USDA

EL YUNQUE NATIONAL FOREST

ATLAS

Forest Service International Institute of Tropical Forestry General Technical Report IITF-GTR-47 JUNE 2018

El Yunque National Forest

and Luquillo Experimental Forest

Atlas

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El Yunque National Forest Atlas

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Contents

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Thank you to the reviewers who offered their time to help improve this atlas. Finally, we thank all the scientists, technicians, administrators, and foresters who dedicate their lives to the study and management of El Yunque National Forest and the Luquillo Experimental Forest. They have helped broaden the science and management of tropical forests and have enlightened us about this very special place in the Puerto Rican culture.

All research at the International Institute of Tropical Forestry is done in collaboration with the University of Puerto Rico.

Preface

El Yunque National Forest Atlas is a collaborative effort by the International Institute of Tropical Forestry and El Yunque National Forest to provide up-to-date maps and analyses of spatial information of an important natural reserve in Puerto Rico and the only tropical forest in the National Forest System of the United States.

El Yunque National Forest Atlas serves as a companion tool to the *El Yunque National Forest 2014 Forest Plan Assessment Report*, Phase One, under the U.S. Department of Agriculture (USDA), Forest Service 2012 Planning Rule. The assessment documents current ecological, socioeconomic, and cultural conditions of the forest and the surrounding landscape, as part of the El Yunque National Forest management plan revision process, which will establish requirements and constraints to make management decisions within the forest. The *El Yunque National Forest 2014 Forest Plan Assessment Report* is available at: https://go.usa.gov/cS5Tk.

This atlas visually summarizes information about El Yunque and the land where it rests, the water that flows from its peaks and the animals and plants that call it home; social and economic data from the municipalities that harbor it; management and research activities within the forest, and recreation and tourism activities available to visitors. The geographic information mapped in this atlas represents the latest available data as of March 2016. We used a numbered reference system, in which the information throughout the atlas has superscripted numbers that corresponds to the references listed in the references section, starting on page 57.

The information presented herein is based on the best available science as compiled by the authors and the El Yunque National Forest Management Plan Interdisciplinary Team, a group of professional scientists, foresters, and managers who were convened to work on the management plan revision process and the *2014 Forest Plan Assessment Report*. Following, is a list of the contributors to the *El Yunque National Forest 2014 Forest Plan Assessment Report*.

El Yunque National Forest 2014 Assessment Report Contributors

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INTRODUCTION

Photo by Jerry Bauer

EL YUNQUE

National Forest, also designated as the Luquillo Experimental Forest, represents many things to many people. It is the easternmost, southernmost, wettest, most biologically diverse forest in the National Forest System of the United States. It has been recognized as a source of forest resources since the days of the Spanish Crown, and as a cultural resource since indigenous people inhabited Puerto Rico. In this atlas we present some of the most recently developed spatial information about El Yunque National Forest and surrounding lands.

The peaks of the Luquillo Mountains where the forest grows, reach heights of just over 1000 meters, and rising air masses release abundant rainfall from moisture-laden trade winds arriving from the east. In the short distance from the coast to the peaks, annual rainfall increases fourfold. Cloud forests rich in endemic species inhabit the peaks and streams flow down all sides of the mountains, bringing clean water to the people of Puerto Rico and connecting the land and sea environments. Fish and shrimp spawning in the sea live in the mountain streams. Birds, bats, coquís, and boas call the mountains home. Most of the oldest primary forest remnants of Puerto Rico are found in these mountains at higher elevations, with novel secondary forest stands in the lowlands. Together, they house more tree species than all the other national forests and grasslands combined.

The forest is a source of recreation, research, and ecosystem services for the people of Puerto Rico, the Caribbean, and the world. This atlas maps the history, land and water resources, habitats and wildlife, and human uses of the forest so that managers, researchers, visitors, and neighbors have a shared vision of the value of El Yunque National Forest.

How to get to El Yunque

from the Luis Muñoz Marín International Airport in San Juan, Puerto Rico

Driving directions:

- Exit main airport road (PR-17) and enter the Román Baldorioty de Castro highway (PR-26) toward the east.
- The highway will merge into highway PR-66 (toll road).
- Continue on PR-66 until it ends on an intersecton with PR-3 Avenue. Turn right (east).
- Stay on PR-3 for approximately 6.3 km.
- Turn right into Triunfo street until it ends at Principal Street (PR-955).
- Here, turn right and take your first left to PR-191— it's a very short distance between turns.
- Continue on PR-191 until you reach the forest. Near the entrance to the forest you will find the El Portal Visitor Center to your right.

Enjoy the forest and all its wonders!

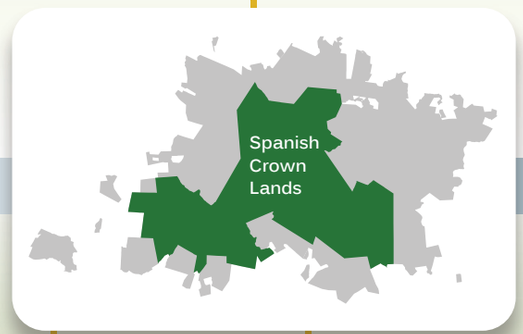
GPS coordinates

Forest Headquarters	18° 20' 18.7" N, 65° 45' 39.9" W
El Portal Visitor Center	18° 20' 22.2" N, 65° 45' 43.2" W
Palo Colorado Visitor Center	18° 18' 03.3" N, 65° 47' 07.5" W

El Yunque National Forest (1876 –2017)[1]

1876

King of Spain Alphonso XII proclaims 10 000 ha (24,710 acres) of forested land in the Luquillo Mountains as a forest reserve.



1903

President Theodore Roosevelt establishes the Luquillo Forest Reserve.

The Sabana River valley was heavily timbered.

1905

The USDA publishes its first detailed report about the forest and its resources.

1931

First mahogany plantations.

The Puerto Rican parrot population is estimated at 2,000 birds.

1932

First National Forest Policy Statement—acquisition of 20 234 ha (50,000 acres) of forest across the island.

1935

Additional land surrounding El Yunque is purchased.

La Mina Recreation Area opens.

1934-1948

Puerto Rico's forests:

- Estimates show only 6% of Puerto Rico to be forested.
- Major reforestation program begins.
- 1589 ha (3,926 acres) of land inside El Yunque are reforested.
- The Civilian Conservation Corps (CCC) constructs 105 km of roads, 80 km of trails, towers, picnic areas, cabins, a fish hatchery, swimming pools, and a restaurant in forests across the island.
- 60 million trees are given to island farmers.

1939

The USDA Forest Service Tropical Forest Experimental Station (later known as the International Institute of Tropical Forestry) is established in Río Piedras.

1940-1943

The Forest Highway (PR-191) and El Verde Research Station are completed and long-term research plots begin.

Wartime needs boost El Yunque timber sales for charcoal production.

1946

Gold mining on the Mameyes River inside the forest is abandoned.

1949

852 ha (2,105 acres) of the Mameyes River valley is designated as the Baño de Oro Research Area.

1953

Low demand stops timber extraction for charcoal production.

1956

The forest is designated the Luquillo Experimental Forest to recognize the growing importance of research.

1961

An arboretum of more than 100 tropical tree species is established.

1963

Yokahú Observation Tower opens.

Juan A. Rivero discovers *Eleutherodactylus hedricki*, a new species of coquí tree frog.

The white-necked crow is last seen.

1968

The Puerto Rican parrot (*Amazona vittata*) is listed as an endangered species; an estimated 13 parrots remain in the wild. Formal research efforts to save the parrot begin.

1971

The elfin woods warbler (*Dendroica angelae*), a bird endemic to Puerto Rico, is discovered at high elevations in the forest.

1976

The forest is designated as a biosphere reserve by the United Nations.

1988

The Long Term Ecological Research (LTER) program begins in collaboration with the University of Puerto Rico.

1996-1997

El Portal Center exhibit opens to promote public education and forest conservation.

The forest Land and Resource Management Plan is approved.

2002

The Icacos, La Mina, and Mameyes Rivers are designated as “Wild and Scenic Rivers.”

2005

El Toro Wilderness Area is established.

2009

The Luquillo Critical Zone Observatory (LCZO) is established within El Yunque.

2012

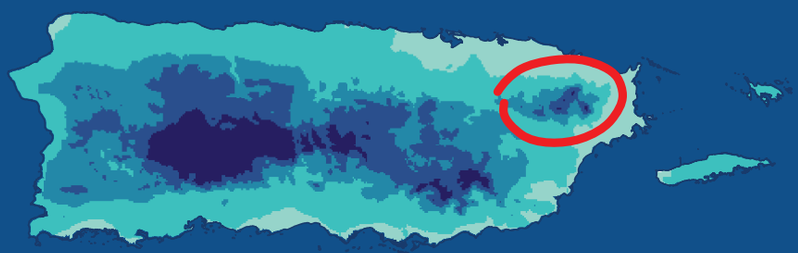
A revised forest management plan starts to be developed based on the best available science and input from the public.

2017

New management plan in final revision process.

Puerto Rico climate at a glance:

Maximum temperatures

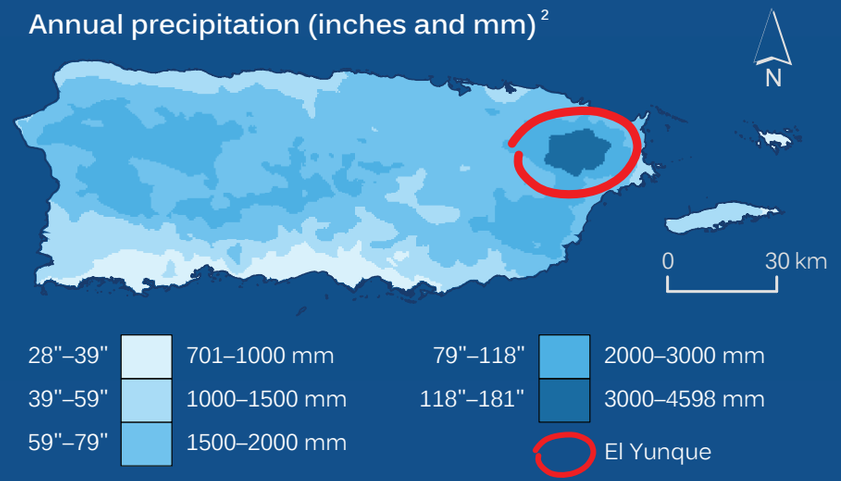


Minimum temperatures

Temperature (annual average) [2]

(°F)	(°C)
87–91	31–33
86–87	30–31
82–86	28–30
78–82	26–28
69–78	21–26
69–73	21–23
66–69	19–21
64–66	18–19
62–64	17–18
57–62	14–17

Annual precipitation (inches and mm) [2]



Climate conditions in El Yunque National Forest [3]

Climate	Tropical maritime
Rainfall (annual)	3860 mm (152 inches) average for the whole forest; increases with elevation
Rainfall record	485 mm (19 inches) recorded on May 19, 1969, on Pico del Este
Temperature (average)	72 °F (22 °C) in the winter to 86 °F (30 °C) in the summer
Temperature extremes	Minimum = 52 °F (11 °C) Maximum = 87 °F (32 °C)
Hurricanes (including hurricanes Irma and María of 2017)	16 are documented to have passed near or over the mountains since 1738

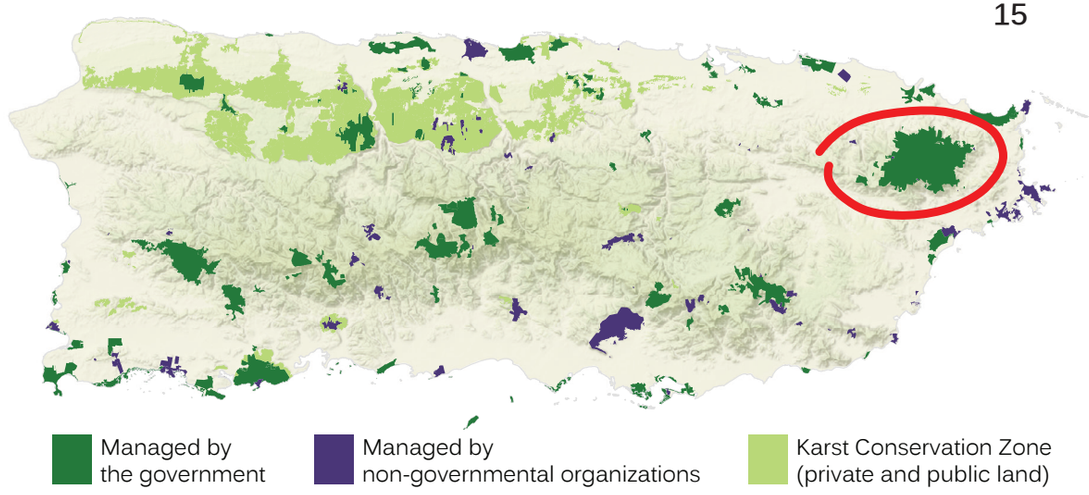
El Yunque as a national forest in the National Forest System of the U.S. [3, 4, 5]

- El Yunque is the only tropical forest in the National Forest System of the United States.
- It is the only U.S. national forest to be designated an experimental forest in its entirety.
- It is the only U.S. national forest located on an island.
- It has the highest percentage of wilderness area (35%).
- It has high biodiversity, with 225 native tree species and 164 vertebrate species documented.
- It is the rainiest of all the U.S. national forests.

Photo by Gary Potts

El Yunque National Forest quick facts

Fauna [3] **(vertebrates)**	164 animal species (24 endemic) Birds = 107 species Reptiles = 19 species Mammals = 16 species Amphibians = 15 species Fish = 7 species
Flora [3] **(vegetation)**	More than 1,000 different plant species 225 native tree species 60 are endemic to Puerto Rico 8 are endemic to the Luquillo Mountains 636 native flora species
Tallest trees [3]	*Dacryodes excelsa* and *Manilkara bidentata* >30 meters
Oldest trees [3]	*Cyrilla racemiflora* and *Magnolia splendens* ≈1,000 years
Hydrology [3]	Ten rivers and seven watersheds within the forest limits 11 migratory species of shrimp live in the forest streams 35 intakes on forest streams supply water for about 750,000 people
Topography [3]	Elevations range from 120 to 1074 meters above sea level Five peaks have an elevation of more than 1000 meters
Geology [3]	Uplifted Cretaceous marine volcaniclastic rocks and Tertiary quartz diorite intrusive rocks



Protected Areas of Puerto Rico [6]

Area and other measurements: [7]

- ✓ **11 540 ha (28,516 acres)**—total area
- ✓ **122 km (76 miles)**—perimeter
- ✓ **53 km (33 miles)**—roads
- ✓ **30 km (19 miles)**—recreational trails
- ✓ **1.1 million visits per year**

OFFICIAL NAME [3, 8, 9]	YEAR
Yukiyú by the Taíno Indians	<1500
Sierra de Luquillo	1885–1898
Luquillo Forest Reserve	1903–1907
Luquillo National Forest	1907–1935
Caribbean National Forest	1935–2007
El Yunque National Forest	2007–present

Physiography of Puerto Rico [10]

El Yunque National Forest Ecosystem Services

Ecosystem Services are commonly defined as benefits humans obtain from nature. The Millennium Ecosystem Assessment,[11] a 4-year United Nations assessment of the condition and trends of the world's ecosystems, categorizes ecosystem services as:

Provisioning services	Provide food, fresh water, fuel, fiber, and other goods.
Regulating services	Processes that help regulate the climate, air quality, water amount and quality, disease and plant production through pollination, among others.
Cultural services	Nonphysical benefits to humans such as science and education, aesthetic, recreation, spiritual and historical values.
Supporting services	Processes that support the ecosystems and habitats that provide us with these services such as soil formation, nutrient cycling, and genetic diversity.

El Yunque National Forest provides a variety of ecosystem services—including clean air, fresh water, and recreation—that are essential to the well-being of people in communities surrounding the forest and beyond.[12] Many of these goods and services are traditionally viewed as free benefits to society, or "public goods"—wildlife habitat and diversity, watershed services, carbon storage, and scenic landscapes, for example. Lacking a formal market, these natural assets are traditionally absent from society's balance sheet; their critical contributions are often overlooked in public, corporate, and individual decisionmaking. When our forests are undervalued, they are increasingly susceptible to development pressures and conversion. Recognizing forest ecosystems as natural assets with economic and social value can help promote conservation and more effective decisionmaking.

Photo by Luis Andrei Muñoz

CHAPTER 1—LAND

"The Luquillo Mountains rise abruptly from the sea to an elevation of 1000 meters, creating a steep topography that stands out in the northeast of Puerto Rico. No other formation obstructs the view toward or from the magnificent mountains in a 30-kilometer radius. Cloud systems originating in the north Atlantic, Africa, and the northeast of the United States cover the Luquillo Mountains at 600 meters."

—Ariel E. Lugo,
director of the International Institute of Tropical Forestry

Photo by Gary Potts

TOPOGRAPHY
Elevation and peaks of El Yunque

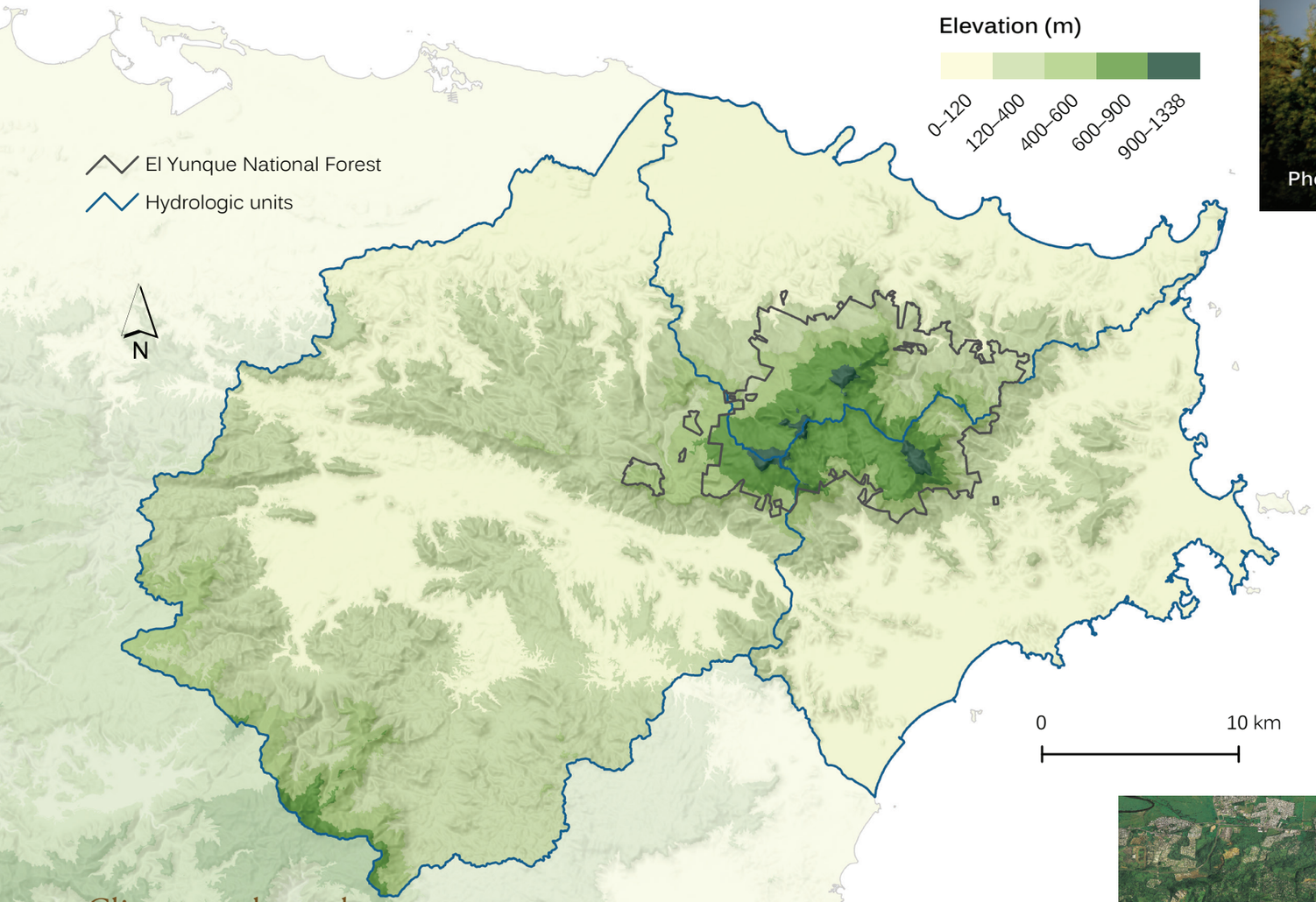
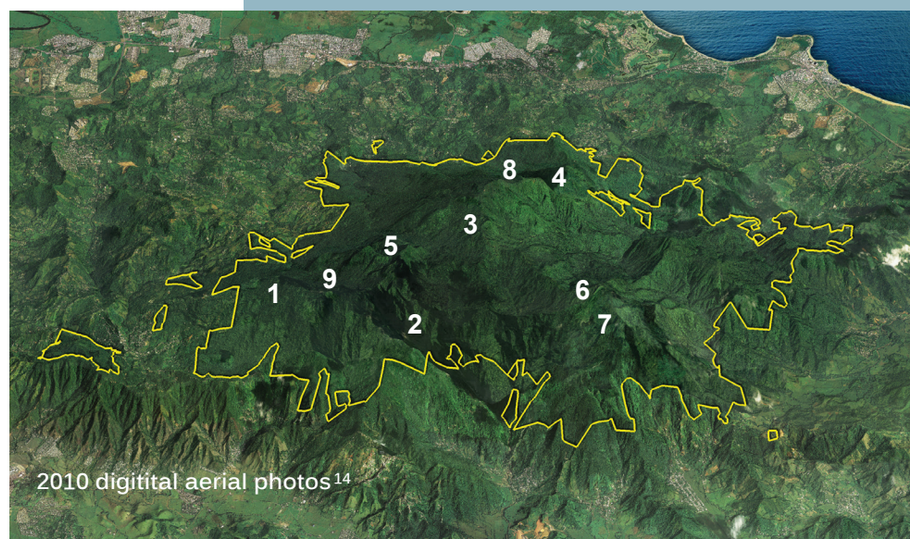



Photo by Jerry Bauer

Most of El Yunque National Forest lies between 400 and 900 m in elevation; only 5 percent lies above 900 m. Five peaks in the forest exceed 1000 m in elevation: El Toro, El Yunque, Pico del Este, Pico del Oeste, and El Cacique. The lowest point is along the northeastern boundary near the town of Sabana.

FOREST PEAKS [3]

	Name	Elevation (m)
1.	El Negro	750
2.	La Mina	931
3.	Mount Britton	941
4.	Los Picachos	968
5.	Cacique	1020
6.	Pico del Oeste	1025
7.	Pico del Este	1051
8.	El Yunque	1065
9.	El Toro	1074



2010 digitital aerial photos [14]

Climate at the peaks

El Yunque National Forest is situated in the Luquillo Mountains, which rise from the coast to over 1000 m above sea level. El Toro Peak (1074 m) is the highest point within the forest. Many environmental gradients reach their extreme values at the mountain summits, such as the highest wind speeds, lowest air temperatures, lowest incoming sunlight, highest rainfall, and lowest oxygen concentrations in the soil. [3, 7, 13]

Moist air from the trade winds arriving from the Atlantic Ocean cools and condenses as it rises up the steep mountain slopes, resulting in the mountain peaks being cloaked in cloud cover most of the time. February and March are the months when the peaks are most likely to be free of clouds.[3] The continuous rainfall at the peaks transforms into the headwaters for six major rivers: Río Espíritu Santo, Río Grande de Loíza, Río Blanco, Río Mameyes, Río Fajardo, and Río Sabana.

LANDFORMS
The shape of the forest

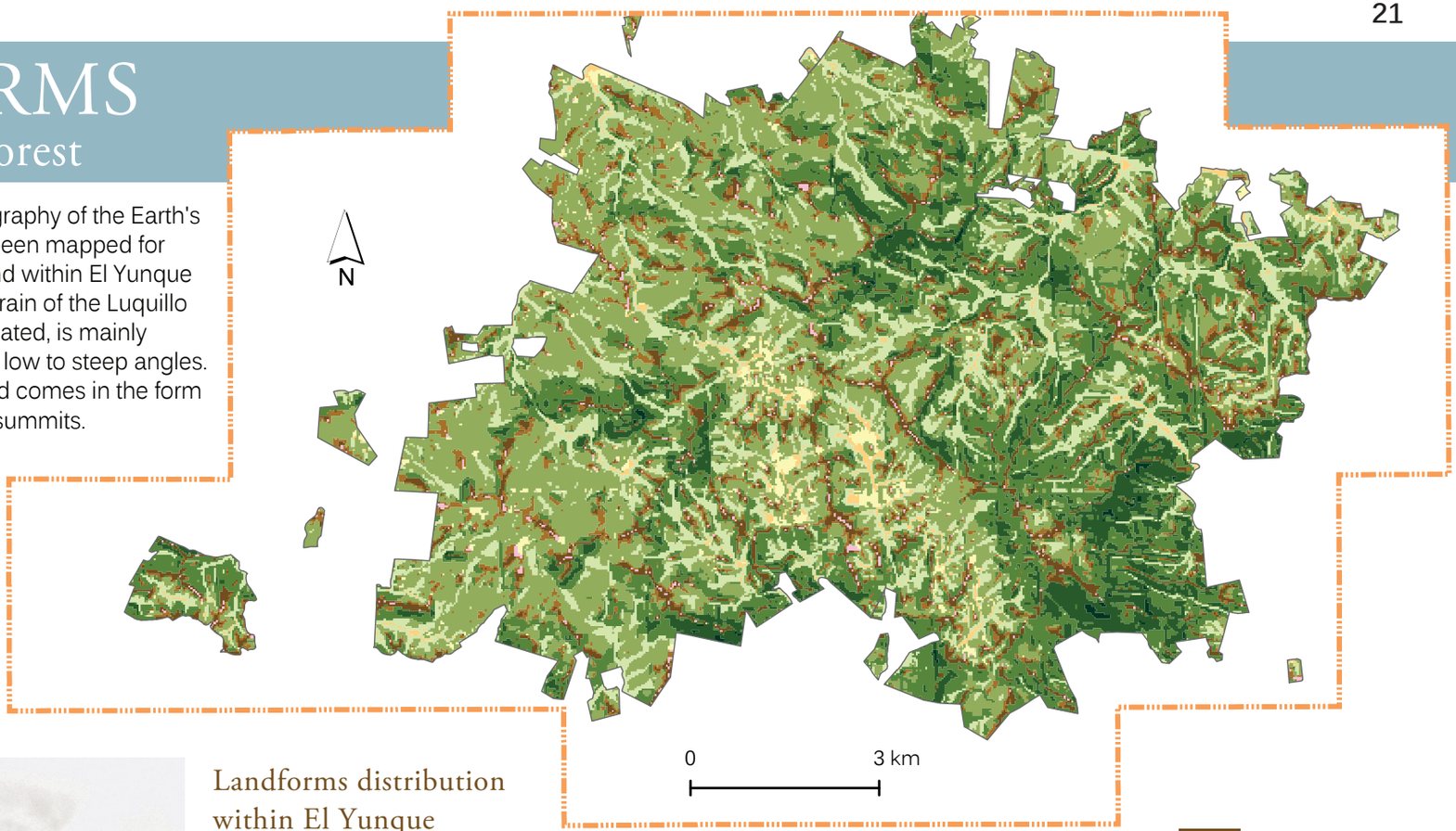
Landforms characterize the topography of the Earth's surface. Twelve landforms have been mapped for Puerto Rico, ten of which are found within El Yunque National Forest.[15] The rugged terrain of the Luquillo Mountains, where the forest is located, is mainly formed by slopes that range from low to steep angles. Flat terrain is rare in the forest, and comes in the form of plains, slope bottoms, and flat summits.

Human settlement, including past agriculture and tree planting at lower elevations, has imposed changes on the El Yunque landscape since the early 1800s.[3] However, most of the terrain above 600 m in elevation escaped human intervention because of inaccessible steep slopes and heavy rainfall levels.[16]

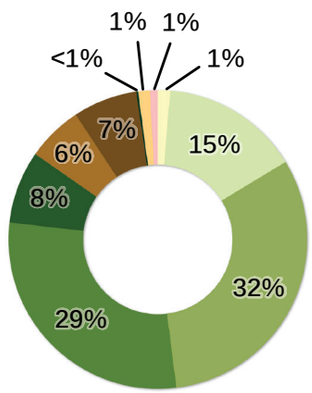

Photo by Jerry Bauer

LANDSLIDES [3]

More than half of the landslides in Puerto Rico are caused by intense rains and winds associated with disturbances such as hurricanes, tropical storms, and tropical depressions. In El Yunque National Forest, the greatest number of landslides occur between 600 and 800 m in elevation. Most of these occur during the hurricane season from June through October.

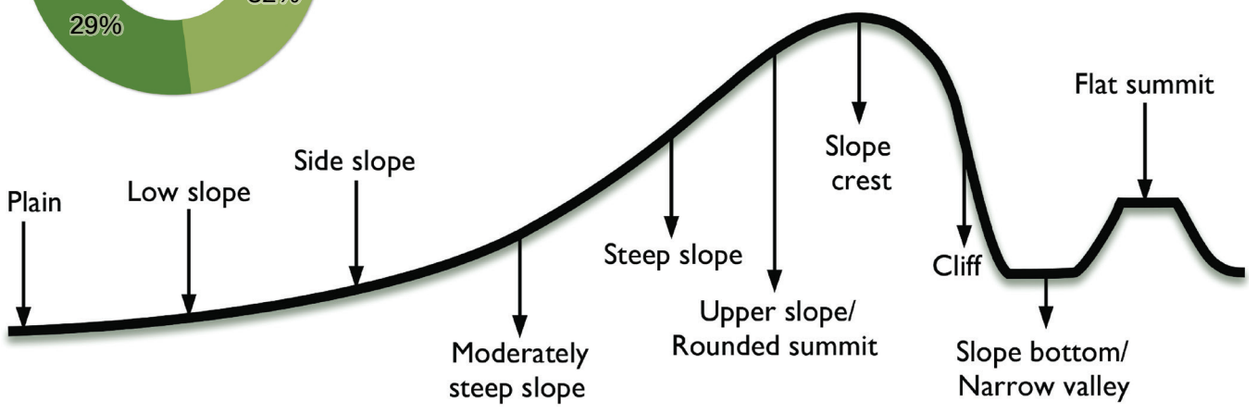


Landforms distribution within El Yunque



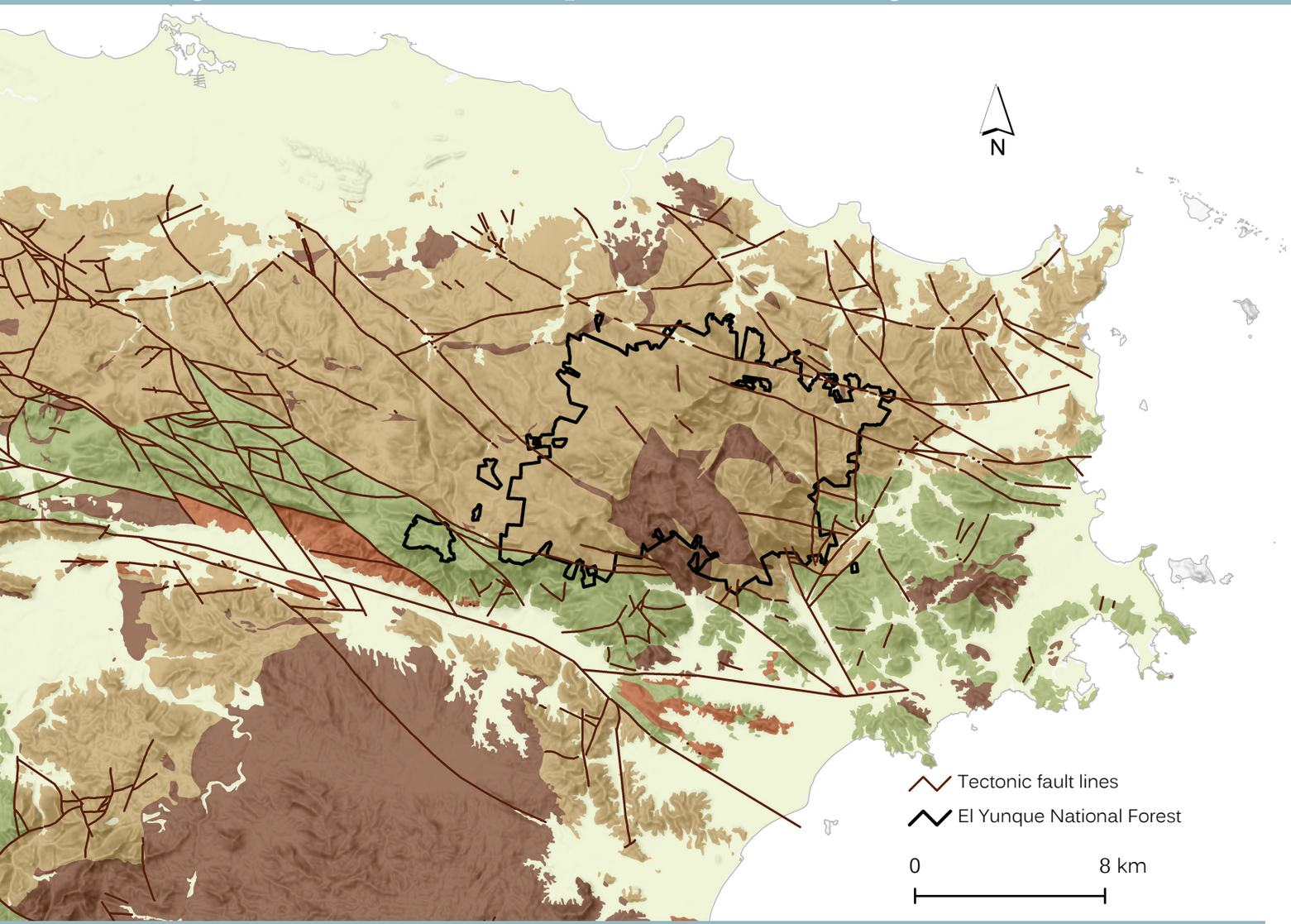
Plain
Low slope
Side slope
Moderately steep slope
Steep slope
Upper slope
Slope crest
Cliff
Slope bottom
Flat summit

Landforms diagram: location across the landscape [15]



GEOLOGY

Geologic terranes of El Yunque and surrounding lands



Geologic terranes [17]

Nonvolcaniclastic

Rock deposits of biogenic material and other rocks without volcanic material. In Puerto Rico, this terrane consists of superficial deposits of alluvium, beach and swamp deposits, landslide areas, artificial fill, and fault breccia—rocks formed by tectonic forces from broken fragments of minerals and other rocks.

Alteration

Areas made of metamorphic rocks of volcanic origin or hydrothermally altered rocks of unknown origin. Hydrothermal alteration occurs when hot water changes the chemical composition of a rock. In Puerto Rico, altered rocks are widespread and represent many different levels of alteration intensity.

Intrusive

Areas made of intrusive rocks. Intrusive rocks are igneous rocks made of hardened magma that form below the surface. In Puerto Rico, copper, gold and other economically valuable metals and minerals are found in intrusive terranes.

Submarine basalt and chert

Areas of basalt rock that formed from rapid cooling lava under the ocean and chert sedimentary rocks. In Puerto Rico, chert is found in association with basalt.

Volcaniclastic

Areas of rock formed from magma erupted from a volcano. In Puerto Rico, most of the volcaniclastic terrane originates from the eruption of underwater volcanoes during the Cretaceous period. Small deposits of volcaniclastic rocks formed above water are also present in the island.

Geology of Puerto Rico [17]

Puerto Rico is a volcanic island. The oldest geologic formations, found in the southwestern side of the island, date back to the late Jurassic period 150 million years ago. Over half of Puerto Rico is formed by igneous and metamorphic rocks from volcanic activity that lasted from the late Jurassic period to the Eocene epoch. Tectonic movement rotated, arched, sank, and uplifted the land masses, further defining the complex terranes and creating the tectonic fault lines found across the island today. Large deposits of marine sediments and alluvium are found along the north, coastal regions, and valleys of Puerto Rico; the product of weathering and erosion processes and tectonic history.

Most of El Yunque lies over marine volcaniclastic and intrusive igneous rocks from the Cretaceous and Tertiary periods.

GEOLOGY

El Yunque National Forest geologic formations[17]

Early Cretaceous

Kd **Daguao Formation**
Interbedded volcanic rocks, sandstone and crystal formations from consolidated volcanic ash.

Kf **Figuera Lava**
Volcanic rocks interlayered with other volcanic rocks, submarine volcanic rocks, sandstone, and siltstone.

Kfa **Fajardo Formation**
Sedimentary rocks made of consolidated ash, with larger pieces of volcanic rock interbedded with sandstone and cherty siltstone.

Kta **Tabonuco Formation**
Fine to coarse grained calcareous—containing calcium carbonate—volcanic sandstone and mudstone with minor volcanic rock pieces.

Late Cretaceous

Kh **Hato Puerco Formation**
Sedimentary rocks, like sandstone and mudstone, made up of volcanic rock pieces and minerals.

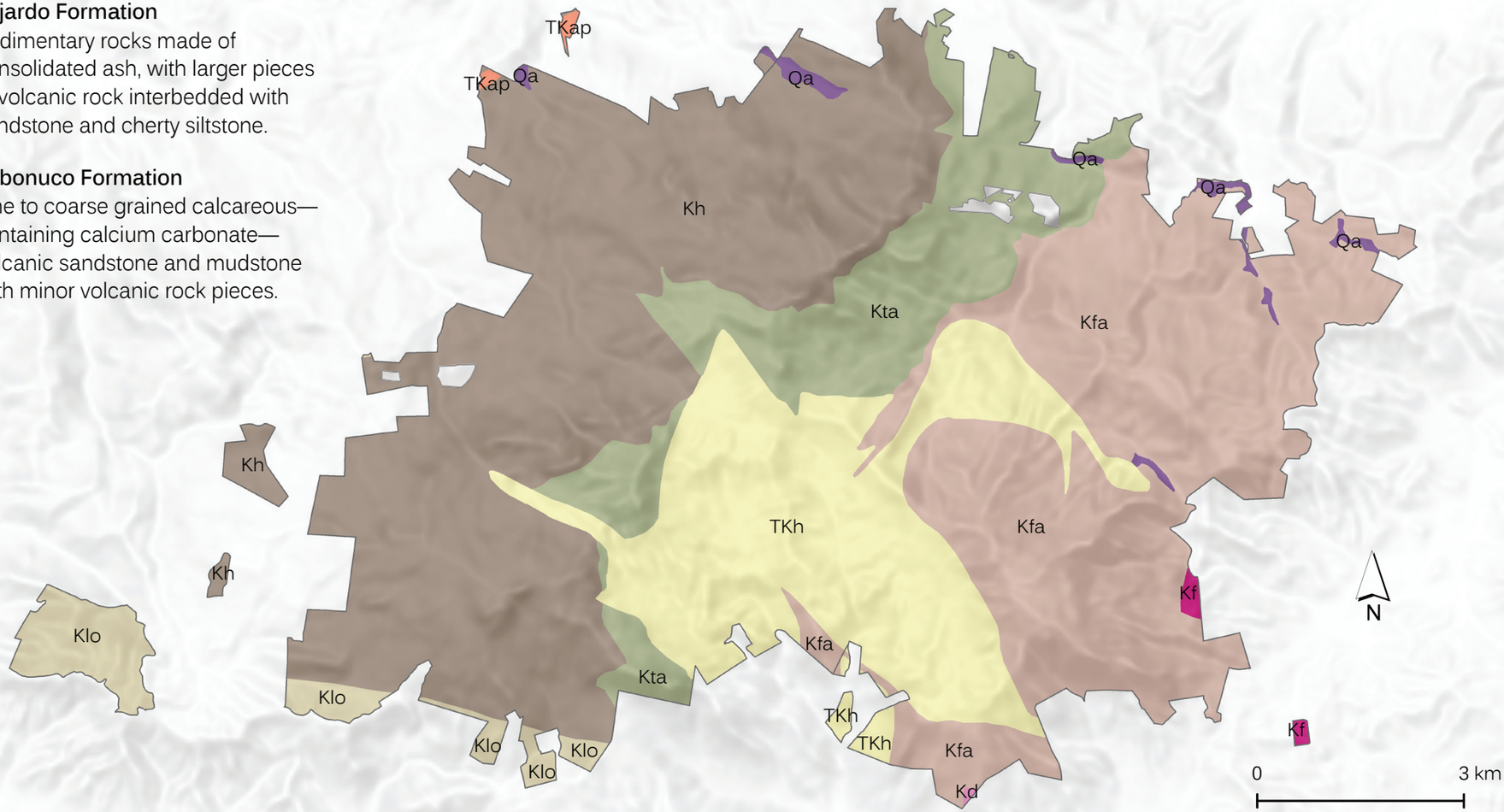
Klo **Lomas Formation**
Volcanic rocks, submarine volcanic rocks and glass, and volcanic sandstone and mudstone.

TKap **Augite andesite porphyry**
Volcanic rocks, igneous rocks with large-grained crystals, and the minerals augite and plagioclase.

TKh **Hornblende quartz-diorite**
Igneous plutonic rocks that formed beneath the earth's surface. It also contains minerals such as quartz, plagioclase, and biotite.

Quaternary

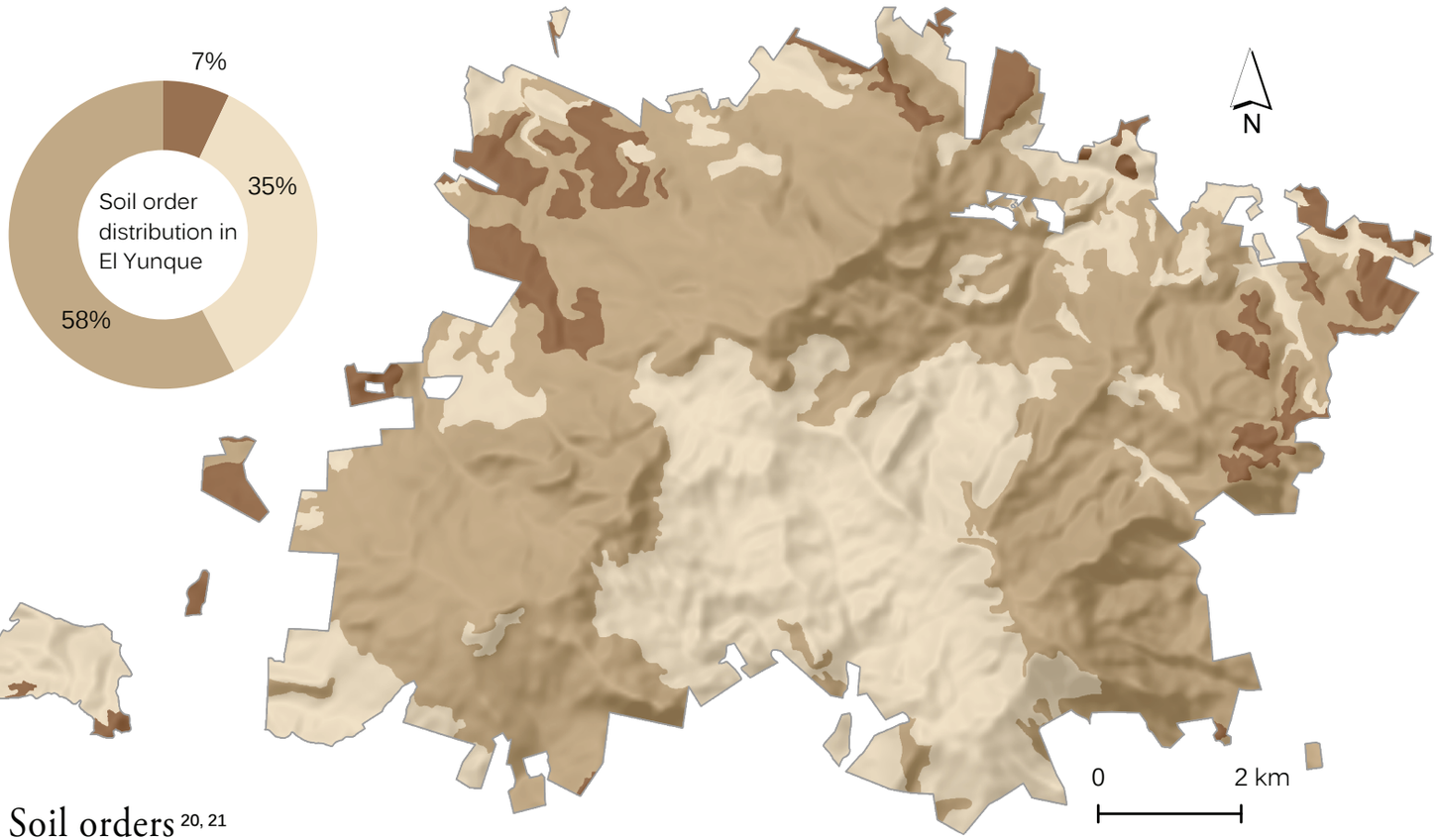
Qa **Alluvium**
Unconsolidated sand and gravel.



SOILS
Soil orders

The soils of El Yunque National Forest are classified into three soil orders.[18] Soil orders are the top rank within the U.S. Department of Agriculture (USDA) Soil Taxonomy classification system developed by the USDA and the National Cooperative Soil Survey. Twelve soil orders are described globally, of which ten occur in Puerto Rico.[19]

Soil orders classify global soils according to their horizons and soil-forming processes.[20] Soil horizons are horizontal layers found within the soil, the product of these soil-forming processes, and hence reveal information about the history and characteristics of the soil.



Soil orders[20, 21]

Ultisols

These soils cover 8% of the world's ice-free land surface. They develop in humid climates from intense weathering and leaching processes. In El Yunque, ultisols form on weathered porous rocks and unconsolidated sediment deposits and generally have a low nutrient content with organic matter limited to the upper portion of the soils.

Inceptisols

These are the most common soils in the world, covering 17% of the world's ice-free land surface. They develop in a wide range of climates and exhibit a wide range of characteristics. In El Yunque, inceptisols are weakly developed and are mostly found on unconsolidated sediment deposits shallow to bedrock.

Oxisols

These highly weathered soils cover 8% of the world's ice-free land surface and develop in humid climates, characteristically in tropical and subtropical regions. Most oxisols are low in fertility and tend to have high permeability and resistance to compaction. In El Yunque, oxisols are found on geomorphologically stable surfaces.

Soil profile from research conducted at El Yunque National Forest[21]

Soils in El Yunque

In El Yunque National Forest, scientists have described 23 soil types and complexes—soils made from a combination of two or more soil types.[3, 21, 22]

Soils form as a result of the effects of climate, living organisms, topographic relief, and time on the rocks and parent material of an area.[20] The dominant parent materials found in El Yunque are igneous and volcanic rocks, which are strongly influenced by the climate, especially rainfall, and the steep topography of the area.[21]

Other factors that influence soil properties in El Yunque include landslides, hurricanes, global wind patterns, Saharan dust, proximity to the coast, and the vegetation communities that grow in the forest.[21] Land use history also affects the soils of El Yunque, especially in the lower slopes, where past agriculture and grazing activities have caused soil erosion and degradation.[3]

SOILS
Hydric soils

Hydric soils form in water-saturated or flooded areas, in which anaerobic conditions develop within the soil. These conditions alter the biological and chemical reactions in the soil, creating unique properties where only specialized plants and microorganisms can survive. Hydric soils, hydrophytic vegetation, and wetland hydrology are the three essential characteristics of wetlands.[22]

Half of El Yunque's surface is covered by dominantly or partially hydric soils.[22] Partially hydric soils have hydric non-dominant components. Most of the hydric soils are found near the peaks at over 600 m in elevation. This is the approximate elevation where clouds form in El Yunque.[3,7]

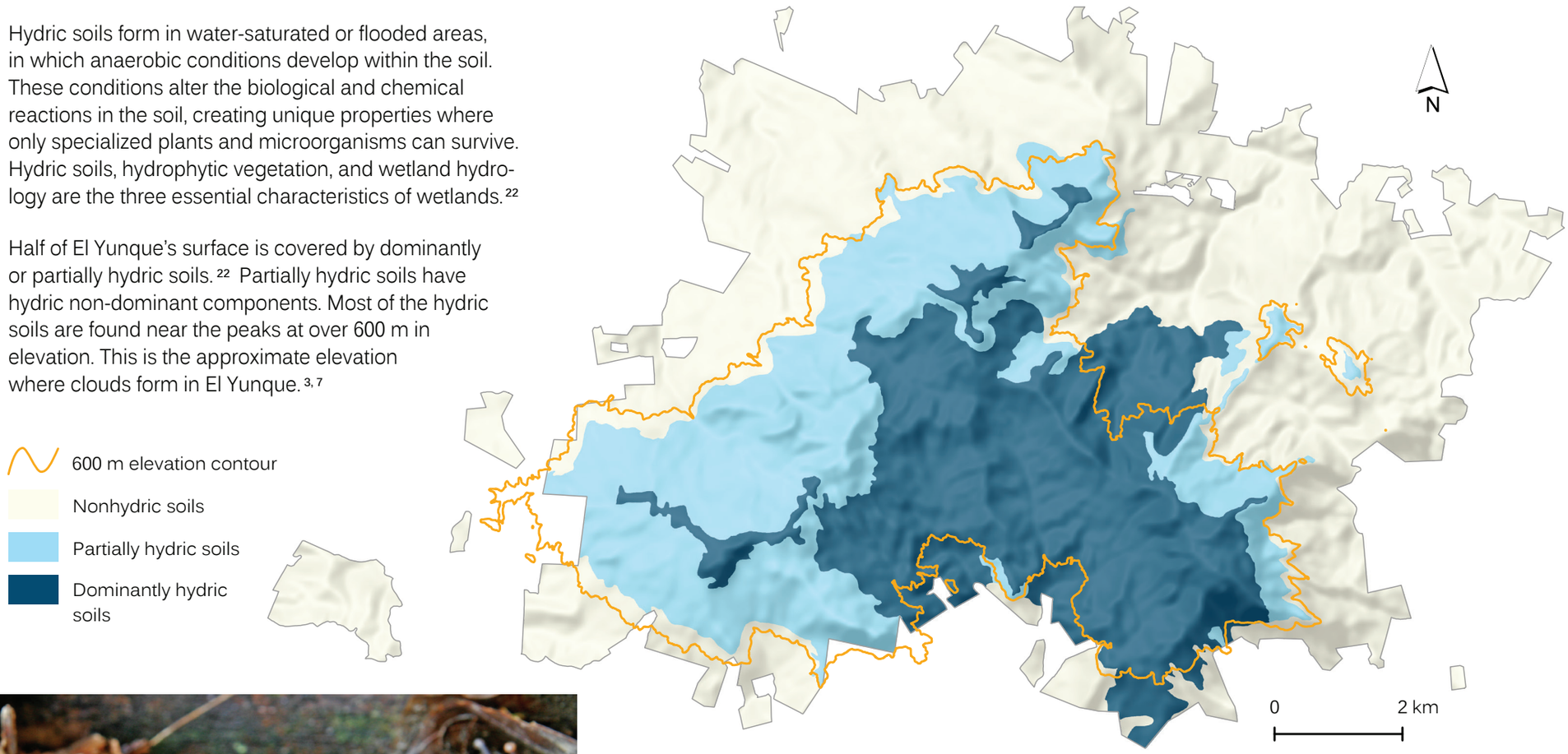



Photo by Jerry Bauer

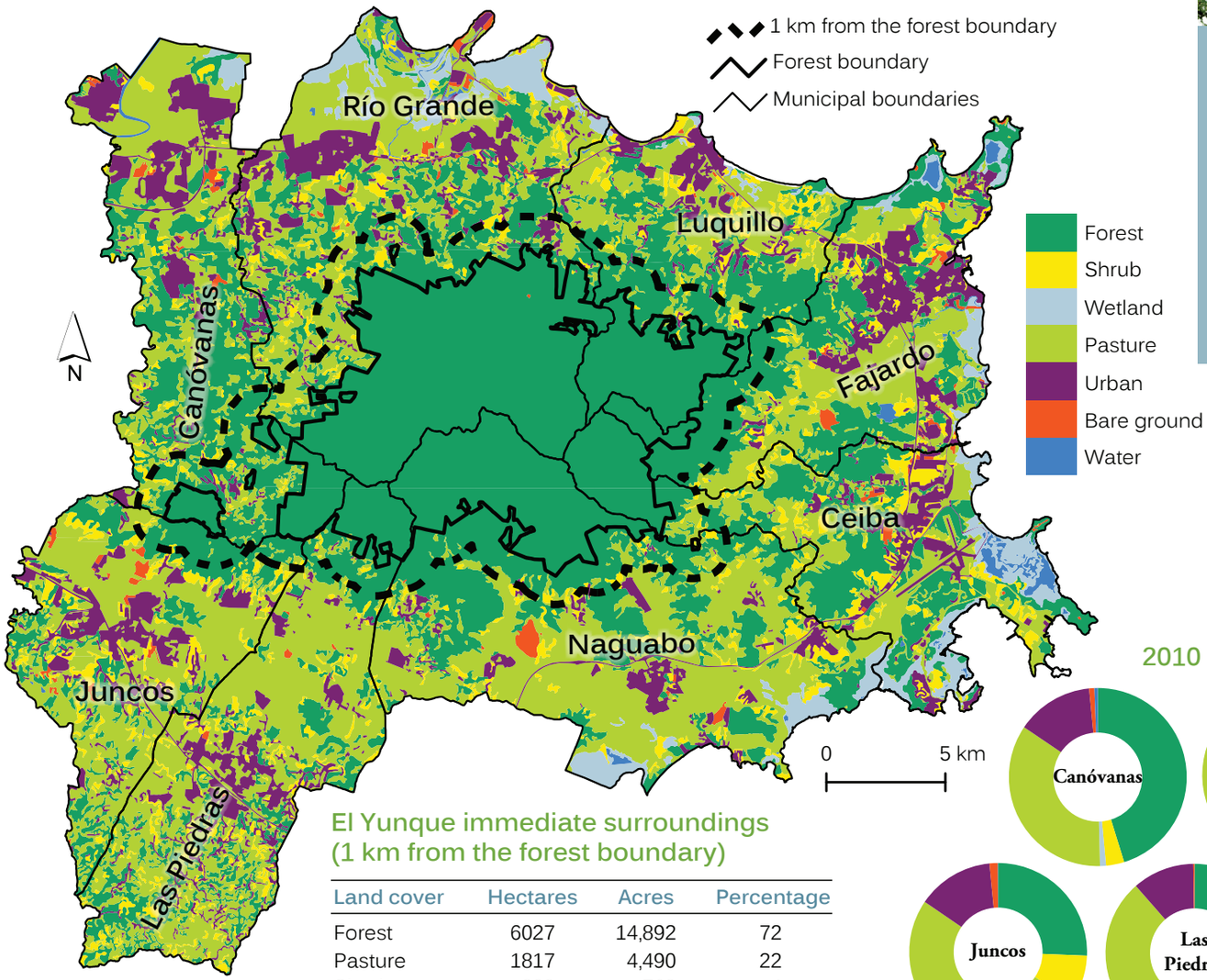
Saharan dust

The strongly weathered soils of El Yunque lose plant-essential nutrients, such as calcium and phosphorus, through the intense leaching caused by the heavy regular rainfall on the steep topography.[21] However, after decades of research at El Yunque National Forest, it was found that the clouds that arrive to the Luquillo Mountains are laden with marine aerosols, dust, ash, and pollution, which influence and supplement the nutrients and chemicals in the soil.[21,23,24]

The African Saharan dust in particular provides vital geochemical constituents to the soils of the Luquillo Mountains and contributes to the fertility of the El Yunque ecosystems.[23,24] Dust from the Sahara-Sahel region in Africa is transported to the American tropics by the trade winds; in Puerto Rico, seasonal peaks occur in June and July.[23,24] In some areas of El Yunque National Forest, Saharan dust is mixed into the soil profile to over one meter deep.[21]

LAND COVER
El Yunque surroundings in 2010

El Yunque National Forest provides a variety of ecosystem goods and services, such as clean air, water, biodiversity, and recreation. The availability of these ecosystem services is influenced not just by the conservation of trees and other natural habitats inside the forest, but by how the land surrounding the forest is used. For example, surrounding forests help protect watersheds from soil erosion, serve as filters to produce clean water, and provide habitat and food for El Yunque's fauna.[12] The conservation of these areas is especially important for animals that move from the coast to the mountains and back throughout their life cycles, such as the freshwater shrimps that live in the waters of El Yunque.



El Yunque immediate surroundings (1 km from the forest boundary)

Land cover	Hectares	Acres	Percentage
Forest	6027	14,892	72
Pasture	1817	4,490	22
Shrub	309	763	4
Urban	208	514	2

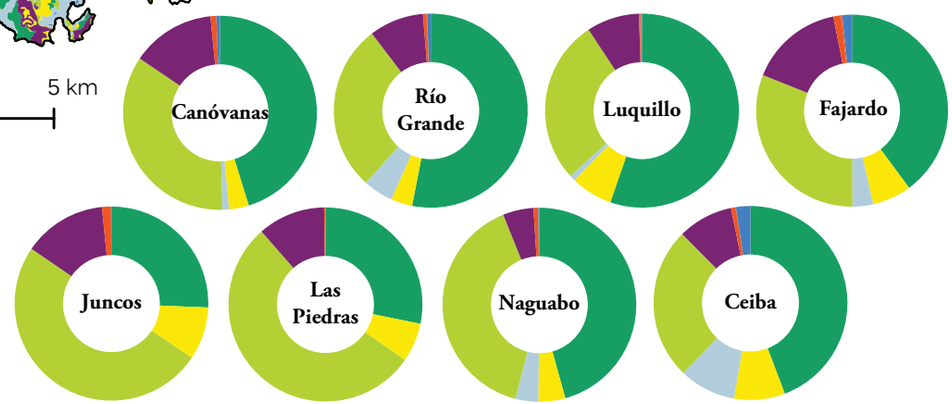
Land cover maps

Land cover maps display vegetation, bare ground, built-up areas, and other physical cover on the earth's surface, facilitating the description, analysis, and research of the world around us. Scientists and technicians often use aerial photos or satellite images to create these maps. The land cover of El Yunque region shown here was created by Tania López-Marrero and Annie Hermansen-Báez using aerial photographs taken in 2010.[26]

Municipalities of El Yunque [26]

Land cover	Hectares	Acres	Percentage
Forest	32 638	80,649	43
Pasture	27 017	66,760	36
Urban	7745	19,138	10
Shrub	4227	10,444	6
Wetland	2423	5,987	3

2010 land cover distribution at the municipal level



CHAPTER 2—WATER

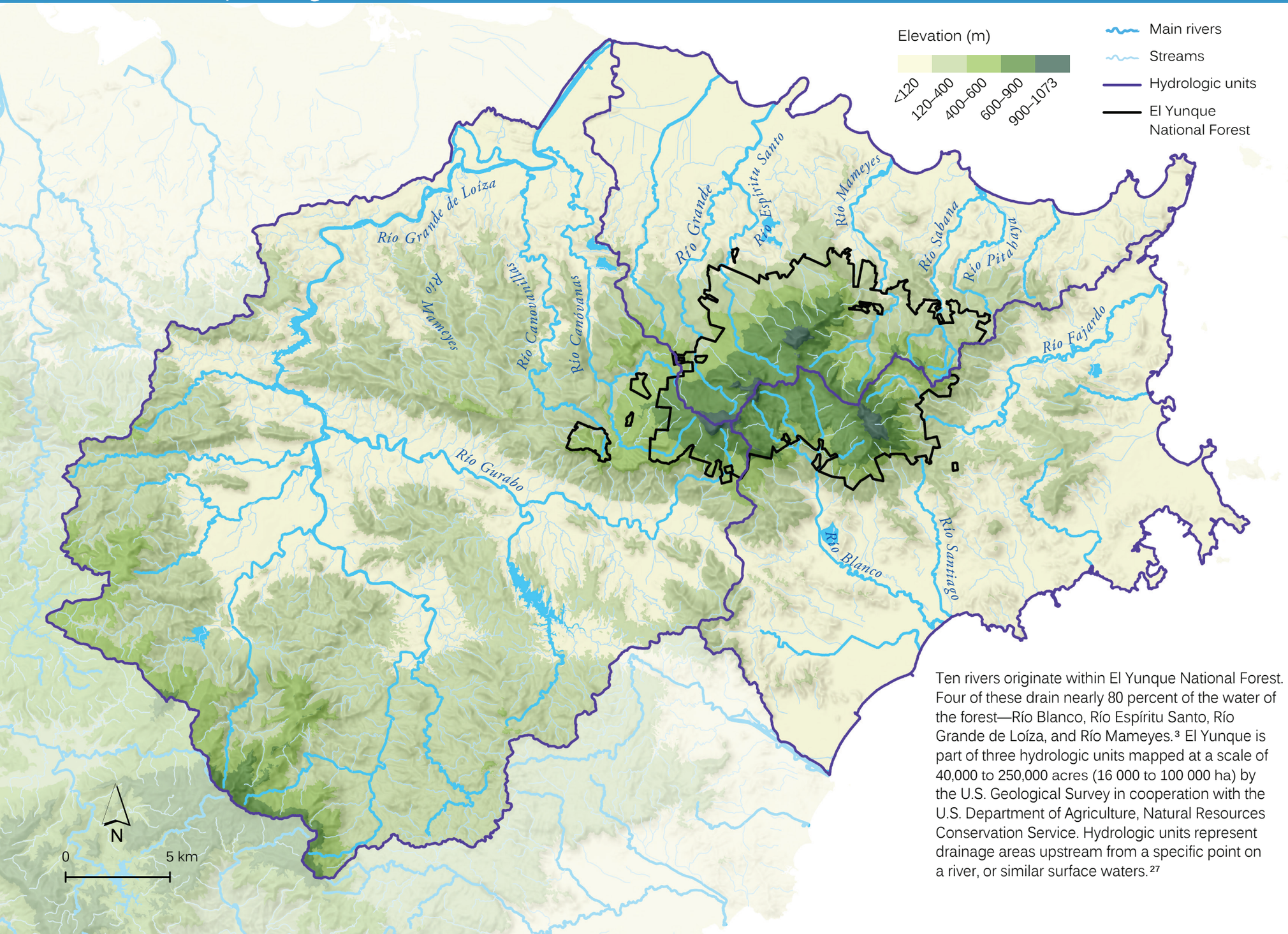
"El Yunque is a story that never ends! The experience of documenting how moisture carried by the wind creates mist-covered scenes at the top of the mountain to produce the freshwater we drink was the first of many fascinating stories I produced. Through the years, I have shared with the researchers and interpreters of El Yunque tales starring the magnitude of the flora that adapts to extreme conditions to survive, or how our Taíno natives revered these White Lands. To communicate stories such as the survival of our charismatic parrot or the important role of a simple earthworm is to fulfill my social responsibility in an attempt for more Puerto Ricans to understand how our forest works so they can protect it."

—María Falcón, communicator and educator

Photo by Maya Quiñones

HYDROGRAPHY

Rivers and hydrologic units



Ten rivers originate within El Yunque National Forest. Four of these drain nearly 80 percent of the water of the forest—Río Blanco, Río Espíritu Santo, Río Grande de Loíza, and Río Mameyes.[3] El Yunque is part of three hydrologic units mapped at a scale of 40,000 to 250,000 acres (16 000 to 100 000 ha) by the U.S. Geological Survey in cooperation with the U.S. Department of Agriculture, Natural Resources Conservation Service. Hydrologic units represent drainage areas upstream from a specific point on a river, or similar surface waters.[27]

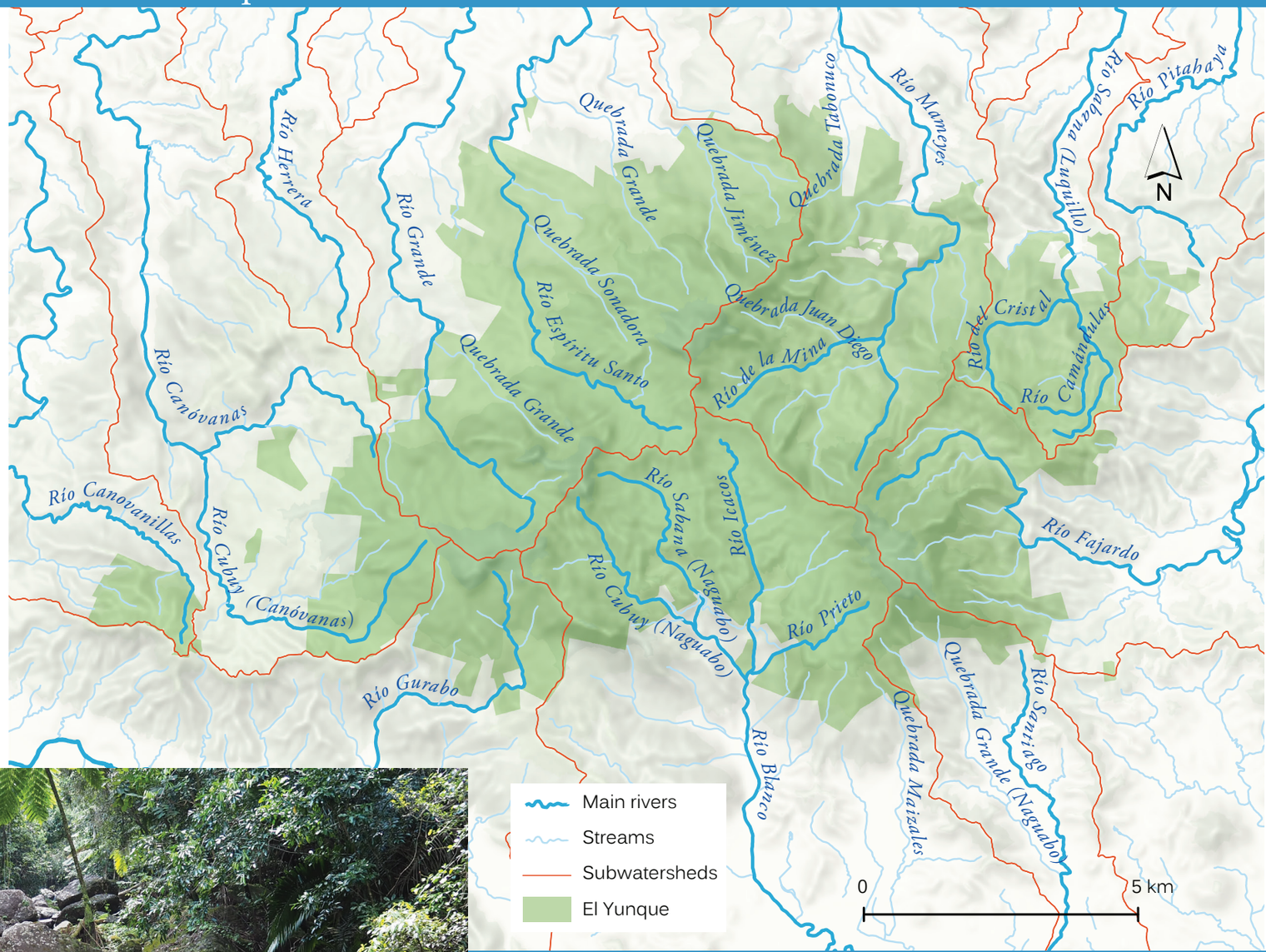
RIVER MORPHOLOGY

The shape of the rivers inside El Yunque

The rivers in El Yunque National Forest are characterized by deep and narrow banks with clear crystalline water and an accumulation of large boulders. The streams flow through long profiles of steep elevational gradients, over waterfalls and rapids of exposed bedrock and boulders, moving downstream to wider valleys, where boulders become smaller and more scattered.[28] Typical of mountainous regions across the Caribbean Greater Antilles, the steep hillsides, high annual rainfall, periodic short-duration high-magnitude rainfall events caused by storms and hurricanes, and volcanic bedrock are the prime factors that influence the shape and behavior of the rivers in the Luquillo Mountains where the forest grows.[28]

The high rainfall and steep topography also create dangerous river flash floods, in which large volumes of floodwater are carried downhill at high velocity within minutes to hours after rainstorms.[3, 28] Rainfall events at the top of the mountains can cause flash floods in the lower slopes without warning.

Quebrada Sonadora, Photo by Gary Potts



Rainfall in El Yunque

Average annual rainfall in El Yunque is 3860 mm (152 inches), equivalent to over 100 billion gallons of water per year.[3, 4] Some areas in the uppermost cloud forest receive more than 5000 mm (200 inches) annually.[4] It usually rains the most during spring and autumn. On average, 60–65% of the rainfall in the forest turns into stream runoff, while 35–40% is lost through evapotranspiration.[3, 7]

WATER RESOURCES
Water extraction and use

Water for public consumption is an important service provided by El Yunque National Forest. Forest cover is associated with suitable water conditions for ecosystem processes and consumption, while bare ground and built-up areas increase sedimentation and flash floods, and contribute to lower water quality.[29]

The water that runs through El Yunque's rivers is documented as the cleanest on the island with high-quality conditions.[7, 29] In 2014, Puerto Rico had 3.5 million inhabitants, of which about 20% depend on the water El Yunque National Forest supplies.[7, 29]

DID YOU KNOW?

On a typical day, over half of all water flowing from the forest is extracted for municipal use and human consumption.[3] Based on the cost paid by consumers, the water extracted from the streams that flow from the Luquillo Mountains is worth about $25 million per year.[7]

Regulatory agencies[7]

Water quality

- Puerto Rico Environmental Quality Board
- U.S. Environmental Protection Agency

Extraction (regulation)

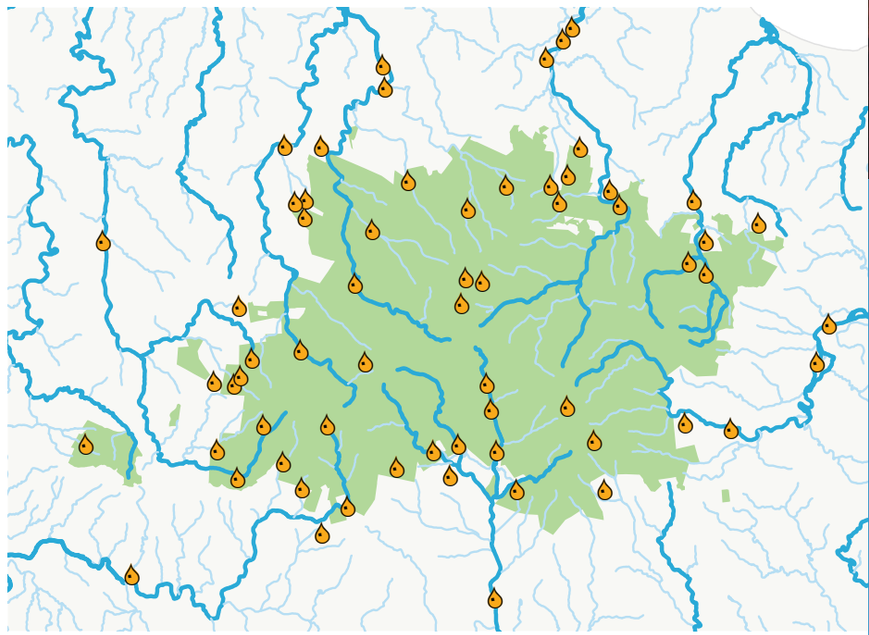
- Puerto Rico Department of Natural and Environmental Resources

Extraction (monitoring)

- U.S. Geological Survey (USGS)

Water intakes

In 2004, there were 34 intakes withdrawing over 66 million gallons of water per day from the forest, compared to 51 million gallons in 1994.[30]

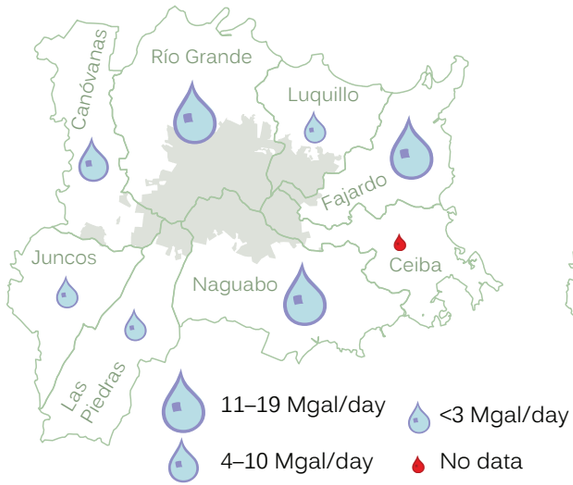



Freshwater shrimp, *Atya innocuous*
Photo by Omar Pérez-Reyes

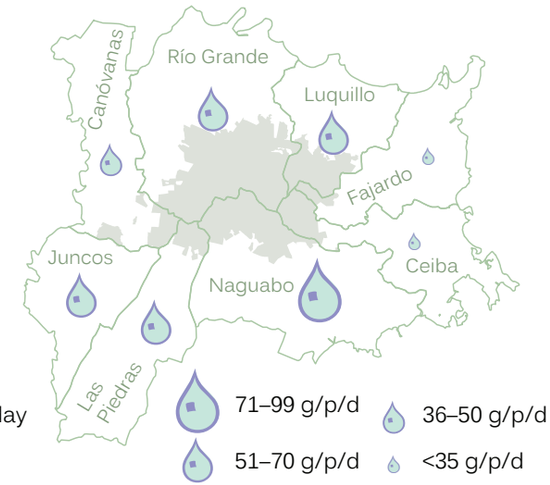
Freshwater Shrimp

Shrimp account for 95% of the biomass living in the rivers and streams of El Yunque.[32] These tiny crustaceans are important decomposers, breaking down leaves and algae and contributing to the health of aquatic ecosystems.[3, 32] Shrimp migrate upstream to the Luquillo Mountains from coastal waters where they hatch. Dams and water intakes break stream connectivity, affecting shrimp migration. However, intakes like the one installed in Río Mameyes are especially designed to alter the river channel less than low-head dams and have minimal effect on migratory aquatic species.[3]

Water withdrawals in 2010[31]

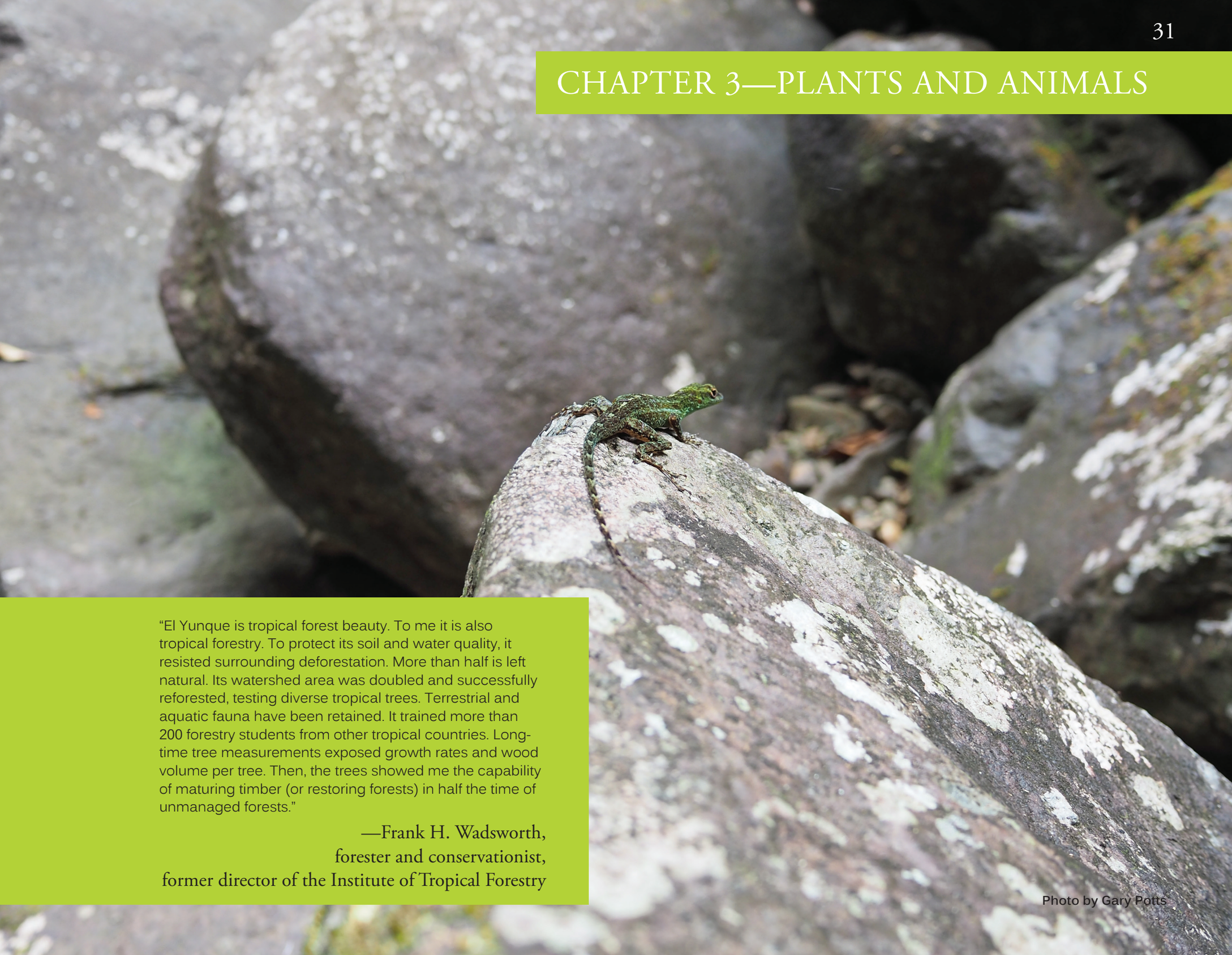


Water for domestic use in 2010[31]



Water-use data for 2010 from the National Water Information System from the USGS[31] reports that water withdrawals in Puerto Rico totaled 677 million gallons per day (Mgal/day), of which 230 Mgal/day were for domestic use. In the municipalities that encompass El Yunque, withdrawals totaled 58 Mgal/day, while domestic use totaled 15 Mgal/day; domestic use ranged from 26–99 gallons per person per day (g/p/d).[31]

CHAPTER 3—PLANTS AND ANIMALS



"El Yunque is tropical forest beauty. To me it is also tropical forestry. To protect its soil and water quality, it resisted surrounding deforestation. More than half is left natural. Its watershed area was doubled and successfully reforested, testing diverse tropical trees. Terrestrial and aquatic fauna have been retained. It trained more than 200 forestry students from other tropical countries. Long-time tree measurements exposed growth rates and wood volume per tree. Then, the trees showed me the capability of maturing timber (or restoring forests) in half the time of unmanaged forests."

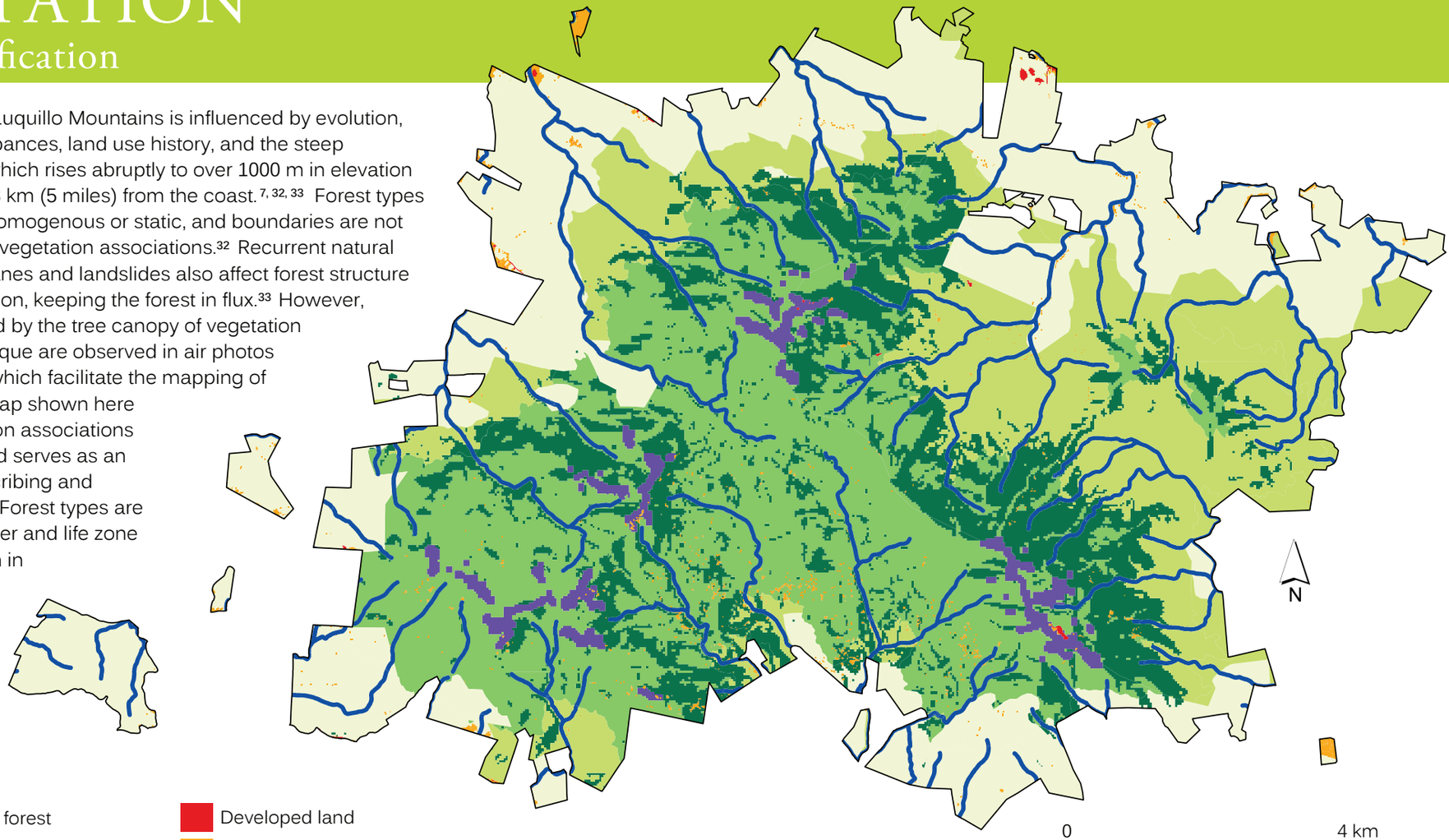
—Frank H. Wadsworth,
forester and conservationist,
former director of the Institute of Tropical Forestry

Photo by Gary Potts

VEGETATION

Forest classification

The vegetation in the Luquillo Mountains is influenced by evolution, climate, natural disturbances, land use history, and the steep elevational gradient, which rises abruptly to over 1000 m in elevation in a short distance of 8 km (5 miles) from the coast.[7, 32, 33] Forest types in El Yunque are not homogenous or static, and boundaries are not always clear between vegetation associations.[32] Recurrent natural events such as hurricanes and landslides also affect forest structure and species composition, keeping the forest in flux.[33] However, spatial patterns formed by the tree canopy of vegetation communities in El Yunque are observed in air photos and satellite images, which facilitate the mapping of forest types.[7, 33] The map shown here simplifies the vegetation associations found in El Yunque and serves as an important tool for describing and managing the forest.[7] Forest types are identified by cloud cover and life zone with a brief description in the following pages.



Forest types

- Riparian forest
- Secondary forest
- Mature tabonuco forest
- Mature palo colorado forest
- Mature sierra palm forest
- Mature *Tabebuia/Eugenia* forest
- Developed land
- Nonforest (grasslands, shrubland, and natural barrens)

CLIMATE CHANGE AND THE FOREST

The effects of climate change on a tropical forest ecosystem such as El Yunque are complex and are still being studied.[7, 34] Records show decreasing rainfall totals and increasing temperatures over the last century in the Luquillo Mountains.[34] Furthermore, statistical models of future climate for Puerto Rico predict an increase in temperatures of 4° to 9° Celsius, declines in rainfall, and an increase in drought intensity and extremes by the end of this century.[35] In general, climate change has the potential to transform El Yunque's forest structure and function, altering its species composition and distribution along the elevational gradient.[34]

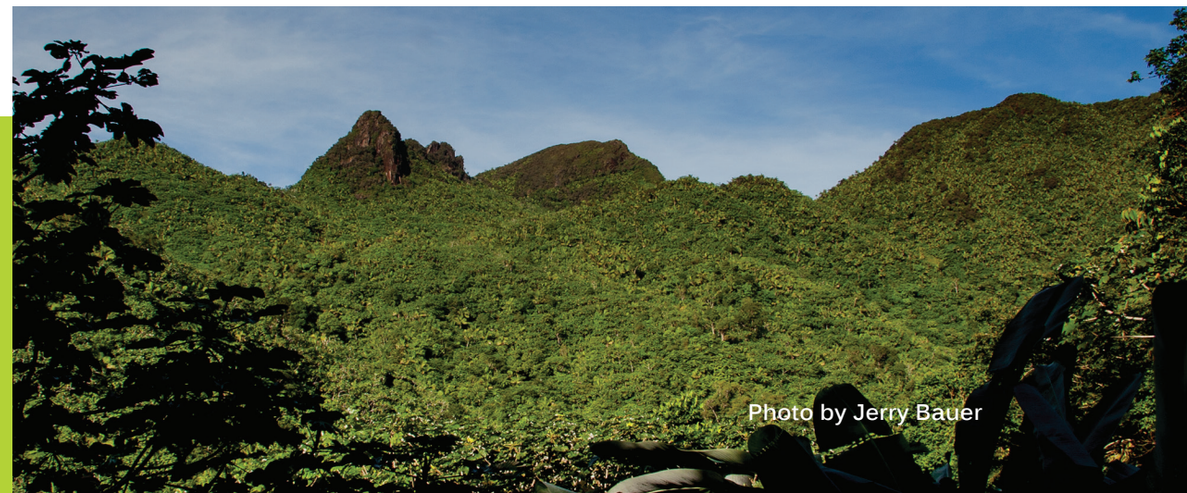
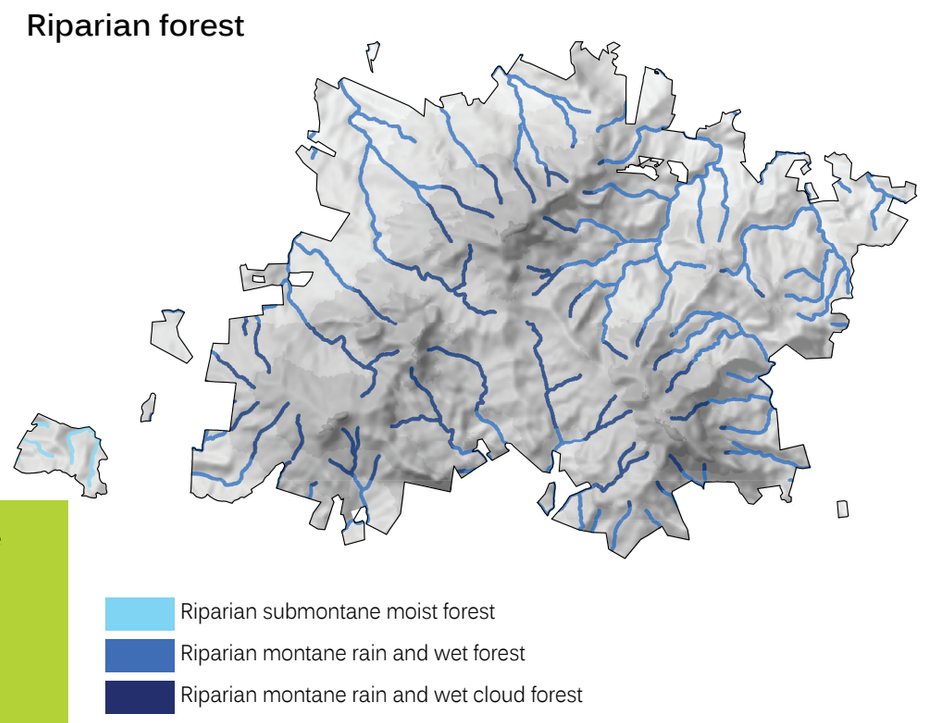


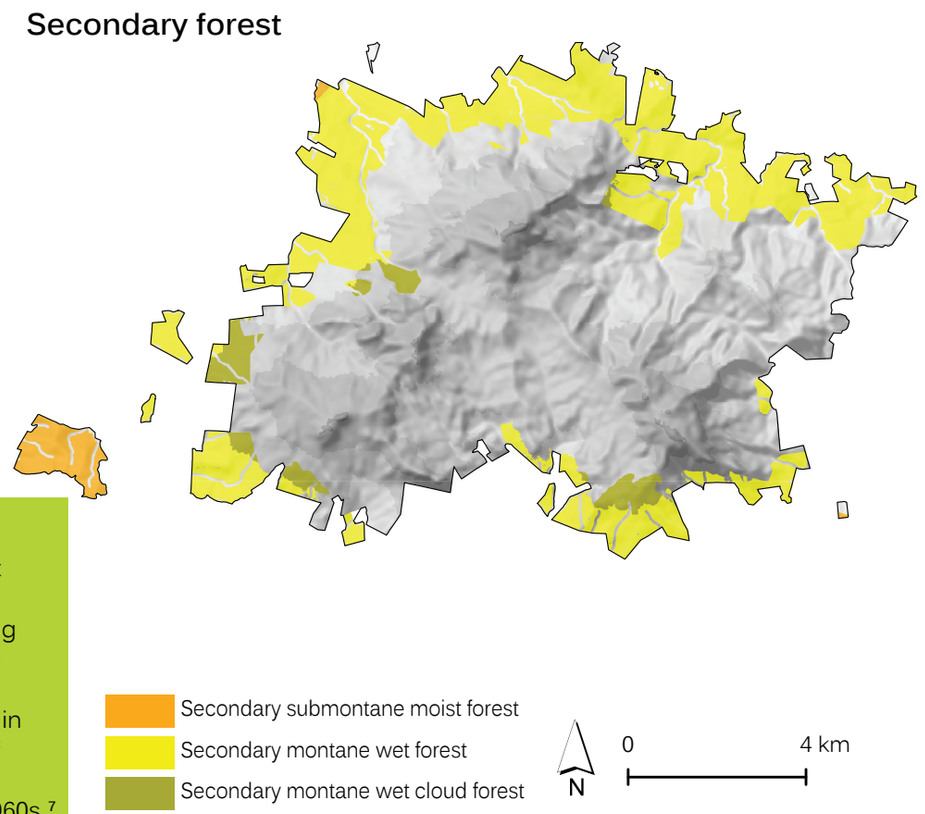
Photo by Jerry Bauer

The riparian zone is located at the interface between the land and river or stream. The vegetation in these areas is similar to surrounding slopes. For management purposes, the riparian forests within El Yunque National Forest are defined at 100 feet (30.48 m) from each river or stream bank.[7]

Photo by Jerry Bauer

Secondary forests are the result of forest regeneration following human disturbance and deforestation of forest ecosystems. These new forests have a different species composition than the original forest cover, often including a combination of introduced and native species forming novel communities that are adapted to anthropogenic environmental conditions.[36] The secondary forest found in El Yunque National Forest is the result of reforestation of agricultural land and the planting of commercial timber tree species, mainly mahogany, during the 1930s and 1960s.[7]





The forest types—altitude, moisture and the clouds

The main forest types found in El Yunque are further defined by their location within the forest.

Frequent cloud cover over the vegetation in the mountains affects the structure of the forest stands. In El Yunque, clouds form at approximately 600 m in elevation, hence forest types above this elevation are classified as cloud forest.[7]

The ecological life zones describe broad bioclimatic units that bear a close relationship to natural and biologically meaningful landscapes.[37] These were developed using the Holdridge model, in which precipitation and biotemperature data are used to delineate the zones, which are then classified based on latitudinal region, altitudinal belt, and humidity province. The ecological life zones of El Yunque help subdivide the forest types into moist, wet, or rain, and montane or submontane.[7]

Elevation (meters)

- > 1000
- 800–1000
- 600–800
- 300–600
- 100–300
- < 100

Distribution of forest types by elevation [32, 33]

1. **RIPARIAN FOREST**: Seen across all elevations, this forest type is found along rivers and streams.

2. **SECONDARY FOREST**: Historical records report timber plantation plots located at 180 m to 600 m; however, planted areas from historical maps range in elevation from 50 m to 800 m.

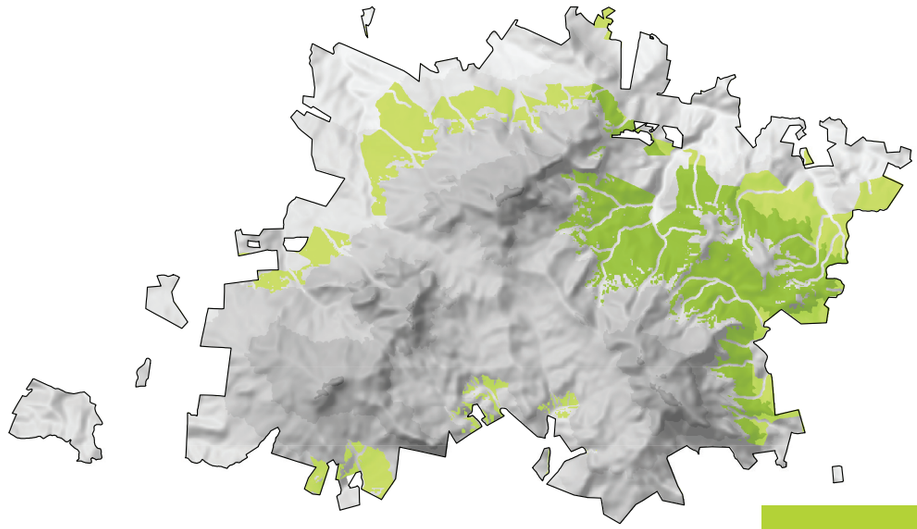
3. **TABONUCO FOREST**: lies between 150 m and 700 m in elevation. Dominant tree species are *Dacryodes excelsa*, tabonuco, and *Sloanea berteriana*, motillo.

4. **PALO COLORADO FOREST**: named after the palo colorado tree, *Cyrilla racemiflora*, it is located between 600 m and 1000 m, mostly on saturated soils.

5. **SIERRA PALM FOREST**: composed mainly of sierra palm, *Prestoea montana*. This forest type can be found above elevations of 450 m, mostly on steep slopes and saturated soils.

6. ***TABEBUIA/EUGENIA* WOODLAND**: occurs on the highest mountain peaks above 900 m. Derives its name from two of its most abundant tree species: *Tabebuia rigida* and *Eugenia borinquensis*. Shrubs, mosses, epiphytes, and sierra palm are also common within this forest type.

Tabonuco forest

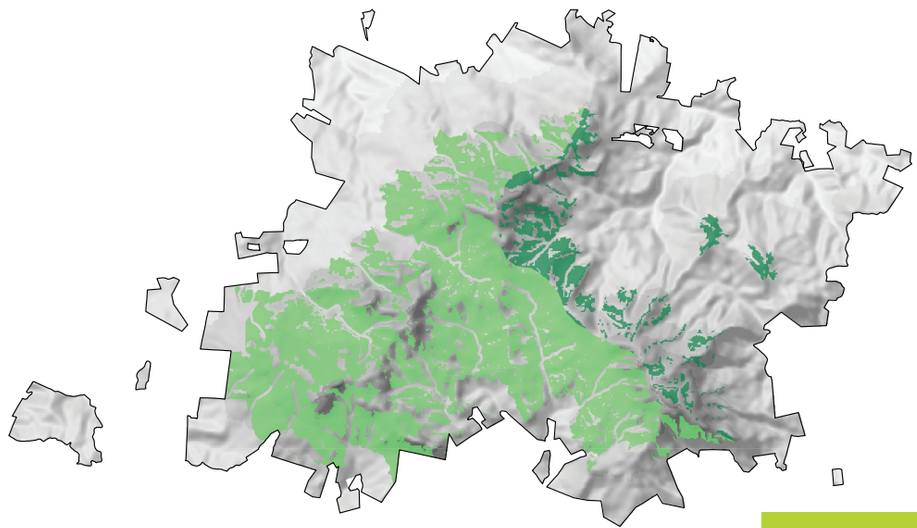


Mature tabonuco montane wet forest

Mature tabonuco montane rain forest

The tabonuco forest is dominated by tall trees with canopies that reach heights of about 30 m (98 feet), and woody vines.[32] This forest type holds more than 80 tree species.[33] The tabonuco rain forest within the subtropical rain forest life zone is characterized by an abundance of rainfall with an estimated annual runoff of 3400 mm (130 inches), more than twice the annual rainfall received by most areas in the world.[7]

Palo colorado forest



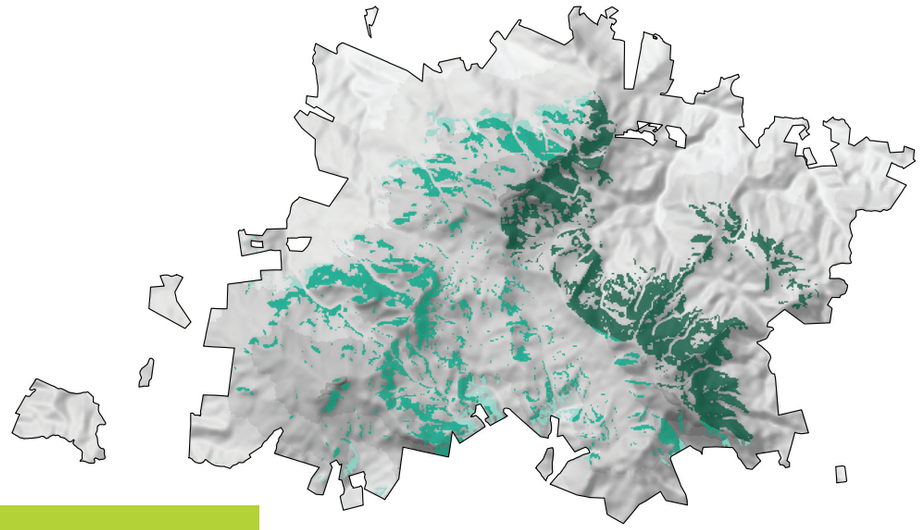
Mature palo colorado montane wet cloud forest

Mature palo colorado montane rain cloud forest

The palo colorado forest has tree canopies that reach about 15 m (50 feet) in height.[3] Sixty-five tree species have been recorded in this forest type, with 10 species accounting for over 70% of the total count.[3] Tree species distribution varies according to topography and aspect, with different species dominating the ravines, ridges, and slopes.[3] On the forest floor, bromeliads, root mats, and exposed soil are common.


Photo by Joel A. Mercado Díaz

Sierra palm forest

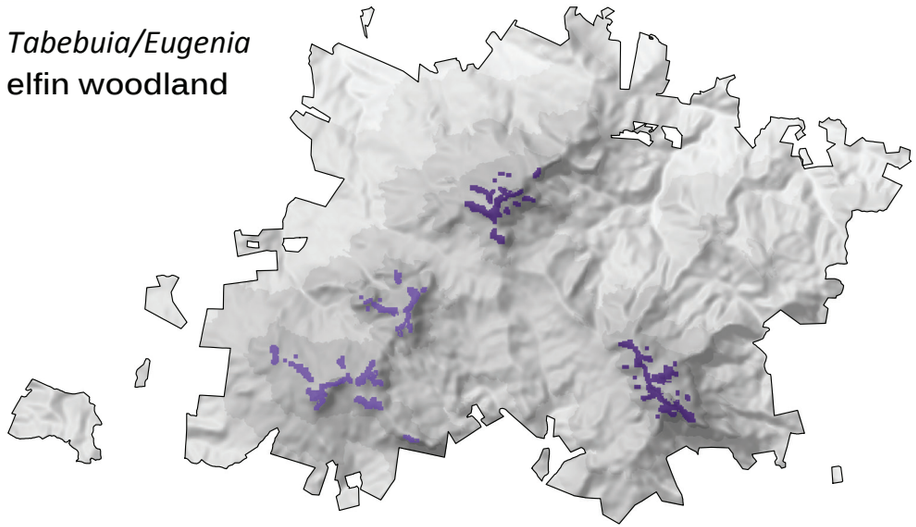


Mature sierra palm montane wet forest
Mature sierra palm montane wet cloud forest
Mature sierra palm montane rain cloud forest

The sierra palm forest, also known as palm brakes, is dominated by sierra palm, *Prestoea montana*, which typically accounts for over half of its total tree count.[3] The palm canopies can reach 15 m (50 feet) in height and tend to survive hurricanes very well.[3, 32] Tree species from surrounding forest types can be found among the predominant palms; and sparse grasses or rocks cover the ground. Palm fruits are part of the basic diet of the Puerto Rican parrot.[3, 7]


Photo by Joel A. Mercado Díaz

Tabebuia/Eugenia elfin woodland



Mature *Tabebuia/Eugenia* elfin woodland montane wet cloud forest
Mature *Tabebuia/Eugenia* elfin woodland montane rain cloud forest

The *Tabebuia/Eugenia* elfin woodland, also known as dwarf forest, occupies the mountain peaks of El Yunque where the combination of low temperatures, high humidity and rainfall, high winds, and almost constant cloud cover create habitat conditions that slow and stunt tree growth. Fewer species have adapted to survive on the exposed summits, with only four accounting for 70% of this forest type: *Tabebuia rigida*, *Eugenia borinquensis*, *Ocotea spathulata*, and *Cyathea bryophila*. The tree canopies typically range from 1 to 6 m in height. This forest type shelters 20 endemic tree species and protects the highest slopes and summits from erosion. Tree trunks here are seldom straight.[3, 33]

Puerto Rico's forest history at a glance

Puerto Rico's forests, abundant across the entire island on the arrival of the Europeans in the 16th century, were converted to pastures and cropland, and its trees were used for timber and charcoal. By the late 1940s, only about 6% of Puerto Rico's land area had any forest left, making it "one of the most severely deforested and eroded regions in the world."[38]

A combination of socioeconomic changes, the abandonment of agriculture, migration from the countryside to the cities and to the United States, reforestation and silvicultural campaigns by the government, natural forest regeneration, and the establishment of a tropical forestry research station allowed and encouraged forest regeneration across the country.[39] As of 2009, Puerto Rico's forests covered 55% of its territory.[40]

El Yunque National Forest, unique among Puerto Rico's forests, holds some of the few remnants of primary or 'virgin' forest in the island—forest that has not been greatly disturbed and therefore has kept its original structure and species composition.[16]

Elevation (meters)

- > 1000
- 800–1000
- 600–800
- 300–600
- 100–300
- < 100

Photo by Gary Potts

VERTEBRATE ANIMALS

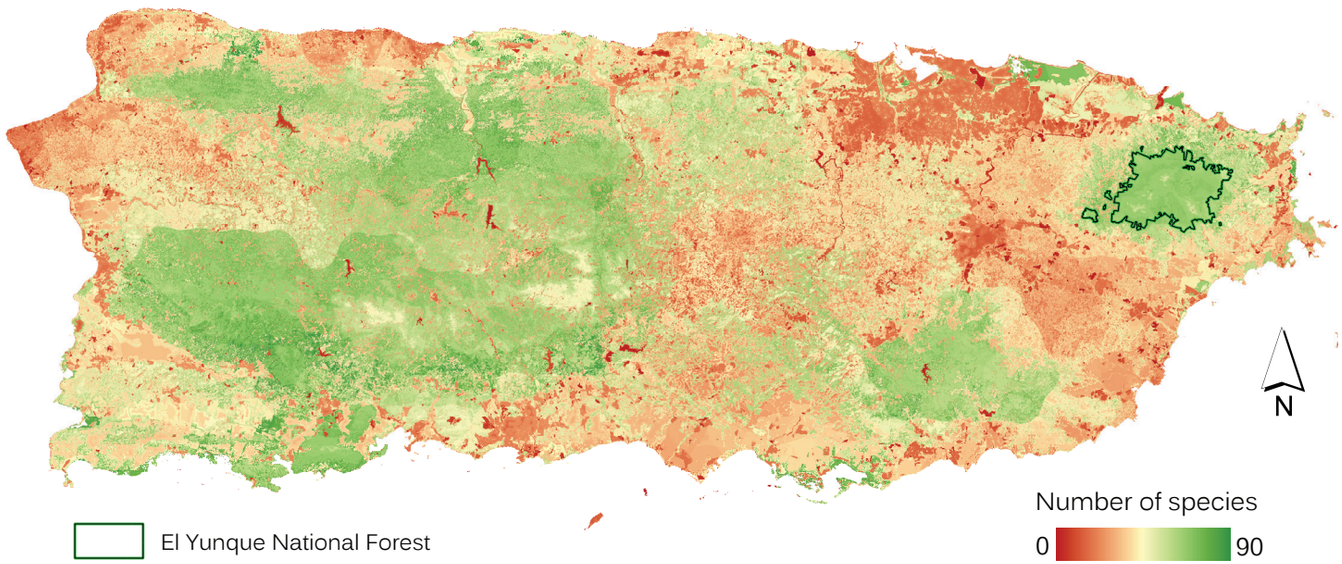
Biodiversity

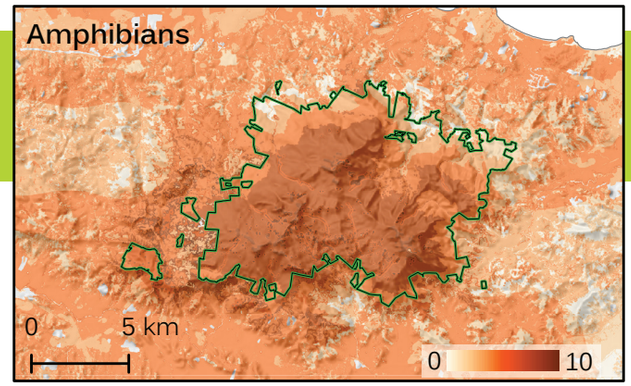
El Yunque harbors 164 vertebrate species, of which 157 are terrestrial and 7 are aquatic.[7]

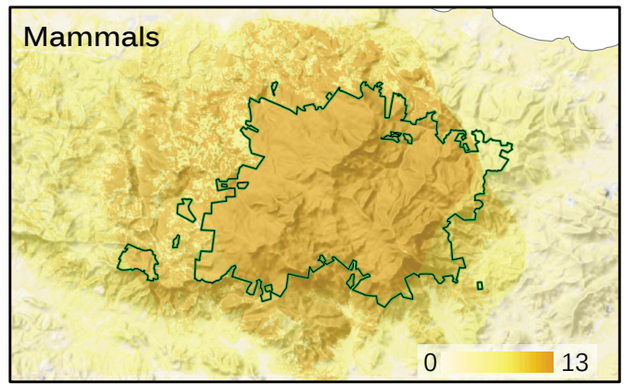
VERTEBRATES	NUMBER OF SPECIES	DESCRIPTION[3]
Birds	107	61 resident (54 native & 7 introduced) + 46 migratory
Reptiles	19	1 endemic + 18 natives 11 lizards + 3 geckos (1 introduced) + 5 snakes
Mammals	16	11 native bats + 5 introduced species
Amphibians	15	14 native frogs (13 endemic) + 1 introduced
Fish	7	6 native + 1 introduced

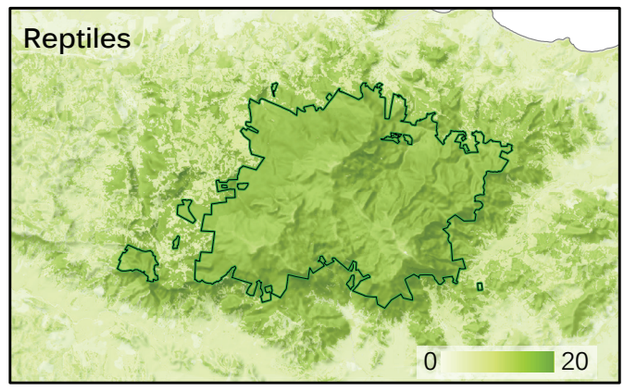
El Yunque National Forest is home to many plants and animals, including endangered and endemic species—species only found in Puerto Rico or the Caribbean region. These maps show the species richness of Puerto Rico's and El Yunque National Forest's vertebrate land animals. **Species richness** refers to the number of different kinds of animals or plants that call a place home. The species richness maps were created by modelling the habitats—natural home environment—of 202 vertebrate land animals that live in all of Puerto Rico, including 18 amphibians, 123 birds, 14 mammals, and 47 reptiles. [41]

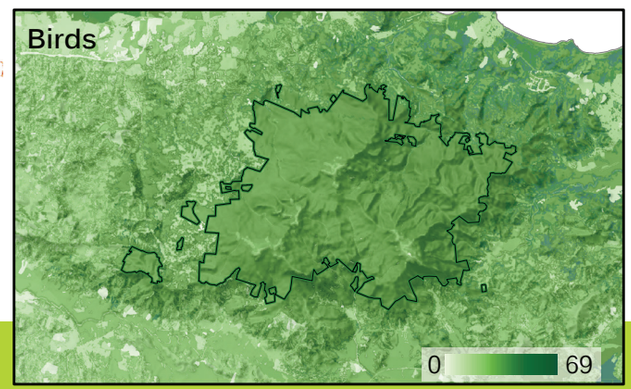
Species richness of vertebrate land animals[41]











FOREST FACT: Snakes are common but rarely seen in El Yunque; the largest is the Puerto Rican Boa, which can grow up to 90 inches (2.25 meters). The forest is a wildlife refuge and hunting is not allowed.

SPECIES OF CONSERVATION CONCERN

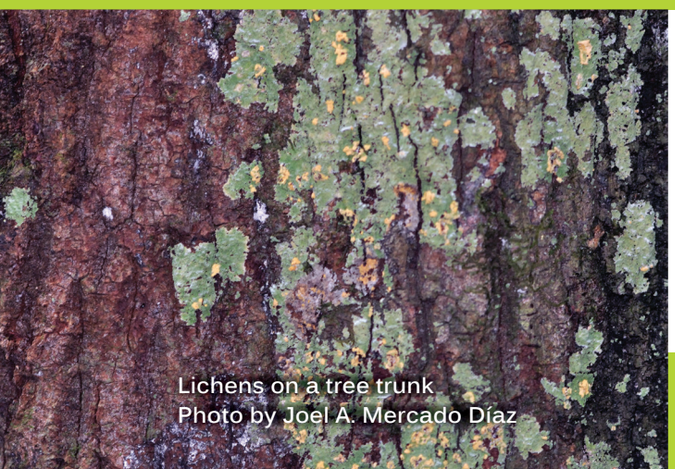
Plants

El Yunque National Forest is a complex ecosystem that fosters life from a wide range of species, from hundreds of tree species[7, 33] and over 160 vertebrate species,[7] to nearly 200 lichens,[42] and thousands of fungi and invertebrate species,[43, 44] some of which are vulnerable or endangered. A species is considered endangered when its individual numbers are sufficiently low as to be in immediate danger of disappearing completely.

Forest managers identify species for which there is substantial concern about their capability to persist over the long term in order to make management decisions that help these species survive; these are called species of conservation concern.[7]

LICHENS [42]

Lichens are symbiotic organisms in which a fungus and an alga species, or a fungi and cyanobacteria species, associate to form a distinct vegetative structure. Symbiosis refers to an interdependent relationship between two or more organisms. Lichens are commonly found on tree trunks and branches, rocks, and on the ground but can colonize every type of substrate. Lichens grow in many colors and shapes.



Lichens on a tree trunk
Photo by Joel A. Mercado Díaz

El Yunque National Forest
Plant species of conservation concern [7]

SCIENTIFIC NAME	COMMON NAME
Herbs	
Justicia martinsoniana	Puerto Rico water-willow
Pilea multicaulis	Luquillo mountain clearweed
Pilea yunquensis	mountain clearweed
Orchids	
Brachionidium ciliolatum	hairy cup orchid
Brachionidium parvum	small brachionidium
Lepanthes caritensis	Carite babyboot orchid
Lepanthes dodiana	island babyboot orchid
Lepanthes eltoroensis	Luquillo mountain babyboot orchid
Lepanthes selenitepala	mountain babyboot orchid
Lepanthes stimsonii	Stimson's Lepanthes orchid
Lepanthes woodburyana	Woodbury's babyboot orchid
Lepanthes veleziana	Puerto Rico babyboot orchid
Shrubs or small trees	
Brunfelsia lactea	jazmin de monte
Brunfelsia portoricensis	jazmin portoricensis
Callicarpa ampla	capa rose
Cybianthus sintenisii	Puerto Rico ridgerunner
Eugenia stahlii	guayabota
Eugenia eggersii	palo de murta
Eugenia haematocarpa	uvillo
Ilex obcordata	cuero de sapo
Marlierea sintenisii	beruquillo
Solanum woodburyi	Woodbury's nightshade
Urera chlorocarpa	ortiga
Varronia wagnerorum	Luquillo mountain manjack
Miconia foveolata	camasey
Ternstroemia heptasepala	saintedwood
Ternstroemia subsessilis	el yunque colorado
Xylosma schwaneckeana	palo de candela
Terrestrial plants	
Lindsaea stricta	smallstalk necklace fern
Vines	
Gonocalyx portoricensis	Puerto Rico brittleleaf
Miconia pachyphylla	camasey racimoso

Lichens on a rock
Photo by Joel A. Mercado Díaz

SCIENTIFIC NAME	COMMON NAME
Trees	
Ardisia luquillensis	mameyuelo
Banara portoricensis	caracolillo
Calyptranthes luquillensis	Luquillo forest lidflower
Calyptranthes woodburyi	Woodbury's lidflower
Coccoloba rugosa	ortegon
Conostegia hotteana	camasey peludo
Eugenia borinquensis	limoncillo
Garcinia portoricensis	palo de cruz
Laplacea portoricensis	maricao verde
Magnolia splendens	laurel sabino
Maytenus elongata	cuero de sapo
Miconia pycnoneura	camasey
Morella holdrigeana	palo de cera
Pleodendron macranthum	chupacallos
Psidium sintenisii	hoja menuda
Ravenia urbanii	tortugo prieto
Styrax portoricensis	palo de jazmín
Symplocos lanata	níspero cimarrón
Ternstroemia luquillensis	palo colorado
Ternstroemia stahlii	palo de buey

El Yunque National Forest has been well studied, but its vast richness in such a small area still has secrets to uncover. In 2014, 12 new species and two new genera of lichens previously unknown to science were discovered inside El Yunque.[45]

SPECIES OF CONSERVATION CONCERN

Animals

Ground coquí
Eleutherodactylus richmondi
Photo by Jerry Bauer

DID YOU KNOW?

The coquí tree frogs are an endemic species to the island of Puerto Rico. Unlike many amphibians, they are born into small adult frogs straight from the eggs with no tadpole stage within their development. The male coquís protect the eggs until several days after the frogs hatch.[7]

Ground coquí
Eleutherodactylus richmondi
Photo by Jerry Bauer

El Yunque National Forest
Animal species of conservation concern[7]

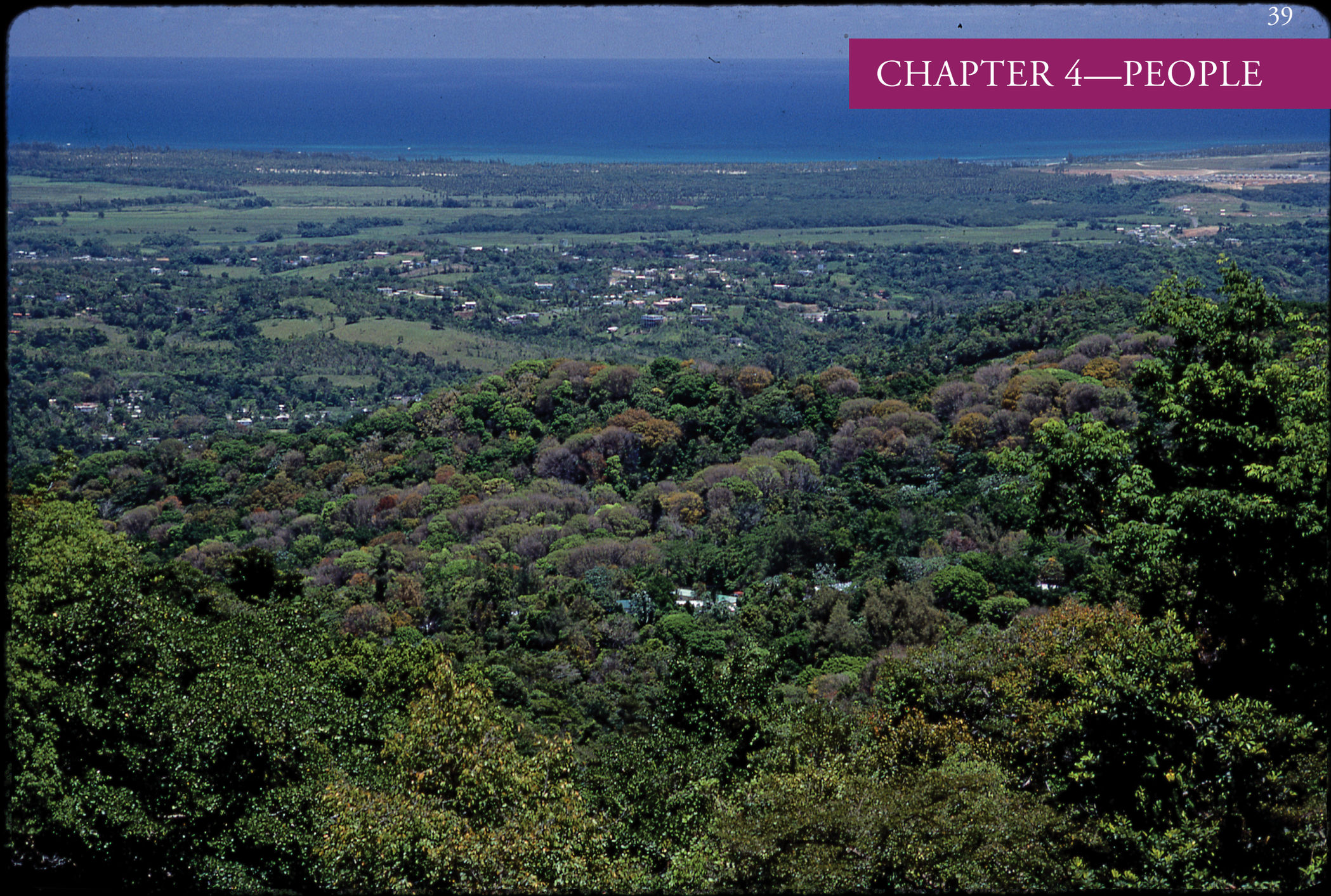
SCIENTIFIC NAME	COMMON NAME
Amphibians	
Eleutherodactylus eneidae	mottled coquí
Eleutherodactylus karlschmidti	web-footed coquí
Eleutherodactylus unicolor	burrow coquí
Eleutherodactylus locustus	warty coquí
Eleutherodactylus richmondi	ground coquí
Eleutherodactylus gryllus	cricket coquí
Eleutherodactylus hedricki	tree-hole coquí
Eleutherodactylus portoricensis	Puerto Rican coquí
Eleutherodactylus wightmanae	wrinkled coquí
Aquatic species	
Anguilla rostrata	American eel
Awaous banana	river goby
Dormitor maculatus	fat sleeper
Eleotris pisonis	spinycheek sleeper
Gobiomorus dormitor	bigmouth sleeper
Macrobrachium carcinus	river shrimp
Macrobrachium crenulatum	bocú shrimp
Birds	
Accipiter striatus venator	Puerto Rican sharp-shinned hawk
Amazona vittata	Puerto Rican parrot
Buteo platypterus brunnescens	broad-winged hawk
Falco peregrinus	peregrine falcon
Icterus dominicensis	black-cowled oriole
Setophaga angelae	elfin woods warbler
Setophaga caerulescens	black-throated blue warbler
Mammals	
Stenoderma rufum	red fig-eating bat
Reptiles	
Anolis cuvieri	Puerto Rican giant anole
Anolis occultus	Puerto Rican pygmy anole
Chilabothrus inornatus	Puerto Rican boa

The Puerto Rican parrot
Amazona vittata
Photo by Jerry Bauer

DID YOU KNOW?

The Puerto Rican parrot, also known as Iguaca, was listed as an endangered species in 1968. Only an estimated 13 individuals were living in the wild by 1976.[7] In 2015 the Puerto Rico Department of Natural and Environmental Resources reported the parrot population, including captive birds in the aviaries, at an estimated 500 individuals.[46]

CHAPTER 4—PEOPLE

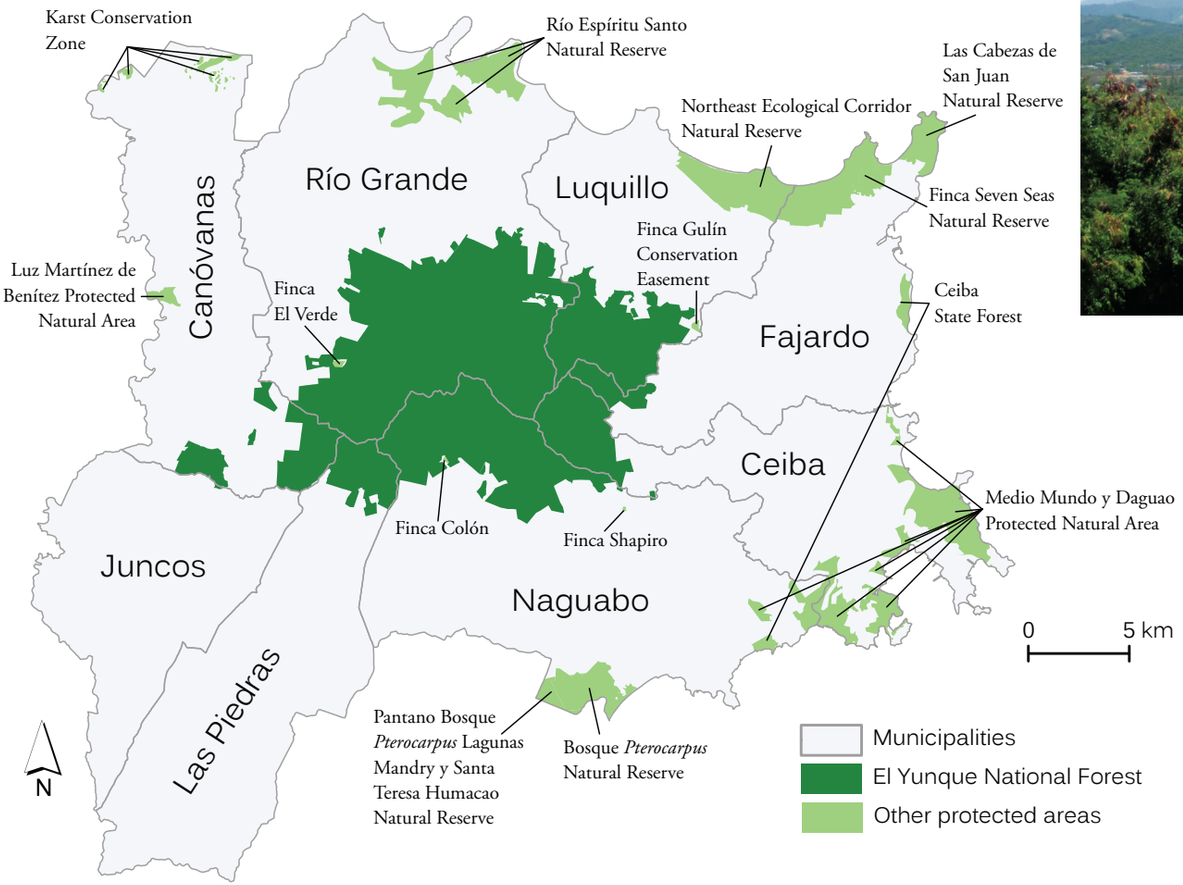


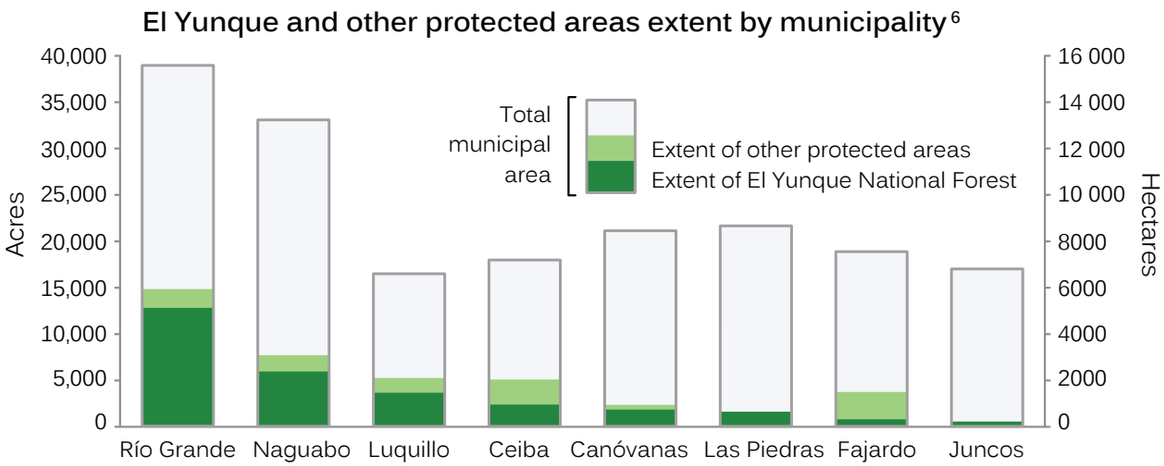
View of the east coast from El Yunque in 1983. Photo by Jerry Bauer

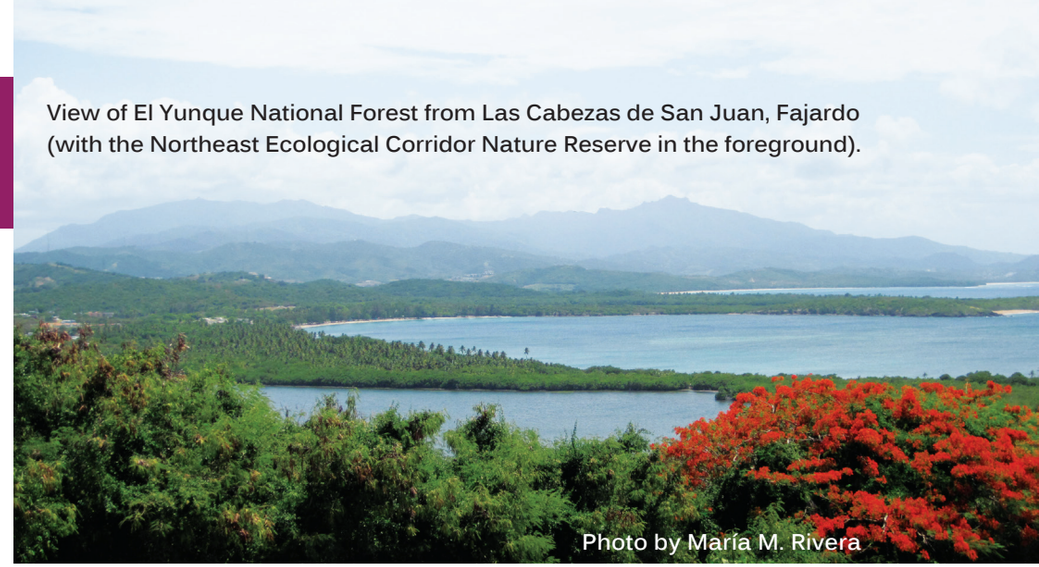
"El Yunque is a blessing for Puerto Rico. Its oxygen, clean water, fresh air, recreation areas, flora and fauna are unique in the world. I have the privilege of living near and see and delight in its enchantments every day. I hope that people today and future generations take care of the forest, so that we can forever enjoy its greatness."

—Richard Washburn, Naguabo community leader

EL YUNQUE REGION
Municipalities and other protected areas







View of El Yunque National Forest from Las Cabezas de San Juan, Fajardo (with the Northeast Ecological Corridor Nature Reserve in the foreground).

El Yunque National Forest stretches across eight municipalities in northeastern Puerto Rico that total just over 75 270 ha (186,000 acres). At 11 540 ha (28,516 acres), El Yunque comprises about 15% of their combined area. Other protected areas in the region account for 4157 ha (10,273 acres), 5.5% of the total area. Together, these municipalities accommodated a growing population and an increasing percentage of Puerto Rico's total population through the early 2000s. Yet, following an island-wide trend, population growth in the region began declining by about 2010 as an increasing number of people emigrated off the island, many in response to the economic situation, and as birth rates declined (e.g., 1990: 18.87 live births/1,000 persons; 2010: 11.34 live births/1,000 persons).[47]

Population in El Yunque region

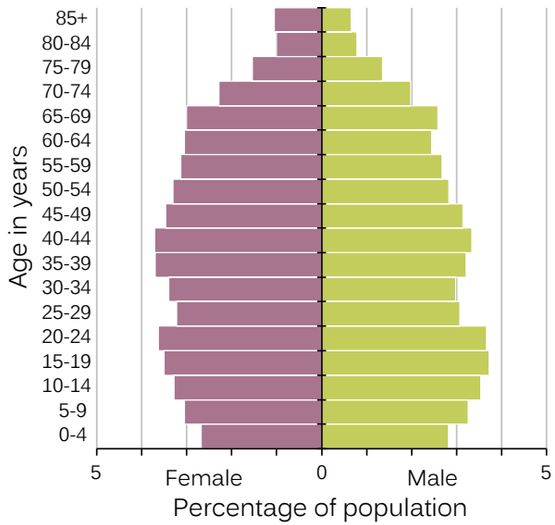
According to the U.S. Census Bureau,[47] the population in the eight municipalities surrounding the forest totaled 271,778 persons in 2014, down by more than 6,500 persons since 2010. Between 2010 and 2014, Naguabo was the only municipality in the region with continued population growth (0.16 %/year), while Fajardo and Ceiba saw the region's highest rates of population loss (-1.99%/year, -1.88 %/year, respectively). The age structure of the regional population also has changed quite dramatically in recent years, having exhibited a pyramidal shape indicative of a growing population through the end of the 20th century, but shifting to a more conical and increasingly top-heavy shape by 2014, indicative of a shrinking population as the percentage of people in older, post-reproductive age groups increases, while those in younger age groups contracts.

POPULATION
Distribution and change

Population by age and gender
El Yunque region

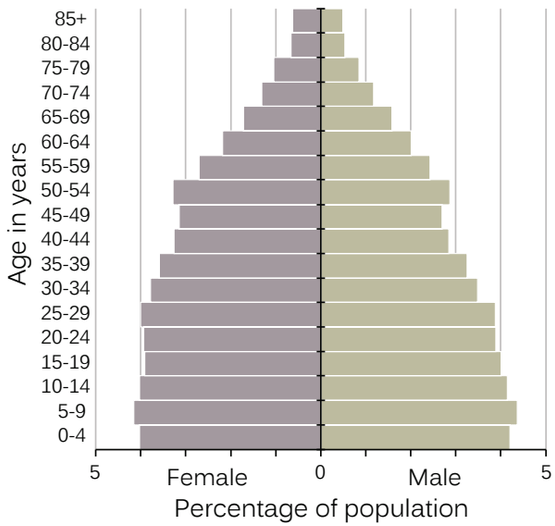
2014

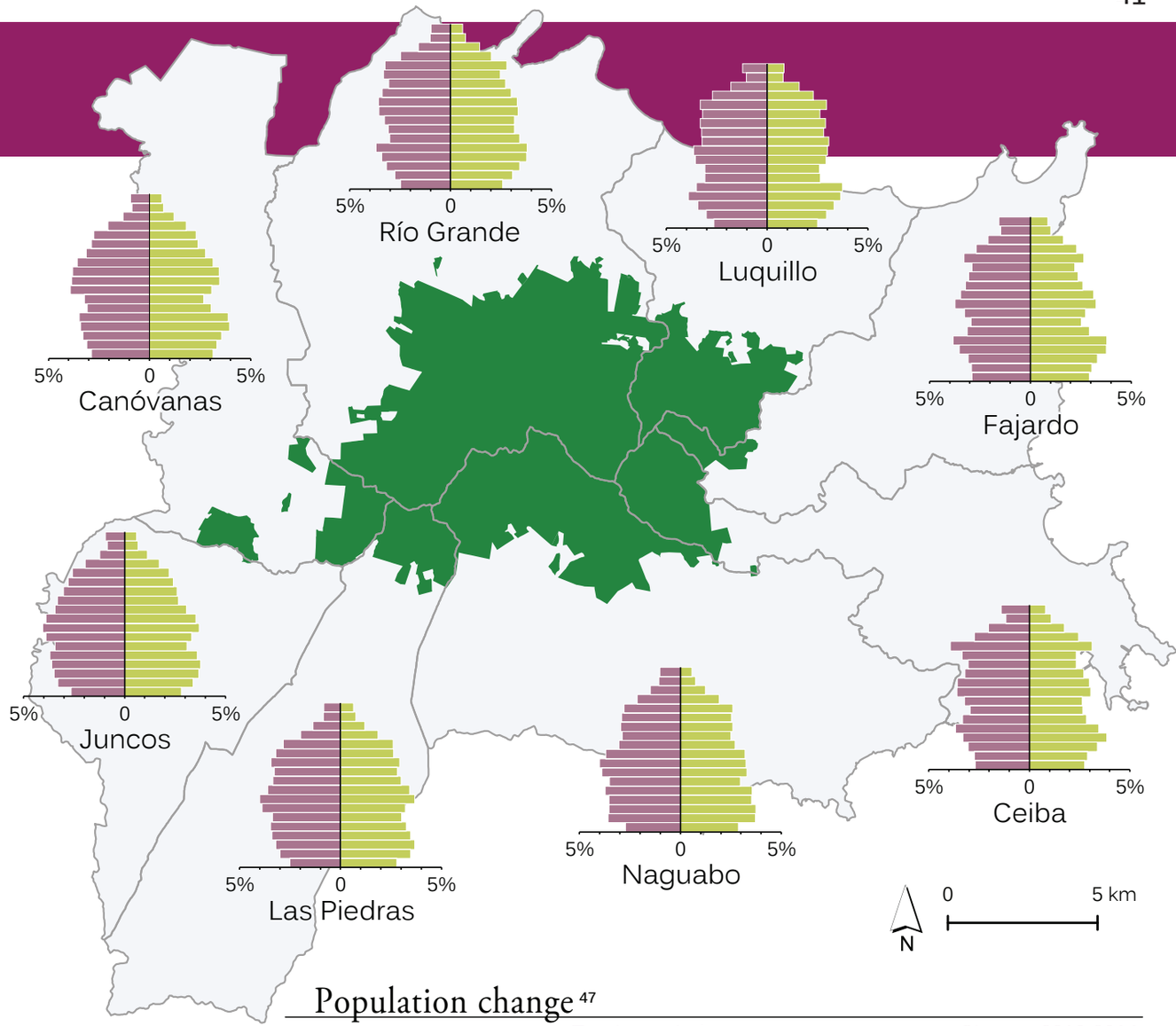
Total Population = 271,778



2000

Total Population = 268,920





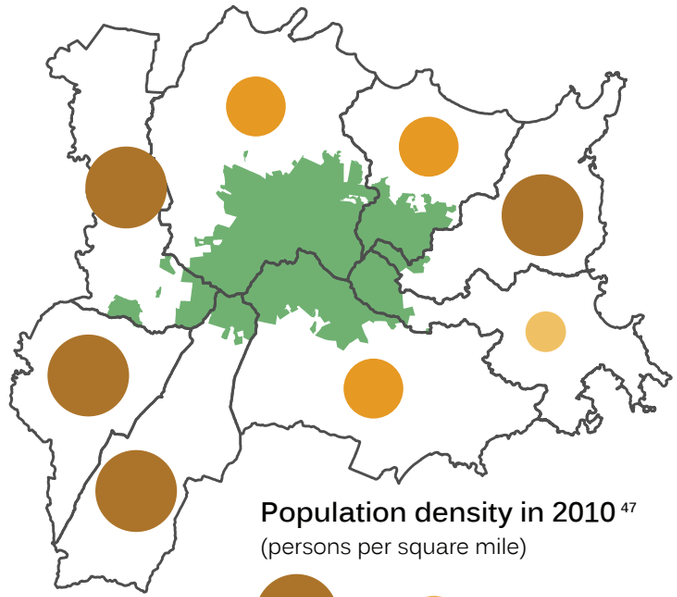
Population change [47]

	Total population				Change 2010-2014	
	1990	2000	2010	2014	Net	%
Canóvanas	36,816	43,335	47,648	47,457	-191	-0.40
Ceiba	17,145	18,004	13,631	12,607	-1,024	-7.51
Fajardo	36,882	40,712	36,993	34,049	-2,944	-7.96
Juncos	30,612	36,452	40,290	40,102	-188	-0.47
Las Piedras	27,896	34,485	38,675	38,671	-4	-0.01
Luquillo	18,100	19,817	20,068	19,338	-730	-3.64
Naguabo	22,620	23,753	26,720	26,886	166	0.62
Río Grande	45,648	52,362	54,304	52,668	-1,636	-3.01
Total region	235,719	268,920	278,329	271,778	-6,551	-2.35
Puerto Rico	3,522,037	3,808,610	3,725,789	3,548,397	-177,392	-4.76

POPULATION
Density and urbanization

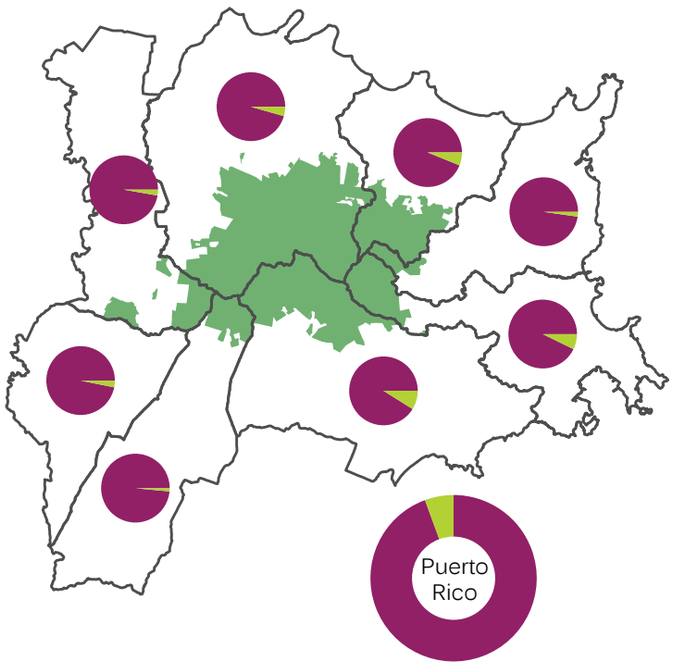
Population density around El Yunque increased throughout much of the 20th century, reaching 955 persons/mi² (369 pers./km²) by 2010; ranging from 470 pers./mi² (182 pers./km²) in Ceiba to 1,521 pers./mi² (587 pers./km²) in Juncos. Given the associated density in residential, commercial, and other built-up areas, 96% of the regional population was classified as "urban" by the U.S. Census Bureau in 2010, up from 37% in 1970.[47]

With decreases in the population around El Yunque since about 2010, population densities have decreased as well, but remain among the highest in the world. For example, while the lowest in the region, Ceiba's population density in 2010 still ranked higher than two thirds of the world's sovereign nations.[48]



Population density in 2010 [47]
(persons per square mile)

>1,000 500–1,000 <500

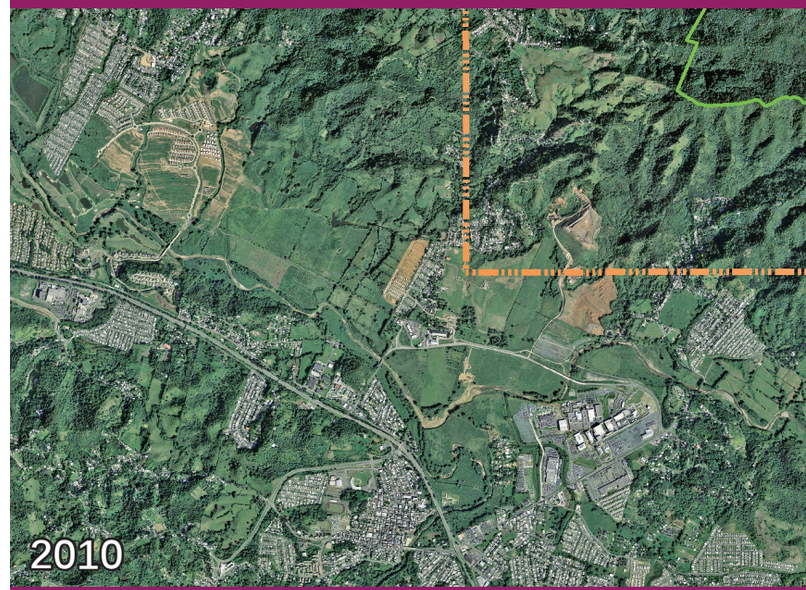


Urban and rural population in 2010 [47]

Municipalities	Urban	Rural	Total
Canóvanas	46,563	1,085	47,648
Ceiba	12,021	1,610	13,631
Fajardo	36,209	784	36,993
Juncos	38,995	1,295	40,290
Las Piedras	37,734	941	38,675
Luquillo	18,289	1,779	20,068
Naguabo	24,481	2,239	26,720
Río Grande	52,916	1,388	54,304
Region	267,208	11,121	278,329
Puerto Rico	3,493,256	232,533	3,725,789

Urban population
Rural population
El Yunque National Forest

Juncos urban center to the southwest of El Yunque. Aerial view from 1998 and 2010.[49, 14]



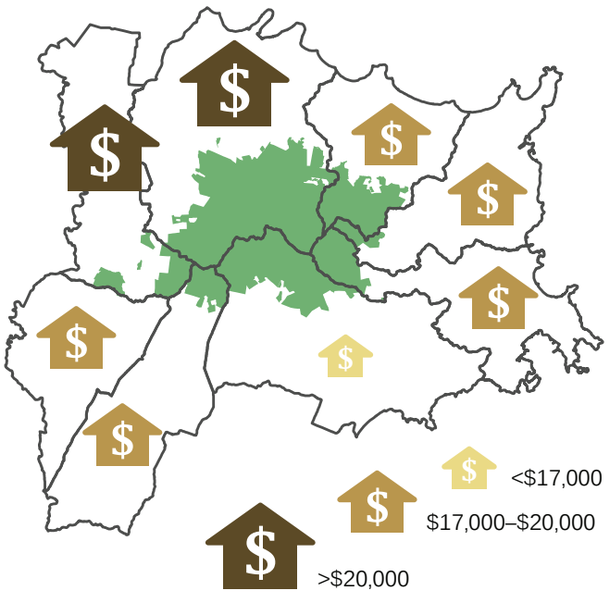
Urbanization around El Yunque

As the population and landscape surrounding El Yunque are increasingly urbanized and built up, there is concurrent loss of green space, disruption of hydrological systems, introduction of nonnative species, and interruption of nutrient cycles, which collectively result in changes in the benefits and services that forests provide.[7] Between 1998 and 2010, studies show that built-up areas increased by 1334 ha (3,297 acres) in the eight municipalities that shelter El Yunque, with Juncos having the highest percentage of change.[50]

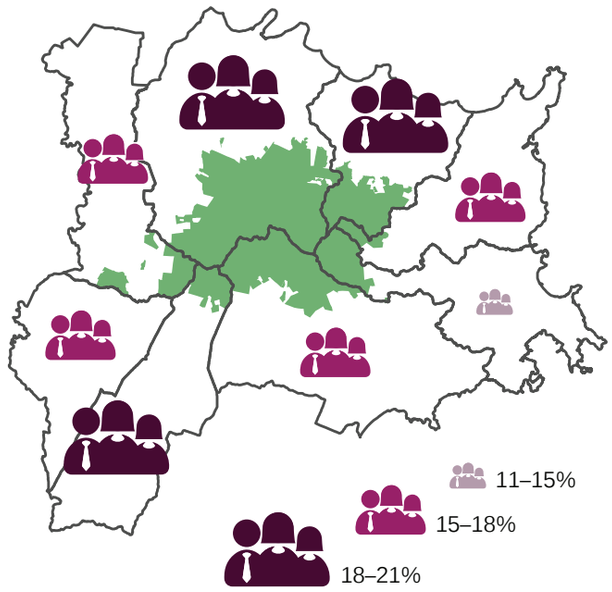
SOCIOECONOMIC STATISTICS

Income, unemployment, and housing in El Yunque region

Median household income in 2010



Unemployment rate in 2010



Per capita income in the municipalities surrounding El Yunque ranged from $7,548 in Naguabo to $10,506 in Luquillo in 2010. Median household income ranged from $15,250 in Naguabo to $21,934 in Canóvanas. Unemployment in the civilian labor force was about 17% in 2010. However, the percentage of the population actively seeking employment that year was significantly lower than in the United States (48% vs. 65%). Income, employment, and many other socioeconomic factors have been influenced by the economic crisis affecting Puerto Rico since the mid-2000s.

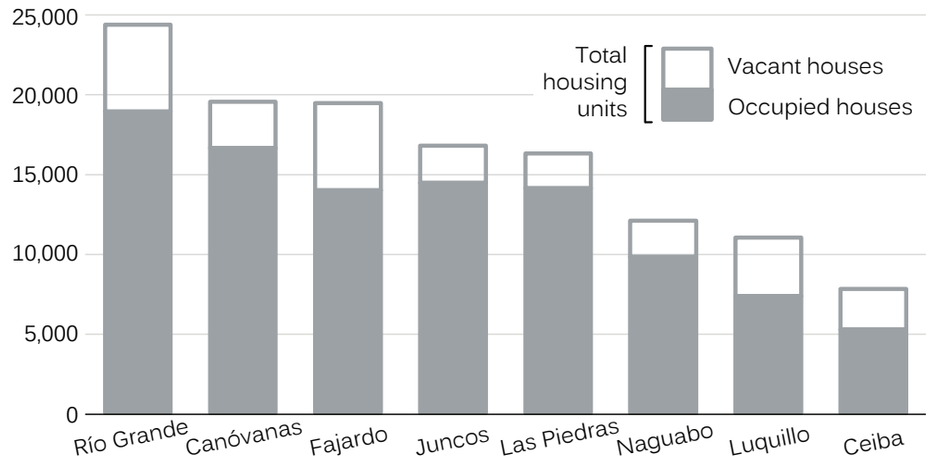
In 2010, about 44% of the regional population was living below the poverty level as defined by the U.S. Census Bureau.[47] Fairly significant intraregional differences existed, with Fajardo and Río Grande having the lowest poverty rates (42%), while Naguabo had the highest poverty rate (53%). In 2010, children (younger than 18) made up a disproportionate share of the poor, representing less than 25% of the total regional population, but more than 33% of those living in poverty.

In 2010, the majority of jobs in the region were in "education, health, and social services" (21%), followed by "retail trade" (13%), "manufacturing" (12%) and "arts, entertainment, recreation, and accommodations" (10%), all of which increased over the 2000 U.S. Census rates, except manufacturing, which declined by 3%.[7]

Income and unemployment in 2010 [47]

Municipalities	Per capita income	Median household income	Unemployed civilian labor force	Total population living below poverty level	Children (<18 yrs) living below poverty level
Canóvanas	$9,852	$21,934	15.3%	42.5%	52.6%
Ceiba	$9,658	$18,461	11.7%	43.1%	52.6%
Fajardo	$9,949	$19,803	17.6%	42.1%	54.6%
Juncos	$8,968	$17,694	15.9%	47.3%	55.6%
Las Piedras	$9,078	$17,680	18.6%	47.5%	56.6%
Luquillo	$10,506	$19,672	21%	44.9%	63.5%
Naguabo	$7,548	$15,250	15.4%	52.6%	64.7%
Río Grande	$10,049	$20,850	19.3%	42.1%	53.3%
Puerto Rico	$10,355	$18,791	16.7%	45.2%	56.3%

Occupied and vacant housing units in 2010 [51]



CHAPTER 5—RESEARCH AND MANAGEMENT

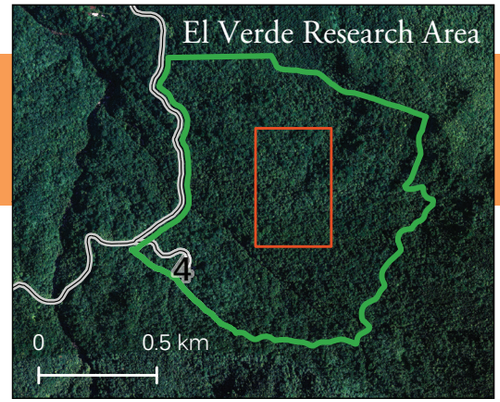
"El Yunque National Forest is a truly dynamic ecosystem where each visit to the field has the potential for adventure, memorable stories, discovery, and physical and mental awareness. The benefits we receive by visiting the Luquillo forest over the long term never get old or wasted as the landscape and the experiences are always changing."

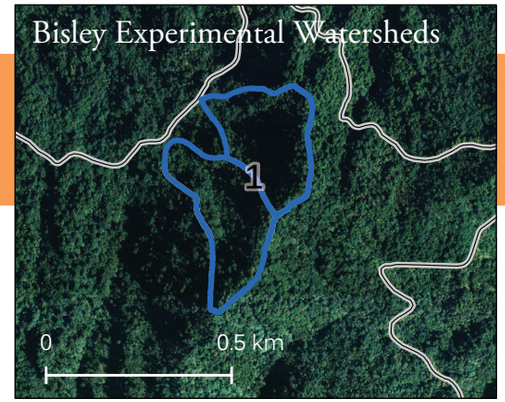
—Grizelle González, research project leader, USDA Forest Service

Photo by Joel A. Mercado Díaz
María M. Rivera, Biologist Specialist

RESEARCH
Sites and plot network

El Yunque National Forest is a living research laboratory. Designated the Luquillo Experimental Forest in 1956, it has provided an array of useful information on local climate, geology, soils, water resources, flora, fauna, and ecology for over a century. In 1988, the National Science Foundation began the Long Term Ecological Research Program and established long-term research sites in the forest. Today, over 1,000 scientific publications have been written based on the research done in El Yunque. [32]





Main research sites

1. Bisley Experimental Watersheds
2. Caracoles Arboretum
3. Catalina
4. El Verde Field Research Station
5. Guzmán plantation
6. Harvey plantation
7. Iguaca Aviary
8. Pico del Este
9. Pico del Oeste
10. Río Grande 3
11. Sabana 4
12. Sabana 8
13. Sabana Field Research Station

Research areas

- Bisley Experimental Watersheds
- El Verde Research Area
- Luquillo Forest Dynamic Plot
- Luquillo Experimental Forest
- Research plots
- Trails
- Roads
- Closed road
- Proclamation area

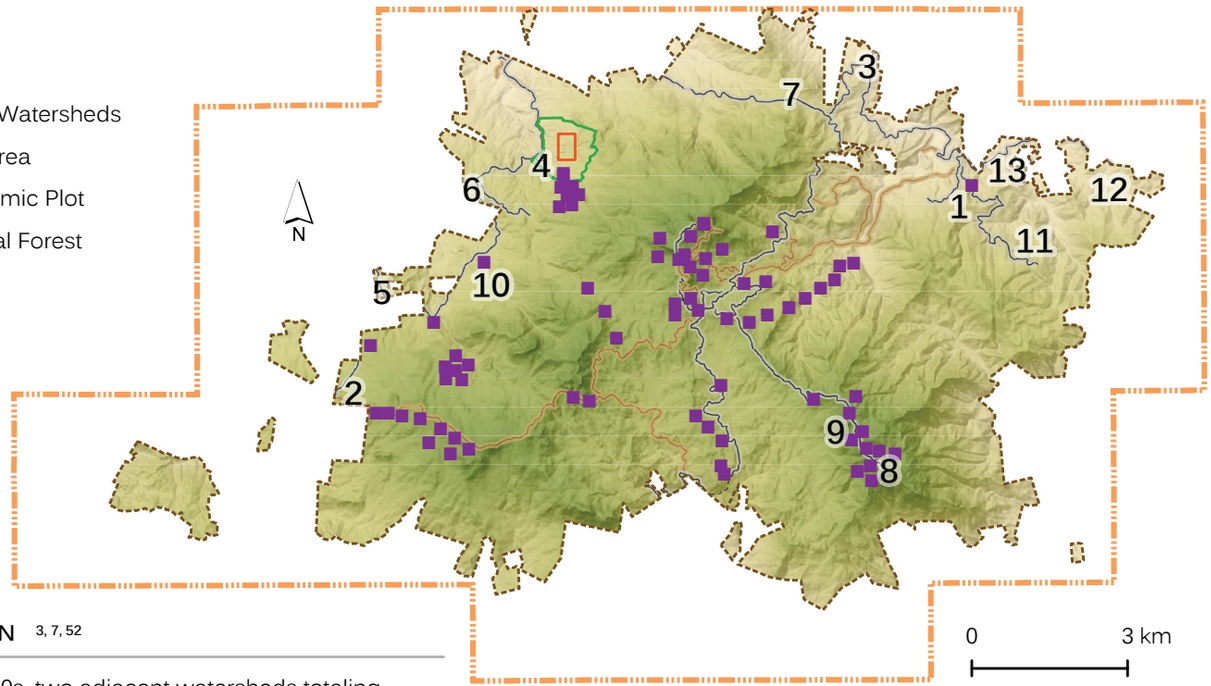



Photo by Joel A. Mercado Díaz

STATION	DESCRIPTION [3, 7, 52]
Bisley Experimental Watersheds	Since the 1980s, two adjacent watersheds totaling 13 ha (32 acres) in the northern part of the forest were designated as Long-Term Experimental Watersheds for the study of climate, water resources, nutrient cycling, flora, and fauna. Ozone monitoring in the site started in 2008. The site has two walk-up canopy towers, climate stations, three stream gages, throughfall and litter collectors, permanent ecological study plots, and areas designated for aquatic research.
Iguaca Aviary	Managed by the U.S. Fish and Wildlife Service, the Iguaca Aviary sits on half a hectare (1.2 acres) of land at 550 m elevation since 1972. It is one of two aviaries in Puerto Rico that house the endangered Puerto Rican parrot (*Amazona vittata*). Its breeding program has enabled the transfer of Puerto Rican parrots back into the wild and between aviaries, increasing both the wild and aviary populations.
El Verde Research Station and Luquillo Forest Dynamics Plot	Scientific research in El Verde began in the 1940s, focusing on forest dynamics, and later in the 1960s on stream ecology, hydrology, and ecosystem processes. Most current research is conducted by the Luquillo Long-Term Ecological Research program. Some of the facilities were constructed in the 1930s and are considered of historic value. In 1990, the Luquillo Forest Dynamics Plot was established near El Verde Station, covering 16 ha (39.5 acres), with elevations from 333 to 428 m.
Sabana Field Research Station	The station is located at 265 m in elevation within a small community on the outskirts of the forest near the Bisley Experimental Watersheds. It holds facilities for water analyses and a mycology—the study of fungi—laboratory, plus living quarters for visiting researchers.

DESIGNATED AREAS
Description and management

Baño de Oro Research Natural Area (1949) [3]

Federal research natural areas are predominantly natural tracts of land with little human influence, preserved for scientific and educational purposes. Designated in 1949, this area covers 745 ha (1,841 acres). This area is one of the wettest in the forest and provides habitat for at least 40 bird species. Total relief is 780 m, ranging from 245 m along the Mameyes River in the north to 1025 m in Pico del Oeste in the south.

El Toro Wilderness Area (2005) [3]

Designated by the U.S. Congress as a wilderness area in 2005 under the Wilderness Act of 1964, El Toro Wilderness Area is the largest undisturbed stretch of land in Puerto Rico, measuring over 4150 ha (10,254 acres). Wilderness refers to land with minimal impact from human activity that remains in its original "wild" state. The Wilderness Act aims to conserve the primeval character and influence of these areas for public enjoyment in perpetuity. Named after the highest peak in the Luquillo Mountains, elevations here range from 370 m to 1074 m; the headwaters of 10 streams that supply water to surrounding communities flow from its peaks.

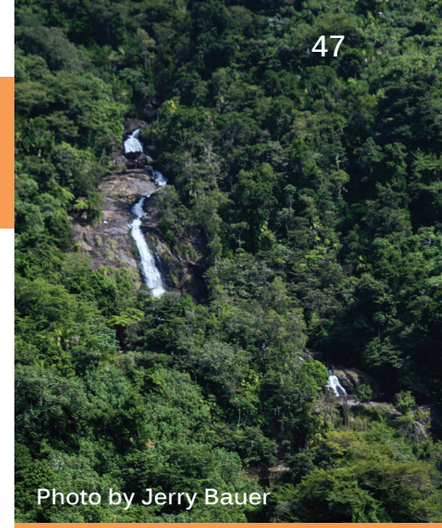
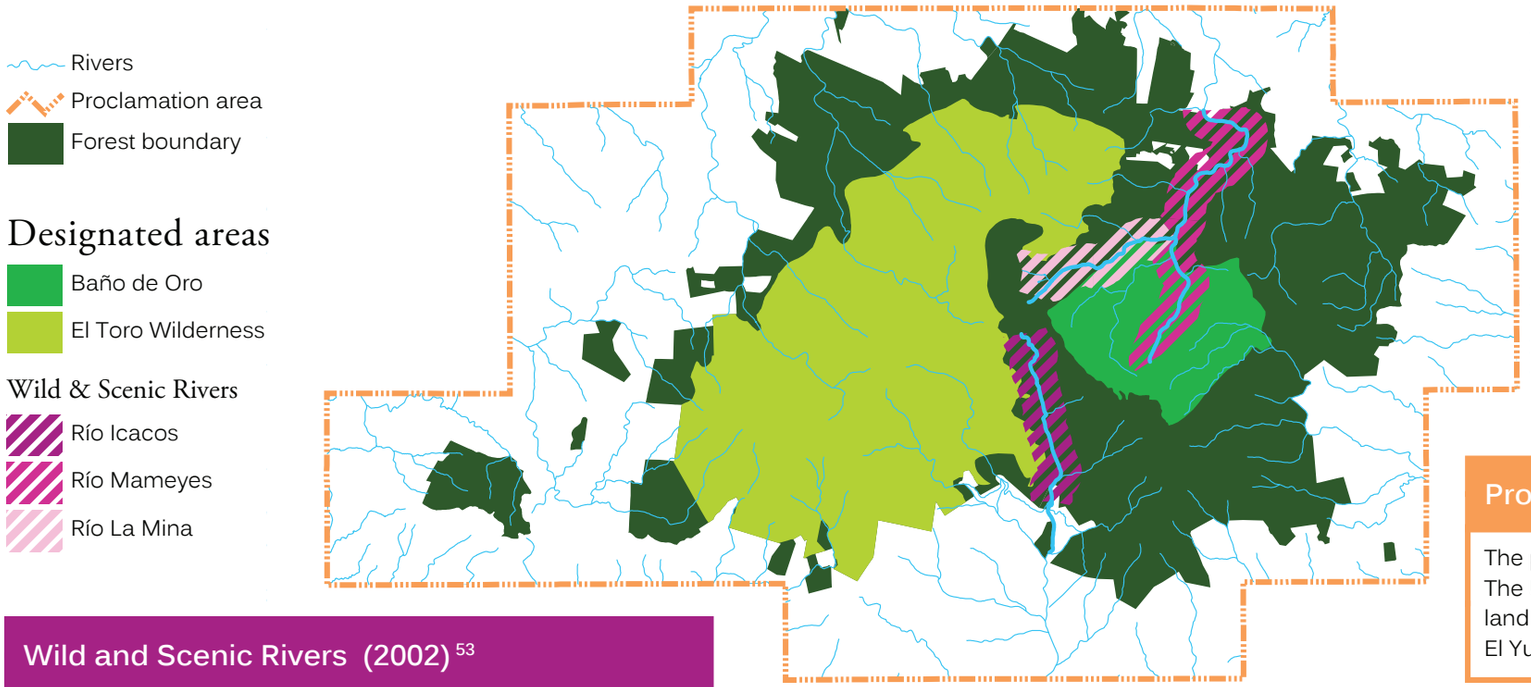


Photo by Jerry Bauer



FOREST FACT

In 1976, the entire El Yunque National Forest was declared the Luquillo Experimental Forest Biosphere Reserve. Biosphere Reserves are internationally recognized protected areas managed to promote biodiversity conservation and sustainable uses. The reserves are nominated by local governments to the United Nations Educational, Scientific, and Cultural Organization (UNESCO).

Proclamation Area (1950) [7]

The proclamation area is a legal delimitation. The USDA Forest Service is permitted to buy land inside this area to incorporate into the El Yunque National Forest.

Wild and Scenic Rivers (2002) [53]

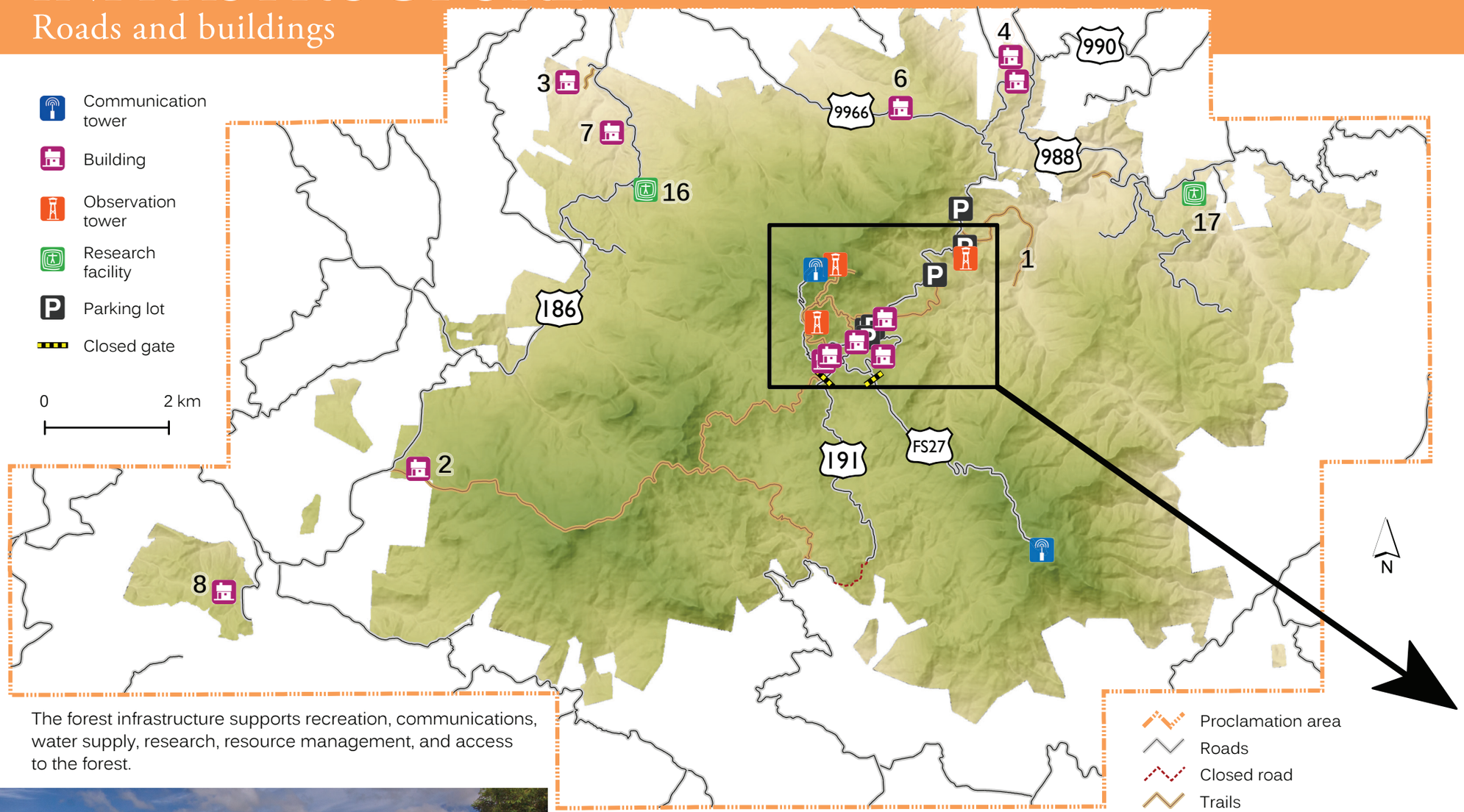
The U.S. Congress designated portions of the rivers Río Mameyes, Río de la Mina, and Río Icacos as National Wild and Scenic Rivers in 2002 for their unique scenic, recreational, geologic, fish and wildlife, historic, and cultural values. These are the only tropical rivers in the National Wild and Scenic River System. Portions of the rivers under this designation are classified as wild, scenic, or recreational, each with its own level of protection, but in general preserving them in their natural free-flowing condition, and accessible mostly by trail. The zones around the rivers are also protected, kept in primitive condition, free of structures or modifications of the landscape. They serve as undisturbed habitat for many species.

RIVER	CLASSIFICATION	LENGTH [54]
Río Mameyes	Wild	1.6 miles (2.6 km)
	Scenic	1.4 miles (2.3 km)
	Recreation	1.0 miles (1.6 km)
Río La Mina	Scenic	1.2 miles (1.9 km)
	Recreation	0.9 miles (1.4 km)
Río Icacos	Scenic	2.3 miles (3.7 km)

Photo by Jerry Bauer

INFRASTRUCTURE

Roads and buildings



The forest infrastructure supports recreation, communications, water supply, research, resource management, and access to the forest.

El Portal Visitor Center, Photo by Jerry Bauer

Constructed in the 1930s, the road system that runs through the forest allows access to resources and communication sites and is essential for recreational, administrative, and research uses. There are about 33 miles (53 km) of roads within the forest.[7] Intense maintenance is needed on many of the roads because of weather conditions in the Luquillo Mountains. Gates on some roads control vehicular access according to road conditions or to limit use for official business and rescue efforts. The forest has a total of 454 parking spaces. There are 18.8 miles (30 km) of recreational trails and 12 miles (19 km) of administrative trails. All trails are restricted to foot traffic (hiking) only. Horses, motorcycles, and mountain bikes are not allowed within the forest.

A section of road PR-191 in the south side of the forest has been closed since a landslide destroyed it in 1981.

Label	Buildings
1.	Catalina (FS Headquarters)
2.	Cienaga Alta house
3.	Eliza Colberg Camp
4.	El Portal Visitors Center
5.	El Yunque Pavilion
6.	Iguaca Aviary
7.	Job Corps Camp
8.	La Condesa School
9.	La Mina barracks and old aviary
10.	La Mina fish hatchery
11.	Molindero cottages
12.	Stone house

Observation towers

13.	El Yunque tower
14.	Mount Britton tower
15.	Yokahú tower

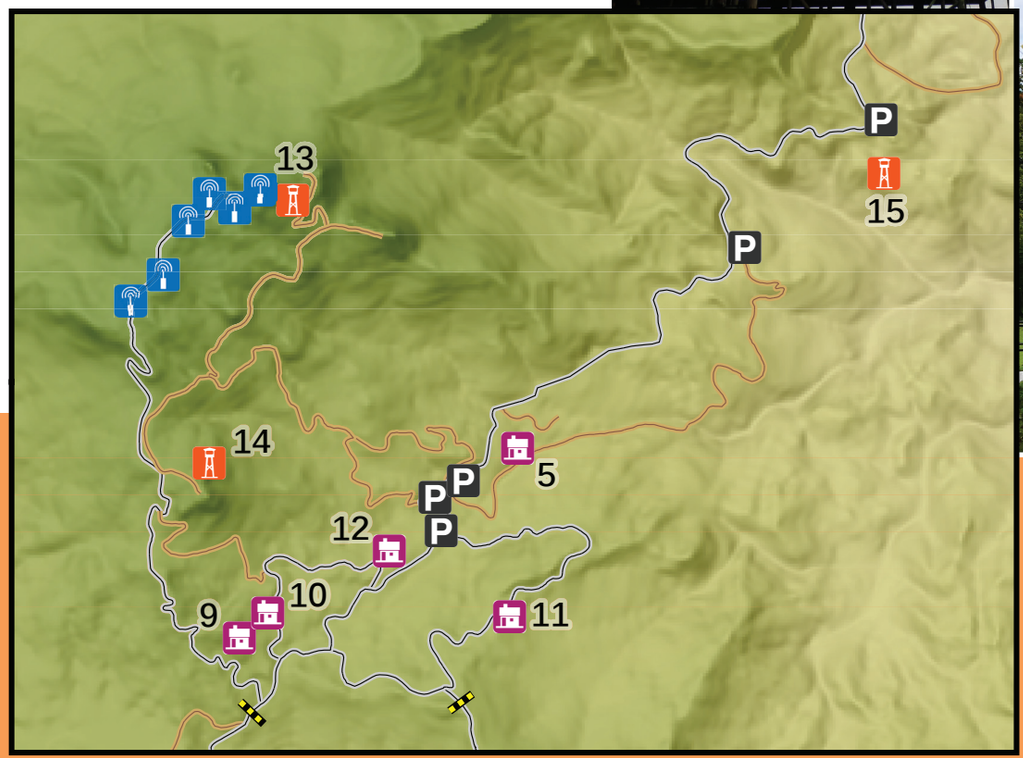
Research facilities

16.	El Verde Field Station
17.	Sabana Field Research Station

Communication tower
Photo by Carl Baker

El Verde Field Research Station
Photo by Gary Potts

Sabana Field Research Station
Photo by Carlos Estrada



International Institute of Tropical Forestry
Photo by Maya Quiñones

INTERNATIONAL INSTITUTE OF TROPICAL FORESTRY

The International Institute of Tropical Forestry is a USDA Forest Service research development and technology transfer institute located in Río Piedras, Puerto Rico. Created in 1939 in cooperation with the University of Puerto Rico, the Institute has long been a leader in tropical forestry research, technology transfer, and technical assistance throughout the world. Through its research the Institute has contributed invaluable information about El Yunque National Forest. The mission of the Institute includes to develop and disseminate knowledge that contributes to the conservation of tropical forests, wildlife, and watersheds.

CHAPTER 6—RECREATION

"El Yunque gave me the opportunity of feeling fulfilled, through my long walks and pouring rain while we evaluated the forest's condition and during the preparation of the land for the planting of mahogany trees. I will not deny that in many occasions I was mesmerized with the sights and sounds of the forest during these experiences, memories that will accompany me until my last days."

—Luis A. Rivera, retired El Yunque forester and tropical vegetation specialist

Photo by Gary Potts

RECREATION

Opening hours and closures

La Coca Falls
Photo by Luis Andrei Muñoz

Enjoying nature is one of the most satisfying recreational activities to connect people with their natural environment. There are few places that can be compared with a tropical rainforest. It's no wonder why people want to protect and enjoy such a special place. With over 600,000 visitors and 1.1 million site visits a year, El Yunque National Forest offers numerous recreation opportunities like hiking trails, guided tours, a visitor center, sheltered picnic areas, and lookout towers. The recreation opportunities provided by the forest's picnic areas, scenic vistas, trails, and streams continue to be scarce and valuable resources to both local and international visitors.

Opens daily from 7:30 a.m. to 6:00 p.m.

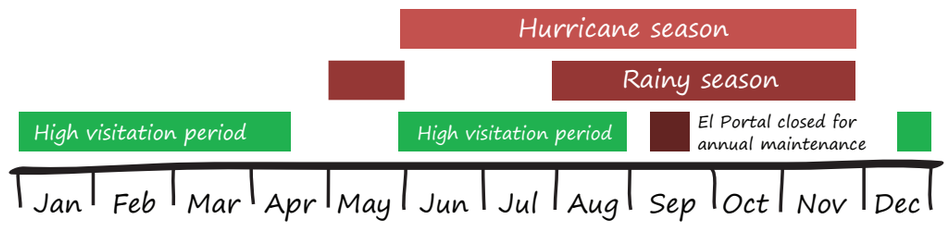
Telephone: (787) 888-1880

Website: https://www.fs.usda.gov/elyunque

@ElYunqueNF

TEMPORARY CLOSURES

The forest is closed on the 25th of December and El Portal Visitors Center closes for annual maintenance and repairs for two weeks in September. The forest may be closed for safety reasons and to ensure the welfare of its visitors, but these closures tend to be of short duration and only happen sporadically during the year. Flash floods and hurricanes are important weather events that can cause dangerous conditions in the forest. These events are closely monitored and the forest is closed when conditions become dangerous or when Puerto Rico is under a tropical storm or hurricane watch or warning. Flash flood events are more common during the forest's rainy season from August through November, while the hurricane season runs from June 1st to November 30th.

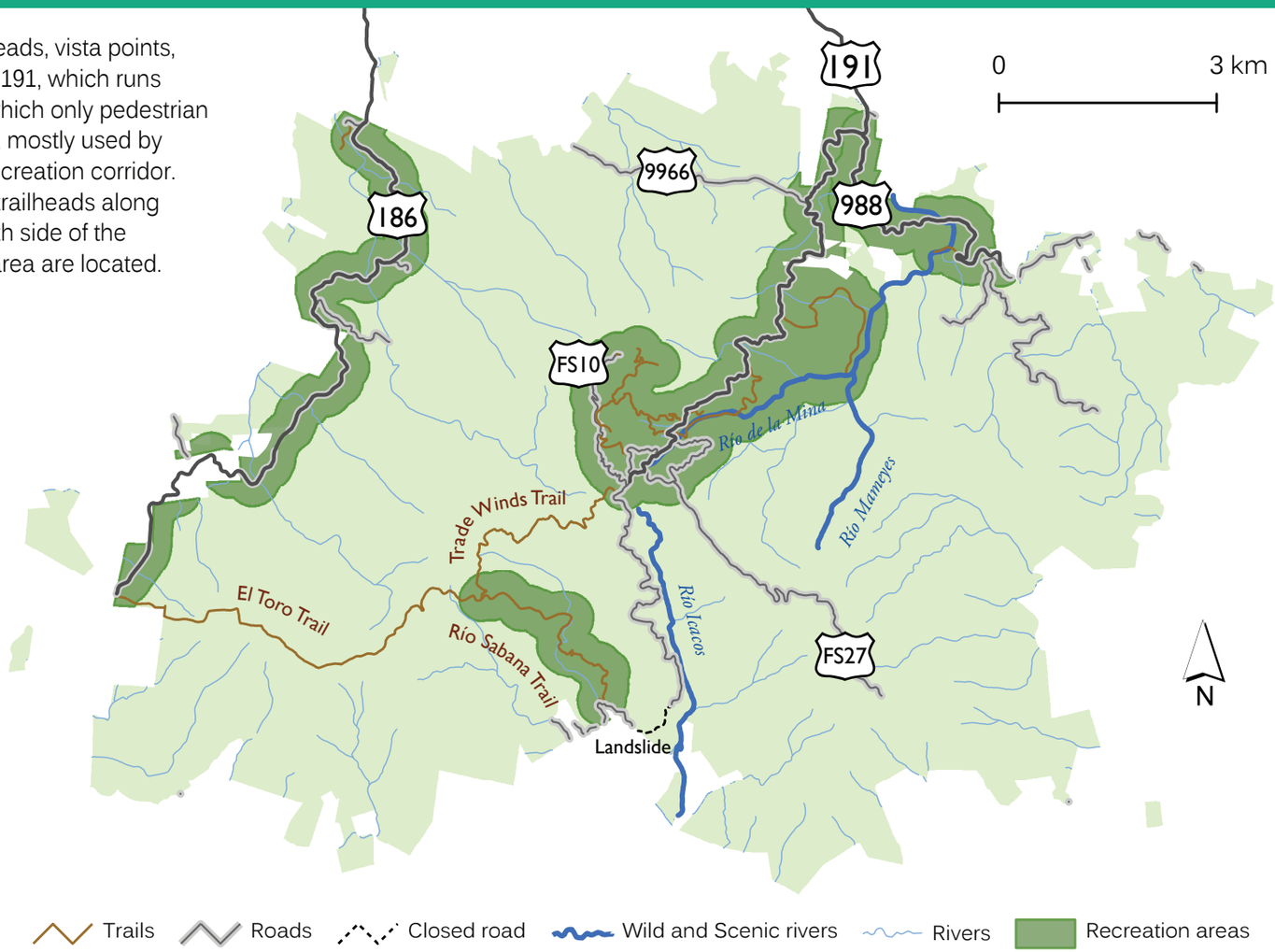


RECREATION

Roads, trails, and recreation areas

The visitor and information centers and most trailheads, vista points, and observation towers are located along road PR-191, which runs north to south and ends at a closed gate beyond which only pedestrian access is permitted. Other recreation opportunities, mostly used by the local community, are found outside the main recreation corridor. These include the Puente Roto River crossing and trailheads along PR-988, PR-186 to the west, and PR-191 on the south side of the forest, where the Río Sabana trailhead and picnic area are located.

Yucahú Tower
Photo by Sonja Baker

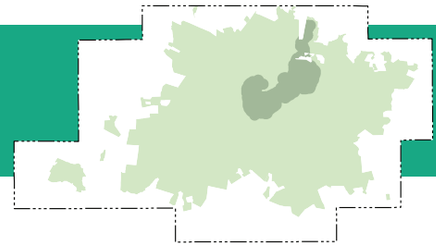


Protect the forest

To protect the biodiversity and natural richness that make El Yunque National Forest special, hunting and fishing activities are forbidden within the forest, and no trails are available for off-road vehicles or horseback riding. Bicycles are allowed only on paved roads. Along the Wild and Scenic rivers, no cooking or sound equipment is allowed. Visitors are asked to "Leave No Trace" and to pack out all trash when they leave the forest.

Vista from Yocahú Tower
Photo by Carl Baker

RECREATION CORRIDOR
along PR-191



The main entrance of El Yunque National Forest is located on road PR-191 travelling from the north, followed by the El Portal Visitor Center, numerous hiking trails, and parking and picnic areas. Signs at each trailhead show the difficulty level of each trail. The Palo Colorado Visitor Center is located near the end of the road with parking, picnic areas, various trailheads nearby, and an information desk. A gate marks the end of the road, beyond which only pedestrian access is allowed.

El Portal Visitor Center

El Portal Visitor Center, constructed in 1996, was especially designed to integrate into the surrounding forest landscape with minimal impact.[7] El Portal houses a theater where an orientation film is featured, an information desk, souvenir store, food stand, and interactive interpretive exhibits. Currently, as this publication goes to press, the entrance cost to El Portal is $4 for adults (16 to 59 years), $2 for seniors (over 60 years), and free for anyone under 15 years. No fees are currently charged for entrance to any of the other facilities in the forest.

El Portal Visitor Center
Photo by Jerry Bauer

El Yunque Hiking Trails

Trail name	Length (one way)	Difficulty level
Trailheads inside the Recreation Corridor along PR-191		
Angelito	0.2 miles (0.4 km)	easy
La Coca	1.8 miles (2.9 km)	difficult
Big Tree	0.9 miles (1.4 km)	moderate
La Mina	0.7 miles (1.1 km)	difficult
Caimitillo	0.4 miles (0.6 km)	moderate
El Yunque	2.6 miles (4.2 km)	difficult
Baño de Oro	0.3 miles (0.5 km)	easy
Mount Britton	0.8 miles (1.3 km)	difficult
Mount Britton Spur	0.3 miles (0.5 km)	moderate*
Los Picachos	0.2 miles (0.3 km)	moderate*
Tradewinds	4.3 miles (6.9 km)	difficult
Trailheads outside the Recreation Corridor		
El Toro	2.3 miles (3.8 km)	difficult
Río Sabana	2.2 miles (3.6 km)	difficult

*Trailhead only accessible through other trails with different difficulty levels.

Hiking trails in El Yunque vary in length and difficulty. The difficulty level is generally based on the trail width, surface and condition, steepness of grades, gain and loss of elevation, and the amount and kinds of natural barriers that may be encountered during the hike.[7]

Supplies like food and water should be taken along, especially on longer trails. There are no kiosks or vending machines on the trails.

Many trails lead to beautiful waterfalls and hidden ponds, like the Big Tree Trail, Angelito Trail, and La Coca Trail, and to breathtaking vistas from atop the mountains, like El Toro Trail, Tradewinds Trail, El Yunque Trail, and Los Picachos Trail.[55]

Bird watching in Mount Britton Trail
Photo by Gary Potts

Photo by Joe Baker

Camping in El Yunque

There are no camping facilities in the forest. However, primitive camping is allowed by special permit. Primitive camping refers to camping in wild natural areas with no facilities or infrastructure. Special permit forms should be submitted at least two weeks in advance. The camping permit and the El Yunque National Forest camping policies can be found at http://www.fs.usda.gov/elyunque

Photo by Maya Quiñones

Photo by Gary Potts

Photo by Gary Potts

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Glossary

Alluvium—Sediment deposits of sand, gravel, and clay product of flowing water.

Anthropogenic—Caused or produced by human activity.

Aviary—A large enclosure to hold birds.

Biodiversity—The Convention on Biological Diversity, established by the United Nations, defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems." [56]

Biogenic—The product of living organisms.

Endemic—Refers to species that are unique to a geographical area.

Endangered species—Species in immediate danger of disappearing completely—becoming extinct.

Fault breccia—Rocks formed by tectonic forces from broken fragments of minerals and other rocks.

Habitat—A place where a species lives.

Hydric soils—The National Technical Committee for Hydric Soils (NTCHS) defines hydric soils as "soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (Federal Register 1994). These soils, under natural conditions, are either saturated or inundated long enough during the growing season to support the growth and reproduction of hydrophytic vegetation." [22]

Hydrophytic plants—Plants adapted to aquatic conditions.

Intrusive rocks—Igneous rocks made of hardened magma that form below the surface.

Ecosystem—The Convention on Biological Diversity defines ecosystem as "a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit." [56]

Ecosystem services—Benefits that humans obtain from nature.

Land cover—The physical material on top of the Earth's surface.

Landforms—Shapes that describe the topography of the Earth's surface.

Life zones—Broad bioclimatic units that bear a close relationship to natural and biologically meaningful landscapes. These were developed using the Holdridge model, in which precipitation and biotemperature data are used to delineate the zones, which are then classified based on latitudinal region, altitudinal belt, and humidity province.[37]

Lichens—Symbiotic organisms composed of both fungi and algae, or fungi and cyanobacteria.

Municipality—A political administrative subdivision used in Puerto Rico.

Mycology—The study of fungi or mushrooms, yeasts, and molds.

Primary forest—Forest that has not been anthropologically disturbed and has kept its original natural vegetation structure and species composition. Also called virgin forest.

Ravine—Steep-sided valley smaller than a canyon, typically the result of erosion by running water.

Riparian—Related to rivers and their immediate surroundings.

Secondary forest—Forest areas that have regrown after significant removal of its original vegetation so as to alter its original species composition.

Silviculture—The practice of planting and controlling the growth and composition of a forest. Silviculture is used for managing forests for timber production, wildlife, water, recreation, and aesthetics, among other uses or combination thereof.

Soil complex—Soil mapping unit made of two or more types of soils.

Species—A distinct group of living organisms that are capable of breeding among themselves.

Species richness—The number of different kinds of animals or plants that call a space home.

Symbiosis—An interdependent relationship between two or more species.

Trade winds—Global wind currents that prevail in the tropics and subtropics worldwide, blowing from the northeast in the northern hemisphere and the southeast in the southern hemisphere.

Trailhead—The place where a hiking trail begins.

Topography—The shape and features of the planet's surface.

Wilderness—Land protected under The Wilderness Act of 1964 (Public Law 88–577), which defines wilderness as "an area where the earth and its community of life are untrammeled by humans, where humans themselves are a visitor who does not remain; [and] an area of undeveloped U.S. federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions." [57]

Abbreviations

ºC — degrees in Celsius

ºF — degrees in Fahrenheit

g/p/d — gallons per person per day

ha — hectares, a measurement of area. One hectare is equivalent to 2.47 acres.

km — kilometer

m — meter

Mgal/day — million gallons per day

mm — millimeters

pers. — persons

PR — Puerto Rico

UNESCO — United Nations Educational, Scientific, and Cultural Organization

U.S. — United States

USDA — United States Department of Agriculture

yr — year