Germán and Lajas series, derived from Cretaceous limestone; of the Jácana, Descalabrado, Guayama, Daguao, Múcara, Picacho, and Naranjito series, derived mainly from Cretaceous shales and tuffs, and in part from igneous rocks, mostly andesitic; of the Mariana and Yunes series, derived from shale and rhyolite; of the Juana Díaz series, derived from sandstone; of the Vieques series, derived from granite; of the Rosario series, derived from serpentine; and rough stony land, derived mostly from hard igneous rocks.

Owing to the soil characteristics and climatic environment, the two outstanding uses for these soils are forestry in the humid sections and the production of grass in the arid, semiarid, and subhumid sections. The raising of cattle for milk, beef, and draft purposes is by far the most important livestock enterprise, and the value of the cattle is much greater than that of the timber produced.

Most of the soils used extensively for pasture produce an excellent quality of grass, because these soils are young, owing to their steep relief or shallowness, and they have not been leached of their bases and plant nutrients to nearly so great an extent as the older, deep soils occurring in the areas of high rainfall. In addition, the soil material within easy reach of plant roots is constantly being rejuvenated by the weathering of the shallow-lying easily disintegrated parent rock. This favorable soil characteristic, combined with a nearly continuous growing period, makes the pastures superior to those of much of the grassland in the United States. On these soils of the uplands, the best pasture is produced on the long gentle slopes where the rainfall is adequate for continuous plant growth but not sufficient to cause serious leaching of plant nutrients from the soil.

Very few, if any, farmers fertilize their pastures. Weeds or brush are obnoxious in certain areas and must be cut once every 2 or 3 years. Some abandoned pastures have been nearly covered with brush and weeds within 5 years' time. The most serious pests in the pastures are guava trees, which spread rapidly in the humid and subhumid areas; zarzarilla (fig. 89), a bush that infests the pastures of the arid sections; and guayacán blanco, or guayacanillo, a noxious weed growing on shallow soils derived from limestone. This weed, especially during pollination, causes irritation of the eyes of the livestock. If the zarzarilla is eaten by the animals it apparently causes them to lose some of their hair.

The most common permanent grasses in the humid areas are grama and cerrillo, with yaragua, or molasses grass, elephant grass, and Guatemala grass the principal planted grasses. In the semiarid areas, guinea grass is the principal cultivated grass and Mexican bluegrass, or horquetilla morada, is the most important native grass. In the arid section, Bermuda grass is the predominant grass, with some guinea grass.

All the soils in this group are adequately or excessively drained, with the exception of a few local seepy areas, and most of the areas are dissected by hundreds of drainageways. Most of the streams flowing

144038—41——15

through the arid and semiarid districts, however, are dry most of the year. Water for both beast and man is more difficult to obtain than in almost any other part of the island. Dug wells, operated by windmills, along the shore and in the valleys supply most of the water for the livestock grazing on the hills. The water near the shore is so brackish that additional salt for the livestock is not necessary. The average depth of the wells is about 35 feet.

In Vieques and Culebra the water supply, rather than the quantity of grass, determines the carrying capacity of the land.

The areas of these soils used for forestry are well adapted for the growing of trees. The climate in certain areas favors some species and eliminates others, but the range in climatic conditions on these different soils is sufficient for the growth of any tree grown in Puerto Rico. Forestry is not so important as it has been or as it might be.

Virgin forests are of limited extent, and the only fairly large areas are within the Caribbean National Forest; other areas have been cut over repeatedly. Practically no systematic plantings have been made on private lands. The trees grow and reproduce by natural selection and natural elimination. When a tree is marketable it is cut and sold. Within the last few years the Insular Forest Service and Federal Forest Service have greatly enlarged their holdings and improved their land by building roads and planting many additional species of trees. Many valuable trees, such as mahogany, cedro, tabonuco, guayacán, or lignumvitae, sabino, granadillo, and maricao, grow on some of the soils of this group.

A common practice among the jibaro farmers is to cut the timber and make it into charcoal. This enterprise gives a cash income, but it cannot be recommended, as it seriously reduces the natural resources of the island.

To facilitate the discussion of these soils, those derived from the same or similar materials will be described briefly, and each soil type will be discussed in detail.

Colinas clay loam, steep phase; Colinas stony clay loam; Colinas stony clay loam, steep phase; Soller clay loam; Soller clay loam, shallow phase; Soller clay loam, hilly phase; Soller clay loam, steep phase; Aguilita clay; Aguilita stony clay; and Aguilita stony clay, shallow phase, are all dark-colored plastic granular soils derived from soft or medium-hard Tertiary limestone. Owing to low rainfall, thin soils, or both, these soils are predominantly used for pasture. They all have some rocks or rock fragments on the surface, the quantity of which varies greatly from place to place. The Soller soils occupy areas receiving from 80 to 100 inches of annual rainfall; the Colinas soils receive slightly less, or from 55 to 80 inches; and the Aguilita soils receive the least, from 35 to 55 inches. The amount of rainfall is reflected in the color of the soils, vegetation, and crop use. The Soller soils are nearly black, the Colinas soils are dark grayish brown, and the Aguilita soils range from brown to dark grayish brown. The vegetation on the Soller soils is mostly mesophytic, and on the Aguilita it is mostly xerophytic. The Colinas soils have some of each. Owing to the high rainfall, the Soller soils have more areas in cultivated crops than have the soils of either of the other series. They are also better for grass.

All these soils are susceptible to erosion under improper management because of their plastic sticky consistence, high lime content, and soft granular structure, which cause the soil to wash away under the dashing tropical showers. The Soller soils have been eroded to a greater extent than the other two soils on equal slopes. The predominant subsistence crops grown are pigeonpeas, corn, beans, and sweetpotatoes, and cultivation of all these crops, except sweetpotatoes, induces erosion.

Owing to the steepness of the relief and porous nature of the lower substratum, these soils are excessively drained. Few drainageways cross areas of these soils, however, and the water penetrates to underground channels. Water for both man and beast is difficult to obtain in many places, especially during dry periods. Within the rough limestone hills receiving more than 80 inches of rainfall, springs are fairly numerous, but in the drier areas, water must be caught from the galvanized roofs of houses or carried a long distance. No wells are drilled in these soils derived from limestone. A few of the hundreds of sinkholes throughout areas of these soils hold water for several months.

Tanamá stony clay, Ensenada clay, and Ensenada clay, shallow phase, are red or reddish-brown permeable slightly plastic softly granular neutral to alkaline soils derived from hard Tertiary limestone. The Ensenada soils occur in areas having less than 35 inches of rainfall, and therefore the predominant type of vegetation is desert shrubs. The Tanamá soils receive from 70 to 90 inches of annual rainfall. They produce a mesophytic vegetation consisting of moca, moral, roble, guaba, capa prieta, ausubo, maría, and guaraguao trees, besides many kinds of small plants.

Sisal has been planted in a few places, but the projects have been abandoned. The centuryplant, or maguey, grows very well on this soil, indicating that the related sisal could be grown on large tracts of this and similar soils in the arid and semiarid sections.

San Germán clay, Lajas clay, and Lajas clay, rolling phase, are derived from Cretaceous limestone. They occur on rolling or precipitous relief, north of the Aguilita soils. These soils are shallow and stony and are used for pasture and forestry. The San Germán soils occur in drier areas than the Lajas soils and for that reason are generally less valuable. Many areas of the Lajas soils, however, are simply limestone outcrops and have no agricultural value.

All the soils of the Jácana, Descalabrado, Guayama, and Picacho series, as well as some soils of the Daguao, Múcara, and Naranjito series that have been classified with this group, are derived from Upper Cretaceous shales, stratified ash and tuff, massive andesitic tuff, and conglomerates. These different rocks are intimately associated, and although each has some influence on the soil directly above it, the mappable soil characteristics are influenced to a greater extent by soil climate than by geology. These soils have many characteristics in common. They are brown or tinged with brown, are shallow, and occur for the most part on high, narrow ∧-shaped ridges and upper parts of slopes. Natural drainage is adequate or excessive. Owing to the rockiness, shallowness, unfavorable relief, dry climate, or a combination of one or more of these factors, grass covers from 75 to 85 percent of the land, and brush, trees, coffee, tobacco, and minor crops occupy the remainder.

The elevation of these soils ranges from sea level along the arid south coast to the high rainfall areas of the interior. Listed in the order of increasing quantities of rainfall received they are: Jácana, Descalabrado, Guayama, Daguao, Múcara, Picacho, and Naranjito soils. Some of them occur in areas having high precipitation, but, owing to their very steep relief, they receive less soil moisture than soils with much less steep relief in areas having less annual rainfall.

A close correlation exists between the soil moisture received and the color and pH value of the soils. Generally speaking, the greater the rainfall, the lower the pH value. Thus, the Jácana soils have the highest pH value, about 7.5, and the Naranjito soils the lowest, less than pH 5.0. The color of the Naranjito soil in the highest rainfall area is slightly red. With decreasing rainfall, the soils become darker. The Daguao soils receive about 65 inches of mean annual rainfall and are nearly black, but as the rainfall decreases the soils become brown, passing by degrees from very dark grayish brown to chestnut brown. The Jácana soils in the driest areas are light brown.

The Jácana, Descalabrado, and Guayama soils occur in the dry section, and nearly all of their area is used for pasture. This area resembles the cattle country of the western Great Plains of the United States, as many large cattle ranches are located on these soils. The common practice is to plant guinea grass after clearing the land of brush and cacti. The grass is of excellent quality, and in general the cattle pastured on these alkaline soils are in good health, sleek, and have firm hard flesh during the rainy season. The grass stops growing soon after the dry season begins, but it cures well and has much strength. It resumes growth and grows very rapidly when the rainy season starts. Based on the natural productivity of the soils, the quantity of grass produced decreases with an increase in slope of the land, with shallowness of the soils, and with a drier climate. Therefore, within each soil type, the carrying capacity has a wide range, as each soil occurs over a rather wide range in climate. In average areas, Jácana clay is the best soil, followed by Descalabrado silty clay; Descalabrado silty clay, rolling phase; Descalabrado silty clay, eroded phase; Guayama clay, colluvial phase; Guayama clay, Descalabrado silty clay, shallow phase; and the very stony areas of Guayama clay.

Most of the streams within this area are dry during the winter, and windmills located in the valleys supply water for the cattle, as well as for the ranchers. With the exception of areas of Descalabrado silty clay, eroded phase, and Descalabrado silty clay, shallow phase, this is probably the most sparsely populated part of Puerto Rico, excluding the national forests.

The Daguao, Múcara, Picacho, and Naranjito soils receive sufficient rainfall for the production of trees and minor crops, and the proportion of their area in grass is not so high as that of the Jácana, Descalabrado, and Guayama soils. Based on their natural productivity, the Daguao soils are the strongest, followed by the Múcara, Naranjito, and Picacho soils. The Múcara and Naranjito soils included in this group are: Múcara silty clay loam, steep phase, Múcara silty clay loam, shallow phase, Múcara silt loam, steep phase, and Naranjito silty clay loam, steep phase.

The Yunes and Mariana soils are not derived from similar material, but they have many characteristics in common. The Yunes soils are derived from acid bedded shale and the Mariana soils from rhyolite, fused glassy rock, and possibly some sandstone. The soils of both series are nearly white, strongly acid, plastic, single grained, and very shallow. The Yunes soils are used mostly for forestry and pasture. The Mariana soils are used for pasture and forestry in the eastern part and for pineapples and pasture in the area near Lajas.

The Juana Díaz soils are the only soils derived from sandstone. They occupy less than 1,000 acres and occur near Juana Díaz. In many characteristics they resemble the Plata soils.

The Rosario and Nipe soils are the only two soils derived from serpentine rock, and in most places they are closely associated. The Nipe soils are deep and occupy the mesas, or tablelands, and gentle slopes; the Rosario soils are shallow and occupy the steep slopes. The deepest areas of them are along the concave slopes where soil washes from adjacent slopes and, as the concave slopes have more soil moisture, the soil-developing processes are more active than in adjacent areas; therefore, the serpentine rock is weathered to a greater depth.

Colinas clay loam, steep phase.—The steep phase of Colinas clay loam differs from the typical soil, previously described, in that it occurs on steeper relief and is used almost entirely for pasture. A few small patches are used for pigeonpeas, beans, and corn near the peons' homes.

The surface soil is grayish-brown or dark grayish-brown granular nearly neutral clay loam, from 2 to 4 inches thick, which becomes black and very plastic when wet. This layer rests on light yellowish-brown clay loam that is slightly heavier, more alkaline, and more plastic than the surface soil. At a depth ranging from 8 to 12 inches, depending on the relief, the gray medium-friable calcareous parent limestone is reached. In a few eroded spots the limestone is exposed, thus decreasing the productivity and the value of the land.

This soil occurs on the steep slopes and ridges of the soft limestone section, from Carolina to Aguada. The largest bodies are between Quebradillas and Manatí.

This soil is valued at prices ranging from $20 to $40 an acre, depending on its location. It is considered one of the best soils of the uplands for the production of good-quality grass, and in most places 2 acres will maintain a cow during the year, without causing overgrazing or serious erosion. The grass most commonly produced is a broad-leaved spreading grama, which is both highly nutritious when grown on these alkaline soils and is also a good plant to prevent soil erosion, as it covers the ground, thereby preventing the water from floating the soil granules down the slope.

This soil varies considerably from place to place, especially in the thickness of the surface soil. Near the bases of the slopes, it may be from 8 to 12 inches thick, but near the hilltops the subsoil may be only 1 or 2 inches below the grass mat.

The mean annual rainfall on this soil is high, but, as the soil is derived from soft limestone and is young, it has not been leached of its plant nutrients to nearly so great an extent as old soils derived from shale or granite and receiving the same amount of rainfall. In most places the organic matter is high, and, owing to the porosity of the

limestone, grass roots penetrate deeply for water and available plant nutrients.

Colinas stony clay loam.—Colinas stony clay loam (fig. 112) is one of the poorest soils derived from limestone. In most places it is less than 3 inches thick and consists of a mixture of numerous small limestone rock fragments and granular calcareous grayish-brown clay loam that rests on fairly hard limestone. Fossils resembling giant oyster-shells are common on the surface. In many places the flat hilltops are bare of both soil and vegetation. This soil occupies low flat hills extending from Río Manatí to Aguadilla.

Agriculturally, this soil is submarginal and is used only for pasture, with the exception of a few acres that are planted to onions and sweet-potatoes, which grow in nearly pure soft limestone rock. The grass is of good quality, but the quantity produced to the acre is low, especially in the driest areas or where small trees, weeds, and brush reduce

FIGURE 112.—Typical view of Colinas stony clay loam. Note the numerous areas of exposed rock. This area is almost continuously fanned by the northeast trade winds, and their effect on the trees and bushes readily can be seen.

Vista de un Colinas pedrego-arcilloso lómico. Véase las rocas expuestas. Esta zona es soplada contínuamente por los vientos del noreste; puede verse su efecto en los árboles y malezas.

the carrying capacity of the land. It is reported that one variety of weed, guayacán blanco, growing on this soil is injurious to the eyes of livestock.

This land is valued at less than $5 an acre, and it is difficult to find a buyer for it even at that price.

The general appearance of the farms on this soil shows little evidence of prosperity. Most of the houses are small—one-room thatched buildings with a lean-to for cooking. The average number of livestock owned by the jibaro farmer includes a few chickens and one or two goats or pigs. The larger landowners have, in addition, a few oxen and one or two horses.

Colinas stony clay loam, steep phase.—The steep phase of Colinas stony clay loam differs from the typical soil in that it has steeper slopes and is slightly more stony. In most areas it would be classified as rough

stony land, as limestone rock is exposed over most of its surface. It occurs along drainageways and along the escarpment near the north coast from Río Manatí to Punta Borinquen. Neither grass nor crops grow on this soil, and the production of trees, for use in making charcoal, is the dominant enterprise. The land is considered non-agricultural but not worthless, as both trees and brush grow surprisingly fast, considering the lack of soil. Large trees will grow in the crevices or on the medium-hard limestone rock, which does not have any visible evidence of organic matter or true soil material. The tree roots do not seem to have any difficulty in penetrating the limestone for moisture and plant nutrients.

Soller clay loam.—Most of Soller clay loam is not so productive as Soller clay, previously described, because it is less deep, owing to erosion, which has been accelerated (1) because of the rolling relief, and (2) because most of this soil is owned by small landowners who continuously plant subsistence crops requiring clean cultivation.

This soil in a virgin field now in grass has a nearly black granular heavy clay loam surface soil about 6 inches thick, underlain by dark-gray friable clay loam mixed with much soft limestone. Below this layer, at a depth ranging from 10 to 14 inches, is slightly hard limestone. On account of the high rainfall, if this land has been in pasture for a number of years, an acre or less will supply food for one animal throughout the year. Under average practices of cultivation, when this soil is planted to subsistence crops much of the rich black soil is lost by erosion, and the fields become less and less productive as erosion continues. Soon only bare limestone is left where there once was rich black productive soil. Rock outcrops are numerous on this soil. There is a house on nearly every 10 acres, and small patches of beans, pigeonpeas, sweetpotatoes, yautias, and corn surround practically every home. Crop yields depend on the length of time the fields have been under cultivation; they are about one-half as large as they were 20 years ago. Practically no fertilizer is used, and each year acre yields become less and less, except in the few small pockets or waterless ravines, which catch the wash from the hillsides. The latter areas, if large enough to be shown on the map, are classified as Camagüey clay.

Most of Soller clay loam occurs between San Sebastián and Central Soller.

Soller clay loam, shallow phase.—The shallow phase of Soller clay loam is associated mainly with the typical soil in the vicinity of Central Soller. It has the same general characteristics as Soller clay loam, but the surface soil and subsoil (if present) are much thinner. This soil, although nearly level and well drained, is less valuable than the typical soil, because it is more shallow and, therefore, is less productive for all crops. It occurs in rather large areas. Owing to the relief, there would be little or no erosion and the depth of the profile should be greater rather than less than in typical Soller clay loam, were it not for the fact that the parent limestone of this shallow soil apparently is of slightly different composition from that underlying the typical soil and weathers much more slowly.

Fewer houses are built on this soil than on the typical soil, but the houses are still very numerous, considering the poorness of the land. Most of the land is used for pastures and subsistence crops. Yields of the cultivated crops are very low, and it requires about 3 acres of

FIGURE 113.—See legend on page 233.

pasture land to feed an ox for a year. There are a few springs on this soil, even on flat hilltops. This adds greatly to the value of the land, as the water supply is limited in this section.

Soller clay loam, hilly phase.—In general, the hilly phase of Soller clay loam is rougher and steeper than Soller clay loam, shallow phase, and fewer people make a living on it. It has a 6-inch granular friable black calcareous clay loam surface soil, which is plastic when wet, overlying medium-hard white limestone. Most areas of this soil are south of the areas of the shallow phase of Soller clay loam. The soil produces fair to good grama grass and is best adapted for pasture. Generally 1¼ acres of pasture land will maintain an animal for a year. On the concave slopes, where there is a rather deep accumulation of soil, corn and tobacco grow well. Sweetpotatoes and beans are grown on the shallower areas and near the small huts. All cultivation is done by hand. Rock piles are conspicuous in the cultivated fields.

Soller clay loam, steep phase.—Areas mapped as Soller clay loam, steep phase, resemble tall cone-shaped haystacks crowded together at the base (fig. 113). The hill rises to a fairly uniform height—approximately 200 feet. Fifty hills were counted on a typical 640-acre area. Not all the hills are cone-shaped, but the tendency is for them to become so. At present some hills are long and narrow, but the factors responsible for soil development gradually are separating the long narrow hills into two or more rounded ones. An average hillside has from 3 to 6 inches of black granular calcareous clay loam or clay overlying a layer, a few inches thick, of gray friable clay loam and disintegrated limestone rock, which becomes more consolidated with depth. The surface soil is plastic when wet and rather dense and cloddy when dry. As the tops of the hills are cone-shaped, the depth of soil is less than on the slopes or at the bases of the hills. These hills are used almost entirely for pasture. They produce fair to good grass and are free from weeds, but from 1½ to 2 acres of pasture land are necessary to maintain an animal a year.

At the bases of some of the cone-shaped hills are small irregular-shaped flat valleys, most of them too small to indicate on the map. Most of the soil in the valleys is Camagüey clay and is very productive.

Areas of Soller clay loam, steep phase, occur between Corozal and San Sebastián, along the southern edge of the limestone area. This includes most of the cuesta, and there are few houses throughout the area of this soil.

Aguilita clay.—Aguilita clay is one of the extensive soils derived from soft limestone in the arid and semiarid southwestern part of the island. It occupies elevations ranging from sea level to more than 500 feet above, and the profile varies somewhat in depth, color, and

---

FIGURE 113.—Vertical aerial view of area near Ciales. The steep cone-shaped hills in the lower right-hand corner consist of Soller clay loam, steep phase. The level area near the stream consists of Estación soils, and most of the soils in the top of the picture belong to the Colinas series. (Photograph taken by U. S. Navy.)

Vista vertical aére acerca de Ciales. Las colinas escarpadas cónicas a la derecha del frente son Soller arcilloso lómico, fase escarpada. La parte llana cerca del río consiste de suelos Estación, y la mayor parte de los suelos en la parte alta de la fotografía pertenecen a la serie Colinas. (Fotografía tomada por la Marina de EE. UU.)

FIGURE 114.—See legend on page 235.

organic-matter content from the arid to the semiarid areas. The native vegetation and land use also change with increasing rainfall. In all areas, however, rainfall is the limiting factor in crop production.

In an average location, this soil has a friable mellow granular calcareous dark grayish-brown clay surface soil 6 inches thick, which gradually changes to a friable mellow granular light-gray clay loam or clay subsoil about 8 inches thick. This layer rests on gray medium-soft porous limestone. In the drier areas the surface soil is shallower, contains less organic matter, is lighter in color, and in places has a distinct red tinge. In the areas of highest rainfall, the surface soil is nearly black and has a high organic-matter content, and the subsoil is yellowish brown. The depth of the profile varies with the degree of slope. Near the base of a long gentle slope, the thickness may be two or three times greater than on the steeper slopes. The relief of this soil ranges from undulating to rolling. In all places the soil is very sticky and plastic when wet, and when unprotected by vegetation it erodes rather readily during intense rains. The native vegetation in the arid section consists of cacti, thorny bushes, such as escambrón and Santa María, and bucare trees; in the semiarid sections the principal trees are almácigo, jagüey, and algarrobo; and the pasture grasses are guinea grass, Bermuda grass, and horquetilla, named in the order of their value.

This soil is correctly used as range land, and it requires from 3 to 7 acres to maintain an animal a year. During the wet season in all except the very dry areas 2 acres will furnish sufficient nutritious feed for an animal, but during the dry season the grass stops growing and a much larger acreage is required. The grass resumes growth within a few hours after the first heavy rain following a long dry spell.

In a few areas, closely associated with Yauco clay, sugarcane fields have been planted on this soil, but the average acre yields are only between 10 and 15 tons. The jibaros may plant a few acres to corn, cotton, tobacco, beans, and pigeonpeas, but the crops are often a failure except in favorable years.

Aguilita stony clay.—Aguilita stony clay differs from Aguilita clay in that it has steeper relief, more rock fragments on the surface, and a thinner surface soil. In many places these two soils are so interlaced that no attempt is made to differentiate them on the map. The stony soil has, as might be expected, low agricultural value and low carrying capacity. Only a very few acres are used for the production of subsistence crops (fig. 114).

The principal sources of income on areas of this soil are cattle and charcoal. The cattle graze on the planted guinea grass pasture lands.

FIGURE 114.—The brush-covered steep hills are nearly valueless Aguilita stony clay, and the level checker-board patterned irrigated sugarcane fields are San Antón soils valued at more than $700 an acre. Picture taken near Central San Francisco. The houses are located only along the main roads. The mean annual rainfall in this area is about 30 inches. (Photograph taken by U. S. Navy.)

Los montes cubiertos de maleza y de Aguilita pedrego-arcilloso valen poco y los campos de caña llanos y bajo riego son suelos San Antón valorados a más de $700.00 por acre. Fotografía tomada cerca de la Central San Francisco. Las casas están situadas solamente a lo largo de las carreteras principales. La lluvia en este sitio es alrededor de 30 pulgadas. (Fotografía tomada por. la Marina de los EE. UU.)

The charcoal is made from the wood of the slow-growing brush and trees. The raising of cattle is by far the most important enterprise, and there are many large cattle ranches. The close proximity to sugarcane fields makes the land especially valuable as pasture for oxen. The grass produced is highly nutritious, whether green or dry. The common practice is to clean the land of cacti and brush, then to plant guinea grass shoots in more or less well-defined checkrows about 2 feet apart. On this soil, the grass does not spread between bunches as it does in the valleys, where the supply of soil moisture is greater and the soils are deeper.

Aguilita stony clay, shallow phase.—The shallow phase of Aguilita stony clay is associated mainly with the typical soil, in areas west of Ponce. It not only is more shallow than the typical soil, but it is also more stony. In many places exposed rocks cover an area of several acres.

This shallow soil is characterized by a 1- to 5-inch grayish-brown, dark grayish-brown, or reddish-brown granular calcareous friable clay loam or clay surface soil, which rests on permeable limestone rock that allows rapid percolation of water and the penetration of grass and tree roots to a depth of several feet.

Practically all of this land is in brush and pasture, and it is considered of less value than Colinas stony clay loam, the soil it most closely resembles, because it occurs in areas of less rainfall and therefore brush and trees grow at a slower rate. Probably only about 50 percent of this shallow soil has been cleared and is in pasture; the rest is in trees and brush. Probably from 10 to 15 acres of pasture would be necessary to maintain an ox properly during the year.

Tanamá stony clay.—Tanamá stony clay is one of the most extensive soils. It occurs from Carolina to Aguadilla, a distance of more than 80 miles. It is derived from a limestone rock that consists predominantly of a series of massive reeflike beds alternating with the bedded chalky strata. In areas of this soil the pepinos, or cucumber-

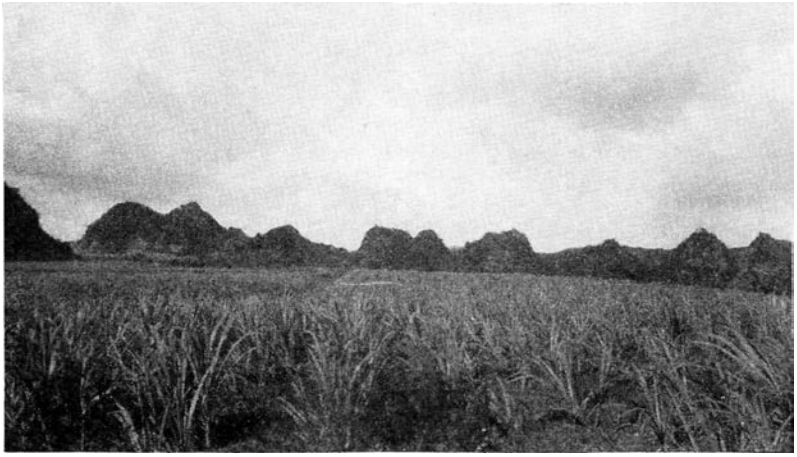

FIGURE 115.—Brush-covered saw-toothed hills of Tanamá stony clay east of Manatí. Sugarcane on Bayamón clay in the foreground.

Colinas serradas cubiertas en maleza de Tanamá pedrego-arcilloso al este de Manatí. Al frente caña en Bayamón arcilloso.

shaped hills, are developed to a very great extent. In places they occur as long narrow east-west chains, such as those near Toa Baja and Vega Alta, and in other places they occur as wide belts of saw-toothed hills crowded together at the bases (fig. 115).

The surface soil of Tanamá stony clay consists of red or reddish-brown clay ranging in thickness from almost nothing to nearly 3 feet. Areas having the thicker surface soil are not common, and the average thickness is about 3 inches. The clay is underlain by hard limestone that weathers very slowly, producing a soil that is red and acid. The surface soil everywhere contains an abundance of angular limestone fragments, but the red soil material is slightly acid in the drier part of the island near Isabela and very acid in the eastern part near Bayamón.

Although the deeper areas of this soil are of irregular occurrence, none of them occurs on the hilltops. They may or may not occur on the lower slopes and near the bottoms of the numerous sinks in this general locality. This soil is very rugged and rough throughout all areas. The hills rise to fairly regular heights; the sinkholes in the intervening depressions are several hundred feet deep and range from a few hundred feet to half a mile in diameter. In some places a sinkhole occurs within another sinkhole. In many places the sinkholes are bounded by steep or even precipitous slopes. This soil is drained almost entirely by underground streams. Ríos Guajataca, Tanamá, Camuy, and Grande de Arecibo flow through deep canyons across areas of this soil. The Tanamá and Camuy Rivers are subterranean through parts of their courses. Water drains to the numerous sinks and disappears.

The soil is so rocky and rough that it is almost entirely nonagricultural, and most of the area is covered by brush and trees. After the virgin trees were cut the land was planted to crops, but yields were so low that the fields were abandoned and grew up to brush and trees. The principal industry on areas of this soil is the gathering of fuel wood and the making of charcoal. The amount of income obtained from an acre is difficult to determine, because only a few trees are cut at a time. If the trees are fairly dense, nearly 1,000 35-pound sacks of charcoal can be made from an acre. Considerable work and much time are required to make the charcoal. The trees most commonly used for the making of charcoal are ausubo, ortegon, guamá, guaba, moca, capá prieta, roble, Santa María, and moral. Some coffee, bananas, and plantains are grown, and usually near each house a fraction of an acre is under cultivation to yautias, sweetpotatoes, beans, and ñames.

Considering the roughness of the country there are many houses in this area, which are accessible only by foot and horse trails. All the products are carried out either on the heads of peons or on the backs of pack animals. The animals used are small hardy horses and mules that are raised on the island.

Ensenada clay.—Ensenada clay may be considered the Red Desert soil of Puerto Rico. This soil occurs in rolling or undulating areas (fig. 16) along the driest part of Isla de Vieques and on the mainland between Río Guayanilla and Bahía Montalva. It is derived from rather hard Tertiary limestone and is characterized by a 2- to 4-inch friable permeable softly granular reddish-brown neutral or alkaline highly colloidal clay surface soil. This is underlain by friable per-

meable brownish-red clay that rests on gray medium-hard limestone at a depth ranging from 6 to 12 inches. The color and depth of this soil vary greatly. Within rather small areas the surface soil may range from brown to red, and the depth above rock ranges from a mere film to 15 inches.

Owing to low rainfall, shallowness of the soil, and no feasible system of irrigation, this land is not suited to cultivated crops. Cacti, almácigo, jagüey, maguey, escambrón, and Santa María are the predominant tree and brush vegetation. Guinea grass will grow if it receives extra good care. More than 15 acres of this land are required to obtain sufficient feed for an ox a year. Goats do very well on this land, as they can live on the brush.

This soil is drained entirely by subterranean streams, and water for livestock and human beings is obtained mainly from wells operated by windmills in the valley on Fraternidad soils. A limited amount is obtained from the rainfall caught from the metal roofs of houses. Probably fewer people live on this soil than on any other upland soil on the island. Parts of the brush-covered areas are nearly impassable and have the appearance of a cactus desert and thorny brush jungle.

Ensenada clay, shallow phase.—The shallow phase of Ensenada clay is little more than bare limestone rock. It is closely associated with the typical soil, and in many places it is impracticable to separate the two on the map. Although both have low value, the shallow soil is the poorer. It is waste land or is used for the production of brush and trees. Such land adds very little to the value of a farm having some good land.

This soil has rolling or hilly relief, and most of the soil material, which is red permeable clay, is encased in pockets and crevices in the medium-hard limestone rocks. Trees growing from these pockets and crevices are slightly superior to those growing from the bare limestone. Many areas are devoid of both soil and vegetation.

Areas of this soil shown on the map with outcrop symbols are worthless as they consist almost entirely of limestone rocks and rock outcrops.

San Germán clay.—San Germán clay resembles Aguilita stony clay, except that it is derived from a harder and older limestone. This soil is developed on east-west ridges, intimately associated with volcanic rocks, in the southwestern corner of the island.

It is characterized by a dark grayish-brown granular mellow calcareous clay surface soil about 6 inches thick, underlain by friable porous brownish-gray calcareous clay loam or clay, resting on hard limestone at a depth ranging from 8 to 10 inches.

The subsoil is not so hard that plant roots cannot penetrate, therefore grass and trees grow equally as well as on Aguilita stony clay. The carrying capacity of the pastures is about 4 acres to an animal. Cows used for dairying as well as for the production of calves comprise most of the livestock. The male animals are used for draft purposes. Some small herds of sheep roam over this land, and nearly every jibaro farmer has a goat or a pig. Houses are not very numerous, as the soil is too shallow and the climate too dry for successful production of subsistence crops. Near the bases of the hills, especially on the north side, where the soil is deeper and the rainfall greater, a few

sweetpotatoes, beans, and pigeonpeas are produced during favorable years.

Nearly all of the areas of San Germán clay have some stones and rock fragments on the surface, but the stony areas shown on the map with stone symbols have many rock outcrops, the land is steeper than in other areas, and it is less valuable for the production of grass. Most of the stony land is covered with brush and trees.

Lajas clay.—Lajas clay is similar in many respects to Tanamá stony clay, but the two soils were differentiated, as the Lajas soil is derived from Cretaceous limestone. It differs from San Germán clay in that it occurs in areas having much higher rainfall. Therefore, the vegetation is more dense, the soils more acid, and the color of most areas is reddish brown.

Lajas clay is distributed in many widely separated small areas from Boquerón to Cayey. It is characterized by a reddish-brown, red, or brownish-red fairly plastic neutral or acid clay surface soil ranging in thickness from 1 to 8 inches. This is underlain by hard comparatively pure limestone rock. The relief ranges from hilly to precipitous, and in many places large areas appear as steep sharp brush-covered pinnacles devoid of soil.

In some places this soil has a nearly black surface soil, but the black and red soils are so intimately associated that no attempt is made to differentiate two separate soil series, although the darker soil probably contains more organic matter and is more plastic when wet than the areas of red soil. Vegetation grows equally well on both.

This soil is used for the production of trees and grass. It is slightly more desirable than Tanamá stony clay, as it occurs in more readily accessible areas. Goats thrive better than other livestock on the vegetation produced from this soil. Subsistence crops and tobacco are often planted in small local spots, many of which are not over 20 feet square. Yields are fair, as the rainfall is sufficient to prevent serious drought. The cutting of brush and trees for the making of charcoal is one of the principal enterprises on this soil.

Lajas clay, rolling phase.—The better areas of Lajas clay that occur on gently sloping or undulating relief are mapped as Lajas clay, rolling phase. This soil is much better than the typical soil, as it has a friable red clay surface soil 6 or 8 inches thick, underlain by an 8- or 10-inch subsoil of red permeable friable clay, which, in turn, rests on limestone. The combined thickness of the surface soil and subsoil is sufficient for the production of sugarcane and most cultivated crops, and, as the relief also is favorable, several areas are planted to crops. As this soil occurs in small areas, however, it is used mostly as pasture land in connection with the closely associated Lajas clay. Cerrillo and grama are the two principal grasses produced. The carrying capacity of the pastures is about 2 acres for an ox.

Most of this soil is in the vicinity of Lajas.

Jácana clay.—Jácana clay occurs on low foothills. It bears the same relationship to Descalabrado silty clay that Juncos clay does to Múcara silty clay loam. In most areas, the Jácana soils are similar to but better than the Descalabrado soils. This soil occurs in areas having less than 30-percent slope, and the surface soil consists of an 8-inch layer of friable irregular-shaped granular alkaline slightly plastic brown clay or silty clay. This layer gradually changes to dense medium-plastic alkaline yellowish-brown or light-brown clay,

8 to 10 inches thick, which grades through disintegrated rotten volcanic rock and rests on hard bedrock at a depth ranging from 15 to 40 inches, depending on the slope. The steeper the slope, the nearer the rock to the surface. In a few small areas, the subsoil is reddish brown.

This soil lies only in sections having low rainfall and is therefore used almost exclusively for pasture. Guinea grass probably occupies over 50 percent of its acreage. Such land would produce fair sugarcane if it were in areas of high rainfall. The carrying capacity of the pastures is higher than of those on Descalabrado silty clay. In most places 1½ acres will maintain an ox most of the year. Some minor crops are produced during favorable years. Corn yields about 600 pounds to the acre and Japanese sugarcane produces from 10 to 15 tons without irrigation or much fertilizer.

Many areas of this soil lie northeast of Parguera.

Descalabrado silty clay.—Descalabrado silty clay and its phases are the most extensive soils south of the Cordillera Central. The surface soil of Descalabrado silty clay consists of a 6-inch layer of semigranular friable alkaline silty clay or clay, which ranges in color from light brown in the arid and semiarid areas to very dark grayish brown in the subhumid areas. The material in this layer grades rather abruptly into slightly decomposed fragmental tuff or tuffaceous shales containing free lime carbonates, especially along the long slender seams in the rocks. The rock becomes harder and more alkaline with depth. This rock is not too hard, however, for the roots of trees and grass to penetrate for a supply of moisture and plant nutrients.

This soil lies almost entirely on slopes ranging from 30 to 60 percent, and nearly all of it is used as pasture and brushland. Many large cattle ranches are located on it. After the brush and cacti are cleared and guinea grass is planted, this land makes excellent pasture during the rainy periods, and at that time supports about one head of livestock to the acre. During long dry periods, however, the grass dries, and starvation of many head of livestock pastured on this soil is not uncommon.

This soil occurs on the islands of Vieques and Culebra and is extensive near Cabo Cabezas de San Juan and between Sabana Grande and Patillas.

Some variations exist within certain areas of this soil type. In places the subsoil is red or reddish brown, and even the partly disintegrated rocks have a coating of red or reddish brown. In areas that join the Múcara soils, the surface layer is much darker than the average because of the high mean annual precipitation. On the concave slopes of the areas having a higher rainfall, the soil is more acid, deeper, and slightly more red than is typical, and such areas are sometimes used for the production of coffee and bananas.

Descalabrado silty clay, rolling phase.—Areas of Descalabrado silty clay that have a slope of less than 40 percent are differentiated as a rolling phase. The two soils are so intimately associated that many areas of the rolling land probably are included on the map with the typical soil. Both soils are used almost entirely for pasture and forestry, but the rolling soils have a higher carrying capacity, higher value, and higher proportion of grass to trees. Large areas of this soil occur in the low foothills south of Sabana Grande, near Coamo,

and near Juana Díaz. East of Guayama an area including some low nearly flat hills has been included in mapping. This area is not extensive and differs from the typical soil, in that the soil above rock in few places is more than 4 inches thick, and in some places bedrock is exposed. This included area is used only for pasture.

Descalabrado silty clay, shallow phase.—The shallow phase of Descalabrado silty clay differs from the typical soil, in that it is slightly more broken in relief and is shallow, due to more severe erosion. This soil occurs on steep knifelike-edged ridges and slopes where the annual rainfall ranges from 55 to 65 inches. It occupies large areas north of Yauco, near Rincón, and south of Sabana Grande. In many places the parent lime shale and calcareous tuffaceous rock outcrop on the tops of the ridges and on the sides of hills.

The soil, to an average depth of 8 inches in a cultivated field, is characterized by a grayish-brown or brownish-gray friable semigranular alkaline silty clay or silty clay loam surface soil that has considerable rock fragments intermingled with the soil particles. In most places the surface soil does not rest on solid rock but gradually changes to partly disintegrated rock, which, in turn, changes to solid bedrock below. The thickness of the surface soil ranges from 4 to 8 inches on the ridge tops and from 8 to 14 inches on the slopes. In areas that have never been cultivated, the surface soil is much thicker and darker than in cultivated fields.

This soil is shallow, steep, and not very productive for cultivated crops. In most countries it would be used only for pasture, but the ever-increasing pressure of population demands the cultivation of such soil. The rainfall on this soil is sufficient to tempt the peons to plant clean-cultivated crops, such as corn, beans, pigeonpeas, yuca, and some tobacco, but it is not sufficient for the rapid growth of plants. When the rainy season begins, the intense rains erode the soil before the vegetation has a chance to retard the flow of water. The extent of erosion is not so great as in the clean-cultivated mountainous areas of some of the tobacco districts, but the harm resulting from the erosion is more lasting. When this soil becomes so unproductive that it is abandoned, small gullies appear before the slow-growing pasture grasses can become established to the extent of combating the onslaught of the dashing rains. This land erodes severely for a year or two, but finally the grass thickens and erosion is arrested. After a long time the land builds up to some extent and is again cultivated, the gullies and catsteps are smoothed over, and the fields present a fairly good appearance.

This soil becomes eroded if it is overpastured, thereby reducing its yearly carrying capacity from 2 acres to 3 or 4 acres for an animal. The best measures now used for the prevention of erosion are crudely constructed brush terraces (fig. 116) and hedgelike strips of guinea grass planted with the contours. More than 50 percent of this soil is in cultivated crops, and the remainder has been in crops at one time or another.

Descalabrado silty clay, eroded phase.—Descalabrado silty clay, eroded phase, is closely associated with Descalabrado silty clay, shallow phase. The difference between the two soils is in their relief. The largest areas of the eroded soil occur in the vicinity of Rincón on slopes of less than 60 percent. This soil is less extensive than Descalabrado silty clay, shallow phase, but it is slightly more desirable, and a

higher proportion of it is in cultivated crops. About 50 percent of it is used for pasture and 50 percent for subsistence crops.

The yearly acre yields of crops on this soil are as follows: From 200 to 300 pounds of pigeonpeas, from 5 to 7 bushels of corn, from 250 to 300 pounds of beans, and from 1,000 to 1,200 pounds of yautias. Often sugarcane is planted on this soil along the highways near a sugar central, but it seldom yields more than 8 or 10 tons an acre, and the crop is difficult and expensive to cultivate and harvest. Sugarcane and yautias are much better for preventing soil erosion than the other cultivated crops.

During dry years yields are low, as the soil is so shallow that it has very low water-holding capacity. Beans and corn often produce little or nothing during very dry years. Drought is more destructive on the ridges than near the bases of the hills, where the soil is deeper and better.

FIGURE 116.—Brush terraces on a steep slope of Descalabrado silty clay, shallow phase, north of Yauco. Erosion is very severe in this district. The annual rainfall is sufficient to tempt the jibaros to plant clean-cultivated crops, but not enough for rapid growth of plants, therefore the water runs the full length of the hill unchecked unless brush terraces are built. (This photograph was taken during a rather heavy rain.)

Bancales de maleza hechas en una ladera escarpada de Descalabrado limo-arcilloso, fase poco-profunda, al norte de Yauco. La erosión es muy fuerte en este distrito. La lluvia anual es suficiente para tentar a los jíbaros a sembrar cultivos que requieren desyerbo, pero como la lluvia no es suficiente para el crecimiento rápido de las plantas, el agua corre a todo lo largo del monte desenfrenadamente, a menos que se hagan bancales de maleza. (Fotografía tomada durante una fuerte lluvia.)

Nearly all the work done on this soil is performed by hand. The population on areas of this soil is very dense. Probably more than 600 people to the square mile obtain an existence from the subsistence crops they grow, supplemented with the wages they receive for part-time work at sugar centrals or for needlework.

Guayama clay.—Guayama clay is readily differentiated from the other soils of the semiarid uplands derived from volcanic rocks by its red color, which is visible for a quarter of a mile or more, especially on

the southern slopes of the hills, where it is more intensified, owing to greater dehydration of the soil.

With the exception of its color, this soil is similar to Descalabrado silty clay. It seems to be derived from a hard greenish-blue volcanic rock that contains some free lime on freshly exposed surfaces and probably has a rather high iron content.

In a virgin area this soil is characterized by a 5-inch dark brownish-red or reddish-brown friable alkaline granular clay or silty clay surface soil, which is abruptly underlain by light-red fairly compact fragmental plastic clay, alkaline in reaction and in few places more than 6 inches thick. At a depth of about 11 inches the soil material is brown or light reddish-brown friable gritty clay loam containing many rock fragments in the process of weathering. This layer rests on bedrock at a depth ranging from 8 to 28 inches, depending on the slope. The rougher and steeper the relief, the thinner and less valuable is the soil for its principal uses—pasture and forestry.

This soil occurs in several widely separated areas, each having a slightly different land use. The largest two bodies cover the steep hills north of Guayama and near the center of the Isla de Vieques. Both are used for pasture. The area occupying the long high rounded east-west ridge west of Parguera is the driest part of this soil and, therefore, has the most scant vegetation, which consists of thorny brush, cacti, almácigo trees, weeds, and a small proportion of planted guinea grass. The soil on the eastern end of the ridge is slightly acid and resembles Yunes clay in many respects. In many places this area contains reddish-green chips of rocks averaging about 3 inches in diameter. The rocks are of many sizes, however, including some rock outcrops. In many places the soil is not more than 3 inches thick above a bed of rock fragments, soil, and large rocks.

The area near Ceiba receives sufficient rainfall for mediocre yields of sugarcane or subsistence crops. This area differs from average Guayama clay in that it has a thicker more acid surface soil and subsoil, probably due to a higher rainfall. This area, as well as areas on Isla de Vieques and elsewhere, have many siliceous rocks on the surface and some outcrops.

Areas of this soil shown on the map with stone symbols are steeper, stonier, and poorer than the typical areas and are, therefore, less valuable for all crops.

Guayama clay, colluvial phase.—The colluvial phase of Guayama clay is very similar in many respects to typical Guayama clay. It differs from that soil in that it has a deeper surface soil and subsoil. It is intermediate in physical and chemical characteristics between Machete clay and Guayama clay.

This soil is characterized by an 8- or 10-inch reddish-brown neutral heavy clay granular surface soil underlain by a brownish-red heavy granular clay subsoil, about 14 inches thick, which rests on partly disintegrated greenish-blue rock. This soil has gently sloping relief, and some areas are irrigated and produce from 60 to 75 tons of sugarcane to the acre. Most of the land, however, is nonirrigated and produces guinea grass for the oxen used as work animals on the nearby sugar centrals. This soil occurs in the vicinity of Guayama, where the rainfall is not sufficient to insure profitable yields of subsistence crops.

Daguao clay, steep phase.—Daguao clay, steep phase, is similar to some of the soils of the southern prairies in the United States. It

occurs in areas of steep relief in the eastern end of the island where the mean annual rainfall is between 65 and 70 inches. It is readily identified by its nearly black surface soil and reddish-brown compact subsoil.

The 6- or 8-inch surface soil is very dark grayish-brown or nearly black neutral plastic granular heavy clay that cracks greatly when dried. This layer abruptly changes to reddish-brown, or brown with a red tinge, compact plastic dense clay, 8 to 10 inches thick, which grades into disintegrated greenish-black alkaline rock fragments resting on solid rock at a depth ranging from 20 to 40 inches, depending on the slope.

Most of this soil has been cultivated at some time, but experience has shown that the moisture reaching the roots of plants is not sufficient to produce a profitable crop except in very wet years, and now most of the soil is used as grassland, for which it is exceptionally well adapted. The carrying capacity of the pastures not only is high, but the livestock feeding on the grasses have firm, hard fat.

Múcara silty clay loam, steep phase.—Areas of Múcara silty clay loam that occupy slopes ranging from 60 to 80 percent are differentiated on the soil map as a steep phase of Múcara silty clay loam. This steep soil is so interlaced with the typical soil that in many places the boundary between the two is drawn arbitrarily. The steeper soil consists of a thin layer of soil and rock fragments over massive tuff or other Upper Cretaceous rocks.

This soil occurs over an area having an annual rainfall ranging from 65 to 80 inches. The amount of moisture retained by the soil depends to a great extent on the degree of slope, and it is reflected by the acidity and color of the soil. The smoother the slope the greater the content of soil moisture, therefore the lower the pH value and the grayer the soil.

The surface soil, which in few places is more than 8 inches thick, ranges from silt loam to heavy silty clay loam that may be grayish brown, dark grayish brown, or very dark grayish brown, depending on the amount of soil moisture received. When wet, the material feels velvety and slightly plastic. This layer grades into a broken mass of partly disintegrated yellowish-brown shale and tuff fragments resting on bedrock. The depth of this soil on the ridge tops ranges from 4 to 8 inches and on the lower slopes from 8 to 14 inches.

This soil occurs in large areas near Cayey as well as in many other places. Practically all the land is cleared of brush and trees and is used for pasture. The carrying capacity of this land is about 2 acres for an animal. The grass has sufficient strength to produce a firm good-quality beef, but it is not so good as in areas having less than 45 inches of annual rainfall on similar soils. A few farmers attempt to grow tobacco and subsistence crops on the steep slopes, but yields are low, and the land is seriously damaged by sheet erosion.

Areas of this soil south of the Cordillera Central crest in the lower rainfall district have a much darker surface soil than the average for this soil. This is especially true in virgin areas where this soil grades into the Descalabrado soils. Such areas are planted to coffee or are in pasture. The yield of coffee is low, and the crop may be harmed by leaf spot. The grass produced is exceptionally good, in both quality and quantity.

Múcara silty clay loam, shallow phase.—Areas of Múcara silty clay loam, shallow phase, might be called steep mountainsides, as they include all areas of the Múcara soils that have slopes greater than 60 percent, and some are more than 120 percent. This soil occupies many high Λ-shaped ridges that are separated by V-shaped canyons, some of which are 1,000 feet deep.

The soil, as may be expected, is thin, rocky, of low value for cultivated crops, and adapted only to trees and grass. Any cultivation of this soil causes erosion, as, when the land is plowed, the clods roll down the hill by gravity and much soil is lost through the action of water. At one time large areas were planted to coffee, which produced fair yields, but recently the coffee and shade trees have been cut. Crops are planted even on 90-percent slopes, but they are not profitable, and the land soon grows up to grass. It produces fairly good pasture, but the soil is too thin for the production of coffee.

Múcara silt loam, steep phase.—Múcara silt loam, steep phase, differs from Múcara silty clay loam, steep phase, in that it has a lighter textured, slightly more acid, and more friable surface soil. All other characteristics are the same, and the land use of the two soils is similar. Both are used extensively for pasture and to less extent for subsistence crops.

This soil occurs in the western part near Añasco and in the west-central part near Utuado. Around nearly every hut is a small area used for the growing of sweetpotatoes, beans, and pigeonpeas. All crop yields are low, but the soil is more desirable than the Yunes or Tanamá soils.

Picacho stony clay loam.—Picacho stony clay loam occurs on very steep hills (fig. 5) and low mountains in the high-rainfall areas of the interior. It is derived mostly from igneous rocks, most of which are andesitic in composition, and partly from hardened shales and conglomerates. The surface soil is characterized by light grayish-brown plastic silty clay loam, clay loam, or clay. The texture is variable, depending on the decomposition of the parent rock, which depends on the rainfall. In the highest rainfall areas and at the heads of drainageways, the surface soil is clay, but on very steep hillsides that have only a thin surface soil only partly decomposed, the texture is gritty clay loam. Beneath the surface soil, which averages about 4 inches thick, is a mixture of partly decomposed rock fragments, yellowish-brown or reddish-brown clay material, and hard rock, resting on the unconsolidated parent material at a depth ranging from 3 inches on the steep slopes to 14 inches at the bases of the hills or along colluvial slopes adjacent to small natural drains. This soil is acid and extremely rocky.

Owing to the high content of stones, unfavorable relief, and shallowness, the land seldom is used for cultivated crops. Because of the high rainfall and comparatively high content of organic matter in the surface soil, coffee produces from 100 to 400 pounds on the best areas. Probably 80 percent of the land is in pasture or forest, the acreage of the two being about equally divided. Charcoal is one of the principal products of the forests. A 35-pound sack of charcoal sells for 10 cents on the farm and about 15 cents when transported to the cities. It is very difficult to estimate the amount of charcoal produced to the acre, as only a few trees are cut each year. Grass grows luxuriantly, but it

is inferior in quality to that produced on the Descalabrado and related soils in the semiarid and arid sections.

Naranjito silty clay loam, steep phase.—Areas of Naranjito silty clay loam that have a relief greater than 60 percent are differentiated as a steep phase. This soil and the typical soil are intimately associated and occur in small areas throughout the interior near Orocovis and Ciales, and elsewhere.

The 6- or 8-inch surface soil consists of light grayish-brown single-grained acid plastic silty clay or clay. It is underlain by plastic clay ranging in color from gray to reddish brown and is streaked with brown, yellowish brown, or red. This layer rests on parent rock, at a depth ranging from 8 inches on steep slopes to 20 inches on long gentle slopes.

This soil is used extensively for pasture and to less extent for tobacco, subsistence crops, and coffee. It is not so desirable a soil as Múcara silty clay loam, steep phase, as it receives more rainfall, is more acid, and is leached to a greater extent. It is also more plastic and harder to cultivate. Lime and fertilizer would benefit this soil for use in the production of crops as well as for pasture.

Yunes clay.—Yunes clay is geologically related to the Río Piedras soils, but it is shallower and may be considered almost a shallow phase of Río Piedras clay. It has a gray or light grayish-brown shallow clay surface soil, which is underlain by a yellowish-brown plastic shallow subsoil overlying fragmental shales. The shales occur at a depth ranging from 6 to 16 inches, depending on the slope. The material in all layers is very acid. The soil appears nearly white from a distance.

This soil occurs on the steepest of the shale hills that are west of Carolina and extend almost to Utuado. A few areas are near Peñuelas. Most of the land is either in pasture or trees. About 2 acres are required to pasture an animal. If the land is cultivated, yields are low. If the forests are cut and the land is planted immediately to sugarcane, yields range from about 20 to 25 tons to the acre the first year or two, but they soon decline to 12 to 15 tons.

Yunes silt loam.—Yunes silt loam is similar to Yunes clay, except in the texture of the surface soil. Most of the silt loam occurs in the eastern part of the island near Fajardo. It is used for the same crops as is the clay. In areas having a rainfall of less than 45 to 50 inches, this soil develops a cemented layer at a depth just above bedrock. This is especially noticeable from Fajardo toward the Fajardo lighthouse. This layer does not interfere with the growth of either grass or trees, but it would seriously affect cultivated crops.

Mariana clay loam.—The surface soil of Mariana clay loam, to a depth of 6 or 8 inches, is pale-gray or yellowish-gray strongly acid clay loam or silt loam, which is friable, fluffy, and powdery when dry but sticky and plastic when wet. This layer is underlain by intermingled rock fragments, soil particles, and roots. In many places the average depth to bedrock is less than 10 inches, and many hilltops are capped with large irregular-shaped black and reddish-brown rocks.

This soil covers many small areas from a point near Daguao in the eastern end of the island to a point near Lajas in the southwestern part. It occupies slopes ranging from 40 to 80 percent.

This is considered a poor agricultural soil by most farmers, but the areas planted to pineapples near Lajas produce very good yields.

Juana Díaz clay loam.—The 6-inch surface soil of Juana Díaz clay loam is dark grayish-brown granular medium-plastic neutral or alka-

line clay loam. It is underlain by a 6- to 10-inch subsoil of brown prismatic medium-compact neutral or alkaline silty clay loam. The substratum, which continues to a depth of more than 6 feet, consists of friable yellowish-brown fine-grained sandstone, with many rounded pebbles and water-worn rocks. Thin seams and small splotches of soft lime carbonate deposits are common.

This soil occurs on rolling or steep hills in the vicinity of Juana Díaz. It is used most extensively for pasture, but a few acres annually are planted to subsistence crops and tobacco. The mean annual rainfall in few places exceeds 45 inches, and crop yields are low. The soil has about the same value for pasture as has Jácana clay. In some places the surface soil is very thin or is absent, and here and there the parent material is exposed by erosion.

Juana Díaz silty clay.—Areas of Juana Díaz silty clay are closely associated with Juana Díaz clay loam, but in most places they occupy the lower, smoother slopes. The silty clay occupies only a few hundred acres in the vicinity of Juana Díaz.

The surface soil consists of an 8- or 10-inch layer of light-brown coarsely granular plastic alkaline silty clay that changes abruptly to reddish-brown compact prismatic plastic clay having an average thickness of 5 inches. This layer rests on yellow friable alkaline clay loam or sandy clay loam that gradually changes to rotten very fine grained sandstone parent material containing considerable soft lime deposits.

This soil is used more extensively for cultivated crops than is Juana Díaz clay loam. A few areas are planted to sugarcane, which yields from 40 to 45 tons to the acre when the land is properly fertilized and irrigated.

Rosario silty clay.—Comparatively speaking, Rosario silty clay resembles a shallow phase of Nipe clay. It occurs on 40- to 180-percent slopes from Mayagüez to Yauco, and serpentine rock lies within a few inches of the surface.

The 2- to 4-inch surface soil consists of friable granular permeable nonplastic purplish-red neutral silty clay that grades into partly weathered serpentine rock at a depth ranging from 4 to 10 inches. Below this material is the green flaky foliated serpentine rock, which feels soapy and polishes readily when rubbed with the hand. During decomposition the topmost flaky rock weathers almost completely before the chemical weathering process starts to decompose the adjoining layer.

This is one of the poorest soils, owing not only to its unfavorable relief and shallowness but to the lack of plant nutrients in the soil material and parent rock. The soil contains considerable chromium and nickel, which probably have a toxic effect on plant roots, thereby reducing the growth of plants.

Most of this land is used for forest. Coffee is grown on the concave slopes, where, through the additional organic matter and water, fairly productive trees are maintained.

This soil is more droughty than soils of the nearby hills derived from tuff and limestone. Cacti and thorny desertlike shrubs are the predominant vegetation on many acres after the virgin timber has been cut. A few acres in virgin timber were noted south of Maricao in the national forest. The trees are small for their age and do not have a healthy appearance. The mat of vegetation covering the soil in virgin areas is 6 to 8 inches thick, very spongy, and light in weight.

Many landslides occur on this soil after unusually heavy tropical rains. Most spots affected by slides are not over 20 feet wide, but some are from 50 to 100 yards long. The foliated slippery character of the serpentine causes the rocks to slide over one another and carry the shallow soil mass with them down the slopes.

Several mineral springs rise in areas of this soil, and the water is exceptionally good for drinking purposes. Very few people live on this land, and the general appearance of the country is exceptionally poor.

The Polytechnic Instituto at San Germán is located on this soil, and by applying large quantities of fertilizer and irrigating, fair yields of guinea grass and minor crops are produced from small acreages.

Rosario silty clay, smooth phase.—Rosario silty clay, smooth phase, differs from the typical soil in that it has smoother relief, is much less red or purple, and occurs in more arid sections. It is characterized by a brown or light-brown friable semigranular silty clay surface soil 5 or 6 inches thick, underlain by a red or brownish-red permeable clay subsoil from 4 to 6 inches thick. This layer rests on partly disintegrated serpentine rock. In most places the depth of soil above the rock ranges from 2 to 12 inches, depending on the slope, but in some places the parent rock is exposed.

This soil occurs in many small irregular-shaped areas where the mean annual rainfall is less than 65 inches. The largest bodies are between Yauco and Sabana Grande and near San Germán. This soil is used only as brush and pasture land. Neither brush nor grass grows very rapidly or becomes very dense. The boundary line between this soil and the adjacent soils is everywhere extremely sharp and can be detected by the vegetation which in few places on this soil is one-third as good as that on the other soils.

Vieques loam, steep phase.—Vieques loam, steep phase, occupies steep hills in the granitic part of the western end of Isla de Vieques and the northern part of Isla de Culebra.

It is similar to Pandura loam, but it occurs in a much drier climate and is more alkaline in reaction. It is used almost entirely for pasture and is considered less desirable than Descalabrado silty clay or Guayama clay for quality and quantity of grass produced. A few banana plants are grown near the jibaros' homes.

This soil is characterized by a very dark grayish-brown friable gritty loam surface soil 6 to 8 inches thick, underlain by an 8- to 10-inch layer of reddish-brown firm but gritty sandy clay loam resting on partly disintegrated coarse-grained granite at a depth ranging from 12 to 20 inches, depending on the steepness of the slope. Large rounded blocks of granite are scattered over the surface.

Rough stony land.—Rough stony land includes areas too rough and broken or too stony for the cultivation of crops. In many places it consists of the high jagged wind-swept moss-covered mountain peaks at elevations above 3,000 feet. In average areas, such trees as sierra palm, treeferns, llagruma, granadillo, and tabonuco are the most conspicuous. Some of the virgin timber is still standing on the most inaccessible areas (fig. 117). The growth of vegetation depends more on climatic conditions than on soil. For example, on the highest peaks of the Sierra de Luquillo the wind is so severe that the trees are dwarfed and have crooked interlacing limbs, and the nearly continuous mist and rain are more favorable for mosses and ferns than for nutritious

grasses. The soil material of this type of land, in the numerous areas of its occurrence, includes many variations in texture, color, consistence, and structure. In most areas it consists of a thin layer of dark grayish-brown or grayish-brown plastic acid clay containing an abundance of leaf litter, moss, roots, and sharp angular rock fragments. This layer rests on hard rocks. At the heads of drainageways or near springs and watercourses, the soil is deep-gray plastic acid waterlogged clay, with many rusty-iron stains at a depth ranging from 16 to 20 inches.

In some spots, the soil is red, permeable, and deep, and in other places the stones are so numerous that a person can travel for a distance of half a mile by stepping from stone to stone. A large area of soil derived from granite, occurring in the vicinity of Pico Este, is

FIGURE 117.—Rain-forest vegetation on rough stony land. The mean annual rainfall exceeds 120 inches.

Bosque en tierra pedregosa quebrada. La lluvia anual excede 120 pulgadas.

included with this land type. This area has a light-colored gritty loam, sandy clay loam, or sandy clay surface soil 3 or 4 inches thick, underlain by a thin light-gray or ash-gray bleached strongly acid silty layer, which, in turn, is underlain by a thin iron crust or a rusty-brown or reddish-brown friable layer high in iron. This material gradually changes to loose gritty friable sandy loam and partly disintegrated quartz diorite rock.

This type of land is best used for its scenic beauty. The many rapids, cascades, and beautiful waterfalls, the cool and invigorating temperature, the rain forest and moss vegetation, precipitous cliffs, and gorgeous views make these areas equal or superior to some of the national parks in the United States.

SOILS OF THE INNER PLAINS

Most of the soils of the inner plains include the low, gently rolling or nearly level valleylike areas between the mountains and the hills adjacent to the coastal plains or within the mountains that have deep plastic residual soils. With very few exceptions these soils have dark

sticky plastic heavy clay surface soils and deep plastic heavy subsoils. The soils are very retentive of moisture, but they are very difficult to plow or cultivate. If a soil auger is bored into the subsoil of most of them, even after a long dry period, the material is still moist and plastic and will stick tenaciously to the auger. Plant roots can penetrate the subsoil and substratum readily and remain in good condition during an average dry period. In a few places artificial drainage is necessary, and careful management is essential everywhere. If the soils of the inner plains are not plowed at about the right moisture content, large, dense clods are formed, which require many dashing rains to slake into fine granules. The surface soil may become dry during long, rainless periods, and cracks 2 inches wide extend to a depth ranging from 10 to 18 inches. This cracking is injurious to the upper roots of the plants, as many of them are stretched and severed by contraction of the soil. The lower roots, however, generally are in good condition.

Most of the soils in this group have a high organic content in the surface soil and are better adapted to sugarcane than to any other crop. Probably more than 80 percent of their total area is planted to sugarcane, and most areas are within economical hauling distance to sugar centrals. Coffee does fairly well on the well-drained sloping areas in the humid sections, but none is planted in the arid sections. Corn grows very well on these soils and is often planted on areas not irrigated or not readily accessible by oxcart roads. These soils are very poor for the production of citrus fruits, as internal drainage is too poor and the heavy plastic subsoils allow insufficient aeration. The few grapefruit orchards planted on some of these soils in the humid sections are growing fairly well on the well-drained convex slopes, but those planted on concave slopes or on level areas are very poor and probably will soon be replaced with sugarcane.

The soils of the inner plains include 29 soil types and phases of the Las Piedras, Mabí, Moca, Dominguito, Río Arriba, Santa Clara, and Camagüey series of the humid sections, and the Yauco, Ponceña, Portugués, Mercedita, Barrancas, Pozo Blanco, Amelia, Río Cañas, and Cabo Rojo series of the arid and semiarid districts.

To facilitate descriptions of the soil types, the soil series having similar parent materials are grouped and briefly described.

The Las Piedras soils are the only ones in this group that are derived from granitic materials. They are somewhat similar to the Cayaguá soils, except that they occur on undulating or nearly level moderately eroded peneplains at an elevation of about 500 feet. They are well-drained fairly deep warm acid soils requiring considerable fertilizer. They are used for tobacco, sugarcane, minor crops, and pasture.

The Mabí soils are the only ones derived from tuffaceous rock in the humid section. They are very similar to the Juncos soils. They occur on long gentle slopes or in nearly level areas in close association with the Juncos and Múcara soils. The elevation of the Mabí soils ranges from 10 to 1,000 feet above sea level. These soils have fair drainage and high fertility, are neutral or alkaline in reaction, and are rather hard to plow or cultivate. They are used almost entirely for the production of sugarcane, which yields very well.

The Moca, Dominguito, and Río Arriba soils are closely related to one another. Apparently they are derived from lower Tertiary shales

and clay. They occur at elevations ranging from 250 to 1,000 feet. They have plastic, acid, heavy surface soils and mottled red, gray, and yellow, plastic, sticky, acid subsoils, which grade into a more friable, acid, gravelly, mottled red, gray, and yellow substratum that also is very plastic when wet. The Moca soils have grayish-brown or brown surface soils. They occur mostly in the north-central part of the island, intimately associated with the Colinas soils. The Dominguito soil occurs in the west-central part, and it has a nearly black surface soil. The Río Arriba soil occurs in the eastern part, and it has a light-gray or light yellowish-brown surface soil. All these soils have undulating or rolling relief, and nearly all of their area is used for sugarcane, coffee, and minor crops. The yields of sugarcane range from fair to good. Coffee yields are fair, and yields of most of the minor crops are very good.

The Santa Clara and Camagüey soils of the humid section of the Yauco, Ponceña, Portugués, Mercedita, and Barrancas soils of the arid and semiarid sections are derived from calcareous materials, mostly limestone and calcareous shales. These soils occur at elevations ranging from 10 to 1,000 feet. They have dark grayish-brown or nearly black, plastic, waxy, alkaline or calcareous surface soils and yellowish-brown sticky, plastic subsoils overlying soft, gray limestone at various depths, depending on the soil series. Generally external drainage is adequate, as most of these soils have sufficient slope for the excess water to drain out. Internal drainage, however, is slow, and on level areas artificial drainage is essential.

These soils are fairly high in organic matter, bases, and plant nutrients, but when cultivated continuously to sugarcane they need commercial fertilizer applied at the rate of about 700 pounds to the acre a year. Most of these soils occur in fairly large uniform areas that can be conveniently managed with modern machinery, and if the mean annual rainfall is greater than 70 inches or if irrigation is practiced, nearly all of the land is planted to sugarcane or is in the process of preparation for that crop. Nonirrigated areas in the arid sections and inaccessible areas in the humid sections are used for pasture, corn, and minor crops. All crops produced on these soils seem to have a high nutritive value.

Salt is a limiting factor in only a very small part of the total area of these soils. Lime chlorosis greatly reduces the production of sugarcane, especially ratoon crops, on nearly all spots in the arid sections where limerock is exposed or lies within 6 inches of the surface. Lime chlorosis is not serious, except for pineapples, in the humid sections, even on bare limestone rock.

The boundary line between many of these closely related soils is drawn arbitrarily in many places. The main distinction between the Santa Clara and Camagüey soils is in the color of the surface soil, which is nearly black in the Camagüey and dark grayish brown in the Santa Clara soils. These soils differ from the Ponceña and Yauco soils in that they occur in areas having from 65 to 110 inches of annual rainfall and therefore are slightly less alkaline and more leached than the Ponceña and Yauco soils, which occur in areas receiving from 30 to 65 inches of annual rainfall. The Yauco soils bear the same relation to the Santa Clara that the Ponceña do to the Camagüey.

The Portugués soils differ from the Ponceña in that they are more calcareous and the limestone rock lies at slighter depth. The Mer-

cedita soils differ from the Portugués soils in that they are derived more from alluvial material washed from the nearby limestone hills and less from residual material.

The Barrancas soils differ from the Mercedita soils in that they have a darker surface soil and occur in long narrow strips adjacent to streams.

The Pozo Blanco soils are derived from material washed from medium-hard limestone. They are reddish brown and fairly friable. They occupy small valleylike positions in the most arid section of the island. These soils are well drained, granular, and very productive if the rainfall is sufficient. Most plants except the xerophytes, however, suffer from drought. A very small proportion of these soils is irrigated, and nearly all areas are used for corn, minor crops, and pasture.

The Amelia and Río Cañas soils are derived from tuffaceous rocks and shales. They occur on long gentle slopes or in valleylike positions at elevations ranging from 250 to 500 feet. These soils are closely associated and somewhat similar to the Jácana and Descalabrado soils, but they are much deeper and more fertile and have smoother relief. They are granular and are brown, dark brown, or nearly black, depending on the annual rainfall received—the greater the rainfall the darker the color. Parent rock lies at a depth ranging from 26 to 36 inches, depending on the slope.

The Amelia soils differ from the Río Cañas soils in that they do not contain free lime, whereas the latter soils have an abundance of lime carbonate below a depth ranging from 15 to 20 inches.

Very small areas of the Amelia soil are situated so that they can be irrigated economically; therefore they are used for pasture and tobacco.

The Cabo Rojo soils are similar in physical and chemical characteristics to the Río Arriba soils, but they occur in a semiarid section, and for this reason the land use of the soils of the two series is somewhat different. Most areas of the Cabo Rojo soils are in pasture or planted to the Uba variety of sugarcane. These are very poor soils that have been affected seriously by both sheet and gully erosion. They occur only in the southwestern part of the island.

Las Piedras clay loam.—Las Piedras clay loam is derived from quartz diorite. It occurs in gently rolling or undulating areas of the moderately eroded peneplains in the vicinity of Las Piedras.

This soil is characterized by a gray or somewhat reddish-gray friable nearly structureless acid clay loam surface soil that ranges in thickness from 4 to 12 inches. This layer is underlain by medium-compact light yellowish-brown acid clay that is fairly plastic when wet and in places is mottled with pink, orange, and bluish-gray splotches. The layer ranges from 2 to 10 feet in thickness. It rests on the disintegrated friable quartz diorite, which in turn grades without any definite line of demarcation into the unconsolidated parent rock.

Las Piedras clay loam is not a very productive soil without the use of amendments high in nitrogen and phosphorus, as it is derived from materials low in plant nutrients and also has been leached to a great extent. This soil, however, occurs in rather large uniform tracts that can be farmed easily with modern machinery, in a section of comparatively high rainfall. It is used extensively for the production of tobacco and sugarcane. During the years 1935 and 1936, when the

acreage in sugarcane was curtailed, many areas of this soil were idle or were producing pasture grass. Sugarcane on this soil produces from 25 to 35 tons of gran cultura when the land is properly fertilized and managed.

Las Piedras clay loam, steep phase.—A steep phase of Las Piedras clay loam lies adjacent to the few U-shaped drainageways that traverse areas of the typical soil. This soil differs from the typical soil not only in relief but also in its thinner surface soil. The parent rock is nearer to the surface in the steep areas. Nearly all of the land is used for pasture, the carrying capacity of which is fairly good. In most places 1 acre will pasture an animal throughout the year. Malojillo grass grows fairly well, especially in the bottoms of the drainageways.

Las Piedras loam.—Las Piedras loam is closely associated with Las Piedras clay loam and the other soils derived from granite in the east-central part.

The 6- or 8-inch surface soil consists of grayish-brown coarsely granular acid friable loam, which is underlain by olive-drab or reddish-yellow acid medium-compact clay loam. This layer is underlain at a depth ranging from 20 to 40 inches by quartz diorite parent rock.

This soil is used for pasture, tobacco, sugarcane, and minor crops, ranking in acreage in the order named. It produces slightly better yields than the Cayaguá soils if it is well fertilized and properly managed. It would be greatly benefited by lime and manure.

Mabí clay.—Mabí clay is a productive soil occurring throughout the island on long low gentle slopes, in close association with the Múcara and related brown shallow soils of the uplands, within the humid section. This soil is derived from material that is in part residual and in part colluvial and alluvial. It is characterized by a grayish-brown neutral plastic heavy clay surface soil about 8 or 10 inches thick, which has good tilth when properly plowed and cultivated. The material in this layer is fairly high in organic matter and plant nutrients. The subsoil is yellowish-brown plastic sticky neutral heavy clay streaked with rust-brown and gray material. This layer gradually changes, at a depth ranging from 30 to 40 inches, to friable brown and yellowish-brown silty clay loam that crumbles readily between the fingers. The material grades into disintegrated tuffaceous rock material at a depth ranging from 4 to 12 feet. Small fine white specks of the rock material occur in all layers, indicating that bases probably are released continually as the specks disintegrate.

Areas of Mabí clay are smooth or slightly undulating with sufficient slope for adequate surface drainage. The subsoil, although plastic and sticky, is more pervious to both water and plant roots than the compact subsoils of the Sabana Seca, Candelero, and related soils.

This soil is moderately fertile, and it produces from 30 to 45 tons of gran cultura sugarcane season after season. It needs fertilizer every year when planted to either cane or tobacco, the two principal crops grown. Probably 85 percent of the land is planted to sugarcane, and 15 percent is in tobacco. Tobacco yields range from 900 to 1,200 pounds to the acre when the land is well managed.

Mabí clay, flat phase.—Mabí clay, flat phase, is an extensive soil occurring throughout the humid part of the island, in close association with the typical soil.

Accessibility Statement

This document is not accessible by screen-reader software. The U.S. Department of Agriculture is committed to making its electronic and information technologies accessible to individuals with disabilities by meeting or exceeding the requirements of Section 508 of the Rehabilitation Act (29 U.S.C. 794d), as amended in 1998. Section 508 is a federal law that requires agencies to provide individuals with disabilities equal access to electronic information and data comparable to those who do not have disabilities, unless an undue burden would be imposed on the agency. The Section 508 standards are the technical requirements and criteria that are used to measure conformance within this law. More information on Section 508 and the technical standards can be found at www.section508.gov.

If you require assistance or wish to report an issue related to the accessibility of any content on this website, please email Section508@oc.usda.gov. If applicable, please include the web address or URL and the specific problems you have encountered. You may also contact a representative from the USDA Section 508 Coordination Team.

Nondiscrimination Statement

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the

Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at http://www.ascr.usda.gov/complaint_filing_cust.html and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by:

(1) mail: U.S. Department of Agriculture
Office of the Assistant Secretary for Civil Rights
1400 Independence Avenue, SW
Washington, D.C. 20250-9410;

(2) fax: (202) 690-7442; or

(3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.