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Guide to the Ecological Systems of Puerto Rico

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Chapter 1: Overview of Puerto Rico

Introduction

Puerto Rico offers a rich tapestry of environments in which to conduct field studies in tropical ecology. It has a mountain range oriented east-west with peaks as high as 1000 meters (4,000 feet). Its boundary on the north is the Atlantic Ocean and to the south, the Caribbean Sea. The island is bathed by the westerly **trade winds**,¹ which interact with the sea and mountains to produce an array of rainfall patterns and orographically induced **habitat** variation. Some areas in the mountains receive more than 5000 millimeters (200 inches) of rain annually. Other areas on the Caribbean **rain shadow** side receive as little as 254 millimeters (10 inches) in some years.

In addition, the rainfall produces considerable runoff that results in many rivers on the island in all directions. The south side has fewer perennial rivers and is a lower energy coast line, thus affording greater stability to **marine ecosystems** such as **coral reefs**, **mangrove swamps**, and **submerged seagrass beds**.

Because of its geographic position, half the year Puerto Rico is also exposed to major tropical storms. **Hurricanes** are one of the main ecological disturbances in Puerto Rico and all adjacent areas of the Caribbean, and have the potential of producing enormous instantaneous and long-term change in all ecosystems, terrestrial and marine.

Pre-Columbian Puerto Rico had no coconut palms,² no grapefruit or orange **trees**, no coffee groves, no mangoes, no flamboyán or African tulip trees with their beautiful flowers, and no sugarcane fields. The mangroves that hugged the coasts were larger and much more widely distributed. The **Taíno** people that lived on the island mostly fished and grew corn, yuca, yams, and cotton to supply their needs. In the 500-plus years since Columbus discovered Puerto Rico (1493, second voyage of discovery), the introduction and growth of nonindigenous European and African human **populations** has resulted in enormous habitat alteration throughout the island. In addition, thousands of **alien** species of plants and animals have been introduced, both intentionally and accidentally. Populations of some **native species** have undergone dramatic declines, whereas many **introduced species** have become naturalized. Destruction of native habitats occurred throughout the island as species such as sugarcane (*Saccharum officinarum* L.), tobacco (*Nicotiana tabacum* L.),

¹ Bold terms are defined in the glossary.

² See appendix 1 for Common and Latin names.

citrus (*Citrus* spp.), coffee (*Coffea arabica* L.), and bananas (*Musa x paradisiaca* L.)—to name just a few—were introduced. Many native habitats and populations were destroyed without any written description of their presence having been recorded. Today, large expanses of agricultural lands are “returning to nature” as much of the sugar plantation land is being abandoned, as sugar is no longer the dominant crop that it was in the 18th, 19th, and first half of the 20th centuries. Consequently, Puerto Rico is an interesting case study in that it is an island undergoing significant natural reforestation. Many former agricultural sites will not return to forest as a result of rapid urban development, growth of tourism centers, golf courses, light industry, and transportation corridors for the rapidly increasing use of private automobiles. Human activity has also reduced and, in some cases, endangered many types of ecosystems, for example, the loss of coral reefs on the north coast, magnificent lowland forests of the **alluvial** coastal plains, coastal dune communities, and the **elfin forests** on the mountain tops, and the damming of numerous rivers.

Puerto Rico is neither a sleepy little Caribbean Island, nor is it a lush tropical paradise, as is sometimes depicted in tourism advertisements. There are places in Puerto Rico where both can be found, but, in fact, Puerto Rico today is the commercial engine of the Caribbean, and in many ways it has most of the contemporary problems and concerns that fully developed economies exhibit: air and water pollution, protection of **endangered species** and their habitats, forest management, regulation of all forms of waste and their disposal, pesticide regulation, marine protection, and others. Puerto Rico has over 2 million automobiles, trucks, and buses constituting one of the highest vehicle densities in the world. At times, its metropolitan traffic jams rival those of California freeways. It is currently building a 17.2-kilometer (10.3-mile) elevated train/subway at a cost of nearly \$2 billion to alleviate traffic congestion in metropolitan San Juan. Old infrastructure is also a big problem for the island’s water supply in that almost 50 percent—about 950 liters (250 million gallons) per day—of all potable water processed by the Water Authority is lost prior to delivery because of leaks, broken hydrants, and unmetered connections to the system. Puerto Rico’s sewerage system is still developing. Fifty percent of the island lacks sanitary sewer lines, and some communities still have difficulty meeting secondary sewerage treatment standards, which is of concern to beach communities and the tourism industry. Sixty-eight treatment plants discharge into the ocean.

Given Puerto Rico’s many wonderful terrestrial and marine species and ecosystems, there is need for a strong **conservation** ethic and commitment to a

sustainable future. Many of these species and ecosystems are interrelated and connected in complex ways and are the result of long-term geologic and biologic evolution. As Puerto Rico's population and associated necessary development increases, the demands and pressures on these ecosystems and species increase accordingly. Human activity in Puerto Rico is again changing Puerto Rico's complex landscape, but instead of being largely restricted to agricultural simplification of the landscape (for which there is an opportunity of recovery), much more destructive and permanent changes are occurring on the island. These include loss of large areas to **urbanization**; serious water pollution associated with improper disposal of sewage, including hazardous and other solid wastes (industrial and municipal); overpumping of critically important ground-water supplies; and the destruction of large numbers of **limestone** hills, sandy beaches, mangroves, freshwater swamps, and other **wetlands**. Development in Puerto Rico is growing at a rate that is surpassing regional carrying capacity in terms of public water supply in many areas, and at the expense of species and habitats. Puerto Rico is at a critical crossroads in its environmental history. Many systems are no longer able to perform their functions, and their restoration will be highly unlikely owing to both cost and complexity. Puerto Rico's complex environmental issues will need to be addressed based on needs assessments for future generations. Puerto Rico is heavily subsidized and depends on the importation of huge quantities of food, fossil fuels, and a vast array of other goods and services (worth \$29 billion in 2002). **Sustainability** must become the island's watchword; and all important decisions must address the three "E's": equity, economics, and the environment.

Although Puerto Rico has undergone rapid development in the last five decades, it still has many special tropical terrestrial and marine habitats and species, and therefore represents an island with a tremendous mix of opportunities for pursuing a study of tropical ecosystems. Additionally, there is an excellent published technical information base for the island. Many current studies sponsored by a variety of federal and commonwealth agencies, universities, and nongovernment agencies are in progress.

In addition, with growing interest in the tropics, many secondary schools, universities, and teacher training institutes now offer experiential education classes centered on various aspects of tropical marine and terrestrial ecology. Less formal experiential education is also available through dozens of ecotourism companies that specialize in guided trips to the tropics. Tourism in general is now the largest industry in the world, and **ecotourism** is the fastest area of growth within this diverse industry. In 2002, Puerto Rico had 2 million hotel guests. Puerto Rico has

seen a substantial increase in ecotourism in the past decade and there is a list of specialty companies in appendix 3. This field guide is designed as an aid in educating these groups.

This publication was written to help guide a diverse audience—the teacher, student, class, or individual reader—in gaining the background needed to understand a select group of tropical ecosystems and species and where to find them while in Puerto Rico. This is by no means a comprehensive list, but a good representation of the main systems that are relatively easy to access.

A selected series of tropical terrestrial and marine ecosystems has been chosen for general description, and some of the species typical of those ecosystems will be highlighted. For more indepth reviews of these species and ecosystems, each section contains references for further reading that provides a broader review of the more technical literature on the topic.

Puerto Rico—Its History, Politics, and Economy

Early History

No one knows with certainty how long Puerto Rico has been inhabited, but it is likely that humans have been present on the island for 2,000 years. The earliest indigenous population is thought to be from a primitive group called the Siboney who hunted and gathered. Somewhat later the Igneri established farms and made pottery. About 700 A.D., the more advanced Taíno were developing population centers in many areas of the **West Indies**. By 1270 A.D., they controlled the island they called Borikén, which is present day Puerto Rico. As you travel throughout Puerto Rico today, you will see many references to Borinquen, which is commonly used as a business name. A form of the word—boricua—is used to designate (with pride) a person born on the island. The Taínos spread throughout the West Indies, probably from their origin in mainland Venezuela of South America. When the Spanish arrived, they called the Taínos the Arawaks. The Taínos were a peaceful agrarian society that grew corn, yams, and a variety of field crops. They made bread from yuca, wove cloth from native cotton, and were skilled potters. They lived in wood frame huts with thatched roofs and played soccer-like ball games on courts called bateyes (see app. 2, p. 368). It is estimated that approximately 30,000 Taínos inhabited Borinquen in 1493.

By the time Columbus discovered the New World, the Taínos had been under heavy attack by a very hostile Indian invader, the **Caribs**. The Caribs burned villages, slaughtered the villagers, took prisoners, and may have practiced cannibalism.



Figure 1—View of ceremonial areas in the Caguana Indígena Park.

It is from their tribal name that the word Caribbean was derived. The Caribs had more advanced technology than the Taínos with which to conduct battles: the bow and arrow. The Taínos only had spears. When the Spanish came to Puerto Rico, the Taíno culture went into rapid decline. Not much remains of the Taíno culture. There are a few words from their language that survive in modern English: barbecue, canoe, hammock, hurricane, and tobacco. In recent years, numerous excavations have been conducted in various places in Puerto Rico, and as a result, we have a better understanding of their society (fig. 1).

The Isle of Borinquen changed forever on November 18, 1493. It was during Columbus's second voyage to the New World that the island was discovered. Columbus's 17-vessel fleet anchored on the west coast on November 20. The ships sent landing parties and took on food and water. They found a Taíno village, but the people had fled to the mountains. Columbus named this new island San Juan Bautista (St. John the Baptist), and it was later renamed Puerto Rico (rich port) in 1521.

As seen in figure 2, Puerto Rico occupies a strategic point at the entrance to the Caribbean. It is the smallest and most eastern of the **Greater Antilles** and sits at the top end of the **Lesser Antilles**, which arc up from South America. Because of its position, it was of military importance and used as a stopover to and from Spain (for groups on their way to and from) and other colonization points in the New World.

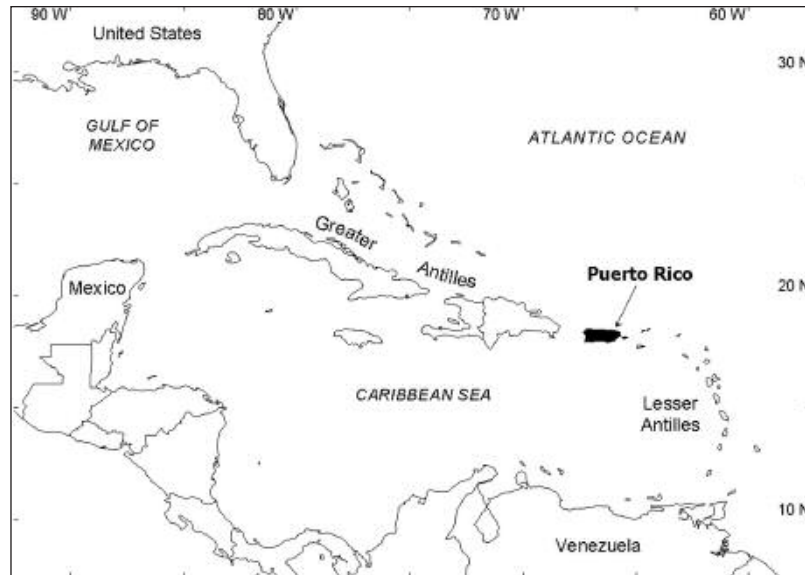


Figure 2—Islands of the West Indies and Caribbean Sea.

The earliest Spanish settlers were conquistadores (conquerors), and one of them aboard the 1493 (second discovery) voyage was Juan Ponce who was from the province of León in Spain. Juan Ponce, now known as Ponce de León, was named governor in 1508 and given royal permission to occupy and explore San Juan Bautista. Initially he searched for gold. In addition to gaining wealth, he was also interested in converting the indigenous population to Christianity and increasing the glory and wealth of Spain. He and his men landed in a well-protected bay on the north coast, which he called Puerto Rico. The bay was later renamed San Juan Bay. The first settlement started by Ponce de León at Caparra proved too distant and unhealthy to be maintained, and so a second settlement was developed on the island that protected the entrance to the bay. This was the start of present-day Viejo San Juan (Old San Juan) and it became the capital in 1521. San Juan is the second oldest city established by Europeans in the New World.

Ponce de León did discover gold and sent tens of thousands of pesos back to Spain annually from 1511 to 1520. In a 30-year period (1509–1539), almost 300,000 pesos were sent to Spain. Puerto Rico never achieved the high colonial status of Cuba, the Dominican Republic, or mainland areas such as Perú or México, because of its small size, lack of large amounts of precious metals, and relatively small areas of easily accessed fertile soil for agriculture.

By the 1570s, most mines were closed down, the Taínos were decimated, and their culture was being assimilated by the dominant European culture through intermarriage.

The Colonial Period

By the mid to late 1500s, it was not certain that the Spanish colonists could support themselves in Puerto Rico. As the mines failed and no other sources of wealth were easily accessible, new sources of cashflow had to be established. By this time, the demand by Europeans for sugar and its various related products was growing. It was therefore very timely that this lush tropical island, ideal for growing sugarcane, was in search of a new and sustainable way to pay its bills. There were, however, big problems associated with sugarcane. The two main problems were that the land had to be cleared of its native forests, and cane plantations required lots of labor. Initially, the Taínos were forced into performing these tasks, but they were rapidly dying out, and later became extinct. However, recent DNA analysis indicates that many Puerto Ricans have an ancestral link to the Taínos.

So where would the labor force come from? The conquistadores? No, conquerors rarely performed manual labor. Early in Puerto Rico's history (1518), 500 African slaves had been brought to Puerto Rico to work in the mines. The need for slaves was transferred to the agricultural sector; thus thousands of slaves were imported, both legally and illegally, beyond the Spanish quotas. As a result of the increased labor, sugar production grew and mills were constructed in various places on the island. Later, production of coffee, tobacco, and ginger also became profitable. Puerto Rico now had a land-based economy and landowners, with many workers. As the mines petered out, San Juan no longer shipped its own gold and silver, but served as a collection center and safe harbor on the perilous sea routes to and from Spain. Spain's treasure fleets were often attacked by pirates, freebooters, or other nation's vessels, so Spain decided to fortify San Juan.

In 1539, the construction of El Morro (app. 2), a classic 16th-century fortress, was initiated. It was not completed for almost 200 years and included moats, ramps, and tunnels all interlinked with the main fortress with its kitchens, troop quarters, powder magazines, and dungeons. As a result of the construction of El Morro and two nearby forts, Puerto Rico became the most fortified colony in the West Indies. El Morro was attacked many times by various countries, pirates, and freebooters, but the Spanish flag did not fall until 1898 when the United States took over the island by attacking the unfortified south coast.

Puerto Rico remained pretty much a Spanish defensive outpost protecting its New World colonies and an agrarian society for the next 300 years. As the sugar industry continued to prosper, by the latter part of the 19th century, Puerto Rico the Spanish heritage of the island were being built in Old San Juan. By the time of the American Revolution, Puerto Rico's population was nearing 100,000. Large

homes reflecting the Spanish heritage of the island were being built in Old San Juan. They were brick and stucco, with ornate arches, many with interior courtyards and balconies. By 1800, the population had grown to nearly 150,000. Spain had opened Puerto Rico to greater colonization and in the early 1800s, many Spanish loyalists sought refuge there from wars for freedom in other Latin American colonies. By the 1830s, Puerto Rico had a plantation economy with sugar, coffee, tobacco, and molasses the main exports.

Steps Toward Autonomy

In 1812, Spain elevated Puerto Rico's status to that of a province, which included representation in the Spanish Parliament. This status was short-lived, and within a couple of years it reverted to colonial status with a series of military governors appointed by the Spanish Crown. This led to resentment and hostility on the part of a growing body of Puerto Rican intellectuals. In 1868, an intellectual-led rebellion occurred in the mountain town of Lares where they proclaimed the free Republic of Puerto Rico. The revolt was put down by Spanish troops. Prior to the revolt, political parties had been outlawed, but shortly after the revolt, the first legal political party was allowed to organize (Liberal Reform Party). Under its influence, the Spanish government outlawed slavery in Puerto Rico in 1873. At that time only 5 percent of the population was African. Puerto Rico, since its colonial period, was pretty much culturally and racially homogenous. The Liberal Reform Party changed its name to the Autonomist Party in 1887 in order to seek autonomy rather than absolute independence from Spain. Autonomy was achieved in 1897 under the leadership of Luis Muñoz Rivera. Once again, Puerto Rico could elect voting delegates to the Spanish Parliament. The newly granted autonomy also permitted the election of Puerto Rico's first legislature in March 1898.

The American Period

These reforms and newly won freedoms were abruptly ended. In April 1898, the Spanish-American War started as a result of the blowing up of the U.S.S. Maine, a battleship at anchor in the harbor of Havana, Cuba. The war was very short, and by August 13, it was over in Puerto Rico. An American military force of 16,000 landed on the south coast at Guánica and marched overland to San Juan, but the war ended before they crossed the Cordillera Central Mountains. On October 18, the Spanish flag was lowered over the governor's residence at La Fortaleza. Under agreements signed at the Treaty of Paris, Puerto Rico was officially ceded to the United States on December 19, 1898.

At the start of the 20th century, Puerto Rico had a population of nearly 1 million that was mostly poor, agrarian, and illiterate with little or no opportunity for education. Most of the island's land was in the hands of a few wealthy families and absentee owners. Coffee was the dominant export product, but it waned owing to new tariffs imposed by the United States and catastrophic hurricane damage.

Almost overnight Puerto Rico's newly won opportunities for self-rule were gone and all local political power was turned over to the U.S. military government. It abolished the newly formed parliament, local governments were reorganized, and new judicial and tax systems were put in place based on American forms of government.

Many Puerto Ricans identified with American principles of democracy and the hard-won freedoms brought about by the U.S. revolution. They were hopeful that the United States would willingly grant Puerto Rico many new political freedoms. This did not occur. Instead, the U.S. Congress passed the Foraker Act (Organic Act) in 1900. It was more restrictive than the freedoms Puerto Rico had won under the autonomy agreements with Spain. Under U.S. rule, the governor would be appointed by the President, as were all other major office holders, including the justices of the Puerto Rico Supreme Court. Local laws passed by the newly established Puerto Rico House of Delegates were subject to veto by U.S. Congress. Puerto Rico could only send a nonvoting resident commissioner to Congress. The Foraker Act also prohibited Puerto Rico from negotiating trade treaties with foreign nations and retired the Puerto Rican peso at 60 cents to the dollar. This caused a breach in international trade relations and a 40-percent rise in the cost of living. It also caused the price of land to fall and allowed the big wealthy U.S. sugar corporations to come to Puerto Rico and acquire vast areas of land, even though no corporation was allowed to own over 202 hectares (500 acres). This then prompted the rapid rise of sugar as the main exportable crop. Because of the foreign trade restrictions, by 1930 more than 90 percent of the island's sugar trade was with the United States and resulted in a **monoculture** economy for Puerto Rico. The big four U.S. sugar companies were able to show huge profits (22.5 percent return on capital) in the 1920s and 1930s. Much of the profit was due to the extremely low wages paid by the companies to the Puerto Rican workers (63 cents for a 10-hour day in 1917).

The Foraker Act was restrictive politically and economically, but did provide for new and expanded economic activities such as free trade with the United States. It also exempted Puerto Rico and its inhabitants from U.S. taxes. Federal excise taxes on rum and tobacco produced in Puerto Rico were returned to the island's

treasury. Although the Foraker Act was economically good for Puerto Rico, it was despised politically and thus resulted in continued local interest in Puerto Rican independence. This undercurrent, coupled with World War I, caused the United States to review Puerto Rico's status resulting in the Jones Act in 1917. This act granted collective naturalized citizenship to all Puerto Ricans on a voluntary basis. There were 1.2 million Puerto Rico residents at the time and all but 288 accepted citizenship. The Jones Act also allowed Puerto Ricans to enter the United States without travel restrictions, and established a Puerto Rico Bill of Rights, which created a new two-house legislature. Popular elections would decide a 19-member Senate and a 37-member House of Representatives. The Jones Act also required Puerto Ricans to serve in the U.S. military, and 18,000 Puerto Ricans served in World War I. After the war, more attempts at autonomy were proposed but were rejected by the U.S. Congress.

Free trade with the United States greatly enhanced sugar trade, and by the 1920s, 75 percent of the employed people in Puerto Rico were involved in the sugar industry controlled by U.S. corporations. When the world's economy collapsed in the late 1920s, the period of the Great Depression was particularly hard on Puerto Rico. By the 1930s, Puerto Rico's population had grown to 1.5 million, and the effects of the depression increased unemployment, which made living conditions worse. Per capita net income dropped from \$122 in 1930, to \$85 in 1933. The U.S. Congress had its hands full at home and basically ignored the plight of Puerto Rico. As a result, for the first time, hostility and resentment fueled a strong independence movement in the 1930s; however, it was not strong enough to defeat the other pro-statehood parties. In 1936, a new political party and leader emerged who was to dominate Puerto Rican politics for three decades. Luis Muñoz Marín founded the Popular Democratic Party (PDP) or Populares. In combination with an enlightened New Deal Governor, Rexford Tugwell, who was appointed by President Roosevelt, they began to reorganize the economic and social structure of Puerto Rico. Unfortunately, the 202 hectares (500-acre) land provision of the Organic Act was never enforced, and by the end of the 1930s, 51 corporations owned more than 100 000 hectares (250,000 acres), much of it not used for food production. This forced Puerto Rico to import (by design) vast quantities of food from the United States at high prices because of U.S. tariffs. The result was to turn farmers into virtual serfs. One of Muñoz Marín's great initiatives was to press Governor Tugwell to help in the passage of a Land Reform Act. This was finally accomplished in 1941 after the U.S. Supreme Court in 1940 said that Puerto Rico had the right to enforce its land reform laws and limit land ownership to 202

hectares (500 acres) or less. True land reform was the result, with many rural residents now able to buy 10-hectare (25-acre) parcels. This allowed them to grow crops for profit for both export and internal use, thereby breaking up the land monopoly of the large sugar companies. Many see this as the seminal event instrumental in the real socioeconomic gains that would come in the late 1940s with the advent of Operation Bootstrap, a massive effort to raise the standard of living for the island's inhabitants and make the island more self-sufficient. Little attention was paid to gaining Puerto Rico's independence for 10 years, and out of frustration, a schism occurred in the PDP and the modern Puerto Rican Independence Party (PIP) formed in 1946.

Upon Roosevelt's death, Harry Truman appointed a new governor, Jesús T. Piñero, the first Puerto Rican to be named to the post. This created better relations with the United States. The U.S.-Puerto Rico relations were also strengthened as a result of the 65,000 Puerto Ricans who served in World War II. In 1947, Congress amended the Jones Act allowing all future governors to be popularly elected and with power to appoint Puerto Rico Supreme Court Justices. In 1948, the first popularly elected governor was Luis Muñoz Marín.

From 1948 to 1960, Puerto Rico and the U.S. government formulated and implemented Operation Bootstrap. The result was 450 new factories and businesses being started and the beginning of a major transition for Puerto Rico from a largely rural agrarian society, to the modern industrial economy it is today. By 1956, industrial development had surpassed agriculture as the principal source of income. New initiatives in public education and vocational training were part of this program. There was a second phase in Operation Bootstrap in the 1970s that was stimulated by *Fomento*, Puerto Rico's Development Bank and Economic Development Administration. This program attracted capital-intensive industries such as petrochemical and pharmaceutical companies. The Operation Bootstrap Program also made it possible to develop a thriving professional class of lawyers, engineers, business managers, and financial executives needed to make these businesses run. It worked, and Puerto Rico became a showcase for other less developed economies in the Caribbean to emulate.

In 1950, following Governor Muñoz Marín's request, the U.S. Congress declared Puerto Rico a Free Associated State (Estado Libre Asociado), or Commonwealth. As a commonwealth, all existing ties to the United States would remain, but Puerto Rico could now write its own constitution. In the watershed election of 1952, the PDP won 67 percent of the vote, PIP 19 percent, and the pro-Statehood Republican Party (SRP) 13 percent. By 1964, when Muñoz Marín retired from the

governorship, the SRP had grown to 36 percent of the vote, and the PIP had slipped to 3 percent. In 1967, there was a plebiscite over Puerto Rico's political status with the options being commonwealth, statehood, or full independence. In that instance, independence was soundly defeated, with statehood coming in second (39 percent) to the island's current commonwealth status (60 percent). Congress in 1979 passed a resolution supporting Puerto Rico's right to self-determination. Under new leadership the pro-statehood party was renamed Partido Nuevo Progresista (PNP) and, to date, has elected three governors. However, even with a PNP governor, in the last political status vote of 1998 the commonwealth received 49 percent, statehood 46 percent, and independence 4 percent. Once again in 1998, Puerto Ricans demonstrated their preference for the status quo. In November 2000, Puerto Rico elected the first female governor, Sila María Calderón, who ran as an anti-statehood candidate for the PDP. The current governor of Puerto Rico, Aníbal Acevedo Vilá, is from the PDP party.

Puerto Rico elects a new legislature and governor every 4 years. Governors can serve a maximum of two consecutive terms. The Governor appoints a cabinet consisting of his or her department heads. The bicameral legislature is made up of two houses; the House of Representatives has 54 members and the Senate 28. Both houses are popularly elected. The government operates on a model similar to that of the United States, and Puerto Rico is set up like 1 of the 50 states. The island has 78 political districts (municipalities; fig. 3) and each has its own local political machine and locally elected officials such as city mayors and town councils.

Puerto Rico now participates in U.S. presidential primaries and sends delegates to the national political conventions, but it still does not have any voting representation in U.S. Congress, nor do Puerto Ricans vote for the President unless they reside in one of the 50 states. Puerto Rico cannot enter into treaties, issue money or passports, maintain armed forces, or exchange diplomats with foreign countries. They still do not pay any federal taxes, but as it turns out, commonwealth taxes are usually as high as U.S. taxes. Should Puerto Rico strongly indicate by vote and formal request its desire to become the 51st state, all that Congress would have to do is pass an enabling act by simple majority of both houses and have it signed by the President. There are three standards for statehood consideration: (1) that the new citizens abide by the American form of government, (2) that the majority of the commonwealth's electorate wants statehood, and (3) that they be able to meet their state and federal obligations.

Contemporary Puerto Rico

Population—

According to the 2000 U.S. census, the island of Puerto Rico has a population of slightly over 3.8 million compared to 3.15 million in 1990. There are also another 3.4 million Puerto Ricans residing in the United States, largely in metropolitan areas such as New York, Philadelphia, Chicago, and Orlando. More Puerto Ricans now live in Florida than in the capital of San Juan. These mainland residents are an outgrowth of a migratory shift in the Puerto Rican population that began in the 1950s and 1960s largely as a result of rapid population growth and poor economic opportunities on the island. Migration had an “Alice in Wonderland” effect, that is, the economy had to run very fast just to stand still because, during that period, Puerto Rico’s birthrate was 35 per 1,000, while its death rate had dropped to only 7 per 1,000, so the population was growing rapidly. This migration trend was still occurring in the 1990s when on average 6,500 people per year left the island. Although Puerto Rico’s population is still growing, its rate of increase is declining and may not be sufficient to replace itself (0.6 percent/year) in the long term.

The island’s population is primarily urban (72 percent), with greater San Juan having a metropolitan population in excess of 1 million. The remaining 28 percent is spread throughout the rural areas except for restricted commonwealth or federal lands. Puerto Rico has one of the highest population densities in the world, in excess of 450 per square kilometer (1,100 people per square mile). Population density in metropolitan San Juan is about 4000 per square kilometer (10,000 per square mile). Life expectancy is slightly lower than in the United States at 80 years for females and 71 years for males. Infant mortality is somewhat higher than in the United States with 13.4 deaths per 1,000 live births.

Puerto Rico has a growing elderly population; people 60 years or older account for over 15 percent of the population. Those under 19 years account for about 33 percent of the population. According to the 2000 census, over 80 percent is white, 8 percent is black, and approximately 12 percent are members of other ethnic groups.

Puerto Rico is Spanish in atmosphere and culture. The island’s population is 99.9 percent Hispanic and the first language is Spanish, with English as its second language. Most Puerto Ricans know some English, as it is a compulsory subject in the school system. Many older people use it sparingly, and school dropouts often do not attain fluency; thus English fluency is estimated to be less than 50 percent. The island’s government is officially bilingual. The language and culture issues are quite contentious, as most Puerto Ricans do not want to give up their Spanish

heritage. Many still identify closely with Spain and Spanish-speaking South and Central American countries and do not want to give up Spanish as their official language. Historically, the religion of the island's people has been mostly Roman Catholic. Many non-Catholic denominations actively came to Puerto Rico looking for converts, especially the Adventists and Mormons. Today the people are 40 percent Roman Catholic, 40 percent Protestant, and 20 percent other religions. Puerto Rico is also North American in status and progress because of its unique commonwealth status with the United States. High standards of health, food preparation, water treatment, education, and the presence of organizations such as the Rotary Club, the Masons, the Lions Club, the Elks, and the Boy Scouts and Girl Scouts of America all provide a North American flavor to the island.

Puerto Rico has a 90 percent literacy rate. There are over 600,000 public school students, making it the third largest school district in the United States. Education is compulsory from ages 5 to 21. About 42 percent of Puerto Rican young people graduate from high school and many pursue advanced education. The University of Puerto Rico was founded in 1903 as a U.S. land grant institution (fig. 4). Its main campus in Río Piedras is a fully comprehensive Ph.D.-granting, teaching/research liberal arts university, with a law and medical school. Its land grant counterpart at Mayagüez offers a full array of degrees, and houses the engineering, agriculture, and marine sciences programs. The university also has a designated liberal arts campus at Cayey and eight other campuses. Total enrollment today is more than 71,000. The university's combined budget is more than \$1 billion per year. There are 30 campuses of higher learning in Puerto Rico, and they graduate nearly 45,000 students per year.

Economics—

Puerto Rico is still very economically dependent on the United States. The U.S. presence affects Puerto Ricans' economic lives every day, from the U.S. currency in their pockets, to the many products sold on their store shelves. The U.S. government subsidizes Puerto Rico with about \$15.48 billion in federal assistance payments yearly, which covers everything from education to food stamps. It is estimated that in 1999, federal subsidies for unemployment compensation and housing for a family of four cost the U.S. government over \$19,000 per year. Should Puerto Rico become the 51st state, it would be eligible for another \$3.5 billion in federal assistance (estimated). Approximately 40 percent of Puerto Rico's economy has been based on special tax exemption legislation that allows U.S. manufacturers to avoid paying federal tax on profits made in Puerto Rico. This is estimated to be in excess of \$4 billion per year. The U.S. industries benefit from operations in Puerto



G. Miller

Figure 4—View of the main campus of the University of Puerto Rico, Río Piedras with the bell tower and royal palms lining the entrance.

Rico and generate billions of dollars in annual revenue. Puerto Ricans also benefit from the federal guarantee on bank savings, and from the millions of dollars received in disaster relief after a hurricane. Per capita income for the island is \$7,600 a year, which is half that of the poorest state, Mississippi, but considerably higher than its nearest Greater Antilles neighbor, the Dominican Republic, where average per capita income is only \$1,600 per year. More than 37 percent of households earn less than \$10,000 per year. Official unemployment fluctuates between 11 and 20 percent, although there is considerable employment in various activities not included in the official statistics. Actual unemployment is probably higher, and may in fact be close to 20 percent. In 2000, 1.15 million people were employed. Nearly 60 percent of the population falls within the U.S. government’s poverty definition, and over 30 percent of the population receives some form of public assistance. This includes some 425,000 families (1.1 million people) who received an average of \$220 a month in the nutritional assistance program. It is estimated that

as much as 50 percent of this money (\$650 million) goes to purchase nonfood items. According to the 2000 census, approximately 73 percent of homes are family-owned, and 64 percent of families own one or two automobiles.

The U.S./Puerto Rico association is also beneficial to the United States. The U.S. economy benefits on the order of \$720 billion as a result of commerce with the island and the many U.S. companies located in Puerto Rico. Puerto Rico must use the U.S. Merchant Marine to transfer its products and cannot engage in international commercial activity without the consent of the United States. The United States has used Puerto Rico as a strategic military base since the turn of the 20th century, and it remained the U.S. Navy's primary training facility for amphibious warfare and carrier-based tactical bombing practice until 2003.

As cited earlier, numerous U.S. manufacturers have built manufacturing plants in Puerto Rico and account for 42 percent of the gross domestic product (**GDP**) employing about 24 percent of the workforce (160,000). Industry is the main source of income for Puerto Rico. The services sector accounts for 37 percent of GDP and employs 291,000 people. Various government agencies produce 11 percent of GDP and have 245,000 employees. The utilities sector also produces 11 percent of GDP, with 32,000 employees. Agriculture today accounts for only 1 percent of GDP and employs 26,000. Construction employs 85,000 people. Puerto Rico now has 70 pharmaceutical firms whose products are viewed as recession-proof. Puerto Rico exports more than \$25 billion in products ranging from medicine, refined petroleum products, scientific equipment and machinery, to rum, clothing, and shoes. Unfortunately, the island's high-value mineral resource base is quite limited. It has a large population on a small land base, and island food production is now low. This results in the need for islanders to spend billions on food imports. In spite of this, Puerto Ricans enjoy the highest standard of living and per capita income in Latin America.

In August 1996, the U.S. government began the phasing out of federal tax benefits that had positioned Puerto Rico as the preferred site for stateside manufacturers. This resulted from the fact that not enough new jobs were being created for the large amounts of tax writeoffs the multinational corporations were receiving. This came at a time when the federal government was also trimming budgets and eligibility for social welfare program spending and preferential treatment for Puerto Rican products. As a result, from 1996 to 2000, Puerto Rico lost 16,500 manufacturing jobs. By early 2002, the total had risen to 27,000 jobs lost. In light of these changes, Puerto Rico's government is developing a new economic development program called the "New Economic Model," which has tax incentives, increased

foreign trade and investment, and greater-self reliance as major themes that will lead Puerto Rico's economy into the new millennium. The Puerto Rico government is also trying to convince Washington to amend Section 956 of the federal tax code, which again would provide favored tax status for controlled foreign corporations operating in U.S. territories. This would permit up to 90 percent of their earnings to be returned to the United States without taxation. There is also discussion about trying to have Puerto Rico included in the Earned Income Tax Credit system of the U.S. tax code, as it would subsidize minimum-wage employees, bringing wages up to \$14,000 or \$15,000 per year.

Another aspect of Puerto Rico's economy, of which little is known, is the informal, unregulated, and illegal underground economy. This is mostly a cash and service economy. The illegal trade of drugs, for example, has an estimated gross cashflow of \$20 billion per year according to the Drug Enforcement Agency. An estimated 20 percent of all cocaine imported into the U.S. enters via Puerto Rico and the U.S. Virgin Islands. Four billion dollars remain in Puerto Rico and surface in the economy. For example, the largest Puerto Rican bank (Banco Popular) was fined \$21 million for not reporting hundreds of millions of dollars in questionable cash transactions in one of its banks in Old San Juan. Some Puerto Ricans take the view that it does not pay to work in the official economy and that they are better off getting welfare payments, food coupons, and taking part in the underground economy. The underground economy may be as high as one third (or more) of the total island economy. All of which is untaxed and unregulated.

For more information on Puerto Rico's history, see Aliotta 1994, Cockburn 2003, Dietz 1986, Fernández 1996, Golding 1973, Haslip-Viera 2001, Lewis 1963, López 1981, Morris 1995, Rouse 1993, U.S. Department of Commerce 2001, and U.S. Department of the Interior 1996.

Physical and Climatic Zones of Puerto Rico

Geography

Puerto Rico is the smallest of the Greater Antilles chain, which also includes Cuba, Jamaica, and Hispaniola (Haiti and the Dominican Republic). Puerto Rico is 145 kilometers (90 miles) from the Dominican Republic to the west and 67 kilometers (40 miles) from the U.S. Virgin Islands to the east. It is 1665 kilometers (1,000 miles) southeast of Miami and 2840 kilometers (1,700 miles) south of New York City. On the north and east side is the Atlantic Ocean, and on the south and west is the Caribbean Sea. It is positioned at the north end of a group of lesser islands that

form an arc running down to Venezuela 847 kilometers (525 miles) to the south. They are called the Lesser Antilles and include the U.S. and British Virgin Islands, French Guadeloupe, Martinique, and numerous other islands down to Grenada, Barbados, and Trinidad. All totaled, in the Greater and Lesser Antilles, there are approximately 7,000 islands that make up what are called the West Indies (fig. 2).

The land area of Puerto Rico and adjacent islands is 8897 square kilometers (3,435 square miles). It is 56 kilometers (35 miles) north to south, 176 kilometers (110 miles) east to west, and is rectangular in shape. Puerto Rico is somewhat smaller than the state of Connecticut. Its coastline is 500 kilometers (311 miles) with numerous harbors and beaches. Its land cover is variable, with much of the center of the island consumed by high mountains (40 percent), surrounded by foothills (35 percent), and a narrow coastal plain (25 percent). Virtually all of the coastal plain is in intensive agriculture, roads, or under urbanization. In a recent study by Helmer et al. (2002), they found that 41.6 percent of the island is now covered by closed forest, 36.7 percent is in pasture and grassland, 5.9 percent is in agriculture, 2.4 percent is in coffee plantations, 10.5 percent is urban/developed, and 3.9 percent is in various other categories including mines, rock/sand areas, salt and mudflats, emergent wetlands, and water bodies. Approximately 5 percent of Puerto Rico's forest area is under protection.

There are a variety of ecosystems distributed laterally and vertically according to **topography**, altitude, soils, rainfall, and a variety of other factors. The island lies directly in the path of the trade winds that blow from the Atlantic Ocean to the east. This assures a fairly reliable source of rain and occasionally a hurricane or two. The presence of high mountains creates a very interesting rainfall pattern resulting in the creation of an **orographic rain shadow** on the Caribbean side of the central mountain ranges, and some rain shadow valleys in the interior sections of the mountains.

The highest altitude on the island is 1338 meters (4,389 feet) in the Cordillera Central range at Cerro de Punta, and there are numerous peaks over 915 meters (3,000 feet). Cerro de Punta is just north of Ponce within the Toro Negro Commonwealth Forest and can be accessed by Route 143 (Luis Muñoz Marín Panoramic Highway). Mountains can be seen from anywhere on the island. The entire center of the island is a continuous series of mountains that basically cuts the island in half as they run east to west from Humacao to Mayagüez. Approximately 25 percent of the island is above 305 meters (1,000 feet) altitude. The high mountains exhibit high degrees of slope to the south and east, and the north slopes are heavily eroded with numerous river valleys. The south slopes tend to be dry much

of the year owing to the orographic rain shadow. During tropical storms and hurricanes, rivers on the south coast may become rapid torrents that flood extensive areas and often kill domestic grazing animals or human squatters living in the dry riverbeds or flood plains. The Cordillera Central has a break in the area of Caguas, and the mountain range located northeast is the Sierra de Luquillo. This range also has a series of peaks in excess of 915 meters (3,000 feet), and these peaks experience the highest amounts of rainfall on the island. The Luquillo range includes the El Yunque National Forest, also designated as the Luquillo Experimental Forest and known as the world-famous Luquillo Rain Forest or El Yunque. This 11 200-hectare (28,000-acre) forest is a biosphere reserve site and attracts about three quarters of a million visitors per year.

The soils of the coastal plain are conducive to agriculture, and much of it was cleared in the 17th and 18th centuries for sugarcane. Adjacent to the coast, the land is fairly level and has been converted to agriculture, urban development, and transportation corridors. Periodically, there are rocky promontories and karst foothills such as those near Arecibo, Fajardo, Cabo Rojo, and Guánica. Sand dune areas and beaches such as at Isabela, Piñones, Luquillo, and Boquerón dot the coastline.

Climate

Puerto Rico is in that large area north and south of the equator called the tropics (25° N and S). Its maritime climate is very pleasant because it is bathed by warm sea breezes throughout the year. This prevents major fluctuations in temperature. Rainfall is distributed throughout the year, with May through November considered the rainy period. January to March is a bit dryer, but may have cold fronts coming in from the temperate zone to the north that can produce 1 to 2 days of rain. Extremes in temperature are rare, with high temperatures rarely going into the mid 30s °C (90 °F) except on the south coast and lows rarely below 25 °C (60 °F) in the mountains. Smallest daily temperature fluctuations occur in the coastal plain 5 to 8 °C (10 to 15 °F), whereas the mountains experience the largest daily fluctuations 8 to 12 °C (15 to 20 °F). There is not much variation seasonally like there is in the temperate zone, in fact there is greater night to day temperature variation than there is seasonally. However, there is considerable variation in temperature and precipitation resulting from variable topography and prevailing winds. The east-west mountain chain intercepts the easterly trade winds; thus it provides the north side with an abundance of rain. The Cordillera Central and Luquillo ranges cause the warm moisture-laden air masses to cool and lose much of their moisture

as they pass over the north and eastern sides. As they pass over the mountains, the amount of rain decreases resulting in the south coast being much dryer (fig. 5).

Areas in the Luquillo Rain Forest often receive more than 5000 millimeters (200 inches) of rain, whereas areas in the Guánica Forest 42 kilometers (50 miles) away may only receive 900 millimeters (36 inches). The capital city of San Juan annually receives 1700 millimeters (68 inches) of rain on the north coast, whereas the second largest city, Ponce on the south coast, receives only 950 millimeters (38 inches). Some areas on the south coast may receive only 254 millimeters (10 inches) in dry years. The island's average rainfall is 1800 millimeters (71 inches) per year.

The mountainous topography produces temperature variation. In general, for every 300-meter (1,000-foot) increase in altitude, temperature decreases 2 to 3 °C (3 to 4 °F). On average, San Juan's coastal temperature will be 4 °C (7 °F) warmer than a town in the mountains such as Barranquitas. Many mountain communities experience almost idyllic climate, with temperature regimes that require neither air conditioning nor heating. People in the warmer, more humid coastal areas may use air conditioning throughout the year. Puerto Rico does not experience freezing temperatures, even in the highest mountains where temperatures rarely fall below 18 °C (65 °F). Much of the island experiences high humidity year round.

Many streams are formed as a result of the mountainous terrain. There are hundreds of mapped streams on the island, 50 of these are classed as rivers. Most rivers on the north side are larger in volume and length. Six major rivers originate in the Luquillo chain. Most of the rivers are dammed and used for regional or community water supplies, irrigation, and power production. The majority of the reservoirs have problems with **sedimentation**, water quality, and introduced exotic aquatic plants such as *Eichornia crassipes* (Mart.) Solms (water hyacinth) and *Pistia stratiotes* L. (water lettuce).

Hurricanes

The island is in the hurricane belt of the western Atlantic and Caribbean. Most hurricanes form as tropical lows off the coast of Africa from June through October and intensify as they proceed west over the warm waters of the Atlantic. Hurricanes are Puerto Rico's number one weather problem because of the catastrophic high winds and waves, large volumes of rain, and the enormous structural change they can produce on natural ecosystems, and on human populations and their infrastructure. Most hurricanes are peripheral and produce minor effects, but those termed killer hurricanes owing to their intensity and direct hits, have the potential to produce

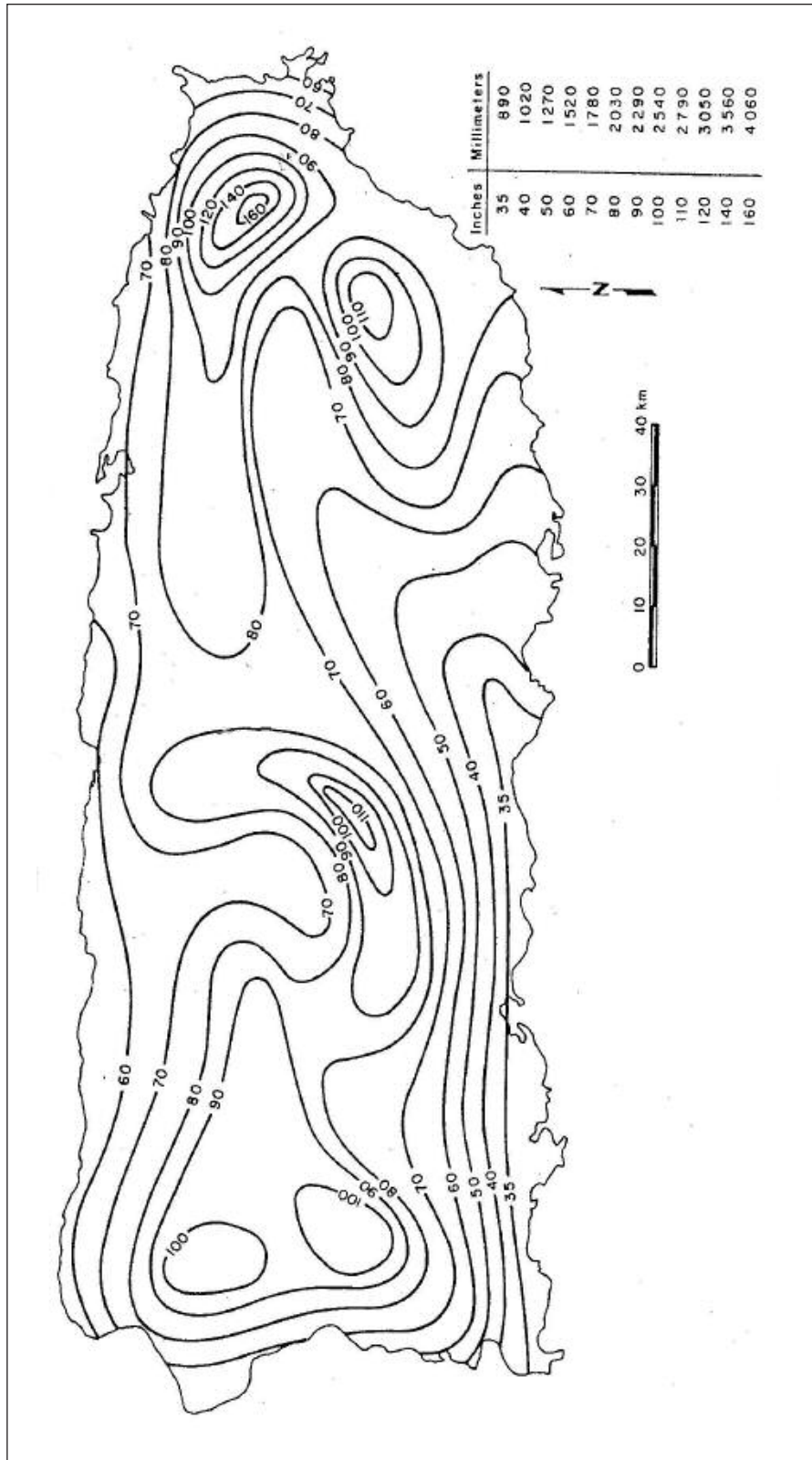


Figure 5—Annual mean precipitation for Puerto Rico.

enormous damage and hardship. Typically, 6 to 10 hurricanes develop yearly in the western North Atlantic region. Hurricanes have impacted Puerto Rico recently, with Hortense, Hugo, and George classed as major hurricanes. A separate section on hurricanes and other disturbances follows, and hurricane effects are discussed in the sections on forest zones and coral reefs.

Geology

Geologically, Puerto Rico is complex. Its origin is volcanic, and it initially arose as a result of seismic activity associated with the Caribbean-North American plate boundary zone. The initial formation was believed to have been 140 to 200 million years ago in the Triassic era. These **volcanic** deposits were then folded, faulted, and uplifted to produce the Cordillera Central Mountains province (fig. 6). Puerto Rico is relatively young, only about 100 million years old. Evidence of its volcanic period can be seen in weathered pillow lavas observable in road cuts south of Cayey on Route 52. Secondary **metamorphic** and **igneous** activities resulted in **gneisses** and **serpentinite** formations. Large outcrops of serpentinite occur on the western end of the Cordillera Central in the Maricao district west to Mayagüez (app. 2). This is a beautiful blue-green rock that produces a soil typically low in calcium and high in chromium or other metals. Some plants in western Puerto Rico show hyper-accumulations of nickel (Brooks 1987).

Younger sedimentary rocks and sediments are present throughout the coastal plain province. The carbonate province is located on the flanks of the central mountain core and is composed of marl, dolomite, and calcareous sandstones. On the north coast there is a spectacular display of karst topography that ranges back to 30 million years. A large area of limestone is located along the south coast and underlays the Guánica subtropical dry forest. In the karst district that runs from Loíza to just east of Aguadilla, many haystack-shaped hills dot the landscape by the thousands. They are locally called mogotes or **haystack hills**.

The rivers that run north from the Cordillera Central in the karst area produce deep cuts in the landscape owing to differential rates of erosion in the limestone. Some of the rivers periodically run underground in association with caves. There are thousands of caves and **sinkholes** in the region (see app. 2). A more detailed description of karst will be presented in the forest zone section.

Puerto Rico's geological formations have yielded very few mineable mineral resources. In the early 1500s, gold was mined, but gold was basically gone by the 1570s. Some commercial gypsum, dolomite, and phosphate have been mined (app. 2). Today, extensive areas of **aggregate** and road metal are being consumed. Most

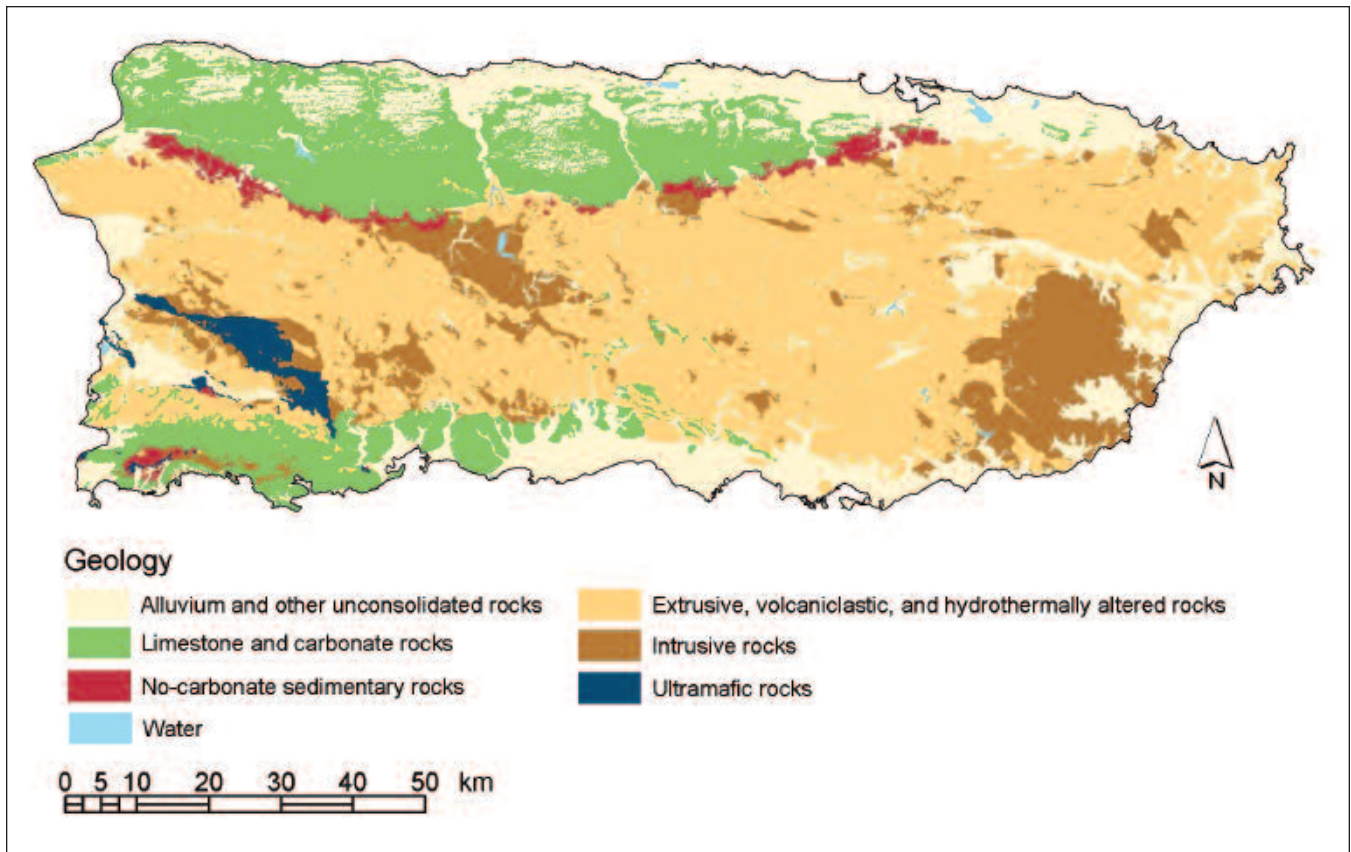


Figure 6—Geology of Puerto Rico.

houses today are constructed from cement. Large quantities of beach sand are mined, but at great expense to commercial grade beaches and resulting in areas of extensive coastal erosion such as at Isabela on the north coast. The most productive aspects of mining are nonmetals such as clays, marble, stone, sand, gravel, limestone, and salt. There are deposits of nickel and copper on the island. There is a large deposit of low-grade copper in the Cordillera Central near Lares. It has not been mined owing to cost, low metal concentration, and environmental concerns. There are peat deposits on the north coast, but probably not extensive enough for commercial mining. Roughly 10,000 workers are employed in mineral-related industries concentrated in the San Juan and Ponce areas. Puerto Rico has no coal, oil, or natural gas deposits. Fossil fuels, mainly oil, supply 90 percent of its power, and they must be imported. About 10 percent of its power is derived from dammed rivers. Many homes and businesses use **passive solar heating** for hot water.

Soils

Soil is the product of the weathering of rocks. When water runs across or through parent geologic strata, erosion and **leaching** occurs. Various other physical, chemical, and biological conditions of the environment further aid in the weakening and disintegration of these strata promoting the accumulation of released particles in the formation of soil. Many conditions are responsible for the characteristics exhibited by each soil type such as composition of the original substrate, slope, temperature, **aspect**, rainfall, acid rain, biological activities, and gaseous content to name a few. These conditions lead to the specific colors, structure, and nutrient availability of each soil. Because of its complex geology and climate, Puerto Rico shows a variety of soils, with 9 of the 11 possible soil orders present. The most extensive soil group is the Inceptisols, which cover 37 percent of the island. Inceptisols are found on steep slopes of 20 to 60 percent in eastern Puerto Rico. Many of these soils are eroded owing to cultivation on steep slopes. Inceptisols are typical of mountainous areas, are only slightly weathered, and their horizons are still developing. Landslides frequently occur on these soils.

Ultisols cover nearly 27 percent of the landscape and are found in uplands of the western sections of the Cordillera Central. These are typical of humid environments, usually nutrient poor, and mostly found on ancient strata or highly weathered alluvial sites. Mollisols constitute 21 percent of the island's soils and are found over limestone in the rain shadow foothills on the south side of the Cordillera Central, on limestone sediments on the north coast, and in various flood plains and alluvial fans in river systems. They have a dark, thick A-horizon; are soft and crumbly; and are high in organic matter. Six other soil orders cover the remaining 15 percent of the landscape (fig. 7).

Puerto Rico has 29 suborders and 164 classified soil series. About 28 percent of the island has soils suitable for agriculture. Much of this was historically used for sugarcane production. Today, some of the best soils are disappearing in areas undergoing rapid urbanization. This is critical because Puerto Rico is heavily dependent on food imports and the loss of the best agricultural soils only increases that dependence. For additional descriptions of the soils of the Caribbean and Puerto Rico, see the recent review by Lugo et al. 2000.

The physical features just described have a direct effect on the distribution of plant species and communities. Plant communities are distributed over the landscape based on elevation, soils, geology, rainfall, temperatures, aspect, and numerous interactions among other plants and animals; the distribution of communities

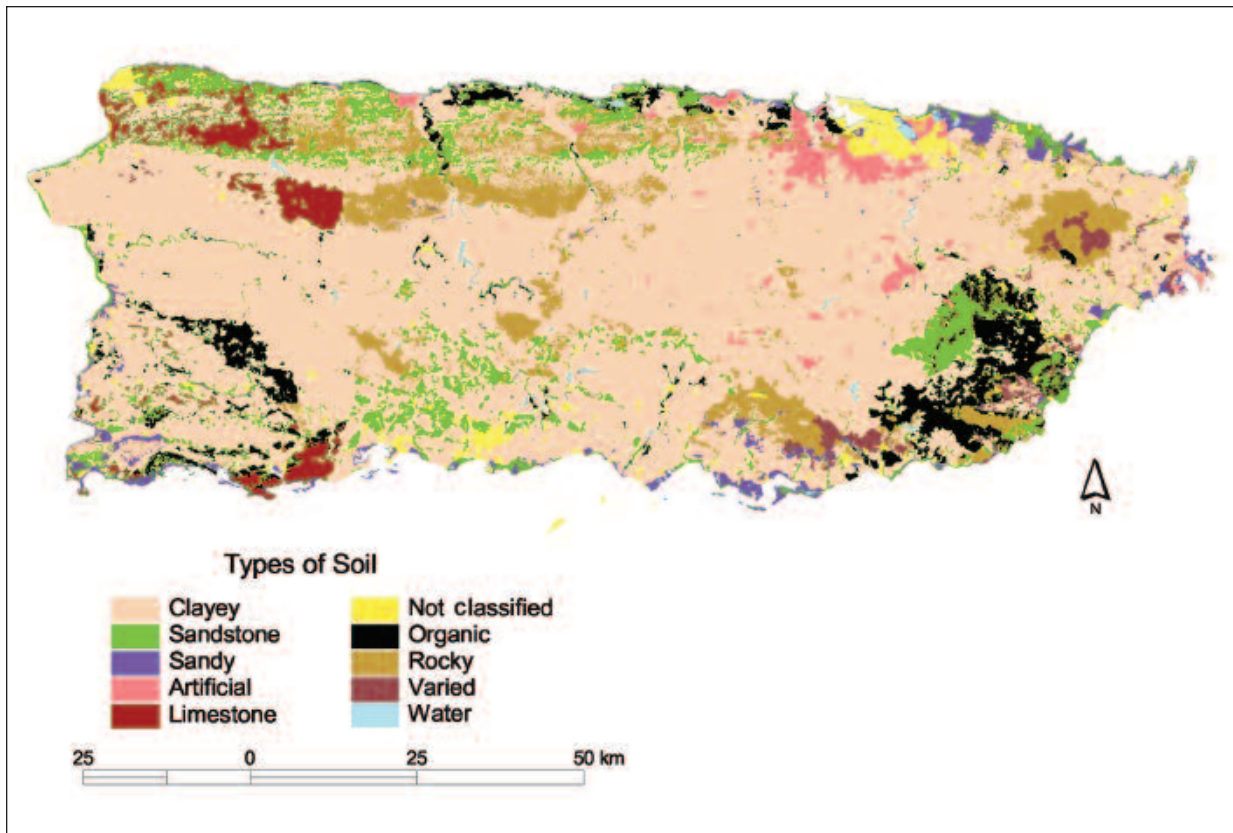


Figure 7—General soils of Puerto Rico.

Table 1—Forest type and distribution of parent material

| Parent material | Forest type based on climate | | | |
|-----------------|------------------------------|--------------|------------|-------------|
| | Dry forest | Moist forest | Wet forest | Rain forest |
| Alluvial | X | X | | |
| Limestone | X | X | X | |
| Ultramaphic | X | X | X | |
| Volcanic | | X | X | X |

that results spatially are referred to as plant geography or **phytogeography**. Later in this document is a description of the major forest types of Puerto Rico that will relate to these factors. However, for now, note that the major forest type distributions are related closely to parent materials as seen in table 1.

For more information on the physical and climatic zones of Puerto Rico, see Beinroth 1969, 1971; Birdsey and Weaver 1982; Bush et al. 1995; Calvesbert 1970; Giusti 1980; Lugo-López and Rivera 1977; Malfait and Dinkelman 1972; Monroe 1980; Picó 1974; and Weaver 1992.

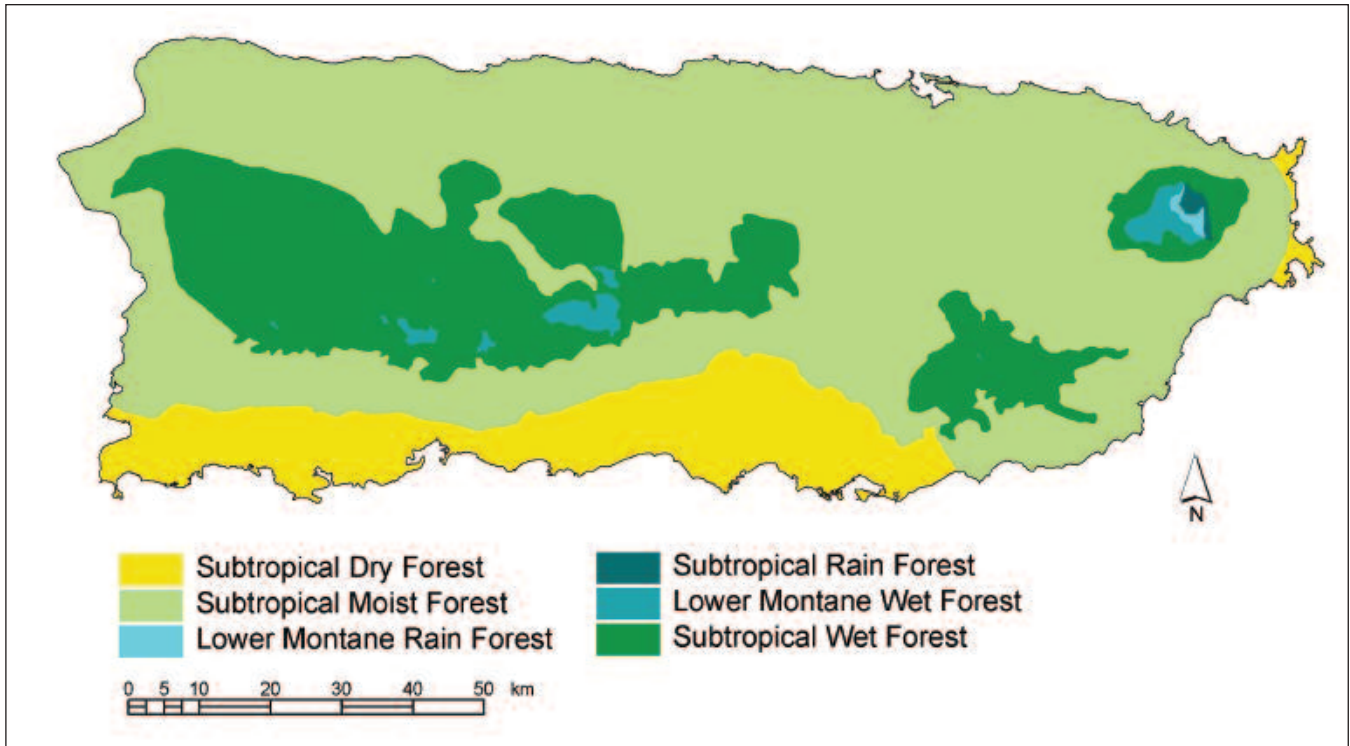


Figure 15—Ecological life zones of Puerto Rico.

- 500 to 1000 millimeters (20 to 40 inches) - dry forest
- 1000 to 2000 millimeters (40 to 80 inches) - moist forest
- 2000 to 4000 millimeters (80 to 160 inches) - wet forest
- 4000 to 8000 millimeters (160 to 320 inches) - rain forest

According to the Holdridge system, Puerto Rico has six subtropical life zones ranging from dry through moist forest zones in the basal, or sea level belt. In the wet and rain forest zones of the lower montane altitudinal belt, there are four forest zones. Figure 15 shows the major forest life zones of Puerto Rico.

The area occupied by each life zone is presented in table 14. The subtropical moist forest is the largest life zone, covering more than 59 percent of Puerto Rico, whereas the subtropical lower montane rain forest is the smallest life zone. Unfortunately, most forests of the subtropical moist forest zone have been destroyed.

The forest zones described in this section can all be seen in the 14 commonwealth forests and nature reserves located throughout Puerto Rico. See the location map and short descriptions in the “Commonwealth Forests and Nature Reserves” section that follows.